ADULT ACTIVITY PATTERNS OF *CNEPHASIA JACTATANA* WALKER (LEPIDOPTERA: TORTRICIDAE)

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ABSTRACT

The New Zealand leafroller *Cnephasia jactatana* Walker is an important pest of kiwifruit. Larvae of this species feed on dead or live plant tissues and damage the surface of the fruit or burrow deep into the flesh. To provide important information for the development of adult monitoring and control methods, we studied circadian rhythms and lifespan activity patterns of *C. jactatana*. The investigation was carried out at $20 \pm 2^\circ\text{C}$, $75 \pm 10\%$ RH and a photoperiod of 16:8 h light:dark. Females needed a significantly longer time to complete their life cycle than males. Most moths emerged during the photophase. On a circadian basis, courtship activity peaked 3 and 6 h into scotophase; mating peaked 4–6 h into scotophase and most ovipositions occurred in the first 2 h of scotophase. In the lifespan of this species, male courtship display started 2 days after emergence and peaked 1 day later; mating and oviposition peaked 3 and 7 days after emergence, respectively. Most females initiated oviposition 1 day after mating.

Keywords: *Cnephasia jactatana*, Circadian rhythms, mating, courtship.

INTRODUCTION

Activities such as hatching, moulting, pupation and emergence in insects have a pronounced circadian rhythmicity (Saunders 1982). Selective advantages of the rhythmicity of these behaviours are the reduction of direct competition between species sharing the same resources or the synchronization of sexual activities in a population, increasing the efficiency of genetic isolation of sibling species (Saunders 1982). The study of circadian rhythms elucidates the spatial and temporal distributions of abundance of individuals, which is important for interpreting adult sampling estimates (Quiring 1994). Similarly, the study of mating and oviposition behaviour can enhance our ability to develop pest management tactics, such as mating disruption or plant resistance, based on non-preference (Quiring 1994).

The black-lyre leafroller, *Cnephasia jactatana* Walker, is native to New Zealand and is an important pest of kiwifruit (*Actinidia deliciosa* (A. Chev.) Liang et Ferguson) (Steven 1990). The larvae feed on kiwifruit leaves, and may damage the skin of the fruit and cause more deep flesh damage than any other leafroller (Steven 1990; van der Geest et al. 1991; Stevens et al. 1995). Furthermore, this species also feeds on other important plants, such as *Vitis*, *Citrus*, *Crataegus*, *Diospyros*, *Eucalyptus* and *Fuchsia* (Spiller & Wise 1982; Wearing et al 1991). Because *C. jactatana* is not present in any of the countries that import New Zealand horticultural crops, it is considered a quarantine pest (Steven 1990).

Foster et al. (1993) identified the female sex pheromone for *C. jactatana*, and Ochieng' - Odero & Singh (1992) and Jiménez-Pérez & Wang (2001) have provided useful information on the biology of this species. However, there has been no report on its adult activity patterns, making the development of behaviour-based and environmentally

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friendly control tactics difficult. For example, it would be difficult to interpret adult trapping data without a good understanding of adult circadian and lifespan activity patterns. The aim of this study was to investigate the reproductive behaviour of *C. jactatana* by observing adult emergence, sexual maturation, and daily and lifespan activity patterns.

MATERIALS AND METHODS

Insects

A colony of *C. jactatana* was established from the colony kept at HortResearch, Mt Albert, Auckland. The insects were mass reared according to Jiménez-Pérez & Wang (2001) at $20 \pm 2^\circ\text{C}$, 16:8 h light:dark photoperiod and $75 \pm 10\%$ RH at the Massey University Entomology and IPM Laboratory, Palmerston North, New Zealand. All experiments were carried out under the above conditions.

Emergence

Pupae were collected from the rearing containers, separated according to sex (Howell 1991), and held individually in glass vials (50 mm high x 16 mm diameter; Samco, England) until adults emerged. To determine the circadian rhythm of adult emergence, the emergence of 492 females and 523 males was recorded on an hourly basis. All pupae were reared from eggs of the same age. A Kolmogorov-Smirnov two-sample two-tailed test was used to determine whether developmental time differed between sexes (Siegel & Castellan 1988). The number of insects which had emerged per hour during photophase (light period) and scotophase (dark period) was compared using Analysis of Variance (ANOVA). All statistical analyses were carried out on SAS STAT 6.12.

Adult activity patterns

To observe adult activity patterns on a 24 h basis, two bioassay rooms were set up. The scotophase in one room was set between 2200 – 0600 h (normal-light regime) and in the other room between 1000 – 1800 h (reverse-light regime). Recently harvested pupae were randomly split into two groups, one for each room. Adult activity patterns were studied by confining 65 pairs of newly emerged moths (< 12 h old) (31 in normal-light regime and 34 in reverse-light regime). Each pair was placed in a clear plastic cylinder (65 mm diameter by 83 mm high; LabServ, Auckland, New Zealand) for the duration of their lifespan. Each plastic cylinder was lined with a multipore plastic film (Wicket bag plain perforated, 15 μm , Cryovac™; W.R. Grace Ltd, Auckland) as an oviposition substrate and was covered with a plastic sheet secured with a rubber band. A 10% sucrose solution was provided in a plastic tube (40 mm high by 10 mm diameter) dispensed with a 3.75 cm cotton wick (Richmond, USA). The tube was inserted through the plastic sheet and was replenished as needed.

As mating and courtship normally lasted more than 1 h (A. Jiménez, unpubl. data), each pair was observed for 20 seconds/hour and their activities (feeding, courtship, mating or oviposition) were recorded. Feeding activity was scored when the insect touched the cotton wick (impregnated with 10% sucrose solution) with its proboscis. Courtship was recorded when the male jumped and fanned the wings over or around the female or if the male exposed his genitalia trying to engage the female's genitalia. Mating was scored if the two insects were engaged by the tip of the abdomen. Oviposition was recorded if a female was observed laying eggs or a new egg mass was found in the container. Points on the graphs represent the total number of times an activity was recorded at a particular hour (Fig. 2) or on a particular day (Fig 3). Observations during the dark period were made under two red photographic safe lamps (Phillips No. B22PF712B, EEC) (Webster & Cardé 1982).

RESULTS

Emergence

Males emerged significantly earlier than females (KS test, $P < 0.01$) (Fig. 1). On the first day of emergence, 7% of males and 4% of the females emerged. By the 3rd day after the first emergence occurred, more than 50% of males had emerged while only

41% of females emerged. ANOVA analysis shows that during photophase insects emerged at a rate of 0.73 ± 0.09 insects/h (mean $\pm$ SE), which was almost 50% higher than the emergence rate of 0.32 ± 0.07 insects/h during scotophase ($P < 0.001$).

FIGURE 1: Daily emergence of females and males of *C. jactatana* (n = 492 females and 523 males). Bars are SEM.

Adult activity patterns

Circadian rhythms of adult activities are summarized in Fig. 2. Feeding occurred throughout the 24 h period, with a major peak at the end of scotophase and two smaller peaks, one at 4 h into the scotophase and the other at the end of photophase. Reproductive activity took place almost exclusively during scotophase. Courtship activity peaked 3 and 6 h into scotophase but was also observed outside of scotophase during the final 4 h of photophase. Mating was limited to scotophase, peaking 4 and 6 h into scotophase. Oviposition peaked 1 h into scotophase, and was rarely recorded during photophase.

Adult activity patterns were strongly influenced by age (Fig. 3). Adults started feeding almost immediately after emergence, with a maximum feeding rate occurring 1 day after emergence. Courtship behaviour was first recorded 1 day after emergence, with most courtship displays occurring 2 days after emergence, followed by 2 small peaks 5 and 11 days after emergence. Mating activity reached a peak 2 days after emergence and then gradually declined with age. Females started to lay eggs 3 days following emergence, with most ovipositions occurring between 5 and 9 days after emergence. Only 15% of females laid eggs on the day when first mating occurred. However, more than 50% of females laid their first eggs 1 day after mating. Remating was observed in 6 out of 34 pairs, all in the reverse-light regime.

FIGURE 2: Daily feeding and reproductive rhythms of *C. jactatana* (0-8 h light off, 8-24 h light on).

DISCUSSION

Our results show that *C. jactatana* females need significantly more time than males to complete their life cycle (Fig. 1). Further, courtship display by males started at least 24 h earlier than mating, indicating that males became sexually interested earlier than females (Figs 2 & 3). Similar results were reported for the tortricid *Lobesia botrana* Den. & Schiff. where 70% of males were able to mate 1 day after emergence but most females

FIGURE 3: Reproductive and feeding activities over the life of *C. jactatana*.

were not receptive to mating attempts by males until 3 days after emergence (Torres-Vila et al. 1995). Benz (1991) found that tortricid males possessed a fully formed reproductive system at the pupal stage while the newly emerged females had few or no mature eggs in their ovaries, requiring time to reach sexual maturity and therefore rejecting early mating attempts. Courtship to sexually immature females by males is unlikely to achieve mating. Protandry (males emerging before females) in insects has been associated with species where males maximise the number of matings and females tend to mate only once (Zonneveld 1996). An early emergence of males results in maximisation of mating opportunities and minimisation of female pre-reproductive death (Wiklund et al. 1996, Zonneveld 1996).

Adult *C. jactatana* is a nocturnal insect and its sexual activities are closely related temporally (Fig. 2). Each of the two large courtship peaks was closely followed by a mating peak, suggesting that courtship displays by males are very important for a successful mating. Species-specific circadian reproductive activity patterns have been reported in many insects. The pattern most similar to that of *C. jactatana* is found in *C. pumicana* Zeller (Chambon 1976), where mating occurs in the last 3-4 h of scotophase and oviposition between dusk and 5 h into scotophase. In the pyralid *Ectomyelois ceratoniae* Zeller, mating takes place between 5 and 6 h into the scotophase and oviposition is concentrated within first hour of scotophase (Vetter et al. 1997). Cho & Boo (1998) reported that in the noctuid *Heliothis assulta* Guenée, oviposition occurs at the beginning of scotophase, and mating occurs during the first half of scotophase. However, in another noctuid species *Agrotis ypsilon* (Rottemberg) (Wang et al. 1983), oviposition mainly occurs 2 h after midnight whereas mating peaks just before dawn. Although activity patterns are variable, these examples have at least one thing in common, i.e. oviposition always took place earlier in the night than mating, suggesting that few females laid eggs on the same day as mating occurred. In *C. jactatana*, about 85% of females did not start to lay eggs until at least 1 day after mating. In *C. pomonella*, the movement of the sperm from the bursa copulatrix to vestibulum where fertilization is achieved requires 4-5 hours (Benz 1991), reducing the time left during the same night, for oviposition. The short time between mating and the end of scotophase may deter female oviposition behaviour until next scotophase. Egg laying is a long process and requires the female to be motionless. This increases the risk of predation, especially if the oviposition period needs to extend into the photophase. This study has provided simple but useful and relevant information for the design of future experiments aiming to explore potential control techniques based on insect behaviour or physiology.

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