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# FACTORS AFFECTING BODY SIZE VARIATION WITHIN A POPULATION OF AN HERBIVOROUS LADY BEETLE, *HENOSEPILACHNA NIPONICA* (LEWIS)

Takayuki OHGUSHI

Entomological Laboratory, College of Agriculture, Kyoto University, Kyoto 606, Japan

## INTRODUCTION

Considerable attention has recently focused on the importance of individual differences to population dynamics (e.g., ŁOMNICKI, 1978, 1980; HASSELL and MAY, 1985; SMITH and SIBLY, 1985). Size variation is considered to be the most important and widespread form of individual variation within a population (BEGON, 1984).

*Henosepilachna niponica* is a univoltine thistle-feeding lady beetle. OHGUSHI (1986) suggested that adult mortality during the period from emergence to reproductive age in the next spring is size dependent. This implies that adult size is a significant fitness component for the lady beetle. Detailed analysis of adult size variation is, therefore, necessary for fully understanding population processes of the lady beetle.

This paper reports the size variation and timing of emergence of adult beetles emerging from different thistle plants, and examines possible factors causing size variation of adult beetles within a population.

## STUDY AREA

This study was conducted at two study sites (sites A and F) situated in different valleys along the River Ado in central Japan (OHGUSHI and SAWADA, 1981). Further descriptions of the two study sites are given in OHGUSHI and SAWADA (1985).

## MATERIALS and METHODS

In this study area, *H. niponica* feeds exclusively on leaves of a thistle, *Cirsium kagamontanum* (NAKAI). Overwintering adult females start to lay eggs in clusters on the undersurface of thistle leaves in early May; the oviposition period sometimes extends up to three months to mid-August. Larvae pass through four instars. New adults emerge from early July to early September. They enter hibernation by early November. Seasonal occurrences of adult and immature beetles are given in OHGUSHI and SAWADA (1981, 1984).

Beetles were censussed at intervals of 1 to 3 days from early May to early November,

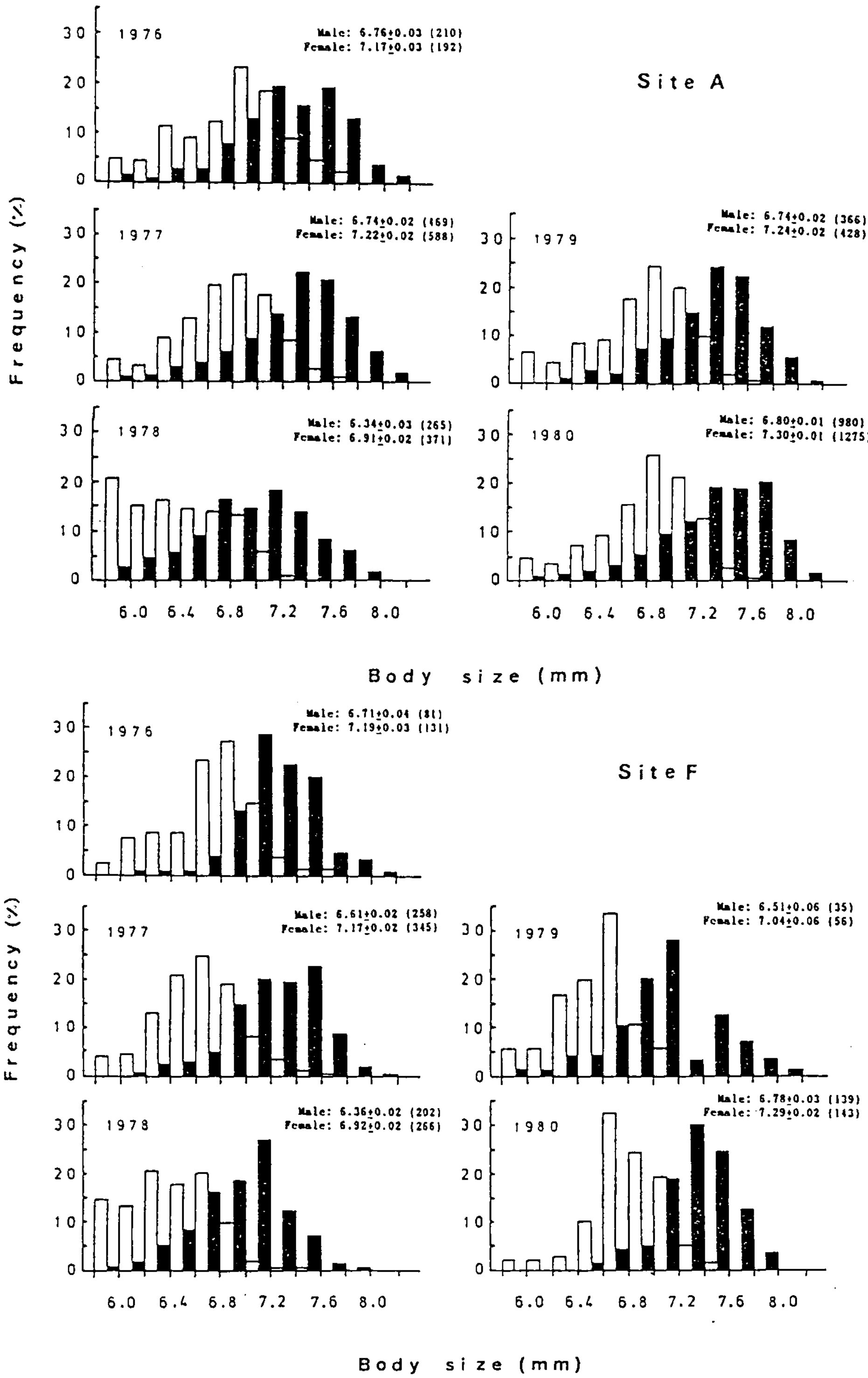


Fig. 1. Frequency distributions of adult size at site A (upper) and site F (lower) for 1976–80. Open and closed bars show males and females, respectively. Numerals in figures are means ± S.E. and number of adults examined (in parentheses).

for the 5 years of the study, 1976–80. All the adult beetles found on every census date were marked individually with lacquer paint. Sex, body size and capture history (date and place) were recorded for individual beetles. Body size from the anterior edge of the head to the posterior edge of the elytra was measured to the nearest 0.05 mm using vernier calipers. In addition, on every census I carried out visual estimation of leaf damage of individual plants by adults and larvae, and each thistle plant was classified into one of ten categories based on the proportion of the leaf area eaten.

## Results

### 1. *Adult size variation within a population*

Frequency distributions of body sizes of adult beetles emerging at sites A and F for 1976–80 are shown in Fig. 1. In general, females are conspicuously larger than males (differences in mean size are significant at $P<0.0001$). In both sexes body size varied considerably among individual adults within a population in every year.

### 2. *Annual changes in body size*

Annual changes in mean body size at sites A and F are shown in Fig. 2. During the 5 year course of the study, mean adult size ranged from 6.3 to 6.8 mm in males at site A; from 6.4 to 6.8 mm in males at site F and from 6.9 to 7.3 mm in females at both sites. Changes in body size over the 5 years were very similar at the two sites, which differed only in 1979.

### 3. *Size variation among adults from different plants*

The relationships between mean body size and leaf damage of the thistle plants on which the beetles developed are shown in Figs. 3A-B. Mean body size apparently declined

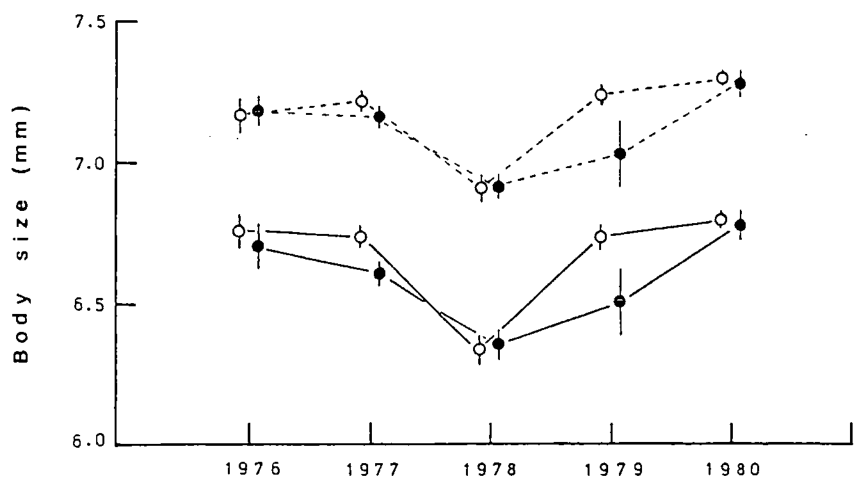


Fig. 2. Annual changes in mean adult size at site A (○) and site F (●). Solid and dashed lines show males and females, respectively. Vertical bars show 95% confidence limits.

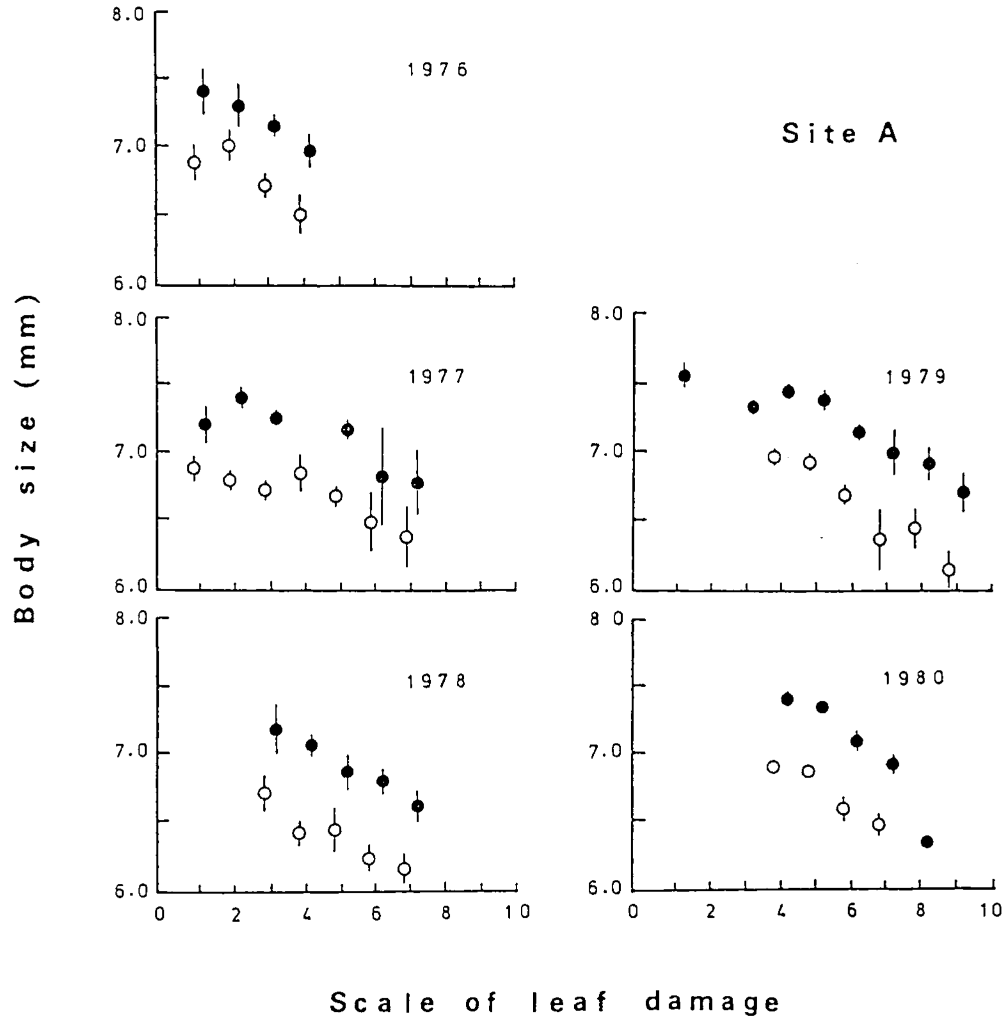


Fig. 3A. Relationships between mean body size and leaf damage of thistle plants on which adults emerged at site A. Open and closed circles show males and females, respectively. Each plant was put into one of ten categories on the basis of a visual estimate of how many tenths of the leaf surface was damaged in late June.

with increasing leaf damage. In other words, beetles of both sexes which developed on plants with serious leaf damage due to beetle feeding were significantly smaller as adults than those on less damaged plants. The two variables showed a significant negative relationship in every year at both of the two sites (Table 1). It should be also noted that the reduction of adult size was found even at lower levels of leaf damage, when a number of leaves remained uneaten.

4. *Size variation among adults emerging at different times*

Now, let us examine body size of new adults emerging at different times of the season. Table 2 shows the results of a linear regression of adult body size on the dates

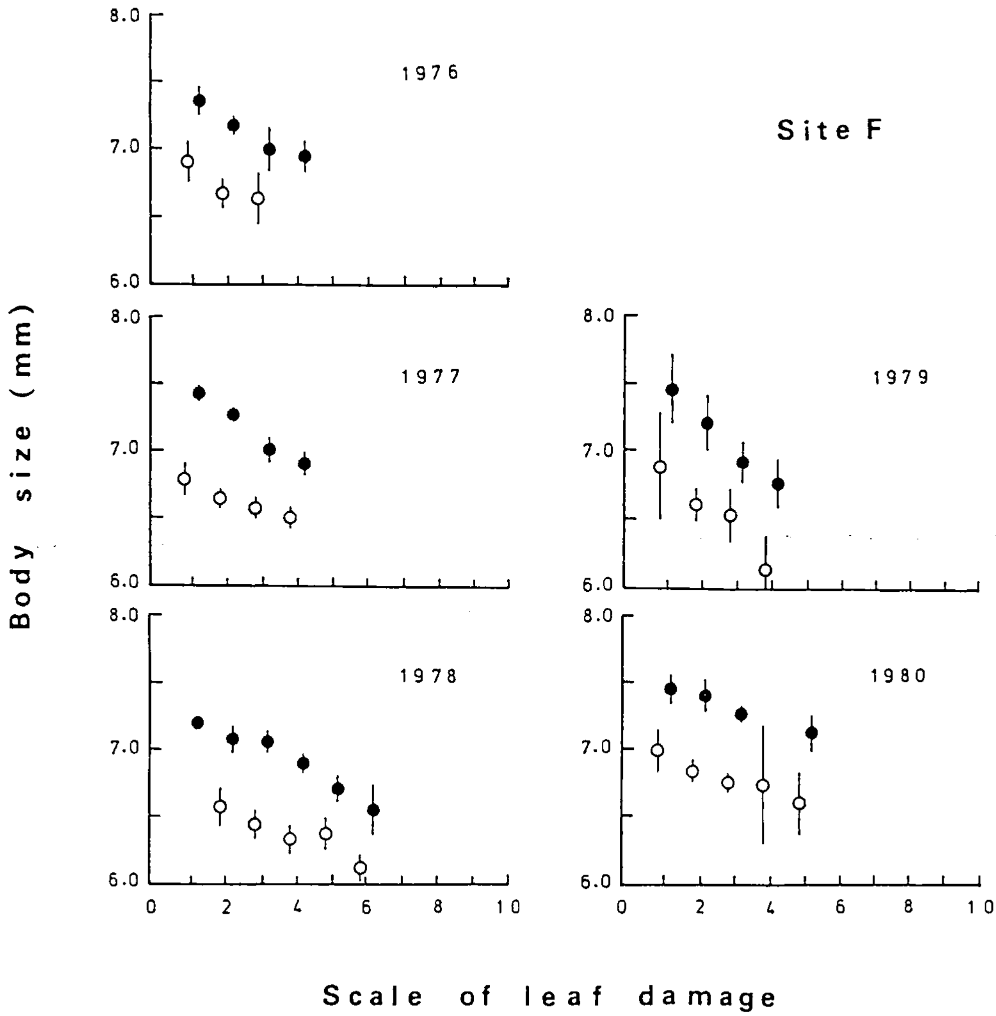


Fig. 3B. Relationships between mean body size and leaf damage of thistle plants on which adults emerged at site F. See Fig. 3A for further details.

on which they emerged. Body size of both sexes was negatively related to the date of emergence; adults emerging later in the season were small compared to those emerging early in the season. This was particularly clear at site A where leaf damage of thistle plants was intensified due to higher larval density.

## Discussion

The present study clearly demonstrated that body size of newly-emerged adults in *H. niponica* sharply declined with increasing leaf damage of the individual plants from which they emerged, which suggests that the most probable cause of small adults is unfavourable food conditions during larval period. This relationship is also supported

Table 1. Results of linear regression analysis of adult body size (mm) on leaf damage of thistle plants. *b* is slope of regression.

| Year | Sex | Site A | | | | Site F | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *N* | *b* | $r^2$ | *P* | *N* | *b* | $r^2$ | *P* |
| 1976 | Male | 208 | −0.29 | 0.09 | 0.0001 | 68 | −0.28 | 0.11 | 0.0059 |
| | Female | 184 | −0.31 | 0.11 | 0.0001 | 118 | −0.35 | 0.17 | 0.0001 |
| 1977 | Male | 449 | −0.13 | 0.07 | 0.0001 | 248 | −0.17 | 0.06 | 0.0002 |
| | Female | 567 | −0.15 | 0.06 | 0.0001 | 333 | −0.37 | 0.27 | 0.0001 |
| 1978 | Male | 238 | −0.22 | 0.10 | 0.0001 | 191 | −0.17 | 0.08 | 0.0001 |
| | Female | 339 | −0.29 | 0.15 | 0.0001 | 254 | −0.30 | 0.18 | 0.0001 |
| 1979 | Male | 352 | −0.28 | 0.31 | 0.0001 | 35 | −0.47 | 0.44 | 0.0001 |
| | Female | 411 | −0.27 | 0.32 | 0.0001 | 56 | −0.51 | 0.38 | 0.0001 |
| 1980 | Male | 955 | −0.31 | 0.13 | 0.0001 | 134 | −0.19 | 0.10 | 0.0003 |
| | Female | 1253 | −0.35 | 0.13 | 0.0001 | 134 | −0.19 | 0.13 | 0.0001 |

Table 2. Results of linear regression analysis of adult body size (mm) on date of emergence. *b* is slope of regression.

| Year | Sex | Site A | | | | Site F | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *N* | *b* | $r^2$ | *P* | *N* | *b* | $r^2$ | *P* |
| 1976 | Male | 208 | −0.017 | 0.09 | 0.0001 | 68 | −0.010 | 0.17 | 0.0005 |
| | Female | 184 | −0.014 | 0.06 | 0.0012 | 118 | −0.003 | 0.01 | 0.2067 |
| 1977 | Male | 449 | −0.006 | 0.04 | 0.0001 | 248 | −0.007 | 0.04 | 0.0017 |
| | Female | 567 | −0.008 | 0.06 | 0.0001 | 333 | −0.008 | 0.06 | 0.0001 |
| 1978 | Male | 238 | −0.009 | 0.03 | 0.0076 | 191 | −0.006 | 0.02 | 0.0377 |
| | Female | 339 | −0.013 | 0.04 | 0.0002 | 254 | −0.008 | 0.05 | 0.0005 |
| 1979 | Male | 352 | −0.018 | 0.09 | 0.0001 | 35 | −0.002 | 0.01 | 0.6905 |
| | Female | 411 | −0.011 | 0.05 | 0.0001 | 56 | −0.009 | 0.03 | 0.1844 |
| 1980 | Male | 955 | −0.009 | 0.06 | 0.0001 | 134 | −0.003 | 0.04 | 0.0198 |
| | Female | 1253 | −0.010 | 0.07 | 0.0001 | 134 | −0.002 | 0.02 | 0.1270 |

by the fact that adult beetles emerging late in the season, with a deteriorating larval food supply, were smaller than those early in the season (see Table 2). Furthermore, the seasonal decrease in adult size was particularly clear at site A where many thistle plants were highly exploited (OHGUSHI, 1986). The importance of larval food availability as a possible factor determining adult size is similarly reported in some other insects in the field (e.g., DANTHANARAYANA, 1976; EVANS, 1982; DEMPSTER, 1982; PALMER, 1984).

Food deterioration, expressed as leaf damage by beetle feeding, involves not only immediate shortage of available leaves but also poor quality of thistle leaves. MYERS and POST (1981) showed an effect of food quality, measured by leaf nitrogen content, on pupal size of cinnabar moth *Tyria jacobaeae*. Water and amino acid contents in thistle leaves in fact are low in plants with a heavy herbivore load compared to undamaged ones, and decline throughout the season (OHGUSHI, 1986). However, the relative importance of quality and quantity of food resources, in determining adult size, is unclear.

Some authors have suggested that high temperature during the larval period produces smaller adults because of shortened larval development (DANTHANARAYANA, 1976; WOOL, 1977; but see PALMER, 1984). The small 1978 adults at both of the sites could be partly due to the warmest summer of the study period. However, at both study sites, no significantly negative relationships were detected between mean adult size and mean temperature in June (male: $r=-0.22$, NS at site A and $r=-0.38$, NS at site F; female: $r=-0.04$, NS at site A and $r=-0.42$, NS at site F) and July (male: $r=-0.77$, NS at site A and $r=-0.75$, NS at site F; female: $r=-0.79$, NS at site A and $r=-0.67$, NS at site F) for 1976–80, when most larvae developed. Furthermore, mean adult size at the upstream site F, at 350 m in altitude, did not significantly differ that at the downstream site A at 220 m in altitude (see Fig. 2). It is unlikely, therefore, that temperature is a predominant factor producing adult size variation within these populations.

OHGUSHI (1986) showed size-dependent adult survival during the period from adult emergence to the reproductive season in the next spring. Thus, small adults, emerging from heavily exploited plants, contribute little reproduction compared to large beetles. This emphasizes the importance of oviposition site selection by reproductive females in terms of the condition of the food resource available to larvae. The lady beetle exhibits a characteristic oviposition behaviour: ovipositing females tend to avoid egg-laying on plants with high egg densities, and to seek plants receiving a low egg load. As a result, egg densities are remarkably constant among different host patches (OHGUSHI and SAWADA, 1985). This oviposition behaviour in seeking less exploited plants for egg-laying thus undoubtedly improves the reproductive success of an ovipositing female.

## SUMMARY

Size variation in newly-emerged adults was examined in two different local populations of an herbivorous lady beetle, *Henosepilachna niponica*, for 1976–80. Mean adult size of both sexes changed rather synchronously in the two populations over 5 years. Body size of adult beetles apparently decreased with increasing leaf damage of the plants on which they developed. Adult beetles which emerged late in the season, associated with increasing food deterioration, were smaller than those which emerged early. Ecological consequences of adult size variation is discussed in terms of oviposition site selection.

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## コブオオニジュウヤホシテントウの成虫サイズを決定する要因

大 串 隆 之

滋賀県北西部の安曇川流域で，アザミを食草とするコブオオニジュウヤホシテントウの個体群調査を1976年から5年間にわたって行い，成虫のサイズを決定する要因について調べた。

上流域と下流域の二つの調査地では各個体群とも成虫サイズには大きな個体変異が見られたが，平均サイズについては有意差はなく，年次変動も5年間を通して同様なパターンを示した。成虫サイズを決定する要因は，主に，羽化してきたアザミ株の食害レベルであった．この食害レベルに対応した成虫の小型化は，食害率が50%以下という食害が比較的軽微な株でも認められた．このため，全ての株で食害レベルが高くなる後期に羽化した個体は前期に羽化した個体に比べて小さくなる傾向がみられた．

この成虫サイズの個体異変の生態学的意義を繁殖雌成虫の産卵場所選択という側面から論じた．