A STUDY IN INSECT PARASITISM.

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Introduction. For a number of years the writer has been interested in insect parasitism and its relation to the control of injurious insects. Occasional notes have been made on different species of parasites and considerable interesting data has been obtained concerning the parasites of one of our common Iowa insects, the "tomato-worm," *Phlegethontius sexta* (Johanssen), sometimes called the "tobacco worm" or the "southern tobacco worm." It is with certain parasites of this particular insect with which this paper has to deal.

The most of this data, but not all of it, represents a part of a study on potato insects, being carried on at the Iowa Agricultural Experiment Station at Ames. The host insect mentioned, not content with tobacco and tomato as food plants, is also quite fond of potato foliage, hence its consideration as a potato insect.

The Host Insect. I think that most of us have seen these long, fat, green "worms," with diagonal white bars on each side, and with a prominent horn at the caudal end. This rather dangerous looking horn has been popularly thought of as being poisonous, but such is not the case. When it is picked up the tomato-worm is likely to bite one's fingers with its mandibles, but there is no danger to be feared from the caudal horn. The "worms" are common insects in Iowa and are found frequently on tomato and potato leaves during the summer.

There are two common species of these insects in Iowa; the "northern tobacco worm," *Phlegethontius quinquemaculata* (Haworth) and the "southern tobacco worm" or "tomato-worm" as it will be called in this paper. The observations herein given refer to the tomato-worm, *Phlegethontius sexta* (Joh.).

A brief account of the seasonal history of the tomato-worm is given herewith. The winter is spent in the soil in the pupa state. Emerging in June, the moths deposit their eggs on the leaves of tomato and potato plants and the larvae appear in July, maturing in late July and early August. A second generation, which is probably only a partial one, occurs in Iowa, since the larvae are found again in September and October. These mature and spend the winter as pupae in the soil.

The Parasites. The most common primary parasite of the tomato-worm is a small, black, hymenopterous insect, a braconid, *Apanteles congregatus* (Say). The small, white, cylindrical cocoons of this parasite are often seen on the tomato-worms, although they are usually mistaken by most people for eggs of some kind. The parasite, however, deposits its eggs inside the host insect, puncturing the skin of the tomato-worm in order to do so. These eggs hatch out and the parasite larvae feed on the inside of the host until they become mature. Then they cut through the skin of the host to the outside and spin their small, white cocoons there, attaching them to the back of the tomato-worm.

The parasitism of *Phlegethontius* by *Apanteles congregatus* was first recorded by Fitch (1865), who reared this parasite from larvae of *Phlegethontius quinquemaculata*. Say (1835) in describing the species, said that he reared it as a parasite of a *Sphinx* larva. Since then this *Apanteles* has been reared by many entomological writers.

In the fall of 1906 I secured several tomato-worms that were literally covered with these small, white cocoons, and reared two species of parasites from them. Rather strange to say, neither of these two parasites were the makers of the cocoons. Both of them were hyperparasites, which had deposited their eggs in the cocoons of the primary parasite after these had been formed on the outside of the tomato-worms. The host larvae, the tomato-worms, were collected at Urbana, Illinois, September 25, 1906, by Mr. J. L. Pricer, and the parasite cocoons from these larvae were removed and placed in small vials in the entomological laboratory of the University of Illinois.

The first of these hyperparasites to emerge was a delicate, light brown species, *Mesochorus luteipes* (Cresson), so determined for me by Mr. J. C. Crawford, of the U. S. National Museum at Washington. Soon afterwards a small chalcid began to appear from the cocoons. This chalcid is the same species described years ago by Fitch and called *Pteromalus tabacum*. Mr. A. A. Girault, however, writes me that this is really *Hypopteromalus viridescens*, described by Walsh. No specimens of the primary parasite, *Apanteles congregatus*, were reared at all from this lot of cocoons, and for a long time the writer thought that the *Mesochorus* was the primary parasite.

On October 1 two specimens of *Mesochorus luteipes* appeared in the vials, and from October 1 to 8 this species emerged abundantly. In leaving the cocoon they cut an irregular, jagged hole near the end of the cocoon, usually at the side of the end.

On October 10 the chalcid, *Hypopteromalus viridescens*, appeared in the vials. The vials were kept in warm laboratory rooms through the winter and the chalcids continued to emerge. On December 28 two specimens of the *Hypopteromalus* emerged; on January 16, one specimen of *Mesochorus;* and on January 26 the *Hypopteromalus* were again coming out of the cocoons. As late as February 11 there was found in one vial a single dead *Mesochorus luteipes*, which could not have emerged many days before.

Fitch (1865) observed this chalcid, and he described it under the name of *Pteromalus tabacum*, correctly interpreting it as a hyperparasite. As such it has since been mentioned by Glover (1874) and by Garman (1894) (1897).

So far as I know, Garman (1894) (1897) is the only one who has recorded *Mesochorus luteipes* in its relationship to *Apanteles congregatus*.

No further observations were made by the writer on these parasites until the fall of 1910, when an abundance of the tomato-worms at Ames brought with it a corresponding abundance of the primary parasite, *Apanteles congregatus*. Large numbers of these *Apanteles* cocoons were collected and brought in to the insectary, where they were placed in vials in the insectary cold room. These vials were examined daily in the fall until late in October, and in the spring from about the middle of March on. This was done to determine how the parasites spent the winter, and to find out something about the relative abundance of the primary parasites and those which were secondary.

Six different lots of *Apanteles* cocoons, 2,393 cocoons all told, were brought in to the insectary at dates ranging from September 7 to October 18. The number of parasites of the three species reared from these cocoons is given in the accompanying table.

Lot.	Date.	No. of Cocoons.	*Apanteles.*	*Mesochorus.*	*Hypopteromalus.*
1	September 7.....	172	92	0	43
2	September 30.....	364	251	0	13
3	October 5.....	373	155	4	147
4	October 10.....	261	119	8	57
5	October 12.....	773	300	10	338
6	October 18.....	450	195	5	181
	Total.....	2393	1112	27	779

Figuring out the percentages of the parasites reared, based on the total number of cocoons, it is found that 46.4%, less than one-half, of the *Apanteles* cocoons gave *Apanteles* adults. Nearly one-third, 32.5%, of the cocoons gave adults of *Hypopteromalus viridescens*, while only 1.1% represents the number of *Mesochorus* reared. From nearly one-fifth of the cocoons, 19.6%, nothing was reared. These cocoons contained either dead larvae or adults of *Apanteles*, occasionally one of the other species of parasites.

Specimens of both the *Apanteles* and the *Mesochorus* were sent to the U. S. National Museum at Washington and examined by Mr. H. L. Viereck, a specialist in parasitic hymenoptera. Mr. Viereck determined the first as *Apanteles congregatus* (Say) and the second as *Mesochorus aprilinus* (Ashmead).

It is interesting to compare the figures just given with those of Garman (1894), who reared three species of parasites from cocoons on tomato-worms collected at Lexington, Kentucky, in 1890. At this time Garman reared 123 *Apanteles*, 97 *Hypopteromalus* and 197 *Mesochorus*. Here, then, the secondary parasites far outnumbered the primary *Apanteles*. The species of *Mesochorus* here concerned was *luteipes*.

From the cocoons brought in to the insectary at Ames, September 7, nearly all the parasites (*Apanteles* and *Hypopteromalus*) emerged in the fall, although a few of the *Hypopteromalus* emerged the next spring. Of the parasites in this lot the *Apanteles* emerged first, followed by the *Hypopteromalus*, after an interval of 10 days or two weeks, during which no parasites emerged.

From those cocoons collected after September 7, occasional parasites of all three species emerged in the fall, but no secondary parasites emerged from cocoons collected October 10 or later. In the spring, from these cocoons, both *Apanteles* and *Hypopteromalus* emerged in great numbers, *Mesochorus* emerging sparingly. Comparatively few *Mesochorus* were reared at all from this material.

The different species of parasites emerged at different times from the vials. A second species did not begin to emerge until the first species had ceased coming out, so that all of one species emerged in a body, quite separate and distinct from the others. In no case were two species found in a vial on the same day, and the vials were examined every day while the parasites were emerging.

To take a concrete example of this kind 50 *Apanteles* cocoons collected October 10 gave the following parasites in the spring of 1911. From April 1 to 10, 11 *Hypopteromalus* emerged; from April 22 to 29, 3 *Mesochorus* emerged; from May 3 to 16, 25 *Apanteles* emerged.

While the several parasites emerged in separate groups, there was a difference in the order in which they emerged. In the fall *Apanteles* preceded *Hypopteromalus* in emerging, but in the spring this order was reversed. With *Mesochorus*, however, the order in relation to *Hypopteromalus* varied; sometimes emerging before that species, again after it, but always maintaining a separate time in emerging. From *Apanteles* cocoons collected October 5 and 12, 14 *Mesochorus* emerged, all preceding *Hypopteromalus*, while from cocoons collected October 10 and 18, 13 *Mesochorus* emerged, following the emergence of *Hypopteromalus*. No difference, then, was noted in the precedence of one species over the other that could be correlated with the time of collection of the cocoons.

It may be noticed that in the lot of cocoons collected September 30 only a very few *Hypopteromalus* were reared, and no *Mesochorus*. The reason for this is not apparent, but it is possible that these cocoons had not been formed long enough to have become very much parasitized. The age of the cocoons at the time of collection would determine to a great extent the degree of parasitism by *Mesochorus* and *Hypopteromalus*.

In the case of *Hypopteromalus viridescens* the males preceded the females in emerging. Out of 730 of this species where the sex was distinguished there were only five cases where the males issued after the females had begun to come out.

The females of *Hypopteromalus* were much more abundant than the males, there being nearly twice as many. Out of 730 *Hypopteromalus* where the sex was noted, 475, or 65% were females, while only 255, or 34.9% were males.

The sexes are easy to distinguish, the males being light green in color, while the females are blue green, much darker than the males. In fact the two sexes might easily be taken for two different species. The sharp pointed abdomen of the female distinguishes it from the blunt ending abdomen of the male.

In leaving the cocoon *Apanteles* always cuts out a tiny cap from one end of the cocoon, in order to make a way out. This cap then fits down nicely over the exit hole, sometimes closing over after the adult has emerged, but usually remaining open. The secondary parasites, however, both make a jagged hole in the *Apantelcs* cocoon, usually at the side of the end, through which they emerge. So by examining the exit hole in the cocoon one can easily determine whether *Apantelcs* or an enemy of the *Apanteles* has emerged.

The excessive abundance of the primary parasite, *Apanteles congregatus*, at Ames in the fall of 1910 had its effect on the tomato-worms. During 1911, both on potato and tomato plants at Ames, not a single larva of this species could be found, although a search was made time and again. A few larvae of the northern species, *Phlegethontius quinquemaculata*, were found, but even these were not at all common. The tomato-worm, however, was not at all in evidence at Ames in 1911, and its absence is no doubt due to the great abundance of the parasite, *Apanteles congregatus*, in 1910.

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