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BIOLOGY OF *ANAGRUS OPTABILIS* (PERKINS) (HYMENOPTERA, MYMARIDAE), AN EGG PARASITOID OF DELPHACID PLANTHOPPERS[1]

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Abstract

Adult behaviours, effect of temperature on the development, effect of food and temperature on the longevity, immature stages and parasitic activity of *Anagms optabilis* are investigated and presented.

Introduction

Anagrus optabilis **(Perkins)** was first described with specimens bred from the eggs of sugarcane leafhopper, *Perkinsiella saccaricida*, which was a serious pest of sugarcane in Hawaii. This parasitoid was used as biological agent to control the sugarcane leafhopper in Hawaii (Perkins, 1905). Recently it is known to attack eggs of many other delphacids including some major pests of rice in Asia. Yasumatsu *et al. (1975)* and Miura *et al.* (1979) reported *Anagms optabilis* as an important egg parasitoid of white-backed planthopper, *Sogatella furcifera* (Horváth), in Thailand. Miura *et al.* (1981) also made a remarkable field study on the parasitic activity of *Anagms optabilis* in Taiwan. According to their report *Anagms optabilis* attacks eggs of *Sogatella furcifera, Nilaparvata lugens* (Stål), and *Laodelphax striatellus* (Fallen) in Taiwan. In addition to the above three delphacids I have reared *Anagms optabilis* from *Saccharosydne procerus* (Matsumura), *Zuleica nipponica* (Matsumura et Ishihara) and *Nilaparvata muiri* China for the first time in Japan. The results of the field investigation of Yasumatsu *et al.* (1975, 1982) and Miura *et al.* (1981) have already indicated the importance of *Anagrus optabilis* **as** biological control agent in Asia and necessiated detailed biosystematical study of this parasitoid as no remarkable work has yet been done in this respect. Perkins has given a short general account of this parasitoid while

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he described it but much essential information remained uncleared and untouched. So the present study has been made to know the essential biological characters of *Anagrus optabilis* as far as possible. Taxonomical part of this parasitoid is treated separately along with the revisionary work of Asian *Anagrus* (Sahad & Hirashima, 1984).

Biology of *Anagrus optabilis*

Materials and Methods

Rearing of *Nilaparvata lugens* in the laboratory being comparatively easy, it was used as host insect throughout the study of various biological characters of *Anagrus optabilis*. Besides, *Anagrus optabilis* was also found to oviposit readily and develop successfully on the eggs of *Nilaparvata lugens*. *Nilaparuata lugens* was collected from the Kyushu Agricultural Experiment Station, Chikugo-City, Fukuoka Pref. and reared in the laboratory similarly to that of *Nephotettix cincticeps* Uhler used for biological study of *Gonatocerus cincticipitis* (Sahad, 1982a, b, c).

The stem and leaf cuttings of *Leersia japonica* Makino and *Zizania latifolia* Turcz. bearing parasitized eggs of *Nilaparvata muiri* and *Saccharosydne procerus* respectively were collected from river and canal side and reared in the laboratory to obtain stock of *Anagrus optabilis*. These wasps were continuously bred on eggs of *Nilaparvata lugens* until the experiment was over. Sometimes they were collected from the field by sweeping net and brought them to the laboratory alive taking in small test tube and then bred on the eggs of *Nilaparvata lugens* as usual. Other materials and procedures for rearing hosts and parasitoids, and conducting experiment were also similar to those used for biological study of *Gonatocerus cincticipitis* (Sahad, 1982a, b, c).

ADULT BEHAVIOURS

Mating. Both male and female are ready to mate immediately after their emergence although female can reproduce parthenogenetically. Male ‘moves around in search of female after emergence. It becomes excited while it finds the female and then grasps the female by the legs from the back and bends down the gaster to intromit the aedeagus into the female gonopore. Usually during first mating the female shows certain eagerness but once mated it refuses for the second time. It takes 15-20 seconds per mating. While there are more than one male in a rearing test tube and only one virgin female is released into it, 3 or 4 males mount on the female at a time.

Oviposition. Immediately after release in the seedlings the female parasitoid begins to move over it in search of host eggs by drumming with the’antennae. While it comes across with host eggs, it gets excited and makes very rapid palpation over the eggs, probably to confirm existence of host eggs. After locating the host eggs by antenna it lies over them stretching its legs by the side of the egg mass and keeps the ovipositor on the egg mass and makes some shallow insertions of ovipositor into the host eggs, probably for further confirmation of the host eggs. After confirmation of the existence and suitability of the host eggs, it inserts the ovipositor into the host egg almost at right angle with the host plant and after 4 or 5 minutes it pushes the ovipositor up to its base for actual delivery of egg. It takes 8-10 minutes for one oviposition but takes almost no interval between two successive ovipositions while fresh eggs are available adjacent to it. It changes its face to opposite direction very swiftly on the same egg mass after every insertion. Oviposition may continue for 8-10 hours without any interval. It does not leave the egg mass until all the eggs are parasitized. Even after completion of parasitization of the entire egg mass the parasitoid does not leave the place and repeatedly checks the egg mass to find healthy eggs.

Superparasitism. During study of the larval development several hundreds of parasitized eggs were dissected and usually one egg or larva was found per host egg. While many parasitoids were exposed to small number of host eggs in a test tube, sometimes two eggs or two larvae were observed in such a host egg but never more than one adult was found to emerge from a single egg. Thus it may be concluded that *Anagrus optabilis* is a solitary primary parasitoid.

REPRODUCTION

Fecundity. *Anagrus optabilis* can reproduce zygogenetically and parthenogenetically. In case of mated female both female and male offsprings are developed from eggs laid by the female, the former being highly dominant. To determine the egg producing ability 10 mated females were released in 10 separate test tubes containing paddy seedlings bearing host eggs. Host eggs were changed everyday until the death of the parasitoid. The oviposited eggs were kept in the incubator at a constant temperature of 25°C. The number of emerged wasps plus dead pupae within the host eggs was regarded as the number of eggs laid per female. To determine the number of dead pupae, the paddy seedlings were dissected to count them after the elapse of normal emergence period of the wasp. On an average 10.1% of the total offsprings

Table 1. Estimated number of eggs laid by 10 mated females of *Anagrus optabilis* and their sex ratios.

Sample No.	No. of Parasitoids		Total Parasitoids	Sex ratio Female : Male
	Female	Male		
1	27	15	42	1.8 : 1
2	24	3	27	8.0 : 1
3	44	5	49	8.8 : 1
4	29	7	36	4.1 : 1
5	30	9	39	3.3 : 1
6	47	14	61	3.3 : 1
7	42	13	55	3.2 : 1
8	46	5	51	9.2 : 1
9	31		35	7.8 : 1
10	59	7	66	a.4 : 1

Table 2. Estimated number of eggs laid by 10 unmated females of *Anagrus optabilis*.

Sample No.	Estimated no. of eggs laid per'female	
	Female	Male
	0	54
2	0	32
3	0	42
4	0	33
5	0	30
6	0	29
7	0	30
8	0	42
9	0	20
10	0	30

of each female was found dead in the last stage of pupa. This seems to be due to rotting or drying off host plants. The total number of eggs laid by 10 females was 461, the average per female and range being 46.1 and 27 to 66 respectively (Table 1).

Sex *ratio.* The sex ratio of the offsprings developed from eggs laid by the 10 mated females were determined. In each case female outnumbered the male to a greater extent. The highest and lowest ratios between females and males were 9.2 : 1 and 1.8 : 1 respectively, the mean ratio being 4.6 : 1 (Table 1).

Parthenogenesis. Fecundity and mode of parthenogenetic reproduction of 10 unmated females were studied. On an average the number of eggs laid by an unmated female was 34.2 with range 20 to 54 (Table 2) showing no significant difference with that of mated females. All the offsprings emerged from the eggs of unmated females were males. Thus *Anagms optabilis* is also an arrhenotokous parasitoid like that of *Gonatocerus cincticipitis* (Sahad, 1982a, c).

EFFECT OF TEMPERATURE ON THE DEVELOPMENT ,

The development of *Anagms optabilis* from egg to adult was investigated at 10°C, 15°C, 20°C, 25°C and 30°C constant temperatures. Considerable number of host eggs after exposing to the parasitoids for three hours were kept in temperature controlled cabinet at 10°C, 15°C, 20°C, 25°C and 30°C with 14 hours photoperiod.

Table 3. Effect of temperature on the development of *Anagms optabilis*.

Temperature °C	No. of emerged adults	Duration of development	Range	Rate of development (I/Day)
15	87	49.47±0.01	48-58	0.020
20	183	24.30f0.07	24-28	0.041
25	275	14.50f0.03	14-16	0.068
30	180	10.80f0.06	10-13	0.093

Developmental periods were found to decrease as the temperature increased from 15°C to 30°C. The times taken for the development from eggs to adults were 49.5, 24.3, 14.5 and 10.8 days at 15°C, 20°C, 25°C and 30°C respectively (Table 3). At 10°C eggs could hatch but the larvae could not develop beyond pupa. The threshold of development was found to be 11.3°C for female (Fig. 1). Based on this thermal constant was calculated to be 199.6 degree-days.

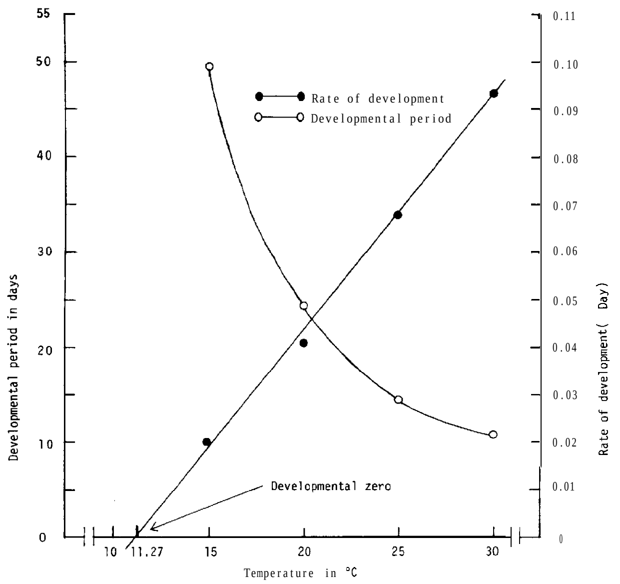

Fig. 1. Effect of constant temperature on the development of *Anagrus optabilis*.

EFFECT OF FOOD AND TEMPERATURE ON THE LONGEVITY OF ADULT *Anagms optabilis*

The longevity of a natural enemy under various conditions is of vital importance for its ability. The greater is the longevity the higher is the ability. The longevity is influenced by climate, temperature and food. Thus it is essential to know the longevity of ***Anagms** optabilis* under different conditions. The longevity of ***Anagms** optabilis* was investigated at controlled temperatures of 15°C, 20°C, 25°C and 30°C with honey and water, and only water as food. Twenty individuals of each sex were studied separately at each temperature. Newly emerged adult parasitoids were taken in a short test tube, one end of which was closed by cotton stopper and the other end by 65 : 35 tetron-cotton cloth with the help of a metal ring. A few droplets or streaks of concentrated honey were provided inside the upper end of the test tube and water was made available by soaking cotton stopper of lower end. They were then kept in 4 separate cabinets set at above mentioned temperatures. Two observations were taken

Table 4. Effect of food and temperature on the longevity of adult *Anagrus optabilis* (average in days).

Name of food	15°C		20°C		25°C		30°C	
	Male	Female	Male	Female	Male	Female	Male	Female
Honey & water	11.2	14.2	6.7	7.1	4.4	5.7	3.0	3.3
Water only	10.6	9.5	5.4	3.7	4.1	2.2	2.4	1.8

everyday at an interval of 12 hours.

In both sexes longevity increased as the temperature decreased from 30°C to 15°C. The longevity was minimum at 30°C and maximum at 15°C. While honey and water were supplied as food, the longevity of female was longer than that of male at all temperatures but while only water was supplied as food the male survived longer than the female at all temperatures (Table 4). The reason may be similar to that of *Gonatocerus cincticipitis* (Sahad, 1982a, c) that is female requires more nutrient than male for survival as it produces eggs. Remarkable difference between the longevities of male and female was observed at 15°C while honey and water were provided as food. The average longevities of male and female were 11.2 and 14.2 days respectively at 15°C while honey and water were supplied as food. There was very slight difference between the longevities of male and female at 30°C in case of either food. Survival percentages of the parasitoids at different temperatures and foods are shown in the Fig. 2.

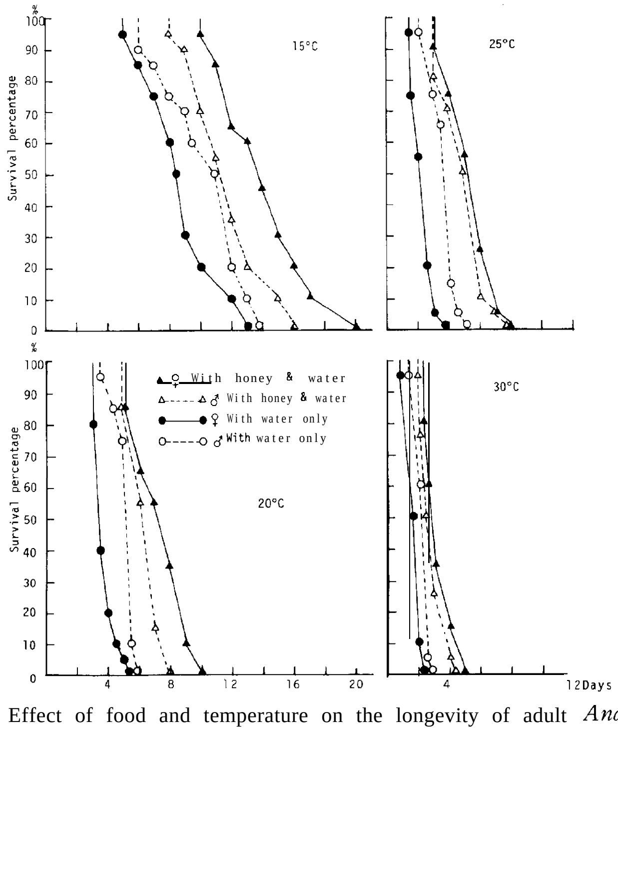

Fig. 2. Effect of food and temperature on the longevity of adult *Anagrus optabilis*.

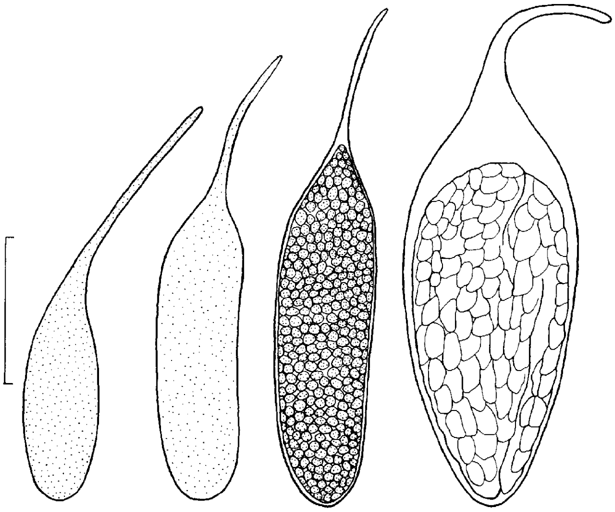

Fig. 3. Egg stage. A. Ovarian egg ; B. Egg after two hours of oviposition ; C. Egg after 14 hours of oviposition ; D. Mature egg showing embryo inside. Scale : 0.05 mm for all.

IMMATURE STAGES

Immature stages were studied by dissection and alive specimens at 25°C.

Egg. The egg is sausage-shaped with a long slender pedicel. The pedicel is slightly more than 1/3 of the total length of the egg. The length and breadth of an ovarian egg are 0.15 mm and 0.02 mm respectively and those of an egg after 2 hours of oviposition are 0.16 and 0.03 respectively (Fig. 3A & B). The egg increases in size during incubation and proportional increase in width is greater than that of length. It increases about 2 times in width and 1/4 in length before hatching. Increase in width at the first-half of egg stage is very slow compared to the second-half. The length and breadth of an egg after 14 hours of oviposition are 0.16 mm and 0.04 mm respectively and those of a mature egg before hatching are 0.20 mm and 0.06 mm respectively (Fig. 3C & D). In mature egg the oval-shaped embryo is visible through the chorion. Because of excessive increase of embryo, chorion expands to its maximum size forcing pedicel to bend down. As mandibles or any movements of the embryo are not observed prior to hatching, it is thought that chorion is ruptured by the expanding pressure of the embryo below the pedicel and moves slowly to the caudal part. The developmental period of egg from oviposition up to hatching is 1-1.25 days.

First instar larva. The 1st instar larva is sacciform, unsegmented, smooth and completely motionless (Fig. 4A). The chorion always remains attached to the caudal part of the larva, probably it is not detached from the body as it does not move at all. As first instar larva is inactive, it is guessed that it takes food materials by diffusion

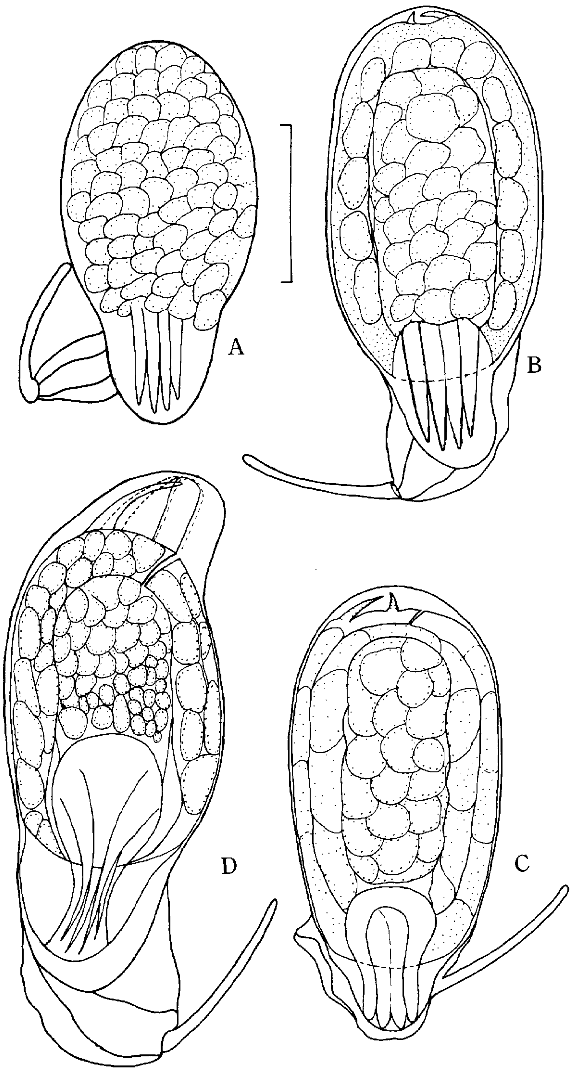

Fig. 4. First instar larva showing the attachment of cast chorion with the caudal end. A. Early stage ; B & C. Middle stage ; D. Last stage. Scale : 0.05 mm for all.

through the skin. The size of a just hatched larva is 0.13 mm in length and 0.06 mm in breadth. The larva is slightly constricted posteriorly, which appears like a caudal tubercle. At the caudal part four needle like processes may be visible, lateral two seem to indicate the caudal processes and median two may indicate the proctodeum. At early stage mandibles of cephalic processes can hardly be observed but as the larva very slowly increases in size, they become visible, and also caudal segment of the larva

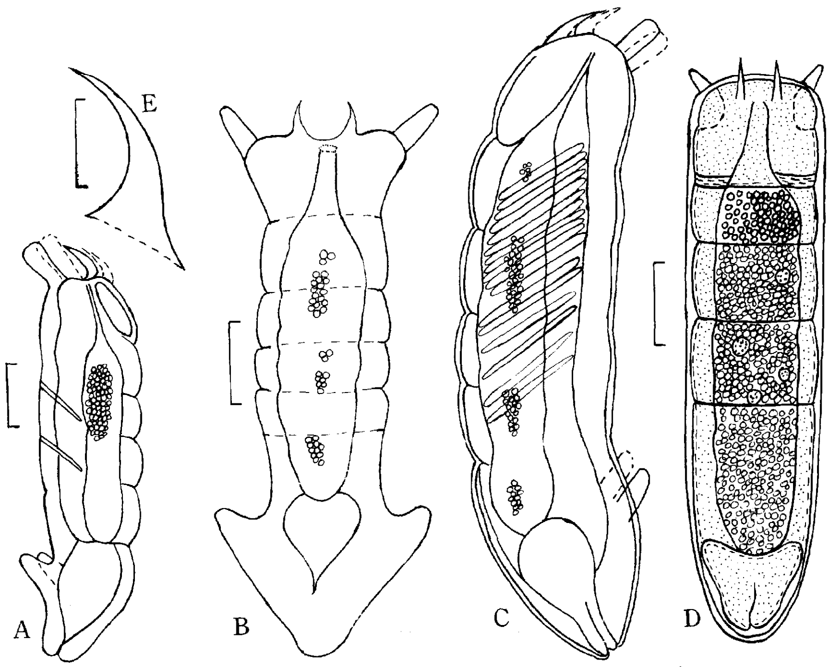

Fig. 5. Second instar larva. A. Early stage ; B & C. Middle stage (B, dorsal view & C, lateral view) ; D. Mature larva ; E. Mandible. Scale for A, B & C : 0.05 mm, D : 0.1 mm and E : 0.025 mm.

becomes distinct (Fig. 4B & C). The bag-shaped larva changes as it approaches near second moulting and both cephalic and caudal ends slightly slantingly protruded (Fig. 4D). The size of a full grown first instar larva is 0.20 mm and 0.07 mm in length and breadth respectively. The 1st instar larval period is 1 day.

Second ins tar larva. The 1st instar larva enters into 2nd instar on the 2nd day after hatching. The 2nd instar larva is somewhat cylindrical compared to the 1st instar larva (Fig. 5A-D). The length and breadth of early stage of 2nd instar larva are 0.33 and 0.88 mm respectively. One pair of long slender mandibles and one pair of cylindrical processes are clearly found at the cephalic end. Similar to cephalic processes but slightly short and conical one pair of processes is attached to the caudal segment. The cephalic processes are considered to give rise to antennae but the function of caudal processes is not known. The caudal processes gradually vanish as the larva develops and completely disappear from the full grown larva before entering into pupa while mandibles and cephalic processes are clearly visible (Fig. 5D). At the initial stage larva remains slightly sluggish for 2 to 3 hours and then gradually becomes very active in movement and feeding the yolk spheres of the host through the mouth. Ingested yolk spheres are visible inside the digestive tract. By the 1st day of the 2nd stadium the larva fills 3/4 of the host egg and by the 2nd day it completes feeding of entire yolk spheres and occupies whole space inside the host egg except some part at the cephalic end (Fig. 6A). Peristalic movement starts at short interval as soon as

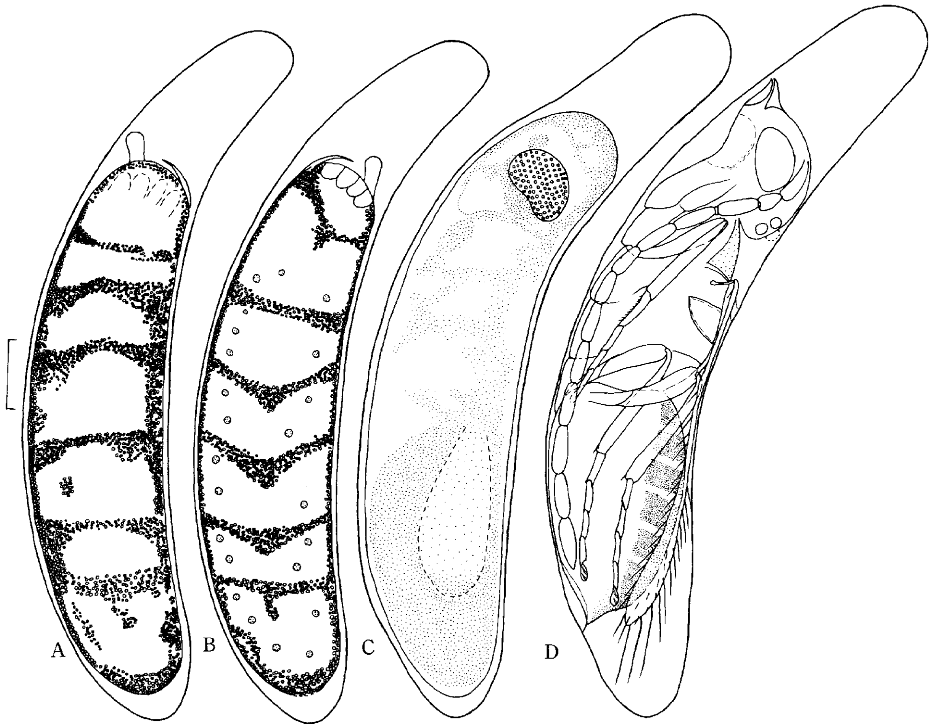

Fig. 6. Second instar and pupal stages. A. Full grown second instar larva inside host egg ; B. Prepupa ; C. Early stage of pupa ; D. Last stage of pupa. Scale : 0.1 mm for all.

feeding is completed. This movement seems to appear help digestion of the ingested yolk spheres. By the end of the 2nd day of the 2nd stadium the larva also develops whitish red color due to the change of color of fat cells inside the alimentary canal. The following day the larva becomes clear red and shows development of 5 or 6 irregular streaks of red fat cells. By the end of 3rd day 25 to 30 dull white concretions are developed inside the digestive tract. These concretions seem to be the digested yolk spheres. At this time in addition to the peristaltic movement occassional right and left rotatory movement also develops. On the 4th day peristaltic movement completely ceases but rotatory movement continues which also becomes very feeble gradually indicating its approach towards prepupa while whitish concretions remain as it is and red color becomes deeper. The length and breadth of mature 2nd instar larva are 0.68 and 0.16 mm respectively. The developmental period of the 2nd instar larva is 4 days.

Prepupa. By the end of the 4th day of 2nd stadium larva shows complete cessation of movement indicating entry into prepupa (Fig. 6B). White concretions are still visible inside the digestive tract. At this stage color becomes vivid red which can be easily recognized by the naked eyes. By this unique color character parasitized and unparasitized eggs can be easily distinguished. Prepupal period lasts for only 1 day.

Pupa. Larva enters into pupa on the 7th day of larval life. Whitish concretions disappear from digestive tract and deposite in the hind gut as a lump of white substance which is considered as waste product (Fig. SC). Development of brownish red eyes and pinkish ocelli becomes clear on the 8th and 9th days respectively while pupa can be distinctly differentiated into head, thorax and gaster. Transparent antennae, legs and wings become visible on the 10th day. Red color continues up to the 12th day after which it abruptly changes to yellowish red and sclerotization becomes distinct. Sclerotization of all organs completes by the 13th or 14th day of pupal life and general color becomes dull brownish yellow. At this stage the head of pupa with protruded mandibles looks like the beak of a bird (Fig. 6D). Emergence starts from the 14th to 15th day. The adult emerges by making a round hole in the egg shell of host and leaf sheath or stem of host plant with the help of mandibles. Pupal period ranges from 7 to 8 days.

OVERWINTERING

Some leaf cuttings of *Zizania latifolia* bearing overwintering eggs of *Saccarosydne procerus* were collected from the bank of Suegawa, Harada, Fukuoka-City, on 1. xii. 1982, while the average daily temperature was below the developmental threshold of *Anagrus optabilis.* These leaf cuttings were dissected to check if there was any parasitized egg but externally no symptom of parasitization was visible. These dissected-out eggs were taken in petri dish and kept in the incubator at 25°C for the development of parasitic larva if there was any. These were checked everyday to observe any change. On the 6th day 3 eggs became yellowish red and movements of parasitic larvae were clearly detected inside the eggs. After three weeks 2 female *Anagrus optabilis* emerged from them. Thus it is understood that *Anagms optabilis* overwinters as egg or first instar larva in the eggs of *Saccharosydne procerus* laid in *Zizania latifolia.*

PARASITIC ACTIVITY IN LABORATORY AND FIELD

Observation on the parasitic activity of *Anagms optabilis* was made in the laboratory and field. Its parasitic ability on *Nilaparvata lugens, Sogatella furcifera* and *Laodelphax striatellus* was tested in the laboratory and on *Saccharosydne procerus, Zuleica nipponica* and *Nilaparvata muiri* was investigated by collecting stem and leaf cuttings of the respective host plants from the field.

Laboratory observation. *Nilaparvata lugens, Sogatella furcifera* and *Laodelphax striatellus* were reared on paddy seedlings in the insectary for using as stock. Paddy seedlings were grown in small pot of 10 cm in diameter. Seedlings grown up to 8-10 cm long were taken in small insect cage, 24 x *10* cm, and then 30-40 female planthoppers were released into it and they were allowed to lay eggs for 24 hours. Four or five seedlings bearing 24 hours-old host eggs were transferred to a long test tube and then two female *Anagms optabilis* were exposed to it for three days. The parasitized eggs were kept in the incubator at 25°C. This treatment was given to all the three host species and five replications were taken for each host. After the elapse of normal emergence period the host seedlings were dissected to count the dead larvae and pupae of parasitoids and dead eggs of the host insects.

Parasitized eggs were calculated by the number of emerged wasps plus dead larvae and pupae of the parasitoids, and the host eggs were calculated by the number of parasitized eggs plus hatched nymphs and dead eggs. Percentage of parasitism was calculated by the formula, $\frac{A+B}{A+B+C+D}$, where A= number of emerged wasps, B= number of dead larvae and pupae, C= number of hatched nymphs and D =number of dead eggs. ***Anagms optabilis*** parasitized the eggs of *Nilaparvata lugens, Sogatella furcifera* and *Laodelphax striatellus* with almost equal efficiency. Percentage parasitism of ***Anagrus optabilis*** for *Nilaparvata lugens,* ***Sogatella furcifera*** and *Laodelphax striatellus* were ***86.7, 79.6*** and ***70.5*** % respectively (Table ***5).***

Table 5. Parasitic activity of *Anagms optabilis* in the laboratory.

Name of planthopper	Name of host plant	No. of egg exposed	No. of egg parasitized	% parasitism
Nilaparvata lugens	paddy	402	348	86.7
Soga *tella furcifera*	paddy	358	329	79.6
Laodelphax striatellus	paddy	374	264	70.5

Field observation. Natural parasitization of ***Anagms optabilis*** on the eggs of ***Saccarosydne*** *procerus* and ***Zuleica*** *nipponica* was first detected from host plant, ***Zizania*** *latifolia,* collected from Chikugo-City, Fukuoka Pref. on 29. viii. 1981. Later on it was recorded from the same host insect and host plant collected from the bank of Suegawa, Harada, Fukuoka-City. Parasitic activity of ***Anagrus optabilis*** was investigated by collecting leaf and leaf sheath cuttings of ***Zizania*** *latifolia* from this locality. Ten leaf and leaf sheath cuttings of ***Zizania*** *latifolia* were taken at random each time at different dates. These were kept in the incubator at 25°C taking in the test tube and petri dish. Percentage parasitism of ***Anagms optabilis*** for the eggs of *Saccharosydne procerus* was not so remarkable although their eggs were abundant. The mean percentage parasitism was 5.4 % (Table 6). The reason of low percentage of parasitism is the unusual ovipositing character of ***Saccharosydne*** *procerus*. After ovipositing it covers the eggs with white mealy substance so as to protect them from the attack of parasitoid. However, some eggs remain partially covered or almost uncovered among a group of covered eggs. These uncovered or partly covered eggs are vulnerable to the attack of parasitoid.

Percentage parasitism of ***Anagms optabilis*** for the eggs of ***Zuleica*** *nipponica* was also not so high. Of course the populations of *Zuleica nipponica* was greatly lower

Table 6. Parasitic activity of Anagrus *optabilis* in the field.

Name of planthopper	Name of host plant	No. of egg exposed	No. of egg parasitized	% parasitism
Saccharosydne procerus	*Zizan ia la tifolia*	1337	72	5.4
Zuleica nipponica	*Zizania latifolia*	160	36	22.5
Ni laparva ta muiri	*Leersia japonica*	135	24	17.3

than those of *Saccharosydne procerus* but percentage parasitism for its eggs was considerably higher than that for *Saccharosydne procerus.* Percentage parasitism for its eggs was 23.5 %.

Although both *Zuleica nipponica* and *Sacchrosydne procerus* lay eggs together on the same host, *Zizania latifolia,* their eggs can be recognized without much trouble because of their characteristic behaviour of oviposition. Besides covering the eggs with white mealy substance another character of *Saccharosydne procerus* is to lay eggs on both the upper and lower surfaces of the mid rib of leaf and leaf sheath, specially on the basal part of leaf and upper part of leaf sheath. *Zuleica nipponica* usually lay eggs at the basal part of the host plant and eggs remain uncovered.

Parasitized eggs of *Nilaparvata muiri* laid in *Leersia japonica* were collected from river and canal side from time to time. They were reared in the laboratory at 25°C as usual and emergence of *Anagrus optabilis* was recorded from them. Dead larvae, pupae and host eggs were counted by dissecting the stem cuttings in order to determine the percentage parasitism. The mean percentage parasitism for its eggs was 17.3 % (Table 6).

Host range of Anagms optabilis. Above mentioned laboratory and field observations indicate that host range of *Anagms optabilis* in large. Until now it has been recorded to develop successfully on the eggs of *Nilaparvata lugens, Sogatella furcifera, Laodelphax striatellus, Saccharosydne procerus, Zuleica nipponica* and *Nilaparvata muiri.* This result of breeding of *Anagms optabilis* on the eggs of above six species of planthoppers indicates that this parasitoid may have more number of hosts in nature. In Hawaii, *Perkinsiella saccharicida* is reported to be one of its best hosts. Thus *Anagrus optabilis* is not host specific, it is highly cosmopolitan in respect of host selection.

Eggs of *Nephotettix cincticeps* were supplied to *Anagms optabilis* many times but parasitization was not successful. After the expiration of normal period of emergence the exposed host eggs were dissected and once some dead pupae of *Anagrus optabilis* were found. The reason of death could not be ascertained.

Discussion

Anagrus optabilis has wide range of host and distribution. In Hawaii it was recorded as an effective egg parasitoid of sugarcane leafhopper, *Perkinsiella saccharicida* (Zimmerman, 1948). Miura *et* ***al. (1981)*** observed it to be a dominant egg parasitoid of rice pests, *Sogatella furcifera,* **Nilaparvata Zugens** and *Laodelphax striatellus,* in Taiwan. They observed the mean percentage parasitism of this parasitoid for individual eggs of *Sogatella furcifera* from 9 localities as 31.7% ranging from 34.0 to 100%, and that of *Nilaparvata* **Zugens** from 9 localities as 19.6% ranging from 2.4 to 43.9% and *Laodelphax striatellus* from 14 localities as 30.5% ranging from 12.4 to 60.0%. Laboratory investigation on the parasitic activity of ***Anagrus*** *optabilis* showed that it equally and effectively parasitized the eggs of ***Nilaparvata Zugens,*** *Sogatella furcifera* and *Laodelphax striatellus* (Table 6). Its natural parasitization of eggs of *Saccharosydne* *procerus, Zuleica nipponica* and ***Nilaparvata*** *muiri,* which are pests of indegenous grasses, is not remarkable (Table 6). These clearly indicate that ***Anagrus optabilis*** is a dominant parasitoid of delphacid pests of economic field crops, paddy and sugarcane.

Because of its wide range of host and distribution, it is thought to be adaptive to the climate of any parts of Asia, where ***Nilaparvata*** *lugens, Sogatella furcifera* and *Laodelphax striatellus* are serious pests of economic crops. Besides, it has great chance of survivability and propagation of generation even when populations of one or two host species are not available. Its mass production is also relatively easy. Hence this parasitoid may be used as biological control agent in case of outbreak of the above pest populations.

The second instar larval form of ***Anagrus*** *optabilis* resembles the "histriobdellid" stage of ***Polynema*** sp. described by Ganin (1869). The ***Polynema*** sp. is believed to be mistakenly used by Ganin in stead of ***Anagms*** sp. as indicates by his figures which show complete similarity to ***Anagms*** (Henriksen, 1922 ; Bakkendorf, 1934 ; Clausen, 1940 ; Debauche, 1948). Perkins (1905) reported that he did not find "histriobdellid" (i. e., histriobdellid form of second instar) in *Paranagrus (= Anagrus)* ***optabilis*** but he observed a third form somewhat resembling Ganin's description of ***Polynema*** sp. while he mentioned nothing about the early stage of larva or first instar larva. I examined several dozens of larvae of ***Anagms optabilis*** by dissection and always found sacciform and motionless 1st instar larva and "histriobdellid" stage (i. e., 2nd instar larva) having both cephalic and caudal processes, the latter disappeared as the larva reached maturity. Thus either Perkins had mistaken in detecting the "histriobdellid" stage with caudal processes in early stage of 2nd instar larva in ***Anagms*** *optabilis* or the Asian specimens of ***Anagms optabilis*** vary in larval character in comparison with Hawaiian specimens, indicating the possibility of former to be a separate species but adults of *Anagrus* ***optabilis*** of these two regions show no recognizable difference except color. For adult character of Hawaiian ***Anagms*** *optabilis* ***I*** had to depend on the original description as its type materials had been reported to be missing. Although on the basis of larval character, adult color and mode of parthenogenetic reproduction, Asian ***Anagrus optabilis*** differs from that of Hawaii, I cannot recognize it as a new species due to lack of distinctive adult character.

Summary

Biology of *Anagrus optabilis* is studied and the results are summarized as follows :

1. *Anagrus optabilis* is a solitary primary parasitoid.

2. Its immature stages **were** investigated at 25±1°C. There are two instars in its larval life. First instar is bag-shaped or ovoid and second instar larva is "histriobdellid" form. The egg, 1st instar, second instar, prepupa and pupal stage last for 1-1.3, 1, 4, 1 and 7-8 days respectively.

3. Developmental period increases as the temperature decreases from 30°C to 15°C. The developmental periods from egg to adult are 49.5, 24.3, 14.5 and 10.8 days at 15°C, 20°C, 25°C and 30°C respectively. The threshold of development and thermal constant are 1.3°C and 199.6 degree-days respectively.

4. Longevity increases as the temperature decreases from 30°C to 15°C. While honey and water were provided as food, longevity of female was longer than that of male at all temperatures of 15°C, 20°C, 25°C and 30°C but this was reverse while only water was supplied as food.

5. It can reproduce by both gamogenesis and parthenogenesis. It requires no preoviposition period. A mated female lays 46 eggs on an average. It is an arrhenotokous parthenogenetic parasitoid.

6. Its host range is wide. Six hosts, *Nilaparvata lugens, Sogatella furcifera, Laodelphax striatellus, Saccharosydne procerus, Zuleica nipponica* and *Nilaparvata muiri,* are recorded. Percentages of parasitism for N. *lugens,* S. *furcifera* and *L. striatellus* were 86.7, 79.6 and 70.5 % respectively in the laboratory and those for S. *procerus,* Z. *nipponica* and N. *muiri* were 5.4, 22.5 and 17.3 % respectively in the field.

7. It overwinters in egg or larval stage in the egg of *Saccharosydne procerus.*

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