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Effect of diet switching on the larval growth of *Heteroneda billardieri* (Crotch) (Coleoptera: Coccinellidae), predator of mango leafhopper in The Philippines

[Kesan pertukaran diet ke atas tumbesaran larva *Heteroneda billardieri* (Crotch) (Coleoptera: Coccinellidae), pemangsa benah mangga di Filipina]

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Abstract
Heteroneda billardieri (Crotch) (Coleoptera: Coccinellidae) is a natural predator of the mango leafhopper (MLH), *Idioscopus clypealis* Lethierry (Hemiptera: Cicadellidae) in the Philippines. With regards to mass rearing and biological control efforts, the effects of diet switching between different prey species and artificial diet on the growth and development of *H. billardieri* larvae was studied. Cowpea aphid, *Aphis craccivora* Koch, *Leucaena* psyllid and *Heteropsylla cubana* Crawford were tested along with MLH and artificial diet. Based on results, switching diets of MLH and psyllid, MLH and artificial diet, and psyllid alone were less suitable for the larvae. However, larval development was faster when the larvae were fed just with either MLH or aphid alone. The most suitable diet was when the larvae were fed with MLH switched to aphid. The study proved that prey switching is an adaptation by *H. billardieri* and can enhance larval growth better than single diet alone. This might contribute positively to the outcome of mass rearing for biological control of MLH in the field.

Keywords: biological control, *Heteroneda billardieri*, predatory lady beetle, diet switching, larval growth

Introduction

Prey or diet switching is a common phenomenon in the insect world especially for generalist predators like the coccinellids. In their natural habitat, they may switch from one prey type to another as the latter becomes abundant or has a higher nutritive quality which increases the predator's preference. The phenomenon of diet switching is important as it may increase an individual's foraging efficiency and therefore its inclusive fitness (Cornell 1976). Diet switching is also necessary for survival whenever the main or natural prey or food type is scarce.

For mass rearing of coccinellids predators in the insectary, diet switching is an important aspect to be considered. Different types of food may have different suitability for the reared insect depending on its type either essential or alternative (Hodek and Honek 1996). Choice of prey or non-prey items is important as it will influence

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the insect's development. Weakening or negative effects have been observed in coccinellids resulting from changes in their diet from suitable to less suitable (Hodek 1973; Hagen 1987). If certain types of diets are not suitable (low nutritional quality), the predator may reject the diet or it may continue feeding but with detrimental effects. The effects include reduced rate of development and survival.

A study by Evans et al. (1999) gave an example of the benefits of diet switching. They found that the egg production of *Coccinella septempunctata* Linnaeus and *C. transversoguttata* Brown were enhanced when the diet was switched from one type of a less suitable food item alone to a combination of two which included one suitable food item. In addition, a mixed prey diet can result in high fecundity of females and increased predator survival (Phoofolo and Obrycki 1997). Munyaneza and Obrycki (1998) observed low survival of *Coleomegilla maculata* DeGeer when fed with eggs of the Colorado potato beetle, *Leptinotarsa decemlineata* Say. However, when the larvae were offered *Acyrthosiphon pisum* Harris and switched to *L. decemlineata* eggs, the rate of development was comparable with that of larvae fed on *A. pisum* only.

In Laguna, Philippines, a lemon-yellow netted lady beetle identified as *Heteroneda billardieri* (Crotch) was observed to become a potential predator of mango leafhopper (MLH), *Idioscopus clypealis* Lethierry (Hemiptera: Cicadellidae) (Adorada 2006). In mass production of *H. billardieri* as a biological control agent, one of the considerations is having more choice of diet or prey besides MLH, its natural prey in the field. To fulfil this demand, diet switching in the rearing laboratory should be considered. Switching between different diets or by mixing them together may have an important bearing on the outcome of mass rearing. Being a generalist, *H. billardieri* has a relatively broad prey or diet ranges. This broad range of variability in the diet will benefit greatly in selection and switching of food items so that the predator can be mass reared successfully.

For this study, two prey species and a mixture of artificial diets were used to test their suitability and their effect on *H. billardieri* larval growth and development in terms of diet switching efficacy. Cowpea aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae) and leucaena psyllid, *Heteropsylla cubana* Crawford (Hemiptera: Psyllidae) were used as alternative preys for rearing of *H. billardieri*. Basically, this study was meant to test the hypothesis that mixed diet given by switching between different diets would enhance larval growth better than single diets alone. It is hypothesised that this study would contribute to developing an effective way for mass rearing of *H. billardieri* thereby enhancing its potential as a successful biological control agent of MLH in the field.

Materials and methods

Place and duration of study

The study was conducted at the Insect Ecology Laboratory, Crop Protection Cluster, University of the Philippines Los Baños (UPLB), College, Laguna, from January until the end of May 2011.

Collection and rearing of study insects

Individuals of *H. billardieri* were collected as adults from mango trees (*Mangifera indica*) along the Institute of Plant Breeding Road, Los Baños, Laguna, and mango trees around UPLB campus. The adults were brought back to the laboratory and kept in rearing cages.

The field collected *H. billardieri* adults were maintained at 23 ± 1 °C with a photoperiod of 10:14 (Light:Day). They were fed with an overabundance or *ad libitum* of either *Leucaena* psyllids (*H. cubana*), MLH (*I. clypealis*), or cowpea aphids (*A. craccivora*). These prey species were collected from the field. *Leucaena* psyllids were collected from ipil-ipil trees (*Leucaena leucocephala*), MLH were collected from mango trees (*M. indica*) and cowpea aphids were collected from cowpea beans (*Vigna unguiculata*). Aside from insect prey, an artificial diet containing a mixture of infant formula (Brand S-26 Gold) and brown sugar also was provided to the field collected adults of *H. billardieri*. A 10ml-bottle of water with a cloth stopper was also provided as drinking source.

Cotton was placed inside the rearing cage (50 cm x 50 cm x 50 cm) as a substrate for the female adults to lay eggs. Laid eggs were separated in petri dishes to preclude egg cannibalism. The eggs were monitored daily for eclosion. Upon hatching, first instar F1 larvae from the same cohort were placed individually in a 250 ml container to avoid cannibalism and were used for the experiment.

Artificial diet

Infant formula (Brand S-26 Gold) manufactured by Wyeth Philippines Inc. was used as one of the diets given in this study. The infant formula was mixed with brown sugar (4:1). The diet mixture, placed in a small cap later was used as one of the treatments in the experiment.

Experimental set up

The experiment was conducted at 23 ± 1 °C with a photoperiod of 10:14 (L:D). Randomly selected larvae from the same egg cohort of different field collected females were separated individually into 250 ml plastic containers. Each was assigned to receive one of the following seven experimental diets as shown in *Table 1*.

All three prey species used for diets were collected from the field populations. They were provided in excess each day such that unconsumed food would still be present in the container on the following day.

For treatments A to D, the prey or diets were given sequentially. In treatments A, B, and C, MLH was replaced with aphids, psyllids and artificial diet respectively, after six days. As for treatment D, MLH was replaced with psyllids after four days and then psyllids were replaced by aphids after the subsequent four days. MLH was given first because this food item is the natural prey of the predator. Replacing different prey species at a certain period was meant to investigate how well the larvae could adapt to diet switching.

Table 1. Different experimental diets used to feed larvae

Treatment	Diet
A	MLH for 6 days and switched to aphids days onwards
B	MLH for 6 days and switched to psyllids days onwards
C	MLH for 6 days and switched to artificial diet onwards
D	MLH for 4 days, psyllids for 4 days, and switched to aphids days onwards
E	MLH only
F	Aphids only
G	Psyllids only

Twenty individuals were used for each treatment. Each larva was provided with water soaked cotton as source of drinking. The larvae were monitored daily for moulting as in the first experiment. Exuviae of molted larvae were removed after moulting. Duration for immature stages was recorded until adult emergence. Number of dead larvae, number of larvae successfully pupated, and number of larvae emerged as adults were also recorded.

Statistical analysis

The experiment used completely randomised design (CRD) with 20 replications. Data was analysed using the Statistical Analysis System version 9.1.3 (SAS Institute 2003) and Minitab version 16 (Minitab 16 Statistical Software 2010).

Paired T-test (PROC TTEST in SAS) was used to examine the influence of different diets on each immature stage duration, total larval duration, total pupal duration, total immature duration and pupal weight.

Analysis of variance (PROC GLM in SAS) was used to analyse larval survival and percentage of pupated larvae. In calculating percentages, data were transformed to Arc Sine prior to analysis. Significant means were compared and separated using LSD Test (α = 0.05).

Life test analyses were carried using PROC LIFETEST in SAS to compare total immature duration among treatments and equality among treatments was determined using Wilcoxon test. Survival probabilities were computed using Regression with life procedure in Minitab.

Results

Rate of development

Figure 1 shows the mean duration of each immature stage of *H. billardieri* fed with seven types of diet. Four of them were sequentially given mixed diets and the rest were single diets. Survival rates for every treatment in each immature stage were varied. For comparing the significant differences between treatments in the larval stage, Treatment C was set as control since the survival rate in every larval stage for the Treatment C was the lowest. For the pupal stage, Treatment B was set as control (*Table 2*).

Duration from the first larval instar to second instar was significantly longer in Treatment C (MLH/artificial diets) (10.5 days) compared to other treatments. Treatments B (MLH/psyllids), D (MLH/psyllids/aphids), F (aphids only) and G (psyllids only) showed no significant difference among them but all were significantly longer than Treatments A (MLH/aphids) and E (MLH only). Larvae fed with MLH only had the shortest first instar duration (2.68 days) and was significantly different compared to Treatment A (P = 0.0109).

As for the second larval instar, the larvae fed with diet on Treatment C took the longest time to moult into third instar followed by Treatment B but there was no significant difference between them (P = 0.0540). All other five treatments had significantly shorter duration compared to Treatments C and B.

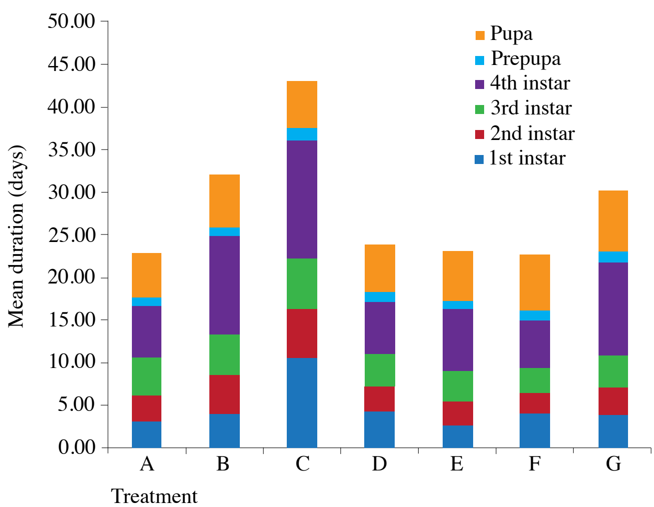

Figure 1. Development period of immature stages of H. billardieri fed with different diets given sequentially. Comparisons of each immature stage among treatments were done using T-Test (α = 5). A = MLH/Aphids, B = MLH/Psyllids, C = MLH/Artificial diet, D = MLH/Pysllids/Aphids, E = MLH only, F = Aphids only, G = Psyllids only

Table 2. Duration of immature stages of *H. billardieri* fed with different diets given sequentially (comparison within treatments)

Treatment (n = 20)	Duration (days) mean ± (SE)											
	n	1st Instar	n	2nd Instar	n	3rd Instar	n	4th Instar	n	Prepupa	n	Pupa
A – MLH/Aphids	19	3.16 ± 0.14^{c*}	19	3.05 ± 0.14^{b}	19	4.32 ± 0.19^{ab}	19	6.26 ± 0.27^{cd}	18	1.00 ± 0.00^{a}	18	5.11 ± 0.08^{c}
B – MLH/Psyllids	17	4.00 ± 0.17^{b}	14	4.50 ± 0.42^{a}	14	4.71 ± 0.22^{ab}	13	11.54 ± 0.71^{b}	8	1.38 ± 0.18^{a}	2	6.00 ± 0.00^{b}
C – MLH/Artificial diet	14	10.50 ± 0.52^{a}	12	5.83 ± 0.52^{a}	12	5.83 ± 0.83^{a}	9	13.89 ± 0.79^{a}	9	1.44 ± 0.24^{a}	9	5.56 ± 0.56^{bc}
D – MLH/Psyllids/Aphids	14	4.21 ± 0.42^{b}	13	3.00 ± 0.11^{b}	13	3.77 ± 0.47^{bc}	11	6.18 ± 0.44^{cd}	11	1.09 ± 0.09^{a}	9	5.67 ± 0.24^{b}
E – MLH only	19	2.68 ± 0.11^{d}	15	2.73 ± 0.12^{bc}	14	3.57 ± 0.25^{c}	14	7.21 ± 0.58^{c}	14	1.00 ± 0.00^{a}	13	5.92 ± 0.31^{b}
F – Aphids only	19	4.05 ± 0.09^{b}	19	2.47 ± 0.14^{c}	19	2.74 ± 0.10^{c}	19	5.63 ± 0.23^{d}	18	1.28 ± 0.11^{a}	17	6.59 ± 0.22^{a}
G – Psyllids only	18	3.83 ± 0.22^{b}	18	3.33 ±0.11^{b}	18	3.67 ± 0.24^{c}	12	11.00 ± 0.56^{b}	7	1.14 ± 0.14^{a}	4	7.25 ± 0.25^{a}

*Means with same letters in the same column are not significantly different at T–Test (α = 0.05). Equality of variances tests were done to determine which method was suitable to calculate the t value (Pooled method for equal variances or Satterthwaite method for unequal variances)

The rate of development for third instar larvae fed with aphids only (Treatment F) was the fastest (2.74 days) but had no significant difference compared to the other treatments with single diet and Treatment D. However, 19 individuals out of 20 still survived at this stage in Treatment F. Among the mixed diet treatments, there were no significant differences except between Treatments C and D (P = 0.0379).

Treatments A, D, and F did not differ significantly for the fourth larval instar duration but were significantly different compared to Treatments G, B, and C. Treatments G, B, and C recorded more than 10 days to enter prepupal stage. Larvae fed with diet of aphids only (Treatment F) had the shortest duration to prepupal stage (5.6 days).

There were no significant differences among all treatments for the prepupal duration. Although larvae in Treatment A had the fewest development days before adult eclosion, it was not significantly different compared to Treatment C (P = 0.4501). Even though these two treatments were similar, the survival rate in Treatment A was higher than Treatment C. The control treatment at this stage (Treatment B) was significantly different compared to Treatment A but similar to other mixed diets (Treatment C and D) and also the single diet of MLH only (Treatment E). Treatment G recorded the longest pupal duration and was significantly different compared with the control (P = 0.0154).

Larvae fed with aphids only (Treatment F) took the fewest days to complete its stage (15 days). The second shortest duration was in Treatment E (16 days) followed by Treatments D, A, G, B, and C (*Table 2*). Larval duration for Treatment F was not significantly different from Treatments E and D (T = 1.16; P = 2.658, T = 1.87; P = 0.0910) but significantly shorter than the rest of the diet regimes. Larvae with diets of MLH switched to aphids, MLH switched to psyllids, and psyllids only (Treatments A, B and G) showed no significant differences among them. Treatments D and E were highly significant compared with Treatments B and C but similar to Treatment A. Diet of MLH switched to artificial diet (Treatment C) prolonged the total duration of the larval stage and recorded the longest larval duration.

As for total pupal duration, larvae that fed sequentially given mixed diet of MLH and aphids had the shortest development but did not differ significantly from those of Treatments D, E, and C (*Table 2*). Treatment B showed a significant difference from Treatment A only (T = –5.24; p <0.0001).

As for overall immature duration, *Table 2* shows that larvae fed with diet in either Treatments A, E, F, or D had the fastest time of development. These four were significantly different compared with the others. Treatments G and B were similar, (T = 1.33; P = 0.2554) but significantly shorter than Treatment C.

Figure 2 shows the emergence rate of the immatures. Treatments A, E, F and D were among the best. With these diets, 100% of the surviving immatures became adult beetles within 22 – 23 days. The next best diets were Treatments G and B which required 6 to 10 days more. The survival rate was the lowest in Treatment C, which took the longest time for the larvae to develop (> 40 days). All treatments were significantly different according to Wilcoxon test (X^2 = 31.55; p <0.0001).

Survival to adulthood and to pupal stage

Figure 3 compares the rate of survival between single diets and sequentially given mixed diets. The survival rate basically went down during the second instar stage for all treatments except for Treatments A, F and G. For treatments A and F, 95% still survived until the fourth instar, but with Treatment G, only 60% survived at this stage and the rate kept on going down until pupal stage. Only four survived as adults for Treatment G and two in Treatment B as shown in *Table 3*. Treatment A recorded the highest number of survivors (18) followed by Treatments F and E (17 and 13 respectively). In contrast to Treatment A, Treatments C and D recorded only nine that

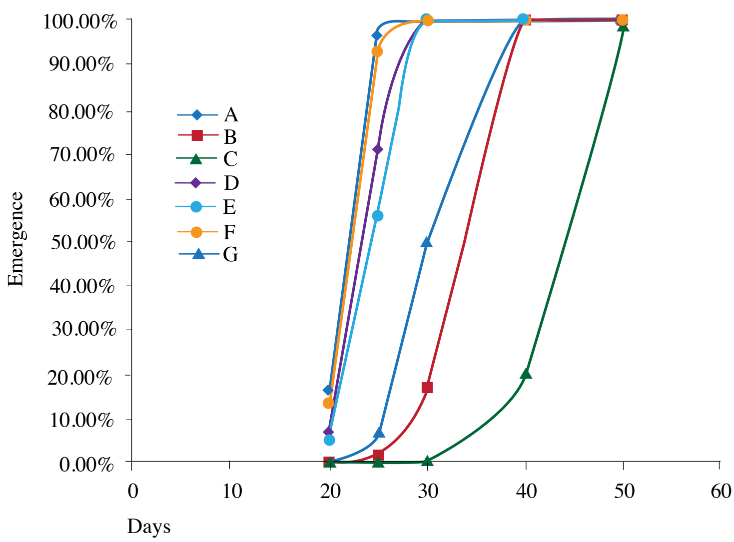

Figure 2. Rate of adult emergence of H. billardieri fed with different diets given sequentially. A = MLH/Aphids, B = MLH/Psyllids, C = MLH/ Artificial diets, D = MLH/Pysllids/Aphids, E = MLH only, F = Aphids only, G = Psyllids only. Graph was derived from the survival probabilities Regression with life procedure of Minitab

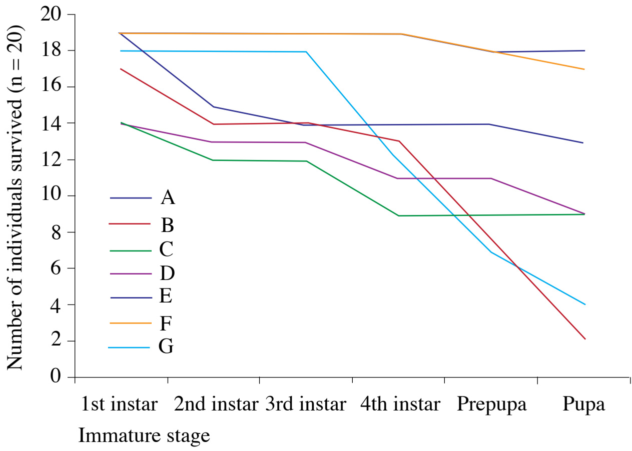

Figure 3. Survival rate of H. billardieri fed with different diets given sequentially. A = MLH/Aphids, B = MLH/Psyllids, C = MLH/Artificial diets, D = MLH/Pysllids/Aphids, E = MLH only, F = Aphids only, G = Psyllids only

Table 3. Larval and pupal development period of *H. billardieri* as affected by different diets given sequentially in the larval stage

Treatment (n = 20)	n	Duration (days) mean ± (SE)		
		Larval	Pupal	Immature
A – MLH/Aphids	18	16.56 ± 0.21[bc*]	6.11 ± 0.08[c]	22.67 ± 0.19[c]
B – MLH/Psyllids	2	25.50 ± 2.50[b]	7.50 ± 0.50[ab]	33.00 ± 3.00[b]
C – MLH/Artificial diets	9	35.67 ± 1.89[a]	7.00 ± 0.41[bc]	42.67 ± 1.72[a]
D – MLH/Psyllids/Aphids	9	16.44 ± 0.73[cd]	6.78 ± 0.28[bc]	23.22 ± 0.92[c]
E – MLH only	13	16.00 ± 0.90[cd]	6.92 ± 0.31[bc]	22.92 ± 1.08[c]
F – Aphids only	17	15.00 ± 0.27[d]	7.94 ± 0.19[a]	22.94 ± 0.30[c]
G – Psyllids only	4	20.50 ± 1.50[b]	8.25 ± 0.25[a]	28.75 ± 1.75[b]

*Means with same letters in the same column are not significantly different at T-Tests ($\alpha = 0.05$). Means included only individuals surviving to adulthood. Equality of variances tests were done to determine which method was suitable to calculate the t value (pooled method for equal variances or Satterthwaite method for unequal variances)

reached adulthood although the diets were mixed and given sequentially to the larvae.

Survival was the highest when the larvae were given the diet in Treatment A (90%) and this percentage was significantly different compared with the rest of the diet regimes ($F = 12.08$; $p < 0.0001$) except in Treatment F (*Figure 4*). Eighty-five and 65% survival were recorded for Treatments F and E respectively but neither was significantly different. These two treatments however had significantly higher survival compared with Treatment G. Survival in Treatments C and D had no significant difference between them or with Treatments E and G but were significantly lower than Treatment F. Only 20% of the larvae completed development on diet of psyllids alone (Treatment G). The lowest percentage that survived to adulthood was in Treatment B (10%). Between Treatments G and B, there was no significant difference.

Figure 5 shows the percentage of larvae that successfully pupated. Sequentially given mixed diets of MLH/ Aphids (Treatment A) and single diet

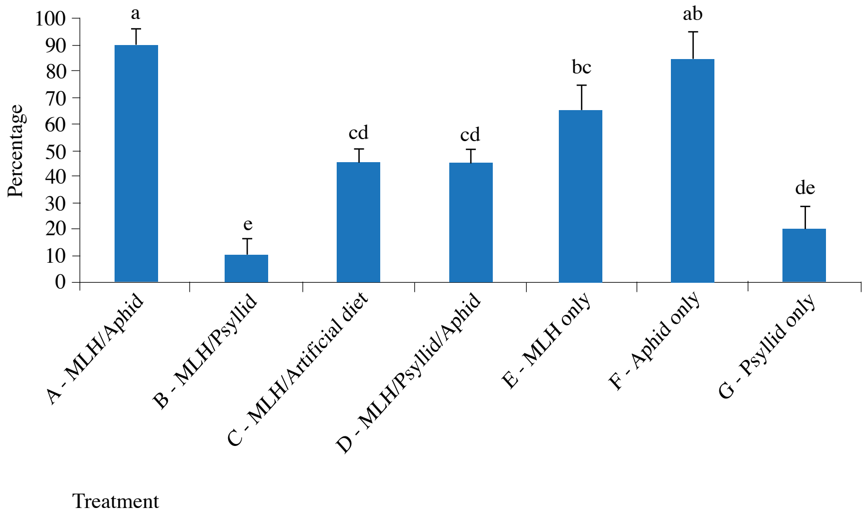

Figure 4. Survival of H. billardieri larvae fed with different diets given sequentially. Means with same letters indicate no significant difference at LSD test (α = 0.05). Data were transformed to Arc Sine prior to analysis

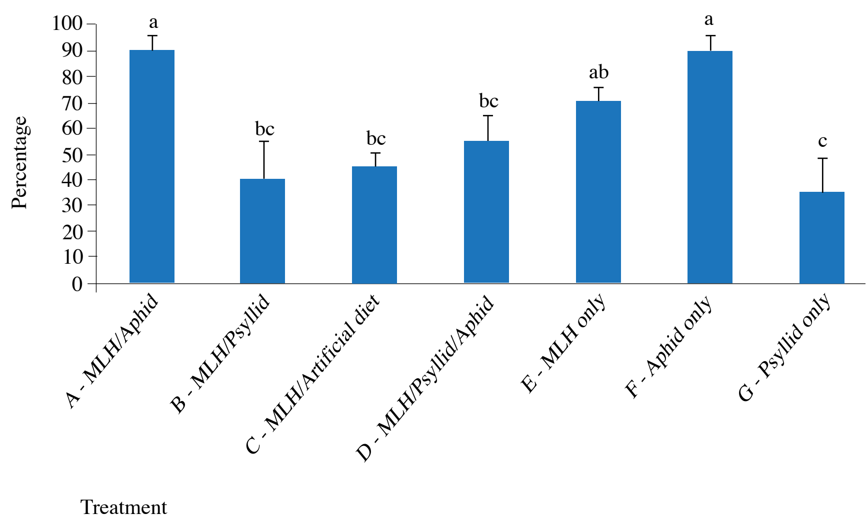

Figure 5. Percentage pupation of H. billardieri larvae fed with different diets given sequentially. Means with same letters indicate no significant difference at LSD test (α = 0.05). Data were transformed to Arc Sine prior to analysis

of aphids only (Treatment F) were both significantly higher compared with the other treatments (F = 5.41; P = 0.0016). Ninety percent of the larvae in both treatments pupated. However both treatments were similar to diet of MLH only (Treatment E). The other three mixed diet regimes (Treatments B, C, and D) had no significant difference among them and with Treatments E and G. Treatment G recorded the lowest percentage (35%), significantly lower than Treatment E.

Pupal weight

Pupal weights from Treatments A, D, E and F had no significant difference among them (*Table 4*). The heaviest weight was from larvae fed with aphids only (21.24 mg). These four treatments however, were significantly heavier than Treatments B, C and G. Average pupal weight in Treatment G was significantly heavier than that in Treatment C (T = –2.47; P = 0.0310) but showed no significant difference from that of Treatment B (T = –0.24; P = 0.8216). Between Treatments B and C, there was no significant difference (T = 1.91; P = 0.0890). Larvae fed with MLH and switched to artificial diet (Treatment C) had a mean pupal weight of 11.56 mg which was the lowest among all treatments.

Discussion

Limited studies have been done on the biology and ecology of *H. billardieri* especially regarding the effect of different prey or non-prey diets on its larval development (Medina and Velasco 2008) in developing a mass rearing protocol for the predator. For this study, it was specifically undertaken to determine the effect of diet switching on larval survival and development.

Based on this study, single prey and mixed diets of different prey given sequentially had different effects on the growth and development of immature *H. billardieri*. Each food regime influenced the development time for each immature stage, total immature duration and survival to adulthood, survival to pupal stage and pupal weight.

Generally, MLH and aphids were the two prey species that greatly influenced the immature development time. Both prey species shortened the immature duration when provided alone but the shortest duration was when the larvae were fed with MLH and then switched to aphids. Sequentially given mixed diets of MLH and psyllids, MLH and artificial diets, and psyllids alone were less suitable for the larvae. The performance however was enhanced when aphids were included in the mixed diet. Survival to pupal stage and adulthood was at the best when the larvae were provided either with sequentially given diet of MLH and aphids or diet of aphids alone. Survival was the lowest when the larvae were fed either with psyllids alone or sequentially given diet of MLH and psyllids. The pupae had the highest average weight gain when the larvae were fed on a diet consisting of MLH and/or aphids.

Table 4. Pupal weight of *H. billardieri* fed during the larval stage with different diets given sequentially

Treatment (n = 20)	N	Pupal weight (mg) Mean ± (SE)
A – MLH/Aphid	18	20.28 ± 0.60^{a*}
B – MLH/Psyllid	2	14.00 ± 1.00^{bc}
C – MLH/Artificial diet	9	11.56 ± 0.56^{c}
D – MLH/Psyllid/Aphid	9	20.11 ± 0.82^{a}
E – MLH only	13	19.92 ± 0.63^{a}
F – Aphid only	17	21.24 ± 0.62^{a}
G – Psyllid only	4	14.50 ± 1.32^{b}

*Means with same letters are not significantly different at T-Tests (α = 0.05). Means included only pupae that survived to adulthood. Equality of variances tests were done to determine which method was suitable to calculate the t value (Pooled method for equal variances or Satterthwaite method for unequal variances)

Psyllids constitutes only an alternative prey in the physiological sense for *H. billardieri* larvae. The larvae cannot develop normally solely on a diet of psyllids because psyllids might have low nutritional value. Furthermore, psyllids might be less preferred due to their size and mobility. Sabelis (1992) mentioned that most generalist predators select their prey according to their relative size. Psyllids could have been overlooked by the larvae due to their small size and escaping abilities. In a study conducted by Barcos et al. (2014), the adults of *H. billardieri* preferred to prey more on psyllids compared to MLH and aphids whether in the prey choice or no-choice test experiment. In her study, the psyllids comprised 64 – 68% of the total consumption of the predatory beetle. However, the number of prey eaten may not be a reliable indicator of preference, especially since psyllids are much smaller compared to the other two. She also mentioned that *H. billardieri* was reared on an artificial diet that included psyllids which may have influenced the predator to prefer the prey to other prey species. Therefore, it is still unclear whether preference of the adult predator is for psyllids more than MLH or aphids. Moreover, Michaud (2005) explained that larvae and adults of predatory lady beetles may not necessarily feed on the same prey, and there are potentially divergent nutritional requirements of different developmental stages.

As mentioned earlier, diet or prey switching in a generalist predator may increase its survival and fitness in nature (Cornell 1976). The switching behaviour is important especially when target or normal prey is scarce. Switching between different prey species in the field not only benefits the predator itself but also can stabilise the number of different prey in the field population (Murdoch 1969). Individual predators may also change their preferences for the prey species due to prey quality as food (Velasco and Walter 1993). Thus, prey switching is an important aspect that fits the behavioural ecology of the predator as it has to search in areas that contain various amounts and quality of food. Prey switching is also adaptive in order to optimise the foraging capabilities of the predator (Dixon 2000).

This behaviour adaptation can also be observed when the predator is brought back to the insectary. In this study, it is suggested that under laboratory rearing conditions, *H. billardieri* larvae managed to adapt to prey switching for food quality that leads to the enhancement of their survival and shorter developmental period. As shown in the results, the larvae generally had better development when they were switched to other diets than when they were maintained on the same diet throughout the experiment. This indicated that mixed diets are more suitable as they can provide a better balance of essential nutrients.

Conclusion

The study showed that switching diets of MLH and psyllids, MLH and artificial diets, and psyllids alone were less suitable for the larvae. However, larval development was faster even when the larvae were fed just with either MLH or aphids alone and the most suitable diet was MLH and aphids given sequentially or by switching these two prey species. This proved that prey switching is an adaptation by *H. billardieri* and can enhance larval growth better than single diet alone. This utilisation of prey switching behaviour also might contribute positively to the outcome of mass rearing for biological control of MLH in the field.

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Abstrak

Heteroneda billardieri (Crotch) (Coleoptera: Coccinellidae) adalah pemangsa semula jadi benah mangga, *Idioscopus clypealis* Lethierry (Hemiptera: Cicadellidae) di Filipina. Kajian berkaitan usaha kawalan biologi dan penternakan besar-besaran tentang pengaruh pertukaran diet antara spesies-spesies mangsa yang berbeza dan diet tiruan ke atas tumbesaran dan perkembangan larva *H. billardieri* telah dijalankan. Afid kekacang, *Aphis craccivora* Koch dan kutu lelompat petai belalang, *Heteropsylla cubana* Crawford telah diuji bersama-sama dengan benah mangga serta diet tiruan. Berdasarkan keputusan kajian, pertukaran diet antara benah mangga dan kutu lelompat, antara benah mangga dan diet tiruan, dan kutu lelompat semata-mata adalah kurang sesuai untuk larva. Walau bagaimanapun, perkembangan larva menjadi lebih pantas apabila diberi makan sama ada benah mangga atau afid semata-mata. Diet yang paling sesuai adalah apabila larva diberi makan benah mangga yang kemudiannya ditukar kepada afid. Kajian ini membuktikan pertukaran mangsa dalam diet adalah adaptasi oleh *H. billardieri* dan dapat meningkatkan tumbesaran larva yang lebih baik daripada diet tunggal semata-mata. Ini dapat menyumbang secara positif kepada usaha penternakan besar-besaran untuk kawalan biologi benah mangga di lapangan.