thought would do. The bundles of parasites were unpacked and repacked in these five trunks, and, the superintendent of the office having approved, the traffic manager started with his five trunks and an additional hamper on the 6.50 train for Paris.

The rest of the story is that he made the journey without accident, got the trunks on the *La Lorraine*, where they were put into the refrigerating room. They arrived in New York on time, were met by the Government Despatch Agent, Mr. I. P. Roosa, hurried through the customs, and shipped to Melrose Highlands, where they arrived in admirable condition, and when Mr. Burgess unpacked them he found that practically all were sound.

No further comments on this incident are necessary.

NOTES ON THE LIFE HISTORY AND ECOLOGY OF *TIPHIA INORNATA* SAY

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The most important parasite, in the United States, of the grubs of the genus *Lachnosterna*, commonly known as "white grubs," is a black Scoliid wasp, *Tiphia inornata* Say. The work on which I have been engaged for the last year, September, 1912, to November, 1913, is the collection of sufficient numbers of the cocoons of *Tiphia inornata* to send to Porto Rico, in order that the species may be established there to aid in the control of the Porto Rican *Lachnosterna* grubs, which are a serious pest of sugar cane and other crops. For the successful collection of large numbers of *Tiphia* cocoons it was necessary to determine what factors limited the abundance of *Tiphia*, to the end that fields and localities might be found where these factors would be negligible, or nearly so, and cocoons would be present in abundance. The great majority of cocoons that have been collected are from localities not far from Urbana (my temporary headquarters) and Bloomington in central Illinois. All the observations here recorded, upon which are based the conclusions that are set forth in the following discussion, were made in central and northern Illinois, and are strictly applicable only to that region.

No attempt has been made to do any taxonomic work on *Tiphia*, for all the adults which emerge in Porto Rico from the cocoons sent from Illinois, after being used in breeding, are forwarded to Mr. S. A. Rohwer, for study and identification. The results of this work are not yet available. The life history notes are incomplete owing to the fact that the cocoons are sent to Porto Rico soon after collection, but observations to supplement the data here given may be expected

from the workers in Porto Rico—Mr. Thomas H. Jones and Mr. E. G. Smyth.

The literature dealing with other than the taxonomic features of *Tiphia inornata* is very meager. Dr. C. V. Riley in his Sixth Missouri Report (pp. 123–126) is the first to record anything of its parasitic habits, life history, abundance and parasitism by *Rhipiphorus pectinatus* Fabr. He also quotes the original description of the adult by Say and adds other descriptive notes, besides figuring the adult, larva and cocoon. Prof. S. A. Forbes in the Twenty-fourth Illinois Report (pp. 157–160) gives much interesting and definite information regarding the life history and habits, and the colored figure (Plate x) of the larva, cocoon and adult is very good. Mr. J. J. Davis in Farmers' Bul. 543 on "Common White Grubs" (pp. 15–16) figures the cocoon and gives some descriptive and life history notes. My attempt in this paper is to add to the life history data and descriptive notes given by others, but the discussion on the ecological factors is entirely original and has not been touched upon by previous writers.

LIFE HISTORY

The adult *Tiphia* is entirely black with many grayish hairs on the head, thorax and abdomen, and is easily distinguished from all other wasps by the color and the constriction between the first and second abdominal segments. The males are smaller and more slender than the females.

The female *Tiphia* is quite often observed on cement walks and on the ground, and indeed she spends the major portion of her time in or on the ground. She has a quick nervous walk, and her movements give one the impression that her eager search is without definite plan. Seldom is flight attempted, although the wings are used to help in short jumps or quick changes of direction. Earthworm holes and all sorts of cracks and holes are explored and often the wasp disappears in a hole in the earth that proves attractive. The females have slight difficulty in working their way through black heavy clay soil in good tilth and seem to be successful in finding grubs even in a field where they are not abundant. The grub is stung by the female wasp until it ceases to resist her attempts to deposit an egg on it, but the effect of the sting is only temporary. Indeed, the grub is often so active in burrowing through the soil that the egg, or even the young maggot, may be rubbed off. Grubs are often found with a brownish lesion showing the point of attachment of a maggot that has been rubbed off. The egg may be deposited on either the dorsal or ventral surface of the thorax of a one-third to fully grown grub. In one instance where the egg was deposited on the dorsal surface of the abdomen,

the maggot died while still very small. The ventral surface of the thorax appears to be a safer and more protected position for the deposition of the egg.

Incubation of the egg and the growth of the maggot while small takes several weeks, but the growth of the maggot from one-third to fully grown takes only two or three days. The grub seems not at all discommoded by the presence of the parasitic maggot while it is small, but when the maggot becomes about one third grown, the grub is less active, its movements being confined to a restricted area. Its feeble movements in the earth appear to have the effect of preparing a cell which is well adapted for the spinning of the cocoon of the parasitic larva. In practically all cases, all of the softer portions of the grub are absorbed by the parasite, and only the heavily chitinized head and legs and the shriveled skin of the grub are left.

In the earthen cell, which is practically empty after the destruction of the grub, the *Tiphia* larva spins its cocoon. This is an elongate pear-shaped affair, or it may be described more exactly as shaped like an Indian club or a summer squash with the neck eliminated. Indeed, comparison of its shape to that of a squash is more nearly correct, as the pointed tapering end is noticeably bent to one side. The cocoon is composed of downy silk of uniform texture, somewhat the color of khaki cloth. Often the color is darker or redder, but the variation is trifling. The silk of the smaller species of *Tiphia* is light yellow or flaxen in color. The color bleaches quickly in bright sunlight, and cocoons found in fields that have been plowed only one or two days previous show the side exposed to the sun faded to a light gray. The cocoon is loosely suspended in the cell by scattered strands of silk, but from the pointed end it is more firmly supported horizontally by a little button of silk in the outer layer of the cocoon. This little button is firmly attached to the side wall of the cell. Although the cocoon appears soft and downy, it is really quite firm underneath the loose outer network of silk, and the inner cocoon, while composed of silk of the same color, is very tightly woven. Entangled in the loose outer threads of the cocoon, the mandibles, skull (head case) and shriveled skin of the grub are usually to be found.

It has been supposed that the eggs are often deposited on grubs too small to furnish sufficient nourishment for the parasite maggot to become fully grown and in such cases small cocoons are formed. It is almost certain, however, that these smaller, flaxen colored cocoons are produced by another smaller species of *Tiphia*, which attacks only small grubs, as these small flabby cocoons are often found in fields where large grubs are abundant. The males of *Tiphia* are considerably smaller than the females and the cocoons from which they emerge are usually smaller than those of the females.

In the late fall a considerable period may elapse after the spinning of the cocoon before transformation to pupa takes place, in fact, pupation may not occur till spring. But if the cocoon is formed early in the fall transformation to adult may be immediate. Indeed, it appears that *Tiphia* may hibernate either as larva, pupa or adult inside the cocoon. During the summer, however, the cocoon is occupied only a short time between the spring and fall generations. The shed pupal skin contains a considerable amount of a dense white fluid, which later dries in a solid mass. If the adult is active in the cocoon, the pupal skin is ruptured and the dried white mass is ground to a powder which is often seen dusted over the adult *Tiphia* when newly emerged. Sometimes the adult is active before the fluid dries and it presents a sorry spectacle, when the cocoon is cut open, as it crawls out covered with large chunks of the dried fluid adhering. Probably with normal emergence the adult is seldom covered with this powder, for many cocoons are found from which the adults have emerged and the pupal skin remains undisturbed and unbroken in the pointed end of the cocoon.

All my observations indicate that invariably the adults emerge through a hole cut in the side of the cocoon towards the surface of the ground. Usually this is also the larger end of the cocoon, where the head is located, but cocoons have been found with the exit hole cut half way, or more, down the side. This condition is not usual, and occurs only in cocoons exposed by the plow. Plowing a field has a most decided effect on the emergence of the adults from the exposed cocoons. Adults which would otherwise hibernate in the cocoon, often emerge late in the fall. Spring plowing may produce an earlier emergence because of the unnatural warmth caused by a few days' exposure to the direct rays of the sun. In 1913, normal emergence was general at Bloomington, Ill., on May 14. Indeed, after this date very few cocoons could be found from which the adults had not emerged. As grubs parasitized with very small maggots are found as late as the middle of September, the evidence seems to indicate two generations during the year. Plowing is not usual during the summer and it is difficult to tell what the normal subterranean habits of *Tiphia* are. The adults which prematurely emerge from their cocoons late in the fall appear to perish without ovipositing, as parasitized grubs are never found as late as October 1 as far north as Bloomington and Urbana, Ill. Early fall plowing, and indeed fall plowing in general, must be very unfavorable to *Tiphia*. Even those cocoons which are deep in the ground and are not disturbed by the plow will be somewhat affected, but the majority of cocoons are formed less than six inches from the surface, or in that part of the soil which the grubs normally inhabit during the summer months, and these are exposed to the

weather and to the attacks of birds and predaceous mammals and insects.

ECOLOGY

The various species of *Lachnosterna* in the Middle West are attacked by a considerable number of parasites and predators, but undoubtedly *Tiphia inornata* is the most important. I am convinced that under favorable circumstances *Tiphia* does greatly reduce the numbers of grubs and in some cases practically exterminates *Lachnosterna* from limited areas. The evidence is this: In some fields (near Randolph, Hendrix, White Heath, Ill., and at many other places) one will find many cocoons from which adults have emerged, a few in which adults are contained, and a very few grubs or beetles. Or in fields in which practical extinction of the grubs has taken place a year or more ago (near Weldon, Minooka, Seymour, Homer, Ill., and at other places) one can find only old rotten cocoons from which adults have emerged several months or a year previously, and few or no grubs and beetles.

The adult females of *Tiphia* are not strong fliers and they tend to remain in the field where their immature stages have been passed. When the grubs are abundant, no difficulty is experienced by the female *Tiphia* in finding sufficient numbers for the deposition of a large number of eggs. The rate of multiplication is rapid, for two generations of *Tiphia* probably occur during the summer. The supply of non-parasitized grubs in a field soon tends to become exhausted, necessitating a more careful search by the female to find a host for her eggs. The female, loath to search at great distances, eventually parasitizes practically all the grubs of suitable size in a field, until the dispersion of the females to new localities is necessary unless large numbers are to perish without depositing eggs. The males can fly long distances and are often collected feeding on the flowers of goldenrod and asters, but the females are less often found in these situations and apparently have difficulty in flying any great distance.

There are, however, several checks to an unusually great increase of *Tiphia* in restricted localities. Under favorable conditions, a fungus (probably *Isaria* sp.) causes a heavy mortality. Cocoons are often found covered with a web of white mycelium densely covered with spores, spreading out into the surrounding earth. It has not yet been determined how infection by the fungus takes place—whether the spores only attack the parasite egg or maggot, or whether the mycelium is able to penetrate the cocoon. It may be that the fungus attacks *Tiphia* only when it is weakened by unfavorable conditions, such as sudden changes in temperature or too much or too little moisture, and is not pathogenic on healthy individuals. Naturally when *Tiphia* is most abundant the fungus will have the least difficulty in spreading and often nearly all the *Tiphia* in a field are killed in this way.

In addition to the fungus, *Tiphia* is attacked by at least two parasites—a bee-fly, *Exoprosopa fascipennis* Say (Bombyliidæ) and a beetle (Rhipiphoridæ). Riley identified the beetle emerging from cocoons collected in Missouri as *Rhipiphorus pectinatus* Fabr., but determinations have not yet been made of the beetles which emerged from cocoons collected in Illinois. The details of the life histories of neither of these parasites have ever been worked out. They seldom infest more than 1 or 2 per cent of the *Tiphia* cocoons. In one field, however (near Randolph, Ill.), a large number of the older cocoons in the field, instead of having a side emergence hole, showed the entire blunt end of the cocoon cut off. This was evidence of heavy parasitism by the Rhipiphorid, as *Exoprosopa* leaves its pupal case in a hole in the side much similar to that cut by the *Tiphia* adult. Cocoons showing no emergence hole are often found in the field pierced with a considerable number of small holes less than 1 mm. in diameter. The interior of such cocoons is entirely empty. What causes this is not known, although it may result from the grass roots which are often found wrapped round cocoons, or possibly the mites which often infest the grubs attack the cocoon when their normal host is destroyed by *Tiphia*. It has been suggested that ants might also cause this type of injury.

Although the parasites and the fungus are important in controlling the numbers of *Tiphia*, the most important check to the natural increase of the species is the lack of host grubs. *Lachnosterna* grubs are not present in noticeable abundance in the great majority of fields in central Illinois. Frequent plowing, rotation of crops, heavy pasturing of meadows and fields to horses, cattle and especially to hogs, which root in the soil after the grubs and destroy large numbers of them, and the absence of nearby trees to furnish a food supply to the adult beetles, may be mentioned as the more important checks on *Lachnosterna*.

The last mentioned factor seems to be of greater importance than is generally realized. The grubs of the species of *Lachnosterna* of which the adults prefer to feed on the leaves of willow and cottonwood (*Populus deltoides* Marshall) are almost invariably found abundant in those fields in which there are several large cottonwood trees. In the more hilly portions of Illinois, where fewer trees have been cut down, or even in fields near orchards or woods of oak, elm, ash, birch, linden, locust and walnut, *Lachnosterna* grubs are sufficiently abundant to cause serious loss to the farmers. Hedge (Osage orange), box elder and maple are the only three common trees that are not acceptable food plants to any *Lachnosterna* beetles, while cottonwood and willow are preferred by most of the common species. Oak and elm are a good third and fourth, but other trees are of minor importance. Despite the state-

ments in literature regarding the dispersion of the adults by flight to parts of the field distant from the food trees, the long flights observed are probably made by the males, for almost invariably grubs are most abundant near the food supply of the adults. In fields half a mile, or even quarter of a mile long, grubs will be abundant in the end near trees, and practically absent at the other end if no trees are near. Of course, grubs are not always abundant near trees, even when all other conditions seem favorable, and occasionally solitary grubs are found in fields a mile or more from the nearest food tree, and sometimes these grubs are parasitized, but these are exceptions. The comparative absence of trees throughout large areas of the more fertile and more valuable portions of Illinois, probably is the most important factor in limiting the abundance of *Lachnosterna*. If an abundance of grubs were to be found in most fields, the dispersion of *Tiphia* females would be greatly facilitated from a field in which most of the grubs have been parasitized, but as the supply of grubs is usually localized to a small area near a woods or clump of trees, the *Tiphia* remain in this locality, destroying all the grubs, and are themselves destroyed by the fungus which can more easily cause an epidemic among its crowded hosts, or else they perish without ovipositing while traveling to distant fields in search for grubs.

Practically all the fields from which the largest numbers of *Tiphia* cocoons have been collected were of these two types, either with several large cottonwood trees in the field or in a nearby hedgerow (near Champaign, Randolph, Wapella, Minooka, Hendrix, Ill.) or near oak or mixed woods (near White Heath and Monticello, Ill.). From only four other fields have collections of any size been made and these were of minor importance (near Rantoul south, Rantoul north, Monticello, Cerro Gordo, Ill.). Even in these cases, cottonwoods, willows, oaks or elms were not more than quarter of a mile away, and in at least two instances the fields had been unpastured meadows for several years prior to being plowed. In the great majority of all the fields, the plowing was for corn (5 to 7 inch deep) on land that had been in sod (clover, red and alsike, or grass) for two or more years and had not been pastured. The deep plowing made collection of cocoons possible and the other factors were of importance in producing an abundance of grubs—a potential host supply for a subsequent abundance of *Tiphia*.

In the more hilly and wooded sections of Illinois, the soil is not the typical black clay and brown silt loam of central Illinois, but is a gray clay of poorer texture, or a sandy, gravelly loam. To both of these types of soil another parasite of *Lachnosterna*, *Elis sexcincta* Fabr., seems to be better adapted, for in collections made near Galesburg,

Peoria, Allentown, Henry, Putnam, Sheridan, Rockford, Freeport, Winnebago and Belvidere, *Elis* is much more abundant and *Tiphia* is found in smaller numbers. Conversely, *Elis* is found in small numbers on the black clay and brown silt loam to which *Tiphia* is better adapted.

Still another factor which is of great importance in restricting the range of *Tiphia* is that only a single generation of the dominant species of *Lachnosterna* is present in some localities. For most species of *Lachnosterna* three years are required for the completion of the life cycle. The year that full grown grubs are abundant there would be an ample supply of hosts for *Tiphia*, but the next year only beetles, eggs and very small grubs would be present. Just this condition occurs in northwestern Illinois and every third year the farmers suffer great losses from the grubs. Probably the condition existing in this region some time ago was that parasites, such as *Tiphia* and *Elis*, were present, feeding in the years when the dominant species occurs as beetles or very small grubs, on the full grown grubs of some other species of *Lachnosterna*. In the year when the grubs of the dominant species were abundant, the numbers of *Tiphia* increased greatly. The next year the grubs of the non-dominant species would be only a meager supply to the large numbers of *Tiphia* and practically all the grubs would be parasitized. This would eliminate the non-dominant species, and in the coming years *Tiphia* would have no host in the years when the dominant species did not occur as large grubs, and it also would be exterminated. The elimination of the non-dominant species may also have been caused by the cutting down of trees that formed the food supply of their adults. Whatever caused the elimination of the non-dominant species, until conditions are again favorable for their increase no possible assistance can be expected from *Tiphia* in the destruction of the dominant species.

There appear to be at least five important factors controlling the abundance of *Tiphia inornata*: (1) Scarcity of large grubs in the years when the dominant species occurs as beetles and small grubs. (2) A permanent scarcity of grubs caused by unfavorable agricultural practices, or the absence of trees to furnish a food supply for the adults. (3) Unfavorable soil—which favors other parasites of *Lachnosterna*. (4) Parasites on *Tiphia* and the *Tiphia* fungus, *Isaria* sp. (5) Fall plowing—which causes premature emergence of adults and exposure of cocoons to predators.