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INVESTIGATIONS OF THE PARASITES OF POPILLIA JAPONICA AND RELATED
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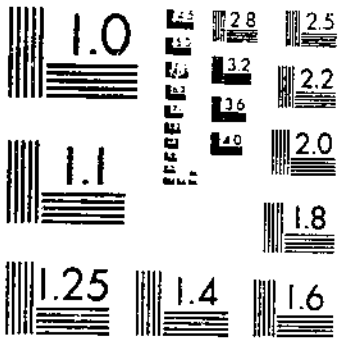

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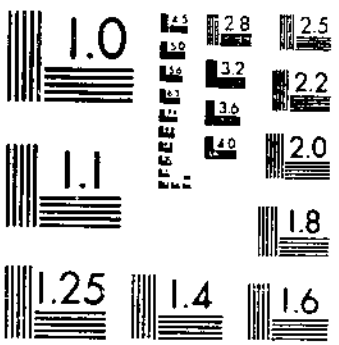

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Investigations of the Parasites of Popillia japonica and Related Scarabaeidae in the Far East from 1929 to 1933, inclusive[1]

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CONTENTS

INTRODUCTION

Investigations of the parasites of the Japanese beetle (*Popillia japonica* Newm.) were begun in the Far East in the spring of 1920, and accounts of these investigations from 1920 to 1928, inclusive, have appeared in previous publications (*9*, *10*).[5] This bulletin, which

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[2] Transferred to the Division of Foreign Parasite Introduction July 1, 1937.
[3] After termination of the investigations in India in 1929, the junior author was transferred to Japan, taking charge of investigations in that country in 1931 when the senior author returned to the United States.
[4] The authors wish to acknowledge the valuable help of R. W. Burrell, who assisted in the work in Japan and Chosen in the summer of 1930 and again in 1932, when he was assigned to the work in those countries; of G. J. Haeussler, who supervised the investigations in 1933 in conjunction with the parasite investigations of the oriental fruit moth; of K. Sato, assistant in Japan since 1921; of S. Fujii; and of H. Sugiura. During the course of the investigations in Japan, Chosen, India, and Taiwan, the writers were greatly aided by the various Government officials of those countries. The late S. I. Kuwana, Chief of the Imperial Quarantine Service, and his staff offered every facility for the work in Japan. The director and staff of the Chosen Agricultural Experiment Station at Suigen, Chosen, have kindly provided laboratory facilities each season. The director and staff of the Taiwan Agricultural Experiment Station at Taihoku, Taiwan, kindly permitted the use of the station collection for determination purposes. The work in India was aided by T. Bainbrigge Fletcher, Imperial Entomologist of that country, and by Col. H. Morrison, Director of the Pasteur Institute at Shillong, India, who provided laboratory-equipment facilities.
[5] Italic numbers in parentheses refer to Literature Cited, p. 35.

covers the work of the 5-year period from 1929 to 1933, inclusive, in Japan, Chosen, India, and Taiwan (Formosa), supplements the previous publications and presents additional information relative to the parasites previously listed, as well as accounts of other species found attacking the genus *Popillia*. In addition, investigations were made on the parasites of *Anomala orientalis* Waterh., *Autoserica castanea* (Arrow), and *Serica peregrina* Chapin,[6] three additional beetles which have become established in the northeastern part of the United States in recent years.

The work in Japan, Chosen, and Taiwan was carried on in a manner similar to that of previous years, and consisted of collecting and rearing parasites of *Popillia* and related Scarabaeidae and shipping these to the United States, together with further studies on the field abundance and distribution of these parasites. The investigations in India, which centered at Shillong, Khasi Hills, Assam Province, were continued along lines previously described, and consisted of collecting, rearing, and shipping parasites of *Popillia*. At the end of 1929 the work in that country was terminated.

No investigations have been carried on in China since 1926, when the work in that country was terminated owing to the unsettled political conditions.

THE PARASITES OF POPILLIA JAPONICA AND THEIR BIOLOGIES

During the period 1929–33 investigations were made in Japan, Chosen, China, India, and Taiwan of the parasites of *Popillia* beetles included in table 1, the idea being to introduce them into the United States for the control of *Popillia japonica*. Under normal field conditions these species are either parasitic on *P. japonica* or attack other members of the same genus. The dexiids are capable of parasitizing other genera in the scarabaeid subfamilies Melolonthinae and Sericinae in addition to *Popillia*.

TABLE 1.—*List of parasites of Popillia investigated in Japan, Chosen, China, India, and Taiwan*

Parasites of—	Countries	Hosts
The adult beetle:		
Tachinidae:		
Centeter cinerea Ald.	Japan	*Popillia japonica.*
Eutrixopsis javana Towns.	do	Do.
		Anomala sp.
Hamaria incongrua Walk.	Japan, Chosen, China, India	*Popillia japonica.* *Popillia quadriguttata* (F.).[1] *Popillia chinensis* Friv. *Popillia cyanea* Hope. *Popillia cupricollis* Hope. *Popillia mutans* Newm. *Popillia pustulata* Fairm. *Anomala orientalis* Waterh. *Anomala rufocuprea* Mots.
Trophops clausseni Ald.	Japan	*Adoretus tenuimaculatus* Waterh.
Pygotidae:		*Popillia japonica* *Anomala rufocuprea.*
Adapsilia flaciseta Ald.	India	*Popillia cupricollis.* *Popillia cyanea.* *Popillia macclellandi* Hope.

[1] In previous publications (*9*, *10*) this species is referred to as *P. castanoptera* Hope.

[6] In a previous publication (*10*) this species is referred to as *S. similis* Lewis.

TABLE 1.—*List of parasites of Popillia investigated in Japan, Chosen, China, India, and Taiwan*—Continued

Parasites of—	Countries	Hosts
The larva:		
Dexiidae:		
Dexia centralis Ald.	Chosen	*Popillia quadriguttata.* *Popillia atrocoerulea* Bates. *Miridiba koreana* N. and K. *Anomala* spp. *Phyllopertha* spp. *Serica* spp.
Prosena sibirita (F.)	Japan, Chosen, India	*Popillia japonica.* *Popillia cupricollis.* *Popillia* spp. *Anomala* spp. *Adoretus* sp. *Serica* spp.
Scoliidae:		
Tiphia matura A. and J.	India	*Popillia cupricollis.* *Popillia* spp.
Tiphia popilliavora Roh.	Japan, Chosen, China	*Popillia japonica.* *Popillia atrocoerulea.* *Popillia quadriguttata.* *Popillia chinensis.* *Popillia formosana* Arrow.
Tiphia pullivora A. and J.	India	*Popillia cupricollis.* *Popillia* spp.
Tiphia vernalis Roh.	Japan, Chosen, China	*Popillia japonica.* *Popillia quadriguttata.* *Popillia chinensis.* *Popillia* spp.
Tiphia sp. Taiwan 5	Taiwan	Do.

Only the investigations pertaining to the life histories, habits, field observations, and rearing and shipping of these parasites in the Far East are dealt with in this bulletin. The methods of handling upon arrival in the United States and the rearing, colonization, and effectiveness of these parasites are dealt with in other publications (*1*, *3*, *4*, *5*, *6*, *11*, *12*, *13*, *14*, *15*, *16*, *17*) emanating from the investigations on the Japanese and Asiatic beetles.

PARASITES OF THE ADULT BEETLE

Investigations were carried on with four species of Tachinidae parasitic on adults of *Popillia japonica* in Japan and one species of Pyrgotidae parasitic on adults of species of *Popillia* in India. No parasites of adult *Popillia* beetles were found in either Chosen or Taiwan, except *Hamaxia incongrua*, which is known to be widely distributed throughout the Asiatic and Malayan Regions. *Centeter cinerea* in Japan and the pyrgotid *Adapsilia flaviseta* in India have but one generation a year and are well synchronized with their hosts in time of appearance in the field. *Eutrixopsis javana* has but one generation a year and its life cycle corresponds closely to that of *Centeter*. In Japan *H. incongrua* and *Trophops clauseni* have two or more generations a year and are present as adults in the field over a longer period than are the *Popillia* beetles, thus requiring other scarabaeid beetles as alternate hosts. These are usually present in sufficient numbers to enable these tachinids to complete their life cycles, but a limited number or a lack of alternate hosts in a new environment presents a serious handicap in the establishment of these two species.

TACHINIDAE

CENTETER CINEREA Aldrich

The biology and habits of *Centeter cinerea*, the most effective parasite of adult beetles of *Popillia japonica* in northern Japan, has been fully dealt with in previous publications (*9*, *10*). The work during the period 1929–33 consisted in the investigation of new areas in Japan to determine the relative abundance and degree of field parasitization, and in the collection of parasitized beetles for the shipment of puparia of *C. cinerea* to the United States.

Investigations on the island of Hokkaido in northern Japan revealed that *Centeter cinerea* was well distributed in practically all the localities where *Popillia* beetles were present. The average parasitization in all the localities investigated was 37.2 percent during the latter part of July and early part of August in 1931. No doubt this average would have been considerably higher had the observations been made earlier in the season, since previous records at Sapporo on the same island have shown that the parasitization drops off very suddenly after the first part of August. On the island of Honshu, just south of Hokkaido, the presence of *C. cinerea* in different sections was distinctly variable and the degree of parasitization considerably lower as contrasted with that found in Hokkaido. In no locality were more than 35 percent of the beetles parasitized. The highest rates of parasitization were found in the hilly and mountainous sections of the northern and western portion of the island, where the winters are severe and snow is present on the ground throughout the winter. In the lowlands of the eastern portion of the island, where the winters are mild and little snow occurs, beetle parasitization was found to be considerably lower, and in the section south of Yokohama no trace of *C. cinerea* was found.

While the distribution of *Hamaxia incongrua* was being investigated in Kyushu in southern Japan in 1932, beetles bearing eggs similar to those of *Centeter* were collected near Ino and Kobayashi in the mountains at the northern end of the island. Emergence of the parasites the following year proved them to be *C. cinerea*. This makes the third island in Japan on which *C. cinerea* is known to occur, and extends the known southern range much beyond that previously recorded.

Popillia beetles bearing *Centeter* eggs were collected for rearing and shipment in 1929, 1930, and 1933. Approximately 85 percent of the parasitized beetles produced *Centeter* puparia. During these years 33,663 puparia were shipped to the United States. The 1933 shipments, consisting of 6,163 puparia, were from beetles collected in the vicinity of Utsonomiya and Tachikawa near Tokyo. The *Centeter* adults occurring in these localities are present in the field the latter part of June and early in July, or approximately 1 month earlier than those at Sapporo in northern Japan, from which all previous shipments of puparia material have originated. In view of this and the corresponding correlation with the time of emergence of the host, *C. cinerea* from this section may prove to be better synchronized in time of emergence with *Popillia japonica* in the United States.

The methods of collecting and rearing were the same as those employed in previous years. In preparing the puparia for shipment great care was exercised in eliminating as much of the beetle body as possible.

HAMAXIA INCONGRUA Walker

Hamaxia incongrua, a parasite of the adults of many species of Scarabaeidae, is widely distributed throughout the Asiatic and Malayan Regions and in various tropical countries. In Japan, where it occurs as a parasite of *Popillia japonica*, it has two and possibly three generations a year. Being of crepuscular habit, it is active mostly during the early morning hours and in the evening. Although the exact method of parasitization is not known, it is presumed that the female deposits fully developed larvae either on the host beetle or on the nearby foliage, and that these enter the beetle through the softer portions of the body.

Although no shipments of *Hamaxia incongrua* have been made to the United States since 1928, observations on distribution and degree of field parasitization were carried on in Japan during the period 1929–33.

During 1930, 1931, and 1932 over 200,000 *Popillia* beetles were collected at 108 localities, representing a wide range of climatic and environmental conditions, on the islands of Honshu, Shikoku, and Kyushu in Japan. These were collected from the middle of June to the end of August, and in some instances collections were made at weekly intervals. Since it is impossible to distinguish the parasitized beetles in the field owing to the larvipositing habit of this tachinid, all collected material was sent to the Yokohama laboratory for observation. *Hamaxia incongrua* was reared from beetles collected at 68 of these localities on the 3 islands. Emergence records from this collected material showed that *Hamaxia* was the more abundant in the hilly places covered with underbrush in the warmer areas. Field parasitization was exceedingly variable in different sections and the general average very low. In no locality were more than 20 percent of the beetles parasitized and in only 13 localities was parasitization above 5 percent.

Parasitized beetles were found in the field in central and western Japan throughout the season, the highest rates of parasitization occurring during the latter part of June and early in July and again the latter part of August. At Obuse, in western Japan, 5.1 percent of the beetles were parasitized on July 9, 1932. Examination of the beetles from the same locality collected July 25, and 29 revealed parasitizations of 2.3 and 3.2 percent, respectively, which increased to 14.3 percent of the beetles collected the last week in August. *Popillia* collected at Takao, near Tokyo in eastern Japan, on July 3, 1932, had a parasitization of 4.1 percent, which dropped to 1.2 and 1.4 percent in collections made on July 19 and 28, respectively, and rose again to 4.3 percent in a lot collected August 19. The differences in these parasitization records are no doubt due to the two generations of *Hamaxia* appearing in the field at these times.

In areas where adults of *Popillia japonica* are present in the field over a period of 2 months or longer, *Hamaxia incongrua* is able to develop two generations on this host, but in areas where this does not occur alternate scarabaeid host beetles are necessary for the preservation of this species.

EUTRIXOPSIS JAVANA Townsend

In 1923 and 1928 a few adults of *Eutrixopsis javana* were reared at the Riverton laboratory from shipments of beetles parasitized by *Centeter cinerea* forwarded from Sapporo, Japan, in 1922 and 1927. Although several attempts have been made to obtain information on this tachinid in Japan, nothing relative to its biology or life history has been found. A careful examination of beetles bearing tachinid eggs collected at Sapporo in 1928 revealed that all the puparia contained within the dead parasitized beetles were those of *Centeter*. More than 100,000 beetles free from external tachinid eggs were also examined, but not a single *Eutrixopsis* puparium was found. In 1930 approximately 10,000 *Popillia* were collected at 9 other localities on Hokkaido Island. More than half of the beetles bore tachinid eggs and the remainder were free from external eggs. Later examination of both parasitized and unparasitized beetles revealed nothing but *Centeter* puparia.

Apparently *Eutrixopsis* at times parasitizes *Popillia* in the absence of some other host and may be considered of little importance as a factor in the control of *P. japonica* in Japan.

TROPHOPS CLAUSENI Aldrich

Trophops clauseni was first discovered in 1928, when 3,000 *Popillia japonica* beetles collected at Tokorozawa, near Tokyo, Japan, late in June revealed a parasitization of 1.2 percent. Beetles collected at this area 1 week later, however, did not contain a single individual.

In 1930, while the distribution of, and field parasitization by, *Centeter cinerea* and *Hamaxia incongrua* were being investigated in Nagano prefecture, western Japan, *Trophops* was again encountered in two localities. In 1931 it was found in several additional localities in the same prefecture. The highest parasitization was found at Obuse, where collections of *Popillia* in 1932 yielded 8.1 and 4.5 percent on July 9 and 13, respectively. The field parasitization of beetles collected in all localities, however, averaged only 1.4 percent in that year. Of several Scarabaeidae present in the field in these localities, *Anomala rufocuprea* appears to be the only other beetle accepted by this tachinid as a host. Although *Popillia* beetles collected at Tokorozawa late in June in 1928 were found to contain *Trophops* larvae, no parasitized beetles were found in Nagano prefecture before July 5. After this date the degree of field parasitization increased until the middle of the month, after which it gradually declined. After the first week in August no parasitized *Popillia* could be found, although *A. rufocuprea* collected late in August were found to contain larvae of *Trophops*. Collections of beetles made in the middle of July showed the sex ratio of the attacked beetles to be 61.3 percent males and 38.7 percent females.

Notes on the Life History of Trophops clauseni

The tachinid fly *Trophops clauseni* is apparently nocturnal in its habits, for it has never been observed in the field. Parasitized beetles are usually found in rather hilly places with dense undergrowth, indicating field habits similar to those of *Hamaxia*. Repeated

examinations of the beetles containing the larvae of *Trophops* showed no traces of external eggs, so it is assumed that the female deposits living larvae, but the exact manner in which it attacks its host or the manner of penetration by the larva into the host beetle has never been determined. The death of the beetle occurs when the parasite larva has reached the early part of the third instar. The period of larval development in the host body is similar to that of *Hamaxia incongrua*, the average time from collection of the beetles to pupation of the parasite being 9 days under normal temperatures prevailing during midsummer. In July and August the pupal stage in *Popillia* covers a period of 15 to 17 days. However, in *Anomala rufocuprea* which were collected in the latter part of August the pupal period was 28 days.

The exact number of generations of *Trophops* in western Japan is not known, although there are at least two a year, the first on *Popillia* and the following one or more on available *Popillia* and *Anomala rufocuprea*. In 1932 *Trophops* emerged during the early part of August from *Popillia* beetles that had been collected in the middle of July, and *A. rufocuprea* collected in the latter part of August were also found to contain larvae of this parasite.

The status of this tachinid as a parasite of *Popillia japonica* is somewhat similar to that of *Hamaxia incongrua*, although its known distribution is more limited. Because of its low rate of field parasitization, as observed in its native habitat in Japan, and its two or more generations a year covering a period of adult activity of 2 months or longer, the value of *Trophops clauseni* as a parasite of *P. japonica* in the United States is questionable.

In 1932 a total of 237 puparia of *Trophops clauseni* were shipped to the United States, from which only 16 adults emerged in the spring of 1933.

PYRGOTIDAE

Adapsilia flaviseta Aldrich

A full account of the life history and general habits of *Adapsilia flaviseta*, a parasite of adult *Popillia* beetles in India, has been given in a previous publication (*10*). In India this pyrgotid fly is restricted to the hilly sections that are covered with widely spaced plantings of pine trees and fairly dense undergrowth of brush at an elevation of about 5,000 feet. It has only one generation a year, the adults appearing in the field about the middle of July. Its normal host in India is *Popillia cupricollis* although *P. cyanea* and *P. macclellandi* are occasionally parasitized. In parasitizing the beetle the female *Adapsilia*, which is diurnal, remains quiescent on the foliage near the feeding beetle until the beetle takes flight, whereupon the fly immediately pounces upon the beetle from above. It then quickly inserts its egg through a long, relatively slender and sharp ovipositor into the mid-dorsal region of the beetle abdomen near the juncture with the thorax.

The work in India in 1929 was devoted to collecting beetles near Shillong and shipping *Adapsilia* puparia obtained from these beetles to the United States. No further work was done with this species after 1929 owing to the discontinuation of the work in that country.

Beetles were collected during the period from July 25 to August 16,

1929, the majority being brought in from August 1 to 9, the period when the synchronization of host and parasite is at its best. During this time 553,885 beetles were brought in by the numerous native collectors. From these, 4,310 *Adapsilia* puparia were obtained, giving a parasitization of 0.78 percent, as compared with 0.53 in 1928.

The manner of rearing and shipping was similar to that employed in previous years. The beetles were confined in heavy cardboard boxes of approximately 1 cubic foot capacity, and to absorb excess moisture the bottoms were lined with fresh moss. Apples were used to feed the beetles and were replenished on alternate days. After 12 days all live beetles, which were evidently unparasitized, were destroyed and the dead ones placed in open trays to allow the *Adapsilia*, which were still in the larval stage, to pupate. After pupation the unconsumed body contents of the host were removed to eliminate decomposition gases that might arise during shipment, to the detriment of the puparia. The puparia were packed between layers of fresh sphagnum moss in small, ventilated rectangular tins, and a number of these, entirely surrounded by a 3-inch layer of fresh moss, were packed in insectproof wooden boxes for shipment.

One shipment consisting of 3,800 puparia was sent to the United States in 1929. This arrived at its destination November 9, having been en route 42 days at a temperature of 40° to 50° F.

Parasites of the Larva

DEXIIDAE

Dexia ventralis Aldrich

Dexia ventralis, the most common of the Chosenese dexiids, was first found at Suigen, Chosen, in 1922 (*9*). Owing to its complicated biology no rearing work for the shipment of parasitized grubs to the United States was attempted until 1925 (*10*). In that year *Popillia japonica* grubs, which do not occur in Chosen, were collected and shipped from northern Japan to Fukuoka in Kyushu, southern Japan, for parasitization by *Dexia* females forwarded from Chosen. By the time a sufficient number of gravid females were available late in June, however, most of the grubs were too far developed for parasitization purposes, and only 850 parasitized grubs were shipped to the United States.

In 1926 it was decided to carry on rearing work in Chosen, utilizing the native Chosenese host grubs. This proved to be very successful, and over 20,000 grubs were parasitized and shipped to the United States in 1926 and 1927. Because of the danger involved in shipping to the United States live grubs other than those of *Popillia japonica*, owing to the risk of an escape of these species, no rearing work was carried on in Chosen in 1928, but a method was developed whereby adult female *Dexia* could be shipped to Yokohama successfully, and in 1929 rearing work was carried on there, the grubs of *P. japonica* being used as hosts.

Table 2 shows the survival of adult females of *Dexia ventralis* forwarded from Suigen, Chosen, to Yokohama in 1929 and 1930, the 2 years that rearing work was carried on. The adults were confined in the shipping containers, which were similar to those employed in transporting Scoliidae, approximately 7 days from the time of collection to the time of removal.

TABLE 2.—*Survival of adult females of Dexia ventralis shipped from Suigen, Chosen, to Yokohama, Japan, in 1929 and 1930*

Year	Generation	Adults shipped	Adults surviving shipment	
		Number	*Number*	*Percent*
1929	First	663	552	83.3
1929	Third	2,281	1,896	83.1
1930	First	890	684	76.8
1930	Second	2,051	1,477	72.0
1930	Third	2,483	2,008	80.9
Total		8,368	6,617	79.1

It was extremely difficult to obtain *Popillia* grubs in any numbers in the vicinity of Yokohama for rearing work with *Dexia*, but this was overcome by collecting and shipping grubs as needed from Hokkaido in northern Japan to Yokohama, a procedure which proved to be very satisfactory and inexpensive. No rearing work was attempted with the second generation of *Dexia* in 1929 owing to the impossibility of securing a sufficient number of grubs in Hokkaido during August. This was the year of grub scarcity in northern Japan, when less than 1 percent of the overwintering grubs having a 2-year life cycle were still in the larval stage at that time of the year.

The parasitized grubs obtained through parasitization with the first and second generations of *Dexia* in June and August, respectively, were shipped to the United States immediately after being parasitized. Development of the parasites took place en route, and the adults emerged shortly after arrival at their destination. Grubs containing the hibernating larvae of *Dexia* obtained through parasitization with the third-generation flies in September and October, were kept over winter at Yokohama in a well-drained plot covered with sod. The winter mortality of these grubs was rather high, as only 17.1 and 16.9 percent were alive when dug up for shipment in the springs of 1930 and 1931, respectively.

Rearing and Shipping Methods

The rearing work with *Dexia ventralis* was accomplished by using a breeding-jar method similar to that employed in previous years. Approximately 50 grubs were placed in the lower half of a 1-quart glass jar with soil. A fine-mesh screen cage containing 5 or 6 *Dexia* females was fitted into this jar and rested on the soil, and through this screen into the soil the deposited larvae passed in search of the host grubs. The grubs were examined each day and those showing the parasite respiratory funnel were removed and replaced with fresh grubs. The flies, which were fed regularly with a solution of sugar and water, lived from 3 weeks to 1 month in the cages and parasitized from 35 to 50 percent of the grubs each day.

In packing the parasitized grubs for shipment, tin-lined boxes, 1 foot square and 6 inches deep, were used. Each box contained 5 cross-section sets separated by tin plates providing a compartment of about 1 cubic inch for each of 500 grubs. For shipment 2 of these boxes were packed together in a strong wooden case. The soil in which the grubs were packed had been thoroughly fumigated with carbon disulfide to eliminate any other insect material which might have

been present. In table 3 is a summary of shipments of parasitized grubs and the percentages of parasite emergence after arrival in the United States.

TABLE 3.—*Summary of shipments of Popillia japonica grubs parasitized with Dexia ventralis from Japan to the United States, 1929–31*

Year	Contents of shipment	Grubs shipped	Parasites emerging	
		Number	*Number*	*Percent*
1929	Grubs parasitized with first-generation *Dexia*	4,500	451	10.0
1930	Overwintered grubs parasitized with third-generation *Dexia*	3,000	377	12.6
1930	Grubs parasitized with first-generation *Dexia*	8,000	1,504	18.8
1930	Grubs parasitized with second-generation *Dexia*	7,000	1,423	20.3
1930	Grubs parasitized with second-generation *Dexia*	2,500	399	16.0
1931	Overwintered grubs parasitized with third-generation *Dexia*.	4,000	345	8.6
Total or average		29,000	4,499	15.5

Owing to the establishment of *Dexia ventralis* in the United States, from which material for recolonization was available, no shipments of this parasite were made after 1931.

PROSENA SIBIRITA (Fabricius)

The dexiid fly *Prosena sibirita*, which is generally distributed throughout the Asiatic and Malayan Regions, is an important parasite of *Popillia japonica* in Northern Japan. It has one generation a year and is capable of parasitizing and developing on numerous species of scarabaeid grubs of suitable size. The life history and habits of this dexiid have been fully dealt with in previous publications (*9*, *10*).

The shipments from 1923 to 1927, inclusive, consisted of field-collected grubs of *Popillia japonica*, which showed a general field parasitization of 10 to 15 percent. Because of the impossibility of detecting the presence of the parasite larva, which is attached to the main tracheal trunk of the host, all collected grubs were shipped. The grubs were dug in Hokkaido early in the spring and immediately forwarded to the United States, arriving there shortly before the emergence of the parasites. Although this method proved satisfactory, the transportation costs were extremely high, and in 1927 it was decided to parasitize the grubs artificially by a method that had been developed in 1921. This was accomplished by dissecting the first-stage larvae from the ovisacs of the gravid females and transferring them to the host grubs by means of a fine brush. To insure penetration by the parasites, the grubs with the small larvae were placed in cells of suitable size in wooden blocks for a period of 24 hours before being placed in the field, where they overwintered.

Late in the summer of 1928, 40,596 grubs were artificially parasitized in northern Japan and placed in a prepared soil plot, well drained, covered with sod, and surrounded to a depth of 18 inches by a fine-mesh screen to prevent the grubs from wandering away. These grubs were dug up early in May 1929, and 19,440 were alive, of which 19,000 were shipped to the United States.

In 1929 it was impossible to secure sufficient grubs for inoculation work. Consequently it was necessary to collect *Prosena* females and

ship them to the Yokohama laboratory and carry on parasitization work there with available, current-year grubs from that vicinity. Only 12 percent of the females were alive on arrival at Yokohama. This high mortality was due to the extremely hot weather prevailing at the time of shipment. Out of 364 females received alive, 159 contained larvae sufficiently developed for this work. During the latter part of August, 6,300 grubs were parasitized and placed in hibernation quarters. As experienced with the overwintered grubs parasitized with *Dexia ventralis*, the winter mortality was exceedingly high in this material and only 900 were alive when dug up the following spring. These with the 19,000 shipped in 1929, together with the 29,000 of *Dexia ventralis*, make a total of 48,900 grubs containing dexiids that were shipped to the United States during the period covered by this bulletin. The method of packing the parasitized grubs for shipment was the same as that described for shipment of grubs parasitized with *D. ventralis*.

No shipments of *Prosena sibirita* were made after 1930, as this parasite was then established in the United States.

SCOLIIDAE

During the course of the investigations from 1920 to 1933, inclusive, on the parasites of *Popillia* and related scarabaeid beetles in the Orient, a large number of Scoliidae, principally of the genus *Tiphia*, were found and intensively studied. Most of these species, which were considered to be new, have since been described (*2, 18, 19, 20, 21*).

In table 4 is presented the known distribution in Japan, Chosen, China, India, and Taiwan of all species of *Tiphia* reared or shipped since the initiation of the work. Of the 29 species listed in this table, 8 are known to occur in Japan, Chosen, and China; 2 in Japan and Chosen; and 1 in Chosen and China. No doubt further investigations will show a much wider dissemination throughout the Orient. Of the species mentioned in this bulletin, only *Tiphia biseculata* and *T. tegitiplaga*, parasites of *Anomala* and occurring in southern Japan, have 2 distinct generations a year.

TABLE 4.—*Record of known distribution of various species of Tiphia in the Orient*

Country and prefecture or province	Locality	*T. agilis*	*T. asericae*	*T. assamensis*	*T. bicarinata*	*T. biseculata*	*T. brevilineata*	*T. burrelli*	*T. castaneaerora*	*T. clauseni*	*T. communis*	*T. frater*	*T. homonculoris*	*T. isolata*	*T. korcana*	*T. matura*	*T. notopolita alleni*	*T. notopolita notopolita*	*T. oridorsalis*	*T. phyllophagae*	*T. popilliavora*	*T. pullitora*	*T. satoi*	*T. sternata*	*T. tegitiplaga*	*T. totopunctata*	*T. vernalis*	*Tiphia* sp. Shillong 1-A	*Tiphia* sp. Taiwan 2	*Tiphia* sp. Taiwan 5
JAPAN:																													
Ishikari-ken	Sapporo																							X					
Akita-ken	Wada						X										X												
Iwate-ken	Koiwai	X	X		X															X	X								
	Kuriyagawa				X																								
Miyagi-ken	Naruko																							X					
Nagano-ken	Nozowa																X												
	Nojiri																				X								
	Obuse				X																								
	Suzaka																X				X		X	X		X			
	Nagano				X								X				X				X		X	X					
	Ueda												X								X		X	X					
	Ikeda																				X								
	Iwamurada																X							X		X			
	Toyosu												X	X			X							X					
	Shimajima																				X		X						
	Kamisuwa																				X		X						
Tochigi-ken	Nasu																				X		X						
Saitama-ken	Kuroiso						X																						
	Chichibu																									X			
Tokyo-fu	Takao																									X			
	Tachikawa								X								X												
	Tokyo				X																		X			X			
	Asakawa																									X			
	Shinmaruko																				X								
	Hashimoto				X																		X						
Kanagawa-ken	Yokohama	X				X							X	X			X				X		X	X		X			
	Musashi																									X			
	Chigasaki					X																							
	Kanunomiya																						X						
Chiba-ken	Narashino								X								X												
	Kiyozumi																												
Shizuoka-ken	Mitho				X	X		X									X	X						X					
	Hamamatsu																												

Yamanashi-ken	Kofu																	X							X					
Aichi-ken	Futugawa																										X			
	Okazaki																										X			
Gifu-ken	Kagamigahara				X			X					X					X			X				X		X			
Nara-ken	Koriyama	X																												
Hiyogo-ken	Rokkosan	X												X																
	Hisazaki							X																						
Fukuoka-ken	Yokohashi																							X						
Oita-ken	Kujyu				X									X							X			X			X			
	Asaji																							X						
	Beppu																				X			X			X			
	Makiguchi																							X						
Kumamoto-ken	Namino													X			X				X									
	Miyaji													X			X				X				X					
Miyazaki	Kobayashi				X									X											X					
Kagoshima-ken	Kirishima													X							X				X					
	Ishiki							X																						
	Yoshimatsu				X																				X					
Nagasaki-ken	Unzen																							X						
	Shimabara																							X						
CHOSEN:																														
Kokai-do	Shariin	X																		X	X									
Keiki-do	Suigen	X	X		X		X						X		X		X	X	X	X	X		X			X	X			
	Gumpojyo																						X				X			
Chusei-nan-do	Iyujyo		X																				X				X			
	Seikwan																										X			
	Taiden																						X				X			
Keisho-hoku-do	Keishu																										X			
Zenra-nan-do	Koshu	X																												
Keisho-nan-do	Masan																						X				X			
CHINA:																														
Kiangsu	Chinkiang										X	X								X										
	Penniu										X						X	X		X	X									
	Yangchow										X									X										
Szechusen																										X				
Chekiang	Hangchow		X								X						X			X	X						X			
	Ningpo										X							X												
	Kuliang	X			X						X						X	X									X			
Anwhei	Sunkiang																										X			
	Nanking										X									X										
Yehzah																											X			
INDIA: Assam	Shillong			X												X						X						X		
	Cherrapunji									X																				
TAIWAN: Taihoku-shu	Hokuto																												X	X

Investigations have shown that the normal host grubs of these species of *Tiphia* occurring in several countries fall within generic rather than specific limits. This may be exemplified by *T. vernalis*, which has *Popillia quadriguttata* as its normal host in Chosen and *P. chinensis* in China, but will oviposit and develop on *P. japonica* equally as well. There is little variation in the biology of those species occurring in different countries or in widely separated areas in the same country other than the time of appearance of adults in the field. This variation in field appearance is due to temperature conditions and the presence of suitable grubs in the soil.

The lack of sufficient adult food and of suitable host grubs in the field are limiting factors that influence the effectiveness and distribution of *Tiphia*. The food supply of the adults consists mainly of honeydew exuded by aphids and other bugs, the blossoms of various plants, principally Umbelliferae and Polygonaceae, and the nectar from glands associated with certain plants such as the sweetpotato. Suitable host grubs are those species which are of sufficient size and are accepted by the *Tiphia*, and are present in the field, usually near the parasite feeding grounds, at the time when *Tiphia* adults appear in the field.

The position of the egg on the host grub for each species of *Tiphia* discussed in this bulletin is illustrated in figure 1. In the previous publications (*9, 10*) the egg position on the host grub is figured for all the species investigated during the period 1920–28, some of which are not mentioned in this bulletin.

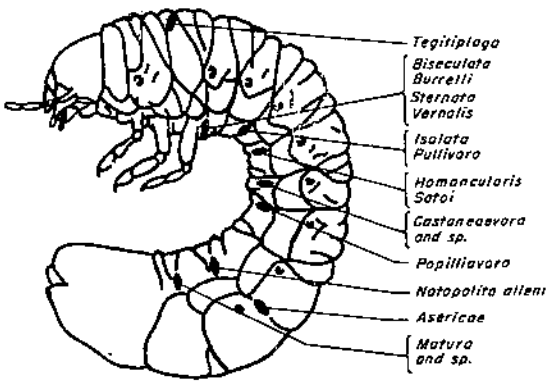

FIGURE 1.—The position of the eggs of various species of *Tiphia* on the host grub.

TIPHIA VERNALIS Rohwer

Tiphia vernalis was first found in Chosen as a normal parasite of *Popillia quadriguttata*, but later investigations revealed that it would oviposit and develop equally as well on *P. japonica*. The present knowledge of the distribution of *T. vernalis* indicates that it covers a greater range of territory than was at first supposed, and it is now known to occur at 7 localities in Chosen, 4 in China, and 16 in Japan. Although a normal parasite of *P. quadriguttata* in Chosen, it is assumed that its normal host in Japan is *P. japonica*, since this beetle occurs in all localities where this *Tiphia* is found. A full account of the life

history and general habits of *T. vernalis* at Suigen, Chosen, has been given in previous publications (*9*, *10*).

Previous to 1926 all shipments of *Tiphia vernalis* consisted of cocoons reared at Suigen. The work of propagating this material not only involved a tremendous amount of labor in rearing and packing, but necessitated laboratory overwintering in the United States and mating of the emerged females the following spring before colonization in the beetle-infested area could be attempted. While studying the life history of *T. vernalis* at Suigen it was found that the females lived approximately 6 weeks under laboratory conditions. In 1926 a trial shipment of adult females was made in specially constructed shipping containers provided with food and water for the females during transit. Although the material was en route approximately 25 days, this method of introduction proved satisfactory, and later investigations in the United States showed that imported females lived an average of 25 days after arrival and deposited an average of 38 eggs per female (*11*).

Shipments

The work on *Tiphia vernalis* at Suigen, Chosen, during the period 1929–33 consisted in collecting adult females in the field and shipping them to the United States. In addition, some rearing work was carried on in 1933. Owing to the rapid transformation of *Popillia japonica* grubs to the pupal stage after the middle of June, all consignments of adult females were forwarded so as to arrive at their destination before June 15. In table 5 is a summary of the various shipments of adult females from Chosen to the United States from 1926 to 1933, inclusive.

TABLE 5.—*Summary of shipments of adults of Tiphia vernalis from Chosen to the United States, 1926–33*

Year	Shipment	Adults shipped	Adults surviving shipment	
		Number	*Number*	*Percent*
1926	First	990	99	10.0
	Second	1,535	43	2.8
	Third	1,800	312	17.3
1927	First	3,584	2,841	79.3
	Second	6,284	2,370	37.7
1928	First	3,298	1,396	42.3
	Second	3,951	159	4.0
1929	First	5,285	4,574	86.5
	Second	5,700	3,689	64.7
1930	First	1,310	1,233	94.1
	Second	5,650	4,942	87.5
1931	First	2,899	2,736	94.4
	Second	2,819	2,523	89.5
1932	First	3,361	3,136	93.3
	Second	8,379	7,133	85.0
1933	First	12,413	10,237	82.5
Total or average		69,257	47,413	68.5
Total or average for the 5-year period covered by this bulletin		47,815	40,193	84.06

It will be seen that, with one exception, the first consignments of adults each year, which were collected shortly after emergence and before any extensive oviposition had been accomplished, gave a higher percentage of survival than those collected later in the season. The percentages of survival in shipments made after 1928 are noticeably higher, and this is accounted for by a change in the food In

the earlier shipments the food consisted of a weak solution of water and honey or sugar. After 1928 the food consisted of pure honey and pure powdered sugar kneaded into a composition resembling candy.

After the termination of collections for shipment in 1933, females were still abundant in the field at Suigen, and it was decided that this material be used in rearing work. From May 24 to June 26 a total of 11,031 females were collected, from which 65,653 parasitized grubs were obtained. These produced 37,045 cocoons, or 56.4 percent. Of this number, 28,380 were shipped to the United States.

Owing to the very successful establishment of several colonies of *Tiphia vernalis* in the beetle-infested area in the United States, from which thousands of females are available for colonization each year, no further introductions of this parasite are necessary.

TIPHIA POPILLIAVORA Rohwer

Tiphia popilliavora was first described from specimens collected at Morioka and Koiwai in northern Japan in 1920. The next year a few individuals were found at Yokohama, and subsequent investigations revealed the presence of this species at 16 localities in Japan, 2 in Chosen, and 2 in China. To date such anatomical differences as have been found in examination of specimen material from these 3 countries have not been sufficiently constant to warrant the assumption that more than 1 species is involved. This is also the opinion expressed by Allen and Jaynes (*2*). As is also pointed out by these authors, however, there are biological differences between the form occurring in Japan and those occurring in Chosen and China, and because of these differences individuals from each country are referred to as a separate strain or race. *T. popilliavora* is distinctly a parasite of the grubs of various species of the genus *Popillia* and depends on the host material available in the country where each strain occurs. In Japan it is parasitic on *Popillia japonica*, in Chosen on *P. atrocoerulea* and *P. quadriguttata*, and in China on *P. formosana*, *P chinensis*, and others of the same genus.

As discussed in a previous bulletin (*10*), the times of adult emergence in the field of the three strains in their respective countries are noticeably different. The Japanese strain in northern Japan emerges about the middle of August, or approximately 2 weeks earlier than the Chosenese strain, although the monthly mean temperatures at Suigen, Chosen, are higher during the period from February to November than the monthly mean temperatures at Koiwai, Japan. At Nanking, China, near which the Chinese strain is found, the monthly mean temperatures are higher throughout the year than at Suigen, but the Chinese strain does not emerge until the latter part of September, or 3 weeks later than the Chosenese strain. Thus there appear to be distinct biological differences in the time of appearance in the field of the three strains regardless of the variation in temperature in the three countries. This 2-week difference in the time of emergence between the Japanese and Chosenese strains also prevails in the United States where both strains have been subjected to the same temperatures.

From 1920 to 1923, inclusive, rearing work was carried on at Koiwai, Japan, with the Japanese strain of *Tiphia popilliavora*, and extensive shipments of reared cocoons were made to the United

States. Owing to the establishment of this strain, no further shipments of it were made after 1923, except for two unsuccessful shipments of adult females in 1925 and 1926. In 1925, 1926, and 1927 large shipments of reared cocoons of the Chinese strain and a very small number of reared cocoons of the Chosenese strain were made.

In 1930 it was felt that the Chosenese strain, because of its later appearance in the field, when the grubs of *Popillia japonica* are larger and more fully developed, would be more suitable than the Japanese strain in the United States. Rearing work was again taken up at Suigen, but owing to a limited supply of females in the field only 979 cocoons were reared and shipped in 1930 and 1931.

Tiphia matura Allen and Jaynes

In 1925 *Tiphia matura*, a parasite of several spring and early-summer species of *Popillia*, principally *P. cupricollis*, was found in the district surrounding Shillong in the Khasi Hills of Assam Province, India. The breeding grounds of this species were located in the sparsely planted pine forests in very hilly country, whereas the feeding grounds were found several miles away at the crest of a range of hills where a considerable growth of shrubs of various kinds was heavily infested with aphids. As pointed out in a previous bulletin (*10*), this wide separation between the breeding and feeding areas, requiring the females to travel through several miles of forest for feeding and then to return for oviposition, calls for a very unusual and interesting habit with this genus.

Extensive rearing work with *Tiphia matura* was carried on at Shillong in 1929, after which the work in India was discontinued. The spring of 1929, like that of 1928, was unusually warm, and the first individuals were found in the field on April 15. They did not become abundant, however, until after the spring rains, which were later than in 1928. On April 17 the sex ratio was about 50:50, after which the number of males increased so that by May 20 the sex ratio was approximately 25 males to 1 female. As a result of clear, warm weather during the last 10 days in May, the ratio of males and females available for collection again became normal. This period of good weather was followed by another spell of rain early in June.

The collection of females for rearing work was begun on April 17 and continued until June 25. The rains during the middle of May and early in June seriously handicapped collecting, and only 7,786 females were collected as compared with 12,606 and 12,418 females in 1927 and 1928, respectively. The maximum number of females in oviposition at one time was 2,168 as compared with 5,054 in 1928. The greatest number of eggs deposited in a single day was 771, from 1,893 females, and the total number of ovipositions obtained during the entire period, mostly on grubs of *Popillia cupricollis*, was 24,845. The general average was 0.30 egg per day per female, as compared with 0.39 in 1928.

In rearing the cocoons in the laboratory, a medium of soil and chopped moss was used instead of the usual composition of soil and sod. This combination improved the physical condition of the soil and retarded excessive loss of moisture, thus increasing the rate of cocoon formation. From the 24,845 grubs parasitized, 8,012 cocoons were obtained, or 32.3 percent.

Shipments of *Tiphia matura* cocoons in previous years did not leave India until the fall, but in 1929 the cocoons were divided into 2 lots and forwarded to the United States in the summer immediately after they were spun. The first consignment comprising 1,800 cocoons left Calcutta, India, July 18, and arrived at the Moorestown laboratory 38 days later. The material was placed on the boat at a temperature of 45° F., with the understanding that this temperature would be maintained throughout the voyage. The method of packing the cocoons differed somewhat from that employed in Japan. Wooden trays 15 inches square and 2 inches deep, fitted with cross-section sets, provided compartments 1 inch square and 2 inches deep. Two cocoons, each surrounded with moss, and separated from each other by a square of tin or celluloid, were placed in each compartment. The trays, each holding 450 cocoons, were then packed in large wooden cases in sets of five surrounded by a layer of fresh sphagnum moss.

The second lot of 6,000 cocoons was shipped from Calcutta August 8, and was en route 38 days at a temperature of 52° F. To simplify the packing and reduce the handling at their destination the cocoons in this shipment were packed individually in 2-inch vials stoppered with absorbent cotton, and these vials were placed in rectangular trays of perforated tin and held in place by cardboard cross sections. The trays, each holding 200 vials and surrounded by a 2-inch layer of fresh sphagnum moss, were packed in large wooden cases.

The condition of the cocoons in these two shipments was exceptionally good on arrival at Mooretown, N. J., as only 16 cocoons showed any signs of external fungus.

TIPHIA PULLIVORA Allen and Jaynes

During the investigations in India a small species of *Tiphia*, later described as *Tiphia pullivora*, was found in the Khasi Hills of Assam Province. This species is found in large numbers in the field from the latter part of July to early in October. Although its principal host under normal field conditions is a small undetermined ruteline beetle, it will also attack and develop on second-instar and early third-instar grubs of *Popillia cupricollis* and another species of *Popillia*. Because of this it was thought that this species might be of some value as a parasite of *P. japonica* in the summer and early part of the fall when the grubs are small.

Previous investigations showed that rearing work with this species was unnecessary owing to the large number of cocoons that could be collected in the field. In the fall of 1929 a total of 21,005 cocoons were collected and stored in a cool place awaiting shipment the following spring. Investigations, however, showed that adults from shipments of this species did not emerge at a time suitable for use against *Popillia japonica* in the United States, and instructions were sent from Moorestown, N. J., to discontinue all work with *Tiphia pullivora* and not to ship any cocoons on hand.

TIPHIA sp. Taiwan 5

At Hokuto, near Taihoku in northern Taiwan, adults of an undetermined species of *Tiphia* were found in the field in 1929 from the latter part of August to early in October. This species oviposited

and developed very readily on grubs of a species of *Popillia*, and it is assumed that the normal host in the field is a member of this genus. The adults feed at the nectar glands found at the base of the leaf petiole of the sweetpotato and other plants.

The egg, which is dark gray, is placed ventrally between the eighth and ninth abdominal segments with the anterior pole directed out (fig. 1). During the latter part of August and early part of September the egg stage covers 4 days and the larval stages approximately 10 days.

Because of the scarcity of this species in the field in 1929, only a few females were collected, and from these 911 parasitized grubs were obtained. These produced 387 cocoons, a percentage of 42.5. Of these, 379 were shipped to the United States.

THE PARASITES OF RELATED SCARABAEIDAE

During recent years three additional scarabaeid beetles from the Orient have become established in the eastern part of the United States. The oriental beetle (*Anomala orientalis* Waterh.), which was first found in Connecticut in 1920, has spread to Massachusetts, New York, and New Jersey; and the Asiatic garden beetle (*Autoserica castanea* (Arrow)), which was originally found in New Jersey in 1920, is now known to occur in Massachusetts, Connecticut, New York, Pennsylvania, Delaware, Maryland, the District of Columbia, and South Carolina. *Serica peregrina* Chapin, which was first found on Long Island, N. Y., in 1927, is not known to occur in any other State. Owing to favorable breeding conditions these pests have increased and spread, causing considerable damage to truck crops, ornamental plants, and lawns, especially in suburban areas, which are particularly suitable to both adult and larval feeding.

Outside the United States *Anomala orientalis* is known to occur in the Hawaiian and Philippine Islands and in Japan. In Japan, so far as is known, there is but one generation a year, the adults being present in the field from the latter part of June to early in September. The adults, which are both diurnal and nocturnal in habit, exhibit little activity in the lowlands during the day, but there is considerable daytime activity in the mountainous regions. Although this beetle is fairly common in some sections of Japan, there are no records in Japanese literature of its being of any economic importance to agricultural crops, and the writers have never observed it feeding to any extent on any plants of importance. Most of the adult feeding is confined to various species of *Polygonum* and other herbaceous plants which are common throughout Japan.

Autoserica castanea occurs in Japan as well as on the Asiatic mainland. In Japan it is the most common of about 35 species belonging to the Sericinae. There is only 1 generation a year, the adults appearing in the field from early in June to September. The adults, being nocturnal, are rarely seen during the day, but on warm, still nights they are abundant in some sections. A favorite place for them to congregate at night is around lights. As a pest of economic importance in Japan it is of little consequence. Some damage has been reported from the feeding of adults on young nursery stock and ornamentals and from grubs feeding in lawns. When grubs of this

species were being dug for parasite-rearing work at Yokohama, they were found to be most abundant in rather dry soil around the roots of *Artemisia* spp. and other weeds.

Serica peregrina is known to occur in Japan, Chosen, and China. It has only one generation a year in Japan, the adults being present in the field from late in June to late in August. Although this beetle is not considered a pest of major importance in Japan and Chosen, the adult is reported to feed at times on apple, pear, mulberry, barley, cauliflower, and asparagus in Japan, and on millet, cotton, and sugar beet in Chosen (*8*).

Although these beetles are considered of little economic importance in the Orient, their spread and increasing importance as pests in the eastern part of the United States has necessitated the investigation and study of their parasites in their native homes.

During investigations in Japan, Chosen, and Taiwan, no suitable parasites of the adults of these three beetles were found. *Hamaxia incongrua*, which is a parasite of both *Popillia japonica* and *Anomala orientalis* in Japan, has three generations a year and requires an alternate host to complete its yearly life cycle. No attempts have been made to introduce this tachinid parasite against *A. orientalis*, as repeated efforts to establish it against *P. japonica* in the United States have failed. In Chosen an undetermined tachinid was found which is parasitic on a species of *Serica*, but this parasite appears in the field during May, which is too early to be of any value against *Autoserica castanea* or *S. peregrina* in the present area of infestation.

Parasites of the Larva

SCOLIIDAE

Many species of *Tiphia* parasitic on *Anomala* and *Serica* were studied in Japan, Chosen, and Taiwan, but only 11 were considered of sufficient importance to warrant introduction. Although some of these, in their native habitat, are parasitic on grubs other than those established in the United States, investigations have shown that the species of *Tiphia* are, in general, generic rather than specific in their choice of hosts. These species of *Tiphia*, moreover, are localized in their distribution and are dependent on a sufficient supply of adult food and suitable host grubs.

During the period from 1929 to 1933 the species listed in table 6 were investigated and 77,270 cocoons and 6,139 adults were sent to the United States.

TABLE 6.—*Species of Tiphia parasitic on scarabaeid grubs of the genera Anomala, Autoserica, Phyllopertha, and Serica, investigated in Japan, Chosen, Taiwan, and China, and shipped to the United States*

Species of Tiphia	Countries	Hosts
T. asericae Allen and Jaynes	Japan, Chosen, China	*Serica* spp.[1]
T. biseculata Allen and Jaynes	Japan	*Anomala schonfeldti* Ohaus.[1] *Anomala orientalis.*
T. burrelli Parker	do	*Anomala cuprea* Hope.[1] *Anomala testaceipes* Mots.[1] *Anomala schonfeldti.* *Anomala rufocuprea.*
T. castaneaerora Parker	do	*Serica* sp.[1] *Autoserica castanea.*
T. homonacularis Parker	Japan, Chosen	*Serica* sp.[1] *Autoserica castanea.*
T. isolata Parker	Japan	*Serica* sp.[1] *Autoserica castanea.*
T. notapolita allani Roberts	Japan, Chosen, China	*Phyllopertha conspurcata* Har.[1] *Phyllopertha pallidipennis* Reitter.[1] *Anomala orientalis.* *Anomala schonfeldti.*
T. satoi Parker	Chosen	*Serica* spp.[1]
T. sternata Parker	Japan	*Serica* spp.[1]
T. tegitiplaga Allen and Jaynes	do	*Anomala schonfeldti.*[1] *Anomala rufocuprea.*[1] *Anomala orientalis.*
An unidentified species	Taiwan	*Phyllopertha conspurcata.* *Anomala* sp.[1]

[1] From field observation.

TIPHIA ASERICAE Allen and Jaynes

Tiphia asericae, a moderate-sized species, was first found at Suigen, Chosen, in 1924, and has since been recorded from China and Japan. In the Chosen area, where it has a 1-year life cycle, it is very abundant and is parasitic on various species of sericine grubs during June and early in July. Its life history has been fully treated in a previous publication (*10*).

During the years 1929 to 1932, inclusive, 167,264 ovipositions were obtained in the laboratory, giving the comparatively high rate of egg production of 0.97 egg per day per female. From these ovipositions 72,606 larvae, or 43.4 percent, developed cocoons, a much higher rate of cocoon development than that obtained in the breeding work carried on in previous years. During this 4-year period 61,270 of these cocoons were shipped to the United States. Early in June 1929 a consignment of 1,656 adult females was forwarded. Although the methods of packing and the food used were the same as in the successful shipments of *Tiphia vernalis,* only a few adults were alive on arrival at their destination. The results of experiments carried on at Suigen in 1929 to determine the longevity of adult females when stored in a cool place under shipping-can conditions indicated that the length of life of this species is considerably shorter than that of other members of the genus which have been worked with to date, and that the high mortality during shipment is due to this factor rather than to faulty shipping methods.

TIPHIA BISECULATA Allen and Jaynes

Tiphia biseculata is normally parasitic on *Anomala* spp., but investigation showed that it would develop readily on *Popillia japonica* in the laboratory. Consequently it was imported into the United States from 1924 to 1928, inclusive, as a parasite of *P. japonica.* Since

investigations in the United States showed that this *Tiphia* was of little value as a parasite of the Japanese beetle in the present areas of infestation, no further work was done with it until 1932. At this time a shipment of cocoons was made from which the emerging females were liberated as parasites of *Anomala orientalis*, which was becoming of increasing importance as a pest in the vicinity of New York.

This *Tiphia* is one of the two species which have two distinct generations a year in Japan. The first brood appears in the field during June and those of the second brood from late in August to late in October. The first brood is much more numerous than the second.

Previous to 1932 this species had been found in only one locality in Japan, at Miho, a small sandy peninsula jutting out a few miles into the sea near Shimizu in Shizuoka-ken. In 1932 *Tiphia biseculata* was found at Yokohama and Chigasaki, Japan, the last-named locality having much the same environmental conditions as those found at Miho.

Experiments carried on with the first generation in 1932 showed that this species accepted grubs of *Anomala orientalis* equally as readily as those of *A. schoenfeldti*, its normal host. Rearing work was carried on with the second generation at Miho from August 23 to October 24, 1932, and during this time 3,649 females were collected. Females were still abundant in the field when collection ceased. A total of 38,939 ovipositions were obtained which produced 8,507 cocoons, or 21.84 percent, of which 616, or 1.58 percent of the total ovipositions, were affected by fungus. This small percentage of cocoon formation, which is low as compared with many species of *Tiphia*, is accounted for by the fact that the parasitized host grubs move about a great deal in the oviposition tins and rearing flats, which tends to dislodge the eggs and young larvae. In the fall 7,692 of these cocoons were shipped to the United States.

Tiphia burrelli Parker

Tiphia burrelli was first found at Kagamigahara, Japan, in 1931 and later was found in small numbers at Miho and Hisazaki on the island of Honshu and at Ishiki on the island of Shikoku. Its normal hosts are the large grubs of *Anomala cuprea* and *A. testaceipes*, but it is parasitic also on *A. schonfeldti* and *A. rufocuprea*. Since no grubs of *Anomala orientalis* were available, laboratory tests with this species were not attempted.

The adults are found in the field from the first of September to the middle of October, feeding on the honeydew of aphids and other insects. There is one generation a year and the winter is passed as the mature larva within the cocoon.

The egg, which is grayish white, is placed ventrally between the last thoracic and first abdominal segment (fig. 1). Under September temperatures at Miho the incubation period is 5 days and the larval feeding period nearly a month. The large cocoon is similar to that of *Tiphia brevilineata* in having a thick feltlike covering pad with an uneven surface. The cocoon is a darker brown than those of most species of *Tiphia*, and somewhat glazed, lacking almost entirely the loose outer strands of silk.

Owing to the scarcity of adults, only 277 ovipositions were obtained in 1932, of which 61 developed to the cocoon stage, giving a develop-

ment of 22 percent. These cocoons were shipped to the United States for colonization against *Anomala orientalis.*

TIPHIA CASTANEAEVORA Parker

Tiphia castaneaevora, which closely resembles *T. asericae* taxonomically, was first found at Narashino, near Yokohama, Japan, in 1931, and the next year it was found at Tachikawa, near Tokyo. In the field it is parasitic on sericine grubs, and in the laboratory it was found to oviposit and develop very readily on *Autoserica castanea.*

The adults may be found in the field from the middle of May to the end of June, feeding in numbers on the blossoms of chestnut and oak. There is a single generation each year, and the winter is passed in the mature larval stage within the cocoon.

The grayish egg is placed in the suture between the fourth and fifth segments of the grub just ventrad of the lateral line and with the anterior pole directed toward it (fig. 1). The incubation period lasts from 3 to 5 days, and the development of the larva to the spinning of the cocoon requires 10 to 12 days. The cocoon is small and light brown, with a moderate filament.

From 1,153 females collected at Tachikawa in 1933 a total of 9,436 ovipositions were obtained, giving an egg-production rate of 0.85 per day per female. These ovipositions yielded 5,390 cocoons, or 57.1 percent cocoon formation. Of these, 5,066 were shipped to the United States for colonization.

TIPHIA HOMONCULARIS Parker

Tiphia homonculuris has been found in five localities in central Japan and at Suigen, Chosen. It is parasitic on sericine grubs and under laboratory rearing conditions develops very readily on *Autoserica castanea.*

The adults, whose food is the honeydew of aphids and other bugs, are found in the field at Yokohama from the first of September to the first of October. There is one generation a year, and hibernation takes place as a mature larva within the cocoon.

The eggs, which are slightly gray, are placed ventrally, usually between the third and fourth abdominal segments on third-instar host larvae, and usually one or two segments nearer the thorax on second-instar grubs, with the anterior pole directed outward. Apparently second-instar and third-instar grubs are equally favored, judging from the numbers of eggs in each of these positions on both field-collected and laboratory-parasitized grubs. The incubation period lasts from 3 to 5 days, depending on temperatures, and the development of the larva to the spinning of the cocoon requires approximately 20 days in September. The cocoon is rather small but otherwise normal in form and color.

This species apparently has a high rate of oviposition, as 66 females in one experiment deposited an average of 1.11 eggs per day per female. Although this species was moderately abundant at Yokohama in 1932, only limited rearing work was carried on owing to difficulty in obtaining a sufficient quantity of sericine grubs. From 1,101 ovipositions 274, or 24.9 percent, cocoons were obtained, of which 10 were affected by fungus. The 264 healthy cocoons were shipped to the United States in 1932.

TIPHIA ISOLATA Parker

Tiphia isolata, a small species parasitic on sericine grubs, was first found at Yokohama and later at Toyosu and Rokkosan on the island of Honshu and at five localities on the island of Kyushu. Laboratory investigations showed that it oviposits and develops readily on *Autoserica castanea*.

In the Yokohama district the adults, which feed on honeydew, are found in the field from the early part of September to the middle of October. There is only one generation a year, and hibernation occurs as the mature larva within the cocoon.

The egg, which is placed, with occasional variation, ventrally near the median line and between the second and third thoracic segments (fig. 1), is nearly white when first deposited but darkens with age. The anterior pole is directed outward. The incubation period covers from 4 to 5 days, and the development of the larval stage requires from 20 to 25 days. The cocoon is normal in color, but small, with no fluffy outer covering.

Owing to the small number of sericine grubs available, extensive rearings were not possible, and in 1932 only 79 cocoons were obtained for shipment to the United States.

TIPHIA NOTOPOLITA ALLENI Roberts

Tiphia notopolita alleni was found in 1922 at Suigen, Chosen, where it is primarily a parasite of *Phyllopertha conspurcata*, although some individuals attack *P. pallidipennis*. In 1924 it was found at Penniu, Hangchow, and Kuliang, China.

In 1931 and 1932 it was found at several widely separated localities on Honshu Island, Japan. At Nagano and Toyosu in central Japan there is evidence to date of a partial second generation similar to that of *Tiphia tegitiplaga*, as some individuals appear late in June and early in July, their progeny emerging in September. This species is much more abundant late in the summer and early in the fall, however, appearing from late in August to late in September. Although no investigations were carried on at Yokohama and Miho with reference to the first generation, it is presumed that the same seasonal cycle prevails in these localities. At Miho and Yokohama the adults are found in the field from the latter part of August to the early part of October. At Nagano the early adults feed on the honeydew of aphids, on soybeans, and on the blossoms of *Polygonum reynoutria*, while the late individuals feed on *Allium odorum*. At Miho they feed on the nectar gland at the base of the leaf petiole of sweetpotato, and at Yokohama they feed on white umbelliferous blossoms.

At Nagano and vicinity *Phyllopertha conspurcata* appears from field surveys to be the normal host. In the laboratory, however, it readily parasitizes *Anomala orientalis*, though cocoon formation on this host was poor. At Yokohama parasitized grubs of *A. orientalis*, *A. schonfeldti*, and *Phyllopertha* sp. were found in the field, and grubs of these species were also used in the rearing work. Second-instar grubs of *A. schonfeldti* were more readily accepted in the laboratory work than third-instar grubs of the same species.

The egg, which is light gray when first laid but turns darker before hatching, is placed between the seventh and eighth abdominal seg-

ments in the depressed area near the lateral margin, with the anterior pole directed outward (fig. 1). The duration of the egg stage is 4 to 5 days and that of the larval stages 15 to 17 days under September temperatures. The winter is passed as a full-grown larva within the cocoon. The cocoon is of medium size, loose and fluffy, and not separated by distinct layers.

In the fall of 1932 rearing work was carried on at Miho, Yokohama, and Nagano. At Miho from 176 females 643 parasitized grubs were obtained, which developed 149 cocoons, or 23.18 percent. At Yokohama 609 females parasitized 3,648 grubs, from which 526 cocoons, or 14.42 percent, were obtained. At Nagano from 709 females a total of 5,593 parasitized grubs were obtained, which developed 919, or 16.4 percent, cocoons. Of these cocoons 1,333 were shipped to the United States, the emerging adults to be used against *Anomala orientalis*.

TIPHIA SATOI Parker

In a previous publication (*10*) *Tiphia malayana* Cam. (*7*) was referred to as occurring in China and Chosen, but at that time it was thought that two distinct species might be involved on account of marked differences in life history and habits. In 1932 a species of *Tiphia* was found in Japan which at first was thought to be *T. malayana*, and biological studies were conducted on both the Chosenese and Japanese forms. In the course of these studies biological differences were observed which prompted a closer investigation of their taxonomic characters. This resulted in the determination of the Chosenese and Japanese forms as two distinct species, and these were later described as *T. satoi* from Chosen and *T. sternata* from Japan. Comparisons of the two species were then made with specimens from China designated as *T. malayana*, and these revealed taxonomic differences by which material from the three regions could be separated. Further study showed that none of the three species in question were *T. malayana*, and the form from China was later described as *T. frater* (*18*).

Tiphia satoi has been found in five localities in central and southern Chosen but never in any great abundance except at Suigen, where it was originally found. It is parasitic on the grubs of various sericine species that are in the third larval instar during the spring.

The adults appear in the field from the middle of April to the early part of June, this being the first species of the genus to appear in the spring in Chosen. For the most part the adults feed on the honeydew of aphids and occasionally on the blossoms of *Forsythia* sp. So far as is known there is only one generation a year, and the winter is passed as the adult, probably in the cocoon. The egg when first laid is white but darkens before hatching. It is placed ventrally between the third and fourth abdominal segments with the anterior pole directed outward (fig. 1). The egg stage requires 10 to 11 days and the larval stages 20 to 22 days in May. The cocoon is of a neutral color, and the outer covering is loose and not separated into layers.

In 1932, longevity experiments under shipping-can conditions were carried on to determine whether or not adults of this species could be successfully shipped to the United States. After being confined for 5 weeks 71.4 percent of the females were still alive and these lived an

average of 2 weeks longer, during which time they were confined with host grubs, and oviposited regularly, parasitizing an average of nearly 10 grubs per female.

In 1931, 86 cocoons, and in 1933, 46 females were shipped. Of the latter, 30 were alive on arrival in the United States.

TIPHIA STERNATA Parker

Tiphia sternata, a parasite of sericine grubs, is taxonomically close to *T. satoi*. It was first found in the vicinity of Yokohoma in 1931 and since then it has been found at nine localities in the central and east-central parts of Honshu and in seven localities in the northern part of Kyushu.

Both sexes appear in numbers from early in September to late in October. The female is believed to hibernate under ground, and during this time the eggs take form within the ovaries. The males apparently do not survive hibernation. These suppositions are based on the results of laboratory experimentation and the fact that to date field observations have shown the males to be very scarce in the spring. Females are again abundant in the field from early in May to the middle of June, when parasitization of the host takes place.

Experiments with fall-emerged and mated females in the laboratory have resulted in a few isolated cases of oviposition, but all other females dissected showed no signs of egg development within the ovaries. Periodical dissection of laboratory-hibernated females showed gradually increasing evidence of egg formation. Spring-collected females oviposit readily under laboratory conditions. As has been said, indications are that the males do not survive hibernation, therefore it may be supposed that males appearing in the spring are the result of occasional fall ovipositions and serve to fertilize the spring-appearing females. It is not known whether this complex exists in Nagano and central Japan where the mean temperatures are lower than those prevailing at Yokohama.

The egg, which is pale gray, is placed ventrally between the third thoracic and first abdominal segments with the anterior pole directed outward (fig. 1). The egg stage in the spring at Yokohama lasts 4 days and the larval period 10 to 12 days. In the few instances of fall oviposition that have been observed the egg stage lasted 4 to 5 days and the larval stage 20 to 22 days, depending on the temperature. The cocoon is normal in color with a small amount of exterior fluffy filament.

In 1931 a total of 200 cocoons were reared at Yokohama from spring-appearing females, and shipped to the United States. In the spring of 1933 2 shipments totalling 4,437 females were collected from the Yokohama-Tokyo district and shipped to the United States. Of these, 3,615 arrived at their destination alive.

TIPHIA TEGITIPLAGA Allen and Jaynes

Tiphia tegitiplaga, which was originally found at Miho, Japan, was later found at nine other localities in Honshu, one in Hokkaido, and four in the southern part of Kyushu.

At Miho there are two generations a year, the first appearing from late in June to the latter half of July and the fall generation from late

in August to the middle of September. In Nagano in central Japan two generations also occur, although individuals of the fall generation appear to be the more abundant. Here the time of field appearance is similar to that at Miho. The appearance of two generations at Nagano, which is much farther north and has a much heavier soil, seems somewhat unusual. These conditions are probably offset by the fact that Nagano is in a large valley where the summer temperatures are excessively high. In both localities hibernation of the fall generation occurs in the larval stage.

The spring generation at Miho feeds on the honeydew excreted by aphids on melon vines, beans, and truck crops, while the fall generation feeds on the nectar glands at the base of the leaf petiole of sweetpotato and the blossoms of buckwheat. Owing to the lack of truck crops and the sweetpotato at Nagano, feeding of the first generation is apparently confined to the honeydew found on a species of *Ligustrum*, and those of the second generation on honeydew on the leaves of mulberry.

At Miho the normal host is *Anomala schonfeldti*, although *A. orientalis*, *Phyllopertha conspurcata*, and a few sericine grubs were also parasitized. *A. rufocuprea* was the host most abundantly parasitized in the fall, and the parasite showed a decided preference for second-instar larvae. With grubs of *A. orientalis* as host material the preference was also for the second-instar larvae. The parasitization of second- and third-instar larvae of *Phyllopertha conspurcata* was equally divided, whereas of the few sericine grubs parasitized all were in the third instar. In the field at Nagano some *Popillia japonica* grubs were found bearing the dark egg scar which characterizes *Tiphia* oviposition, and in the proper position for parasitization by *T. tegitiplaga* (fig. 1). Although this *Tiphia* accepted *P. japonica* readily in the laboratory the percentage of cocoon formation was exceedingly low.

The pale-gray egg is laid dorsally on the second thoracic segment, usually near, and sometimes on, the median line, the anterior pole directed outward. The duration of the egg stage is 4 to 5 days and the larval stage 18 days for each generation. The females laid 0.92 egg per day in the laboratory.

Rearing work was carried on with the fall generation at both Miho and Nagano in 1932. A total of 2,020 ovipositions were secured at Nagano, but only 84 larvae developed to the cocoon stage. At Miho 7,363 ovipositions were obtained, and from these 1,367 cocoons developed. A total of 1,180 cocoons were shipped to the United States in the fall of 1932.

TIPHIA sp. Taiwan 2

An unidentified species of *Tiphia* was collected in very limited numbers at Hokuto, near Taihoku in northern Taiwan, late in the summer and early in the fall of 1929. This *Tiphia*, the adults of which feed on the nectar glands associated with the sweetpotato, are present in the field from late in August to early in October.

The pale-gray egg is placed ventrally between the fourth and fifth abdominal segments with the anterior pole directed outward (fig. 1). The egg hatches in 4 days, and the larval stage covers a period of 12 to 14 days in September.

Owing to the scarcity of this *Tiphia* in the field only a few females were collected, from which 155 ovipositions were obtained in 1929. These developed 47 cocoons (30.3 percent). Of these, 39 were shipped to the United States.

PARASITES ON WHICH NO INVESTIGATIONS WERE CARRIED ON DURING THE PERIOD 1929–33

During the course of investigations of the parasites of *Popillia japonica* and related Scarabaeidae in the Orient from 1920 to 1928, inclusive, the parasites listed in table 7, which were studied and imported into the United States, were, for various reasons, not included in the work carried on from 1929 to 1933, inclusive.

TABLE 7.—*Species of parasites of Popillia japonica and related Scarabaeidae studied in Japan, Chosen, China, and India during the period 1920–28 and imported into the United States, but not included in the work during the period 1929–33*

Species	Countries	Hosts[1]
Tachinidae:		
Peromyia genalis Aldrich	Japan[1]	*Popillia japonica*.[1]
Scoliidae:		
Campsomeris annulata (Fabricius).	Japan, Chosen, China	*Phyllophaga diomphalia* Bates.[1] *Anomala* sp.[1] *Popillia* spp.
Tiphia agilis Smith	do	*Serica orientalis* Mots.[1] *Serica* sp.
Tiphia assamensis Allen and Jaynes.	India	*Popillia cupricollis*.
Tiphia bicarinata Cameron	Japan, Chosen, China	*Anomala sieversi* Heyd.[1] *Phyllopertha pubicollis* Waterh.[1]
Tiphia brevilineata Allen and Jaynes.	Japan, Chosen	*Anomala sieversi*.[1] *Phyllopertha pubicollis*.[1]
Tiphia clauseni Allen and Jaynes.	India	*Popillia mutans*. *Popillia* sp.[1]
Tiphia communis Allen and Jaynes.	China	*Miridiba trichophorus* Falrm.[1] *Autoserica* sp.[1] *Popillia formosana*.
Tiphia frater Parker[2]	do	*Adoretus* sp.[1] *Serica* sp.[1]
Tiphia koreana Rohwer	Chosen	*Anomala sieversi*.[1] *Popillia atrocoerulea*. *Phyllopertha pubicollis*.
Tiphia notopolita Allen and Jaynes.	China	*Popillia chinensis*.[1] *Popillia formosana*.[1]
Tiphia occidorsalis Allen and Jaynes.	Chosen	*Serica* sp.[1]
Tiphia totopunctata Allen and Jaynes.	Chosen, China	*Anomala sieversi*.[1] *Phyllopertha pubicollis*.
Carabidae:		
Craspedonotus tibialis Schaum	Japan	*Anomala* spp.[1] *Serica* spp.[1] *Popillia japonica*.

[1] From field observation.
[2] In the second report (*10*) this species was listed under the name of *Tiphia malayana*. Subsequent studies of material from China disclosed the fact that this was an undescribed species. It has since been described as *T. frater* (*18*).

The tachinid *Peromyia genalis* was reared at the Riverton, N. J., laboratory from adults of *Popillia japonica* collected in central Japan in 1925 and shipped for rearings of *Hamaxia incongrua*. Since that time it has never been encountered in the work in Japan.

Because the work in China was discontinued at the end of 1926, no further investigations have been carried on with *Tiphia communis*, *T. frater*, or the Chinese form of *T. notopolita*, which, so far as is known,

occur only in that country. Termination of the work in India in 1929 brought to a close all work on *T. assamensis* and *T. clauseni*.

Rearing work with *Tiphia agilis*, *T. bicarinata*, *T. brevilineata*, *T. koreana*, *T. ovidorsalis*, and *T. totopunctata* was discontinued because of their time of appearance in the field. These species occur during July and August when the grubs of *Popillia japonica*, *Anomala orientalis*, *Autoserica castanea*, and *Serica peregrina* have pupated or are too small to be accepted by these parasites.

Adult shipments of *Campsomeris annulata* were discontinued at the end of 1926. Although this scoliid will oviposit and develop on full-grown grubs of *Popillia japonica* in the laboratory, its normal hosts in the field are of the larger ruteline species, particularly species of *Anomala and Phyllophaga*. This species has three generations a year, one of which is present in the field during midsummer when the grubs of *P. japonica* are very scarce in the present area of beetle infestation in the United States.

Shipments of the carabid predator *Craspedonotus tibialis* were discontinued after 1921 because attempts to establish this species were unsuccessful, probably because of the decided change in the ecological conditions.

REARING AND SHIPPING OF SCOLIIDAE

Rearing Scoliidae

The same general methods of rearing scoliid cocoons for shipment were employed as those used in former years and discussed in previous bulletins (*9, 10*). In India a composition of soil and chopped sphagnum moss was used in the rearing cross sections instead of the usual medium of soil and sod used in Japan and Chosen. This composition retarded the excessive loss of moisture and improved the physical condition of the soil, thus increasing cocoon formation. A summary of the rearing results obtained with the different species of *Tiphia* which have been studied during the period from 1929–33 is given in table 8. It will be seen from table 9 that of the five species of *Tiphia* that attack *Popillia japonica* (*T. popilliavora*, *T. vernalis*, *T. matura*, *T. pullicora*, and *Tiphia* sp. Taiwan 5), a total of 37,538 were shipped as reared cocoons during the period covered by this bulletin. The variance in the ratio of cocoons produced to the number of ovipositions, as between the different species, ranging from 4.6 percent in *Tiphia isolata* to 80.0 percent for *T. satoi*, may be attributed to differences in temperature and soil conditions existing in the various localities rather than to differences in the species themselves.

TABLE 8.—*Rearing results with various species of Tiphia*

Species of *Tiphia*	Country from which obtained	Year	Oviposition	Cocoons produced	Ratio of cocoons to ovipositions		Cocoons discarded	Ratio of discarded cocoons to produced cocoons	
					By year	By species and source		By year	By species and source
			Number	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
T. asericae	Chosen	1929	17,407	7,052	40.5	43.4	377	5.3	15.6
	do	1930	39,504	15,233	38.6		3,975	26.1	
	do	1931	65,804	31,662	48.1		3,191	10.1	
	do	1932	44,549	18,659	41.9		3,793	20.3	
T. biseculata (second generation)	Japan	1932	38,939	8,507	21.8	21.8	616	7.2	7.2
T. burrelli	do	1932	277	61	22.0	22.0	0	0	0
T. castaneaecora	do	1933	9,436	5,390	57.1	57.1	324	6.0	6.0
T. homan-ularis	do	1932	1,101	274	24.9	24.9	10	3.6	3.6
T. isolata	do	1932	1,648	76	4.6	4.6	9	11.8	11.8
T. matura	India	1929	24,545	8,012	32.2	32.2	212	2.6	2.6
T. notopalia alieni	Japan	1932	9,366	1,594	17.0	17.0	236	14.8	14.8
T. papilliacora	Chosen	1930	2,689	474	17.6	23.1	139	29.3	10.2
	do	1931	5,220	1,351	25.9		47	3.5	
T. satoi	do	1931	250	200	80.0	80.0	164	82.0	82.0
T. sternata	Japan	1932	410	208	48.4	48.4	8	3.8	3.8
T. tegitiplaga	do	1932	9,383	1,451	15.5	15.5	210	14.5	14.5
T. ursalis	Chosen	1933	65,653	37,045	56.4	56.4	6,665	18.0	18.0
Tiphia sp. Taiwan 5	Taiwan	1929	911	387	42.5	42.5	8	2.1	2.1
Tiphia sp. Taiwan 2	do	1929	310	86	27.7	27.7	8	9.3	9.3

During the course of rearing work with Scoliidae the young larvae in the cross-section trays come in contact with various factors in the soil which weaken them to such an extent that death often occurs after the spinning of the cocoons. The more important of these detrimental factors are attacks by fungi and disease, and unsatisfactory soil conditions, including insufficient moisture. Usually dead material can be distinguished by fungus growth and dark-brown discolorations on the exterior of the cocoons. Table 8 also shows a summary of the cocoons of the various species of *Tiphia* that were discarded at the time of packing because of the death of the larvae within the cocoons.

SHIPPING COCOONS AND ADULT FEMALES

The methods of handling and packing cocoons for shipment during the period 1929–33 were much the same as those that had given satisfactory results in previous years. Extreme care was taken in separating the cocoons from the soil in rearing trays, and in eliminating all fungus-affected, diseased, and crushed cocoons prior to packing.

The cocoons from Japan and Chosen were placed, with a small quantity of slightly moist sphagnum moss, in small individual containers 1 inch in diameter and $\frac{1}{2}$ of an inch deep. These tins were packed for shipment in a medium of slightly moist moss in tight wooden cases. Cocoons reared in India were packed individually, with a small quantity of slightly moist sphagnum moss, in tin cross-section sets, each compartment of which was of about 1 cubic inch

capacity. The cross sections were separated from one another by sheets of tin. On arrival at the Moorestown, N. J., laboratory the cocoons were taken out of their containers, placed individually in small vials, and stored in the temperature-control chambers for hibernation and emergence the following season.

With those species of Scoliidae that were sufficiently abundant in the field and that had an average longevity of 30 days or more, it was found to be more satisfactory and economical to ship adults than cocoons. In this case the adult females are released in the beetle-infested areas almost immediately on arrival, whereas with cocoon shipments field releases cannot be made until the following season, necessitating the added problems of overwintering of cocoons and mating.

The only change in the method of shipping adult females from that described earlier (*10*) was in the matter of food. In the early shipments from Japan, Chosen, and China the food consisted of a weak solution of either honey or sugar and water. This was followed in 1927 and 1928 by the use of a semisolid food consisting of Japanese agar mixed with either honey or sugar syrup in equal proportions, with greatly improved results. During the period 1929–33 still better results were obtained by the use of "good" candy, a composition commonly used as bee food. This was made by mixing and kneading powdered sugar, free of starch, into pure honey, which had been slightly heated, at the rate of 5 pounds of sugar to 2 pounds of honey. The resulting mixture was packed into the holes of a wooden food block and wired to the inside of the shipping can.

SUMMARY OF PARASITE SHIPMENTS TO THE UNITED STATES

From the inception of the project in 1920 to 1933, inclusive, large numbers of the various parasites in different developmental stages have been shipped to the United States. In table 9 is given a record of these shipments. The shipments from 1920 to 1928, inclusive, are given as a total for this period while the shipments made during the following 5-year period are listed separately under each year. Table 9 shows the country of origin of each parasite and the various stages of development of the parasites at the time of shipment.

TABLE 9.—*Record of shipments of parasite material to the United States for the control of the Japanese beetle and related Scarabaeidae, 1920–33*

Family, genus, and species	Stage of development	Source	1920–28	1929	1930	1931	1932	1933	Total
			Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Tachinidae:									
Centeter cinerea	Parasitized beetles, dead	Japan	603,495	18,000	9,500			6,163	637,158
Eutrixopsis javana	do	do	288						288
Hamaxia incongrua	Field-collected beetles, living	do	300,400						300,400
Trophops clauseni	Puparia	do					237		237
Pyrgotidae:									
Adapsilia flaviseta	do	India	17,662	3,800					21,462
Dexiidae:									
Dexia ventralis	Parasitized grubs	Chosen	21,324	4,500	20,500	4,000			50,324
Prosena sibirita	do	Japan	13,600	19,000	900				33,500
	Field-collected grubs	do	159,000						159,000
Scoliidae:									
Campsomeris annulata	Adult females	Japan, Chosen, China	31,060						31,060
	Reared cocoons	do	348						348
	Parasitized grubs	do	6,416						6,416
Tiphia agilis	Reared cocoons	Chosen	197						197
Tiphia asericae	Adult females	do	9,604	1,656					11,260
	Reared cocoons	do	935	6,675	11,258	28,471	14,866		62,205
Tiphia bicarinata	do	do	5,720						5,720
Tiphia bisculata	Adult females	Japan	3,651						3,651
	Reared cocoons	do	13,033				7,692		20,725
Tiphia brevilineata	do	Chosen	91						91
Tiphia burrelli	do	Japan					61		61
Tiphia castaneaevora	do	do						5,066	5,066
Tiphia communis	Adult females	China	107						107
	Reared cocoons	do	1,480						1,480
Tiphia frater	Adult females	do	1,216						1,216
	Reared cocoons	do	200						200
Tiphia homocularis	do	Japan					264		264
Tiphia isolata	do	do					79		79
Tiphia matura	do	India	27,470	7,800					35,270
Tiphia notopolita	do	China	33						33
Tiphia notopolita alleni	do	Japan, Chosen	42				1,333		1,375
Tiphia ocidorsalis	do	Chosen	99						99
Tiphia phyllophagae	do	Chosen, China	1,409						1,409
Tiphia popilliavora	Adult females	Japan, Chosen, China	2,249						2,249
	Reared cocoons	do	30,854		335	644			31,833
Tiphia pullirora	Field-collected cocoons	India	81,657						81,657
Tiphia sutoi	Adult females	Chosen						46	46
	Reared cocoons	do				86			86
Tiphia sternota	Adult females	Japan						4,437	4,437
	Reared cocoons	do				200			200
Tiphia tegitiplaga	do	do					1,180		1,180
Tiphia totopunctata	do	Chosen	476						476

Tiphia vernalis	Adult females	Chosen, China	21,442	10,985	6,960	5,718	11,720	12,412	69,237
	Reared cocoons	do	21,455					28,380	49,835
Tiphia sp. Taiwan 5	do	Taiwan		379					379
Tiphia sp. Taiwan 2	do	do		39					39
Carabidae:									
Craspedonotus tibialis	Adult beetles	Japan	16,450						16,450

SUMMARY

This bulletin is based on the results of further investigations on the natural enemies of *Popillia japonica* and related Scarabaeidae in Japan, Chosen, India, and Taiwan (Formosa) during the period from 1929 to 1933, inclusive.

Investigations were carried on with four species of Tachinidae and one species of Pyrgotidae parastitic on adult *Popillia* beetles, and with two species of Dexiidae and five species of Scoliidae parasitic on the grubs of *Popillia*.

Hamaxia incongrua and *Trophops clauseni* have two or more generations a year in Japan and are present in the field as adults over a longer period than the *Popillia* beetles and so require alternate hosts.

Centeter cinerea, the most effective parasite of *Popillia japonica* in northern Japan, was found to be well distributed on the island of Hokkaido, where it effects a high rate of parasitization each year. On the island of Honshu just south of Hokkaido it was found most abundant in the hilly and mountainous sections of the northern and western portions of the island, although its presence in various localities was distinctly variable and the degree of parasitization was considerably lower than that found in Hokkaido. *C. cinerea* was also found in the mountainous section of Kyushu, the most southern of the larger islands of Japan. From 1929 to 1933 a total of 33,663 puparia were reared and shipped to the United States.

Hamaxia incongrua, which occurs generally throughout the Orient, was found in many new localities on the islands of Honshu, Shikoku, and Kyushu in Japan, but the general rate of field parasitization was exceedingly low and variable.

No further records of *Eutrixopsis javana* as a parasite of *Popillia* were obtained. *Trophops clauseni* was found in several new localities in western Japan, but the percentage of parasitization in *P. japonica* was very low.

Further records of *Adapsilia flaviseta*, a pyrgotid parasite of *Popillia* beetles in India, revealed the same low rate of parasitization in the field as had been previously reported. In 1929 a total of 3,800 puparia of this parasite were reared and shipped.

Considerable rearing work was carried on with the two dexiids, *Dexia ventralis* in Chosen and *Prosena sibirita* in Japan. During this period 48,900 *Popillia* grubs were parasitized in the laboratory by these 2 dexiids and shipped to the United States.

Investigations were carried on with five species of *Tiphia* parasitic on *Popillia japonica*. *T. popilliavora* and *T. vernalis* occur in both Japan and Chosen, while *T. matura* and *T. pullivora* occur only in India. The presence of these species in abundance in the field was always localized, sometimes changing from year to year, being seemingly dependent on a sufficient supply of adult food and suitable host grubs. Extensive rearing work was carried on with these species of *Tiphia* and a total of 37,538 reared cocoons were shipped during the 5-year period. In addition, 47,815 adult females of *T. vernalis* were collected in the field and shipped, of which approximately 84 percent arrived in the United States alive.

During the course of the investigations on the parasites of *Anomala orientalis*, *Autoserica castanea*, and *Serica peregrina*, no suitable parasites of the adult beetles were discovered. A large number of species of *Tiphia* parasitic on grubs of *Anomala* and *Serica* were found, but only 11 species were considered of sufficient importance to warrant introduction. Of these *Tiphia biseculata*, *T. burrelli*, and *T. tegitiplaga* occur only in Japan and are parasitic on *Anomala*, while *T. notopolita alleni*, also a parasite of *Anomala*, occurs also in Chosen and China. *T. castaneaevora*, *T. isolata*, and *T. sternata*, all parasites of *Serica*, occur only in Japan, while *T. asericae* and *T. homoneularis*, also parasites of *Serica*, occur in both Japan and Chosen. *T. satoi*, which is very close to *T. sternata* taxonomically, is a parasite of *Serica* and occurs only in Chosen. Of all the *Tiphia* studied in Japan and Chosen, only *T. biseculata* and *T. tegitiplaga* have two generations a year. Like the *Tiphia* parasites of *Popillia*, these species of *Tiphia* are very localized and their effectiveness and distribution are dependent on a sufficient supply of adult food and suitable host grubs. Shipments of adults and reared cocoons of these 11 species from 1929 to 1933, inclusive, totaled 6,139 adult females and 77,270 cocoons.

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