GROWTH AND LONGEVITY OF THE INSECT PREDATOR, *Sycanus dichotomus* STAL. (Hemiptera: Reduviidae) FED ON LIVE INSECT LARVAE

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ABSTRACT

The suitability of Tenebrio molitor *Linn. (Coleoptera: Tenebrionidae) and* Corcyra cephalonica *Stainton (Lepidoptera: Pyralidae) larvae as food sources for the general insect predator,* Sycanus dichotomus *Stal. (Hemiptera: Reduviidae) was evaluated by examining the effects of different prey consumption on the predator's growth parameters and longevity. The growth parameters assessed in this study were developmental period, body weight and femur length. Compared to single prey species, a combination of prey consisting of* C. cephalonica *and* T. molitor *larvae generally increased the growth and development of nymphal and adult stages of* S. dichotomus. *Different food sources showed different degrees of suitability:* C. cephalonica *significantly (P<0.01) shortened the developmental period of nymphal and adult stages compared to* T. molitor *larvae and combination of both larvae by 17.5% and 6.9%, respectively. Moreover,* C. cephalonica *larvae alone represent a more suitable food source for 1ˢᵗ and 2ⁿᵈ nymph instars development, compared to late nymphs and adults. However, the combination of both larvae had the shortest nymph's developmental period (95 days), higher body weight and longer femur length, plus improved the adults' longevity (69 days). The ratio of male adults was higher in the treatment which fed on* T. molitor *larvae and combination of both larvae, in contrast to the* C. cephalonica *larvae treatment. It is suggested that future works should examine the nutritional quality of the prey species to support these findings.*

INTRODUCTION

Oil palm is an important commodity crop in Malaysia, which covers 5.39 milion hectares of plantation areas in Malaysia, in 2014 (MPOB, 2015). When there is a breakdown in natural control, pest numbers increase, leading to outbreak. Bagworms (*Metisa plana* and *Pteroma pendula*) and nettle caterpillars (*Darna* spp. and *Setora nitens*) are major insect pests of oil palm. These two bagworms species frequently damage the oil palm leaves, leading to serious crop losses (Basri, 1993). Biological control methods are favoured to suppress the bagworms and nettle caterpillars population, including beneficial plants for sustaining the parasitoids and predators, pheromone trapping (Norman *et al.*, 2010) and application of biological insecticides (Siti Ramlah *et al.*, 2011).

The majority of the assassin bugs (Reduviidae) are general insect predators with a wide variety of prey (Chandra *et al.*, 2014). Several studies have shown that reduviid predators such as *Sycanus*

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sichuanensis Hsiao (Liu *et al.*, 2012), *Rhynocoris marginatus* Fab. (Shahayaraj and Sathiamoorthi, 2002) and *Phonoctonus* spp. (Schaefer and Ahmad, 1987) are suitable as biological control agents for the nymphal and larval stages of insect pests. To date, the bionomics and use of Sycanus species for biological control have been reported such as *S. croceovittatus* for *Dendrolimus punctatus*, *Latoia lepida*, *Scopelodes contracta*, *Artona funeralis* and *Selepa celtis* (Kershaw, 1909; Hoffmann, 1934; Huang *et al.*, 1991), *S. indigator* for *Galleria mellonella* and *Spodoptera frugiperda* (Bass and Shepard, 1974; Greene and Shepard, 1974), *S. affinis* for lepidopteran larvae in coconut groves (Satpathy *et al.*, 1975), *S. reclinatus* for *Heliothis armigera*, *Earias insulana*, *E. vitelli*, *Spodoptera litura* and *Dysdercus cingulatus* (Vennison and Ambrose, 1992), *S. versicolor* for *H. armigera* and *E. insulana* (Kumaraswami and Ambrose, 1992), *S. macracanthus* for *Mahasena corbetti* and *Setothosea asigna* (Tiong, 1996) and *S. aurantiacus* for *Plutella xylostella* and *Crocidolomia pavonana* (Ishikawa *et al.*, 2007; Yuliadhi *et al.*, 2015).

Sycanus dichotomus Stal. (Hemiptera: Reduviidae) is a general predator that attacks bagworms and nettle caterpillars in oil palm plantations in Malaysia. Reported as one of the important predator for bagworms (De Chenon *et al.*, 1989), they are commonly found at the ground level in oil palm plantations (Norman *et al.*, 1998). The food sources may be a limiting factor for the effectiveness of predation by *S. dichotomus* as a biological control agent. Thus, evaluation on the alternative prey species is essential to measure the quality of the available food. The quality food may influence the growth and development of the predator and can be useful in future mass rearing. Previous studies showed that *S. dichotomus* can successfully develop and reproduce on a wide range of alternative prey larvae such as *Plutella xylostella* (Lepidoptera: Plutellidae), *Corcyra cephalonica* (Lepidoptera: Pyralidae) (Zulkefli *et al.*, 2004) and *Tenebrio molitor* (Coleoptera: Tenebrionidae) (Syari *et al.*, 2011; Yusof and Fairuz, 2011).

According to Symondson *et al.* (2002), generalist predators are polyphagous and can maintain their population on a wide range of alternative prey when any single pest species is absent. In agricultural systems, alternative prey may improve generalist predators' survival when target pests are occasional (Ehler and Miller, 1978; Eubanks and Denno, 2000). Fecundity can be increased and speed the development by providing additional nutrition (Halaj and Wise, 2002; Rana *et al.*, 2002). Thus, alternative prey should be beneficial from the predator's perspective. Similarly, McMurtry (1992) revealed that the generalist phytoseiids (Mesostigmata: Phytoseiidae) are frequently observed for long periods on plants in the absence of prey and feed on alternative food.

Therefore, studying the potential alternative prey species for *S. dichotomus* is an important step in understanding the potential of the prey for future predator mass production in laboratory. The present study was undertaken to evaluate the effect of two alternative prey species and their combination as food sources on the developmental period, body weight and femur length of *S. dichotomus*. The preferred food sources could also be suggested by evaluating the growth parameter of *S. dichotomus*. In this study, the live larvae of *C. cephalonica* and *T. molitor* were chosen as food sources for *S. dichotomus* because they are commonly available in market, easy to rear and require simple maintenance in the laboratory.

MATERIALS AND METHODS

The study was conducted in the Entomology and Ecological Research Laboratory, Malaysian Palm Oil Board, Bandar Baru Bangi, Selangor, Malaysia. All insects rearing and experiments were conducted in an environment controlled room at day temperature of 27 ± 1°C, night temperature of 24 ± 1°C, with a photoperiod of 12:12 (L:D) hr and 50%-70% RH, monitored by a hygrothermograph (Dickson brand) (Siti Nurulhidayah *et al.*, 2011).

Insects Rearing

Sycanus dichotomus. The predator, *S. dichotomus* adults were collected from various oil palm plantations in Teluk Intan, Perak, Malaysia and were maintained in the laboratory. The adults were paired and caged in a transparent cylinder container (measuring 12.5 cm diameter × 23.5 cm height) with a ventilated lid. Small ferns and oil palm leaflets were provided in the rearing container to simulate their concealed microhabitat and for egg laying. Oil palm leaflets were cut and placed through a hole in the transparent plastic lid of a glass vial containing water. The adults were fed daily with the mealworm, *T. molitor* larvae as food source and provided with 10% honey solution in a wet cotton ball. These cylinder containers were examined daily for occurrence of oviposition and eggs collection. The new eggs laid were then transferred to a petri dish until they hatched. The newly hatched nymphal stages were used for this study.

Tenebrio molitor. The mealworm, *T. molitor* was reared on sliced bread and oat bran in a plastic rearing container (measuring 20 × 10 × 12 cm) while the adults were reared on oat bran and sliced fresh potato. The live larvae of *T. molitor* were used as food source for *S. dichotomus*.

Corcyra cephalonica. The rice moth, *C. cephalonica* was obtained from Universiti Putra Malaysia,

Serdang, Selangor, Malaysia. A colony of *C. cephalonica* was reared on corn and rice in a plastic rearing container (measuring 25 × 35 × 12 cm). Both cereals were ground separately. The ratio of corn to rice used was 1:2 and was autoclaved in 121°C for 20 min. Similarly, the live larvae of *C. cephalonica* was used as food source for *S. dichotomus*.

Live Insect Larvae Suitability for *S. dichotomus*

The influence of *T. molitor* larvae, *C. cephalonica* larvae and combination of both larvae on the individual growth of *S. dichotomus* was evaluated separately under the same rearing conditions. The suitability of live insect larvae as food sources for *S. dichotomus* was evaluated by measuring *S. dichotomus* developmental period, body weight and femur length for all stages after moulting to the next stage.

Developmental Period, Body Weight and Femur Length of *S. dichotomus*

Pre-imaginal developmental period was estimated by observing the *S. dichotomus* individuals on daily basis, from egg to emergence of the adult. The newly hatched nymphs were transferred from the petri dish with a soft brush and placed individually in a small plastic cup (measuring 6 cm diameter × 4.5 cm height). The nymphs were assigned to either *T. molitor* larvae, *C. cephalonica* larvae or combination of both larvae. A 10% honey solution was also provided for each cage. After moulting to the 3rd instar, the nymphs were transferred to a larger individual transparent cylinder cage (measuring 12.5 cm diameter × 23.5 cm height) with a ventilated lid. The live insect larvae consumed were replaced at two-day intervals. Mortality were also recorded at two-day intervals.

The period between moulting was used as a basis to calculate the developmental period for each nymphal instar of *S. dichotomus*. The life span of the *S. dichotomus* adult was determined from its emergence until it died. Its body weight and femur length was measured after each moult. The femur length measured was the hind femur, the thick and most muscular segment of the insect leg, situated between the trochanter and the tibia. The newly moulted nymphs were weighed individually using a Sartorius ED 224S analytical balance with a precision of 10^{-5} g. The same procedure was repeated until the *S. dichotomus* reached the adult stage.

Longevity and Gender Ratio of *S. dichotomus*

S. dichotomus adult individuals were placed in individual transparent cylinder cage (measuring 12.5 cm diameter × 23.5 cm height) with a ventilated lid to evaluate their longevity. The gender of *S. dichotomus* can only be determined after the 5th nymphal stage moulted to the adult stage. Individual adults were assigned to either *T. molitor* larvae, *C. cephalonica* larvae or combination of both larvae. A 10% honey solution was also provided for each cage. The adult weight at emergence was measured individually using a Sartorius ED 224S analytical balance. The main difference between the males and females of *S. dichotomus* is the abdomen shape. According to Syari *et al*. (2011), the female's abdomen is V-shaped while the male, U-shaped. The female size is also generally bigger and the abdomen is wider compared to the male. The sex ratio was recorded for adults which emerged on all treatments. Each adult was observed at two-day intervals to record its longevity.

Statistical Analysis

Experiments were replicated three times with 20 individuals in each treatment for each replication. Samples were first described as means and standard errors. Analyses of variance (ANOVA) were conducted on all data except gender ratio using SAS software (SAS 9.1 for Windows, 2003). Where statistical differences existed between the data sets (P < 0.05), Fisher's Least Significant Difference (LSD) tests were used to separate the differing means.

RESULTS AND DISCUSSION

The developmental period, body weight and femur length for each life stages of *S. dichotomus* fed on the three categories of food sources were examined and varied in suitability to the food sources. In this study, three food categories given had relatively supported the growth and development of *S. dichotomus* but differ in terms of its developmental period, body weight and femur length. The total nymphal stage duration (95 days) for *S. dichotomus* fed on combination of both larvae was significantly shorter (P < 0.01) compared to *T. molitor* (115 days) and *C. cephalonica* (98 days) larvae alone, by 21.3% and 2.8%, respectively (*Table 1*). The mean life span of *S. dichotomus* fed on *C. cephalonica* larvae was significantly shorter (P < 0.05) at 154 days, whereas *S. dichotomus* fed on *T. molitor* and combination of both larvae were significantly longer at 181 days and 164 days, respectively. *Tenebrio molitor* larvae ranked second due to longest duration during 5th nymphal stage, resulted in an overall slower rate of predator's developmental period which caused an extended life span (*Table 1*).

After the 3rd nymphal stage, the growth and development of *S. dichotomus* fed on *C. cephalonica* larvae had relatively decreased compared to other food sources, with exception of 5th nymphal stage, in terms of body weight and femur length. However,

TABLE 1. DEVELOPMENTAL PERIOD IN DAYS (mean ± S.E.) OF *S. dichotomus* FED ON *T. molitor* LARVAE,
C. cephalonica LARVAE AND COMBINATION OF BOTH LARVAE

Stage	Food sources						ANOVA
	Tenebrio molitor larvae	LLV ULV	*Corcyra cephalonica* larvae	LLV ULV	Combination (*T. molitor* and *C. cephalonica* larvae)	LLV ULV	
1st nymph	19 ± 0.62a	12.5 24.5	15.2 ± 0.44b	11 19	18 ± 0.47a	11.5 23.5	**
2nd nymph	17.8 ± 1.04a	7.5 27.5	13.9 ± 0.50b	6.5 22.5	15.2 ± 0.39b	11 19	**
3rd nymph	20.7 ± 0.45a	14.5 26.5	18.2 ± 0.8b	7.5 27.5	16.6 ± 0.88b	10.5 22.5	**
4th nymph	25.4 ± 0.72a	15.5 35.5	21.3 ± 0.45b	15.5 27.5	20.6 ± 0.85b	6.75 32.75	**
5th nymph	32.2 ± 0.77a	21.25 43.25	29 ± 0.6b	25 33	24.5 ± 0.81c	14.5 34.5	**
Adult	65.5 ± 2.38a	40.5 92.5	56.1 ± 1.8b	37.5 73.5	69.4 ± 2.41a	51.5 87.5	**
Total	180.6 ± 8.31a	113 249	153.7 ± 2.31b	144 160	164.3 ± 6.83ab	102.5 234.5	*

Note:
LLV - lower limit value.
ULV - upper limit value.
n.s. - not significant.
**Significant at P < 0.01.
* Significant at P < 0.05.
Different letters within a row indicate significant differences.
ANOVA - analysis of variance.

C. cephalonica represents a preferred diet for the 1st and 2nd nymphal stages based on the shorter nymphs' duration and higher body weight, but was not a suitable food source for the 3rd nymphal stage to adults (*Table 2*). It was observed that the early nymphal stages can easily consume *C. cephalonica* because the outer skin of larvae are silky soft and easy to be penetrated by the younger predator compared to *T. molitor* larvae.

It was observed that the longest duration in survival within the life span was the adult stage. Regarding the adult longevity, there were significant differences between the food sources: adult life span was significantly longer when fed with the combination of both larvae as the food source (69.4 days) and shorter when fed with either *T. molitor* or *C. cephalonica* larvae alone (66 and 56 days, respectively) (*Table 1*). The longer adults' life span will possibly enhance the predation ability of the predator at its adult stage. Several studies have shown that food quality affects the developmental period and survival of several predators (Isıkber and Copland, 2002; Kalushkov, 1998; Kalushkov and Hodek, 2004), as well as affecting the reproductive performance of the adults. In contrast, according to Vivan *et al*. (2003), the prolonged developmental period has been observed is an undesirable characteristic under field conditions, causing a lower number of generations per year, lower predator population growth, and hence reduced biocontrol efficiency.

Sycanus dichotomus fed with the combination of both insect larvae grew bigger in their body, shown in their weight (*Table 2*) and femur length (*Table 3*), with adults lived considerably longer and healthier. The adults reared with the combination of both larvae, tended to have higher weights than those reared on the *C. cephalonica* and *T. molitor* larvae alone, by 18.4% and 7.7%, respectively. An earlier study by ElHag and Zaitoon (1996) have also observed higher survival rates of *Coccinella undecimpunctata* (61.5%) when they used a mixed diet of two aphids, *Brevicoryne brassicae* L. and *Rhopalosipum padi* L. (Homoptera: Aphididae). With exception of the 1st and 2nd nymphal stages, the body weight of *S. dichotomus* that fed with combination of both larvae were significantly higher than those fed with *T. molitor* and *C. cephalonica* larvae alone (*Table 2*). The higher weight of nymphs achieved by the 3rd, 4th and 5th nymph instars, when provided the combination of both larvae, reinforces the higher quality of this food category. According to Vivan *et al*. (2003) in their study, the 5th nymphal instar of stinkbug *Podisus nigrispinus* (Dallas) (Heteroptera: Pentatomidae) have emphasised development of the reproductive organs, and this higher quality food group may affect the adult weight of *S. dichotomus* (*Table 2*). However, the mean body weight had differed significantly among the three food sources for all life stages except for the 1st, 5th nymphal instars and adults.

Similarly, the mean femur length of the adult *S. dichotomus* fed with the combination of both larvae was significantly longer (11.2 mm) than those fed with *C. cephalonica* and *T. molitor* larvae alone (P < 0.01) by 4.7% and 13.1%, respectively (*Table 3*). This matched the significantly higher body weight gained by the combination of both larvae treatment for 3rd and 4th nymphal stages (*Table 2*). There was a significant difference among the three food sources in femur length parameter for all life stages except for the 1st, 2nd and 5th nymph instars.

The sex ratio among all treatments was also observed (*Figure 1*). The male sex ratio was higher (5.8:4.2 and 7:3) in treatment which was fed with *T. molitor* larvae and combination of both larvae, respectively, while the female sex ratio was higher (9:1) when they were fed with *C. cephalonica* larvae. Thus, in all treatments, the body weight and life duration for females were always higher and longer than males. Similar trend was also observed in an

earlier study conducted by Rana *et al*. (2002) on generalist ladybird beetle, *Adalia bipunctata reared* on *Acyrthosiphon pisum* and *Aphis fabae*.

Overall, the experiments revealed that the differing suitability for two types of live insect larvae as food sources for *S. dichotomus*. The assumption of the nutritional quality of different prey as food for generalist predators therefore contradicts with the results gathered. Similar results have been reported for other generalist predators such as *Coccinella undecimpunctata* (Coleoptera: Coccinellidae) and *Clitostethus arcuatus* (Rossi) (Coleoptera: Coccinellidae) (Cabral *et al.*, 2006; Yazdani and Zarabi, 2011). The nutritional value might differ among the prey species. According to O'Neil and Wiedenmann (1990) in their insect predator study, *Podisus maculiventris* maintains its weight and reproductive output only when it has abundant prey. Reproduction can also be maintained on a diet of small prey, indicating the capacity

TABLE 2. BODY WEIGHT IN GRAM (mean ± S.E.) OF *S. dichotomus* FED ON *T. molitor* LARVAE, *C. cephalonica* LARVAE AND COMBINATION OF BOTH LARVAE

Stage	Food sources			ANOVA
	Tenebrio molitor larvae	*Corcyra cephalonica* larvae	Combination (*T. molitor* and *C. cephalonica* larvae)	
1st nymph	0.0017 ± 0.0012a	0.0019 ± 0.0002a	0.0018 ± 0.0002a	n.s.
2nd nymph	0.0019 ± 0.0002b	0.0051 ± 0.0003a	0.0046 ± 0.0003a	**
3rd nymph	0.0278 ± 0.0012b	0.018 ± 0.0010c	0.0412 ± 0.0026a	**
4th nymph	0.0706 ± 0.0013b	0.0656 ± 0.0021b	0.1227 ± 0.0042a	**
5th nymph	0.1427 ± 0.0022a	0.1512 ± 0.0050a	0.1668 ± 0.0179a	n.s.
Adult	0.2047 ± 0.0057a	0.1862 ± 0.0192a	0.2204 ± 0.0115a	n.s.

Note:

n.s - not significant.

** Significant at P < 0.01.

* Significant at P < 0.05.

Different letters within a row indicate significant differences.

ANOVA – analysis of variance.

TABLE 3. FEMUR LENGTH IN MILLIMETER (mean ± S.E.) OF *S. dichotomus* FED ON *T. molitor* LARVAE, *C. cephalonica* LARVAE AND COMBINATION OF BOTH LARVAE

Stage	Food sources			ANOVA
	Tenebrio molitor larvae	*Corcyra cephalonica* larvae	Combination (*T. molitor* and *C. cephalonica* larvae)	
1st nymph	1.04 ± 0.04a	1.12 ± 0.04a	1.08 ± 0.04a	n.s.
2nd nymph	1.71 ± 0.06ab	1.6 ± 0.07b	1.74 ± 0.05a	n.s.
3rd nymph	4.25 ± 0.12b	3.7 ± 0.11c	5.12 ± 0.09a	**
4th nymph	6.91 ± 0.14a	5.95 ± 0.17b	6.64 ± 0.1a	**
5th nymph	9.55 ± 0.24ab	9.1 ± 0.2b	9.8 ± 0.13a	n.s.
Adult	10.7 ± 0.1b	9.9 ± 0.25c	11.2 ± 0.13a	**

Note:

n.s - not significant.

**Significant at P < 0.01.

*Significant at P < 0.05.

Different letters within a row indicate significant differences.
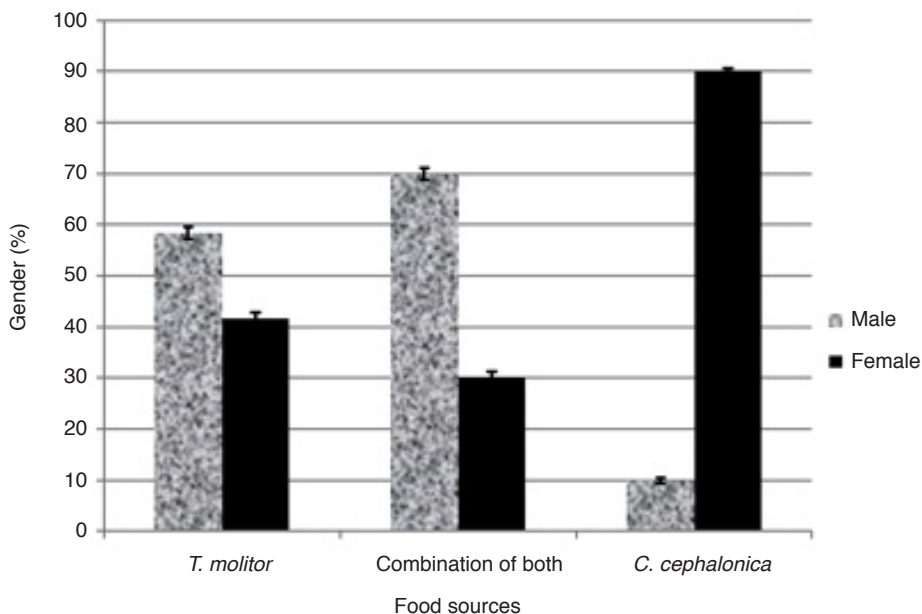
ANOVA – analysis of variance.

Figure 1. The gender percentage of Sycanus dichotomus *fed on different larvae treatments.*

for flexible foraging and proficient extraction of nutrients (Mills, 1982). The presence of low quality prey species may therefore counteract the benefits of mixed food sources for the predators. The performance, in terms of the parameters measured, was better when the predators were fed on combined prey than on single prey, especially during the nymphs' development.

It was also observed that the 1st and 2nd nymphal stages of *S. dichotomus* developmental period were much longer when fed with *T. molitor* larvae than other diets (*Table 2*), possibly due to the inability of young nymphs to penetrate the *T. molitor* larva's cuticle with their rostrum. In the combined diet treatment, we observed that the 1st and 2nd nymphal stages preferred to consume on *C. cephalonica* larvae rather than *T. molitor* larvae. In terms of developmental period and body weight, *S. dichotomus* fed with *C. cephalonica* were relatively shorter and higher. Thus, it can be concluded that *C. cephalonica* larvae were the preferred prey for early nymphal stages of *S. dichotomus*. The suitability of different prey types as food sources for the predators could be varied. Many predatory insects appear opportunistic in the field, feed on a wide range of prey species, but this behaviour may not clearly indicate prey suitability and predator nutritional requirements (Thompson, 1951; Thompson and Hagen, 1999). Predator diet specificity, feeding preferences and capacity for population increases are the factors that largely depend on prey suitability (Dixon, 2000).

Nevertheless, the developmental and reproductive performance of *S. dichotomus* fed on combination of both larvae need to be assessed over subsequent generations. This is because the nutritional imbalances within the diet are possibly expressed only in the subsequent generations (De Clercq *et al*., 2005), similarly suggested by Nguyen *et al*. (2013) in their predatory mite, *Amblyseius swirskii* study.

CONCLUSION

The study of developmental period, body weight, femur length of each life stage, as well as longevity and gender of adults with live larvae of *T. molitor, C. cephalonica* and their combination allows the evaluation of the suitability of the food sources. This finding indicates that *S. dichotomus* can enhance its growth and development if adapted to combination of both larvae compared to two other single prey species, especially during nymphal stages. Thus, combination of both larvae diet is more suitable to be used as one of food candidates in *S. dichotomus* mass rearing system. It was indicated that the alternative prey as food sources has shown potential to the mass production of this economically important biological control agent.

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