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Occasional Publication of the Biological Laboratory
Fukui University, Japan

No. 10.

THE NESTING BIOLOGY OF *STIZUS PULCHERRIMUS* F. SMITH (HYM., SPHECIDAE) WITH SPECIAL REFERENCE TO THE GEOGRAPHICAL VARIATION*

BY K. TSUNEKI

SEPTEMBER 30, 1965

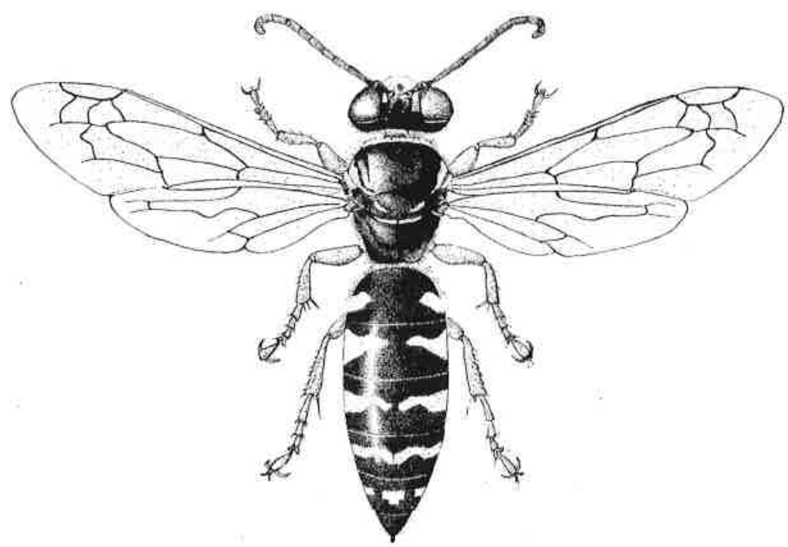

Fig. 1. *Stizus pulcherrimus* F. Smith, ♀

(K. Tsuneki del.)

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(Biological Laboratory, Fukui University)

CONTENTS

I. INTRODUCTION

The study on the biology of the wasps belonging to the genus *Stizus* has remained quite inadequate. The sole literature given in some detail was a paper published by me in 1943. It was regretted, however, that the paper was given in Japanese and could not be understood by the foreign entomologists. Since that time, therefore, I have frequently been requested personally to translate parts or whole of the paper in English.

The biology of this genus is particularly of interest in relation to those of the allied genera, *Bembix* and *Bembecinus,* since these genera are believed to have close evolutional relationships and the two genera mentioned are well known to occupy a particularly advanced position in their methods of brood rearing.

It seems, therefore, not necessarily of no use to give again the accounts in English. More-

* *Contribution No. 87 from the Biological Laboratory, Fukui University, Japan.*

over, in my previous paper I dealt with the Korean observations only and the accounts were given in a rather summary form. On this occasion, I will add my observation made in East Mongolia and will give the accounts in more detail based on my field notes. Further, it seems interesting to attempt a comparison in biology between the two natural populations, because they show a marked difference not only in the structure of their nests, but also in the method of rearing the young and afford a suggestion regarding the differentiation in instictive behaviour.

Stizus pulcherrimus Smith is a beautiful species, bearing reddish yellow legs and wing veins, with a rich ivory white maculation scattered over the body which is pitchy black (Fig. 1). It measures 20–25 mm in length, with a *Bembix*-like feature of the body. The species lives not only in the sandy area, but also in the area of fairy hard soil. It has been found so far in North China, Manchuria, East Mongolia, Korea and Japan. According to my knowledge it is not rare in certain parks of Peking, in the suburbs of Seoul and in the steppe of East Mongolia, but it is rare in Japan, only known from scattered and restricted locations of Kyushu, Shikoku and the southern half of Honshu. The biology of the species was observed only in East Mongolia and Korea, and not yet studied in Japan, except for a prey record (Katayama, 1933).

II. THE OBSERVATION AT APAKA, EAST MONGOLIA

In the steppe of East Mongolia the species can not unfrequently be met with on the wild floweres.

On August 29, 1939, a very glorious day, at 13:20, while I was talking with a Mongol I took notice of a large-sized wasp entering an opening with a prey under her body. The burrow was open under the roof of a house, close to the base of the wall, only 7 cm apart from it. I covered the opening with a glass bottle and captured the wasp when it came out of the burrow. It was a wasp of this species, and the discovery of its nest was the first record to my note books.

I dug up the nest at once and could confirm the facts given in the following:

Tunnel The entrance is 7 mm across, just the width to permit the passage of wasp's body. It was closed when the owner was absent, because I saw the wasp clear the opening stoppage. One centimeter from the entrance the tunnel was enlarged to about 11 mm in diameter and soon narrowed again to 9 mm and retained the same width up to the front of the larval cell. In the vertical view the tunnel showed a gentle turn at the enlarged portion to the right and thenceforth went in straight for 22 cm and connected with the larval cell. In the lateral view it penetrated into the earth at an angle of about 30° to the earth surface and turned gradually horizontal. There were three layers of soil stoppage of soft texture, each 7–8 mm in thickness, 10, 15 and 21 mm from the entrance respectively (Fig. 2).

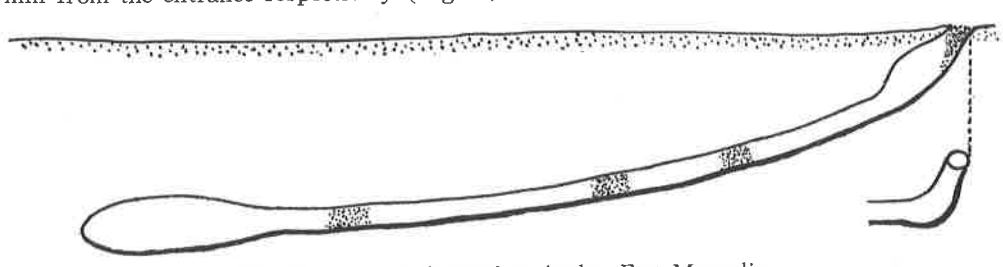


Fig. 2. A nest observed at Apaka, East Mongolia.

Larval cell It was connected in a straight line with the end of the tunnel and lay horizontal. It was ellipsoid in shape, 50 mm in maximum length and 13 mm in maximum height, with the upper wall at 47 mm below the earth surface. It was slightly wider than high, measuring 17 mm in maximum width. The soil of the wall is smoothly pressed.

Prey All were small forms of Orthoptera, Locustidae, including nymphs and imagoes, the former being 6 and the latter 2 in number. They were laid head in and venter up, and more or less piled in the cell. The order of the pile indicated that the two imagoes were provisioned last. The imagoes measured 20 and 19 mm and the nymphs 17, 19, 15, 16, 15 and 14 mm respectively. Later when I came back to Japan Dr. H. Furukawa kindly identified the prey-insects with *Chorthippus dubius* Zub., all belonging to one and the same species.

Larva When I took out the prey one by one I found the larva of the wasp, already 8 mm in length, attached to the nymphal prey laid innermost which was the smallest of all. The larval wasp was attached to the ventro-lateral corner at the base of the abdomen with its mouth and hang down somewhat obliquely across the base of the mid femur, as given in Figure 3. Judging from the knowledge later obtained, however, it did not show the original position of the egg laid by the wasp.

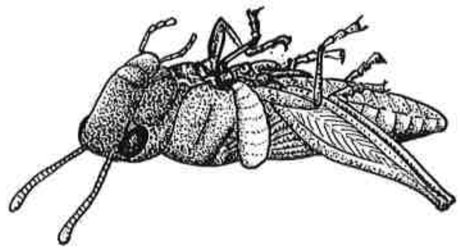


Fig. 3. The larval wasp sucking the prey (at Apaka).

Larval growth I reared the larva in the artificial cell made in a tin half filled with sand, It grew very slowly and on September 10 reached 16 mm in length, but it died on that date, passing 13 days after being taken out of the nest, probably about 20 days after being laid as an egg. During the time of my rearing none of the prey changed their morphological appearance, This was due to the particular mode of eating of the larva. It did not gnaw or bite the prey, but sucked them through the skin or through the small hole made by it. The room temperature of the day of the larval death was at 0.5°C in the morming.

I searched for another nests, but could not find any more.

III. THE OBSERVATIONS IN THE SUBURBS OF SEOUL, KOREA

On the ground with reddish brown soil mixing gravels which were derived from gneiss, I found on June 26, 1941, a large number of nests of several species of the digger wasps. It was on a hill near the then Keijo aerodrome. The place was planted with the chestnut trees, but they were still young and could not densely cover the ground with their canopy. The floor of the plantation was sparsely scattered with short grasses, but the proportions of the bare ground far surpassed the covered area. Within about 20 squaremeters occupying the southern edge of the plantation near the steep bank bording the old river bed of Kanko the nests of the wasps were concentrated.

The most abundant inhabitants were *Cerceris albofasciata* Rossi, with about 50 nests and the next abundant *Lestica alata* Panzer. The former took in their burrows the flattened Chrysomelid beetles, *Cassida* spp. and the latter various forms of the small moths. Among them were scattered the nests of some other species of *Cerceris* and those of *Philanthus coronatus* hither and thither. Mixing with these wasps the activities of the red-legged *Stizus* were quite outstanding because of their larger size and their gorgeous coloration. Some twenty of their nests were marked with the heaps of débris at their burrow entrances, some of which were partly concealed under the weeds.

Hunting, prey carriage and storage

At 10:00, while I was confirming the distributien of their nests I suddenly saw a wasp capture a short-horned grasshopper. It occurred about 2 m in front of my eyes. The wasp caught the insect from the back with her legs and flew to a leaf of the chestnut tree, standing about 3 m apart from there. Instantly she stung the prey twice at the ventral side of the thorax, bending her abdomen from the side of the insect. But the wasp, being frightened by the too close approach of me, flew up with the prey and landed on another leaf 5 m apart from the first leaf. There she hung down from the edge of the leaf with one of her hind legs, turned the prey insect round so as to hold it venter to venter and head to head. She then caught it by the antennae with her mandibles and flew to the trunk of a chestnut tree (Fig. 4). She climbed it a little and flew off to go to her nest. Near the ground she flew through the grass leaves and landed on the ground. About 10 cm in front of her several holes were open with the d bris by their sides. The wasp proceeded, capturing the prey by the antennae with her mandibles and holding it with her mid legs from both sides (Fig. 5). She reached near the holes, but did not enter any of them, but suddenly began to dig the earth in front of them with her front pair of the legs where not the least trace of the burrow was apparent. Soon, however, the entrance to the burrow came to appear and the wasp penetrated into it at once. At this moment the prey carried by her was pushed backwards to the tip of her abdomen and was dragged in the burrow. The manner was quite the same as observed in *Bembix* species when they carry in their rests the Dipterous prey.

Fig. 4. A wasp capturing the prey. See hind legs trembling.

Fourty centimeters apart from this another nest was present to which the owner of the burrow came back with her prey. She also cleared the entrance stoppage and entered it carrying the prey. This wasp, however, left the prey half appearing from the entrance opening and after a while pulled it into the burrow.

Hunting at this time of the day was very active. I saw several other wasps successively bring their victims to their burrows. The second wasp that I saw also carried in her nest at the several minutes intervals successively three further grasshoppers. But she, as in others, no more did leave the prey at the entrance of the nest where the body of the grasshopper was visible from outside. The manner I saw first of this wasp, therefore, must be quite exceptional. However, it indicated that the wasp of this species usually left the prey at the antrance gallery soon after entering the nest, inspected the larval cell empty-handed and then turned back to take the prey to the cell. The method is quite the same as observed in many species of *Bembix*. According to my observation on *B. niponica* the wasp sometimes leaves the prey (fly) at the entrance gallery of the nest visible from outside while it examines the interior.

Nests distribution and their external character

Within an area of about half squaremeter (100×50 cm) I found 6 nests closely distributed, including those of the first and second wasps that I observed. The area was gently roundly

Fig. 5, A. A wasp coming back to her nest with the prey.

elevated along the medial length axis. The entrances of the nests of the wasps were scattered at the side-edges of the area and dug in the earth shallowly against the medial elevation (Fig. 6). Nest 3 was the burrow of the first wasp and nest 4 that of the second wasp.

Fig. 5, B. A wasp with the prey going to her nest.

The entrance to the nest was always closed during the time of the absence of the owner. Close to it, however, several shallow holes were always left open. I at first thought that they were abandoned burrows that were stopped digging by some reason or other. But later, it was clarified that they were nothing else than the side holes that were always constructed by the Sphecine wasp, *Sphex argentatus fumosus* Mocsáry, in Japan.

The side holes were two in number as a rule, dug one on each side of the true entrance which was always closed. They were usually 3-4 cm in depth, sometimes only 1 cm and rarely more than 5 cm. They were more steeply penetrated into the earth than does the true burrow. The variation in distribution and in number of these accessary holes was just the same as in *Sphex argentatus* (Tsuneki, 1963): Sometimes 2 on one side and none on the other, sometimes 2 on each side, or 1 on one side and 2 on the other.

Nests structure and their contents

On the day when I found the colony I dug up the six nests shown in Figure 6, on the 28th and 29th of the same month I examined three and two further nests and on July 5 and 10, one and two more nests respectively. I thus investigated totally 15 nests of this species in Korea. The structure of these nests in the vertical view was given in Figures 7-15 and their contents in Table 1.

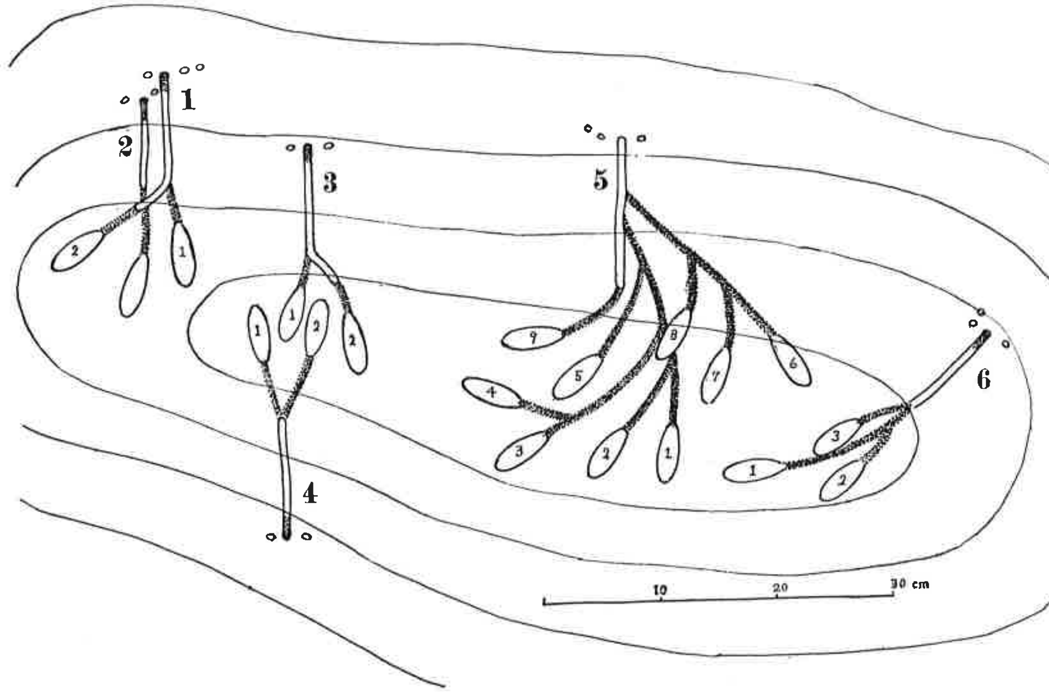


Fig. 6. Six nests aggregating in a small area and their structure.
(The contour lines showing difference of 2 cm)

Generally the nests are shallowly made, at first entering the earth at an angle of about 25–30° to the ground surface and then gradually turning horizontal. In structure they are compound and of the simple branched type, containing several cells within, which are made one at each end branch of the burrow. The larval cells are located 4–6 cm below the earth surface (depth to the cell-ceiling). The tunnels leading to the cells are from 10 to 50 cm in length, 7 mm or so in diameter and rounded in the cross section. Each branch is so compactly stuffed with soil after completing provisioning to the end cell that it becomes hardly possible to follow its running feature in detail. As a rule, the tunnel leading to the cell which is considered in the course of provisioning is loosely packed with soil for 2–3 cm in front of it, but sometimes it is completely left open. The cell is smaller on an average than that observed in Mongolia, measuring 40 mm or so in length, 15–17 mm in width and slightly less in height. It is a characteristic feature of the nest of this species that the side holes are always present.

In the following a brief comment will be given to each nest:

Nest 1. Sides holes 3, depth at B 6 cm, distance B–C 3 cm. Branch tunnels leading to the cells were closed for about 3 cm respectively. *Cell 1*: 40(l)×18(w)×15(h) mm, a prey (20 mm) green form, other 3 (25, 24, 21 mm) brown, all head in, one venter up, others side up; abundant excrement of the prey in the cell; the innermost smallest prey carrying a waspling, attached to the prey's pleuron just in front of the left metacoxa with its head. *Cell 2*: Size similar, all the prey nymphs, 2 green and 4 brown, 22, 21, 21, 20, 21 and 23 mm; all lying side up. To the innermost prey the wasp's egg was atached: Glued to the left fore wing bud with its posterior end, with the anterior end free, reaching the lower portion of the mesopleuron, crossing obliquely the area. It is 4.3×0.9 mm in dimensions, slightly curved.

Nest 2. It lies close to nest 1 and the tunnels of both nests are crossed in the interior

Table 1. Data on the nests of *Stizus pulcherrimus* Smith

Nest No.	Cell No.	Cell depth*	Prey: Species, number	Imago	Nymph	♂	♀	Total	Offspring or cell condition
1	1	4.8	S 1, P 2, U 1	1	3	3	1	4	Larva 6 mm
	2	5.0	P 4, U 1	–	6	5	1	6	Egg
2	1	5.0	P 2	–	2	2	–	2	Egg, incomplete
3	1	5.0	U 3	–	3	–	3	3	Egg
	2	5.2	U 1	–	1	–	1	1	Egg, incomplete
4	1	6.0	U 2, P 2, Ai 1	–	5	2	3	5	Larva 7 mm
	2	5.5	P 2	–	2	2	–	2	Egg, incomplete
5	1	4.2	? 4	–	4	?	?	4	Larva 17 mm
	2	4.7	U 1, ? 4	4	1	?	?	5	Destroyed by parasites
	3	6.0	U 4	–	4	–	4	4	Larva 7 mm
	4	5.5	U 4	–	4	–	4	4	Larva 5 mm
	5	6.0	P 3, U 1	–	4	2	2	4	Larva 4.3 mm
	6	4.4	U 3	–	3	3	–	3	Egg
	7	5.4	P 2	–	2	–	2	2	Parasityzed by maggots
	8	5.0	U 2, P 2	–	4	2	2	4	Egg
	9	5.5	U 4	–	4	–	4	4	Egg
6	1	5.5	? 4	–	4	?	?	4	Putrefied
	2	5.5	? 4	–	4	1	3	4	Larva 7 mm
	3	5.5	P 3	–	3	1	2	3	Egg
7	1	6.5	P 1, Ai 1, U 1	1	3	2	2	4	Larva 4.5 mm
	2	5.5	P 2	1	1	2	–	2	Egg, incomplete
8	1	5.0	P 2, Ai 2	2	2	4	–	4	Larva 4.5 mm
	2	4.8	P 2, U 2	2	2	2	2	4	Egg
9	1	5.0	P 4	–	4	2	2	4	Covered with mould
	2	5.0	P 4	–	4	?	?	4	Covered with mould
	3	5.0	P 2, Q 1	1	2	3	–	3	Larva 4.5 mm
	4	5.0	P 4	–	4	?	?	4	Putrefied
	5	6.0	P 2, Ai 1	1	2	3	–	3	Egg
10	1	6.5	P 5	–	5	?	?	5	Larva 20 mm
	2	6.0	P 4	1	3	4	–	4	putrefied
	3	4.0	P 5	–	5	–	5	5	Larva 10 mm
	4	4.3	P 3	1	2	–	3	3	Egg
	5	4.5	P 1, X 1	–	2	1	1	2	Egg
11	1	4.0	? ?	?	?	?	?	?	Larva spinning cocoon
12	1	4.3	P 2	–	2	?	?	2	Egg eaten by maggots
13	1	6.0	Ai 1, T 1	–	2	–	2	2	Egg
14	1	5.0	?	?	?	?	?	?	Cocoon
	2	4.7	?	?	?	?	?	?	Cocoon
	3	6.0	P 4, Ai 1, C 1	3	3	?	?	?	Larva 5.5 mm
15	1	4.5	Ai 7	–	7	?	?	7	Larva 9 mm
M	1	4.7	Ch 8	2	6	?	?	8	Larva 8 mm, incomplete

Remarks. M, in the column of Nest No ... Mongolian instance

Abbreviation of species: P ... *Paraplourus aliaeus* Germ. S ... *Stauroderus schmidti* Ikon. Ai ... *Aiolopus tamulus* Fabr. C ... *Conocephalus maculatus* Gouil. Ch ... *Chorthippus dubius* Zub. T ... *Trilophida annulata* Thun. U ... Undetermined species of Locustidae.

* Depth to the roof of the cell.

(Fig. 6), with a single cell (depth 5 cm) at the apex of the 11 cm tunnel, 4 cm of which is closed with soil, cell size similar, with 2 brown nymphs, 20 and 21 mm, one of which carries the wasp's egg. The place and state of its attachment as in cell 2 of nest 1. The cell incomplete.

Nest 3. Side holes 2, tunnel at A 5 cm in depth. *Cell 1* : Prey all head in, side up, all green, 24, 24 and 23 mm, the innermost one carries the wasp's egg attached to the upper portion of the right mesopleuron. *Cell 2*: Green nymph 1, head in and side up, the egg attached to the posterior portion of the right wing bud with its posterior end.

Nest 4. The burrow is dug in against nest 3 and the larval cells of both nests lie nearly in a line. *Cell 1*: Prey green 2 (23, 25 mm), pale brown 3 (18, 20, 20 mm), mixing nymphs of *Paraplourus alliaeus* and *Aiolopus tamulus*, larval wasp attached to the smallest and innermost prey. *Cell 2*: All the prey head in and side up, all *Paraplourus alliaeus*, pale brown, 21 and 19 mm, the egg attached to the right wing bud with its posterior end.

Nest 5. Including 9 cells, yet the wasp was working for provisioning for the young. During my observation she brought in 4 prey successively to her nest at the intervals of 5–10 min. In my previous paper I denoted the cells by the order of their discovery. In the present paper I changed it to the presumed order of their construction. In the following the length numeral of the prey with an asterisk indicates the pedestal to the wasp's egg. *Cell 1*: Prey 4, heavily devoured by 17 mm larva, details unknown. *Cell 2*: Prey all green, 4 of which were devoured by two maggots of the parasitic fly, 7 mm in length. *Cell 3*: Prey all green, 24, 25, 24 and 20* mm, larval wasp 7 mm, attached to the ventro-pleural border in front of the hind coxa with its month. *Cell 4*: Prey all green, 24, 26, 20 and 23* mm. waspling laid as the egg, with posterior end still on the wing bud, but with anterior end attached to the larval skin in front of the hind coxa. *Cell 5*: One prey (18 mm) green, others brown (25, 20, 19* mm), larval wasp just after hatching. *Cell 6*: Prey all green, all side up, 27, 25 and 18* mm. The egg attached to the left wing bud. *Cell 7*: Prey 2 brown nymphs, destroyed by the parasitic fly maggots. *Cell 8*: Prey all side up, 2 green (25, 24* mm) and 2 brown (20, 21 mm), the egg on the right wing bud. *Cell 9*: 38×17×14 mm in dimensions, prey green, 23*, 24, 24 and 27 mm, the egg attached to the right wing bud with its posterior end.

Nest 6. Including 3 larval cells. *Cell 1*: Prey heavily covered with mould and completely putrefied. *Cell 2*: Larva 7 mm, still with the caudal end on the right wing bud. *Cell 3*: Prey all brown nymphs, the egg on the right wing bud.

Two days later (June 28) I visited the same place at 14:00. The time was approximately the same as in two days before, but the activities of the wasps were markedly lowered. By searching in the plantation I could find 7 nests, some of which might be made by the wasps whom I deprived of their previous nests. Three nests were dug open,

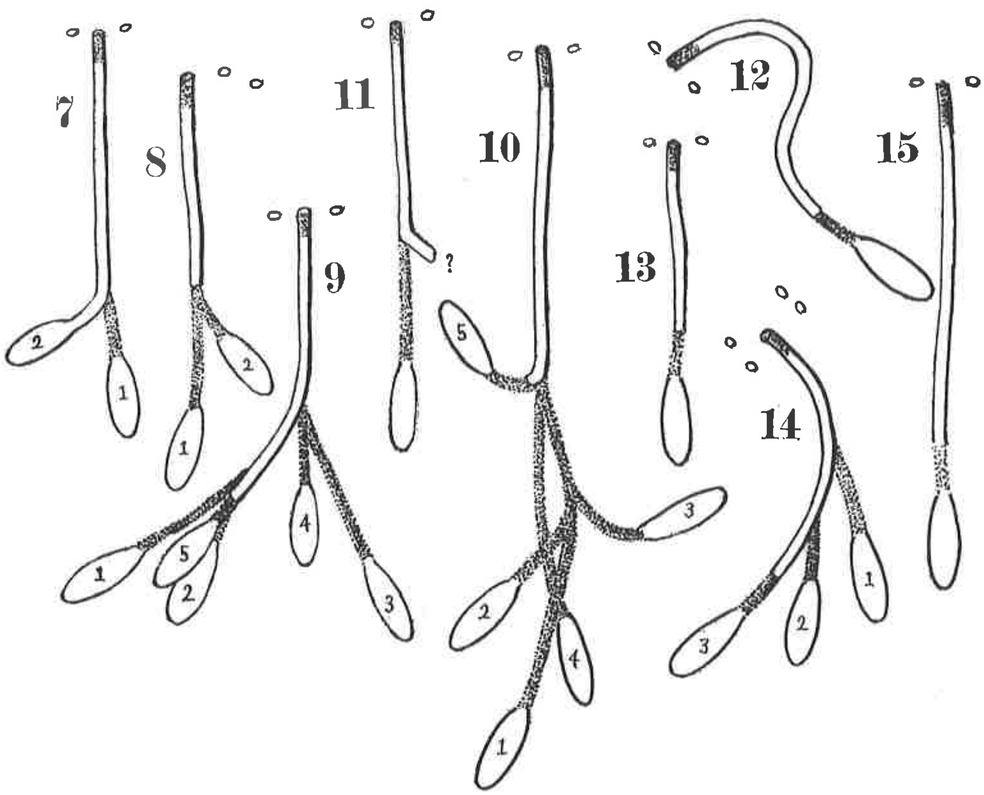
Nest 7. Two side holes, one on each side of the entrance, 3.8 and 3.0 cm respectively in depth, with steep inclination. *Cell 1*: Prey green 3 and brown 1, the smallest of which carried the just hatched larva of the wasp, attached to the right wing bud with its caudal end. *Cell 2*: The tunnel in front of the cell was not closed. The egg was destroyed by the crumbled soil. Prey, 25 and 20 mm.

Nest 8. Two side holes, both on one side in a low with the true entrance, one 3 cm and the other 6 cm in depth. *Cell 1*: Prey, 25, 24, 21 and 20* mm in length from the outside. A just hatched larva on the right wing bud. *Cell 2*: 47×18×17 mm in dimensions, prey 25, 25, 24, 22* mm, the egg on the left wing bud.

Nest 9. Two side holes, one on each side of the true entrance, 3.5 and 1.0 cm in depth.

Cell 1: All putrefied. *Cell 2*: Ibid. *Cell 3*: A just hatched larva on the right wing bud of the nymphal prey laid innermost. *Cell 4*: Putrefied. *Cell 5*. The egg was attached to the right wing bud of the innermost prey.

Nest 10. With two side holes, one on each side, 5.5 and 2.5 cm apart respectively from the true entrance and 4.5 and 2.5 cm in depth, both very steep, nearly perpendicular. *Cell 1*: Prey 5, already turned remains, with nearly full-grown larva. *Cell 2*: Thickly covered with mould. *Cell 3*: The larva, 10 mm in length, already dropped from the pedestal prey. *Cell 4*: 50 mm in length, egg on the base of right fore wing of an imago. *Cell 5*: Egg on the right wing bud of a nymph. The branch tunnel loosely packed with soil.



Figs. 7-15. Structure of nest 7 – nest 15.

Nest 11. With two side holes, one on each side. The tunnel was missed and blind search digging brought to me a larval cell which lay 35 cm away from the entrance and with the ceiling 4.0 cm below the earth surface. In the cell a full-grown larva was spinning the cocoon. Other cells might be present, but could not be found out.

Nest 12. July 5. The tunnel drew a half circle and then went straight (Fig. 12). Such a curved tunnel was very curious among many that ran straight. It was loosely closed in front of the larval cell that contained 2 very small (about 15 mm) nymphal prey. One of the prey carried the wasp's egg attached to the wing bud. But it was just eaten by several very little maggots of the parasitic fly. Probably they were laid on the 2nd prey while it was laid in the entrance tunnel.

Nest 13. The tunnel went straight in for 23 cm and enlarged into a brood-cell. It was loosely closed for 3 cm in front of the cell which contained 2 prey. One was *Trilophida annulata*, nymph ♀ (13 mm) and the other *Acrida lata*, nymph ♂ (23 mm). The wasp's egg was attached to the right metapleuron of the *Acrida* with its posterior end.

Nest 14. July 10. Having 4 side holes, 2 on each side. *Cells 1 and 2*: Contained cocoon and remains covered with mould. *Cell 3*: Prey 6, including a longhorned grasshopper, *Conocephalus maculatus* nymph.

Nest 15. Two side holes, one on each side. The tunnel ran straight for 19 cm and connected with the larval cell. The tunnel in front of the cell was loosely closed for 4 cm. In the cell 7 nymphs of *Aiolopus tamalus*, from interior 18, 15, 16, 10, 11, 10 and 12 mm in body length. On the largest one was a 9 mm larva, attached still to the left wing bud with its caudal end.

IV. ON SOME ASPECTS IN THE NESTING BIOIOGY

Structure of the nest

Types of the structure In *Bembix niponica* I could confirm the presence of both the nest types, simple and compound, in Japan. In this respect, the nests of the Korean representatives are doubtlessly of the compound type, those containing a single larval cell only being probably incomplete ones. On the other hand, it can not definitely be determined that the nests made by the Mongolian population are of the simple type, though the nest that I examined was a case of the simple nest. However, judging from the stability in the working manner of the wasp I would venture to say that it was a representative of the Mongolian population.

Side holes The side holes are observed in the nests of the Korean population only. Here I only explain why I used such a term. In my book entitled "The Japanese Hunting Wasps, Their Ecology and Psychology" (1946) I called the side holes 擬孔, meaning "False burrow". Recently H. E. Evans (1957, 1964) quite independently uses the same term to designate the similar structure found in the nests of *Bembix troglodytes* Handlirsch and *Philanthus lepidus* Gresson. In my paper on the biology of East-Asiatic Sphex I dealt with the similar structure at the entrance to the nest of *Sphex argentatus fumosus* Mocsáry, but I avoided to use the term, false burrow, having a very distinct ecological significance and adopted the term, side holes, that has only the morphological meaning. The reasons for this are that, although I believe that the ecological significance of the holes, if any, may be really false burrows towards the enemy of the wasps, yet there are still some opposed or different opinions regarding the biological significance of the holes among the investigators and it seems not always justified to adopt the term which restricts the significance to a single opinion only; and, moreover, the term, false burrow, has a very strong anthropomorphic odour, giving us an impression that the insects see and take these as we do. On the other hand, the morphological term seems to be much free from the maybe misapprehension and proper to represent the structure only. These are the reasons why I replace my first ecological term with the term of morphology.

The side holes of *Stizus pulcherrimus* F. Smith is structurally quite identical with those found in the nests of *Sphex argentatus fumosus* Mocsáry occurring in Japan. As regards the ecological or evolutional significance I agree with H. E. Evans in opinion. Details on this problem were discussed in my paper on *Sphex* (1963).

Order of cell construction In their multicellular nests the wasps of this species do not show a certain definite inclination in the order of cell construction. Although we can perceive a more or less general trend of cell construction from interior to exterior, there are too many exceptions to take this as a general rule. The constant portion of the tunnel usually called main burrow is considered very short in this species. being very often much shorter than the branch tunnels leading to each cell. Moreover, the branch is not always simple, sometimes irregularly repeating dichotomy, that is to say, the basal portion of the branch takes a part of "sub-main-burrow". The length of the branch tunnel is also quite varied, ranging from 5 to 30 cm. These tendencies in cell construction do not allow the formation of a rule regarding the order in their cell construction.

From the facts above mentioned we may conclude that this species is primitive in the construction of the compound type of the nest. The fact that the main burrow is short and the branch tunnels are comparatively long shows that each cell including its own branch tunnel is approximate to the separate simple nest. Aggregatien of simple nests made by one individual may lead to the common use of a short main tunnel, and eventually to the formation of the compound nest.

Prey

As given in Table 1, the prey captured by this species belonged all to Orthoptera, mostly to Locustidae and rather exceptionally to Tettigoniidae. The prey record of each nest given in Table 1 can be summarized with respect to species and their numbers as follows:

In Mongolia (1) *Chorthippus dubius* Zub. (キシダヒナバッタ) …………… 8

In Korea (1) *paraplourus alliaeus* Germer (イナゴモドキ) …………… 69

(2) *Aiolopus tamulus* Fabricius (マダラバッタ) ……………… 13

(3) *Stauroderus schmidti* Ikonnikov (ヒゲナガバッタ) ……… 1

(4) *Acrida lata* (Motschulsky) (ショウリョウバッタ) ……… 1

(5) *Trilophida annulata* Thunberg (イボバッタ) …………… 1

(6) Lucustidae, gen. sp*. ……………………………………… 32

(7) *Conocephalus maculatu*. (le Gouillon) (ホシササキリ) … 2

* Closely resembles *Oxya vicina* Brunner von Wattenwyl.

In Korea, these species are rather irregularly mixed, but the species, (3), (4), (5) and (7) are considered exceptions.

The number per one cell is in the Korean instances 2–6, most usually 4, while in the Mongolian instance, though a single observation, it reaches as many as 8.

As for the colour forms of the prey both the green and pale brown forms are captured without discrimination. As for the developmental stages the nymph is overwhelmingly preferred to the adult. But it seems noteworthy that in one instance an adult insect was first brought in the nest and on which oviposited. As for the body size of the prey it ranges mostly from 20 to 23 mm, sometimes over this but not larger than 25 mm and sometimes less than 20 mm but not less than 15 mm.

The prey are deeply paralyzed. But we can see the antennae and palpi move and the legs tremble, the abdomen pulsate and the excretion regularly performed for the first several days. But they can not move their bodies.

The prey in the cell is always placed head in, but the orientation of the venter is uncertain, sometimes venter up, but mostly side up. This is probably due to the body structure of the prey insects. They are more or less piled up in the cell. The later stored victims are placed half or wholly on top of the earlier brought in, when the space of the cell does not permit to lay them side by side.

Oviposition

According to my observation *Bembix niponica* brings in the nest the first prey prior to the preparation of the brood cell. In *Stizus pulcherrimus* the brood cell to receive the provision and the egg of the wasp is always prepared prior to prey hunting. As soon as the first victim is brought in the brood cell the wasp lays an egg upon it.

The egg is 4.3–4.5 mm in length, 0.9–1.0 mm in width, banana-shaped, in colour pale yellow and glossy.

In the case of the nymphal prey the egg is, as a rule, glued to its wing bud with its posterior end. The body of the egg lays on the pleuron and the free anterior end reaches the ventro-pleural border. In the case of the adult prey, the egg is laid on the base of one of the fore wings. Sometime, however, the place of attachment is more or less deviated, coming to the metapleuron just above the hind coxa, or to the mesopleuron slightly above the interval between the mid and hind coxae. But the cephalic end of the egg is always directed towards the ventral side of the thorax. This is always so with no relation whatever with the body orientation of the pedestal victim, whether venter up or side up.

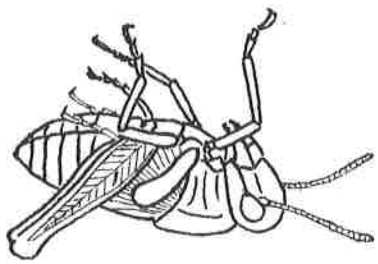


Fig. 16. The egg of the wasp attached to the wing bud of the prey with its posterior end.

Method of provisioning

As above mentioned, the wasp of this species lays the egg to the first prey brought in the cell and later adds the necessary amount of the prey to the side of it. In such a mode of provisioning there is a question as to whether it is made progressively or massively.

In the instance observed in E. Mongolia I found a larva, about 8 mm in length, attached to the prey laid innermost. As the nest was dug up just after the wasp carried in a prey there is no doubt that it is an instance of the so-called progressive privisioning. However, the mode of its provisioning is very primitive as such. Because the waspling was only before the half of its growth progress and the prey provided for it were considered already approximated the full provisioning. On the other hand, it must also be considered that the provisioning activity of the wasp to the cell was performed very slowly, for a considerable period of time. Because, as the procedure of my rearing shows the growth of the larva was very slow at that time, and it is presumed that the larva had passed already a week or more before I found it at the length of 8 mm in the cell. The prey insects must have been accumulated very slowly during the time. The delayed provisioning is not due, however, to the bad weather that inhibits the wasp's activity. According to my diary the weather of 10 days before the day of observation was very clear, except the 24th (5 days before) when overcasted from time to time with a little rain. Therefore, if the wasp wanted, provisioning of the cell could easily and promtly be completed within a day. The delayed provisioning is, therefore, entirely dependent upon the innate tendency of the wasp.

In *Bembix niponica*, and probably in many other species of the genus, provisioning is progressively and daily carried out as far as the larva remains within the lst to 3rd instars. However, as soon as or some time after the larva reaches the final instar (in this respect there are individual differences) the mother wasp collects within a few hours a large amount of the prey necessary to complete the rest of the larval growth and closes the cell permanently. The amount accumulated at that time is usually several times as much as that provided to the larva up to that time. The manner is quite similar to the method of the wasps performing the mass provisioning.

By thus considering it becomes obvious that the method of *Stizus pulcherrimus* is not so distantly apart from those of *Bembix*, although there is no doubt that it is more primitive.

On the other hand, it is rather strange that in the adequate instances in Korea I could not find even a single instance in which there was a larva in the cell to which prey storing of the mother wasp was still going on. The offsprings found in such cells were always in the stage of the egg. Moreover, it was an usual matter that in a cell or two, sometime even 3, already completed we could find an egg attached to one of the prey laid innermost. Therefore, the mode of provisioning of the wasps in Seoul belongs completely to the typical case of the mass provisioning. Indeed, some wasps are considered to complete even two cells within a day. The fact that the wasps of Korea make more than 5 larval cells in a nest within several days (this is concluded from the larval size in the early made cells) tells us that mass feeding is the rule among them. Furthermore, in some nests several cells with the waspling and the prey are completely destroyed by the mould. Such a fact does not occur in the cells to which the prey insects are brougth in by the wasp day by day.

V. BIOLOGY OF THE LARVAL WASP

Mode of eating the prey

The larva reared by me in Mongolia only sucked the prey from the beginning to the last of its life when it reached 17 mm in body length. As it did not normally eat the prey, the latter retained their appearance intact until the last.

While in ten larvae reared in Korea the prey were completely devoured except those used for the pedestal of the egg that were sucked. Later, however, when the larvae ate the accumulated prey one after another the egg-pedestal prey that were left aside after being suckd were also devoured. They left only the hard sclerites of the head, thorax and genitalia and the wings of the adult prey.

To the larva in Mongolia the prey provided are far larger in amount as well as in number than those observed in Korea, so that it is allowed to it to eat the prey very luxuriously. While the larvae in Korea are provided with so megre an amount of food, half or less as compared with the food for the Mongolian waspling, that they can not carry out the full growth, had they not utilized every eatable portion of the prey. Apart from their innate tendencies, therefore, the difference in the amount of food provided seems to have bearing with the difference in the mode of taking nourishment from the prey.

In *Bembix* the larval wasp is furnished by the mother wasp with a surplus food. Yet it does not develop such a peculiar mode of taking food as observed in the larva of the Mongolian *Stizus pulcherrimus*. Considering as such, the mode of eating the prey in the larva of the Mongolian *Stizus* may be a quite independent and exceptional instance in the instinctive evolution among the tribes, Bembecini and Sitzini.

Growth process

In Korea I reared 10 larvae, a half from the egg, by the tube-bottle method. A tube bottle, 15 mm across and 100 mm in length, is used. A block of favourably wet sand is compactly pressed in at the bottom for 20–25 mm. Then the prey with an egg or a larva are introduced. Giving them a space of 40–50 mm in length the opening is tightly closed with a cotton plug. The bottles thus equipped are laid with small blocks on both sides in a proper box with a lid. The box must avoid the direct sunshine and is preferably kept in the cool place with the lid. Unless, the water drops evaporated attached to the glass wall. They not only make the inside invisible, but sometimes also the waspling die. High moisture, if the waspling can resist it, finally deprives it of the support for cocoon-spinning and eventually leads to its death.

According to my observations using this method of rearing, the egg hatches out, under the room temperature, 24–30 hours after oviposition. The chorion is so thin and delicate that the acculate time of hatching is always indistinct. The hatched larva attaches its posterior end to the wing bud of the nymphal prey and begins to suck the body juice of the pedestal insect with its free mouth which reaches the lower portion of the pleuron. Probably it perforates a small hole in the skin and through which sucks the juice. It takes 24–36 hours to empty the first prey, when the larva becomes 6–8 mm in length. Then the larva leaves it to eat the second prey. In most of the cases the second prey was bored a hole at the neck, thence the larva inserted first its head, later gradually greater part of its anterior body and devoured from the thorax to the abdomen. Towards the time when it eats up the second prey it becomes 13–15 mm, but with the body still very slender. The place from which the third, fourth and fifth prey are begun to eat is undetermined, since the larva becomes powerful enough to begin to eat from anywhere it touches. Thus, some are eaten from the abdomen and some from the thorax. Towards the time the prey are eaten from the outside and the hard portions alone are left undevoured. The larva attains 18–20 mm in length after eating up the third prey, but it is still slender. The prey accumulated in the cell including the abandoned pedestal are succcessively devoured and finally in the cells with scanty food the legs are also completely eaten up. The larva reaches 25 mm or more in length and becomes plumped. It takes 6–7 days to finish its growth.

An egg presumably laid in the afternoon of June 25 was just hatching when taken at 16:00 of the next day. The larva reached 7 mm at 15:00 of the 27th and had finished its growth in the morning of the 2nd of July. It began to spin the cocoon at 14:00 of the day.

Method of cocoon spinning

The full-grown larva moves about in the chamber slowly, picking at the wall from time to time. A considerable amount of sand is dropped from the inner sand block. In the natural state the remains of the prey might be covered with the sand grains by such behaviour of the larva. Then it begins to stick its silk thread to the wall, first to the lower portion. By sluggishly repeating the silk-sticking activities from the bed to the right and left walls, turning round from time to time a whitish silk hammock comes to appear and the larval body is supported by the sheet. The time spent for this work is about 2 hours. Then the larva sticks the silk thread higher and higher between different points of the glass walls and between the walls and the bed sheet. Its anterior body is strikingly stretched forwards and backwards and its mouth parts are actively moved as if to bite something, probably to pull out the thread and to stick it to the supports. Such behaviour is continued without cease for 4–6 hours and the shape of the thin cocoon becomes visible. It is an elongate ellipsoid in shape and slightly obliquely hung, with the internal end (in reality the anterior or cephalic end) directing the sand block at the bottom of the bottle high. This end of the silk cocoon, still almost transparent, is widely open and again divergently widened into a funnel, the brim of which is attached to the sand wall. The external end (in reality the posterior or caudal end) of the cocoon is completely closed and a thick bundle of silk threads that extends from the cocoon end is suddenly bent downwards and attached to the floor of the chamber like a stalk. An hour passed and the wall of the cocoon becomes semitransparent and its form more distinct. It becomes obvious that the upper portion of the funnel is widely open as if to spread a sheet of silk cloth. Apparently the larva in the cocoon is tightly enclosed by the silk pouch. Notwithstanding, it continues to add the silk thread to the inner wall of the cocoon by stretching and bending its anterior body. By doing so it can spin the half of the cocoon in which its anterior body is rested. When it must spin the other half of the cocoon it turns round in the cocoon. Apparently it is impossible for the larva to do so, since the cocoon is too tightly made around it. But the larva performs turning without the least difficulty. First it inserts its head and neck (thorax) beneath its ventral side of the body. Gradually it moves its anterior body backwards and its posterior body forwards. The body is folded in two and the two parts are crossed each other, sliding on each other's ventral face. The cocoon is expanded by its elasticity and enables the waspling to do so. The way is quite skilful.

The mode of attaching silk is slightly changed. The larva bends its head ventrally and by stretching it forwards it adds the silk thread to the restricted place of the cocoon wall. By rotating its body little by little and by repeating this spinning performance patiently the cocoon is thickened at a zone having a certain width. Then the larva proceeds or retreats to spin the next zone of the cocoon.

A larva that began to lay hammock at 7:00 completed the silk cocoon with a funnel and the stalk at 15:10, when it began to take in the sand grains to the cocoon. To describe the sand inlaying activity of the larva I will follow the work of this larva.

The larva stretched more than a third of its body out of the anterior opening on to the funnel and collected the sand grains from the bottom block. It moved its head up and down against the sand block and scraped down the grains on the funnel. In doing so it gradually proceeded forwards and at 15:20 about a half of its body was protruded from the cocoon. A considerable amount of sand was gathered on the funnel and at 15:30 the larva began to retreat in the cocoon. It then raked in the cocoon the sand grains thus collected on the funnel by moving its head forwards and backwards. During the time the larva showed very interesting behaviour of selecting the sand grains and unfavourably large ones ware discarded. It was performed by catching the grains between the mandibles and moving quickly the head upwards and forwards. The grain thus treated was thrown away up to the distance of 10 mm or more. The timing of letting off the graing was very nice. Such selection was successively performed. It was quite wonderful to find such an ability in the maggot-like waspling. At 15:45, it again protruded its anterior body out of the cocoon and resumed sand gathering behaviour. Again the large grains were successively flung away and the remainder was taken in the cocoon. The performance was continued even when the bottle was taken up to observe the larval behaviour in detail. Finally the larva retreated into the cocoon again and a mass of sand was collected near the opening under the thorax of the larva.

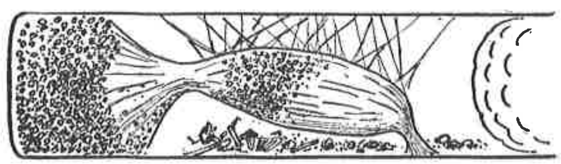


Fig. 17. The cocoon at the beginning of the sand inlaying stage. (The tube bottle method)

The larva thrust its head beneath the thorax, moistened a small amount of sand with the secretion of the silk gland, carried the pellet thus formed to the left upper side of the cocoon, and pressed and extended it over a small area. It again inserted its head beneath the thorax, mointened the sand grains and this time extended the pellet sideways. Next it carried the pellet upwards and extended it over the area adjacent to the previous. The same manoeuvre was twice further repeated and the sand grains were attached to the inner wall of the silk pouch. During such sand-inlaying work the larva made further choice of the material and the large sand grains were thrown out of the cocoon throngh the opening.

At 16:00 the larva protruded itself for the second time from the opening and collected the material. When it resumed the sand embedding work I concentrated my attention to observed the process in detail and found that besides the sand pellet inner wall of the cocoon where the pellet was to be attached was also moistened with the silk gland secretion and the larva pressed the pellet to the place and roughly extended it over the area with its mouth. The point moistened with the secretion became yellowish and glittering.

Towards 16:30, a belt of sand was about to accomplish as given in Figure 17, when I had to go to my official work. However, another larva which was also spinning the cocoon at the same time and in which the process was by about 3 hours preceded supplemented the observation on the above larva. According to the work of this larva the sand belt formed by the first larva was further extended backwards to reach slightly over the equatorial zone. To perform the work the larva had to stretch its head and thorax markedly backwards along its abdomen, also it rolled its body slightly to the right and left. When the sand covered the anterior 3/5 of the cocoon the larva began to thicken the covering of the equatorial zone. The outer zone, slightly apart from the opening, was left in the state of the thin layer. Then the larva collected a comparatively larger amount of sand in the cocoon (with sand selecting behaviour) and turned round so as to face in the opposite direction. This time the inner portion of the cocoon was gradually set with the sand grains. The time spent for this work was about 40 min. At 16:00 when my observation was stopped this larva was at this stage of the cocoon spinning. However, I missed to confirm whether or not the larva took in the material further during the time. But, judging from the fact that my attention was not particularly attracted by the larva, it seemed that it did not turn round twice to collect the material further.

At 20:30 I had a chance to observe the larvae in my recess and could confirm that in the earlier larva the opening was already closed and in the later one the cocoon was completely lined with a layer of sand, but the opening was still left untouched and the larva was from time to time pushing the wall of the equatorial zone from inside. The place was pushed out in the form of the larval mouth (probably the behaviour relating to the construction of the respiratory pores). Since that time I could not return home until the evening of the next day.

When I came back the two cocoons above mentioned were already completed and another two larvae were in the course of cocoon spinning. Fortunate enough, one of them was just closing the opening of the cocoon.

The opening was slightly more narrowed than in the earlier stage and a layer of silk already covered the area. The larva attached the sand pellet to the silk lid from within and cemented the grains with the silk gland secretion. During the time its work was not restricted to the lid. It was observed that the cocoon was pushed out simultaneously at the adjacent area. After a while the lid of the opening was completely set with the sand grains. Apparently the sand cemented cocoon was completed by this closure, but to complete the inner layers of the cocoon at least further 2–3 days were needed. The sand cocoon just after the entrance lid is made is quite wet. It takes a day to be completely dried up.

Further work of the larva within the cocoon could be observed in my case through an abnormal cocoon spun by one of the larvae which was found spinning the cocoon in the evening of July 2. This larva after completing a silk cocoon with the funnel and stalk slept out of the silk pouch, probably by mistake at the time of sand collecting manoeuvre. When I observed it had already spun up a new silk cocoon on the first silk pouch. What was interesting was that the cocoon newly made had no opening whatever. It was only an elongated ellopsoidal pouch. The larva in it was well visible through its semitransparent silk layer. It became already somewhat yellowist. In the next morning (July 3) at 7:00 the larva continued to spin the cocoon which had a yellow tint and represented obviously the second layer of the normal cocoon that lined the sand cocoon. At 19:00 of the day the larva in the cocoon became more strongly yellowish and the semitransparent cocoon with much more yellowish tint was glued to the side glass wall, probably by the silk gland secretion which was at that time not spun into the thread but smeared as a sticky liquid. It was observed that the larva was still obeying the cocoon constructing work. In the evening, the cocoon much increased the yellowish coloration. This was due to the tissueless expansion of the secretion. The next morning (July 4), I found the cocoon changed into dark brown in colour. This was due to the substance usually found as the innermost layer of the cocoon and believed to derive from the excrement.

Orientation of the cocoon

All the larvae that I succeeded in rearing directed the funnel of their silk cocoons towards the sand block at the bottom of the tubes. In nature the cocoon of this species is always directed with its anterior end (the end with the funnel) towards the entrance of the cell. This seems favourable for the emerged wasp to get out of the confinement. In my larvae the orientation of the cocoon is completely reverse. The results seem to show that the atmospheric condition has nothing to do with the determination of the cocoon orientation, since in no cocoons the anterior end was not directed towards the opening which was separated only by a cotton plug. On the other hand, the curvature of the outer wall of the cell is considered also to have no relation whatever with the orientation of the cocoon, since in the natural cell the entrance wall is convex to the larva and the interior wall is concave, and in the experimented tube the cotton plug is convex and the sand block is flat, but the cocoon is not directed with its anterior end towards the cotton plug. The remaining difference between the inner and outer wall in the natural cell is that of the surface smoothness of the wall, the inner one being smooth and the outer one rough owing to the simply stuffed soil. If the larva is guided by the rough wall as contrasted to the smooth one to direct the funnel of its silk cocoon the results of my rearing are explicable.

The mechanism is much the same as that clarified by Cooper (1957) with the American Eumenid, *Ancistrocerus antilope* (Panzer) which makes a linearly arranged multicellular nest in the tubular cavity. The mechanism of the "Digital communication" between the mother wasp and her young is widely prevailed, therefore, among not only the tube-renters but also the digger wasps, since in the majority of the species of this group the nest condition is similar to that of *Stizus pulcherrimus*.

Cocoon

The cocoon is morphologically very similar to that ef *Bembix niponica* F. Smith (Tsuneki, 1956). But, in this species the form is not streamlined as in *Bembix*, but with both ends similarly narrowed and rounded. The anterior end is, however. discernidle through the trace of the funnel. The lid that is finally spun is slightly more flattened as compared with that of *Bembix*. The cocoons taken out of the natural nests are made of soil, with grains indistinct.

I did not examine at that time the respiratory pores of the cocoons of this species. But, later when I investigatd the structure of the cocoon in *Bembix niponica* I examined the cocoons of this species kept at my hand and found that the same structure was present on the equatorial zone of the cocoons of this species. The cocoons were only 4 in number, of which 2 were collected from the nests in nature and the remaining 2 were spun in my tube bottles. I could count on them 5, 5, 6 and 3 respiratory pores respectively, distributed on the equatorial zone as in *Bembix*. The external appearance and structure of the pores are much the same as in *Bembix*, but the central hole at the bottom was not clearly outlined, rather indistinct. The internal appearance which was in *Bembix* roundly swollon was also indistinct in this species, rather flattened. But the places of the pores, 3–5 mm across, were thickly smeared with colloidal substance, yellowish white in colour, and the outside of which was covered with a brownish layer of silk threads, so that the place of the pore was markedly distinguished.

Fig. 18. The cocoon accomplished. The respiratory pores are visdle at the equatorial zone.

Cannibalism between larvae placed in a rearing bottle

In the morning of July 2 I placed two larvae in the chamber of a bottle equipped as mentioned previously. I gave them, however, an approximately 60 mm space and between them I piled up a mass of their food, consisting of 8 prey. One of the larvae was nearly full-grown and the other was also in the final instar, but just after the ecdysis. This was the larva that hatched from the egg obtained on June 28. They were fairly difference in body size, especially in plumpness. In the evening of the day when I came back home the two larvae were too close to each other and they were distantly separated. But in the morning at 7:00 of the next day (July 3) I found that the smaller larva was killed and its anterior half was already missed, evidently devoured by the larger larva. The prey given to them remained amply. Therefore, the cannibalism was not due to the lack of food, but to the larval nature that it first destroys the competitor in the same chamber, a nature usually found in the parasitic wasps, such as the ruby-tailed wasps. The larger larva was eating the given prey and thence it devoured them roughly and luxuriously one after another. But its body size was not so increased as presumed from the amount of food. When fully grown I placed it in a normally equipped tube bottle. It lay calmly without making any attempt to spin the cocoon and finally died.

I observed in *Sphex argentatus fumosus* Mocsáry, *Anterhynchium flavomarginatum mikado* (Kirsh) and some other species the similar eventual death of the larvae that ate the companion of the same species, although I do not know whetherthis is the inevitable result or not.

Appendix. It is observed on the larvae at the final instar that they frequently excrete liquid from their posterior end of the body. But they do not eject any solid particle. It is generally believed that the anus is opened after completely passing the eating period in Aculeate Hymenoptera, in some species after, in others before spinning the cocoon. In this species, however, the final instar larva excretes liquid while it is still eating the prey. It is therefore presumed that a fine passage is already open between the intestine and the anus at this stage of growth. The same fact was confirmed in the larvae of *Cerceris albofasciata* Rossi and *C. arenaria* Linné.

Parasite and unfavourable event

As parasite the parasitic flies of the genus *Miltogramma* are commonly observed around the nests of this species. In my observation I found some of the larval cells are ravaged by their maggots. I have not seen the actual larviposition of the fly. But as alluded to in relation to the prey storage, the wasp of this species always lays aside the prey in the entrance of the burrow while it enters deeply to inspect the cell. Sometimes the prey thus dropped is partly apparent from the outside. At any rate, the ungarded prey gives the parasite a quite favourable chance. The fly may easily larviposit upon the prey indifferent to whether it is left invisible in the tunnel or visible from outside.

In one of the nests destroyed by the fly-maggots, they were soon after being brought to the nest. On the egg of the wasp which was glued to the first victim several maggots were found eating it and by the side of the victim the other victim just carried in was laid. Judging from the size of the maggots and their habits, there was no doubt that they were brought in with the second victim and they had just found out the wasp's egg which they were used to search as soon as they reached the larval cell.

In the nest of the wasps that have the habits of progressive provisioning, it is not unusual that the fly maggots become commensalismic parasites (Tsuneki, 1956). There may be something related, therefore, between the fact that the Korean *Stizus* does not collect the prey progressively and the fact that the parasitic fly maggots directly destroy the wasp's egg there.

Other accident that is unfavourable to the wasp is that in a considerable number of cells observed in Korea the prey together with the wasp's offspring were completely putrefied by the invasion of the mould. Probably this was induced by a large amount of the excrement discharged by the paralyzed prey. The prey were certainly alive, but the powerful mould grown on the excrements attacks and spoils the living substance and the prey were putrefied from the posterior portion towards the anterior.

In some instances, however, some of the prey may be stung to death by the wasp and the dead insect may lead to the whole putrefaction of the cell.

VI. GEOGRAPHIC DIFFERENCE IN BIOLOGY

The instance observed in East Mongolia is very interesting as contrasted to those of Korea. Single instance as it was it has a high probability to be the representative case of the population.

In this instance the nest structure is of the simple type, without provided with the side holes at the entrance, and the method of provisioning belongs to the progressive type. In relation to the last mentioned character the prey given to the larva are abundant and luxurious and the duration needed for provisioning is very long, presumably over 10 days at that late season.

While in the instances in Korea, the nest is of the compound type, always provided with the side holes at the entrance and the method of provisioning belongs to the mass type. The prey given to a larva are approximately less than half as many as those in the Mongolian instance and the provision is very promptly carried out, one cell or two is accomplished within a day.

The differences in biology are so large that we are led to suppose that they may belong to a different species respectively. Morphologically as well as in the colorific distinctions there is no difference at all between the specimens of the two populations save those that are considered individual variations.

If the biological differences are seriously taken into consideration in the taxonomic field the two populations mentioned seem to merit a different subspecies respectively.

Apart from the taxonomy, it is an important problem which of the two represents the biology of the typical species. To speak from the general view it seems that the Mongolian case represent the typical biology in this species and the Korean examples a deviation or a sideward development in their instinctive evolution. A case in *Bembix niponica* affords a strong support to this consideration:

I saw particular habits in a population of *Bembix niponica* occurring in Chiba in which the wasps made, as a rule, multicellular nests (but in which they still retain the habits of progressive provisioning). In other populations observed in various districts of Japan the wasps made, as a rule, unicellular nests. Therefore, to make the unicellular nest is considered a rule in this species and the method of the population in Chiba is a deviational development in this *Bembix*.

On the other hand, however, we can not deny the possibility that the reverse may be the case in this *Stizus*. Therefore, the biological observations on the population of this species living in Japan are particularly needed.

VII. COMPARISON WITH *BEMBIX NIPONICA*

As my observations on the biology of *Stizus* are quite insufficient as compared with those on *Bembix niponica* I can not compare both species in the details in biology. But it seems of some interest to attempt such as far as the present knowledge allows to do so.

(1) Prey. Orthoptera in *Stizus* and Diptera in *Bembix*.

(2) Method of oviposition. It is substantially identical in both species in respects of that (a) the egg is laid on the first of the paralysed prey taked in; (b) it is attached to the prey with its caudal end and the cephalic end is left free; (c) it is placed at the base of the wing. The differences: (a) No particular manipulation is given to the prey in *Stizus*, while various kinds of manipulations are given in *Bembix*; (b) the egg is exceptionally large in *Bembix*, while that of *Stizus* normal in size, much smaller, as far as the Korean representatives are concerned; (c) in *Stizus* the egg is attached to the upper surface of the wing, while in *Bembix* it is on the underside (but, this may be attributed to the difference in the structure of the prey — difference in the body orientation when laid); (d) the egg is laid along the body of the prey in *Stizus* while it is perpendicularly erected in *Bembix*.

(3) Structure of the nest. Apart from the Korean instances, it is very similar except for the absence of the accessory branch (spur ... Evans) in front of the cell. As for the Korean instances the differences already mentioned in relation to the geographic variation are also applicable here.

(4) Method of provisioning. Except for the Korean instances it is similar, but much primitive in *Stizus*, where provisioning is performed certainly in a leisurely manner, but with apparently no relation with the growth of the larva. In *Bembix*, as a rule, provisioning is carried out with direct relation with the growth of the larva, as far as it remains within the first — third instars. The Korean *Stizus*, on the other hand, follows the method of mass provisioning and the amount of food per one cell is much smaller.

(5) Larval biology. (a) Mode of prey eating. Apart from the Mongolian *Stizus* it is generally similar, except for the fact that *Stizus* sucks the body juice only from the first (pedestal) prey. Generally in *Bembix* mode of eating is much rougher and more luxurious owing to the abundance of food. The Mongolian *Stizus* sucks the body juice only from whole the prey. (b) Mode of cocoon spinning. Substantially similar, except for the fact that *Stizus* makes elaborate selection of the size of the grains of sand. (c) Cocoon. Similar in general in structure, but the respiratory pores are much less in number in *Stizus*.

SUMMARY

Stizus pulcherrimus F. Smith is a species of the solitary wasps living widely in East Asia. The nest is made shallowly in the earth and provisioned with the short-horned grasshoppers (rarely the longhorned grasshoppers are mixed), mostly of the nymphs. There are marked differences in biology between the populations of E. Mongolia and Korea. The former makes the unicellular nest without the side holes at the entrance and provisions it progressively, and its larval wasp sucks the body juice only of the prey, while the latter makes the multicellular nest with the distinct side holes at the entrance, provisions its cells massively with a comparatively small amount of the prey and its larval wasp devours the prey excetp the first (pedestal) which is sucked.

The egg of the wasp is deposited on the first prey. It is glued to the base of one of the wings or the wing buds with its posterior end, lying across the pleuron (sometimes the base of a hind leg) and reaches pleuro-sternal border of the thorax with its anterior end which is always free.

The method of spinning the cocoon is much the same as in *Bembix niponica*. First it spins a silk pouch with a funnel at the anterior end and with a bent stalk at the posterior end, then it is inlayed with sand grains collected through the funnel opening, first near the anterior end, then medial portion, then posterior portion and finally a lid is spun at the funnel opening. During the

sand collecting work the larva makes elaborate selection of the size of the grains. The cocoon completed is similar in appearance to that of *Bembix*, but with the respiratory pores much less in number.

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