DEVELOPMENTAL RATES AND EMERGENCE OF VEGETABLE LEAFMINER¹ PUPAE AND THEIR PARASITES REARED FROM CELERY FOLIAGE²

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ABSTRACT

Vegetable leafminers, Liriomyza sativae Blanchard, were reared from ‘2-14’ celery foliage held at different constant temperatures to determine the influence of temperature on pupal development and on host and parasite emergence. Significantly (P<0.05) greater numbers of leafminer pupae were obtained from celery leaflets held at 32.2°C than at 15.6°C. The percent emergence of adult leafminers was significantly greater (P<0.05) at the higher rearing temperature (75% emergence above 20°C and 45% emergence below 20°C). Larval parasite emergence (Dicyphus intermedius (Grit.) and Chrysomatomyia formosa (Westwood)) was significantly (P<0.05) greater at temperatures below 25°C (49%) than at higher temperatures (29%). Leafminer pupal developmental time under constant rearing temperatures increased from 5-7 days at 22.2°C to 21.0 days at 15.6°C.

Pupal development required a mean 127.8 degree-days, with an estimated lower threshold temperature of 10.0°C. The degree-day requirements for pupal development were not significantly different at constant rearing temperatures of 15-35°C.

RESUMEN

Los minadores de hojas de vegetales, Liriomyza sativae Blanchard fueron criados en el follaje de apio ‘2-14’ mantenidos a distintas temperaturas constantes para determinar la influencia de la temperatura sobre el desarrollo pupal y el surgimiento del huésped y el parásito. Un número significativamente mayor (P<0.05) de pupas de minadores de hojas fueron obtenidos en hojas de apio mantenidas a 32.2°C que de las mantenidas a 15.6°C. El porcentaje de producción de adultos de los minadores fue significativamente mayor (P<0.05) a temperaturas muy altas (75% a más de 20°C, y 49% bajo 20°C). El surgimiento de parásitos larvales (Dicyphus inter-

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medius (Grit.) y Chrysonomia formosa (Westwood) fue significativamente mayor (P=0.05) a temperaturas bajo 23°C (43%) que a temperaturas más altas (29%). El tiempo de desarrollo de pupas de mina doros de hojas bajo temperaturas de cria constantes subieron de 5-7 días a 32.2°C, a 21.0 días a 15.6°C.

El desarrollo pupal tomó un promedio de 127.8 días de grados, con un mínimo de temperatura estimado a 10.0°C. El requerimiento del desarrollo pupal no fue significativamente distinto a temperaturas constantes de 15-35°C.

Only general information is available concerning the biology of serpentine leafminers, Liriomyza (Diptera: Agromyzidae) and their parasites, largely because of the difficulty in identifying the leafminer species. Several temperature regimes are used in this study to provide data to calculate developmental rate, percent emergence and estimation of degree-days for the leafminer pupae, Liriomyza sativae Blanchard, and its parasite, Opilus spp. Information about the influence of temperature on the biology of the leafminer is essential for explaining leafminer population dynamics. Such data may explain not only fluctuations in field populations but help evaluate the influence of laboratory rearing environments on samples used to estimate population density.

The rate of insect development often approximates a linear function of temperature and this relationship is the basis for computing accumulations (Abrami 1972). The theory of temperature summation defines an index for heat energy required to complete a given stage of development (Eckenrode and Chapman 1972). Degree-days, or heat units, have been useful methods in predicting developmental times for insects (Williams and MacKay 1970, Reid and Laing 1976). Allen (1976) provides a modified sine wave method for calculating degree-days and modifications for local geographical biases. In Florida, nocturnal temperatures are relatively constant, thus the sine wave model tends to over-estimate degree-day values.

Materials and Methods

Vegetable leafminers were obtained from leaflet samples collected from commercial fields of '2-14' celery in May 1978 at Belle Glade, Florida. These samples were placed in 165 pint-size paper sherbet containers each with 12 trifoliolate celery leaflets and were taken to the laboratory at the University of Florida, Gainesville. Fifteen containers were placed at each of 11 temperature regimes in growth chambers. Eight samples were held at constant temperature of 32.2°C, 29.4°C, 26.7°C, 23.9°C, 22.2°C, 21.1°C, 18.2°C, or 15.6°C (±0.5°C each). Two other samples were exposed to fluctuating temperatures. One regime simulated Orlando, Florida during January 1978 and was based on historical data from U.S. Weather Bureau statistics with an average daily high and low temperature of 16°C and 2°C, respectively, and with 7 nights of subfreezing temperatures (−0.5 to −4.0°C). The other regime, a 16°C day and 2°C night temperature cycle (12 h each temperature) eliminated the influence of freezing on leafminer emergence and development. The average R.H. in each of the growth chambers was 54%. The 11th regime was in an outdoor rearing cage in Gainesville, Florida, during June 1978. The average daily high and low temperatures in this cage were 32.4°C
and 21.9°C, respectively with R.H. ranging from 74% to 90% (average was 89%).

All newly formed leafminer pupae were removed daily from the rearing containers, placed in separate 4 oz. plastic vials, and were held at the same temperature regime from which the pupae were collected. Each day both containers and vials were observed and emerged leafminer adults and their parasites were removed, identified and counted. Degree-day values were determined for each experimental temperature trial using Allen's (1976) Fortran program. Development rates (1/time) were calculated for each of the 8 constant temperatures.

RESULTS AND DISCUSSION

Temperature was a significant factor influencing the mean number of leafminer pupae collected per celery leaf (Table 1). The leafminer pupae parasitized by the pupal parasite, Opius spp., were not identified and separated until adults of both insects had emerged. Percent emergence of adults from leafminer pupae (leafminer and Opius spp.) was greater at constant temperatures above 21.1°C (75% emergence). Of the total adults (leafminer and Opius spp.) emerging from leafminer pupae, leafminer adults formed 94% of the emerging adult population. The fluctuating Gainesville regime resulted in 62% emergence. This lower value was attributed to decay of foliage in rearing containers and vials. The Orlando regime with 7 nights of subfreezing temperatures reduced adult emergence to 13.9%. At the

<table>
<thead>
<tr>
<th>Rearing temperature regimes (°C)</th>
<th>Mean number leafminer pupae/trifoliolate</th>
<th>% Adult emergence from pupae</th>
<th>% Adult parasite emergence from pupae</th>
<th>% Total parasite parasitism</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.2</td>
<td>7.3a</td>
<td>84.7a</td>
<td>6.9ab</td>
<td>28.2b</td>
</tr>
<tr>
<td>29.4</td>
<td>6.1ab</td>
<td>86.8a</td>
<td>4.6ab</td>
<td>22.8b</td>
</tr>
<tr>
<td>20.7</td>
<td>5.6b</td>
<td>88.3a</td>
<td>5.5ab</td>
<td>23.4b</td>
</tr>
<tr>
<td>23.9</td>
<td>5.4b</td>
<td>77.4a</td>
<td>3.5b</td>
<td>18.5b</td>
</tr>
<tr>
<td>22.2</td>
<td>5.6b</td>
<td>78.3a</td>
<td>5.0ab</td>
<td>45.7a</td>
</tr>
<tr>
<td>21.1</td>
<td>5.3b</td>
<td>78.5a</td>
<td>6.2ab</td>
<td>49.5a</td>
</tr>
<tr>
<td>18.2</td>
<td>5.2b</td>
<td>47.1b</td>
<td>8.2ab</td>
<td>53.7a</td>
</tr>
<tr>
<td>Orlando</td>
<td>0.7—</td>
<td>13.9—</td>
<td>2.3—</td>
<td>51.5—</td>
</tr>
<tr>
<td>Gainesville</td>
<td>12.6—</td>
<td>62.1—</td>
<td>9.7—</td>
<td>21.9—</td>
</tr>
<tr>
<td>16.2a</td>
<td>1.8—</td>
<td>48.2—</td>
<td>17.7—</td>
<td>70.1—</td>
</tr>
</tbody>
</table>

1Leafminer and Opius spp. adults.
2Opius spp. only.
3Includes Opius spp., Chrysanthomyia formosa and Dialyphus intermedius.
4Regime simulated daily Orlando, Florida high and low temperatures during 4-30 January 1978.
5Reared in protected cages outdoors in Gainesville, Florida during 1-19 June 1978.
612h:12h temperature cycle of 16°C day and 2°C night.
7Means followed by the same letter in each column are not significantly different according to Duncan's multiple range test (P=0.05). Means without letters were not included in the analysis.
cooler temperatures the number of *Opinus* spp. adults emerging from leafminer pupae was significantly greater (P<0.05) than the adult leafminer emergence. Under 16°:2°C temperature regime there was significantly (P<0.05) more *Opinus* spp. parasitization (17.7%) than under the Orlando regime (2.3%). This suggests that cool and freezing temperatures affected survival of the parasite or of the parasitized host.

Total parasitism included *Opinus* spp. (3.2%), and the 2 larval parasites *Chrysonotomyia formosa* (Westwood) (74.4%) and *Diglyphus intermedius* (Girault) (22.4%). These latter 2 parasites kill leafminer larvae and emerge as adults directly from celery foliage. The proportion of total parasitism significantly (P<0.05) increased as rearing temperatures decreased and ranged from 18-28% parasitization above 23.9°C and 43-70% at temperatures below 23.9°C. *Chrysonotomyia formosa* was the most numerous of the 3 species of parasites reared. Both *C. formosa* and *Opinus* spp. had greater emergence than the leafminer at cooler temperatures. The freezing temperatures of the Orlando regime increased preadult mortality of *Opinus* spp. parasitoids (in vials). Under field conditions leafminers pupae parasitized by *Opinus* spp. would be insulated by a layer of soil. This may protect the parasitized pupae from subfreezing (−4°C) temperatures. Previously, Harding (1965) observed a high rate of parasitization and an associated decrease in numbers of miners during the colder months in Texas.

Developmental times for leafminer and *Opinus* spp. increased significantly as temperatures decreased (Table 2). Developmental times for leafminer pupae ranged from 5.7 days at 32.2°C to 21.9 days at 15.6°C. In the same temperature range, *Opinus* spp. emergence ranged from 6.4 days to 27.4 days. In all trials this parasite required a longer average time (1 day) to mature than did the leafminer.

The longer developmental times for *Opinus* spp. relative to the leafminer may provide it a competitive advantage over other leafminer parasites when the life cycle of the leafminer and parasite population are synchronized. *Opinus* spp. females preferentially parasitize 1st instar leafminers (Tama and Poe 1979). A slight delay in adult parasite emergence would result in an increase in available leafminer larvae. The stages in the life cycle of leafminer field populations are generally synchronized only during initial periods of invasion.

Emergence of adult leafminers and parasites occurred during a longer period of peak emergence (70%) of time at cooler temperatures (7-9 days when reared at 32.2°C, 10-16 days at 23.9°C, 19-89 days at 15.6°C and 21-53 days at the 16°C:2°C temperature regimes). Emergence of adult *Opinus* spp. did not demonstrate such a large increase in the number of days to peak emergence (70%) (9-10 days at 32.9°C, 13-14 days at 23.9°C, and 31-36 days at 15.6°C). Five percent of the total adult *C. formosa* and *D. intermedius* emerged 7 weeks or later after collection when reared at the cooler Orlando or 16°:2°C temperature regimes. *Chrysonotomyia formosa* was predominant (97.9% of total adult insects) among late emerging parasites. Leafminer adults at lower temperatures rarely emerged 30 days after collecting the leaf samples (0.8%). The cooler temperatures of the winter months in central Florida permit leafminer and parasite population survival by significantly extending the length of time for their pupal maturation.
TABLE 2. MEAN DEVELOPMENTAL RATE AND DEGREE-DAY VALUES FOR VEGETABLE LEAFMINER, *Liriomyza sativae* BLANCHARD, PUPAE AND PARASITE, *Opinus* spp., REARED FROM '2-14' TRIFOLIATE CELERY LEAVES AT 11 TEMPERATURE REGIMES.

<table>
<thead>
<tr>
<th>Rearing temperature (°C)</th>
<th><em>Opinus</em> spp.</th>
<th><em>Liriomyza sativae</em> pupae</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Developmental time (days)</td>
<td>Degree-days above 10.2°C</td>
</tr>
<tr>
<td>32.2</td>
<td>6.4de</td>
<td>143.6b</td>
</tr>
<tr>
<td>25.4</td>
<td>6.8de</td>
<td>134.7b</td>
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<tr>
<td>26.7</td>
<td>8.1d</td>
<td>138.4b</td>
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<td>23.9</td>
<td>9.8cd</td>
<td>141.9b</td>
</tr>
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<td>22.2</td>
<td>10.8c</td>
<td>140.1b</td>
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<td>21.1</td>
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<td>124.6b</td>
</tr>
<tr>
<td>18.2</td>
<td>20.0b</td>
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<tr>
<td>15.6</td>
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<td>134.5a</td>
</tr>
<tr>
<td>Orlando²</td>
<td>12.1-</td>
<td>55.8-</td>
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<tr>
<td>Gainesville³</td>
<td>9.3-</td>
<td>130.4-</td>
</tr>
<tr>
<td>16.2⁴</td>
<td>23.3-</td>
<td>31.9-</td>
</tr>
</tbody>
</table>

¹Average time for *Opinus* spp. adults to emerge from leafminer pupae after leafminer pupation.
²Temperature simulated Orlando, Florida during 4-30 January 1978 in growth chamber. Mean temperature 16°-2°C (day/night), 7 nights of freezing (—4°C coldest).
³Protected outdoor cages in Gainesville, Florida, 1-19 June 1978. 33.7°C/22.4°C day/night average (3.4H. 62-99%).
⁴Growth chambers EHL: 2hD—165.7°C cycle.
⁵Means followed by the same letter in each column as not significantly different according to Duncan's multiple range test (P=0.05).
The growth curve for the leafminer was calculated using % development/day from degree-day values (Fig. 1). Degree-day calculations require a low temperature threshold for pupal development and 10.0°C used. This low threshold temperature for development of leafminer pupae appeared realistic when substantiated by Jensen and Koehler (1970) who found 24% emergence of adult *Liriomyza* sp. at 12.8°C, by data available on other Diptera (Allen 1978, pers. commun.), by *L. sativae* adult emergence of 54% at 15.6°C (Table 1) and 0% at 8.1°C (pers. obs.).

The average heat unit requirements for 2500 leafminer pupae and 210 *Opious* spp. reared at 8 different constant temperature regimes were 127.8 and 141.2 degree-days’ C respectively. These 2 means were not significantly different (P=0.05) from degree-day values for each constant temperature regime. These degree-day values reflect the delay in emergence of *Opious* spp. adults relative to the adult leafminer. The only inconsistent degree-day estimations were with pupae reared at the 16°C;2°C and Orlando regimes with degree-day values of less than 100. Apparently subthreshold temperatures (10°C) affect critical developmental mechanisms within pupae. There is no indication of diapause.

Degree-day requirements and developmental rates for all stages of

![Graph](image)

Fig. 1. Influence of constant temperatures on developmental rates of *Liriomyza sativae* Blanchard pupae reared from ‘2-14’ celery foliage (Belle Glade, Fla., Spring 1978, N = 15, 12 trifoliolate leaves per sample; y = developmental rate; x = °C).
Liriomyza will help in predicting population densities vital to developing effective pest management tactics.

LITERATURE CITED


A REVIEW OF FRANKLINIELLA BRUNERI WATSON AND DESCRIPTION OF F. KELLIAE, N. SP. (THYSANOPTERA: THRIPIIDAE)

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ABSTRACT

Frankliniella brunerii Watson, 1925 was rediscovered for the first time in the past 55 years to be a valid species, and is reclassified. Frankliniella pseudotritici Priesner, 1932 and inornata Moulton, 1936 are newly found synonyms. Frankliniella kelliae, n. sp., mounted together with the type series of brunerii, has otherwise long been confused with another well known species, F. difficilis. Both F. brunerii and kelliae are widely spread and common general flower feeders in the Caribbean area.

RESUMEN

Frankliniella brunerii Watson, 1925, fue descubierto de nuevo después de 55 años como una especie válida, y se diagnostica de nuevo. Frankliniella pseudotritici Priesner, 1932 y F. inornata Moulton, 1936 son sinónimos nuevos. Frankliniella kelliae n. sp. montada junta con la serie típica de F.