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OVIPOSITION STRATEGIES OF *COCCINELLA SEPTEMPUNCTATA (COL.: COCCINELLIDAE)*

Y. SAKURATANI & Y. NAKAMURA

Entomological Laboratory, Faculty of Agriculture, Kinki University, Nara 631, Japan

In central Japan, females of *Coccinella septempunctata brucki* laid eggs preferably on the under side of metal cans, wood and other materials, and the walls of a concrete gutter in sunny grasslands with colonies of aphids, in winter and spring. These materials have a high thermal conductivity, and are warmed readily by solar radiation. The development of eggs attached to these materials was accelerated by the heart from the materials. Most eggs attached to the upper surface of such materials did not hatch because they were either desiccated by direct solar radiation or eaten by predators. The under surface of metals is heated on sunny days by solar radiation, and the eggs are protected from desiccation and cannibalism. The shortening of incubation may be an adaptation to the rapid growth of aphid populations in early spring, and may reduce the chance of cannibalism.

KEY-WORDS: *Coccinella septempunctata,* oviposition, thermal conductivity, heat.

In winter, in central Japan, adults of *Coccinella septempunctata brucki* Mulsant emerge (Sakuratani *et al.,* 1986), and all stages are found in sunny grasslands with growing aphid populations (Sakuratani,1988). During mid-December to early March, however, the daily maximum air temperature (Japan Meteorological Agency, 1991) is less than 11.0°C, the lower developmental threshold (from egg to adult) of this insect (Kawauchi, 1990). However, adults of *C. septempunctata* lay eggs on dead leaves, stones and other materials in the field in April in Japan (Takahashi, 1987) and in England (Banks, 1954), at a time when aphid densities are very low. These materials have high thermal conductivities (Kaye & Laby, 1986), and are warmed by solar radiation. Coccinellid must have mechanisms that enable them to develope in winter in central Japan. We studied oviposition in *C. septempunctata* in the field and discuss the significance of oviposition in winter.

MATERIALS AND METHODS

FIELD OBSERVATIONS

The substrates on which eggs were laid and the number of eggs were recorded in the grasslands on the bank of the Yodo River in the Osaka Plain in 1993-1994. Even in winter, large numbers of aphids were present on herbaceous plants such as *Vicia angustifolia* and *Rumex japonicus*. Quadrats, 70 × 70 cm, were set up in areas where drink cans and other materials were dumped. The number of eggs of *C. septempunctata* laid on these materials

and on the leaves of plants was counted, and the temperature of these substrates measured with the aid of a radiation thermometer. The areas of the various substrates were also measured.

Oviposition on the walls of a concrete gutter

Oviposition on the vertical walls of a concrete gutter on the campus of Kinki University was observed during April 1993. Many adults of *C. septempunctata* and aphids occurred in the adjacent vegetation. The gutter was 30 cm wide and 30 cm deep, and ran from east to west. The number of eggs of *C. septempunctata* laid on the north and south walls was counted every day, and the temperature measured.

Preference for ovipositing on various materials and egg survival

To determine whether females of *C. septempunctata* have a preference for ovipositing on particular substrates, thin plates of eight kinds of material: aluminium, copper, black styro-foam, white styro-foam, black rubber, white rubber, corrugated paper and crushed rusty drink can, each 6.5 × 12 cm and replicated eight times, a total of 64 plates, were placed in sunny grassland on the campus of Kinki University in spring 1993, which is a good habitat for *C. septempunctata*. The number of eggs of *C. septempunctata* was counted. In addition, one egg batch of 20-40 eggs was placed on one side of a plate, which was then placed in the field with the eggs either on the under or upper surface. The mortality and viability of these eggs were recorded. The temperature of the plate was measured with the aid of a radiation thermometer.

RESULTS

Field observations

The number of eggs laid on the various materials and the temperature of the various materials are shown in table 1. No eggs were laid on the leaves of plants growing in the quadrats. On 18th February 1993, the materials for oviposition were paper, metal, wood and plastic. On 13th March 1993, most eggs were laid on paper and metal. On 17th April 1993, and 19th January 1994, most eggs were laid on metal. The number of eggs per unit area of material was greatest on metal, wood, paper and concrete. On a sunny day in winter the temperature of leaves was 10-14°C whereas that of materials oviposited was between 13-25°C. In spring, the temperature of materials oviposited was higher than that of leaves.

Oviposition in the concrete gutter in grasslands

Figure 1 shows the daily changes in the numbers of egg batches laid on the north and south walls of the concrete gutter. Most eggs were laid on the south wall of the gutter in early and mid-April, but in late April more eggs were laid on the north wall. The temperature of the south wall was higher than that of the north wall on every day, and exceeded 30°C in late April (fig. 2).

Experiments on the preference for ovipositing on particular materials and egg survival

Twenty egg batches were laid on the materials put out in the field, 19 of which were laid on the under (shaded) surface of the materials ($\chi^2 = 16.2^{***}$, $p < 0.001$). Most eggs were

TABLE 1

Number of eggs laid on the various materials dumped on the bank of Yodo River, Osaka Japan, and temperature of materials. Area of one plot is 0.5 m^2

Material	Area of material (cm^2)	No. of egg batches	No. of eggs	No. of eggs per 100 cm^2 of material	Temperature (°C)
18 Feb. 1993 (Total of 30 plots)					
Paper	4545	2	32	0.70	—
Metal	5631	2	55	0.97	—
Wood	640	1	31	4.84	—
Styro-foam	364	0	0	0	—
Plastic	472	2	16	3.39	—
Other	2003	0	0	0	—
13 Mar. 1993 (Total of 25 plots)					
Paper	8148	12	453	5.56	26.3-31.1
Veneer	3450	2	57	1.65	27.2-33.6
Metal	2107	7	172	8.16	23.7-37.5
Vinyl	2031	0	0	0	—
Styro-foam	791	1	10	1.26	16.2-20.1
Plastic	26	0	0	0	—
Other	687	0	0	0	16.3-19.3*
17 Apr. 1993 (Total of 20 plots)					
Paper	458	2	62	13.54	28.7-34.8
Metal	1438	10	256	17.80	23.7-36.5
Wood	470	1	39	8.30	28.4-31.4
Concrete	240	1	23	9.58	49.7
Other	80	0	0	0	19.5-25.1*
19 Jan. 1994 (Total of 11 plots)					
Paper	65	0	0	0	—
Metal	1419	9	222	15.64	12.6-25.2
Vinyl	148	0	0	0	—
Styro-foam	893	0	0	0	—
Other	364	0	0	0	10.3-14.0*

*: Temperature of plant leaf.

laid on the rusty cans and black styro-foam plates in late March to mid-April (fig. 3). However, from 15th April to 20th May, most eggs were laid on the white rubber plates, though a few eggs were laid on the cans. No eggs were laid on the other materials.

Figure 4 shows the viability of the eggs placed on the various materials. Very few of the eggs on the upper (sunny) surfaces hatched, where most eggs died from desiccation or predation. On the hottest materials, the rate of death from desiccation was higher than on the coolest materials. In contrast, proportionally more egg hatched on the under side of cool materials than those on the upper side. But on the hotter materials eggs rarely hatched and most were eaten by predators.

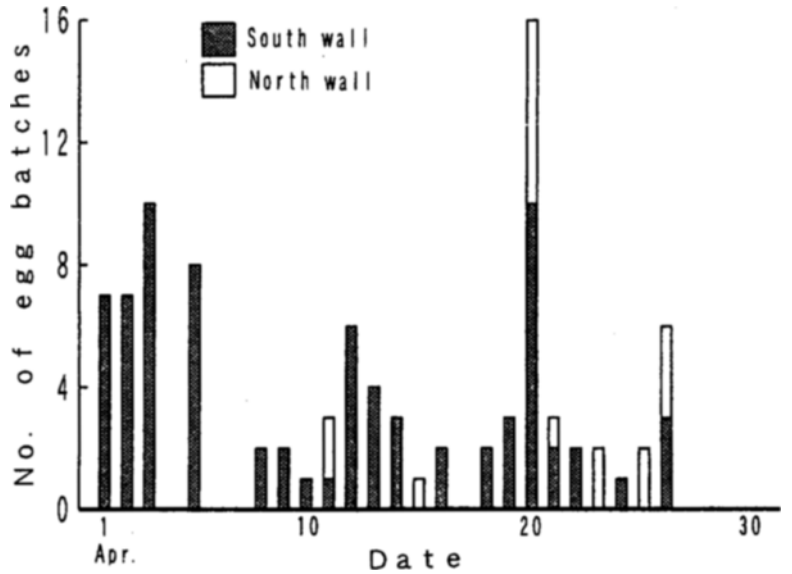

Fig. 1. Changes in the numbers of egg batches of *C. septempunctata* laid on the north and south sides of a concrete gutter (30 cm wide, 30 cm deep and10 m long) in sunny grassland on the campus of Kinki University.

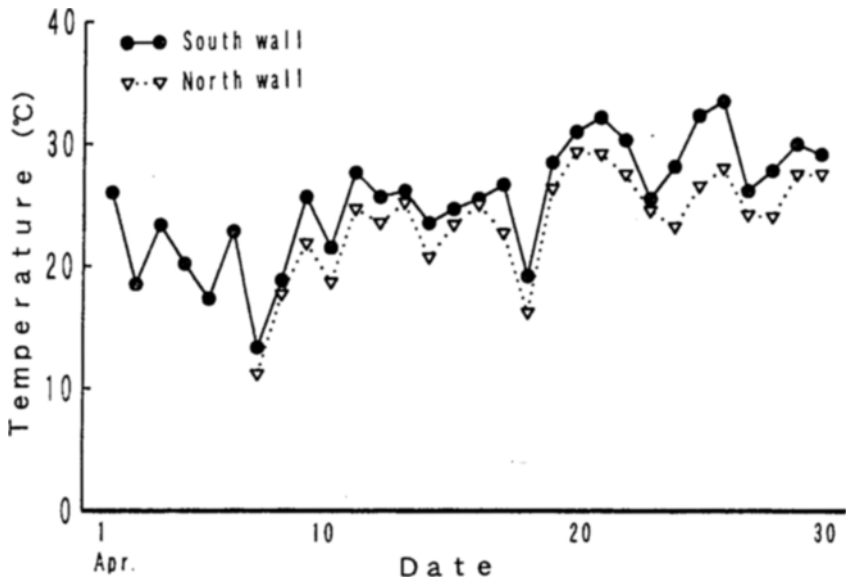

Fig. 2. Changes in time in the temperature of the south and north walls of the concrete gutter.

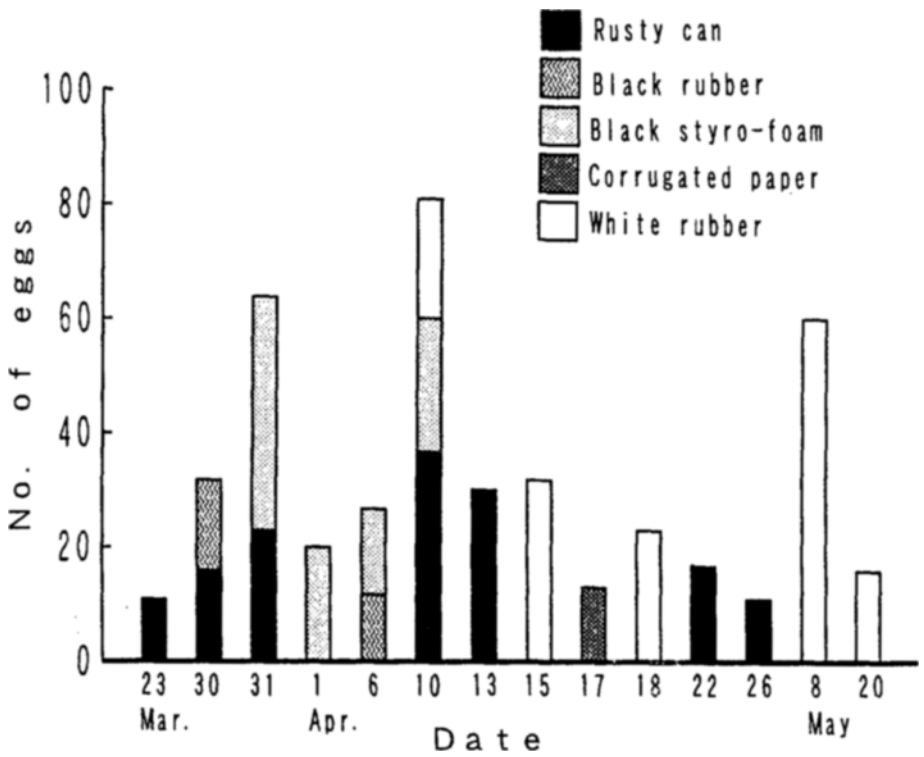

Fig. 3. Seasonal changes in the number of *C. septempunctata* eggs laid on the various materials put out in the sunny grasslands of the campus. No eggs were laid on the other materials.

Figure 5 shows the relation between the mean temperature of the materials and the incubation period of the eggs laid on those materials. The higher the temperature, the shorter the incubation period. Thus the nature of the material on which the eggs were laid affected the incubation period.

DISCUSSION

Populations of aphids change greatly in a short time (Way & Camell, 1971). The predators of aphids adapt to this in various ways. In central Japan, aphids are present in winter and populations begin to grow in late winter. The pupae of *C. septempunctata,* which are attached to stones and other materials with a high thermal conductivity receive heart from those materials and are warmed directly by solar radiation (Sakuratani, *et al.,* 1991). Adults, therefore, can emerge even in winter. Similarly the eggs of this species also utilize the thermal conduction of heat from materials such as metals and can therefore hatch in winter. However, as direct solar radiation and/or high temperature desiccate the eggs, the eggs are laid on the under (shaded) side of materials with high thermal conductivity. In late

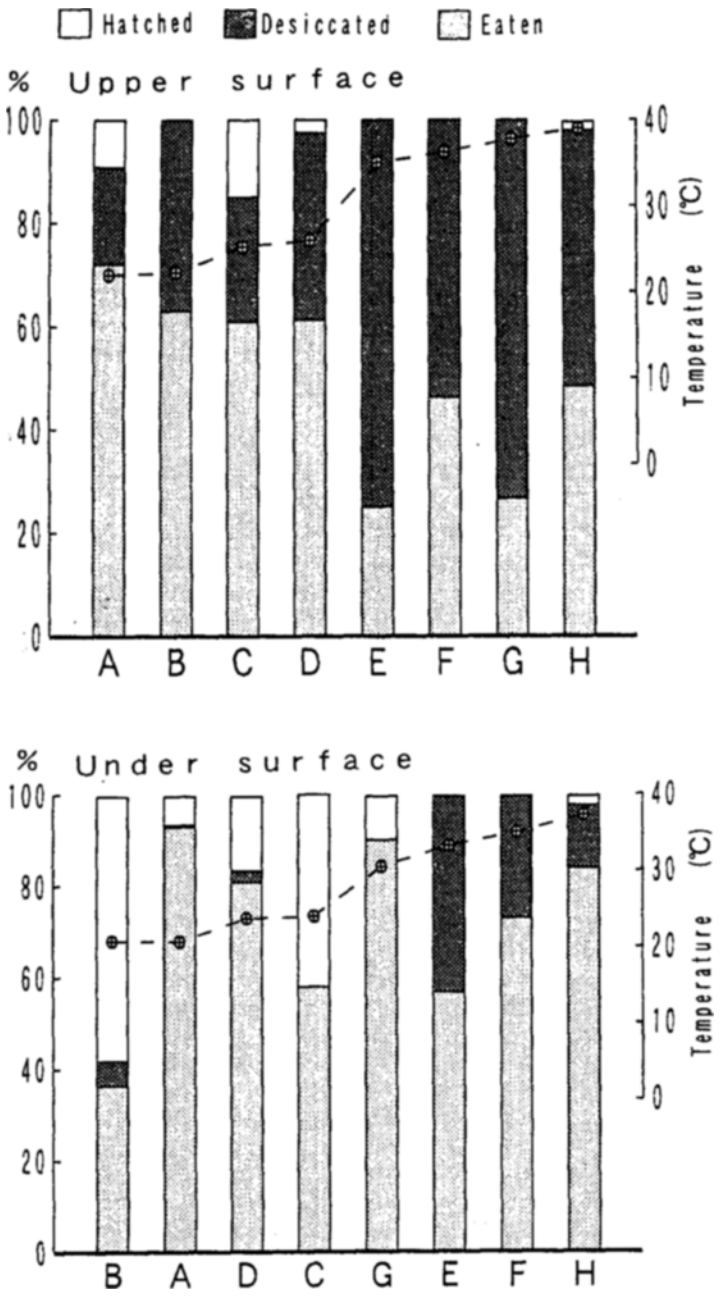

Fig. 4. Viability of the eggs placed on the upper and under surface of the various plates relative to the mean temperature of the plates. A: Aluminium, B; White styro-foam, C; White rubber, D; Corrugated paper, E; Copper, F; Black rubber, G; Black styro-foam, H; Crushed rusty drink cans.

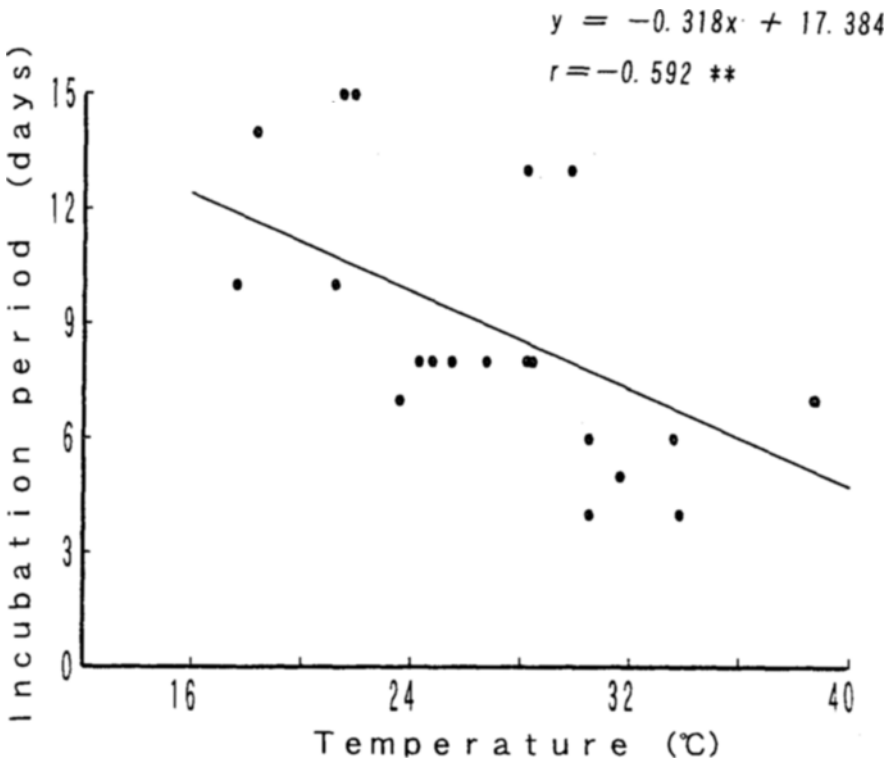

Fig. 5. Relation between the mean temperatures of the various substrates and the incubation period of the eggs.

spring when the temperature is higher, the eggs are laid more frequently on the under side of materials with low thermal conductivity, such as white rubber and leaves. Shortening the incubation of eggs may have two advantages: it reduces egg cannibalism (Mills, 1982) and predation, and/or is an adaptation for exploiting prey populations that grow rapidly in late winter and spring.

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RÉSUMÉ

Stratégies d'oviposition de *Coccinella septempunctata* (Col. : Coccinellidae)

Dans le centre du Japon, on a observé que des femelles de *Coccinella septempunctata brucki* pondaient leurs oeufs de préférence sur la face inférieure des boîtes de conserve, du bois et autres

matériaux, et sur les parois d'une gouttière en ciment, dans les prés ensoleillés où se trouvent des colonies de pucerons, en hiver et au printemps. Ces matériaux ont une conductivité thermique élevée et sont rapidement chauffés par les radiations du soleil. Le développement des œufs fixés sur ces matériaux est de ce fait accéléré par la chaleur réémise par ces matériaux. La plupart des œufs fixés sur la surface supérieure de tels matériaux n'éclosent pas car ils sont soit désséchés par le soleil soit dévorés par des prédateurs. La surface intérieure des objets en métal est chauffée pendant les journées ensoleillées et les œufs sont protégés de la dessication et du cannibalisme. Le raccourcissement de la durée de l'incubation peut être une adaptation à l'augmentation rapide des populations de pucerons au début du printemps et peut réduire le risque de cannibalisme.

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