BIOLOGY OF THE BLACK AND GREEN LEAF FOLDERS OF SWEET POTATO

Dely P. Gapasin and Lina Z. Rebadulla

Associate Professor and former Research Assistant, Department of Plant Protection, Visayas State College of Agriculture, Baybay, Leyte, Philippines.

Funded by Philippine Council for Agriculture and Resources Research Project 343 (1).

ABSTRACT

The biology of the black leaf folder, *Brachmia* sp., and the green leaf folder, *Psara hipponalis* Walker, considered important defoliators of sweet potato, were studied in the laboratory. The total developmental period of the black leaf folder (20 days) is shorter than the green leaf folder (24 days) and did not vary between sexes. Both species have 5 larval instars. A female laid an average of 44 and 90 eggs/day and the adults lived for 5 and 6 days for black and green leaf folders, respectively. Morphologically, the black leaf folder larva has prominent black and white markings on the thorax and abdomen while the green leaf folder larva is greenish yellow with dark brown head and prothoracic plate and found inside the folder leaf. The adults are about the same size but the black leaf folder moth is grayish black while the green leaf folder is yellowish brown with dark brown markings on its wings. Besides sweet potato, black leaf folder can complete development only on *Ipomoea triloba* and I. *aquatica* while the green leaf folder on *Ipomoea purpurea, I. aquatica, I. pes-caprae; I. triloba* and *Mekania macrantha. Brachymeria* sp. and another hymemopterous parasite attack green leaf folder while *Macrocentrus* sp. and an earwig species attack black leaf folder.

Ann. Trop. Res. 3:37-50.

KEY WORDS: Sweet potato. Insect biology. *Brachmia* sp. *Psara hipponalis*. Defoliator. Development. Morphology. Seasonal abundance. Laboratory experiments. Leaf folders.

INTRODUCTION

One of the major constraints in the production of sweet potato in the Philippines, which results to low production, is the damage caused by various pests. Sweet potato is attacked by a number of insect pests, in both its underground and above-ground parts. There are 31 species of insects, of which 25 are foliage feeders (Gapasin, 1981). Two leaf folder species: the black leaf folder, *Brachmia* sp., and the green leaf folder, *Psara hipponalis* Walker, are prevalent species of defoliators which attack sweet potato during all stages of its growth. These species were not mentioned by Gabriel and Esguerra (1969) and Gabriel (1975) in their lists of insect pests attacking sweet potato in the Philippines. However, more recent studies by Gonato (1978), Duatin (1979) and Gapasin (1981) showed that these two leaf folders are abundant at the Visayas State College of Agriculture in Baybay, Leyte.

The larvae of these two species feed inside the folded leaf. Only one larva is found per leaf fold. The damage caused by these two species can easily be distinguished from each other by the manner in which the leaf margin is folded. The black leaf folder larva folds the leaf margin only once (Fig. 1a) while the green leaf folder larva folds it twice (Fig. 1b) and the folded area shows webbing outside and appears moist. The holes resulting from the feeding of the larvae of the two species also differ in size; that of the green leaf folder being larger than those of the black leaf folder. Both damage results in a lacelike appearance of the leaf since the main leaf veins are left intact.

Benchmark information on the life history, host range, natural enemies and other biological data regarding these insect pests are important considerations in the

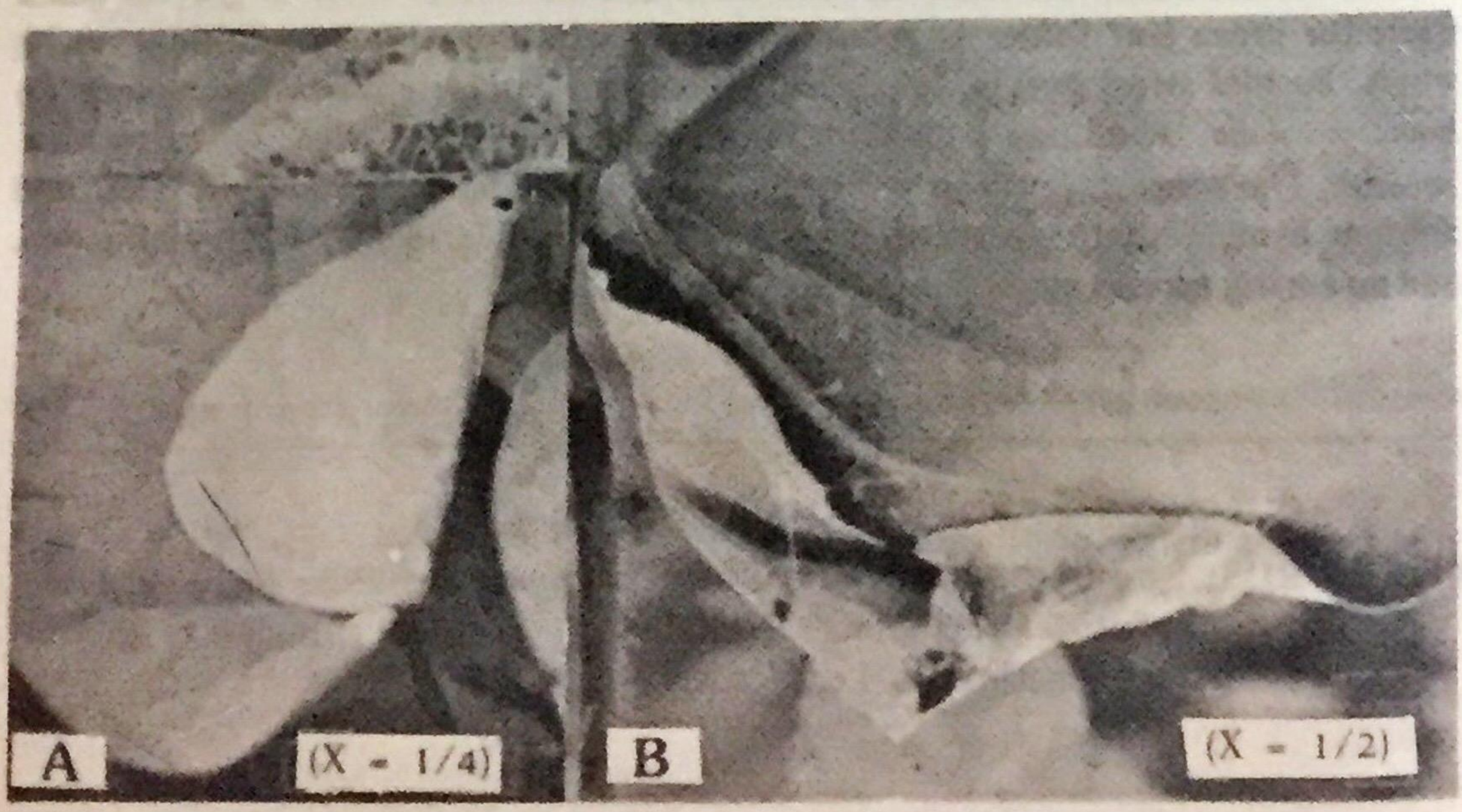

Fig. 1. Folded area of leaves caused by black leaf folder (A) and green leaf folder larva (B).

selection or formulation of control strategies for their effective management. Such information are not available in the literature.

MATERIALS AND METHODS

Mass Rearing of Insects. — Larvae of the black and green leaf folders were collected from the field to start stock cultures of insects for testing. The larvae were placed in plastic containers (22 cm L x 12.5 cm W x 6.5 cm H) with wire screen tops (Fig. 2a) and were provided with sweet potato leaves as feed. Adults that emerged from these field-collected larvae were placed in wire-screen cages (38 cm L x 31 cm W x 31 cm D), provided with cotton balls soaked in 10% sugar solution as food and sweet potato leaves as oviposition substrate. The eggs laid by these adults were incubated and newly hatched larvae were used in the biological studies conducted.

Study of Life History and Behavior. — The life cycles of both the black and green leaf folders were studied for 2 or 3 generations. Newly laid eggs gathered from the stock culture were placed in Petri dishes lined with moist absorbent paper and incubated at room temperature. The incubation period and changes in appearance of the eggs from oviposition to hatching were recorded.

Upon hatching, 100 larvae were placed individually in small glass jars (10 cm H x 4 cm D) or Petri dishes (Fig. 2b) provided with fresh sweet potato leaf as feed. Moist cotton was placed at the base of the petiole to keep the leaf fresh for a few days. Fine-meshed nylon cloth secured around the rim with rubber band served as cover to prevent the larvae from escaping. The individual cultures were then placed in aluminum trays and kept in a large wire-screened rearing cabinet (80 cm H x

Fig. 2. Plastic container used for mass rearing (A) and Petri dish used for individual cultures (B) of black and green leaf folder larvae in the laboratory.

47 cm D). Changes in the appearance of the larvae, number of instars, duration of each stadium, total developmental period, feeding behavior of larvae, manner of molting and other pertinent biological observations were noted. Upon emergence, the adults were sexed and the male-to-female ratio was computed. Mating pairs were transferred to glass jars to study their mating behavior, fecundity of females and longevity of adults.

Study of Morphological Features.— Eggs, larvae, pupae and adults of the two species were examined under a stereoscopic microscope and descriptions of the various stages were made. Close-up photographs were taken using a macro-lens attached to a 35 mm camera. Prepared slides of legs, wings, genitalia and other minute structures were examined and photographed under a compound microscope.

Determination of Alternate Hosts.— Leaves of plant species belonging to Family Convolvulaceae and other plant species commonly found with sweet potato and suspected as suitable hosts of the black and green leaf folders were collected from the field and introduced into glass jars containing larvae and were allowed to feed for 24 hr. The plant species which showed feeding within this time were considered as potential hosts and were further tested in the laboratory using individual cultures. Plant species not fed on were discarded and were not tested further.

The procedures described in the life history studies were followed for rearing the insects on the different alternate hosts using 25 individuals for each plant species. Similar observations were made such as duration of the developmental stages, mortality rate and feeding behavior. The data obtained were compared with insects reared on sweet potato.

Studies on Natural Enemies and Seasonal Abundance.— Eggs, larvae and pupae of the black and green leaf folders were collected from the field and were reared out separately to observe their parasites and extent of parasitism. The appearance of parasitized and healthy insects was compared. Parasites that emerged were examined under a stereoscopic microscope and preliminary identification was done using appropriate keys. Specimens were also sent to specialists at the UPLB Natural History Museum in Los Baños, Laguna for confirmation of identification. Field observation was made to record predatory species.

The seasonal abundance of the two insect species and their parasites was recorded in 1978 and 1979 by conducting a biweekly collection of insects from different plots planted to sweet potato at ViSCA. At each field, 100 leaves were randomly selected and placed in plastic bags and brought back to the laboratory for examination. The species of insects present and the number of individuals per batch of

samples were recorded. The larvae were also examined closely for signs of parasitism. These field-collected specimens were reared in the laboratory until the parasites emerged.

RESULTS AND DISCUSSION

Life History and Description

Comparison of the Length of Life Cycle. Table 1 presents the average duration of the different developmental stages of the black and green leaf folders. The length of life cycle from egg-laying to adult emergence of black leaf folder is shorter (mean of 20.76 and 20.71 days for male and female, respectively) than that of the green leaf folder (mean of 24.10 and 24.53 days for male and female, respectively) also indicating no variation between sexes. Both species underwent 5 larval instars with total larval period of 12.06 days for the male and 12.02 days for the female black leaf folder and 13.95 days for the male and 14.37 days for the female green leaf folder. The pupal period varied slightly between the two insects with mean of 4.97 and 5.03 days for the male and female black leaf folder and 6.26 and 6.11 days for the male and female green leaf folder. In both species, the females lived longer than males, which is the usual pattern for most insects.

Oviposition and Incubation of Eggs. The oviposition period of the female black leaf folder lasted from 4-6 days during which it laid an average of 44.63 eggs/day. On the other hand, the female green leaf folder laid twice as many eggs (mean of 90 eggs/day) during an oviposition period of 3 days. The eggs of the black leaf folder are laid

Table 1. Comparison of the average duration (in days) of the developmental stages of black and green leaf folders of sweet potato.[1]

Developmental Period	Black Leaf Folder		Green Leaf Folder	
	Male (113 individuals)	Female (147 individuals)	Male (72 individuals)	Female (73 individuals)
Incubation of Eggs	3.73 ± 0.50	3.66 ± 0.56	3.89 ± 0.87	4.05 ± 0.89
Larval Period				
First Stadium	2.81 ± 0.53	2.81 ± 0.43	2.69 ± 0.75	2.96 ± 0.99
Second Stadium	2.66 ± 0.49	2.70 ± 0.49	3.17 ± 1.31	3.46 ± 1.46
Third Stadium	2.19 ± 0.39	2.18 ± 0.28	2.93 ± 1.14	2.93 ± 1.17
Fourth Stadium	2.23 ± 0.42	2.18 ± 0.39	2.73 ± 0.84	2.63 ± 0.82
Fifth Stadium	2.17 ± 0.40	2.15 ± 0.44	2.43 ± 0.96	2.40 ± 0.93
Total Larval Period	12.06 ± 1.14	12.00 ± 0.94	13.95 ± 0.67	14.37 ± 1.33
Pupal Period	4.97 ± 0.88	5.03 ± 0.87	6.26 ± 0.65	6.11 ± 0.86
Egg-Laying to Adult Emergence	20.76 ± 1.52	20.71 ± 1.42	24.10 ± 3.34	24.53 ± 1.59
Longevity of Adults	5.00 ± 1.02	5.52 ± 1.42	6.31 ± 1.31	6.41 ± 1.69

[1]Data based on 2 and 3 successive generations for black and green leaf folders, respectively.

singly along the veins on the underside of the leaf or on the terminal shoots. They are oval, yellowish white when newly laid and turn pinkish yellow when about to hatch. Those of the green leaf folder are laid singly or in groups on the upper surface of the leaf, usually near the midrib. They are elongate, shiny and greenish and covered by a scale-like white gelatinous material.

The average incubation period was 3.66 days for the black leaf folder and 4.05 days for the green leaf folder (Table 1). The hatching larvae of both species behave similarly, biting the egg shell in order to free themselves. After making an opening, they slid slowly out of the shell with the head and thorax coming out first followed by the rest of the body. The young larvae did not feed immediately after hatching.

Larval Development. A newly hatched larva of the black leaf folder is whitish at first turning greenish yellow later but without any markings. Markings appear only in the second instar with distinct black and white marks appearing on the head, thorax and first and second abdominal segments. The later instars retain the black markings which become larger and more prominent as the larva matures (Fig. 3a). A full-grown larva measures about 14.82 mm.

In contrast, the green leaf folder larva is light yellow with dark brown head (Fig. 3b). A dark brown sclerite appears on the dorsal part of the prothorax in the second instar which later becomes divided and appears circular. The body of the later instars turn darker green and the integument appears moist and waxy. It measures about 13 mm when fully grown.

The first and second instars of both species do not fold the leaf margin. Instead, they feed on the undersurface of the leaf scraping the lower epidermis, but do not produce holes. Only the third and later instars fold the leaf margins together using silk threads which they spin. They stay inside the folded leaf until they pupate. When a larva is transferred to a fresh leaf, it folds the margin first before it starts feeding.

In all instars, the larva ceases feeding and becomes inactive several hours prior to molting. The larva anchors its legs firmly on the leaf surface and its body alternately expands and contracts until the integument on the dorso-thoracic region split. The newly molted larva does not feed immediately. It takes from 1-2 hr before the cuticle hardens and attains its normal sclerotized appearance.

Pupation. Before pupation, the fifth instar larva undergoes a short pre-pupal period during which it ceases feeding and the body shortens to almost half the length of the fifth instar. The prepupa of the green leaf folder spins a scanty cocoon between the leaf folds. The pupa of both species is obtect and found inside the folded leaf.

The pupa of the black leaf folder is about 7 mm, yellowish brown at first, turning dark golden brown

Fig. 3. Close-up of larva of black leaf folder (A) and green leaf folder (B).

Fig. 4. Close-up of pupa of black leaf folder (A) and green leaf folder (B).

later (Fig. 4a). It has a tuft of hairs at the tip of the abdomen and is enclosed in a scanty cocoon. On the other hand, the pupa of the green leaf folder is about 8 mm long, yellowish white at first and becoming reddish brown (Fig. 4b). The abdomen tapers anteriorly and has a distinct constriction. Pupation is completed in 8-15 hrs for the black leaf folder while it took at least 24 hr for the green leaf folder.

Emergence of Adult, Sex Ratio and Fecundity. During emergence, the dorso-thoracic region of the body split due to constant movement of the pupa. The adult moth slid out slowly with the dorso-thoracic region coming out first followed by the legs and the head. At first, the wings are crumpled but soon after emergence, the moth stretched out its wings to expand them.

The black leaf folder adult (female is about 8 mm long) is a grayish black moth with scattering of white scales on the body and appendages (Fig. 5a). The adult green leaf folder is similar in size (female is 8.5 mm long) but is yellowish brown with dark brown markings on the wings (Fig. 5b). In both species, the female moth is larger than the male.

Out of 340 black leaf folder larvae reared in individual cultures, 260 or 76.50% reached the adult stage. There were 113 males and 147 females giving a male-to-female ratio of 1.0:1.3. For the green leaf folder, 145 out of 224 or 64.73% of the larvae reached the adult stage. There were 73 males and 72 females giving a male-to-female ratio of 1.0:1.0.

Mortality of Larvae and Pupae. A total of 23.50 and 35.54% mortality was reported for black and green leaf folders, respectively (Table 2). For both species, higher mortality rates were observed during the earlier instars. Few mature larvae and pupae of black leaf folder died but more for the green leaf folder. Death during the early instars

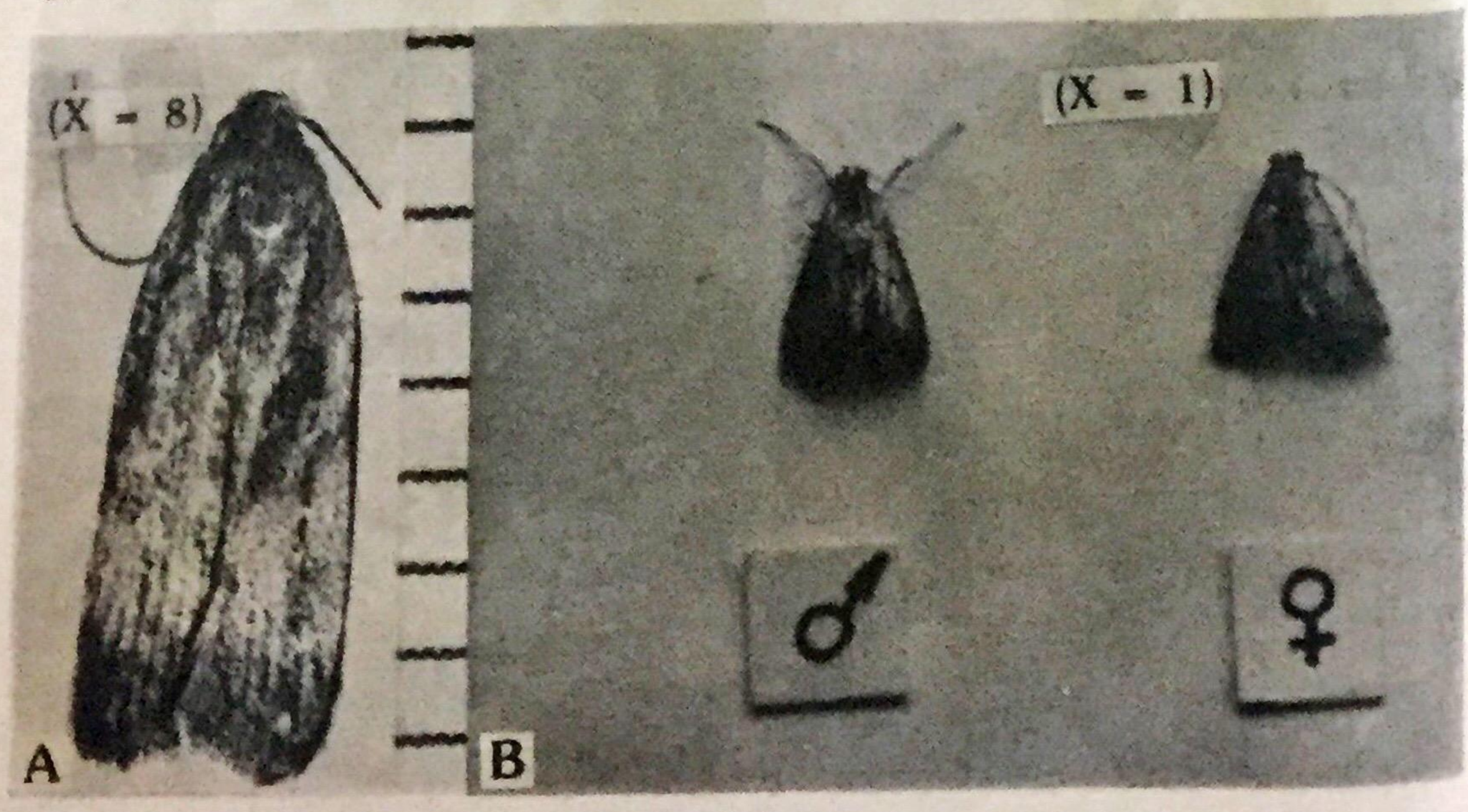

Fig. 5. Close-up of adult moth of black leaf folder (A) and green leaf folder (B).

was due mainly to disease. A mortality of 1.18% of the black leaf folder pupae was mainly due to the attack of ants during the first generation.

Younger larvae were more susceptible to mortality factors since at this time they were still unprotected because they have not folded the leaf margins. The mortality of third and fourth instars maybe due to handling because the substrate had to be changed often and the larvae have to fold the leaf anew during each change to fresh leaf.

Host Range

Twelve different plant species were tested as alternate hosts of black and green leaf folders. The results showed that black leaf folder has narrower host range compared to green leaf folder. The former can complete its development only on two plant species tested aside from sweet potato. These plants include: "muti-muti", *Ipomoea triloba* Lin.. and swamp cabbage, *I. aquatica* Forsk. On the other hand, green leaf folder larvae completed development on six species including sweet potato. The following plants were proven as alternate hosts of this insect: morning glory, *Ipomoea purpurea* (Lam.); swamp cabbage, *I. aquatica* Forsk; "lambayong", *I. pes-caprae* (Forsk.); "muti-muti", *I. triloba* (Linn.); and "asiang", *Mekania macrantha* (Mick.) All these species, except *M. macrantha,* belong to the Family Convolvulaceae like sweet potato.

Table 2. Comparison of the average mortality (%) of different larval instars and pupae of the black and green leaf folders of sweet potato.

Developmental Stage	Black Leaf Folder [1]	Green Leaf Folder [2]
First Instar	5.58	2.68
Second Instar	6.76	10.09
Third Instar	4.71	12.24
Fourth Instar	4.41	6.78
Fifth Instar	0.88	3.75
Pupa	1.18	0
Total	23.52	35.54

[1]Data based on 340 individually reared insects for 2 successive generations.
[2]Data based on 224 individually reared insects for 3 successive generations.

Table 3 gives a comparison of the life cycle of black leaf folder reared on three host plants. Those reared on sweet potato, which is the preferred host, have slightly shorter life cycle (mean of 19.42 days) than those reared on *I. triloba* (mean of 19.80 days) and *I. aquatica* (mean of 20.61 days). Moreover, the life span of adults reared on sweet potato is longer (mean of 6.44 days) in comparison with those reared on the other two host plants. The slight

differences indicate that both species are as suitable as sweet potato for rearing the black leaf folder.

Table 4 shows the average duration of the developmental stages of green leaf folder reared on sweet potato and 5 alternate hosts. Insects reared on *M. macrantha* had the longest life cycle (mean of 28.80 days) compared to those reared on the other host plants which ranged from mean of 22.00 days (on *I. triloba*) to 25.40 (on *I. pes-caprae*). The average life cycle on sweet potato is 24.48 days. The insects reared on *I. triloba* and *I. purpurea* had shorter life cycle than those reared on sweet potato. The prolonged life cycle indicates that *M. macrantha* was not a suitable host as the other plant species for green leaf folder. The adult moths emerging from larvae reared on *I. batatas, I. pes-caprae* and *M. macrantha* lived for about 6 days. Those reared on *I. triloba, I. aquatica* and *I. purpurea* lived about one day shorter but this difference was slight.

Although the insects completed development on all these alternate hosts, there was a difference in the larval mortality obtained between insects reared on the different host plants as shown in Tables 5 and 6 for the green and black leaf folders, respectively. Larvae of both insect species reared on sweet potato had the lowest mortality (21%) compared to those reared on other host plants. The highest mortality of black leaf folder was obtained from insects reared on *I. aquatica* (40%) while it was 49% for green leaf folder reared on *M. macrantha*. Differences in mortality rates show that although the insects can complete their development on the

Table 3. Comparison of the average duration (in days) of the developmental stages of black leaf folder reared on three host plants.

Developmental Period	Sweet Potato *(I. batatas)*	"Muti-muti" *(I. triloba)*	Swamp Cabbage *(I. aquatica)*
Incubation of Eggs	3.73	3.80	3.75
Larval Period			
First Stadium	2.69	2.50	3.25
Second Stadium	2.71	3.20	2.50
Third Stadium	2.10	2.20	2.12
Fourth Stadium	2.00	1.70	2.37
Fifth Stadium	1.71	1.70	2.37
Total Larval Period	11.21	11.30	12.61
Pupal Period	4.48	4.70	4.25
Egg-laying to Adult Emergence	19.42	19.80	20.61
Longevity of Adults	6.44	5.40	4.87

[1]Data based on 25 individually reared insects per host plant.

Table 4: Comparison of the average duration (in days) of the developmental stages of green leaf folder reared on six host plants.[1]

Developmental Period	Sweet Potato *(I. batatas)*	"Muti-muti" *(I. triloba)*	Morning Glory *(I. purpurea)*	Swamp Cabbage *(I. aquatica)*	"Lambayong" *(I. pes-caprae)*	"Asiang" *(M. macrantha)*
Incubation of Eggs	3.52	3.40	4.27	3.42	3.40	3.40
Larval Period						
First Stadium	3.72	3.20	2.81	2.85	2.60	3.00
Second Stadium	2.60	2.20	3.00	2.71	4.60	4.40
Third Stadium	2.88	2.60	2.72	4.14	3.20	4.20
Fourth Stadium	2.36	2.20	2.09	2.43	2.80	3.20
Fifth Stadium	3.00	1.90	1.72	2.71	2.40	4.20
Total Larval Period	14.56	12.10	12.34	14.84	15.60	19.00
Pupal Period	6.40	6.50	6.54	6.14	6.40	6.40
Egg-Laying to Adult Emergence	24.48	22.00	23.15	24.40	25.40	28.80
Longevity of Adults	6.37	5.20	4.72	5.00	6.20	6.00

[1]Data based on 25 individually reared insects per host plant.

alternate hosts, sweet potato is still the most suitable substrate. Higher mortality may be due to the less amount of food taken in by the larvae because of non-preference thereby leading to starvation or due to the presence of some chemicals which may be toxic to the larvae. However, this was not determined in the study.

Natural Enemies

A species of earwig (Order Dermaptera) (Fig. 6a) and ichneumonid parasite, *Macrocentrus* sp. (Fig. 6b), were found attacking the black leaf folder larvae in the field. *Macrocentrus* sp. was observed to be more abundant than the earwig in the field. It attacks young larvae while they have not folded the leaf margins. A percentage parasitism of 7 to 14 was recorded due to this parasite during the months of January to March in 1978 and 1979. Parasitism was lower at other times although this parasite was found to be normally associated with the pest in the field.

Table 5. Comparison of the average mortality (%) of black leaf folder reared on three host plants.[1]

Larval Instar	Sweet Potato *(I. batatas)*	"Muti-muti" *(I. triloba)*	Swamp Cabbage *(I. aquatica)*
First	7	10	10
Second	9	10	15
Third	5	5	5
Fourth	0	5	10
Fifth	0	1	0
Total	21	31	40

[1]Data based on 25 insects reared per host plant.

Table 6. Comparison of the average mortality (%) of green leaf folder reared on six host plants.[1]

Larval Instar	Sweet Potato *(I. batatas)*	"Lambayong" *(I. pes-caprae)*	Swamp Cabbage *(I. aquatica)*	"Muti-muti" *(I. triloba)*	Morning Glory *(I. purpurea)*	"Asiang" *(M. macrantha)*
First	8.00	12.00	8.00	12.00	8.00	16.00
Second	9.09	9.09	17.39	22.73	26.08	33.33
Third	4.76	0	5.26	0	5.88	0
Fourth	0	0	0	0	0	0
Fifth	0	0	0	0	0	0
Total	21.85	21.09	30.65	34.75	39.96	49.33

[1]Data based on 25 individually reared insects per host plant.

Green leaf folder is attacked by two species of hymenopterous parasite. *Brachymeria* sp., a chalcid wasp, attacks the pupae (Fig. 7a) and another unidentified species parasitizes the larvae (Fig. 7b). Both parasites were observed throughout the year although their population was not very high.

Seasonal Abundance of Pests

Black and green leaf folder

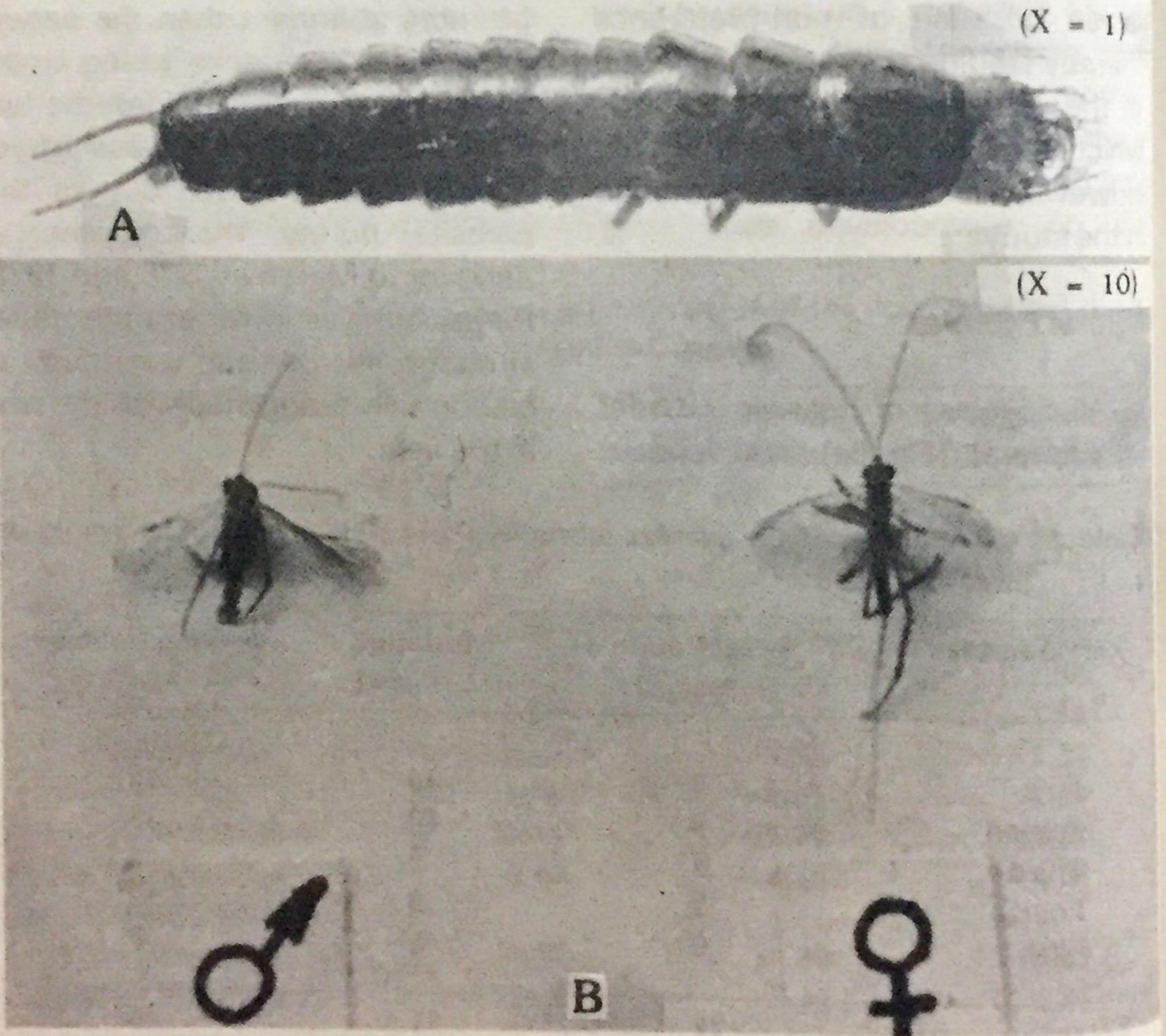

Fig. 6. Natural enemies of black leaf folder larvae: (A) predatory earwig and (B) *Macrocentrus* sp., an ichneumonid larval parasite.

Fig. 7. *Brachymeria* sp., a chalcid wasp parasiting the pupae of the green leaf folder.

larvae were found in the field throughout the year as shown in Fig. 8. In 1978 and 1979, black leaf folder was more abundant than the green leaf folder. In 1978, the population of black leaf folder was

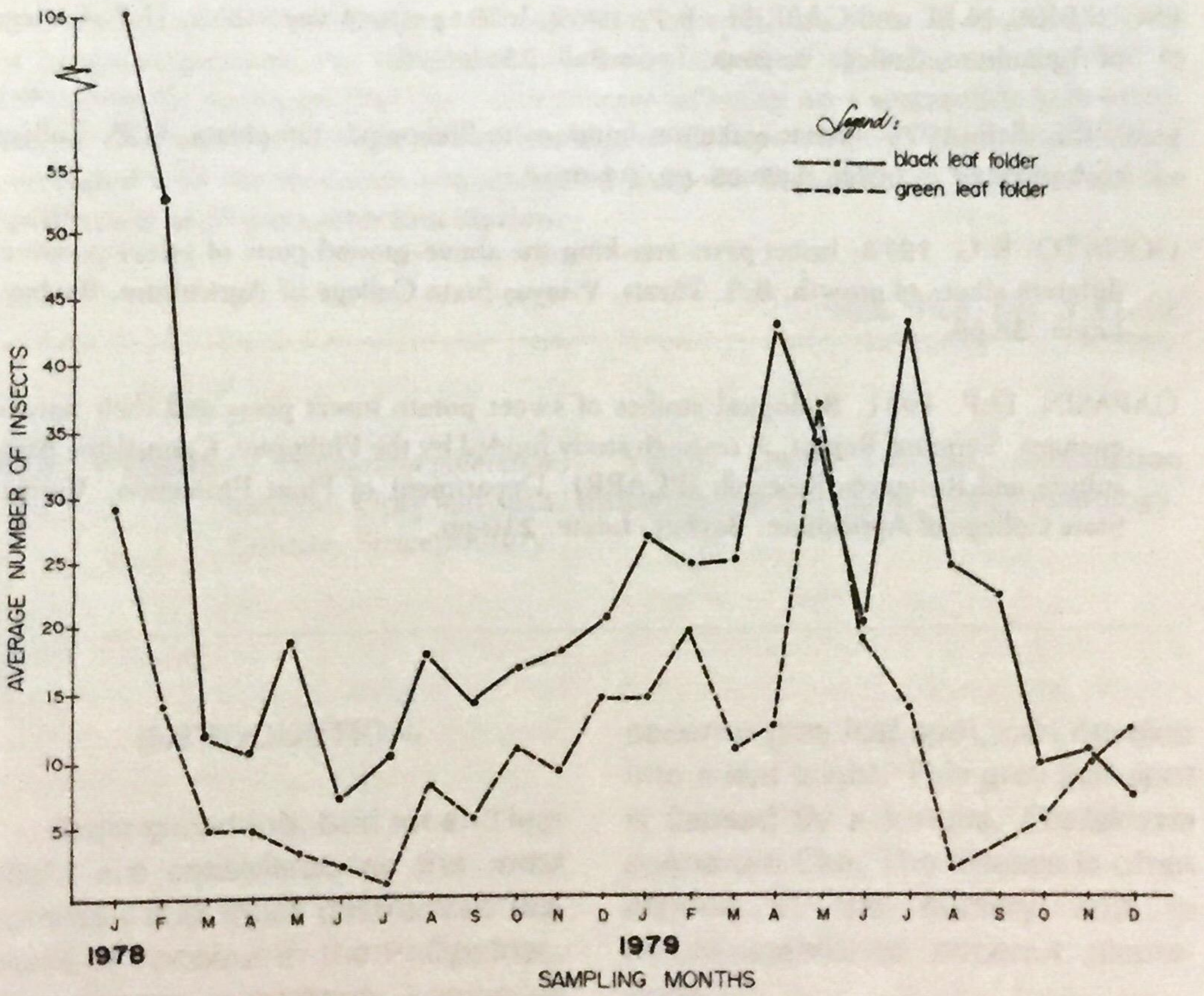

Fig. 8. Monthly population of black and green leaf folders during four croppings of sweet potato planted in January 1978 to December 1979 at ViSCA.

highest during January (105) and February (52) and in April (43) the following year. For green leaf folder, the highest population (29) was also observed in January 1978 with slightly higher number (37) of individuals observed in May 1979.

LITERATURE CITED

DUATIN, M.A.Y. 1979. Influence of foliage color and shape on the abundance of insect pests attacking sweet potato *(Ipomoea batatas* L.). B.S. Thesis, Visayas State College of Agriculture, Baybay, Leyte, 51 pp.

ESGUERRA, N.M. and GABRIEL, B.P. 1969. Insect pests of vegetables. U.P. College of Agriculture, College, Laguna, Tech. Bull. 25: 84-95.

GABRIEL, B.P. 1975. Insects and mites injurious to Philippine crop plants. U.P. College of Agriculture, College, Laguna, pp. 64-66.

GONATO, R.G. 1978. Insect pests attacking the above-ground parts of sweet potato at different stages of growth. B.S. Thesis, Visayas State College of Agriculture, Baybay, Leyte, 35 pp.

GAPASIN, D.P. 1981. Biological studies of sweet potato insect pests and their natural enemies. Terminal Report. A research study funded by the Philippine Council for Agriculture and Resources Research (PCARR), Department of Plant Protection, Visayas State College of Agriculture, Baybay, Leyte, 210 pp.