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THE BIOLOGY OF STIZUS PULCHERRIMUS (F. SMITH)
IN JAPAN (HYM., SPHEC., NYSSONINAE)

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M I S H I M A

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The nesting biology of the sand wasp, Stizus pulcherrimus (F. Smith, 1856) has been known through the representatives of the species of East Mongolia and Central Korea (Tsuneki, 1942, 43, 65). The wasps of this species have occasionally been collected also in Japan, but because of their rarity, except a glimpse of a prey-carrying female by H. Katayama (1933), nothing has been observed with respect to their life in this country.

Recently, however, a flourishing colony of this species has happened to be discovered in Fukui Prefecture and I could visit the place and make detailed observations on their behaviour and habits in comparison with those of the Continental populations.

It is natural that the biology of the species occurring in Japan is essentially the same as that of the Mongolian and Korean populations, but it is also natural that it includes the local characters and the observations were made in more detail, so that the results obtained seem to be worth recording again.

On this occasion I express my sincere thanks to Dr. H. Sasaji, Fukui University, who communicated to me the discovery of the colony, to Dr. T. Yamazaki, Saitama University, who identified some difficult species of the prey captured by the wasps and to Messrs H. Okuno and H. Kurokawa, both Fukui, who aided my investigation in various ways and offered me the fine photographs taken by them.

General environmental conditions

The colony of the species is located on the almost deserted car road, about two meters wide, running from north to south through the pine forest that was planted for windbreak more than 30 years ago along the seashore of the Japan Sea. The forest consists purely of the pine trees of 10-30 cm in diameter at the eye height and about 10 m high, standing with interspaces of 2-5 m. The ground is originally the sand dune, but at present the bed of the forest reserves a considerable humidity and the surface is broadly covered by the moss of Rhizogonium mixing some beach weeds and partially also by shrubs such as Videx trifolia, Elaeagnus sp. etc. But as the foliage is not dense the ground can receive a fair amount of sunshine, especially where the pines are partly dead or removed. The car road on which the wasps' colony is settled is longer and more brightly shined during a considerable period of the day.

The road is also colonized by about the same number of Bembix niponica. The wasps of both species live side by side in some places, with frequent conflicts between them. However, as the nest of the Bembix is not provided with the accessory burrows (side hollows or false burrows) by the side of the closed entrance, leaving the sand heap alone in front of it, it is easy to distinguish it from that of the red-legged Stizus. The road is also inhabited by some individuals of two species of the spider wasps, Batozonellus annulatus and Episyron sp. and the leaf cutter bee, Megachile kobensis, all of them making their nests in the ground of the road, but their existence has almost no relation with the life of the burrowing females of the red-legged sand wasp. Further, the road as well as the bed of the forest is frequently visited by the males of the Campsomerid wasps, flying low over the ground and giving rise to the mistaken pursuits on the Stizus males.

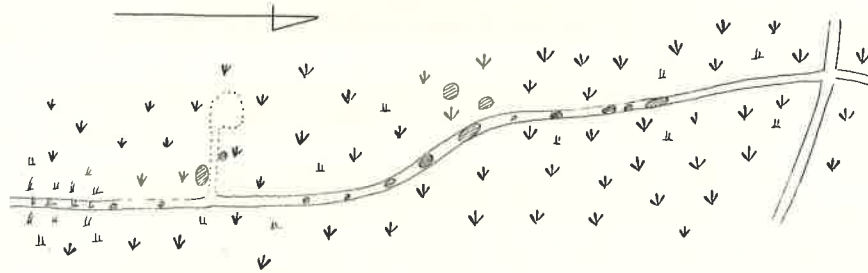


Fig. 1. Environment of the colony (hatched circlets subcolonies).

The form of the colony

The nests of the wasps are scattered over the road for about 300 m beyond which the road is densely covered by the grass of Festuca ovina at the southern end and crossed by another similar but frequented car road at the northern end, with a vacant interval of about 100 m in front of it. This uninhabited space is considered to have played an important rôle in keeping the colony of the wasps undiscovered and undisturbed during a long period of time.

The nests of this species, known from a heap of debris and two closely located deep open hollows at its end, are in some places crowded, about 10-15 heaps are observed within a small restricted area, forming a distinct subcolony, while in other places they are very scatteringly spaced, only 1-3 heaps are found closed together. Besides the road we can find some subcolonies on the forest bed, not far from the road, some being located on the nearly bare sand areas but some on the sparse bed of the moss where the heaps of sand dug out strikingly mark themselves. Possibly the latter may have been invaded by the plant during the repeated nesting by generations of the wasps.

One of the subcolony groups particularly observed by us was under the condi-

tion as given in Figure 2 and the nest distribution in subcolony A during August 17-22 was as given in Figure 3.

The surface of the road was fairly broadly covered with the fallen needles of the pine trees and they formed irregular accumulations by rain streams from place to place and the wasps choiced the bare parts of the road to make their

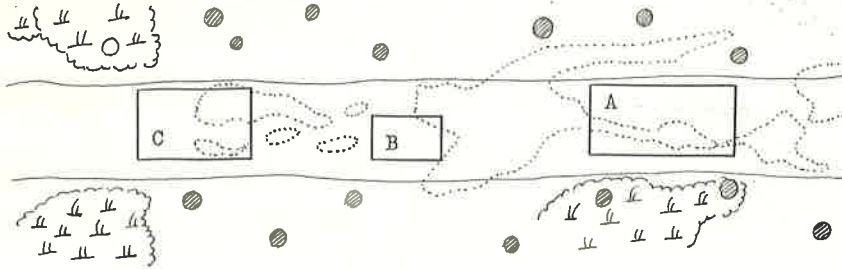


Fig. 2. Environment of subcolonies A, B and C.

Areas enclosed with dotted lines are densely covered with fallen pine needles. Hatched circlets are pine trees.

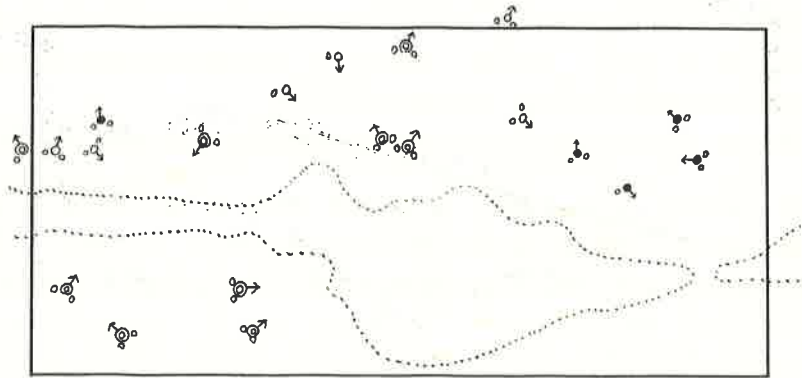


Fig. 3. Nest distribution within subcolony A.

Nests shown with simple circle were observed on August 17 and 20, those with double circle on 20 alone and those with black spot on 21 and 22. Arrow shows the direction of the burrow and the lateral circles the side hollows.

burrows. This is partly due to that the fallen needles are heaped at the low parts of the road and the wasps have tendency to dig their nests against the inclination.

The weather was inconstant during the period of our observations and our work was frequently interrupted by rainy days. As a result the sand heaps at each subcolony were considerably varied in number when we visited basing upon that some of the old heaps were levelled by the rain action and the new burrows were added by some wasps.

Behaviour of the wasp

(1) Behaviour of the male

During the sunny time of the day, or towards the mid-day when the sky is not heavily overcast the males make the so-called sun-dance. But it is not so noisy and so continuous as observed in the village of Bembix. They rather alight on the fallen twigs or low shrubs and when some one, mostly scoliid male, comes near they suddenly fly up and fly about in pursuit of them. Only occasionally they fly about of their own accord low over the ground in search of the female. When such a male finds something moving on the ground he at once flies down upon it, wrestles with it. It may be the digging female of its own species, but more often it is the female of the working Bembix. Every time he is refused. In so far as my observations go the digging females do not accept such a male.

(2) Behaviour of the female

Burrowing The female when she intends to dig a burrow she makes always the nest site selection. She begins to dig at one place, but soon she ceases to dig and abandons it without closing the hole and resumes digging at a second place, not far from the first. The same behaviour is repeated several times by the wasp who apparently makes her nest for the first time.

Digging behaviour is much the same as in Bembix niponica, excepting somewhat slower tempo. This slower tempo as compared with the Bembix is on all other behaviour observed. The time spent by the wasp to dig up one burrow was measured with wasp S. She began to dig the nest at 11:00, stopped the work at 11:38, closed the entrance simply and after making a simple orientation flight flew away. At 12:45 she turned back and resumed the digging work. She then continued to work and at 15:07 closed the entrance temporarily and began to dig the accessory burrow. In this instance the time spent by a wasp to complete the burrow is substantially 2 hours and 22 minutes, but as the time inserted in the work for the rest may be variable and, further, the time needed to dig the accessory burrows is about one hour or more (Fig. 4) it seems probable that the wasp spends about half a day to prepare one nest, even under the favourable conditions.

Closing Closing behaviour of the nest is also much the same as in Bembix, namely, the wasp creeps out of the tunnel little by little, collecting sand grains with her front pair of legs under her thorax. She thus utilizes her body as the moving stopper to prevent the sand grains to penetrate deep into the burrow. Finally when she draws completely her body out of the tunnel the entrance is thinly but perfectly closed with the collected sand. This method of the entrance closure is every time observed when the wasp leaves her nest during the period of provisioning and is called the temporal closure. While the closure finally made when

the nest is completely provisioned and the wasp lastly leaves her nest is much more elaborate and called the permanent closure. It is about 3-4 cm in thickness as against about 1 cm in the temporal closure and much more compactly pressed with the last tergite of the abdomen which can be moved quite freely and dexterously as in Bembix niponica. During the provisioning period the wasp further closes the burrow in front of the brood cell. The closure is thick, measuring 3-7 cm, and fairly compact, though it is temporal and is opened every time when the wasp provisions the cell. However, whether the wasp uses the tip of her abdomen in constructing the closure or not remains still uninvestigated. But it is certain that the wasp spends a considerable time before coming out of the burrow at the time when she carries the prey in the nest.

Digging the accessory burrow When the wasp completes digging of her nest and closes the entrance temporarily she begins to dig the accessory burrow, as a rule, one on each side and slightly in front of the entrance to the nest. Usually they are made continuously after the completion of the nest, but sometimes after

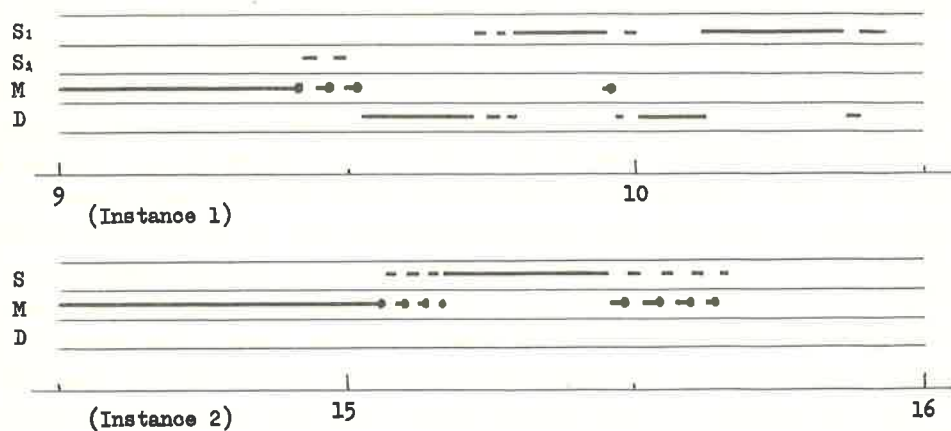


Fig. 4. Time process of side hollow digging (abscissa: time - hour)
 M: main burrow. S₁: left side hollow 1. S₂: left side hollow 2. D:
 right side hollow. Thick line means digging, black circlelet closing.

the wasp passed some time in the field. As contrasted to the eager manner of digging of the true nest the accessory burrows are constructed in somewhat a lukewarm attitude, just as in Spheg argentatus fumosus which makes the similar accessory burrows by the side of the nest entrance. Sometimes the second burrow is begun after the first is completed (Fig. 4, instance 2), but more often both are, roughly say, alternately dug (ditto, instance 1). During the work the wasp frequently goes to the entrance of the true nest, opens the closure, penetrates, at once comes out and returns to the accessory burrow after simply closes there, as

shown in Figure 4.

Orientation flight When the wasp leaves her nest for the first time the behaviour of the so-called orientation flight is always observed. The wasp flies up 50-100 cm above the ground, keeping her head towards the entrance, circles round and alights in front of the entrance to resume the same behaviour. As the flight is successively repeated the flight range becomes gradually broader and higher. Especially characteristic in this colony is that the wasp circles up higher between the covering branches of the pine trees, selecting the broader space among them and then circles down through the same space to the nest entrance. This is several times repeated and finally the wasp reaches above the forest crown and thence circles down to the nest. Towards the end of the flight the wasp leaves the colony from the top of the forest crown, but soon returns to her nest through the same space between the pine trees.

During our observations we very frequently confirmed that the prey-carrying wasp circled down from above through the space between the pine branches. Further, it is also observed that the wasp whose nest site is disturbed used to try repeatedly to trace the course of the orientation flight up and down.

Hunting A wasp found a large nymph of Aiolopus japonicus sitting on the road near one of the subcolonies and pounced upon it. The two insects rolled about as a mass. After a while they became still and the wasp caught the grasshopper from the side. She at once curves her abdomen, directing its apex towards the neck of the prey. Apparently she stung there. A few moments later, however, the hopper suddenly jumped up, with the wasp clinging to it. It alighted on its legs carrying the wasp on its back which held the hopper with the legs, keeping her body axis parallel to that of the prey. She then became crosswise to the hopper, turned her abdomen and stung it on the underside of the thorax. The hopper tried to jump up again, but at this moment its movement was quite powerless, only weakly kicked the ground. The wasp stung it again, then turned it and laid it on its side and began to bite the base of the hind leg. After a moment the hopper again tried to kick, but its legs were only weakly stretched in vain and minutely trembled. The wasp stung it once more. She touched the hopper at the occipital area with her antennae and then began to malaxate the nape of the prey insect.

At this moment the wasp was frightened by the slight movement of the observer and flew off. Soon she came back and searched for the prey. She continued to search for some minutes in vain and finally flew away without returning there again. The prey was completely paralysed and its left leg was lost from its base (after Okuno).

According to this observation the hunting behaviour of the wasp observed in Japan is similar to that of Central Korea in that it stings the underside of the thorax of the prey, but it differs from this in that (1) it stings first the neck

of the prey, (2) it more numerously stings the ventral side of the thorax, (3) it bites off one of the hind legs and (4) it malaxates the nape area of the prey. Of the four items above listed (3) is apparently an instance of adaptation against the very long legs of the prey which must be a hindrance to the storage of it in the narrow brood-cell. But in reality the behaviour is quite exceptional, because we can find no other instance among scores of prey taken out of the nests we examined in which even one of the hind legs is amputated. As to other items in order to confirm whether or not such is a constant habit in the members of the colony further observations are necessary.

Prey carriage The mode of carrying the prey is the same as observed in the representatives of Korea and Mongolia, namely, the prey is held from above, venter up and head forwards, with the middle pair of her legs and transported on the wing. When it lands on the ground in front of her nest, walks to it in the same posture, opens the entrance closure with the front pair of legs without letting the prey off and enters it with the prey. In this case the wasp pushes the prey posteriorly and drags it behind her to pass the narrow tunnel smoothly. In the account of my initial observation in Korea I wrote that the wasp used the mandibles, besides the middle legs, to hold the prey and caught it by the antennae. This is certainly an error based on the obscure observation. The fact is proved by the photographs of the prey-carrying wasps taken on the days of observation. Further, it is presumed mechanically impossible to grasp the antennae with the mandibles, in the case of the short-horned grasshopper, unless it is held "dorsum up". At any rate in the Sanriham population in no case could we observe the wasp that caught the prey by the antennae with her mandibles even as supplemental means.

Lost prey searching Wasp No. 3 happened to be jumped upon by a nymphal locust while she was walking with a prey in front of her nest. She was frightened, dropped the prey off and flew away. After a while she came back and flew and walked about in search of the prey. The prey was left at the east side of the road, she did not come near to it, but walked about with short flyings only on the central and western part of the road, and after about 5 minutes' vain search she flew away, possibly to hunt a new prey. Similarly the wasps who left their prey by being interfered by the observer had marked difficulty in rediscovering it and very often abandoned them and flew off. This quick resignation is also observed in regard to the following item.

Tenacity to the nest The female of Bembix niponica when her nest is destroyed and the surface of the area is levelled shows a strong attachment to the nest. She digs the ground where the entrance to the nest had been with great eagerness, continuing the digging work for a long time. Usually she digs the area by changing the site little by little for more than half a day, almost without

taking the least recess. Very frequently the work is continued till the next day, resulting in a very large hole there.

While, the Stizus here studied, when she is plunged into a similar situation, shows much less adherence to the nest. She digs the place where her nest entrance had been in search of it, first holding the prey, then letting it off and empty-handed. But she did not continue so long. After about one or two hours' search, with the repeated attempts of following the return route of the orientation flight, the wasp simply gives up the nest and sooner or later begins to make a new nest.

The difference between the two species in the tenacity to the nest may have some connection with the difference in the method of rearing their larvae.

Final closure of the nest The behaviour of the wasp of the present species in this aspect is also very similar to that of Bembix niponica. The wasp remaining in the entrance tunnel rakes the sand grains in the tunnel under her body and then packed them down with the tip of her abdomen. She then scrapes the sand in the tunnel again and packed it in place tightly with the curved tip of her abdomen. The same behaviour is repeated. Often she comes out of the burrow to collect much material from in front of the entrance, then backed in it to resume the packing movement. The behaviour is well observed when the rest of the burrow becomes shallow. Finally when the hollow at the entrance is completely closed level with the surroundings, she walked about, scraping sand grains towards the entrance site but soon stops the work and flies away without closing the accessory burrows. Soon, however, she comes back, scraping the surface of the entrance site again with her fore legs, but she does not try to fill the accessory burrows with sand, nor does she level the sand heap in front of the nest. After once or twice repeating the same procedure she usually begins to choose the new nesting site.

Structure of the nest

Near the entrance to the nest of the Japanese representative of this species there are always some accessory burrows (side hollows, false burrows) opened, as a rule, one on each side and slightly and obliquely in front of the true burrow which is closed. This structure is quite similar to that of the Korean population. In the colony of Sanrihama studied the accessory burrows are usually dug rather close to the entrance of the true burrow, most usually they are 1.5-2.0 cm from it. They are 3-5 cm in depth, divergent below and more steeply inclined than the true burrow. However, their number, direction, inclination and relative site to the true burrow are more or less variable, sometimes one on one side alone sometimes one on one side and two on the other, rarely two on one side alone and more rarely one opposite burrow in the opposite direction (the so-called back burrow). In one instance, I observed, two burrows in the normal site are inclined,

quite exceptionally, in the opposite direction. The accessory burrows are usually 8-10 mm in diameter, rounded, but the form at the entrance is varied during the lapse of time (Pl. I, Fig. 3; Pl. II, Figs. 2, 3 and 6).

The tunnel of the true burrow is about 8-10 mm in diameter, but slightly wider than high and usually 25-35 cm in length, gently and smoothly inclined towards the interior. In the dorsal view the tunnel curves gently once or twice, or runs almost straight, but sometimes it is strongly curved at the apical portion (Fig. 5). The brood-cell is at the end and in the straight extension of the tunnel, 3.5-8.0 cm in depth till its roof and 1.7-2.0 cm in width, with height slightly less than width (Table 1).

The nests of the Sanrihama population of this species are, so far examined (more than 70), simple unicellular type, similar to that of the Mongolian population and different from that of the Korean representative which includes more than one cells in the nest, that is the multicellular type.

In the completely dug up nest the tunnel is thickly closed in front of the brood cell, irrespective as to whether the brood cell is still empty or already provisioned*. It is 3.5-7cm in thickness and considerably hardly packed. In the

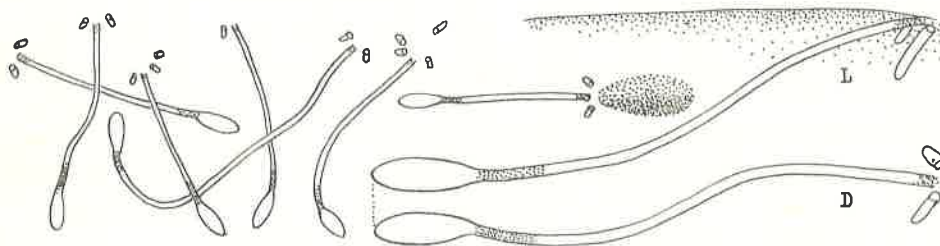


Fig. 5. Structure of the nest (dorsal view; L, lateral view).

nest having the brood cell completely provisioned the closure is thicker and more compactly pressed as is similarly so the closure at the entrance (the permanent closure).

Prey

Kind and size The prey caught by this species as food for the larva are always the short-horned grasshoppers (Locustidae) in the Sanrihama population. Some are always nymphs, some include nymphs and imagoes, but never imago alone:

* In nest Nos. 5 and 7 in Table 1 the closure in front of the brood cell is lacking. This is due to that they were dug in the course of the work of the wasps.

1. Trilophidia annulata japonica Saussure (imago and nymph)
2. Patanga japonica Bolivar (nymph)
3. Chorthippus bicolor Charpentier (imago and nymph)
4. Mongolotettix japonicus Bolivar (nymph)
5. Aiolopus japonicus Shiraki (imago and nymph)
6. Oedaleus infernalis Saussure (nymph)
7. Acrida turrita Linneus (nymph)
8. Atractomorpha lata Motschulsky (nymph)
- Add. 9. Chorthippus latipennis Bolivar (imago and nymph)

Table 1. Data regarding the nests examined (dimension $\frac{1}{4}$ mm).

No.	Burrow length	L of s.h.		Cell depth	Cell size			Length t.c.	Prey		Egg loco.
		D	S		L	W	H		N	I	
1	26.0	3.0	7.0	8.0	3.5	1.7	1.7	3.5	3	1	S
2	20.0	4.5	-	6.0	4.5	1.7	1.5	4.0	4	2	S
3	21.0	3.5	3.0	5.0	4.0	1.7	1.5	3.0	3	3	S
4	23.5	3.5	3.0	7.0	4.2	1.8	1.7	6.0	?	?	?
5	25.0	-	6.0	3.5	4.0	1.8	1.6	-	2	0	D
6	26.0	6.0	3.5	4.0	3.7	1.8	1.7	6.0	0	0	-
7	35.0	4.5	6.0	3.5	4.0	1.7	1.5	-	0	0	-
8	26.5	2.0	3.5	4.5	4.2	1.8	1.7	7.0	9	0	S
9	21.0	3.5	3.0	4.5	4.5	1.9	1.8	4.0	8	1	S
10	24.0	4.0	4.0	4.0	4.0	1.8	1.6	4.0	6	1	D
11	26.0	4.0	3.5	5.0	4.0	1.9	1.7	4.5	13	0	?

Abbreviation: L ... Length. D ... right. S ... left. W ... Width.
 H ... Height. s.h. ... side hollow. t.c. ... temporal closure in front of the brood cell. N ... Nymph. I ... Imago. loco. ... location.

Remarks. Cell depth is down to the roof of the cell.

Of the prey species above listed Atractomorpha lata M., always small nymphs, appears only late in the season, but fairly abundantly, in the brood cells examined. The specimens of Aiolopus japonicus, both imagoes and nymphs, are always most numerous, and among them we can find some nymphs of Oedaleus infernalis Saussure. The curiously long-headed specimens of Acrida turrita, always nymphs mixing both green and brown forms, are considerably large in number. These prey insects are mostly 15-20 mm in body length, rarely 10 mm or so, but the nymphs of Acrida are always 30-40 mm in length and very conspicuous among the stocked prey.

Exceptional mode of carrying in As mentioned earlier in this paper the wasp of the red-legged Stizus usually carries her prey in the burrow without letting it off at the entrance, but rarely she lets it off at the entrance without any understandable reason or circumstance. The behaviour of the wasp in this

Table 2. Provisioning time of the wasp members of subcolony A observed on August 18 and 22, 1976.

No.	10	11	12	13	14	15	16	17	18
1			* *				-		
2		* * *	* *	* *	* *		-		
3					* *		-		
4	*	*	* *	* *	* *		-		
5			* *	* *			-		
6		* *	* *	* *		* *	-		
7			*	*	*		*	-	
8			*	*	*	*	*	-	
9				*			*	-	
10						*	-		
11			*	*	*		*	+	-
12			*			+	*		+
13			*	*	*	*			+
14				*	*		*	*	+
15						*	*		-
16					*				* ±
17								*	-
18							*		-

Remarks. * ... A prey is carried in. - ... Observation is stopped.
 + ... Return to the nest without the prey.
 Observation is begun at 10 o'clock on wasp Nos. 1-10 and at 11
 on wasp Nos. 11-18. No burrow was finally closed till the end
 of the observation.

case is similar to that of most of the digger wasps. She places the prey before the entrance, opens the closure, penetrates head foremost, turns round in the nest and returns to the entrance. She thrusts her anterior body from there, catches the prey by the base of one of the front legs and drags it backing into the burrow.

Number per cell On account of that almost all the nests were examined during the course of provisioning the number of the prey provisioned per cell is not exactly known to me. But judging from the numbers found in the cells that were examined in the evening it can be presumed that the number per cell is usually from 7 to 10, of course it is changeable according to the size of the prey (Table 1). In nest 11 in which 13 nymphs of *Atractomorpha lata* M., all small in size, had been provisioned the wasp brought back one more nymph of the same species after the nest was examined at about 17:30 (Table 1). This instance, however, may be an exception.

States in the cell The prey are laid head in and venter or side up, usually they are half piled from in to out, but such a long insect as *Acrida turrita* are irregularly piled till inside. The prey are able to move weakly the apical portion of the legs and there are some feces at each caudal area.

Rate of provisioning Observation could not be commenced from early in the morning and the activity of the wasps before 10:00 was unknown. The data given in Table 2 were collected by Okuno and Kurokawa at subcolony A. According to the

Table the rate of provisioning is considerably different from individual to individual. The best worker was wasp No. 6. She brought to her nest the first of the prey observed at 10:30 and a ninth at 14:45, but she did not make the final closure at this time. The Table shows that some of the wasps begins to provision in the afternoon, in some of which, it seems, the provisioning work is continued till the next day. Certainly in this species the mass provisioning is the rule.

Egg

The egg is cylindrical, with both ends rounded, slightly curved, 4.3-4.5 mm in length and 0.8-0.9 mm in diameter, pale yellow in colour except both ends which are semitransparent whitish. The mode of attachment to the prey is just as in the case of other regions, namely, it is glued with its caudal end to the wing bud in the case of the nymphal locust, or to the mesopleuron in the case of the imago and with its cephalic end freely directed to the outer side of the mesocoxa. So far examined most of the eggs were laid on the left side, but sometimes it is attached to the right side also (Table 1). The prey that carries the egg is always laid side up so as the egg comes to be up. It is always placed at the interior-most part of the cell, that is, the first of the prey collected. It is usually a nymph, but sometimes it is an imago. Judging by the large percentage of the nymphal prey it seems that the wasp is indifferent to the developmental stages of the prey insects used as the egg pedestal. This is also the case as to the size of it. Frequently, therefore, the nymph of Acrida turrita is used as the pedestal of the egg, the largest of the prey in the cell.

Larval growth

Three larvae were reared each in a glass vial, 15 mm in diameter, one of which was comparatively well recorded as to its growth process.

The egg was laid presumably between 9:00-11:30 of August 10. The day was heavy cloudy and rained between about 8:00-9:00 and 11:30-13:00. During 9:00-11:30 some of the colony members were observed working and the nest from which the egg was obtained was closed, having the accessory burrows and the sand pile in front of it. When we resumed the observation at 14:00 no fresh sand was seen in front of the nest. The nest was examined at 15:20. The egg of the wasp was on the right wing bud of a slender brown nymph of Acrida turrita Linné, 38 mm long. The pedestal insect carrying the egg of the wasp was put in a glass vial, 10 mm in diameter, held firmly down with cotton plugs on both ends so as to keep the egg in safe and brought to my lodging by car, running for about 50 km. The glass vial was laid horizontally on the table. The next day at 5:00 when I saw, about 16.5-19 hours after the oviposition the egg was not as yet hatched.

The same day (August 11) at 19:30 when I returned from the collecting trip it had been hatched already. It was 31-33.5 hours after the presumed oviposition. The larva was almost the same in size as the egg and was sucking the juice from the prey, attaching its mouth near the mid coxa.

On 12 at 7:00 the posterior portion of the larva became fat, about 5 mm in length and still sucking the prey. Then the glass vial was put in my rucksack and transported to my house, travelling for about 500 km by car, train and walking. When I examined it at 18:00 of the day the larva was left from the pedestal and was lying on the glass floor. Whether it was shocked off or left for itself from the pedestal was unknown. It was 6 mm long, slightly fatter than in the morning but remained motionless and its integument was dull, without the glossy lustre. I thought that it was either before the death or in the resting stage before moulting. At any rate I shifted the prey and the larva with the pincette into another glass vial having the diameter of 15 mm together with 5 additional prey that had been collected from other wasp's nest. The larva resisted when caught with the pincette, but lay still again when placed among the prey.

On 13 at 4:00 the larva lay as before with the body size and form unchanged, but its body colour became lively. It was at the edge of prey mass, so I moved it among them. When caught it turned and twisted its body. At 8:00 the larva lifted its head and moved its anterior body as if to search for food. At 10:00 it was at the side of a second prey (Chorthips^m bicolor, nymph, 15 mm) and attached its mouth to it. I was surprised to know its unexpected toughness. At noon it became slightly larger, 7.5 mm in length, apparently still sucking the second prey. At 18:00 it reached 10 mm in length and 3.0 mm in the maximum width at a third segment from the caudal end. It had left the Chorthips^m and was eating the first prey, Acrida turrita.

On 14 at 2:20 the larva was actively eating a third prey (Aiolopus japonicus imago, 25 mm) A second prey that had been sucked remained apparently intact. The larva became markedly large, 18 mm in length in the posture with the head bent ventrally. At 7:00 it was 20 mm long, but became strikingly fat. It was the time to prepare the cocoon spinning room for the larva. I used the glass vial method which had usually been used by me with success to observe the spinning procedure of the sand cocoon by a waspling. A vial, 15 mm in diameter, was hardly packed with lightly wet sand at the bottom for 15-20 mm in thickness, then the larva together with the prey remained, intact and half devoured, was placed in front of the sand packing and, leaving for them 40 mm space, the open end of the vial was closed with a cotton plug. It was laid horizontally on the table. Recovering from the shock the larva soon resumed its feeding. At 8:10 it ate up the Aiolopus and began to eat the second prey (Chorthips^m) that it has sucked up. The larval growth at this stage was very rapid, already it reached 22 mm. At noon it became 25 mm

and was eating voraciously a fourth prey (Trilophidia annulata japonica, imago, 20 mm). At 18:00 it was still eating the Trilophidia. When the body was stretched it was nearly 30 mm in length. At 20:30 it was amply 30 mm in length in the posture with head bent down.

On 15 at 1:20 it was eating a fifth prey (Mongolotettix japonicus, nymph, 15 mm) and its body length was 28 mm, this was due to that the larva shrank its body and becoming much thicker. At 2:00 the Mongolotettix had been almost completely eaten up. A droplet of water evaporated from the cell contents attached to the roof of the brood chamber and it was removed by means of a slit of filter paper. At 6:00 it was attacking the final prey (Patanga japonica, nymph, 20 mm) the body length was unchanged, but becoming thicker, with the lateral processes very marked. At 10 the final prey was almost devoured up and the larva thrust its head in the head capsule of the locust. I exchanged the rearing equipment for a new one, because again the droplets of water attached the glass vial and it was considered that the condition was unfavourable to the larva to attach the silk thread to the cell wall. This time a cotton layer was placed at the bottom end of the vial, then much more lightly moistened sand was pressed and all others were arranged as before. Apparently the larva received almost no shock from the capture with the pincette and at once begins to search for food. It became pale yellowish at its lateral processes, with the heart movement slower and the imbibing movement no longer observed. At 12:00 remains of food were hard sclerites of the heads, legs and wings of the imago alone. At 15:00 the larva lay still on its venter, with the head bent downwards. At 17:00 ditto, it is 28 mm long in this posture and very plump, having 14 segments including the head. It then began to spin the cocoon.

According to this and two other records the egg period is approximately 24-28 hours and the larval period is 4 days and 2-6 hours till the work of encasement.

Cocoon spinning behaviour

Succeedingly at 18:00 (on August 15) the larva turned its body over, directing its head towards the entrance cotton plug, but soon it returned to its original orientation and faced the inner sand packing. At 19:20 when I saw the larva proceeded to the sand packing and was crumbling down the sand grains with its mandibles. A small amount of sand was collected under its head. At 21:15 the larva lay, head out and dorsum up, picking and patting the surface of the glass floor with its mouth. Possibly it was preparing the place of attachment of the posterior end of the silk pouch which the larval wasp span at first. It then turned round to its original posture and further turned over on its side to rub gently its own ventral side with the mouth. At 21:40 it had again turned round, head

out, dorsum up, and was tapping and patting the glass floor under its head.

General process of encasement Before entering the account of the detailed observation it seems convenient to have a general knowledge concerning the sand cocoon spinning technique of the larval wasp of this species hitherto obtained with the Korean representative in order make a comparison with the result of the present study. According to my previous reports the waspling first spins a thin silk cocoon or pouch which is elongated ellipsoid in form, obliquely hung, higher and open at the anterior end and lower and closed at the posterior. At this end the silk threads are bundled into a short petiole which is suddenly bent downward and glued to the floor of the chamber. At the anterior end the opening is widely expanded outwards into a semifunnel (upper half is simplified or omitted). The larva half creeps out of the opening to collect sand into the pouch. At this time the sand selecting behaviour is observed. The sand collection is several times repeated. Sand grains thus taken in the pouch are smeared over the inside of it with the secretion of the silk gland. The work is proceeded from the anterior portion to the posterior. Finally, after collecting a small mass of sand in the pouch the anterior end is closed with a lid of silk spun by the larva and then the lid is covered with sand from within. From the distortion of the still moistened and elastic sand cocoon thereafter it is presumed that the waspling produces some so-called respiratory pores at the equatorial zone of the cocoon and broadly and thickly covers the inner surface with silk threads. After a day the cocoon is dried up and becomes hard.

The present observation General procedure of the encasement is all the same as in the previous investigation. This is natural from the specific constancy of the instinctive behaviour. No note-worthy geographical variation could be observed. But the observation was done in more detail and could obtain some supplementations.



Fig. 6. The silk pouch first woven by the waspling.

Right, lateral view, sand packing at the left side shows the state crumbled and dug by the waspling. Left, dorsal view, in the course of sand smearing; h is a small hole arisen in the collected sand by the final collection of sand of the larval wasp.

On August 16 at 1:15 when I saw the larva it was about to turn round to direct itself towards the outer side. Several silk threads were spun between the glass walls of the chamber. Judging from the movement it was clear that the larva

was spinning the silk hammock, though the thread from its mouth could not be discerned. At 3:00 the wall of the chamber became slightly whitish, but the movement of the waspling was well observed. It was head in and dorsum up, lifted its head high, then bent the anterior body strongly backwards, tapping with its mouth hither and thither the glass ceiling above the middle of its body. At this time, however, the posterior part of the body of the larval wasp was still on the floor of the chamber. At 5:30 it was already on the hammock. I took up the glass vial and saw from the side. The silk pouch was already formed, though the upper side of it was very thin. It was elongated oval, 27 mm in length, 10 mm in maximum width, with the broad inner side widely open and with the posterior end narrowed into a short bent petiole attaching to the floor of the cell in front of the cotton plug (Fig. 6). At this time, however, apparently the funnel at the broad anterior end of the pouch was not as yet woven. At 6:30 the pouch became somewhat thicker, but the waspling was fairly well observed. It was still adding silk threads to the cocoon and the funnel at the anterior end became distinct. At 7:40 the waspling thrust its anterior $2/3$ of its body forwards out of the pouch and was digging the lower part of the sand packing, collecting sand grains under its head. It then retreated little by little, moving its head forwards and backwards to carry sand grains towards the entrance of the pouch. At 8:10 it was still continuing sand collecting activity. Five minutes later the waspling crept out of the pouch again and stretched its body towards the sand packing. It reached more than 30 mm in length and the posterior $2/3$ of the pouch became empty. After digging down the sand packing it retreated and began the sand collecting activity as before. At this moment I could reconfirm that the larva selected the sand grains, rejecting some of the particles forwards. In the course of the sand raking movement of the head it was from time to time suddenly lifted forwards to throw possibly some unfavourable material. Sand grains had been piled up considerably on the funnel and at the entrance of the pouch.

At 8:20 the larval wasp completely retreated into the pouch, lifting its anterior part of the body upwards and backwards with a small mass of sand between its jaws and attached it to several spots of the upper side of the pouch (Fig. 7, A). It continued the same behaviour till 8:30, when the pouch was smeared with sand layer as given in Figure 7, B. At 8:33 as in the same Figure, C. The waspling rolled its body over, becoming venter up and gluing the sand grains to the

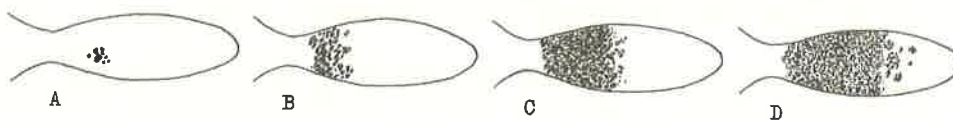


Fig. 7. Sand smearing process of the cocoon.
A at 8:22, B at 8:30, C at 8:33 and D at 10:00.

upper wall near the entrance. After a minute it rolled again to the normal position and smeared the grains to the floor and sides of the pouch.

At 8:40 it crept out of the pouch, proceeded forwards and backwards between the entrance of the cocoon and the sand packing and collected the material in front of the entrance. At 8:50 the sand packing was deeply hollowed out at the lower half (Fig. 6, right) and the surface of the posterior part of the pouch that became broadly empty glittered whitish. The waspling backed in the pouch and raked the sand grains collected on the funnel into the pouch. Sand smearing work is resumed. At 10:00 the anterior $\frac{3}{5}$ of the pouch was covered inside with sand grains (Fig. 7, D) and the waspling except the caudal part became invisible. At 10:40 the larva thrust its head and thorax part out of the pouch and raked in it again the sand grains that had been accumulated in front of the entrance. It backed in, stretched its anterior body upwards and backwards to pick at the upper side of the cocoon from the equatorial zone towards the entrance opening (10:43).

At 10:53 the larval wasp again crept out of the cocoon till its sixth segment, crumbled the sand packing and moved the material on to the funnel in front of the entrance. Under the binocular microscope the opening and closing movement of its mandibles was well observed. At 10:57 it backed a little, shrank its anterior body and by the movement of its head raked in the sand grains collected in front of the entrance into the pouch. Again the sand selecting behaviour was well observed under the microscope. At 11:00 the waspling was completely hidden in the cocoon. The upper surface of the cocoon was not as yet smoothly rounded, but some places were flattened or slightly concave and some places were irregularly swollen out. This was possibly due to that at this stage the sand layer smeared was not uniform in thickness. The waspling was extending the sand layer over the floor and lateral walls, the upper side remained without touch. It then stretched the two anterior segments out of the opening and again raked the sand grains into the pouch (11:04). At this time the anterior constricted part of the silk pouch and the narrow posterior part (about $\frac{1}{6}$) in front of the silk bundle were still remained without the sand layer (11:04). During 11:07-11:15 the waspling in the cocoon picked the upper side broadly about, the mouth reaching $\frac{1}{5}$ from the caudal end of the cocoon without turning round. In accordance with the movement of the larva the cocoon was markedly distorted in form. At 11:23 raked the sand grains on the funnel into the cocoon, stretching its 4 anterior segments (from 5th posteriorly there are whitish corpuscles - oenocytes) out of the opening. Using this material the waspling smeared roughly the posteriormost part of the cocoon, leaving as yet many semitransparent windows free from the sand. At 11:30 the silk threads that hang and supported the cocoon became well visible, possibly owing to the desiccation. The waspling was seen through the opening and the narrow anterior sandless part of the cocoon. It lay on its venter and was mov-

ing sand grains, that had been collected in the cocoon just behind the opening, backwards under its belly. In the course of this activity it grasped a large sand grain between its mandibles and threw it out of the opening. The behaviour was distinctly observed under the microscope. It then turned the anterior body upwards and it was observed that the upper side of the cocoon was from point to point pushed out from within. Certainly the waspling was adding the silk thread and or sand grain with its pointed mouth.

At 11:32 the larva crept out of the mouth, showing the anterior 6 segments, and crumbled and dug the sand packing and then, backing little by little, collected by the forward and backward movements of its head the sand grains in front of the opening. Soon it backed completely into the cocoon and resumed the sand smearing activity. At 11:35, the larva exposed its 4 anterior segments out of the cocoon and raked into the cocoon the sand grains collected in front of the opening. Here again the sand selecting behaviour appeared. After about 5 minutes of inside work the larva showed its head at the entrance, held the rim of the opening which remained still free from the sand embedding between its jaws and bit the place. It changed its holding place little by little sideways, sometimes with venter up, sometimes with side up, apparently it was adding the secretion of the silk gland to the rim. It then retreated and pushed up hither and thither the upper layer of the sand cocoon still moistened and elastic. At 11:50, the larva turned round and smeared the posteriormost part of the cocoon with sand. At 12:02 it turned round again and began to spin the silk lid over the opening. At 12:15 the rounded silk cap was already formed and it was observed through the semitransparent layer that the larva was still adding silk threads to it. The caudal end was completely lined with sand grains. Hereafter the waspling alternated further weaving of the entrance cap and pushing out with its mouth hither and thither the upper and lateral walls of the sand cocoon, the latter work being possibly the same tightening behaviour as the former by the addition of silk threads.

At 13:00 the membranous silk cap at the entrance was completely covered from inside with the layer of sand and the cocoon that was still wet and quite elastic was from place to place pushing out by the mouth of the larva. The same behaviour of the waspling was continued till 14:00 when I went out. Returning at 16:00 I found 2 closely situated small holes were open at the upper side of the equatorial zone and around each the surface was successively picked out from within. Certainly the larva was constructing the so-called respiratory pores.

At 17:30 the cocoon became apparently hardened and no partial deformation of the cocoon could be observed, but it was still moistened.

At 21:00 the condition was unchanged.

On August 17 at 2:45 when I saw the cocoon it was already dried up. On 18 at noon and in the evening no change was observed.

On August 19 at noon the cocoon had become dirty brown at about the posterior 4th. Doubtless it was due to the mass excretion of the larva. The part was as yet moistened. Therefore, it must have been done not long before.

Cocoon

On October 1 the cocoon was taken out of the glass vial and was observed. It is 24 mm long, 9 mm in maximum width and typical in form in this species (Fig. 8, D). The previous opening, now closed as the cocoon lid or cap, is completely encircled by the base of the funnel. The funnel under the microscope is a rough network in texture which is shorter and more strongly divergent upwards than downwards. The part of the downward expansion is long and broad, still supporting a considerable mass of sand grains on it which contain comparatively large proportion of larger ones. The cocoon lid or cap is a nearly flattened (slightly convex) layer of sand grains tightly cemented together. The grains appear, on an average, somewhat larger than those used for the body of the cocoon. The silken stalk at the posterior end is a white band, 4 mm long and 2 mm wide, consisting of numberless silk threads, white in colour and slightly shrunk, densely woven together. Over the surface of the cocoon body white coloured silk threads are tangled, not dense, that had hung and supported the cocoon from the glass wall. (The inner surface of the glass vial is fairly thickly covered with silk threads so as to become somewhat dim and obscure to ensure the solid support.) The grains of sand used to make the cocoon case are comparatively fine, fairly uniform in size, but mixing a considerable number of the larger ones, despite the apparent selecting activity of the larval wasp. At the equatorial zone there are 4 minute cones, a, b, c, d (Fig. 8, P) projecting from the surface which consist of one to several comparatively large sand grains. In a, b, c the projection is strong and conspicuous, each involving 4-6 grains and at the centre there is a minute hole encircled by a short cylinder which is slightly convergent upwards, dark brown to black in colour and plastic-like in quality, while in d it is only weakly projected and at the side of the hole there is only one medium-sized grain. These structures are the so-called respiratory pores. There are, however, 3 further similar projections, one is widely deviated from the equatorial zone and two on this zone (Fig. 8, Q: k, l, m). In these projections, however, there is no hole at the centre or the side of the sand cluster. Furthermore, on the equatorial zone there are three small weakly depressed spots (Fig. 8, P: w, x and Q: y), extending over 5-6 sand grains where the grains are cleaned and very thinly covered with silk gland secretion.

These structures inform us of the process of the construction of the respiratory pores. According to this the construction of the pores are begun after the

sand layer is completely attached to the silk pouch, but before the inner lining with silk threads is performed. During the course of addition of silk gland secretion to the sand layer the wasp tries to perforate it hither and thither mainly in the equatorial zone. The resulted holes are not always completed into the respiratory pores. This is proved by the fact that the holes observed 16th August at 16:00 are different in situation from the respiratory pores finally resulted on the cocoon. In the pore made while the cocoon is still quite elastic the sand grains are not projected into a cone, but that which is made while the cocoon is becoming hard by desiccation the grains are projected into a cone. Possibly in such a case the wasp will add further grains under the elevated pebbles. However, these cones are not always constructed into the respiratory pores, as shown by k, l, m in Figure 8, Q. On the other hand, the holes that are left alone after being perforated are considered to close of themselves by the elasticity of the sand layer and result in the small depressions on the surface. In short, all the structures of these kinds mentioned inform us of the trial-and-error perforation of the larval wasp, as well as the time of such behaviour in the course of the activity of encasement.

The structure of the inner surface of the cocoon is very much like that of Bembix niponica (Tsuneki, 1956). The surface is not smooth under the binocular microscope and is densely covered with secretion of the silk glands. The medial or equatorial zone is remarkably whitish for about 4-5 mm in width and the part anterior to the zone including the stopper cap of the cocoon is deep brownish, gradually somewhat paler towards the equatorial zone. While the area posterior to the zone is changing backwards from brown to dark brown or black. The white of the equatorial zone is due to the white silk threads very densely covering the brownish glutinous layer that glues the sand grains together, and not due to the white paste often observed in the cocoon of Bembix niponica. The threads are extended towards both ends, but they are not so dense and much less so as they go farther and the ground brownish glutinous layer is as much more exposed. The dark colour of the posterior area of the cocoon is derived from the smearing of the meconium finally excreted by the larva.

In this instance the equatorial zone is uniformly covered with the white silk threads and there is no bottom disc of the respiratory pore which is a gently raised rounded area and always well observed in Bembix niponica.

Variations in the characters of the cocoon

I have examined 10 other cocoons of this species, of which 3 are the old ones casually dug out while I examined the provisioning nests and the remainder the new ones derived from the marked nests and each containing a larva within.

The old cocoons are cut open circularly by the wasps emerged just behind the entrance cap which is always discovered with the shed skins of the larva and the nymph at the posterior part of the cocoon that is firmly stuffed with sand. This

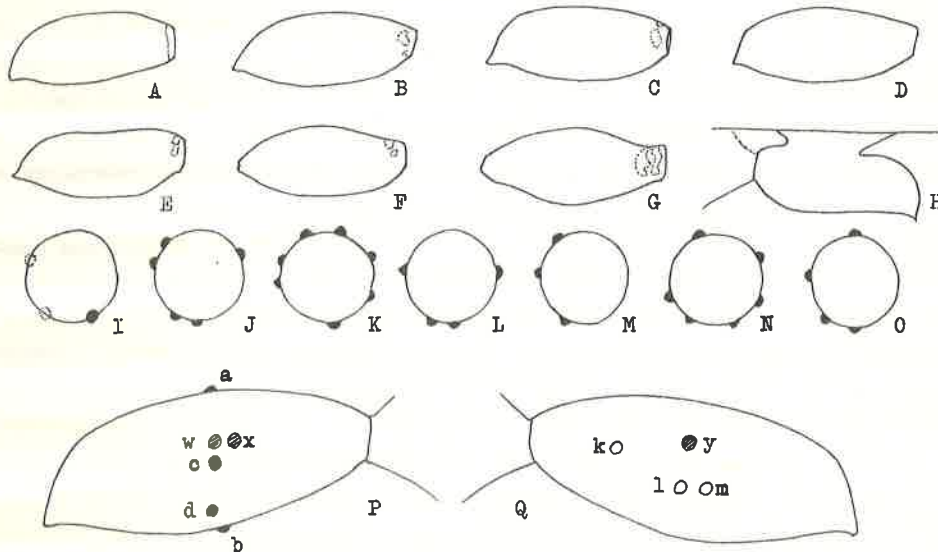


Fig. 8. Variations in the form and structure of the cocoon.

A-D: typical form. E-G: atypical form. H: sandless cocoon under rear-rearing. I-O: location of the respiratory pores on equatorial zone. P and Q: the cocoon obtained from rear-rearing, black spots: respiratory pores, white circlelets: minute projections without hole and hatched circlelets: minute depressions (A-H, P and Q lateral view and I-O posterior view.).

indicates the fact that the newly emerged wasp first moves backwards the cocoon cap cut off and then makes its initial way to proceed by filling the empty cocoon with sand in front.

Size and form The cocoon is 21-24 mm in length, 8.5-10 mm in maximum diameter and in form in lateral view typically as given in Figure 8, A-D, namely, the anteriorly subtruncate at the entrance cap which is 3.5-4.0 mm in diameter and posteriorly somewhat pointed at the apex which is located much below the central axis of the cocoon, with the upper marginal line steeply curved down near the end. This characteristic in the form depends upon the supporting way of the silk pouch which is fastened at the posterior end to the floor of the brood chamber by means of a short petiole. It is also of use to us to determine which side of the free cocoon is dorsal. In some cocoons, however, the character appears less conspicuous (Fig. 8, F, G) or somewhat abnormal in form (Do., E). In such a case we can ascertain the original orientation of the cocoon by examining the state of the rem-

nant of the funnel net at the periphery of the entrance cap, because in the cocoon dug out the remnant is very frequently lost at the dorsal area, or it is very sparse and rough at the upper margin.

Sand layer The size of the sand grains used is variable naturally according to the site of the nest, sometimes comparatively large, sometimes small, usually, however, fairly fine and uniform in size, but always including a considerable number of the larger ones. The grains attached to the entrance lid are usually somewhat larger than those of the cocoon body. Besides the respiratory pores some minute tubercles consisting of several sand grains are usually observed on the surface of which explanation is given at some length in connection with the cocoon obtained from rearing. Usually the sand grains are everywhere densely and compactly cemented together, leaving no interspace between. Occasionally, however, the grains are here and there not compact and the interspace is filled with the glutinous substance alone, or covered with a gelatinous film at the top alone, or leaving in it a minute hole. In one of the old cocoons a considerable number of the fine holes are scattered over the equatorial zone.

Worthy of especial mention is the fact that some more or less broad areas just behind the entrance cap are sandless and filled with the gelatinous secretion of the silk gland alone (Fig. 8, B-G, areas shown by dotted lines). In the cocoon obtained from my rearing there is no such a sandless patch, but the sand grains used behind the lid are especially fine and the area is easily to break. It seems that the structure above mentioned must have some bearing upon the extrication of the emerged adult wasp from the rigid sand case of which the surface is smooth, the texture is hard and there is no other place easily breakable by the pick of the wasp's jaws.

Respiratory pores The so-called respiratory pore is usually at the centre of the pebble cone as given in the preceding section, but it is often at the side of the pebble mass. The pebbles are usually larger than those used for the basic layer of the cocoon and varied in number from 1 to 7 so far examined, sometimes 1 or 2 of which are conspicuously large and highly protruded. In the case of small number they can not enclose the pore completely. Sometimes there is no particular pebble at the site of the structure. The pore is always encircled by a gelatinous cylinder, dark brown in colour and more or less convergent upwards. It is usually extended up to the top of the pebble cone when it is at its centre. When it is at the side of the cone or almost lacks the surrounding pebbles the cylinder is only very slightly produced above the ground layer or it is ended level with the surface. In the last mentioned case the cylinder is somewhat expanded at the margin.

The respiratory pores are restricted in the distribution, as a rule, to the

equatorial zone, and located on the medial line, rarely more or less deviated from the line and very rarely from the equatorial zone, with the interval between them quite uncertain, sometimes on one side alone (Fig. 8, M, O). The number per cocoon varies from 1 to 7, namely 4(2), 3(1), 3(3), 1(2), 5(1), 7(0), 4(2), 3(2), 6(1), 4(3) so far examined (numerals within parentheses are the number of pebble cones without pore). As to the physiological function of the pore see the footnote*.

Interior structure The lining of the inner surface of the cocoon is, except Nos. 5 and 8, generally as observed in the first instance given in the preceding section, although the width of the whitish equatorial zone and its distinction as contrasted to the adjacent areas are more or less variable. As to No. 5 special mention will be given below. In No. 8 the general lining is similar, but in this cocoon on the equatorial zone just below the respiratory pores there are 4 very distinct rounded discs, each gently convex just as in Bembix niponica. I thought at first glance that the cocoon might belong to a waspling of this species. But on the surface of the cocoon the ejected feces of the Orthopteran insect were attached and there was no doubt that the owner of the cocoon was a larva of Stizus pulcherrimus.

Cocoon No. 5 is very characteristic and exceptional in the interior structure. On cutting open the cocoon I was surprised to find that the inner surface was covered with a thick layer of dark brown silk threads, about 1 mm in thickness. The fine threads were woven into a dense network and among them a number of thick threads were irregularly running like blood vessels. In order to observe the surface lining a part of the silk layer had to be removed. It was a nearly uniform lining of the greyish gelatinous layer except the posterior portion and there was no distinct equatorial zone easily distinguishable in colour. Moreover, the layer of the meconium on the posterior part of the cocoon was also abnormal. It consisted of many layers of very thin paper-like extensions, black in colour and easily broken to pieces. I tried to take out the waspling from the cocoon by means of the pincette. It could not easily be pulled out, because the lateral processes of its body were caught by the network layer. To take it out safely a considerable effort was needed. The waspling (prepupa) lay on its back with the head deeply bent and inserted between segments 4 and 5 of the body and in the external appearance (60X) it had no difference at all from others of the normal cocoons.

In this instance the cocoon is also somewhat abnormal in its external appearance. The form is not typical, having the slightly constricted neck region and upon the area two large irregular-formed sandless patches (Fig. 8, G). On

* The pore may be of use not only to ensure the air circulation, but also to regulate the moisture inside the cocoon, especially at the time of the two succeeding ecdyses.

the equatorial zone three minute pebble cones are present of which only one has the pore and one of the others a pale yellowish gelatinous stain on top, possibly the same substance as used for the inner layer of the cocoon and pressed out of the pore then present by the waspling. The form of the posterior part of the cocoon is not typical as given in Figure 8, G.

Prepupa

The larva in the cocoon is in the stage of the so-called prepupa. It is

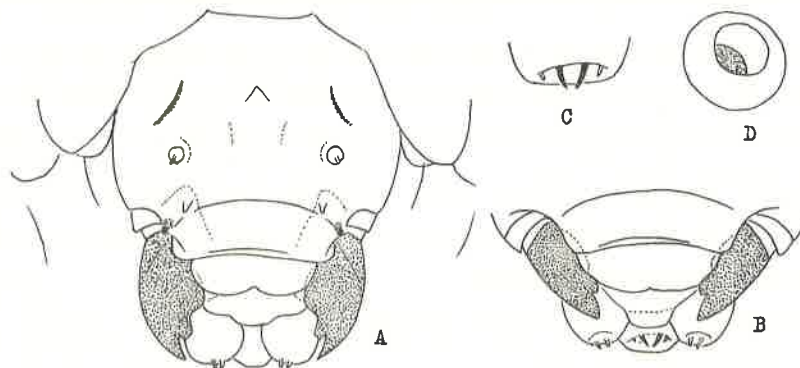


Fig. 9. Prepupal characters.

A: head seen in front. B: Mouth parts seen somewhat from beneath.
C: labium. D: spiracle.

cream yellow in colour, markedly shrunk, with the lateral processes well developed and with the numerous whitish spots (= oenocytes) scattered over segments 4-13. But the spots are in body segment 4 rather less in number and in some individuals partly collected into several large whitish patches or bands on posterior segments as if to be attacked by the mold. The segments except the head are 13 in number of which segments 1-11 except 3 carry a pair of spiracles.

The head is usually strongly bent ventrally and inserted in the fold between ventral segments 3 and 4. Being pulled out of the fold and seen in front it is as in Figure 9, A. The mouth parts seen somewhat from beneath: ditto, B, labium: ditto C and the external appearance of the spiracle: ditto D. The characters as above shown in figures well agree with those given by Evans (1964) with a Korean specimen of this species.

Comparative notes

Comparison with the Korean representative The chief difference in biology between the Korean and the Japanese populations observed lies in the pattern of

the nest structure, namely, in the former the nest belongs to the multicellular type, while in the latter to the unicellular type, as in the Inner Mongolian population. A second but less important difference is that the wasps in Korea often hunt as their prey the insects of Tettinoniidae as well as Locustidae, but the wasps in Japan, so far observed, capture only the Locustid insects. In other respects the wasps and the wasplings of both populations very well agree in their nesting biology and in their technique for the encasement, e.g. the two modes of prey carriage into the cell, sand selection behaviour of the larval wasp etc.

Comparison with *Bembix niponica* Similar in the general structure of the nest, in the existence of two types of the nest pattern locally (multicellular and unicellular), in the manner of prey carriage and behaviour at the time of entry and exit to and from the nest, in the habits of laying the egg on the first prey, in the exact place of oviposition (base of wing - in the case of the nymph), in the mode and process of the encasement of the larval wasp and in the general structure of the cocoon. But it is different in having the accessory burrows (= side holes, side burrows, faulse burrows) at the side of the entrance to the nest, in lacking the spur in front of the brood-cell, in the kind of prey (Orthoptera : Diptera), the place of oviposition (mesopleuron : wing base - in the case of the adult prey), the mode of provisioning (mass : progressive, though in the final stage practically mass provisioning even in the *Bembix*), in lacking the contact with the larva and lacking the behaviour in connection with the larval care accordingly, in the lack of the basal disc of the so-called respiratory pore on the inner surface of the cocoon and in the smaller number of the pores. On the other hand, the difference in the mental ability is fairly marked, namely, in the *Stizus* much less developed. The fact is easily observed in the difficulty of locating the situation of the lost prey and the site of the nest examined and in the lower degree of persistency in searching for anything. The state at the midway in the evolution of the method of construction of the so-called respiratory pores also belongs to this category. Further, general activity is much slower in tempo.

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EXPLANATION OF THE PLATES

Plate I

1. The pine wood through which the Stizus-colony bearing car-road runs.
2. The deserted car-road — the place of the Stizus colony.
3. The main burrow (middle; the wasp is within) and two accessory burrows.

Plate II

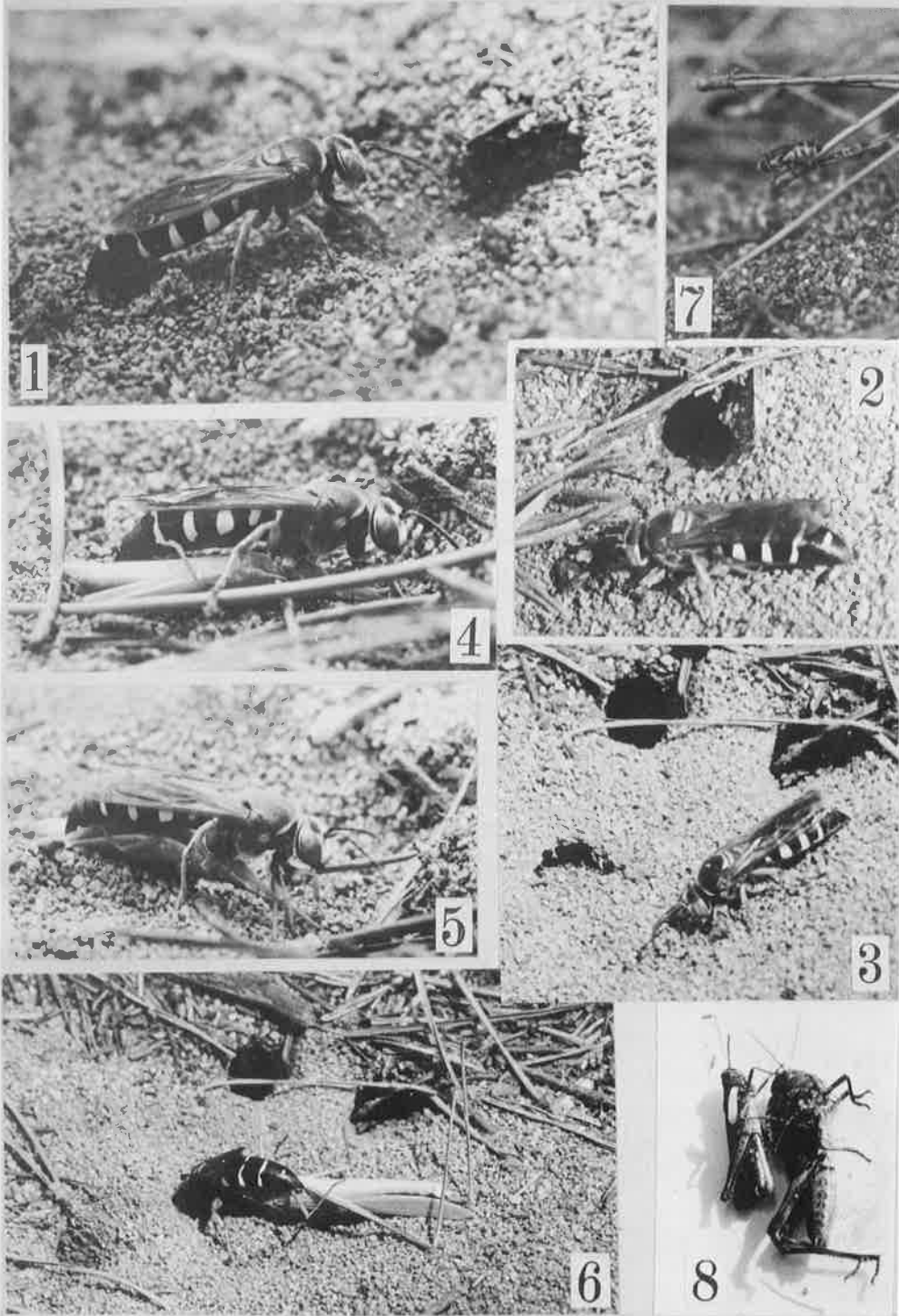
1. A burrowing wasp.
2. A wasp examining the main burrow while she is digging the accessory burrows one of which is seen above.
3. The same wasp as in Figure 2 digging a third accessory burrow.
- 4, 5. The prey-carrying wasp.
6. A wasp just entering the burrow with a prey pushed backwards (the same wasp as shown in Figure 3).
7. A parasitic fly watching the prey-carrying wasp.
8. Two prey, one of which carries the egg of the wasp that is about to hatch

Plate III

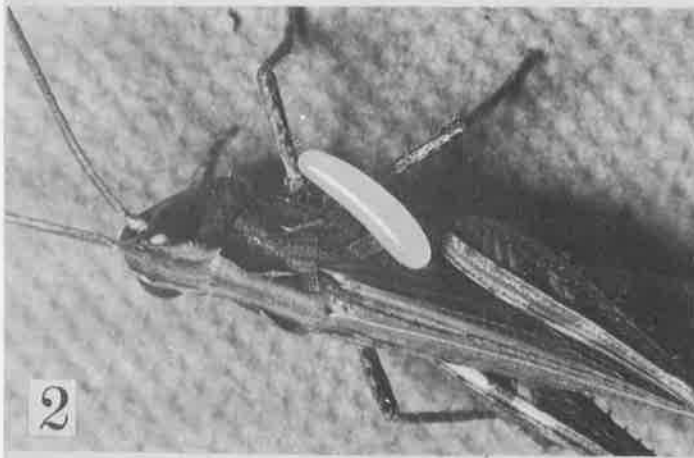
1. The egg of the wasp laid on the wing bud of a nymph of Acrida turrita.
2. Ditto, but the prey is an adult insect of Aiolopus japonicus.
3. Two prey in the brood-chamber, one of which carries the egg soon before hatching. Notice the feces ejected by Atractomorpha lata.
4. The prey found in an incomplected cell, one of which is attached with the egg of the wasp.
5. The larva of the wasp eating the prey.
6. The full-grown larva.
7. The cocoon, the right end is the cocoon cap.



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