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Survivorship and Fertility Schedules of Three Phytophagous Ladybird Beetle Species (Coleoptera: Coccinellidae) under Laboratory Conditions in Bogor, West Java*

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ABSTRACT Three species of epilachnine beetles, *Epilachna* sp. 3 (aff. *emarginata*) (EM) feeding on *Mikania* sp. (Compositae), *E. vigintioctopunctata* (EV) and *E. enneasticta* (EN) both feeding on *Solanum torvum* (Solanaceae), were reared to study the survivorship and fertility schedules under laboratory conditions. Duration for the development of the immature stages, mean longevity of adults, mean length of the pre- and post-reproductive period, and total number of eggs produced per female were recorded. The demographic parameters such as the intrinsic rate of natural increase (r), reproductive value (V_x / V_0), and mean length of a generation (T) were calculated.

Key Words: *Epilachna* / Coccinellidae / West Java / Indonesia / Survivorship and fertility schedules

In the preceding papers, we reported the demographic traits of three epilachnine beetles obtained in Padang, Sumatra under laboratory conditions. The beetles, *Epilachna septima* Dieke and *E. dodecastigma* Wiedemann, both feeding on cucurbitaceous plants showed more prolonged longevity and fertility schedules than temperate species, including Japanese epilachnine beetles. These species are obviously well adapted for living in tropical environment like Padang (Nakamura *et al.*, 1984; Abbas *et al.*, 1985; Inoue *et al.*, 1993). The present article will describe the reproductive schedules of three epilachnine species, *Epilachna* sp. 3 (aff. *emarginata* Dieke; see Katakura *et al.*, 1992; thereafter abbreviated as EM), *E. vigintioctopunctata* Fabricius (EV) and *E. enneasticta* Mulsant (EN), which were collected in Bogor, West Java, under laboratory conditions, and compare them with the previous results obtained in Padang, Sumatra.

MATERIALS AND METHODS

Climate: The study was carried out in the Bogor Botanical Gardens (Kebun Raya Bogor, 6°37'S, 106°32'E, 260 m elevation from the sea level). Bogor is located at the eastern fringe of the humid tropical climate range (Inoue & Nakamura, 1990). Nakamura *et al.* (1994)

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summarized the climate of Bogor (represented at Muara) as follows: Mean monthly temperature fluctuates only from 25.3 °C (January) to 26.8 °C (May and September). The average annual rainfall for 1980-1989 is 4075 mm (range, 3370 to 5025 mm). The driest months of the year are June to August and the wettest, November to January. The cycles of dry and wet seasons are less distinct and more irregular than those of central and east Java. Compared to Padang, where our previous studies were done, Bogor has more seasonal rainfall and more severe droughts.

***Host plant and habitat*:** All the three epilachnine species are common in Indonesia and occur in disturbed habitats. EM feeds on a herbaceous vine, *Mikania* sp. (Compositae), EV and EN on solanaceous crops such as eggplants, potatoes, and a shrubby weed, *Solanum torvum* (Solanaceae) (Katakura *et al.*, 1992). Elevational ranges of EV and EM are wide, ranging from the sea level to 1400 m, while EN is found only over 500 m. EN and EV are frequently found together on the same host plants, although the former is far less abundant than the latter (Katakura, *et al.*, 1988).

Observations The following observations were carried out from 19 November 1990 to 26 March 1991 (EM), 7 November 1990 to 18 February 1991 (EV), and 15 January 1991 to April 1991 (EN) in the laboratory of Bogor Zoological Museum located in the Bogor Botanical Gardens, under room temperatures ranging from 27 to 30 °C.

[Observation 1] Adults of EM and EV were collected from *Mikania* sp. and *S. torvum*, respectively, in Bogor, and EN from *S. torvum* in Cibodas (42.6 km east of Bogor, 1425 m elevation from sea level). Adults were reared in the laboratory to obtain eggs for this observation. Each egg mass was isolated in a transparent plastic cup (10 cm in diameter and 5 cm in depth) with fresh leaves of *Mikania* sp. (EM) and *S. torvum* (EV and EN), and records were kept daily of hatching and of larval molts in order to know the developmental time. Ten, 25 and 18 cups were used for EM, EV and EN, respectively.

[Observation 2] A pair of newly emerged adults obtained in Observation 1 was confined in a plastic cup of the same size as in Observation 1 to learn their survivorship and fertility schedules. Eight (EM and EN) and 7 (EV) pairs were reared with daily checking and exchange of the food plant leaves during the study period.

RESULTS

1. Developmental times of the immature stages

The results of Observation 1 show that the mean duration of successive immature stages was 27.7 days (EM), 22.1 (EV), and 29.5 (EN) (Table 1).

2. Survivorship and fertility schedules

Figures 1-3 show the survivorship (l_x) of female and male adults, and the age specific fertility,

Table 1. Mean duration of each immature stage of three epilachnine species under laboratory conditions in Bogor.

Species/Stage	Egg	L1	L2	L3	L4	Pupa	Total
Epilachna sp. 3	4.0	4.0	2.0	5.8	6.2	5.7	27.7
E. vigintioctopunctata	3.0	3.9	2.8	2.8	5.4	4.2	22.1
E. enneasticta	4.0	4.8	4.1	4.4	6.3	5.9	29.5

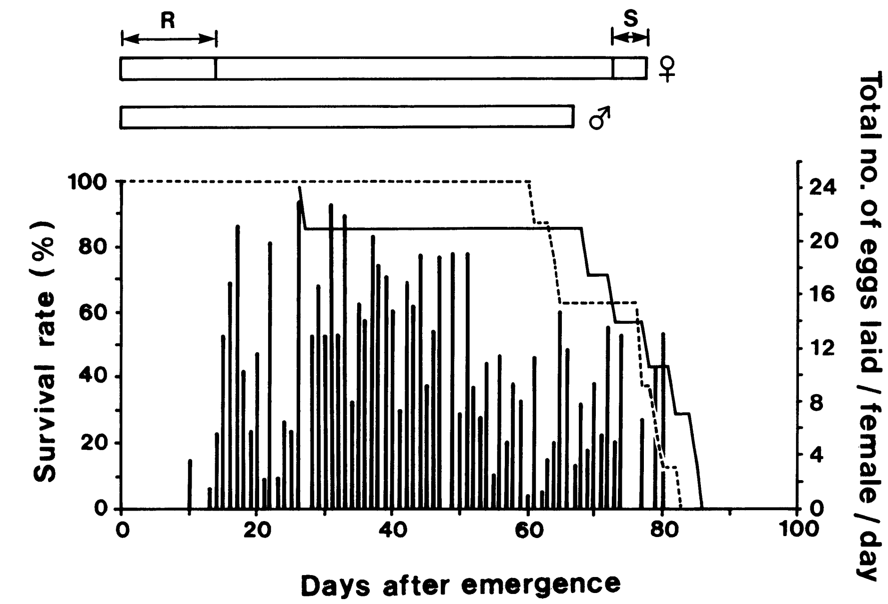

Fig. 1. Survivorship and fertility schedules of *Epilachna* sp. 3 (aff. *emarginata*) under laboratory conditions. Solid and dotted lines refer to survivorship curves for females and males, respectively, and the histogram shows the number of eggs laid per female per day. Two horizontal bars depict the average longevity for both sexes, and *R* and *S* the average length of the pre- and post-reproductive periods.

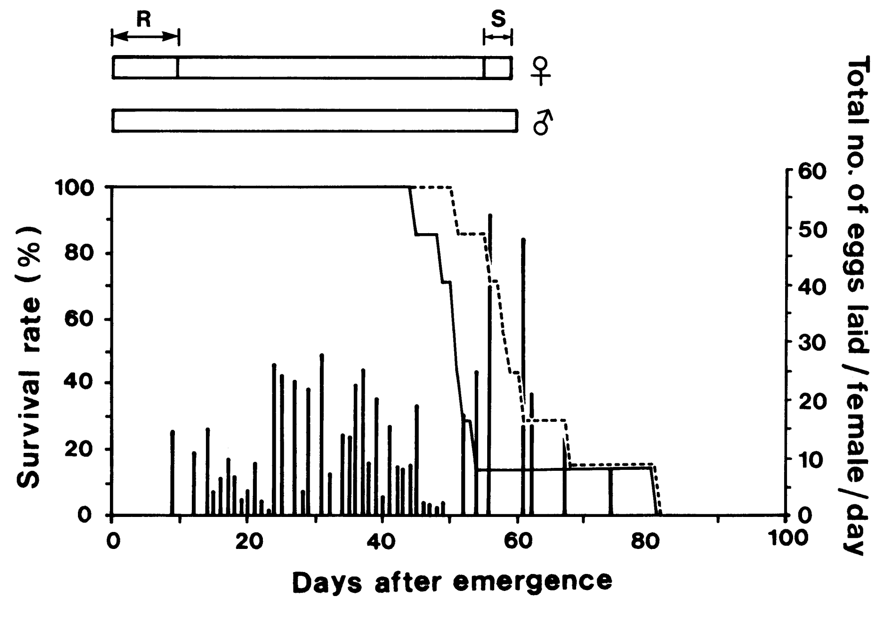

Fig. 2. Survivorship and fertility schedules of *E. vigintioctopunctata* under laboratory conditions. Explanations as in Fig. 1.

which is expressed as the change in the number of eggs laid per female per day. Although sex ratio was not recorded in these observations, a 1:1 ratio was reported for EV (Abbas *et al.*, 1985) and EN (Nakamura *et al.*, unpublished) in Sumatra and for EM in Bogor (Nakamura *et al.*, 1992). On the basis of the expected 1:1 sex ratio the age-specific fertility in these figures

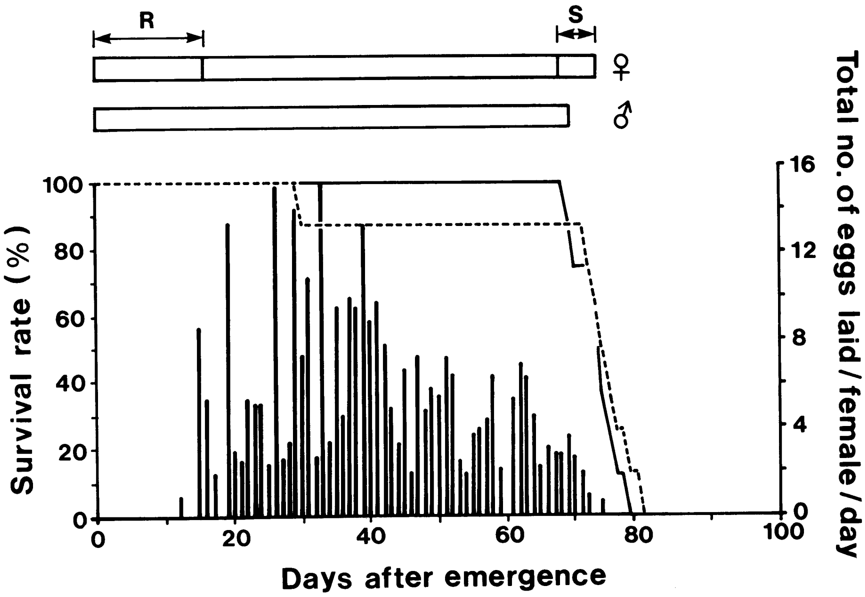

Fig. 3. Survivorship and fertility schedules of *E. enneasticta* under laboratory conditions. Explanations as in Fig. 1.

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 histogram giving age-specific fertility shows that females produce eggs at a nearly constant rate throughout their long reproductive period (Figs. 1-3). Table 2 summarizes the longevity, pre- and post-reproductive periods, fertility, intrinsic rate of natural increase (r), and mean length of a generation (T).

(a) Longevity, pre- and post-reproductive periods: Mean longevity of EM and EN were almost equal, and females lived longer than males: 66.7 days (EM) and 69.9 (EN) in male, and 77.4 days (EM) and 73.6 (EN) in female. Longevity of EV was 60.4 days (male) and 59.3 (female), and shorter than that of the other two species (Table 2). However, none of these differences were significant. The maximum longevity of these species was roughly 90 days. The mean length of the pre-reproductive period (13.9 days in EM, 9.6 in EV and 15.9 in EN) was much longer than that of the post-reproductive period (4.6 days in EM, 4.1 in EV and 5.6 in EN).

(b) The 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 age in days (Birch, 1948). We need the life table of both the immature and adult stages for the calculation of r, and we assumed that (1) no death occurred in the immature stages because the eggs, larvae and pupae rarely died unless we mishandled them and (2) the length of the immature stage was 27.7 days (EM), 22.1 (EV) and 29.5 (EN), i.e. the averages of total immature periods in Table 1. The r value thus derived was 0.100 (EM), 0.118 (EV) and 0.081 (EN).

(c) The net reproductive rate R_0 and mean length of generation T: The R_0 (= $\Sigma l_x m_x$) is the average number of female eggs produced per female adult. The mean length of generation T was derived from

$$T = logR_0 / r$$

The values of R_0 and T thus derived were 325.2 and 57.8 days in EM, 213.1 and 45.4 days in

Table 2. Survivorship and fertility schedules of three epilachnine species under laboratory conditions in Bogor.

Species		*Epilachna* sp. 3	*E. vigintioctopunctata*	*E. enneasticta*
Host plant		*Mikania* sp. (Comp.)	*S. olanum torvum* (Solanac.)	*Solanum torvum* (Solanac.)
No. of replications		8	7	8
Longevity	Male	66.7 ± 19.8 (27-86)*	60.4 ± 10.7 (51-81)	69.9 ± 15.9 (31-80)
(in days)	Female	77.4 ± 6.2 (65-86)	59.3 ± 12.0 (45-81)	73.6 ± 3.0 (69-78)
Pre-reproductive period (in days)		13.9 ± 3.4 (9-21)	9.6 ± 3.6 (6-16)	15.9 ± 4.5 (11-25)
Post-reproductive period (in days)		4.6 ± 1.9 (3-8)	4.1 ± 2.7 (1-7)	5.6 ± 3.5 (2-13)
Fertility (Total no. of eggs laid per female)		650.4 ± 140.4 (378-889)	426.1 ± 142.4 (226-634)	322.1 ± 63.1 (228-412)
Intrinsic rate of natural increase (per capita per day), *r*		0.100	0.118	0.081
Mean length of a generation (in days), *T*		57.8	45.4	62.7

*Average ± S.D. (range)

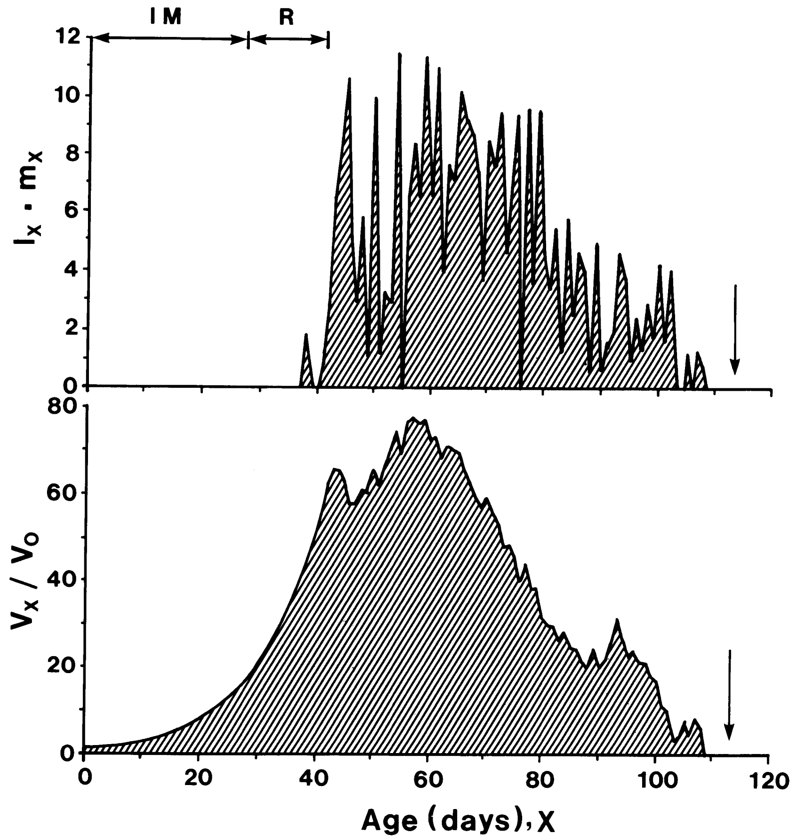

Fig. 4. Reproductive function ($l_x m_x$, top) and reproductive value (V_x/V_0, bottom) plotted against age after oviposition for *E.* sp. 3 (aff. *emarginata*) under laboratory conditions. IM: duration of the immature stages. *R*: mean duration of the pre-reproductive period. Vertical arrow shows the death of the females.

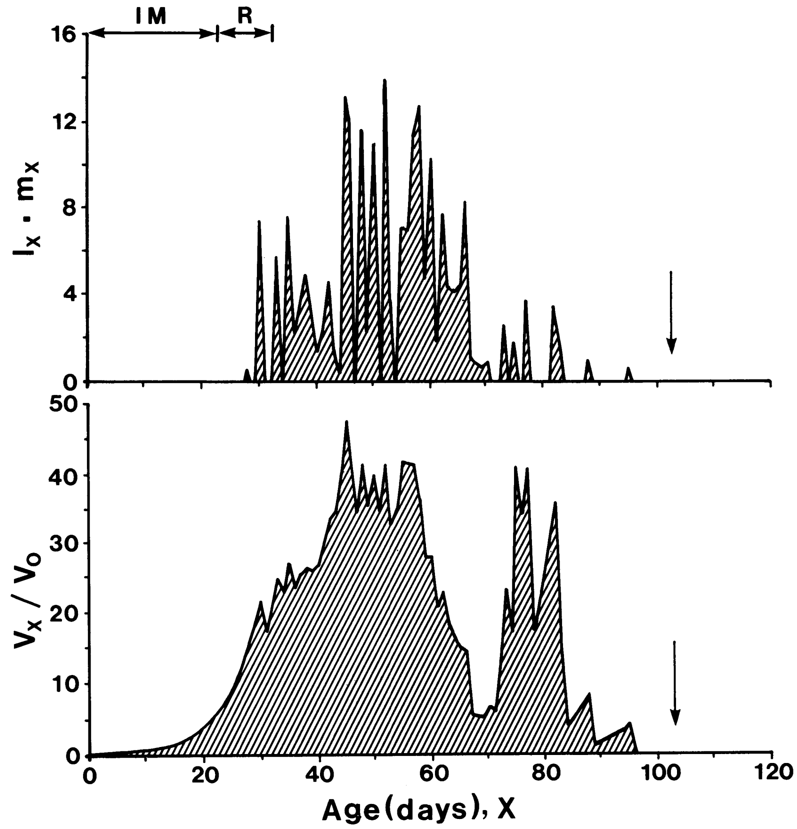

Fig. 5. Reproductive function ($l_x m_x$, top) and reproductive value (F(V_x/V_0), bottom) plotted against age after oviposition for *E. vigintioctopunctata* under laboratory conditions. Explanations as in Fig. 4.

EV, and 161.1 and 62.7 days in EN (Table 2). The total number of eggs produced per female was 650.4 (EM), 426.1 (EV) and 322.1 (EN), which is twice the value of R_0.

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

$$V_x / V_0 = e^{rx} / l_x \sum_{t=x}^{\infty} e^{-rt} l_t m_t \Delta t$$

where Δt is an interval for measuring l_x and m_x ($\Delta t = 1$ in this case). The reproductive value of the three species reached a peak after 15.1 days (EM), 9.6 (EV) and 13.1 (EN) of female's reproductive period, respectively, and then the value dropped gradually until near the end of the female's life span (Figs. 4-6). The reproductive value of EV had a second peak 30 days after the first peak (Fig. 5), which need to be confirmed by additional rearings.

DISCUSSION

Compared with the temperate species, three Sumatran *Epilachna* beetles studied in Padang were characterized by lower but more constant daily oviposition rate and resulting prolonged life-span (Nakamura *et al.*, 1984 for *E. dodecastigma* and *E. septima*, and Abbas *et al.*, 1985 for *E. vigintioctopunctata*). These species are pests of crops and weeds (Katakura *et al.*, 1988, 1992). Higher activity of the beetles has also been confirmed by direct observation during the population census. The approach of observers evoked active flights on and around host plants

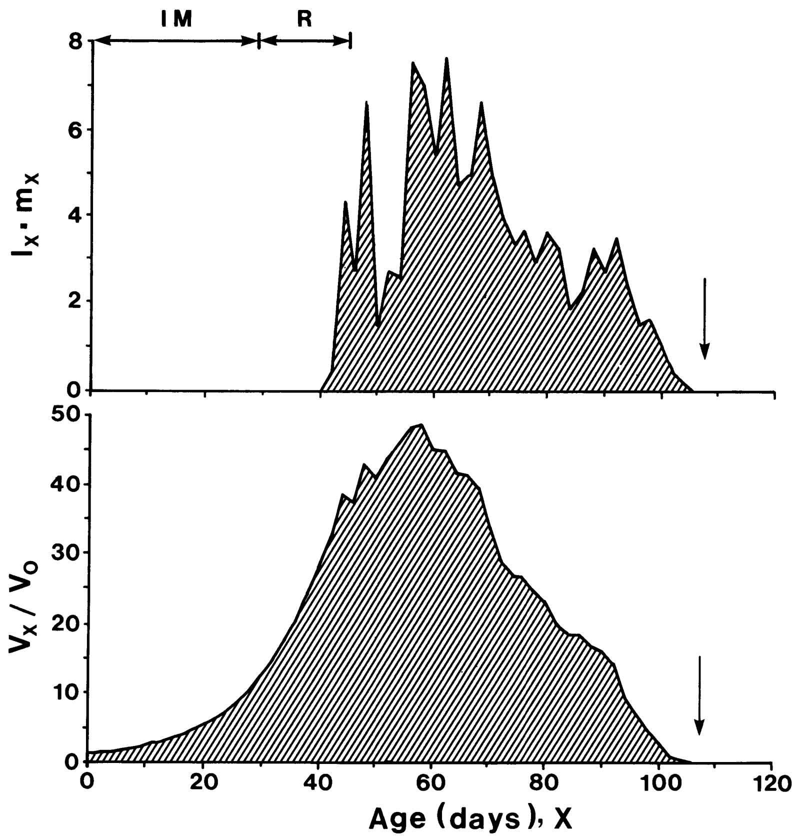

Fig. 6. Reproductive function ($l_x m_x$, top) and reproductive value (F(V_x / V_0), bottom) plotted against age after oviposition for *E. enneasticta* under laboratory conditions. Explanations as in Fig. 4.

(K. Nakamura, personal observation). These traits are adaptive for living in highly disturbed tropical environments of Padang, where rainfall is ample but unpredictable, and food resources are available throughout the year in patchily distributed habitats (Nakamura *et al.*, 1984; Abbas *et al.*, 1985; Inoue *et al.*, 1993). The present study indicates that all three epilachnine species (EM, EV and EN) studied in Bogor have prolonged reproductive schedules similar to those of the Sumatran species. These traits are also advantageous for living in the conditions of Bogor, predominated by a tropical rain forest climate, although Bogor has more seasonal rainfall compared to Padang (Nakamura *et al.*, 1994).

Although the number of replications was not large enough in both present and previous studies to compare the traits in detail, the following points should be noted: (1) Demographic traits of EV in Bogor were similar to those in Padang (Abbas *et al.*, 1985), e.g. duration of immature stages (22.1 days in Bogor vs. 23.4 in Padang), pre-reproductive period (9.6 days vs. 11.0), post-reproductive periods (4.1 days vs. 2.3), female longevity (59.3 days vs. 57.7) and mean length of a generation *T* (45.4 days vs. 47.6). In Bogor, however, fertility was lower (426.1 eggs per female vs. 770.7), resulting in a lower *r* value (0.118 vs. 0.125). (2) EM, a pest of a climbing weed in Bogor, tends to fly as actively as the species studied in Padang. Fertility of EM (650. 4) was as high as that of the species in Padang (ranged 651.9-770.7). Duration of immature stages of EM was longer than that of the Padang species (27.7 days vs. 22.5-23.4). (3) In EN, population density is low and adult seems to be sedentary (Nakamura, personal observation), which is somewhat different ecologically from other studied species.

EN was characterized by slow development (duration of immature stages was 29.5 days and *T* 62.7 days), low fertility (322.1 eggs per female), and a low *r* value (0.081). However, it should be noted that EN, collected in Cibodas, was reared in Bogor, where the temperate was approximately 6°C higher than the original habitat. This might cause an anomaly in the development and reproduction. EN should be reared under the same conditions as Cibodas.

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中村浩二，L. E. Pudjiastuti，片倉晴雄　**インドネシア共和国西ジャワ州ボゴールにおける食葉性テントウムシ３種の生存-繁殖スケジュール**

ボゴール周辺に分布する食葉性テントウムシ３種，*Epilachna vigintioctopunctata* Fabricius (以下EVと略す)，*E. enneasticta* Mulsant (EN)，*Epilachna* sp. 3 (EM) を実験室内で飼育して，生存-繁殖スケジュールを明らかにし，パダン産 (スマトラ西部州) の近縁種３種 (EVをふくむ) の結果とも比較した．

EVとENはナス科を食草とし，前者は日本産ニジュウヤホシテントウと同種である．EMは*E. emarginata*と類似の種で，キク科のツル草である*Mikania* sp.を食草とする．EVとEMは平地から海抜1400メートルまで分布する普通種であり，成虫の分散力は強い．ENは海抜500メートル以上にのみ分布しEVと共存するが，密度と成虫の分散力は，EVよりも低い．

１．卵から羽化までの発育日数は，22.1(EV)，27.7(EM)，29.5(EN) であった．

２．成虫の寿命 (日) は，オス60.4 (EV)，66.7 (EM)，69.9 (EN)，メス59.3 (EV)，73.6 (EN)，77.4 (EM) であった．

３．産卵前期間 (日) は，9.6(EV)，13.9 (EM)，15.9 (EN)，産卵終了から死亡までの日数は，4.1 (EV)，5.4 (EM)，5.6 (EN) であった．

４．１メスあたり産卵数は，322 (EN)，426 (EV)，650 (EM) であり，メスは，成熟してから死亡まで一定のペースで産卵し続けた．

５．世代期間 T (日) は，45 (EV)，58 (EM)，63 (EN)，内的自然増加率 r は，0.081 (EN)，0.100 (EM)，0.118 (EN) であった．