Biological Control 65 (2013) 176–183

Contents lists available at SciVerse ScienceDirect

Biological Control

journal homepage: www.elsevier.com/locate/ybcon

Larvae of the firefly *Pyrocoelia pectoralis* (Coleoptera: Lampyridae) as possible biological agents to control the land snail *Bradybaena ravida*

Xinhua Fu [a,*], V. Benno Meyer-Rochow [b,c]

[a] Hubei Insect Resources Utilization and Sustainable Pest Management Key Laboratory, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, Hubei, China

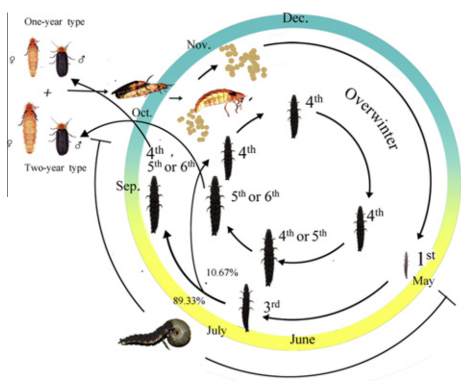
[b] Jacobs University Bremen, Faculty of Engineering & Sciences, D-28725 Bremen, Germany

[c] Department of Biology, University of Oulu, SF-90014 Oulu, Finland

HIGHLIGHTS

- The firefly *Pyrocoelia pectoralis* was successfully bred.
- There are two types of larvae occur after the third instar.
- Environmental conditions affected larval development and were studied.
- The effectiveness as a predator on the pest snail *Bradybaena ravida* was assessed.
- Use as a biological control agent is discussed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 25 July 2012
Accepted 15 February 2013
Available online 28 February 2013

Keywords:
Development
Feeding capacity
Land snails
Firefly
Pyrocoelia pectoralis

ABSTRACT

Rearing experiments with the firefly *Pyrocoelia pectoralis* demonstrated that the species can be successfully bred under laboratory and field conditions and that there are two types of larva: overwintering and non-overwintering. Comparisons showed that the differentiation between the two larval types occurred after the third larval stage. In the field, non-overwintering larvae pupate in September, emerge in October and produce a second annual generation, while overwintering larvae begin to grow more slowly from the 3rd instar onward, then overwinter to ultimately reach a larger size than the non-overwintering larvae and to pupate in September. Adults emerge in October. Larval development at 15, 20, 25, 30 and 35 °C was investigated under a photoperiod of L:D = 12:12. At 15 °C all larvae died as 4th instars, but from 20 °C to 30 °C larval phases became increasingly shorter, while at 35 °C they lengthened again. Larval feeding capacity increased with higher temperature up to 30 °C, but decreased at 35 °C. Under three photoperiods, i.e., L:D = 16:8, 12:12 and 8:16 at 25 °C, the larval period was shortest under L:D of 16:8 and longest under L:D = 8:16. Feeding capacity of the larvae exhibited a positive correlation with the duration of the dark period. Larvae under longer periods of illumination pupated considerably earlier than those kept one under shorter periods of light exposure. No significant differences in the numbers of overwintering larvae were found in connection with different temperatures and photoperiods.

* Corresponding author.
E-mail address: fireflyfxh@mail.hzau.edu.cn (X. Fu).

1049-9644/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.biocontrol.2013.02.005

1. Introduction

Terrestrial snails are known to be destructive agricultural pests, capable of causing severe damage to vegetables, ornamentals and other plants. Pest snail attacks of plant seeds, seedlings, underground tubers, leaves and fruits can lead to major losses (Baker, 1989; Barker, 2002, 2004). The terrestrial species *Bradybaena ravida* (Pfeiffer, 1850) is a common land snail widely distributed throughout China, Japan, Korea and Russia (Chen, 2004; Wang, 2008). Recently numerous cases of damage to vegetables, peaches, grapes, and corn were attributed to this species. In 2006 over 3000 hectares of corn were damaged by it in Qi County, Kaifeng City, Henan Province alone (Wang, 2008; Liu and Wu, 2011).

Fu and Meyer-Rochow (2012) emphasized that larval aquatic fireflies have the potential of serving as biological control agents in the fight against disease transmitting freshwater snails. Therefore, it is now relevant to investigate if terrestrial snail-consuming firefly larvae might not also be usable in controlling pest land snails. Support for this notion comes from observations on terrestrial fireflies by Kaufmann (1965), Buschman (1984, 1988), Barker (2004) and Wang et al. (2007), which state that their larvae consume primarily land snails and therefore can be considered as the snails' natural enemies. Wang et al. (2007) reported that specifically larval *Pyrocoelia pectoralis,* which distributed in Hubei Province feed on the snail *B. ravida* and indicated that the larvae might be a possible biological agent to control the snail *B. ravida*. Tests towards this end were, however, never conducted.

Depending on the species of firefly, some have one, others have two or even three generations per year (Balduf, 1935; Schwalb, 1961; Naisse 1966; Wootten, 1976; Fu et al., 2006; Ho et al., 2010). To obtain a sufficient number of larvae to be of potential use as biological agents to control the pest snail, a short larval period and successful larval development are key factors. The larval developments of several Old World lampyrids have been described, e.g., *Lampyris noctiluca* L. (Balduf, 1935; Schwalb, 1961; Naisse, 1966; Wootten, 1976), *Lamprohiza splendidula* (LeConte) (Balduf, 1935; Schwalb, 1961), *Lamprigera tenebrosus* (Walker) (Bess, 1956), *Luciola discollis* Laporte (Kaufmann, 1965), *Luciola cruciate* Motschulsky (Minami, 1961; Yuma, 1981), *Aquatica leii* Fu and Ballantyne (Fu et al., 2006). The firefly *Pyractomena lucifera* (Melscheimer) was reared successfully under laboratory and field conditions (Buschman, 1988) and Ho et al. (2010) bred the aquatic firefly *A. ficta* at temperatures ranging from 18 °C to 30 °C. However, very few studies other than that by Buschman (1988) focus on quantitative assessments of larval feeding capacity during larval development.

The firefly *P. pectoralis* was chosen, because it is a common local firefly and known to be an effective predator of the pest land snail *B. ravida*. Our investigation provides details on the larval development of a Chinese terrestrial lampyrid maintained under laboratory conditions and explores larval feeding capacity under different conditions of photoperiod and environmental temperature.

2. Materials and methods

2.1. Egg treatments

Wang et al. (2007) had reported that eggs of *P. pectoralis* enter diapause to overwinter and hatch in April the next year. We confirmed that the egg period lasts for about six months. In order to accelerate hatching of the eggs and to obtain newly-hatched first instar larvae for some observations on growth and development, we exposed the eggs to a temperature of 6 ± 1 °C for 40 days. Additional small larvae, measuring no more than 10 mm in length, were collected in May, 2010 from Xianjian Village, Hongshan District, Wuhan City (Hubei Province), revealing themselves to the human collector by their own glow. Head widths, body lengths and body widths of the collected larvae were measured and compared with larval developmental parameters available from the earlier growth experiments, demonstrating that the collected larvae represented 2nd instars. Twenty larvae per transparent plastic box (30 cm × 20 cm × 5 cm) were maintained on moist filter paper with living specimens (usually 5) of the land snail *B. ravida* added as prey.

After eclosion, males and females were allowed to mate in the plastic box, where the females laid their eggs on the moist filter paper available to them. Three days later, the eggs were removed with the aid of a moist Chinese brush pen and placed into a similar plastic box lined also with moist paper. For 40 days the box was kept at a temperature of 6 ± 1 °C under natural photoperiod. Then the eggs were transferred to a climate chamber set at 25 °C, a photoperiod of 12:12 (*L*:*D*) and humidity of 75% for hatching.

2.2. Confirmation of and comparisons between the two types of larva

It was reported that both larval *P. pectoralis* and their eggs overwintered from November to next April (Wang et al., 2007). Thus, there would be two types of larva in the wild, namely overwintering larvae and non-overwintering larvae, the latter appearing from May to September. To explore how the two types of larva might arise, three groups of 50 newly-hatched larvae reared in the laboratory at a temperature of 25 °C, photoperiod of 12:12 *L*:*D* and 75% humidity were used. Larval duration and feeding capacity (fresh body mass of land snails) at each larval stage were recorded. Body length, body width, head width, and body mass of each instar were measured. Because both overwintering as well as non-overwintering larvae could pupate as 4th, 5th and 6th instar larvae, we compared only larvae of the two types when they pupated as 6th instars.

2.3. Larval development and predation on land snails

2.3.1. Impact of temperature on larval development and predation on land snails

Newly-hatched larvae were reared at 15, 20, 25, 30, and 35 °C in an artificial climate chamber (SPX-250IC: Shanghai Boxun Corporation), with relative humidity of 70 ± 10% and 12:12 *L*:*D* photoperiod. Each treatment contained 45 larvae in a fully randomized setup. Each larva was reared in a transparent plastic box (7 cm × 7 cm × 6 cm) with moist filter paper covering bottom and sides. The filter paper was replaced every two days. The following parameters were evaluated: number of instars; duration spent as instars at each of the larval periods; fresh body mass of snails before and of empty shells after predation; survival at different larval stages; body length, body width, head width, and body mass of every larva at each larval instar; number of overwintering larvae and number of larvae turning into pupae. Vernier calipers were used in morphometric assessments and an analytical balance (AUY120, Shimadzu, Japan) was used for weighing the snails before and after feeding to determine feeding capacity. With 1st to 3rd instars, we used a small piece of snail meat put on a square plastic sheet to feed them. As usual plastic sheet and the food on it were weighed before and after feeding.

2.3.2. Impact of photoperiod on larval development and predation on land snails

Wang et al. (2007) reported that the optimum temperature for larval activity of *P. pectoralis* was 18–30 °C. Thus, the newly-hatched larvae were reared at 25 °C in an artificial climate chamber