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TACHYTES SINENSIS F. SMITH

In my previous paper in Japanese (Seibutsu, Vol. 1, No. 3, 146–149, 1946) I dealt with this apecies as *T. etruscus* Rossi and the record was cited by Pulawski (1962) in his monograph of the genus of the Palaearctic region with a foot note of my remarks that the species was not *T. etruscus*, but a closely allied relative. The identification of the specimen that I observed was made when I attempted the taxonomic study of the genus in Japan and was published in No. 5 (1964) of this Publication. It was an exceptionally small individual of the species dealt with here, with the somewhat abnormal hair bands on the abdomen.

August 4, 1943, a fine day, at about 11:00, in the valley of Shoyozan, Central Korea, during my observation on the life of *Sphex haemorrhoidalis* I took notice of a *Tachytes*-wasp carrying a prey along the road. The wasp mounted on the back of the prey astride, caught it by the base of the antennae and was proceeding, sometimes on foot and sometimes on the wing from grass to grass. The prey was a long-horned grasshopper and was apparently a male of *Ducetia japonica* Thunberg. I at once followed her. She soon went aside out of the road to a heap of fallen leaves and from a crevice among them penetrated with the prey into the heap. The crevice was a somewhat rounded opening, showing that it had repeatedly been used by the wasp as a passage to her nest below. In the opening the prey was partly seen to be left there. In less than a minute the grasshopper was moved from within and little by little disappeared out of my sight. I at once raked aside the leaves and found there the entrance to the nest of the wasp which was closed with soil pushed out of the tunnel. I covered the entrance with my insect net and waited for her coming out. She did not reappear for about 5 minutes. So I began to dig the nest.

The entrance gallery ran in a gentle inclination for about 2 cm and this portion was loosely packed with soil. Then it opened to the empty tunnel, about 10 mm in diameter and began to incline, describing a parabolic curve. It went in 17 cm perpendicularly, then suddenly turned at a right angle and proceeded further 13 cm. There I found the wasp eagerly close the tunnel. I caught her. The horizontal part of the tunnel was somewhat sloped up toward the interior. The end of her closure became concave and I could suppose that the wasp used her head in pressing the soil. I further followed the filled portion of the tunnel with some difficulty for 15 cm and reached the brood-cell (Fig. 1). It was only the end part of the tunnel, without being enlarged (10 mm across) and roundly narrowed apically. The space where the prey was packed was 37 mm in length, slightly raised inward.

In the cell were collected 3 prey, all head in, but their bodily orientation was uncertain:

The innermost and lowermost one ... *Xiphidion* sp., ♂, nymph, dorsum up.

The middle one ... *Ducetia japonica* Thunberg, ♂, imago, side up.

The outermost and uppermost one ... The same as above, venter up.

The last was the prey that I observed and to it the egg of the wasp was deposited. It was

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glued between the front and middle pairs of legs, somewhat closer to the middle pair and on the median line with its anterior end, lying crosswise, with the other end produced sideways. It was 4.5 mm in length, pale yellow in colour, slightly thickened toward the end.

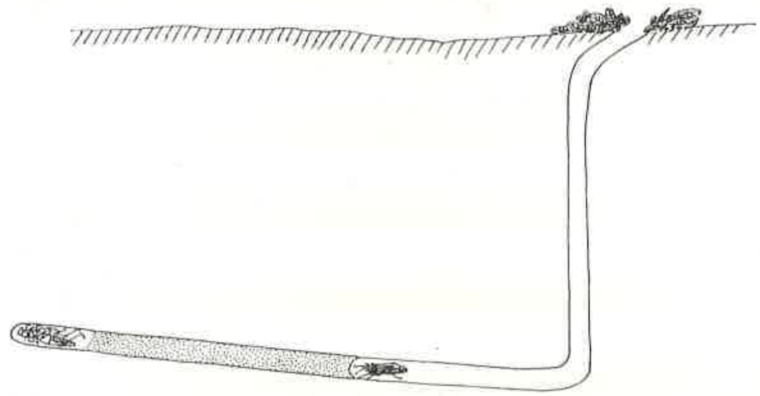


Fig. 1. The nest observed of *Tachytes sinensis* F. Smith.

Probably the wasp intended to close the horizontal part of the tunnel completely and to dig a new tunnel in some other direction to make a new larval chamber. I thought that another larval cell or cells might have deen made elsewhere and searchd for it by enlarging the excavation from the end of the perpendicular tunnel. But it ended in vain.

This species occurs also in Japan, distriduted from the south- to the central region, but is not abundant. In the collection of the Osaka Museum of Natural History I found a female specimen accompanied by the prey on the same insect needle. It was a nymph of probably *Holochlora japonica* B. v. W.

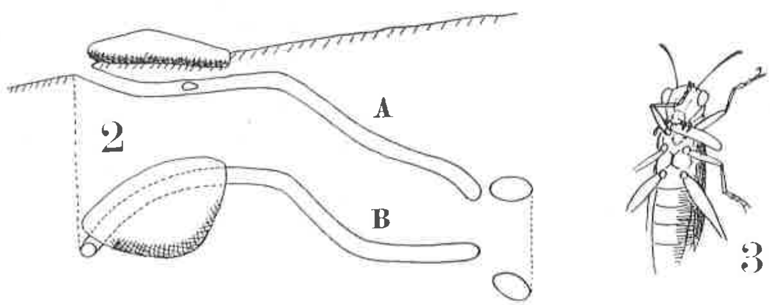
Recently Iwata (1964) published his observation on the biology of fossorial wasps in Thailand. On page 368–369 of his paper he recorded a prey of *Tachytes sinensis*. It belonged to the short-horned grasshopper (!), *Sphingonotus* sp. It seems very strange, because in Japan and Korea *T. sinensis* is always a hunter of the long-horned grasshopper. The reexamination of the wasp specimen seems to be needed.

TACHYTES EUROPAEUS ORIENTIS PULAWSKI

The nest and the prey of this species were recorded by me in Japanese in my book, A Naturalist at the Front (1942), under the name, *Tachytes obsoletus* Rossi. Recently W. J. Pulawski in his monograph on the Palaearctic *Tachytes* (1962) cited the account and presumed that the material was not *T. obsoletus*, but was a closely resembling species, *T. europaeus* Kohl and would correspond the subupecies *orientis* Pulawski. I examined the specimens at hand and could confirm that his presumation was correct. My observation on the biology of this subspecies was performed in 1939 in the grassland of Inner Mongolia.

On a small terrace along a dried valley between hills sparsely covered with grass there was a patch of land where the grass was much sparser and several species of the ground nesting wasps, such as *Sphex maxillosus* F., *Cerceris* spp. were found nesting.

When I found the wasp she was running among herbs with a prey, a short-horned grasshopper of about 13 mm in length, with the greenish venter. It was caught by the wasp by the base of the antennae with her màndibles. The wasp was hurriedly running about; from time to time she climbed up the grass stem to fly from the top, hanging the prey from her mouth. The distance covered by a flight was considerable great. Finally she reached her nest, after crossing the grassland more than 15 m, the entrance of which was open at a side of a flat stone of the palm size. The wasp left the prey at the entrance and entered the nest free-handed. But soon she turned back, caught the prey by the antennae and dragged it backing into the tunnel.



Figs. 2-3. 2 ... A nest of *Tachytes europaeus orientis* Pulawski (A ... Dorsal view; B ... Lateral view). 3 ... A prey of this species with the egg of the wasp.

After waiting a while I examined the nest. It was as shown in Figure 2. The tunnel was about 8 mm in diameter and was closed before the larval cell which was slightly bent sideways against the direction of the tunnel. In front of the closure the wasp was found resting and was caught by me. The cell was 15 mm in length, about 10 mm in height and contained 2 prey, both head in, one venter up and the other (inner one) side up. To the latter the egg of the wasp was laid. It was attached to the inside of the right procoxa, lying slightly obliquely across the breast and produced a littte from between the fore and middle legs of the left side (Fig. 3). In the tunnel below the stone a pebble, about twice as large as the head of the wasp, was placed. It seemed to me that the wasp intentionally carried it in from outside the nest to block the tunnel. The deviation of the terminal of the tunnel from the direction of the cell was considered to show that the wasp had finished the provisioning to the cell and was working to dig a branch tunnel to build a second cell at its end.

The prey were later identified by Dr. H. Furukawa with:

1. *Dasyhippus barbipes* Fisch. W. ♂, nymph (ultimate instar),
2. *Chorthippus dubius* Zub., ♀, nymph (ultimate instar).

TACHYTES NIPPONICUS TSUNEKI

On October 11, 1963, toward 14:00, I took notice of a wasp that came flying and dropped on to the ground, 1 m in front of me, with a prey. I thought that she was on the way of her prey transportation to her nest and as it seemed impossible to follow her I captured her, robbed her of her prey and let her go. Soon she came back to the place and began to search for the prey. During the observation several wasps of this species came to the area and walked about among the grass. The place was the west-faced slope of the embankment of the River Kuzuryu, near the mountain region of Fukui Prefecture. The grass covered so densely the slope that I could not follow the wasp with my eyes. Hereupon I understood that the place was the nest ing site of these wasps and regretted that I had treated the above mentioned wasp so roughly. I waited for about an hour, but I could not see any wasp come back with a prey. I searched among the grass for some nests, but could not find out even a single of them.

The prey I obtained was the female adult long-horned grasshopper, *Conocephalus gradiatus* Redtenbacher.

Sibuya's observation. In 1950 Sibuya reported in Japanese his observation made in Tottori Prefecture on a species of *Tachytes* which he called *T. etruscus* Rossi. However, this species does not occur in Japan, but a species closely allied to this which I named *T. nipponicus* is not rare in the hilly regions of the Japan-sea side of Japan proper and so his observation was probably done on this species. In the following what he reported will summarily be cited.

A colony of this species, consisted of about 10 females was found on the well trodden clayey ground of a Middle School and observed by him during 2–8. X. 1949. Burrowing is made usually early in the morning, but sometimes also in the day. In digging the wasp comes out to the entrance backing with a burden of soil holding it with the front and middle (?) pairs of legs. Then she hands it over to the hind legs which with the cooperation of the pygidial area push it out to all sides of the opening, thus forming a mound of soil at the entrance. The entrance was slightly broader than the tunnel, 10×9, 13×13 in two instances. The wasp with a prey returns to the nest always on the wing. When she lands the prey (*Conocephalus* sp.) is seen to be held venter up. It is captured by the wasp by the base of antennae, but none of the legs cooperates to keep the prey. He did not examine the nest.

According to these observations the habits of this species is supposed to be similar to those of the preceding species.

TACHYSPHEX BENGALENSIS JAPONICUS IWATA

Tachysphex japonicus Iwata, Trans. Kansai Ent. Soc., 4: 27, 1933 (original description).
Tachysphex japonicus: Sibuya, Ibid., pp. 51–64, 1933 (biology, in Japanese with English summary).
Tachysphex japonicus: Masuda, Ent. World (Tokyo), 7 (61): 161–167, 7 (62): 229–236, 1939 (biology, in Japanese, but partim).
Tachysphex bengalensis japonicus: Tsuneki, Etizenia, 20: 52, 1967.

The biology of this species was first recorded by Sibuya (1933) and later by Masuda (1939). But Masuda confused this species with *Liris japonica* and in his report the biology of the two species are given in confusion. Before describing my own observations the contents of the two papers will briefly be given.

Sibuya's report: The wasp makes the nest on the sandy area, well shined by the sun. The time needed to dig a burrow is about 50–80 minutes. While the wasp is out the entrance to the nest is left open. The tunnel is 5–6 mm in diameter. The nest belongs to the compound type, including 2–3 cells, most usually 2 cells. The cell is 17–18 mm long and 10 mm or so in maximum width. The prey are all nymphs of *Oxya vicina* (due probably to the existence of the paddy field near the nesting site which is the main feeding place of the prey-insects), 8–18 mm in length. (Iwata observed as prey *Chrysochraon japonicus*). The number of the prey in one cell is 1–4. In transporing the wasp catches the prey by the base of one of the antennae, holding it venter to venter with her front (?) and mid pairs of legs. In operating the prey the wasp mounts the back of the prey astride, bends her abdomen and stings the underside of the thorax 1–3 times. In carring the prey into the burrow the wasp does not let it off at the entrance, but enters it with it. In closing the burrow finally the wasp uses the tip of her abdomen to pound the closing material, and later made comouflaging at the nest, by gathering together the pebbles, bits of wood, fragments of dried grass and the like. The egg is laid on the prey which is uncertain in the order of storing, but mostly to the first or the second prey carried in*. The egg is milky white, 2.5–2.8×0.7–0.8 mm, banana-shaped, and attached to the underside of the thorax just posterior to one of the front coxae, crossing obliquely the thorax and reaches just anterior to the hind coxa of the other side. The egg period is about 1 day, eating period 2–4 days and to spin the cocoon the larva needs about 2 days. The cocoon is dirty brown, lined inside with violet-brown substance. It is 6.5–9 mm long and 3–4 mm wide. (His larva was reared in a bottle without being given sand grains).

Masuda's observation. In 1939 H. Masuda also published his observations. But, according to his morphological and biological descriptions and figures there is no doubt that he confused this species with *Liris japonica* (Kohl) and dealt with the biology of both species as that of one and the same species. This

* This is according to his explanation. According to the table given by him, however, 9 eggs were laid to the last prey taken in, 3 eggs to the ones before the last, 3 eggs to the third from the last and only 1 egg to the fourth and at the same time the innermost one. Moreover, there remaims some doubt as to the method of counting of the order in his case.

is, I think, partly due to that the Japanese local name of this species — Nukadaka-bachi — given by the original author is incorrect. Because it means a front-raised wasp, but this does not agree with the character of the locust hunter dealt with here, but with the cricket hunter of the genus *Liris*. In the following I picked up some of his records that are considered to be of the presend species.

The prey: *Acrida lata* Motschulsky, *Euprepocnemis shirakii* Boliver (?), *Locusta danica* (?), all nymphs. The number of the prey per cell is 1–9. In the nest including 9 prey the wasp began to dig at 9:30, finished it at 9:55 and, after twice coming back without the prey, provisioned at the following time: 10:15, 23, 30, 35, 48, 57, 11:05, 09 and 19. She left the nest after 100 seconds and at 11:28 returned empty-handed and stayed long in the nest. At 11:38 she appeared to carry out the debris from the nest, probably to dig a new tunnel for the second cell. She brought the first prey to the second cell at 14:30. Examination of the nest performed some time after showed that it contained 4 completed cells and 1 incompleted cell, involving respectively 9, 9, 9, 9 and 4 prey. including the larva, larva, larva, egg and none respectively. The egg was laid on the last or before the last prey, the manner of oviposition being the same as given by Sibuya. The tunnel of the burrow was 5–7 cm in length and the cell being 15–20×10 mm in size. According to the records of rearing the egg period was 1–1.5 days, eating period 3–6 days; the cocoon was the silk-woven common one, not inlaid with sand grains. 8×3.5–4 mm in dimensions and the larva needed 2–5 days to spin the cocoon.

My own observations

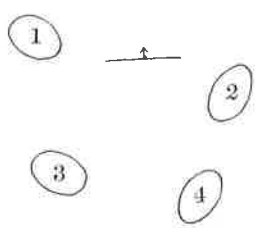
July 4, 1947, in the northern suburbs of Sapporo, in one of the *Bembix* villages. While I was searching for the cocoons of *Bembix niponica* with the purpose of transplantation of the colony I happened to dig out a brood-cell of a wasp of this species. I enlarged the excavation and could find out 3 further brood-cells. They were found about 7–10 cm below the surface of the sand slope covered sparsely with grass. The distribution of the cells was as given in Figure 4, and their dimensions being about 13–16×8–10 mm. The contents of the cells:

Coll 1. A considerably grown larva of the wasp with 2 prey remained, the nymphs of probably *Oedaleus infernalis* Saussure.

Cell 2. Six nymphs of the same species as above, on one of which a just hatched young larva was attached. Judging by the direction of their heads it was the one that was latest carried in. The young attached its mouth to the underside of the thorax of the prey and lay crosswise. The sketch made the next day: Fig. 5.

Cell 3. The same species of the prey, all nymphs of 7–12 mm in length, 6 in number, all head in, but the orientation of the dorsum was uncertain, the outrmost one carried the egg of the wasp under the thorax, lying crosswise, the point of attachment was the same as that recorded by Siduya.

Cell 4. The same species of the prey, all nymphs, 5 in numder, none of them carried the egg of the wasp.



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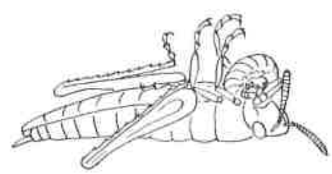

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Figs. 4–5. 4... Distribution of 4 cells of *Tachysphex bengalensis japonicus* Iwata (dorsal view). 5... A prey of the species carrying a young larva of the wasp.

Two days later, July 6, during my observation on *Bembix niponica* I saw several wasps of this species bring prey to their nests. The wasp came flying with a prey under her body, capturing it by the base of antennae and holding it with her middle pair of legs. In most cases the locust was held side up, but sometimes venter to venter with the wasp. The wasp flew about around the nest for some time and occasionally rested on sand (when the method of holding was observed). The nests were scattered among the stocks of grass and their entrances were left open while the wasps were absent.

I saw one of the wasps close her nest finally. She threw the sand backward from under her body into the opening, then backed into the tunnel and packed the collected material with the end of her abdomen. When she went out of the entrance somewhat afar to collect material she returned to it head foremost and entered it, then turned round at once in the tunnel and went backing to the bottom of the hole. The tapping manner with the tip of the abdomen was much like that of the *Bembix*. During the time of the final closure the wasp from time to time flew up at the entrance, alighted on a blade of grass, but at once flew down to resume the closing work. The manner resembles somewhat that of *Sphex* (*Prionyx*) *albisectus* Lep. at the time of her final closure, except that the flight in the present species is very much less in height. In the case of the *Sphex* the next nest was soon made near the first and the flight was considered to have some meaning in connection with the locality study. As to whether the similar was the case in the *Tachysphex* also, or not, my note book does not tell any more.

I tried the excavation of several nests, but failed to get safely to even a single brood cell. This was chiefly due to the crambling-down of the sand when I followed the tunnels between the entangled grass-roots and partly to my want of zeal to the work which I thought at that time as a side job.

Growth process. I put the contents of the brood-cells of the first mentioned nest separately in each tube bottle between the tampons of cotton and brought them to my laboratory on the bicycle by the unpaved road for 10 kilometers. In spite of the violent bump, apparently the egg and the larvae were in good condition. I placed the bottles on the table, covered them with a sheet of black paper and observed twice a day.

The larva of cell 1 finished the meal on the 8th and spun the cocoon in the bottle the next day. The cocoon was greyish brown in colour, cylindric in form with both ends rounded and comparatively small as against the large brood-cell, 7.5 mm in length, 3.0 mm in width, having hither and thither a semitransparent spot based on the thinner membrane of the area. Further, several grains of sand that were brought in the bottle together with the prey were attached to the surface of the cocoon. I thought that the lack of the sand compelled the larval wasp to spin such an abnormal cocoon (Sibuya and Masuda thought it to be a normal cocoon). I therefore moved the 2 larvae from cell 2 and cell 3 from the bottle each into a hollow made on the wet sand in a Petri-dish and observed the cocoon spinning technique.

The egg of cell 3 hatched out the next day (Aug. 5) and ate up the pedestal insect on which it was laid after about 2 days and a half, leaving the legs and the hard sclerite of the head and thorax. Then it began to eat the second prey and then the third. The part from where it began to eat as to the 2nd, 3rd, 4th prey and so on was uncertain. Apparently it began to eat from any part of the body it happened to touch, except for the hard sclerite. It took 4 further days to finish its eating and on the llth it was seen to be rested in the cell. It began to spin the cocoon the next day.

The larva in cell 2 also needed 6 days to eat up its diet (from 4th p. m. to 10th p. m.) and on the 7th day began to spin the cocoon. According to the result the egg period in this species is about 24–30 hours as in most of the digger wasps and the eating period is 6 days. It rests for about half a day and begins to spin the cocoon. Sibuya's record of eating period, 2–4 days, at least 2–3 days, seems to be too short. Masuda gave for it 3–6 days, though in confusion with *Liris* *japonica*. The record of 3 days at least seems also to be too short, even if we take into account the difference of the temperature between the localities. Even under the high temperature the larva will need to eat 4–9 prey at leat 4–5 days. The fact was proved by my rearing of the larvae of various species in Formosa. But, under the insufficient supply of food the matter is quite another thing.

State of the prey. About half of the prey that were taken out of the larval cells were considerably vigorous. They could move legs, antennae and palpi, and their abdomen pulsated for the respiration. Some of them even managed to walk. One grasshopper that was deprived of a wasp on the 6th very activery responded to the stimulus on the 10th and it could still move its legs on the 11th. But it lost its vigour the next day and apparently died on the 13th. This told us that the operation of this species was not so strong as in the large-sized hunting wasps in which the paralysis lasted forever.

Similar instance of the weak operation we can find in many of the small-sized spider wasps, in which the prey robbed of the wasp is completely immovable, but after several hours it recovers its vitality and becomes to be able even to run about. When we dig the nest of such a spider wasp we are surprised very frequently to find the prey bearing the wasp's egg spring out of the nest and run about to escape our catch.

In the *Tachysphex* the recovery is not so much in degrees, but it is sure that the prey recovers its vigour to a certain extent several hours after operation.

Cocoon building. As given earlier I began to observe the process of cocoon building by the waspling. The technique of the cocoon building in this group of wasps was observed by J. H. Fabre as early as 1886.

Larva 2 began to spin the cocoon late on the 10th or very early on the 11th. Larva 3 was delayed by about 24 hours in the work. This larva, however, died by accident on the way and its process could not be followed up to the end. The first larva worked certainly up to the end of the cocoon building. But its final part of the process was abnormal. However, the process seems to be sufficient to presume the normal course of the cocoon-building work of the larva. In a sense, it may be more fabourable than the normal one. In the following, therefore, the account will be given in some detail.

On July 10, at 16:00, I placed the full-grown larva in the cell made on the wet sand in a Petri-dish and covered it with a slit of the cover-glass of the microscope.

When I saw it the next day at 8:00 it was building the cocoon with sand. Apparently it had alreaby built about one third of the cocoon. At 10:00 I could observe the way of the cocoon building under the binocular microscope. The state at that moment was as given in Figure 6.

1) Under the naked eyes it appeared that the cocoon was building from the inner end, but under the microscope it was confirmed that the end remained still opened.

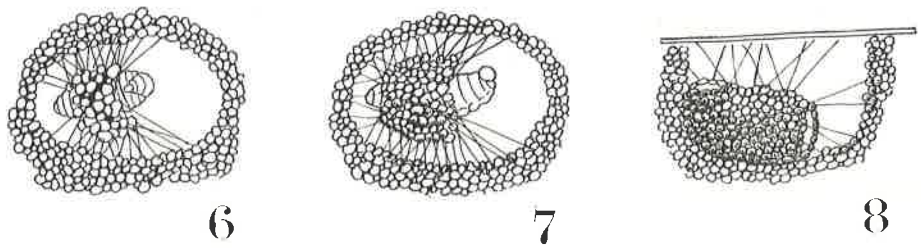
2) The sand was attached as given in the figure.

3) The silk threads were stretched only at the portion where the sand grains were attached.

4) The sand grains attached were completely wet and glittering.

Judging from the observations it seems that the larva first stretched some silk threads between the inner walls of the cell, then attached it a grain of sand and then stretched the threads to glue to them a sand grain, and so forth.

Now, the larva spins the silk thread and then it arranges the layer of sand from inside. At 11:20 the larva lies side up, with the body folded and is working with a grain of sand. The sand grains attached to the cocoon margin are moistened and glittering. At 14:00 the cocoon has a little been lengthened and the larva has turned round in it, with its head produced from the inner end of the cocoon, lying up-side-down and is spining around the sand grains already attached. At 15:00, the same spinning work, with the same body orientation. The larva protrudes its anterior body out of the broad ring made of sand grains, showing its well developed lateral tubercles. Under the binocular microscope I can count 4 segments except the head that are produced out of the cocoon (Fig. 7). The larva is still up-side-down, bending its head ventrally and is spinning between the grains of sand which have irregularly been bound together. At the end of the cocoon-ring there is a more or less empty interspace between the grains where a few silk strings are stretched. At 16:00, the silk string stretched at the inner end of the cocoon ring has increased in number. The string seen as such is a bundle of very fine silk thread pulled out of the larval mouth.



Figs. 6-8. The process of cocoon building of the larva of *Tachysphex bengalensis japonicus*.

At 17:00, the inner opening has become considerably small, but is still open. The larva has again turned round and its head is protruded from the opening at the outer side. The ring of sand has become a little longer. The larva picks up a grain between its mandibles and attaches it to the upper side of the outer margin of the cocoon-ring. It lies up-side-down, but it can pick up the sand grains under this posture by stretching its flexible thoracic region. The grain held between its mandibles is thoroughly moistened with the secretion of the silk gland and is shining. It is stuck to the silk string and in part also to the adjacent sand grains. The larva now secretes a fair amount of silk substance to the interspace between the sand grains and then entangles the threads of silk around the grains now attached. The grain is moved and completely glues to the next grain. The larva then stretches its body out of the opening upward and moves its head hither and thither along the cover-glass, probably sticking its silk thread. The next moment it bends its body backward and picks up a grain from the floor. It takes it completely in the mouth and moves it as if to chew. It then raises its head and at the same time spews the grain slowly out of the mouth, catches it between the mandibles, takes it to the outer end of the cocoon-ring and glues it there. At this time I took notice of a new string stretched between the upper middle of the cocoon opening and the lower wall of the obliquely front side. At 17:15 the larva is repairing the arrangement of the sand grains from the inside of the cocoon. On the upper side 2 irregular-shaped small openings are observed. It seems interesting to ascertain whether they will become the so-called respiratory pores or not. At this moment the cocoon appears to be like a sand house of the caddis worm. At 17:20, the larva is moistening the sand grains attached to the outer margin of the cocoon with the secretion of the silk gland.

I observed the movements of the larva from time to time till 19:00. It was continuing the sand spinning work very slowly with the same technique as above mentioned. At 19:00 it lay dorsum up, inserting its mouth-part into the floor of sand as if to dig there. At 20:00, the opening at the outer side of the cocoon became considerably small. The larva was building the lower side of the opening. At 20:20 it was sticking the upper wall of the cocoon from the inside where a more or less interspace still remained between the sand grains. At 20:30 I stopped the observation.

The next morning (the 12th) at 5:00 I went to the laboratory and resumed observation. The inner portion of the cocoon was slightly extended, with the opening narrowed and directed upward. The outer portion was also somewhat extended and narrowed. The larva was at that time spinning a silk thread between sand grains at the brim of the outer opening and then added the glutinous substance to their interspace. The work was very slow and tedious, although I could not see the larva at any moment resting.

Apparently the underside of the cocoon was not supported by the net of silk to be free from the sand floor of the cell, as in the case of the Bembicine wasps, but the grains of sand of the cell floor were spun together as they were to turn to the underside of the cocoon. The larva was dorsum up, bent its head and manipulated the sand grains at the floor, probably to stick them together. At 9:00 the larva was still working at the outer opening, showing the tip of its abdomen out of the opening at the inner end. At 12:00, the head of the larva was seen at the inner opening. It was spinning the silk thread between the adjacent sand grains. The outer opening had certainly become somewhat narrower, but it was still open. How tedious and dull to see such a sluggish progress of the work, although the movements of the larval mouth-parts appeared very busy to work. At 15:00, the larva was still working at the inner opening. The hole was surely somowhat narrowed, but was still distinctly open. At 18:00 the larva had been turned round, it was repairing the upper opening. Apparently the form of the cocoon remained unchanged. Through the inner opeing the end of the abdomen of the larva could be seen to move.

On the 13th, at 5:00 the cocoon had been somowhat exteded outwards and the larval body was completely hidden within, but the two openings remained as they had been, though both were slightly more narrowed and the brim was more nicely arranged. The tip of the abdomen of the larva was seen through the inner opening to move. But what the larval wasp was doing could not be observed. At 14:00 apparently the cocoon remained utterly unchanged, but the larva was still working.

On the 14th, at 8:30, the larva protruded its head a little out of the inner opening and was adding the silk substance to the brim. The form of the cocoon was as given in Figure 8. At 9:00, the larva was working at the outr opening, inserting its head in the sand floor at the brim. On the 15th, at 8:00 the larva had ceased its work and lay still in the incompleted cocoon.

Judging from the procedure, in the normal process of the cocoon spinning the cocoon must be closed at both ends under the condition observed on the 12th, that is to say. a third day from the beginning. The succeeding process must be the lining process of the sand cocoon under the normal condition. Probably the larva needs 2–3 days to build the sand case and 2 further days to line the inside.

As a whole, it can be said that the general process is just the same as related by J. H. Fabre in his Souvenirs entomologiques, Sér. 3. (1886) in regard to that of his *Tachytes* (including *Tachysphex*, *Liris*, *Larra*), *Stizus* and *Paralus*.

The second observation on the nests and the contents. On July 14, toward 9:30 I visited the colony of this species and dug 5 nests. Having obstructed by the roots of the grass, this day too, I failed to ascertain the course of the tunnel to the larval cells. But I could confirm the following matter:

1) The brood-cells are located 3–5 cm below the surface. The place is a little after entering the moistened sand layer below the surface layer of the dried sand.

2) The larval cells are found in group of 1, 2, 2, 3 and 4 within a limited area respectively,

showing that the nest of this species is compound in structure, or at least some nests are gregariously constructed.

3) The prey belong to 2 species, the brownish and the greenish, the former is doubtless the nymph of *Oedaleus infernalis* Saussure and the latter that of some species of the genus *Oxya*. They can move the mouth-parts, legs and antennae. The number in one cell: 1, 2, 2, 3, 3, 4, 4, 4, 4, 5, 5 and 6 (including the count of the remains), all head in, but their body orientation is undetermined.

4) I could obtain 6 eggs and 1 young larva attaching to each pedestal prey. The attach point was the same as given in Figure 5. The egg is pale yellow, waxy in lustre, nearly 3 mm in length, fairly strongly curved. The grade of the curvature is variable under the microscope.

5) So far confirmed with 3 cells the egg-carrying prey were all placed at the upper- or outermost part of the collection.

6) Two cocoons were obtained, both made of sand grains, about 8 and 10 mm in length and 4 and 5 mm in width, without the respiratory pore as observed on the cocoons of the Bembicine wasps.

Rearing of the larvae. I brought back all the booty to my laboratory. Three eggs were dropped from the pedestal prey and one of them was lost. I put the contents of each cell separately in the hollows made on the moderately moistened sand stuffed in the Petri dishes. This time I covered them each with a slit of card board. The dropped eggs were put on the prey. The preparation was done on the 15th.

July 16, at 8:00, one of the eggs began to addle and three of them including the dropped ones began to shrink. The larva continued to eat and one of the two remaining eggs was hatched. But, it was about to be destroyed by a maggot of the parasitic fly. Where it had been hidden I did not know. But it was certain that it attacked the larva prior to begin to eat any other prey. Most of the locust excreted and they could move fairly actively. One of them when touched with the pincette crawled out of the cell. It could even leap. But it could not continue to leap. At 17:00, the single egg remained had hatched and began to suck the body fruid of the prey.

July 19, when I returned from my journey I knew that all the contents of the cells had been decomposed and covered with mould. The first large lerva had been died. To my surprise, however, the second larva that hatched in my laboratory was still alive and was eating the prey at the lower portion of the cell. Probably the prey it was eating must have been more or less rotten. I collected 4 locusts that were comparatively in a good condition from among the prey and gave them to the larva.

July 20. The larva continued to eat the apparently rotten prey and toward evening it ate up the greater part of the locusts placed in the cell. I covered the cell with a slit of glass. The next day the underside of the cover glass was lined with a layer of sand and the movement of the waspling became unobservable.

On July 22, I removed the coverglass. The larva was less vivid and the work of cocoon building was not progressed. I removed the larva to a new cell made of the fresh sand, but it died the next day.

An observation in Korea. In the ground of the Dzizai-an Temple in the valley of Shoyo-zan, Central Korea, I found a wasp of this species that was about to take in a prey to her nest. When she came out after provisioning the prey I caught her and dug the nest. The tunnel went shallowly in the gravelly earth for 5 cm and ended in a cell which was 1.5 cm below the surface to its ceiling. In the cell 3 nymphs of some species of Tettigidae were stored without the egg of the wasp. I searched for another by enlarging the excavation and found the other cell which was located 2 cm apart from the first cell and included also 3 nymphal grouse locusts. The egg of the wasp was laid on one of the locusts placed near the entrance of the cell. The manner of oviposition was as explained on the Japanase representative.

An observation on the Island of Amami-Ohshima. In 1961, during my journey on the Island of Amami-Ohshima, the Ryukyus, I found a colony of this species on a deserted road near Tomori. It was on July 6. The place was near the seashore and the ground was composed of fine grains of sand, but the surface was well trodden and hard. The wasps frequeutly brought back the prey, apparently the grouse locusts of the moderate size and entered the respective nest. I dug one of the nests and found two larval cells. The cells were found 5 and 6 cm below the surface and included 2 and 5 prey respectively. One of the prey in the second cell that was considered to be carried in last bore the egg of the wasp. The place and the way of egg laying were as usual in this species.

Summary

This species livses in sandy area and its nest is shallowly made in sand, usually 5–7 cm below the surface of the ground. Apparentely the nest is compound in structure, including 4–6 larval cells. But as the tunnel to each cell is almost separately dug the nest structure is very approximate to the aggregation of the separate simple nests. The cell is 13–15 mm in length and 8–10 mm in width. The number of the prey per cell is 4–9. In operating the prey the wasp stings it 2–3 times at the underside of the thorax and in carrying the prey the wasp cathes it by the base of the antennae, holding it mostly venter to venter, with the mid pair of legs. At the time of entering the nest the wasp does not let the prey off at the entrance as a rule. The prey are stored in the cell, all head in, but their dorsum orientation is uncertain. The paralysis of the prey is weak and after several hours the prey considerably recovers from it and becomes to be able to move the antennae and legs and sometimes even to leap. The egg of the wasp is laid, as a rule, on the prey last carried in. Occasionally, however, one or two further prey may be added afterward (but as the reports hitherto made are somewhat doubtful in this regard further study is needed). The egg is about 2.5–3.0×0.7–0.8 mm and is attached with its anterior end to the prey between the front and mid coxae of the same side, lying somewhat obliquely crosswise.

The entrance of the nest is left open when the wasp is out. The prey are successively and very promptly carried in and one cell is usually completed within a day, sometimes even within a few hours. Under the reared condition the egg period is 24–30 hours and the eating period of the larva is 5–6 days. The larva needs about 4 days to complete the cocoon building, including the work of lining of the inner wall. Under the natural condition the cocoon is always made of sand grains. In building such a cocoon the larva first makes a ring of sand having a certain width, possibly with the aid of the silk threads stretched between the walls of the cell, then extends it toward both ends, by gluing the sand grains one by one as we build the stone wall. When it becomes a sand pouch the larva closes the openings (possibly the inner opening first and then the outer) and then obeys the lining work of the inner surface of the cocoon. The process is just the same as related by J. H. Fabre (1886) in regard to his *Tachytes*, *Stizus* and *Paralus*. The cocoon is comparatively small, 8–10 mm in length and 4–6 mm in width.

* * *

Recently Iwata (1964) published his study on the biology of the typical form of this species made in Thailand. According to this:

(1) The entrance is left open. (2) Orientation flight is made. (3) Green Short-horned grasshoppers belonging to Catantopinae are hunted. (4) The prey are caught by the antennae and transported on the wing. (5) The burrow is 6–8 cm in length, the cell measuring 12×7 mm, not horizontally placed. (6) The number of the prey per cell is 1–5, most usually 2. (7) The egg measures 2.12×0.49 mm and the

position and manner of oviposition are the same as in our subspecies.

No mention was made regarding the place or the order of provisioning of the eggcarrying prey, also the state of the prey after the paralysis.

LIRIS (*DOCILIRIS*) *DOCILIS* (SMITH)

In 1938 Iwata reported in Japanese his observations on the habits of 3 species of the Larrine wasps of which one was given under the name of *Notogonidea docilis* Smith. In those days, however, this species was confused with *Liris japonica* and it was uncertain, therefore, to which of the two species his observation concerned. Judging from the contents of his description it seems to me that he dealt with the two species in confusion. At the end of this section I will cite a part of his report that seems to me to be of the present species. On the other hand, this species was included by Williams in his *Notogonidea subtessellata* (Tsuneki, 1967, Etizenia 20) and, therefore, the habits of this species may be included in the biology of his *N. subtessellata* (1926).

In the suburbs of City Tsu, Mié Prefecture, on April 18, 1956, toward noon. Under a small cliff of a hill facing the south, there was a patch of the bare ground and on the area some wasps of this species were seen repeating to go in and to come out to and from the crevices and holes scattered there. Soon I found a wasp of this species come on foot carrying a prey, a nymph of the cricket of her body size. It mounted on its back astride, catching it by the base of the antennae. By the side of the nest which was open close to the base of a herbaceous plant it dropped the prey, entered the opening, came out at once and dragged the cricket backing into the burrow.

About 4 hours later I dug the nest. The tunnel entered the earth perpendicularly and just below the entrance the wasp was hidden and was caught. From about 7 cm below the surface a cricket crawled out and fairly vigorously walked about. It differs from the normal cricket only in that it could not leap. I caught it and found that an egg of the wasp was attached to the underside of its thorax. It was laid crosswise between the front and middle pairs of legs. It was considerably long, a little more than 3 mm in length and fairly strongly curved. Its anterior end was glued to the sternum at the posterior and slightly outer spot to the right front coxa and the other end was also tightly attached. Therefore, it could not be detached nor crushed even when the cricket vigorously walked about. I could not found the larval cell and it remained unknown whether the other prey was or were stored in the cell or not. But I could discover a cocoon of the wasp near below the opening which was yellowish in colour, elongated egg-shaped, about 10 mm in length. Judging from the structure of the cocoon (because it was not made of sand grains) it was doubtful that the cocoon was spun by the larva of this wasp.

As I was not ready for the study and the time was limited I could not bring back the booty in safe and the succeeding observation ended in failure.

If the cocoon was of the first larva of the wasp observed it becomes that this species makes the compound nest shallowly in the earth. Apart from the fact, that the wasp stayed near the opening seems to support this consideration. The tunnel was closed behind her and during my search digging I found the cricket which carried the wasp's egg crawl out. Therefore, probably the larval cell to which the cricket was carried in must have been completed and the wasp was in the intention to make the next cell the next day.

On the same place, about 1.5 m apart from the first nest I found a similar hole left open. I dug it. The tunnel went in perpendicularly for about 7 cm and near the end it was slightly inclined and ended in a cell which was also fairly steeply inclined. It was still empty and 17 mm in length and 8 mm in width. The wasp was in the tunnel and retreated as my digging proceeded and finally entered the empty cell.

This nest informed me of the state of the tunnel and the larval cell.

From the Iwata's observation. The nest is mostly simple, but sometimes branched once, having a single cell at each end. The tunnel is mostly perpendicular and also the cell which is situated 5–12 cm below the surface, and is 15–24 mm long and 9–10 mm wide. The prey are the crickets (nymphs), the number per cell is 1–3, but most usually 2. The egg is laid between the front and middle pair of legs. When the final closure is made the wasp uses the tip of her abdomen to pound the packing. After completing the final closure the wasp camouflages the nest site by collecting fragments of various materials. As to which of the prey collected in a cell is laid the egg by the wasp no mention was made by him.

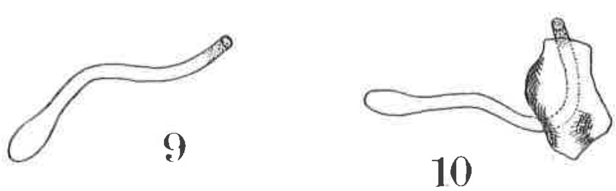
LIRIS (NIGLIRIS) JAPONICA (KOHL)

Regarding the biology of this species Haneda (1961) and myself (1959) recorded each observation. The wasps reported by Iwata (1938) on the biology under the name of *Notogonidea docilis* Smith may, at least in part, belong to the present species. Further, the species was also described concerning the nesting biology by Masuda (1939), but as pointed out in connection with *Tachysphex bengalensis japonicus* it was made in confusion with this species. All these reports, however, were made in Japanese.

On April 22, 1956, in the ground of a temple in the suburbs of Fukui city several wasps of this species were running about, frequently entering and coming out of the chasms and holes. Toward the noon I saw one of them walk with a prey under her abdomen. Having suddenly attacked by a large worker of *Camponotus japonicus* it flew low over the ground with the prey about 8 m at a flight and landed. I hurried there and saw that the wasp soon entered a hole near her landing place. It was understood that return to the nest by the individual was very exactly carried out. The wasp left her prey — a nymphal cricket — at the entrance before entering the opening and then dragged it backing into the tunnel.

Nest 1. Late in the afternoon of the day I dug it out. The tunnel was left open and the wasp was in the tunnel. She backed little by little driven by my hand shovel and finally took refuge in the larval cell. The cell was oak-seed-shaped, 11×6 mm in length and width, not placed in a horizontal situation, but in a steep inclination of about 70°. When I captured the wasp a nymph of the cricket, about 6 mm in body length, crawled out of the cell, following the wasp and moved vigorously the antennae. I examined it and confirmed that the egg of the wasp was not as yet laid to its breast. The tunnel went obliquely in the earth for about 4 cm.

Nest 2. I found this nest also by following a prey-carrying wasp. I dug it late in the afternoon. The entrance was slightly less than 3 mm in diameter and the tunnel, after twice describing a curve, connected with the larval cell without any stopping earth layer on the way or before the cell (Fig. 9). In the cell were stored already 4 prey of small nymphal crickets, *Scapsipedus aspersus* Walker, 3–5 mm in body length and all were well movable. I examined them carefully one by one, but could not find out the wasp's egg. I tried search digging, but none could be found from around the cell.



Figs. 9–10. Nests of *Liris (Nigliris) japonicus* (Kohl) (dorsal view).

Nest 3. This nest was also found and dug at the same time with the above mentioned nests.

The larval cell was situated 2.5 cm horizontally apart from the entrance and 2.5 cm below the surface of the ground and was inclined nearly perpendicularly. In the tunnel the wasp was hidden as in other nests. But in this nest the tunnel was closed before the cell for about 10 mm. In the cell 3 young crickets were collected and on the outermost prey the egg of the wasp was laid. The place and the method of oviposition were the same as in the preceding species.

In this nest probably the wasp was in the intention of constructing further cells in the burrow.

Nest 4. The same ground, but 3 days later. I dug a nest and found 3 larval cells as expected from the observation of nest 3. They were situated close together, 3–4 cm below the surface, and the wasp was found in the tunnel leadining to the last cell. The tunnels leading to cells 1 and 2 were very compactly stuffed with soil and the cells contained 4 and 5 prey of the young crickets respectively, outermost one of which in both cells carried the egg of wasp. The manner of oviposition was the same as in nest 3. The third cell was still in the course of provisioning and 2 prey only were stored without the egg of the wasp. The tunnel leading to the cell remained thoroughly open. All the cells in this nest were also steeply inclined, having the length axis nearly perpendicularly laid.

An observation in Korea. On June 6, 1943, in the ground of the temple, Dzizan-an, in the valley of Shoyozan, Central Korea, I saw a wasp of this species carry in her burrow a cricket. When she came out I caught her and about an hour later I dug the nest (Fig. 10). The larval cell was 12 mm long, 7 mm wide and high, and about 7 cm below the surface of the ground to its roof. In the cell 2 nymphal crickets were stored, dorsum up, without the egg of the wasp. The inner one of the crickets could move its antennae and legs fairly vigorously. The entrance of the nest was closed while the wasp was out.

This species, together with the preceding one, hibernates in the adult form in Japan. On the warm day in winter it is observed that the wasp comes out of the hollow in the bank facing the south and flies about under the sunshine.

Haneda's observation. Twelve nests observed were all simple in structure (probably because of the observation at the early season). In 3 the tunnel was perpendicular throughout, in 2 first perpendicular and then oblique and in 7 wholly oblique; the length of the tunnel ranged from 3 to 6 cm. The hunting is performed mainly in the forenoon and 1–4 prey are rapidly collected, some of which are considered to be the continuation of the previous day. While the nest closure is done mainly in the afternoon, using the tip of the abdomen. In hunting the wasp mounts on the back of the prey crosswise and stings it between the front and middle pairs of legs. Sometimes she reoperates the prey recovered and fled out of the burrow. The prey placed in the cell is at first always venter up, but later it rights up by itself. The number of the prey per cell was from 2 to 5, mostly 2–4 (all nymphs). Oviposition as in my observation; the larval cell containing a cocoon is slightly larger than that at the time of provisioning, 15×8 mm, probably because of using the earth grains for the cocoon building. The cocoon measures 7–8×2.5–3 mm, yellowish brown and its outer surface is covered with grains of sand and earth.

Summary. The nest is made shallowly in the earth. The tunnel is comparatively short and the larval cell is situated mostly 2–4 cm below the surface up to its roof. The cell is usually steeply inclined, with its length axis lying 60°–80° against the level, oak-seed-shaped, 10–13 mm in length and 5–7 mm in width. It is provisioned with 2–5 prey, the paralysed nymphal crickets of *Scapsipedus aspersus* Walker. The egg is laid to the prey finally brought in, on the underside of the thorax crosswise, between the front and mid pairs of legs. The paralysis does not last long and after several hours the prey considerably recovers. When one cell is accomplished the tunnel leading to it is largely closed with soil by the wasp using the tip of the abdomen and a new tunnel from near the entrance is dug to make a new cell at the end. Thus the nest becomes compound in structure, but except for the common utilization of the entrance it is close to a group of separate simple nests gregariously constructed close together.

LARRA CARBONARIA EREBUS SMITH

As given first by Williams and later by Iwata this species is a very good material to observe the method of paralysis by the hunting wasp under the artificial condition. As the female wasps are easily obtained within the ground of our University we used to utilize this species as a teaching material.

Observation of the hunting activities. A glass vessel, 10 cm in diameter and 15 cm in height, is used. The bottom is covered with moderately moistened sand to about 1 cm in depth and on it a little pot including a bit of sponge or the like immersed in sugar water is placed. A female wasp is put in it and the vessel is covered with the wire gauze. Under such a condition the wasp can live usually 10–20 days vigorously. With these wasps I have tried with students the observations of their hunting activity numberless times almost always with success. The results can be summarized as follows:

1) The wasp that passed about 24 hours in the vessel is better for the material than that soon after being captured and imprisoned.

2) The mole cricket, *Gryllotalpa africana* P. de Beauvois. is indifferently accepted by the wasp, in regard to the size, age and sex, except for a very small one, but apparently the wasp prefers the moderate-sized one.

3) The prey is set free in the vessel either before introducing the wasp, or later directly in front of the imprisoned wasp. In the first case the mole cricket at once penetrates into the sand and the introduced wasp, if she has been in other vessel for more than 2 hours or so, soon begins to hunt the prey. In the second case, when the wasp's condition is similar the hunting manoevre is soon developed under our eyes.

4) The wasp penetrates into the tunnel of the prey. If the tunnel is completely closed the wasp digs the sand and soon finds it out to follow. The mole cricket hurriedly crawls out of the tunnel and runs about on the sand floor in confusion.

5) The wasp follows after the insect and sometimes directly mounts on its thorax, but more often mounts on its abdomen and proceeds forward on the back of the running prey till she reaches the dorsum of the thorax.

6) When reached, the wasp turns her body crosswise against the body axis of the prey and inserts the tip of her abdomen under the thorax of the mole-cricket.

7) Sometimes the wasp stings the prey under this posture, but more often she turns over up-side-down, with the prey held crosswise on her breast. Under the condition the molecricket itself becomes up-side-down. In both cases the prey insect violently strives against the wasp, either by running madly faster and faster or rolls over and over on the floor. In order to hold the prey on her breast it appears that the wasp utilizes this power of resistance of the mole-cricket.

8) In the second case of the wasp's operation, the body of the prey insect is up-side-down and the points of her stings are most easily observed. The first coup is given on the median line between the front and mid pairs of legs and the second is inserted also on the median line in front of the front legs, that is to say, at the throat.

9) After the second coup the prey becomes almost immobile, but its maxillary and labial pulpi can move and in most cases the head is also more or less movable. Sometimes the wasp gives further the elaborate *malaxation* to the place just posterior to the front pair of legs — the place of her oviposition.

10) The wasp, then, took the posture of stinging again, either mounting crosswise on the

back of the prey when the mole-cricket is dorsum up, or holding it crosswise on her breast when it is venter up, and lays her egg crosswise at the membraneous area medianly just anterior to the middle pair of legs, usually a little deviating to the right or the left.

11) The egg is comparatively small, about 2.2–2.4 mm in length, 0.7–0.8 mm in width, wax-white in colour and is likely to be overlooked without particular attention. But its shell is apparently very rigid.

12) Toward the time of finishing the oviposition the mole-cricket begins to recover from the paralysis and in less than a minute it rights up, walks about and soon burrows in sand as vigorously as usual.

Growth process of the larva. The egg of the wasp thus attached to the underside of the thorax of the prey is kept quite in safe against every movement of the mole-cricket.

1) It takes about 2 days before the egg hatches out.

2) The succeeding growth of the larva is very slow. After a week the larva is usually only about 4 mm in length and 1.2 mm in width at its widest part near the caudal end, attaching still to the position laid by the mother wasp.

3) The mole-cricket is quite vigorous. Its movement is without any apparent change, and eats voraciously the earth worm put in the bottle as its food.

4) The selected place of oviposition prevents the waspling from being crushed by the movement of the prey-insect and as to the growth of the larva there is no apparent influence whatever from the activity of the prey.

5) After about a week the growth rate of the larva is suddenly increased. Within 2–3 days it becomes approximately twice as large as its original size, reaching nearly 10–12 mm in length. Judging from the growth process in other species of Sphecidae the larva of this species needs about a week before it reaches the final instar, when it begins to grow very rapidly and conspicuously.

6) Toward the time the mole-cricket loses its vigour in inverse proportion to the growth of the larval wasp. It becomes soon immobile and finally it is compltely eaten up except for the hard sclerites of the body.

7) The time needed up to the full growth of the larva is usually 10–12 days and the larva reaches 17–20 mm in length.

Cocoon spinning. 1) The cocoon spinning is a work of the slow process and tedious for the observation, although the waspling works very actively without resting.

2) The method is similar to that employed by the waspling of *Tachysphex* already described.

3) In order to observe I used the same technique as in the case of *Tachysphex*, but I left one end of the hollow free from the covering.

4) The process of the cocoon building can be divided into 5 stages: Spinning the ring-shaped hammock, lining it with sand grains to form the central part of the cocoon, extending it inward to form the inner part, building the outer part to complete the sand case of the cocoon, and finally lining it with silk, though this process can not be observed from outside.

5) In order to make the central part of the sand case the larva spins first a rough ring of silk thread and then inlays it with sand-grains.

6) In order to make the inner and outer parts, however, the waspling does not use the same technique as above. It spins the silk pouch, but at the same time it attaches the sand grains to it. Therefore, in reality the process is that it stretches strings of silk between the different parts of the edge of the central ring of the cocoon and then attaches the sand grains to it, gluing

them together with the liquid from the silk gland. The process is, therefore, very similar to the human work of building the stone wall.

7) The sand grains used for the material is first taken into the mouth, moistened and then attached to the silk string which is composed of several silk therads, or to the adjacent grains already attached.

8) At the final scene of stage 3 the posterior end is completely closed and then the larva turns round to make the outer part.

9) At the final act of stage 4 the opening at the anterior end is completely closed and the movement of the waspling becomes invisible.

10) The time needed up to the end of stage 4 is about 2 days.

11) After the waspling becomes invisible its movement is perceived through the distorting or partial swelling of the cocoon which still remains quite elastic.

12) After a further half day or so the cocoon becomes dried up, but probably the waspling will work a further day or more to complete the lining work.

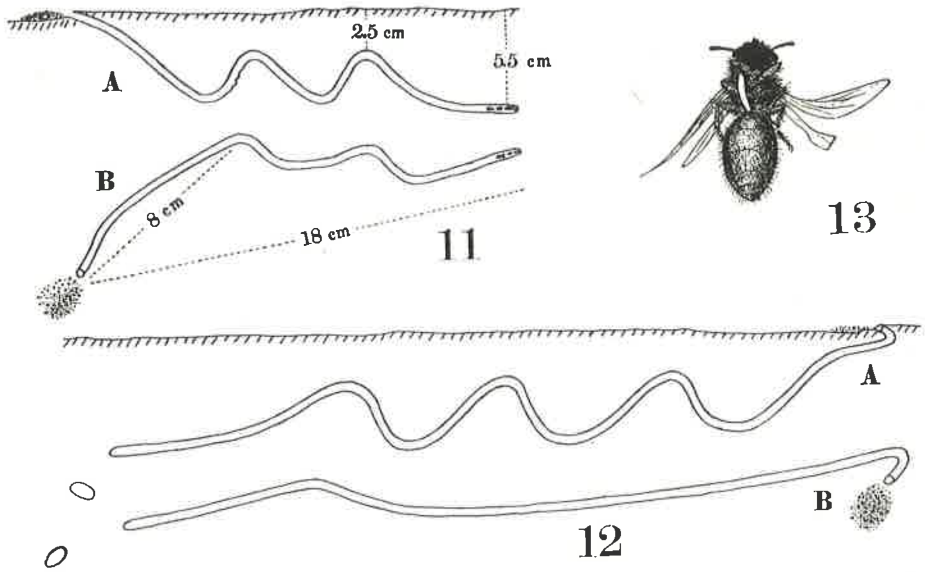
13) The cocoon is elongate egg-shaped, but the difference in curvature between both the ends is not large, hence it is approximate to the oak-seed in form, in accordance with the form of the brood-cell. In size it is fairly varied according in the main to the difference of the size of the prey. In nature, however, this is considered to be connected by the mother wasp with the difference in the sex of the larva. It is 7-12 mm in length and 4-7 mm in maximum width.

PALARUS VARIEGATUS VARIUS SICKMANN

The nesting biology of the typical race of this species has been studied by such authors as Dufour (1841), Girard (1879), Ahrens (1925), Nielsen (1933), Móczár (1952) and Grandi (1961). The biology of the East-Asiatic race was first described by Sato (1926) basing on his observation conducted at Suigen, Central Korea, under the name of *P. saishuensis* Okamoto and later by myself (1942) upon the basis of the observations made on the circling road of Tiendang, Peking, North China. But the descriptions were made both in Japanese and have been unavailable to the western entomologists.

Sato dealt with the structure of the tunnel of the nest, the prey insects (Apidae, s. l., Sphecidae including *Oxybelus*, *Cerceris*, Scoliidae s. l. including *Tiphia*, *Myrmosa*), behaviour of the parasitic fly and the fact that the egg is not laid until the provisioning is completed. But apparently he does not take notice of the provisional storing of the prey in the tunnel. He did not observe the egg and larva of the wasp.

During my stay in Peking in 1938, the above-mentioned circling road of Tiending was deserted and was occupied by various species of non-social wasps and bees. On May 28, at about 15:00 I saw a wasp of this species carrying a prey under her abdomen. She walkd 20 cm to reach the entrance to her burrow and dropped the prey to clear the block free-handed. She raked out the closing soil, entered the opening head foremost, soon came out, captured the prey by the antennae and dragged it backing into the tunnel. Two minutes later the wasp appeared at the entrance, closed there by raking together the dug-out soil and then came completely out of the burrow. She flew up, circled round above the nest and after landing once near the entrance flew away. About 10 min. later I took notice of the wasp carrying a new prey in her burrow. This time she did not come out soon. As my time was limited I had to examine the nest at once. The complicate structure of the nest will more easily be understood by the aid of the figure than to narrate tediously: Fig. 11, A (lateral view) and B (dorsal view). It was very similar to



Figs. 11–13. 11 and 12 ... Nests of *Palarus variegatus varius* Sickmann (A, lateral view; B, dorsel view). 13 ... The egg-carrying prey of the species.

those interpreted by Sato and nicely illustrated by Móczár. The strange upward and downward turns of the tunnel was not dependent upon the obstacles such as stones, wood chips and the like, but was considered to be made intentionally (instinctively) by the wasp. At the first upward turn on its posterior wall I found 3 small impressions, from where the wasp might take the material to close the entrance from within. The tunnel was open throughout except for the entrance and ended nearly horizontal. There the wasp was manipulating the 3 prey — 2 solitary bees and 1 solitary wasp — and at the extreme end where no particular enlargement could be observed 1 solitary bee was placed, head in and dorsum up, but without the egg of the wasp laid. The tunnel was at first 3–4 mm in diameter, but from toward the steep inclination of the first section it was somewhat enlarged to about 5–6 mm in diameter.

Later study showed that the bees of the prey belonged to *Halictus pekingensis* Blüthgen and the wasp to *Pison punctifrons* Shuckard.

From the above observarion it can be said that:

(1) This species begins to hunt the prey before the complete preparation of the larval cell and stores them provisionally at the end portion of the tunnel, somewhat as in the species of *Cerceris*.

(2) In respect of hunting the aculeate Hymenoptera as their prey the present race is consistent with typical species.

Nest 2. I found another nest from which the wasp was carrying out the debris and dug it out. But it was the nest soon after commencement of digging. However, during my excavation I happened to go across a tunnel of an old nest. By following along the tunnel I could know the more complicate structure of the nest of this race. It was as given in Figure 12, A and B. As was understood from the figure, in this nest the tunnel repeated thrice the up- and down-ward turn. At the end the tunnel was loosely packed with soil. During my search digging around the end of the tunnel I found an old cocoon attached with the remains of bees. In the project the tunnel was 26 cm in length and 6 cm in the utmost depth.

Later, whenever I visited the road of Tiendang (the visit was frequently made) I paid my attention to the movement of the wasp of this species. But I could not meet with the wasp that was in the course of provisoning the larval cell. I dug out several nests, but all were in the course of digging, but in one of them I found a male *Cerceris pekingensis* stored in the tunnel. Toward the evening a number of the wasps were seen to dig the tunnel. But it was uncertain whether these tunnels were made for the nests or merely for passing a night.

PALARUS VARIEGATUS VARIEGATUS (FABRICIUS)

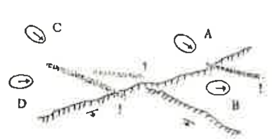
As mentioned in connection with the preceding race the nesting biology of this species has been well observed on the European representative. It is a rather astonishing fact that a great number of species of the prey, almost all confined to the aculeate Hymenoptera, are hunted by the wasps of this species (Dufour, 1841, including the Ichneumon fly; Girard, 1897; Ahrens, 1925; Móczár, 1952 and Grandi, 1961).

During my stay in the Inner-Mongolian steppe I happened to have a chance to observe the nests of this species which were made in the "Village of Wasps", a bare area along the upper edge of a dried rain ditch between hills in Apaka, near Beidzumiao. The village was crowded by a number of inhabitants of *Bembix niponica picticollis*, *B. weberi*, *Cerceris* spp., *Psen bicolor*, *Dienoplus laevis*, *Tachysphex* spp., *Halictus* spp., *Andrena* spp., *Colletes tsunekii* etc.

Nest 1. On September 15, 1939, after examining the nests of *Bembix* I enlarged the excavation and happened to discover a mass of remains of prey of some species of Sphecidae. I carefully took out the mass and found that it included a cocoon made of sand grains. I put whole the acquisition in a tube bottle and measured the pocket that included the cocoon. It was a small ellipsoidal chamber, about 12 mm in length and 5 mm in width and situated horizontally about 5 cm below the surface of the ground.

After returning to my camp I examined it under the magnifying glass. The remains consisted of the head capsules, thorax- or propodeum-cases, separated wings and legs, and from these it was presumed that the prey belonged to a species of the genus *Tiphia*. The number of the head capsules showed that the prey consisted of 8 individuals of the same species. The cocoon was apparently similar in structure to that of *Bembix*, but much smaller, measuring only 10 mm in length.

From the kind of the prey I presumed thad the huntress must have been a wasp of *Palarus varietatus* (in those days known as *P. flavipes* F.) which had been known to me to occur in the district.



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Figs. 14–15. Nests of *Palarus variegatus variegatus* (F.) (dorsal view).

Nest 2. Three days later, on September 18, while I was examining a nest of *Cerceris* in the same wasps' village I again happened to open a larval chamber of possibly the above-mentioned species. A further search brought to me 3 further brood-cells which were distributed as given in Figure 14 (dorsal view). But it was undetermined whether these 4 cells really belonged to a single nest or to two different nests (A, B and C, D), because the tunnel leading to each cell was completely compactly closed and moreover, the following of the main tunnel was impeded by the presence of entangled burrows of other wasps. The data regarding each cell:

Cell A. At the depth of 6.5 cm to the roof, including a cocoon.

Cell B. 〃 6.5 cm 〃 〃

Cell C. 〃 12.0 cm 〃 , including the remains of prey only.

Cell D. 〃 12.0 cm 〃 , including a cocoon.

The cells were comparatively varied in size, 15–20 mm in length, 7–10 mm in maximum width, ellipsoid in form and included the cocoon, when present, at the front portion and the remains at the rear portion. The cocoons were also varied in size, the largest (in A) being 12.3×5.0 mm and the smallest (in C) 10.5×4.2 mm and the middle (in B) 11.7×4.8 mm in length and width.

Prey. In A 6, in B 6, in C 8 and in D uncountable owing to a blow of wind. From the remains of the head capsule some of the prey were identified to the species, some to the genus:

A. *Cerceris quadricolor* 1, *Andrena* sp. 1, *Halictus* sp. 1, *Hylaeus* sp. 2 and some unknown bee genus 1.

B. *Cerceris quadricolor* 1, *Cerceris* sp. 1, *Astata* sp. 1, *Andrena* sp. 1, *Hylaeus* sp. 1.

C. *Hylaeus* sp. 8.

D. *Cerceris quadricolor*, an intact specimen, others were blown away during examination.

Nest 3. On the same day I saw a wasp of this species enter her nest with a prey. The entrance to her nest was closed and she laid the prey aside while she cleared the block. It was a species of *Tiphia*. The manner of her carrying in the prey to the burrow was the same as observed with the Peking race. When she appeared I caught her and at once dug the nest. However, in this nest also, by being disturbed by the intricately crossing tunnels of other wasps, especially those of *Bembix*, I could not follow the tunnel up to the end which was complicately waved up and down at least at first. But I could found 2 larval cells during my search digging which were located as given in Figure 15.

Cell A. Depth to the cell ceiling 6.5 cm, measuring 14×6 mm, including 4 prey (3 *Andrena* sp. and 1 parasitic Pompilid, *Ceropales maculatus* F.), without the egg of the wasp.

Cell B. Depth 7.0 mm, 15×7 mm, 5 prey (2 *Andrena* sp., 1 *Halictus* sp. and 1 *Nomada* sp. and 1 Ichneumon fly — *Amblyteles vadatorius* Illiger), with the wasp's egg.

The prey were placed venter up, and on one of the *Andrena* sp. which was put on top of the collection of the prey the egg of the wasp was laid. The manner of attachment of the egg (Fig. 13) was essentially the same as illustrated in the book of G. Grandi (1961).

Other nests. On September 21, while I was investigating the nests of other solitary wasps in the village of the wasps I obtained several small cocoons inlaid with earth grains that were considered to belong to this species. Most of them were the old ones with the rounded end broadly broken by the emerging wasp. They were fragile and easily crumbled to pieces under a simple pressure between the fingers. All of them were found about 4–5 cm below the surface of the ground. In one of the cells in which the egg did not hatch the prey were left untouched in a dried mass. It consisted of 11 insects containing some Ichneumon flies and the winged ants. I further obtained several dried specimens of *Cerceris* and *Tiphia* from other pockets in the earth.

I could brought back the cocoons to Japan without receiving the steam disinfection. The next year, from two of them the adult male wasps of *Palarus variegatus* emerged. The intact dried up prey from 2 cells were also brought back without examination. They proved to be 1 *Nomada* and 5 *Tiphia* from one of the cells and 1 *Cerceris* and 3 *Andrena* from the other.

According to my observations the prey of ***Palarus variegatus variegatus*** in Inner Mongolia include such genera of Hymenoptera as ***Cerceris, Astata, Ceropales, Tiphia,*** winged ants of ***Camponotus,*** Ichneumon flies of ***Amblyteles*** etc, ***Andrena, Halictus, Hylaeus, Nomada,*** and some parasitic bees of the genus unknown to me in those days.

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