On the bionomics of Itoplectis narangae (Ashmead) : (Ichneumonidae, Hymenoptera)

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On the bionomics of *Itoplectis narangae* (Ashmead) (Ichneumonidae, Hymenoptera)*

Yoo-Hang SHIN and Keizo YASUMATSU

Contents

I. Introduction

An ichneumon fly, *Itoplectis narangae* (Ashmead) is widely distributed all over Japan, Korea, Taiwan, the Philippines the Kuriles, Hawaii, Okinawa, Mexico, the Ryukyus, Sakhalin and China proper in the Paci-

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fic area. This species has long been known to be a parasite of the larvae and pupae of major insect pests which usually attack rice plants. However, no one has so far studied the bionomics of this species. Aside from the description of a new taxon, most of the accounts in the literature concerning this species deal with host-parasite relations.

The present paper is the outcome of the author's two years study on the bionomics and the mass production of this species for the future use as a controlling agent against the major rice pests.

II. Historical review

Itoplectis narangae was first described by Ashmead (1906) as a new species under a new genus, ***Nesopimpla naranyae,*** based on the adult emerged from the larva of ***Naranga aenescens*** Moore by Matsumura. Thereafter, ***Nesopimpla*** was synonymized under the genus ***Itoplectis*** by Townes (1940). Watanabe (1966) claimed that the species name ***narangae*** should be used instead of ***naranyae*** due to an careless error of the original spelling with a view that it was first described as a parasite of the host ***Naranga aenescens.***

Ashmead (1906), Cushman (1922), Kuwayama (1928), Ozaki (1938), Yasumatsu and Fukushima (1945) reported that the species is parasitic on the larva of ***Naranga aenescens.*** U. Nawa (1912), Y. Nawa (1913), Cushman (1922) and Chéng (1935) also reported that it is a parasite of the pupa of ***Naranga aenescens.*** In addition, U. Nawa (1912), Y. Nawa (1913), Sonan (1930) and Minamikawa (1953) discovered that it is parasitic on the larva and pupa of ***Sesamia*** *inferens* Walker. Kuwayama (1932) reported that it parasitizes the larva and pupa of ***Oulema oryzae*** (Kuwayama). This is the first record of this species from the Coleopterous larva and pupa besides the Lepidopterous larva and pupa.

Sakai et al. (1941) observed that this species is parasitic on the larva and pupa of ***Cnaphalocrocis medinalis*** Guénée and Kamiya (1941) reared this species from the pupa of ***Adoxophyes orana*** Fisher von Röslerstamm. Sonan (1930) confirmed the emergence of this species from the larvae of *Homona coffearia* Nietner and *Borbo cinnara* Wallace in Taiwan.

Y. Nawa (1913) reported that this species is a parasite of the pupa of *Chilo* ***suppressalis*** Walker. Although Zwaluwenberg (1929) and Watanabe (1966) also wrote that it is a parasite of *Chilo suppressalis*, they did not indicate the parasitized stage of the host. Hidaka (1965) observed that this parasite is parasitic on the larva of *Chilo* ***suppressalis.*** Yasumatsu (1967) recorded it as a parasite of pupa of *Chilo* ***suppressalis*** and the occurrence of the species in the Philippines.

In his paper on the ecological observation of ***Naranga aenescens,*** Ozaki (1938) reported that the percentage parasitism of this species was 9.1. This is the first record of the species on its field activity.

Iwata (1960) dealt with this species in his study on the comparative anatomy of the ovary of Hymenoptera. In his study carried out in the truck crop field at Hakozaki, Fukuoka city, Hirose (1966) put on record this species in the list of carrot flower visiting parasitic Hymenoptera. Wu (1967) recorded it as a secondary parasite of ***Diadromus*** sp.

III. Materials and methods

Field studies were carried out mainly in the paddy field of Hakozaki, Fukuoka city and its vicinity from September 1967 through the end of 1968.

Laboratory experiments were conducted mainly in a 25°C insectary together with the phytotron and incubator if necessary. The parasites used for the experiments were those collected from the paddy field and reared continuously with the pupae of *Galleria* ***mellonella*** (Linné) as an alternate host in the insectary. Two petri dishes were used as an oviposition unit ofthe parasites with an improved sandwich method (B. R. Subba Rao, 1955) as illustrated in Fig. 1. The open sides of the petri dishes were covered with gauze and tied up with rubber bands. The para-

Fig. 3. Containers. Right: Container A, Left : Container B.

sites *were* kept on the upper dish and fed with undiluted honey and water which was absorbed in cotton, and a small amount of water was kept in the lower dish so as to maintain a constant humidity in the dishes. The author used two kinds of such containers (petri dishes) for the present experiments; in the case of the first containers the upper one was 9.5 cm in diameter and 2.0 cm in height, the lower one was 8.7 cm in diameter and 9.0 cm in height (hereafter this is referred as Container A) ; in the second ones, the upper one was 16.2 cm in diameter and 3.2 cm in height, the lower one was 15.4 cm in diameter and 3.5 cm in height (hereafter this is referred as Container B). The size of adult parasites used was controlled properly in accordance with the size of host pupae.

The methods applied in the present experiments are given in detail in each section of this paper.

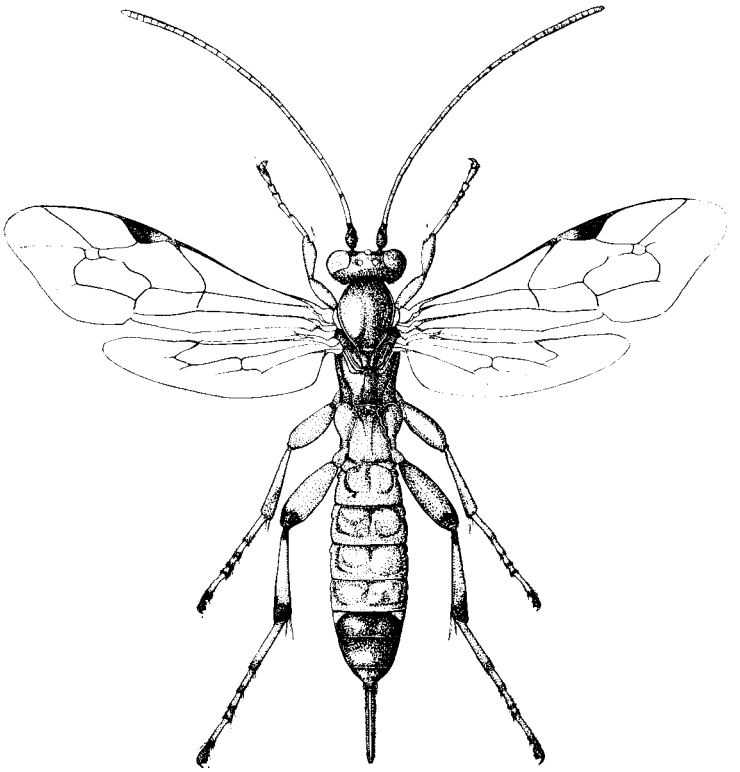

Fig. 2. *Itoplectis narangae* (Ashmead)(♀). (Drawn by Miss M. Honda)

IV. Field observation

Investigation on the field activity of this species was carried out in the paddy field of Fukuoka and its vicinity for the period from September, 1967 to the end of 1968.

1. **Seasonal fluctuation.**

This species was collected for approximately an hour at certain paddy field by a regular sweeping method in order to investigate the seasonal fluctuation during the period from the middle of May to the first part of December, and the results are given in Fig. 3. As seen superficially from Fig. 3, the appearance of the adults was observed three times a **year.**

The first appearance occurred between the middle of May and the early part of July, and the middle of June was the peak of its emergence. The middle and later parts of May when the first appearance began coincided with the blooming period of milk vetch, ***Astragalus sinicus*** Linné in the paddy field. The emerged parasites were seen commonly on the stack, ridge and around the weeds of the ditch side surrounding the paddy field. The transplanting of rice plants was not done until the middle of June. Therefore, during this period the parasite might be searching for the host pupae of the other insect pests infesting the plants other than rice. The second appearance began from the later part of July and continued until the middle of August. Almost no field activity of this species was observed during the period from the later

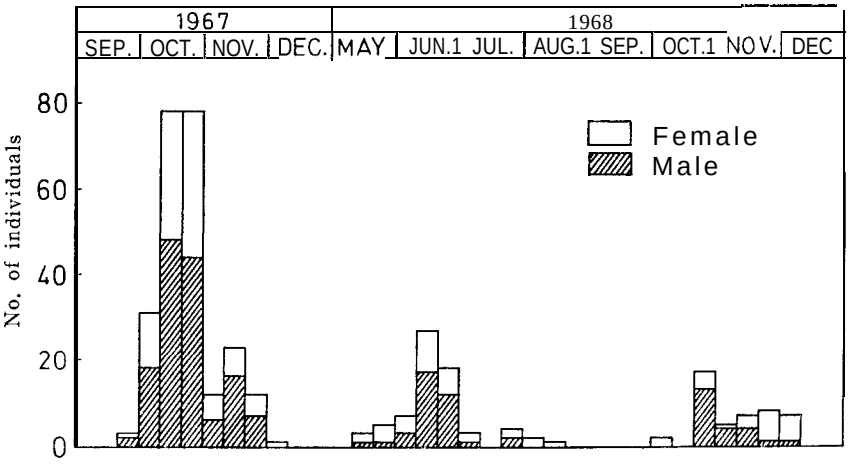

Fig. 3. The seasonal fluctuation of the number of both sexes of ***Itoplectis narangae*** collected in the field.

part of August to the middle of September. However, it is not clear whether this may be attributable to 1) the difficulty of collection due to small number of individuals, 2) the host relations or 3) the insecticidal application or other artificial factors. The third occurrence was observed from the middle of September until early December with a peak in the middle and later part of October. It is felt, however, that two or three generations might have passed during this period. It is thought that some of the offspring emerged in the later part of October, probably some in the middle of November, but some went to hibernation in the larval stage. The harvest of the paddy field began from early November and ended in the middle of the same month.

This species was observed searching for the hosts until early December on and between the stack in the sun, stubble and straw spreading over the field after the harvest. During this period the author observed that this species was caught in the web of a spider, ***Neoscona doenitzi*** (Boesenberg et Strand) around the stack.

2. Hibernation.

This species in its natural environment passes through the winter in the final instar larval stage within the body of its host pupa. It is presumed, therefore, that the place of hibernation is the stubble and stack of rice plant or the paddy field as in case of the host.

Fourty-two pupae of ***Cnaphalocrocis medinalis*** hibernating on the stubble and field surface were collected in the paddy field of Hakozaki, Fukuoka on January 11, 1968. Three final inrtar larvae of this species were found among these pupae.

3. **Relationship between the height above the ground of the pupation site of the host and parasitism.**

The outbreak of ***Cnaphalocrocis medinalis*** was observed throughout the western part of Japan in 1967 and the damage was severe in the rice plant. Of course the paddy field of Hakozaki where the field investigation has been made was not exceptional and relatively large numbers of this species were observed by the author.

According to Sakai et al. (1941) the pupation site of C. ***medinalis*** is seen commonly at 9-12 cm above the ground in the case of rice plant. During the field investigation the pupae were found between the leaf sheath and culm or within the rolled leaf located both above and below the level of 12 cm above the ground.

In order to elucidate the relationship between the pupa of C. ***medinalis*** and the parasite activity at each different height of the place of pupation, investigation was conducted on 388 hills of rice plant (about 75

cm in height) for four days from November 1 through 4, 1967 in the paddy field where there was a high possibility of collecting as many parasites as possible by the sweeping method.

The pupae and casted pupae of C. *medinalis* which were attached to the stems were collected from different height above the ground for the purpose of obtaining the percentage of parasitism by *Itoplectis narangae* at the corresponding height.

The result of this investigation is shown as in Tables 1 and 2 and Fig. 4.

Ichneumon fly, Coccygomimus *nipponicus* (Uchida) was rarely reared from the pupae of C. *medinalis* in the paddy field, but the percentage of parasitism by this parasite was very low or almost negligible. Actually, only two adults of this parasite were reared from the field collected material from September through December, 1967. Therefore, the presence of *Coccygomimus nipponicus* does not give any actual influence on the percentage parasitism of C. *medinalis* by *Itoplectis narangae.*

As seen clearly from Table 1, the pupation site of C. *medinalis* occupies 69 % of the total number of pupae collected at less than 15 cm above the ground. However, the casted pupae located in such height have never been parasitized by this Ichneumon fly. Only the casted pupae located higher than 16 cm above the ground were observed to be parasitized, the highest value of parasitization having been 75 % in the

Table 3. Relation between heights of the pupation site of *Cnaphalocrocis medinalis* above the ground and number of casted pupa, the contents of which were devoured by the larva of *Itoplectis nurangae (1967).*

Height above the ground (in cm)	No. of casted pupae collected	No. of casted pupae showing the trace of parasitization	Percentage parasitism
1-10	139		
11-15	70		
16-20	26	2	7.7
21-25	21	15	71.3
26-30	11	8	72.7
31-35	8	7	87.5
36-40	7	7	100.0
41-45	7	4	57.1
46-50	2	1	50.0
51-55	2		
56-60	1		
Total	274	44	

Table 2. Relation between heights of the pupation site of *Cnaphalocrocis medinalis* above the ground and number of pupae parasitized by *Itoplectis narangae (1967).*

Height above the ground (in cm)	No. of pupae collected	No. of pupae parasitized	Percentage parasitism
1-10	*86*		
11-15	*44*		
16-20	*20*		
21-25	*1*		
26-30	*2*	*1*	*50.0*
31-35	*4*	*2*	*50.0*
36-40	*2*		
41-45	*2*	*1*	*50.0*
46-50	*2*		
51-55	*2*		
56-60	*2*		
Total	167	4	

pupae located between 21 cm and 50 cm in height above the ground. This may indicate that the searching activity or zone of this parasite is limited to the height of more than 16 cm above the ground and below this height the host pupae are quite free from the attack of the parasite. In the laboratory, this parasite attacks the pupae of *Cirphis unipuncta* Haworth readily, but entirely not in the field. The reason is the same as the case of C. *medinalis* and the pupae of *Cirphis unipuncta* are always found at the sites below 15 cm above the ground. The oviposition of this species on the pupae of C. *medinalis* on stubble could be observed from the middle of November after the harvest season. This phenomenon is sufficient enough to suggest the characteristic of searching behavior of this species.

Flanders (1947) points out that for parasite females the power to occupy host-inhabited areas is an attribute which constitutes the elements of the power of host discovery and that it depends on the responses of the female parasite to such factors as plant surfaces, odors, air movement, light, temperature and humidity. As Flanders pointed out, the microclimate of paddy field and the reaction of positive phototaxis of this species along with the growth of rice plant are considered to be the primary factors of its failure to search its hosts which are locating as deep as the lower part of rice plant. It is felt necessary to carry out further field studies and laboratory experiments on such problems in the future.

The ovipositional behavior of this species as described above is also

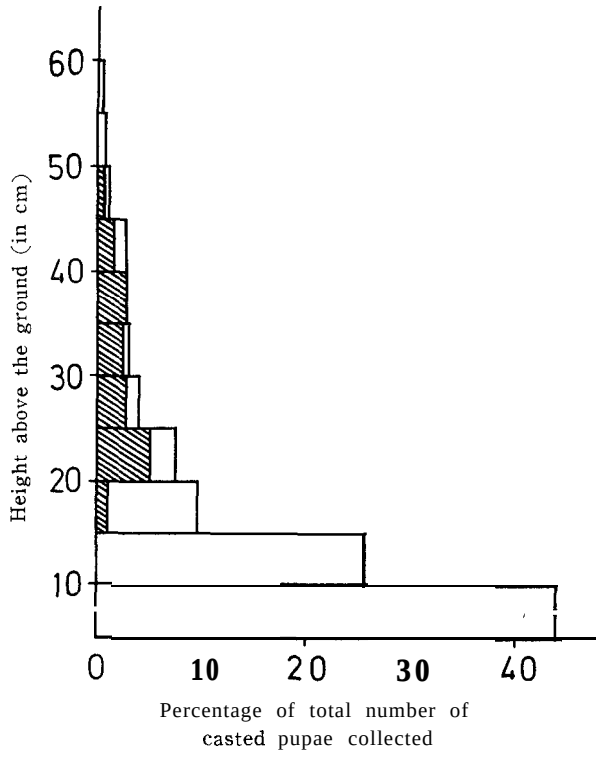

Fig. 4. Parasitization by ***Itoplectis narangae*** of the pupae of ***Cnaphalocrocis medinalis*** at different heights above the ground. The data based on the collection of Nov. l-4. Slantly hatched area represents the percentage parasitism.

considered to be one of the major factors that lower the percentage parasitism, as a whole, of *C. **medinalis*** on the growing rice plant.

V. Laboratory observation on the life history

1. Descriptions of the immature stages and developmental period.

The developmental period of a parasite is one of the most important factors in evaluating its effectiveness in biological control. The author investigated the developmental period of this species and observed its immature stages.

Method: The pupa of ***Galleria mellonella*** was exposed for an hour to this species in a 25°C insectary for oviposition. Several host pupae

which were oviposited by the parasite were dissected in water every day, and the shape of egg and the larvae were investigated. Spiracle was also investigated in a manner similar to that used by Finlayson (1960) ; the cast larval skins were removed from the host pupa and softened by soaking in 10 percent potassium hydroxide at room temperature for several hours. Then the skin was washed in water, immersed for 30 seconds in a weak solution of carbol fuchsin stain, washed again in water, sealed with Faure's solution and mounted on a microscope slide.

The terminology used in the description of the larval instars is that of Short (1959).

1) Descriptions of immature stages.

The eggs laid in the host pupa and full-grown larva in each instar were measured, and the results of which are given in Table 3.

It may be seen from Table 3 that the size of larvae after the fifth instar is strongly influenced by the size of the pupae of *Galleria mellonella* provided. Each instar larva except for the cephalic structure is readily discriminated by the width of head capsule.

Table 3. The measurement in millimeters of eggs, larvae and pupae of *Itoplectis narangae* reared on *Galleria mellonella.*

Stages or instar	No. of individuals measured	Average length and S. E.	Average width and S. E.	
			Widest point	Head capsule
Egg	20	1.34±0.02	0.23±0.02	
First instar	20	2.06±0.17	0.51±0.03	0.23±0.02
Second instar	20	2.85±0.29	0.78±0.09	0.34±0.02
Third instar	20	3.89±0.49	1.23±0.25	0.49±0.03
Fourth instar	20	6.44±0.36	2.08±0.24	0.69±0.05
Fifth instar	20	9.72±1.23	3.04±0.42	0.95±0.05
Prepupa	20	9.08±1.29	2.64±0.62	
Pupa ♂	20	10.43±0.69	2.57±0.36	
Pupa ♀	20	10.19±1.19	2.48±0.67	

Egg (Fig. 5, A) : smooth, shinning, pearly-white in color and elongate-oval in shape. Anterior end more bluntly rounded than posterior end.

First instar larva (Fig. 5, B, C and D) : spindle-shaped with 13 body segments. Head well defined and somewhat quadrate in outline. Each segment on both sides of dorsal line from the third metathorax to the eighth abdominal segment is protruded like tubercle, remarkable immediately after hatching but becomes blunt slightly at the end of the instar. Mandible (Fig. 5, D) long and sharp, distinctly curved posteriorly.

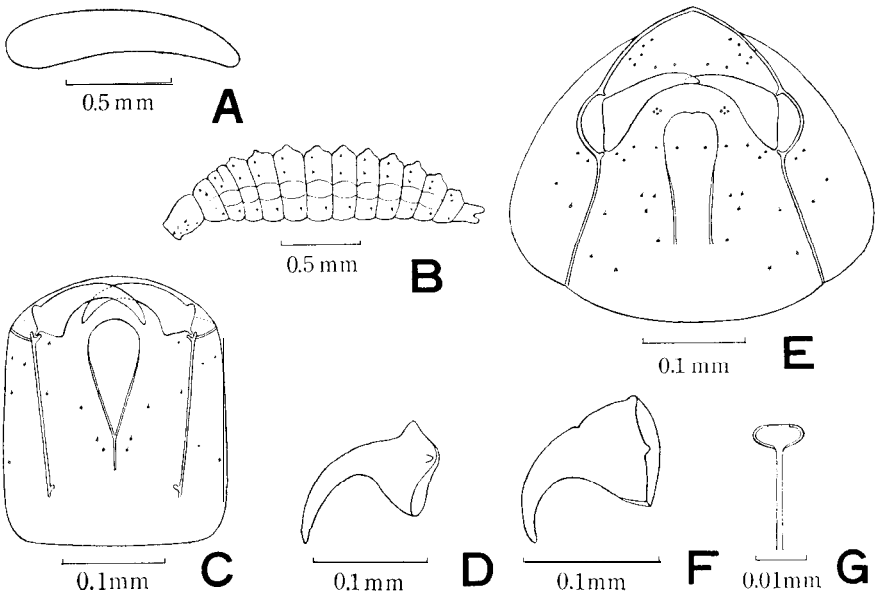

Fig. 5. *Itoplectis narangae. A:* Egg, B: Lateral view of first instar larva, C: Ventral view of head of first instar larva, D: Mandible of first instar larva, E: Ventral view of head of second instar larva, F: Mandible of second instar larva, G: Spiracle of second instar larva.

Setae present on the body surface as shown in Fig. 5,B. No open spiracles present on the exuviae.

Second *instar larva* (Fig. 5, E, F and G) ; similar in shape, but larger and more robust than the first instar. Nine pairs of open spiraclcs present (Fig. 5, G), one pair on prothorax and one on each of the first to eighth abdominal segments. Spiracles of uniform size, diameters of atria of 20 spiracles averaged 0.01 mm. Head (Fig. 5, E) shorter in proportion to its width than that of the first instar. Epistoma complete.

Third instar larva (Fig. 6, A, B and C) : larger and more robust than those of the previous instars. Spiracles (Fig. 6, A) similar to those of second instar except for size; average diameter of atria of 20 spiracles 0.021 mm. Head (Fig. 6, B) wider in proportion to its length than in the previous instars.

Fourth instar larva (Fig. 6, D) : similar to the fifth instar in general shape except for size. Spiracle similar to those of the third instar in shape except for size. Average diameter of atria of 20 spiracles 0.03 mm. Maxillary and labial paipi readily discriminated.

Fifth instar larva (Fig. 7, A, B, C and D) : widest at the second abdominal

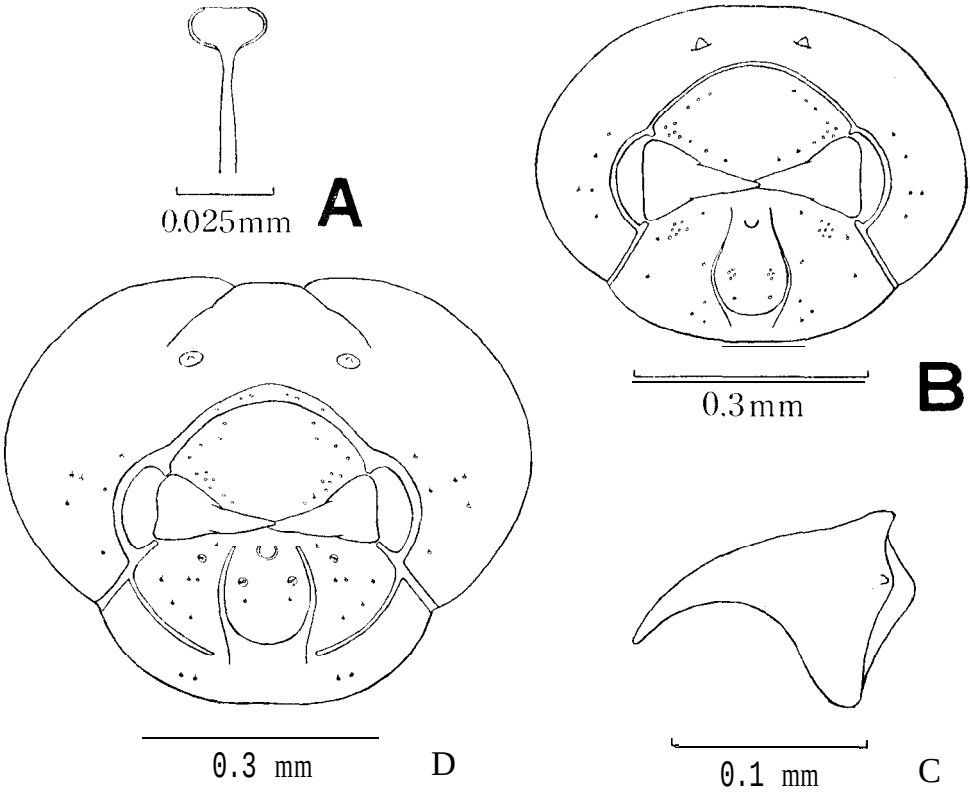

Fig. 6. *Itoplectis narangae.* A. Spiracle of third instar larva, B: Ventral view of head of third instar larva, C : Mandible of third instar larva, D: Ventral view of fourth instar larva.

segment and tapering towards both ends. Fat balls in the body are seen through the skin as small milky-white points along the sides from dorsum. Distribution of setae on all body segments as illustrated in the figure. Tracheal system well developed and open spiracles on prothorax and first to eighth abdominal segments clearly observed. Shape and size of spiracle remarkably different from those of the previous instar. Atrium of spiracle (Fig. 7, C) oval in shape, about two times as wide as deep, with many protuberances on the walls. Average diameter of atria of 20 spiracles 0.05 mm.

Cephalic structure of this instar (Fig. 7, D) heavily sclerotized. Epistoma complete, joining pleurostoma and hypostomal spurs to form a ring which is broken only by labial sclerite. Each of superior mandibular processes well-formed. Unlike the previous instars, hypostomal arms lacking: indentation present in a region where hypostoma would

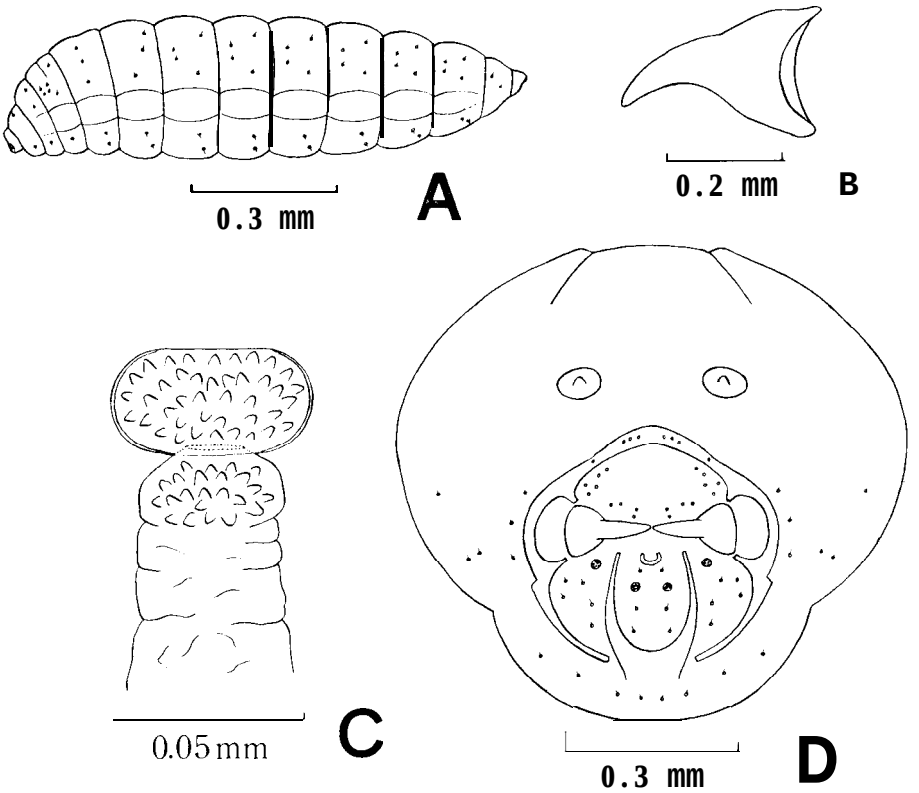

Fig. 7. *Itoplectis narangae*. A : Lateral view of fifth instar larva, B: Mandible of fifth instar larva, C: Spiracle of fifth instar larva, D : Head of fifth instar larva.

normally arise. Each hypostomal spur heavy-based and long, resting on medial end of small stipital sclerite close to labial sclerite. Basal portion of labial sclerite thickened, with its ventral part slightly rounded; dorsal arms thin, each narrowing dorsally. Silk press lightly sclerotized. Mandible large, without protuberance or teeth. Maxillary and labial palpi each with one large and about six smaller sensoria. Antenna small, disc-like.

Pupa : prepupa yellowish-white and imaginal eyes brown, semicircular, present beneath the skin of pro-mesothorax as time elapses. It changes gradually to the same color of adult at pupal stage. Ovipositor of female pupa starting from the end of the fifth abdominal sternite, running posteriorly and curving along the rear end of the eighth abdominal segment and finally recurving forward covering the dorsum,

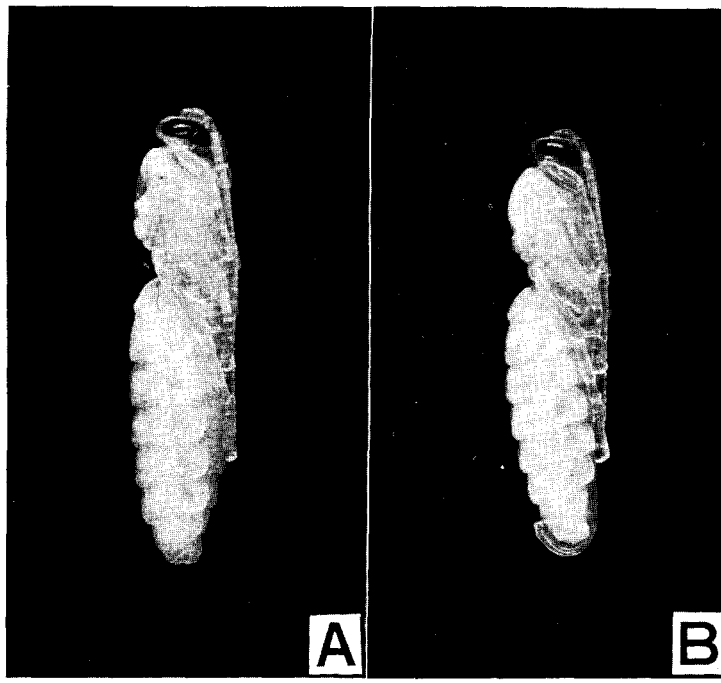

Fig. 8. Itoplectis narangae.
A: Male pupa, B: Female pupa.

thus the tip being beyond the base of seventh abdominal tergite.

2) Developmental period.

The developmental period of this species within the host in a 25°C insectary was investigated, the results of which are illustrated in Fig. 9.

Egg period was about one day. The larva moved continuously within the egg shell before hatching. Each of the larval period 1, 2, 3 and 4 instars was about one day. When more than 2 eggs were deposited in a single host, there occurred a competition between the parasite larvae and supernumerary parasites were always eliminated. In no instance did more than one parasite complete development in a host. When one larva hatched before the others, the larva destroyed the other eggs with its mandibles. The elimination of supernumerary parasites within the host occurred before the second instar. The super-parasitized pupa of *Galleria mellonella* dissected on the third day after oviposition showed patches of melanin pigment which were caused by the deposit of melanin on the wounded portions of destroyed parasite

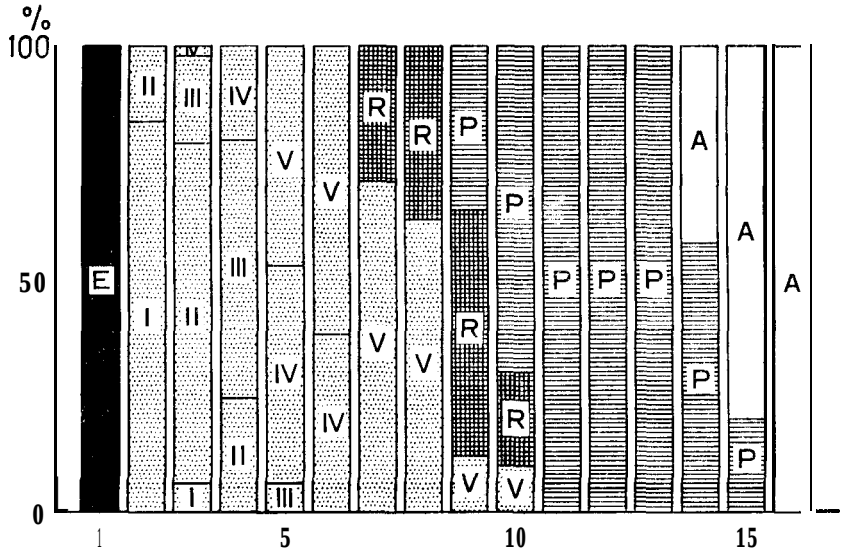

Fig. 9. Developmental stages and period of ***Ztoplectis*** *narangae* reared on ***Galleria*** *mellonella* at ***25°C.*** I: First instar, II: Second instar, III: Third instar, IV: Fourth instar, V: Fifth instar, A: Adult, E: Egg, P: Pupa, R: Prepupa.

larvae, as observed by Fisher in the case of ***Nemeritis*** *canescens* Gravenhorst and ***Horogenes chrysostictos*** Gmelin. The presence of supernumerary larvae did not appear to alter the rate of development or the size of the surviving parasite. The fifth instar was 3 or 4 days. Some of the contents of the host body were observed until the fourth instar, but all of them were completely consumed at the fifth instar larval stage of the parasite. Prepupal period was only one day, while pupal period lasted 5 or 7 days. The adult emerged by gnawing an irregular hole (average diameter 3.5 mm) through the host pupal skin usually from the anterior region but sometimes also from the posterior region. When the egg was deposited in the older host, this species sometimes emerged from the abdomen. The average developmental period from egg to adult varied in male and female, the former emerged earlier than the latter. Table 4 shows the developmental period at different temperatures after being oviposited in different host species.

The developmental period varies according to the host species and the individuals reared on the pupae of *Chilo* ***suppressalis*** seemed to spend somewhat longer period than those reared on ***Galleria mellonella*** pupae. However, in any case the developmental period was shorter at 30°C than at 25°C. The male always emerged earlier than the female.

Table 4. Mean developmental period in days of *Ztoplectis narangae* at different temperatures in different host species.

Host species	Sex of parasite	25°C		30°C	
		No. of parasites observed	Developmental period	No. of parasites observed	Developmental period
*Galleria mellonella	♂	30	14.0	25	12.0
	♀	30	14.9	15	14.0
Chilo suppressalis	♂	20	15.9	20	12.5
	♀	20	17.3	20	13.4
*Leucania separnta	♂	2	20.0		
	♀	12	21.5		
*Tryporyza incertulas	♂	1	15.0		
	♀	1	16.0		
Sesamia inferens	♂	–			
	♀	1	20.0		
*Parnara guttata	♂	2	17.5		
	♀				
Cnaphalocrocis medinalis	♂	2	14.3		
	♀	1	15.0		
Naranga aenescens	♂	1	14.0		
	♀				

* Asterisk denotes the unnatural host.

The pupae of *Galleria mellonella* which were parasitized were placed under the room temperature condition (max. 23°C, min. 8°C, mean 17.1 °C) from October 17 to December 2, 1968. The developmental period was investigated with 18 males and 24 females, the results of which showed 37.7 days for male and 41.8 days for female, indicating more than two times the period reared at 25°C.

3) *Effect of temperatures on the color variation.*

Studies on the color variation of parasites emerged at different temperatures have been reported occasionally. Although no morphological difference was reported in the adults of this species reared at different temperatures, a remarkable difference was observed in the development of pigment. According to the work done by Quednau (1960) in the species of *Trichogramma,* yellow color predominated in the body coloration if reared at higher temperatures and black color specific to each species is well pronounced when reared at low temperature. Similar phenomenon was also observed in this species. Black color was well developed in those reared at low temperature while the reverse was true in those reared at high temperatures.

The color variation of this species reared at different temperatures is summarized in Table 5.

Table 5. Color variation of *Itoplectis narangae* adult reared on *Gaileria mellonella* at different temperatures.

		17°C	25°C	30°C
♂	Thorax	Black	Black	Reddish-brown
	Abdominal segment	7 to 8 black	7 to 8 dark-red	7 to 8 pale ferruginous
	Coxae	Brown	Lemon yellow	Lemon yellow
	Femur	Proximal 1/4 black	Proximal 1/5 black	Proximal 1/7 black
	Tibia	An annulus at base and proximal 1/2 black	An annulus at base and proximal 1/3 black	Without an annulus, proximal 1/5 to 1/4 black
♀	Thorax	Black	Black	Reddish-brown
	Abdominal segment	6 to 8 black	8 black	6 to 8 pale ferruginous
	Coxae	Brown	Lemon yellow	Lemon yellow
	Femur	Proximal 1/5 black	A black annulus at apex	Without annulus
	Tibia	A black annulus at base slightly longer than the black part of femur proximal 1/3 black	A dark brown annulus at base, proximal 1/5 black	Apex dark brown

The material collected from the paddy field of Hakozaki, Fukuoka were analyzed by the Table 5. It is interesting that the color of those collected in the later part of May was similar to that of the individuals reared at 17°C. The seventh and eighth abdominal segments were black in the females collected in the months of June, October and November. It seemed to correspond nearly the neutral color of those reared at 17°C and 25°C. The females with the black eighth abdominal segment and the light reddish-brown sixth-eighth abdominal segments were mixed among the material collected in the later part of July. This seemed also nearly neutral color of those reared at 25°C and 30°C.

It may be possible to estimate the approximate developmental period of this species by observing these remarkable color variations affected by temepratures.

VI. Habits

1. Feeding habit of the adult parasite.

It has been known by many workers that most of the adults of Hymenopterous parasites feed on honey of flowers, aphid honeydew, host body fluids and other rnaterials which are essential for their

survival and reproduction.

The adults of some Hymenopterous parasites visit flowering plants of many different families to obtain nectar and pollen (Leius 1960). If there is some ***flowering*** plants within the area of activity of the parasites in the field, the flower plays an importants role as the source of food for the reproduction or maintenance of the parasite population (Györfi 1951).

Hirose (1966) reported that this species visits flowers in the carrot field around the paddy field where the author conducted the field study. This indicates that the carrot field plays an important role in the activity of this species.

The host body fluid is an important source of protein diet necessary for oögenesis of the female of synovigenic species (Flanders 1942). Although the host feeding by the females of this species in the field was not observed, the body fluid of pupae of ***Galleria mellonella,*** *Chilo suppressalis*, ***Leucania separata*** and ***Parnara guttata*** were observed to be fed by this parasite in the laboratory. Similar observations were made by Johnston (1913), Leius (1961) and Arthur (1963) in ***Ztoplectis conquisitor*** (Say) and also by Nozato (1969) in ***Ztoplectis cristatae*** Momoi.

Experiment (Tables 18 and 19) on the reproductive capacity of this species showed the host feeding almost every day during the oviposition period, but host feeding has never been observed before and after the oviposition period. The adult female of this species deposited her egg by inserting her ovipositor into the host and then fed on the host fluids exuded from the hole immediately after withdrawing her ovipositor. But, the host feeding after egg laying was not done at each oviposition. For example, the adult female fed on the host fluids without depositing any egg, but in case the amount of host fluids was small in quantity, the ovipositor was inserted 2 or 3 times repeatedly into almost the same puncture hole or was pumped and circulated with the inserted ovipositor to enlarge the hole for ready feeding of as much host fluids as possible. In this case, almost all of the host fluids were fed and only the pupal skin remained. Therefore, the role played by this species in the field as a form of predation (DeBach 1943, Flanders 1953) is presumed to be significant.

Townes (1958) pointed out that moisture, particularly in the form of dew, is an important requirement of ichneumonids, and in many cases its scarcity is a limiting factor.

Observation was further made on this species feeding on water on the leaf of rice plant in the field after rains. In the laboratory it also fed on as much water as possible almost every day during the survival period. When this species was liberated immediately after emergence

in the Container A which was supplied with water and honey, it fed on water and then honey or vice versa whichever it was found first.

Leius (1960) states that aphid honeydew is an important source of food and moisture, especially in early spring and late autumn when flowering plants are scarce. The author observed this species taking honeydew from aphids (species name unknown) on the ear of rice plant in the middle of November when no water was usually available. It is felt, therefore, that this may endorse what Leius states.

2. **Mating habit.**

Males emerge, on an average, slightly ahead of the females and wait for an emerging female. The females were ready to mate immediately after emergence. The mating ratio of older males is higher than that of younger ones, but some males mate soon after emergence. Usually, if not always, the newly emerged males come in contact with the unmated females but do not try to mate. The males become excited when they touch the unmated females with their antennae and then run after and mount them. The male may curl his abdomen around either side of the female, and inserts his genitalia into the females genital chamber which is just above the seventh sternite.

In the laboratory an unmated female was kept together with 4 males in a test tube (28 mm in diameter and 196 mm in length). One of the males whose antenna came first in contact with the unmated female was successfully mated. The other males mounted on each upon the other and on the mating male. They mated one by one after the accomplishment of mating of the first male, and the male once contacted with the unmated female attempted sexual intercourse with females and even with males near by.

Thus an unmated female successfully mated with 4 males. In this case the time spent for coition was the longest in the first and became shortened gradually from the second to fourth. It may be seen from this observation that the frequency of mating of this species is as a rule only once but the females may be able to mate 2 or 3 times if the newly emerged females encounter a number of males in the field.

They are motionless during mating, but the male's wings and antennae vibrate rhythmically after the lapses of certain times in coitus. The vibration varies in frequency. The time required for coition is shown as in the following Table 6.

The unmated females can mate with males throughout her life. A pair of male and female which mated immediately after emergence was put in the Container A and observed their behavior by giving ***Galleria mellonella*** pupae as host insects. The male did not usually

Table 6. Time required for coition and frequency of vibration.

Obsv. no.	Time required for coition	Time from coition to vibration	Frequency of vibration
1	2 min. 35 sec.	1 min. 35 sec.	61
2	3 〃 45 〃	1 〃 30 〃	195
3	5 〃 15 〃	2 〃 35 〃	271
4	6 〃 25 〃	5 〃 25 〃	64
5	14 〃 55 〃	12 〃 0 〃	145
6	1 〃 20 〃	1 〃 5 〃	15

show any response against the female even contacting with her, but tried to mate when the female laid her eggs on the host provided. In this case, if the male tried to mount the female, she promptly brushed him off with her hind legs or resisted against the male by vibrating her wings. However, it was observed occasionally that the male succeeded in coition by vibrating its wings 2 or 3 times. The duration of vibration was relatively shorter than that required for mating of females immediately after emergence.

3. **Oviposition habit.**

1) Searching for host and oviposition.

According to the observation in the Container A in the laboratory, the oviposition by the gravid female started within 1 minute after the detection of host, if the pupa of ***Galleria mellonella*** was provided. They inserted their antennae deeply or thinly through the mesh of gauze, or sometimes inserted the entire antenna of one side with the head leaning to one side to search for the host. Sometimes they were observed to clean their antennae with fore legs. When the host was discovered, they moved around once or twice on the host body vibrating their antennae incessantly to tap the host. If a suitable place was located for oviposition, the female erected her ovipositor vertically to the host body, then moved her body slightly backward and inserted her ovipositor at an angle of 75°–80° to the host body surface after confirming the tip of the ovipositor not slipping off from the host body. The full length of the ovipositor was usually inserted for oviposition, but sometimes withdrew it slightly after the full length insertion as if to adjust the depth. After oviposition they rubbed their ovipositors on the gauze and cleaned the host body fluid thereon. When the pupa of ***Galleria mellonella*** was nakedly exposed, some individuals found the host and oviposited within one minute, as in the case of Container A. On the other hand, some did not show any response even when

they moved frequently on the host body. It took some time for these individuals to find the host and oviposit.

In the field the female of this species was observed moving around on the leaf vibrating its antennae which seemed to tap softly the leaf surface. In the case of the stem, however, she behaved with her antennae holding the stem in the manner described above. When a hole or a crevice was found on the stem, she inserted her one-side antenna fully into the hole or the crevice in order to search for the host.

From these observations it is felt that this species is not only adapted to search for naked host but also adapted to search for the host in hidden places for oviposition. The time required for oviposition is 15 seconds in the shortest case and sometimes more than 14 minutes in the longest case. According to the laboratory observation oviposition occurs more frequently on the thorax rather than on the abdomen of the host pupae. This may be probably attributable to the fact that the host pupa refuses the attack of parasites by moving its abdomen at the time of oviposition.

The relation between the frequency of insertion of the ovipositor and the number of eggs laid was investigated with 10 parasites to each of which one pupa of ***Galleria*** *mellonella* was provided. The host was taken out and dissected after one insertion of the ovipositor to count the number of eggs deposited. Similar experiment was conducted on the host in which the ovipositor was inserted twice. As shown in Table 7, it was clearly proved that only one egg was deposited by one insertion of the ovipositor.

Table 7. Relation between the frequency of insertion of the ovipositor of ***Itoplectis narangae*** into the pupa of ***Galleria mellonella*** and the number of eggs deposited.

Frequency of insertion of ovipositor	Parasite number									
	1	2	3	4	5	6	7	8	9	10
1	1	1	0	0	1	1	0	1	1	1
2	12	2	2	2	2	1.2			0	1

2) ***Relation between the age in days of the host pupa and the number of eggs deposited.***

Experiments were conducted to see the effect of the age in days of the host pupa on the oviposition of this species.

Methods : In the first experiment which was performed by using the

Container B, 3 pupae of ***Galleria mellonella*** uniform in size and younger than 24 hours old were exposed to a single parasite. This experiment lasted for 8 days using 6 adult females each of which was provided daily with 3 pupae of different ages ranging from 1 day to ***8*** days successively.

Container B was also used for the second experiment and the pupae of *Galleria mallonella* of each different age in days were arranged and pasted on a cardboard as illustrated in Fig. 10 (the figure in circle represents the age in days of each host).

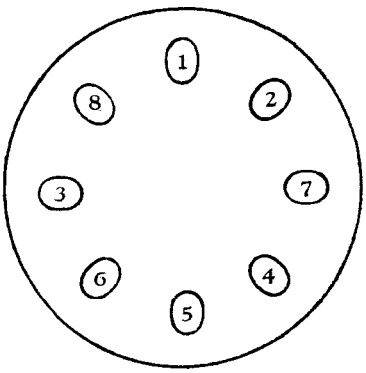

Fig. 10. Arrangement of hosts.

They were exposed simultaneously to each of 10 adult females for 24 hours. The dissection of the hosts was made under a binocular microscope to count the number of eggs deposited.

Results : The results of these experiments are presented in the following Tables 8 and 9.

From Tables 8 and 9, it seems that the oviposition takes place evenly throughout the age-range 1 to 8 days. Therefore, the difference of the age in days seems to have no effect upon the parasite oviposition. The difference in the number of eggs deposited by the age in days does not indicate a declining tendency, and particularly no difference by the age in days may be noticed.

Table 8. Age in days of the pupae of ***Galleria mellonella*** and number of eggs deposited by ***Itoplectis narangae.***

Age in days	Parasite number						Total
	1	2	3	4	5	6	
1	***25***	***18***	***16***	***11***	***9***	***18***	97
2	***27***	***17***	***11***	***1***	***27***	***10***	93
3	***23***	***13***	***14***	***4***	***16***	***9***	79
4	***12***	***12***	***15***	***2***	***12***	***13***	***66***
5	***10***	14	***10***	***4***	***20***	***11***	***69***
6	***14***	***19***	***21***	***11***	***28***	***9***	***102***
7	***16***	***14***	***13***	***6***	***21***	***11***	***81***
8	19	10	11	***5***	***15***	***9***	***69***

Table 9. Number of eggs deposited by *Itoplectis narangae* when the pupae of *Galleria mellonella* of different ages were given simultaneously.

Age in days	Parasite number										Total
	1	2	3	4	5	6	7	8	9	10	
1	0	7	4	6	3	3	2	12	3		31
2	9	7	17	6	3	3	7	4	7	5	68
3	3	3	7	2	3	3	3	5	3	7	39
4	10	1	2	1	1	3	5	2	7	3	35
5	7	4	2		13	6	5	4		13	36
6	4	0	13		7	18	4	2		4	34
7	3		1110		2	3		3		11	16
8	3	5	3	1	6	6	3	4	2	0	33
Total	39	28	37	21	26	27	36	27	25	26	

3) *Relation* ***between the dorsal and ventral sides of the host pupa and the number of eggs deposited.***

The ventral and dorsal sides of the pupa of ***Galleria mellonella*** differ slightly, the former being smooth with thin pupal skin, while the latter having many small processes with thick pupal skin.

Experiment was further conducted by using the Container A to see whether such differences have any influences on the oviposition of the parasite.

Method : Three host pupae (one-day, three-days and five-days old) were pasted with their ventral or dorsal side kept upward on a cardboard and exposed to five parasites for 24 hours at 2 days interval. The dissection of the hosts was made under a binocular microscope to count the number of eggs deposited.

Result: The results are presented in Table 10.

No remarkable difference was observed between the oviposition on

Table 10. Number of eggs deposited to the dorsal and ventral sides of the pupae of *Calleria mellonella* by ***Itoplectis*** *narangae.*

Age in days	Dorsal side					Total	Ventral side					Total
	1	2	3	4	5		1	2	3	4	5	
1	*43*	*28*	*40*	*21*	*29*	*161*	*27*	*22*	*28*	*30*	*30*	*127*
3	*33*	*12*	*40*	*16*	*10*	*111*	*11*	*17*	*23*	*25*	*18*	*94*
5	*37*	*26*	*31*	*9*	*12*	*115*	*22*	*17*	*16*	*35*	*16*	*106*

the dorsal and ventral sides. The number of eggs deposited on the dorsal side was slightly superior to that on the ventral side. This indicates that the small processes and thickness of the pupal skin have no relation to the oviposition behavior.

4) ***Relation between the size of the host pupae and the number of eggs deposited.***

A considerable difference was observed in the size of the pupae of ***Galleria mellonella*** according to their nutritional condition during the larval stages. Investigation was carried out to see whether the size of the host pupae affects the parasite oviposition.

Method: The host pupae were grouped into 2 plots according to their size, large and small and pasted on a cardboard by using the Container A and then 5 parasites were provided to each plot. The hosts were renewed every day for 3 days. The dissection of the hosts was made under a binocular microscope to count the number of eggs deposited.

It may be seen from Table 11 that the size of the host pupae give no effect in particular upon the parasite oviposition.

Table 11. Number of eggs deposited by ***Itoplectis narangae*** to ***Galleria mellonella*** pupae of different sizes.

Date of experiment	Large size					Total	Small size					Total
	1*	2	3	4	5		1	2	3	4	5	
1st day	7	8	13	9	11	48	14	18	14	23	18	87
2nd day	39	9	13	11	25	77	14	17	10	14	19	74
3rd day	31	11	15	22	22	101	13	20	13	17	23	86

Large size: Length of host pupae 15.0 -15.5 mm
Width of host pupae 4.0 – 4.5 mm

Small size: Length of host pupae 9.0 – 9.5 mm
Width of host pupae 2.3 – 2.5 mm

* Asterisk represents the parasite number.

5) Superparasitism.

Even if this species superparasitized a single host pupa, only one parasite developed without any exceptions. Therefore, it seems important to prevent superparasitism to a minimum extent so as to increase the percentage of parasitism and to prevent the loss of efficiency per female due to the wasting of eggs for the mass production of this species.

The following experiments were conducted for this purpose.

Methods: Experiment was carried out in the Container B and the

pupae of ***Galleria mellonella*** of nearly uniform in size were used as hosts. The parasites were provided with undiluted honey and water for diets. A proper number of the hosts necessary for the experiment was pasted at regular intervals on cardboards as illustrated below.

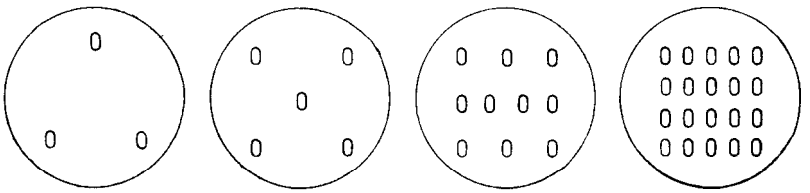

Fig. 11. Arrangement of hosts.

The dissection of the hosts was made under a binocular microscope to count the number of eggs deposited.

In the first experiment one parasite was provided with 3, 5, 10 and 20 hosts respectively for 3 hours. This procedure was repeated 10 times. In the second experiment, one parasite was exposed to 10 and 20 hosts respectively for one and three hours and repeated 10 times. In the third experiment, the following combinations of hosts and parasites were tried, i. e., one parasite with 10 or 20 hosts and three parasites with 10 or 20 hosts, and each experiment was repeated 10 times.

Results: The results of these experiments are presented in Tables 12, 13 and 14.

Table 12. Results of exposing 3, 5, 10 and 20 pupae of ***Galleria mellonella*** to 1 female *Itoplectis* ***narangae*** for 3 hours (10 replicates).

No. of hosts exposed	No. of eggs deposited in host pupae																	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
3	1	1	2	2	4	6	1	5	2	1	1	1	-	1	1	-	1	
5	6		715		7		4		3		6	-		11	-	-	-	-
10	16		27		20		14		12		6	2	3	-	-	-	-	-
20	90		63		31			12		3		1	-	-	-----		-	-

No. of hosts exposed	Total no. of hosts	Total no. of parasite eggs	% of hosts super-parasitized	% parasitism	Average no. of eggs per host	Average no. of eggs laid per female
3	30’	186	93	97	6.2	18.6
5	50	142	74	88	2.8	14.2
10	100	220	57	84	2.2	22.0
20	200	178	24	55	0.9	17.8

Table 13. Results of exposing 10 and 20 pupae of *Galleria mellonella* to 1 female of *Itoplectis narangae* for 1 hour and 3 hours (10 replicates).

No. of hosts exposed	Period of exposure	No. of eggs deposited in host pupae							
		0	1	2	3	4	5	6	7
10	1 hour	27	31	25	10	4	2	–	1
	3 hrs.	16	27	20	14	12	6	2	3
20	1 hour	108	57	24	9	2	–	–	–
	3 hrs.	90	63	31	12	3	1	–	–

No. of hosts exposed	Period of exposure	Total no. of parasite eggs	% para-sitism	% of hosts super-para-sitized	No. of eggs per host	No. of eggs laid per female
10	1 hour	144	73	42	1.4	14.4
	3 hrs.	220	84	57	2.2	22.2
20	1 hour	140	46	18	0.7	14.0
	3 hrs.	178	55	24	0.9	17.8

Table 14. Results of exposing 10 and 20 pupae of *Galleria mellonella* to 1 female and 3 females of *Itoplectis narangae* respectively for 3 hours (10 replicates).

No. of hosts exposed	No. of para-sites	No. of eggs deposited in host pupae																
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	– 29
10	1	16	27	20	14	12	6	2	3	–	–	–	–	–	–	–	–	–
	3	8	4	7	7	8	10	12	6	7	4	8	5	4	4	1		5
20	1	108	57	24	9	2	–	–	–	–	–	–	–	–	–	–	–	–
	3	27	25	31	34	18	18	18	10	9	4	2	1	1	1	1	–	–

No. of hosts exposed	No. of para-sites	Total no. of parasite eggs	% para-sitism	% of hosts super-para-sitized	No. of eggs per host	No. of eggs laid per female
10	1	220	84	57	2.2	22.0
	3	672	92	88	6.7	22.4
20	1	178	55	24	0.9	17.8
	3	707	86.5	74	3.6	24.0

The average number of eggs deposited per host increases when a small number of the hosts is exposed, while the average number of eggs deposited per host decreases as the number of the hosts becomes increased. However, no difference was observed in the average number of eggs deposited per female. This may indicate that the parasites do not tend to concentrate their oviposition on the hosts and that the oviposition has no relation to the number of hosts.

Observation on the actual oviposition showed that the parasite left the site after oviposition and moved around in search for other hosts. The largest number of eggs laid by one host was 16. The oviposition of more than 2 eggs occupied 93 % of the case in which 3 hosts were provided and 24 % in case of 20 hosts. The number of hosts which were not oviposited was figured out to be 90 out of 200 hosts provided. Therefore, it is felt that this species seems to be unable to discriminate the parasitized or unparasitized hosts.

As shown in Table 13, the average number of eggs deposited per female increased when the hosts were exposed for 3 hours as compared with that of 1 hour. Usually this species leaves the host after ovipositing 5 to 6 eggs, rests for a while and feeds honey and again starts for oviposition. Of course, this observation was made in the laboratory. In the field the hosts are not so abundant as in the laboratory condition. Therefore, it seems that the host feeding is essential to maintain the energy for the next searching and ovipositing behavior of the parasite.

If we take the total number of eggs deposited during 3 hours as a standard (100 %), the total number of eggs depostited for the first 1 hour corresponds 65 79 % as shown in Table 13. It may be seen from this that the percentage in the number of eggs will be decreased as the lapse of time. In another word, an increase in the number of eggs deposited will eventually enhance the percentage of parasitism and superparasitism.

As seen in Table 14, it may be said that the more the parasites the higher the percentage of parasitism or superparasitism. But this does not mean that some remarkable variations may be observed in the average number of eggs deposited per female.

Observation was also made on the oviposition by exposing 10 parasites to 20 hosts. Almost all of them oviposited simultaneously and 2 or 3 parasites also laid eggs at the same time on a single host.

These experiments may offer fundamental clues to develop a proper method of mass production of this species to enhance the percentage of parasitism and reduce the superparasitism. This procedure may include the shortening of the exposure time of the host pupae so as to prevent the chance of superparasitism.

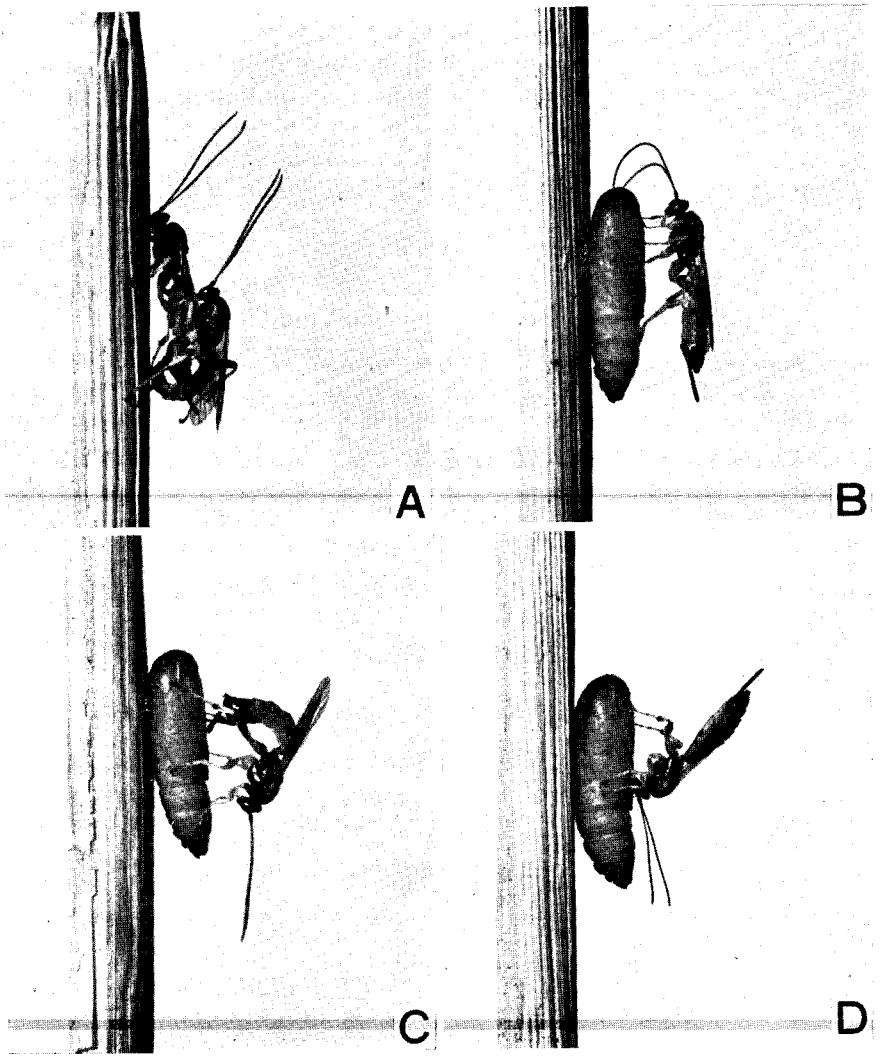

Fig. 12. Habits of *Itoplectis* ***narangae.*** A: Copulation, B: Searching for host, C: Oviposition, D: Host feeding.

VII. Reproductive capacity

The reproductive capacity of parasites is one of the most important factors in estimating and evaluating the effectiveness of natural enemies.

In order to see the reproductive capacity of this species, the develop-

mental process of matured eggs in the ovary of adult females was investigated together with the number of eggs deposited by the parasites into the host pupae of ***Galleria mellonella*** in a 25°C insectary.

1. Number of matured eggs in the ovary.

Methods: Adult females soon after emergence were put in the Container B, reared in a 25°C insectary and separated into two groups, the first fed with of those which were undiluted honey and water and the second unfed. Ten females of each group were dissected every day for 10 and 4 days for the former and latter groups, respectively, and then the number of matured eggs in the ovaries were counted under a binocular microscope.

Results: The results of this experiments are presented in Tables 15 and 16 and Fig. 13 which illustrates the mean value with 95 % confidence limit.

Table 15. Number of matured eggs in the ovary of unfed *Itoplectis narangae.*

Days after emergence	Number of matured eggs in the ovary of 10 females										Average
0	0	0	0	0	0	0	0	0	0	0	**0**
1	2	6	0	1	0	2	0	0	1	5	1.7±1.9
2	3	0	8	7	2	3	4	11	1	0	3.9±2.7
3	0	0	0	3	1	6	5	0	0	0	1.5±1.9
4	1	0	0	0	0	3	0	0	0	0	0.4±0.6

Table 16. Number of matured eggs in the ovary of *Itoplectis narangae* fed with undiluted honey and water.

Days after emergence	Number of matured eggs in the ovary of 10 females										Average
0	0	0	0	0	0	0	0	0	0	0	
1	0	0	2	3	3	0	2	0	0	0	1±0.9
2	7	5	14	1	13	6	5	8	5	0	6.4±1.1
3	8	11	17	6	10	13	7	9	5	17	10.3±3.1
4	14	7	14	8	11	8	8	2	8	5	8.5±2.6
5	6	8	11	18	9	3	8	11	3	10	8.7±3.0
6	10	12	10	8	8	10	7	2	12	10	8.9±2.1
7	4	6	6	18	7	5	8	6	10	9	7.9±3.0
8	11	7	5	10	4	4	3	15	10	5	7.4±2.8
9	11	7	4	9	5	8	2	3	7	11	6.7±2.3
10	5	11	3	7	5	5	5	10	3	6	6.0±1.8

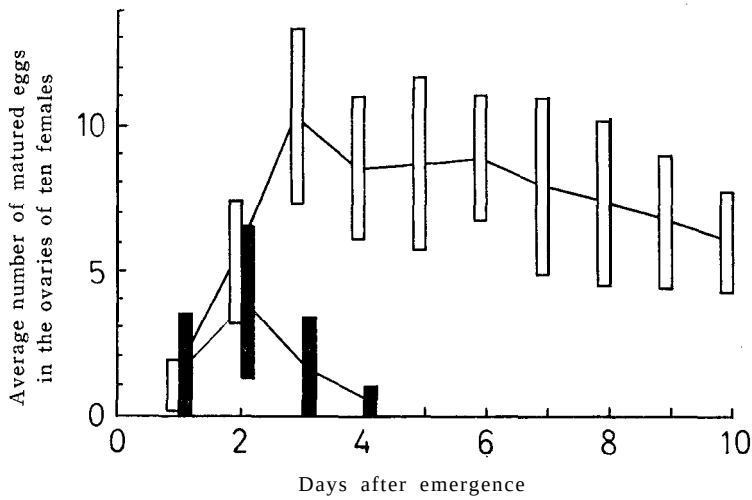

Fig. 13. Average number of mature eggs in the ovaries of *Itoplectis narangae* unfed (black) and fed with honey and water (white).

As shown in Table 16, soon after emergence no matured eggs were observed in the female fed with undiluted honey and water. The number of matured eggs were increased rapidly from the first day after emergence and reached the maximum on the third day and remained constant during the following three days and began to decrease by the o&sorption which took place gradually from the seventh day.

There is practically no difference in the number of matured eggs between the females fed and unfed until the first day after emergence as shown clearly in Tables 15 and 16. However, the number reached the maximum on the second day, and thereafter the oösorption took place rapidly, and dead individuals were seen after the fourth day. It seems that the number of matured eggs produced on the second day by unfed females was probably the limit number that might be produced by the nutrients preserved at the time of emergence. This may indicate that the females are seemed to be able to deposit a few eggs even if shc can find no diet for about one day after emergence. The number of matured eggs laid by the female fed with undiluted honey reached the maximum one day later than that found in the case of unfed females. Edwards (1954) stated that this difference is presumed attributable to small amount of protein in the honey that was used for egg production.

Table 17 shows the comparison of the number of ovarioles of 3-day old females of this species reared on undiluted honey and water after

emergence in relation to the number of matured eggs.

It may be seen from Table 17 that the number of matured eggs is about 50 % of the number of ovarioles and that there are no cases 2 matured eggs in a single ovariole (matured egg is always located on the distal portion of the ovarioles). Therefore, it seems that at the time of emergence the number of matured eggs produced by the use of its own nutrients and further supplied with honey does not increase in number as to the same level as those of the ovarioles.

Table 17. Number of ovarioles of S-day old female fed on undiluted honey and water in relation to the number of matured eggs.

Parasite number	Number of ovarioles			No. of matured eggs in the ovary
	Left	Right	Total	
1	8	9	17	8
2	12	13	25	11
3	10	10	20	17
4	9	7	16	6
5	10	9	19	10
6	11	11	22	13
7	7	8	15	7
8	8	8	16	9
9	9	9	18	5
10	9	10	19	17
Total	93	94	187	103

2. **Number of eggs deposited.**

Methods: Investigation was conducted on 10 mated and 10 unmated adult females of different size. The newly emerged parasite was put in the Container A, and then 3 host pupae of ***Galleria*** *mellonella* not older than 3 days after pupation were given every day until the parasite died. The host pupae were taken out daily and dissected to count the number of eggs deposited. Length of forewing of the dead adult females was measured and then dissected. The number of matured eggs remained in the ovary was also counted. During the course of experiment, undiluted honey was provided once every 3 days, water once every day and the container was renewed once every week.

Results: The results of this experiment- are presented in Tables 18 and 19.

The adult females after emergence became inactive, very sluggish

Table 18. Number of eggs deposited by ten mated females of *Itoplectis narangae*.

Days after emergence	Parasite number									
	1	2	3	4	5	6	7	8	9	10
				5						
3			2	11			6		6	
4	3		4	11			3		6	
5	3	13	6	12	7	3	14	2	25	4
6	7	13	13	13	7	8	21	5	13	
7	4	18	15	11	14	11	14	5	23	
8	7	13	13	15	18	4	23	6	27	1
9	20	15	10	6	15	11	18	4	21	6
10	21	33	19	5	14	15	20	4	17	
11	9	25	9	8	14	8	20	3	28	
12	1	22	20	2	10	9	24	4	24	
13	5	27	8	2	8	6	20	7	34	4
14	1	30	15		10	15	17	4	27	
15		33	1	1	15	21	5	5	20	8
16		19	11		15	16	16	5	40	15
17	1	17	1	1	13	20	12	4	33	8
18					4	16	11	9	28	7
19			4		9	7	7	3	21	4
20					8	12	7	3	30	
21		5	1		12	11	4	3	13	2
22			1		13	7	9	1	37	2
23		3			16	10	6	3	21	
24		2			5	16			28	
25		7			7	3		2	24	
26					4	1		4	27	3
27		8			3		3	3	35	
28		2		1	2			8	16	1
29		4			3	8	6	2	19	1
30		13					1	12	13	
31		5			2	3		7	16	
32		8			2		6	11	14	
33		6			7	3		1	11	
34		1			1	1	3	3	14	
35		10			5	1			15	
36					2			2	4	
37		5							1	
38		1							1	
39		4					*	4		
40										
41		*			*			1		
42									*	
43										
44			*			*				
45	*			*				*		*
46										
47										
Total eggs deposited	82	362	151	104	265	246	296	139	732	70

* Asterisk denotes the date of death.

Table 19. Number of eggs deposited by ten unmated females of *Itoplectis narangae.*

Days after emergence	Parasite number									
	1	2	3	4	5	6	7	8	9	10
1										
2		2						9		
3	4	10		1				21	2	6
4	11	18		10	3			16	19	12
5	27	10	4	20	5	3		25	24	16
6	19	10	5	9	6	7		16	13	12
7	32	10	2	20	13	24		26	22	23
8	25	7	10	8	18	29	9	18	21	32
9	30		8	4	10	19	1	23	27	24
10	22	1:	8	6	15	47	14	18	25	25
11	28	15	6	5	8	23	17	22	17	27
12	17	1	6		20	36	30	10	21	24
13	17	8	6	5	12	46	35	16	6	27
14	22	4	6	3	18	35	40	12	30	22
15	20	2	6	7	18	21	38	20	3	19
16	23	4	6		12	31	30	24		28
17	21	2	2		13	32	30	24		9
18	17	1		2	9	36	35	12	3	9
19	23	2			13	33	36	19	4	12
20	14	1	1		18	26	38	11	6	10
21	12		3		23	30	21	8	4	12
22	20	1	7		4	19	36	18	2	5
23	7	1	4		8	16	18	6	6	
24	7	2	3			14	37	7		2
25	19	6	8		6	31	29	19	1:	
26	6	3	2		2	43	34	12		
27	11	6	1		1	27	30	4	6	
28	2					21	19	14		
29	3	1	2	*		5	19		1	
30	1	1	3			4	13		1	
31	2		1			10	17		1	
32						21	15			
33			3			6	22		1	*
34			4			6	29			
35						1	12			
36						2	12	*		
37		1				3	14		3	
38							18			
39		*				2	17			
40			*				14			
41							13		1	
42							21			
43						1	15			
44							8		*	
45	*						8			
46							3			
47					*					
48							*			
49										
50										
51										
52						*				
53										
Total eggs deposited	4 6	2147	117	101	255	710	859	425	281	356

* Asterisk denotes the date of death.

during the preoviposition period after feeding on honey and water in the container. The preoviposition period was ranging from 1 to 7 days according to the individuals. Upon consulting the above tables together with Tables 23, 24 and 25, it was presumed that the preoviposition period of 1 and 2 days was predominant. The oviposition period varies remarkably between the individuals, being 11 days in the shortest and 39 days in the longest. Large adult female oviposits, in general, a large number of eggs daily from the start of oviposition and its oviposition period is also long. The reverse is true in the smaller one. The highest number of eggs deposited by one female was 859 and the average for the 20 was 300. The greatest number of eggs deposited by one female in one day was 47.

Nozato (1969) reported that 2 eggs were deposited by a single female per day in *Itoplectis cristatae* and Arthur (1963) recorded that 39 eggs were deposited per day and 476 eggs were the maximum number of eggs deposited by one female in *ltoplectis conquisitor.*

Subsequently, it was presumed that the reproductive capacity of this species was larger than the above mentioned species of the same genus.

Tables 20 and 21 indicate the relation between the number of matured eggs deposited and those remained in the ovary of the dead adult female. The number of matured eggs remained in the ovary was always very small, and the percentage of the number of eggs deposited against the estimated total number of ovarian eggs (total number of eggs deposited plus those remained in the ovary) was more than 94.5 %.

Table 20. Number of eggs deposited by a single mated female of *Itoplectis narangae.*

Parasite number	Number of eggs			P	No. of ovarioles	Preoviposition period	Oviposition period	Longevity of adult
	deposited	Remained in ovary	Total					
1	82	1	83	99.2%	37	3	13	45
2	362	6	368	98.7	14	4	35	41
3	151	0	151	100.0	16	2	20	44
4	104		101			1	27	45
5	265	0	265	100.0	18	4	32	41
6	246	0	245	100.0	22	4	31	44
7	296		296			2	32	39
8	139	1	140	99.3	16	4	37	45
9	732	16	748	97.9	18	2	36	42
10	70	1	71	98.6	17	4	36	46

P: Percentage of deposited egg number against the estimated whole ovarian egg number (total number of eggs deposited and remained in ovary).

Table 21. Number of eggs deposited by a single unmated female of *Itoplectis narangae.*

Parasite number	Number of eggs			P	No. of ovarioles	Preoviposition period	Oviposition period	Longevity of adult
	deposited	Remained in ovary	Total	%				
1	462	3	465	99.4	23	2	29	45
2	147	2	149	98.6	15	1	36	39
3	117	7	124	94.5	15	4	30	40
4	101	3	104	99.1	18	2	16	29
5	255	1	256	99.7	15	3	24	47
6	710	13	723	97.2	23	4	38	52
7	859	6	865	99. 9	23	7	39	48
8	425	3	428	99.9	21	1	27	36
9	283		281	-	-	2	39	49
10	356	6	362	99.6	18	2	22	33

P: Percentage of deposited egg number against the estimated whole ovarian egg number (total number of eggs deposited and remained in ovary)

3. **Fluctuation of oviposition,**

The data of Tables 18 and 19 are adjusted so as to make easy to understand or to compare with the data in Table 22 and Fig. 14.

Namely, in this table the oviposition of all the females was adjusted to be started on the same day. As shown in Table 22 and Fig. 14, it may be seen that the number of eggs deposited increased rapidly from the date of oviposition started and reaches the peak on the sixth day, and active oviposition continues for the first 14 to 21 days and decreases gradually thereafter. The daily fluctuation shows the continuation of increase and decrease and vice versa. The number of eggs deposited per day is not the same. It is felt that this is probably attributable to the physiological control of the parasite itself. Four parasites out of 10 unmated females oviposited more than 400 eggs, about 70 % of which were oviposited for 21 days after the start of oviposition, and the other 6 parasites oviposited less than 400 eggs, about 85 % of which were oviposited during the same period. This fact must be noticed to be important to facilitate this species an efficient oviposition in making mass production.

4. **Relation between the size of parasite and fecundity.**

The effect of the size of parasite on the number of eggs deposited have been reported occasionally (Salt 1940, Flanders 1935, Yasumatsu and Yamamoto 1953, Nohara 1956, Shiga and Nakanishi 1968, etc.).

Table 22. Number of eggs deposited daily by ten mated and ten unmated females of *Itoplectis narangae*.

Days after oviposition	Unmated female			Mated female		
	No. of living females	No. of eggs deposited	P	No. of living females	No. of eggs deposited	P
1	10	43	1.2	10	51	2.1
2	10	101	2.7	10	65	2.7
3	10	167	4.5	10	111	4.6
4	10	157	4.1	10	105	4.3
5	10	198	5.3	10	123	5.1
6	10	222	6.0	10	160	6.6
7	10	194	5.2	10	135	5.5
8	10	200	5.4	10	114	4.7
9	10	216	5.8	10	115	4.7
10	10	187	5.0	10	140	5.8
11	10	142	3.8	10	147	6.0
12	10		5.4	10		5.4
13	10	192	4.1	10	131 89	3.7
14	10		3.9	9		4.3
15	10	143	3.5	9	104 69	2.8
16	10		3.1	9	63	2.6
17	10	146	3.8	9	65	2.7
18	10		3.5	9	59	2.4
19	10	198	2.6	9	50	2.1
20	10	90	2.4	9	70	2.9
21	9	90	2.4	9	46	1.9
22	9	87	2.3	9	40	1.6
23	9	82	2.2	8	38	1.6
24	8	70	1.9	8	40	1.6
25	7	54	1.5	8	56	2.3
26	7	41	1.1	8	31	1.3
27	7	58	1.6	8	43	1.8
28	6	36	1.0	8	35	1.4
29	6	25	0.7	8	28	1.2
30	5	24	0.6	7	35	1:o
31	4	20	0.5	7	17	0.7
32	4	19	0.5	7	26	1.1
33	4	17	0.5	5		0.7
34	4	13	0.3	4	16 8	0.3
35	4	26	0.6	3	5	0.2
36	4	16	0.4	3	2	0.1
37	3	8	0.2	1	1	0.04
38	3	9	0.2			
39	2	4	0.1			
40	1					
Total eggs deposited		3,721			2,433	

P: Percentage of daily deposited egg number to the total number of eggs deposited by all females.

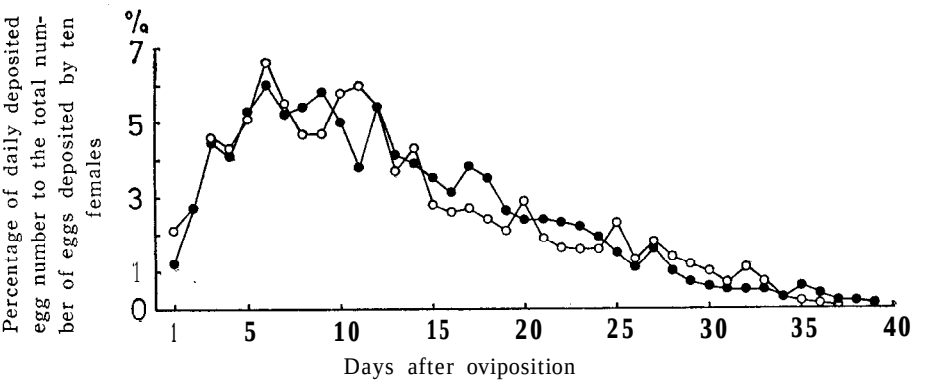

Fig. 14. Oviposition curves of mated (hollow circle) and unmated (solid circle) female of *Itoplectis narangae*.

Fig. 15 illustrates the relationship between the size and fecundity of 20 females used for experiments (Tables 18 and 19). The size of the adult females is represented by the length of forewing for the sake of convenience. As seen in the figure, high positive correlation of r= 0.660 was observed between the fecundity and the size of this species (significant at 1 % level).

5. Relation between the size of parasite and the number of ovarioles.

The size of this species is affected by the species, size, age in days and other factors of the hosts.

The frequency distribution of the number of ovarioles is very wide according to the parasites. The results of investigation based on the data presented in Table 16 are illustrated in Fig. 16. The difference of the number of ovarioles within the individual parasite was remarkable ranging from 11 to 28. This agrees with the data observed by Iwata (1960). Among the 100 parasites investigated about 25 % had the ovarioles 18 and 19 in number, and about 25 % showed a symmetrical distribution in the number of left and right ovarioles. As shown in Fig. 17 the relation between the size of parasites and the number of ovarioles was r=0.167, indicating almost no correlation between them. Therefore, it seems that the effect of the fecundity by the size of parasite has no relation to the number of ovarioles.

VIII. Effect of the period of lacking hosts on the number of eggs deposited

Synovigenic species (Flanders 1935) ceases the oögenesis of parasites

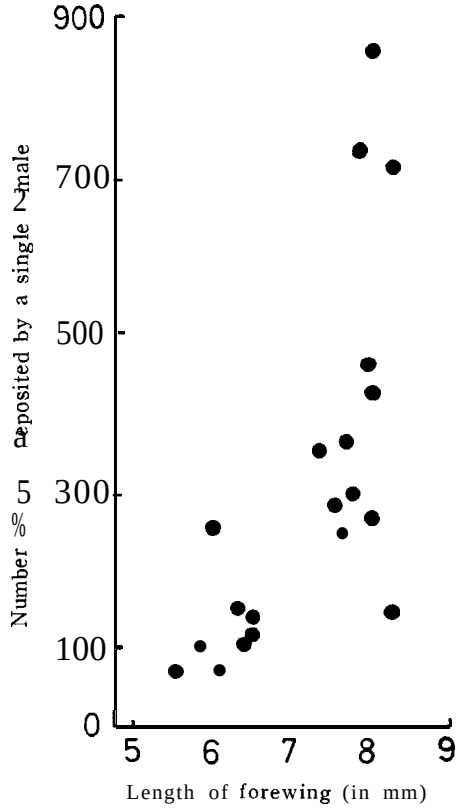

Fig. 15. Relation between the length of forewing and the number of eggs deposited by a single female.

if hosts are not available for oviposition and the matured eggs in the ovaries are absorbed. The oijsorption phenomenon is helpful for the maintenance of reproductive capacity of the parasites and the conservation of reproductive material is related to high searching capacity (Flanders 1950). The oijsorption phenomenon of the parasites is very significant from the point of view of biological control, and there are many instances of successful results in biological control with such parasites (Flanders 1942, Yasumatsu 1953, etc.).

The author conducted the following experiments in order to investigate the ability to maintain the reproductive capacity during the long period of absence of suitable hosts.

Methods: Three groups of 10, 6 and 10 parasites were given hosts for oviposition for the first 5 days from the date of oviposition started, thereafter each group was withheld from hosts for 10, 15 and 20 days,

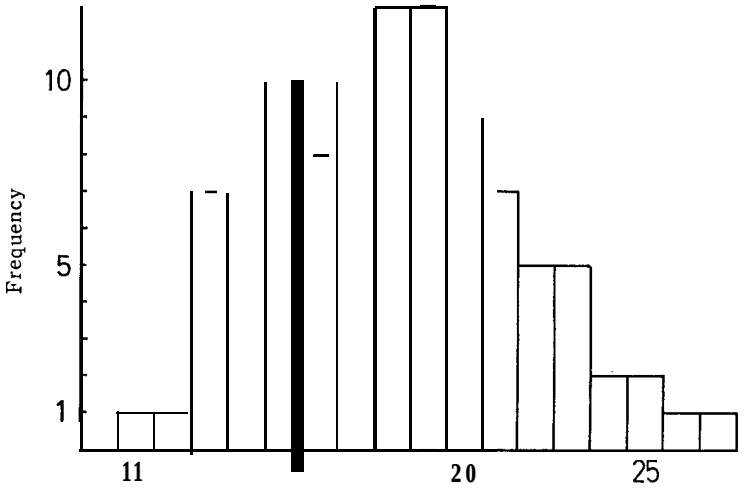

Fig. 16. Frequency distribution of the number of ovarioles of ***Itoplectis narangae.***

respectively, and then were given hosts again for oviposition. Three host pupae of *Galleria mellonella* **were** given daily and the pupae are renewed every 24 hours and then the hosts were dissected to count the number of eggs deposited under a binocular microscope. The adult females were fed with undiluted honey and water and the Container A was used for the laboratory experiments in a 25°C insectary.

Results : The results of these experiments are presented in Tables 23, 24, 25, 26, 27 and 28 and Fig. 18.

In every group this species responded rapidly to a given host after each of 10, 15 or 20 day absence of hosts and began to lay eggs immediately. The number of eggs laid on the first day was the largest in those which were not given hosts for 10 days and fewer in order of those which were not given hosts for 15 and 20 days. The number of eggs laid on the second day decreased markedly in comparison with the first day and recovered slowly from the third day. It reached the peak on the fifth day and then began to decrease gradually. It is felt that those matured eggs which remained unabsorbed in the ovaries were probably oviposited on the first day. Therefore, it may be seen that the o&sorption is enhanced as the non-host period is prolonged and matured eggs remained in the ovaries decreased gradually as the period of lacking hosts is lengthened. A remarkable decrease of the number of eggs laid on the second day is probably explained by the fact that the immature eggs remained in the ovaries require usually more than

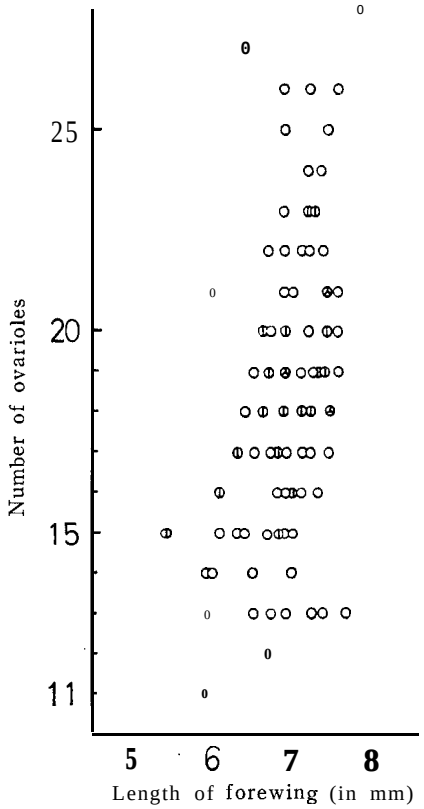

Fig. 17. Relation between the length of forewing and the number of ovarioles of *Itoplectis narangae*.

Table 23. Number of eggs laid when hosts were given after being withheld from hosts for 10 days during the oviposition period.

Days after emergence	Parasite number									
	1	2	3	4	5	6	7	8	9	10
1										
2	2		1	3	1			1	3	1
3	4	2	4	5	7	1	1	7	16	5
4	13	8	9	7	10	5	10	11	20	18
5	21	15	18	18	45	26	16	14	34	27
6	24	23	33	26	34	22	39	29	40	36
7		39				30	37			
8										
9										
//										//

Days after emergence	Parasite number									
	1	2	3	4	5	6	7	8	9	10
16										
17	15		11	14	10			10	13	16
18	5	11	4	3	4	8	16	3	13	9
19	9	1	11	7	14	6	2	12	18	5
20	19	11	20	17	20	8	12	11		
21	13	8	18	22	15	11	19	11	28	
22	1	2	22	27	32	9	23	4	23	*
23	1	24	28	28	11	13	20	6	8	
24	2	22	25	15	18	6	12	12	20	
25		20	16	18	19	4	20	19	18	
26		17	30	12	24		23	14	16	
27		8	21	14	12		13	14	16	
28		11	17	18	12		8	12	21	
29		14	13	16	10		9	17	23	
30	*	14	24	8	12		19	15	23	
31		7	8	9	10	x	6	23	24	
32		1	5	15	14		1	10	11	
33		7	5	17	3		3	17	18	
34		10	2	18	4		4	9	22	
35		7	1	10	9			4	18	
36		7	4	1	8			3	20	
37		3	3	17	4			7	18	
38		3		7	4		13		15	
39		4	1		3			2		
40		3	1		2					
41		5			7					
42		10			4		3	*	28	
43		5	x		5		2		1	
44		5					2		9	
45		5		3					8	
46		3			*					
47		1		1						
48				1						
49										
50							*		8	
51										
52										
53		*							*	
54										
55										
56										
57										
58										
59										
60										
61										
62										
63										
64			*							

* Asterisk denotes the date of death.

x Mark denotes the date of death by the abnormal distension of the abdomen,

Table 24. Number of eggs laid when hosts were given after being withheld from hosts for 15 days during the oviposition period.

Days after emergence	Parasite number					
	1	2	3	4	5	6
1						
2					4	1
3	3	2	1	5	7	0
4	8	9	3	5	6	14
5	19	11	11	11	27	22
6	27	27	8	14	30	34
7	26	21	11	19		
8						
9						//
//						
21						
22					6	8
23	8	4	3	2	2	3
24		1				2
25	10	10	2	3	3	
26	5	5	3	12	6	1
27	11	5	12	16	14	1
28	13		1	19	9	
29	22		7	15	10	
30	14	3	7	21	10	3
31	13	1	3	16	7	9
32	15	1	4	15	4	
33	9		6	9	5	3
34	11		1	5	4	2
35	10			1	2	
36	15	*		13	4	1
37	16		2	18	3	
38	9			9	2	1
39	15		5	8	1	
40	11			9	1	
41	10		1	6		
42	6			3		
43	4			3		x
44	14			4		
45	7					
46	2			1		
47	1					
48				1		
49				1	*	
50				1		
51	3		*			
52						
53						
54						
55	1					
56						
57						
58						
59						
60	*			*		
61						

* Asterisk denotes the date of death.

x Mark denotes the date of death by the abnormal distension of the abdomen.

Table 25. Number of eggs laid when hosts were given after being withheld from hosts for 20 days during the oviposition period.

Days after emergence	Parasite number									
	1	2	3	4	5	6	7	8	9	10
	2									
	5	7	9	2	4			4	3	1
4	14	13	15	2	1	3	8	3	6	7
5	30	10	15	7	12	5	9	11	12	11
6	28	16	21	8	23	21	19	21	13	21
7		35	24	17	25	24	32	27	25	16
8						23	27			
9										
//										//
27										
28			2	6	11			10	2	13
29			3	2		5	4			1
30			11	6			2			2
31		x	1	10	1	2	3			15
32			9	5		2	3			6
33	x		10	12	1	4	9	2	6	13
34			8	11		4	14	4	3	8
35			9	8		1	6	3		9
36			9	5		5	2	1		9
37			7	2		3			x	1
38			8	6			10			1
39			4			1	2	2		
40			4	1			1			
41			4							
42			3							
43			6	x	*			*		
44			3							
45			3							2
46			1							1
47										2
48			4							1
										*
						*	*			
57										
58										
59										
60										
61										
62										
63			x							

* Asterisk denotes the date of death.

x Mark denotes the date of death by the abnormal distension of the abdomen.

Table 26. Number of eggs laid when hosts were given after being withheld from hosts for 10 days during the oviposition period

Parasite number	Fore-wing length	Total no. of eggs laid	No. of eggs laid after being with-held from hosts for 10 days	Oviposition period after being with-held from hosts for 10 days	No. of ovarioles	No. of matured eggs in ovaries	Lon-gevity
1	6.7	129	65	8	15	0	30
2	6.9	336	249	30	17	0	53
*3	7.2	355	290	24	23	1	43
4	7.2	377	318	32		_	64
5	7.7	387	290	27	15		46
*6	6.6	149	65	8	16	1	31
7	7.1	333	230	27			50
8	6.6	297	235	23	15	-	42
9	7.5	572	459	34	20	3	53
10	7.0	117	30	3	17	-	21

* Asterisk denotes the parasite death by the abnormal distension of the abdomen.

Tabe 27. Number of eggs laid when hosts were given after being withheld from hosts for 15 days during the oviposition period.

Parasite number	Fore-wing length	Total no. of eggs laid	No. of eggs laid after being with-held from hosts for 15 days	Oviposition period after being with-held from hosts for 15 days	No. of ovarioles	No. of matured eggs in ovaries	Lon-gevity
1	7.7	337	254	33	17	5	60
2	6.9	98	30	10			36
3	5.8	93	59	23	10	0	51
4	5.7	265	211	28	16	0	60
5	6.3	168	94	20	17	0	49
*6	7.2	105	34	17	18	4	43

* Asterisk denotes the parasite death by the abnormal distension of the abdomen.

24 hours to become mature eggs following the host feeding after the oviposition of mature eggs. Subsequently the number of eggs to be laid increases gradually. Taking into consideration the size of the parasites, the number of eggs deposited and the oviposition period as previously mentioned, there is a tendency that the larger the adult females the more the number of eggs deposited. This tendency may be also observed in the oviposition when hosts were not given for 10, 15 and 20 days respectively. Although the oviposition period is related

Table 28. Number of eggs laid when hosts were given after being withheld from hosts for 20 days during the oviposition period.

Parasite number	Fore-wing length	Total no. of eggs laid	No. of eggs laid after being with-held from hosts for 20 days	Oviposition period after being with-held from hosts for 20 days	No. of ovarioles	No. of matured eggs in ovaries	Lon-gevity
1	6.9	79			15	5	33
*2	6.4	81					31
3	7.1	194	110	23	16		63
*4	6.0	110	74	13	12		43
5	7.2	78	13	6	14		43
6	4.1	103	27	11	16		54
7	7.3	151	56	12	23		54
8	6.7	88	22	12	13		43
*9	6.8	70	11	7	16	15	37
10	6.3	140	91	21	19		52

* Asterisk denotes the parasite death by the abnormal distension of the abdomen.

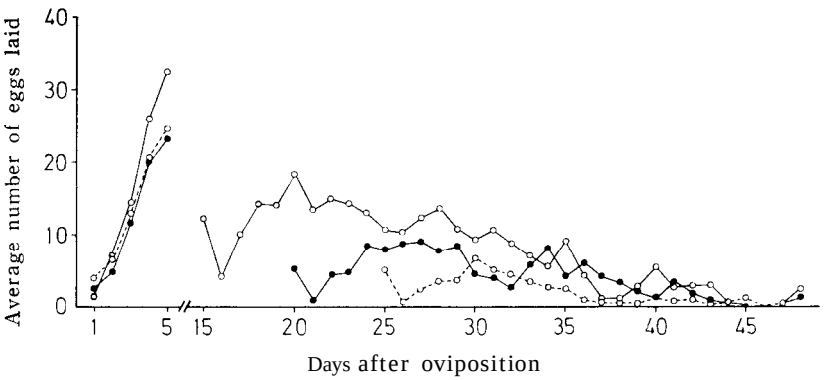

Fig. 38. Oviposition curve when hosts were given after being withheld from hosts for 10, 15 and 20 days during the oviposition period.

○——○ 10 parasites withheld from hosts for 10 days.
●——● 6 parasites withheld from hosts for 15 days.
○·····○ 10 parasites withheld from hosts fos 20 days.

to the number of egg deposited per day, it tends to be prolonged as the number of egg deposits increases.

It is very difficult to compare the results obtained on the longevity of the parasites in this experiment with that of those made in the previous one (Chapter VII, Tables 20 and 21), because the number of

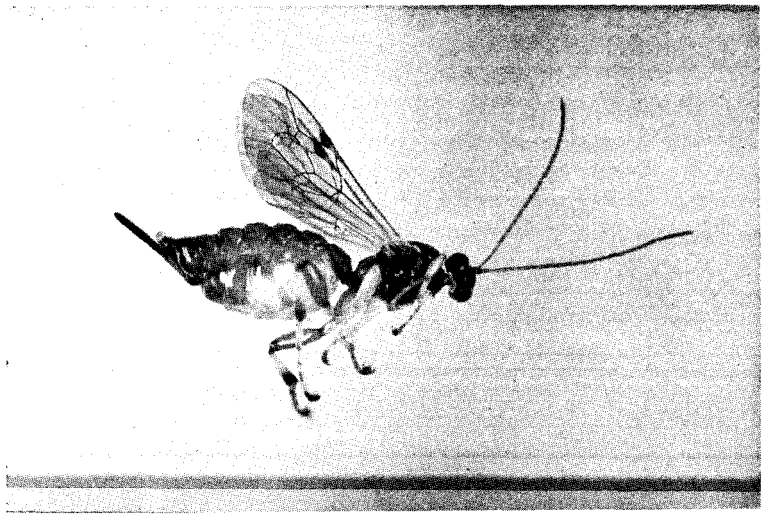

Fig. 19. The dead *Itoplectis narangae* by the abnormal distension of the abdomen.

parasites investigated was limited and there were also observed some dead parasites, as shown in Fig. 19, which seemed to be caused by the abnormal distension of the abdomen during the present experiments, but not by the natural death. Although these parasites may oviposit for one or two more days after the proceeding of distension, the number of egg deposited decreases sharply in comparison with that laid in the normal state. Even though the oviposition behavior may be observed on the third or fourth day, the abnormal distension of the abdomen interrupts actual oviposition, and finally, the parasites die almost on the fifth or sixth day. The cause of such distension is not clearly known. The result of dissection of the dead parasites revealed that the distended abdomen was filled with gas and the ovaries of some parasites were hardly discriminated. If these parasites were excluded, the mean longevity of the 20 parasites which were laying eggs daily (Tables 20 and 21) was 42.3 days, while those which were not given hosts for 10 days lived for 44.8 days and those not given hosts for 15 or 20 days survived for 49.8 days. Although the latter seems to survive somewhat for a longer period, it is not certain whether such longevity is attributable to either the difference among the individual parasites or the period during which the host pupae were not given.

As seen from the results of the present experiments and Tables 18 and 19, there were many individuals of this species which survived for a long period even after the stop of oviposition. Flanders (1942) stated that oögenesis is in many, if not most anhydropic species of

Hymcnoptera may proceed without interruption until the death of the female. Contrary to the statement of Flanders the females of this ichneumon fly may survive much longer period even after the completion of oviposition, and it seems that such females still maintain their potential reproductive capacity. But, actually they did not oviposit. Discontinuation of oviposition may indicate that the capacity of making oögenesis was declining as the age in day advances.

IX. Longevity of adult

The longevity of adult parasites depends largely upon the species, temperatures, diets, oviposition, illumination time and meteorological conditions. It is important for practical purposes to know the longevity of adult parasites under different conditions.

Methods: Males and females were studied separately at constant temperatures of 25°C (insectary), 30°C (phytotron) and 33°C (phytotron) when fed with different diets. Twenty individuals of each sex were observed at each temperature. In the phytotron the parasites were not exposed to the direct rays of the sun. Each one of the parasites was put in the petri dish of 9.5 cm in diameter and 1.8 cm in depth, the mouth of the petri dish being covered with gauze and tied up with rubber bands. Undiluted honey was given for diet once in 3 or 4 days and water was also given once every day to the absorbent cotton attached to the inside of the petri dish. The container was renewed once in 10 days to prevent contamination.

Results : The results of this experiment are presented in Table 29. Although it is somewhat difficult to derive the conclusion from the results definitely due to the limited number of parasites investigated, general tendency may be understood. The longevity of the adult parasites became shorter gradually as temperature rose. A great differ-

Table 29. Mean longevity in days of the adult *Ztoplectis narangae* at different temperatures when fed with different diets. (Means based on 20 observations.)

Temp. of rearing room	Sex	Diets			
		None	Water	Honey	Honey & water
25°C	♂	5.8	7.8	13.5	36.1
	♀	5.7	7.1	26.0	46.8
30°C	♂	2.8	4.9	3.0	24.8
	♀		4.9	4.8	23.6
33°C	♂	2.7	4.4	2.4	23.8
	♀	3.0	4.0	4.7	17.5

ence was observed between 25°C and 30°C, while it was not so between 30°C and 33°C. When the parasites were unfed or fed with water only, the longevity of the male was a little longer than that of the female. It seems that the water supply was helpful to extend the longevity of the parasites. The undiluted honey was also helpful for the extension of the longevity of the adult parasites markedly at 25°C, while it was shorter at 30°C and 33°C, respectively, than that of the parasites fed with water. The longest survival period when undiluted honey and water were given was 52 days in the male and 63 days in the female at 25°C; 41 days in the male and 33 days in the female at 30°C; and 40 days in the male and 35 days in the female at 33°C. It may be presumed that such an ability of prolonged survival under relatively high temperature of 33°C may explain clearly the wide distribution of this species. The mean longevity of 20 adult females fed daily with undiluted honey, water and given hosts was 42 days under 25°C condition (Tables 18 and 19), and that of the adult females fed with undiluted honey and water was 46.8 days without hosts under the same temperature condition. This may suggest that the host fluid is not essential for the maintenance of life of the adult parasites (Edward 1954).

It may be presumed from these observations that the survival period of this species is probably longer under favorable field conditions than the mean value of the present experiments at the constant temperatures.

X. Factors affecting the size of this species

There have been a good many reports concerning the facts that the size of parasites is considerably influenced by the host species, size, age and other factors. It has been also reported that the various factors of hosts may influence the reproductive capacity, behavior, longevity and morphological aspects etc. of adult parasites (Flanders 1935, Salt 1940, Ohgushi, 1959, Wylie 1963, 1964 etc.).

In this species which has a wide host range, it may be fully conceivable that the size of adult parasites is affected by the host species, size, age and other factors. As shown in Figs. 24, 25 and 26, this species collected from the field actually shows a wide range of body size. Some of the factors affecting the size of adult parasites were investigated.

1. Relation between the size of host pupae and adult parasites.

Investigation was conducted on the relation between the size of host

pupae and adult parasites emerged.

The pupae of ***Galleria*** *mellonella* reared in a 25°C insectary and the same of ***Chilo suppressalis*** collected from their hibernacula were used as hosts. These pupae were not older than 2 days after pupation. The size of host pupa is expressed as the body length x maximum body width and that of adult parasite emerged from the host pupa by the length of forewing for the sake of convenience.

As indicated in Figs. 20 and 21, the size of adult parasites is greatly affected by the species and the host size. The adult parasites show an increasing tendency in size as the host size of either the parasite of C. ***suppressalis*** or G. ***mellonella*** becomes large. There may be observed a high positive correlation, r=0.789, between the size of host pupa of C. ***suppressalis*** and that of adult parasite, and, r=0.779, between the size of host pupa of G. ***mellonella*** and that of adult parasite.

The author gave the pupa of ***Parnara guttata (25*** mm x5 mm in length and maximum width) for oviposition of the parasite, and the male offspring emerged from the pupa had the forewing 8.5 mm in length. This length was by far the largest one experienced by the author during his experiments and field observations.

2. **Effect of host age on the size and developmental period of the parasite.**

As mentioned before (Page 22), this species oviposits irrespective of

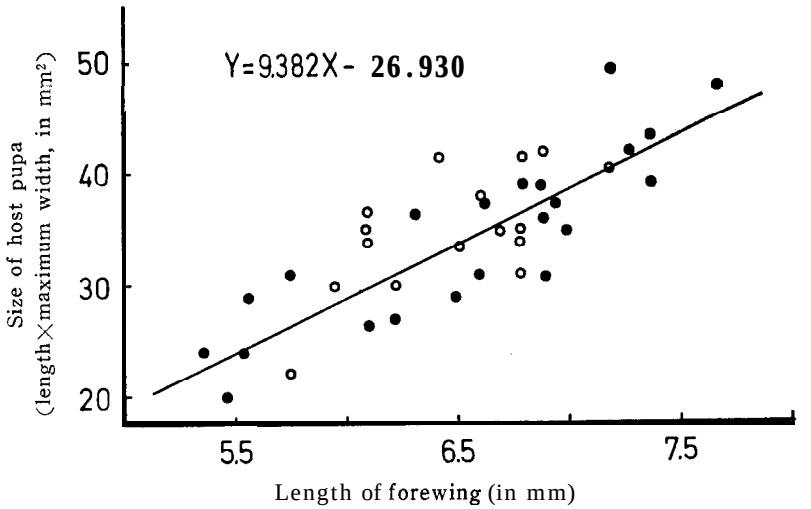

Fig. 20. Relation between the size of host pupa (***Chilo suppress&s)*** and that of adult parasite (***Itoplectis narangae).*** Open circle : female, Solid circle: male,

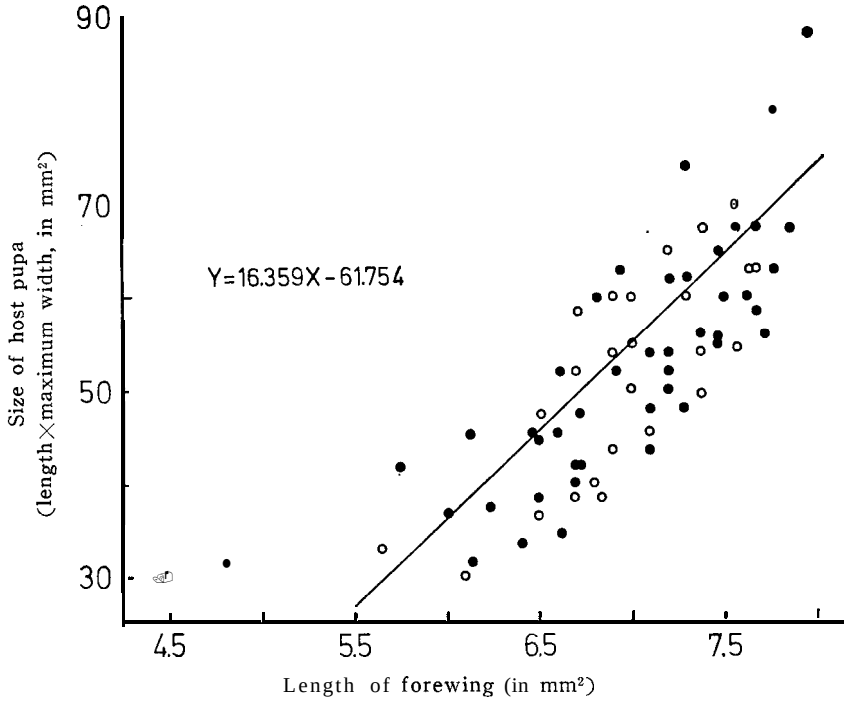

Fig. 21. Relation between the size of host pupa (*Galleria* ***mellonella)*** and that of adult parasite ***(Itoplectis narangae).*** Open circle: female, Solid circle: male.

host age. In this case it may be conceivable that various host age probably has some effects on the immature stage of this species growing within the host body. Wylie (1962, 1963 and 1964) studied in detail the effect of host age by using ***Nasonia vitripennis*** (Walker) (Hym., Pteromalidae). He made it clear that the size of parasites becomes small and the developmental period is prolonged as host age advances.

The author investigated by using the pupae of G. ***mellonella*** how host age affects the size and developmental period of this species.

Methods : The adult parasites and alternate host pupae of G. *mellonella* used for the present experiment were reared in a 25°C insectary. To get the parasites of uniform size for experimental purposes the host pupae of 13.5-14.0 mm in length were exposed to the parasites. Next, in starting the experiment, the host pupae of 13.5-14.0 mm in length were again used and devided into 5 groups by host age: Group I 1-2 days old, Group II 3-4 days old, Group III 5-6 days old, Group IV 7-8 days old and Group V 9-10 days old and to each group the parasites were supplied, After the deposition of one egg into the host pupa, the pupa

was confined to a small tube. The duration of developmental period of this species was recorded together with the measurement of the length of forewings. These experiments were conducted in a 25°C insectary and the results are indicated in Table 24 and Fig. 20.

As shown in Table 30 and Fig. 22, the size of this species became

Table 30. Length of forewing of *Itoplectis narangae* reared from *Galleria mellonella* pupae of different ages.

Sex	Host age group	No. of specimens	Mean length (in mm)	S.D.	Confidence interv. (95%)
Male	I	20	7.18	0.12	7.12-7.24
	II	20	7.12	0.09	7.08-7.16
	III	20	6.93	0.20	6.83-7.03
	IV	20	6.78	0.28	6.65-6.91
	V	20	6.00	0.78	5.64-6.36
Female	I	20	7.19	0.24	7.08-7.30
	II	20	7.07	0.19	6.98-7.16
	III	20	6.95	0.29	6.81-7.09
	IV	20	6.74	0.27	6.62-6.86
	V	20	6.01	0.78	5.64-6.38

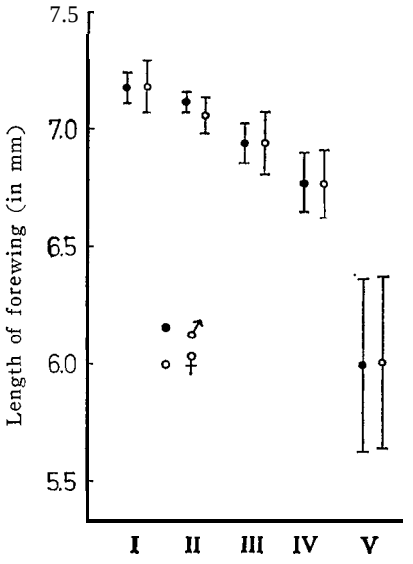

Fig. 22. Average length of forewing of *Ztoplectis narangae* reared from *Galleria mellonella* pupae of different age groups,

apparently smaller with the increase of host age, and no difference was observed in the size of the male and female of each host age groups.

No marked difference was observed between the Group II and the Group I, while the Groups III, IV and V became small significantly. Especially the Group V was markedly smaller than the other groups. The adult of the Group I and II emerges from the host pupa by making an exit hole on the head, while almost all of the parasites of the Group V emerged from the host pupa by making an exit hole on the abdomen. The dissection of the host pupa of the Group V revealed that the contents of fluid-like substances were only found in the abdomen in which the development of the imaginal internal tissues or organs were in progress.

Assuming these results, the size of this species seems to become smaller due to the decrease of sufficient nutrient with the increase of host age.

Table 31 and Fig. 23 show the period of the post development of both sexes of this species parasitized on the host pupae of the five age groups. The developmental period of this species is apparently prolonged as the host age advances, and the male emerges generally earlier than the female. In the Group V the period is prolonged about one day on an average compared with the Group I. There is no great difference in the developmental period of the Groups I and II, while a prolonged tendency of the development may be observed in the Group III in comparison with that of the Group I. This tendency appears also in the size of this species which becomes small in the Group III in comparison with that of the Group I. This may suggest that the

Table 31. Developmental period of *Itoplectis narangae* reared from *Galleria mellonella* pupae of different ages.

Sex	Host age group	No. of specimens	Mean period (in days)	S. D.	Confidence interv. (95 %)
Male	I	*46*	*14.9*	*0.* a3	14.7-15.2
	II	45	14.8	1.08	14.4-15.1
	III	44	15.2	0.94	15. o-15.5
	IV	28	15. 9	0.88	15.6-16.2
	V	23	16.0	1.31	15.4-16.6
Female	I	*23*	*15.0*	*1.13*	*14.5-15.5*
	II	21	15.0	0.71	14.7-15.3
	III	29	15.7	0.96	15.3-16.1
	IV	20	16.5	0.67	16.1-16.8
	V	23	16.4	0.78	16.1-16.7

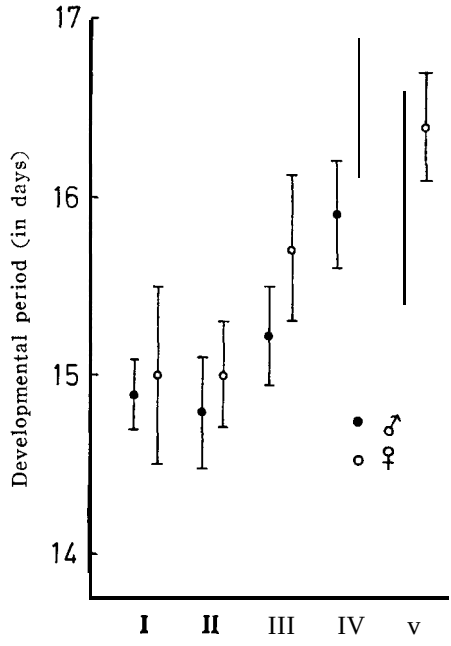

Fig. 23. Average developmental period of ***Ztoplectis narangae*** reared from ***Galleria mellonella*** pupae of different age groups.

difference in the content of host pupa has a remarkable effect on the developmental period of the larva of this species in the Group III. The effect of host age on the developmental period of the parasites which are produced by the difference of quality and quantity of food for parasite larva has been recorded by several workers (Salt 1938, Hafez 1961, Fisher 1961, etc.).

As described above, the effect of host age on the size and developmental period of this species is closely related to the selection of age of the ***Galleria mellonella*** pupa as an alternate host in the mass production of ***Itoplectis narangae.*** It has been already stated (Page 37) that the larger the size of this species the more eggs are laid. Therefore it is needless to say that the parasites having a large reproductive capacity are desired in making the mass production of ***Itoplectis narangae*** for the biological control purpose.

XI. Morphological comparison between the specimens of *Itoplectis* ***narangae*** collected in the paddy field and those obtained from the materials emerged from ***Galleria mellonella*** pupa in the laboratory

The investigation was conducted between the parasites which were reared successively from the alternate hosts in the laboratory and collected in the paddy field to observe the morphological differences if any.

Methods: Twenty-eight males and seventeen females of ***Ztoplectis narangae*** were collected for a period from the later part of September to that of November, 1967 in the paddy field at Hakozaki, Fukuoka City. Twenty one males and twenty seven females were emerged from the pupae of ***Galleria mellonella*** in the laboratory. The length of forewing, width of thorax, width of head and the length of ovipositor of the parasites were measured with the micrometer under a binocular microscope for the sake of comparison.

Results: In Figs. 24, 25 and 26 illustrate the relative growths of the width of head, width of thorax and the length of ovipositor between the individual parasites which were collected in the paddy field and reared in the laboratory. Generally, the size of the specimens collected

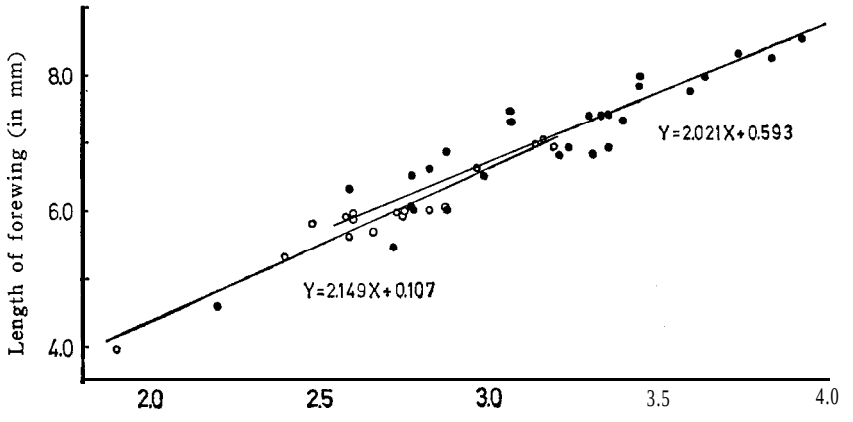

Fig. 24. Relation between the length of forewing and the length of ovipositor of ***Ztoplectis narangae*** which were collected in the paddy field in 1967 and reared from the pupae of ***Galleria mellonella*** in the laboratory.

○: collected in the paddy field.
● : emerged from the pupae of ***Galleria mellonella*** in the laboratory.

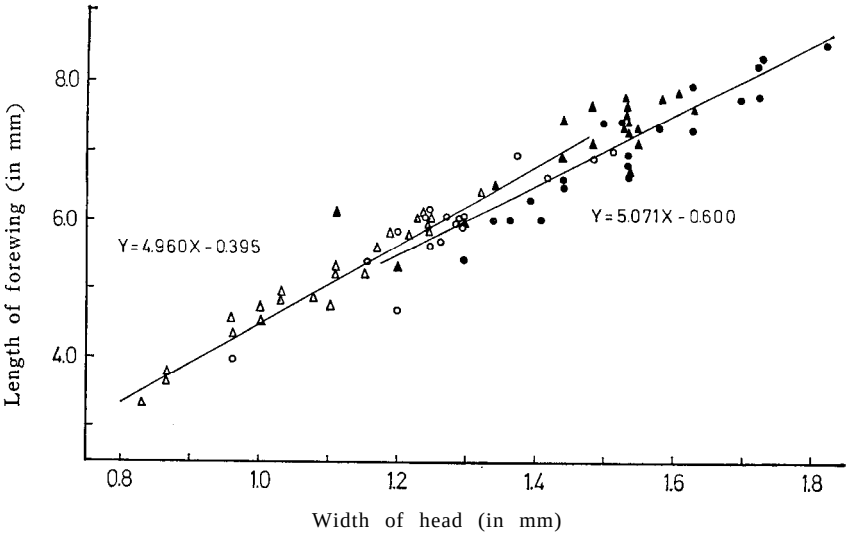

Fig. 25. Relation between the length of forewing and the width of head of ***Itoplectis narangae*** which were collected in the paddy field in 1967 and reared from the pupae of ***Galleria mellonella*** in the laboratory.
△ male, ○ female: collected in the paddy field.
▲ male, ● female: emerged from the pupae of ***Galleria mellonella.***

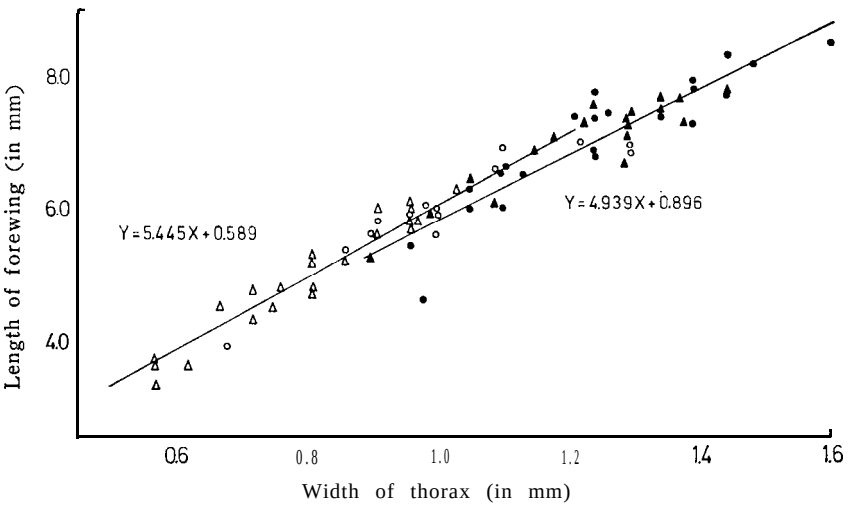

Fig. 26. Relation between the length of forewing and the width of thorax of ***Itoplectis narangae*** which were collected in the paddy field in 1967 and reared from the pupae of ***Galleria mellonella*** in the laboratory.
△ male, ○ female: collected in the paddy field.
▲ male, ● female: emerged from the pupae of ***Galleria mellonella.***

in the paddy field was apparently smaller than that of those reared in the laboratory, and the male was also somewhat smaller than the female. The host of the specimens collected in the paddy field was unknown. However, at that time there occurred an outbreak of ***Cnaphalocrocis medinalis,*** one of the hosts of ***Itoplectis narangae.*** Therefore, it is presumed that most of the parasites might have emerged probably from the pupae of C. ***medinalis*** and that the smaller size of the pupae of ***C. medinalis*** caused the smaller size of the parasite collected in the paddy field as compared with those reared from the larger pupae of G. *mellonella.*

There was also observed no morphological difference except the relative growth affected by the size of parasites.

XII. Effect of some insecticides on the adult and immature stages of Itoplectis *narangae*

It is a well known fact that some insecticides have detrimental effects on the parasite-predator populations. In recent years to eliminate an unfavorable condition produced by one-side application of insecticides without giving any consideration on the natural enemies an integrated control has been extensively discussed (Stern et al. 1959, van den Bosch and Stern 1962, Bartlett 1964, Beirne 1967, etc.).

On the effect of some insecticides on the adult parasite in the paddy field Tsutsui (1949) reported that DDT and BHC affect seriously ***Trichogramma japonicum*** Ashmead which is an egg parasite of ***Chilo suppressalis.***

The author investigated the effect of some insecticides which have been used for the control of insect pests of the rice plant in the paddy field on this parasite at Hakozaki, Fukuoka City. The annual frequency of insecticidal appplications w-as 4 or 5 times, the first application in early July, the second one in early August, the third one in the middle of August, the fourth one in the later part of September, and the fifth one in the early October. Of course, the application frequency varied in accordance with the increase of insect pests, Although there were available many different kinds of insecticides from the makers, they were mainly the mixtures of γ-BHC, Sevin and Sumithion, and the dust was exclusively applied by using the duster, but the emulsion was not used at all.

Some experiments were performed with the above-mentioned three insecticides **in a** 25°C insectary.

1. Effect of insecticides on the adult *Itoplectis narangae*.

This experiment was conducted with the use of insecticides of the ordinary concentration and of those diluted in various low concentrations. Parasites which were reared on honey for 3-4 days after emergence were used for the experiment in the laboratory.

For the methods of contact, filter paper dusted with insecticide was put in the test tube (3 x 20 cm in diameter and length) containing 20 adults so as to make them move over it for a certain time. And also a small amount of dust insecticide was put in the test tube containing 20 adults and the tube was shaked ligthtly to contact the adults with the insecticide. In the former case, observation was made continuously within the test tube after taking off the dusted filter paper and in the latter case, the adults were observed after removing them to a clean petri dish (16.2 x 3.2 cm in diameter and height).

Results : The results are presented in Table 32.

Table 32. Effect of various insecticidal dusts and some other inert materials against the adult *Itoplectis narangae* at 25°C.

Dust	No. of individuals used	Knock-down in 10 min.	Mortality (%) after 1 hr.	Mortality (%) after 24 hrs.	Method of insecticide application
γ-BHC (3 %)	20	100	100	100	Dusting
Sevin (1.5%)	20	55	100	100	
Sumithion (2.0%)	20	100	100	100	
r-BHC (3 %)	20	100	100	100	Contact with their legs
Sevin (1.5%)	20	0	100	100	
Sumithion (2.0%)	20	100	100	100	
Talc	20	0	0	0	Dusting
Diatomaceous earth	20	0	0	0	

It may be seen that all the individuals were knocked down within 10 minutes by dusting γ-BHC and Sumithion, while more than half were knocked down by Sevin. In either case all individuals were killed within 24 hours. The results obtained by walking on the insecticides was not much different from that of the dusting method. Although no knocked down individuals were seen within 10 minutes by Sevin, all were cramped and knocked down within an hour after dusting. For comparative purpose, both talc and diatomaceous earth, the commonest diluents, were dusted. The result showed that the individuals tried to shake off such dusts hardly for a while at the beginning of dusting, but gradually they resumed their normal condition after an

hour and continued normal survival. γ-BHC, Sevin and Sumithion of the ordinary concentration showed strong insecticidal action on the parasites which were dusted or walked on the dusted paper.

A similar experiment to that described above was performed with the insecticides of the low concentrations as shown in Tables 33, 34 and 35.

As shown in Table 33, all individuals were killed within 24 hours by dusting 0.6 and 0.3 % γ-BHC. Although all of the individuals were cramped and knocked down within an hour by 0.2 % dusting, 40 % of them died and 60 % resumed their normal condition after 24 hours. In case the parasites walked on the paper dusted with 0.6 % γ-BHC, 65 % was cramped and knocked down within an hour.

The dusting of 0.4 % and 0.2 % Sumithion knocked down all individuals within an hour and caused death within 24 hours. Although no individuals were seen knocked down within an hour by the contact of dust with their legs, more than half died within 24 hours after showing the symptom of pain.

Table 33. Effect of the insecticidal dust of γ-BHC against the adult *Itoplectis narangae* at 25°C.

Dust	Concentration (%)	No. of individuals used	Knock-down in 10 min.	Knock-down in 1 hr.	Mortality (%) after 24 hrs.	Mortality (%) after 48hrs.	Method of insecticide application
r-BHC	0.6	20	100	100	100		Dusting
	0.3	20	40	100	100		
	0.2	20	0	100	40	45	
	0.6	20	10	65	10	10	Contact with their legs
	0.3	20	0	35	10	10	
	0.2	20	0	0	0	0	

Table 34. Effect of the insecticidal dust of Sumithion against the adult *Itoplectis narangae* at 25°C.

Dust	Concentration (%)	No. of individuals used	Knock-down in 10 min.	Knock-down in 1 hr.	Mortality (%) after 24 hrs.	Mortality (%) after 48 hrs.	Method of insecticide applicatin
Sumithion	0.4	20	0	100	100		Dusting
	0.2	20	0	100	100		
	0.13	20	0	40	100		
	0.4	20	0	0	65	80	Contact with their legs
	0.2	20	0	0	40	60	
	0.13	20	0	0	0	15	

Table 35. Effect of the insecticidal dust of Sevin against the adult ***Itoplectis narangae*** at 25°C.

Dust	Concentration (%)	No. of individuals used	Knock-down in 10 min.	Knock-down in 1 hr.	Mortality (%) after 24 hrs.	Mortality (%) after 48 hrs.	Method of insecticide application
Sevin	0.3	20	0	0	65	65	Dusting
	0.15	20	0	0	10	20	
	0.1	20	0	0	0	0	
	0.3	20	0	0	0	0	Contact with their legs
	0.15	20	0	0	0	0	
	0.1	20	0	0	0	0	

The insecticidal effect of Sevin was markedly weak as compared with that of the two dusts described above, i. e. 65 % was killed within 24 hours by the dusting of 0.3 % Sevin, but none of the individuals were cramped and knocked down within an hour either by dusting or contacting with their legs. In the latter case the individuals were seemed to be suffered to some extent but the contact effect was not fatal.

Thus, the insecticidal effects of the three insecticides described above on the adult ***Itoplectis narangae*** were stronger in the following order: γ-BHC, Sumithion and Sevin within the range of the ordinary and low concentrations. Especially γ-BHC and Sumithion act strongly. It may be presumed that if these insecticides are dusted over the paddy field and the dusts are attached to the leaves and stems of rice plants or the adults of ***Itoplectis narangae,*** their effects on this parasite must be great and may cause eventually the discontinuation of their activities for a while.

2. Effect of some insecticides on the immature stages of *Itoplectis narangae* within the host body.

Investigation was performed to observe how the γ-BHC, Sumithion and Sevin dusts of the ordinary concentration affect the immature stages of this species within the host body.

Methods: Twenty pupae of ***Galleria mellonella*** younger than 3 days old were pasted on a cardboard of 14.5 cm in diameter and exposed to 5 females of ***Itoplectis narangae*** by using the Container B. They were taken out of the container after oviposition for 2 hours and the parasitization was confirmed by checking the puncture holes. Subsequently they were kept in a clean petri dish. The γ-BHC, Sumithion and Sevin dusts of the ordinary concentrations were applied 4, 7 and 10 days after the

parasitization and then the counts were made on the number of emerged adult parasite and on the dead parasite larvae within the host bodies by dissection. This experiment was conducted in a 25°C insectary.

Results: The result of this experiment is as shown in Table 36. The proportion of the number of emerged adults after insecticidal treatment against the pupae of ***Galleria mellonella*** was indicated in terms of percentage emergence.

Table 36. Effects of some insecticides on the immature stages of ***Itoplectis narangae.***

Dust	***No.*** of host pupa parasitized	Days between parasitization	No. of adults emerged	Percentage emergence	No. of dead individuals: became adult but died just before emergence	No. of dead individuals: died in larval stages
r-BHC	**20**	4	18	90		
	20	7	19	95		
	20	10	14	70	2	2
Sevin	20	4	16	80		2
	20	7	15	75	3	1
	20	10	17	85		1
Sumithion	20	4	15	75	1	2
	20	7	16	80	2	1
	20	10	12	60	1	4
Check	20		16	80	1	1

It may be seen from Table 36 that there is no much difference in the percentage of emergence between the non-treated check plot and the treated one. It seems, therefore, that the three insecticides of the ordinary concentrations which have strong insecticidal action on the adult parasite do not affect the immature stages of ***Itoplectis narangae*** within the host body.

XIII. Approach to the mass production

It is possible to make mass production of ***Itoplectis narangae*** by using the pupae of G. ***mellonella*** as an alternate host. G. ***mellonella*** is widely used as an alternate host of the parasites and nematoda and for the insect pathological study. The technique of its mass rearing has been also developed remarkably.

Haydak (1936), Peterson (1953) and Dutky et al, (1962) have studied

the mass rearing of G. ***mellonella*** on artificial diets.

On the mass production of ***I. narangae*** by using the pupae of G. *mellonella* two methods may be employed according to the size of the mass production scale. To make a small scale mass production the modified sandwich method (hereafter referred as S. M.) described at the outset of this paper is convenient. The author could get the necessary amount of ***I. narangae*** for the laboratory experiments in the rearing room by using this method. However, the S. M. is not suitable for a large scale mass production owing to its troublesome procedure. The S. M. using gauze between the pupae and parasites for oviposition and the direct ovipoistion method without using anything between the pupae and parasites (hereafter referred as D.M.) are compared in the following lines:

1) The oviposition response of parasites against hosts is more rapid by the S. M. than that found by the D. M.

2) The handling of parasites is very simple in the S. M. as compared with the D.M.

3) The gauze is usually contaminated with the body fluid as a result of the host feeding by the parasites and should be renewed once every 3 or 4 days when the S. M. is used, but such a consideration is entirely unnecessary in the D.M.

4) In the S.M. the parasite must hold the gauze with its legs at the time of inserting her ovipositor. Therefore, this act often prevents the correct insertion of her ovipositor into the pupae and the parasite becomes tired rapidly. On the other hand, in the D. M. the parasite can hold directly the host to lay her eggs.

5) In the S. M. a small amount of the body fluid is absorbed by the gauze, thereby the host feeding by the parasite becomes difficult and the body fluid is wasted. However, in the D. M. the parasite can utilize the body fluid completely.

Thus, the D. M. is more superior to the S. M. in making a large scale mass production of the parasite. The author designed an parasitization unit for this purpose as illustrated in Figs. 27 and 28.

1. Parasitization unit.

This oviposition box is consisted of the upper, middle and lower sections. The size may be properly determined according to the schedule of mass production. The figure was designed to handle 300 host pupae at the same time.

1) Upper section: A 10 W fluorescent light is installed on the interior side.

2) Middle section: The upper side is covered with a 3 mm thick transparent plate glass that can be removed, if necessary, and a sliding door of transparent glass is fitted on one side of the front wall. In addition to the sliding door a 34 mm diameter hole is opened and the hole can be closed by a plastic sliding plate. Of course this hole may serve to release the parasites into the middle section. A space is also made on the lower side of the section to allow the setting of a free transparent plastic plate.

3) Lower section: A nylon net is spread over the upper side to prevent the escape of the parasites and a door that can be opened forward is fitted in the front. A 10 W fluorescent light is also installed on the interior base.

The three sections can be separable freely, and the size of the box is 30.5 cm in length, 58 cm in breadth and 44 cm in height.

2. **Direction for handling the parasitization unit.**

After switching- on the fluorescent light of the upper section, the mated adults are released in the box through a hole of the middle

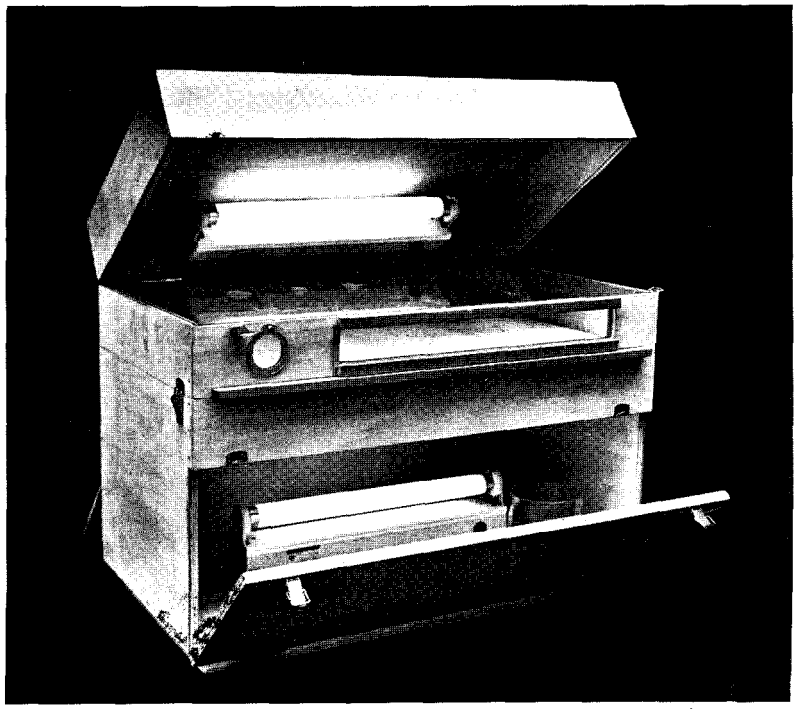

Fig. 27. Parasitization unit (designed by the author).'

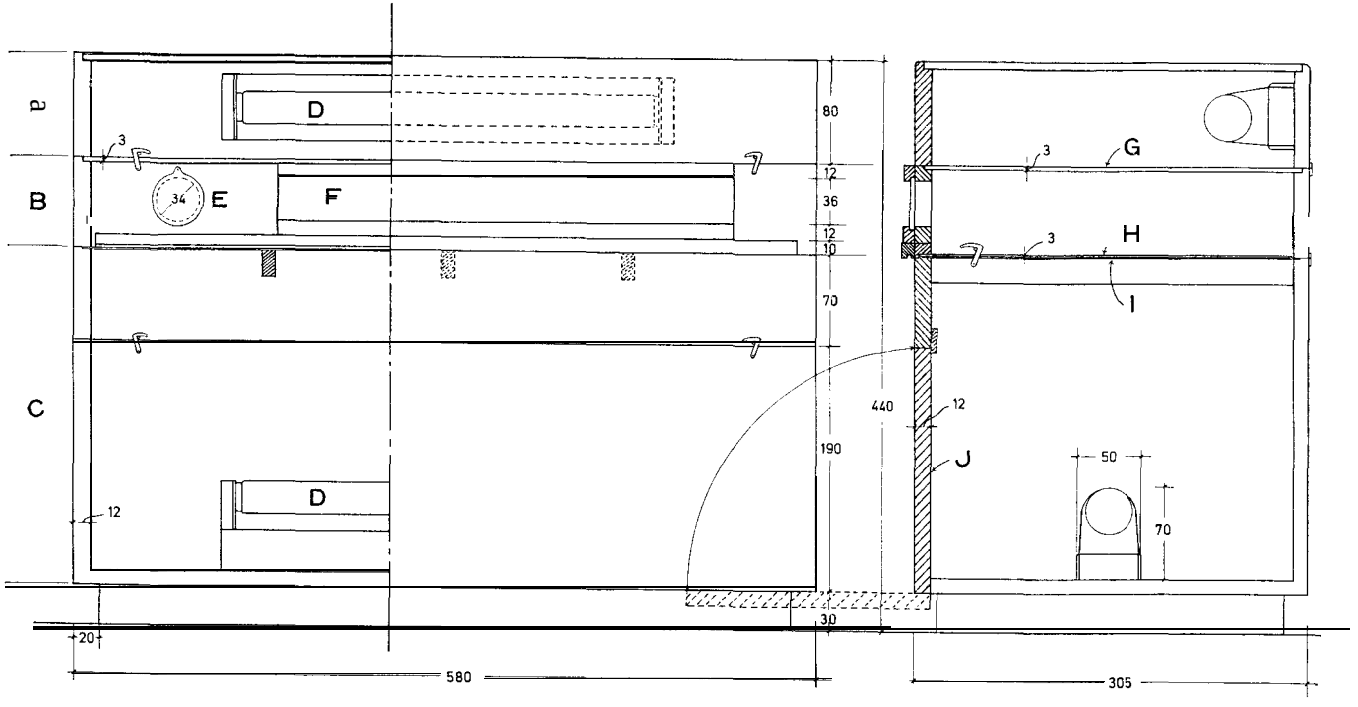

Fig. 28. Parasitization unit. A: Upper section, B: Middle section, C: Lower section, D: Fluorescent light, E: Hole, F: Sliding door, G: Transparent plate glass, H: Transparent plastic plate, I: Nylon net, J: Door. The figure indicates the scale in milimeter.

section and then the hole is closed up with a plastic cover so as to prevent the escape of the adult parasites. The adults are forced to come in touch with the glass surface of the middle section by the positive phototaxis. Prior to the introduction of parasites into the middle section undiluted honey and absorbent cotton soaked in a small amount of water are put on the glass plate of the middle section. Corrugated cardboard is cut in the same size as the plastic plate which is to be placed between the middle section and the lower section to separate both sections. The pupae of G. *mellonella* are placed on each groove of corrugated cardboard and this cardboard is put on the plastic plate. Next, the plastic plate with corrugated cardboard is inserted between the middle section and the lower section and switch off the fluorescent light of the upper section and then switch on the same of the lower section. The constant humidity in the box is maintained by placing a cylindrical petri dish containing water on the base of the lower section.

As described before, the adult ***I. narangae*** is poor in the discrimination of the parasitized or unparasitized hosts. Therefore, it is desirable to increase the number of parasites and shorten the exposure time in order to minimize superparasitism and enhance the percentage parasitism.

According to the preliminary experiments the percentage parasitism was 86.5 % with 74 % superparasitism when 20 hosts were exposed to 3 adult females of ***I. narangae*** for 3 hours. The results of rearing experiment with this oviposition box are presented in Tables 37 an 38.

As shown in Tables 37 and 38, the percentage parasitism is the highest when 100-200 host pupae of G. ***mellonella*** are exposed to 20 parasites. This percentage parasitism is lower than the actual percentage in the parasitization unit, because those which died within the host body at the immature stage were not counted in this percentage. In all experiments the number of males was about 3 times as many as that of females.

Table 37. Results of exposing 100,200 and 300 host pupae of ***Galleria mellonella*** to 20 females of ***Itoplectis narangae*** for 5 hours.

No. of host pupae exposed	No. of parasites released	Time of exposure	No. of parasites emerged	Sex of parasites emerged ♂	Sex of parasites emerged ♀	Sex ratio (♀%)	Percentage* parasitism
100	20	5 hrs.	76	76	27	36	76
200	20	5 〃	146	103	43	30	74
300	20	5 〃	168	121	47	28	56

* The ratio of the number of parasites emerged to the number of hosts exposed.

Table 38. Results of exposing 100, 200 and 300 host pupae of *Galleria mellonella* to 10 females of *Itoplectis narangae* for 5 hours.

No. of host pupae exposed	No. of parasites released	Time of exposure	No. of parasites emerged	Sex of parasites emerged ♂	Sex of parasites emerged ♀	Sex ratio (♀%)	Percentage* parasitism
100	10	5 hrs.	66	41	15	23	66
200	10	5 〃	131	93	38	29	66
300	10	5 〃	100	78	22	22	33

* The ratio of the number of parasites emerged to the number of hosts exposed.

The host feeding is the most important factor for the maintenance of reproductive capacity of the adult female and must be considered for the mass production. A large and younger alternate host is most favorable. As the parasite used for oviposition declines gradually in its reproductive capacity 2 or 3 weeks after oviposition started, it is desired to renew it with newly emerged parasite. After oviposition the fluorescent light of the lower section should be switched off and in turn the same of the upper section should be switched on. The plastic plate was then removed after the adult parasites left the host. When the host oviposited is removed to the insectary of 25°C temperature and relative humidity 50-70 percent, the parasite emerges in 14 to 16 days.

XIV. Conclusion

– *Itoplectis narangae* as a natural enemy of major insect pests of rice plant –

It is intended to discuss in this chapter on the usefulness of this species from the practical point of view based on the results obtained from the field and laboratory experiments, although there still remain many problems left unsolved.

1. The average reproductive capacity of this species is about 300 eggs per female. It is also a synovigenic species which can lay eggs for a prolonged period and maintains its reproductive capacity even during the absence of hosts. The oviposition of ***I. narangae*** is not affected by the size and age in days of the hosts.

2. It develops rapidly and emerges in 14 to 16 days under 25°C constant temperature condition. This fact suggests that the possibility of parasitism and the multiplication capacity may be enhanced on the presence of such hosts as ***Naranga aenescens*** and ***Cnaphalocrocis medinalis*** which have 4 to 5 generations a year.

3. Not a single parasite against *I. narangae* has been observed during the field investigations except only those which were caught in the spider's web. Therefore, in the case of this species it is not necessary to consider its parasite.

4. The emergence of this parasite almost coincides with the appearance of hosts from the middle of May to early December, and attacks the hosts not only during the growth stage of rice plants but also before the hibernation of major rice pests after harvest so long as it survives.

5. The attacking activity of *I. narangae* continues vigorously during day time and its searching flight for the hosts is seen even in the hidden places. Once the host is found, it never flies away from the host until it lays eggs to the host successfully.

6. It seems to be unable to discriminate the parasitized or unparasitized hosts. Therefore, the phenomenon of superparasitism may be expected. As indicated by Iyatomi (1943), the superparasitism influences not only the decline of the percentage of parasitism but those of the increasing ratio of the number of parasites. But such superparasitism as observed in the narrow space of the laboratory experiment may not be observed in the field. Of course, in the case of high parasite density, the superparasitism will possibly appear.

7. This species is widely distributed throughout the vast rice growing areas of Asia ranging from the Kuriles in the north to the Philippines in the south. This may suggest that *I. narangae* is most adaptable to a wide range of climatic conditions.

8. The mass production is possible by using the pupae of G. *mellonella* as an alternate host.

As discussed above, *I. narangae* is a vigorous parasite both in its attacking and reproductive ability. It may be recognized that this species is privileged with favorable natures as an excellent parasite. If this species is used for the control of one or small number of species of specific insect pests in the paddy field, no favorable results may be expected because its host range is too wide. However, it seems impossible to neglect the effectiveness of this species in the case of major insect pests, in controlling the pests in question to some extent. On the other hand, there are many difficult problems involved in the possibility of its utilization for the enhancement of the practical control effect by facilitating the activities of this species.

1. The microclimate in the close planting paddy field for multiyields restricts the searching zone of *I. narangae.* Accordingly, those insect pests which are living out of this searching zone can be free from the attack of parasites, There will arise eventually a problem

how to remove the barrier of its activities in order to keep the insect pests to be attacked within the searching zone of the parasites. This problem has a close connection with the cultural method and yields of rice crops.

2. At present and even in the future, no rice culture can be considered without insecticidal applications. In recent years, insecticidal application has been widely introduced, especially a motorized dusting equipment and the use of helicopter or airplane have made it possible to dust insecticides over a vast area at the same time and in a short period. In any case, if we use the strong contact insecticides, such insecticides may restrict the activities of the parasite, decrease the number of parasite and create a buffer zone of *I. narangae*. But, it is a good tendency that recently the use of contact insecticides like chlorinated hydrocarbon or organophosphorus insecticides against the rice stem borers has been decreasing in the paddy field. The development of systemic use or soil application of granules of insecticides may overcome the difficulty of protecting the natural enemies of rice stem borers. Therefore, it is one of the most important problems how to apply the insecticides reasonably and how to use natural enemies as the controlling agents of insect pests. In another word, how to conserve the natural enemies is one of the most important problems to be considered at the moment and also in the future.

XV. Summary

The present work was carried out in the field and laboratory for two years in order to clarify the bionomics and the mass production method of *Itoplectis* ***narangae*** for the future use as a controlling agent against the major rice pests. The results are summarized as follows:

1. This species develops 4 or 5 times a year from the middle of May to early December and hibernates as the final instar larval stage within the host body. It seems that the searching zone in the paddy field is closely correlated to the microclimate and that the lower part of rice plant is not searched by this species.

2. The larval stage ends at the fifth instar and each instar can be discriminated by the width of head capsule. The developmental period varies according to the rearing temperature and host species. The average developmental period on the host pupa of ***Galleria mellonella*** under the constant temperature condition of 25°C is 14.0 days in male and 14.9 days in female. The body color also varies according to the rearing temperature and black color does not develop as temperature rises,

3. The host feeding was observed during the oviposition period. It was observed that this species sucked water on the leaf of rice plant in the field and visited flowers in the carrot field to get nutrient from them. It was also observed that the species was taking honeydew excreted by the aphids on the ear of rice plant.

4. The male emerges earlier than the female. The female mates soon after emergence.

5. It seems that the oviposition is not affected by the age in days, dorsal and ventral sites and sizes of the host.

6. This species is unable to discriminate the parasitized or unparasitized host. There was no case in which more than one parasite emerged from the superparasitized host.

7. Arrhenotokous parthenogenesis is seen in this species.

8. Mature eggs in the ovaries are produced from the first day after emergence irrespective of feeding. It reaches the peak in the second day when unfed and in the third day if fed with diets. Thereafter, the o&sorption proceeds gradually and the number of matured eggs decreases.

9. This parasite is a synovigenic species. The preoviposition period is 1 to 2 days on an average. There is no difference in its reproductive capacity between the mated and unmated females. A female lays 300 eggs on an average, but the number of eggs deposited varies greatly according to the individuals. High positive correlation was observed between the fecundity and the size of this parasite. The daily fluctuation of oviposition shows the continuation of increase and decrease and vice versa.

10. The number of eggs deposited increases rapidly until the sixth day after the start of oviposition and active oviposition takes place for the first 14 to 21 days and decreases gradually thereafter. More than 70 % of the total number of eggs deposited is laid for 20 days after the start of oviposition.

11. The number of ovarioles observed is ranging from 11 to 28 and about 25 % of which are formed symmetrically. It seems that the size of this species is not correlated to the number of ovarioles.

12. The longevity is shortened as temperature rises. Water is somewhat helpful to extend the longevity of this species. The parasite fed with water survived longer than that fed with honey under high temperatures. The unfed parasite survived for about 5.7-5.8 days on an average under the constant temperature condition of 25°C while those fed with undiluted honey and water survived for 36.1 days in male and 46.8 days in female respectively.

13. When the parasite was given hosts after being withheld from

hosts for 10, 15 and 20 days, oviposition behavior proceeded immediately. The o&sorption of matured eggs in the ovaries took place during the period of lacking host. However, matured eggs remained in the ovaries and the reproductive capacity was still maintained even after the elapse of days indicated above.

14. The size and age in days of the host pupa affected the size of this species, and the developmental period was somewhat prolonged as the age in days advanced.

15. There was observed no morphological difference between this species reared on ***Galleria mellonella*** in the laboratory and those collected in the field, expect the relative growth affected by the size of host and other factors.

16. The insecticidal action of γ-BHC, Sevin and Sumithion of the ordinary concentration on the adults of this species was remarkable while the immature stage within the host pupa was not affected at all. The insecticidal action of these three insecticides was strong in the order of γ-BHC, Sumithion and Sevin. The survival of this species was not affected by talc and diatomaceous earth used as diluents.

17. The mass production is possible by using the pupae of G. ***mellonella.*** The parasitization unit was designed to facilitate the handling of parasites for the mass production.

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