Effect of Temperature and Supplementary Nutrition on the Development, Longevity and Oviposition of Conopomorpha sinensis (Lepidoptera: Gracillariidae)

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EFFECT OF TEMPERATURE AND SUPPLEMENTARY NUTRITION ON THE DEVELOPMENT, LONGEVITY AND OVIPOSITION OF *CONOPOMORPHA SINENSIS* (LEPIDOPTERA: GRACILLARIIDAE)

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Abstract

We studied the effect of temperature and supplementary nutrition (honey water) on development, longevity and oviposition of the litchi fruit borer, *Conopomorpha sinensis* Bradley (Lepidoptera: Gracillariidae). Temperature had significant effects on the duration of the pupal period, pupal emergence rate, adult longevity and oviposition. The pupal period increased as the temperature declined. Pupal emergence rates were significantly higher at 20 °C, 25 °C and 30 °C than at 15 °C and 35 °C. When the temperature was lower, adult longevity was longer. The provision of supplementary nutrition significantly increased adult longevity, but there was no significant difference in longevity among a series of concentrations. In addition, temperature had a significant effect on oviposition, with the most eggs being laid at 25 °C. There was no significant difference in the numbers of eggs laid at supplementary nutrition levels of 5, 10, 20, 30, 40 or 50% honey water, although the number laid was approximately 6.33-7.56 fold greater than in the control. We found that the biological characteristics of *C. sinensis* change with temperature or concentration of honey water and these results provide a reference for rearing *C. sinensis* artificially and for forecasting.

Key Words: *Conopomorpha sinensis*; temperature; honey water; development; longevity; oviposition

Resumen

Se estudió el efecto de la temperatura y de nutrición suplementaria (agua con miel) sobre el desarrollo, la longevidad y la oviposición de pupas y adultos del barrenador del fruto de litchi, *Conopomorpha sinensis* Bradley (Lepidoptera: Gracillariidae). Los resultados mostraron que la temperatura tuvo efectos significativos sobre la duración de la etapa de pupa, la tasa de la emergencia de las pupas, la longevidad de los adultos y la oviposición. La duración de la emergencia del estadio de pupa incrementó con la diminuación de temperatura. La tasa de emergencia de la pupa fue significativamente mayor a los 20 °C, 25 °C y 30 °C que a los 15 °C y 35 °C. Cuando la temperatura fue mas baja, la longevidad de los adultos fue mas larga. La provisión de nutrición suplementaria aumentó significativamente la longevidad del adulto, pero la cantidad no fue significativamente diferente entre una serie de concentraciones de agua con miel. Además, la temperatura tuvo un efecto significativo sobre la oviposición, con la mayoría de los huevos puestos a los 25 °C. No hubo una diferencia significativa en el número de huevos puestos en los niveles de nutrición suplementados con 5, 10, 20, 30, 40 o 50% de agua con miel, aunque el número de huevos puestos fue aproximadamente 6.33-7.56 veces mayor que en el grupo de control. Encontramos que las características biológicas de *C. sinensis* cambian con la temperatura y la concentración de agua con miel. Estos resultados proveen una base de referencia para la cría artificial de *C. sinensis* y la previsión del crecimiento de la población.

Palabras Clave: parámetros biológicos, agua con miel, desarrollo, longevidad, oviposición

The litchi fruit borer, *Conopomorpha sinensis* Bradley (Lepidoptera: Gracillariidae), is a destructive pest of litchi (*Litchi chinensis* Sonn.; Sapindales: Sapindaceae) and longan (*Dimocarpus longan* Lour.; Sapindales: Sapindaceae), causing significant economic losses (Zhang et al. 2011). Little is known about its biological characteristics because of its boring habit, and artificial rearing technology is not mature (Tsang & Liang 2007). We have been studying *C. sinensis* for several years (Chen et al. 2010; Chen et al. 2011; Zhao et al. 2012). According to our laboratory-based observations, the growth and behavior of *C. sinensis* is influenced by external temperature, humidity and supplementary nutrition conditions. However, little is known about these factors may affect natural populations of *C. sinensis*.

Until now, there are no reports on biological characteristics of *C. sinensis* under different temperatures and supplementary nutrition (honey water). Temperature and concentration of honey water were 2 major factors influencing the growth and behavior of *C. sinensis*. Temperature influences the whole life cycle of the pest, including the pupal, adult, egg and larval stages (Du et al. 2009; Zhang et al. 2011; Shi et al. 2011). Honey solutions used as adult food have been reported to increase longevity and the length of the oviposition period of the cabbage looper, *Trichoplusia ni* (Hübner) (Noctuidae), and soybean looper, *Chrysodeixis includens* Walker (Noctuidae) (Shorey 1963; Jensen et al. 1974), pink bollworm, *Pectinophora gossypiella* Saunders (Gelechiidae) (Lukefahr & Griffin 1956), tobacco budworm, *Heliothis virescens* (F.) (Noctuidae), corn earworm, *Helicoverpa zea* (Boddie) (Noctuidae), and cotton leafworm, *Alabama argillacea* (Hübner) (Noctuidae) (Lukefahr & Martin, 1964).

In the current study, we examined the effects of different temperatures on pupal duration, emergence rate, adult longevity and oviposition. We also compared water-fed adults with those fed with different concentrations of honey water in regard to their longevity and length of oviposition. This study provides a reference for rearing *C. sinensis* artificially and for forecasting populations in the field.

Materials and Methods

Individuals of *C. sinensis* were collected from litchi or longan orchards at the Guangdong Academy of Agricultural Sciences. The insects were kept in constant temperature 50 × 50 × 210 cm incubators (GXZ380B, Ningbo Jiangnan Instrument Factory, China) at 85 ± 5% RH and 14:10 h L:D. Honey used in the experiment was sourced from the local market. Diluted honey with water at 0, 5, 10, 20, 30, 40, 50% (v:v) was provided to moths on a cotton wick, respectively.

Pupal Duration and Emergence Rate

We collected litchi fruit every 5 days from the orchards from 1 Jul 1 to 11 Aug 2011. The fruits were placed in white porcelain dishes (30 × 40 cm) and covered with paper, as described by Tsang & Liang (2007). The dishes containing the fruit were then placed in an insectary at 85 ± 5% RH and 14:10 h L:D. We gathered abundant numbers of *C. sinensis* pupa from the paper every day. Each pupa was then immediately transferred to a glass tube (1 × 10 cm), which was then put in 1 of 5 constant temperature incubators, set at 15 °C, 20 °C, 25 °C, 30 °C, or 35 °C. Ten glass tubes were used in each treatment and each treatment was repeated 3 times. Each tube was observed on a daily basis until pupal eclosion. Pupal duration and adult emergence rates were then determined.

Adult Longevity

Conopomorpha sinensis pupae were collected by the same method mentioned above from a longan orchard every 3 days from 1 Jul to 21 Aug 2011. After the pupa eclosed, male and female moths were distinguished by the abdomen terminal. The abdomen terminal of the female is blunt or rounded, while that of the male is pointed. The moths were put together in pairs (1 male and 1 female) in white, transparent mineral water bottles (2 L) and fed with 1 concentration of honey water (either 5, 10, 20, 30, 40, or 50%), or with water as a blank control (0%). The bottles were then placed in constant temperature incubators at 15 °C, 20 °C, 25 °C, 30 °C, or 35 °C, respectively. In total, 20 females and 20 males were used in each treatment, which was repeated 3 times. To determine longevity, each bottle was observed on a daily basis until the moths had died.

Oviposition

Conopomorpha sinensis moths were collected as mentioned above from a longan orchard every 3 days from 1 Jul to 21 Sep 2012. In total, 20 males and 20 females were placed in each oviposition cage (50 × 50 cm) and provided with fresh longan fruit. The female moths are known to oviposit on the pericarp of longan fruit. When testing the effect of temperature (15 °C, 20 °C, 25 °C, 30 °C, or 35 °C) on oviposition rate, supplementary nutrition was provided in the form of 10% honey water. When testing the effect of the concentration of honey water (5, 10, 20, 30, 40, or 50%), the experiments were conducted in insectary at 25 °C, 85 ± 5% RH and 14:10 h L:D. Treatments were replicated 3 times. The number of eggs laid each day was recorded until all the females had died.

Statistical Analysis

Data were analyzed using one-way analysis of variance (ANOVA) using the software SPSS11.5. The difference between means was tested by Least-Significant Difference (LSD) ($P < 0.05$) and Tukey's HSD test

Results

Effect of Temperature on Pupal Duration and Emergence Rate

As shown in Table 1, pupal duration and eclosion rate of *C. sinensis* were significantly different depending on the temperature. Pupal duration was longest at 15 °C, and then declined with temperatures > 15 °C, and the shortest pupal duration occurred at 35 °C. The highest emergence rates were at 25 °C, 20 °C and 30 °C, which were significantly higher than at either 15 °C or 35 °C. Therefore, 15 °C was found to be suitable for extending pupal duration, whereas 25 °C was most suitable for maximum eclosion.

Effect of Temperature and Supplementary Nutrition on Longevity of Females

As the temperature declined (Table 2), female longevity was gradually extended to reach the maximum at 15 °C and 5% honey water, while the minimum longevity occurred at 35 °C and 0% honey water. Female longevities at 30 °C, 25 °C and 20 °C were not significant different ($P > 0.05$), but these longevities were significantly longer than at 35 °C and significantly shorter than at 15 °C.

As the concentrations of honey water provided to the females were increased (Table 2), the longevities of females increased from 1.33 to 28.29 days. Although there was no significant difference in female longevities at the different concentrations of honey water, all groups of females that received honey water regardless of concentration lived significantly longer than females fed only water (blank control) except that females fed 10% honey water lived an average of 11.55 days, which was not significantly longer than the 2.59 days lived on average by those fed 0% honey water.

Effect of Temperature and Supplementary Nutrition on Longevity of Males

As the temperatures increased (Table 3), the longevities of *C. sinensis* males gradually de-

Table 1. The durations of pupal development and adult emergence rates of *Conopomorpha sinensis* at different temperatures.

Temperature (°C)	Pupal stage (days)	Emergence (%)
15	13.93 ± 0.34 d	66.67 ± 3.33 a
20	10.03 ± 0.34 cd	93.33 ± 3.33 b
25	7.60 ± 0.66 c	96.77 ± 3.33 b
30	6.60 ± 0.64 b	90.00 ± 5.77 b
35	5.70 ± 0.44 a	56.67 ± 3.33 a

Note: Each datum is the mean ± SE. Different lower case letters in the same column show results that are significantly different at $P < 0.05$.

Table 2. The longevities of *Conopomorpha sinensis* females at various combinations of temperature and various concentrations of honey provided as supplementary nutrition.

Temperature /Honey concentration	Longevity (days)					
	15 °C	20 °C	25 °C	30 °C	35 °C	Average
0% (CK)	5.44 ± 1.03	1.89 ± 0.35	2.30 ± 0.26	2.00 ± 0.24	1.33 ± 0.14	2.59 ± 0.40 a
5%	28.29 ± 1.41	12.50 ± 0.68	11.00 ± 0.66	8.50 ± 0.70	5.62 ± 0.35	13.18 ± 0.76 b
10%	24.00 ± 1.80	11.67 ± 1.31	11.20 ± 1.40	5.78 ± 0.60	5.11 ± 0.20	11.55 ± 1.06 ab
20%	25.48 ± 1.33	12.75 ± 0.72	13.77 ± 1.29	13.54 ± 0.61	5.83 ± 0.30	14.27 ± 0.85 b
30%	27.84 ± 2.46	17.87 ± 1.14	14.62 ± 0.79	13.60 ± 0.60	6.29 ± 0.89	16.04 ± 1.18 b
40%	27.70 ± 2.18	14.94 ± 1.06	13.81 ± 1.19	7.93 ± 0.87	5.23 ± 0.69	13.92 ± 1.20 b
50%	23.04 ± 2.41	16.58 ± 1.12	11.08 ± 1.38	7.39 ± 0.63	6.38 ± 0.26	12.89 ± 1.16 b
Average	23.11 ± 1.80 c	12.60 ± 0.91 b	11.11 ± 1.00 b	8.39 ± 0.61 ab	5.11 ± 0.40 a	—

Note: Each datum is the mean ± SE. Values in the last column on the right followed by the same lower case letter are not significantly different (LSD test, $P < 0.05$). Similarly, values in the bottom row followed by the same lower case letter are not significantly different (LSD test, $P < 0.05$).

Table 3. The longevities of *Conopomorpha sinensis* males at various combinations of temperature and various concentrations of honey provided as supplementary nutrition.

Temperature Honey concentration	Longevity (days)					
	15 °C	20 °C	25 °C	30 °C	35 °C	Average
0% (CK)	5.44 ± 1.03	1.88 ± 0.30	1.92 ± 0.19	1.58 ± 0.19	1.00 ± 0.00	2.36 ± 0.79 a
5%	29.16 ± 1.25	12.54 ± 0.64	11.44 ± 0.63	9.00 ± 0.68	3.80 ± 0.33	13.19 ± 4.27 b
10%	29.81 ± 1.44	11.40 ± 0.33	13.10 ± 1.42	6.75 ± 0.33	3.33 ± 0.16	12.88 ± 4.57 b
20%	24.95 ± 1.57	12.07 ± 0.57	12.69 ± 1.01	11.71 ± 0.33	6.14 ± 0.33	13.51 ± 3.09 b
30%	30.50 ± 2.27	18.06 ± 1.29	14.06 ± 1.16	13.18 ± 0.40	6.47 ± 0.26	16.45 ± 3.97 b
40%	27.70 ± 2.18	15.06 ± 1.13	13.56 ± 1.32	7.45 ± 0.63	5.88 ± 0.46	13.93 ± 3.86 b
50%	25.26 ± 2.42	16.18 ± 1.15	11.53 ± 0.86	7.31 ± 0.66	6.38 ± 0.26	13.33 ± 3.45 b
Average	24.69 ± 3.31 c	12.46 ± 1.98 b	11.19 ± 1.59 b	8.14 ± 1.42 ab	4.71 ± 0.78 a	—

Note: Each datum is the mean ± SE. Values in the last column on the right followed by the same lower case letter are not significantly different (LSD test, $P < 0.05$). Similarly, values in the bottom row followed by the same lower case letter are not significantly different (LSD test, $P < 0.05$).

creased, just as the longevities of females decreased. Also there was no significant difference ($P > 0.05$) in male longevities at 30 °C, 25 °C and 20 °C. Male longevity at 35 °C was significant higher than at 30 °C, 25 °C and 20 °C, and male longevity at 15 °C was significant less than at 30 °C, 25 °C and 20 °C.

As the concentrations of honey water provided to the males were increased (Table 3), the longevities of males increased from 1.00 to 30.50 days. Although there was no significant difference in male longevities at the different concentrations of honey water, all groups of females that received honey water regardless of concentration lived significantly longer than males fed only water (blank control).

Effect of Temperature and Supplementary Nutrition on Oviposition Rate

At 25 °C (Fig. 1) *C. sinensis* females laid significantly more eggs than females kept at any other temperature. Oviposition was almost extinguished at 15°C, whereas there was no significant difference in the numbers of eggs laid at 20, 30 or 35 °C.

At all honey water concentrations of 5-50% females oviposited significantly more eggs than females fed only water (Fig. 2). However, there was no significant difference among the number of eggs laid at the different concentrations of honey water.

Discussion

We found that longevity of *C. sinensis* moths was significantly extended by temperature. In terms of the relation between phytophagous pests and their host plants, the longevity of the pests is an important factor as it contributes to the size of the pest population. Increased longevity also means that the pests have more opportunity to damage the host plant, and also to produce more offspring. But, low temperature also affects the

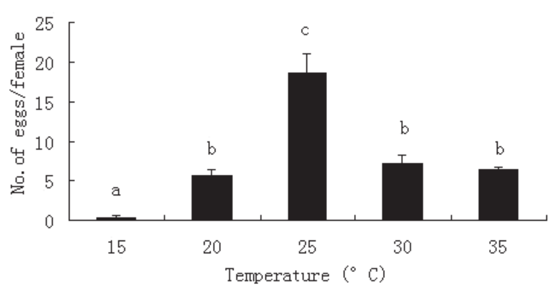

Fig. 1. Egg production by *Conopomorpha sinensis* females at different temperatures. Different lower case letters above bars show significantly different results at $P < 0.05$ (Tukey's test).

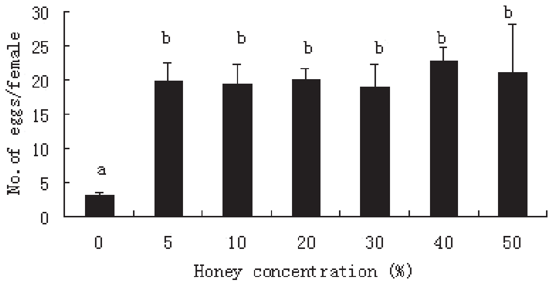

Fig. 2. Egg production by *Conopomorpha sinensis* females fed ad libitum with different concentrations of honey water. Different lower case letters above the bars show significantly different results at $P < 0.05$ (Tukey's test).

activity level, and less active adults at low temperatures might damage the host plant less, even though they live longer. Temperature is an important factor that is known to affect insect longevity. Similar results have been reported by Dyer & Landis (1996), McDougall & Mills (1997), Uckan & Ergin (2003) and Chen et al. (2005).

The results of the current study show that there is no linear relation between the concentration of honey water and adult longevity, and similar results reported by Gu et al. (2010). In fact, high concentrations of sugar solution appeared to have an adverse effect on the longevity of *C. sinensis*, although this was not statistically significant. The reasons might be that consuming a higher concentration of honey water results in increased osmotic pressure, which may have a negative impact on the physiology of the insect. In addition, these results indicate that honey water should be used to feed *C. sinensis* in laboratory cultures to assure and extend their survival. Similar results were reported by Elmer & Barber (1992), Jacob & Evans (2000), Leatemia et al. (1995), Leius (1961), Olson & Andow (1998), Spafford & Evans (2004) and Uckan & Ergin (2002). Jensen et al. (1974) showed that the soybean looper, *C. includens,* laid significantly more eggs, lived longer and mated more frequently when adults were fed either 10% honey or nectar from cotton blossoms than when fed only water. Based on the number of spermatophores found in the bursa copulatrix, soybean loopers fed honey for just 2 days mated more often and laid vastly more eggs than those fed water only.

Further research into the optimum temperature for the development, emergence and oviposition of this important economic pest is both necessary and vital to its artificial rearing control and forecasting of populations in the field.

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