Biology of the Sugarcane Stem Maggot

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Introduction

On November 13, 1964, at Makurazaki in the southern region of Satsuma-peninsula, Kagoshima Prefecture, the senior author was afforded an opportunity to examine discolored and wilted spindles (folded leaves) of young shoots of sugarcane and consequently perceived that the injury was due to the feeding of a maggot of hitherto unrecorded species, which rendered each shoot bored. From the maggots reared in the laboratory, a female fly belonging to the genus *Atherigona* (Muscidae, Diptera) emerged on May 10, next year. In 1967 the specimens were sent to Dr. A. C. Pont, Department of Entomology, British Museum, for the identification through Dr. A. Nagatomi, and recently (November, 1968) this species was described as new to science naming *Atherigona shibuyai*.[1] The present authors gave it a common name of "Satôkibi-kuki-hanabae" (the sugarcane stem maggot). This paper is an account of the life history and habits of this species studied during 1966-1967.

Materials and Methods

Studies were carried out at Entomological Laboratory, Faculty of Agriculture, Kagoshima University during 1966-1967. Laboratory studies were accompanied with investigations conducted at the sugarcane fields of Satsunan Sugar Manufactory at Makurazaki distant about 45 km southwestwards from the laboratory.

Field investigations were carried out 28 times in all, during the two years, to ascertain the seasonal life history of this species. Every time the injured young shoots were cut and the number of the various stages found in them was recorded. The position and area of the field investigated were not always the same. Immature stages collected were allowed to emerge in the laboratory to obtain materials of laboratory studies.

For records of oviposition, newly emerged adults were held in a glass cylinder 30 cm in height and 17 cm in diameter with plastic screen top, which was set over a pot planted with a young shoot of sugarcane. Every 5 to 10 days, a little mixture of honey and yeast (50 : 50) for food was coated on the screen top and water was supplied with moistened cotton.

For the developmental studies larvae were reared in the following manner : a newly hatched larva was carefully introduced into a piece of young shoot cut 4 to 5 cm long through an artificial incision. The piece of shoot treated thus was placed on filter paper moistened with water in a petri dish 6 cm in diameter or in a test-tube 20 cm in length and 3 cm in diameter plugged with moistened cotton. When the piece decayed, the larva was transferred to a new one. Rearings were performed under the laboratory conditions as far as possible, if not mentioned otherwise.

Results

I. Distribution and food plants

It is so far known that this species is distributed in the mainland of Kagoshima Prefecture and at Okinawa Island (Mr. S. Azuma, Ryukyu Agricultural Experimental Station, collected 3 larvae and 2 pupae at Nakijin, the northern part of the Island, on Oct. 30, '67), and feeds on sugarcane, *Saccharum officinarum* L. and *Miscanthus sinensis* Anderss

Table 1. Field counts of various stages

Date	Egg	Larva		Pupa	Adult
		Young	Mature		
Jan. 15 '66			++		
May 27			+	++	1 (♀)
Jun. 21			+		
Jul. 27			+		
Aug. 27					
Sep. 13	+	+	+		
21		+	+		
28			+		
Oct. 6			+		1 (♂)
19		++	++		1 (♂)
Nov. 4	++*		++		
Dec. 1			++		
Feb. 1 '67			++		
27			+	+	
Mar. 20				+	
Apr. 13					
28					4 (♀)
May 19			++		
Jun. 9				+**	
30			+		
Jul. 19		+	+		1 (♀)
Aug. 9			+		
Sep. 6					
Oct. 2		+	+		
19			+		
Nov. 1					
24		+	++		
Dec. 21					

Note …… Blank : none, + : less than 11, ++ : more than 10,
*; egg shell, ** : puparium

(Jap. name, "Susuki"), a perennial wild grass. The latter plant was confirmed by the junior author on July 14–16, 1967 at the foot of Mt. Kurinodake in the northern part of Kagoshima Prefecture where no sugarcane had been cultivated, and he collected 1 female, 5 males and 14 mature larvae. Shortly after this discovery (on July 19) he also captured 1 mature larva from the same grass growing in the vicinity of sugarcane field at Makurazaki. Further investigations may, in all probability, reveal that this species has ranged widely, feeding on *Miscanthus* in the region of non-cultivation of sugarcane.

II. Time of occurrence of various stages in the field

The number of various stages found in the field investigations is shown in Table 1.

It is inferred from Table 1 that this species overwinters in the mature larval stage and subsequent pupation and emergence take place in February to March and in April to May, respectively. The detailed life history will be mentioned later.

III. The duration of various immature stages

Data of duration of immature stages obtained from rearing at room temperatures are indicated in Tables 2–5.

Table 2. Duration of egg stage at room temperatures

Month of oviposition	Mean temp. of oviposition month	No.	Duration (days)	
			Mean	Range
Oct. '66	21°C	5	2.8	2 - 3
Nov.	20	8	4.0	3 - 5
Apr. '67	20	46	3.6	3 - 5
May	23	41	3.0	3
Nov.	21	6	3.0	3

Table 3. Duration of larval stage at room temperatures

Month of hatching	Mean temp. of hatching month	No.	Duration (days)	
			Mean	Range
Apr. '67	20	11	15.9	11 - 26
May	23	8	14.9	12 - 22
June	27	7	11.6	9 - 14

Table 4. Duration of pupal stage at room temperatures

Month of pupation	Mean temp. of pupation month	No.	Duration (days)	
			Mean	Range
Apr. '67	20	4	10.5	8 - 13
May	23	15	10.9	9 - 14
June	27	1	9.0	9
July	29	6	8.5	7 - 10

Table 5. Duration of combined larval and pupal stages at room temperatures

Month of hatching	Mean temp. of hatching month	No.[1)]	Duration (days)	
			Mean	Range
Apr. '67	20	19	29.1	19 - 37
May	23	12	25.3	21 - 36
June	27	16	20.8	16 - 24
Oct.	22	2	43.0	37 - 49
Nov.	22	1	48.0	48

1) In addition to 26 individuals in Tab. 3 & 4, 24 individuals measured without separation of larval and pupal stages were included.

Generally speaking, incubation period was fixed to be 3-4 days, larval stage lasted 12-16 days, pupal stage 9-11 days and combined larval and pupal stages 21-48 days.

When reared outdoors at Kagoshima, of 9 eggs laid on April 20, 8 hatched on April 27 and the remaining 1 on April 28, incubation period 7 and 8 days, respectively ; one egg laid on April 22, 1967, developed into an adult on June 23 after the lapse of 62 days, while 2 eggs laid on May 4 resulted in adults on June 19 and 20, 46 and 47 days after oviposition, respectively.

Since the succession of temperature to which various stages reared were subjected fairly coincided with that in the period at Makurazaki shown in Fig. 1, it was possible to presume the length of immature stages in the corresponding period at Makurazaki from the data mentioned above.

IV. Critical temperatures of development of egg and larva

Eggs incubated at 10°C over 10 days became gradually yellowish and did not hatch at all. A few of the eggs kept for 10 or 11 days at 10°C hatched 2 days after removal to the room temperature of about 26°C. From these results, it appeared that the embryonic development advanced to a certain degree but was prevented from being completed at 10°C. The developmental threshold of the egg seemed to be about 11°C.

The larvae newly hatched in May and July did not feed and died at 10°C. On the other hand, of 7 mature larvae introduced into 10°C in June, 3 died within 10 days, while 4 survived 100 days. Of the latter 4 larvae transferred to 25°C, 3 died without pupation, but 1 emerged after 15 days. Thus it may be safely said that newly hatched larvae can not live at 10°C and mature larvae (in non-overwintering gerations) can resist this low temperature for considerably long time but can not reach pupal stage.

At the high temperature of 35°C, though newly laid eggs hatched after 2 days, larval development was left in complete, i. e. of 5 individuals, 1 died at the 2nd instar and 4 reached the 3rd instar but died during the 1st to the 11th day of that instar.

V. Development of immature stages under constant temperatures

Owing to the restriction of equipments, temperatures adopted were 15°, 20°, 25° and 30°C and light conditions were not kept uniform : 15°C-light ; 20°C-natural photoperiod,

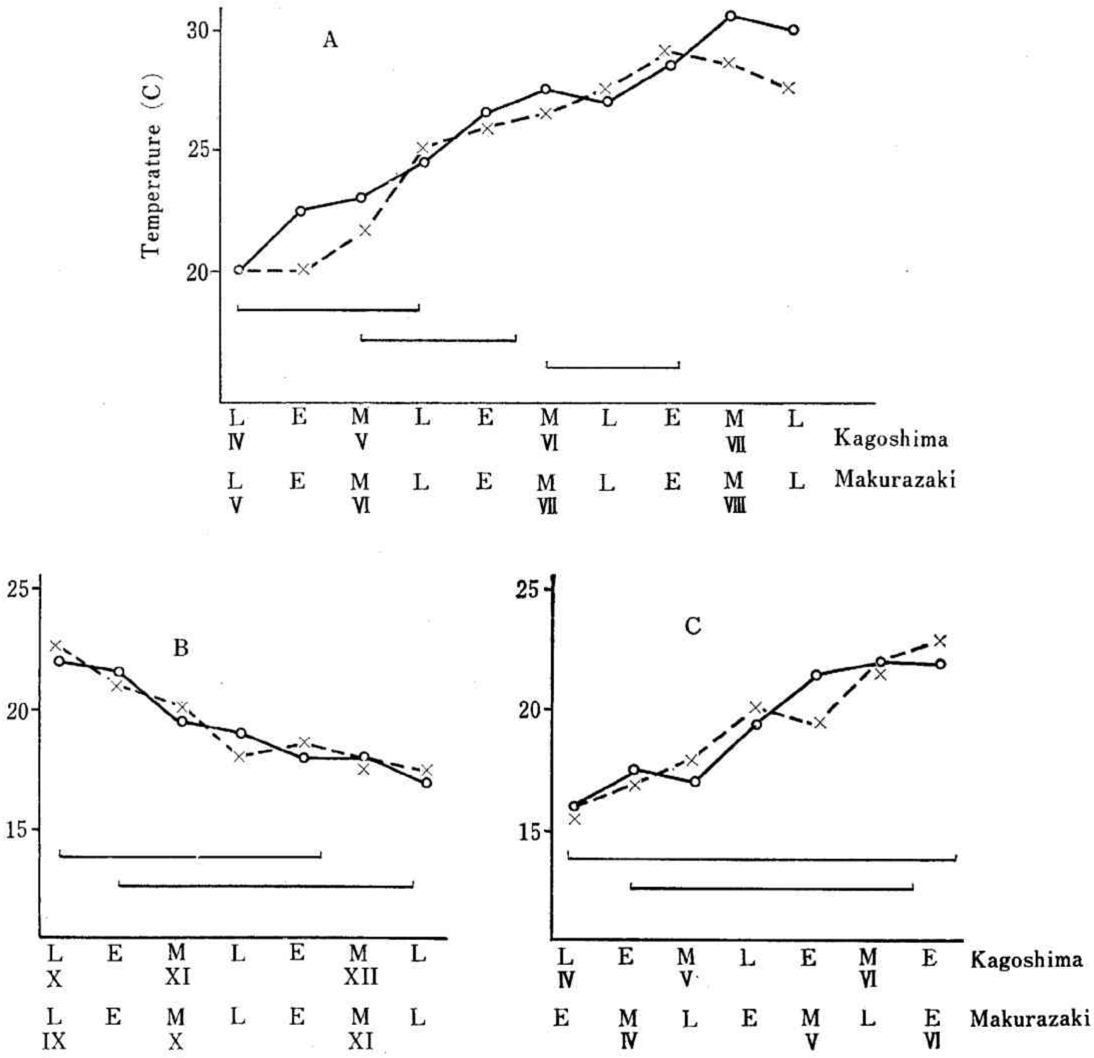

Fig. 1. Temperature successions at Kagoshima (—○—) and at Makurazaki (- - × - -), and duration of immature stages

In A & B, mean temperatures of laboratory at Kagoshima and those of field at Makurazaki, and the duration of combined larval and pupal stages are shown. In C, mean outdoor temperatures at both places and the durations from oviposition to emergence are indicated.

IV, V, - - - : April, May, - - -, respectively
E, M, L : early, mid, late, respectively

light and dark ; 25°C-light and dark ; and 30°C-dark. Since the data obtained in light and in dark at the same temperature differed slightly from each other, the average value of them were taken into consideration. However, the data under natural photoperiod at 20°C was kept out of consideration, for they were considerably longer (larval stage, 18.0 and pupal, 16.0 days) compared with those under other light conditions (larval 13.3 and pupal 12.6 days).

As seen in Table 6, the developmental velocity increased with the rise of temperature,

Table 6. Mean duration (D) and mean velocity (V) of development of immature stages under constant temperatures

Temp.	Egg		Larva		Pupa		Total	
	D	V[1)]	D	V	D	V	D	V
15	7.1 days	14.1	33.3 days	3.0	34.1 days	2.9	74.5 days	1.3
20	3.7	27.0	13.3	7.5	12.6	7.9	29.6	3.4
25	3.0	33.3	12.3	8.1	10.4	9.6	25.7	3.9
30	2.0	50.0	11.0	9.1	8.0	12.5	21.0	4.8

1) $V=1/D \times 100$

but was not proportional to temperature. It was remarkable that the rate of increase of the velocity delineated a steep slope below 20°C and a gentle one over 20°C (Fig. 2).

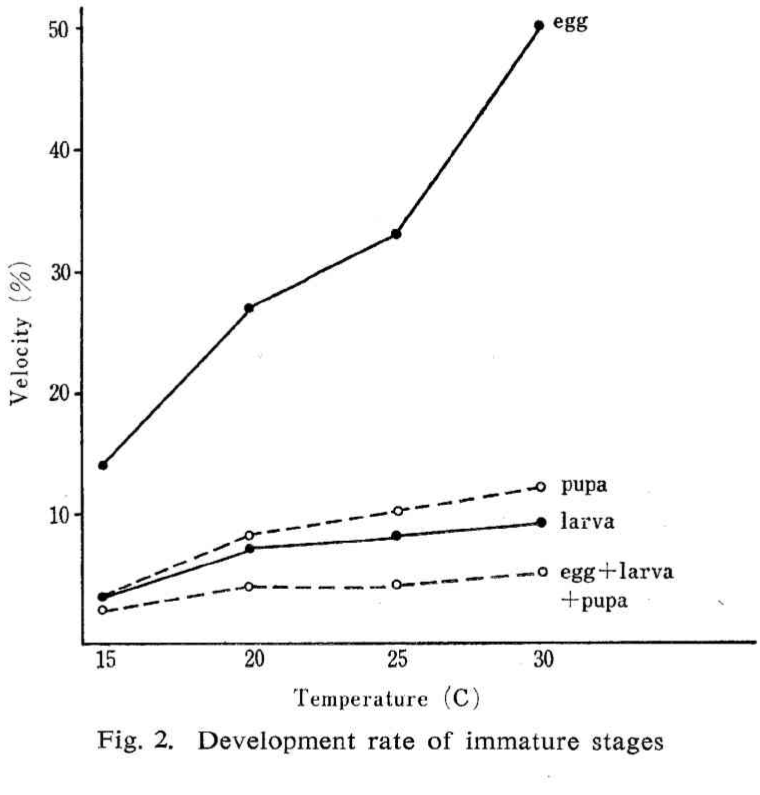

Fig. 2. Development rate of immature stages

VI. Longevity of adult

Longevity of adults fed with mixture of honey and yeast was shorter in warm season than that in cool season and females generally outlived males (Table 7). When supplied with water alone (in June), both sexes lived only 2–5 days. As a matter of course the longevity in nature must be affected by feeding. Although the investigation of the feeding habit of adults in nature was not yet attempted, judging from the observation by the junior author who encountered a female fly lapping honey dew of aphids on a weed, *Artemisia* sp. at the foot of Mt. Kurinodake, honey dew of aphids would be one of the main food sources.

Table 7. Longevity of adults provided with food (days)

Season	Rearing place	Female			Male		
		No.	Mean	Range	No.	Mean	Range
Spring-Summer	Indoors	6	33.7	21-43	6	18.7	2-35
Autumn-Winter	Indoors	10	39.1	19-102	11	28.2	13-57
Winter	Outdoors	2	41.5	41-42	2	30.5	21-40

VII. Seasonal life history

As already mentioned, this species overwinters as a mature larva, pupates in late February to late March, and emerges in April to May. Such wide range of the emergence-time of the first adult[1] may result in the overlapping of subsequent generations. Moreover, much variation in the length of each subsequent generation (Table 5) and the wide range of the oviposition period of one female (as mentioned later) may increase the generation-overlapping-degrees still more. Thus it was not easy to decide directly the seasonal life history according to the data of field counts (Table 1). However, allowing for the rearing-results under various temperatures (Fig. 1) as well as the results of field investigations, it was inferred that emergence of adults took place in the following months : the 1st adult, in April to May; the 2nd, in June; the 3rd, in July; the 4th, in August to September ; and the 5th, in October to November. Larvae from eggs laid by the early 4th adults developed into the 5th adults, while larvae arisen out of the late adults went into hibernation with those out of the 5th adults. Therefore, this species seemed to complete 4 or 5 generations a year.

VIII. Habits

A. Emergence

An adult liberated from a puparium, with the rupture of its 3rd segmental fracture, ascends along the tunnel of stem made by larval feeding and gets out of the upper part of host plant through aperture. In about 1 hour after emergence from the host plant, wings are extended and ptilium is withdrawn. Emergence occurs mainly in the forenoon.

B. Mating

On Dec. 13, 1967, a behavior considered to be a premating one was observed in the laboratory. A male and a female were side by side, facing in the opposite directions. The male was moving his projected trifoliate process, keeping it near the antennae of the female having a drop of cloudy-white fluid, about half the size of her head, attached, probably vomitted, on the mouth parts. If the female moved away, the male followed her and again displayed the gesture just mentioned. Now and then, the male stretched legs to lift the posterior body and swang the trifoliate process up and down. However, no mating took place during the observation time lasting for about 30 minutes. It seems that the trifoliate process of the male is an organ playing a role to lure the female.

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1) The adult resulting from overwintering larva and producing the 1st generation larvae is designated the 1st adult, and those giving rise to the 2nd, the 3rd, the 4th and the 5th generation larvae, the 2nd, the 3rd, the 4th and the 5th adult, respectively.

On April 20, 1967, a pair in copulation was encountered in a rearing cage. The female on her back kept hold of the under surface of the screen top of cage and the male mounted on the back of the female, curving his abdomen so as to join his genitalia to hers. It was noteworthy that the male had the same drop of liquid on his mouth parts as that possessed by a female at the time of premating mentioned above. When and how the drop was transferred as well as what the role of the drop was, were left unascertained so far as the observation was concerned. Mating came to an end 13 minutes after the start of the observation.

The number of mating times necessary for a female to fertilize her whole eggs seemed to be once.

C. Oviposition

(1) Pattern of oviposition behavior — An impregnated female alights on a host plant and crawls about, lapping the surface of plant until she reaches a suitable site to oviposit (several minutes) ; determines the laying position and protrudes the abdominal tip, the oviposition (about 1 minute) ; deposits one egg, crawls upward and flies off (several seconds).

(2) Oviposition site — In a rearing cage, eggs were laid on various parts of the young shoot of sugarcane : mainly on the inner side of the auricle of unfolded leaf or bract leaf, occasionally on the sheath or unfolded blade, and rarely on the part where the

Table 8. Preoviposition period, oviposition period, fecundity and rate of egg-laying

No.	Date of emergence of female	Age (in days) of female mated with male	Preoviposition period	Oviposition period	Fecundity	Rate of egg-laying[1)]	Longevity of female
				Autumn			
1	Oct. 7 '66	9	14	24	32	1.3	41
2	Oct. 29	0	9	8	16	2.0	30
3	Nov. 23	2	10	32	14	0.4	48
4	Oct. 18 '67	5	9	11	54	4.9	22
5	Nov. 19	0	9	21	27	1.3	-
6	Nov. 23	0	26	1	5	5.0	30
	Mean	-	12.8	16.2	24.7	1.5[2)]	-
				Spring-Summer			
7	Apr. 6 '67	0	12	5	28	5.6	-
8	Apr. 10	0	6	37	72	1.9	44
9	May 13	2	6	18	60	3.3	29
10	May 27	0	4	13	36	2.8	-
11	Jun. 7	3	9	18	85	4.7	33
12	Jun. 11	13	14	2	37	18.5	21
13	Jun. 12	1	5	25	94	3.8	33
14	Jul. 4	0	3	1	11	11.0	-
	Mean	-	7.4	14.9	52.9	3.6[2)]	-

1) fecundity/oviposition period 2) mean fecundity/mean oviposition period

shoot was in contact with the soil. Usually a single egg was deposited on one portion, but occasionally 2 to more than 10 eggs were laid in a group.

(3) Oviposition time — Oviposition took place in the daytime, though, under the artificial illumination, one female oviposited at night (22 : 30).

(4) Fecundity — In addition to fecundity, preoviposition period, oviposition period and rate of egg-laying are indicated in Table 8. Preoviposition period was not only different individually and seasonally, but also depended upon the age of female mated with male. Presumably virgin females failed to oviposit even if eggs were fullgrown.

Although there was no significant seasonal difference in oviposition periods, fecundity lessened in autumn, compared with that in spring and summer. Consequently, rate of egg-laying was low in autumn and high in spring and summer.

Accumulated numbers of eggs laid daily by females whose fecundity exceeded 50 was plotted in Fig. 3, which indicated that oviposition generally continued for 1 to 4 days, with recesses of various duration, usually 1 to 3 days. The maximum number of eggs

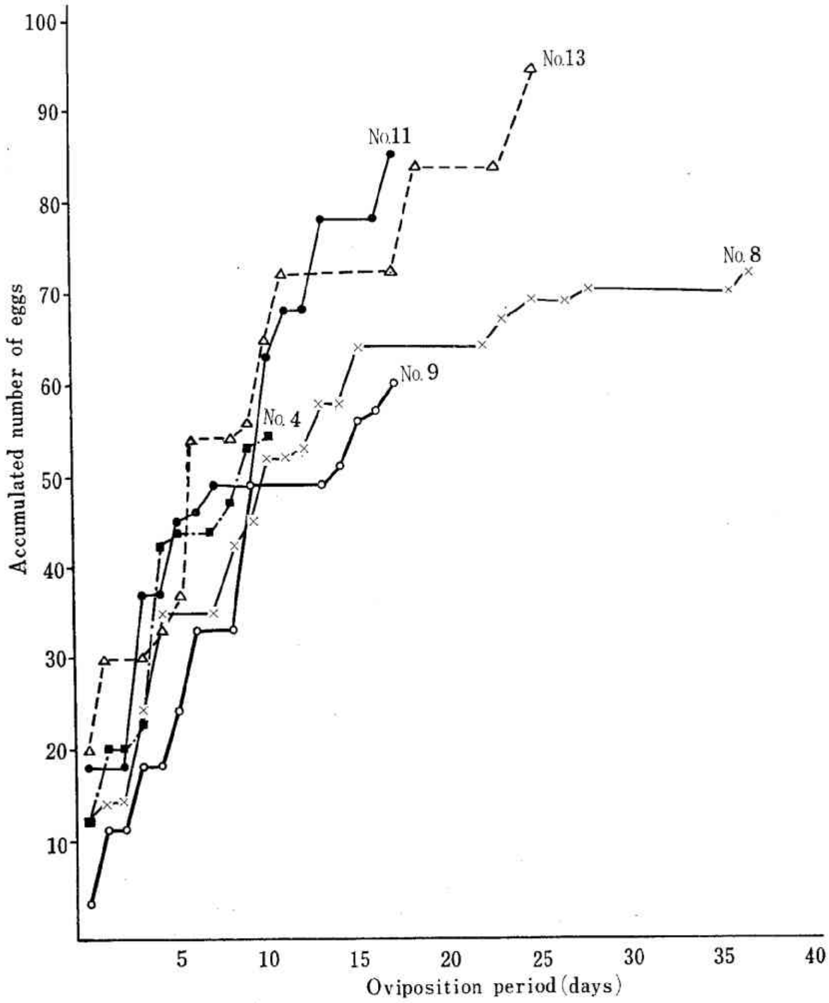

Fig. 3. Curves of accumulated number of eggs laid daily (5 examples: numbers of curves correspond to those in Table 8.)

laid a day by these individuals was 18 (No. 4), 12 (No. 8), 16 (No. 9), 19 (No. 11) and 20 (No. 13), respectively.

D. Hatching

When hatching approached, dark mouth parts which moved in all directions came to be perceived through egg-coverings. The larva ruptured the inner chorion and then pushed up the antero-dorsal part of the outer protective case with mouth parts and came out. In one example, it took 65 seconds to hatch.

It seemed that hatching was induced by the light stimulus, as the eggs kept in darkness till the completion of embryos hatched, uniformly, several minutes after exposure to natural light. Under natural light condition, hatching usually occurred in the morning, though some in the day time.

According to the observations in a petri dish, newly hatched larvae crept about along the fold of filter paper or the border line between paper and dish owing to thigmotaxis. Sufficient moisture was essential for larvae to live and creep. Thus it appears that hatching early in the morning while host plants in field are still wet with dew is of ecological significance.

E. Behavior entering a host plant

In order to observe the behavior of larva entering a host plant, newly hatched larvae were put on the provisional hatching sites of the young shoot of sugarcane. The plant was sprayed with water using an atomizer to prevent the death of larvae from desiccation. The liberated larvae crept until they reached the inner side of auricle of the first unfolded leaf, where they attempted to enter in vain. Then they moved to the overlapping margin of the folded leaf and continued to climb along the edge. During this course they failed in the repeated trials to enter crevice, but eventually gained an entrance through the aperture of upper loose part. The lapse of time between liberation and entrance in 4 examples observed was 8, 9, 15 and ca. 180 minutes, and the distance crept meanwhile was 8, 4, 4, and 8 cm, respectively.

F. Feeding behavior of larva

The feeding behavior of larva was inevitably observed by dissecting the host plant. The 1st instar which entered the sugarcane shoot descended through the crevice of the folded leaf and fed the part at the same level as the base of the first unfolded leaf, inflicting a characteristic spiral wound 1 to 4 cm long. The part of the folded leaf above this wound was destined to turn yellow and wilt. In late May, this discoloration occurred 4 to 6 days after the entrance of the larva. The direction of larva was not definite and almost no faeces were found. The 2nd instar, moving up and below with its head down, expanded the spiral wound below about 8 to 9 cm. The 3rd instar advanced further downward till the spiral wound reached the bottom of shoot, and, in case of shortage of food, even to the inner part of seed piece. The head was constantly kept downwards and the tunnel was filled with faeces.

Notwithstanding the occasional egg-laying in group on one plant, it was, without exception, a single larva that was found in the plant.

The sugarcane which is subjected to the attack of the larva is the young shoot sprouted from cuttings planted in spring or autumn, and the tender ratoon from stubbles, both in 2- or 3- leaf stage about 20 cm in height. The growing point of thin plant is entirely destroyed, while that of thick plant occasionally escapes from being fed up but the growth is remarkably retarded.

G. Pupation

A mature larva, directing its head upward, pupated usually inside the basal part of infested shoot, sometimes at considerably upper part.

H. Overwinter

This species, as already mentioned, overwinters as mature larva, within the bottom of the infested plant sprouted in autumn. Whether or not the larva undergoes diapause has not been determined yet.

Acknowledgement

Appreciation is extended to Dr. A. Nagatomi for his help and suggestions during this study, to Mr. J. Yukawa for his help in the preparation of the manuscript, and to Mr. R. Oishi for his help in the field investigations. It might also be mentioned that this study was supported by the grant-in-aid from the Sugarcane Research Association.

Reference

1) Pont, A. C.: A new Japanese species of *Atherigona* Rond. (Diptera: Muscidae), reared from sugar-cane. *Bull. Ent. Res.* 58: 201-204. (1968).