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Survivorship and Fertility Schedules of a Non-Pest Phytophagous Lady Beetle, *Epilachna pytho* (Coleoptera, Coccinellidae) under Laboratory Conditions

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ABSTRACT A non-pest Sumatran phytophagous lady beetle, *Epilachna pytho* was reared under laboratory conditions to study survivorship and fertility schedules. The species is found above 600 m from sea level, mainly depending on wild cucurbits such as *Trichosanthes tricuspidata*, *T. ovigera*, *Gynostemma pentaphyllum, Mukia javanica* and rarely occurring in cultivated fields of *Sechium edule*. The development of the immature stages of *E. pytho* required 33.6 days. The mean longevity of males (94.4 days) was shorter than that of females (106.3 days). The mean length of the pre-reproductive period (25.4 days) was longer than that of the post-reproductive period (3.6 days). Females laid eggs continuously throughout their reproductive period (77.3 days). The average number of eggs produced per female was 609.9. The intrinsic rate of natural increase *r* was 0.067 per capita per day. These life history traits of *E. pytho* was similar to *E. enneasticta*, a non-pest species feeding on Solanaceae and living in high lands. *E. pytho* exhibited 1) longer immature stages, 2) longer mean length of the pre-reproductive period, 3) lesser fertility and 4) smaller *r* and larger *T* values than four pest epilachnine species, living at a wide elevational range.

Key words: Coccinellidae / *Epilachna pytho* / phytophagous lady beetle / survivorship and fertility schedules / West Sumatra

In our previous articles, we reported the survivorship and fertility schedules of five species of phytophagous lady beetles (subfamily Epilachninae) from Sumatra and Java, Indonesia (Nakamura *et al*., 1984 for *Epilachna septima* and *E. pusillanima*, previously treated as *E. dodecastigma*, cf. Booth & Pope, 1989; Abbas *et al*., 1985 for *E. vigintioctopunctata*; Nakamura *et al*., 1995 for *E. vigintioctopunctata*, *E. enneasticta*, and *E.* sp.3; Nakano *et al*., 1997 for *E. enneasticta*). Among these five epilachnine species, high densities of four species occurred from a lower to a higher elevation frequently as pests of crops, i.e. *E. pusillanima* and *E. septima*, both depending on cucurbitaceous crops (0-1100 m in altitude), *E. vigintioctopunctata*, depending on solanaceous crops and weeds (0-1400 m) and *E.* sp.3, depending on a weedy vine *Mikania micrantha* (Compositae) (0-1400 m)(Katakura *et al*., 1988; Nakamura *et al*., 1995). The last one, *E. enneasticta*, feeding on solanaceous plants, occurs with a low density at higher elevations (400-1400 m)(Katakura *et al*., 1988).

The present species, *E. pytho* Mulsant is found at higher regions (between 600 and 1300 m in altitude) in the Province of Sumatera Barat (Nakano, 1999) and mainly feeds on cucurbitaceous weeds such as *Trichosanthes ovigera*, *T. tricuspidata*, *Gynostemma pentaphyllum* and *Mukia javanica* but rarely on the cucurbitaceous crop, *Sechium edule* (Katakura *et al* ., 2001; Nakano unpubl.). *E. pytho* was always found only sporadically and at a low density on the cucurbitaceous weeds and at an even lower density on the crop, *S. edule* (Nakano, unpubl.). Compared with the previously studied five species, it is much more difficult to find eggs and larvae of *E. pytho* in the field, although oviposition pattern by egg mass is the same as the above five species (Nakano *et al*., 2001)

The purpose of this article is to clarify survivorship and fertility schedules under laboratory conditions of a non-pest epilachnine, *E. pytho*, and compare the life history traits with those of previously studied five species, especially between pest and non-pest species and between species living at a wide elevational range and those living only at a higher elevation.

MATERIALS AND METHODS

Experiments were carried out from October 1988 to August 1989 at the Sumatra Nature Study (SNS) Laboratory of Andalas University in Padang, Central Sumatra (Province of Sumatera Barat). All rearings were carried out under relatively constant temperature (24.5 to 26 °C) and natural day length (12L/12D). But it should be noted that the rearing temperature was 4-5 °C higher than the natural condition and that a diet of *Cucurbita moschata* leaves was used, because *S. edule* and the wild cucurbitaceous host plants did not occur near the laboratory, and furthermore *E. pytho* preferred *C. moschata* leaves (Nakano, unpubl.).

Experiment 1. Developmental times of immature stages

E. pytho adults were collected from a crop, *S. edule*, at Kayu Jao (1250 m alt.), 46 km southeast of Padang. They were mass-reared with *C. moschata* leaves in plastic boxes (22.0×30.5×6.0 cm) in the laboratory to obtain eggs. The food plants were checked daily for eggs. Each egg mass deposited was isolated in a transparent plastic cup (10 cm in diameter and 4.3 cm in depth), and fresh *C. moschata* leaves were put into the cup just before hatching. Dates of oviposition, hatching, and larval molt were recorded daily to determine the developmental times. From the fourth stadium onward, the number of larvae reared in each cup was restricted to ten at most to avoid overcrowding. Thirty first stadium larvae from three egg masses were used for this experiment.

Experiment 2. Survivorship and fertility schedules

Recently emerged (within two days) males and females were confined in pairs to the same plastic cups as used in Experiment 1. To study survivorship and fertility schedules, the number of eggs deposited and the dates of oviposition and adult death were recorded for 19 pairs.

RESULTS

1. Developmental times of immature stages

Table 1 shows the duration of successive immature stages of *E. pytho*. The total developmental time

Table 1. Duration of successive immature stages (in days) of *Epilachna pytho*. Numbers in parentheses indicate number of individuals examined.

Species	Egg	L1	L2	L3	L4	Pupa	Total
E. pytho	6.4	5.1	3.9	4.1	4.4	9.7	33.6♀:34-35[a]
	(30)	(30)	(29)	(29)	(29)	(27)	(27)♂:34-35

[a] Range of total developmental times.

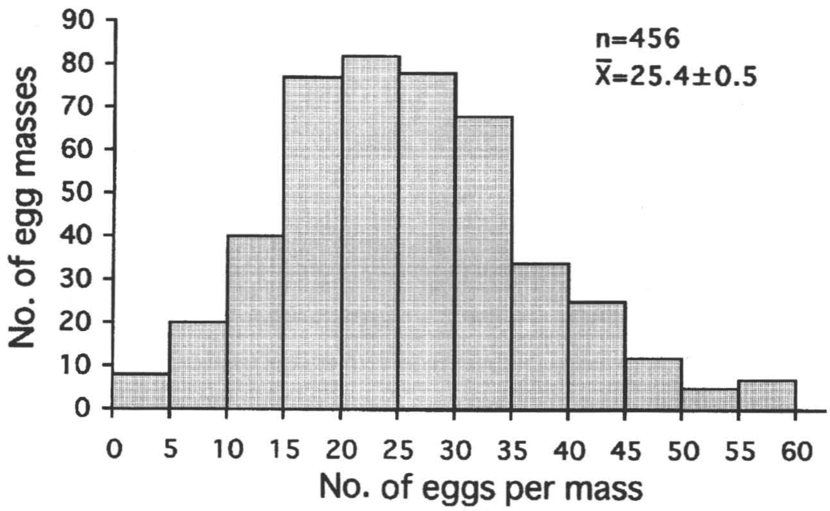

Fig. 1. Frequency distribution of *E. pytho* egg mass size. The number of masses examined (n) and the means ($\bar{x}$) with 95% confidence limits are shown.

of *E. pytho* was 33.6 days.

2. Sex ratio of newly emerged adults

Newly emerged adults (12 females, 15 males) showed no significant deviation from the expected 1:1 sex ratio (p=0.221, binomial test).

3. Egg mass size

Fig. 1 shows the frequency distribution of egg mass size. The mean size of egg masses was 25.4 (N=456).

4. Survivorship and fertility schedules

Fig. 2 shows the survivorship (l_x; the number of living individuals/19×100) of female and male adults and the age-specific fertility, which is expressed as the change in the number of eggs laid per female per day. Since the sex ratio of the newly emerged adults was 1:1, the age-specific fertility in Fig. 2 is equivalent to $m_x \times 2$ (m_x is usually defined as the number of living females born per female per unit time, Southwood, 1978). The shape of the age-specific fertility curve shows that females produced eggs continuously throughout their long reproductive period (Fig. 2). It should be noted that females which were alive more than 150 days after emergence could still oviposit as many eggs as

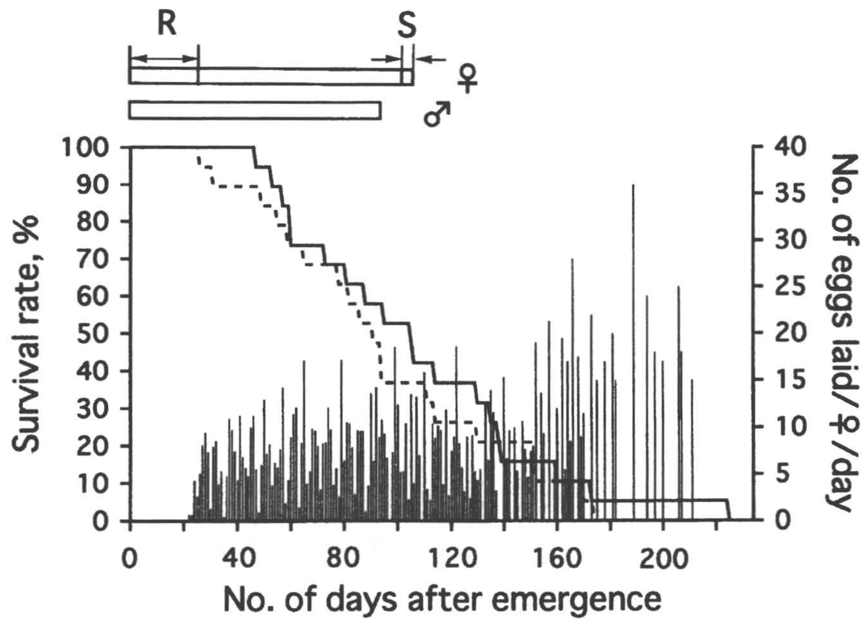

Fig. 2. Survivorship and fertility schedules of *E. pytho* under laboratory conditions. Solid and dotted lines refer to survivorship curves for females and males, respectively. The histogram shows the number of eggs laid per female per day. Two horizontal bars depict the average longevity for both sexes. *R* and *S* are the average length of the pre- and the post-reproductive periods, respectively.

they did during the younger period (Fig. 2). The number of eggs laid per female per day fluctuated to some extent because (1) individual females tended to oviposit at intervals of 1-6 days and (2) the number of females examined was not large. Table 2 shows the longevity, pre- and post-reproductive periods, fertility, intrinsic rate of natural increase (r), and mean generation length (T) of *E. pytho* along with those of five other species.

(a) Longevity, pre- and post-reproductive periods: The mean longevity of the males (94.4 days) was shorter than that of the females (106.3 days), but the difference was not significant ($U=157.5$, $p>0.05$, Mann-Whitney U-test). The mean length of the pre-reproductive period (25.4 days) was much longer than that of the post-reproductive period (3.6 days). The duration of the pre-reproductive period of the females varied considerably from 21 to 35 days. Kendall's rank tests revealed that the female's age at first oviposition (in days) was not significantly correlated with either age at final oviposition ($\tau=0.061$, $p>0.05$) or with age at death ($\tau=0.043$, $p>0.05$).

(b) Intrinsic rate of natural increase r : The r was determined by solving the equation

$$\Sigma\, e^{-rt} l_t m_t = 1$$

for r, where t is the age in days (Birch, 1948). The life table for both the immature and adult stages was needed for the calculation of r. However, because eggs, larvae, and pupae rarely died on *C. moschata* leaves (Nakano, unpubl.) unless we had mishandled them, we assumed no death in the immature stages. The r value thus derived was 0.067 per capita per day.

(c) Net reproductive rate R_o and mean generation length T: The R_o (= $\Sigma l_x m_x$) is the average

Table 2. Survivorship and fertility schedules of *Epilachna pytho* and five *Epilachna* species previously studied under laboratory conditions.

Species	*E. pytho*	*E. enneasticta*	*E.* sp.3
Host plant	*Sechium edule* (*Cucurbita moschata*) [a]	*Solanum torvum*	*Mikania* sp.
Rearing temperature	24-26.5°C	24-26.5°C	27-30°C
No. of replications	19	18	8
Longevity (in days) male	94.4±21.4 (25-173)[b]	90.4±17.3 (35-167)	66.7±16.6 (27-86)
female	106.3±22.8 (46-224)	71.4±10.4 (35-110)	77.4±5.2 (65-86)
Larval period (in days)	33.6	28.7	27.7
Pre-reproductive period (in days)	25.4±1.5 (21-35)	30.1±3.0 (20-43)	13.9±2.8 (9-21)
Post-reproductive period (in days)	3.6±1.5 (0-13)	2.4±0.9 (1-8)	4.6± 1.6 (3-8)
Fertility (total no. of eggs laid per female)	609.9±180.4 (134-1307)	425.4±125.3 (102-1044)	650.4±117.4 (378-889)
Intrinsic rate of natural increase (per capita per day), r	0.067	0.070	0.100
Mean length of a generation (in days), T	85.4	76.6	57.8
Reference[c]	Present study	4	3

Species	*E. vigintioctopunctata*	*E. septima*	*E. pusillanima*
Host plant	*Solanum torvum*	*Momordica charantia*	*Cucurbita* sp.
Rearing temperature	24-32°C	24-32°C	24-32°C
No. of replications	10	9	11
Longevity (in days) male	87.6±3.3 (80-94)	70.5±17.5 (17-99)	88.6± 16.4 (55-133)
female	57.7±8.0 (43-81)	63.8± 11.7 (35-84)	63.9±7.8 (49-83)
Larval period (in days)	23.1, 23.6	22.5	23.0
Pre-reproductive period (in days)	11.0± 1.5 (8-15)	18.9±4.7 (11-27)	15.5±3.7 (9-23)
Post-reproductive period (in days)	2.3±1.3(1-7)	4.0±2.5(1-11)	5.2±2.4 (2-15)
Fertility (total no. of eggs laid per female)	770.7±108.2 (590-1115)	651.9±309.1 (121-1224)	763.8±204.8 (341-1185)
Intrinsic rate of natural increase (per capita per day), r	0.125	0.100	0.120
Mean length of a generation (in days), T	47.6	58.1	49.5
Reference[c]	2	1	1

[a] *E. pytho* adults used in the present study were collected from *S. edule* and were reared with *C. moschata* in the laboratory. The other five epilachnine species were reared with the same plants they were collected from.
[b] Average ±95% confidence limits (range).
[c] 1:Nakamura *et al.* (1984), 2: Abbas *et al.* (1985), 3: Nakamura *et al.* (1995), 4: Nakano *et al.* (1997).

number of female eggs produced per female adult. The mean length of generation T was derived from

$$T = \frac{\log R_o}{r} \quad .$$

The values of R_o and T thus derived were 305.0 (eggs per female), and 85.4 (days) (Table 2). The total number of eggs produced per female was 609.9 (Table 2), which is twice the value of Ro .

(d) Age-specific fertility and reproductive value: Fisher's (1930) reproductive value is given by

$$\frac{Vx}{Vo} = \frac{e^{rx}}{l_x}\sum_{t=x}^{\infty} e^{-rt}\, l_t m_t \,\Delta t \ ,$$

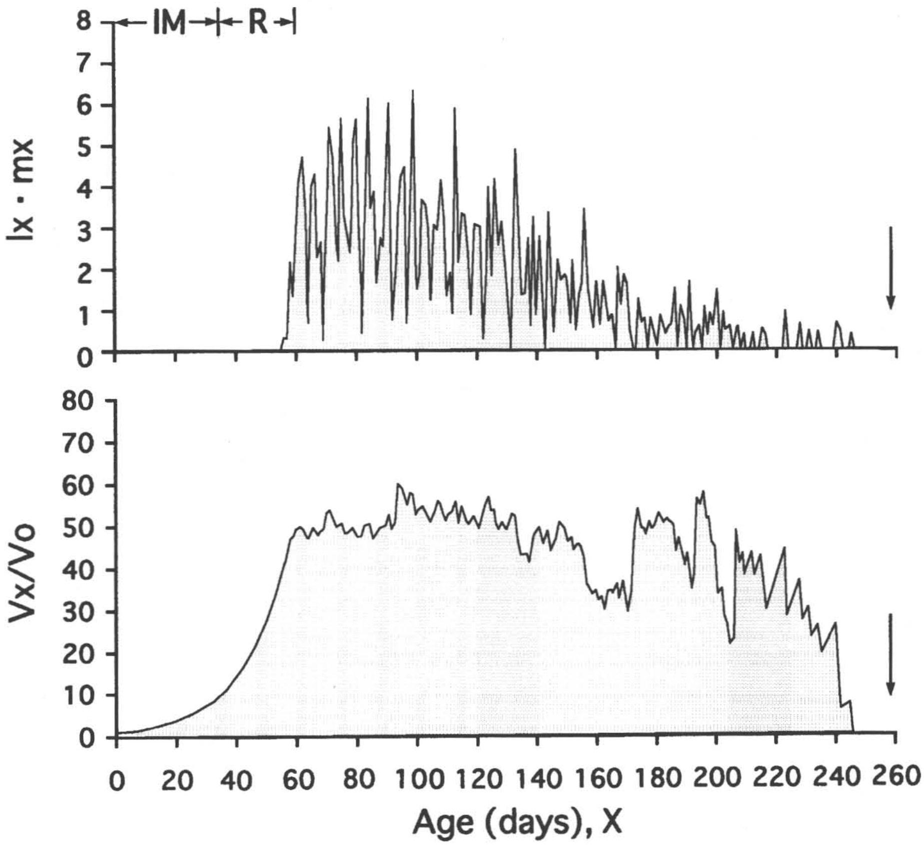

Fig. 3. Reproductive function ($l_x m_x$, top) and reproductive value (V_x/V_o, bottom) plotted against age after oviposition for *E. pytho* under laboratory conditions. *IM*: duration of the immature stages. *R*: mean duration of the pre-reproductive period. Vertical arrows represent death of females.

where Δt is the interval used for measuring l_x and m_x (Δt = 1 day in this case). The reproductive value of *E. pytho* showed a plateau with small peaks which spanned nearly 100 days and the highest peak value was attained at 93.6 days (i.e., 60.0 days and 34.6 days after the start of the female's adult life and of her reproductive period, respectively). Although the reproductive value dropped between 160-170 days and also around 200 days, its value remained relatively high with a few exceptions until the end of the female's life span (Fig. 3).

DISCUSSION

Table 2 summarizes the life history traits of *E. pytho* and five *Epilachna* species previously studied. *E. pytho* feeds on mainly wild cucurbits such as *Trichosanthes tricuspidata*, *T. ovigera*, *Gynostemma pentaphyllum* and *Mukia javanica* with a low density and also, much more rarely, on the crop species, *S. edule*, at higher elevations (600-1300 m alt.) in West Sumatra (Katakura *et al.*, 2001; Nakano, unpubl.). Therefore, it is regarded as a non-pest species. Among the five species in Table 2, the life history traits of *E. pytho* is most similar to those of *E. enneasticta* whose elevational range (400-1400 m) is also similar to *E. pytho* (Katakura *et al*., 1988; Nakano, 1999). Although *E. enneasticta* has been regarded as a pest species of solanaceous crops (Katakura *et al*., 1988; Nakano *et al*., 1997), recent study shows 1) *E. enneasticta* in West Sumatra utilizes nine solanaceous weeds as well as two solanaceous crops (*S. tuberosum*, *S. melongena*) (Katakura *et al*., 2001), and 2) *E. enneasticta* is collected more easily on these solanaceous weeds than on crops because of a wider distribution of these weeds in West Sumatra (Nakano, unpubl.). Further, a long term population study of *E. enneasticta* and *E. vigintioctopunctata* on *S. torvum* showed that the field population of *E. enneasticta* remained low levels while the population of co-occurring *E. vigintioctopunctata* sometimes reached high peaks at Sukarami (980 m alt.) in West Sumatra (Hasan *et al*., unpubl.). Thus, *E. enneasticta* also can be classified mainly as a non-pest species, though it occurs at a high density only locally.

These two non-pest species, living only in higher regions, exhibited the following common traits: 1) the duration of the immature stage was relatively long; 2) the mean length of the pre-reproductive period was also long; 3) the fertility was a little smaller (*E. pytho*) or about two-thirds (*E. enneasticta*) of the other four species; 4) the r value was smaller, and T was larger (Table 2). In the fields, moreover, adults of *E. pytho* and *E. enneasticta* are also sedentary. They remained on the food plants even when disturbed (Nakamura *et al*., 1995; Nakano *et al*., 1997; Nakamura, unpubl.), while those of the pest species exhibited active and strong dispersal power by flight (Nakamura *et al*., 1984 for *E. septima* and *E. pusillanima*; Abbas *et al*., 1985 for *E. vigintioctopunctata*; Nakamura *et al*.,1995 for *E.* sp.3 and *E. vigintioctopunctata*).

Shirai (1987, 1990), Shirai & Morimoto (1997), and Richards & Filewood (1988,1990) compared the life history traits between pest and non-pest populations of the same species and showed that the number of eggs laid per female or that per day was much larger in pest and non-pest populations reared with crop host plants than in those reared with wild host plants. In the present study *E. pytho* was reared with the leaves of squash (*C. moschata*) instead of *S. edule*, the host crop where specimens were collected. Under laboratory conditions, *E. pytho* showed a strong preference for cucurbitaceous crops such as *C. moschata* and *S. edule* as well as a weed host plant, *Trichosanthes tricuspidata*. There was no difference in survival rate during immature stages among specimens utilizing these host plants (Nakano, unpubl.). Furthermore, *E. pytho* was reared under a higher temperature than natural conditions which may cause a shorter developmental time. Thus, the fertility (the total number of eggs per female) and r value of *E. pytho* in the present study may appear to be overestimated when compared to those values obtained by rearing with the original host plant under lower temperatures. However, there was no clear difference in fertility between *E. pytho* preliminarily reared on *T. tricuspidata* and that reared on *C. moschata* (Nakano, unpubl.). Detailed comparison of fertility among females reared on *C. moschata*, *S. edule* and *T. tricuspidata* is necessary in future study.

The reasons why *E. pytho* does not become a pest of *S. edule* and other cucurbit crops which *E. pytho* prefers and where *E. pytho* showed the high survival of immature stages also should be analyzed in the field with the study of mortality factors such as rainfall and natural enemies.

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中野 進，中村浩二，Idrus Abbas **非害虫の食植性テントウムシ，*Epilachna pytho*（甲虫目，テントウムシ科)の生存ー繁殖スケジュール**

スマトラ産の食植性テントウムシ *Epilachna pytho* を実験室内で飼育して生存ー繁殖スケジュールを明らかにし，これまでに報告されている5種の *Epilachna* の結果と比較した。

Epilachna pytho は海抜 600 m 以上の高地に分布する。ウリ科野草の *Trichosanthes tricuspidata*, *T. ovigera*, *Gynostemma pentaphyllum*, *Mukia javanica* を主な食草とするが，まれにウリ科作物の *Sechium edule* でも採集される。卵から羽化までの発育日数は 33.6 日，成虫の寿命はオス 94.4 日，メス 106.3 日であった。産卵前期間は 25.4 日，産卵終了から死亡までの日数は 3.6 日であった。1メスあたり産卵数は 609.9 であり，メスは産卵期間中一定のペースで産卵し続けた。内的自然増加率 r は 0.067 であった。

これらの *E. pytho* の生活史特性は，やはり高地に分布し，ナス科の野草を広く利用する *E. enneasticta* とよく似ている。一方，これまでに調べられた4種の害虫と比べると，*E. pytho* は，1) 幼虫期間がより長く，2) 産卵前期がより長く，3) 産卵数はより少なく，4) より小さい内的自然増加率 r と，より長い世代期間 T を持つことが明らかになった。