Annals of Tropical Research 43 (2):102-119(2021)
https://doi.org/10.32945/atr4329.2021

Biology of tortoiseshell beetle (*Aspidimorpha miliaris* Fabr.) on sweetpotato (*Ipomoea batatas* Lam.) and its relatives as affected by hosts' nutritional profiles

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ABSTRACT

Received: 1 July 2021 | Accepted: 7 December 2021

Several insect pests attack the foliage of sweetpotato at different stages of crop growth which contribute to yield reduction. Weeds belonging to the same genera as the main host can act as alternate hosts of insect pests. The study evaluated the biology of tortoiseshell beetle in the laboratory at an ambient temperature of 27-30°C and 85-90% RH on sweetpotato (*Ipomoea batatas*) as main host and four other *Ipomoea* species: three-lobe morning glory *(I. triloba),* beach morning glory *(Ipes-caprae),* swamp morning glory *(I. aquatica)*, and five-finger morning glory (*I. pentaphylla* Syn. *I. cairica*) as alternate hosts. The beetle underwent four developmental stages - egg, larva, pupa, and adult. It completed its development within 4-6 weeks from egg-laying to adult emergence of 26-40 days, an average of 27.55 to 39.01 days. The total development period of male and female *A. miliaris* on *I. batatas, I. triloba, I. pes-caprae, I. aquatica*, and *I. pentaphylla* were 27.55 and 30.72, 27.52 and 30.49, 29.94 and 35.06, 33.25 and 38.11, and 33.70 and 39.01 days, respectively. Adult longevity of males and females was longer on *I. batatas* and *I. triloba*, followed by *I. aquatica*), *I. pentaphylla*, and lastly, *I. pes-caprae*. The highest number of eggs laid was recorded in *I. batatas* (202.7), followed by *I. triloba* (173.2), *I. pes-caprae* (76.0), *I. aquatica* (71.7), and *I. pentaphylla* (59.7). The highest egg viability of more than 90% was recorded in *I. batatas* and *I. triloba.* Mortality occurred towards the later part of larval development, with the lowest mortality of 8.33% in *I. batatas.*

The host plants ' high protein, N, P, and K contents influenced the shorter life cycle, higher reproductive rate, high percentage egg hatchability, lower mortality, and longer life span. Increased mortality and abnormal wet frass in *I. pes-caprae* could be accounted for by exceptionally high sugar content in the leaves and

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secondary metabolites present, especially in other host plants that may have insecticidal activity. Since *A. miliaris* was also able to complete its life cycle and reproduce on the four weed species, the insect continues to survive without sweetpotato. Any management strategy for this insect by destroying the Ipomoea weed hosts eliminates other sources of infestation in the field.

Keywords: Tortoiseshell beetle, *Aspidimorpha miliaris*, host suitability, *Ipomoea* species, host nutrient contents

INTRODUCTION

The tortoiseshell beetle, *Aspidimorpha miliaris* (F), is one of the major defoliators attacking sweetpotato (*Ipomoea batatas* Lam.) in many countries in Asia, including the Philippines (Vasquez and Sajise1987, Amante et al 2003). The larvae and adults feed heavily on the leaves and often strip off the leaves, causing a significant reduction in yield, primarily if defoliation occurs during the first two months after planting.

The biology of the insect has been studied on other *Ipomoea* species apart from sweetpotato such as *I. fistulosa* in Bangladesh (Miah et al 1993); *I. carnea* in Sumatra, Indonesia (Nakamura and Abbas 1987a, Nakamura and Abbas 1987b); *I. angulata* and *I. palmata* in India (David and Muthaim 1960, Manjunatha et al 1987); and *I. purpurea, I. aquatica, I. alba* in the Philippines (Baltazar 1971). It is also able to survive on non-*Ipomoea* species such as *Merremia tuberosa, M. gamella* and *Capsicum frutescens* (Baltazar 1970).

Although the biology of *A. miliaris* had been investigated on several *Ipomoea* species, no studies have yet been done on *I. triloba, I. pentaphylla*, and *I. pes-caprae* which are weeds usually associated with sweetpotato production and are usually present in neighboring fields. These plants are also seen as alternate host of the insect.

Alternate hosts play a big role in the tortoiseshell beetle-sweetpotato ecological system. They continuously provide host substrate to the tortoiseshell beetle, and the latter serves as prey to predators or host to entomopathogens as biological control agents. In the absence of sweetpotato, *A. miliaris* as a polyphagous pest may shift its population to different hosts during its life cycle to survive. According to Saeed et al (2017). the demographic evaluation of alternate hosts is vital for effective pest management.

In the study of the biology of the insect, it is also worth analyzing the nutritional components of these plants to give insights on the differential biology as the basis for effective pest control strategies. The need to conduct a biological study is crucial in the total management of the pest under investigation. Any pest management attempt cannot be thoroughly achieved without the knowledge of pest biology. The level and severity of infestation can be estimated in a given period of time, and appropriate management activities can be formulated. Knowledge and understanding of the pest's life cycle, reproductive potential, insect behavior, and associated natural enemies are indispensable to pest management's paramount importance.

MATERIALS AND METHODS

Planting of Host Plants

Vine cuttings of sweetpotato var NSIC Sp30, water spinach or swamp morning glory with purple flower (*I. aquatica Forssk.*), and beach morning glory (*I. pes-caprae* (L.) L. Br.) and newly-germinated seeds of three-lobe morning glory *(I. triloba*), five-finger morning glory *(I. pentaphylla* (L.) Jacq. Syn. *Ipomoea cairica* (L.) Sweet) were planted in a black polyethylene plastic pot #3 (5x5x8 in) filled with sterilized garden soil. They were maintained in the screenhouse until they were ready for use in the laboratory for insect rearing, and macronutrient and mineral analysis.

Mass Rearing of Aspidomorpha Miliaris

Late instar larvae and pupae were collected in the sweetpotato fields of PhilRootcrops experimental area at Calbigaa, Pangasugan, Baybay City, Leyte and brought to the laboratory as an initial source of insects for mass rearing. Thirty to 40 insects were placed in each silkscreen-netted PVC pipe-framed insect cage. Individual cage was provided with potted sweetpotato var NSIC Sp30, water spinach or swamp morning glory with purple flower, three-lobe morning glory, five-finger, and beach morning glories. To prevent desiccation, the insects that pupated at the same time were transferred to a Petri dish (14cm dia) lined with moist tissue paper. Newly- emerged female and male adults were paired and transferred to the screened cage for mating. Five pairs were introduced into each cage containing the host where they were previously reared.

The ootheca containing eggs laid in mass on the leaf were removed from the plant and incubated in the Petri dish lined with moist filter paper until the eggs hatched. Neonate larvae were used for individual cultures on the five host plants.

Biological Studies

Upon egg hatching, the first instar larvae were transferred singly to Petri dishes (14cm dia) containing fresh mature leaves of each of the five host plants. The insects were reared individually on the leaves of each of the host plants. The petiole of the leaves was wrapped with moist cotton to maintain its freshness. The leaves were changed daily with fresh ones. The different instars, prepupae, pupae, and adults were observed daily, and mortality was recorded. After adult emergence, mating, pre-oviposition, and oviposition, the number of ootheca laid per female and the total number of eggs per ootheca were recorded. The size of the ootheca, immatures, and adults reared on each host plant was measured using a 0-150mm digital stainless steel with LCD display Vernier caliper (Traceable ± 0.03mm accuracy Tesco Brand).

The experiment was laid in Randomized Complete Block Design (RCBD) with three replicates. Each replicate consisted of 20 individual cultures for the growth and developmental studies and 5 pairs for the fecundity study. In measuring the size, 10 randomly selected immatures and adults were used per replicate. The biological studies were conducted in the laboratory under the ambient condition at 27-30°C and 85-90% RH.

Moisture Content, Macronutrients and Minerals Analyses of the Host Plants

Moisture content

The moisture content of the leaves used to feed the tortoiseshell beetle was measured using the gravimetric method (oven-dry method). Fresh mature leaves of each of the five host plants were randomly taken from the potted plants maintained in the screen house and brought to the laboratory. One hundred grams of leaf samples were weighed using a digital balance (Ohaus Adventurer Pro AV 2102 with 210g capacity and 0.01g readability) and dried at 70°C in a convection oven for several hours until the dry weight of the leaves remained constant. The moisture content was then computed using the formula:

$$MC(\%) = \left[(W2 - W3) \div (W2 - W1) \right] x100$$

Where: W1 - the weight of the container, W2 - the weight of the container and sample before drying, and W3 - the weight of the container and sample after drying.

Three samples were taken from each host plant, and each sample constituted a replicate.

Carbohydrate and Protein Analysis

Total Carbohydrates. This was determined using the Anthrone Method which involved dehydrating with concentrated H_2SO_4. The green color complex was measured by colorimetric method at 620nm wavelength using a Hitachi U-2900 spectrophotometer. Anthrone reacts with dextrins, monosaccharides, disaccharides, polysaccharides, starch, gums, and glycosides.

Crude Protein (%CP). Total crude protein was calculated by multiplying the results obtained from the total nitrogen analysis by Kjeldahl Method with the traditional conversion factor of 6.25 on the assumption that protein, in general, contains 16% nitrogen (Jones 1941).

Minerals Analysis

Total N. Analysis of total N in the plant tissue followed the Micro-Kjeldahl procedure of Nelson and Sommers (1973). A 0.2g of oven-dried ground sample was weighed in a 100mL Kjeldahl flask. It was added with approximately the same weight of salt-catalyst mixture (50:10:1 ratio of K_2SO_4; $CuSO_4$; and Selenium salt) and 3mL of concentrated H_2SO_4. Kjeldahl flasks with the samples were placed in the digestion block and digested at 300°C temperature for 6h. High-temperature digestion converted organic and inorganic forms of N to ammonium. The ammonium in the digest was determined by acidimetric titration using standardized 0.1M HCl following alkaline distillation of ammonia using 4% H_3BO_3 as trap and 40% NaOH, respectively.

Total P and K. Plant tissue analysis of P and K followed the procedure of Mylavarapu and Kennelley (2002). One gram of oven-dried, ground plant tissue sieved in 250µm sieve (60 mesh) was weighed (accuracy 0.01g) into a high form glazed porcelain crucible and placed in a muffle furnace set at 550°C for 6-8h. The

cooled ashed sample was dissolved in 5mL 6M HCl; the suspension was left to stand for 30mins and diluted with deionized water to a 50mL volumetric flask, filtered with Sartorius #393 filter paper. Concentrations of total K were quantified using a 220 FS Varian Atomic Absorption Spectrophotometer at 769.9nm wavelength. Total P was determined using Murphy and Riley (1962) for color development, and P concentration was quantified using a Hitachi U-2900 spectrophotometer at 882nm wavelength.

Data Analysis

The data were subjected to statistical analysis using Statistical Tool for Agricultural Research (STAR). Significant differences of treatment means were measured using Tukey's test for multiple comparison and Linear correlation using Pearson's *r*.

RESULTS AND DISCUSSION

Description and Behavior of the Different Stages of Development (Figure 1)

Egg

The eggs were laid underneath a fully opened leaf enclosed in a creamy parchment-like membrane during egg-laying and appearing like scales. Two sheets of translucent membrane housed 2-3 eggs. An egg mass (ootheca) consists of 10-25 membranes. The eggs are creamy-white to light yellow, elongated with one end broader than the other. A single egg measured approximately 1.5-2mm.

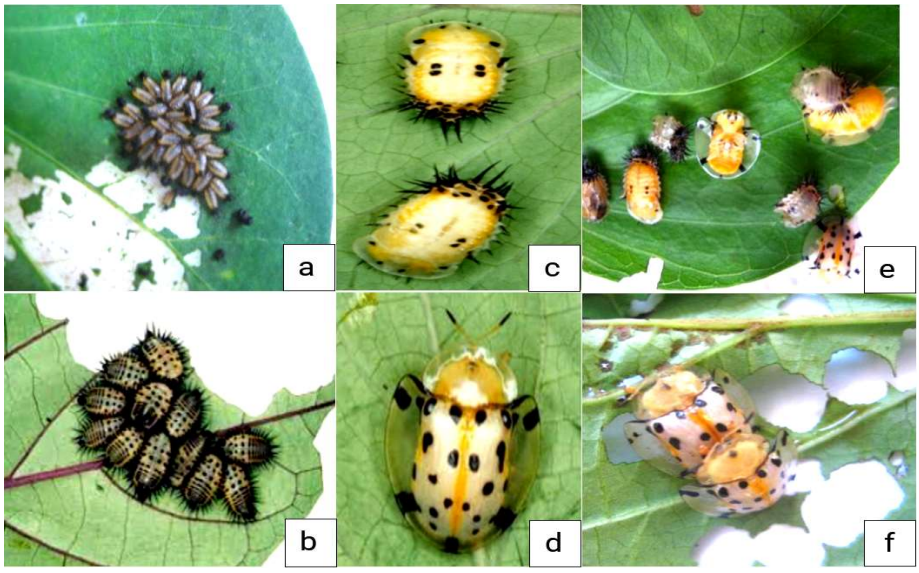

Figure 1. Tortoise shell beetle, *Aspidomorpha miliaris* Fab.: (a) 1st instar larvae in aggregate (b) third instar larvae (c) pupae, (d) female adult, (e) pupae and ewly -emerged adults and (f) adults in copula (Photos a-f: EAVasquez, Photos b & c also appeared in https://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/Media/Html/TheProblems/Pest-leafChewingInsects/TortoiseBeetles/tortoise%20beetles.htm)

Larvae

First Instar. Newly emerged larvae were creamy-white and surrounded with 20 black long thin branching spine-like projections. It has a well-developed head and thoracic legs. No distinct spots are seen on the body.

The larvae are gregarious and preferred to settle at the lower surface of the leaf. They fed in a group with the head oriented toward the center and scraped the epidermis. Before molting, the color changed to grayish brown.

Second Instar. After the first molt, the second instar carried the exuvium of the first instar at the tip of the stiff spines on the last abdominal segment. The larva appeared light yellow with 10 black square-rounded spots on the dorsal thoracic region and 7 continuous black lines across the abdominal area. Spiracles were visible on the lateral side of each body segment. The spine-like projections were similar to the first instar with a slightly flattened body. The larvae behaved and fed similarly to the first instar.

Third Instar. The 10 black spots of the dorsal thorax appeared more rounded and prominent, and the 7 continuous black lines across the abdominal region. Each of the abdominal lines became separated into two, resulting in 14 lines which appeared as two distinct rows. The branching spine-like projections looked broader and shortened. The body appeared more flattened than the second instar. The exuviae of the previous molts were carried in the same manner as in the first and second instar. The larvae were gregarious during the earlier stage after molting. They eventually dispersed and fed singly by chewing out the lower and upper surfaces and producing round holes on the leaves.

Fourth Instar. The features were similar with the third instar except in bigger size, body-color turned grayish brown, and the two abdominal lines split, turning them into distinct rows. The previous molts' exuviae were piled up on the other, with the last exuvia on the lowest part. The larvae were dispersed farther and fed voraciously, producing larger round holes.

Fifth Instar. Two faint light gray spots were seen on the anterior part of the body. Eight prominent rounded spots were found on the dorsal thorax. The 7 lines across the dorsal abdomen split into four rectangular spots, forming 28 black spots. The larva retained the exuvium of the fourth molt below the exuviae of the previous molts. The larvae were more voracious and fed individually and may consume the entire leaf if only a few leaves were available. They also nibbled the petiole until they ceased feeding.

Pupa

The abdominal tip of the pupa was firmly glued to the surface of the leaf. The newly-formed pupa was yellow and devoid of spots. The branching spines were concentrated on the 7th to the last abdominal segment with a wrinkled body. The cerci on the last abdominal segment were conspicuous. The prothoracic shield became prominent with four transparent spines on the cephalic margin. The first 5 lateral abdominal segments carried a pair of transparent scale-like plates ending in

a black spine. Two black spots are seen on the 1st and 2nd segments of the abdomen and another two black spots on the side of the head capsule. The compound eyes became conspicuous. The spine-like projections on the lateral side of the 1st-6th segments of the abdomen widened and appeared as a continuous projection from the shell-like structure in the lateral side of the abdomen.

Adult

Newly-emerged adults were pinkish with transparent elytra showing faint spots, which gradually turned darker. The elytra contained a total of 16 black spots on the male and 22 on the female. The transparent margin of the elytra had two irregular-shaped black spots on each side. The distal tip of each of the elytra showed a square black spot. Females were more or less round, while the males were slightly oval. The prothoracic shield completely covering the head had one black spot in the middle. The head was prognathous, and the antenna was capitate with a black tip. As the adult became older from 2-3 weeks after emergence, the body color changed to orange. Adults ate and produced large holes in the leaves.

Growth and Development

The tortoiseshell beetle, *A. miliaris, c*ompleted its life cycle and reproduced successfully on sweetpotato (*I. batatas*) and other *Ipomoea* species, namely*: I. triloba, I. aquatica, I. pes-caprae*, and *I. pentaphylla*. The duration of the growth and development from egg to adult and adult life span is presented in Table 1a & 1b and the corresponding sizes of the different stages in Table 2. A shorter life cycle, higher reproductive rate, lower mortality rate, longer life span, and bigger size were observed on sweetpotato and *I. triloba* than on the other three *Ipomoea* species. While sweetpotato is considered as the primary host, the comparable values in the biological parameters measured allow *I. triloba* to be a primary host.

The findings are almost in agreement with those reported in earlier biological studies wherein the life cycle was less than a month as the primary host and a week longer on alternate hosts of adults, and sizes of the different stages (Baltazar 1970, Manjunatha et al 1987, Nakamura et al 1987, Miah et al 1991).

The other three plant species that supported the complete life cycle with lower reproductive and higher mortality rate are considered alternate hosts of the tortoise shell beetle in the absence of sweetpotato.

Differences in the duration of the life cycle, reproductive and survival rate obtained in this study from those previously reported by Manjunatha et al 1987, Miah et al 1991, Tsai et al 2012 could also be accounted for by the rearing conditions regarding temperature and RH and plant hosts offered. *A. miliaris* reared at 15°C had a longer life cycle and life span, higher reproductive rate and higher mortality (Tsai et al 2012) than those reared at higher temperature (Baltazar 1971, Miah et al 1991, Manjamurtha et al 1987, and Nakamura et al 1989).

Life Cycle

Egg. The incubation period lasted from 6-9 days, with a mean of 6.33 to 8.33 days, depending on the host plants. In general, females had longer incubation than males regardless of host plants. A shorter incubation period was observed in *I. batatas* and *I. triloba*, while the longest was in *I. aquatica* in both sexes.

Table 1a. Development period (days) of *Aspidomorpha miliaris* reared on five *Ipomoea* species.

Host Plants	Incubation Period		Total Larval Period (L1-L5: Damaging stages)*		Pre-pupal Period		Pupal Period		Total Developmental period		Adult longevity	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
I. batatas	6.33b	7.00bc	14.88d	16.81d	1.00c	1.00c	5.33b	5.92b	27.55c	30.72c	31.93a	85.53a
I. aquatica	7.33a	8.33a	17.73b	19.89b	2.00a	2.00a	6.19a	7.30a	33.25a	38.11a	29.27a	43.40b
I. pentaphylla	7.67a	8.00ab	18.92a	21.78a	1.39b	1.81a	6.47a	7.42a	33.70a	39.01a	22.53ba	33.27c
I. pes-caprae	7.00ab	7.33abc	16.24c	20.12c	1.11c	1.44b	5.50b	6.08b	29.94b	35.06b	21.53b	35.07c
I. triloba	6.33b	6.67c	14.96d	17.18d	1.00c	1.00c	5.22a	5.97b	27.52c	30.49c	33.33a	82.60a
CV (%)	7.45	8.55	2.97	2.01	9.23	8.33	3.12	3.15	2.94	2.68	10.45	6.03

In a column, mean values followed by the same letter are not significantly different ($p<0.05$).

Table 1b. Larval development period (days) of the damaging stages from first to fifth stadia of *Aspidomorpha miliaris* reared on five *Ipomoea* species.

Host Plants	1st Larval Stadium		2nd Larval Stadium		3rd Larval Stadium		4th Larval Stadium		5th Larval Stadium	
	Male^{ns}	Female^{ns}	Male	Female	Male	Female	Male	Female	Male	Female
I. batatas	2.00	2.33	2.11b	2.44b	2.36c	2.89b	3.11a	3.53c	5.30b	5.61c
I. aquatica	2.28	2.81	2.33ab	2.64b	2.72ab	3.36a	3.78a	4.56a	6.61a	7.45a
I. pentaphylla	2.30	2.78	2.78a	3.50a	2.89a	3.56a	3.67a	4.28b	6.53a	7.67a
I. pes-caprae	2.30	2.61	2.78a	3.56a	2.44bc	3.56a	3.33b	4.47ab	5.39b	6.00b
I. triloba	2.08	2.53	2.22b	2.61b	2.22c	2.78b	3.22b	3.64c	5.22b	5.61c
CV (%)	6.13	6.66	9.78	3.67	6.01	5.91	4.13	3.53	2.73	2.96

In a column, mean values followed by the same letter are not significantly different (p<0.05).

Table 2. Sizes (mm) of larval and pupal stages of *A. miliaris* reared on five *Ipomoea* species.

Host Plants	1st Larval Instar				2nd Larval Instar				3rrd Larval Instar			
	Male^{ns}		Female		Male		Female		Male		Female	
	Length	Width	Length	Width^{ns}	Length	Width	Length	Width	Length	Width	Length	Width
I. batatas	2.22	1.40	2.62a	1.55	4.53bc	2.98b	5.21a	3.24a	6.50ab	4.01c	7.54b	4.90a
I. aquatica	2.19	1.19	2.34b	1.24	4.71b	2.74b	5.41a	3.37a	7.09a	5.02a	8.03a	5.21a
I. pentaphylla	2.02	1.25	2.67a	1.58	4.16c	2.29c	4.51b	2.40b	5.91b	3.64d	6.78c	4.18b
I. pes-caprae	2.34	1.44	2.62a	1.64	4.25c	2.19c	5.19a	3.21a	6.49ab	4.43b	7.35b	4.73a
I. triloba	2.39	1.52	2.82a	1.48	5.13a	3.46a	5.50a	3.52a	6.40ab	4.91a	7.37b	4.82a
CV (%)	6.21	8.65	5.52	14.31	4.41	6.94	3.82	8.22	5.71	4.28	2.49	5.62

Host Plants	4th Larval Instar				5th Larval Instar				Pupa			
	Male		Female		Male		Female		Male^{ns}		Female^{ns}	
	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
I. batatas	8.45b	5.70a	9.57b	6.47c	10.44b	7.54ab	11.70a	8.20a	9.73	6.55	10.84	7.40
I. aquatica	8.76a	5.73a	9.57b	6.69a	10.25c	7.12bc	11.43b	7.37b	9.42	7.03	10.98	7.38
I. pentaphylla	7.66c	5.25b	9.19c	6.07c	10.20c	6.34d	11.24b	6.90b	9.58	6.68	10.58	7.36
I. pes-caprae	8.78a	5.68a	10.16a	6.62a	10.79a	6.87cd	11.40b	7.57ab	9.59	7.80	10.90	7.44
I. triloba	8.45b	5.34b	9.61b	6.45b	10.45b	7.82a	11.81a	8.23a	9.37	7.07	11.50	8.32
CV (%)	1.97	2.68	1.95	4.10	2.74	4.18	1.21	5.47	3.62	13.43	3.24	5.84

In a column, mean values followed by the same letter are not significantly different (p<0.05).

Table 2 continued

Host Plants	Adult				Ootheca (Egg Mass)	
	Male ns		Female ns			
	Length	Width	Length	Width	Length	Width
I. batatas	10.22	9.31	11.76	10.08	6.53b	6.10a
I. aquatica	10.23	9.51	11.74	9.50	6.57ab	6.13a
I. pentaphylla	9.94	8.12	11.36	9.36	5.27c	4.97b
I. pes-caprae	10.10	9.05	12.05	10.35	7.23ab	6.07a
I. triloba	10.24	9.23	11.93	9.71	7.40a	6.17a
CV (%)	3.27	6.79	2.67	6.45	6.76	4.73

In a column, mean values followed by the same letter are not significantly different ($p<0.05$).

Larva. The beetle underwent five larval instars, and each larval stadium lasted 2-3 days for the first instar, 2-4 days for the second to the third instar, 3-5 days for the fourth instar, and 5-8 days for the fifth instar (Table 1b) with extended 1-2 days non-feeding prepupal period. The shortest larval stadia were recorded in *I. triloba* and *I. batatas* and the longest was in *I. pes-caprae* from first to fifth larval stadia. In general, males developed earlier than females.

The damaging larval period ranged from 2 to 3 weeks with an average of 14.88 to 19.89 days; the male had a shorter duration than the females. All insects produced solid and relatively dry fecal materials during the larval development except those reared on *I. pres-caprae,* which have wet frass.

Pupa. It took 5-8 days with an average of 5.22 to 7.42 days for the beetle to remain in the quiescent stage before becoming an adult. The same trend as in the earlier stage of development was observed in the pupal period wherein a shorter period was recorded in beetles reared both on *I. batatas* and *I. triloba*. A more extended pupal period was required for those raised in the other three host plants.

Total developmental period. The egg-laying to adult emergence needs 26-40 days with an average of 27.55 to 39.01 days, the shortest of which were those fed on *I. batatas* and *I. triloba*, followed by equal duration but faster than *I. pes-caprae.*

Adult Longevity. Males usually have a shorter life span than females regardless of host plants. The average longevity of the males lasted for 3-5 weeks. Host plants that provided a shorter life cycle and better growth rate, such as *I. batatas* and *I. triloba* produced adults that lived longer than those which required more extended development and relatively smaller adults as in the other three hosts.

Sizes of Different Stages of Development

The sizes of the different stages of development were affected by the host plant (Table 2). Except for the length of the females, there was no significant difference in the first larval instar size in the males and width of females regardless of the host plants. Significant effects started on the second instar until the fifth instar. However, as the insect reached the pupal stage until it became an adult, no more substantial effect was observed. According to Blau (1981) and Wickman et al (1990), most insects accumulate mass quickly during larval growth.

It was noted that larval instars, pupae, adults, and ootheca laid by females were relatively bigger when fed with *I. batatas, I. triloba* and *I. pes-caprae* than with *I. aquatica* and *I. pentaphylla*. The former three *Ipomoea* species have higher protein, N, K, and P, than the latter species (Table 6). The growth and development, survival, and overall insect performance depend on the nutrition of host plants. Improvement of the host plant chemistry by nitrogen enhanced better insect development (Bala et al 1980). Proteins as enzymes and as structural and regulatory proteins are needed by the insect to complete its life cycle (Kola et al 2015). The total nitrogen of the crop affects the performance of insect herbivores due to its involvement in metabolic processes, cellular structure, and genetic coding (Mattson 1980).

Mortality usually occurred towards the latter part of larval development. There was no death in the earlier instars (L1 and L2). The onset of morbidity leading to death appeared from L1 and progressed as the insects matured. The lowest mortality of 8.33% was on *I. batatas* followed by *I. triloba of* 16.67%, while the rest of the host plants had beetle mortality of more than 50% but less than 65% (Table 3). The quality of the host plants determines the insect's metabolisms, which affects the life history and survival rate in phytophagous insects. Biologically active defense compounds like alkaloids, terpenoids, phenolics, and glucosinolates in high amounts are toxic, acting as antifeedant or repellant, can significantly reduce insect performance (Bezemer et al 2014). The genus *Ipomoea* contains three alkaloids, ergoline, indolizidine, and nortropane; phenolic coumarin and isocoumarine; norisoprenoids, diterpenes, and triterpenes for the terpenoids; anthocyanins, glycolipids, and lignans (Meira et al 2012). Pyrrolizidine alkaloids are strong deterrents and mutagenic in insects (Hartmann 2004).

Table 3. Total mortality of *A. miliaris* from first larval instar to pupa reared on *Ipomoea* species as hosts.

Host Plants	Mortality (%)
I. batatas	8.33d
I. aquatica	55.00b
I. pentaphylla	60.00ab
I. pes-caprae	61.67a
I. triloba	16.67c
CV (%)	7.16

In a column, mean values followed by the same letter are not significantly different ($p<0.05$).

Reproductive Capacity

Table 4 presents the reproductive capacity of *A. miliaris* reared on five different host plants. Each female laid 2-6 oothecae during the entire oviposition period with 30-40 eggs per ootheca—the number of ootheca and the total eggs within depending on the longevity of the adult females. The highest number of oothecae and the total number of eggs laid were recorded on those female insects fed with *I. batatas* and *I. triloba* with the longest life span. In insects with multiple matings like the tortoiseshell beetle, a longer life span allows several copulations to produce more oothecae and longer oviposition. The size of the females also affects the size of the ootheca. Bigger females reared on *I. triloba* and *I. pes-caprae* have bigger oothecae with more eggs. The significantly high P content in these two plants may also contributed to the production of bigger ootheca (Table 6).

Table 4. Reproductive capacity of *A. miliaris* on *Ipomoea* species as hosts.

Host Plant	Number of Ootheca laid per female	Number Of Eggs per Ootheca	Total Eggs Laid Per Female	Egg Hatchability (%)
I. batatas	5.67a	35.83bc	202.67a	95.67a
I. aquatica	3.67b	34.92c	71.67bc	59.00b
I. pentaphylla	2.00b	29.58d	59.67c	50.33b
I. pescaprae	2.00b	38.00ab	76.00bc	36.00c
I. triloba	4.33a	40.00a	173.20ab	92.67a
CV (%)	14.97	3.75	17.97	6.07

In a column, mean values followed by the same letter(s) are not significantly different ($p<0.05$).

Large female insects usually have high potential fecundity. Honek (1993) reported that the size of the female is the principal constraint in potential fecundity. He stated that there is 0.81% increase in ovariole number for each 1% increase in dry body weight in 10 species of Coleoptera (to which the insect under study belongs), Diptera, Hymenoptera, and Orthoptera.

While females reared on *I. aquatica* and *I. pes-caprae* produced more eggs per ootheca than on sweetpotato, the total number of eggs laid per female was significantly lower since the number of ootheca laid was less (Table 4). The lowest number of oothecae laid and the number of eggs housed per ootheca produced in females reared on *I. pentaphylla*. These findings suggest that it is not only the longevity that determines the egg-laying capacity of *A. miliaris* but probably the secondary metabolites present as well, which may have some toxic effect on the production of eggs. *I. pentaphylla also* significantly lowers the fecundity and egg hatchability of *Aedes albopec-tus* and *A. aegypti*, along with different morphological and physiological anomalies (Zuharah et al 2016).

Host Plants Nutritional Profiles

The macronutrients, mainly in the form of carbohydrates and proteins and two essential minerals, P and K, of the five *Ipomoea* host plants are presented in Table 6. The amount in the fresh weight, which the insect ate, is based on the moisture content (Table 5). In decreasing order, *I. batatas* contained the highest amount of carbohydrates, protein, and minerals, followed by *I. triloba, I. pes-caprae pentaphylla,* and *I. aquatica*. The different biological parameters were significantly affected by the nutrients present in each host plant. The survival, growth, and fecundity of an insect is affected by the nutritional regime, particularly the protein and carbohydrate ratio (Wang et al 2018).

A Pearson product-moment correlation coefficient was computed to assess the relationship between the biology of *A. miliaris* and the different nutrients present in the five host plants. There was a positive correlation between the other variables from very weak to very strong depending on the parameters in question (Table 7). A strong correlation existed between protein and the developmental period, fecundity, and sizes of the different stages. High protein in the host plants shortened the life cycle, increased fecundity, and body size. According to Awmack and Leather (2002)

as cited by Dancewicz et al (2018), the quality of the host plants determines the fecundity of herbivorous insects, and the components such as carbon, nitrogen and other secondary metabolites directly affect the potential and achieved fecundity. Nitrogen plays a central role in all metabolic processes, and thus is a critical element in the growth of all organisms (Mattson 1980). The nitrogen content in all host plants followed the same trend as that of the protein. There was a strong correlation between the starch and egg hatchability and body sizes while the sugar was correlated with the life cycle, longevity, and body sizes.

Table 5. Moisture Content (MC) of the mature leaves of the five *Ipomoea* species.

Host Plants	Moisture Content (%)
I. batatas	84.67b
I. aquatica	88.19a
I. pentaphylla	87.24a
I. pes-caprae	85.25b
I. triloba	84.80b
CV (%)	0.58

In a column, mean values followed by the same letter are not significantly different (p<0.05).

A strong correlation was only found between P and the size of the male pupa and adults and a medium correlation on egg hatchability for the minerals. The high P diet produced significantly larger adults in cricket (*Acheta domesticas*) (Visanuvidol and Bertram 2011). Low P levels decreased larval growth rate and lengthened the stadium in the final molt in *Manduca sexta* (Perkins et al 2004) and mayflies (Frost and Elser 2002). Except for the size, there was a very weak to none at all correlation between K and almost all biological parameters.

Overall, carbohydrates, proteins, and nitrogen showed most of the medium to strong correlations. On the other hand, the mineral ions play a role in the hatchability and body size of the late stages of insect development.

CONCLUSION AND RECOMMENDATION

The beetle survived and reproduced on the five species of *Ipomoea*. *I. triloba* offered the best host substrate comparable with that of *I. batatas.* Although the beetle completed its life cycle on *I. aquatica, I. pes-caprae,* and *I. pentaphylla,* the growth and development took longer, fecundity was lower, and mortality was higher.

The biology of the sweetpotato tortoiseshell beetle (*A. miliaris*) was highly influenced by the nutritional contents of the host plants. The important elements that affect the growth and development, reproductive capacity and mortality are carbohydrates, protein and two important minerals, phosphorus and potassium. The macronutrients and minerals can be used as indicators of the susceptibility of a sweepotato variety to this insect pest.

Table 6. Macronutrients and minerals of *Ipomoea* species as hosts of *A. miliaris*.

Host Plants	Carbohydrates				Crude Protein & Nitrogen				Minerals			
	Starch (%)		Sugar (%)		Protein		Nitrogen		P (ppm)		K (%)	
	Fresh*	Dried	Fresh*	Dried	Fresh*	Dried	Fresh*	Dried	Fresh*	Dried	Fresh*	Dried
I. batatas	3.19a	20.78a	0.70c	4.58d	4.11ab	28.25a	0.66ab	4.41ab	41.06a	267.88b	0.54a	3.55a
I. aquatica	2.34c	19.92b	0.63c	5.30c	3.72b	28.37a	0.60b	4.98a	35.67b	302.02a	0.41c	3.49ab
I. pentaphylla	2.31c	18.06c	0.88b	6.92b	3.43b	23.81b	0.55b	4.43b	32.68b	256.10b	0.44c	3.46ab
I. pes-caprae	2.64b	17.96d	1.25a	8.48a	3.40b	21.76b	0.58b	3.45b	40.64a	275.53b	0.48b	3.30b
I. triloba	1.90d	12.26e	0.58d	3.73e	4.72a	30.63a	0.76a	4.81a	40.96a	269.48b	0.54a	3.52a
CV (%)		0.22		2.28		14.40		14.29		4.33		2.67

*Based on moisture content In a column, mean values followed by the same letter are not significantly different (p<0.05).

Table 7. Correlation (r) between biological parameters and nutritional profile of *Ipomoea* host plants.

Biological Parameter	Nutritional Profile					
	Starch	Sugar	Protein	Nitrogen	Phosphorus	Potassium
Size						
Larva (L5):						
Female - Length	0.710	0.405	0.895	0.624	0.065	0.027
- Width	0.536	0.160	0.286	0.167	0.106	0.014
Male - Length	0.833	0.152	0.955	0.687	0.032	0.239
- Width	0.505	0.146	0.687	0.956	0.102	0.063
Pupa:						
Female - Length	0.118	0.549	0.993	0.993	0.056	0.172
- Width	0.085	0.450	0.728	0.728	0.102	0.055
Male - Length	0.879	0.624	0.475	0.475	0.915	0.835
- Width	0.258	0.191	0.158	0.158	0.570	0.666
Adult:						
Female - Length	0.699	0.405	0.345	0.565	0.004	0.212
- Width	0.075	0.138	0.565	0.345	0.031	0.182
Male - Length	0.923	0.942	0.979	0.979	0.453	0.935
- Width	0.259	0.656	0.229	0.229	0.383	0.894
Life Cycle:						
Female	0.271	0.617	0.797	0.630	0.013	0.001
Male	0.185	0.894	0.435	0.311	0.002	0.000
Longevity:						
Female	0.163	0.934	0.197	0.112	0.001	0.006
Male	0.210	0.642	0.271	0.139	0.000	0.002
Mortality	0.462	0.046	0.594	0.774	0.187	0.050
Fecundity	0.174	0.284	0.920	0.635	0.109	0.096
Egg Hatchability	0.886	0.003	0.300	0.395	0.497	0.183

A better understanding of the biology of the sweetpotato tortoiseshell beetle is necessary for formulating an effective control measure. The four other *Ipomoea* species, which are common upland weeds and are often associated in sweetpotato fields and vicinity, especially *I. triloba,* need to be appropriately managed to break the cycle of the insect in the absence of sweetpotato. The beetles harboring on them will not become the source of the infestation in the next sweetpotato planting season. Although there are instances where weeds play an essential role in an ecosystem by providing continuous food substrate for the pests and the latter as hosts for biological control agents, the benefits should outweigh the detriment. In the case of the tortoiseshell beetle, which is only attacked by pupal parasitoid with very low pupal parasitism, destruction of the weed hosts is deemed necessary.

REFERENCES

Amante V, Vasquez E, O'Sullivan J & Norton G. 2003. A field guide to sweetpotato problems in the Philippines. University of Queensland, Australia

Awmack C and Leather S. 2002. Host plant quality and fecundity in herbivorous insects. *Annual Review of Entomology* 47:817-844

Bala K, Sood AK, Pathania VS & Thakur S. 2018. Effect of plant nutrition in insect pest management: A review. *Journal of Phamacognosy and Phytochemistry* 7(4):2737-2742

Blau WS. 1981. Life history variation in the black swallow-tail butterfly. *Oecologia* 48(1):116-122

Baltazar EP. 1970. Biological study of *Aspidomorpha miliaris* (Fabricius) (Chrysomelidae, Coleoptera), withe a consideration of its host range and natural enemies. *Philippine Entomologist* 1(5):365-377

Bezemer TM, Harvey J & Cronin J. 2014. Response of native insect communities to invasive plants. *Annual Review of Entomology* 59(1):119-141

Frost PC and Elser JJ. 2002. Growth reponse of littoral mayflies to the phosphorous content of their food. *Ecology Letters* 5(2):232-240

Hartmann T. 2004. Plant derived secondary metabolites as defensive chemicals in herbivorous insects: a case study in chemical ecology. *Planta* 219(1):1-4

Honek A. 1993. Intraspecific variation in body size and fecundity in insects - a general relationship. *Oikos* 66(3):483-492

Jones DB. 1941. Factors for Converting Percentages of Nitrogen in Foods and Feeds into Percentages of Protein. United State Department of Agriculture, Washington D.C. Circular No. 183. Issued August 1931, slightly revised February 1941

Mattson WJ. 1980. Herbivory in relation to plant nitrogen content. *Annual Review of Ecological Systematics* 11:119-161

Meira EP, da Silva JM & David JP. 2012. Review of the genus Ipomoea: traditional uses, chemistry and biological activities. *Revista Brasileira de Farmacognosia-brazilian Journal of Pharmacognosy* 22:682-713

Miah MI, Bhiya BA & Mohiuddin M. 1991. Some aspects of the biology of *Aspidomorpha miliaris* (Coleoptera: Chrysomelidae, Cassidinae). *Bangladesh Journal of Entomolology* 1(1):11-17

Murphy J and Riley JP. 1962. A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* 27:31-36

Mylavarapu RS and Kennelley ED. 2002. UF/IFAS Extension Soil Testing Laboratory (ESTL), Analytical Procedures and Training Manual, Circular 1248

Nakamura K and Abbas I. 1987a. Preliminary life table of the spotted tortoise beetle, *Aspidomorpha miliaris* (Coleoptera: Chrysomelidae) in Sumatra. *Researches on Population Ecology* 29:229-236

Nakamura K and Abbas I. 1987b. Long-term fluctuations in adult numbers and egg mortalities of the tortoise beetles, *Aspidomorpha miliaris* and *A. sanctaecrucis*, in Sumatra. *Chrysomela* 16:12-13

Nakamura K, Abbas I & Hasyim A. 1989. Survivorship and fertility schedules of two Sumatran tortoise beetles, *Aspidomorpha miliaris* and *A. sanctaecrucis* (Coleoptera: Chrysomelidae) under laboratory conditions. *Researches on Population Ecology* 31:25-34

Nelson DW and Sommers LE. 1973. Determination of Total Nitrogen in Plant Material. *Agronomy Journal* 65(2):109-112

Perkins MC, Wood HA, Harrison JF & Elser JJ. 2004. Dietary phosphorous affects the growth of larval *Manduca sexta*. *Archive on Insect Biochemistry and Physiology* 55(3):153-168

Saeed Q, Ahmed F & Saeed S. 2017. Development and survival of *Spodoptera exigua* (Lepidoptera: Noctuidae) on alternate crops in crotton cropping patter, with implications to integrated pest management. *Environmental Entomology* 46(3):595-601

Tsai HJ, Cheng CL & Hsiao WF. 2012. Preliminary studies of life history of Tortoise beetle, *Aspidomorpha miliaris* (Fabricius) (Coleoptera: Chrysomelidae). *Plant Protection Bulletin* 54(3):77-90

Vasquez EA and Sajise CE. 1987. Pests of sweetpotato: insects, mites and diseases. PRIS and PRCRTC. Visayas State College of Agriculture

Visanuvidol L and Baertram S. 2011. How dietary phophorus availability during development influences condition and life history traits of the cricket, *Acheta domesticas*. *Journal of Insect Science* 11(1):1-17

Wang Z, Wang X, Li C, Xia Z & Li S. 2018. Effect of dietary protein and carbohydrates on survival and growth in Larvae of the *Henosepilachna vigintiooctopunctata* (F.) (Coleoptera: Coccinellidae). *Journal of Insect Science* 18(4):1-7

Zuharah W, Dieng H, Rami A, Thiagaletchumi M & Fadzly N. 2016. Evaluation of sublethal effects of *Ipomoea caraica* Linn extract on life history traits of dengue vectors. *Revista do Instituto de Medicina Tropical de Sao Paulo* 58:44