Res. Popul. Ecol. (1988) 30, 25–41.

POPULATION DYNAMICS OF THE PHYTOPHAGOUS LADY BEETLE, *EPILACHNA VIGINTIOCTOPUNCTATA*, IN AN EGGPLANT FIELD IN SUMATRA[1,2,3]

Koji NAKAMURA*, Idrus ABBAS** and Ahsol HASYIM**,[4]

*Ecological Laboratory, Faculty of Science, Kanazawa University, Kanazawa 920, Japan
**Department of Biology, Faculty of Science, Andalas University, Padang, Sumatera Barat, Indonesia

INTRODUCTION

The 28-spotted lady beetle, *Epilachna vigintioctopunctata* (FABRICIUS) (Evp) is a serious pest of solanaceous crops such as eggplants and potatoes over a broad geographical area from Japan (NAKAMURA, 1976a) to South Asia and Australia (RICHARDS, 1983; KALSHOVEN, 1981). Evp is one of the most abundant epilachnine pests in the Province of Sumatera Barat, Indonesia (KATAKURA et al., 1988). Since 1980 we have studied the biology, ecology and, in particular, the population dynamics of Evp and some allied species in Sumatera Barat (NAKAMURA et al., 1983). In preceding articles, we reported as follows: First, Evp and three other congeneric pests were recorded from Sumatera Barat with notes on the food plants they attacked and geographical distribution of each species in the surveyed area (KATAKURA, et al., 1988). Second, Evp in Sumatera Barat exhibited rich intraspecific variations in body size, shape and size of elytral and pronotal spots, color tone of elytra, melanization of ventral parts, etc. The geographical variation of elytral spot pattern that was most conspicuous among these variations was documented by ABBAS et al. (1988). Third, Evp is characterized by more prolonged longevity and fertility schedules under laboratory conditions than temperate species, including Japanese epilachnines (ABBAS et al., 1985, in which Evp was referred to as *Epilachna sparsa* like "species A").

From December, 1981 to December, 1982, a field population of Evp depending on eggplants was studied in Padang, Sumatera Barat by marking-recapture of adults and construction of a life table. Some detailed studies were conducted on the population ecology of Evp in Japan (e.g., NAKAMURA, 1976a, b, 1983; HIRANO, 1984, 1985a,

1. Contributions to the knowledge of population dynamics of phytophagous lady beetles in Sumatra 5.
2. Contribution No. 29 of Sumatra Nature Study (Entomology).
3. Partly supported by Grants from Japan Society for Promotion of Science for JSPS-DGHE Scientific Cooperation (1980, 1982) and Grants-in-Aid for Overseas Scientific Survey from Ministry of Education, Science and Culture of Japan (Nos. 56041027 and 58041030).
4. Present address: Sukarami Research Institute for Food Crops, P. O. Box 34, Padang, Sumatera Barat, Indonesia.

b); no quantitative studies have been carried out on the Indonesian Evp, however, despite its economic importance. The present article aims, firstly, to describe adult population parameters (e.g., daily survival rate, longevity, and sex ratio) and a life table; secondly, to document the elytral spot pattern variations in the population; and thirdly, to compare the demographic characteristics of Sumatran and Japanese species. Also indicated is the fluctuation of population size during the 1-year study period, with special attention given to the change in the frequency of elytral spot variations.

Materials and Methods

Climate

The study was carried out in eggplant fields at Lubuk Minturun (80 m alt.), a northern suburb of Padang city in the Province of Sumatera Barat from 10 December 1981 to 7 December 1982. Padang lies on the equator (0°53'S, 100°21'E), predominated by a tropical humid-equatorial climate: the mean monthly air temperature fluctuated only between 26.7 (September to December) and 27.5°C (May) and the annual rainfall was 4764 mm without a distinct alternation of wet and dry seasons (Ogino, 1984). Figure 1 shows the rainfall and temperate records at Tabing, 4 km SW of the study site, obtained by the Center for Meteorology and Geophysics (Ministry of Tourism, Post and Telecommunications of Indonesia). Annual rainfall in 1982 was 3755 mm, showing no prominent seasonal cycle during the study period (Fig. 1, top).

Study site

The main study field (9.5 m × 12.5 m) contained 91 eggplant plants, *Solanum melongena*, planted in mid November, 1981 (i.e., 3-4 weeks before the onset of the present study) and arranged in three furrows. The average height of the plants in this field increased from 43 cm to 250 cm throughout the study period (Fig. 1, bottom). The plant leaves were soft and fresh, although damaged by Evp during the first 3-4 months, but thenceforth they became tougher and were less suitable for Evp.

There were two additional eggplant fields in the vicinity: Fields A and B, both located 55 m east and 20 m SE of the main plot, contained 61 and 104 eggplant plants, respectively. The seedlings in A and B were planted after the onset of routine census for the main plot, i.e., in early January and early February, 1982, respectively. Unless specified, the plants described are those in the main field. Surrounding the study area were palm gardens, orchards, pastures and paddy fields. The orchards contained tree crops such as clove *Eugenia aromatica*, nutmeg *Myristica fragrans* and rambutan *Nephelium lappaceum*. Eggplants and *S. torvum*, an alternative host plant of Evp, were found sporadically on roadsides, fields and in gardens, but no such large clumps as in the study site were found within a radius of at least 500 meters from the study

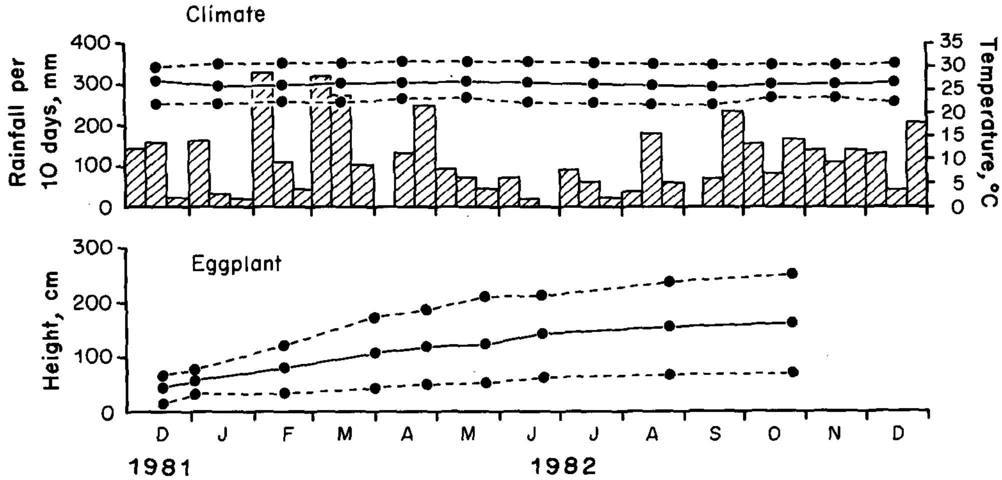

Fig. 1. Top: Meteorological data observed at Tabing, about 4 km SW of the study area (histogram: total amount of rainfall per 10 day period; line: mean, maximum and minimum monthly temperatures). Bottom: Changes in the mean (solid line), maximum and minimum (broken line) height of eggplants.

site. *S. torvum* is a perennial shrub-like weed, known as "rimbang" (Sumatera Barat) and "takokak" (Java) in local languages.

The routine census

Censuses were carried out at 4–7 day intervals from 10 December 1981 to 21 February 1982, and thenceforth weekly until 7 December 1982. A mark-recapture of adult beetles was carried out throughout the study period, but regular counting of immature stages from egg to adult emergence for construction of a life table was done only from 10 December 1981 to 21 February 1982.

1. Marking and recapture of adults: All beetles found were sexed and their elytral spot patterns recorded (see below); they were then individually marked with lacquer and immediately released on the same plant. The adult population parameters, such as survival rate and total number of beetles at each census were estimated using the JOLLY (1965)-SEBER (1973) method. Unless specified, the two sexes were collectively processed throughout the JOLLY-SEBER analysis, because in most cases the parameters estimated were not significantly different between the sexes.

2. Dispersal of adults: Fields A and B were examined less intensively at each census to record marked beetles dispersed from the main field from 13 February to 7 December 1982 (not surveyed from 22 June to 17 August).

3. Description of elytral spot patterns: Figure 7 shows the standard elytral spot pattern of epilachnine beetles: The basic pattern consists of six black "persistent" spots (1-6) on each elytron. This pattern may be modified by the addition of one to eight "non-persistent" spots (*a-h*) on each elytron, or by the enlargement and confluence of several spots (DIEKE, 1947). Individuals were classified according to the position of non-persistent spots, to the total number on each elytron, and to the type of confluences. For example, an individual with non-persistent spots "*agh*" is counted independently in columns *a, g,* and *h,* and is arranged in the "3 non-persistent spots" class.

4. Construction of life table: Eggs were laid in batches on the undersurface of the leaves, stems and flowers of the host plants. All egg masses were counted and labeled to prevent double counting. The total number of eggs laid was obtained by adding these data. The number of eggs hatched was assessed by counting the empty shells which remained after hatching. Eggs attacked by parasitic wasps developed black spots and then became dark. The eggs which remained unhatched and shriveled were categorized as "hatching failures" in the life table (Table 1). Egg cannibalism by adults and larvae was sometimes observed, but this could not be counted. The size of larvae in their early instars was so small that they could not be counted accurately; hence only 3rd and 4th instar larvae were counted. The number of *i*th instar larvae at the medial age of their instar (N_{Li}) was derived by S_{Li}/L_{Li}, where S_{Li} is the area enclosed by the seasonal prevalence curve and time axis (Fig. 12, top), and L_{Li} is the mean duration of the *i*th instar (SOUTHWOOD and JEPSON, 1962). L_{L3} and L_{L4} were 3.9 and 5.3 days at room temperature (ABBAS et al., unpublished), and this value was used to derive N_{Li}. All pupae were labeled to prevent double counting. Numbers of larvae and pupae attacked by parasitic wasps were assessed by a direct count of corpses which became dark and remained on the host plants. The total number of newly emerged adults was estimated by direct counting of pupal exuviae.

RESULTS

I. Ecology of adults

1. Estimation of population size, $\hat{N}_i$. Figure 2 shows the flucuations in the number of adults estimated by JOLLY-SEBER's formula ($\hat{N}_i$) and of those actually observed (n_i), indicating that Evp adults were found throughout the year in the equatorial climate of Padang. Sampling ratio ($n_i/\hat{N}_i$) fluctuated from 0.2 to 0.5, with a mean of 0.25, for most of the study period. Marking ratio was rather high, usually in the range from 0.4 to 0.9, with an average of 0.58. Seasonal change in adult population size was a gradual process with a peak in mid January (10 January, $\hat{N}_i=55.2$, $n_i=41$), a low in early March (9 March, $\hat{N}_i=12.0$, $n_i=5$), and a second peak in late April (20 April, $\hat{N}_i=84.5$; 27 April, $n_i=31$); thereafter the population size remained at a lower level with small peaks. In the two larger peaks, increase and decrease processes were gradual, each lasting about two months. The amplitude of fluctuation in the population size was 7-8 during the study period. A rise of population suggested by $\hat{N}_i$ in July-August, 1982, seems superifical, because observed numbers (n_i) in this period remained low and the standard errors for $\hat{N}_i$ were too large. All 15 beetles that were captured on 16 November, 1982 were accidentally killed, which caused a drop in $\hat{N}_i$ in this census.

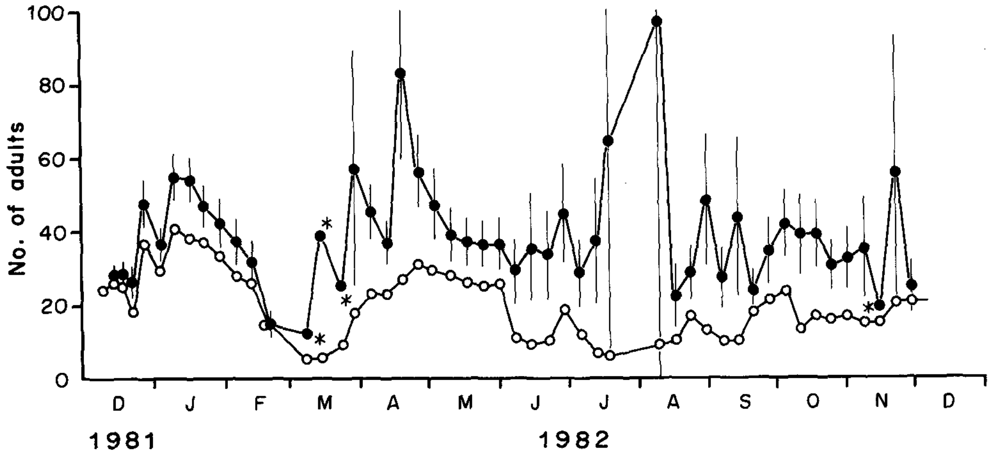

Fig. 2. Seasonal fluctuation in the number of *E. vigintioctopunctata* adults in the eggplant field. (○), the number of beetles observed (n_i); (●), the number of beetles estimated by the JOLLY-SEBER method ($\hat{N}_i$). Vertical line shows the standard error (*, no standard error was derived).

Without this accident, the population size would have been higher at the end of November-early December, 1982.

2. *Sex ratio.* A total of 202 males and 195 females were marked during the one year study period; there was no significant deviation from the expected 1:1 ratio (cf. χ^2-value=0.06 and $\chi^2_{p=0.05}=3.84$). The unity in the sex ratio was also confirmed by laboratory rearings, using leaves of rimbangs (ABBAS et al., 1985) and eggplants (ABBAS et al., unpublished) as food. Figure 3 shows the sex ratio in each census, which was derived by $\hat{N}_{Fi}/\hat{N}_i \times 100$, where $\hat{N}_{Fi}$ and $\hat{N}_i$ are the number of females and the total of females and males at *i*th census estimated by the JOLLY-SEBER formula. The sex ratio fluctuated around 50% with no clear seasonal trend.

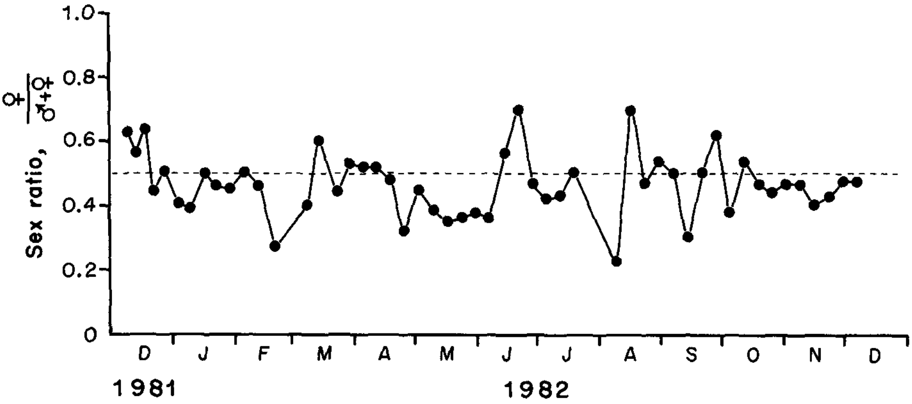

Fig. 3. Seasonal fluctuation in the sex ratio of *E. vigintioctopunctata* adults in the eggplant field. Broken line indicates the 0.5 level.

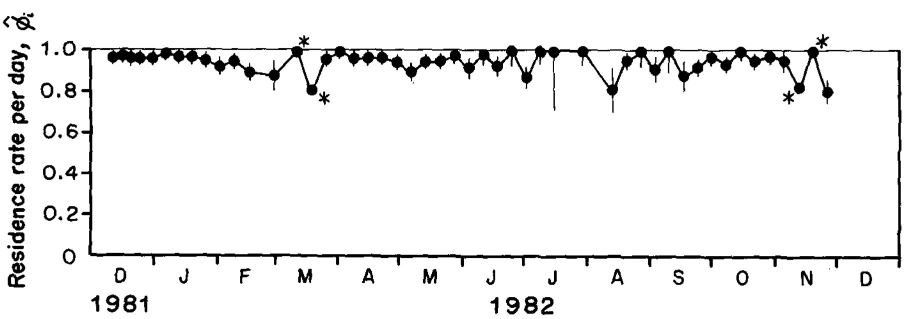

Fig. 4. Seasonal fluctuation in the daily residence rate ($\hat{\phi}_i$) of *E. vigintioctopunctata* adults estimated by the JOLLY-SEBER method. Vertical lines show the standard error (*, no standard error was derived).

3. *Daily rate of residence,* $\hat{\phi}_i$. The term "residence" instead of "survival" is used for $\hat{\phi}_i$ values derived by the JOLLY-SEBER formula, because the study site was small relative to the flying activity of the Evp adults. The value of $\hat{\phi}_i$ was more than 0.95 for the first two months of the study period, and then it fluctuated from 0.9 to 1.0 with some temporal drops to about 0.8 (Fig. 4). Drop of $\hat{\phi}_i$ was followed by decrease of $\hat{N}_i$ in January-February, late April-May, August, and November, 1982 (Fig. 4).

4. *Minimum length of residence time,* L_m. The minimum length of residence (L_m) was determined from the distribution of intervals between the first and last captures. In individuals which were captured only once, L_m was operationally treated as 0 day. In order to show the seasonal change in L_m, newly marked adults were totaled every month and change of monthly mean of L_m is plotted in Fig. 5. Monthly mean of L_m fluctuated from 10 to 25 days in most months with high values in June, 1982,

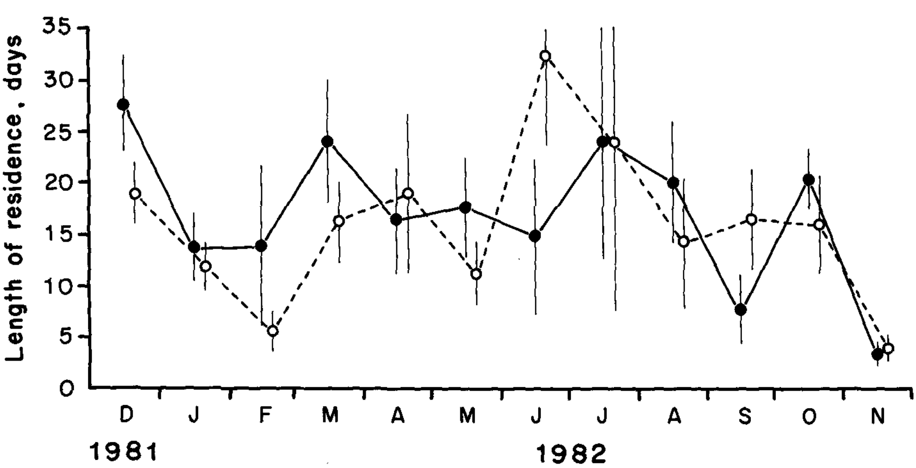

Fig. 5. Seasonal fluctuation in the monthly mean of the minimum lengths of residence time (L_m) of *E. vigintioctopunctata* adults. (●), male; (○), female. Vertical lines show the standard error.

(32.4 days, female), and in December, 1981 (28.0 days, male). L_m in November, 1982 may be greatly underestimated, because the study was concluded on 7 December, 1982. No significant difference in L_m values was detected between the sexes (Fig. 5).

The mean L_m for the one year study period was 16.5 days (male) and 15.2 (female) (Fig. 6). No significant difference in the mean L_m was detected between the sexes. Thirty-six and one-tenth percent of male adults and 37.4% of female adults were captured only once. The maximum L_m was 105 days in males and 133 days in females.

5. *Dispersal of marked adults.* Eleven males out of 202 (5.4%) and seven females out of 195 (3.6%), which were marked on the main field were found at A or B. Three beetles among these eighteen (16.7%) were later again rediscovered on the main field. Adults of Evp were so active that they frequently dropped off plants or flew away when the host plant was approached or slightly disturbed. The beetles had a much higher flight and dispersal activity than the allied or conspecific species that one of the authors (K. N.) studied in Japan (NAKAMURA, 1976a; NAKAMURA, 1983).

6. *Variation in elytral spot patterns.* Records of elytral spot patterns in adults were classified using the categories given in Fig. 7. Among adults marked during the year, 56.9% of male individuals and 39.0% of females had neither non-persistent spots nor confluence. The average number of non-persistent spots per elytron was 0.52 in males and 1.08 in females; non-persistent spots appeared more frequently in females than in males (significant at 0.5% level by KOLMOGOROV-SMIRNOV two sample test) (Fig. 8, top). The frequency of adults decreased monotonously with increase of total number of non-persistent spots on each elytron (0: male 73.8%, female 54.9%; 1: male 14.9%,

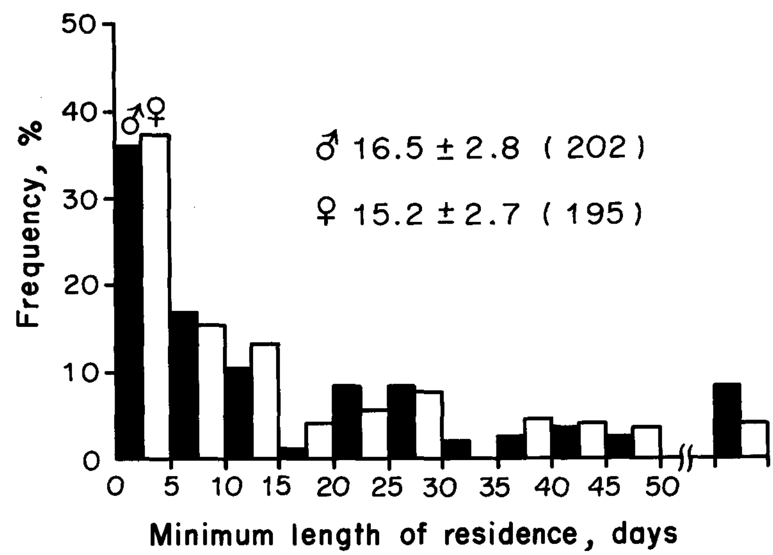

Fig. 6. Frequency distributions of the minimum lengths of residence time (L_m) of *E. vigintioctopunctata* adults in the eggplant field for the one year study period. Numerals show the mean ±95% confidence limits. Numbers of individuals examined are parenthesized.

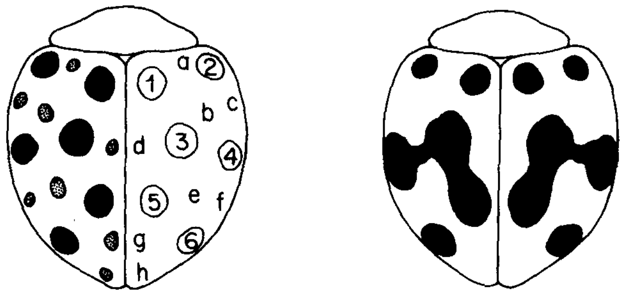

Fig. 7. Left: Standard elytral spot pattern of *E. vigintioctopunctata*, showing codes for persistent (1-6) and non-persistent (*a-h*) spots, modified from DIEKE, 1947. Right: the confluence of spots, exemplified by 4+3+5.

female 22.1%; 5<: male 3.2%, female 7.7%) (Fig. 8, top). Comparing non-persistent spots according to their positional codes, the most frequent spot was "*h*", appearing in 25.3% of males and in 43.1% of females. The most infrequent one was "*a*" which never occurred in this population. The relative frequency of non-persistent

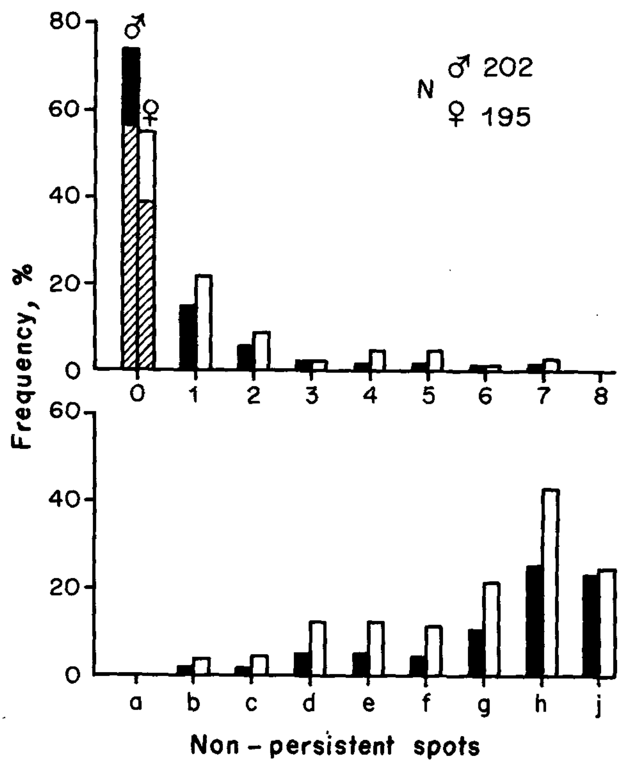

Fig. 8. Frequency distribution of elytral spot patterns in *E. vigintioctopunctata* adults in the eggplant field for the one year study period. Top: Total number of non-persistent spots per elytron. Shaded area shows the individuals with neither non-persistent spots nor confluence. Bottom: Positional codes of non-persistent spots; *j* shows confluence.

spots showed the following order in the two sexes: $h>g>f=e=d>c=b>a$ (Fig. 8, bottom). As to confluences, one was found in 22.3% of males and 24.1% of females; two in 1.0% of males and in 0.5% of females (Fig. 8, bottom, *j*). Frequent combinations of confluences detected were as follows:

Combinations	No. of individuals	Percentage
4-3-5	64	16.1
1-2	9	2.3
3-5	8	2.0
3-4	7	1.8
4-3-5-6	7	1.8
5-5	2	0.5
4-5	1	0.3
Total no. examined	397 (both sexes combined)	

Again there was no sexual difference in this aspect.

Combining all adults which appeared (=marked) every month, seasonal change in elytral spot patterns are presented in Figs. 9 and 10. Despite a 7-8 fold fluctuation in population size during the study period, the relative frequency of each spot type in terms of positional code of (Fig. 9) and total number per elytron of (Fig. 10) non-persistent spots was rather stable and no definite seasonal tendency was detected.

Finally, the minimum length of residence time, L_m, of adults marked during the

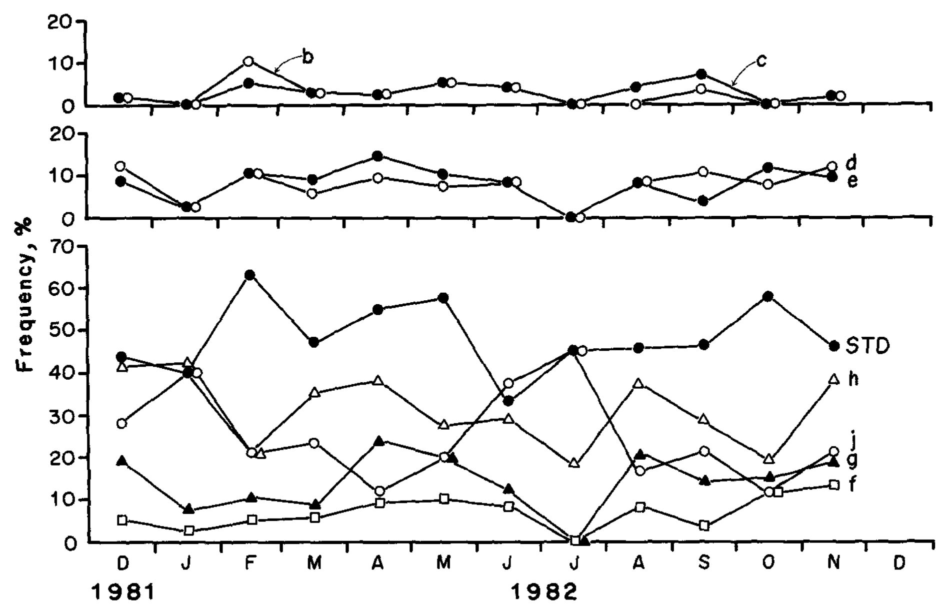

Fig. 9. Seasonal fluctuations in the frequency of *E. vigintioctopunctata* adults with different numbers of non-persistent spots on each elytron. *STD* indicates the individuals with neither non-persistent spots nor confluence. The frequency was calculated monthly.

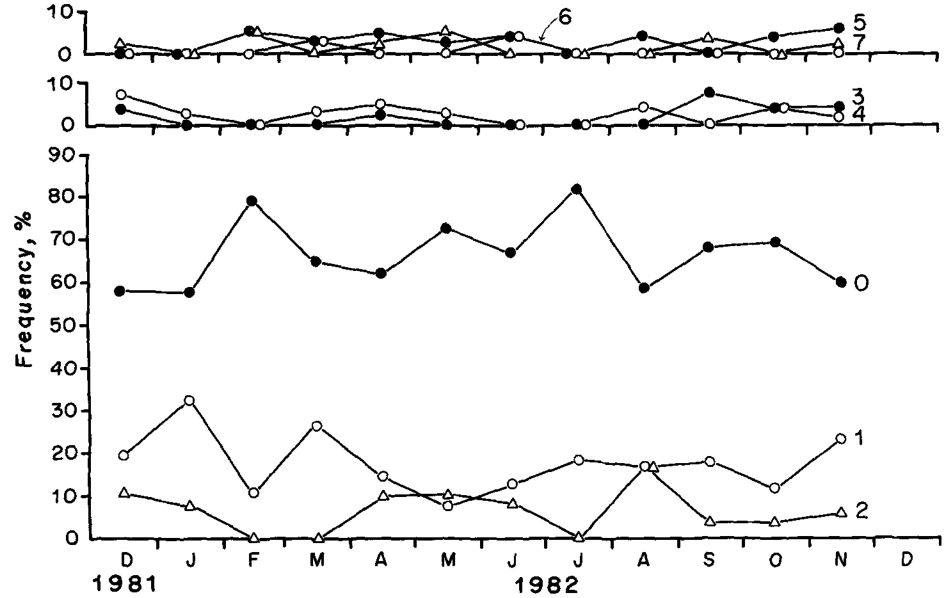

Fig. 10. Seasonal fluctuations in the frequency of *E. vigintioctopunctata* adults with non-persistent spots of different positional codes. The frequency was calculated monthly.

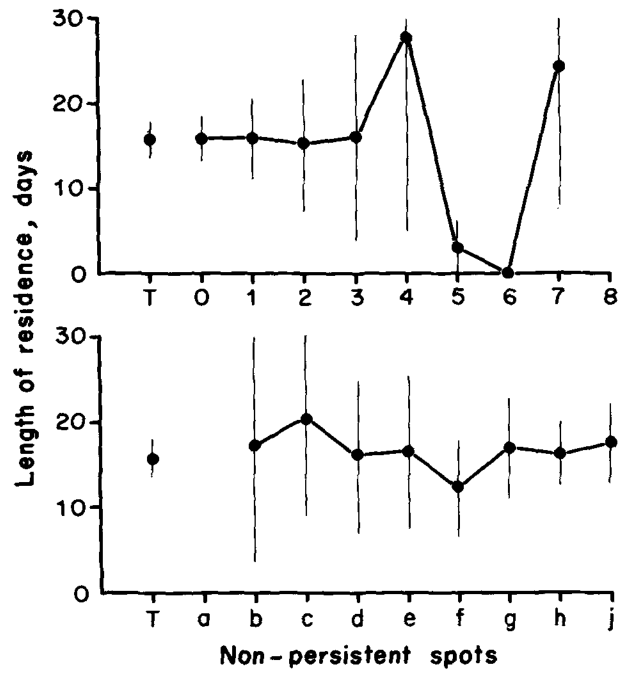

Fig. 11. Comparison of the minimum lengths of residence time (L_m) among different elytral spot patterns of *E. vigintioctopunctata* adults marked in the eggplant field for the one year study period. Top: Comparison by total number of non-persistent spots on each elytron. Botton: Comparison by positional codes of non-persistent spots. *T* indicates the total of the adults. Vertical lines show 95% confidence limits.

study period was compared among various spot patterns (Fig. 11). Adults of all types, either in number of non-persistent spots or in relative frequency in positional codes, had similar minimum residence time L_m (Fig. 11).

II. Ecology of immature stages

1. Seasonal fluctuation in the number of immatures. Figure 12 shows seasonal changes in the number of eggs laid per day, of 3rd and 4th instar larvae (top), of adults estimated by the JOLLY-SEBER formula, and of those newly marked at each census, with the ratio of tenerals (bottom). The number of eggs laid per day exhibited three peaks about 30 days apart (19 December, 1981; 17 January, 1982; 13 February, 1982). At the onset of the census on 10 December, 3-4 weeks after the planting of eggplant seedlings, there were only 1st to 3rd instar larvae on the plants and damage to the leaves was light. Therefore, the first peak of eggs (Fig. 12, top) must have been produced by adult colonizers. Judging from the sequence of the number of teneral adults (Fig. 12, bottom), the second and third egg peaks were probably caused by adults which emerged in the main field and started oviposition after the pre-reproductive period lasting 11 days (ABBAS et al., 1985). Despite the formation of three distinct peaks, the number of eggs per day reached 40 even during the valleys between the peaks (Fig. 12,

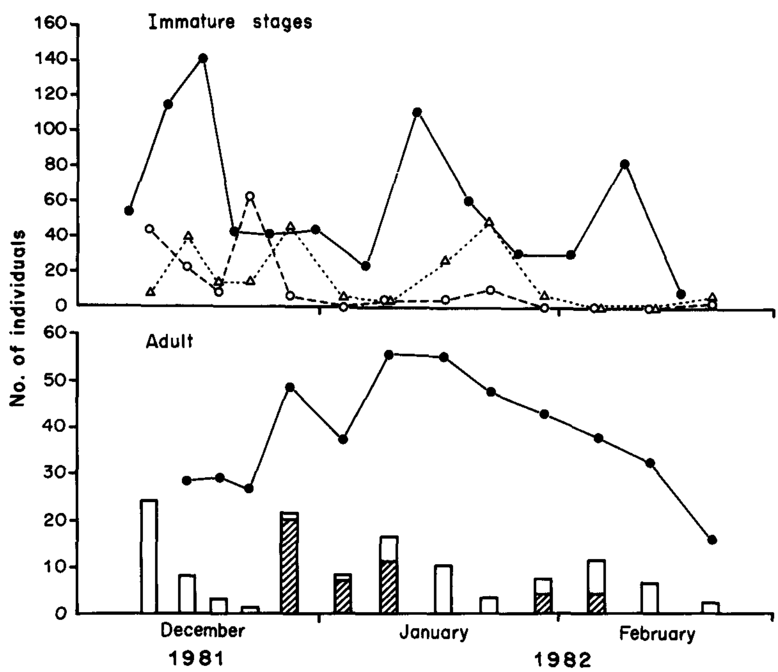

Fig. 12. Top: Seasonal changes in the number of immature stages of *E. vigintioctopunctata* in the eggplant field. (●), eggs laid per day; (○), 3rd instar larvae; (△), 4th instar larvae. Bottom: (●), seasonal change in the number of adults estimated by the JOLLY-SEBER method, $\hat{N}_i$. Histogram, seasonal change in the number of newly marked adults. Shaded area shows teneral ones.

top), and the number of adults did not exhibit a conspicuous peak (Fig. 12, bottom). These facts indicate a continuous immigration of adults to the site, though the number of immigrants gradually decreased with time.

2. *Life table.* The life table is shown in Table 1. Parasitized immatures were not particularly sampled in the study field, but they were continuously sampled for a three year period (1982 to 1985) from an Evp population feeding on the rimbang *S. torvum* in Ulu Gadut, 13 km NE of the present study site (manuscript in preparation). The parasites identified from the Ulu Gadut population were: *Tetrastichus* sp. B from eggs and *Tetrastichus* sp. C and *Pediobius foveolatus* (CRAWFORD) from larvae and pupae, all belonging to Eulophidae.

Egg: The egg mass size was 32.2±2.4 (mean±95% confidence limits, $n=100$), ranging 5 to 65. The ratios of hatching, parasitism by wasps and predation were 24.5,

Table 1. Life table of *E. vigintioctopunctata* in the eggplant field at Lubuk Minturun, Padang, from December, 1981 to February, 1982.

Age class	Mortality factor	No.	No. dying	% dying	LX[1]
Egg		4498.0			1000.00
	Parasitic wasps[2]		437.0	9.7	
	Hatching failures		1190.0	26.5	
	Predation		400.0	8.9	
	Disappearance		1347.0	29.9	
	Unknown		24.0	0.5	
	Total		3398.0	75.5	
Larva hatched		1100.0			244.55
	Unknown		924.2	84.0	
3rd instar		175.8			39.08
	Parasitic wasps		0.0	0.0	
	Unknown		—	—	
	Total		—	—	
4th instar		223.7			49.73
	Parasitic wasps		1.0	0.4	
	Unknown		202.7	90.6	
	Total		203.7	91.0	
Pupa		20.0[3]			4.45
	Parasitic wasps		7.0	35.0	
	Predation		2.0	10.0	
	Disappearance		10.0	50.0	
	Total		19.0	95.0	
New adult		1.0 (47)[4]			0.22 (10.45)

[1] LX: % survival in terms of eggs laid.

[2] List of parasitic wasps collected at Ulu Gadut, 13 km NE of the study site, was presented in the text.

[3] Total no. found.

[4] Total no. of teneral adults marked.

9.7 and 8.9%, respectively. Some arthropods such as entomophagous coccinellids, both larvae and adults, ants and spiders which were numerous on the host plants were most suspect as egg predators. The coccinellids abundant in the study field were: *Menochilus sexmaculatus* (FABRICIUS), *Lemnia bisellata* (MULSANT), *Coelophora inaequalis* (FABRICIUS), and *Chilocorus melanophthalmus* (MULSANT).

Larva: The ratio of parasitism was negligible (absent in 3rd instar, only one individual in 4th instar). Two mortality factors of probable importance were (1) the arthropod predators like the coccinellids, ants and spiders, and (2) a shortage of food as suggested by a number of defoliated plants, although this was not quantitatively measured.

Pupa: only 20 pupae were discovered but a total of 47 tenerals was marked, indicating that many individuals pupated apart from the plants. Among the 20 pupae, seven (35%) were parasitized and two eaten by unidentified predators. Only one pupal exuvia was confirmed (Table 1). The total number of teneral adults was used as the minimum estimate of the total of those newly emerged, though, again, this value might have been underestimated (Table 1).

DISCUSSION

1. Colonization in newly formed habitats as a reproductive strategy of Evp in Sumatra

In and near Padang, eggplants are usually cultivated in small fields, each of which is settled and replaced with a cycle of about 5–6 months. Rimbangs are found only sporadically and aged ones are readily removed. These host plants are found throughout the year in larger habitat units, but their availability is variable in both time and space on a smaller scale. ABBAS et al. (1985) showed that the mean longevity of an Evp female was 87.6 days. After a pre-reproductive period (11.0 days), the females laid eggs at a nearly constant rate throughout their reproductive period (post-reproductive period lasted only 2.3 days). This prolonged reproductive schedule and the high dispersal tendency of Evp in Padang are certainly advantageous in exploiting the patchily distributed food plants.

The present study documents the sequence of population growth of Evp in a newly formed habitat: In the initial phase, a newly settled field was heavily colonized by adult immigrants, which oviposited massively soon after their arrival (Fig. 12). A first peak of oviposition was achieved by them and a second and third peaks by their descendants (Fig. 12). Despite the gradual growth of host plants (Fig. 1, bottom), the height of oviposition peaks successively decreased (Fig. 12, top), certainly due to intensified defoliation accompanied by the rapid population increase during the 1–2 months after planting. Thereafter, the multiplication rate of Evp dropped due to serious defoliation. Three to four months later, the plants recovered their leaves, but the leaves were tough or hairy, probably making them unappealing to Evp. This is indicated by the low population level after the peak in April, 1982 (Fig. 2), though the detailed process is unknown as counting of immatures was stopped on February 21, 1982.

ABBAS and NAKAMURA (1985a) studied the population dynamics of *E. septima* (=*E. sparsa* like "sp. C"), feeding on bitter cucumber, *Momordica charantia*. Demographic traits of *E. septima*, which is also an exploiter of patchily distributed food plants, were similar to those of Evp mentioned in this article: Adults had a prolonged l_x-m_x schedule (NAKAMURA et al., 1984) with active dispersal tendency, and immature stages suffered from a high diversity and level of wasp parasitism.

2. Comparison of demographic traits between Evp populations in Sumatra and Japan

NAKAMURA (1976a) constructed life tables of Evp in Kyoto, Japan, where it had two generations a year and frequently reached a level where serious defoliation occurred. Evp in Japan and in Padang exhibited similar demographic traits as a pest of crops, but the two were quite different in the diversity and levels of parasitism. Evp in Padang had three species of parasites, which killed a substantial portion of individuals in the egg and pupal stages (Table 1). In contrast, Evp in Japan had no egg parasite and only a small percentage of 4th instar larvae and pupae were attacked by *Pediobius foveolatus*. HIRANO (1984) who studied Evp populations in Nagoya in central Japan confirmed this low level of parasitism by *P. foveolatus*.

3. Elytral spot pattern variation in the Evp population

Rich intraspecific variations in elytral spot patterns have been reported in epilachnines in Indonesia (e.g., DIEKE, 1947; KALSHOVEN, 1981; ABBAS and NAKAMURA, 1985b) and in Australia (RICHARDS, 1983). Populations of Evp in the Province of Sumatera Barat were divided into four major groups (I–IV) by the incidence of non-persistent spots and confluences (ABBAS et al., 1988). Western coastal plains centered around Padang were recognized as Group II, in which non-persistent spots were absent in about 60% of the specimens and 20–30% had confluence(s), as found in the study field. In and near Padang, Evp populations in adjacent localities were similar in the vairation trends of their spot patterns (Fig. 5 in ABBAS et al., 1988).

The average number of non-persistent spots per elytron was positively related with the elevation of sample sites when all four groups were combined, though the relation was not clear-cut when examined within each group (ABBAS et al., 1988). This fact suggests the environmental determination of spot patterns. On the other hand, crossing experiments showed that the frequencies of Evp adults with a spot pattern the same as that of their parents distinctly increased by selective mating, suggesting the participation of genetic factors in the spot determination (ABBAS and NAKAMURA, in prep.). At present, it seems probable that both environmental and genetical factors are responsible for determination of elytral spot variations in Evp as in many species of coccinellids (see literature cited in ABBAS et al., 1988). The present study found no direct links between various spot types of Evp and ecological factors: Firstly, despite a 7-8 fold fluctuation in population size during the study period, no seasonal trend was found in the relative frequency of a single spot type (Figs. 9 and 10). Secondly, adults of all spot types had a similar minimum residence time (Fig. 11). In laboratory rearings of Evp adults with different spot patterns no conspicuous difference was recognized among the spot types in their l_x-m_x schedules such as duration of immature stages, adult longevity, or total number of eggs produced per female (ABBAS and NAKAMURA, in prep.). The relation of spot pattern variations to ecological characteristics like fertility, longevity and dispersal tendency remains to be studied under field and laboratory conditions.

SUMMARY

From December, 1981 to December 1982, the population dynamics of the phytophagous lady beetle *Epilachna vigintioctopunctata* (FABRICIUS) (Evp) was studied by mark-recapture of adults and the construction of a life table in an eggplant field in Padang, Sumatra, Indonesia.

(1) After planting of the host plants, adults of Evp soon colonized and oviposited massively, resulting in a rapid population growth for 1-2 months; thereafter, the population increase slowed due to defoliation. Three—four months thereafter the host plants recovered their leaves, but leaf quality was less suitable for Evp and, as a result, the population remained at a low level during the rest of the study period. Adult population size fluctuated 7-8 fold during the study period.

(2) Adult Evp showed a 1:1 sex ratio.

(3) The daily rate of residence, ϕ_i, derived by the JOLLY-SEBER formula fluctuated from 0.9 to 1.0.

(4) The estimated mean length of residence of adults was 16.5 days (male) and 15.2 (female), but this was probably much shorter than the actual longevity, because the adults were so active that they flew away or dropped off the plants when they were approached or were slightly disturbed.

(5) Adults showed a rich variation in elytral spot patterns. The average number of non-persistent spots per elytron was 0.52 in males and 1.08 in females; 23.3% of males and 24.6% of females had confluence(s).

(6) The life table shows that parasitism by wasps, which killed 9.7% of eggs and 35.0% of pupae, and starvation by overcrowding contributed most to the total mortality from egg to adult emergence (>98%).

(7) The high dispersal power of adults, coupled with their prolonged l_x-m_x schedules was advantageous for exploiting food plants which were variable in space and time.

ACKNOWLEDGMENTS: We thank all the members of the Sumatra Nature Study, in particular Profs. S. KAWAMURA (Kyoto University), R. OHGUSHI (Kanazawa University) and Dr. A. BAKER (Andalas University) for their encouragment. We are grateful to Prof. Sh. F. SAKAGAMI (Hokkaido University) for his critical reading of an early draft of this manuscript, to Dr. H. SASAJI (Fukui University) for identification of the coccinellids, and to Dr. K. KAMIJO (Hokkaido Forest Experiment Station) for identification of the parasitic wasps. We are indebted to Mr. M. KAWAMOTO for drawing the figures in this article and to Mr. K. MUKAI for devising the study apparatus (Kanazawa University).

REFERENCES

ABBAS, I. and K. NAKAMURA (1985a) Variation of elytral spot patterns in a field population of lady beetle *Epilachna* aff. *sparsa* (Coleoptera: Coccinellidae) feeding on bitter cucumber in Sumatra. *Sci. Rep. Kanazawa Univ.* **30**: 27–32.

ABBAS, I. and K. NAKAMURA (1985b) Adult population parameters and life tables of an epilachnine beetle (Coleoptera: Coccinellidae) feeding on bitter cucumber in Sumatra. *Res. Popul. Ecol.* **27**: 313–324.

ABBAS, I., K. NAKAMURA and A. HASYIM (1985) Survivorship and fertility schedules of a Sumatran epilachnine 'species' feeding on *Solanum torvum* under laboratory conditions (Coleoptera: Coccinellidae). *Appl. Ent. Zool.* **20**: 50–55.

ABBAS, I., K. NAKAMURA, H. KATAKURA and H. SASAJI (1988) Geographical variation of elytral spot patterns in the phytophagous ladybird, *Epilachna vigintioctopunctata* (Coleoptera: Coccinellidae) in the Province of Sumatera Barat, Indonesia. *Res. Popul. Ecol.* **30**: 43–56.

DIEKE, G. H. (1947) Ladybeetles of the genus *Epilachna* (sens. Lat.) in Asia, Europe and Australia. *Smithsonian Misc. Coll.* **106**: 1–183.

†HIRANO, K. (1984) Population dynamics of a phytophagous lady beetle *Henosepilachna vigintioctopunctata* (FABRICIUS), living in spatio-temporally heterogeneous habitats. *Doctor's Thesis, Faculty of Agriculture, Nagoya University.*

*HIRANO, K. (1985a) Study on the movements of the 28-spotted lady-beetle, *Henosepilachna vigintioctopunctata* by the mark-recapture method. *Jpn. J. Appl. Ent. Zool.* **29**: 7–13.

HIRANO, K. (1985b) Population dynamics of a phytophagous lady-beetle, *Henosepilachna vigintioctopunctata* (FABRICIUS), living in spatio-temporally heterogeneous habitats. I. Estimation of adult population parameters based on a capture-recepture census. *Res. Popul. Ecol.* **27**: 159–170.

JOLLY, G. M. (1965) Explicit estimates from capture-recepture data with both death and immigration. *Biometrika* **52**: 225–247.

KALSHOVEN, L. G. E. (1981) *Pests of crops in Indonesia* (P. A. VAN DER LAAN, rev. and transl.). P. T. Ichtiar Baru-Van Hoeve, Jakarta.

KATAKURA, H., I. ABBAS, K. NAKAMURA and H. SASAJI (1988) Records of epilachnine crop pests (Coleoptera, Coccinellidae) in Sumatera Barat, Sumatra, Indonesia. *Kontyû* **56**: 281–297.

*NAKAMURA, K. (1976a) Studies on the population dynamics of the 28-spotted lady beetle, *Henosepilachna vigintioctopunctata* F. I. Analysis of life table and mortality process in the field population. *Jap. J. Ecol.* **26**: 49–59.

*NAKAMURA, K. (1976b) Studies on the population dynamics of the 28-spotted lady beetle, *Henosepilachna vigintioctopunctata* F. II. Analysis of regulatory system under semi-natural and laboratory conditions. *Jap. J. Ecol.* **26**: 125–134.

NAKAMURA, K. (1983) Comparative studies on population dynamics of closely related phytophagous lady beetles in Japan. *Res. Popul. Ecol. Suppl.* **3**, 46–60.

NAKAMURA, K., I. ABBAS and A. HASYIM (1983) Population dynamics of some phytophagous lady beetles in Sumatera Barat. 57–62. In R. OHGUSHI (ed) *Ecological study on social insects in central Sumatra with special reference to wasps and bees*. Sumatra Nature Study (Entomology), Kanazawa.

NAKAMURA, K., I. ABBAS and A. HASYIM (1984) Survivorship and fertility schedules of two epilachnine 'species' feeding on cucurbitaceous plants under laboratory conditions (Coleoptera: Coccinellidae). *Appl. Ent. Zool.* **19:** 59–66.

OGINO, K. (1984) General introduction. 1–9. In M. HOTTA (ed) *Forest ecology and flora of G. Gadut, West Sumatra*. Sumatra Nature Study (Botany), Kyoto.

RICHARDS, A. M. (1983) The *Epilachna vigintioctopunctata* complex (Coleoptera: Coccinellidae). *Intern. J. Entomol.* **25:** 11–41.

SEBER, G. E. F. (1973) *The estimation of animal abundance and related parameters*. Griffin, London.

SOUTHWOOD, T. R. E. and W. F. JEPSON (1962) Studies on the populations of *Ocinella frit* L. (Dipt.: Chloropidae) in the oat crop. *J. Anim. Ecol.* **31:** 481–495.

(†, in Japanese; *, in Japanese with English summary)

スマトラのナス畑におけるニジュウヤホシテントウムシの個体群動態

中 村 浩 二・Idrus ABBAS・Ahsol HASYIM

スマトラ島パダン市のナス畑において，1981年12月から1982年12月までの1年間，ニジュウヤホシテントウ (*Epilachna vigintioctopunctata* FABRICIUS) の個体群動態を成虫の標識再捕と生命表作成により調査した．

1. ナスを植栽すると成虫がすぐに飛来し，大量に産卵したので，最初の1－2カ月は急速に個体群が増殖したが，その後ナスが激しく食害されたので増加率は抑えられた．さらに3－4カ月たつと，ナスは回復したが葉が堅く多毛になり餌として不適になったので，個体群は低い密度にとどまり続けた．調査期間中の成虫個体群サイズの変動幅は7－8倍であった．

2. 成虫の性比は1：1であった．

3. JOLLY 法により推定した日当り生存率（調査地内滞留率）は0.9–1.0であった．

4. 初めてマークした日と最後に再捕した日の間隔から求めた滞留日数（調査地内）は，16.5日（雄成虫），15.2日（雌成虫）であった．成虫の分散力に比して調査地が狭かったので，これらは過小評価であろう．

5. 成虫の鞘翅斑紋は非常に変異に富んでいた．片翅 (elytron) あたり6個の「常在斑紋 persistent spots」のほかに，平均0.52個（雄成虫），1.08個（雌成虫）の「非常在斑紋 non-persistent spots」が出現した．雄成虫の23.3％，雌成虫の24.6％に「斑紋結合 confluences」がみられた．

6. 生命表によれば，卵から羽化までの死亡率（＞98％）の主要因は，寄生蜂（卵と蛹の死亡率のそれぞれ9.7％，35.0％を占める）と餌の食いつくしによる餓死であった．

7. 調査地周辺では，食草は場所を変えながら小規模に1年中存在している．成虫の強い分散力と長い寿命の末期まで一定のペースで産卵し続ける性質は，このような餌を利用するのに有利であろう．