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Diapause and Photoperiodic Response in *Coccinella septempunctata brucki* MULSANT (Coleoptera: Coccinellidae) in Hokkaido, Japan

Takashi OKUDA and Ivo HODEK[1]

Department of Insect Physiology and Behavior, National Institute of Sericultural and Entomological Science, Tsukuba, Ibaraki 305, Japan

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The regulatory function of photoperiod and temperature on the life-cycle of *Coccinella septempunctata brucki* MULSANT in Hokkaido populations was investigated. Dissection of adults from Sapporo (43°N) in mid-October showed diapausing adults (partly hidden in grass tussocks) possessing enlarged fat body, ovaria without vitellinized oocytes and at a beginning of regression of testicular follicle tissue. Some of the females had sperm in their spermathecae. Experimental rearings under contrasting photoperiods (12L–12D, 16L–8D) and three temperatures (20, 25 and 30°C) of insects sampled in early September, and of their offspring, showed that the Sapporo population has a long-day photoperiodic response adequate for the induction of winter diapause. This is in contrast to short-day response inducing summer diapause in the Nagoya (35°N) and Kanto (36°N) plains, but similar to *C. septempunctata septempunctata* in France and central and northern Europe, i.e. regions with climate similar to Hokkaido.

Key words: *Coccinella septempunctata brucki*, diapause, photoperiodic response, Hokkaido

INTRODUCTION

Long-day photoperiodic response was found in *Coccinella septempunctata septempunctata* L. in central Europe (HODEK and CERKASOV, 1961; HODEK and RUZICKA, 1979), France (BONNEMAISON, 1964; HODEK et al., 1977) and northern Europe (HÄMÄLÄINEN and MARKKULA, 1972; SEMYANOV, 1978). This is in concert with the induction of winter diapause of the subspecies in this area. A summer diapause was, however, reported from the Nagoya plain in central Honshu, Japan, for *C. septempunctata brucki* MULSANT (SAKURAI et al., 1981; HIRANO et al., 1982) and a reverse, short-day photoperiodic response was ascertained in samples from two years of this population (OKUDA and HODEK, 1983; HODEK et al., 1984). While this response is adequate for the climate of central Honshu with very mild winters when not only non-dormant adults but also developmental stages may be found (SAKURATANI et al., 1986; SAKURATANI, 1988), it appears unsuitable for northern Honshu where SAKURATANI (1988) found in late December only inactive adults.

The distribution area of *C. s. brucki* includes also Hokkaido with a still harsher climate (SASAJI, 1971), where the regulation of life-cycle has never been studied. We

[1] Present address: *Institute of Entomology, Czech Academy of Sciences, Branisovska 31, 370 05 C. Budejovice, Czech Republic* (this is also the address for correspondence)

have tried to get at least a preliminary picture by (1) dissecting an autumnal sample, (2) attempts at activation of beetles from the autumnal sample at contrasting photoperiods, (3) rearing their progeny at such conditions.

MATERIALS AND METHODS

Beetles for dissection were sampled in the Hokkaido University Campus, Sapporo (43°N) on Oct. 12, 1993 and dissected two days later. The beetles which were found on the vegetation without previous disturbance were isolated from those sampled later, after mechanical disturbance of grass tussocks. The reared sample was collected on Sept. 7.

The rearing conditions were 20 ± 0.5, 25 ± 0.5 and 30 ± 0.5°C, 12L–12D and 16L-8D photoperiods. The aphid *Acyrthosiphon pisum* HARRIS reared on *Vicia faba* was used as food. Eggs from collected long-day females were used for the cultures of F_1 generations. The insects were reared in group cultures until the first egg batch has been laid. They were then isolated into individual pairs. Surplus of aphids was provided in all rearings to prevent induction of diapause by shortage of prey. The oviposition was recorded daily.

The population from Tsukuba, Kanto Plain (36°N), sampled around the Campus of the National Institute of Sericultural and Entomological Science, was dissected for comparison.

RESULTS

Gonads and reserves in the autumnal sample

All females possessed tiny inactive ovaria with ovarioles lacking vitellinized oocytes, and hidden in the mass of the largely increased fat body (Table 1). The spermatheca was covered with a layer of fat tissue and was full of sperms only in a part of the females. The gut was empty or partially full. No difference was found between the females sampled from vegetation without prior mechanical disturbance and those collected after having intensively moved the grass tussocks. In two of 13 males the regression of the testicular follicle tissue has already proceeded, leaving only apical cells in the distal

Table 1. The dissection of *Coccinella septempunctata brucki* females collected in Sapporo in mid-October (and in Tsukuba in early October)

Sampling on plants		Vitellinized oocytes in ovaries		Sperm in spermatheca		Fat body[a]				Gut		
		Absent	Present	Absent	Present	—	+	++	+++	—	+	++
Without disturbance	3	3	0	1	2	0	0	1	2	1	1	1
After disturbance	3	3	0	1	2	0	0	0	3	1	2	0
Total	6	6	0	2	4	0	0	1	5	2	3	1
Tsukuba	2	2	12	0	14	0	10	2	2	0	1	13

[a] —: undeveloped, +: slightly developed, ++: developed, +++: well developed.

Table 2. The dissection of *Coccinella septempunctata brucki* males collected in Sapporo in mid-October (and in Tsukuba in early October)

Sampling on plants	Tissue of testicular follicles		Seminal vesicles			Fat body[a]				Gut		
	Active	Regressed	Full	+	Empty	−	+	++	+++	−	+	++
Without disturbance	4	0	4	0	0	0	0	2	2	2	1	1
After disturbance	7	2	9	0	0	0	0	0	9	7	2	0
Total	11	2	13	0	0	0	0	2	11	9	3	1
Tsukuba	16	0	13	2	1	0	8	6	2	0	10	6

[a] −: undeveloped, +: slightly developed, ++: developed, +++: well developed.

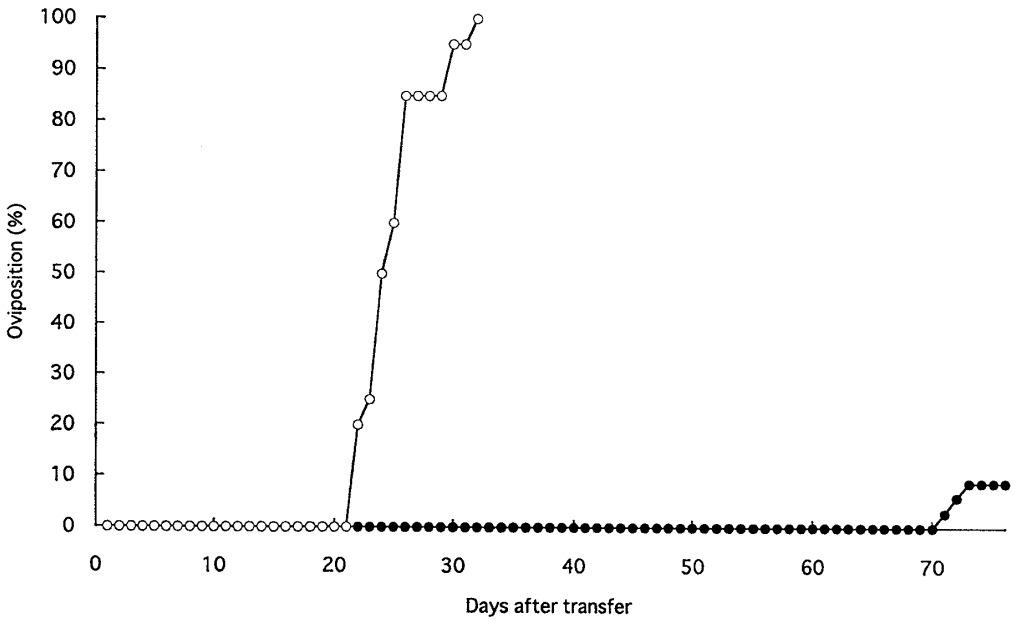

Fig. 1. Oviposition in females of *Coccinella septempunctata brucki* from Hokkaido, sampled on Sept. 7 and reared at 16L–8D and 25°C (n=20; open circles) or 12L–12D and 20°C (n=34; solid circles).

end of follicles and spermatocytes of the second order in their proximal end (Table 2). These two males were collected after the disturbance of grass tussocks, where they were apparently already hidden. This subsample slightly differs also by most developed fat body in all males. The two groups did not differ in other parameters, i.e. in having filled up seminal vesicles and emptied at least partially the gut.

The comparison between the populations from Sapporo in Hokkaido and Tsukuba in the Kanto plain (Tables 1 and 2) shows a contrast, related to the difference in latitude and temperature, and to the ensuing difference in life cycle.

Response of the autumnal sample to contrasting photoperiods

At long days of 16L–8D and 25°C all females (n=20) started the oviposition within 32 d (Fig. 1), with the shortest pre-oviposition period of 22 d and median 27 d. Long-

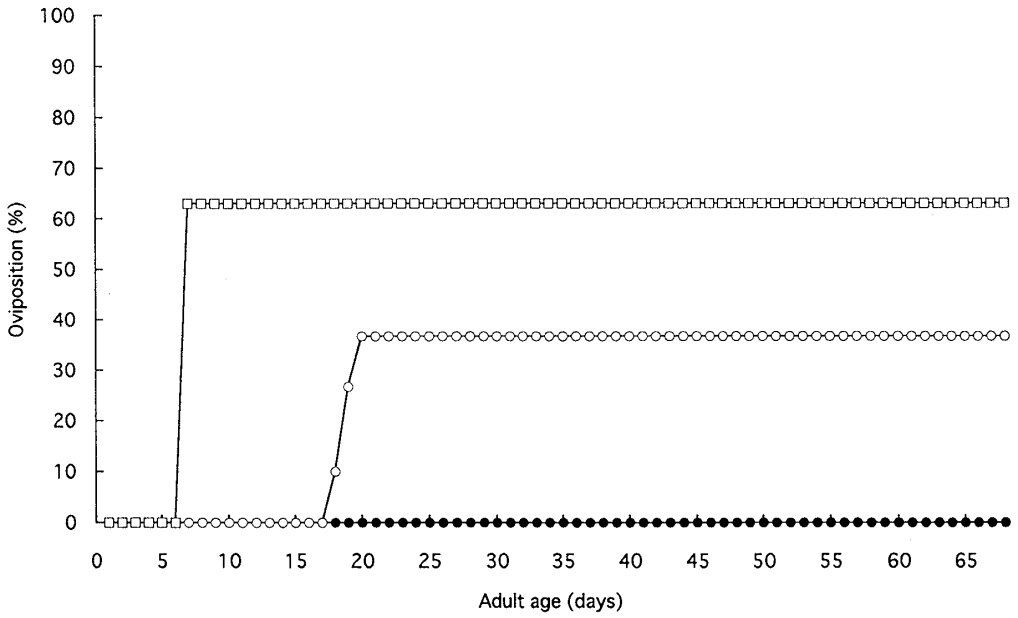

Fig. 2. Oviposition in *Coccinella septempunctata brucki* females which were the progeny (F_1) of the autumnal sample (see Fig. 1). They were reared at 16L–8D and 25°C (n=30; open circles), 16L–8D and 30°C (n=19; open squares) or 12L–12D and 20°C (n=32; solid circles).

day photoperiod and high temperature thus clearly represent diapause averting conditions. Short days of 12L–12D combined with 20°C, however, inhibited the reproductive activity of most females from the sample (n=34), so that only three started oviposition after 71 to 73 d.

Photoperiodic and temperature response in the progeny of autumnal sample

Under long-day photoperiod of 16L–8D combined with 25°C diapause was averted in 37% (n=30) and the min. pre-oviposition period was 18 d and median 19 d. When the temperature of long-day rearing was increased by 5 to 30°C the proportion of diapause aversion increased to 63% (n=19) and the duration of pre-oviposition period was shortened to 8 d (Fig. 2). At short days of 12L–12D and 20°C the beetles aggregated after a short period of feeding and did not begin to oviposit (n=32) until the age of 68 d when the experiment was discontinued.

DISCUSSION

Plasticity of Coccinella septempunctata

It has already been emphasized by several authors that *C. septempunctata* belongs among the insects which can exploit very diverse opportunities to assure the survival of the species (e.g. Hodek, 1973; Hodek and Ruzicka, 1979). The plastic strategy, based on polymodal responses (often polyphenism is concerned) has apparently been one of the principal reasons for the successful advancement of the species through N. America from the East to the West in the last several years (Angalet et al., 1979; Schaefer and Dysart, 1988).

The polymodal response to photoperiod is one of the aspects of the plastic strategy.

It was found in Europe that a great fraction of *C. septempunctata septempunctata* population (min. 60%) enters diapause in spite of favourable conditions (HODEK and CERKASOV, 1961; HODEK, 1973). A similar situation was also observed in the Nagoya population of *C. septempunctata brucki* (OKUDA and HODEK, 1983; HODEK et al., 1984) when 62 and 79% of females oviposited within 36 and 30 d, resp., in favourable, diapause averting conditions. Such a lower proportion entering diapause, around 20–40%, is evidently due to the generally bivoltine life-cycle of *C. s. brucki* in the Nagoya plain (vs. the prevalent univoltinism of *C. s. septempunctata* in Europe). The relatively high (63%) incidence of diapause in the F_1 progeny of the Hokkaido sample appears high when compared with the Nagoya bivoltine population, but is similar to the univoltine populations of *C. s. septempunctata* from central Europe.

Photoperiodic response and life-cycle in Hokkaido

Long-day photoperiod of 16L–8D combined with high temperature of 25°C was found to avert diapause in the Sapporo population. This was evidenced both by the relatively fast activation of the entire autumnal sample (Fig. 1) and by the 40% incidence of reproductive females in the F_1 progeny (Fig. 2). The increase to 65% in the proportion of reproducing females at very high temperature of 30°C (at 16L–8D) indicates also a long-day type insect (Fig. 2). The lower temperature of 20°C, used with short-day photoperiod of 12L–12D, would have enhanced the diapause averting activity of short days if the population was of short-day type (SAKURAI et al., 1987).

Although only stationary photoperiods were used and the experiments were not performed under the entire range of photoperiods, they strongly indicate that the Sapporo population of *C. septempunctata brucki* has the long-day photoperiodic response in contrast to the population from central Honshu. *C. s. brucki* from Hokkaido is in this respect similar to *C. s. septempunctata* from central Europe (HODEK and CERKASOV, 1961; HODEK and RUZICKA, 1979) and some other European populations (BONNEMAISON, 1964; HÄMÄLÄINEN and MARKKULA, 1972; HODEK et al., 1977; SEMYANOV, 1978). This similarity in photoperiodic response is appropriate to ensure a similar life cycle, i.e. to induce winter diapause in both climatically similar regions with long harsh winters.

In the Kanto plain, with a climate not much different from the Nagoya plain (aver. temperature for the trimester of Dec.–Jan./1961–1990/4.9°C and 4.5°C, resp.) dissections (Tables 1 and 2) indicate the same bivoltine life cycle which apparently is regulated by the short-day photoperiodic response inducing summer diapause. An intriguing question has still remained to be solved: what happens in the transition zone between the two populations in northern Honshu. Preliminary data on the population from Hirosaki region show a very low incidence of ovipositing females at 12L–12D and 25°C: 8% after a long preoviposition period of 39 d (SAKURATANI, personal communication).

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REFERENCES

Angalet, G.W., J.M. Tropp and A.N. Eggert (1979) *Coccinella septempunctata* in the United States; recolonization and notes on its ecology. *Environ. Entomol.* **8**: 896–901.

Bonnemaison, L. (1964) Observations écologiques sur la Coccinella à 7 points (*Coccinella septempunctata* L.) dans la région parisienne. *Bull. Soc. Entomol. France* **69**: 64–83.

Hämäläinen, M. and M. Markkula (1972) Possibility of producing *Coccinella septempunctata* L. (Col., Coccinellidae) without a diapause. *Ann. Entomol. Fenn.* **38**: 193–194.

Hirano, T., H. Sakurai and S. Takeda (1982) The factors inducing aestivation of *Coccinella septempunctata bruckii*. *Proc. Kansai Plant. Prot. Soc.* **24**: 61 (in Japanese).

Hodek, I. (1973) *Biology of Coccinellidae*. Dr. W. Junk, The Hague, 260 pp.

Hodek, I. and J. Cerkasov (1961) Prevention and artificial induction of imaginal diapause in *Coccinella septempunctata* L. (Col.: Coccinellidae). *Entomol. Exp. Appl.* **4**: 179–190.

Hodek, I. and Z. Ruzicka (1979) Photoperiodic response in relation to diapause in *Coccinella septempunctata* (Coleoptera). *Acta Entomol. Bohemoslov.* **76**: 209–218.

Hodek, I., G. Iperti and F. Rolley (1977) Activation of hibernating *Coccinella septempunctata* (Col.) and *Perilitus coccinellae* (Hym.) and the photoperiodic response after diapause. *Entomol. Exp. Appl.* **21**: 275–286.

Hodek, I., T. Okuda and M. Hodková (1984) Reverse photoperiodic responses in two subspecies of *Coccinella septempunctata* L. *Zool. Jb. Syst.* **111**: 439–448.

Okuda, T. and I. Hodek (1983) Response to constant photoperiods in *Coccinella septempunctata bruckii* populations from central Japan (Coleoptera, Coccinellidae). *Acta Entomol. Bohemoslov.* **80**: 74–75.

Sakurai, H., K. Goto, Y. Mori and S. Takeda (1981) Studies on the diapause of *Coccinella septempunctata bruckii* Mulsant. II. Role of corpus allatum related with diapause. *Res. Bull. Fac. Agric. Gifu Univ.* **45**: 17–23 (in Japanese with English summary).

Sakurai, H., T. Hirano, K. Kodama and S. Takeda (1987) Conditions governing diapause induction in the lady beetle *Coccinella septempunctata bruckii* (Coleoptera: Coccinellidae). *Appl. Entomol. Zool.* **22**: 133–138.

Sakuratani, Y. (1988) Overwintering stages of *Coccinella septempunctata brucki* in Japan. In *Ecology and Effectiveness of Aphidophaga* (E. Niemczyk and A.F.G. Dixon, eds.). SPB Acad. Publ., The Hague, pp. 79–82.

Sakuratani, Y., K. Shimizu and E. Shirou (1986) Adult emergence of *Coccinella septempunctata bruckii* Mulsant (Coleoptera: Coccinellidae) in winter in central Japan. *Appl. Entomol. Zool.* **21**: 476–478.

Sasaji, H. (1971) *Fauna Japonica. Coccinellidae (Insecta: Coleoptera)*. Acad. Press Japan, Tokyo, 340 pp.

Schaefer, P.W. and R.J. Dysart (1988) Palearctic aphidophagous coccinellids in North America. In *Ecology and Effectiveness of Aphidophaga* (E. Niemczyk and A.F.G. Dixon, eds.). SPB Acad. Publ., The Hague, pp. 99–103.

Semyanov, V.P. (1978) Structure of populations and peculiarities of photoperiodic reaction of *Coccinella septempunctata* L. (Coleoptera, Coccinellidae). *Trudy Zool. Inst. Leningrad* **69**: 110–113 (in Russian).