Technical Bulletin 6
December, 1974

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Tech. Bull.
TARC
No. 6

Tropical Agriculture Research Center
Ministry of Agriculture and Forestry
Nishigahara 2-2-1, Kita-ku
Tokyo, Japan

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ABSTRACT

To clarify on ecology and control of the rice gall midge, the present studies have been carried out mainly at the Pan Rice Experiment Station in northern Thailand from 1968 to 1972.

It was revealed that the rice gall midge is distributed in north, northeastern, and east Thailand, and recently the insect was found at some places in Central plain. There is a missgiving that the insect can extend her distribution rather easily when high yielding but susceptible varieties of rice such as RD 1, RD 2, and RD 3 will be used widely by farmers.

The highest damage was observed in Chiengrai Province in 1969, where the percentage of infestation was more than 60%. The rice gall midge showed a trend to reduce her population from 1970 to 1972. It is said that outbreak of the midge has occurred every 5 to 6 years in the past in Thailand.

The insect adult began to appear from March to May and disappeared usually in the middle of November in every year. The peak of occurrence was observed at the end of September. Number of generations was 9 to 12, and peak generation was at the 4th generation counted after transplanting. The insect which appeared from March to May on rice seedling were those migrated from wild host plants. Information in the insect occurrence in the early season gives an important key point for forecasting the insect occurrence in that season.

The most important factors among climatic condition affecting the insect incidence was relative humidity due to rainfall. Rainfall in May was very important for adult emergence and larval growth on the weeds. High humidity in paddy field after transplanting favoured egg laying, longevity of adult, emergence, egg hatching, and larval entrance to growing points of rice plants.

The insect population increase was proportional to the increase of tillers and hence growing points of the plants. In northern Thailand, the midge increased in number from July to September, reaching a peak at the maximum tillers stage. The insect population decreased sharply after the panicle primordium initiation stage, because no larvae could survive on the panicle primordia.

A peak of emergence was seen between 2200 and 2300 hours. Pupae climbing up inside the gall showed a negative phototaxis. Sex ratio (male to female) was 1 to 2.5. Parthenogenesis was not recognized at all. Ususally a male could mate to 2.5 females in an average. The adult longevity was 2.3 days in male and 2.6 days in female. A peak of the insect flight to light was 2100 to 2200 hours. Average number of egg laid per female, ovarian eggs, and eggs remained in ovary after egg laying were 221.3, 276.1, and 54.9 respectively. Time of peak of egg laying was 100 and 200 hours. More eggs were laid on leaf blade than on leaf sheath. Average incubation period was 3.2 days. A peak of egg hatching was seen between 300 and 400 hours. The larvae have 3 instars, with a larval period of 3.4 days in the first instar, 5.5 days in the second, 7.0 days in the third. Length of gall was less than 1 cm during the first instar stage and less than 4 cm at the second and third instar stages. Galls could not be observed from outside during these stage. Prepupal and pupal periods were 5.6 and 5.3 days, respectively. The gall rapidly grew up to 9.1 cm long in the prepupal stage and 27 cm long in the pupal stage. Pupation was seen at the basal part of the gall. It is suggested that the gall formation was induced by a particular substance secreted by the larvae.

Three species of the Hymenopterous parasites such as *Platygaster oryzae*, *Platygaster* sp., and *Neanastatus gracillius* and one species of predator such as *Ophionia indica* were found as natural enemies of the rice gall midge. The natural enemies began to appear in the field in

August, and their control effect on the midge was recognized from the end of September to November. A remarkable decrease of population density of the midge which occurs during the period from September to November is caused not only by shifting of plant stage from vegetative growth period to the reproductive stage but also by the attack of natural enemies. *Platygaster oryzae* was predominant in number than the other parasites. The parasite rapidly increased her population density during a rice season and reached more than 70% of the total number of natural enemies. Parasitism of *Platygaster oryzae* was significantly higher with later transplanting of rice than early transplanting, with a greater reduction of the midge population in the former case.

The wild host plants found in northern Thailand are wild rice, *Ischaenum aristatum, Paspalum distichum, Leersia hexandra*, and *Echinochlora colonum*. Habitat of *I. aristatum* and *P. distichum* is paddy fields but seeds of the plants remain dormant in soils during the rice season (June to October). Usually they appeared from November to May during the dry season. The midge appeared on wild rice throughout a year. The midge had a peak of occurrence during March to May and November. The insect maintained low population from July to October and December to February. The insect on *I. aristatum* began to appear on May 2nd, and disappeared on July 11th, with a peak of its density at the first of June. The insect on *L. hexandra* appeared in the middle of May and disappeared at the end of July, with a peak in the middle or at the end of June. During the dry season, the midge on the wild host plants, growing in dry area, stayed at larval stage mostly at the first and second instar. Number of the insect larvae on wild host plants was in order of wild rice, *P. distichum, I. aristatum*, and *L. hexandra*. The midge bred on the wild host plants was significantly smaller in body size. Size of gall on the wild host plants was also remarkably small. Female bred on rice plants laid eggs on wild host plants and the larvae developed normally, although the adult became small in body size and dark in colour. On the other hand, when adults bred on wild host plants were transferred to rice plants, they laid eggs and larvae grew normally on the rice plants.

Number of larvae entered into the main culm was more abundant and larval instar was more advanced than that entered into tillers. Galls produced on main culm were longest as compared with galls on primary and secondary tillers. Seedlings infested by the midge can be easily distinguished from the healthy one by such characters as short plant height, younger leaf age, more tillers, inhibited growth of uppermost leaf, dull green color, and round-shaped basal part of stem.

When same number of eggs was applied experimentally to rice plants as different growth stages. Larval development differed with different stages. Damaged tillers began to increase after transplanting, reached a peak at the maximum tillers stage and then decreased sharply during the reproductive growth period of rice plants. It was suggested that the tillering stage during which the insect population pumps up is the best time for insecticidal application and release of natural enemies for the control.

From the screening test for resistant varieties of rice EK 1263 and EK 1252, Indian strains were found highly resistant. Hydridization between Thai varieties and EK strains was done to develop resistant lines with good type and grain quality. The hydrid lines were out of more than 2000 hydrid lines, five resistant lines were selected in 1972 and distributed to farmers for field trials. One of them was named RD 4, and officially registered by the Government as a recommended new variety. An important difference was that the larval development was inhibited in resistant varieties, in which the larvae remained only at the first or second instar stage. Indian variety EK 1263 developed panicle primordium one month earlier than other varieties. It was considered that this fact may also be related to high mortality of the larvae.

Less infestation of the midge and high yield of rice were obtained when transplanted at the end of August in northern Thailand. This late planting caused a short tillering period, which permitted a cycle of only three generations of the insect. In case of late planting, the midge proceeded only one generation in the tillering stage and two generations after panicle primordium formation stage.

Effective control of the insect was achieved by the application at 14 and 28 days after planting. Insecticides were applied at a rate of 2 kg (a.i.) per hectare. Diazinon granule was very effective. Diazinon coated on the tape which is named Diazinon tape was also very effective. Therefore, the application at early time of tillering period is most effective to the midge and also can avoid the killing of natural enemies which occur mostly in the later period of rice season.

CONTENTS

1. Introduction

The rice gall midge, *Orseolia oryzae* (Wood-Mason), in the Family Cecidomyiidae, is one of the important insect pests of rice and is widely distributed in south-east and west Asian countries including southern China, Indonesia, India, Sri Lanka, Thailand, Bangladesh, Burma, Cambodia, Laos, and Vietnam. The rice gall midge in Thailand is distributed in north, northeast, eastern, and some parts of the central plain. The insect causes severe damage to rice plants by producing gall (hollow tube) as long as 30 to 40 cm. Plants which are severely damaged do not produce panicles, resulting in grain yield reduction by as much as 60 percent. The rice gall midge outbreaks every 5 to 6 years suggesting that factors affecting monthly and annual fluctuation of population density are involved.

In the past some research works have been done in Thailand with regard to damage to rice, certain aspects of insect bionomics, and mass rearing. However, systematic studies leading to the development of control methods have still been wanted. In addition, the insect bionomics has not been sufficiently clarified.

The studies reported herein were conducted at the Pan Rice Experiment Station located in Chiengrai Province, northern Thailand under a cooperative research programme between the Rice Department (now Department of Agriculture) of Thailand and the Tropical Agriculture Research Center of Japan from 1968 to 1972. The station is approximately 800 km north of Bangkok or 100 km south of the Burma and Laos borders at a latitude of 20° north.

The present study aimed at clarifying ecology of the rice gall midge and establishing effective control measures for the insect. Major emphasis was placed on obtaining data to be used for developing integrated control methods and outbreak forecasting methods.

2. Acknowledgement

The authors wish to express hearty thanks to Dr. Bhakdi Lusanandana, Director-General, Department of Agriculture, Dr. Sala Dasananda, former Director-General of Rice Department, Dr. Prakov Kanyanasoon, Deputy Director-General, Department of Agriculture, Dr. Tanongchit Wongsiri, Head of Entomology and Zoology Division, Mr. Pairoth Sophanaratana, Head of Rice Division, and Dr. Kovit Kovitvadhi, Chief of Applied Entomology Section, Entomology and Zoology Division, Thailand for their strong support and encouragement given in the course of the study.

The authors wish to also express their appreciation to Mr. Thep Lekagul of the Forest Department for his valuable cooperation.

Thanks are especially due to Mr. Chumnong Pulsawadi, Chief of the Pan Rice Experiment Station for his favorable consideration extended in many ways. The present study could not have been completed without his support and cooperation. The authors wish to also thank all staff members of the Rice Entomology Section in Thailand for their kind helps given in the course of the study.

The authors are grateful to Dr. S. Takagi, former Director, Department of Entomology and Plant Pathology, Dr. T. Kono, Head of Entomology Division, Dr. H. Hatai and Dr. S. Nasu of the National Institute of Agricultural Sciences in Tokyo, Dr. T. Koyama, Agricultural Chemical Research Institute, Nippon Kayaku Co. Ltd. in Saitama Prefecture, Dr. H. Ishikura, Director-General, Center for Marine Science in Japan, Dr. K. Yasumatsu, an adviser for the Integrated Pest Control in Thailand under FAO, Dr. S. Uchida, Dr. S. Ishii, and Dr. Watabe of

Kyoto University, Japan, Dr. J. Takahashi and Dr. H. Matsuo of FAO for their helpful advice.

The authors would like to express their thanks to Dr. Ben R. Jackson, an expert of rice breeding in Thailand under the Rockefellor Foundation for his valuable suggestions.

Finnaly, Hidaka, one of the authors, is indebted to Dr. Insee Chansathit, Chairman of the National Research Council of Thailand, Dr. Pradisth Cheosakul, Secretary General of the National Research Council, Mrs. Boonthom Dhancharee, former Division Chief and Miss Praparsri Thanassukarm, Division Chief of Compilation and Coordination of the Council for the permission of the foreign scientist long term stay in Thailand granted to him. He wishes to also thank Dr. N. Yamada, former Director of the Tropical Agriculture Research Center, Dr. K. Murakami, Director of the Tropical Agriculture Research Center, Mr. K. Nagai, former Head of Research Division, Mr. S. Hatta, Head of Planning and Coordination Division, Dr. H. Kawanabe, Head of Research Division, and Dr. M. Yoshimeki of the Tropical Agriculture Research Center for their encouragement and advice.

3. Taxonomy of the rice gall midge

The rice gall midge is identified by rules of the zoological nomenclature as follows:

Arthropoda
- Class Insecta
  - Order Diptera
    - Family Cecidomyiidae
      - Genus Orseolia
        - Species Oryzae (Wood Mason)

The synominic list of the species is listed up as follows:

1881 *Cecidomyia oryzae*, Wood-Mason, in Riley American Naturalist: 19.
1890 *Cecidomyia oryzae* Cotes, Indian Mus. Notes 1: 103.
1921 *Pachydiplosis oryzae* Felt, Mem. Dep. Agric. India, Entom. Ser. VII: 16.
1928 *P. oryzae* Senior White, Cat. Indian Ins., Pt. 15: 14.
1934 *P. oryzae* Mani, Rec. Indian Mus. 36: 433—437.
1973 *Orseolia oryzae* Delfinado and Hardy, Univ. Press Hawaii: 506-507.

A Japanese name "INENOSHINTOMETAMABAE" of the insect was given by T. Koyama and T. Hidaka who reported on recent status of the rice insect study in Thailand and Malaysia in 1967. The insect in Thailand is called as "Maleng Bua" which is generally well known one of the important insect pests of rice by Thai farmers.

4. Morphological characteristic of the rice gall midge and gall

1) Adult (Fig. 4-1, Photo. 1). Length of body 4.8 mm in female and 3.5 mm in male, length of fore wing 3.8 mm in female and 3.0 mm in male.

(Female) Body is light reddish. Antenna, pronotum and lateral pleuron on thorax are dark. Compound eyes are black. Basal half of halter, genital segments and legs are light yellow or dark yellow. The 1st antennal segments, head, mouth part, thorax, and trocanter are yellow. Fore wing is semitransparent with light dark. Body is covered with small and erect hairs. Fore wing is densely haired. Apical and basal margins of antennal segments bear spines and the middle portion of the segment has sparse hairs. Each segment of legs is with dense and short haris. Basal margin of abdominal segments has long hairs.

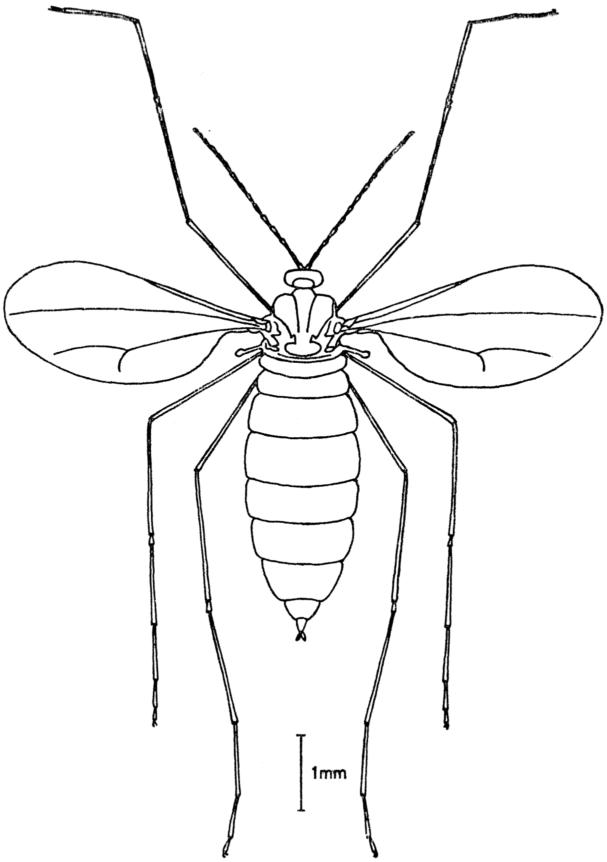

Fig. 4-1. Adult (female) of the rice gall midge

Compound eyes occupy more than half of head. Antennae (Fig. 4-2) insert from central portion of frons and consist of 15 segments. The 1st and 2nd antennal segments are largely swollen, the 3rd to 14th antennal segments are cylindrical and slender but their basal parts are slightly excavated. The 15th segment is the shortest and triangle in shape. Length of antennae is about 2.3 mm and as long as 1/2 of body length. Pronotum is 1 mm long and concave dorsally. Posterior margin of scutellum is round. Dorsal portion of thorax has 2 longitudinal ditches which do not reach anterior and posterior margins of thorax. Abdomen with 9 segments including genital segments is 3.7 mm long. The 3rd and 4th abdominal segments are broader than the other segments. Apex of genital segments has a pair of appendixes which are cylindrical in form. Four veins on fore wing are clearly seen. Halter is 0.8 mm long and apex with globe in shape. Legs are very slender. Especially tarsus consists of 5 segments, the 1st segment being shortest and the 2nd the longest. Order of length of dorsal segments is 2 3 4 5 1. Tarsus is as long as femur and tibia combined together. Hind legs are 7 mm long. 2nd segment of tarsus is as long as tibia.

(Male) Body colour is similar to female. Abdomen is brown. Apices of a pair of clasper are black. Antennal segments (Fig. 4-2) connected alternately with globe and cylindrical in form, antennal segments sparsely haired. Apex of fore wing is extending apex of abdomen. Abdomen is comparatively small, genital segment has a pair of large clasper,

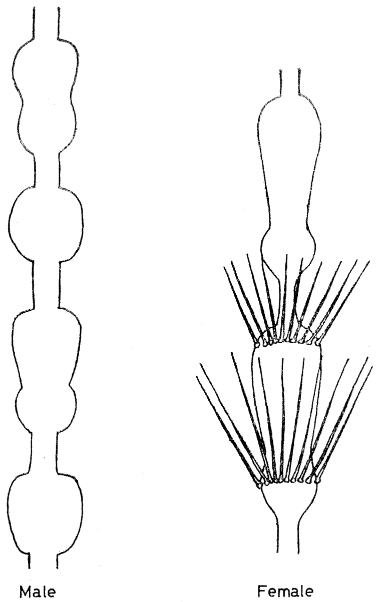

Fig. 4-2 Male and female antennal segments of the rice gall midge

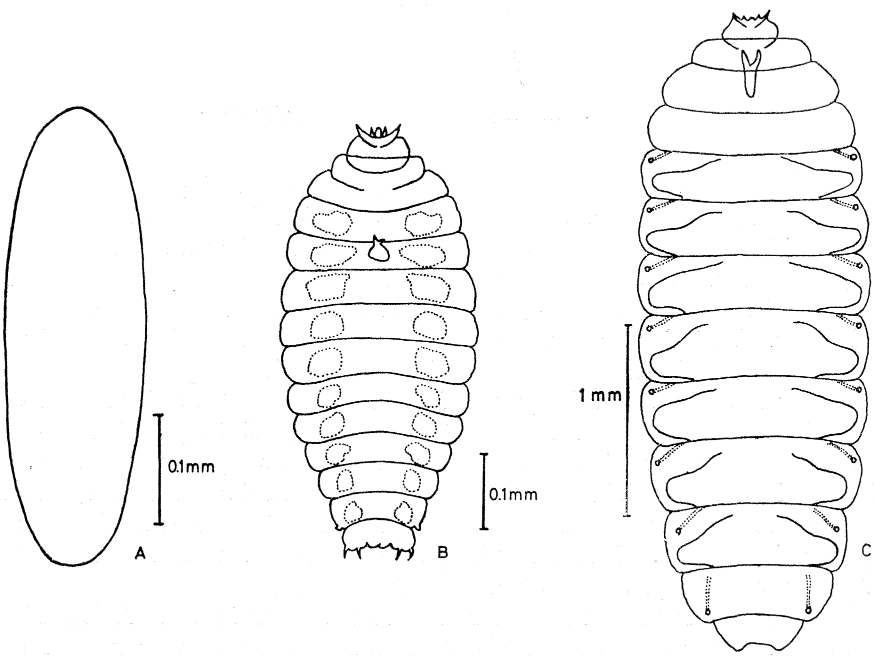

Fig. 4-3. An egg (A), the 1st instar (B) and the 3rd instar larvae (C) of the rice gall midge

their apices are strongly and inwardly curved. Genitalia projected outwardly at the middle portion of basal area of claspers, apex of genitalia is pointed, basal portion of genitalia sparsely haired.

2) Egg (Fig. 4-3A). Length of egg is 0.45 mm, width 0.25 mm. Egg is whitish just after egg laying, embryo became light yellow 2 days after egg laying, and reddish eye point is seen just before egg hatching. Egg is ellipse in shape. Surface of egg is smooth and shinning.

3) Larvae (Fig. 4-3 B and C). Larvae have 3 instars. The 1st instar larvae (Photo 2): Length of larvae is 0.57 mm. Body is light whitish. Fatty body is easily seen. 2 pairs of spines are on both sides of the 12th abdominal segment and 4 pairs of spines on 13th abdominal segment. The 2nd instar larvae: body is 1.7 mm long and similar to that of the 1st instar larvae. Eyes spots are very clear. 3 pairs of short spines are on both sides of the 13th abdominal segments. The 3rd instar larvae: body is 3.5 mm long and milky white. Mouth part and spiracles are light brown. Y-shaped spatula is brown. Each segment of body is extremely clear. A pair of spiracles are located on both sides from the 1st to 8th abdominal segments. Tracheal veins connected with spiracles are also clear. Body is smooth without hairs. Y-shaped spatula ventrally presents between meso amd metanota. Three pairs of extremely short hairs are on both sides of the 13th abdominal segment.

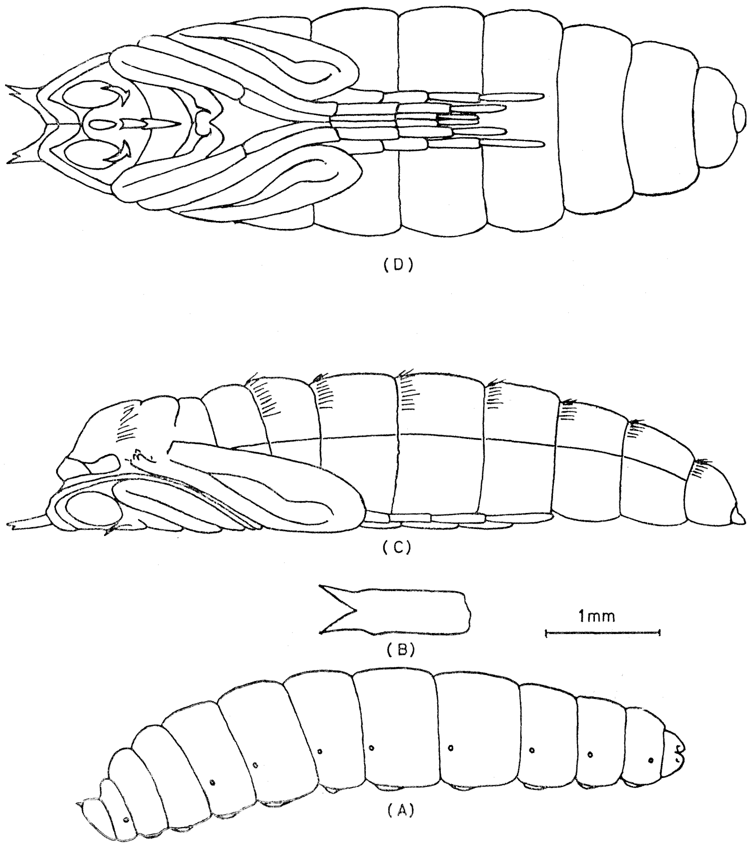

Fig. 4-4. A prepupa (A), sternal spatula (B), lateral (C) and dorsal (D) view of pupae of the rice gall midge

4) Prepupae (Fig. 4-4A). Body length is 5.1 mm in female and 3.5 mm in male. Body is milky white, spiracles are black. Y-shaped spatula is brown. Body clearly swollen and fatty body is well developed. Body segments are not clear. Apex of head is forewardly projected. Mouth part is slightly chitinized. Body segment has 2 rows of small and convexed parts which occupy anterior half of each segment. Spiracles are distributed on pronotum and 1st to 8th abdominal segments. Y-shaped spatula is 0.25 mm long.

5) Pupae (Fig. 4-4 C and D, Photo. 3). Body length is 5 mm in female and 4 mm in male. Body is light reddish in both sexes. Male is lighter in colour than female. Compound eyes are black. Clasper is dark. Head, wing and leg are dark yellow. Antennae, femora and 2 pairs of spines on vertex on head are also dark. Two pairs of spines (with apices divided into two parts) on vertex sharply projected. A pair of spines arises from inner margin of basal part of eyes and a pair of long spines reaching to the 3rd antennal segment arises on anterior margin of eyes. Antennae inserted from basal part of 2 pairs of spines on vertex are located between middle and hind femora. Apices of antennae are extending to basal margin of first abdominal segment. Pronotum distinctly convex, pro- and mesonota are very clear. Dorsal part of thorax is longer than wide. Fore wing is located on thoracic pleura and the apex reached to 2nd abdominal segment. Legs are located from thoracic pleura to dorsal surface of abdomen, apex of hind leg is extending to 5th abdominal segment

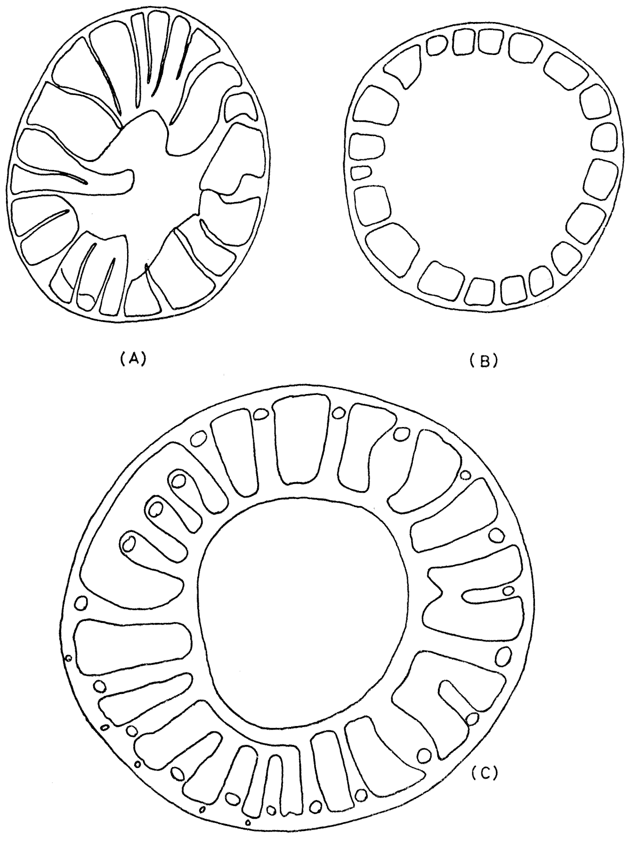

Fig. 4-5. Longitudinal section of internal structure of gall.
A and B: Spongy part, C: Basal part of gall.

and those of fore and middle legs to 4th abdominal segment.

Abdomen largely swollen but abdominal segments are distinct. A row of short spines are seen on anterior margin of 2nd to 7th abdominal segment and posterior margin of the 8th abdominal segment, 9th abdominal segment is remarkably small with a pair of appendixes on the apex. Posterior margin of 2nd to 7th abdominal segment and abdominal beneath covered with dense and small hairs. Spiracles are located on both side of 2nd to 7th abdominal segment. Male has short spines on anterior margin of 2nd to 8th abdominal segment. Apex of hind leg reached to 6th abdominal segment.

6) Morphological characteristics of gall (Fig. 4-5). A gall consists morphologically of three parts i.e. a) leaf sheath, b) spongy part, and c) leaf blade.

a) Leaf sheath occupies the longest part of the gall which is called as onion tube. Veins of leaf sheath is distinctly seen on surface of gall. It is considered that growth of gall takes place mainly in part of leaf sheath of gall. Cross section of the leaf sheath of gall is given in Figure 4-5. Gall shapes apparently the form of onion tube. Surface of gall is made of soft tissue, but it prevents water coming into the gall. Larvae, prepupae and pupae of the midge living in the gall are located at the vicinity of growing points of rice plants that are still under the water surface of paddy fields, so that the leaf sheath of gall plays an important role in enabling the midge to fully respire. Leaf lamellae of young gall conglutinate when the larvae attained to 2nd instar.

b) Spongy tissue

This tissue formed by whitish sponge is located between leaf sheath and leaf blade. The spongy part is 3 to 4 mm long in fully grown galls. Leaf blade of young gall during larval stage is occupied by the sponge. This is the tissue derived from the ligule at lamina-joint.

c) Leaf blade

This part is very short; 3 to 4 cm long in grown gall. Leaf blade with leaf veins conglutinates hardly and sharply pointed at the apex, the blade being slender toward the apex. Apical half of the leaf blade does not conglutinate but it curls inwardly. In some instances, a small leaf is seen at the apex.

On the other hand, abnormal forms of gall are found at an extremely low frequency on fields. There are spiral (Photo. 12) and twisted (Photo. 13) galls. The former means that all part of onion tube-shaped gall curls spirally. The spiral gall does not have a spongy part. It is not yet known how the spiral gall is formed. The spiral gall, however, is similar with ordinary gall in length and diameter. In the latter, middle part of gall is slightly concave and clearly twisted. Leaf blade and spongy part are distinctly seen. It is supposed that the twisting may occur when the normal growth of galls is inhibited for some reasons. Length of gall is same as normal gall.

In case of a variety Dawk Mali 3, the ordinary gall is 25.5 cm long in average. Diameter of gall is 2.5 mm in the middle part. Usually length of gall is in proportion to height of rice varieties.

5. Historical review of the rice gall midge in Thailand

In Thailand, the insect is mainly distributed in 15 provinces, in total, of northern, northeastern, and eastern regions (Ladell 1931, Hatai, 1965), and is one of the importamt rice pests from viewpoint of severe damage on rice plants (Pholboon 1952, Okamoto 1962). In Chiengrai, Lampang, Prae, and Nan Provinces in northern Thailand, the insect occurred in 1.5 million rai, reducing rice yields by as much as 50% because of severe damage. Percentage of infestation varied place by place up to 56% of damaged tillers. Extreme cases of 100% of damaged tiller were observed in Lampang Province. It was recorded that farmers in Ubol Province in northeastern Thailand were migrated to Laos because of severe incidence of the insect (Ou 1961, Hatai 1965, Kovit 1966, Plumb 1967).

A part of the insect life histroy had been revealed; Length of one generation was 26 to 35 days under 28.2°C and 73% relative humidity. A female laid 136 eggs in an average. Time for egg laying was between 2000 and 2300 hours. Adult male emerged between 2000 and 2100 hours and female 2400 and 100 hours. Sex ratio was 5 to 6 (Prakob 1968). A large number of the insect was attracted to light of 40 and 60 watts bulbs during surveys by light trap. Two peaks of the insect occurrence was seen from August 7th to October 13th (Hatai 1965, Kovit 1966). According to screening tests of rice varieties against the rice gall midge, Muey Nawng 62 M, a glutenous rice, was found highly resistant. But due to its liability to lodge and difficulty of threshing farmers dislike the variety. Therefore it was suggested that the variety should be examined as a possible breeding material for resistant varieties (Ou 1961, Kovit 1968). In screening tests of insecticides for control of the rice gall midge in fields, Thimet granule was the most effective followed by BHC and Sevin. Insecticides at the rate of 4 kg/0.1 hec were applied 2 and 4 weeks after transplanting. Both dipping and spraying were not effective at all (Hatai 1965, Cantello 1967). Mass rearing of the rice gall midge was successful. For example, adult female was released to lay eggs on 25 to 30 days old plants of a susceptible variety after sowing, and the plants with eggs were transferred to rearing cages of which the upper part was covered by cloth to prevent direct sunlight, and the bottom was fully watered to keep moisture. The plants were kept in the rearing cages until adult emergence. Number of adults collected was 500 to 600 heads per day (Prakob 1968). Thus, a member of good studies on the rice gall midge had been done in Thailand although they were only fragmental.

(I) Studies on ecology of the rice gall midge

6. Distribution of the rice gall midge in Thailand

METHOD

Distribution of the insect was surveyed mainly by checking the crop damage during the rice growing season from June to December. Additional information was obtained by checking the insect occurrence on wild host plants during dry season from January to May. In some cases, the writers inquired of farmers directly about the insect occurrence in their paddy fields. References kept at Pest Control Unit as well as Agricultural extension and rice officers working at Government office in Provinces were also very useful sources of information.

RESULTS

1) Distribution of the rice gall midge before 1967

The insect was recorded for the first time from Prae Province in northern Thailand and Trat Province in east Thailand by Ladell in 1931. Hatai mentioned the inesct was distributed in 15 provinces in total i.e. Prae, Lampang, Chiengrai, Chiengmai, and Nan from northern Thailand and Nakornrachajima, Ubol, Chaipung, Khonken, Udonthani, Sakonnakorn, Nakonpanong, Nongkai, Nakornnayork, and Prachinburi from northeast Thailand. Kovit (1966) reported that the insect was densely distributed along the Mekong river and the insect damage

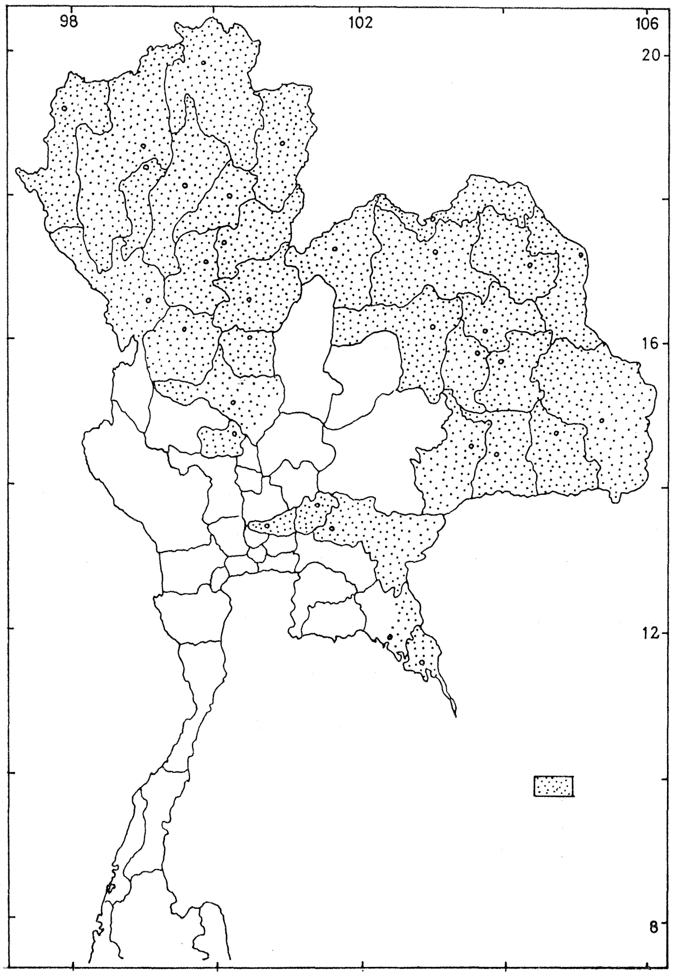

Fig. 6-1. Distribution of the rice gall midge in Thailand

inclined to be low in places from the Mekong river. Places where high percentages of damaged tillers, at least 20 to 60%, was observed were as follows. Ubol, Nakornpanong, Sakornnakon, Nongkai, Udonthani, Loei, Prae, Nan, Chiengrai, Lampang, and Nakornnayok.

The insect had not been known yet in Central plain and southern peninsula. Total area of paddy fields attacked by the insect was estimated more than 1.8 million hectares, 1/4 of the total paddy field area in Thailand.

2) Distribution of the insect since 1968

Surveys conducted by the writers since 1968 revealed the distribution of the insect in 8 provinces in north, 6 provinces in northeast and 3 provinces in east Thailand. The insect was recently found in some places in the Central plain, for example, Rangsit and Chinat. It was found by the authors that the insect was distributed in the northern parts of the Central region extending from Nakornsawan (Fig. 6-1).

There are some indications that the insect is continuing to spread within the Central plain. For example, Dr. Yasumatsu has collected parasites of this insect in the Chachaensao area although no specimens of the rice gall midge itself have yet been reported.

It is anticipated that the introduction of new high yielding varieties highly susceptible to the insect such as RD 1 throughout the Central plain may accelate the insect spreading. Unless environmental factors are not conducive for its growth and reproduction, it is conceivable that the rice gall midge will also spread to the southern rice producing areas.

7. Survey on damage caused by the rice gall midge in northern Thailand

The survey aimed to clarify seasonal and annual fluctuations of the insect in northern Thailand, and also important factors affecting the fluctuation.

METHOD

During two years, 1968—1969, the infestation was determined at every 15 kms from Maesai to Payao in Chiengrai Province. The distance between the two places was 160 kms or more. Since 1970, the survey was extended to Lampang and Chiengmai Provinces where the distance was as far as 300 kms. The infestation was determined once a month not only

Table 7–1. Places selected for survey on the midge occurrence and damage on rice varieties in northern Thailand, 1968—1972

Name of province		Place	Distance from Pan (km)	Field	Rice variety
Chiengrai	1.	Maesai	120	LR	NSW
	2.	Maesai	115	UR	
	3.	Santhonpui	105	LR	NSW
	4.	Maechan	76	LR	MN–62M
	5.	Maechan	72	UR	
	6.	Pasang	61	LR	NSW
	7.	Chiengrai	45	LR	NSW
	8.	Pakodum	30	LR	NSW
	9.	Huaysaikao	15	LR	MN–62M
	10.	Pan	0	LR	NSW
	11.	Pafek	15	LR	NSW
	12.	Pronkua	30	LR	NSW
	13.	Payao	40	FR	
	14.	Payao	45	LR	NSW
Lampang	15.	Ngao	100	LR	DDP
	16.	Bansai	155	LR	NSW
	17.	Ponwang	170	LR	NSW
	18.	Lampang	181	LR	NSW
	19.	Thunkudai	195	LR	NSW
	20.	Yan-oi	210	LR	NSW
Chiengmai	21.	Sanpathong	300	LR	DM–3

LR; lowland rice, UR; upland rice, FR; floating rice, NSW; Niawsanpatwang, MN–62M; Muey Nawng 62 M, DDP; Dodoput, DM-3; Dawk Mali-3

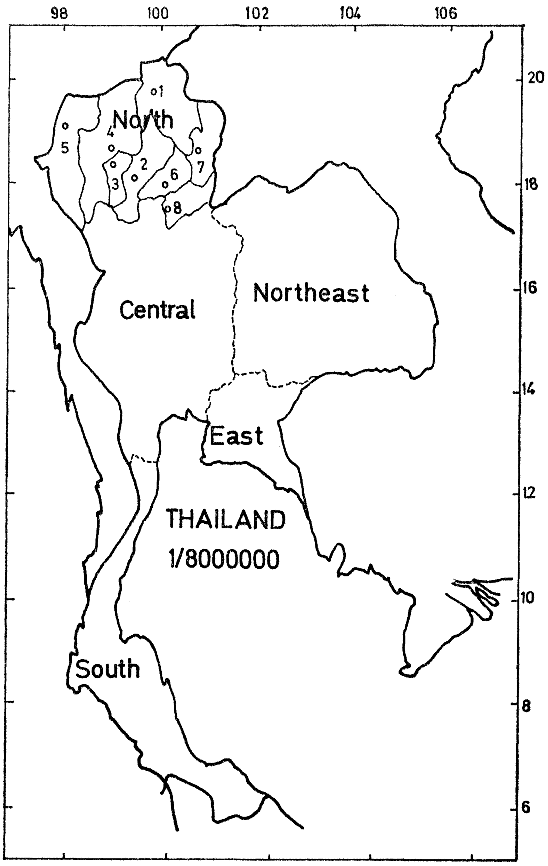

Fig. 7-1. Agricultural regions in Thailand and Provinces in northern Thailand, 1. Chiengrai, 2. Lampang, 3. Lamphun, 4. Chiengmai, 5. Maehongsorn, 6. Prae, 7. Nan, 8. Uttaradit.

with lowland rice but also upland rice. Total number of locations where determinations were made during the planting season was 21, consisted of 14 paddy fields including 2 upland fields in Chiengrai Province, 6 in Lampang Province, and one in Chiengmai Province. 50 hills of rice plants were sampled at random for each paddy field, number of galls and healthy tillers were counted, and height of rice plants was also measured with 10 hills for each place. During the survey, the same paddy fields were used for studies. The planting date and name of rice varieties were given by farmers upon on-the-spot-questions. No fertilizer and insecticide were used except at Sanpathong Rice Experiment Station in Chiengmai Province. Survey locations are given in Table 7-1 and Figures 7-1 to 3.

RESULTS

1) Insect occurrence and crop damage in northern Thailand

In Chiengrai Province, upland rice is sown in May when rainy season started, usually in sloping areas of mountain region. The harvesting is done in October. At the northern end of the Payao lake, floating rice is grown on about 3 rai (one rai 1600 m^2) area. The floating rice is direct sown after ploughing during June, and is harvested in November. Lowland

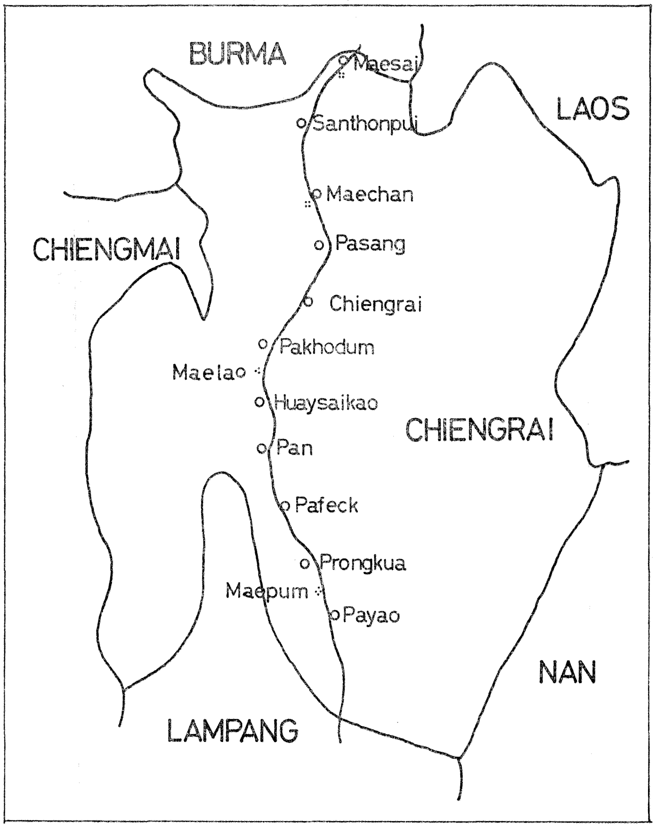

Fig. 7-2. Places selected for surveying damage caused by the rice gall midge in Chiengrai Province, Thailand, 1968—1971.
○ Lowland rice; :: Upland rice; .·. Wild rice;
·:· Floating rice

rice is sown in June, transplanted in July, and harveted in December.

During the dry season, there was no rice crop in farmer's paddy fields in Chiengrai and Lampang Provinces because of lack of water, but in Chiengmai Province where irrigation water is available. The second crop of rice was seen on more than 10,000 rai.

The results obtained from the survey conducted for 4 years are as follows:

a) Upland rice (Fig. 7-4)

The rice gall midge began to appear from June. The time of appearance was eariler than those for lowland and floating rice. The rice gall midge bred on wild host plants attacked seedlings of upland rice during May. The infestation was examined from 1968 to 1970 in two places i.e. Maesai and Maechan where upland rice was grown in the same place at least for 3 years, and then shifted to other slope of the hill, where rice was grown only for one year because the land was utilized for teak plantation. The peak of the damage caused by the insect was seen during September at Maechan 1968 and Maesai 1969, although results of 3 years observation indicated the peak of the damage appeared during August. However, percentage of damaged tillers was not so high; 23% at Maechan 1969 and 6.5% at Maesai 1969. These figures are extremely low as compared with that of lowland rice.

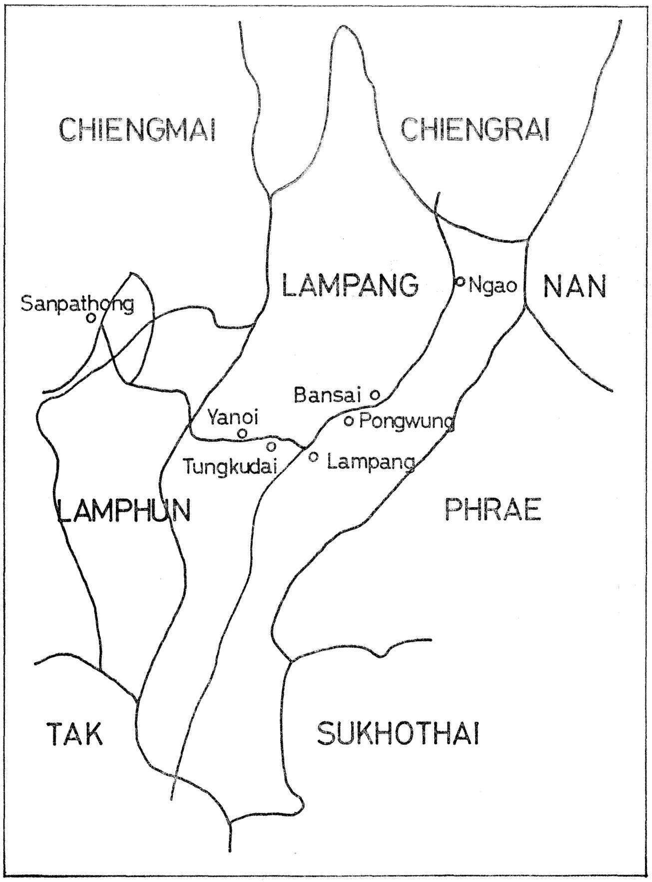

Fig. 7-3. Places selected for surveying damage caused by the rice gall midge in Lampang and Chiengmai Provinces, Thailand, 1968—1971. ○ Lowland rice.

It was made clear that the gall midge bred on upland rice was the same species which attacks lowland rice judging from the morphological comparison and hybrid test between both gall midges. A careful test to ascertain the identity of both midges was conducted. Eggs from the both midges were innoculated alternately to upland and lowland rice and it was made certain that the both insects were same species which could normally grow in two types of rice plants. The galls of the lowland rice were of same length as galls of upland rice. No differences was observed in the gall formation between upland and lowland rice. Low percentage of infestation observed with upland rice is accountable by a low humidity in upland rice fields, especially micro-humidity which affects egg laying and hatchability.

It is also known that the infestation was prominently fluctuated by month or by year (Fig. 7-4). The annual infestation on an average was 8.37% at Maechan and 2.28% at Maesai.

b) Lowland rice (Fig. 7-5 to 10)

With lowland rice growing at 18 locations of survey, it was observed that the population density of the midge was remarkably varied monthly and even annually. Rice seedlings were seen during June in Chiengrai and Lampang Provinces. The gall occurrence on the

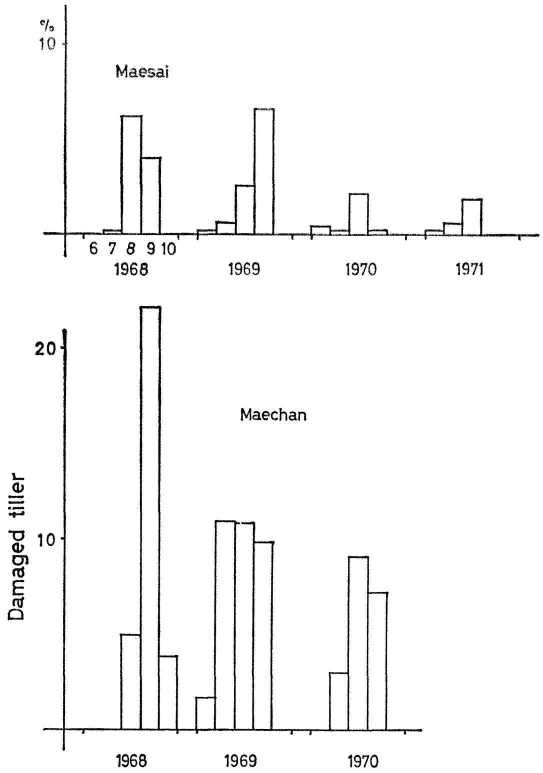

Fig. 7-4. Monthly fluctuation of damage caused by the rice gall midge on upland rice

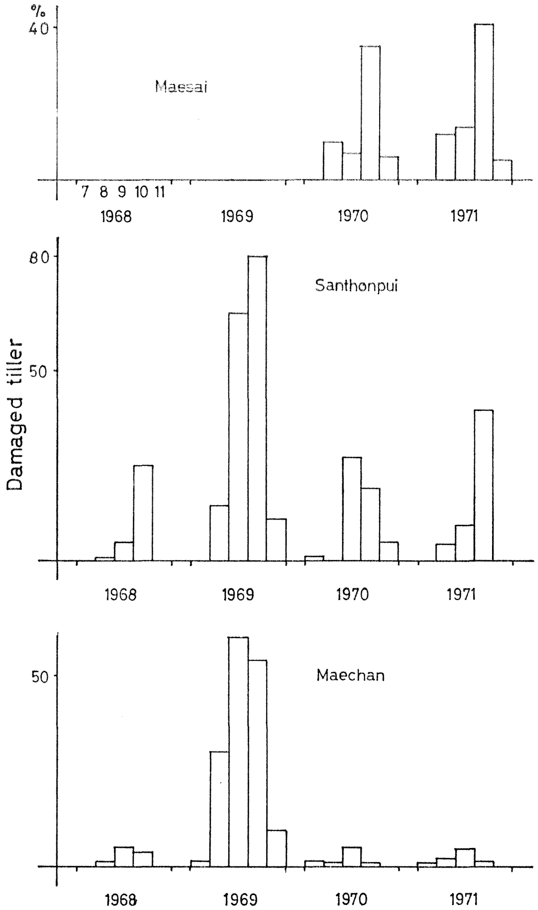

Fig. 7-5. Monthly fluctuation of damage caused by the rice gall midge on lowland rice

seedlings was less in number than that at the tillering stage. Damage caused by the insect during the seedling stage was usually less than 10%, but 27% of the damaged tillers were observed at Huaysaikao in 1969. This was a record of the highest damage observed in the present survey.

At 4 locations i.e. Ngao, Pasang, Chiengrai, and Pakhodum, where rice was sown in the middle of June, small number of galls was collected at nursery beds where the infestation was less than 4% of damaged tillers.

On the contrary, the midge began to prominently increase her population density from August, and the peak of damage was seen during September especially from the middle to the end of September. The damage reached 85% at Pan in September 1969. But the highest damage also occurred at Santhonpui in October 1969. Exceptionally the two places i.e. Ngao and Bansai in Lampang Province showed the highest damage in August. In the former place, a local variety "Dow Dow Put" which is a susceptible variety against the gall midge was transplanted very early at the end of June. Therefore, the insect occurred earlier on plants than other lowland rice fields surveyed.

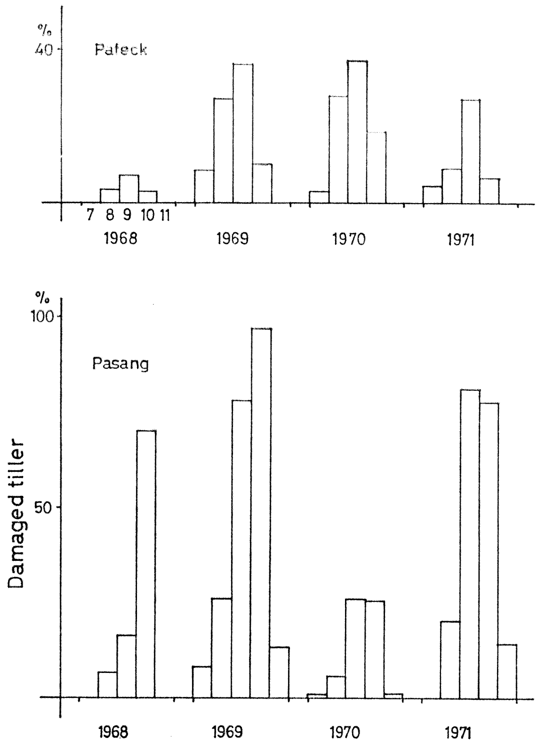

Fig. 7-6. Monthly fluctuation of damage caused by the rice gall midge on lowland rice

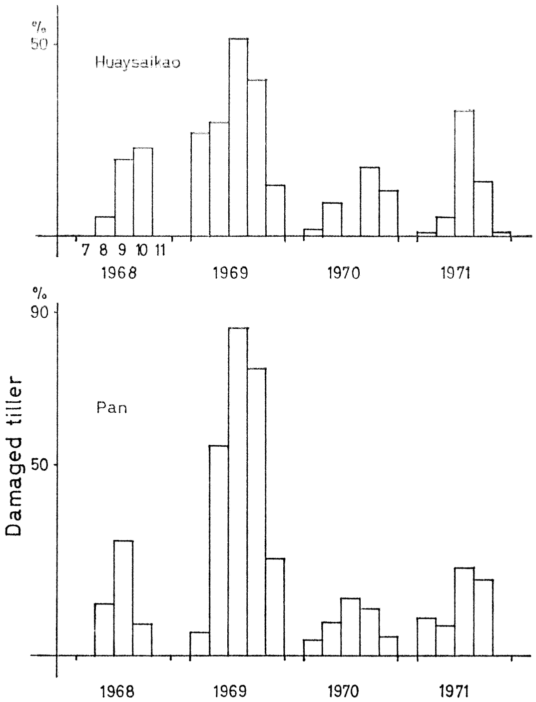

Fig. 7-7. Monthly fluctuation of damage caused by the rice gall midge on lowland rice

The fact that plants transplanted early are more severely infested than late-transplanted ones was experimentally proved by the study presented in detail in Chapter 19.

The damage on rice plants during October was generally lower than that of September. It is suggested that this is related to the formation of panicle primordia in rice plants; panicle primordia formation induces high mortality of the insect larvae. Thus, the population density began to gradually decrease from the middle of October to November. The infestation became less than 15% of damaged tiller, and in December the insect disappeared completely in every places.

So far as the present survey in Chiengrai Province is concerned, the highest damage on rice plants occurred in areas from Maesai to Pan in 1969. The damaged tillers in September was over 50% in the following places i.e. Santhonpui, Maechan, Pasang, Huaysaikao, and Pan. The same extent of infestation was observed during October too in these places except Huaysaikao. At Pasang, damage more than 50% continued from August to October in 1969. In southern part of Chiengrai Province, i.e. Maechai and Payao districts, the infestation was always lower than 25% throughout 4 years. At Payao, however, the damage showed a steady increase from year to year (1968 to 1971), an exceptional phenomenon.

It was a distinct tendency that the high peak of damage was seen in 1969 in all places, except Payao, whereas in 1968 and 1970 the infestation was apparently less than 1969. A big annual fluctuation of the insect damage actually exists. It has been believed that the severe damage occurs in every 5 to 6 years. The survey in Lampang Province conducted in 1970 and 1971 by monthly observation covering the areas from Ngao to Yan-oi proved that the

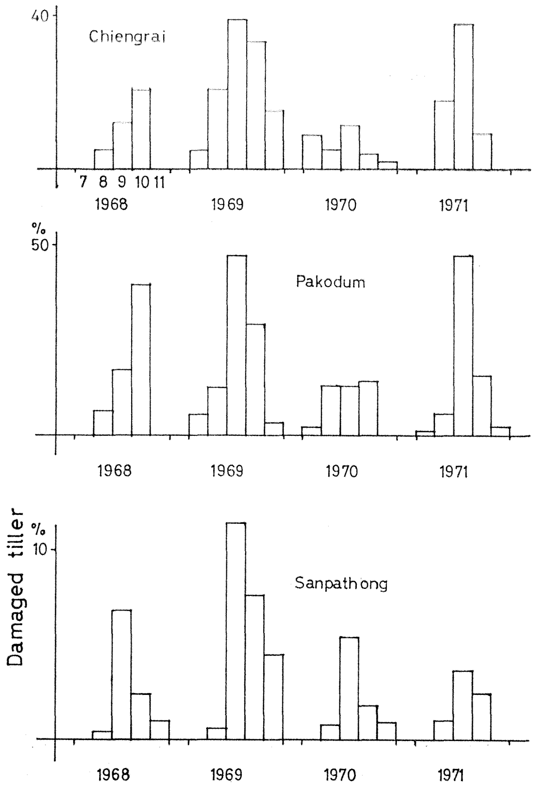

Fig. 7-8. Monthly fluctuation of damage caused by the rice gall midge on lowland rice

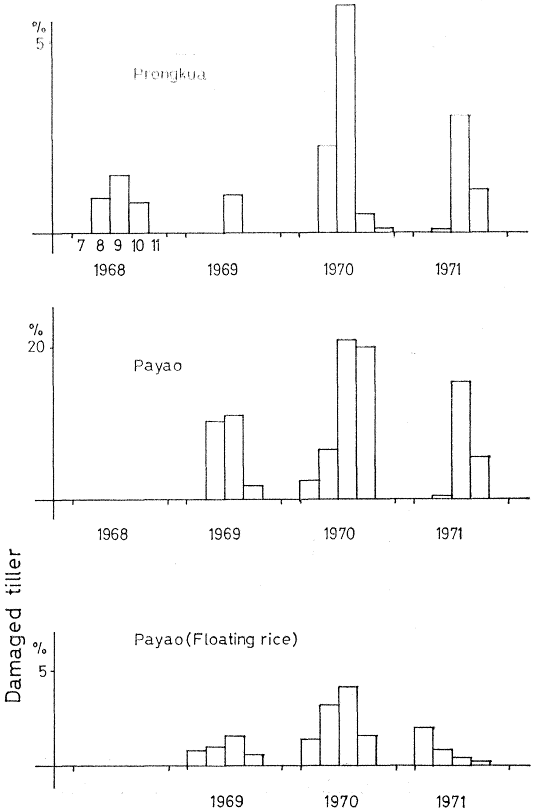

Fig. 7-9. Monthly fluctuation of damage caused by the rice gall midge on lowland rice

damage in Lampang Basin was lower than 20.5% of damaged tillers. Even in Bansai area where paddy fields were isolated and rice plants were early transplanted, the damage was only less than 35%. The result coincides with the general belief of low infestation in that Province. The peak of damage during the planting season was seen in September.

c) Floating rice (Fig. 7-9)

The occurrence of the insect on floating rice was distinctly lower than that of upland rice. The infestation on floating rice was at least 5% of damaged tillers in every years. The rice gall midge began to appear in June and disappeared in October with peak occurrence in September. The insect could not occur during November.

2) Damage in relation to monthly fluctuation of the insect occurrence

The rice gall midge began to lay eggs on rice seedlings in June, and the seedlings into which the insect larvae penetrated were transplanted to the paddy fields. When seedlings became older than 40 days after sowing, galls appeared before transplanting. The damage was usually at the seedling stage.

In paddy fields, the insect population increased from July to September and decreased from October to November, with a peak at the end of September, the insect completely disappeared at the end of September.

This pattern of the insect occurrence in a year was same with lowland, upland or floating

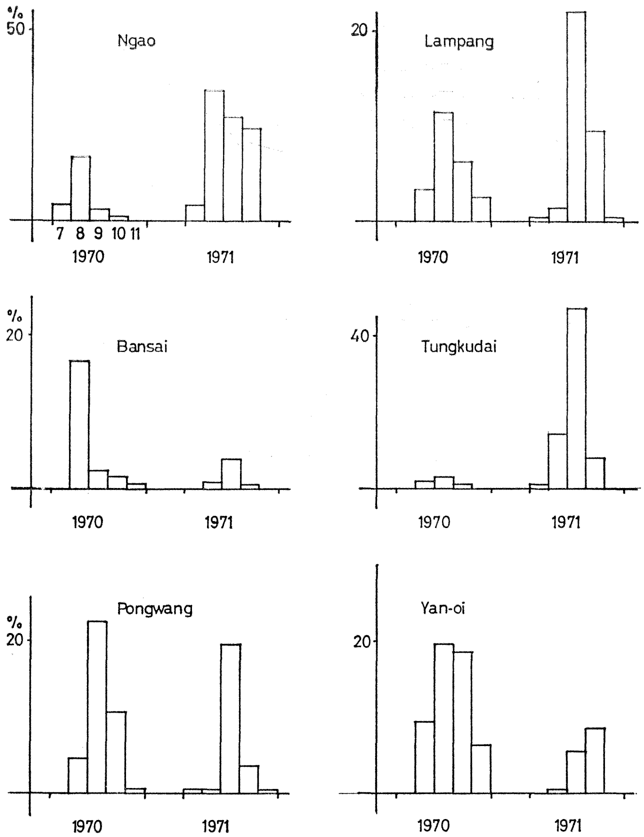

Fig. 7-10. Monthly fluctuation of damage caused by the rice gall midge on lowland rice

rice. However, due to an early sowing date of upland rice the insect occurrence was earlier with upland rice by one month than lowland rice, followed by a peak in August and insect disappearance in October. Lowland rice, however, when transplanted early followed the same pattern as upland rice, as shown at Ngao, Lampang Province. The insect damage is mainly caused by larval feeding at the tillering stage of plants, but the damage is much at the panicle primordium stage. It is important to note that the insect damage during July to September affects greatly rice yields.

3) Damage in relation to annual fluctuation of insect occurrence

Annual occurrence of the insect and crop damage during 4 years are given in Figures 7-4 to 9. In 1969, a severe outbreak of the insect was observed in Chiengrai Province except southern part of Chiengrai. As population density of the insect was extremely high, infestation more than 50% of damaged tillers was recognized in many places north of Pan. At the Pan Rice Experiment Station, percentage of damaged tillers in September was 85 in 1969 as compared with 30% in 1968, 15% in 1970, and 24% in 1971. It is apparent that population density of the insect in 1969 was significantly higher in a period of population increase between July and August than usual year. Rainfall in May and a resultant population increase of the insect bred on wild host plants between May and June responsible for such an increased population density during tillering stage of rice plants.

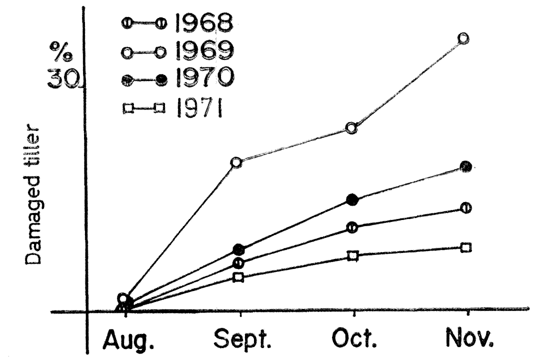

Fig. 7-11. Cummulative curve of the rice plants infested by the rice gall midge at San-pathong, 1968—1971

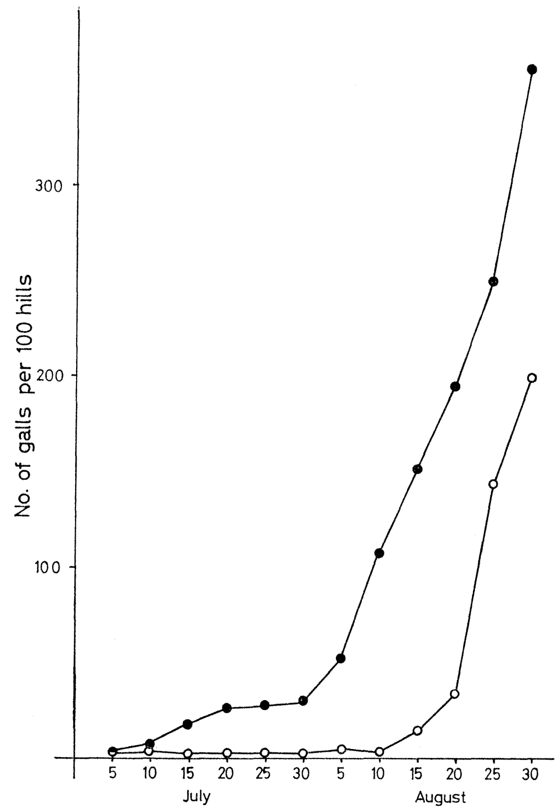

Fig. 7-12. Cummulative curves of the number of galls occurred within 2 months after transplanting at Pan in 1969 •—• and 1971 ○—○

As given in Figure 7-11, cummulative curve of damage of rice plants in 1969 was higher than that of 1968 and 1970 at the Sanpathong Rice Experiment Station where the insect population density increased rapidly from August to September in 1969, although the population density at the beginning of August was as same level as every year so far observed. It is very interesting to note that number penetrated into rice plants during July, an initial stage of insect outbreak, was great in 1969 (Fig. 7-12). It is generally thought that severe outbreak of the insect occurs every 5 to 6 years in Thailand. Survey on annual infestation on rice plants is needed to establish forecasting method of insect outbreak.

8. Seasonal prevalence of the rice gall midge

It is important to grasp real situation of seasonal prevalence of the insect for planning successful control of the insect. The forecasting method of insect occurrence could also be established if appearence, peak, and disappearance of insect occurrence are properly surveyed for long term. At the same time, analystical works on effect of environmental factors on the insect occurrence will be needed. In this context, the following studies were carried out.

METHOD

The insect adults were collected by light trap with a 40 watts transparent bulb which was usually kept lighted from just after sunset to before sunrise. The adults were instantly killed by cyanid gas contained in a glass bottle of 14 cm long×14 cm wide×15 cm high. Every morning, number of adults collected by light trap were counted in the laboratory. The survey was conducted at the Pan Rice Experiment Station from 1968 to 1972.

RESULTS

1) Seasonal fluctuation of the adult insect

Results are given in Figure 8-1 to 8. The first appearance of adults varied year by year. Adults appeared at the beginning of May during the outbreak in 1969, at the end of March in 1970, and in the middle of May in 1971 and 1972 respectively. The adult disappearance was in the middle of November in all years studied.

Peak of adult occurrence was recognized at the end of September or beginning of October. This is the time just before the panicle primordium formation stage of photoperiod-sensitive varieties. The insect repeated 6 generations from July to November in 1968, 9 from May to November in 1969, and 9 in each of 1970, 1971 and 1972 respectively. It was found that the adults of the 1st to 2nd generations were bred on wild host plants and laid eggs on rice seedlings in June. Peak population of the insect observed in the middle of September are consisted of the 4th generation adults. The insect bred on wild host plants were greater in number and smaller in body size than those bred on rice plants, It is supposed that the damage at the seedling stage is mainly caused by the insect came from wild host plants. The insect bred on rice plants gradually increased in number from the end of June to July. Source of the insect occurrence in early season could give an important key to the forecasting method of the insect occurrence.

2) Relation between the adult occurrence and climatic factors.

a) Effect of temperature on insect occurrence

Circumstances of the insect occurrence with regard to temperature and rainfall are given in Figure 8-1 to 8. Although not big fluctuation exists in mean temperature in the tropics, it is shown that a period from April to the middle of November has mean temperature higher

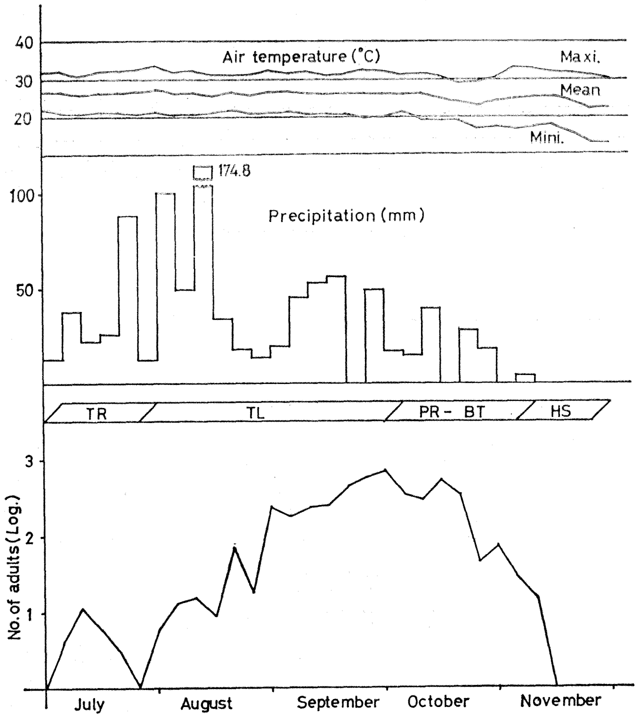

Fig. 8-1. Number of adults collected by the light trap at Pan, 1968. TR: Transplanting stage, TL: Tillering stage, PR: Panicle primordium initiation, BT: Booting stage, HS: Heading stage.

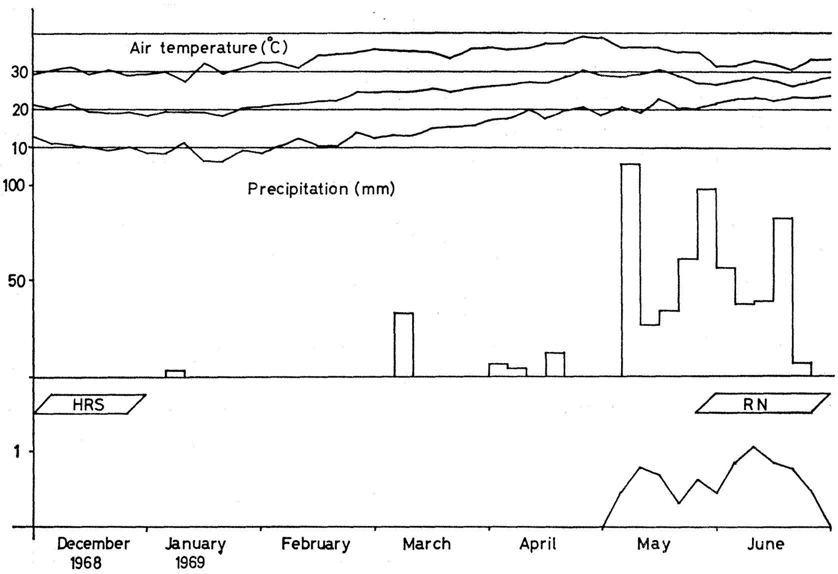

Fig. 8-2. Number of adults collected by the light trap at Pan, 1969 HRS: Harvesting, RN: Rice nursery

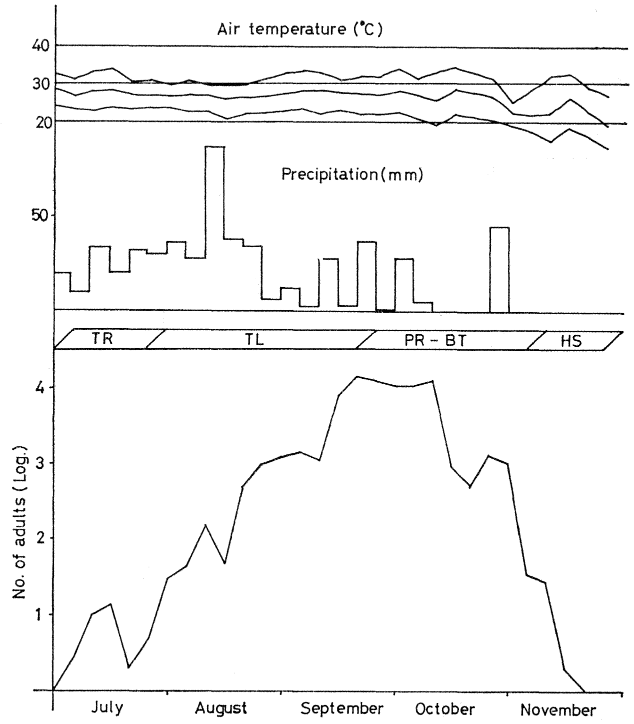

Fig. 8-3. Number of adults collected by the light trap at Pan, 1969

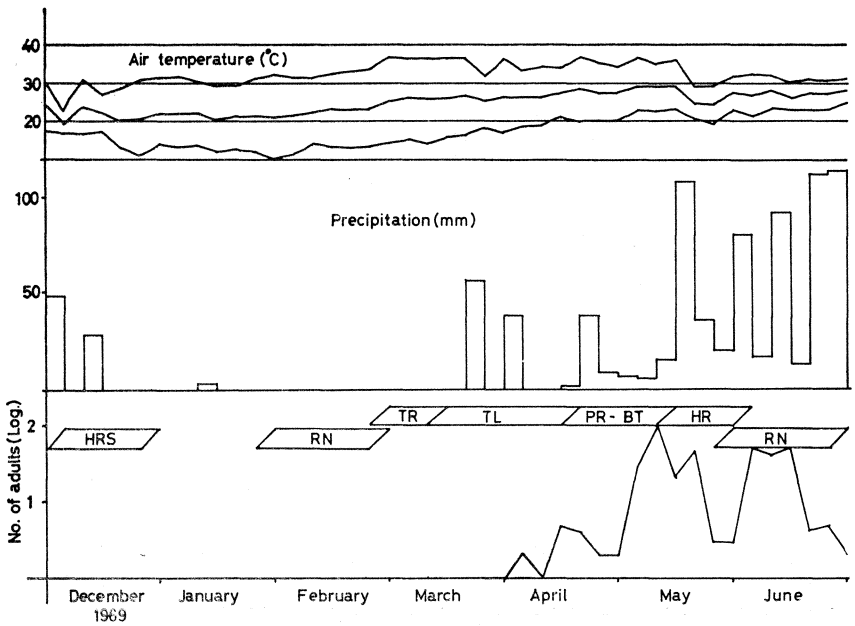

Fig. 8-4. Number of adults collected by the light trap at Pan, 1970

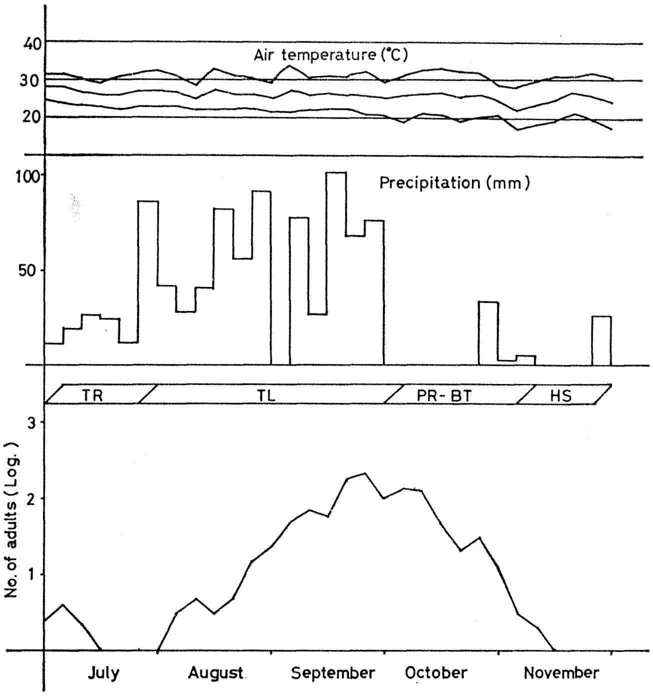

Fig. 8-5. Number of adults collected by the light trap at Pan, 1970

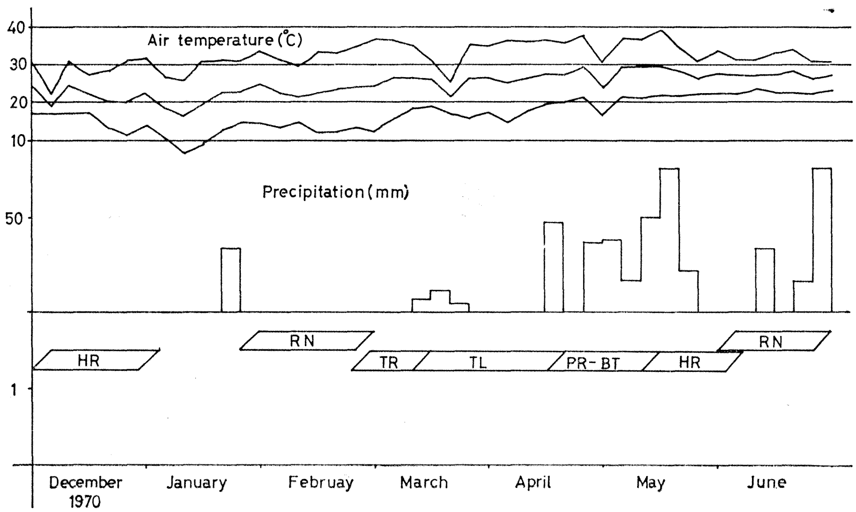

Fig. 8-6. Number of adults collected by the light trap at Pan, 1971

than 24°C, and this period corresponds to the season of insect occurrence. On the other hand, mean temperature is lower than 24°C from December to March, especially the temperature shows 19°C from December to February. Occasionally cold damage of rice plants occurs during the dry season due to the lowest temperature, 8° to 10°C, in northern Thailand. In

Chiengrai Province, northern Thailand, air temperature decreased to 6°C in December to February 1969. Differences between the highest and lowest temperatures are more than 20°C in the dry season but 7–8°C during the wet season. Effect of this temperature difference in the dry season on the larval development is not known yet. Thus, the optimum range of mean temperature for insect occurrence and development is regarded as 23°C to 27°C. It can be said that the insect is able to occur all year round under the mean temperature in the tropics, but a limiting factor is relative humidity which depends on rainfall.

b) Effect of relative humidity on the insect occurrence

It is proved that the relative humidity gives an important effect on egg hatching (Tab. 11-12), larval penetration to rice plants (Tab. 11-17), oviposition behavior of adults (Tab. 11-11), and emergence respectively. But at the following stage, larvae, prepupae, and pupae are not affected by relative humidity because they lives inside of rice plants. Relative humidity is a main factor effecting adult activities. Maximum humidity higher than 90% was observed from January to April and in the subsequent rainy season. 90% humidity took place only in the night time: 2000 to 800 hours in January, and 2400 to 800 hours in February. During the early half of March, humidity did not reach 90%, showing 80% and more from 2000 to 900 hours. In April, the humidity higher than 90% was shown only in a short time from 300 to 500 hours, whereas humidity higher than 80% was maintained from 1800 to 900 hours. Thus, the high humidity favorable to activities of the insect adults occurred in the night. The humidity in the daytime decreased to a low level (at least 30%) during the dry season. The lowest humidity was in descending order of January, February, March and April. The occurrence of the insect was not observed under the conditions where paddy field soils are dried and cracked under a low humidity.

Eggs laid on rice plants during the dry season could not hatch due to low humidity. When eggs were exposed to a low humidity for a time, the development of embryo was completely prohibited and egg shell was concaved due to loss of water. The concaved egg does not return to normal shape even after exposed to high humidity again. The low humidity affects longevity of adults so that number of eggs deposited per female is reduced even under high humidity at night. Diurnal activity of the insect is considered to be closely related with relative humidity at night.

Thus, the insect population decreased due to low humidity during the dry season. On the other hand, the humidity during the wet season, fluctuating from 60 to 90% from May to the middle of November, gave an optimum condition for development of the insect especially adult longevity and egg laying. Even in the day time, humidity higher than 60% occurred quite after from July to August due to cloudy or rainy days. In addition, the insect is given a good condition for increasing population density at the tillering stage of rice plants between July and August.

c) Effect of rainfall or water on the insect occurrence

As given in Figure 8-1 to 8, although rain pattern varied year by year, much precipitation occurred during August when the population density of the insect began to increase in every year. Rice plants were at the vegetative stage, with active tillering. The larvae of the insect were able to penetrate easily into growing points of tillers during August.

Continued rainfall and high humidity in August made the survival rate of adult higher, number of eggs per female increased, egg hatching at high percentage, and almost all of newly hatched larvae penetrate into rice plants. Egg laying of the 2nd generation after transplanting and subsequent larval penetration to plants were seen during August.

As the rainfall is a major factor influencing the insect occurrence and population density, it can be understood that the date of start of rainfall just after the dry season effects the time of initiation of growth of wild host plants and larval development on the hosts. As given

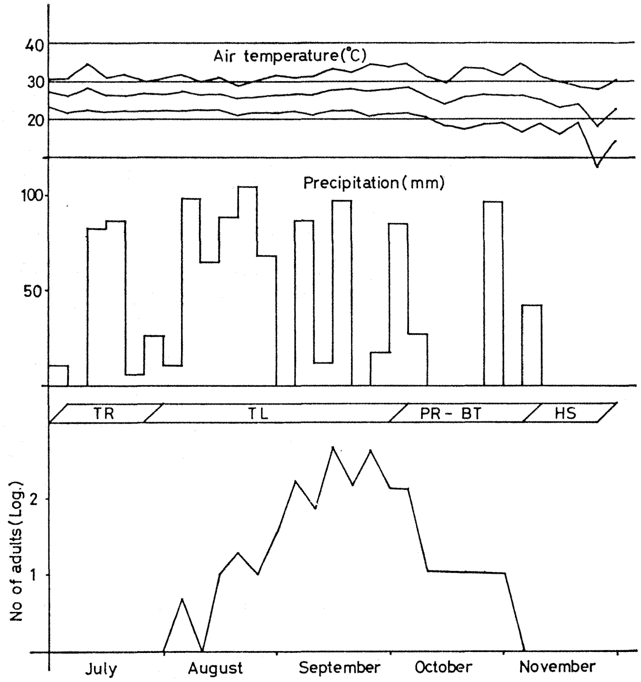

Fig. 8-7. Number of adults collected by the light trap at Pan, 1971

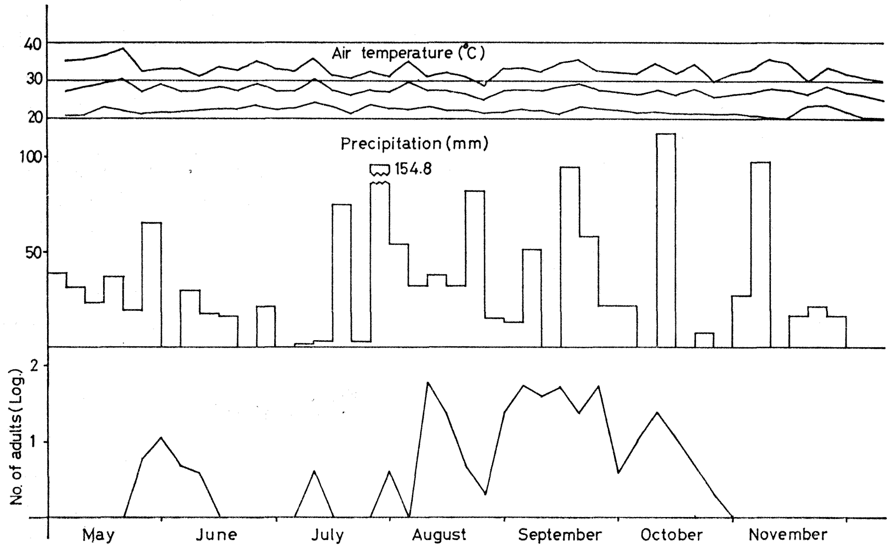

Fig. 8-8. Number of adults collected by the light trap at Pan, 1972

in Figure 8-1 to 8, if rainfall starts earlier than usual year, the rice gall midge also appears early in the season. It is presumed that larval development of the insect during the dry season is hastened by rainfall, it is also judged easily in the fact that the insect occurs from wild host plants i.e. wild rice, which is growing in swamped place, throughout all season.

9. Growth status of rice plants and insect population

This study aimed at examining the population of larvae and pupae of the insect feeding on rice plants growing paddy fields.

METHOD

Two rice varieties, Dawk Mali 3 and Leuang Twang, were transplanted at the beginning of July. Twenty hills each of the varieties were sampled at random every 7 days, and number of tillers and galls, number of growing points, panicle primordium formation, number of panicles, and height of plants were measured. The growing points of plants were taken out by foreceps or a razor and were kept in vials with 75% alcohol. Later, the growing points were carefully dissected under a binocular microscope to examine number of gall, larvae, pupae, and natural enemies. The study was carried out for 3 years from 1969 to 1971, at the Pan Rice Experiment Station in 1969 and 1970 and at Pan and Pasang in Chiengrai in 1971.

RESULTS

1) Increase of the insect population density

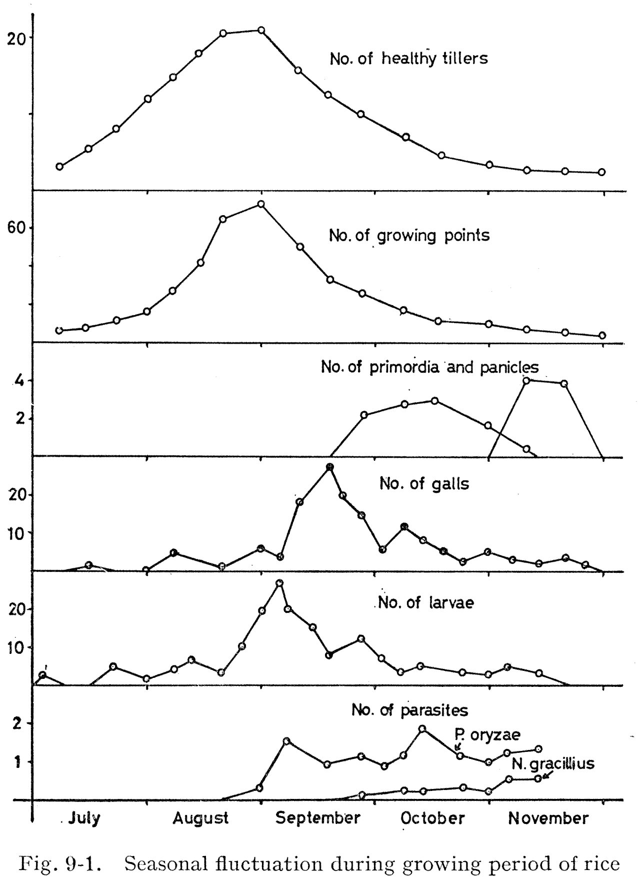

Fig. 9-1. Seasonal fluctuation during growing period of rice plants at Pan Rice Experiment Station, 1969

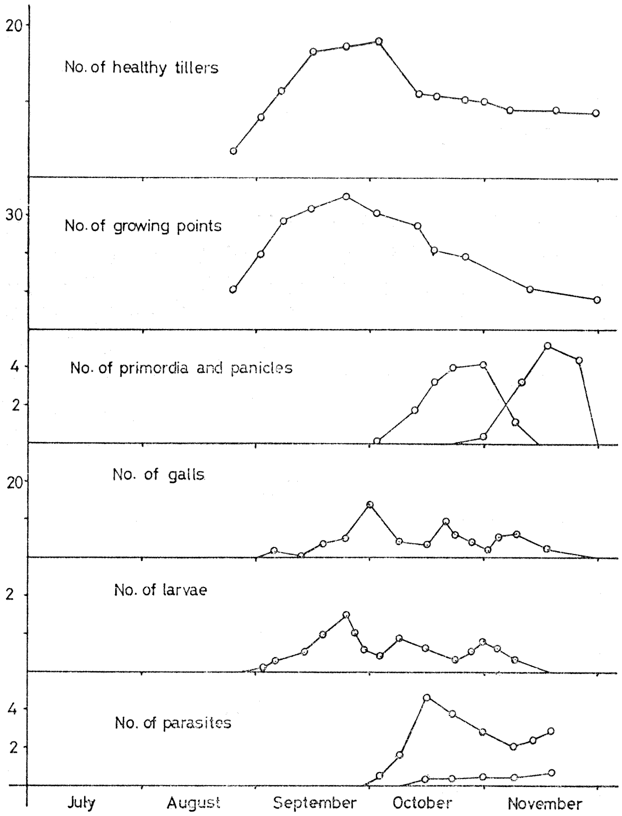

Fig. 9-2. Seasonal fluctuation during growing period of rice plants at Pan Rice Experiment Station, 1969

No significant difference was observed in the process of the insect occurrence in 3 years, although the adult population fluctuated year by year. As given in Figure 9-1 to 3, larvae appeared on rice plants at the beginning or the middle of July. The larvae growing in seedlings produced galls soon after transplanting. The 1st to 3rd generations of the insect increased their population density during August when the rice plants were at the tillering stage. An important fact was found at this stage; the population density of the insect increased in proportion to the number of tillers and growing points of plants until the maximum tillers stage at the end of August or at the beginning of September. The highest population density of the larvae was seen in the 4th generation at the maximum tillers stage, and hence the peak of number of galls was recognized between the maximum tillers stage and panicle primordium formation stage. Thus, it was made clear that the insect increased in number during the tillering stage in proportion to the numbers of tillers and growing points.

2) Reduction of the insect population density

After the maximum tillers stage, the population density of larvae of 5 to 7th generations began to decrease and finally disappeared from the fields. This decrease of population density is closely related to the panicle primordium formation and reduction in number of tillers and growing points as given in Figure 9-5. The facts that the survival rate of larvae decreases remarkably after the panicle primordium formation, and that most of galls occurred on invalid

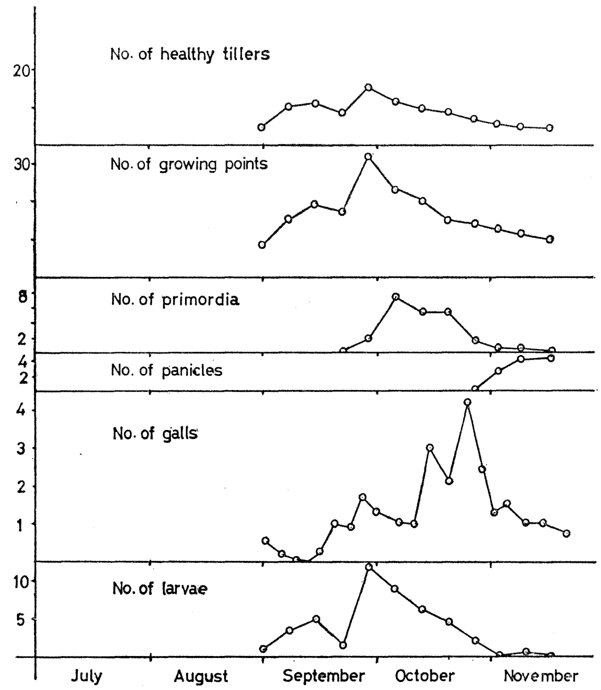

Fig. 9-3. Seasonal fluctuation during growing period of rice plants at Pan Rice Experiment Station, 1970

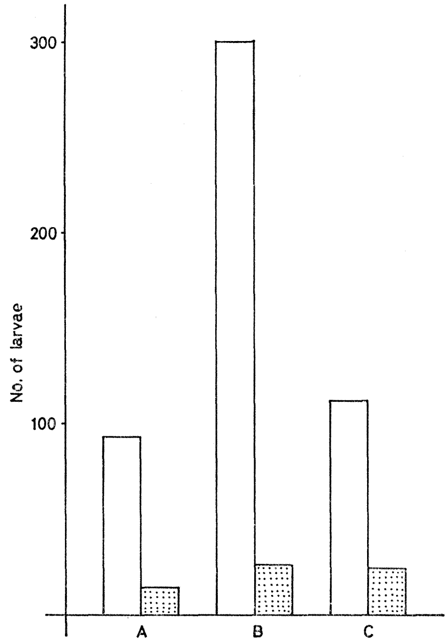

Fig. 9-4. Number of larvae survived in the vegitative ☐ and reproductive ▒ growth periods of rice plants at Pan (A 1971 and C 1970) and Pasang B 1971.

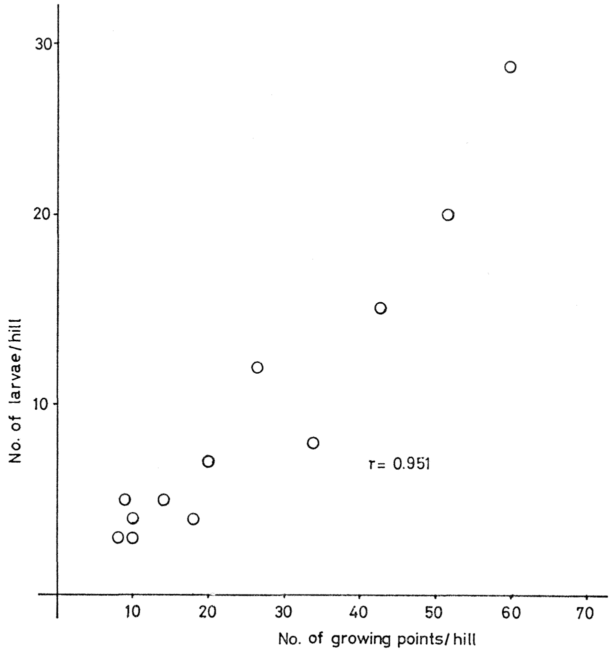

Fig. 9-5. Relation between numbers of larvae and growing points at Pan, 1969

tillers after the heading stage suggest strongly that the panicle primordium does not permit the survival of larvae. Thus, an increase and decrease in the insect population is controlled by the growth status of rice plant itself.

3) Insect occurrence in the late transplanting of photoperiod-sensitive variety

With Dawk Mali 3, transplanted at the end of August, it was found that population density of the insect proceeded in a low level. As given in Figure 9-2, a period from transplanting to panicle primordium formation was shortened to only 35 days, during which the insect was able to complete only one generation. The shortening of the vegetative growth period caused by the late transplanting can be used as a practical means to reduce population density of the insect. Variation in the insect population observed from year to year can partly be explained by different transplanting date which influences the length of vegetative duration with photoperiod-sensitive varieties.

4) Insect occurrence with photoperiod non-sensitive variety

Unlike photoperiod-sensitive varieties, Leuang Twang, a typical nonsensitive variety has 60 days of vegetative growth duration irrespective of the date of transplanting. Total growth period is about 120 days. When Leuang Twang was transplanted at the end of August. Panicle primordium was formed at the end of September. On the other hand, the midge population reached a peak at the end of September. As a result, a large number of galls appeared after the panicle primordium formation stage. Thus, the majority of larvae survived in invalid tillers and their number decreased remarkably later.

5) Discussion

Interesting relationships were revealed between plant growth and insect population as well as infestation. The insect population increases during the vegetative growth period (tillering stage) in proportion to number of tillers produced and hence number of growing points developed, reaching the peak at the maximum tillers stage. It is suggested that control measures should be established during the tillering stage. After panicle primordium were developed, the survival rate of the larvae declines because of a decreasing number of vegetative growing points. With photoperiod sensitive varieties, duration of vegetative growth period is reduced by late transplanting. This has a definite influence on a recycling of generations of the insect. For example, with Dawk Mali 3 transplanted at the end of Augusut the insect completed only one generation during the vegetative growth period, resulting in a low level of population. This fact furnishes a possibility of an agronomic control method to the insect.

10. Natural enemies of the rice gall midge

As an important biological environmental factor, natural enemies should not be neglected. The present study was carried out with an aim of searching for promissing natural enemies for the biological control.

METHOD

1) In order to clarify relationships between natural enemies (parasite and predator) and the rice gall midge, the survey was carried out at 10 places, Payao, Pan, Chiengrai, Pasang, and Santhonpui in Chiengrai Province, Ngao, Bansai, Lampang, and Yan-oi in Lampang Province, and Sanpathong in Chiengmai Province, from August to November in both 1970 and 1971. Percentage of damaged tillers was examined once a month and 200 galls were collected from each place a week. The galls were dissected using a binocular microscope, and number of the rice gall midge and its natural enemies were counted.

2) Seasonal activities of Hymenopterous parasites of the rice gall midge on wild rice were studied throughout the year. Galls occurred in 5 m^2 of wild rice field were counted once a week with 3 replications. All of them were sampled. Number of adults emerged and parasites on the gall were counted in the laboratory.

3) In paddy fields at the Pan Rice Experiment Station and Pasang in Chiengrai Province, occurrence of galls was counted on 100 hills per plot with 3 replications every 3 to 4 days. Number of adults and parasites on galls was recorded.

4) Twenth hills of rice plants were sampled at random in the fields once a week. Number of the midges, galls and parasites on the galls collected was counted. Besides, number of tillers, growing points, panicle primordia, and panicle was also counted.

RESULTS

1) Species and distribution of natural enemies of the rice gall midge.

a) Hymenopterous parasite.

Three primary parasites of the host insect were found as listed below.

(1) *Platygaster oryzae* (Cameron), Platygasteridae
(2) *Platygaster* sp. Platygasteridae
(3) *Neanastatus gracillius* (Masi) Eupelmidae

b) Predator

Only one sepcies of predator was recorded.

(1) *Ophionia indica* (Thunberg) Carabidae

2) Parasitic activities of parasites.

a) In case of Chiengrai Province, 1970

Results of parasitic activities of parasites were given in Figure 10-1 to 5. More than 50%

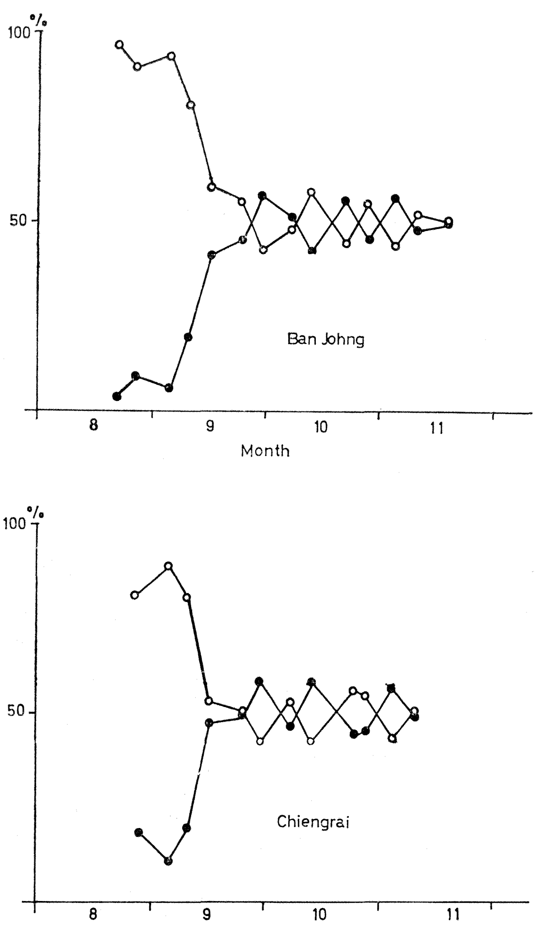

Fig. 10-1. Percentage of parasitism and that of infestation of the rice gall midge at Johng and Chiengrai, 1970.
•—• Parasite and predator, o—o The rice gall midge

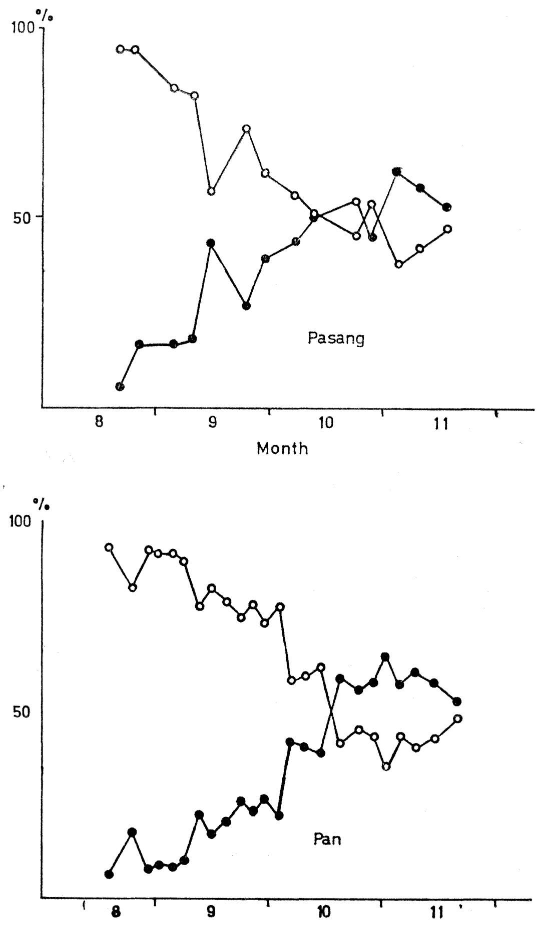

Fig. 10-2. Percentage of parasitism and that of infestation of the rice gall midge at Pasang and Pan, 1970.
•—• Parasite and predator, o—o The rice gall midge

of parasitism was attained on September 29 at Maesai, October 23 at Pasang, September 29 at Chiengrai, October 19 at Pan, and September 15 at Payao respectively.

The date when the parasitism reached 50% was earliest at Payao followed by Maesai, Chiengrai, Pan, and Pasang. It was revealed that if parasitism reached 50% in early date, damage of rice plants was definitely reduced, for example, less than 10% of damaged tillers at Payao whereas more than 50% at Pasang. Population of the rice gall midge was well controlled by the parasite which began its activity at an early date. It can be said in general, if 50% parasitism is attained before a peak of the insect damage at the end of September, damage is prominently reduced, but not when it occurs later. Parasitism was maintained higher than 50% from the date of 50% attainment to the harvesting in all places surveyed. Average parasitism during a crop season was 46.86% at Payao, 43.2 at Chiengrai, 38.6 at Maesai, 33.3 at Pan, and 36.6 at Pasang. Less crop damage was seen where the parasitism

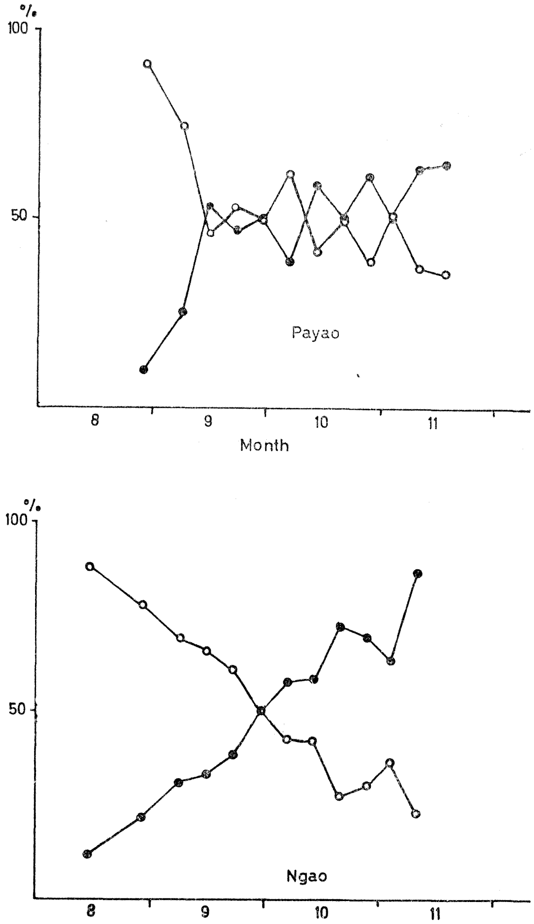

Fig. 10-3. Percentage of parasitism and that of infestation of the rice gall midge at Payao and Ngao, 1970.
•—• Parasite and predator, o—o The rice gall midge

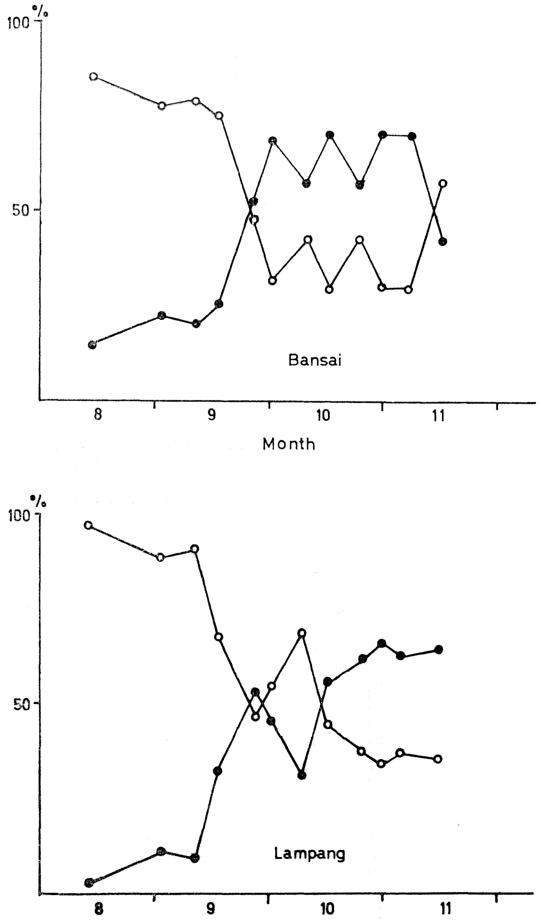

Fig. 10-4. Percentage of parasitism and that of infestation of the rice gall midge at Bansai and Lampang, 1970.
•—• Parasite and predator, o—o The rice gall midge

was high.

b) In case of Lampang Province, 1970

Results are given in Figures 10-3 and 4. It was recognized that the parasitism reached 50% in a period from September 26 to October 1st. An early transplanting of local varieties was a usual practice at Ngao. The transplanting was made in June, 30 days earlier than other places. The parasitism, however, was low although population density of the rice gall midge was high during the tillering stage between July and August. Afterward, the parasitism increased to as high as 76.9% in the middle of September, resulting in more than 50% of the midge population suppressed in October. The parasitism at other places; Bansai, Lampang, and Yan-Oi, showed the similar trend as Ngao. Average parasitism at four locations surveyed was 45 to 50% higher than that observed in Chiengrai Province. This can account for the fact that there was no outbreak of the insect recently.

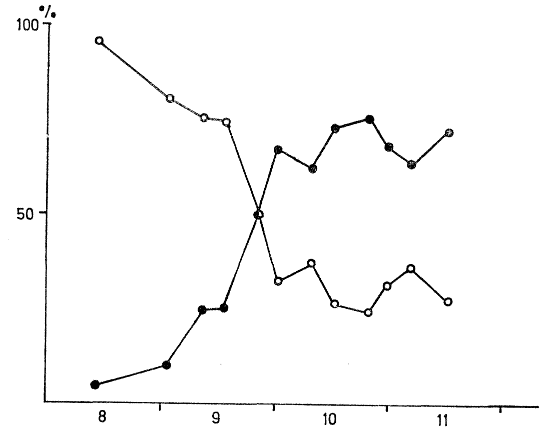

Fig. 10-5. Percentage of parasitism and that of infestation of the rice gall midge at Yan-oi, 1970.
•—• Parasite and predator, o—o The rice gall miage

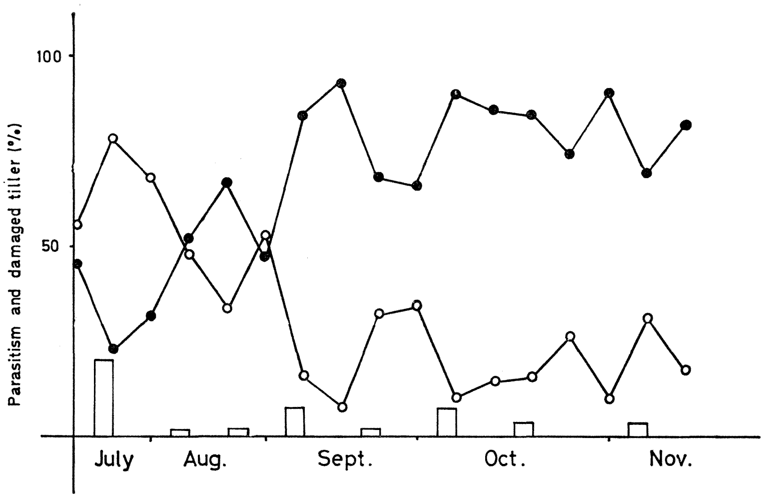

Fig. 10-6. Parasitic relationship between the rice gall midge and natural enemies at Sanpathong Rice Experiment Station, 1970. o—o Natural enemies, •—• The rice gall midge, ▭ Damaged tiller

c) In case of the Sanpathong Rice Experiment Station, Chiengmai Province, 1970.

Results are given in Figure 10-6. Chiengmai Province has been famous for the double cropping of rice in Thailand. Fortunately the outbreak of the rice gall midge has not been recorded at all. It is interesting to note that the parasitism reached 50% at rice nuseries in the middle of August, and the rice gall midge population was kept suppressed due to high parasitism more than 60%. This phenomenon could not be seen in Chiengrai and Lampang Provinces.

d) Chiengrai Province, 1971

Results are given in Figures 10-7 to 9. In 1971, the parasitism was apparently lower

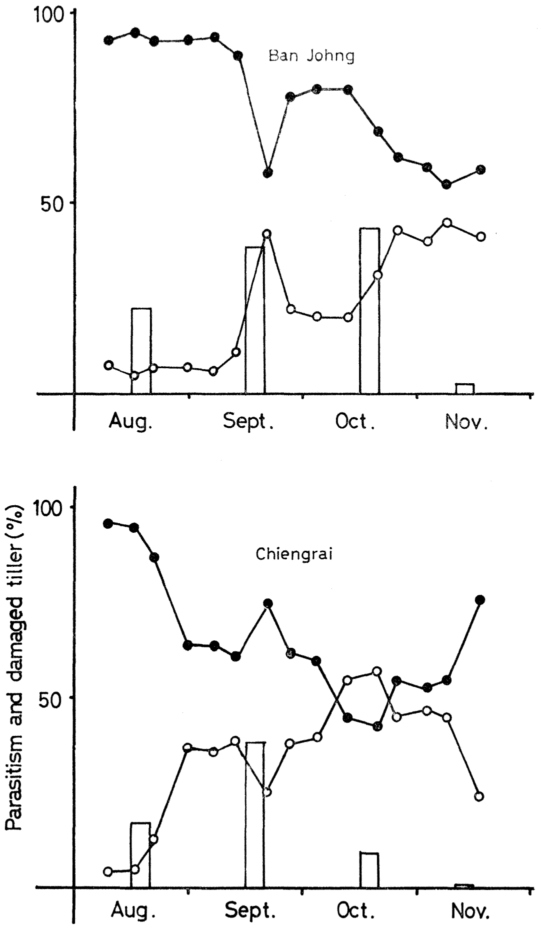

Fig. 10-7. Percentage of parasitism and that of infestation of the rice gall midge at Johng and Chiengrai, 1971.
o—o Parasite and predator, •—• The rice gall midge, ▭ Damaged tiller

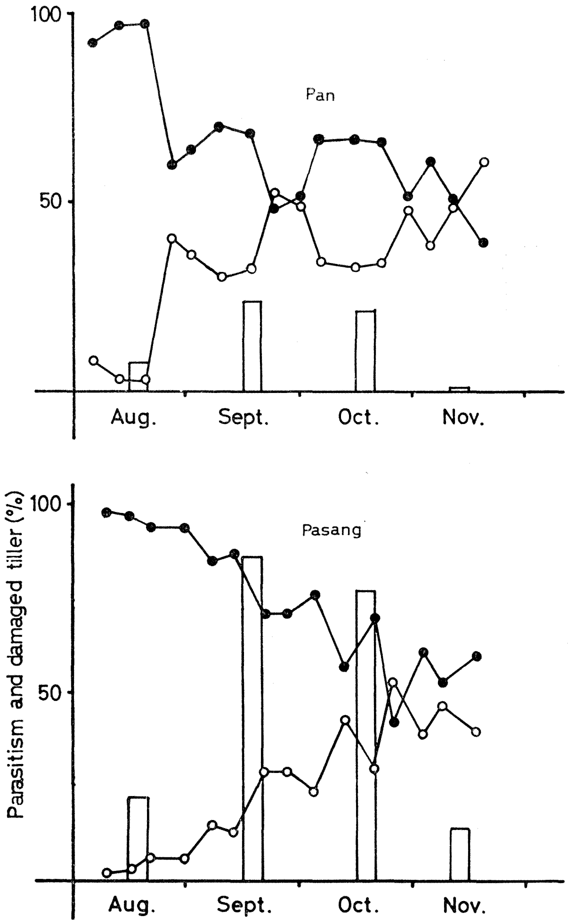

Fig. 10-8. Percentage of parasitism and that of infestation of the rice gall midge at Pan and Pasang, 1971.
o—o Parasite and predator, •—• The rice gall midge, ▭ Damaged tiller

than the previous year. The parasitism reached 50% on October 25 at Pasang, October 12 at Chiengrai, September 24 at Pan, and September 29 at Payao, but did not at Maesai in 1971. The parasitism was from 20 to 40% for each place after the above date. At Maesai, the rice gall midge increased in number but the parasitism was lower than that in 1970. The percentage of damaged tillers was higher than 50. Average parasitism in 1971 was 24.3% at Maesai, 26.6 at Pasang, 36.6 at Chiengrai, 32.3 at Pan, and 27.3 at Payao respectively.

e) Lampang Province in 1971.

As given in Figure 10-10, high percentage of parasitism were observed from the middle of September to harvesting time. The date when the parasitism reached 50% was September 29 at Ngao, October 6 at Bansai, October 6 at Lampang, and September 30 at Yan-oi. Average for the season was 33.5% at Ngao, 30.1 at Lampang, and 46.4 at Yan-oi. Especially at Yan-oi, 80%, highest in Lampang Province, was recorded from the end of October to the

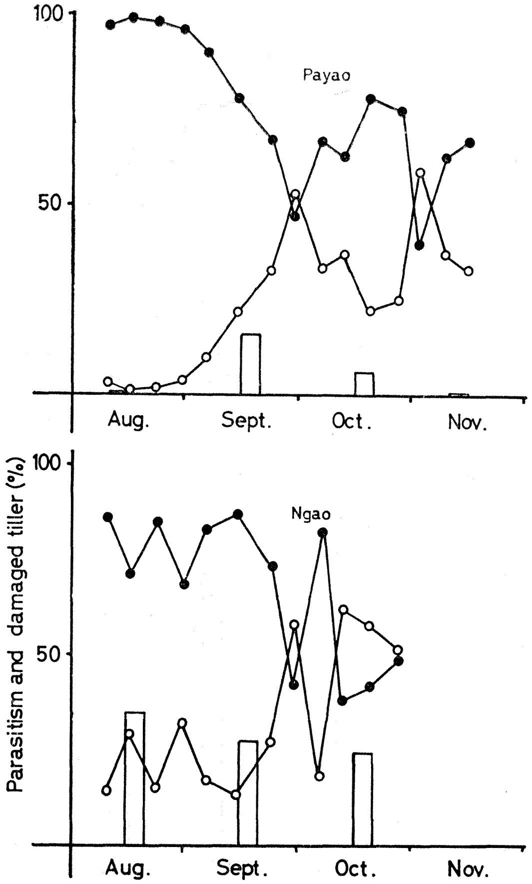

Fig. 10-9. Percentage of parasitism and that of infestation of the rice gall midge at Payao and Ngao, 1971. o—o Parasite and predator, •—• The rice gall midge, ☐ Damaged tiller

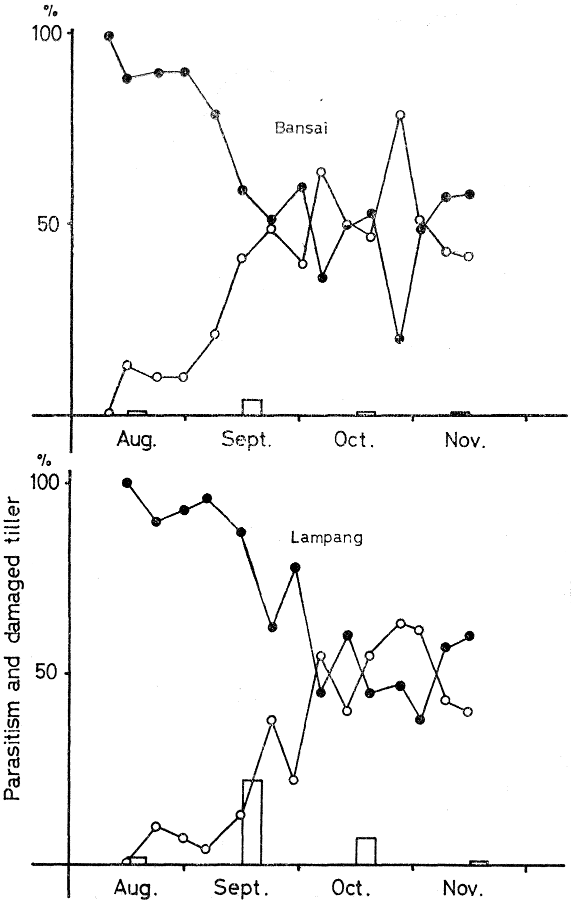

Fig. 10-10. Percentage of parasitism and that of infestation of the rice gall midge at Bansai and Lampang, 1971.

beginning of November, and damaged tillers was less than 5%.

f) Sanpathong Rice Experiment Station in 1971.

Results in 1971 were quite different from 1970 as given in Figure 10-11. The parasitism reached 50% on October 20, two month later than the previous year. Occurrence of the rice gall midge on RD 1 was numerous but parasitic activities of parasites were reduced.

3) Dominant relationships between parasites and predators.

a) Struggle among the parasites.

Platygaster oryzae (Cameron) is an egg-larval, polyembryonic, endoparasite which emerge from matured larvae of the rice gall midge. *Platygaster* sp. and *N. gracillius* (Masi) are larval parasites, monoparasitic and external parasitic. The parasites emerge from matured larvae of the host insect as *P. oryzae* (Cameron) does.

A predator *Ophionia indica* (Thunberg) of the family Carabidae feeds on larvae or pupae

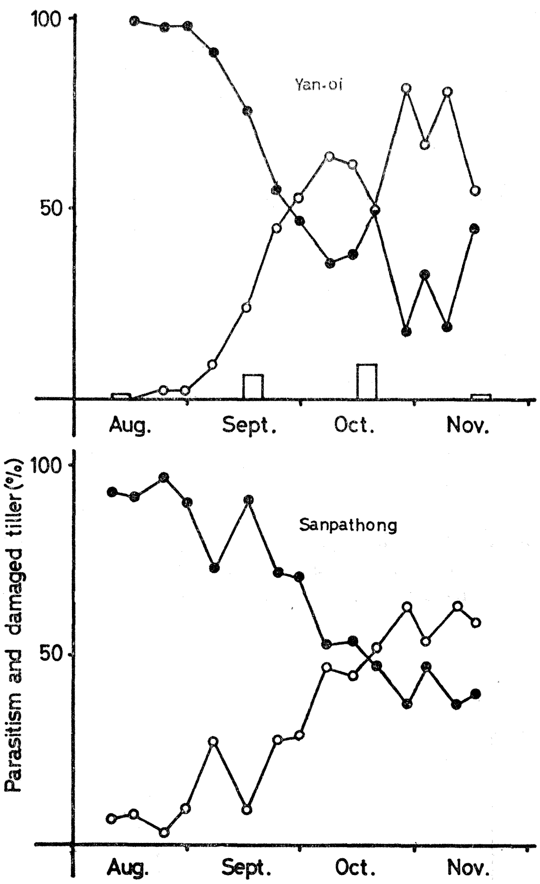

Fig. 10-11. Percentage of parasitism and that of infestation of the rice gall midge at Yan-oi and Sanpathong, 1971. o—o Parasite and predator, •—• The rice gall midge, □ Damaged tiller

of the rice gall midge in gall. The carabid larvae penetrate into galls through punctures made by strong larval mandibles.

Results obtained from the survey are give in Figures 10-12 to 18. *Platygaster oryzae* (Cameron) was most dominant in population in all places except the Sanpathong Rice Experiment Station throughout a rice season. It occupied more than 50% of primary parasites and rapidly increased from September to November. *Platygaster* sp. outnumbered *N. gracillius* (Masi) at Payao, Chiengrai, Bansai, Ngao, Yan-oi, Lampang, and Sanpathong while the latter outnumbered the former at Pan and Pasang in Chiengrai Province. Both Chiengrai and Ngao Districts showed much higher population of *Platygaster* sp. than *N. gracillius* (Masi).

Seasonal fluctuation of population density of the parasites at the Sanpathong Rice Experiment Station in 1970 is as follows: Population of *Platygaster* sp. was higher in August and September than other parasites. *Platygaster* sp. and *N. gracillius* (Masi) attacked the rice gall midge in rice seedlings from July to August, and the parasitism reached 70% in the middle of August. At Sanpathong the parasites occurred 30 to 40 days earlier than in Lampang

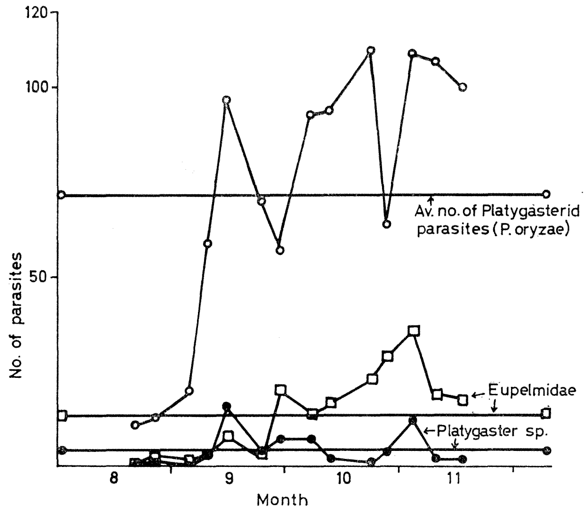

Fig. 10-12. Population dynamics of the parasites of the rice gall midge at Pasang, 1970. o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*, •—• *Platygaster* sp.

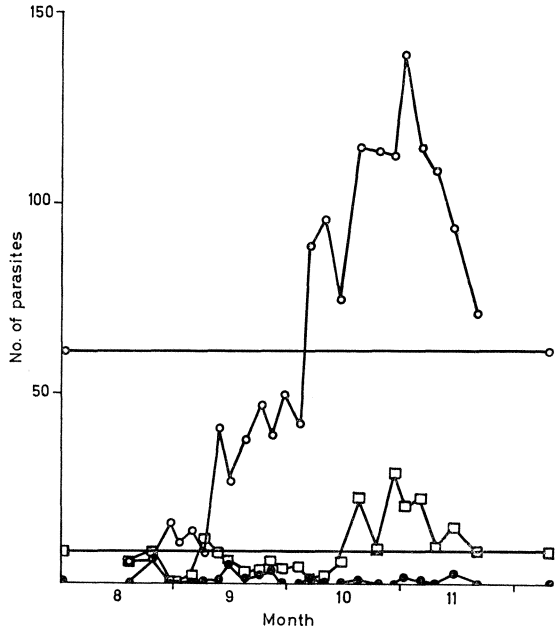

Fig. 10-13. Population dynamics of the parasites of the rice gall midge at Pan, 1970. o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*, •—• *Platygaster* sp.

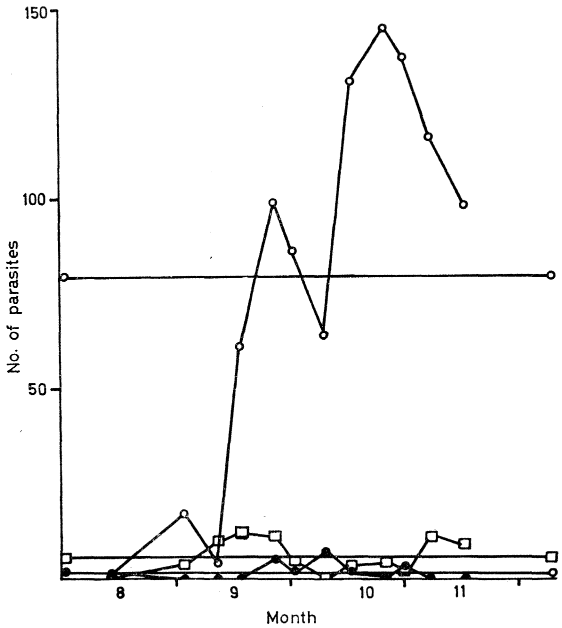

Fig. 10-14. Population dynamics of the parasites of the rice gall midge at Lampang, 1970. o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*, •—• *Platygaster* sp.

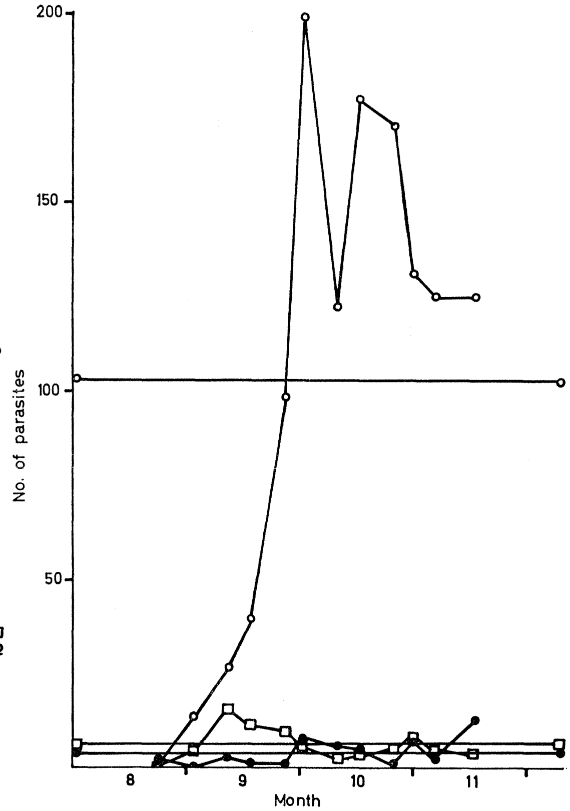

Fig. 10-15. Population dynamics of the parasites of the rice gall midge at Yan-oi, 1970. o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*, •—• *Platygaster* sp.

and Chiengrai Provinces and suppressed the population of the rice gall midge particularly in a later period from September to November. Damaged tiller was found at least 5% throughout a growing season. Emergence of the insect was 10 to 15% between September and October. Then, *Platygaster oryzae* began to build up her population at the end of September and it occupied 35% of total number of parasites at the beginning of November, while *Platygaster* sp. declined to 10% from September to November. Apparently the dominant species was shifted. A high population of the parasites occurred from the middle of July at Sanpathong can be explained by the fact that the parasites grown on the dry season rice crop in Chiengmai migrated to seedlings of the wet season rice from June to July. In 1971, however, population increase of the parasites on rice seedlings was not recognized, because an insecticide was applied to rice seedlings. But *P. oryzae* (Cameron) began to increase in number from the end of September, reaching a peak of population, as observed in Lampang and Chiengrai Provinces. Rate of damaged tiller was 20% with RD 1 and less than 5% with other varieties in Sanpathong.

b) Predator in 1970 and 1971.

Population density of *O. indica* (Thunberg) was less than Hymenopterous parasites.

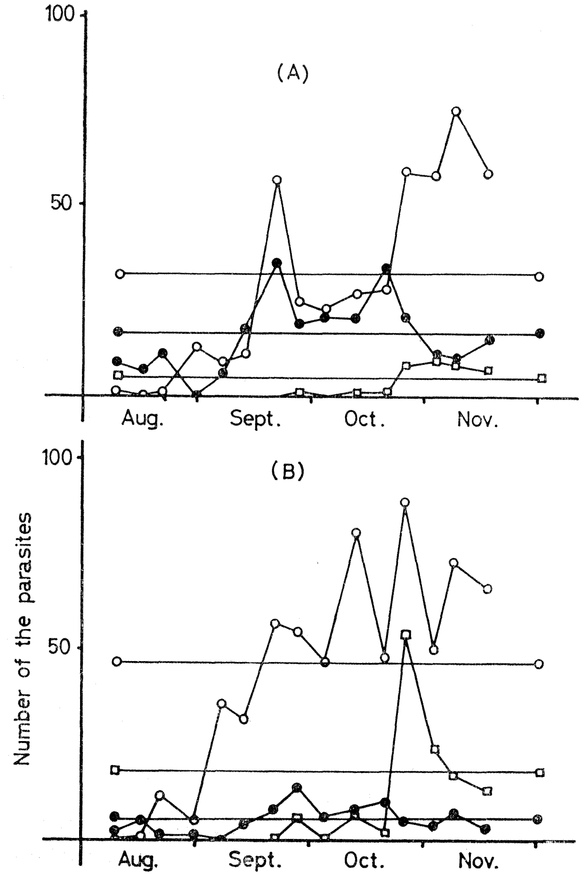

Fig. 10-16. Population dynamics of the parasites of the rice gall midge at Johng (A) and Pasang (B), 1971.
o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*,
•—• *Platygaster* sp.

The predators attack not only larvae and pupae of the rice gall midge but also other insects in paddy fields. As the number of the predator larvae collected at random in paddy fields was very few, seasonal fluctuation of population density of the predator was not made clear in 3 provinces. As predation was only 0.46 to 10% in fields, it is probable that the predator did not affect population fluctuation of the rice gall midge.

4) Occurrence of the rice gall midge and parasitic activity of natural enemies on wild rice.

a) Pan Rice Experiment Station, 1970

Wild rice was found growing around ponds in swampy areas throughout the year. Wild rice growing in the dry season is a very important source of rice insect pests. Therefore, the rice gall midge and natural enemies on the wild rice were surveyed during the dry and wet seasons.

As given in Figure 10-19, the parasitism was 8 to 21% in April and May with two peaks in the middle of April and end of May. From June to the end of September, the parasitism varied from 0 to 25%, with peaks occurring in each month. In October, the parasitism

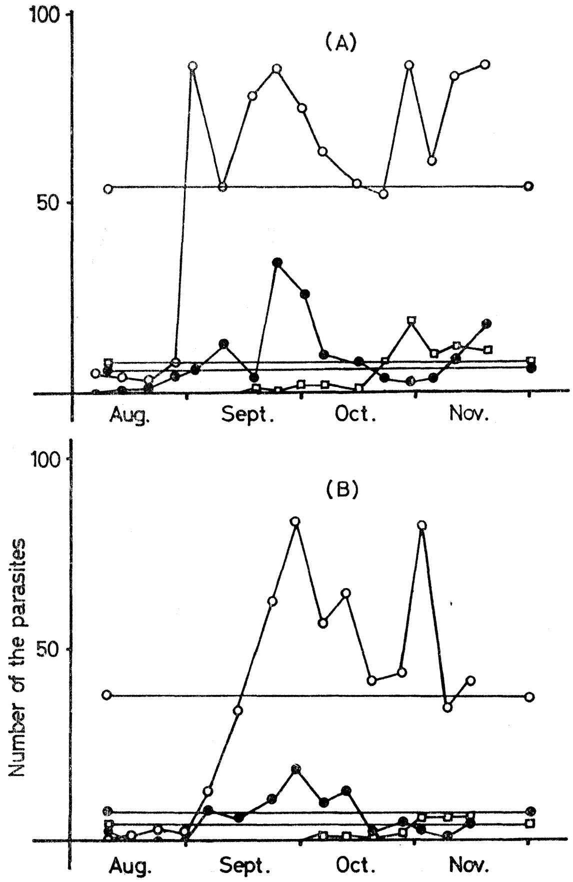

Fig. 10-17. Population dynamics of the parasites of the rice gall midge at Pan (A) and Payao (B), 1971.
o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*,
•—• *Platygaster* sp.

increased rapidly to a level of 28 to 53%. This increase was about a month later than the usual time of increase with cultivated rice, being caused by an increasing number of the rice gall midge migrated from cultivated rice to wild rice. Dominant species was *P. oryzae* (Cameron) in the wet season as well as dry season. However, *Platygaster* sp. and *N. gracillius* (Masi) appeared from October, with the former appearing mainly in November.

b) Pan Rice Experiment Station, 1971

As given in Figure 10-20, parasitism was 25 to 88% between January and February, 4 to 50% between March and May, 0 to 35% between June and October except 100% observed in July, and 61% at the beginning of December. *P. oryzae* (Cameron) was a dominant species, and two other parasites occurred intermittently at low level of population density.

c) Pan Rice Experiment Station, 1972

The rice gall midge are collected intermittently from January to May. In some periods during the survey, the parasites could not be seen at all. Growth of wild rice was very good as usual year. It is presumed that the rice gall midge is controlled by the parasites occurred

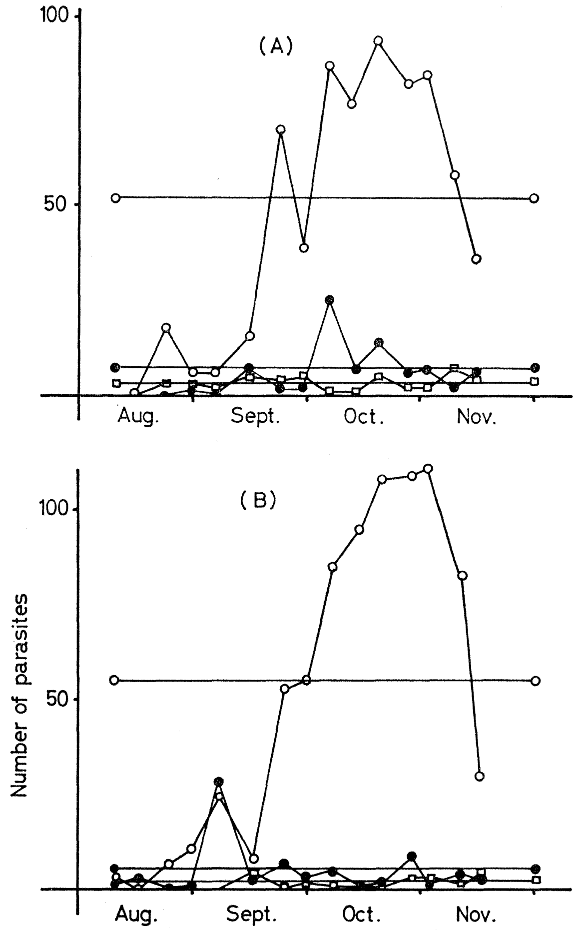

Fig. 10-18. Population dynamics of the parasites of the rice gall midge at Lampang (A) and Sanpathong (B), 1971.
o—o *Platygaster oryzae*, □—□ *Neanastatus gracillius*, •—• *Platygaster* sp.

at the end of the previous year.

d) Maelao in Chiengrai Province, 1970.

In this area, wild rice seeds remain in a dormant state under soil and germinate with rainfall at the beginning of the wet season. Thus, the wild rice grows only in the wet season.

The survey was carried out every 4 or 5 days starting from August 7. Results are given in Figure 10-21. Parasitism was more than 50% in September and November, and 10 to 35% in August and October. Dominant species of natural enemies was *P. oryzae* (Cameron). Number of the parasite collected for each survey was 38.4 in an average. Annual average parasitism was 26.9%. Dominant relationship between the rice gall midge and its natural enemies is given in Table 10-1. *P. oryzae* (Cameron) occupied 85% of total number of natural enemies.

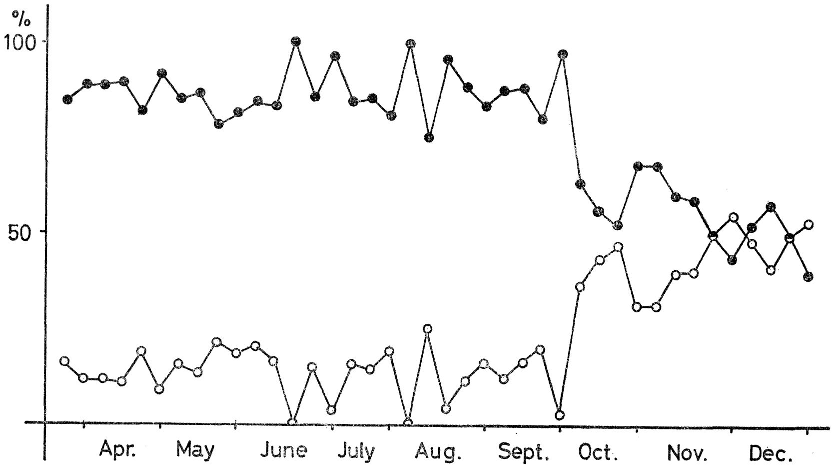

Fig. 10-19. Percentage of parasitism of the Hymenopterous parasites of the rice gall midge on wild rice at Pan, 1970. ○—○ The parasites, •—• The gall midge.

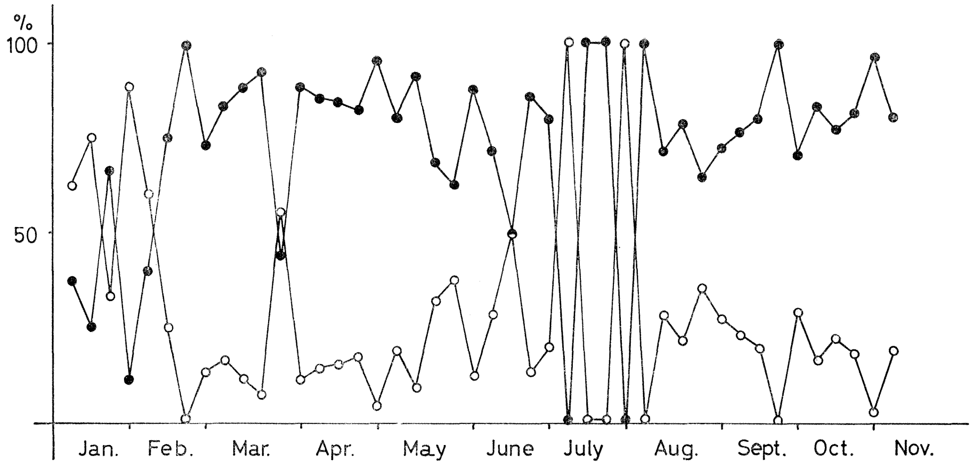

Fig. 10-20. Percentage of parasitism of the Hymenopterous parasites of the rice gall midge on wild rice at Pan, 1971. ○—○ The parasites, •—• The gall midge

e) **Maelao in Chiengrai Province, 1971.**

Total of 1746 galls were collected from wild rice at Maelao. Annual parasitism was 3.37% in an average. The rice gall midge began to appear from the end of June and parasitism more than 50% was observed on November 3rd and 17th. As shown in Table 10-2, population density of the natural enemies was remarkably lower than the previous year. *P. oryzae* (Cameron) was slightly dominant in number than other parasites.

5) **Relationships between parasitism and planting dates of rice plants.**

As clearly shown in Figure 10-23, a late transplanting of rice caused the distinctly high

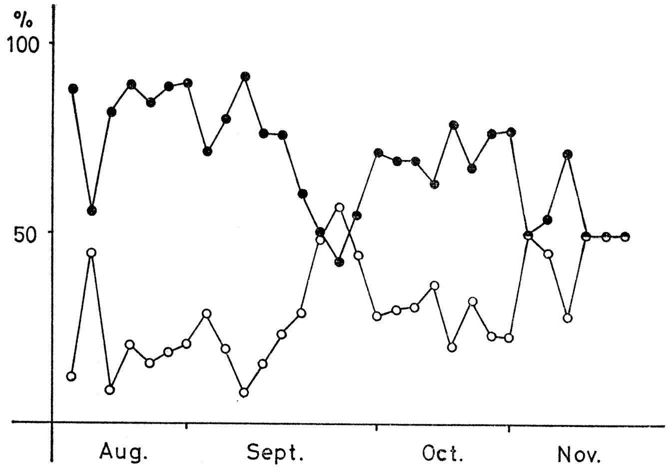

Fig. 10-21. Percentage of parasitism of the Hymenopterous parasites of the rice gall midge on wild rice at Maelao in Chiengrai, 1970. o—o The parasites, •—• The gall midge.

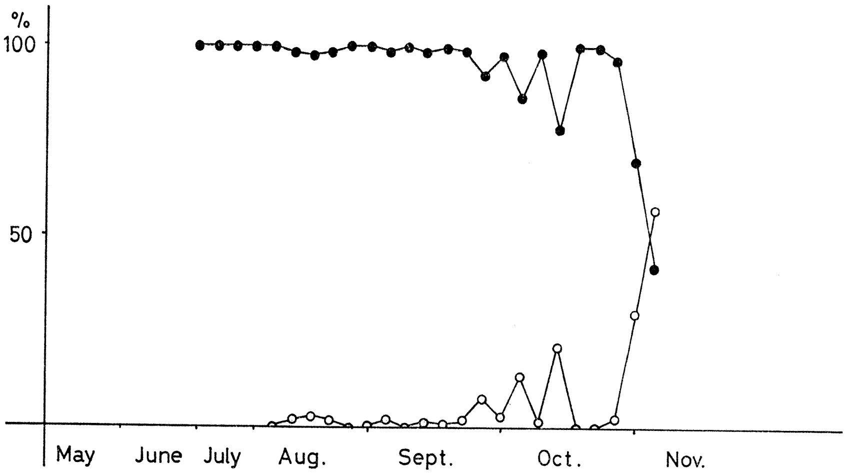

Fig. 10-22. Percentage of parasitism of the Hymenopterous parasites of the rice gall midge on wild rice at Maelao, 1971. o—o The parasites, •—• The gall midge.

parasitism both with Dawk Mali 3 and Leuang Twang. The reason for that high parasitism can be explained by the fact that the rice gall midge growing in the late transplanted plants was exposed to the concentrated attack of the parasite which increased its population in September. The parasite, *Platygaster oryzae* (Cameron), was collected for the first time on September in an early transplanting and October 5 in a late transplanting of Dawk Mali 3. These dates were 60 and 40 days after transplanting respectively. Period of the occurrence of the parasite was 69 days in the early planting and 41 days in the late planting of Dawk Mali 3,

Table 10–1. Dominant relationship between the rice gall midge and its natural enemies on wild rice at Maelao, 1970

Species	Average no. of individuals collected	Average parasitism (%)
The rice gall midge	98.89	69.29*
P. oryzae	38.39	26.90
Platygaster sp.	3.50	0.03
N. gracillius	4.20	0.15
Pteromalid sp.	6.44	0.14
Predator	1.70	0.04
Parasites+Predator	43.82	30.70

* For the midge, percent emergence of adult is given

Table 10–2. Parasitic activities of the Hymenopterous parasites and Coleopterous predator to the rice gall midge on wild rice at Maelao, 1971

Species	Average no. of individuals collected	Average parasitism (%)
The rice gall midge	58.89	94.38*
P. oryzae	3.20	2.74
Platygaster sp.	1.0	0.01
N. gracillius	1.20	0.03
Predator	0	0
Parasite+Predator	3.47	3.37

* For the midge, percent emergence of adult is given

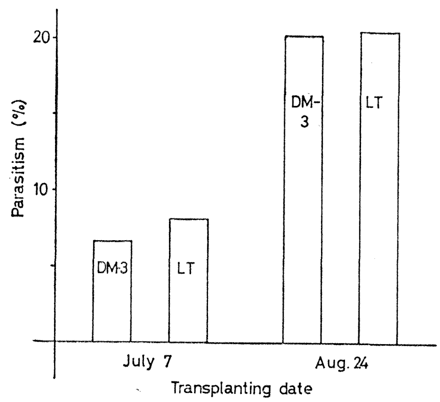

Fig. 10-23. Effect of transplanting dates of rice plants on parasitism of the Hymenopterous parasites at Pan, 1970. DM-3; Dawk Mali-3, LT; Leuang Twang.

Table 10-3. Relation between parasitism of the Hymenopterous parasites and planting dates of the two rice varieties at Pan, 1970

Rice variety	Transplanting date	Emergence of gall midge (%)	Parasitism (%)			
			P. oryzae	*Platygaster* sp.	*N. gracillius*	Predator
DM-3	July 7	91.86	6.77	0.67	0	0.67
	Aug. 24	59.32	35.59	2.96	0.84	1.27
Leuang	July 7	93.15	6.39	0	0	0.45
Twang	Aug. 24	44.10	53.80	1.33	0.19	0.38

and 48 days and 76 days in the early and late plantings of Leuang Twang respectively. No relationship was found between the time of parasite occurrence and the panicle primordium formation. In an early planting of Leuang Twang and late planting of Dawk Mali 3, the parasite occurred at the panicle primordium formation stage whereas it occurred 2 weeks and a month prior to the panicle primordium formation stage in an early planted Dawk Mali 3 and late planted Leuang Twang respectively. The parasitic activity of *P. oryzae* (Cameron) was not related to the stage of rice plants, but it depended on the population of rice gall midge larvae, which increased after the primordium formation in a late planting.

As a result, the emergence of the rice gall midge in a late planting was reduced to a half of that of early planting, as shown in Table 10-3. Population of the parasite, *P. oryzae* (Cameron) as well as that of the predator was found apparently higher in a late planting than those in an early planting.

These results furnish a clear evidence that the parasite is very effective in suppressing the rice gall midge population, and that the late planting of rice is able to take advantage of the parasite to a full extent.

11. Bionomics of the rice gall midge

Detailed investigation on the ecology of the rice gall midge will provide a basis for establishing control measures of the insect. Ecological features of each development stage of the insect and the behavior related to the gall formation were studied.

A. Studies on emergence

1) Emergence of the rice gall midge

METHOD

In order to know the time of emergence on paddy fields, galls produced on 10 hills of rice plants per plot with 3 replications were observed every one hour from 1800 hours in the evening to 500 hours in the next morning in September 20, 30, and October 10. Number of adults emerged from the galls was counted using flash light on the paddy field, and the galls from which adult emerged were marked with ink to distinguish from the remaining galls.

For pot experiments, 30 days old seedlings of Dawk Mali 3 were transplanted at a rate of 3 plants per pot (20 cm in diameter and 25 cm high), 10 pots were kept in insect breeding cages (1.0 m wide × 1.2 m high × 2.5 m long) until emergence was observed. 50 eggs were placed on rice plants per pot, and growth of gall, time of emergence of adult, and sex ratio were examined.

RESULTS

The emergence began at 1800 hours and ended at 400 hours in the morning, with a peak between 2200 and 2300 both on the paddy fields and in pot test as given in Table 11-1. No emergence was observed in the day time. Emergence was related to the high humidity at night, more than 80%.

2) Relation between light and emergence of the rice gall midge.

It was noted that the insects which were just climbing up the inside wall of galls went down when they were exposed to the flash light. Later, the insects began to climb up again within 15 minutes. A further study was therefore carried out to know the effect of light on the insect emergence.

Table 11-1. Time of emergence of the rice gall midge at Pan Rice Experiment Station, 1968

Time (hours) 24 hour cycle	Replications							Total no. of adults	Sex ratio male : female
	A	B	C	D	E	F	G		
18:00—19:00	4	0	1	2	0	2	1	10	5 : 0
19:00—20:00	3	2	9	9	7	5	5	40	21 : 5
20:00—21:00	21	11	9	11	7	10	8	77	8 : 28
21:00—22:00	15	16	18	2	9	12	9	81	8 : 24
22:00—23:00	30	28	36	20	17	21	15	167*	12 : 61
23:00—24:00	21	15	13	13	5	4	2	73	7 : 17
24:00—01:00	5	10	9	3	4	7	5	43	3 : 16
01:00—02:00	6	3	5	9	3	5	4	35	0 : 21
02:00—03:00	4	2	6	0	2	1	2	17	1 : 4
03:00—04:00	0	5	8	0	0	1	0	14	0 : 1
04:00—05:00	0	0	0	0	0	0	0	0	0 : 0

METHOD

Both dark and light room were set up at night. In the latter, 3 flurescent lamps of 40 watts were installed one meter about the rice plants in pots. The light room was covered by the insect net to avoid an invasion of other kinds of insects attacked by light. 5 pots were used for each experimental plot.

RESULTS

Number of adults emerged in the lightened plot was much less than that of the dark plot as give in Table 11-2. Observations indicated that the upward of the insect was prohibited by the light. Minimum illumination necessary for the effect is not known but the study is in progress.

3) Sequence of emergence between male and female.

METHOD

Newly emerged adult was collected every one hour and their sex was identified. 50 eggs were placed per pot, and 10 pots were kept in a insect breeding cage for the study.

Table 11-2. Effect of lighting on emergence at Pan, 1968

	No. of pots	Replications A	B	C	D	Total no. of adults
Lighting	1	0	0	1	2	3
	2	0	1	1	3	5
	3	0	0	2	5	7
	4	0	2	3	0	5
	5	0	0	1	3	4
	Total	0	3	8	13	24
Dark	1	7	7	2	5	21
	2	7	11	15	9	42
	3	3	8	19	11	41
	4	5	20	22	14	61
	5	9	6	13	19	47
	Total	31	52	71	58	212

RESULTS

More number of males than female emerged from 1800 to 2000 hours, i.e. an early stage of emergence. Afterwards, more females than males emerged, as given in Table 11-1.

4) Sex ratio of the rice gall midge.

METHOD

In paddy fields located in areas between Maesai and Chiengmai, pupae were collected from galls every week during the rice season, and their sex ratio was determined.

RESULTS

A pot experiment conducted in 1968 showed the sex ratio (female to male) of 63 to 179 as given in Table 11-1. The results of the present survey at 10 locations in 1971 showed the ratio of 433 to 901 as given in Table 11-3. On the other hand, sex ratio of the adults collected by light trap at the Pan Rice Experiment Station was 308 to 892 in 1970 and 337 to 1331 in 1971. Female was more numerous than male. Tanongchit et al. (1969) reported that sex ratio examined in mass rearing of the rice gall midge was 1 to 1, while Soeharjan (1971) in Indonesia reported that much more female was found than male when the insect adults were collected by the light trap. It is well known that some species of the Family Cecidomyidae are able to perform the parthenogenesis. Therefore, the following observation was made to know whether the rice gall midge is parthenogenetic or not.

5) Parthenogenesis of the rice gall midge.

METHOD

Virgine and mated females were introduced separately into glass cylinders (12 cm in diameter $\times$ 20 cm high) with wire net cover, containing rice plants. 5 each of mated and virgine females were used in the experiment which was repeatedly conducted in August September, and October.

RESULTS

There was no difference in number of eggs laid between mated and virgine females. How-

Table 11-3. Sex ratio of the rice gall midge observed in Chiengrai, Lampang, and Chiengmai Provinces, 1971

Date	Pan male : female	Pasang	Chiengrai	Lampang	Total
Aug. 9	1 : 2	2 : 3	5 : 6	8 : 12	16 : 23
16	7 : 7	11 : 17	1 : 2	3 : 4	22 : 30
21	13 : 25	8 : 11	4 : 8	0 : 4	25 : 48
31	5 : 7	3 : 3	2 : 1	8 : 18	18 : 29
Sept. 7	5 : 10	2 : 5	0 : 4	1 : 1	8 : 20
13	3 : 4	4 : 8	2 : 3	2 : 7	11 : 22
21	3 : 1	3 : 13	8 : 11	3 : 4	17 : 29
27	2 : 1	4 : 23	2 : 2	0 : 8	8 : 34
Oct. 4	1 : 5	3 : 6	0	0 : 1	4 : 12
12	2 : 7	5 : 11	2 : 8	0	9 : 26
20	2 : 3	2 : 15	0 : 3	0 : 2	4 : 23
25	2 : 12	15 : 41	1 : 5	1 : 1	19 : 59
Nov. 3	3 : 11	3 : 17	1 : 4	1 : 4	8 : 36
8	8 : 11	3 : 14	0	3 : 2	14 : 27
17	0 : 4	6 : 4	1 : 2	0	7 : 10
Total	57 : 110	74 : 191	29 : 59	30 : 68	190 : 428

Table 11-4. Sex ratio of the rice gall midge collected by the light trap at Pan, 1970 and 1971

Year	Every 5 days	July	Aug.	Sept.	Oct.	Nov.	Total no. of male : female
1970	1	2 : 2	1 : 2	10 : 40	31 : 91	0 : 3	44 : 137
	2	0 : 2	2 : 3	19 : 49	45 : 76	0 : 1	66 : 181
	3	0 : 1	1 : 2	15 : 38	11 : 37	0	27 : 78
	4	0	2 : 3	51 : 113	3 : 15	0	56 : 131
	5	0	5 : 10	50 : 242	11 : 19	0	66 : 271
	6	0	7 : 22	39 : 111	3 : 10	0	49 : 143
	Total	2 : 5	18 : 42	184 : 593	104 : 248	0 : 4	308 : 892
1971	1	0	0 : 1	42 : 120	29 : 98	0	71 : 219
	2	0	0	21 : 53	4 : 12	0	25 : 65
	3	0	2 : 4	75 : 402	0 : 10	0	77 : 416
	4	0	4 : 14	50 : 105	1 : 3	0	55 : 122
	5	0	1 : 2	75 : 340	1 : 1	0	77 : 343
	6	0	0 : 3	31 : 109	1 : 4	0	32 : 113
	Total	0	7 : 24	294 : 1129	36 : 128	0	337 : 1331

ever, eggs laid by virgine females could not hatch, showing no embryonic development and no egg colour change. Egg hatching of mated females was more than 90%. It can be concluded that the mating is required for producing normal eggs.

Table 11–5. Comparison of egg-hatching between the virgine female and mated female of the rice gall midge at Pan, 1971

	Replications	No. of adults examined	Total no. of eggs deposited	No. of eggs hatched
Virgine female	1	5	456	0
	2	5	531	0
	3	5	451	0
Mated female	1	5	480	472
	2	5	525	496
	3	5	514	511

6) Copulation of the insect.

It is very rare to be able to observ the insect mating in the field because it takes place in the night. Adult males emerged earlier than females were waiting for the emergence of adult females. The newly emerged females stayed for about 20 minutes on leaf sheath or leaf blade until her wings were completely expanded. Males are usually attracted to females before her wing expansion and mated. The mating lasts for 5 minutes. Two types of copulation were seen: a male rides on dorsal surface of female or male hangs on female. The former was more frequent than latter. As females are much more in number than males, the frequency of mating was studied.

METHOD

Rice seedlings at the 4th leaf age were kept in glass cylinders with high humidity. A healthy male and 5 females just after emergence (A plot) or a healthy female and 5 males just after emergence (B plot) were introduced into the cylinder, and the frequency of mating was counted carefully. In A plot, mated females were marked by enamel solution to distinguish from virgine females, and in B plot mated males were marked.

RESULTS

A male mated with 2.5 females in an average as give in Table 11-6. A female mated

Table 11–6. Number of times of mating of male and female of the rice gall midge at Pan, 1968

Male : female	Replica-tions	Mating number of times	Male : female	Replica-tions	Mating number of times
1 : 5	1	2	5 : 1	1	1
	2	3		2	1
	3	3		3	1
	4	2		4	1
	5	4		5	1
	6	3		6	2
	7	2		7	1
	8	2		8	2
	9	2		9	1
	10	2		10	1
	Total	25		Total	12
	Average	2.5		Average	1.2

Table 11–7. Mating days after male emergence of the rice gall midge at Pan, 1968

Sex	Days after emergence	Replications A	B	C	D	Total no. of individuals
Male	1	0	0	3	0	3
	2	10	11	8	13	42
	3	2	1	0	2	5
	4	0	0	0	0	0
	Total	12	12	11	15	50
Female	1	5	5	5	5	20
	2	0	0	0	0	0
	3	0	0	0	0	0
	4	0	0	0	0	0
	Total	5	5	5	5	20

with male only one time with an exceptional case of more than one time. A male mates again after resting on leaf blade for 30 to 60 minutes. In general, males mate on succeeding days, but females mate only after emergence as given in Table 11-7.

7) Longevity of the adult.

METHOD

Male and female emerged at the same night were separately put into glass cylinders in which relative humidity was kept constantly higher than 80%. 10 adults per plot were examined with 4 replications. The adults which fell down on the bottom of the cylinder and could not move at all were recognized to be died.

RESULTS

Longevity of male was 2.25 days in an average as given in Table 11-8. Adults live on morning dew formed at leaf blade peripheries. The adults could not be attracted to honey at all.

Table 11–8. Longevity of adult at Pan, 1968

Sex	Days after emergence	Replications A	B	C	D	Total no. of adults
Male	1	1	0	0	0	1
	2	7	9	6	7	29
	3	1	1	4	3	9
	4	1	0	0	0	1
	Total	10	10	10	10	40
Female	1	0	0	0	0	0
	2	5	4	4	3	16
	3	5	6	5	7	23
	4	0	0	1	0	1
	Total	10	10	10	10	40

Table 11-9. Time of flight of the rice gall midge to light trap at Pan Rice Experiment Station, 1968

Time (hours) 24 hour cycle	Replications A	B	C	Total no. of adults
18:00—19:00	21	18	31	70
19:00—20:00	15	24	23	62
20:00—21:00	47	33	36	116
21:00—22:00	72	81	85	237
22:00—23:00	11	9	8	28
23:00—24:00	0	1	2	3
24:00—01:00	0	0	0	0
01:00—02:00	3	0	0	3
02:00—03:00	0	0	1	1

8) Time of flight to light trap.

METHOD

A light trap using 25 watts flurescent lamp was set up above the wooden wall, and number of adults collected per 4 m^2 of the wall was counted every one hour. This work was carried out for 3 concecutive days; 21, 22, and 23 October.

RESULTS

A peak of flying to the light trap was seen between 2100 and 2200 hours as given in Table 11-9. The adults began to fly from 1900 hours and ended at 2400 hours, but sometimes only few of them flew between 200 and 300 hours in early morning. As mentioned before, the peak of emergence of adults took place between 2200 and 2300 hours. Therefore, it is suggested that the adults are not attracted to the light trap within about 24 hours after their emergence. No flight is seen when it rains and wind blows.

B. Activity on egg laying of the rice gall midge

1) Number of ovarian and laid eggs.

METHOD

Healthy females were placed on rice seedlings in breeding cages. Number of eggs laid on seedlings was counted. At the same time eggs remaining in their ovary after laying eggs were also counted by dissecting abdomen. The sum is the total number of eggs produced per female. 15 females were used in the present test.

RESULTS

Average number of eggs laid per female was 221.26. Total number of eggs produced was 276.12, and eggs remained in ovaries 54.86. Eggs were laid mainly in the night as given in Table 11-10.

2) Effect of relative humidity on egg laying.

METHOD

Relative humidity in desiccators was kept 0, 50, and 90%. The 0% means a day condition

Table 11-10. Number of ovarian eggs and deposited eggs of the rice gall midge at Pan, 1968

	Total no. of eggs	Average no. of eggs	Mini.—Maxi.
No. of eggs laid	3319	221.26	102—301
No. of ovarian eggs	823	54.86	3—171
Total no. of eggs	4142	276.12	218—371

in the desiccator and saturated solution of sodium dichromate and sodium sulfate were used to make 50 and 90% humidity. Plastic tubes sized 2.5 cm in diameter and 7 cm long covered with the gauze were placed in each desiccator, and the light blue paper rolled inside the plastic tubes was used as a bed for egg laying. Each plastic tubes contained one female, and 5 females were used for each humidity.

RESULTS

Number of eggs laid increased in proportion to humidity, i.e. number of eggs per female was 1.75, 102.4, and 217.4 in 0, 50, and 90% humidity respectively as given in Table 11-11. The latter number of eggs is similar to those observed on rice plants in the field.

Table 11-11. Relation between relative humidity and egg laying of the rice gall midge at Pan, 1968

No. of female	R.H. (%)		
	0	50	90
1	0	115	245
2	45	97	173
3	0	126	190
4	0	71	261
5	0	103	218
Total no. of eggs	45	512	1087
Average no. of eggs per female	0.90	102.40	217.40

3) Effect of relative humidity on egg hatching.

METHOD

Five levels of relative humidity, 0, 20, 50, 76, and 90% were set up in the desiccator. Saturated solutions of sodium acetate and sodium chloride were used to keep the humidity at 20 and 76% respectively. Eggs laid on paper under 90% humidity were selected for uniformity, and transferred into the desiccators with different humidity. One hundred eggs were examined at each level of humidity.

RESULTS

As given in Table 11-12, egg hatching more than 90% took place at the humidity higher than 76% while less than 25% of egg hatching occurred at the humidity lower than 20%. Obviously high humidity is required for the hatching.

Table 11-12. Relation between relative humidity and egg hatching of the rice gall midge at Pan, 1968

Relative humidity (%)	No. of eggs examined	No. of eggs hatched
0	100	5
20	100	26
50	100	74
76	100	93
90	100	95

4) Time of egg laying

METHOD

Hourly trend of egg laying was examined using 10 females contained in a glass cylinder with rice seedlings. The cylinder was placed outdoor.

RESULTS

Egg laying was made in the night, from 2200 to 600 hours, with a peak between 100 to 200 hours, as given in Table 11-13. The time of peak was later than that of flight of the insect.

Table 11-13. Activity for egg laying of the rice gall midge at Pan, 1968

Time (hours) 24 hour cycle	Total no. of eggs deposited
21:00—22:00	0
22:00—23:00	34
23:00—24:00	191
24:00—01:00	261
01:00—02:00	849
02:00—03:00	568
03:00—04:00	180
04:00—05:00	68
05:00—06:00	10
06:00—07:00	0
Total no. of eggs	2161

5) Position of egg laying on rice plants.

METHOD

Plant samples taken from paddy fields and from pots placed inside the insect net were examined. In the latter case, 10 females were introduced to a rice plant (Dawk Mali 3) growing in a pot (16 cm diameter × 15 cm high).

RESULTS

The insect prefers leaf blade especially the lower surface of leaf blade for egg laying. The insect showed a preference for the 4th leaf rather than 5th or 3rd leaf as given in the Table

Table 11–14. Position of egg laying on rice plants at Pan, 1969

	Leaf position (counted from stem base)	Leaf sheath	Leaf blade Upper surface	Leaf blade Lower surface	Total no. of eggs
Paddy field (A)	1	0	1	0	1
	2	1	6	0	7
	3	12	0	7	19
	4	17	8	23	48
	5	9	2	18	29
	6	12	4	5	21
	7	0	13	23	36
	Total no. of eggs	51	34	76	161
Pot (B)	1	0	0	0	0
	2	0	1	25	26
	3	10	9	241	260
	4	117	7	337	461
	5	52	6	256	314
	6	23	15	168	206
	7	0	8	95	103
	Total no. of eggs	202	36	1122	1360

11-14. Although the leaf blade and sheath are the major beds for egg laying, it was found that the insect laid eggs on water surface. It was also found that the insect laid eggs on upland rice severely damaged.

6) Incubation period and time of hatching.

METHOD

Eggs laid on the paper were kept in desiccators with 90% humidity. A total of 3376 eggs was examined with 5 replications.

RESULTS

Incubation period was 3.22 days in an average, as given in Table 11-15. Time from larval movement in eggs to hatching was 1.44 minutes in an average. The peak of egg hatching

Table 11–15. Incubation period of the rice gall midge at Pan, 1968

Days after egg laying	Replications A	B	C	D	E	Total no. of eggs
1	0	0	0	0	0	0
2	118	159	0	0	0	277
3	311	32	588	273	965	2169
4	520	0	185	33	98	836
5	62	0	18	3	3	86
6	8	0	0	0	0	8
Total no. of eggs	1019	191	791	309	1066	3376

Table 11-16. Time of egg hatching of the rice gall midge at Pan, 1968

Time (hour) 24 hour cycle	Replications A	B	C	Total no. of eggs hatched
21:00—22:00	4	3	8	15
22:00—23:00	6	9	5	20
23:00—24:00	21	33	25	79
24:00—01:00	37	20	20	77
01:00—02:00	45	33	40	118
02:00—03:00	35	51	53	139
03:00—04:00	82	134	76	242
04:00—05:00	19	21	23	63
05:00—06:00	11	14	20	45

was between 300 and 400 hours as given in Table 11-16. Egg hatching did not occur during day time.

C. Studies on larval behavior

1) Behavior of the newly hatched larvae on rice plants.

Newly hatched larvae began to crawl on leaf sheath and blade wetted by morning dew. It seems that the larvae have no definite direction in their movement, but finally found their way along an inner space of leaf sheath to growing points on which they feed. The larvae are not able to bore a hole in leaf sheath.

2) Encroachment of larvae.

METHOD

Newly hatched larvae were carefully transferred to rice plants of 5 to 6th leaf age by using a hair pencil. They were placed on leaf sheath at the height of 3 to 5 cm above the rooting portion. Then, a half of the plants was kept under dry condition in a room and the other half under high humidity by spraying water. As it is known that the larvae survive in water for a long time, the larvae were transferred to the water in which plants are growing in order to examine whether the larvae penetrate into roots or not.

RESULTS

Results are given in Table 11-17. Under the dry condition, the larvae did not move and could not enter into rice plants. Some of the larvae tried to bore an inter-vein area of leaf sheath without success. Under the wet condition, the larvae crawled actively and

Table 11-17. Encroachment of larvae into rice stem at Pan, 1969

Condition	No. of larvae applied	No. of larvae entered	Time for wandering after application (min.)	Time for completing larval entrance (min.)
Dry	50	0	—	—
Wet	50	50	11.54	7.06
Water	50	12	16.0	4.16

stealed into an inner space of leaf sheath. It took 11.54 minutes in an average after the larvae were placed on plants. The larval head entered at first, and it took 7.06 minutes for the entrance of a whole body. Thus, all the larvae completed their encroachment into plants with an average time of 18 minutes (12 to 21 minutes) after transferred to the plants.

The larvae released into the water reached root area of plants, climbed up leaf sheath, and finally entered into spaces of leaf sheath. It took about 20 minutes. However, this process could be followed by only young larvae, aged less than 2 days after hatching, and older larvae remained wiggling in the water. In this case, only 24% of larvae succeeded.

D. Larval development and gall formation

METHOD

Five seedlings of rice were planted to a pot, and 50 eggs of the insect were placed on the

Table 11–18. Relation between larval development and growth of gall at Pan, 1968

Days after emergence	Egg hatching	Larval instar			Prepupa	Pupa	Adult emergence	Length of gall (cm)
		1st	2nd	3rd				
1	0							0
2	3							
3	1917							0
4	120							
5	7	114						0
6								
7		153						0.52
8								
9		85	7					1.61
10								
11		9	88	1				3.70
12								
13			121	5				4.18
14								
15			91	54	1			6.10
16								
17			7	114	39			6.85
18								
19				31	90	22		9.11
20								
21				16	64	31		15.13
22								
23					22	93	5	27.32
24							18	
25					4	61	19	28.70
26							25	
27						7	76	29.15
28							31	
29							18	29.23
30							10	
31								29.25
Total	2047	391	314	221	220	214	202	

plants per pot. 4 pots were sampled every one day to examined the larval development at the growing points by dissecting carefully under binocular microscope. A total of 52 pots of a variety, Dawk Mali 3, was used.

RESULTS

Larval period was 3.2 days in the 1st instar, 4.9 in the 2nd, and 6.6 in the 3rd as given in Table 11-18. A peak of egg hatching occurred on the 3rd day after egg laying, that of the 1st instar on the 7th day and that of the 2nd and 3rd instar on the 23rd and 17th day respectively.

A morphological change occurred at the growing points of plants after the larvae reached there. Lateral lamellae of the growing points seemed to form a chamber-shaped space to receive the larvae. Later, the lamellae fused each other to form cylinder-shaped gall (Photo. 5). The gall was very short at the larval stage and could not be observed from outside.

E. Prepupal and pupal development and growth of gall

METHOD

The same materials and methods used in D above were used continuousely.

RESULTS

Prepupal period was 5.7 days, and pupal period was 5.0 days in an average. A peak of the occurrence of prepupae, pupae and adults was on 19th, 23rd, and 27th after egg laying respectively. Thus, the period from the peak of egg hatching to the peak of adult emergence was 24 days which can be considered as an average period of one generation.

Galls elongated rapidly during the period from prepupal to pupal stage; from 9.1 cm to 27 cm. This rapid elongation is necessary for adult emergence. Pupation took place at the basal part of galls, and pupae climbed up to the spongy part of galls. Unless the galls were extruded outside the surrounding leaf sheath, the adults could not emerge.

The pupae have spines on the dorsal surface of each abdomen. During the upward movement of the pupae, it was observed that the spines were wiggling. Thus, the pupae could climb up with spines piercing into the wall of galls. The pupae could reach at least 25 cm high from the bottom of galls: the distance was as long as 50 times of length of pupal body. Time required for that movement was 4.5 minutes. Pupae reached the spongy part, pierced a pair of spines on vertex into the wall of galls and broke the gall with spines moving up and down. An emerging hole is irregular in shape and slightly larger than abdomen of the pupae. In course of the emergence of pupae from the hole, they stayed for a while by fixing their body to the hole (Photo. 4), after the 4 or 5th abdominal segments appeared. Time from piercing gall to fixing body on gall was 10.5 minutes. Time from fixing body to emergence was 25 minutes. The gall was extended at least 0.5 mm long after emergence.

As mentioned above, the galls continued to grow from the time of larval encroachment to the pupal stage. The growth of gall is possibly induced by either substances secreted from larvae or contained in larval excrements. This idea is based upon the fact that prepupae and pupae do not feed on growing points of gall. It is also considered that spines on head, abdomen, and genital segments might give a stimulation to plant tissue. Studies on substances inducing the gall growth will be done in near future.

12. Wild host plants of the rice gall midge

Ecological studies on the insects living during the dry season will supply a basis for developing the insect occurrence forecasting method. It is known that population density of the insect during the dry season is closely related to the crop damage in the wet season. How do they live in the dry season in the tropics, and how do they migrate from wild host plants to rice plants are questions to be answered. Some works on the wild host plants have been done in India and Thailand.

A. Species and growth period of wild host plants

METHOD

Wild plants of the Family Graminaceae grown in paddy fields were examined by dissecting their growing points to know whether larvae are present or not. Wild host plants showing galls were also collected, and larval development and adult emergence were investigated. Species and growth period of wild host plants were surveyed.

RESULTS

a) Species of the wild host plants.

five species of the Family Graminaceae were found as listed below.

1. Wild rice
2. *Ischaenum aristatum*
3. *Paspalum distichum*
4. *Leersia hexandra*
5. *Echinochlora colonum*

b) Occurrence of the wild host plants.

(1) Wild rice. (i) In swampy areas.

Wild rice grows in swampy areas throughout the year (Photo. 16). As the period of growth was 4 months, different growth stages could be observed at any time of the year.

(ii) On dry land

Rainfall starts usually at the beginning of May in northern Thailand. Seeds of wild rice germinate at the end of May just after the beginning of rainy season. The wild rice matures in October, and ripened seeds fall into the surface layer (2—3 cm) of soils. The seeds become dormant, so that they do not germinate even when rainfall lasts for a few days during the dry season.

(2) *Ischaenum aristatum* (i) In paddy fields

This plant does not grow in paddy fields during the rice growing season. The plant began to germinate in November and grow 2 to 3 cm high after water in the fields subsided. The plant grows only in relatively shallow water. Maturing stage was from the middle to the end of June, and their seeds fell down into the soils. Seeds in the soil was dormant during the rice season. *Paspalum distichum,* which grows 3 to 4 cm high, has a growth cycle similar to *Ischaenum aristatum.*

(ii) On dykes

Ischaenum aristatum was observed all year round, but the flowering and maturing stages were in the wet season, and the plant withered after the maturity. *Paspalum distichum* continued to be stunted due to the water shortage during the dry season and began to grow actively when rainy season started. As farmer repair dykes by usually coating one side of the dyke with paddy soils, all kinds of weeds grow freely on the other side of the dyke.

(3) *Leersia hexandra*

The species is distributed in all parts of Thailand. In northern Thailand, the plant grows on ditches and swampy areas, forming big flora. The plants growing at the water's edge are green even in the dry season and reach 25 to 30 cm high. But in dry areas they grow only 3 to 5 cm high. The flowering season is around June once a year. This plant propagates by subterranean roots and is also alternate host plant of rice pests such as the green rice leaf hopper and grasshopper which occur all year round. It is interesting that the plant leaves curl inwardly at night. This disturbs the egg laying of the rice gall midge as discussed later.

(4) *Echinochlora colonum*

The plant is distributed in Thailand and grow wild at water's edge. The maturing stage is during July and August. The plant grows at least 60 to 70 cm high and forms rather small flora in northern Thailand. During the dry season, the plant is 10 cm high, but it grows rapidly after rainy season started in May. Usually, *Echinochlora* could not be found in paddy fields according to the observation at Maesai in Chiengrai Province. However, a small flora with an area of 2 m^2 was found between rice hills at the end of October and which proceeded into the dry season.

Thus, it can be concluded that all the wild host plants, except wild rice growing on dry lands, are serving as the host for the insect during the dry season.

B. Seasonal fluctuation of gall occurrence on wild host plants

METHOD

Places selected for observations are: for wild rice Pan, Chiengrai as a swampy area and Maelao in Chiengrai as a dry area. For *Ischaenum aristatum* the Pan Rice Experiment Station and for *Paspalum distichum* Pan and Payao in Chiengrai. For *Leersia hexandra* the Pan Rice Experiment Station, and for *Echinochlora colonum* Pan and Maesai in Chiengrai were selected. The observation was mainly done during the dry season from December to May, but as far as wild host plants were recognized in the fields the observation was made. Number of galls occurred, number of the midge adults, and natural enemies were examined every 3 to 4 days. Obsevation of galls on *Paspalum distichum* and *Ischaenum aristatum* collected at the field and brought back to the Pan Rice Experiment Station was also made in insect breeding cages.

RESULTS

a) Wild rice (Photo. 15)

The wild rice grows all year round if water is available in swampy areas. As given in Figure 12-1, the gall formation was recognized throughout the year, indicating that the gall midge could emerge and lay eggs on the plant during the dry as well as wet seasons. Peak of gall occurrence was seen between March and May. It is suggested that the gall midge preferred the wild rice to other wild host plants during the dry season. The insects on the wild rice migrated to rice seedlings in June so that population density of the insects and gall formation on the wild rice decreased in a period from July to October. The rice plants at the heading stage in November were no more suitable as a food of the rice gall midge, the midge migrated to the wild rice and other host plants so that number of galls produced on the wild rice increased markedly in November. However, the number of galls decreased during a period from December to February due to low temperature. Air temperature in northern Thailand at that time was 15°C in mean temperature with 6°C of the lowest temperature.

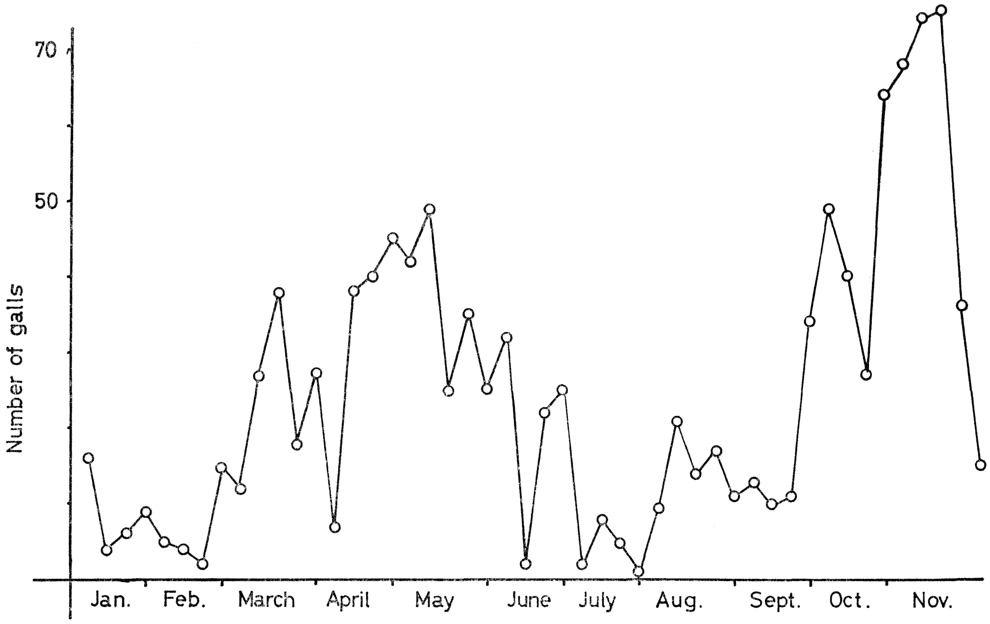

Fig. 12-1. Seasonal fluctuation of gall occurrence on wild rice at pond side at Pan, 1971.

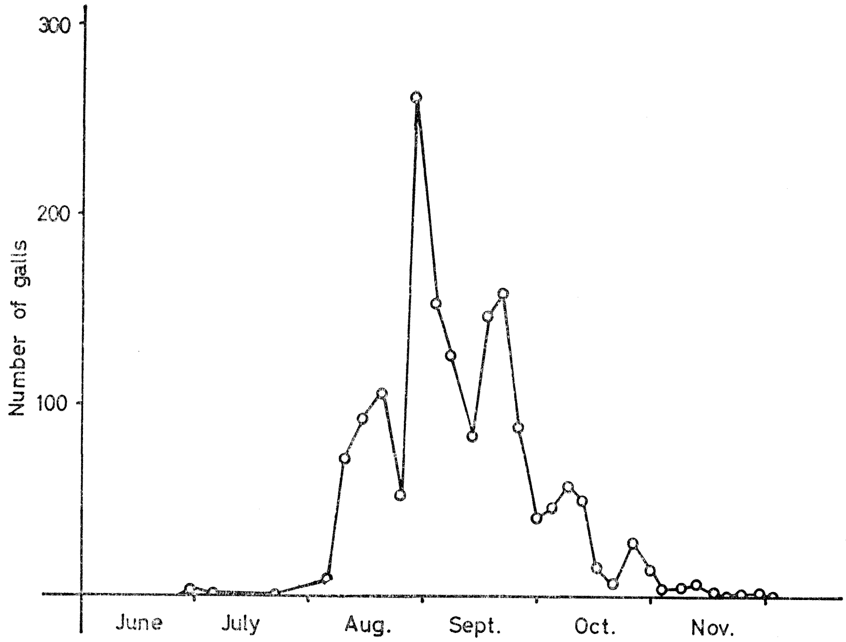

Fig. 12-2. Seasonal fluctuation of gall occurrence on wild rice on dry field at Maelao in Chiengrai Province, 1971.

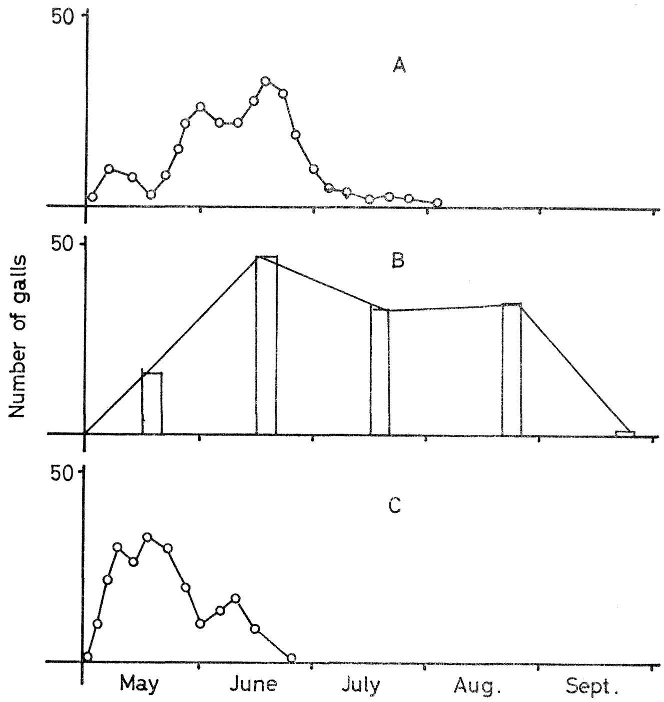

Fig. 12-3. Gall occurrence on two kinds of the alternate host plants. A: *Paspalum* sp. at Pan in Chiengrai, B: *Paspalum* sp. at Tungkudai in Lampang, C: *Ischaenum aristatum* at Pan, 1971.

With the wild rice growing on dry lands, the seasonal pattern of gall occurrence was quite similar to that of the cultivated rice, as shown in Figure 12-2. A gall was found firstly in the middle of July. Number of galls increased gradually, reaching a peak in September, and then decreased in October. At the end of November no gall was found. The wild rice is highly susceptible to the insects, suffering from severe damage. Because of the similarity of seasonal pattern of insect occurrence between cultivated rice and wild rice, it was impossible to estimate the migration of the insect from wild rice to cultivated rice.

b) *Ischaenum aristatum* (Photo. 18)

At Fang in Chiengmai Province, a gall was found at first on May 2nd, a peak of gall occurrence was in the beginning of June, and no gall could be seen in the middle of July. As given in Figure 12-3 C, at the Pan Rice Experiment Station, the first occurrence of gall was on May 1st, peak of gall occurrence on May 20, and no gall found on July 26. Duration of gall occurrence on *Ischaenum aristatum* was less than 2 months. In other words, galls and adults occurred in a short period which coincided with an early half of nursery period of rice. *Ischaenum* growing wild in paddy fields before the planting of rice assumed a rapid growth after rainfall, and larval development and gall formation were accelerated during the short period before the planting of rice.

c) *Paspalum distichum* (Photo. 19)

At Pan and Payao in Chiengrai Province, the plant was growing on paddy fields before the rice season. Galls began to appear from the middle of May and disappeared at the end of July. On the other hand, the gall formation ended in the middle of September at Thunkudai, where the plant was growing on dykes. At Thunkudai in Chiengrai Province, flora of *Paspalum* sp. was recognized throughout the year, but gall could not occur from October to April. Peak of gall occurrence was in the middle of June at Pan and Payao, and at the end of June at Thunkudai as given in Figure 12-3A and B.

d) *Leersia hexandra* (Photo. 20)

The plant was found all year round. Galls occurred in both wet season and dry season but no peak of gall occurrence was recognized. The leaves curled inwardly in the night, restricting the beds for egg laying of the midge, so that only few galls were usually produced.

e) *Echinochlora colonum* (Photo. 17)

Gall occurrence on *Echinochlora* was very few; less than that on *Leersia hexandra*. It is because the flora of *Echinochlora* was small as compared to other wild host plants. At Maesai, galls occurred on the plants in the middle of November. The midge must have migrated from rice plants to attack the young plants of *Echinochlora colonum* in the middle of October. When the insect larvae attacked the growing points of bud, the plant responsed in a different way from other host plants: axillary buds developed into additional tillers which also offered the site for the insect attack, so that 5—8 tillers, all with galls, developed from each stem node were observed. However no galls were found from December to April, and only a few was observed in May. In other place, the rice gall midge occurred irregularly and no peak recognized.

C. Relation between larval development of the gall midge during the dry season and growing stage of wild host plants

It was found that larvae of the insect could not advance their growth on wild host plants during the dry season without water available. The present study was carried out to examine the relation between larval development and growing stages of wild host plants.

METHOD

To know developmental stages of the insect larvae during the dry season, wild host plants were collected in the field every 15 days from December to May, and galls and larvae were examined. Sampling of plants was made at Pan and Ban Due in Chiengrai Province. Additional sampling was also made intermittently at Lampang and Chiengmai. Wild host plants collected were wild rice, *Paspalum distichum*, *Ischaenum aristatum*, and *Leersia hexandra*, all growing on dry lands.

RESULTS

a) Larval development of the gall midge

Larvae remained at the 1st to 2nd instars from December to March. With the rainfall in April, the plants resumed their growth, and concurrently the larvae resumed their development, with the gall formation in May. Rain in April and May is an important factor affecting the larval developement. No differences in larval development among these host plants were recognized.

b) Relation between number of larvae on wild host plants and gall formation.

Number of larvae was different with different kind of plants as given in Table 12-1. Number of larvae per 100 tillers was in a decreasing order of wild rice, *Paspalum distichum*, *Ischaenum aristatum*, and *Leersia hexandra*. In particular, survival rate of larvae was highest on wild rice. Percentage of gall formation was in proportion to survival rate of larvae as seen in wild rice.

Table 12-1. Number of larvae on the host plants at Pan, 1970

Name of the host plants	Jan.	Feb.	March	Total no. of larvae
Wild rice	85	71	38	194
Paspalum distichum	49	31	30	110
Ischaenum aristatum	3	2	4	9
Leersia hexandra	0	1	1	2

D. Biological characteristic of the gall midge bred on wild host plants

METHOD

Larvae, pupae and adults of the gall midge collected from wild host plants and rice plants were preserved in 75% alcohole for morphological comparison, some of the wild host plants were transplanted to pots to study adult emergence, gall formation and plant growth.

RESULTS

a) adults.

The results are given in Table 12-2. The gall midge bred on *Ischaenum aristatum* was

Table 12-2. Morphological differences of the gall midge bred from rice plants and *Ischaenum aristatum* at Fang, Chiengmai Province, 1968

	The gall midge bred from	
	Rice plants	*Isch. aristatum*
Body length (mm)	4.30	3.90
Fore wing	3.67	2.66
Halter	0.59	0.51
Hind femur	1.85	1.25
Hind tibia	1.40	1.04
Hind tarsi 1	0.14	0.13
2	1.41	1.02
3	0.79	0.58
4	0.49	0.36
5	0.26	0.18
No. of eggs per female	269.8	159.4
Length of an egg	0.29	0.27
Width of an egg	0.08	0.08

smaller in size than that bred on rice plants, particularly with considerable differences in body length, fore wings, and length of hind legs. Number of ovarien eggs was also different: 159.4 on *Ischaenum aristatum* and 269.8 on rice plants in average, although there was no difference in the size of eggs. As given in Table 12-3, body colour of the midge bred on *Ischaenum aristatum* was darker than that on rice plants.

Table 12–3. Body colour of the gall midges bred from rice plants and *Ischaenum aristatum* at Fang, Chiengmai Province, 1968

	The gall midge bred from	
	Rice plants	*Isch. aristatum*
Pronotum and pleura of mesothorax	brown	dark brown
Median portion of 1st to 7th ventral segment of abdomen	dark spots disappeared or with light spots	with dark spots
Fore femur	pale	dark

b) Pupae.

As given in the Table 12-4, pupae growing on wild host plants except wild rice were apparently small as compared to the pupae on rice plants. The size of the pupae bred on *Leersia hexandra* was same as that bred on *Paspalum distichum* and that on *Ischaenum aristatum* was smallest. These differences might be caused by different form of growing points and nutritional condition of the host plants.

Table 12–4. Morphological differences of pupae of the gall midge bred from rice plants and the host plants at Pan, 1971

Name of the host plants	Width of spines on head		Length of body	
	male	female	male	female
Wild rice	0.26	0.28	3.80	4.50
Leersia hexandra	0.24	0.26	3.50	4.0
Paspalum distichum	0.24	0.25	3.50	4.0
Ischaenum aristatum	0.23	0.24	3.40	3.78
RD 1	0.26	0.29	3.81	4.68

c) Growth of gall.

As given in Table 12-5, galls on rice plants were 40.2 cm long in an average, and those wild rice were 30.6 cm long. Galls on *Leersia hexandra* and *Paspalum distichum* were of same length and shorter than those on wild rice. Galls on *Ischaenum aristatum* were shortest, at least 5.6 cm. Interesting is that the length of galls is closely related to survival rate of the gall midge; the higher the survival rate the longer is gall. It is also interesting that the preference of the gall midge to host plant is indicated by length of galls.

Table 12–5. Galls from rice plants and the host plants at Pan, 1971

Name of the host plants	Leng th of gall (cm)	Maxi.—Mini.
Wild rice	30.57	60.0—16.0
Leersia hexandra	7.44	11.5— 4.5
Paspalum distichum	8.04	12.0— 4.0
Ischaenum aristatum	5.55	7.0— 3.0
RD 1	40.19	58.0—24.0

E. Encroachment of larvae into wild host plants

METHOD

The wild host plants were sampled once a month at Pan in Chiengrai Province from April to December and were dissected to examine developmental stage of larvae, number of galls and stems. Frequency of larval encroachment was expressed by number of larvae/number of growing points $\times 100$.

RESULTS

The results are given in Table 12-6. During the dry season, larvae were recognized on both wild rice and *Paspalum distichum* but they were not able to proceed with development with gall formation. Larvae and galls were not seen in growing points of *Leersia hexandra*

Table 12–6. Larval encroachment and developmental stages of the rice gall midge on the several host plants during the dry season at Pan, 1969—1970

Name of the host plants	Observed date			No. of tillers	No. of galls	No. of growing points	No. of larvae	No. of pupae	Total no. of the gall midges	Percentage of encroachment
Wild rice	Dec.	20	69	85	11	145	217	0	217	149.65
	Jan.	20	70	86	0	158	120	0	120	75.94
	Feb.	10	70	95	0	139	117	0	117	84.17
	March	20	70	88	0	125	125	0	125	100.0
	April	22	70	82	3	131	118	0	118	90.07
Paspalum distichum	Dec.	20	69	56	0	213	16	0	16	7.51
	Jan.	20	70	60	0	92	46	0	46	50.0
	Feb.	10	70	85	0	135	64	1	65	48.14
	March	20	70	67	0	115	60	1	61	53.04
	April	22	70	81	0	131	108	3	111	84.73
Leersia hexandra	Dec.	20	69	28	0	105	1	0	1	0.95
	Jan.	20	70	30	0	111	0	0	0	0
	Feb.	10	70	41	0	128	0	0	0	0
	March	20	70	38	0	117	0	0	0	0
	April	22	70	29	0	108	0	0	0	0

Table 12–7. Larval encroachment and developmental stages of the rice gall midge on *Echinochlora colonum* at Pan, 1969—1970

Checking date			No. of tillers	No. of galls	No. of growing points	No. of larvae	No. of pupae	Percentage of penetration
Sept.	25	69	59	46	176	38	21	67.04
Dec.	20	70	17	51	181	2	3	12.15
Jan.	20	70	0	45	150	0	0	0
Feb.	10	70	0	61	287	0	0	0
March	20	70	0	50	163	0	0	0
April	22	70	0	15	63	0	0	0

since December. Pupation in *Paspalum distichum* started from April and galls appeared in May. Number of larvae in wild rice was most abundant with the highest percentage of frequency. However, no damage was found on *Leersia hexandra*.

Larvae could not be seen on *Echinochlora colonum* during the dry season as given in Table 12-7. The insects bred on the plants might have entirely emerged from the plants at about the harvesting season.

F. Preference of the gall midge to wild host plants

METHOD

Cultivated rice, wild rice, *Paspalum* sp., *Leersia hexandra*, and *Echinochlora colonum* were examined with regard to the insect preference. 5 seedlings made of one from each of these five kinds of plants were transplanted per pot and each pot was covered by insect net separately. Adult females collected at night were applied at a rate of 10 females per pot, and number of egg laid on the plants was counted in the next morning. Gall formation was counted in a period of one month. A total 5 pots were used for replication. The experiment was carried out between September and October in 1969.

RESULTS

A large number of eggs was laid on rice plants and a similar number on wild rice as given in Table 12-8. Less eggs were laid on *Paspalum* sp. and *Echinochlora colonum*. Number of eggs on *Leersia hexandra* was one seventh of that on rice plants and one thirds of *Paspalum distichum*. Number of galls was in proportion with number of eggs laid.

Table 12–8. Preference of host plants for egg laying of the rice gall midge at Pan, 1969

Name of the host plants	Total no. of eggs	No. of eggs per pot	No. of galls per pot
Wild rice	672	134.4	86.4
Paspalum distichum	381	76.0	33.0
Leersia hexandra	115	23.0	9.6
Echinochlora colonum	392	78.4	37.2
Oryza sativa	711	142.4	95.2

G. Larval development on rice plants and wild host plants

METHOD

a) Adult females collected from the wild host plants which were kept in insect cages were released to 25 days old seedlings of rice to examine gall formation and larval development on the rice plants. After egg laying, water was sprayed several times a day to ensure egg hatching. The experiment was carried out from May to June, 1969.

b) Adult females collected from rice plants were released to each kind of wild host palnts. The experiment was carried out from September to October 1969.

RESULTS

a) The insect transferred from *Paspalum distichum* and wild rice to rice plants.

A large number of eggs was laid on rice plants. Body size and colour of the insects became to be same as the rice gall midge transferred from rice to rice. Results are given in Table 12-9.

Table 12–9. Larval development of the gall midge transfered from other host plants to rice plants at Pan, 1969

Adults emerged from	No. of adults	Applied to	No. of eggs deposited	Period from egg laying to emergence (days)	No. of adults	No. of galls
P. distichum	7	rice plants	321	27—36	22	22
Wild rice	10	rice plants	511	24—32	134	137
Rice plants	10	rice plants	825	26—31	225	225

Duration from egg laying to emergence was 27—36 days with the insect transferred from *Paspalum* sp., 24—32 days with the insect from wild rice, and 26—31 days with the insect from rice plants. However, no significant difference was observed in survival period among these three groups.

b) Insect transferred from rice to wild host palnts.

Results are given in Table 12-10. It has a tendency that number of galls occurred from the wild host plants was in proportion with number of eggs laid on the plants. Number of eggs laid on rice plants by insects transferred from wild host plants was less in varying degree than that of the insects transferred from rice to rice. No difference was observed in the larval development and the duration required from egg laying to emergence was 24—32 days in all cases.

Table 12–10. Larval development of the rice gall midge transfered from rice plants to wild host plants at Pan, 1971

Adults emerged from	Applied to	No. of adults examined	No. of eggs deposited	Period from egg laying to emergence (days)	No. of adults	No. of galls
Rice plants	Wild rice	5	471	25—31	170	170
	Paspalum distichum	5	311	24—32	63	62
	Leersia hexandra	5	158	26—29	14	11
	Echinochlora colonum	5	336	25—30	68	68
	Rice Plants	5	525	25—32	131	131

H. Discussion

In this Chapter, kinds of wild host plants found in northern Thailand, their distribution, seasonal growth and their role as insect source were reported. The gall midge emerged from the wild host plants migrated to rice plants to attack them during the wet season. During the dry season, the gall midge stayed at the larval stage on growing points of the wild host plants on dry areas. After the rains began, larvae resumed their growth and development coincidentally with the rapid growth of plants caused by rainfall. On the other hand, the insects occurred all year round on the wild host plants grown on swampy areas. Although less in number, they continue to grow as the host plants grow actively with water available.

Morphological and physiological differences between the gall midges bred on wild host plants and on rice plants were clearly recognized. However, when the insect bred on wild host plants were transferred to rice plants, these differences disappeared, suggesting that such differences were caused by the difference in nutritional condition between the wild host plants and rice plants. The gall midge prefered to lay eggs on wild rice and therefore, the wild rice served a most important source of insect at the beginning of rice season. Survival rate of larvae was highest with wild rice followed by *Paspalum distichum*, *Ischaenum aristatum*, *Echinochlora colonum*, and *Leersia hexandra*. Population density of the gall midge was extremely low during the dry season. How far does the population density of the insects on rice give effect on the population in the subsequent dry season is not known. Information on this relation will be useful for developing forecasting method.

13. The insect infestation on rice seedlings

In Chiengrai Province, rice is usually sown from the middle to end of June and 30 day old seedlings are transplanted in July. The insect infestation on rice seedlings was studied.

METHOD

A rice variety, Dawk Mali 3, was sown at a rate of 50 g per 1 m^2. Twenth to thirty day old seedlings were dissected under binocular microscope to examine larval development. A study was also made to find out a method to identify infested seedlings at an early date.

RESULTS

a) Comparison on between healthy and infested seedlings.

Results are given in Table 13-1. The infested seedlings were characterized by a short plant height, delayed leaf age, and an abnormally increased tillers. The uppermost leaf remained unprotruded and the second leaf failed to grow fully, but the third leaf showed abnormal growth with infested plants. The damaged tillers were dull green or light green. Basal part of the damaged seedlings were round-shaped in a cross section. These morphological changes appeared on 10 to 15 days after germination, in another words, the damage can be detected at the stage of the 3rd instar larvae.

Table 13–1. Morphological differences between healthy and damaged seedling at Pan, 1968

Items observed	Damaged seedlings	Healthy seedling
Height of plant	24.21 cm	32.74
Leaf age	4.95	6.12
Tillering	1—4	1—3
Leaf emergence	Topmost leaf remains unprotruded. For example, when the 5th leaf emerged fully from the sheath of 4th leaf, the 6th leaf still remained unprotruded inside the sheath of 5th leaf. In case when the 6th leaf happened to emerge, the angle between the 5th and 4th leaf was wider than normal	Topmost leaf growing normally
Colour	dull green	green
Others	Basal part of seedling is rather hard and round-shaped	Basal part of seedling stem is soft and flat

b) Damage of seedlings caused by the insects.

Damage of seedlings as related to different sowing dates is given in Table 13-2. Although the damage increased with later sowing, the extent of the damage was generally very low, being less than 7% of damaged tillers, because of low population density of the insect in the nurseries. It is sure that rice seedlings grow better at the border area of the nursery bed than the central portion and they are mainly exposed to the attack of the insect. Therefore, seedlings grown at the border area showed not be used for transplanting in case of the insect incidence.

Reasons for the low infestation to seedlings were analized as follows.

(1) When sown in June, population of the insect migrated from wild host plants to rice seedlings was still low so that the damage was only 1% in rice seedlings.

(2) When sown in August, the insect occurrence was at its peak and rice plants in that area were at the maximum tillers stage. Therefore, the insects were mostly attracted by that plants instead of the seedlings.

As given in Table 13-3, seedlings with sowing dates later than August showed a decrease in damage. This is because of the migration of the insects from rice plants at the reproduction stage to wild host plants. After the middle of November, no insect was found on seedlings. During the dry season, seedling growth as well as insect growth was inactive due to water shortage as shown in Table 13-4. During a period of 3 months after egg laying in rice seedlings

Table 13–2. Change of damage caused by the rice gall midge on rice seedlings in different sowing dates at Pan, 1968

	Sowing date	Observed date	Damaged tillers (%)	Height of plants (cm)	Leaf age
1.	June 8	July 15	1.80	25—28	6.0—6.5
2.	July 13	Aug. 3	3.60	25—27	6.0—6.5
3.	Aug. 12	Sept. 15	4.30	25—28	6.0—6.5
4.	Sept. 10	Oct. 1	6.40	28—30	5.5—5.0

Table 13–3. Larval development of the rice gall midge and damage on rice seedling growings during the usual harvesting season at Pan, 1968

Sowing date	No. of stems	No. of galls	Damaged tiller (%)	Length of gall	Leaf age	Height of plants	No. of larvae	No. of adults	No. of parasites
Oct. 15	980	68	6.93	14.80	9.7	66.37	22	17	29
Nov. 1	770	5	0.64	9.35	8.9	48.23	4	1	0
Nov. 15	726	0	0	0	4.9	18.15	0	0	0

Table 13–4. Larval development of the rice gall midge on rice seedlings during the dry season at Pan, 1968—1969

No. of stems examined	No. of galls	Length of gall (mm)	Height of plant (cm)	Leaf age	Larval instar 1	Larval instar 2	Larval instar 3
73	67	0.50	19.21	4.1	0	67	0

* Egg laying on rice plants was on Oct. 14, 1968, larval development was observed on Jan. 25, 1969

on October 14, the larvae attained only to the second instar, with the formation of galls 0.5 mm long.

c) Feeding preference of larvae to different parts of seedlings.

Infested seedlings were dissected under a binocular microscope to study whether the larvae have a feeding preference to different parts of seedlings. As given in Table 13-5 and 6, a largest number of larvae was found on the growing points of main stem, followed by secondary tillers. Larvae on the main stem were at the most advanced stage than others with the formation of longest galls. However, the result was sufficient enough to prove the existence of feeding preference of the insect, when the time sequence of tillering was taken into account.

Table 13–5. Larval development on different parts of rice plants at Pan, 1969

No. of tillers	No. of damaged tillers	Tillering		No. of larval instar		pupae	adults	galls	Length of galls (cm)
				2	3				
238	37	main stem	16	3	11	1	0	15	8.11
		Secondary	12	2	0	0	0	2	0.5
		First	9	2	0	0	0	2	0.5

Table 13–6. Relation between developmental stages of the rice gall midge and tillerings of rice plants at Pan, 1969

Tillering	No. of larvae			No. of prepupae	No. of pupae	No. of galls	Total no. of gall midges
	1	2	3				
1st	22	42	21	8	25	20	138
2nd	61	10	4	0	3	2	80
3rd	39	10	6	1	2	0	58
4th	29	6	1	0	3	0	39
5th	11	1	0	0	0	0	12

d) Developmental stages of the insects fully grown galls.

Rice seeds were sown at the end of June, and galls were sampled between July 26 and 28. As given in Table 13-7, galls protruded outside when they elongated to 25 cm long in an average. From these galls only 3 larvae, a large number of adults, and less number of pupae were found; ratio of pupae to adults were 1 to 8. With fully grown galls, it was also observed that adults

Table 13–7. Relation between larval development and growth of gall at Pan, 1969

Replication	No. of galls	No. of larvae	No. of pupae	No. of adults	No. of parasites	
					A*	B*
1	253	0	30	210	2	11
2	515	1	50	404	14	44
3	754	2	80	595	7	70
Total	1522	3	160	1209	23	125

* A: *Platygaster* sp. B: *Platygaster oryzae* (Cameron)

Table 13–8. Developmental stages of the rice gall midge observed in small and immature galls collected from the rice field at Pan Rice Experiment Station, 1969

Replication	No. of galls	larvae	pupae	adults	Length of galls (cm)
1	24	24	0	0	2.81
2	18	18	0	0	4.87
3	24	24	0	0	2.67
Total	76	76	0	0	3.44*

The mark * represents mean value

had already emerged or just before emergence and pupae were also matured. Prepupae infested by the Hymenopterous parasites were found at a middle portion of galls. The parasites had already emerged or some of the parasites were just before emergence.

In unmatured galls, 3.4 cm long in an average, almost all of the insect was at larval stage of 2—3 instars.

14. Effect of growing stage of rice plants on larval development and gall formation

METHOD

By sowing rice seeds in pots consecutively at an interval of 14 days, plants at seven different growth stages were provided for the application of eggs of the insect. Three plants were grown in each pot of 25 cm high × 19 cm in diameter containing clay loam soil. The fertile eggs one day before hatching were applied at the same time at a rate of 40 eggs per pot. Adult females captured by the light trap were introduced into a plastic tube (6 cm long and 2 cm in diameter) with a piece of paper rolled inside the wall and closed by a plastic cap and a wet cotten ball at one side. The insects were kept in the tube overnight for egg laying. The development of the larvae and pupae was also investigated by dissecting rice plants and the galls. In the present test, a lot of 9 pots was used for each growing stage with 4 replications. A variety, Leuang Twang, which is photoperiod non-sensitive with 120 days of growth duration and highly susceptible to rice gall midge was used. Ammophose (N: P: K: =16: 20: 0) was applied at a rate of 60 kgs per rai (=1600 m^2). The experiment was conducted at Entomology and Zoology Division, Department of Agriculture, Bangkok and at the Pan Rice Experiment Station in 1968 to 1969.

RESULTS

1) Plant height and number of tillers at the time of egg application.

As shown in Figure 14-1 and 2, plant height reached 120 cm at 70 days after sowing, with no more increase at 84 and 98 days. Date for each growth stage as expressed in number of days after sowing was as follows; the beginning of tillering on 14 days, active tillering stage 28 days, the maximum tillers stage with panicle primordium initiation 56 days, the booting stage 70 days, heading 84 days, and grain development stage 94 days. Average number of tillers per hill at the seven growth stages when the insect eggs were applied was 4.5, 12.5,

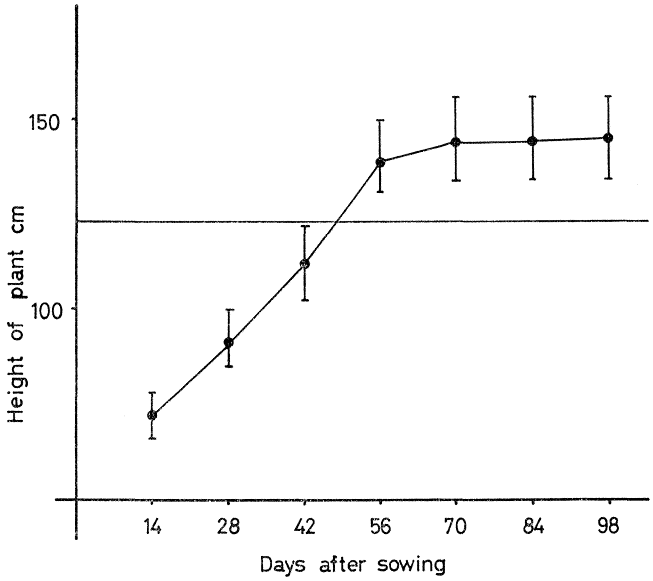

Fig. 14-1. Height of plant at the time when eggs of the rice gall midge were applied at Pan, 1968

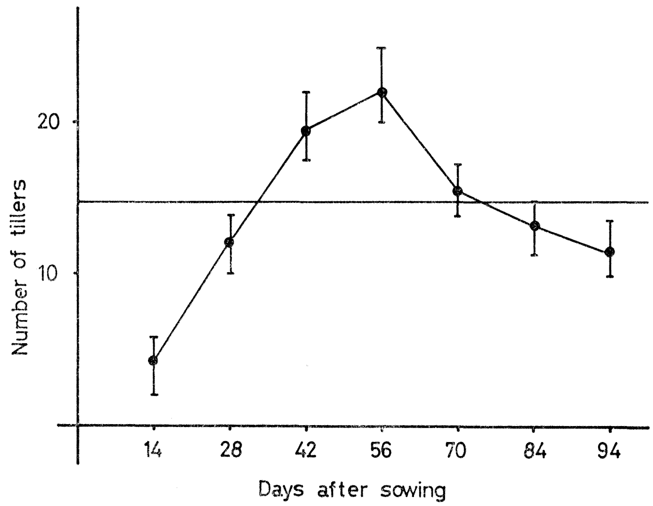

Fig. 14-2. Number of tillers at the time when eggs of the rice gall midge were applied at Pan, 1968

19.5, 22.5, 15.5, 13.0 and 11.5 respectively.

2) Larval encroachment at different growth stages of rice plants.

As mentioned above, 40 eggs were applied per hill. Number of the larvae encroached to growing points showed no differences among the seven growth stages. All of the larvae entered into plants even at the grain development stage, but their location was limited to only auxiliary buds.

3) Larval development in relation to growth stages of rice plants.

The larval development after entering into rice plants was apparently affected by the growing stages as signified by the curve shown in Figure 14-3. Significantly higher survival rate was observed in 28 day old plants. Percentage of the survival was in a decreasing order of 42, 14, and 56 days of age. It was also observed that mortality of the larvae was prominently high from 70 to 120 day old plants in which the 1st instar larvae failed to develop to the following instar. Thus, the survival rate of larvae was much higher in the tillering stages than that of the generative growth period conversely, mortality of larvae became high after the panicle primordium formation, due to lack of favorable habit and possibly of nutritional substance. Survival rate of pupae also was apparently higher in vegetative period than in the generative period of rice plants.

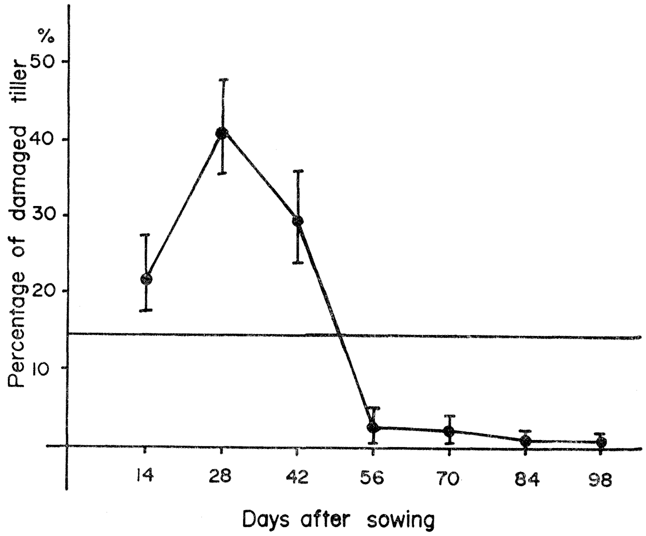

Fig. 14-3. Relation between damaged tiller and growing stages of rice plants at Pan, Chiengrai, 1968.

4) Gall formation at different growth stages.

Number of galls counted at 30 days after egg innoculation is also given in Figure 14-3. A largest number of galls was formed with 28 day old rice plants, but the number decreased markedly with older plants. This trend reflects the survival rate of the larvae. In rice plants older than the booting stages, gall occurred only on invalid tillers, and some of the galls remained unprotruded.

DISCUSSION

It was made clear that the rice gall midge attacked rice plants, causing severe damage, mostly at the vegetative growth period, so that control methods to be used at that time should be developed. In the present study, a photoperiod non-sensitive variety was used. However, the result can be applied to photoperiod sensitive varieties. With the latter varieties, a period of vegetative growth can be shortened by adopting late transplanting. This is an effective was to reduce the insect attack and hence crop damage.

It is worthy to note that 28 to 42 day old rice plants were most seriously infested by the insect. Therefore, if 25 day old seedlings are transplanted to paddy fields, an effective control date must be within 14 days after transplanting. On farmer's fields the first gall appears usually within 7 to 14 days after transplanting. Based on these facts, the authors recommended that if an insecticide is to be used, the first application should be done within 14 days after transplanting or immediately after the first appearance of galls. In this district, at least two times of insecticide applications, 14 days and 28 days after transplanting, will be needed for plants with long vegetative growth period whereas only one application will be enough for plants with a shorter vegetative period like Leuang Twang and RD 1. For plants older than the panicles primordium initiation stage it is useless to apply insecticides. The above date of application has an advantage of not killing Hymenopterous parasites and predators, because they usually appears from the middle of August.

15. Occurrence of the rice gall midge on rice ratoon

A survey was carried out to know whether or not the insect can survive in rice ratoon during the dry season.

METHOD

The survey on rice ratoons was conducted from November to January between 1968 and 1969. On 6 locations, 5 in Chiengrai Province (i.e. Chiengrai, Pan, Pasang, Maechan, and Maesai) and one in Chiengmai Province (Sanpathong). At Maechan and Maesai, upland rice was studied but at all other places lowland rice. Number of tillers, ratoons, larvae and galls were examined.

RESULTS

Galls occurred on rice ratoons at each locations as given in Table 15-1. However, the frequency was extremely low. Galls on upland rice ratoons must have been produced by the insects migrated from paddy fields to upland rice in October. When rice plants came to the reproductive stage. Length of ratoons was 16 to 19 cm long. Galls were 13 to 14 cm long. Adults emerged from galls was of same number as larvae. Damage of upland rice ratoons was low in percent, but that of lowland rice ratoons was lower than upland rice. All larvae were at 2nd instar at the time of the survey. At Sanpathong, adults emerged from

Table 15-1. Number of larvae and galls of the rice gall midge occurred on rice ratoon at Pan, 1968—1969

Place	Checking date	No. of tillers	No. of ratoons	Larvae	Galls	Length of gall (cm)	Growing stages of ratoon				Height of plant (cm)
							Tiller-ing	Primor-dium	Boot-ing	Head-ing	
Chiengrai	Dec. 28 68	111	120	1*	1	0.95	35	76	2	3	20.29
Pan	Jan. 19 69	149	156	1*	1	5.30	45	89	11	5	26.05
Pasang	Jan. 15 69	64	74	3*	3	0.33	31	37	0	6	25.01
Maechan**	Jan. 29 69	135	140	1*	5	0.97	54	83	0	3	25.40
Maesai**	Nov. 9 68	158	143	18*	18	14.31	79	64	0	0	19.29
Chiengmai	Nov. 9 68	161	151	9*	9	13.0	103	48	0	0	16.13

** Upland rice, * The 2nd instar larvae

4 galls of 5 examined, but the chance for egg laying and developing larvae again on ratoons must be very limited because larvae can not survive on withered ratoons during the dry season. Only on the ratoons produced from rice plants harvested early, the insect can survive for a certain period of time. It can be concluded that rice ratoons are not important in influencing population density of the insect of next generation.

16. The insect occurrence and damage of the second crop of rice

METHOD

A rice variety "Leuang Twang," which can be grown any time of the year, was planted as the second crop with irrigation at the Pan Rice Experiment Station during the dry season in 1970. Sown on January 30 at a rate of 50 g per m^2., 25 day old seedlings were transplanted on February 25, with spacing of 25×25 cm with 3 seedlings per hill. Total area of the experimental field was 400 m^2. Dosage of fertilizer was equivalent to 60 kg per rai (1600 m^2). No insecticide was applied. Four hundred hills of rice plants were selected at random to examine the damage caused by the insect every 15 days after transplanting. Another 20 hills of plants were sampled every week and all growing points collected were preserved in 75% alcohol for study of larval development of the insect.

RESULTS

Although the plants grew normally to the height of 129 cm with the supply of irrigation water, as given in Figure 16-1, no galls were found from the outside as shown in Table 16-1. However, a detailed examination of growing points found out two larvae on April 7 and 21, and two young galls developing on ineffective tillers on May 26 and June 2. The panicle primordium formation stage of the plants was at about April 7, and the heading stage started on May 5. The percentage of damaged tillers was less than 0.5. The two larvae found were at the second instar, with smaller body size than normal one. These larvae might have originated from the insects migrated from wild host plants at the beginning of April.

Table 16-1. Infestation of the rice gall midge on the 2nd crop of rice at Pan, 1970

Checking date	No. of tillers per 100 hills	No. of galls	Height of plant (cm)
March 9	351.25	0	36.40
23	852.25	0	50.40
April 8	1181.0	0	72.0
23	1259.0	0	84.65
May 7	1123.25	0	113.96
22	704.50	0	129.0
June 6	753.50	0	129.85

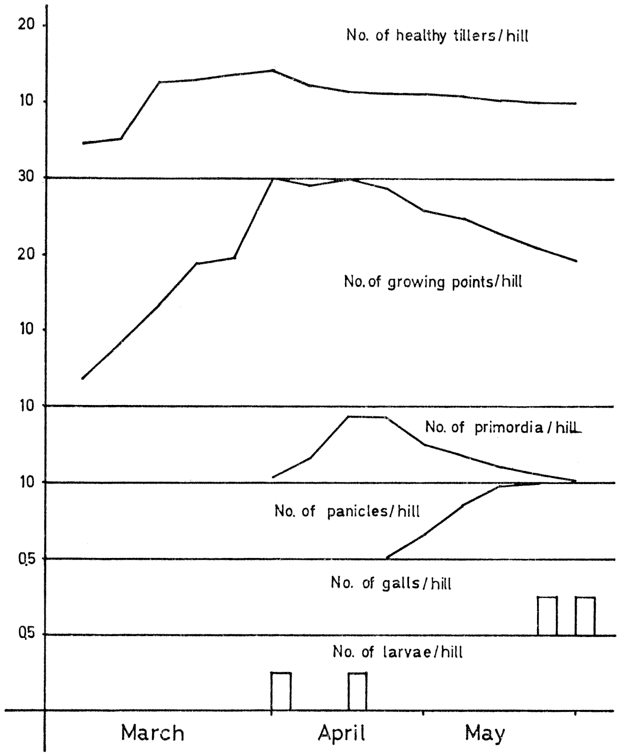

Fig. 16-1. Occurrence of larvae and galls of the rice gall midge on the 2nd crop of rice at Pan Rice Experiment Station, 1970.

DISCUSSION

The population density of the rice gall midge could not increase even under the irrigated condition during the dry season. It is suggested that the main reasons for that would be strong solar radiation and resultant low relative humidity. The finding that the second rice crop was markedly less damaged by the insect is very important from the practical point of view. The second rice crop is recommended to evade severe damage caused by the insect.

17. Effect of fertilizer on infestation of midge

Fertilizer use by farmers will increase from year to year, particularly with a wide spread of fertilizer responsive improved varieties. In this context, an experiment was made to determine the effect of fertilizers on the insect infestation. Silicate fertilizer which is effective to control rice stem borer was also tested.

METHOD

A variety, Dawk Mali 3, was transplanted at a rate of 3 seedlings per hill with the spacing of 25×25 cm at the beginning of July. A plot size was 50 m^2 (10×5 m) with 4 replications and 25 hills per plot were sampled for determination. Fertilizers were applied at one day before transplanting and top dressing of nitrozen was applied at the panicle primordium formation stage. Amount of fertilizers applied was 750 g (basal)+500 g (top) of N, 1250 g of P_2O_5, 215 g of K_2O and 2500 g of SiO_2. The experiment was run in September and October in 1970 and 1971.

RESULTS

Results are given in Table 7-1. It is interesting enough that unlike other rice pests, the gall midge infestation showed no response to fertilizer application; a specific phenomenon of the midge. It is suggested that the nutritional component of the growing point tissue might be maintained to be rather constant with or without fertilizer application. In case of the silicate fertilizer, it is particulary true because silicate is distributed into leaf blade and leaf sheath and may not utilized as a component of growing points.

Table 17-1. Influence of fertilizer on the damage caused by the rice gall midge at Pan, 1970 and Paruak, 1971

Name of fertilizer	Damaged tiller (%)	
	1970	1971
Check	18.73	64.47
Nitrozen	23.18	67.47
$N+SiO_2$	24.74	61.38
SiO_2	21.12	60.30

(II) Control of the rice gall midge

18. Varietal resistance to the rice gall midge

Under the natural environment of paddy fields and economic condition of most farmers in southeast Asia, the development of ecological control measures against the rice gall migde is most strongly required. Use of resistant varieties is considered one of the most effective and feasible approach to the insect control problem.

Therefore, a series of experiment was carried out on the screening and breeding of resistant varieties as well as analysis of the mechanism of resistance.

METHOD

a) Field screening test.

Twenty five days old seedlings were transplanted in early July at a spacing of 25×25 cm with one seedling per hill. A total of 95 hills (19×15 hills) in 1969 and 361 hills (19×19 hills) in 1970 and 1971 was planted for each variety with 3 replications. 25 hills were sampled from each variety at 30 days, 60 days, and 90 days after transplanting. Amophose (N: P: K= 16: 20: 0) was applied at a rate of 60 kg per 0.16 hectare.

b) Seedling test for screening.

Ten gramme of seeds for each variety were sown in a row on upland seed bed of 1.5 m wide × 7 m long. Standard varieties for the screening such as EK 1263 (highly resistant), Muey Nawng 62M (moderate resistant), and Dawk Mali 3 (susceptible) were sown every 10 test varieties. The experiment was carried out with 4 replications. Number of galls and healthy tillers was counted at 40 days after sowing. Amophose was applied at a rate of 10 kg per rai.

c) Laboratory screening test with seedlings.

Seeds of each variety were sown in a row in rice seeding box of 25 cm wide × 50 cm long × 20 cm high. Distance between rows was 2 cm. The boxes were covered by screen net and adults of the rice gall midge were introduced to the boxes 15 days after sowing. The experiment was carried out with 4 replications. Damage was examined 40 days after egg laying under a binocular microscope.

RESULTS

a) Classification of resistant varieties.

Varietal resistance identified by seedling tests and field tests was given in Table 18-1 and Figure 18-1. The varieties, EK 1263 and 1252 from India, were graded as highly resistant. They are photoperiod nonsensitive, liable to lodge, and suffers from rice thrips at the Pan Rice Experiment Station. They are tall indica type varieties with purple colored leaf sheath and rather small reddish grains of poor quality. High resistance was not recognized with Japanese varieties examined. Hatsunishiki was moderately resistant, and percentage of damaged tillers was less than Miyoshi, Towada, and Fujisaka No. 5. Japanese varieties showed extremely short period of growth, only 3 months, in Thailand. Plant height was only 50 cm with poor tillering. TKM 6 from India is known as a resistant variety for stem borers, but moderately resistant to the rice gall midge. TKM 6 was also of short duration of 3 months with narrow stem.

Recommended varieties of Thailand, RD 1, RD 2, and RD 3, which were released in 1969 were identified as susceptible to highly susceptible to the midge, showing more than 70% of

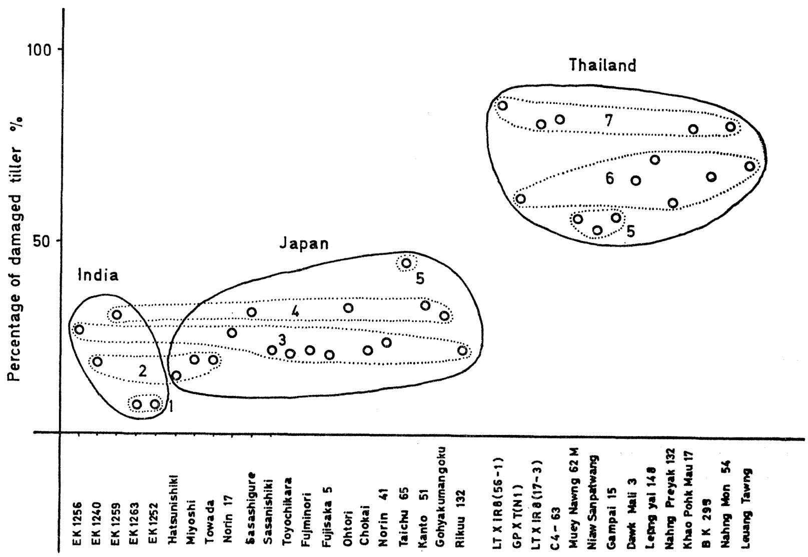

Fig. 18-1. Screening test of varietal resistance against the rice gall midge at Pan Rice Experiment Station, 1969.

Table 18-1. Classification of resistant varieties against the rice gall midge at Pan, 1968—1972

Classification by damaged tiller (%)	Name of rice varieties examined
1. Highly resistance, lower than 10%	EK 1263, EK 1252
2. Resistance, 11 to 20%	EK 1240, Mahk Muang, Leuang Awn (Pw 64-21-888), LT × IR 8 B-1-67, A-1-23, A-1-316, HR 63, TKM 6, Mudgo × IR 8 693, Burma 12, Hatsunishiki, Miyoshi, Fujisaka No. 5, Towada
3. Highly moderate, 21 to 30%	EK 1256, Eswarakorra, Nam Sa Gui 19, Lt 505-2-64, LT × IR 8 (B-1 3 lines), A-1-48, HR 42, IR 8 × TKM 6 (IR 580-75381), Sasanishiki, Toyochikara, Fujiminori, Rikuu, Chokai, Norin 17, Norin 41
4. Moderate, 31 to 40%	EK 1259, MN-62M, Daw Hawn 26, Khitom Yai 98, Gampei 41, Niaw Pey 609-4-10, LY 34 × Rahk Pai (SPT 55-8-215), Mudgo × IR 8 605, Leuang Yai 228-2-148, Tewadah 232-16-60, PTB 18 and 21, LT × IR 8 B-1-35, NSPT × IR 262 (1 line), Sasashigure, Ohtori, Kanto 51, Gohyakumangoku
5. Susceptible, 41 to 50%	Hang Yi 71, IR 262 × TKM 6, MN (64-G 1 U, 6 lines), Daw Leang, MN (64-G 2 U 5 lines), GR 21 × KDML 53, Paung Aew 562-1-7, Daw Dawk Prao 456-2-82, Ma-Kheua 626-8-99, Pawng Ahw 614-4-12, Dawk Mai 397-14-147, Puang Ngern × Zuiho (SPT 58-22-346), Niaw Pey 609-4-2, LA458 × Zuiho (SPT 57-26-1308), 55 NMS-4NEU (MNN 1-6), LT × IR 8 (B-1 3 lines and A-1 2 lines), Mudgo × IR 8 624, Taichu No. 65, IR 8 × TKM 6 (4 lines), TKM6/2 × T(nl) 3 lines, IR 20, GP × T(N) 1, KDML × IR 262
6. Highly syusceptible, more than 51%	Dawk Mali 3, RD 1, RD 2, RD 3, Leuang Tawng, Niaw-sanpatwang, Gampei 15, C4-63, Leuang Yai 148, Nahng Prayah 132, Khao Pohk Man 17, BK 293, Nahng Non 5-4, IR 8, IR 11, IR 262-43, 666-1, IR 22, MN (64-G 1U 8 lines and 64-G2U 10 lines), LT × IR 8 7 lines, Peta 2 × T(N) 1 × MN, Sanpatwang 2 lines, CP-SLO-MAS, Peta × BPI 76, MN 62M × IR 262 (62 lines), Nahng Dam (2 lines), Daw Dawk Put, Jao Daeng 3 lines, Pawng Aew 420-6-112, 562-1-5, Jao Khao 404-2-88, Hahng Yi 563-2-20, Puang Gaew 659-9-40, Daw Poo Tan 454-8-34, LY34 × Rhak Pai (SPT 55-8-215), Ma-Kheua 625-2-41, Nam Ahng 3 lines, Pawng Ahw 629-2-41, Nahng Nuan 625-9-38, In Tok 621-1-13, Rhak Pai × PN 16 (3 lines), Ngan Dong 618-1-43, LY2-B-72 × PN 16, Dawk Mali 618-3-17

damaged tillers.

b) Breeding of resistant variety.

The Rice Breeding Division in cooperation with the Entomology Branch of Rice Protection Research Center has carried out the breeding programme for resistant varieties by utilizing EK lines as breeding materials. The objectives of the programme was to develop resistant varieties with good plant type, good tillering, high yielding potential, and good rice quality. More than 2000 lines crossed with EK lines were tested. As given in Table 18-2, the following

Table 18-2. The EK hybrid lines resistant to the rice gall midge at Pan, 1968—1973

	Crossing parents	Lines	Generation
1.	(17-1 LT × IR 8) × EK 1240	6742-5-1-2, -5-2-1, -11-2-2, -12-1-1, -26-2-1	F 8
2.	(17-1 LT × IR 8) × EK 1263	6743-20-1-1, -51-1-2, -77-1-1, -77-1-5, -88-1-1, -94-1-1, -94-1-2, -100-1-2, -105-1-2, -105-1-3, -111-1-2, -111-1-3, -111-1-5	F 8
3.	(14-1 LT × IR 8) × EK 1263	6746-18-1-1, -22-1-1, -51-1-1, -89-1-1, -89-1-3, -89-1-4, -93-1-1, -93-1-2, -121-1-1, -132-1-1, -132-1-4, -146-1-2, -151-1-1, -177-1-1	F 8
4.	(17-1 LT × IR 8) × EK 1251	6744-21-2, -21-7, -21-17, -21-19, -21-38, -2-6, -2-8, -2-9, -16-1, -16-2, -16-3, -16-6, -16-8 1754-16-11, -16-14, -16-17, -35-1-3, -17-1-3 6744-71-1-2, -118-1-1, -150-2-1, -15-2-3	F 8
5.	(17-1 LT × IR 8 × EK 1252) × GP2-T(N) 1	BKN 6805-2, -7, -22	F 7
6.	(17-1 LT × IR 8 × EK 1259) × GP 2-T(N) 1	BKN 6806-16, -18, -34, -36, -46	F 7
7.	(LY 2 × T(N) 1 × EK 1263) × GP 2-T(N) 1	BKN 6811-2	F 7
8.	(LY 2 × T(N) 1 × EK 1256) × GP 2-T(N) 1	BKN 6809-51, -63, -64, -74, -82	F 7

two group of lines were used as the basal breeding materials; (1) 17-1 LT 14-1 LT × IR 8 × EK and (2) Leuang Yai/2 × T(N) 1 × EK. Crossing Gampei × T(N)1 was also combined with (1) and (2) groups. Two varieties such as Niawsanpathong, representative variety in north Thailand, and Hand Yi were also crossed to (1) and (2) lines. It must be added here that RD 1 and RD 3 were bred from the crossing of Leuang Tawng × IR 8, and RD 2 from Gampei × T(N) 1.

A total of 69 resistant lines were selected from crossing with EK lines and they were in generation of F 7 and F 8 in 1973. In 1972, the seeds of lines such as BKN 6805-2, BKN 6805-22, BKN 6806-46, BKN 6806-18, and BKN 6809-74 were distributed to farmers for practical trials on farmers fields. As the line BKN 6086-46 is glutenous rice, it was selected for the use in north and northeast Thailand where people prefer glutenous rice. The other four BKN lines were non-glutenous with long grains. On April 2nd 1973, the line BKN 6806-46 was registered as a new variety RD 4 resistant against the rice gall midge.

c) Mechanism of resistance

METHOD

(1) Preference in egg laying on rice varieties.

Twenty one rice seedlings each of EK 1263, MN-62M, and Dawk Mali 3 were transplanted alternately in a pot (30 × 30 cm) covered by screen net. 3 adults of the midge were released to the pot, and eggs laid on the plants were counted.

(2) Larval entrance into rice plants.

Plants were dissected 24 hour after hatching to count the larvae on the growing points.

25 day old seedlings were transplanted with 3 seedlings per pot (20 cm in diameter). A total of 40 eggs just before hatching was placed on plants per pot.

(3) Larval development in rice varieties.

Dawk Mali 3, RD 1, MN-62M, and EK 1263 were transplanted with one seedlings per hill in the beginning of July. Larvae, gall, tillering and plant height were examined 5 times every 15 days after transplanting. Five hills were used to examine growing points and larval developments. Damage on rice plants was determined with 50 hills per variety with 4 replications. Amophose was applied at a rate of 60 kg per rai.

RESULTS

(1) Number of eggs.

No difference was found between different varieties in the number of egg laid, as shown in Table 18-3. Furthermore, no difference was found with the position of egg laying on plants,

Table 18-3. Egg laying and hatching of the rice gall midge on resistant and susceptible varieties at Pan, 1969

Condition	Rice varity	No. of eggs on: Leaf sheath	No. of eggs on: Leaf blade upper surface	No. of eggs on: Leaf blade lower surface	Total no. of eggs	No. of egg hatching	Percent egg hatching
Pot tets*	EK 1263	479	151	290	920	—	—
	MN-62M	563	160	201	924	—	—
	DM-3	489	181	307	977	—	—
Paddy field*	EK 1263	1453	471	978	2902	2900	99.93
	MN-62M	1681	417	813	2911	2871	98.62
	DM-3	1528	504	984	3016	2999	99.43
Paddy field**	EK 1263	121	28	59	208	—	—
	MN-62M	183	37	58	278	—	—
	DM-3	116	35	62	213	—	—

* Adults of the rice gall midge were released to the test field.
** Eggs laid naturally in the field were collected.

Table 18-4. Encroachment of the 1st instar larvae of the rice gall midge into rice plants at Pan, 1969

Condition	Rice variety	No. of eggs	No. of eggs hatched	Percent egg hatched	No. of larvae penetrated	Percent larval penertation
Pot test*	EK 1263	920	904	98.26	815	90.15
	MN-62M	924	914	98.91	839	91.79
	DM-3	977	953	97.54	841	88.24
Pot test**	EK 1263	400	372	93.0	359	96.50
	MN-62M	400	374	93.50	352	94.11
	DM-3	400	365	91.25	344	94.24

* Data from the pot test in the Table 17-3
** Data indicate total no. of eggs per 10 pots for each variety

and in percentage of egg hatching.

(2) Entering of larvae into plants.

As given in Table 18-4, no difference was shown in the number of larvae entered into the

Table 18–5. Larval developnemt on rice plants at Pan, 1969

Rice variety	Replication	No. of eggs	No. of eggs hatched	No. of larvae 1st	2nd	3rd	No. of prepupa	No. of pupae	No. of adults
EK 1263	1	160	153	152	1	0	0	0	0
	2	160	144	130	11	3	0	0	0
	3	160	155	124	16	5	6	0	0 A
	4	160	144	113	8	10	5	7	0 B
	5	160	151	117	10	9	3	5	7
DM–3	1	160	156	143	13	0	0	0	0
	2	160	156	39	76	36	5	0	0
	3	160	145	9	30	75	21	10	0
	4	160	150	13	22	18	21	42	17 C
	5	160	142	13	21	13	14	18	45 D

4 larvae escaped from rice plants during the test in A, as well as 1 in B, 17 in C, and 18 in D respectively.

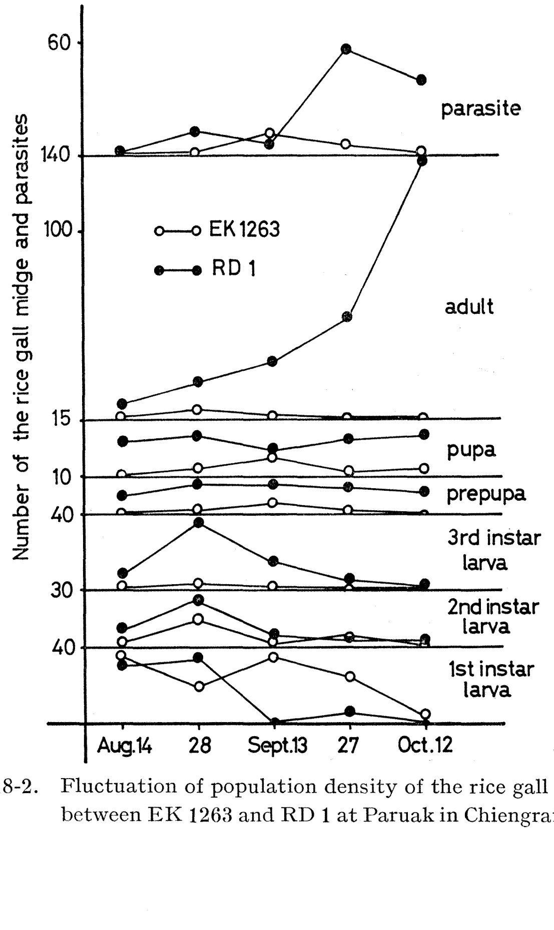

Fig. 18-2. Fluctuation of population density of the rice gall midge between EK 1263 and RD 1 at Paruak in Chiengrai, 1971

plants; % of newly hatched larvae entered into plants of different varieties.

(3) Larval development after entering plants.

Majority of larvae entered into EK 1263 grown in the pot remained at the 1st instar. On the contrary, further developmental stages were observed in Dawk Mali 3 as shown in Table 18-5. This difference in larval development found between different varieties was confirmed by the results of field experiment, as shown in Figure 18-2 and 18-3. No larval development took place, whereas larvae developed well with RD 1. Length of pupal body and width between two paird spines on head were smallest in EK 1263 and became larger in an increasing order of MN-62M, Dawk Mali 3, and RD 1. The gall formation in EK 1263 was less in number resulting only 3% of adult emergence.

High larval mortality and inhibited larval development in resistant variety suggested the existence of some inhibiting substance or the lack of substance neccessary for larval development.

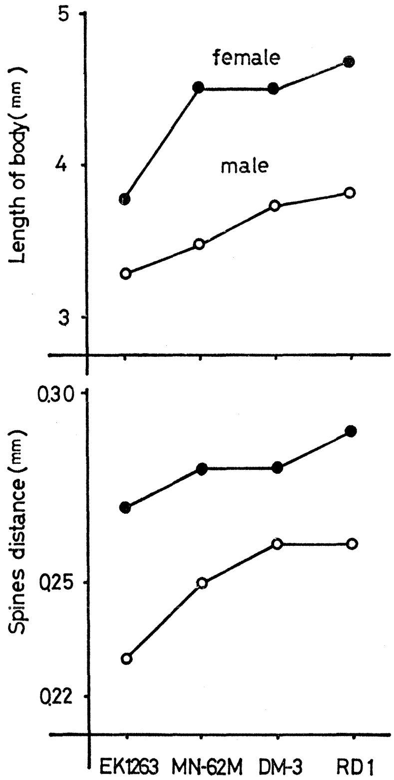

Fig. 18-3. Relation between pupal body size and rice variety at Paruak in Chiengrai, 1971.

d) Difference in gall formation and size of insect between resistant and susceptible varieties.

(1) Damage caused by the rice gall midge.

As given in Table 18-6, susceptible varieties, RD 1 and Dawk Mali 3, showed the peak of 68 and 57% of damaged tillers on September 27, whereas damage of the resistant variety,

Table 18–6. Seasonal fluctuation of damaged tillers and plant height in four rice varieties at Paruak in Chiengrai Province, 1971

Checking date	EK 1263		RD 1		MN–62M		DM–3	
	Damaged tiller (%)	Height	Damaged tiller (%)	Height	Damaged tiller (%)	Height	Damaged tiller (%)	Height (cm)
Aug. 14 71	0	87.20	8.93	64.50	5.57	90.30	5.60	82.30
28 71	0.22	118.0	35.59	74.40	29.32	106.40	32.63	104.50
Sept. 13 71	5.25	163.4	62.98	75.30	47.54	116.60	53.66	110.30
27 71	5.78	173.9	68.50	85.90	42.57	135.80	57.61	111.70
Oct. 12 71	6.04	176.7	54.80	91.30	33.41	153.40	49.88	123.40
Average damage transformed	13.36	—	75.44	—	61.32	—	69.64	—

EK 1263, was only 5.7%. Such a big difference was expressed from the end of August to October although no difference in damage was recognized untill the middle of August. As the galls which appeared at the end of August were produced by the larvae entered in plants at the end of July, the insect of the second generation were inolved in causing such big difference in damage. It was also found that high infestation of the insects to susceptible varieties caused a significant reduction in plant height and formation of abnormal tillers. These tillers, small and young, were liable to be attacked easily by the insects.

(2) Length of galls.

Results are given in Table 18-7. Growth of gall is usually proportional to plant height, but as seen in EK 1263, galls occurred in the resistant variety were extremely short. Galls were significantly longer in susceptible variety than that of the resistant one. An important finding is that the length of galls can be used as a criterion in identifying resistant varieties. Weight of galls on the resistant variety was also lighter than that of suceptible variety, the former was 1/4 of the latter.

Table 18–7. Growth of gall in four rice varieties at Paruak in Chiengrai, 1971

Rice variety	Length of gall (cm)	Height of plant (cm)	Weight per gall (gr.)
EK 1263	19.97	149.3	0.23
RD 1	40.19	75.3	0.83
MN–62M	30.71	153.4	0.74
DM–3	42.37	123.4	0.77

(3) Pupal development in rice varieties.

(i) Body length of pupae.

Results are given in Figure 18-3. Body size of pupal female bred in each variety examined was larger than that of male. Both male and female pupae bred from the resistant variety were distinctly small, being shorter than 4 mm long whereas female pupae in the susceptible variety was 4.7 mm long. Body length of pupal male was shortest in EK 1263 followed by MN-62 M, DM-3, and RD 1 in an incresing order.

(ii) Width between spines on pupal head.

As given in Figure 18-3, a similar relationship as observed with body length of pupae was found with the distance between two paired spines on pupal head: a short distance on resistant varieties than that on susceptible varieties.

e) Growth characteristics of resistant varieties.

So far as varieties used in the present experiment are concerned, number of tillers varied from variety to variety. Especially, EK 1263 produced 30% more tillers than three other varieties. Tillers per hill was more than 10 in EK 1263 but less than 7 in three other varieties.

Therefore it can be said that EK 1263 offered more abundant growing points to the insects. Nevertheless the variety showed a high resistance to the insects. On the other hand, the variety initiated its panicle primordium formation in the middle of August, about one month earlier than other varieties. This must have contributed partly to the high mortality of larvae occurred with that variety.

f) Relation between damage and number of panicles.

Results are given in Figure 18-4. Damage of tillers in Japanese varieties was 11 to 17% but number of panicles per hill was 11 to 13. On the other hand, the resistant variety EK 1263 had 7% of damaged tillers and produced 11 panicles per hill. The other resistant lines had 6 to 15% of damaged tillers and 8 to 9 panicles per hill. Susceptible varieties produced only 4 to 7 panicles per hill when damaged tillers were more than 50%. In Generally, it is recognized that higher percentage of damage resulted in fewer panicles.

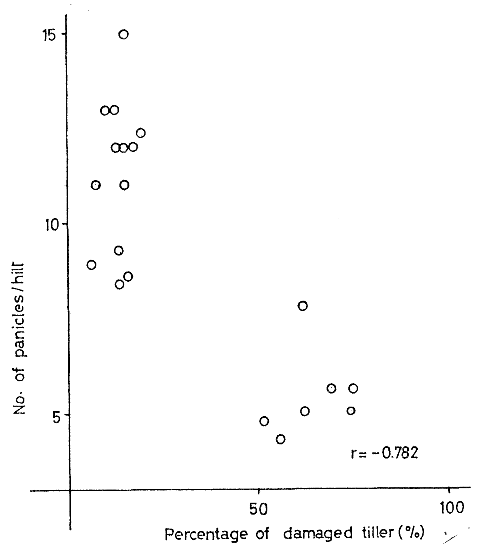

Fig. 18-4. Relation between no. of panicles per hill and damaged tillers (%) at Pasang, Chiengrai, 1971.

19. Effect of planting dates of rice plants on occurrence and damage of the rice gall midge

As reported already in the previous Chapter of this paper, crop damage caused by the rice gall midge is remarkably influenced by the date of transplanting of rice. This fact furnishes a possiblity of developing an agronomic control measure against the insect. Therefore, an extensive experiment was carried out at several locations of different condition to make clear the effectiveness of late-planting in reducing the insect damage and hence in increasing grain yield.

METHOD

The present experiment was done in the Pan Rice Experiment Station, the Sanpathong Rice Experiment Station, Farmer's fields at Fang in Chiengmai Province, Pibun Mansahan in Ubol Province, and the Sakonnakorn Rice Experiment Station from 1968 to 1970. The experiment was also carried out at the Pan and Chung pae Rice Experiment Stations in 1969 and 1970. Planting dates, although varied to some extent according to the customary practice of each location, were June, July, August, and September in Main crop season and January for second rice crop. Transplanting of 25 day old seedlings with 3 seedlings per hill at a spacing of 25×25 cm was done every 30 days in 1968 and every 15 days in 1969 and 1970. Dawk Mali 3, RD 1 (only in 1970), and Leuang Twang (in dry season) was used. Total area of experimental areas was 400 m^2. Amophose was applied at a rate of 60 kg per rai. 100 hills were sampled at random with 3 replications once a month in 1968 and every 15 days in 1969 and 1970. As the outbreak of the rice gall midge occurred at the Pan Rice Experiment Station in 1969, 20 hills were sampled every 10 days. Items studied were number of tillers, fluctuation of growing points, number of galls, and developmental stages of the insect including the natural enemies.

RESULTS

1) Insect occurrence and crop damage from 1968 to 1970.

a) Pan Rice Experiment Station in 1968.

As shown in Table 19-1, plants transplanted early (July 7) were severely attacked by

Table 19-1. Change of damaged tillers as related to different planting dates at Pan, 1968

Checking date	Damaged tillers (%)			
	1st	2nd	3rd	4th
Aug. 7 68	1.26	8.77*	—	—
Sept. 7 68	29.79	2.66	0.23*	—
Oct. 7 68	8.38	5.0	0.38	1.28*
Nov. 7 68	2.83	1.83	12.37	2.52
Dec. 7 68	0	0	0.45	1.84
Average damaged tiller	25.15	9.91	9.95	4.51

* Damaged tiller was checked on 24 of each month.
Transplanting dates were as follows, 1st on July 7, 2nd Augst 7, 3rd Sept. 7, and 4th Oct. 7.

Table 19-2. Rice yield and damage as related to different planting dates at Pan, 1968

Planting date	No. of panicles per hill	Length of panicles (cm)	Dried straw per hill (gr)	Height of plants (cm)	Paddy rice per 1000 panicles (kg)
1st	7.40	24.10	4.86	162.0	2.195
2nd	7.64	22.90	3.30	140.0	2.575
3rd	7.77	22.25	2.66	115.0	2.549
4th	10.04	20.81	1.32	77.0	2.714

the midge, giving 29.8% of damaged tillers on September 7. Damage was 9.9% with the second and 3rd planting and 4.5% with the fourth planting. Thus, the damage decreased remarkably with late plantings from July to October. However in this year, insect infestation more than 30% was not observed.

Growth and yields of rice are given in Table 19-2. Plant height was 162 cm with early planting and 77 cm with late planting. Paddy rice per 1000 panicles was 2.195 kg in early planting and 2.714 kg in the late planting.

b) Fang in Chiengmai Province in 1968.

Although the midge occurrence in 1968 was few and hence a small damage of rice plants, it was recognized that late planting resulted in less damage, as shown in Table 19-3.

c) Sanpathong Rice Experiment Station in 1968.

Rice plants transplanted on July showed 6.6% of damaged tillers, while only 0.3% with plants transplanted in September 20 as given in Table 19-3.

Table 19-3. Damage caused by the gall midge as related to different planting dates in some locations in Thailand, 1968

Location	Checking date	Damaged tillers (%) 1st	2nd	3rd planting
Fang, Chiengmai	Aug. 27	0.24	—	—
	Sept. 22	7.41	1.18	—
	Nov. 3	1.61	2.71	2.22
Sanpathong, Chiengmai	Aug. 30	0.40	—	—
	Sept. 26	6.62	0.74	—
	Oct. 30	2.46	0.95	0.30
Ubol	Sept. 17	30.86	—	—
	Nov. 17	20.87	1.43	1.51

d) Pibun Mansahan in Ubol Province in 1968.

This place was selected as a site of experiment, because the rice gall midge has been endemic there. However, being far away from Bangkok and Chiengrai, observation was made only two times. Nevertheless, it was clearly found that crop damage was more severe with early planting than late planting. Damage of crop transplanted in the middle of August was 20 to 30% of damaged tillers, but only 1.7% with late planting, as given in Table 19-3.

e) Pan Rice Experiment Station in 1969.

In 1969, an extremely severe outbreak of the midge occurred at Pan. The result obtained in this particular year also clearly showed that early planting gave 91.4% damaged tillers while only 50% with late planting, as given in Table 19-4. Number of galls produced per hill was 39 with early planting and 18 with late planting. Number of healthy panicles per hill was 3.1 in early planting and 7.3 in late planting as given in Table 19-5. Thus, the former

Table 19-4. Damage caused by the rice gall midge as related to different planting dates at Pan, 1969

Checking date	Damaged tiller (%)			
	1st	2nd	3rd	4th planting
July 24	0	—	—	—
Aug. 9	0.10	1.96	—	—
Aug. 23	3.76	0.79	9.78	—
Sept. 8	27.70	7.71	2.57	1.46
Sept. 27	91.41	93.16	85.72	50.0
Oct. 13	70.85	73.53	73.14	71.04
Oct. 28	48.65	47.55	45.12	45.08
Nov. 17	35.02	25.21	17.35	11.49

Transplanting dates were 1st on July 6, 2nd July 25, 3rd Aug. 7, and 4th Aug. 25 respectively.

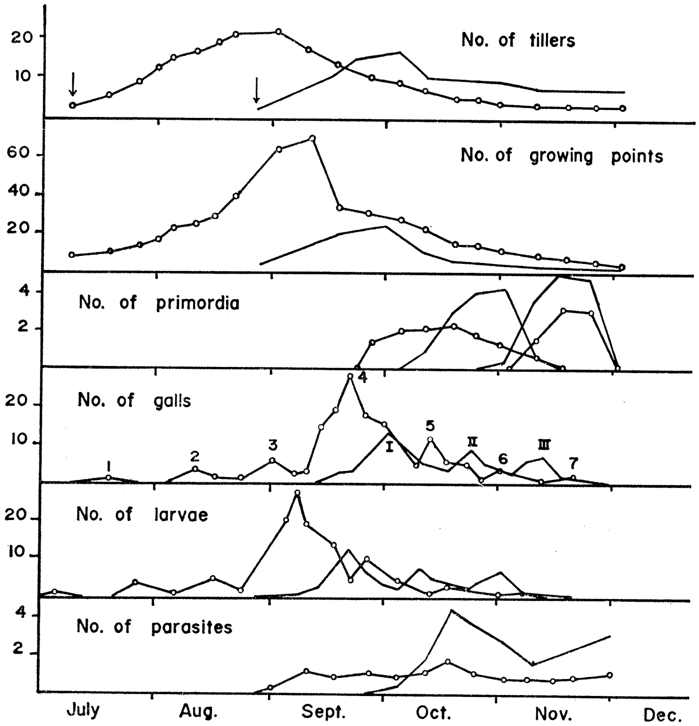

Fig. 19-1. Effect of planting dates of rice plants on gall occurrence and parasite of the rice gall midge at Pan, 1969. o—o Early and —— late transplanting dates, ↓; Transplanting date, 1···7 and I···III; Peak of each generation.

Table 19-5. Rice yield as related to different planting dates at Pan, 1969

Planting date	No. of grains/ panicle	Healthy grains (gr)	Dried straw/hill (g)	No. of panicles/ hill	Healthy grains/ $4m^2$	Healthy kernels (%)	Yield/ hec. (ton)
July 7	121.54	2.96	10.10	3.10	892.33	89.31	1.71
July 25	110.05	2.72	10.80	3.50	865.33	87.0	1.65
Aug. 7	102.82	2.67	11.83	3.90	863.33	90.77	1.64
Aug. 25	102.78	2.67	15.90	7.30	1143.33	93.15	2.19

yielded 1.7 tons of grain in contrasted to 2.2 tons per hectare of the latter. Difference in straw weight and number of grains per panicle was also very clearly recognized. Plant damage was so severe with early planting, that number of tillers was reduced considerably, and as a result of compensation number of grains per panicle was increased.

As illustrated in Figure 19-1, there appeared seven peaks of gall occurrence with early planted rice, reflecting the cycle of seven generations of the insect from transplanting to harvesting. On the other hand only four peaks of gall occurrence were recognized with late planting, reflecting the cycle of four generations.

f) Paruak in Chiengrai Province in 1969.

Here again, marked difference in damaged tillers, number of galls and healthy tillers was observed between early and late transplanting. Grain yield was 0.93 tons (rough rice) with early planting whereas 2.41 tons with late planting.

Table 19-6. Infestation of the rice gall midge in relation to different planting dates at Paruak and Maekam in Chiengrai Province, 1969

Place	Checking date	Damaged tiller (%)	
		1st	2nd planting
Paruak	Aug. 29	15.44	—
	Sept. 24	84.36	11.95
	Oct. 24	89.57	33.58
Maekam	Aug. 29	51.68	—
	Sept. 24	79.13	5.91
	Oct. 24	40.58	34.16

Table 19-7. Rice yield in relation to different planting dates at Paruak and Maekam in Chiengrai, 1969

Place	Planting date	Damaged tiller (%)	No. of panicles/ hill	Paddy rice/4 m^2 (kg)	Dried straw/hill (g)	Yield/ hec. (ton)
Paruak	July 25	89.57	4.06	470.66	28.25	0.93
	Aug. 25	33.58	12.74	1259.33	36.76	2.41
Maekam	July 25	74.47	7.70	1484.33	36.13	2.81
	Aug. 25	34.16	12.60	1557.66	32.43	2.95

g) Maekam in Chiengrai in 1969.

Although marked difference were observed in damaged tillers, number of galls and tillers, and plant height in a same way as expressed at other experimental sites between early planting and late planting, no difference in grain yield was recognized. This result can be attributed to the fact that the early planted rice recovered from the severe damage due to a good weather lasted during the maturing period of the early planted rice.

h) Chunpae Rice Experiment Station.

As given in Table 19-8, percentage of damaged tillers decreased markedly with late transplanting and number of tillers per hill was more with late planting than early planting when counted in November. However, yield difference was not so remarkable as expected.

Table 19–8. Infestation of the rice gall midge in relation to different planting dates at Chunpae in Kohn Kaen, 1969

Checking date	Damaged tiller (%)				
	1st	2nd	3rd	4th	5th planting
Aug. 5	0.03	0.02	—	—	—
Aug. 22	2.17	0.98	0.22	—	—
Sept. 18	7.14	7.07	2.52	0.98	0
Nov. 10	3.66	8.07	6.78	2.11	0.82

The 1st to 5th transplanting dates were July 1st, July 15th, Aug. 1st, Aug. 15th, and Sept. 1st respectively.

i) Sanpathong Rice Experiment Station

Relation of planting date to damage was not clear, because of low incidence of the insect.

j) Pan Rice Experiment Station in 1970.

With a photoperiod sensitive variety, Dawk Mali 3, relation of planting date to damage was not clearly observed, although late-planted rice showed more panicles, shorter plant height, and slightly higher grain yield (1254 gr per 4 m^2) than early planted rice.

With a photoperiod non-sensitive variety, Leuang Twang, the late transplanting showed less damaged tillers, more panicles per hill (9.7 in contrast to 7.6 of early planting), short plant height (103 cm as compared to 148 cm of early planting), and higher grain yield (1645 gr per 4 m^2 as compared to 617 gr of early planting).

k) Paruak in Chiengrai Province in 1970.

As given in Table 19-9, remarkable difference was observed between early planting and late planting in percentage of damaged tillers, number of galls per hill, number of panicles per hill and grain yield with both varieties Dawk Mali 3 and Leuang Tawng. Grain yield

Table 19–9. Infestation of the rice gall midge in relation to different planting dates at Paruak, Chiengrai, 1970

Rice variety	Transplanting date	Damaged tiller (%)	Total no. of galls/hill	No. of panicles/hill	Yield/4 m^2 (g)
DM–3	July 7	74.14	44.03	3.71	686.6
	Aug. 25	27.43	5.33	9.81	1765.0
Leuang twang	July 7	81.13	65.38	3.18	425.3
	Aug. 25	44.94	17.66	11.70	1634.0

per 4 m^2 was 686 gr and 1765 gr with Dawk Mali 3 in early and late plantings respectively, and with Leuang Twang that of late planting was as high as 4 times that of early planting.

2) Comparison of growth of plants and insect infestation between early and late plantings.

As shown in Figure 19-1, growth duration of late planted rice was only 4 months as compared with 6 months of early planted rice. However, as the panicle primordium initiation took place at about the same time with both cases, a period of tillering stage differed with each other. During the long growth duration of the early-planted rice the insect completed 7 generations whereas with late-planted rice only 3 generations were completed. Number of galls reached a peak at the end of September in both cases. With the early-planted rice the peak of number of galls occurred at the fourth generation of the insect, whereas it occurred at the first generation with the late-planted rice. Thus, the insect population became very high during a long period of tillering stage of the early-planted rice, resulting in more severe damage than that of the late-planted rice.

20. Damage and grain yield of different varieties with different planting dates

Damage by the insects and grain yields of resistant and susceptible varieties were examined with early planting and late planting. Diazinon, an insecticide effective to the insect, was used as a treatment for getting varying degree of damage.

METHOD

Four varieties, DM-3, MN-62M, Leuang Twang, and EK 1252, were transplanted on July 7 and August 24. The former two varieties were photoperiod sensitive and the others non-sensitive. Area of a plot was 10 m^2, with three replications. Diazinon, 3% in granular form, was applied 14 and 28 days after transplanting at a rate of 2 kg of active ingredient per hectare. Amophose was applied at a rate of 60 kg per rai. Crop damage by the insect was examined on September 12 and October 9. Number of galls and healthy tillers was counted with 50 hills per plot, and grain yield was measured on 4 m^2 area per plot.

RESULTS

1) Damage caused by the rice gall midge in each variety.

Results are given in Figure 20-1, although the insect infestation was not so high in 1970, showing only damaged tillers of 24% at the highest with susceptible variety, the effect of Diazinon in reducing the damage was apparent both with early planting and late planting. However, it was recognized that the difference in damage by varieties was far more remarkable than the difference caused by the insectcide application. EK 1252 is a variety highly resistant to the insect. MN-62M is moderate resistant, DM-3 susceptible and Leuang Twang highly susceptible. With all the varieties, except MN-62M, an early planting gave higher grain yields than late planting. The insecticide application also increased grain yields, though the effect was not remarkable. Low yields of EK 1252 was caused by the lodging which occurred at the heading stage. The other varieties did not lodge. Grain yields of MN-62M were highest among varieties used, in spite of severe damage by the insect. This might be due to a high compensation capacity of the variety.

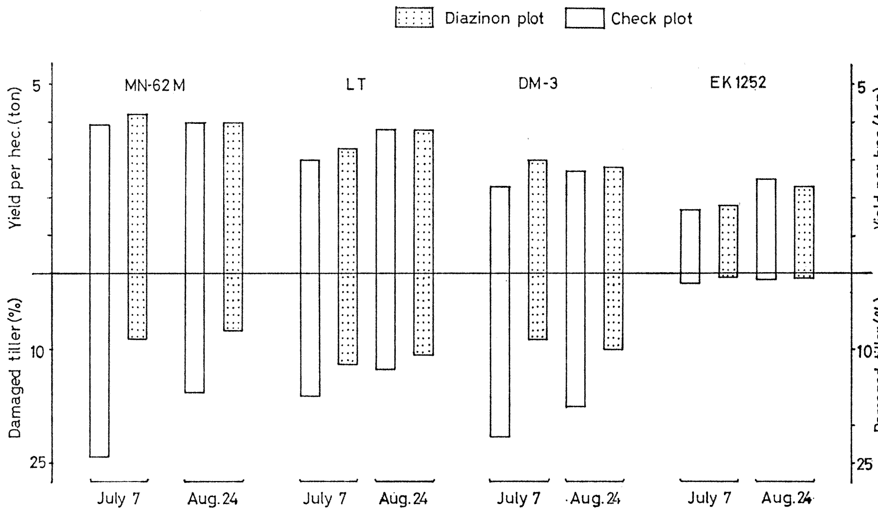

Fig. 20-1. Damage caused by the rice gall midge and yield of different rice varieties at Pan, 1970.

21. Control of the rice gall midge by the insecticides

In addition to the use of resistant varieties and other agronomic control measures, discussed in the previous part of this paper, a series of experiment was carried out on the insecticidal control of the midge, because the authors consider that the insecticidal control might play an important role at the time of serious outbreak of the insect.

In Thailand at present, 22 pest control units of the Department of Extension, Ministry of Agriculture and Cooperatives are distributed throughout the country. Pest control inspectors working at the Units are keeping watch on outbreaks of pests.

The Government purchases 200000—3000000 tons of insecticides annually. Although most of them are used to other crops like cotton, maize, citrus, etc, a part of them has been used for pest control on paddy fields.

From the view points of easy handling by farmers without requiring particular instrument for application, of saving labor and time for application, and of less effect on natural enemies of rice pests, granular insecticides were tested in the present study.

METHOD

1) Paddy field test.

Insecticides tested were 12 kinds in 1968, 5 in 1969, 4 in 1970, 5 in 1971 and 1 in 1972, all of them were Japan-made. Test was conducted at Pan Rice Experiment Station between 1968 and 1970, Pasang in Chiengrai Province in 1971, and Pafek in Chiengrai Province in 1972. A plot size was 15 m^2 (3×5 m) with 3 replications. Dawk Mali 3 was transplanted with 3 seedlings per hill in early July at a spacing of 25×25 cm. Amophose was applied at a rate of 60 kg per rai.

The insecticidal application was done 14 and 28 days after transplanting at a rate of 1 to 2 kg of active ingredient per hectare. Observation on the insect damage was done every

30 days after transplanting. 50 hills per plot were used for counting damaged tillers and galls, and 4 m^2 area was used for measuring plant height, number of panicles, and grain yields.

2) Seedling test.

Dawk Mali 3 was sown during the planting season. A plot size was 1 m^2. Amount of seed was 50 gr per 1 m^2. Insecticides were applied 10 days after sowing at a rate of 2 kg of active ingredient per hectare. Number of galls and healthy tillers was counted 30 days after sowing. The experiment was done with 3 replications.

3) Pot test.

Twenty five day old seedlings of Dawk Mali 3 were transplanted to pots (30 cm in diameter and 30 cm high). Three seedlings for each pot. Eggs just before hatching were applied per pot. Insecticides were applied 14 days and 7 days before and after larval penetration at a rate of 2 kg of active ingredient per hectare. Results were examined 30 days after insecticidal application.

RESULTS

1) Insecticide effectiveness by seedling tests.

Results are given in Table 21-1 and 2. Diazinon 3%, BHC 6%, and Thimet 10%, were

Table 21-1. Screening test of granular insecticides for control of the rice gall midge on rice seedlings at Pan, 1968

Name of insecticide	Application time	Active ingredient/hec. (kg)	Damaged tiller (%)
Diazinon 3%	1	2	1.57**
BHC 6	1	2	1.77**
Thimet 10	1	2	0.84**
BHC+Dysiston 6	1	2	5.41
BHC+Sevin 16	1	2	3.78
Check	0	0	4.76

** significant with provability 95%

Table 21-2. Screening test of granular insecticides for control of the rice gall midge on rice seedlings at Pan, 1969

Name of insecticides	Time of application	Active ingredient/hec (kg)	Damaged tiller (%)	Height of plant (cm)	
				Infested	Healthy
Diazinon 3%	1	2	1.75**	42.33	59.66
	1	4	0.87**	41.0	57.0
BHC 6%	1	2	3.15	41.66	56.66
	1	4	2.51	39.66	49.66
Dysiston 5%	1	2	2.69	42.33	55.33
	1	4	2.36	40.33	53.66
Pestan 3.5%	1	2	2.63	42.0	53.60
	1	4	2.03	43.0	56.33
Dimethoate	1	2	2.79	43.0	56.50
	1	4	1.92**	43.0	55.66
Check	0	0	4.46	41.33	55.33

found very effective. Although Thimet 10% was most effective, it could not be recommended to farmers because of its high toxicity. Diazinon 3% was as effective as BHC 6% in 1968. Results of 1969 showed that Diazinon 3% was most effective, but BHC, Disyston, and Pestan were not so effective. Diazinon seems to have an effect to promote plant height.

2) Insecticide effectiveness by field tests.

a) 1968.

Results are given in Table 21-3 and 4. In this year, the insecticidal application was done 30 and 60 days after transplanting. Diazinon 3% and Thimet 10% were very effective followed by BHC 6%. The other insecticides were ineffective. Grain yield in Diazinon plot was 535.6 kg per rai, 15% more than the untreated plot. No significant relation was found between damaged tiller and yield, because of lower damage in this year. Results obtained on the sandy soil field of Phibul Mansahan in Ubol Province are given in Table 21-4. Effectiveness of insecticides was in order of Thimet 10%, Diazinon 10%, and Birlane 10%.

Table 21-3. Effectiveness of granular insecticides for control of the rice gall midge at Pan, 1968

Name of insecticide	Time of application	A.I./hec (kg)	Damaged tiller (%)			Transformed damage (%)	Yield/rai (kg)
			Aug. 22	Sept. 13	Oct. 17		
Baycid 5%	2	2	0.24	7.74	22.38	18.55	503.6
BHC+Dimethoate 6%	2	2	0.77	6.79	24.63	19.73	541.6
BHC+Sevin 16%	2	2	0.67	8.73	10.33	13.75	483.6
BHC 6%	2	2	0.63	5.86	6.99	9.66**	492.8
PSP-204 5%	2	2	0.30	10.98	26.42	21.71	464.6
BHC+NAC 14%	2	2	0.75	7.46	11.25	13.70	500.8
Sancide 5%	2	2	0.36	9.81	23.59	20.42	462.8
BHC+Dysiston 8%	2	2	0.35	6.61	15.40	14.77	526.0
Pestan 3.5%	2	2	0.48	11.02	24.13	20.87	500.0
Diazinon 3%	2	2	0.92	4.10	8.89	9.72**	535.6
Dysiston 5%	2	2	0.45	8.60	24.85	19.98	483.6
Thimet 10%	2	2	0.86	5.38	5.16	8.45**	493.6
BHC+Dysiston 13%	2	2	0.89	6.81	12.56	13.28	530.0
BHC+PHC 11%	2	2	1.23	6.76	11.00	12.65	538.0
Dimethoate 5%	2	2	0.69	7.53	24.59	19.27	481.2
Check	0	0	0.46	8.47	19.16	17.33	463.6

** significant with provability 95%

Table 21-4. Effectiveness of granular insecticides for control of the rice gall midge at Ubol, 1968

Name of insecticides	Time of application	A.I./hec (kg)	Damaged tiller (%)
Diazinon 10%	2	2	5.25**
Pestan 3.5%	2	2	14.99
Birlane 10%	2	2	7.79**
Dysiston 5%	2	2	23.79
BHC+Sevin 16%	2	2	11.61
Thimet 10%	2	2	3.93**
Check	0	0	29.73

b) 1969.

In this year, a severe outbreak of the rice gall midge occurred at Pan, Chiengrai Province. Percentage of damaged tillers from the end of September to early October were more than 80% in some places and usually more than 45% as given in Table 21-5. One time of application may not be effective, but three times of application requires large amount of insecticides and time and labor. Therefore, the effectiveness was determined with 2 times of application. Diazinon 3% at a rate of 2 to 4 kg of active ingredient per hectare, 4 kg of BHC 6%, and 4 kg of Dysiston 5% were found fairly effective. Diazinon 3% at a rate of 2 kg (a.i.) per hectare can reasonably be recommended.

Grain yields were increased in proportion to times of application and amount of insec-

Table 21-5. Effectiveness of granular insecticides for control of the rice gall midge at Pan, 1969

Name of insecticide	Time of application	A.I./hec. (kg)	Damaged tiller (%)	Rice yield/rai (kg)
Diazinon 3%	1	2	31.40	294.19
	2	2	12.08*	324.25
	3	2	4.09*	365.21
	1	4	32.11	281.96
	2	4	4.04*	329.30
	3	4	1.14*	425.33
BHC 6%	1	2	34.91	251.63
	2	2	26.64	253.49
	3	2	25.07	316.54
	1	4	36.93	247.64
	2	4	10.50*	339.41
	3	4	8.15*	368.67
Dysiston 5%	1	2	40.76	292.60
	2	2	32.04	295.26
	3	2	31.40	295.26
	1	4	37.55	287.28
	2	4	17.64	348.19
	3	4	10.90*	348.72
Peatan 3.5%	1	2	41.37	220.24
	2	2	36.79	225.03
	3	2	35.23	236.22
	1	4	45.55	268.39
	2	4	38.72	292.60
	3	4	28.45	336.20
Dimethoate 5%	1	2	42.44	249.24
	2	2	38.28	250.04
	3	2	37.28	284.35
	1	4	40.18	217.58
	2	4	31.51	238.86
	3	4	19.51	280.36
Check	0	0	47.20	211.20

* significant with provability 95%

ticides used. Highly significant relation was recognized between number of damaged tillers and grain yields. Three times application of Diazinon 3% at the rate of 4 kg gave a grain yield of 4.25 kg per rai, that was 73% more than the untreated plot. One time of application gave 39% yield increase.

c) 1970.

As given in Table 21-6, Teracurr-P 5% was most effective with 2 times of application at a rate of 1 kg (a. i.) per hectare. Effectiveness of Diazinon 3% was slightly less than Teracurr-P 5%. Teracurr-P 5% is highly toxic, as Thimet and Diazinon is expensive (20 baht per kg). Both are not recommendable.

Table 21-6. Effectiveness of granular insecticides for control of the rice gall midge at Pan, 1970

Name of insecticide	Time of application	A.I./hec. (kg)	Damaged tiller (%)	Rice yield/rai (kg)
Diazinon 3%	1	1	19.05	488.4
	2	1	10.45*	524.8
	1	2	18.66	478.8
	2	2	7.32*	518.8
	1	3	11.09	448.4
	2	3	6.71*	523.2
BHC 6%	1	1	20.19	492.4
	2	1	17.95	483.6
	1	2	15.79	486.8
	2	2	9.48*	534.5
	1	3	13.87	454.8
	2	3	9.88*	472.4
Furadan 5%	1	1	23.74	427.6
	2	1	18.43	473.6
	1	2	20.38	446.0
	2	2	12.28	498.8
	1	3	16.57	468.8
	2	3	6.32*	512.0
Teracurr-P 5%	1	1	13.49	493.2
	2	1	5.25*	510.4
	1	2	6.43*	492.0
	2	2	1.29*	516.0
	1	3	5.85*	484.8
	2	3	1.48*	566.8
Check	0	0	22.98	448.0

* significant with provability 95%

d) 1971.

In this year, an experiment was carried out at Pasang, Chiengrai Province. Four kinds of Diazinon formulae were tested; Diazinon tape (0.5 gr of active ingredient per meter), micro-granular Diazinon 5%, granular Diazinon 5%, and Diazinon E.C. 50%. Results are given in Table 21-7. The most effective formulation was Diazinon-tape with 2 times of application, Damaged tillers were reduced to 0.44%. One time of application of Diazinon tape was also effective but less than 2 times of application. Micro-granular and granular formulations were

Table 21-7. Effectiveness of different formula of Diazinon for control of the rice gall midge at Pasang, Chiengrai, Thailand, 1971

Name of insecticide	Time of application	A.I./hec. (kg)	Damaged tiller (%)	Height of plant (cm)	No. of panicles/ hill	Yield/rai (kg)
Diazinon tape 0.5 g/m	1	2	23.27*	150.10	8.13*	637.20
	2	2	0.44*	180.70	9.64*	712.53
Diazinon MG 5%	1	2	47.89	150.0	7.57	566.40
	2	2	35.85*	150.20	7.93	598.66
Diazinon G 5%	1	2	61.94	150.20	6.78	590.66
	2	2	36.17*	155.20	8.54*	649.46
Diazinon E 50%	1	1 : 500	74.28	128.10	6.36	511.36
	2	1 : 1000	73.88	134.10	5.90	437.46
Check	0	0	75.63	118.0	4.90	352.66

* significant with provability 95%
MG, Microgranule; G, Granule; E, Emulsion

with 2 times of application but Diazinon EC 50% was ineffective.

Diazinon tape is a new insecticide with gas effect. Gas evaporated from the tape is able to kill adult midges instantly or keep them away. However, any effect on larvae inside plants was not recognized.

Height of rice plants reached 180 cm with two times of application of Diazinon tape, 155 cm with Diazinon granule with 2 times of application, 150 cm with micro-granulae Diazinon 130 cm with Diazinon EC, and 118 cm in a check plot. Number of panicles per hill was 9.6 with Diazinon tape, 8.5 with Diazinon granule, and 5.5 with Diazinon EC as compared to 4.9 of the check plot. Rice yield was 712 kg per rai in Diazinon tape plot, 649 kg with Diazinon granule, and 352 kg in check plot.

3) Insect effectiveness by pot test.

Since the same numer of eggs was applied to each pot, the percentage of damaged tillers observed this experiment signified a preventive effect of insecticides. The preventive effect was recognized in all treated plots, when insecticides were applied 7 days before the larval entrance into plants, but Dysiston 5% was less effective than other insecticides, as shown in Table 21-8.

Insecticides, applied after the larvae entered into rice plants, showed no effect, as shown in Table 21-9. Appliaction at 7 days prior to or just before the larval encroachment gave a highest effect. From these results it can be concluded that the insecticide application should be practiced at right time, an early date, and a long lasting residual effect is desirable for an effective control.

Thus, a series of screening tests on insecticides made clear that:

(1) Diazinon granule and Diazinon tape were most effective in controlling the rice gall midge, when applied 14 days and 28 days after transplanting at a rate of 2 kg (a.i.) per hectare.

(2) Effect of the insecticides was preventive one to the midge adult, but not to larvae already entered into rice plants. Therefore, the insecticides should be applied before the larval entrance.

(3) Diazinon tape generates gas, which is able to kill adult insect or keep them away.

(4) Thimet and Teracurr-P were highly effective, but they are very toxic. Because of their toxicity, these insecticieds are not recommendable to farmers use.

Table 21-8. Pot test of granular insecticides for control of the rice gall midge at Pan, 1968

Name of insecticide	Time of application	A.I./hec. (kg)	Damaged tiller (%)	Height of plants (cm)
Diazinon 3%	1	2	0.61	81.0
	1	4	0	86.3
BHC 6%	1	2	1.27	81.6
	1	4	0	82.3
Dysiston 5%	1	2	8.03	79.6
	1	4	3.44	81.6
Pestan 3.5%	1	2	0.80	82.0
	1	4	0	90.0
Dimethoate 5%	1	2	0.62	81.0
	1	4	0	82.3
Check	0	0	50.0	73.6

Table 21-9. Effect of Diazinon granule applied to rice seedling before and after the insect infestation at Pan, 1969

Timing of insecticides application	Damaged tiller (%)	No. of panicles/hill	Height of plant (cm)
14 days after infestation	34.75	9.0	88.25
7 days after infestation	15.08	14.0	95.25
0 days after infestation	5.50	16.0	98.75
7 days before infestation	0.55	16.75	100.50
14 days before infestation	0.14	15.25	99.0
Check (no insecticide)	62.57	7.50	78.50

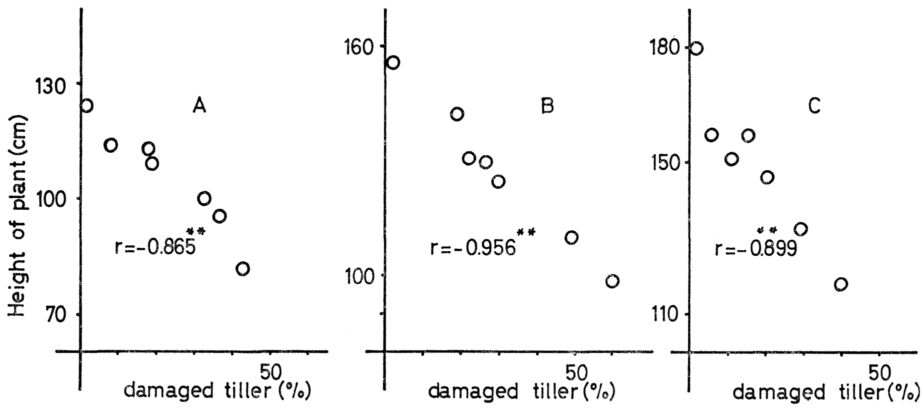

Fig. 21-1. Relation between plant height and damaged tillers at Pasang in Chiengrai, 1971. A: Sept. 7, B: Oct. 4, C: Nov. 3.

(5) Granular insecticides are also toxic to fishes, an important local source of protein. However, Diazinon tape can be used safely because of its gas effect. The authors consider the utilization of gas effect as a new control method.

4) Relation between crop damage and grain yields observed in insecticide screening tests.

From all the data obtained in the insecticide screening tests, relationships between crop damage (in term of percentage of damaged tillers) and plant height or grain yields were determined. As shown in Figure 21-1, high correlations were observed between damaged tillers percentage and plant height. The correlation coefficients were approximately around+0.9. Similarly, high correlation were found between damaged tillers percentage and number of panicles per hill as well as between damaged tillers percentage and grain yields. Correlation coefficient was approximately+0.9 for both cases.

The difference in yield levels between Pasang in Chiengrai Province (1971) and the Pan

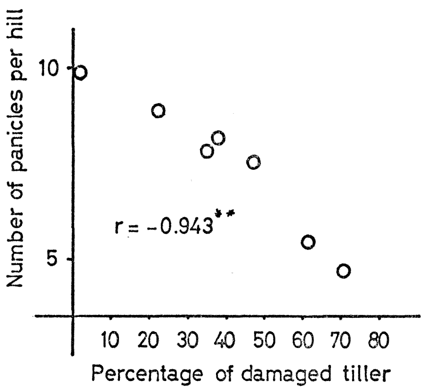

Fig. 21-2. Relation between number of panicles and damaged tillers at Pasang in Chiengrai, 1971.

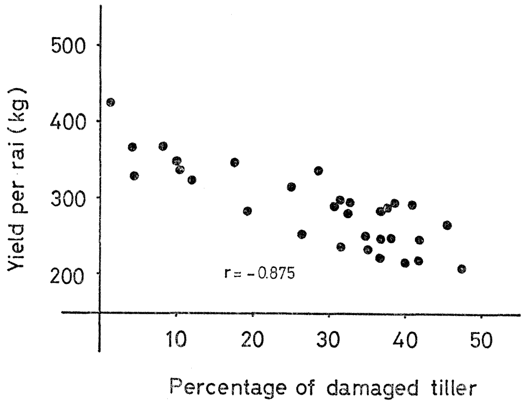

Fig. 21-3. Relation between damaged tillers and yield at Pan, 1969.

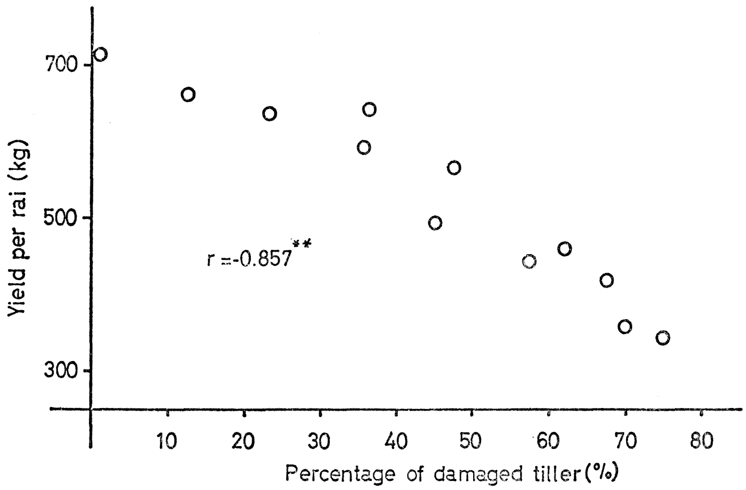

Fig. 21-4. Relation between damaged tillers and yield at Pasang in Chiengrai, 1971.

Rice Experiment Station (1968 to 1970) was considered to be due to the difference of soil condition. At Pasang, plants suffered from the insect with 70 to 80% of damaged tillers produced about 350 kg of yield per rai, whereas only 200 to 300 kg per rai of yield was obtained with 40 to 50% of damaged tillers at Pan. Compensation of plants to the damage seems to be influenced by the difference of soil fertility.

22. General discussion

The present study aimed at establishing effective control methods against the rice gall midge by clarifying the insect ecology. The study revealed that the seasonal fluctuation of population density of the insect was closely related to the growth stage of rice plants. Population of the insect increased prominently at the tillering stage of plants. The rate of insect survival was also highest in the 28 to 48 day old plants. It is suggested that this period is a right time for insecticidal application and release of natural enemies. The result obtained indicates clearly that the first application of insecticide should be done at 14 days after transplanting.

Number of grwoing points of plants, on which larvae fed, increased during the tillering stage, and population of larvae increased in proportion to the number of growing points. This is one of the reasons why the survival rate of larvae was high during the vegetative growth period of plants.

High humidity due to rainfall during the tillering stage from July to August favors adult longevity, egg-laying, egg-hatching and an encroachment of larvae into plants. On the other hand, activities of natural enemies were still low during that period.

After the rice plants reached the panicle primordium formation stage, the population density of the insect decreased remarkably. The larvae are not able to live on the reproductive growing points, and hence their mortality was increased apparently. Peak of the insect population density occurred at the 4th generation at the end of September. After that time, although all of newly hatched larvae entered into plants, no larvae could survive on the panicle primordium. Only those approach to the growing points of invalid tillers could survive with very low rate of survival. Another important factor affecting the insect population decrease was parasitic activities of the natural enemies, that began to increase from October. Thus, it is now clear that insecticides should not and need not be applied at and after the panicle primordium initiation stage.

It is an important fact that the length of duration of vegetative growth stage and hence the length of tillering period was markedly varied by date of transplanting with photoperiod sensitive varieties; the shorter duration with the later date of transplanting. During a shortened period of the tillering stage, the insect can proceed a cycle of only less generations, resulting in a low population of the insect and less crop damage.

Screening of rice varieties for resistance to the insect was carried out using local varieties of Thailand as well as varieties from India and Japan. Indian lines, EK 1263 and EK 1252 were found extremely resistant to the insect, and therefore they were utilize as a breeding material. They were crossed to Thai recommended varieties, RD 1 and RD 2. As a result of selection from 2000 lines, a new variety named RD 4 was developed through the cooperative programme of Entomology and Breeding Division in 1973. RD 4 is photoperiod non-sensitive and glutenous. This variety was officially registered by the Ministry of Agriculture and Cooperatives of Thailand on April 2nd 1973, as a new improved variety resistant to the rice gall midge.

A clear evidence was shown that the insect larvae could not grow and develop on the growing points of resistant varieties, suggesting that the resistant varieties contain some substance which inhibit larval growth or are lacking some critical substance required for larval growth.

It was also shown that rice yield is usually not affected when the damage is lower than 10% in term of percentage of damaged tillers.

Investigations on annual fluctuation of the insect population density in relation to climatic condition, cultural practices, natural enemies and wild host plants should be continued from year to year in order to fully analyse mechanism of the fluctuation and to establish forecasting method of the insect infestation.

23. Summary

In the present paper studies on eclogy and control of the rice gall midge conducted in Thailand are reported. The present studies have been carried out mainly at the Pan Rice Experiment Station in northern Thailand from 1968 to 1972.

1. Morphological characters of egg, larvae, prepupae, pupae, and adults of the rice gall midge are described. Gall formation was studied in detail morphologically.

2. Since the rice gall midge was reported at first in 1933 by Ladell on specimens collected from Prae and Trat Provinces, some research works on the insect have been done in Thailand, for instance, chemical control, screening test of varietal resistance of rice plants, mass rearing, distribution, and some aspects of the insect bionomics, etc.

3. The survey made by the authors revealed that the rice gall midge is distributed in northern, northeasterm, and east Thailand, and recently the insect was found at some places in Central plain. There is a missgiving that the insect can extend her distribution rather easily when high yielding but susceptible varieties of rice such as IR 8, RD 1, RD 2, and RD 3 will be used widely by farmers.

4. 1) The survey on crop damage caused by the rice gall midge has been conducted once a month from July to December for 5 years (1968—1972). The places selected for survey were located between Maesai in Chiengrai Province and Sanpathong in Chiengmai Province, a distance between them being 300 km. The rice gall midge appeared on paddy fields during main crop season of rice, with a peak of the occurrence at the end of September. The rice gall midge increased in number remarkably from July to September and sharply reduced her population density from October to December. Percentage of damaged tillers was quite different year by year. The highest damage was observed in Chiengrai Province in 1969, where the percentage of infestation was more than 60%. The rice gall midge showed a trend to reduce her population from 1970 to 1972. It is said that outbreak of the midge has occurred every 5 to 6 years in the past in Thailand.

2) Heavy precipitation during June favours population increase of the insect, especially those bred on gramineous weeds. The insect outbreak was closely related to population increase in an early stage of the planing season.

5. Population density of the rice gall midge was recorded by using light traps. The adult began to appear from March to May and diappeared usually in the middle of November in every year. The peak of occurrence was observed at the end of September. Number of generations was 9 to 12, and peak generation was at the 14th generation counted after transplanting. The insect which appeared from March to May on rice seedlings were those migrated from weeds (wild host plants), because the insects bred on the weeds became less and less

before and after the transplanting of rice. Information in the insect occurrence in the early season gives an important key point for forecasting the insect occurrence in that season.

6. 1) The most important factor among climatic condition affecting the insect incidence was relative humidity due to rainfall, although the insects existed throughout a year because of high temperature in the tropics.

2) Rainfall in May was very important for adult emergence and larval growth on the weeds. In addition, high humidity in paddy field after transplanting favoured egg laying, longevity of adult, emergence, egg hatching, and larval entrance to growing points of rice plants. A critical reason why the population density of the midge does not increase during the dry season is low humidity.

7. Population of the midge increased in the vegetative growth period of rice plants and decreased in the reproductive growth period. The insect population increase was proportional to the increase of tillers and hence growing points of the plants. In northern Thailand the midge increased in number from July to September, reaching a peak at the maximum tillers stage. The insect population decreased sharply after the panicle primordium initiation stage, because no larvae could survive on the panicle primordia.

8. 1) A peak of emergence was seen between 2200 and 2300 hours. Emergence was likely to be inhibited by light. Pupae climbing up inside the gall showed a negative phototaxis. Number of adults emerged in the night was less when lighted than in dark. More male adults emerged from 1800 to 2000 hours than female which began to emerge after 200 hours. Sex ratio (male to female) was 1 to 2.5. Parthenogenesis was not recognized at all. Adult female just after emergence mated for 5 minutes. Usually, a male could mate to 2.5 females in an average, ranging between 2 and 4 females. A female could not mate twice. Male was apt to mate in the next day after emergence. The adult longevity was 2.3 days in male and 2.6 days in female. They prefer morning dew produced on lateral margins of leaf blade. A peak of the insect flight to light was 2100 to 2200 hours. The adult newly emerged were not attracted to light within 24 hours after emergence.

2) Average number of eggs laid per female, ovarian eggs, and eggs remained in ovary after egg-laying were 221.3, 276.1, and 54.9 respectively. Number of eggs laid per female increased with higher humidity, for instance, 102.4 eggs in 50% humidity and 217.4 eggs in 90%. The optimum humidity for egg hatching was higher than 76% and at that humidity more than 90% of haching took place. Time of peak of egg laying was 100 and 200 hours. Eggs were laid on both leaf blade and leaf sheaths, although more eggs were laid on leaf blade than on leaf sheaths. Average incubation period was 3.2 days. Time required for larval eclosion from egg shell was 1.4 minutes in an average. A peak of egg hatching was seen between 300 to 400 hours.

3) Larvae newly hatched in early morning usually crawled on wet leaf blade and sheath until the larvae found their way into inside of leaf sheath, and finally reached growing points of rice plants. The larvae released on dry surface of rice plants died after crawling for a while. Encroachment of larvae into leaf sheath took about 18 minutes after hatching, with more than 95% of the larvae, under moist condition. When larvae were released into water, only a few of them climbed up the rice plants and entered into the plants. The larvae have 3 instars, with a larval period of 3.4 days in the first instar, 5.5 days in the 2nd, 7.0 days in the 3rd. Length of gall was less than 1 cm during the 1st instar stage and less than 4 cm at the second and third instar stages. Galls could not be observed from outside during these stages.

4) Prepupal and pupal periods were 5.6 and 5.3 days, respectively. The gall rapidly grew up to 9.1 cm long in the prepupal stage and 27 cm long in the pupal stage. At its basal part, pupation was seen. The pupae climbed up inside of galls and bore the gall sheath at the spongy part. After the apical half of the pupal body came out of the gall, the pupae

stayed at the bore until her emergence. About 25 minutes were taken for the emergence. It was suggested that gall formation was induced by a particular substance secreted by the larve.

9. Three species of the Hymenopterous parasites and one species of predator were found as natural enemies of the rice gall midge:

Hymenopterous parasites

1. *Plastygaster oryzae* (Platygasteridae)
2. *Platygaster* sp. (Platygasteridae)
3. *Neanastatus gracillius* (Eupelmidae)

Predator

1. *Ophionia indica* (Carabidae)

Dates on which parasitism including predatorism were reached 50% were from September 15 to October 23, although the dates varied from place to place. The natural enemies began to appear in the field in August, and their control effect on the midge was recognized from the end of September to November. A remarkable decrease of population density of the midge which occurs during the period from September to November is caused not only by the shifting of plant stage from vegetative growth period to the reproductive stage but also by the attack of natural enemies. *Platygaster oryzae* was predominant in number than the other parasites. The parasite rapidly increased her population density during a rice season and reached more than 70% of the total number of natural enemies. On the other hand, at the Sanpathong Rice Experiment Station in Chiengmai Province, *Platygaster* sp. controlled the midge on rice seedlings so that less damage on rice plants was resulted after transplanting. The parasite of the midge on wild rice was mainly *Platygaster oryzae*, her parasitism reached 8 to 21% between April and May, 0 to 25% between June and September, and 28 to 53% between October and December. Parasitism of *Platygaster oryzae* was significantly higher with later transplanting of rice than early transplanting, with a greater reduction of the midge population in the former case.

10. 1) All of the wild host plants found in northern Thailand belong to the Family Graminaceae. They are wild rice, *Ischaenum aristatum*, *Paspalum distichum*, *Leersia hexandra*, and *Echinochlora colonum*. Habitat of *I. aristatum* and *P. distichum* is paddy fields but seeds of the plants remain dominat in soils during the rice season (June to October). Usually they appeared from November to May during the dry season. The other host plants grow in swampy areas throughout year.

2) The midge appeared on wild rice throughout a year. The midge had a peak of occurrence during March to May, and then the insect maintained low population from July to October; a rice growing season. The population density increased again in November, and then decreased from December to February due to slow-down of larval development at low temperature in northern Thailand. The insect on *I. aristatum* began to appear on May 2, and disappeared on July 11, with a peak of its density at the first of June. The insect on *P. distichum* appeared in the middle of May and disappeared at the end of July, with a peak in the middle or at the end of June. The insect occurred in less in number on *Leersia hexandra* which is not suitable for egg laying due to curling leaf blade at night. During the dry season, the midge on the wild host plants, growing in dry areas, stayed at larval stage mostly at the first and second instars. This retardation in larval development was caused by a physiological condition of the plants suffering from drough. Number of the insect larvae on wild host plants was in order of wild rice, *P. distichum*, *I. aristatum*, and *L. hexandra*. The midge bred on the wild host plants was significantly smaller in body size, especially length of fore wing and hind leg, pupal body length, and width between cephalic spines than that feeding on rice. Body colour was darker. Size of gall on the wild host plants was remarkably small.

For instance, galls on *L. hexandra* and *P. distichum* were only 7 cm long and that on *I. aristatum* 5.5 cm long, but galls on wild rice were same as that of rice plants. The midge prefered rice plants and wild rice to the other wild host plants for egglaying. Eggs laid on *P. distichum* were same in number as *Echinochlora colonum*. Female bred on rice plants laid eggs on wild host plants and the larvae developed normally, although the adult became small in body size and dark in colour. On the other hand, when adults bred on wild host plants were transferred to rice plants, they laid eggs and larvae grew normally on the rice plants. When the midge bred on *P. distichum* was transferred to rice and wild rice, a life cycle of the insect on rice plant was 25—31 days and on wild rice 25—33 days.

11. Occurrence of damaged tillers on rice seedlings was less than 7%, irrespective of different sowing dates. Number of larvae entered into the main culm was more abundant and larval instar was more advanced than that entered into tillers. Galls produced on main culm were longest as compared with galls on primary and secondary tillers. Almost all of the midges was adult stage at the time of gall appearence from rice seedlings. The midges were larval stage in prematured gall which could not seen from outside of rice seedlings. Seedlings infested by the midge can be easily distinguished from the healthy one by such characters as short plant height, younger leaf age, more tillers, inhibited growth of uppermost leaf, dull green color, and round-shaped basal part of stem. These characters appeared before the larvae developed to the third instar stage after their entrance.

12. When same number of eggs was applied experimentally to rice plants at different growth stages, number of larvae entered into plants showed no difference. However, larval development differed with different stages. Damaged tillers began to increase after transplanting, reached a peak at the maximum tillers stage and then decreased sharply during the reproductive growth period of rice plants. It was suggested that the tillering stage during which the insect population pumps up is the best time for insecticidal application and release of natural enemies for the control.

13. The insect laid eggs on rice ratoon and emerged from galls produced on ratoon, but the infestation was very few. Only on the ratoon developed from an early harvested rice, the insect could emerge. Thus, the ratoon has no important effect on population density of the midge.

14. Infestation of the midge on the second rice crop also very low. Percentage of infested tiller was only 0.5, and by dissecting growing points only 2 larvae and galls were found between April and May. When the midge emerged from the wild host plants happened to lay eggs on the second rice crop. They can not develop normally under the condition of the dry season.

15. No effect of fertilizers on the insect infestation was observed. Not only nitrozen and phosphorus, but also silicate fertilizer was ineffective. The midge feeds on growing points, and the physiological status of growing points may not be influenced directly by fertilizer application.

16. From the screening tests for resistant varieties of rice, EK 1263 and EK 1252, Indian strains were found highly resistant, but they were not recommended to farmers bacause of poor plant type and grain quality. A Japanese variety, Hatsunishiki, showed a moderate resistance. All Thai varieties so far tested were susceptible or highly suspeptible. Hybridization between Thai varieties and EK strains was done to develop resistant lines with good plant type and grain quality. The hybrid lines were out of more than 2000 hybrid lines, five resistant lines were selected in 1972 and distributed to farmers for field trials. One of them was named RD 4, and officially registered by the Government as a recommended new variety. No difference was found in egg laying and the encroachment of insect larvae into plants between resistant and susceptible varieties. An important difference was that the larval development

was inhibited in resistant varieties, in which the larvae remained only at the first or second instar stage. With the resistant variety, damaged tillers were less than 5.7%. Length of galls was extremely short, and the midge bred on the resistant variety was small, with short distance between two paired cephlic spines. Indian variety EK 1263 developed panicle primordia one month earlier than other varieties. It was considered that this fact may also be related to high mortality of the larvae.

17. Less infestation of the midge and high yield of rice were obtained when transplanted at the end of August in northern Thailand. This late planting caused a short tillering period, which permitted a cycle of only three generations of the insect, in contrast to 7 generations in an early planted rice. With an increase of number of generations, the insect population increased. In case of late planting, the midge proceeded only one generation in the tillering stage and two generations after panicle primordium formation stage.

18. A close relationship of $r=-0.943$ was recognized between damage and grain yield among rice varieties planted at different dates. Similarly a high correlation of $r=-0.922$ was found between yield and total number of galls per hill.

19. Fifteen different kinds of granular insecticides were tested in the field since 1968. Effective control of the insect was achieved by the application at 14 and 28 days after planting. Insecticides were applied at a rate of 2 kg (a.i.) per hectare. Diazinon granule was very effective. Diazinon coated on the tape (2 cm wide) which is named Diazinon tape was also very effective. Gas evaporated from the tape exerted a repellent effect and killing effect to the insect adults. Insecticides effect on adults, but not on larvae after entered into rice plants. Therefore the application at an early time of tillering period is most effective to the midge and also can avoid the killing of natural enemies which occur mostly in the later period of rice season.

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Explanation of photo

1. An adult of the rice gall midge at the Pan Rice Experiment Station.
2. Larvae penetrated into the growing points of rice plants (Plum, 1969).
3. A pupa of the midge at the Pan.
4. A pupal ecdysis fixed with a gall at Pan.
5. A gall occurred on young rice plants after transplanting at Pan.
6. Three galls on upland rice plants at Chiengrai.
7. Galls occurred on each tillers of rice plants at Chiengrai.
8. Severely infested rice hill at Pan, Rice variety IR 8.
9. Severely damaged rice plants in screening test field of varietal resistance at Pan.
10. Severely damaged rice fields at Prae.
11. Double galls at Pan.
12. Spiral galls at Pan.
13. Twisted galls at Pan.
14. Healthy (right) and damaged (left) rice plants at Prae.
15. Galls occurred on wild rice at Pan.
16. Wild rice field at Chiengrai.
17. Galls occurred on *Echinochlora colonum*.
18. Galls on *Ischaenum aristatum*.
19. Galls on *Paspalum distichum*.
20. Galls on *Leersia hexandra*.
21. A pupal mass of Hymenopterous parasite, *Platygaster oryzae*.
22. Normal galls (long) and parasitized galls (short).
23. Pot test of gall occurrence on rice plants at Pan.
24. Office of the Pan Rice Experiment Station.

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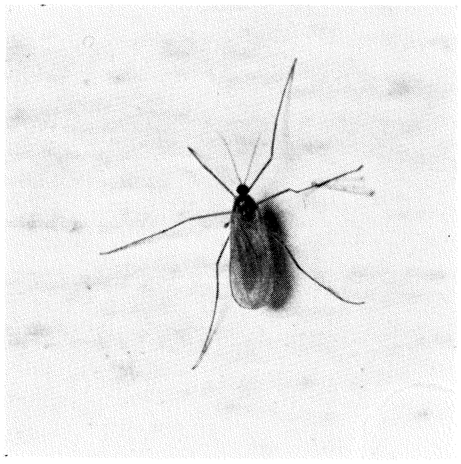

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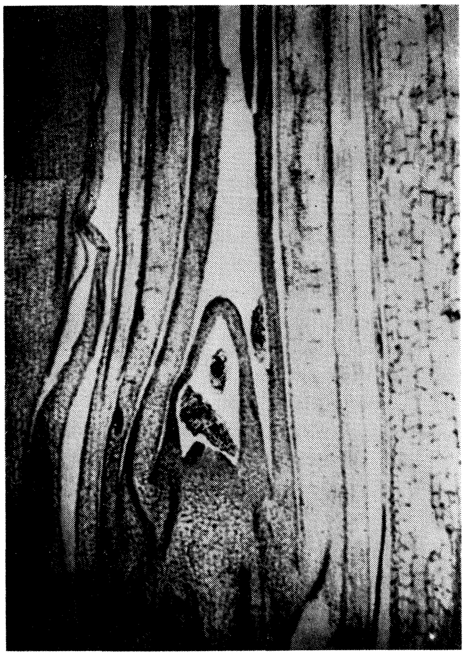

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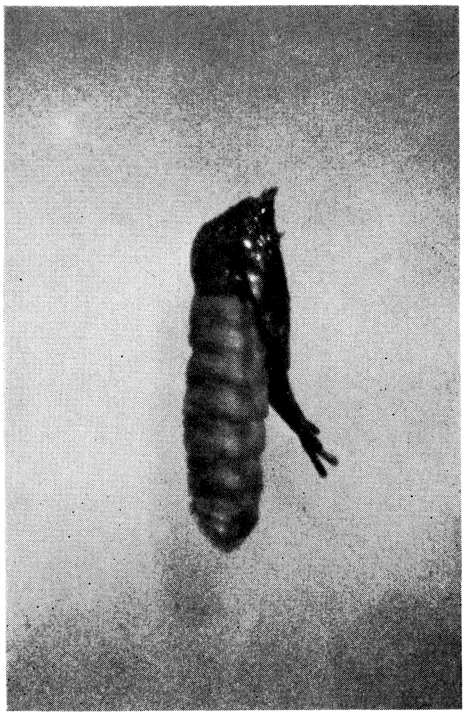

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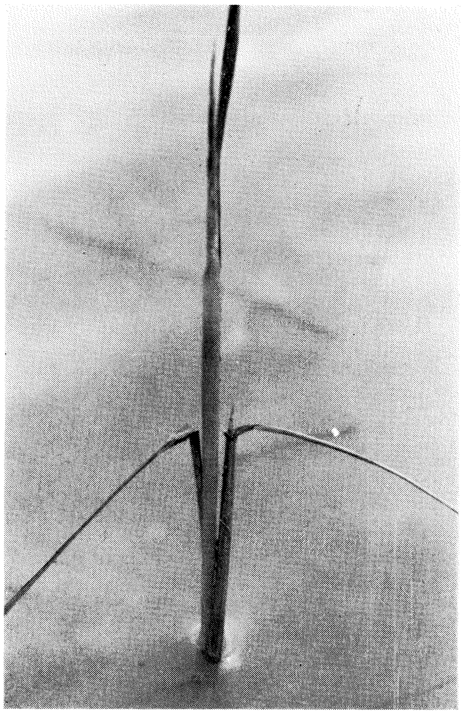

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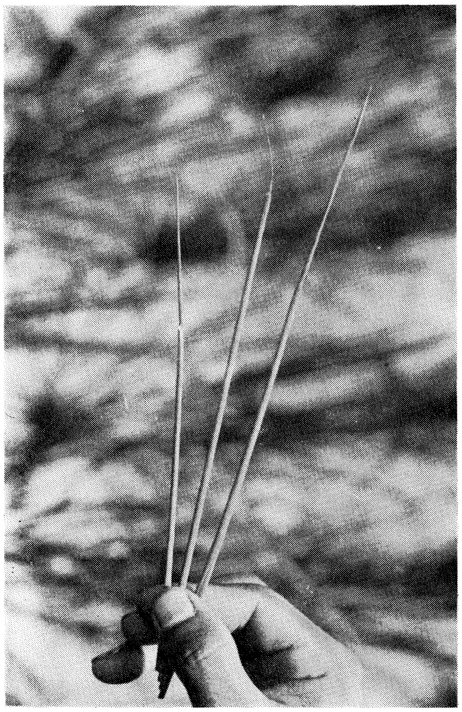

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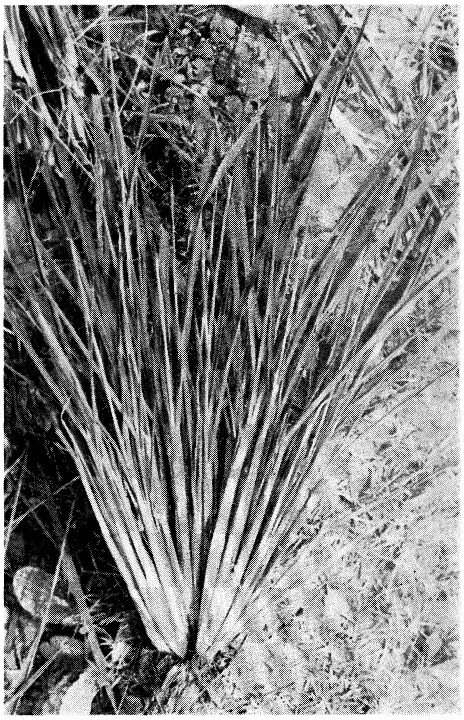

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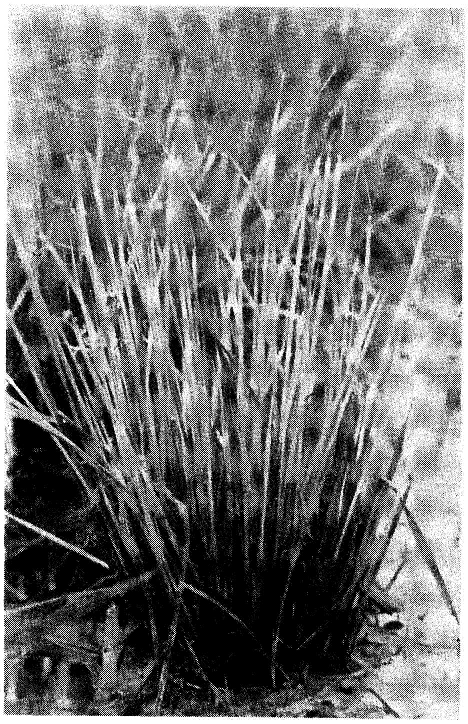

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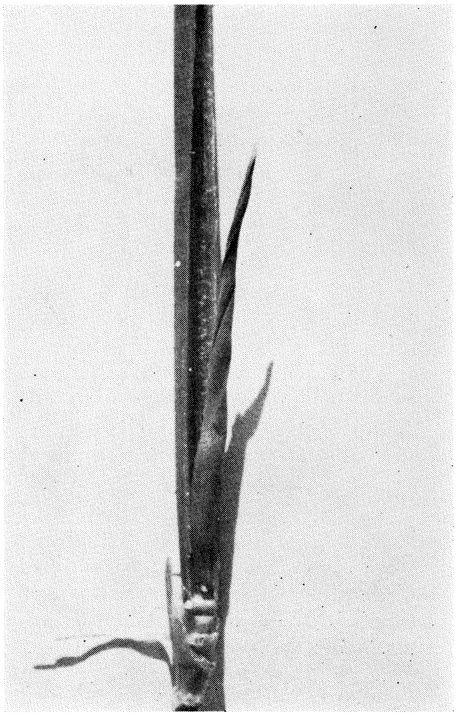

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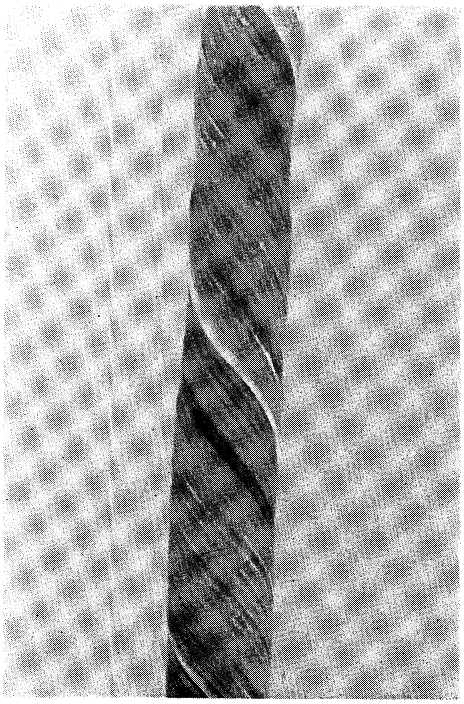

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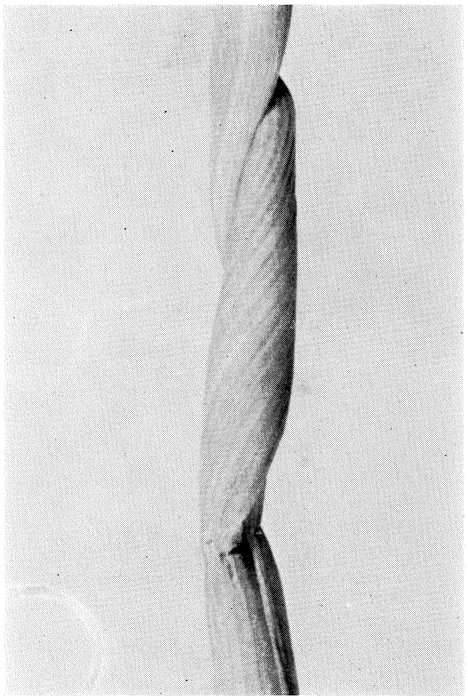

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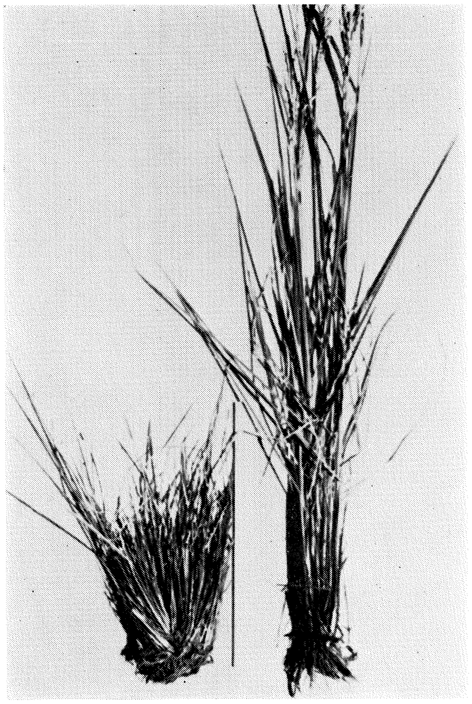

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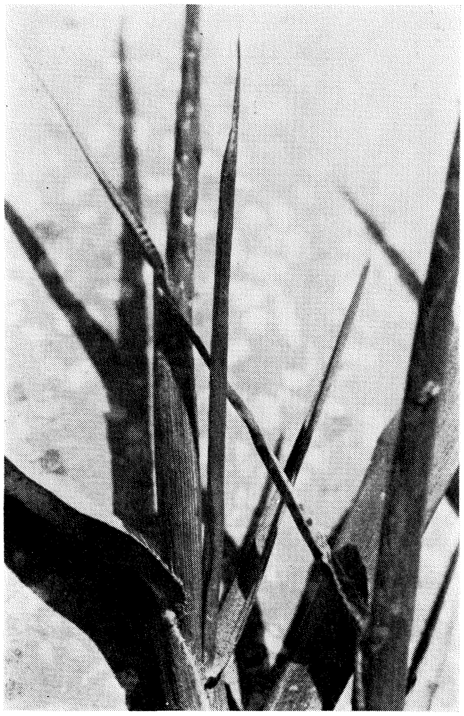

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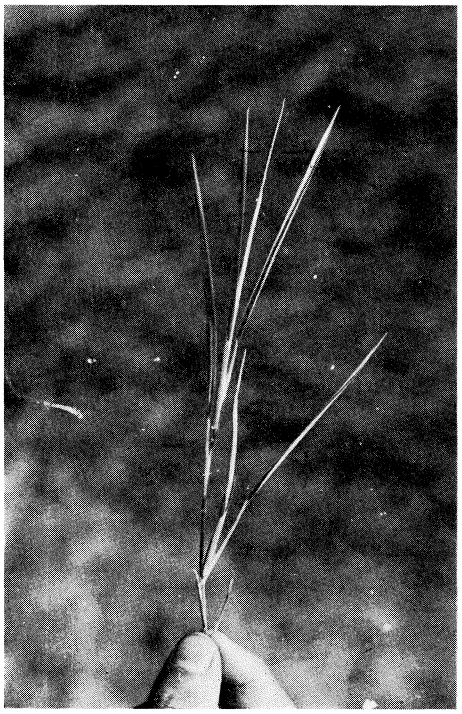

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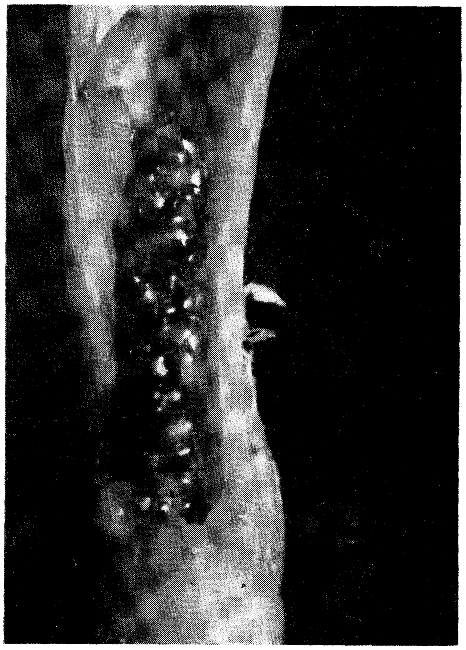

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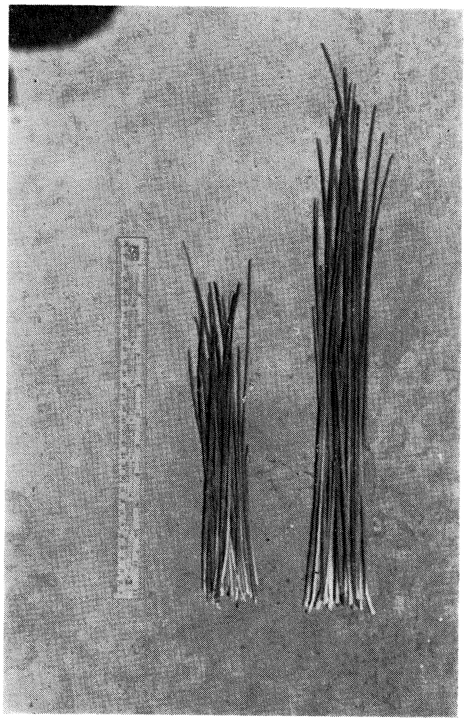

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