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Emergence of the Ladybird Beetle, *Coccinella septempunctata bruckii* Mulsant in the Field*

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SUMMARY

Emergence of the ladybird beetle, *Coccinella septempunctata bruckii* Mulsant in the field was studied, with special reference to fluctuation of adult population through a year, focussing to the elytron colour and ovarian development. It was observed that adults emerged 3 times in a year, i.e. in the late spring (lst-generation), the autumn (2nd-generation) and the early winter. The lst-generation adults simultaneously entered the aestivation after late June and diapaused at the foot part of weeds.

The 2nd-generation adults entered the hibernation after December, but active behavior of them were shown around the vegetable fields in sunny warm day of midwinter. From the elytron colour and ovarian development, it was demonstrated that the emergence in early winter is minor population, not regarded as the 3rd-generation. A close relationship was observed between the elytron colour grade and the corpus allatum size. The elytron colour could be utilized as an index as well as the ovarian development to estimate the adult age among the overlapping generation individuals.

INTRODUCTION

Recently it has been criticized that pesticides cause serious problem to the natural environment. Consequently utilization of natural enemy for pest control became revaluated. The ladybird beetles are well known as the natural enemy to the aphids and coccids. For utilization of ladybird beetles in biological control of pests, life cycle of the beetles must be clarified. The authors have studied the life cycle of aphidphagous beetles from physiological point of view[1~5]. On physolological characteristic of diapause in *Coccinella septempunctata bruckii* Mulsant, it was pointed out that the aestivation is the true adult diapause and the hibernation is not. To know the diapausing situation of this beetle in detail in the field, ecological study on its life cycle is important.

The present paper deals with study on the emergence of *C. septempunctata* in the field, with special reference to fluctuation of adult population and changes in elytron colour and ovarian development throughout the year.

MATERIALS AND METHODS

Field survey of the adult population

The adult population was studied in the weed plants of areas around the former campus of Gifu University locating in Kakamigahara-city, Gifu prefecture. Experimental plots were set at 4 places,

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in which adult emergence had been ascertained before by preliminary study. Field survey was done for one year from October in 1977 to the next October. The outline of experimental plots are described in Fig. 1 and Table 1. Observation was performed generally at the time from 10 a.m. to 3 p.m. of fine weather day. The adult number was counted on the weed plant of each plot, taking within one hour. Also the elytron colour of adults on the weed was observed and recorded as the colour grade.

Determination of the elytron colour

After aging of *C. septempunctata* adults, the background colour of elytra beside the spots gradually changes from yellow to red. With special reference to this change, the adult age was estimated with the elytron colour. The grade of elytron colour was determined referring the colour chart, which was prepared using 5 kinds of paint (Holbein Gouche) (Table 2) . It comprises 10 grades of colour and each grade comprises 10 colour series. In practice for the field and the laboratory studies, each two proximate colour grades in the chart were gathered and totally 5 grades were utilized as the index of elytron colour.

Measurement of the corpus allatum area

Female adults were dissected in 0.9% saline under the microscope. The length and the width of corpus allatum (CA) were measured and recorded in units of 20μm. The CA area was expressed as the units multiplied $(20\mu m)^2$.

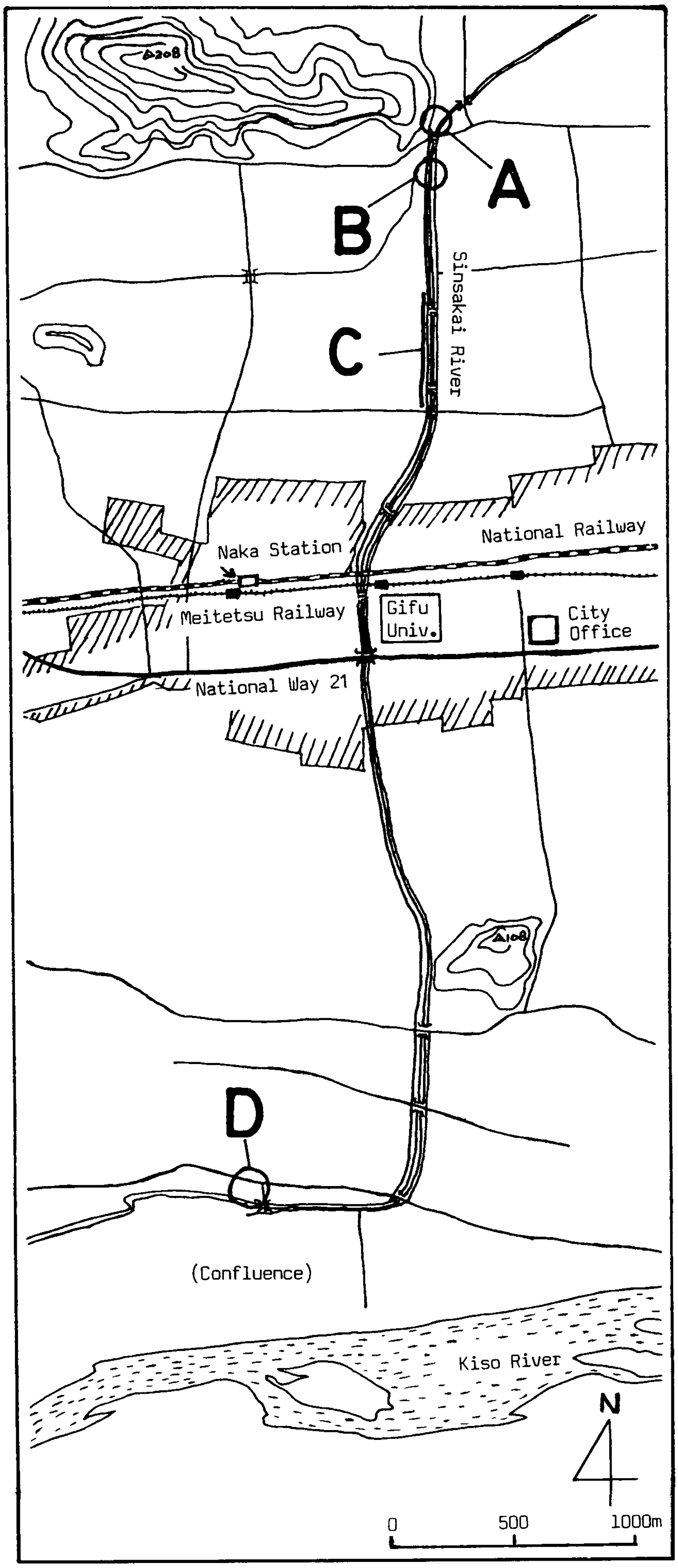

Fig. 1. Map showing sites of experimental plots.

Table 1. Geographical situation of the experimental plots

Experimental plot	Geographical situation
A	Vacant lot (200m²) neighbouring to the Sinsakai River, distant about 2km to northernward from the former campus of Gifu University.
B	Inner slope area (200m²) of the Sinsakai River's bank, distant 100m to southernward from the Station A.
C	Road side (500m length) on the Sinsakai River's bank, distant about 500m to southernward from the Station B.
D	Inner slope area (100m²) of the Sinsakai River's bank, situating in the confluence of the Kiso River, distant about 4km to southernward from the Gifu University.

Table 2. Preparation of colour chart

Colour* grade	Paints used as base colour
1	Cadmium yellow (Holbein Gouche 824)
2	Cadmium yellow and Cadmium yellow orange (Holbein Gouche 821) (2 : 1)
3	Gadmium yellow and Cadmium yelloworange (1 : 1)
4	Cadmium yellow orange
5	Cadmium yellow orange and Briilliant orange (Holbein Gouche 808) (1 : 1)
6	Brilliant orange
7	Brilliant orange and Flame red (Holbein Gouche 807) (1 : 1)
8	Flame red
9	Flame red and Carmine (Holbein Gouche 802) (1 : 1)
10	Carmine

*Each colour grade comprises 10 colour series, prepared with slight additioning of black colour to each base colour.

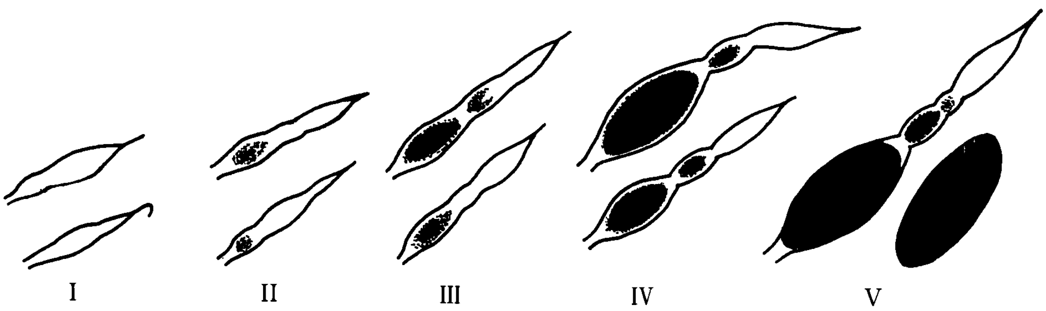

Fig. 2. Schematic representation of oogenesis in *Coccinella septempunctata bruckii* Mulsant.

Determination of the ovarian development

To determine the ovarian development, the oogenesis of the first follicle was observed. The oogenesis was divided into 5 stages (Fig. 1): Stage 1 is the follicle undeveloping stage, Stage 2 is the follicle-growing stage, Stage 3 is the previtellogenic stage, Stage 4 is the midvitellogenic stage, Stage 5 is the postvitellogenic and mature egg stages.

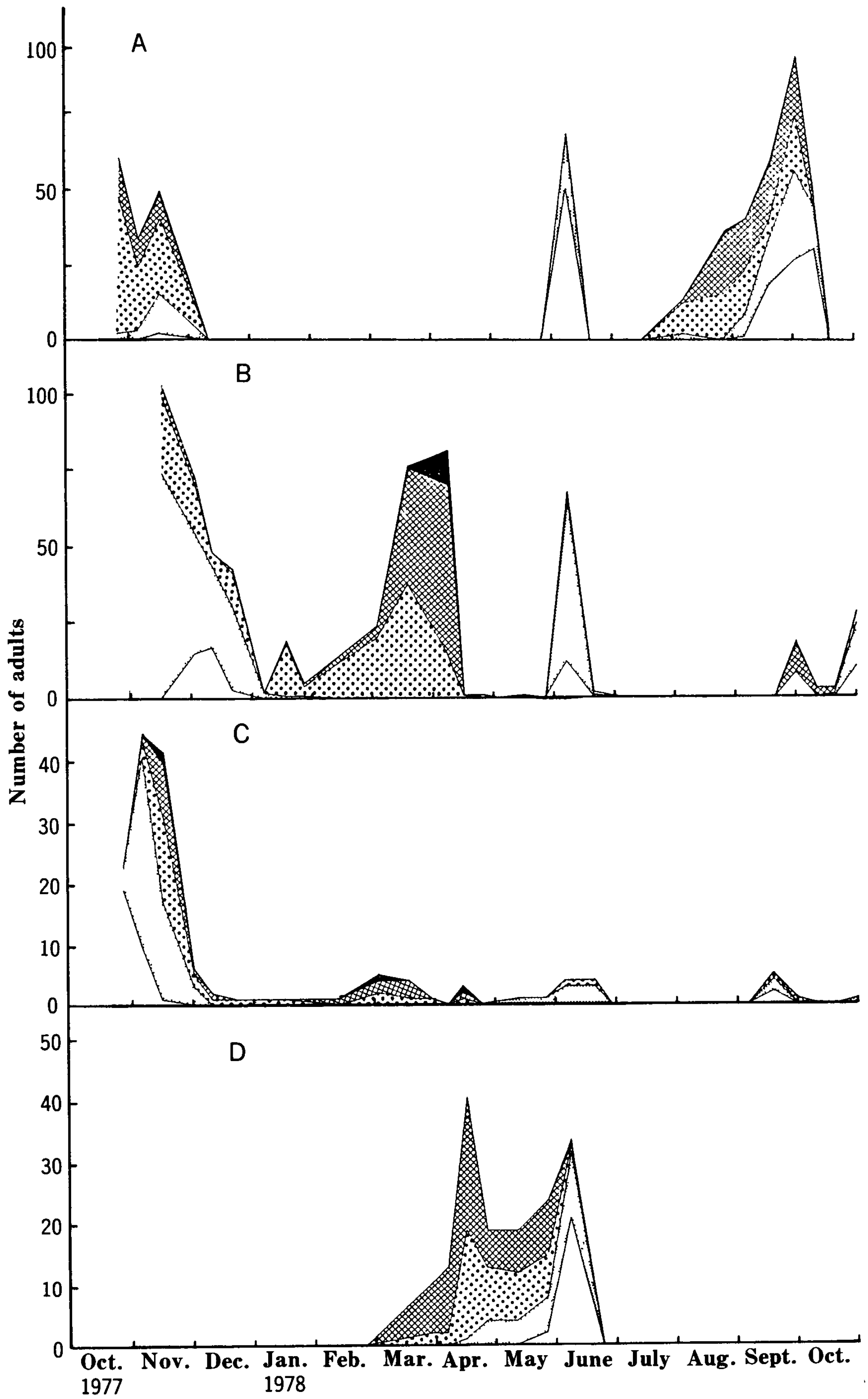

Fig. 3. Seasonal changes in adult number in the field and its elytron colour. A, B, C and D show each experimental plot.

Colour grade, 1, 2 ; 3, 4 ; 5, 6 ; 7, 8 9, 10.

RESULTS

Seasonal changes of adult population

The number of adults and their elytron colour were studied seasonally in 4 experimental plots. Results are given in Fig. 3. In the figure, emergence of new adults are shown with the presence of adult of Grade 1, 2.

Plot A: Emergence of new adults was observed early June in *Vicina sativa* Linne and early September to early October in *Erigeron sumatrensis* Retz. After August the number of adult increased in *E. sumatrensis* and fed on the aphids.

Plot B: New adults emerged autumn and early winter in *Brassica campestris* Linne and *Artemisia vulgaris* Linne. New adults were also observed early summer in *V. sativa*, *B. campestris*, *Rumex spp.*, *A. vulgaris* and *Oenanthe javanica* DC. In midwinter a small number of adults were fed on the aphids of *B. campestris* and a large number were quiescence among dried grasses. In spring the adults were actively fed the aphids on *B. campestris*, *Vicina hirusta* Koch and *Veronica persica* Poir and *Capsella bursa-pastaris* Medik. Fluctuation of adult population in *B. campestris* was very likely to that in the fields of Chinese cabbage (*Brassica pekinensis* Rupr) and raddish (*Raphanus sativus* Linne), near to the experimental plot.

Plot C: In early winter, new adults emerged in *E. sumatrensis*. In early spring and early summer, a few adults were also present in *A. vulgaris*, *V. hirusta* and *Rosa polyantha* Siebold et Zuccarini.

Plot D: The hibernated adults appeared and oviposited in *V. sative* and *V. hirusta* after early spring. Then new adult emerged from late spring to early summer. During other season, vegetation was restricted to *Zoysia japonica* Steudel and the beetles were not observed. These tendencies in adult population were very similar to that in the field of chinese milk vetch (*Astragalus sinicus* Linne) near to the plot.

In all the plots the adults were simultaneously disappeared after late June. This suggests migration of the lst-generation adults to the aestivation site. The adults feeding on aphids were observed on the weed after mid August, indicating their removal from the aestivation. The adults decreased in number after December, which suggests migration of the 2nd-generation adults to the hibernation site. After February the adult population increased at plot B, C and D and showed active feeding the aphids on weeds in March.

Seasonal changes of the elytron colour

Seasonal changes of elytron colour were studied in the female adults (Fig. 4). During the dormancy period of aestivation and hibernation, the elytron colour was studied separatedly with active and quiescent adults. In the figure the number of each colour grade was expressed as frequency (%). Emergence of new adults can be estimated with the presence of Grade 1, 2 individuals. It was pointed out that new adults emerged 3 times in a year : i.e. from November to January, early May to early June and around October. Compared with the former two periods, population of the latter one was very low. During the aestivation period of late June to mid August, the elytron colour did not so change, below Grade 5, 6. After removal from the aestivation, the color of the elytra became more dense. During the hibernation period, the elyron colour was more dense compared with the aestivating adults. The number of insects of Grade 9, 10 increased slightly with lapse of winter season.

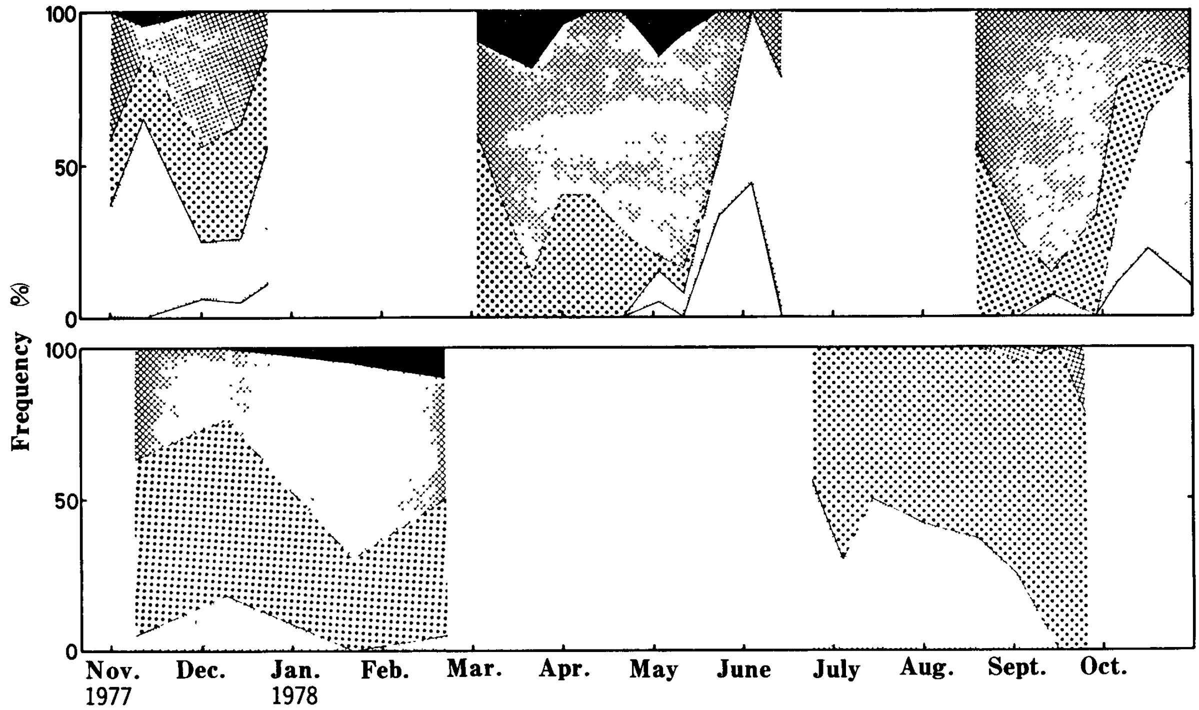

Fig. 4. Seasonal changes in the elytron colour of female adults.
Upper figure shows the active adults and lower one is the quiescent adults.
Colour grade, 1, 2 ; 3, 4 ; 5, 6 ; 7, 8 ; 9, 10.

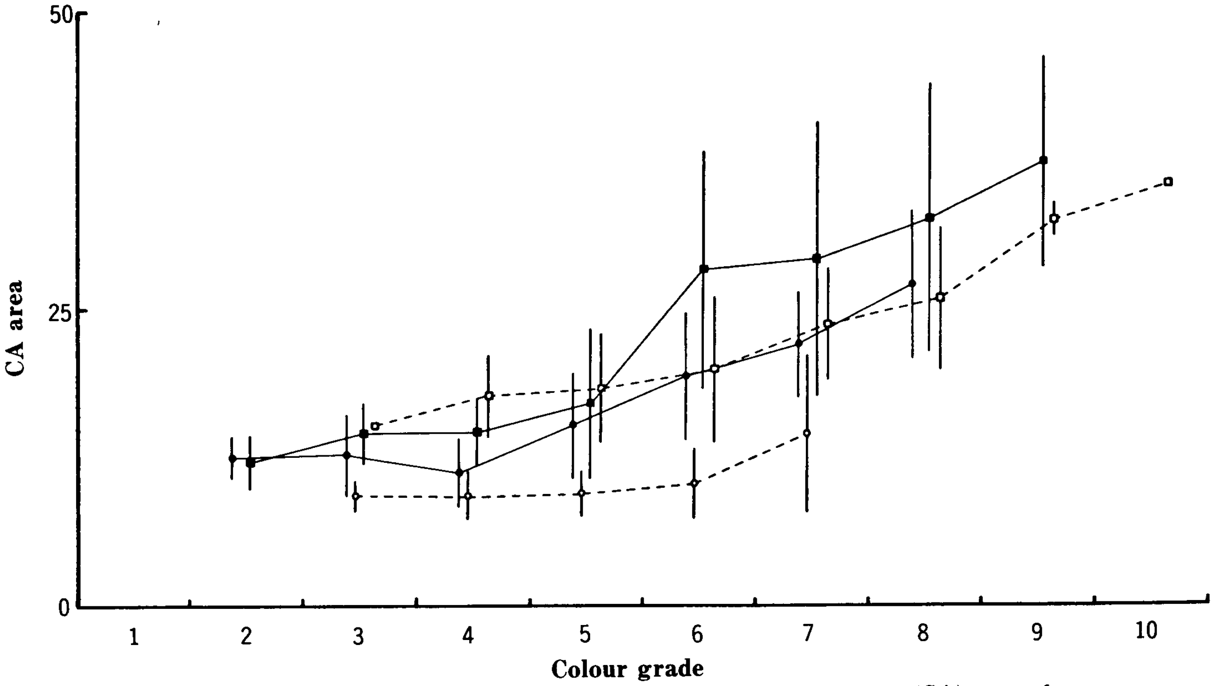

Fig. 5. Relationship between the elytron colour and the corpus allatum (CA) area of female adults. Unit in the CA area is $(20\mu m)^2$ and the vertical line in the value is the standard deviation.

● : Active adults of the lst-generation, ○ : Aestivating adults of the lst-generation,
■ : Active adults of the 2nd-generation, □ : Hibernating adults of the 2nd-generation.

Relationship between the elytron colour and the corpus allatum area

Relationship between the elytron colour and the corpus allatum (CA) area of females is given in Fig. 5. Correlationship was shown between the colour grade and the CA area: The colour grade ascended with increase of CA size. In the lst-generation, the CA size of active one was bigger than that of the aestivating one and increased paralleling to ascent of colour grade. In the 2nd-generation, the CA area of active one was bigger than that of hibernating one at the colour grade above 6. Compared with the aestivating one, the CA of hibernating one was very big.

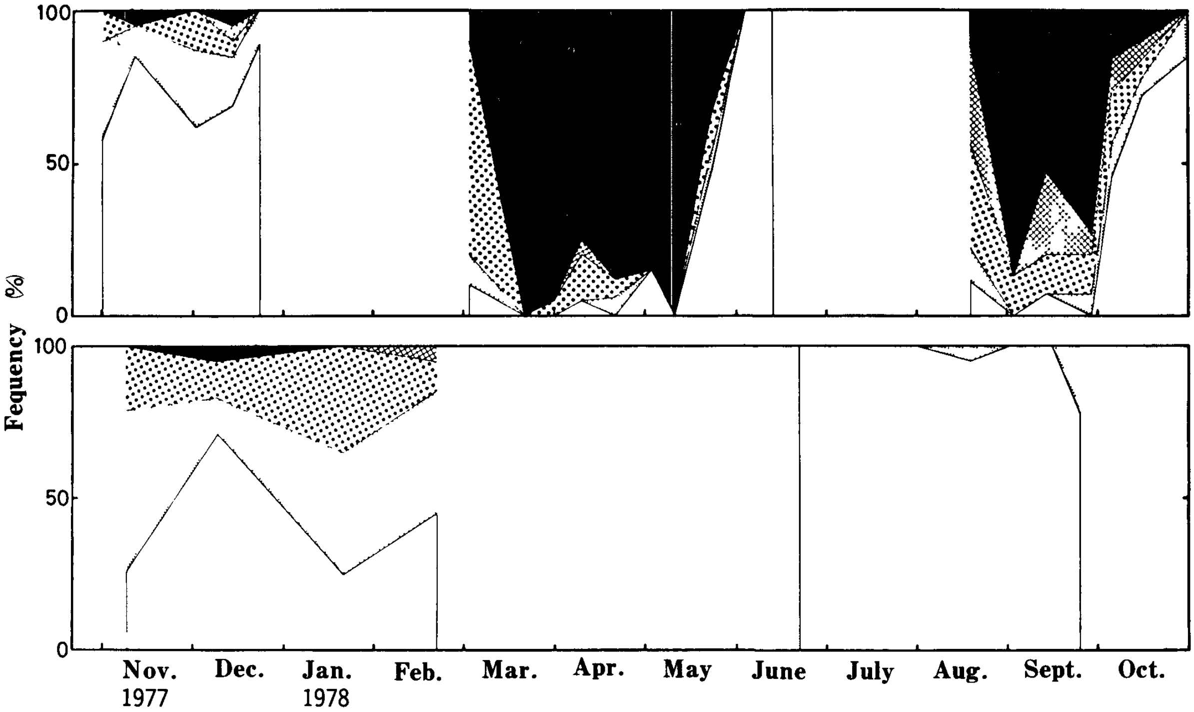

Fig. 6. Seasonal changes in the ovarian development.
Upper figure shows the active adults and lower one is the quiescent adults.
Ovarian growth stage, □ I ; ▒ II ; ⁘ III ; ▩ IV ; ■ V.

Seasonal changes of the ovarian development

In the female adults of which the elytron colour was determined, the ovarian development was studied seasonally (Fig.6). During the periods of spring and autumn, conspicuous development of ovary was observed. Most adults had mature ovary during late March to early May and around September. The ovarian maturation during the former period relates to the overwintered females and the latter one is to the oversummered females. During November to December in 1977, a few adults showed the ovarian maturation. From the ovarian development, it was suggested that *C. septempunctata* reproduces mostly 2 times and exceptionally 3 times in a year.

DISCUSSION

The situation of adult emergence in the field was very different among the experimental plots (Fig. 3). This may reflect difference of vegetation among them, which relates to abundance of aphids. *C. septempunctata* is very gluttonus and migrative bettles, so that setting of many experimental plots in the field is necessary for exact estimation of their life cycle. From the adult population and elytron colour, it was estimated that new adults emerge 3 times in a year in the fields, which are the late spring (lst-generation), the autumn (2nd-generation) and the early winter.

The lst-generation adults simultaneously entered the aestivation after late June and were not observed in any plots. This indicates that the adults migrate to the aestivation site. Generally the aestivation is taken place at foot part of weeds, especially Japanese pampus grass (*Miscanthus sinensis* Anderss) and the adults rest gathering around lower portion of stem. The aestivating adults resumed action on the weeds after mid August, though a part of population was still aestivating untill late September.

The 2nd-generation adults decreased in number after December and entered the hibernation. The hibernation was taken place at the weed lot as well as the field of Chinese cabbage and raddish. In the experimental plots, the adults hibernated around the foot part of weeds and dried grasses. Beside the plots a number of adults hibernated at the vegetation of Japanese pampus grass. Even in midwinter, active behavior of adults were observed on the Chinese cabbage and raddish in sunny day.

The number of new adults emerged in the early winter was very low compared with those of the lst- and 2nd-generations. The elytron colour construction of the early winter population was very different from that of the spring and the autumn populations (Fig. 4): After emergence of the spring and the autumn populations, the colour construction so much changed and were mostly occupied with young colour instars. Whereas in early winter population, the colour changed scarcely after their emergence. This indicates that emergence of the early winter population takes place in a small number. Such aspect can be ascertained with the ovarian development (Fig. 5): Before emergence of the spring and the autumn popultions, a large number of females possessed the mature ovary. In contrast to this, only a few females showed the ovarian maturation before the early winter. This fact would indicate that emergence of *C. septempunctata* in early winter is a minor population.

With physiological situation of diapause in *C. septempunctata*, Sakurai et al.[3~5] demonstraed that the aestivation is true diapause, while the hibernation is not. The aestivation is induced with depression of CA function, whereas in the hibernating adults the function of CA is active. In the present study it was demonstrated that the elytron colour of aestivating adults was very pale, while that of hibernating ones was more dense (Fig. 4). Also the CA of aestivating adults was very small, while that of hibernating ones was big (Fig. 5). These indicate that the aestivation is true diapause, while hibernation is not. On the diapuse of *C. septempunctata* Linne in Czechoslovakia, Hodek et al.[6~8] demonstrated that the hibernation is true diapause, induced with depression of CA function under the short-photoperiod. Therefore the diapause situation of *C. septempunctata* in central Japan is very different from that of Czechoslovakia. A close relationship was shown between the elytron colour and CA function (Fig. 6). Juvenile hormone (JH) is generally concerned in regulation of adult oogenesis[9] and in *C. septempunctata* it induces ovarian development of aestivating females[4]. JH might induces aging effect on the elytron colour through metabolic process. Thus the elytron colour seems to be a suitable index as well as the ovarian development to estimate the adult age among the overlapping generations.

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ナナホシテントウの野外における発生消長

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要　約

ナナホシテントウの野外における発生状況を知るため，翅鞘の色彩および卵巣の発達度の季節的変化を中心として，成虫個体数の年間の変動を検討した。新成虫は晩春（第1世代），秋（第2世代）および初冬と3回の発生がみられた。第1世代成虫は6月下旬より一斎に夏眠に入り，雑草の根元で休眠した。一方第2世代成虫は12月下旬より越冬に入るが，真冬でも晴れた温暖な日には活動個体が野菜畑の周囲で観察された。翅鞘の色彩および卵巣の発達度から，初冬にみられる新成虫の発生は少数個体によるもので，第3世代個体とみなされないように思われた。そして翅鞘の色彩の程度とアラタ体の大きさの間には相関がみられることから，世代の重なり合う時期における成虫の令を推定するのに，翅鞘の色彩は卵巣発育とともに有効な指標であることが示された。

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