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RESEARCH ARTICLE

FEEDING AND DEVELOPMENT OF *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae) ON DIFFERENT HOST OF MEDICINAL PLANTS (*Orthosiphon stamineus, Gynura procumbens, Cantella asiatica and Capsicum frutescens*)

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ABSTRACT

Beet armyworm, *Spodoptera exigua* is a well-known insect pest of various crop plants, commercial trees, ornamental plants and flowers. This insect has a wide range of host plants around the world, therefore it has a potential to become pest of medicinal plant plantations in commercial use. A study was conducted to determine the suitability of four medicinal plant species as host plants: *Gynura procumbens* (Sambung Nyawa), *Cantella asiatica* (Pegaga Daun Besar), *Orthosiphon stamineus* (Misai Kucing) and *Capsium frutescens* (Cili Api), for the growth and development of beet armyworm. The fresh host plant leaves each species with the fix size (2½ cm diameter) were given to fed at the first instars of larvae until the pre-pupation stage. Based on the survival and mortality rates, developmental time, and pupae weight, *G. procumbens* was found more suitable for faster growth and development of larvae compared to *O. stamineus* which had survived only for nine days. Duration of the larval stage development was shortest on *G. procumbens* which only 9.11 days and longest on *C. asiatica* which 15.03 days. But numbers of survival are highest on C. asiatica, 24% and lowest on *G. Procumbens*, 13%. Whereas, the larvae on O. stamineus failed to survive. Over all, the arrangement suitability of the host plants were *G. procumbens* > *C. frutescens* > *C. asiatica* > *O. stamineus*. The physical and chemical characteristic of these different host plants may influence the differences of development and growth of *S. exigua* larval. The finding of this study can be used to estimation for controlling this insect to become pest in medicinal plant plantations if it was going to commercial planted.

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INTRODUCTION

According to Yoon (1999), medicinal plants are either feral plants or cultivated plants which can be used for medicinal purpose directly or indirectly, owing to their active ingredient content. They are trees, herbs and shrub. A medicinal plant is any plant that contain in one or more of its organs, substances that can be used for therapeutic purpose or which are precursors for chemo-pharmaceutical semi-synthesis. Malaysia is one of the top 12 biodiversity-rich countries and comes to number fourth in biodiversity-rich countries behind China, India and Indonesia in Asia.

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In Malaysia, there is more than 1,230 species of flowered plant been used in traditional treatment (Latif, 1994), and more than 6 000 to 7 000 species of plants that have been reported to have medicinal properties and have been used for many generations by herbal practitioners (Yoon, 1999). The current high rate of demand of harvesting medicinal plants, particularly from the wild, for the herbal market has lowered natural population sizes for many species. As land use intensifies under large scale commercial cultivation, the needs of crop protection on medicinal plants will concomitantly increase since this sort of cultivation and the environment there in, unlike the rather stable natural ecosystem from where the plants were derived, is conducive towards the proliferation of various and pathogenic problems. Direct feeding by insects has often resulted in economic losses in yield of food and other plant products. Often, severe infestation may kill the plants (Ooi, 1988). Insect with chewing mouth parts could feed on leaves, flowers, fruits, and other parts of the plant. Besides loss of valuable plant parts, the injuries cause serve as portals of entry for plant pathogens. The most popular foliage-eating insects that are present in practically at many crop and plantation are *Spodoptera* sp. (anon, 1982). One of the common species of *Spodoptera* is *Spodoptera exigua* (Hübner). It was has highly mobile larval and adult stages, and is known to feed on more than 50 plant species from over ten families around the world (Wilson, 1932; Smits *et al*., 1987). This species apparently originated in southern Asia, and was introduced into the USA in Oregon in 1876 and again in California in 1882 (Wilson, 1932). Since its introduction to California, *S. exigua* has become an important pest of celery, *Apium graveolens* L. (Umbelliferae) (Van Steenwyk & Toscano, 1981; Diawara *et al*., 1996). However, *A. graveolens* is not necessarily a preferred host. Recent studies have demonstrated that the larvae prefer the common weed *Chenopodiummurale* L. (Chenopodiaceae) over *A. graveolens* (Berdegué & Trumble, 1996; Berdegue *et al*., 1998).

Increasing demand of medicinal plant nowadays became a monoculture plantation of that product, and it was directly wide open to insect pests and disease. The common insect that wide range damaged the crop plantations *Spodoptera exigua* (Hübner) or beet armyworm (Anon, 1982) was lack information damaged the medicinal crop. Development of efficient strategies for controlling beet armyworm will require knowledge of its biological relationships with various host plants. Among these, an important component will be an understanding of host suitability. Quantitative analysis of consumption and utilization of host plants by insect herbivores is a commonly used tool in studies of plant insect interactions (Scriber and Slansky 1981). Variables describing the consumption of food by an insect, how well this food is converted to insect biomass and the rate at which the insect grows can lead to an understanding of how particular insect species respond to variation in host plant suitability (Greenberg *et al*., 2001).

Study of the effect of food on the biology of insects is of particular importance in understanding host suitability of plant infesting species and evaluating the magnitude of injury to the crops attacked by them. This may help, accordingly, in designing more economic control strategies. Various studies have evaluated host plant effects on beet armyworm growth potential (Strastova, 1959; Afifi *et al*. 1971; East *et al*. 1989, 1994) or investigated the impact of insect feeding on yield reduction (Shelton *et al*. 1982). Published information about other aspects of beet armyworm feeding biology, such as survival and reproductive potential, is incomplete (Greenberg *et al*., 2001). The objective of this study is to determine the influence of different host plants on developmental time, pupae and food consumption of S. *exigua.* Several insect pathogens may prove to be useful for suppression of beet armyworm. A nuclear polyhedrosis virus isolated from beet armyworm is fairly effective as a bioinsecticide under greenhouse conditions, where inactivation by ultraviolet light in sunlight is not a severe problem. The fungus *Beauveria bassiana* has the same attributes and limitations. Entomopathogenic nematodes (Rhabditida: Steinernematidae and Heterorhabditidae) successfully infect both larvae and adults of beet armyworm. The beet armyworm has a wide host range, occurring as a serious pest of vegetable, field, and flower crops. Among susceptible vegetable crops are asparagus, bean, beet, broccoli, cabbage, cauliflower, celery, chickpea, corn, cowpea, eggplant, lettuce, onion, pea, pepper, potato, radish, spinach, sweet potato, tomato, and turnip. Field crops damaged include alfalfa, corn, cotton, peanut, safflower, sorghum, soybean, sugar beet, and tobacco.

Weeds also are suitable for larval development, including such common plants as lambs quarters, *Chenopodium album*; mullein, *Verbascum* sp.; pigweed, *Amaranthus* spp.; purslane, *Portulaca* spp.; Russian thistle, *Salsola kali*; parthenium, *Parthenium* sp.; and tidestromia, *Tidestromia* sp. (Capinera, 1999). While not as omnivorous as other armyworms, this species is fond of many of the field and vegetable crops and some ornamentals. The host range of the pest includes broccoli, beets, beans, cabbage, carrot, Chinese broccoli, Chinese cabbage, corn, cotton, grain, green bean, head cabbage, lettuce, onion, sorghums, peas, pepper, potato, soybean, spinach, sweet potato, tomatoes, rose and chrysanthemum. All can sustain heavy beet worm damage (Mau and Kessing, 1991). Also weeds, asparagus, cotton, corn, soybean, tobacco, alfalfa, table and sugar beets, pepper, tomato, potato, onion, pea, sunflower and citrus. Plantain, lambsquarters and redroot pigweed are important wild hosts (Roberts and Guillebeau**,** 1999).

MATERIAL AND METHODS

The experiment was conducted in the Entomology and Pathology laboratories in the Faculty of Forestry, Universiti Putra Malaysia, under ambient environment of 28±2ºC and 12:12 (L: D) light regime.

Insects and rearing

Laboratory colony of *S.exigua* was used in this study. The eggs of the insect were obtained from MARDI, Serdang, Selangor. The larvae were reared on leaves of *C. asiatica* (Pegaga Daun Besar) inside a square plastic container, (14 x 9 x 6 cm) in size, to continue the colony used for these studies. The emerged adults were released in the round plastic cage as oviposition cage (3½ x 6 cm) initially lined with white paper and fed 10% honey solution soaked in cotton ball (plate 1).

Plate 1. Oviposition cage with the cotton ball at the lid

The paper with eggs was cut off and kept separately for hatching in other rounded plastic container similar in size like the ovipisition cage (3½ x 6 cm). Larvae were divided into four groups of host plants but reared for one generation on the same host plant species on which the following generation was evaluated and the larvae from the next generation were used for these studies.

Host Plants

Four types of host plants leaves were used in this study. The plants were Sambung nyawa (*Gynura procumbens*), Pegaga Daun Besar (*Cantella asiatica*), Misai kucing (*Orthosiphon stamineus*) and Cili api (*Capsium frutescens*) (plate 2, 3, 4 and 5). These host plants were selected based on their importance as medicinal plants or have a value to become medicine. There plants were obtained from “Taman Pertanian Universiti” (TPU) at “Unit Tanaman Ubatan dan Ulam-ulaman”, Universiti Putra Malaysia, Serdang, Selangor.

Plate 2. *Gynura procumbens*
Scientific name: *Gynura procumbens*
Local name: Sambung Nyawa, Akar Sebiak, Kelemai
Family name: Compositae/Asteraceae

Plate 3. *Cantella asiatica*
Scientific name: *Cantella asiatica*
Local name: Pegaga Daun Besar
Family name: Apiaceae / Umbeliferae

Feeding and development

Leaves for the larval were taken from the upper 2/3 of the plant canopy, which had reached its full dimensions. The leaf was cut off in fixed sized about (2½ cm diameter) (plate 6). The leaf was placed inside a round plastic cage (1½ inch. x 1 inch.) in size (plate 7); with one first instar of larva. The container was changed to the bigger sized about (1½ inch. x 2½ inch.) following the increase in the size of larvae. Collected leaves were soaked in the about 1% of bleach to sterilize them, before used as food for the larvae. This process was continued daily for each sample of larva until feeding ceased in the pre-pupa stage (plate 8).

Plate 4. *Orthosiphon stamineus*
Scientific name: *Orthosiphon stamineus*
Local name: Misai Kucing, Remujung, Ruku hitam
Family name: Labiatae/Lamiaceae

Plate 5. *Capsicum frutescens*
Scientific name: *Capsium frutescens*
Local name: Cili api
Family name: Solanaceae

Plate 6. Fix sized of host plant leaves (2½ cm diameter) in size

All of the 120 samples of larvae from four treatments were placed inside a big square of plastic box about 50 x 34 x 28.5 cm in size. These represented one replicate. There were held in an environmental chamber at 28± 2°C and a photoperiod of

12:12 (L: D). Daily food consumption per larva was estimated by weighing the remaining of leaves (plate 9) after it was oven-dried in a temperature 65 - 70ºC in 24 hours (plate 10). The pieces of leaves were placed into plastic bag (3 x 5 inch.) (plate 11) before oven-dried. All pupae were weighed, and estimated their length and width, upon emerged into adult stage the sex was determined and the moths were allowed to mate. The fecundity by female in each pair was recorded daily until female death. Adults were supplied with a cotton ball soaked with 10% of honey solution for feeding daily. Cages were examined daily to record female mortality, pre-ovipositor period, and number of eggs laid. The overall survival of beet armyworm on different host plants were calculated as number of eggs (or larvae, or pupae) hatched (or developed to the next stage) divided by the initial number. Time for development from egg to adult was recorded for each individual.

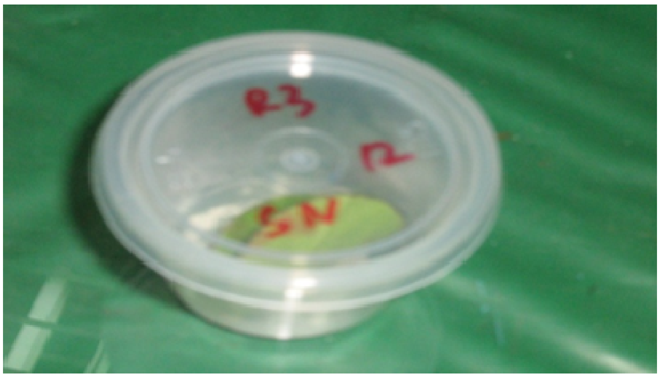

Plate 7. First instars of larvae inside the cage with the piece of leaves as a food

Plate 8. Pre-pupation

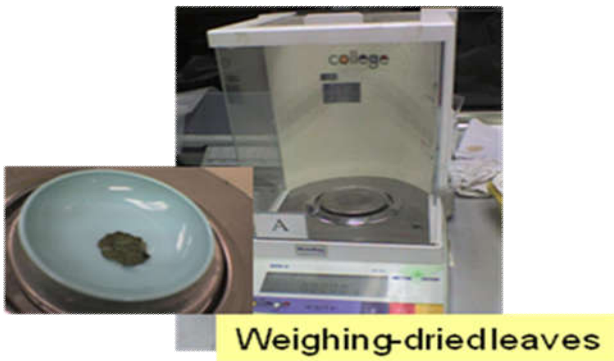

Plate 9. Determine the consumption rate (weight loss) of the host plant leaves

Plate 10. Oven-dry for dried the leaves balance

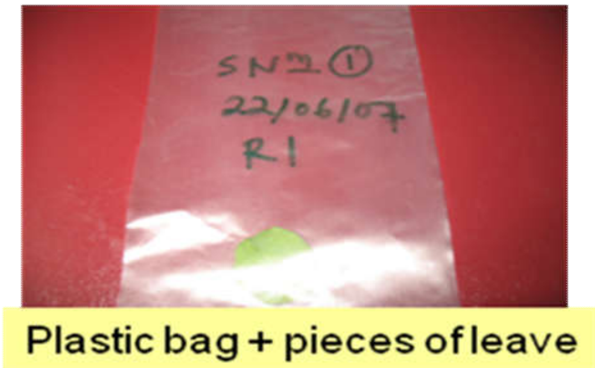

Plate 11. Plastic bag with the balance of food

Data recorded

Growth measurement

Four parameters for growth performance were recorded. They were the number of survive larvae, moulting period, pupae size (weight, length and width), and adult emerged (time and length of life).

Mortality

Mortality of insect was recorded daily.

Fecundity

The emerged adults were sexed and paired for mating and subsequently for ovipositor. The paired moths (1 male: 1 female) were placed inside the ovipositor cage (1½ inch. x 2½ inch.) initially lined with white paper. A cotton ball soaked in 10% of honey solution was supplied as moth food. The white paper was changed daily and the numbers of eggs were counted.

Experimental set-up

The eggs of rearing insect, immediately after hatching, the young larvae or first instars larvae of beet armyworm were put into round plastic cage (1½ inch. x 1 inch.) in size, for the first until third instars, and change the cage size like ovipositor cage size at the fourth instars until pre-pupation stage. The larvae were placed individually with the fix-sized of leaves of host plants inside the container, the fresh leaves were changed daily until pupation. Kept at 28±2ºC and (L: D) light regime. (Plate 12)

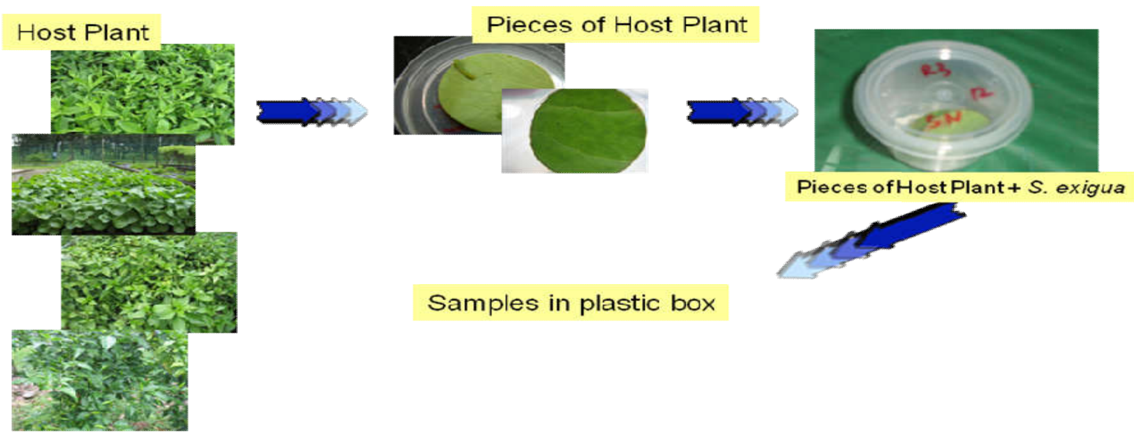

Plate 12. Set-up larvae in cage

Experimental Design

In this study, the first instars of beet armyworm and fix size of host plants leaves about 2½ cm diameters in size were used. Four treatments of each replicate were conducted in this experiment where the different host plants (*G. procumbens, C. asiatica, O. stamineus* and *C. frutescens*) were used as treatments. Each treatment was repeated four times. Thus, this experiment had four replicates and each replicate had four treatments, then each treatment had 30 samples of larvae that were placed individually in a container with the leaves of host plants.

Statistical Analysis

The data on larval consumption rate and developmental time of *S. exigua* were evaluated using one-way analysis of variance (ANOVA). Means associated with host plant for each variable were separated using the Tukey honestly significant difference (HSD) test when significant *F* values were obtained. It was calculated using Statistical Packages for Social Science (SPSS for windows version 12.0). For each type of host plant, simple linear regression analysis was used to examine the relationship between the amount of diet consumed and pupal weight, as well as the relationship between female pupal weight and progeny fecundity.

RESULT AND DISCUSSION

Feeding test

The larvae of *S. exigua* could not survive when fed on *O. stamineus*. The consumption rate of food was highest on *G. procumbens* and lowest on *O. stamineus* (Figure 1). However, when the insect fed on *C. asiatica* and *C. frutescens* were not significant different in the amount of feeding. There was a different in the daily consumption of food by larvae in the different host plants. The daily consumption was high on *G. procumbens*, followed by *C. frutescens,* and *C.* asiatica. Lowers consumption was on *O. stamineus* (Figure 2).

Development time

The development time of *S. exigua* larvae fed on the different host plants is shown in the Table 2, Figures 3, 4, and 5.

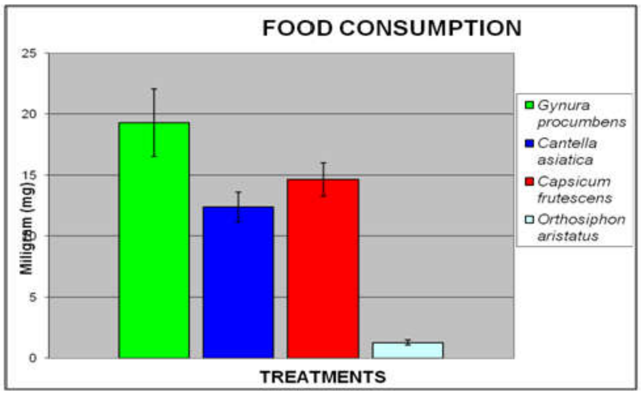

Figure 1. Consumption of food by larvae of *S. exigua* on the different host plants

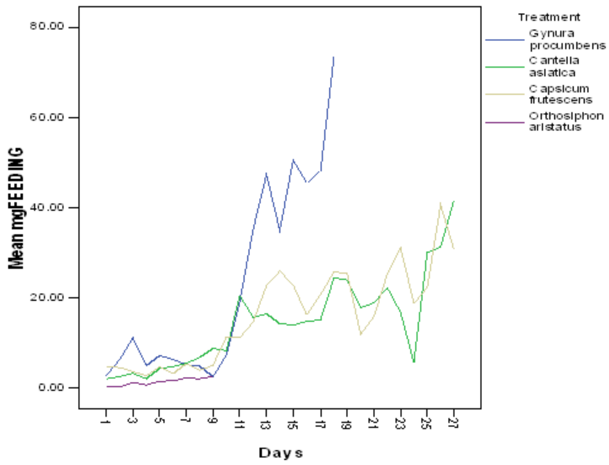

Figure 2. Consumption rate of larvae *S. exigua* fed on the different host plants

There was no significant different in development time when fed on the *C. frutescens* and *C. asiatica*. The larval period before pupation was faster period than the other when fed on *G. procumbens*. That was followed by *C. frutescens* and *C. asiatica*. The larva fed on *O. stamineus* actually could not survive which lived only 3.45 days. The moulting period is shown in Figure 3 and Table 2.

Table 2. Developmental time of larva, pupa and adult of *S. exigua*

Host Plant	Mean of Larval Period (days)	Larval Stadia							Mean of Pupal Period (days)	Mean of Adult Longevity (days)
		1	2	3	4	5	6	7		
Gynura procumbens	9.11	5.23	2.86	2.76	3.47	3.35	3.89	2.67	6.04	4.32
Cantella asiatica	15.03	4.32	2.56	2.69	2.98	3.77	4.53	5.03	5.87	4.53
Capsicum frutescens	10.83	3.69	3.26	3.21	4.01	3.65	3.88	5.44	5.40	3.15
Orthosiphon stamineus	3.45	2.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

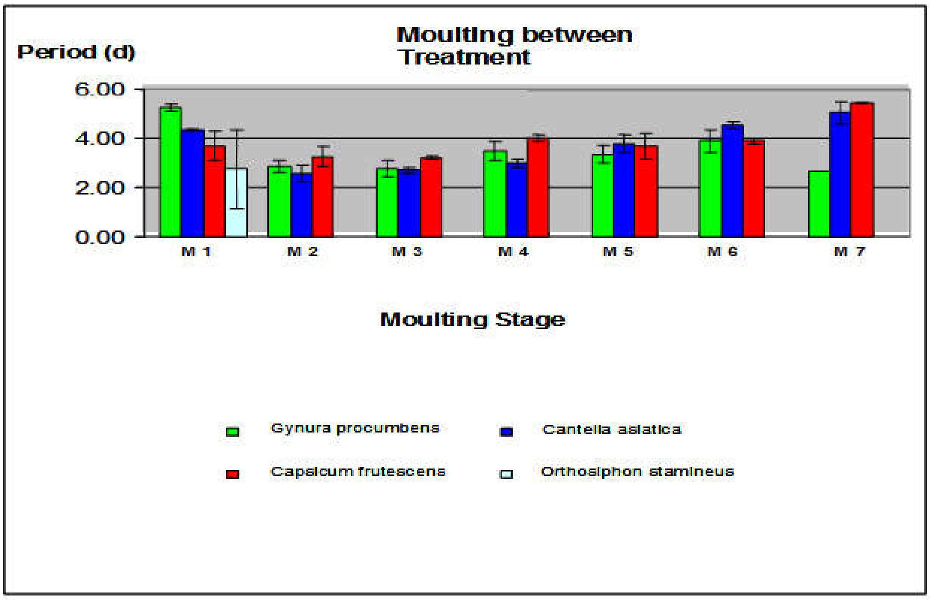

Figure 3. Mean period of moulting in the different stage and host plants

Overall, all larvae that fed on the different species of plants went through seven stages of moulting process was found when they are feeding at the three host plant, namely *G. procumbens, C. asiatica* and *C. frutescens.* The longest period taken on pupa development and adult longevity were on *G. procumbens* and the lowest at *C. frutescens*. They took only 5.4 days and 6.04 days on *G. procumbens* respectively. Then adult lived for 3.15 days on *C. frutescens* and 4.32 days on *G. procumbens*. (See Table 3) During molting process, consumption rate of the larvae *S. exigua* decreased. After the moulting process, the body size of the larva increased (Plate 13).

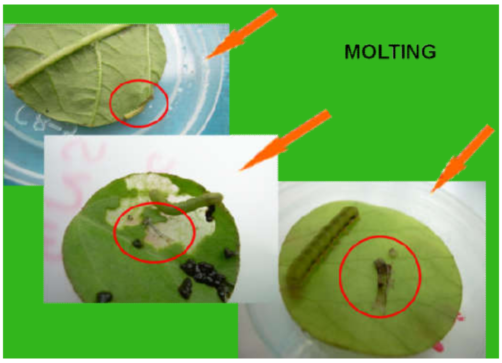

Plate 13. Molting process

Duration pupation of *S. exigua* that had been reared on different host plants is shown at the Figure 4. The longest period was on *G. procumbens* and lowest on *C. frutescens.*

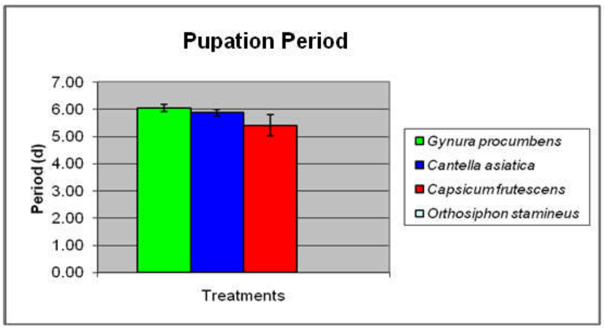

Figure 4. Comparison of pupal period on the different host plants

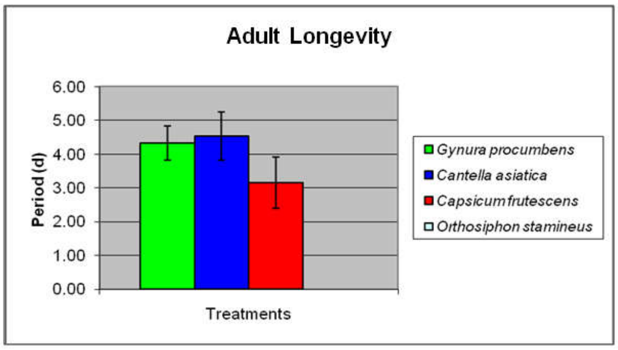

Figure 5. Comparison of adult longevity time on the different host plants

Figure 5 shows the longevity of adults stage when the larval were fed on different host plants. The adult longevity on *C.*

asiatica was took highest period time then followed by *G. procumbens* and *C. frutescens*.

Survival

The percentages of larval survival fed on *C. asiatica* were 24% followed by *C. frutescens* 13.5% and *G. procumbens* 13%. The lowest larval survival was recorded from larval fed on *O. stamineus* about 3.5%. (Figure 6)

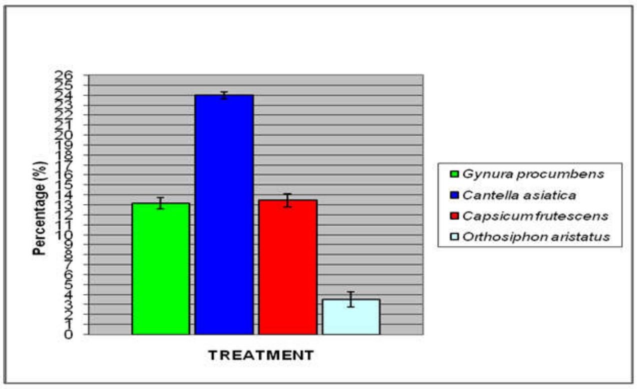

Figure 6. Survival percentage of larvae on the different host plants

The survival rate of larvae when fed on the different host plants is shown in Figure 7. The highest mortality of larvae was on *O. stamineus* and the lowest of mortality was larvae fed on the *C. asiatica* plant.

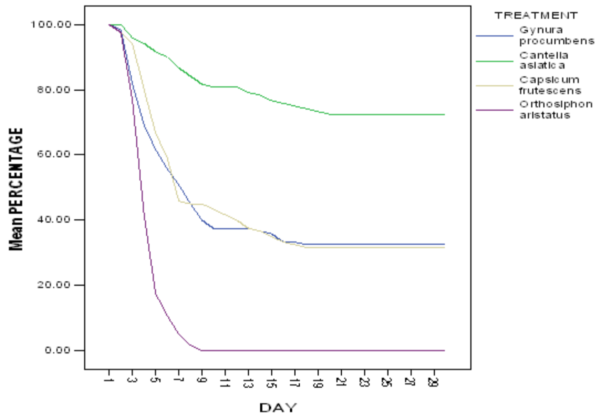

Figure 7. Survival percentage of larvae *S. exigua* on the different host plants

Growth measurement

There was no significant different in the weight, length and width of pupa, when there are fed on the three different host plants. Table 3 shows the differences of pupa size and weight.

Table 3. Mean of pupa (±SE) weight, length and width between different host plants.

Host Plants	Pupa		
	Weight (mg)	Length (mm)	Width (mm)
Gynura procumbens	68.93 ± 1.47	10.24 ± 0.13	3.23 ± 0.07
Cantella asiatica	68.89 ± 1.64	10.36 ± 0.12	3.29 ± 0.05
Capsicum frutescens	67.59 ± 1.98	10.20 ± 0.41	3.13 ± 0.05

Even thought the weight of pupa were not significantly different, but when the larva fed on the *G. procumbens* had a higher pupal weight, than pupal weight of larvae fed on other host plants (Figure 8).

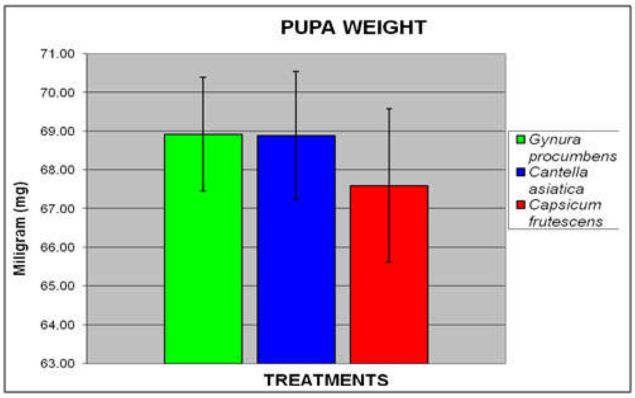

Figure 8. Comparison of the mean of pupal weight

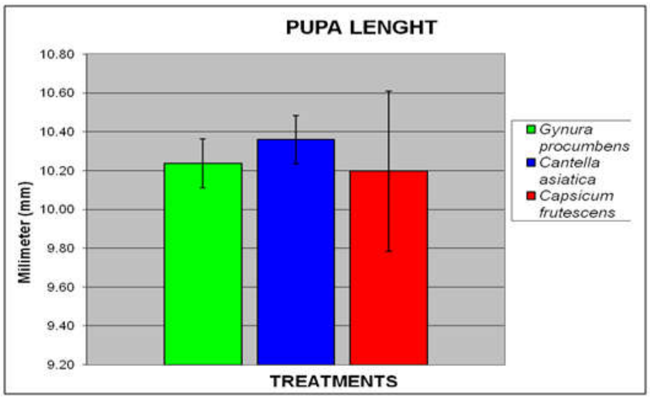

Figure 9. Comparison of the mean of pupal length

Figures 9 and 10, show about the different length and width of pupae by the host plants. Pupa longest length and width found when their fed on *C. asiatica* and shortest when fed on *C. frutescens.* The measurement was using millimeter (mm).

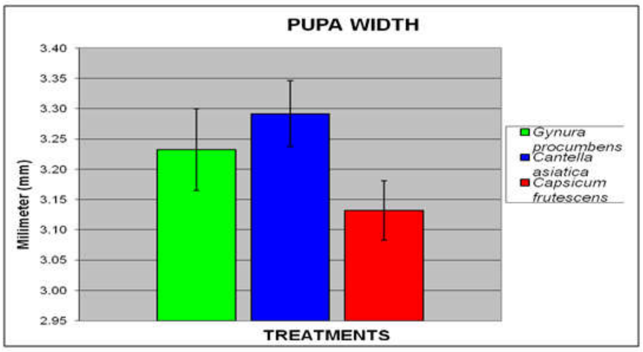

Figure 10. Comparison of the mean of pupa width

Plate 14 shows the pupa stage from the early pupa stage to mature pupa stage before they emerged to adult stage. At the early stage, the pupa was green with brownish in colour. Then they turned to brown and then to black brownish before emerge to adult.

Plate 14. Stage of pupa from the early emerged to matured

There was an example the adult stage when fed on the *G. procumbens*. Showed the back and front side of adult (Plate 15).

Plate 15: Adult of *S. Exigua*

Plate 16. Mating process of *S. exigua* adult

After the pupa emerged to adult, the male adult and female adult were placed in the same cage for mating and oviposition occurred in 3 – 5 days or until the female adult died (Plate 16).

Fecundity

The number of eggs laid by female at the different host plant is shown in Figure 11. The highest numbers were 479.5 eggs per female when fed on *G. procumbens*, only 398.5 eggs per female on *C. asitica* and the lowest number of eggs laid was on *C. frutescens*, 369.5 per female.

Table 4. Mean of eggs lay per female

TREATMENTS	N	Subset for alpha = .05	
		1	2
Capsicum frutescens	4	369.50	
Cantella asiatica	4	398.50	
Gynura procumbens	4		479.50
Sig.		.574	1.000

Figure 11 and table 4 was show the fecundity per female of the *S. exigua* adult. Ranges of the eggs lay are around 350 to 500 per female assume all the treatments.

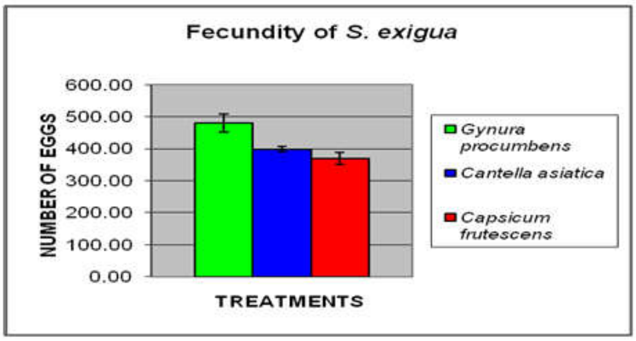

Figure 11. Number of eggs lay per female on different host plant

General development *S. exigua* larva

The an example general development of *S. exigua* larvae on *G. procumbens*, that is one of the using host plants, from the eggs form to the adult stage were show on plate 17. *S. exigua* eggs form, the hatched eggs (first, third and fifth instars of larva), pre-pupation, pupa form and the adult stage also shows on plate 17.

Plate 17. An example of general development of beet armyworm, *S. Exigua*

In this study, *S. exigua* larvae feeding on Sambung nyawa (*Gynura procumbens*), Pegaga daun besar (*Cantella asiatica*), Misai kucing (*Orthosiphon stamineus*) and Cili api (*Capsicum frutescens*) all exhibited similar patterns of consumption. Consumption rates (measured as milligrams) increased to a peak less than halfway through the larval stage, then declined before pupation. Larvae feeding on *G. procumbens* sustained high consumption rates until pupation, resulting the higher total consumption per larva. Total larval consumption of *C. asiatica* was lowest among all treatments. Within each feeding treatment, weight of leaf consumed was positively related to pupal weight. The larvae fed on *C. frutescens* showed the higher mortality compared to larval fed on *G. procumbens* and *C. asitica*. According to Azidah and Sofian (2006) larvae did not develop beyond the first instar when fed on chilli. *Gynura procumbens* was found to be the most suitable host plant and provided the best food quality for *S. exigua* compared to the other host plants. The number of larva survived was higher in

the *C. asitica* compared to the other treatments even though the consumption food rate and development time was higher on *G. procumbens*. The phenomena could be caused by such factors as physical and chemical properties on the host plants. The different in insect acceptance to the host plant may be due to the physical characteristics of host plant leaves. Several differences among the foliage of herbs, shrubs and tree could be attributed to the relationship which affect their suitability of food for Lepidoptera larva (Fenny, 1970). The degree of maturity of host plant leaves may influence the sensitivity of first instar larvae, *L. dispar* (Fenny, 1970). Generally, the mature leaves of the plants are tougher and higher in fiber content and lower in water and nitrogen content compared with most herbaceous leaves. The nutrient quality of non-preference host could influence the differences of growth and development of insects (Bhalani, 1989). Growth and development of Lepidoptera larva may often be limited by availability of water and nitrogen in their food (Fenny, 1970). Generally, to continue their development, a larvae needs to consume the food. As a result, the food intake allowed the larva to continue living even though they may differences in the quality of the food source.
The number of pupa formed and percentage of survival were higher when larva fed on *C. asiatica* than those fed on the other host plants.

The differences might be due to adaptation difference when they were introducing to a new host plant. Pupa of the larvae fed on *G. procumbens* was heavier weight compared the other host plants. However the differences were not significant. The different of the weight of pupae could be attributed to the nutritive quality between different host plants. Such differences in fecundity which was affected by nutritional quality of the host plant had been observed in Spear-Marked Black Moth, *Rheumaptera hastate* (Lepidoptera: Noctuidae) (House, 1966). The resultant impact of the nutritive value of the plant, could be reflected the larval development rate, pupa weight, female fecundity, survivorship and behaviors of the insects (Capinera and Barbosa, 1976, 1977; Barbosa, 1978; Hough and Pimental, 1978; Barbosa and Greenblatt, 1979; Lance and Barbosa, 1981; Barbosa *et al*., 1983). These phenomena have been shown in laboratory and in the field tests (Barbosa *et al*., 1979; Lechowicz, 1983; Lechowicz and Jobin, 1983; maufette *et al*., 1983). The higher mortality and not survive of the larvae where fed on Misai Kucing might be also have a relationship between the chemical content of the plant.

Conclusion

The defoliage insect larval of beet armyworm, *S. exigua* has a highest potential being pest to *G. procumbens* (Sambung nyawa), *C. frutescens* and *C. asiatica* (Pegaga daun besar) compare *O. stamineus* (Misai kucing). Their rapid development on these three host plant indicate that beet armyworm is very well adapted to monoculture plantation of these plant if it's going to commercial use, especially on *G. procumbens.* Whereas, the development and suitability of beet armyworm larvae on *C. frutescens* (Cili api) was higher attacked by beet army worm was already recorded compare than the other host plants. But from this study, suitability more higher than others when fed on *G. procumbens.* The growth and development of beet armyworm larvae were affected by host plant leaves given. Based on four times experiments, the suitability of four host plants could be arranged in the following order;

G. procumbens > *C. frutescens* > *C. asiatica* > *O. stamineus*

Based on the results obtained, it is hereby recommended that the following studies be undertaken to controlling this beet armyworm like biological control, obstruct there to attack the several of plants especially medicinal plants that are become wide range to plant for commercial use.

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