and Tauber, 1973). According to this standard, diapause in *R. clavatus* is less intense when induced under a photophase near the critical value than under more typical short-day photoperiods, as in *Ostrinia nubilalis* (McLeod and Beck, 1963).

Thus, the photoperiodic termination of adult diapause in *R. clavatus* is related to the photoperiodic history of the individuals in two different ways: The terminating response is invoked by an increase in photophase, and a low-intensity diapause is induced under a photophase near the critical value. Ecological significance of these effects is unclear: Hibernated adults of *R. clavatus* may lay eggs even under a short-day photoperiod in spring, because the critical daylength for the diapause termination decreases gradually under a short-day photoperiod (Numata and Hidaka, unpublished).

REFERENCES


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Early Termination of Summer Diapause by Mechanical Shaking in Pupae of *Antheraea yamamai* (Lepidoptera: Saturniidae)\(^1\)

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Many artificial stimuli are known to be effective for early termination of diapause in insects (Lees, 1955; Beck, 1980). They include physical and chemical factors such as electrical or heat shocks, wounding, and treatments with acid and some chemical agents.

In a univoltine saturniid silkworm *Antheraea yamamai*, pupal summer diapause is regulated by photoperiod and temperature (Kato et al., 1979; Kato and Sakate, 1981; Sakate et al., 1982).

Long-day photoperiod induces and maintains the summer diapause, and short-day photoperiod is effective for its inhibition and early termination. Relatively low temperature is also effective for the early termination. During experiments where oxygen consumption was examined in diapause pupae of *A. yamamai* using Warburg's manometer, we found that pupal duration of some of the diapause pupae examined was shortened in spite of the decrease of oxygen consumption to a diapause level, and supposed that this shortening might be due to the acceleration of diapause development by frequent shaking of the pupae (Sakate and Kato, in preparation). In the present paper, some results supporting this assumption are reported. This is the first report on the effect of shaking on early termination of diapause.

To obtain the diapause pupae, larvae of *A. yamamai* were reared under a long-day photoperiod of 16L-8D at 25°C from hatching till pupation. Non-diapause pupae were also prepared, which were obtained by rearing larvae under a short-day photoperiod of 12L-12D at 25°C. Fresh leaves of *Quercus actissa* were given as food. A small rotary shaker (Tokyo Rikakikai, SS-80S) was

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Table 1. Shortening effect of mechanical shaking on pupal duration and the other developmental events in *A. yamamai* pupae

<table>
<thead>
<tr>
<th>Pupa</th>
<th>Treatment</th>
<th>No.</th>
<th>Successful adult emergence</th>
<th>Developmental failure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>%b</td>
<td>Pupal durationc (days)</td>
</tr>
<tr>
<td>ND</td>
<td>Unshaken</td>
<td>9</td>
<td>100 (9)</td>
<td>23.3±1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>100 (13)</td>
<td>24.8±3.1</td>
</tr>
<tr>
<td></td>
<td>Shaken</td>
<td>13</td>
<td>46.2 (6)</td>
<td>25.8±3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>83.5 (5)</td>
<td>23.8±1.9</td>
</tr>
<tr>
<td>D</td>
<td>Unshaken</td>
<td>8</td>
<td>100 (8)</td>
<td>102.5±21.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>100 (5)</td>
<td>96.4±31.4</td>
</tr>
<tr>
<td></td>
<td>Shaken</td>
<td>16</td>
<td>37.5 (6)</td>
<td>34.1±6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>85.7 (6)</td>
<td>30.8±5.7</td>
</tr>
</tbody>
</table>

a ND: non-diapause type, D: diapause type.
b Numerals in parentheses show number of animals.
c Mean ± standard deviation.
d In ND, complete adults were formed within 30 days after pupation, whereas in D it took 40 days.
e Incomplete adults died within 40 days after pupation.

used to shake the pupae. Each newly eclosed pupa was taken out of the cocoon, put into a small petri dish placed on the shaker, and then shaken for one hour each day till emergence. Speed of the shaking was set at about 90 r.p.m. and during the shaking, the pupae rolled and struck the wall of the dish. This treatment was done for diapause and non-diapause pupae. Throughout the experiments, both pupal groups were kept in 16L–8D or 12L–12D at 25°C, respectively.

The results are shown in Table 1. In the case of non-diapause pupae, no difference in pupal duration was observed between the unshaken and shaken groups. Pupal duration was 23–25 days in both sexes. However, when the pupae were shaken frequently, about half of them which had accomplished adult differentiation, failed to emerge from a pupal exuvia. Curiously, such failure of emergence occurred at a higher rate among males than females. In the case of diapause pupae, a great difference in pupal duration was found between the two groups. Pupal duration was 96–102 days in the unshaken group, whereas it was 30–34 days if the shaking was done. In this case too, a sexual difference was observed in the failure of adult emergence or differentiation. About half the male pupae treated died in the course of adult differentiation within 40 days after pupation. In previous experiments where the intensity of the shaking was more moderate, few developmental failures occurred. Perhaps these accidents were due to damage to the pupal body resulting from frequent and quick shaking, but the reason for the sexual difference among those damaged is unknown. Thus, shortening of the pupal duration by frequent shaking is evident in the diapause pupae. This indicates that diapause development, but not adult differentiation, was accelerated by the mechanical shaking.

In addition, diapause pupae of another saturniid silkworm *A. peryyi*, were shaken for the same period of time, 1–2 months, as the *A. yamamai* pupae. In *A. peryyi*, however, no effect of the shaking on early termination of the diapause was found. Pupal diapause is more strict and intense in *A. peryyi* than in *A. yamamai*. Therefore, it seems likely that the shaking effect is related to diapause intensity.

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Sex Pheromone of the Rice Stem Borer, *Chilo suppressalis* (Walker) (Lepidoptera: Pyralidae): the Third Component, Z-9-Hexadecenal\(^1\)\(^2\)

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The sex pheromone of the female *Chilo suppressalis* was previously identified as a mixture of Z-11-hexadecenal (Z-11-HDAL) and Z-13-octadecenal (Z-13-ODAL) (OHTA et al., 1976; NESBETT et al., 1975). Field tests using the synthetic compounds showed that these two components were essential for male attraction, although less attractive than live virgin females (TATSUKI et al., 1977, 1979). These results suggested the presence of additional pheromone component(s) as known in other Lepidoptera (e.g., ROELOPS et al., 1975; TAMAKI et al., 1979; KLEN et al., 1980). We preliminarily report here Z-9-hexadecenal (Z-9-HDAL) as the third pheromone component identified in the hexane extract of ovipositor tips of *C. suppressalis*.

Insects used were obtained from laboratory stocks successively reared on rice seedlings (UCHUMI, 1974). For extraction, ovipositor tips of 1–2-day-old virgin females were carefully removed with fine eye-surgical scissors so that other body fragments such as scales and hairs were not included. The removed tips were then soaked in a minimum volume of redistilled n-hexane for 0.5–1 hr at room temperature. This extraction procedure allowed analysis of the crude extract by capillary-gas chromatography (GC) without any purification. Combined and concentrated extract (ca. 2,000 F.E.) was analyzed with a Shimadzu CC-Mini® gas chromatograph using a glass capillary column (0.28 mm I.D. × 50 m, CHDMS-WCOT, split ratio 1:99) at 170°C isothermally. This column had proven performance in separating various isomers of the pheromone components and related compounds. With 9 major peaks obtained (Fig. 1a), retention times (Rt) of P1, P3, P5, P6 and P7 were quite similar to those of authentic hexadecanal (HDAL), Z-11-HDAL, Z-11-hexadecen-1-ol (Z-11-HDOL), octadecanal (ODAL) and Z-13-ODAL, respectively (Fig. 1b). Exact coincidence of Rt among corresponding peaks was further obtained by co-chromatography of the extract with the above authentic compounds under the same GC conditions. P2 was expected to be one of the isomers of hexadecanal since it was located in the chromatogram between peaks of HDAL and E-11-hexadecenal (Fig. 1). Comparison of Rt of P2 and several isomers of hexadecanal including Z-7-, Z-9-, E-10- and E-11-isomers was made by means of co-chromatography at both 170°C and 150°C (incomplete separation of Z-9- and E-10-isomers was shown at 170°C), indicating that Rt of P2 always coincided completely with that of Z-9-HDAL.

Further characterization of suspected compounds was conducted by GC-mass spectrometry (GC-MS) with a JEOL DX-300® mass spectrometer interfaced to a JEOL MS-GCGO5® gas chromatograph. A fused-silica capillary column (0.35 mm

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