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REFERENCES

- FUJIHARA, M. and G. TOYOHARA (1992) *Jpn. J. Ecol.* **42**: 71–79 (in Japanese with English summary).
- KIYOHARA, T. and Y. TOKUSHIGE (1971) *J. Jpn. For. Soc.* **53**: 210–218 (in Japanese with English summary).
- KOBAYASHI, K., M. OKUDA and R. HOSOKAWA (1976) *Trans. 87th Ann. Meet. Jpn. For. Soc.* pp. 239–240 (in Japanese).
- MAMIYA, Y. and N. ENDA (1972) *Nematologica* **18**: 159–162.
- MORIMOTO, K. and A. IWASAKI (1972) *J. Jpn. For. Soc.* **54**: 177–183 (in Japanese with English summary).
- SHIDEI, T. (1972) *Ringyō Gijutsu* **383**: 1–5 (in Japanese).
- TAKESHITA, K., Y. HAGIHARA and S. OGAWA (1971) *Bull. Fukuoka For. Exp. Stn.* **24**: 1–45 (in Japanese with English summary).

Adult Diapause of the Fleabeetle,
Argopistes biplagiatus MOTSCHULSKY
(Coleoptera: Chrysomelidae)
III. Effects of Low Temperatures
on Termination of Winter Diapause¹

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Argopistes biplagiatus MOTSCHULSKY is a univoltine fleabeetle, with hibernation occurring during the adult stage (INOUE, 1990). Oviposition of the species is observed only in the spring, with new adults emerging in early summer (INOUE, 1990, 1992). Adult beetles undergo aestival (summer) and autumnal-hibernal (winter) diapause (INOUE, 1992, 1993). In previous papers (INOUE, 1992, 1993) I had reported that the feeding and oviposition activities of the adults were greatly affected by the photoperiods, and that long (or increasing) days break the winter diapause under laboratory conditions. However, there is no experimental evidence that non-photoperiodic factors affect the

diapause termination of *A. biplagiatus*. This paper aims at determining the effects of low temperatures on the termination of winter diapause in *A. biplagiatus*.

MATERIALS AND METHODS

The adults were collected from fields near the Faculty of Horticulture, Chiba University, Matsudo, Chiba Prefecture, Central Japan on September 1–2 and December 7–9 in 1990. The host plant was *Fraxinus japonica* BLUME. Single females were reared in glass cylinders (15 cm in length, 3 cm in dia.) kept in climatized chambers. They were supplied with new sprouts of *Ligustrum obtusifolium* SIEB. et ZUCC., with stems wrapped in water-soaked absorbent cotton. Food was renewed every five days, and the numbers of oviposited females were counted at the same time.

Females were first exposed to a temperature of 20°C, 15°C, 10°C or 5°C under a long-day (15L–9D) or a short-day (12L–12D) conditions for 40–70 days. They were then transferred to 20°C under the long- or short-day conditions, and reared for the next 40–60 days. The procedures of the experiment are summarized in Table 1. When the females were exposed to cold, buffering periods were not provided.

RESULTS

The incidence of oviposition in different experimental conditions is shown in Table 1. No females

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Table 1. Incidence of oviposition in *Argopistes biplagiatus* females collected in September and December from the field under different temperature conditions

Month of field collection (Experiment group)	No. of females tested	Early condition			Late condition (Temp.: 20°C)			
		Temp. (°C)	Photoperiod (L-D)	Exposing period (days)	No. of dead females	Photoperiod (L-D)	No. of dead females ^a	No. of females oviposited within 60 days after the transfer
September								
S-1	15	15	15- 9	50	2	15- 9	0	0(13) ^b
S-2	13	15	15- 9	50	1	12-12	1	0(11)
S-3	16	15	12-12	50	0	15- 9	0	1(16)
S-4	16	15	12-12	50	2	12-12	0	0(14)
S-5	15	10	15- 9	50	2	15- 9	0	0(13)
S-6	16	10	15- 9	50	0	12-12	0	0(16)
S-7	16	10	12-12	50	1	15- 9	1	1(14)
S-8	16	10	12-12	50	1	12-12	1	0(14)
S-9	16	5	15- 9	50	7	15- 9	1	0(8)
S-10	15	5	15- 9	50	3	12-12	1	0(11)
S-11	16	5	12-12	50	5	15- 9	1	0(10)
S-12	17	5	12-12	50	8	12-12	1	0(8)
December								
D-1	15	15	12-12	40	0	12-12	1	0(14)
D-2	17	15	12-12	70	0	12-12	0	0(17) ^c
D-3	15	10	12-12	40	0	12-12	0	1(15)
D-4	17	10	12-12	70	1	12-12	1	12(15) ^c
D-5	15	5	12-12	40	0	12-12	2	6(13)
D-6	17	5	12-12	70	0	12-12	1	14(16) ^c
D-7	16	20	12-12	—	—	12-12	0	0(16)

^a Number of females which died without oviposition.

^b Numerals in the parentheses represent the numbers of females analyzed.

^c Females were reared for 40 days after the transfer.

Table 2. Pre-oviposition period of *Argopistes biplagiatus* females collected in December under 12L-12D at 20°C

Experiment group ^a	No. of females oviposited	Pre-oviposition period (days) ^b			
		Mean		SD	Range
D-4	12	11.7	(81.7) ^c	5.97	2.5-22.5
D-5	6	25.0	(65.0)	11.29	12.5-42.5
D-6	14	13.2	(83.2)	4.32	7.5-17.5

*, $p < 0.05$; **, $p < 0.01$ by MANN-WHITNEY's *U*-test.

^a See Table 1.

^b Days after the transfer.

^c Numerals in parentheses represent the means when the chilling periods were added.

laid eggs when kept at 5°C-15°C. Most females collected in September (S-1-S-12) laid no eggs when they were first exposed to 5°C, 10°C, or 15°C for 50 days and thereafter transferred to 20°C. Among the females collected in December (D-1-D-7), the females of D-7, which were kept under 20°C throughout the experimental period, laid no eggs. Also, exposure to 15°C did not lead to oviposition under subsequent exposure to 20°C, irrespective of the duration of the exposure period (D-1 and D-2). When the females were exposed to 10°C or 5°C for the first 40 days (D-3 and D-5), a few of them laid eggs, and when the chilling period extended to 70 days (D-4 and D-6), more than 80% of the females laid eggs even though they were kept under a short daylength of 12L-12D.

Pre-oviposition periods of *A. biplagiatus* females collected in December are shown in Table 2. The pre-oviposition period of D-5 was the longest.

DISCUSSION

The low temperatures (5°C-10°C) led to prompt oviposition under subsequent exposure to 20°C among the females collected in December as contrasted with those collected in September (Table 1). In many insect species, the lower temperature threshold for diapause development rises during the course of the winter diapause (TAUBER and TAUBER, 1976). Of the females collected in September, a few laid eggs when they were first exposed to 10°C or 15°C and were then kept under 15L-9D (long-day condition) at 20°C. However, chilling at 5°C did not lead to oviposition after subsequent warming to 20°C (Table 1). Therefore, the winter diapause of *A. biplagiatus* may not

have been induced sufficiently in early September. It is possible that the moderately low temperatures during autumn gradually induce the winter diapause of the species in the field.

Chilling is not always a prerequisite for the completion of hibernation diapause (HODEK and HODKOVÁ, 1988). Also, it is difficult to distinguish the effect of low temperature from the effect of an increase in temperature (DANKS, 1987; HODEK and HODKOVÁ, 1988). Among the females collected in December, the pre-oviposition period of D-5 was longer than that of D-6. However, if the time spent under chilling was included (HODEK and HODKOVÁ, 1988), D-5 had a shorter period to initiate oviposition than D-6 (Table 2). Low temperatures play an important role in the synchronization of the life-cycle of the insects (HODEK and HODKOVÁ, 1988). In the family Chrysomelidae, the termination of the adult diapause (appearance from the soil) of *Gastrophysa stercoraria* synchronized as the 5°C storage period increased (ASHIDA, 1980). This may apply to *A. biplagiatus*, because the range of pre-oviposition period in D-6 was the shortest and the variances of D-5 and D-6 were significantly different ($F_0=6.82$, $p < 0.01$, Table 2). Further studies are needed to clarify the effects of temperature on the summer diapause of *A. biplagiatus*.

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REFERENCES

- ASHIDA, Y. (1980) *Ôdôkon-Chûgoku* No. 22: 41–44 (in Japanese).
- DANKS, H. V. (1987) *Insect Dormancy: An Ecological Perspective*. Biological Survey of Canada, Ottawa, 439 pp.
- HODEK, I. and M. HODKOVÁ (1988) *Entomol. exp. appl.* **49**: 153–165.
- INOUE, T. (1990) *Jpn. J. Appl. Entomol. Zool.* **34**: 153–160 (in Japanese with English summary).
- INOUE, T. (1992) *Jpn. J. Appl. Entomol. Zool.* **36**: 159–168 (in Japanese with English summary).
- INOUE, T. (1993) *Appl. Entomol. Zool.* **28**: 313–318.
- TAUBER, M. J. and C. A. TAUBER (1976) *Annu. Rev. Entomol.* **21**: 81–107.

Field Trap Responses of Male
Spodoptera exigua (HÜBNER)
(Lepidoptera: Noctuidae) to
(Z,E)-9,12-tetradecadien-1-ol
and (Z)-9-tetradecenyl acetate^{1,2}

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The beet armyworm, *Spodoptera exigua* (HÜBNER), is a serious pest of various agricultural crops in Asia, Europe and North America. TURLINSON et al. (1981, 1990) identified 12 compounds from the pheromone extracts of the virgin females of the North American population. They demonstrated that two of these components, (Z,E)-9,12-tetradecadienyl acetate (Z9,E12-14: Ac) and (Z)-9-tetradecen-1-ol (Z9-14: OH), were essential for male attraction. In the field tests, optimum blends were a 10:1 mixture of Z9,E12-14: Ac and Z9-14: OH in Florida (MITCHELL et al., 1983) and Taiwan

(CHENG et al., 1985), and a 70:30 mixture in Japan (WAKAMURA, 1987).

In the Japanese population, however, (Z)-9-tetradecenyl acetate (Z9-14: Ac) and (Z,E)-9,12-tetradecadien-1-ol (Z9,E12-14: OH) were identified in the extracts of the sex pheromone glands of virgin females as well as the attractive components, Z9,E12-14: Ac and Z9-14: OH (MOCHIZUKI et al., 1993). In the subsequent electrophysiological study, single sensillum recording revealed two things. First, Z9,E12-14: OH stimulated the corresponding cells for Z9-14: OH at almost the same level as Z9-14: OH. Secondly, Z9-14: Ac stimulated the receptor cells for Z9,E12-14: Ac at about 1,000 times higher dose level than Z9,E12-14: Ac. Based on these results, it was predicted that Z9,E12-14: OH might have any attractant activity like Z9-14: OH when mixed with Z9,E12-14: Ac, and that Z9-14: Ac is unlikely to be detected by male sensilla during mating behavior (MOCHIZUKI et al., 1993), but Z9-14: Ac was expected to show any activity at much higher dose level than Z9,E12-14: Ac when mixed with Z9-14: OH. In the present study, field tests were conducted in order to confirm these predictions.

MATERIALS AND METHODS

Chemicals. All the pheromone chemicals used were supplied by the Shin-Etsu Chemical Co., Ltd. They were purified by column chromatography on silica gel impregnated with 16.7% of AgNO₃ to become more than 99% pure with respect to positional and geometric isomerism. Chemicals were diluted with hexane and applied

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