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EFFECTS OF TEMPERATURE ON EMERGENCE DYNAMICS OF *CONOPOMORPHA SINENSIS* (LEPIDOPTERA: GRACILLARIIDAE)

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ABSTRACT

Conopomorpha sinensis Bradley (Lepidoptera: Gracillariidae) is a destructive pest of litchi (*Litchi chinensis* Sonn.; Sapindales: Sapindaceae) and longan (*Dimocarpus longan* Lour.; Sapindales: Sapindaceae). We studied the effects of temperature on the emergence of the litchi fruit borer at 5 temperatures (15, 20, 25, 30, and 35 °C), 80% RH and 14:10 h L:D. Temperature significantly affected the emergence duration and emergence rate, but not the sex ratio and the emergence pattern. The duration of emergence increased as the temperature decreased. The emergence rates at 20, 25, and 30 °C were significantly higher than at 15 and 35 °C. The sex ratio of *C. sinensis* under the different temperature treatments remained at approximately 1:1, and was unaffected by temperature. The emergence pattern of females was similar to that of males in that both had 2 peaks. Most moths emerged primarily from 20:00 (4 h after the onset of darkness) to early in the morning. More females emerged during a first peak, whereas most males emerged during a second peak. As shown in the 24-h-long record, the greatest emergence per h of females occurred at 20:00, and that of males at 0:00. This pattern did not vary significantly among the various temperatures. This study supports artificial rearing and the forecasting of *C. sinensis* populations in the field.

Key Words: duration of emergence, emergence pattern; emergence rate; sex ratio, litchi fruit borer

RESUMEN

Conopomorpha sinensis Bradley (Lepidoptera: Gracillariidae) es una plaga destructiva de lichi (*Litchi chinensis* Sonn.; Sapindales: Sapindaceae) y longan (*Dimocarpus longan* Lour.; Sapindales: Sapindaceae). Se estudió el efecto de la temperatura sobre la emergencia del barrenador del fruto de lichi en 5 temperaturas (15, 20, 25, 30 y 35 °C), 80% HR y 14:10 horas L: O (Luz: Oscuridad). La temperatura afectó significativamente la duración y tasa de emergencia, pero no la proporción de sexos o el patrón de emergencia. La duración de emergencia aumentó a medida que la temperatura disminuyó. La tasa de emergencia a los 20, 25 y 30 °C fue significativamente mayor que a los 15 y 35 °C. La proporción de sexos de *C. sinensis* bajo los diferentes tratamientos de temperatura se mantuvo en aproximadamente 1:01 y no fue afectada por la temperatura. El patrón de emergencia de las hembras fue similar al de los machos en que ambos tenían 2 picos. La mayoría de las polillas emergieron principalmente desde las 20:00 (4 h después de la aparición de la oscuridad) hasta temprano en la mañana del siguiente día. Más hembras emergieron durante el primer pico, mientras que la mayoría de los machos emergieron durante el segundo pico. Como se muestra en el registro de 24 horas, la mayor emergencia por hora de las hembras sucedió a las 20:00, mientras la mayor emergencia por hora de los machos fue a las 0:00, y esta diferencia en el patrón no varió significativamente entre las varias temperaturas. Este estudio apoya la cría artificial y la previsión de las poblaciones de *C. sinensis* en el campo.

Palabras Clave: duración de emergencia, patrón de emergencia; tasa de emergencia; proporción de sexos, barrenador de la fruta lichi

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) that causes significant economic losses. Many studies have reported on the forecasting and prevention

of *C. sinensis* in the field, and several papers have discussed the biological characteristics of adults (Chen et al. 2011; Tsang et al. 2007; Li et al. 2013). According to our indoor observations, the growth and development of *C. sinensis* were strongly affected by external conditions, such as temperature, and humidity. Emergence behavior

provided important clues for forecasting and pesticide application. However, little is known about the emergence behavior of adult *C. sinensis*. Thus, we conducted this study to determine the systematic emergence characteristics of *C. sinensis* under laboratory conditions.

Our study was prompted by observations that the emergence time of *C. sinensis* varied markedly throughout the day, which suggests the possibility of a diel rhythm in the emergence biology of this insect. To further understand how *C. sinensis* responds to variations in its environment, we examined the effects of different temperatures on adult emergence patterns, i.e., emergence time, emergence rate, sex ratio, and emergence duration. The results can be useful for further determining the optimum time of applying chemical control of *C. sinensis* adults and to better understand the population dynamics and the spatio-temporal distributions of the species under field conditions.

MATERIALS AND METHODS

We collected litchi fruits every 3rd day from the orchards of Guangdong Academy of Agricultural Sciences during 1 Jun to 11 Aug 2013. The fruits were placed in white porcelain dishes (30 cm × 40 cm) and were covered with folded paper, as described by Tsang & Liang (2007). We gathered the *C. sinensis* pupae from the paper every day. In Guangzhou, the period of *C. sinensis* development is in May to late Sep., and the mean temperature during this period ranges between 26 °C and 30 °C, with temperatures often exceeding 35 °C during Jun to Aug. The influence of various temperatures (15, 20, 25, 30, and 35 °C) on the emergence behavior of *C. sinensis* was investigated in five 50 cm × 50 cm × 210 cm constant-temperature incubators (GXZ380B, Ningbo Jiangnan Instrument Factory, China) at 14:10 h L:D (scotophase: 20:00 to 06:00). Because the summers in Guangzhou are rainy, we maintained the RH at 80%. Pupae collected on the same day were kept in 20 cm-long × 3 cm-diam glass tubes whose ends were covered with fine mesh gauze. Fifty pupae were placed in each tube. Two glass tubes of adults were used for each replicate and the experiment was replicated 3 times.

Five treatments were administered in this study, with a total of 300 pupae used in each treatment. All the tubes were placed in an incubator that was maintained at the indicated temperatures. Emergence was observed every 2 h, and a dim red light (220V, 50Hz) was used for observations during the dark period. Emergence duration, adult emergence rates and the number and time of emerged females and males were recorded.

Statistical Analysis

The statistical analyses were performed by the SPSS 11.5 statistical package (SPSS Inc., Chicago, Illinois, USA). Data were subjected to a one-way ANOVA with temperature as a factor, and the differences between means were determined by a Least-Significant Difference (LSD) analysis at the appropriate level of probability ($P < 0.05$).

RESULTS

Effects of Temperature on Emergence Rate, Emergence Duration, and Sex Ratio of *C. sinensis*

Emergence rates did not differ significantly between the 20 °C, 25 °C, and 30 °C treatments, but emergence rates at 15 °C and 35 °C were significantly less than those at the other temperatures ($P < 0.05$, Table 1).

As shown in Table 1, the emergence duration of *C. sinensis* differed significantly depending on the temperature ($P < 0.05$). The duration of emergence was greatest (117 h) at 15 °C and significantly less at all temperatures >15 °C. However, the duration of emergence did not differ significantly among temperatures ranging from 20 °C to 35 °C.

The percentages of emergence were the smallest and did not differ significantly at 15 °C and 35 °C (Table 1); however the latter percentages (60.6% and 52.8%, respectively) differed significantly from the percentages of emergence at 20 °C, 25 °C and 30 °C, which were 93.0%, 95.0% and 90.0%, respectively.

The sex ratio (♀:♂) of the *C. sinensis* adults was approximately 1:1, and did not vary significantly among the 5 temperatures (Table 1).

TABLE 1. EMERGENCE DURATION (HOURS), EMERGENCE RATE, AND SEX RATIO OF *CONOPOMORPHA SINENSIS* AT VARIOUS TEMPERATURES.

Temperature/°C	Emergence duration (h)	Emergence rate (%)	Sex ratio (female:male)
15	117.00 ± 3.00 b	60.50 ± 1.15 a	1.10 ± 0.03 a
20	52.00 ± 1.36 a	93.00 ± 3.51 b	0.97 ± 0.07 a
25	51.00 ± 2.04 a	95.00 ± 6.35 b	1.00 ± 0.06 a
30	51.32 ± 1.84 a	90.00 ± 6.08 b	1.01 ± 0.06 a
35	43.66 ± 1.96 a	52.83 ± 1.17 a	0.96 ± 0.05 a

Note: All data are presented as mean ± SE. Different lowercase letters in each column show significant difference at $P < 0.05$.

Circadian Rhythm of Emergence of *C. sinensis*

DISCUSSION

The *C. sinensis* adults emerged at about 5 days to 13 days after pupation, and both sexes clearly showed circadian rhythms of emergence at all experimental temperatures (Figs. 1 and 2). Most adults emerged from midnight to early morning, but the females emerged significantly earlier than the males. The peaks of emergence were similar at different temperatures. The number of emergence peaks was also unaffected by temperature because two peaks appeared at all temperatures (Figs. 1 and 2). The first emergence peak of females was high, with 70% of the females emerging during the first peak, and 20% of females emerging during the second peak (Fig. 3). However, the second emergence peak of males was higher than that of females. Thus 34% of males emerged during the first peak and 53% emerged during the second peak. The interval between peaks did not differ significantly between females and males under different temperatures: 4 h for females and 6 h for males.

Not surprisingly, emergence of *C. sinensis* is strongly influenced by temperature, and about 90% of adults successfully emerged between 20 and 30 °C. The low temperature of 15 °C and the high temperature of 35 °C reduced percent emergence, but did not prevent emergence. The observed declines in emergence rates at the lowest and highest temperatures in this study are consistent with the observations of Li et al. (2013). Similar results were observed in *Plutella xylostella* by Golizadeh et al. (2007) who studied its temperature-dependent development on cabbage, and also found that pupal development times decreased with increasing temperature.

In our observations, *C. sinensis* pupal development required approximately 5.70 days to 13.93 days at different temperatures and there were significant differences among the 5 temperatures (Li et al. 2013). There were no significant differences among emergence durations at 20, 25, 30, 35°C. The statistical methods of analysis of

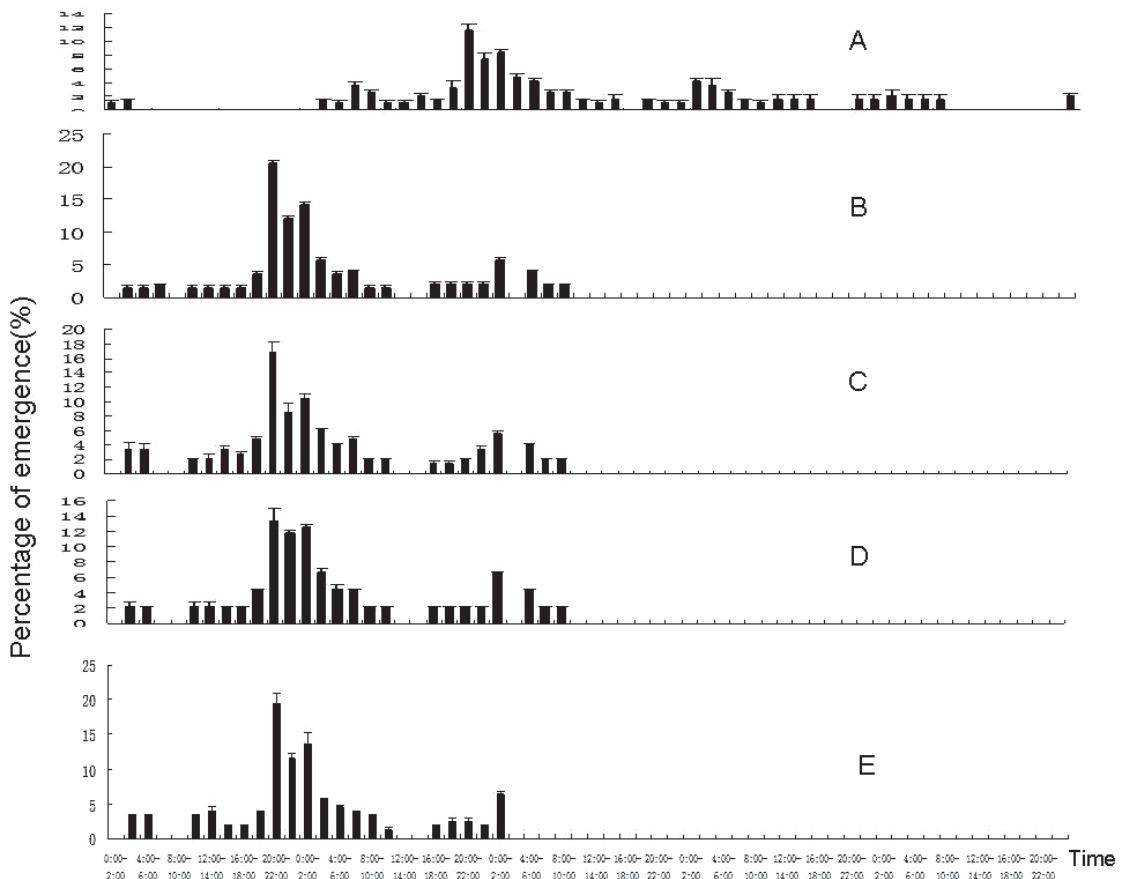


Fig. 1. Emergence patterns of *Conopomorpha sinensis* females at different temperatures (A, 15 °C; B, 20 °C; C, 25 °C; D, 30 °C; and E, 35 °C) during 120 hours of observations.

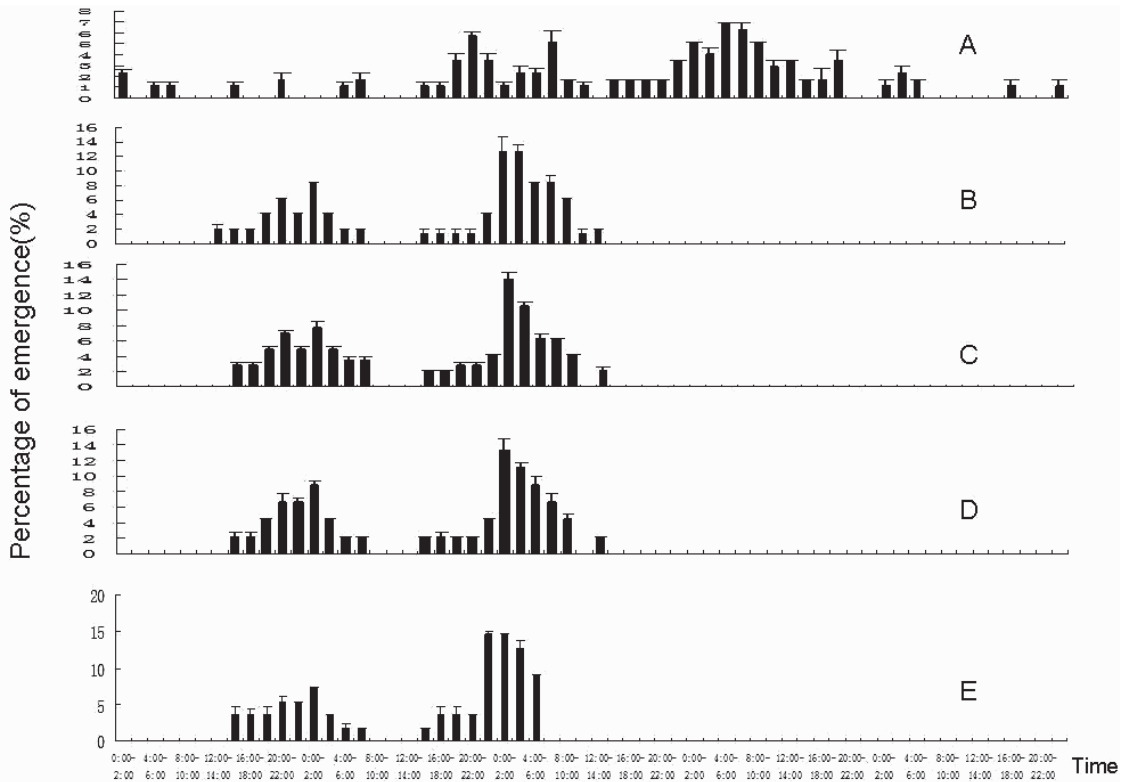


Fig. 2. Emergence patterns of *Conopomorpha sinensis* males at different temperatures (A, 15 °C; B, 20 °C; C, 25 °C; D, 30 °C; E, 35 °C) during 120 hours of observations.

data pertaining to pupal development (Li et al. 2013) and adult emergence in this study were different. Although data from the 5 temperature treatments varied, the female to male ratio of *C. sinensis* adults was approximately 1:1 regardless of temperature, and this is consistent with previous findings for *C. sinensis* and many other insects (Yao et al. 2009; Lee & Lee 2008; Infante et al. 2005). Use of sex pheromone traps in the field would skew the sex ratio toward females, and reduce the probability of mating success of females. Disruption of communication using synthetic sex

pheromones is principally used to reduce daily mating opportunities or to disrupt mating, and thereby reduce the production of eggs. In *Spodoptera exigua*, delaying mating for more than 4 days after emergence reduces the number of eggs and lowers the hatching rates (Wakamura 1990). In many other insects, delayed mating reduces the fecundity and fertility of females (Krann & Straten 1988; Wang et al. 2011; Jones & Aihara-Sasaki 2001; Wu et al. 2012). Therefore, the female to male ratio may be conducive for the proliferation of *C. sinensis* populations.

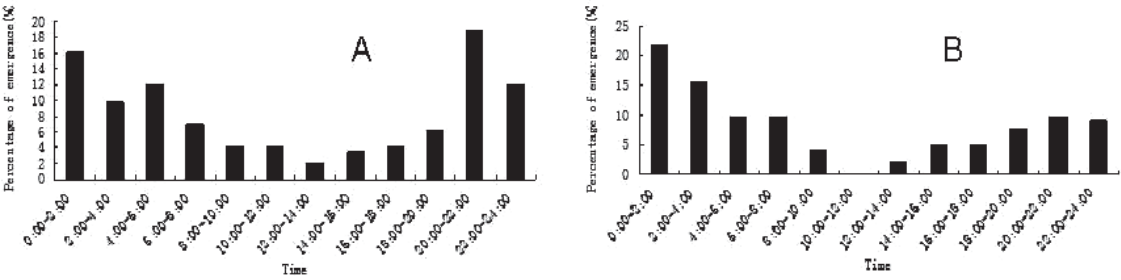


Fig. 3. Emergence patterns of *Conopomorpha sinensis* at 25 °C (A, females; B, males) during 24 hours of observation.

In some other insect species, males emerge significantly earlier than females (Oshiro & Azuma 1978; Fantinou et al. 1998; Nagayama et al. 2004; Luo et al. 2012). Nadel & Lack (1992) stated that the emergence of males somewhat earlier than females could ensure that all females would encounter males. Sometimes there was the phenomenon of strongly female-biased sex ratios, and yet all females can still encounter males. But in our study, the largest peak of females emerged approximately 24 h earlier than males, which was contrary to observations in some other species. Lee & Lee (2008) also studied the adult emergence rhythm of the beet armyworm, *Spodoptera exigua* (Hübner), and their conclusion agrees with our results. Thus, females of *C. sinensis* emerge earlier than males and die later than males (Li et al. 2013), which implies a certain reproductive strategy of *C. sinensis*.

Yao et al. (2009) indicated that the emergence time of *C. sinensis* males is similar to that of females, which differs from our conclusion. Maybe Yao et al. (2009) only analyzed emergence over 24 h but not over 120 h, so they failed to observe that the highest peak of female emergence was 24 h earlier than males. The differences between our results at the same temperatures also can be attributed to differences in space-time and host plants.

This study was carried out under constant conditions, but several other environmental factors also influence the biological characteristics of adult insects, such as humidity, illumination and so on. Alsaaffar et al. (1996) found that humidity affects the pupal mortality rates of *Drosophila melanogaster* Meigen (Diptera: Drosophilidae), and that water loss explains why *D. melanogaster* usually pupates near humid habitats and adults need access to water. Ecological factors that affect the biological characteristics of *C. sinensis* under field conditions should be further investigated to evaluate their effects. More detailed data should then be surveyed and analyzed in a framework to improve our understanding of *C. sinensis* population dynamics. The cycle of day–night rhythm and host plant physiology and biochemical characteristics that influence physiologic responses, such as fruit nutrients, phototaxis, attraction and pesticide application (Gould et al. 2005), might also be involved. Detailed laboratory and field experiments are necessary to reveal the effects of these factors on the behavior of *C. sinensis*. More extensive knowledge regarding the population dynamics of *C. sinensis* and the interactions among the environmental factors, host plant and insects would help improve sustainable control strategies.

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