Scientific Notes

SCIENTIFIC NOTES

EFFECT OF PHOTOPERIOD ON LARVAL EMERGENCE
AND ADULT ECLOSION RHYTHMS IN LIRIOMYZA SATIVAE
(Diptera: Agromyzidae)

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The vegetable leafminer, Liriomyza sativae Blanchard, is a serious pest of vegetable
and ornamental crops in the United States (Spencer & Steyskal 1986). L. sativae is
reared at The Land, EPCOT Center, as a host for the parasitoid Opius dissitus
Muesebeck. The time of emergence of third instar L. sativae from leaves is important
in rearing because it dictates when plants are to be placed over funnels to collect emerging
larvae (Pettitt 1988).

Dipteran larvae typically emerge from their food source prior to pupation in specific
phases of the light:dark (L:D) cycle (Tauber & Tauber 1966), but in some species
emergence does not occur in constant light (Roberts et al. 1987). Adult eclosion rhythms
in Diptera are also typically influenced by L:D cycles (Winfree 1980, Saunders 1982,
and references therein). This research examines the effects of constant light (L:L) and
a L:D cycle on larval emergence from leaves and adult eclosion by L. sativae.

Bush lima bean plants (Phaseolus lunatus L. 'Henderson') were grown with two
plants per 15 cm diameter pot in a steam-pasteurized peat-vermiculite mixture (Speeding
Inc., Sun City, FL) and watered with a modified Hoagland solution (Pettitt 1988). Seedling
lima beans were grown in a screen cage (52 mesh) in the greenhouse to keep them
leafminer-free until they were 10-14 days old. After 10-14d, 6 pots of lima beans were
placed in a cage with adult L. sativae from 0930 to 1530 hours EDST for oviposition
on primary leaves. Following oviposition, three pots were placed in each of two incubators,
one with L:L and the other with 14L:10D with the photophase beginning at 0700 hours
EDST. Cool-White™ fluorescent bulbs (General Electric, Bloomington, IL) provided a
photon flux density of 60-85 µmol·s⁻¹·m⁻². Light intensity was measured with a Li-Cor
radiation sensor (Model LI-190S, Li-Cor Inc., Lincoln, NE) calibrated to measure
spectral radiance between 400 and 700 nm. Temperature was maintained at 25 ± 1°C. A
datalogger monitored temperature at leaf height and maintained running averages.
Degree-days were calculated using the lower development threshold temperature of
10°C (Pettitt et al., 1991).

Trays formed from aluminum foil were placed under plants to intercept emerging
larvae. Emerging larvae were removed, counted, and placed in 30ml diet cups every 2h
in the L:L chamber and every 2h during the photophase in the L:D chamber. Trays in
the L:D chamber were checked for larvae at the beginning of each photophase to count
any larvae that might have emerged during the scotophase. This experiment was re-
peated four times.

In experiments 2 and 3, half of the collected larvae were returned to the same
photoperiod regime and half were transferred to and held in the alternate regime during
pupal development. Adult flies were counted and removed daily at 0700, 1400, and just
prior to 2100 hours. Pupal development times were calculated and were compared using
Student's t-test (Steel & Torrie 1960). Calculation of degree-days were not necessary
for comparison of pupal development times because incubator temperature averages
were within 0.1°C.

Emergence of L. sativae larvae from leaves maintained in constant light occurred
continuously from 97 to 134 degree-days (DD) (Fig. 1 A-D). The cumulative emergence
Fig. 1. (A-D) Cumulative percentage of larvae emerged from leaves in L:D (bars) and L:L (lines) in experiments 1-4, corresponding degree-day accumulation from *L. sativae* oviposition. Black and white sections of horizontal bar represent scotophase and photophase, respectively.

Larval emergence from leaves in L:D conditions, however, occurred almost exclusively during the photophase (98%) with large “bursts” of larval emergence occurring during the first 5h of the photophase. In experiments 1-4, 99%, 82%, 90%, and 97%, respectively, of the total number of larvae to emerge from leaves in L:D did so between 0700 and 1200 hours. Median larval emergence in L:D conditions occurred at slightly lower DD accumulations than in L:L.

*L. sativae* larvae emerged from leaves primarily within 5h of the onset of photophase in L:D and continuously in L:L. Larval emergence near the onset of photophase in L:D conditions has also been observed in other agromyzids including *L. trifolii* (Burgess) (Leibee 1984), and *Phytomyza lanati* Spencer (Tauber & Tauber 1966), but larval emergence in *L. brassicae* (Riley) takes place generally in the afternoon or evening (Beri 1974).

In adult eclosion experiments, almost all pupae (98.5%) which developed in L:D conditions eclosed during photophase (69% during the first 7h), while those held in L:L conditions eclosed throughout the 24-h cycle (Table 1). The photoperiod to which larvae were exposed had no effect on diel timing of adult eclosion.

Development times from larval emergence to adult eclosion were significantly longer (ca. 1 d longer) for pupae exposed to constant light (Exp. 2, t = 24.0, df = 172, P < 0.001; Exp. 3, t = 19.5, df = 208, P < 0.001) (Table 1). Lighting conditions during larval development did not affect development times of pupae in constant light.
### TABLE 1. Diel timing of adult eclosion and development time for pupae held in either L:D or L:L, following larval development in either regime.

<table>
<thead>
<tr>
<th>Lighting Conditions for:</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupae Larvae</td>
<td>L:D&lt;sup&gt;a&lt;/sup&gt;</td>
<td>L:D&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>L:D</td>
<td>L:L</td>
</tr>
<tr>
<td>Time of Adult Eclosion (hours)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0700-1400</td>
<td>39</td>
<td>15</td>
</tr>
<tr>
<td>1400-2100</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>2100-0700</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>19</td>
</tr>
<tr>
<td>Pupal Development Time (d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\bar{x})</td>
<td>10.3</td>
<td>10.4</td>
</tr>
<tr>
<td>s</td>
<td>0.33</td>
<td>0.44</td>
</tr>
</tbody>
</table>

<sup>a</sup>L:D represents a 14:10 light:dark regime with “lights on” at 0700 hours.

<sup>b</sup>L:L represents a constant light regime.

Short increases in time to pupariation (ca. 1–2 h at 25°C) have been reported for *Liriomyza trifolii* (Burgess) in L:L (Leibee 1986). The fact that the pupal development time of *L. sativae* increased by one full day in L:L suggests that other developmental processes in addition to pupariation were affected.

Adult eclosion occurred during the photophase in L:D as it does in many dipterans (Saunders 1982), but it occurred continuously in L:L. The entrainment to a L:D cycle that occurred during the larval stage in *L. sativae* does not persist to affect timing of adult eclosion. *L. sativae* and many other dipterans (but not all) are responsive to light cycles during the pupal stage (Winfree 1980).

The first larval emergence in these studies occurred at 88.8 DD (0.2% of total), corresponding well with previous occurrence at 87.8 DD (0.1% of total) (Petitt et al., 1981). Placement of plants over collection funnels by 96 DD as previously recommended would have captured 99.5% of larvae emerging in these experiments (L:L and L:D).

I thank Rick Etzel for preparation of Fig. 1, David Wietlisbach for technical assistance, and Hank Robitaille for reviewing the manuscript.

### REFERENCES CITED


FIELD EVALUATION OF ENTOMOPATHOGENIC NEMATODES AGAINST CITRUS ROOT WEEVILS (COLEOPTERA: CURCULIONIDAE) IN FLORIDA CITRUS

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Several species of weevil, including Diaprepes abbreviatus (L.), Pachnaeus litus (Germar), Pachnaeus opalus (Oliver) and Artipus floridanus Horn, are known to infest citrus in Florida. These species are similar in their biology. The adults feed on young, tender foliage and lay eggs in masses on the leaves. Newly hatched larvae burrow into soil and begin feeding on roots of citrus trees, resulting in a weakened, stressed tree (Schroeder & Beavers 1977). Feeding of the larvae on roots also opens wounds for entrance of fungi and other pathogens.

The potential for entomopathogenic nematodes to serve as biological control agents of insects has been explored for several decades (Poinar 1971). Diaz & Hernandez (1978) and Montes et al. (1981) reported on the successful use of Steinernema carpopusae (= S. feltiae = Neoapectina carpopusae) for control of P. litus in potted citrus trees in South America. Beavers et al. (1983) found both S. carpopusae and Heterorhabditis spp. to be pathogenic to D. abbreviatus larvae in laboratory evaluations. Research by Schroeder (1987, 1990a, 1990b) confirmed this activity in additional laboratory and field trials.

The purpose of this research was to compare the efficacy of two species of entomopathogenic nematodes, S. carpopusae All strain (BioVector™ - Biosys, Palo Alto, CA)

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