

SHORT COMMUNICATION

Effects of photoperiod and temperature on the development of *Bonagota cranaodes*

MIRYAN D. A. CORACINI¹, PAULO H. G. ZARBIN¹,
MARIE BENGTSSON², ADALÉCIO KOVALESKI³,
EVALDO F. VILELA⁴, LUCIANA L. TOREZAN³,
EDUARDO R. HICKEL⁵ and PETER WITZGALL²

¹Department Chemistry, Federal University of Parana, Curitiba-PR, Brazil, ²Chemical Ecology Group, Swedish University of Agricultural Sciences, Alnarp, Sweden, ³EMBRAPA/CNPV, Vacaria-RS, Brazil, ⁴Department Animal Biology, Federal University of Viçosa, Viçosa-MG, Brazil and ⁵EPAGRI/Videira, Videira-SC, Brazil.

Abstract. The Brazilian apple leafroller, *Bonagota cranaodes* (Meyrick) (Lepidoptera: Tortricidae) is reared in the laboratory under a long-day (LD 14 : 10 h) and a short-day (LD 7 : 17 h) photoperiod at 22 °C, and under two different temperatures (10–13 °C and 21–22 °C). The development time from larval to adult eclosion do not differ between the two photoperiods, but did between the two temperature regimes. However, the larvae do not enter diapause, even under short day conditions and low temperatures. The number of adults obtained does not differ with temperature and light conditions. Field captures with pheromone traps show that Brazilian apple leafroller occurs in apple orchards throughout the year and the population densities are lower in winter. Accordingly, control measures should be taken during the off-season.

Key words. Diapause, field trapping test, insect control, monitoring, sex pheromone.

Introduction

Insects in temperate climate zones are challenged to endure harsh temperature regimes and the absence of food resources during winter. They survive such unfavourable conditions in diapause. Some univoltine species undergo an obligatory, genetically fixed diapause. In other univoltine and all multivoltine species, diapause is induced by external cues that indicate the end of the summer, such as decreasing day length or temperature (Beck, 1980; Tauber *et al.*, 1986).

The Brazilian apple leafroller, *Bonagota cranaodes* (Meyrick) (Lepidoptera: Tortricidae), is considered to be a major leafroller pest of apple in Southern Brazil (Lorenzato, 1984; Kovaleski, 1992). Larvae feed mainly on leaves but will also attack fruits superficially when they are in contact with leaves. There is little information available about the biology of *B. cranaodes* but studies show that this insect occurs in apple orchards all year round at highly variable

population densities, necessitating multiple sprays (Lorenzato, 1984; Kovaleski, 1992; Eiras *et al.*, 1994).

Information on the seasonal cycle of a pest at different environmental conditions is vital to the understanding of its population dynamics. Therefore, present study examines (i) the role of photoperiod and temperature in the development of larvae and (ii) the occurrence of adult *B. cranaodes* in apple orchard throughout the year to discover whether *B. cranaodes* undergoes diapause in laboratory or field conditions.

Materials and methods

Insect rearing

Bonagota cranaodes were obtained from a laboratory at Embrapa, Vacaria, Brazil, where the insects are reared on a semiartificial agar-based diet (Mani *et al.*, 1978), at 21 °C, and a photoperiod of LD 14 : 10 h. Field-collected insects are added to the colony every year. Insects were reared from first-instar larvae until adults under four conditions, involving two photoperiods (LD 7 : 17 h and LD 14 : 10 h) and two temperatures (10–13 °C and 21–22 °C).

Correspondence: M. D. A. Coracini, Department Chemistry, Federal University of Parana, Box 19081, 81530-990 Curitiba-PR, Brazil. Tel.: +55 41 33613174; fax: +55 41 33613186; e-mail: miry-ancoracini@quimica.ufpr.br

Development under different photoperiods

Two containers (1.5 L of diet) infested with 500 first-instar larvae (first generation) were kept under a LD 7 : 17 h photoperiods. The adults eclosing from these containers were counted daily and transferred for mating and oviposition to cages that were kept in the same room. Four days after the last moth had emerged, the diet container was checked for remaining larvae and pupae. These were transferred to plastic Petri dishes (9 × 3.5 mm) containing moistened filter paper. Eclosed adults were counted daily.

The larvae hatching from the oviposition cages (second generation) were placed in batches of 500 into containers with 1.5 L of agar diet. One of these containers was kept under a LD 7 : 17 h photoperiod and the other one under a LD 14 : 10 h photoperiod, both at a constant temperature of 22 °C. Adults were counted after eclosion and the diet was checked for dead larvae.

Development under different temperatures

In this experiment, 500 newly-hatched larvae (first generation) were placed in groups of 25 larvae into small plastic containers with 75 g of agar diet. The containers were kept inside two climatic chambers, one at a temperature of 10–13 °C and the other at a temperature of 21–22 °C, both under a constant photoperiod (LD 7 : 17 h). The same procedure was used for counting dead larvae/pupae and adults eclosion as described above. Adults were transferred for mating and oviposition to cages that were kept in a climatic chamber.

The larvae hatching from the oviposition cages (second generation) were placed in groups of 25 larvae each into small plastic containers (with 75 g of agar diet), and kept inside the same climatic chamber as the first generation. Dead larvae/pupae and adults that had eclosed were counted.

Field trapping tests

Trap tests were carried out at Rubi Apple Orchard, Vacaria-RS, Brazil, from January to December, 2004. Tetra traps (Arn *et al.*, 1979) were baited with 10 µg of the optimized four-component sex pheromone blend (Coracini *et al.*, 2001), formulated on red rubber septa (Merck ABS, Dietikon, Switzerland). The chemical and isomeric purity of the com-

pounds was > 99.5%. Traps ($n = 10$) were placed at a distance of approximately 1.7 m from the apple trees. Traps were placed 5 m apart, and were arranged in random order in a line along tree rows. Traps were inspected once a week.

Statistical analysis

Prior to statistical analysis, data were checked for analysis of variance assumptions and, if needed, transformed to avoid heterogeneity of variances. The number of days required for *B. cranaodes* adults to emerge, and the number of adults obtained under different photoperiods, different temperatures and different generations, were compared using Fisher's exact test. $P < 0.05$ was considered statistically significant.

Results and discussion

The development time from first-instar larvae to eclosion of adult was very similar under the long- and short-day photoperiods (Table 1). The mean development time in these experiments was in the range 52–59 days, which compares with a development time of 53.4 days for continuous laboratory-rearing under a LD 14:10 h photoperiod ($n=12$ generations). There was no difference between the numbers of adults emerging under the two photoperiods (Table 1). Although the ecology of insect diapause has been studied extensively in insects, most of the available data concern insects from temperate zones, where insects are subject to marked seasonal changes in photoperiod, temperature and availability of food resources. Diapause is usually induced by decreasing day length (Chippendale and Reddy, 1973; Goettel and Philogène, 1978; Boyne *et al.*, 1985). The situation is quite different in the Tropics because there are only minor seasonal changes in daylength (Tanzubil *et al.*, 2000). Under such conditions, the key environmental factors influencing diapause are rainfall, temperature and food in conjunction with photoperiod (Adkisson *et al.*, 1963; Scheltes, 1978; Denlinger, 1986; Kfir, 1993). Our results shows that exposure to a short daylength does not induce *B. cranaodes* to enter diapause, and has no influence on the reproductive behaviour during the two generations of exposure to different photoperiods. Observations of mating and oviposition behaviour under long and short photoperiod do not indicate a difference between the treatments. Matings occur within the first hour after lights off, and female oviposition behaviour is the same, under both photoperiods.

Table 1. Development of Brazilian apple leafroller *Bonagota cranaodes* larvae under two different photoperiods.

Treatment	Generation	Photocycle (LD)	Larvae used (n^a)	Dead insects (n)	Adults emerged (n)	Development time (days) ^b
Dark	First	7 : 17 h	500	33	326 ^a	51.9 ^a
Dark	First	7 : 17 h	500	52	325 ^a	52.3 ^a
Dark	Second	7 : 17 h	500	51	249 ^a	58.9 ^a
Light	Second	10 : 14 h	500	43	228 ^a	51.8 ^a

^aAll treatments began with recently-emerged larvae.

^bMean value for growth period from larvae to adult.

Within the same column and same generation, numbers followed by the same superscript letter are not significantly different (Fisher's exact test, $P > 0.05$).

Table 2. Development of Brazilian apple leafroller *Bonagota cranaodes* larvae under two different temperatures.

Temperature (°C)	Generation	Photocycle (LD)	Larvae used (n) ^a	Dead insects (n) ^a	Adults emerged (n) ^a	Development time (days) ^b
10–13	First	7 : 17 h	500	45	237 ^a	167.1 ^a
10–13	Second	7 : 17 h	500	47	241 ^a	155.6 ^a
21–22	First	7 : 17 h	500	34	273 ^a	45.3 ^a
21–22	Second	7 : 17 h	500	41	257 ^a	42.8 ^a

^aAll treatments began with recently-emerged larvae.

^bMean value for growth period from larvae to adult.

Within the same column and same temperature, numbers followed by the same superscript letter are not significantly different from each other (Fisher test, $P > 0.05$).

Larval development time from hatching until adult emergence depended on temperature, but a similar number of adults emerged for both temperatures (Table 2). There was no difference between the number of adults emerged for both generations and both temperatures ($P < 0.02$) (Table 2). However, approximately 43 days was needed to obtain the first adult at 21–22 °C, and 160 days at 10–13 °C ($P < 0.02$). The results show that low temperature does not induce *B. cranaodes* to enter diapause.

In many insect species from temperate climate zones, larval exposure to low temperatures is not necessary for diapause development. However, low temperatures that might

have occurred during the larval development could have an impact on diapause development (Veerman and Vaz Nunes, 1980). Many of the photoperiodic responses are also temperature-dependent, with temperature affecting circadian entrainment, photoperiodic summation and aspects of general physiology involved in diapause induction (Veerman and Vaz Nunes, 1980). For example, this is observed for the tortricidae species *Adoxophyes orana*, *Choristoneura fumiferana* and *Endopiza viteana* (Han and Bauce, 1996; Tobin et al., 2002; Milonas and Savopoulou-Soultani, 2004) and for the noctuidae specie *Sesamia nonagrinoidea* (Fantinou et al., 2003). For *B. cranaodes*, the interaction between short

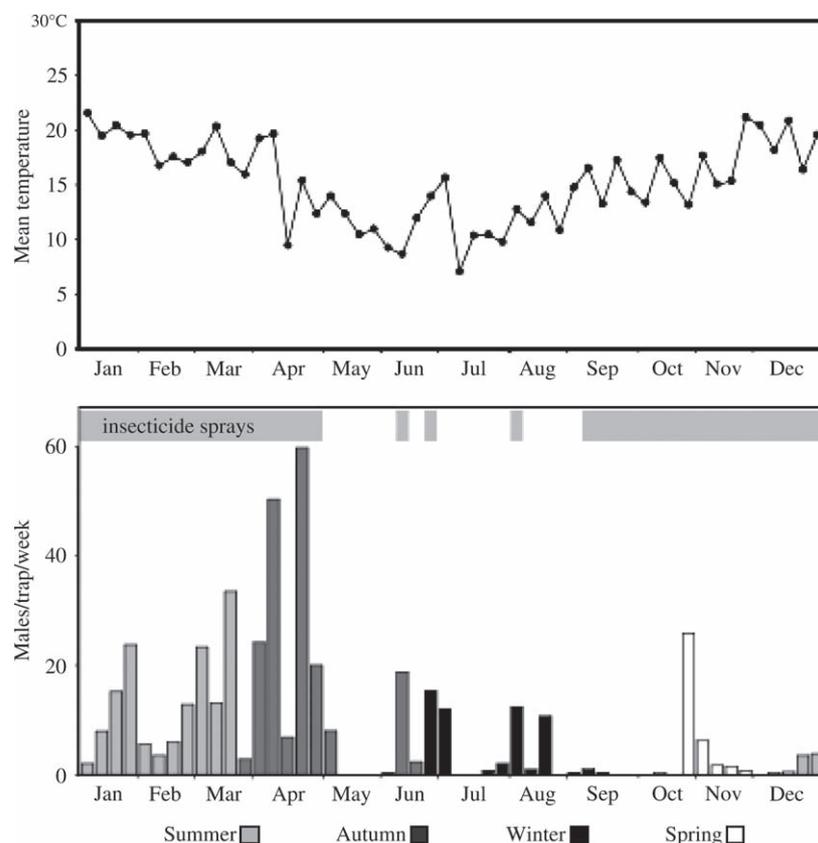


Fig. 1. Weekly mean air temperature and trap catch of Brazilian apple leafroller *Bonagota cranaodes* males in pheromone traps at Schio Orchard, Vacaria-RS, Brazil, from January to December 2004.

day and low temperature does not lead to diapause (Table 2). Under these conditions, *B. cranaodes* larvae slow down their growth and development. It may be that the low temperature provides a shorter period suitable for feeding, which in turn reduces metabolic functions and retards larval development.

In the present study, 4 days after the last moth had emerged, there are only few larvae at the last instars and few pupae remaining in the diet recipients for both generations in different photoperiods/temperatures, showing that the individuals do not stop the development at some stage.

The most important mortality factor is migration of larvae out of the diet boxes. During the last instars, *B. cranaodes* larvae try to find a safe place to pupate, and it is at this stage that they are more active and try to escape. Pieces of corrugated paper inside the diet recipients provide the larvae with places to pupate but, nevertheless, many of do not remain in the diet recipients.

Captures in pheromone traps show that *B. cranaodes* adults are present in the apple orchard all year around, even during the winter (Fig. 1). Rather high captures of *B. cranaodes* are recorded during the end of the peak growing season from February to April, when multiple insecticide sprays are applied to control *B. cranaodes* and *Grapholita molesta* infestations. This field test shows also that 10- μ g lures baited with the optimized four-component pheromone remain attractive over 6 months.

The control level recommended for *B. cranaodes* is when weekly pheromone trap captures surpass 30 males per trap. However, in autumn and winter, the grower sprays insecticide when any increase of the adult population is detected (June, July, and August) (Fig. 1). From September onward, there is frequent insecticide use due to the occurrence of *B. cranaodes*, *G. molesta*, and *Anastrepha fraterculus* (Diptera: Tephritidae).

Our field tests corroborate the results of the laboratory tests and confirm that *B. cranaodes* does not diapause. The adults are present all year around, despite the lower temperature and shorter day regime during winter. Population densities are lowest during the off-season and attempts should be made to further reduce population densities before the onset of the new apple growing period.

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