

## Developmental Characteristics and Life History of the Korean Native Firefly, *Luciola lateralis*

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To study the ecological characteristics of the Korean native firefly, *Luciola lateralis*, development and life history of *L. lateralis* were investigated throughout the indoor rearing. Average size of egg with an oval shape was  $0.51 \times 0.56$  mm and an egg period of *L. lateralis* was approximately 25.8 days. The larvae were pupated at the 5<sup>th</sup> instar and the body length of the matured larvae was 15.8 mm. The total periods of larval stage to the end of the 5<sup>th</sup> instar were approximately 271.7 days. Pupae formed soil cocoon and average pupal period was approximately 28.7 days. Average number of eggs oviposited by a female was approximately 97. The body size of female in the pupa and adult were larger than that of male.

**Key words :** Firefly; *Luciola lateralis*; Development; Life history

### Introduction

Fireflies are well known as luminous beetles, and approximately 2,000 species are found worldwide, except for the South Pole and the North Pole (Minami, 1983). The luciferase genes from the firefly have been studied deeply in some species (de Wet *et al.*, 1987; Masuda *et al.*, 1989; Tatsumi *et al.*, 1992; Devine *et al.*, 1993; Ohiyama *et al.*, 1995; Cho *et al.*, 1999) and are increasingly used as a highly-effective reporter gene in many organisms (Jacobs

*et al.*, 1993; Howard *et al.*, 1988; Miller *et al.*, 1992; Vikas *et al.*, 1995; DiLella *et al.*, 1988; Kondo *et al.*, 1992).

In Korea, eight firefly species have been reported (The Entomological Society of Korea and Korean Society of Applied Entomology, 1994). Among eight species of fireflies known, three species have been reported as major fireflies in Korea: *Luciola lateralis* and *Hotaria unmunzana* belonging to Luciolinae, and *Pyrocoelia rufa* belonging to Lampyrinae. Of the major fireflies in Korea, *L. lateralis* is widely distributed in Japan, Siberia and Korean Peninsula (Suzuki, 2001). Isolation and expression of the luciferase gene of the Korean native firefly, *L. lateralis*, have been reported (Cho *et al.*, 1999; Woo *et al.*, 2000). Furthermore, genetic subdivision of *L. lateralis* in Korea was determined by mitochondrial cytochrome oxidase subunit I gene sequences (Kim *et al.*, 2001). However, ecological characteristics concerning the development and life cycle of the Korean native firefly, *L. lateralis*, are not reported yet. *L. lateralis* is known to occur in extremely limited habitats such as terraced rice fields and wet fields and it is difficult to study ecological characteristics because it has a long life cycle, which takes approximately 1 to 2 years in wild fields.

In this regard the objective of current study was aimed to obtain some ecological information of the Korean native firefly, *L. lateralis*. In this paper, the development characteristics and life history of the Korean native firefly, *L. lateralis* are described.

### Materials and Methods

#### Insects

Adults of the Korean native firefly, *Luciola lateralis*, were

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collected at Solchon-myon, Muju-gun, Chollabuk Province, Korea, from June to July 1998.

### Indoor rearing

The collected adult fireflies of *L. lateralis* were reared in a device for mating and oviposition (Fig. 1A). Female and male adults with a ratio of 2:3 were placed with population of 20 adults per 100 cm<sup>2</sup> in a device for mating and oviposition. The device for mating and oviposition was added with lichen for the wet condition and incubated at 23°C and over 80% R.H. After oviposition, hatched larvae were reared in a device for larvae rearing (Fig. 1B and C). The device for larvae rearing was added with sands and pebbles for the favorable condition for rearing, and aerated with an air-bubbler. The diet for larvae of *L. lateralis* was used with *Semisulcospira tegulata* as needed. The device for larvae rearing was incubated at 23°C under a natural photoregime. For the pupation and emergence, the final instar larvae were put into the device designed to induce pupae and adults (Fig. 1D). The mature larvae were placed with population of approximately 10 larvae per 100 cm<sup>2</sup> in a device. The device for pupation and emergence with moistened soils was incubated at 23-25°C and 80% R.H.

### Development and life history

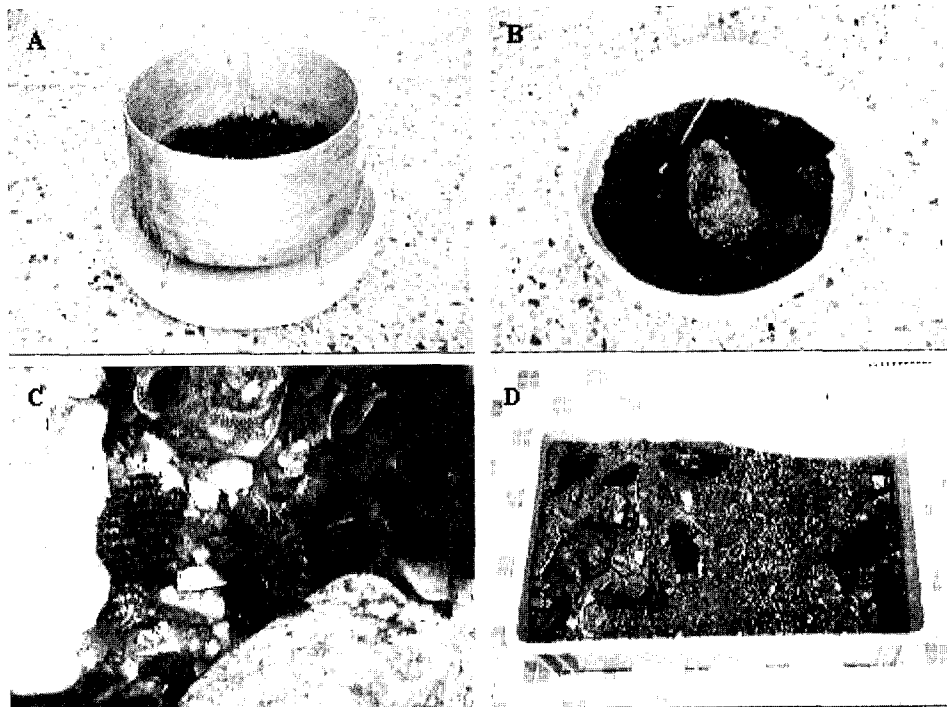
The size of egg, larva, pupa and adult of *L. lateralis* was

measured with micrometer at a magnification, chemical balancer and caliper (Mitutoyo, Japan). The average number of eggs laid, egg period and hatchability were examined. The larval development of *L. lateralis* was measured by larval size after or before molting. The larval period of each instar was also measured. The larval marking during each stage was photographed with a stereo microscope (Olympus, Japan). The morphology of the egg, larva, pupa and adult was also photographed with a stereo microscope. The size of pupae and adults was sexually measured. Pupation and emergence rates were examined. The period and longevity of pupae and adults were respectively measured.

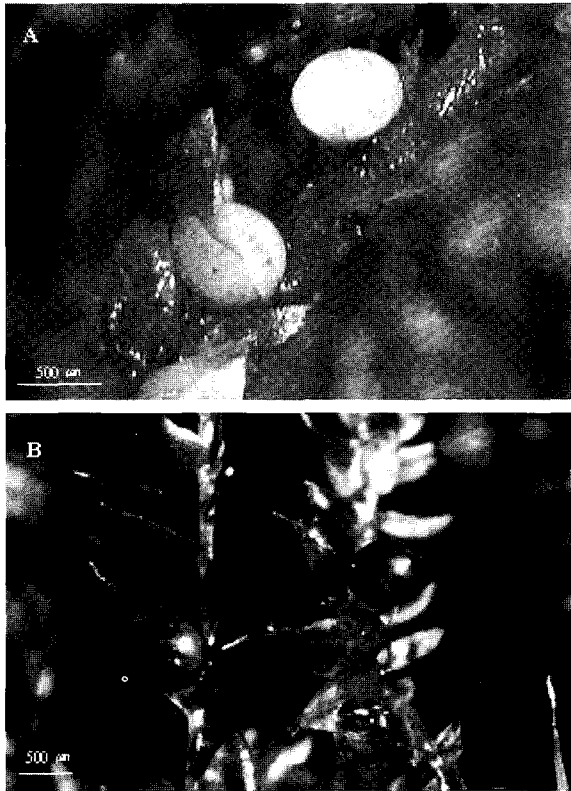
## Results and Discussion

### Egg

The shape of egg of *L. lateralis* was an oval and the color of the just-oviposited egg was yellow white, changing into thick brown with embryogenesis (Fig. 2). The egg size of *L. lateralis* was estimated as 0.51 × 0.56 mm (Table 1). Average number of eggs oviposited by a female was approximately 97 and egg period was approximately 25.8 days (Table 2). After mating, a female adult laid eggs during 4 days and most of its oviposition occurred at the 1<sup>st</sup> day (33.4%) and 2<sup>nd</sup> day (38.2%) (Fig. 3). In this study,



**Fig. 1.** Indoor rearing of the firefly, *L. lateralis*. A, a device for mating and oviposition; B, a device for larvae rearing; C, larvae feeding diet; D, a device designed to induce pupae and adults.



**Fig. 2.** Egg of *L. lateralis*. A, just-oviposited egg; B, egg before hatching.

**Table 1.** Egg size of *L. lateralis*

Egg size (mm)	
Major axis	Minor axis
$0.56 \pm 0.06$	$0.51 \pm 0.04$

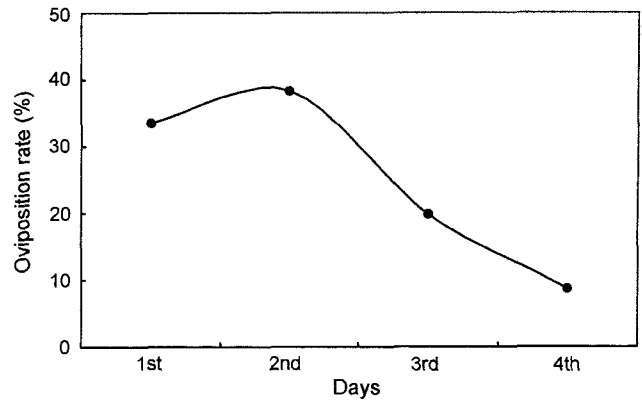
**Table 2.** Number of egg laid, hatchability and egg period of *L. lateralis*

Number of egg laid per a female	Hatchability (%)	Egg period (days)
$97 \pm 24$	$93.2 \pm 6.8$	$25.8 \pm 0.9$

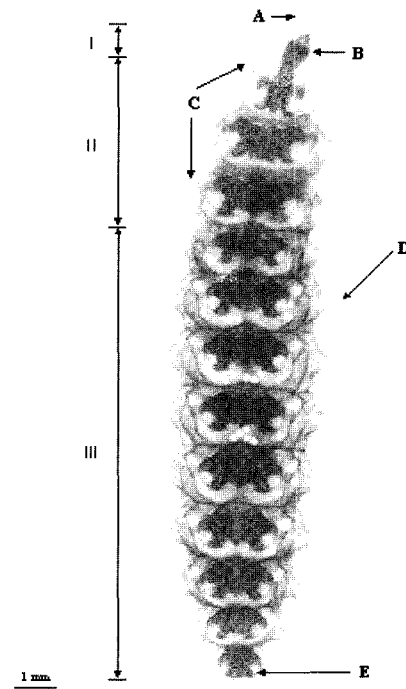
hatchability of *L. lateralis* eggs was approximately 93.2% (Table 2).

### Larva

After the hatching, latched larvae immediately moved downward into a device for larvae rearing and started to feed. Body color of just-hatched larva was gray brown and its body length was approximately 2 mm (Fig. 4). External morphology of larva divided into three parts: head, thorax with three segments and abdomen with nine segments (Fig. 4). Head contained a pair of antenna and compound



**Fig. 3.** Daily oviposition rate of the female adult of *L. lateralis*.



**Fig. 4.** External morphology of *L. lateralis* larva. I, head; II, thorax; III, abdomen; A, antenna; B, mouth parts; C, thoracic leg; D, tracheae; E, caudal leg.

eye, and the mouth part with mandible, labium and labrum (Fig. 5). The thorax consists of three segments with thoracic legs (Fig. 4). Interestingly, specific larval marking of *L. lateralis* was observed in the first segment of the thorax, changing into the cross shape with a thick brown with a larval development (Fig. 6). The abdomen consists of nine segments and its each segment has tracheae for the respiration during the period that the larva progresses (Fig. 4). This result was previously reported in the Japanese native *L. lateralis* larvae (Mitsubishi, 1996). Larval light

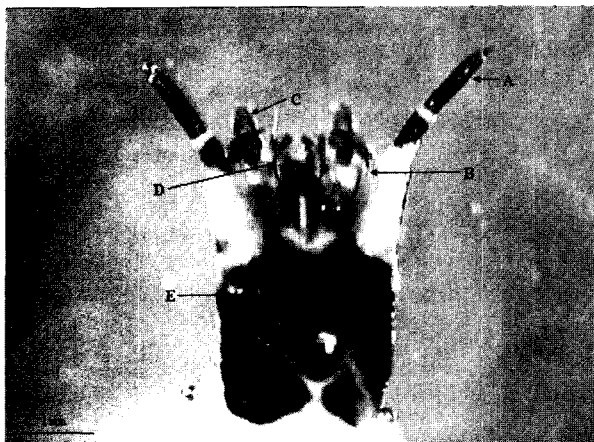


Fig. 5. Head morphology of *L. lateralis* larva. A, antenna; B, mandible; C, labium; D, labrum; E, compound eye.

organ and five pairs of caudal legs were observed in the 8th segment and last segment, respectively.

The growth of larvae in terms of larval body length was significantly increased with a larval development (Fig. 7). The larval body length from 1st instar to 5th instar was ranged from 1.7 mm to 15.8 mm. The span of each instar was also increased with a larval development (Table 3). Particularly, the span of each instar of 4th and 5th instars was prolonged over one month. Consequently, the total periods of larval stage to the end of the 5th instar covered approximately 271.7 days.

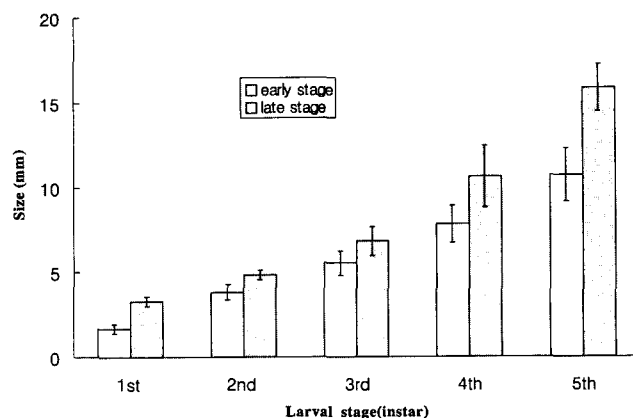


Fig. 7. Body length of each instar of *L. lateralis* larva.

### Pupa

The mature larvae moved from the water to the outside soil (Fig. 1D), formed cocoon of long elliptical shape with soils for 3 to 4 days, and were pupated within its soil cocoon (Fig. 8 and 10). The soil cocoon of *L. lateralis* pupae was similar to that of the Japanese native *L. lateralis* pupae known (Ohba, 1986). The pupation rate was approximately 75.8% and the pupal period was approximately 28.7 days (Table 4). The mortality in the larval or pupal stage and the non-pupated larvae were correlated with pupation and emergence rate (Table 4). The non-pupated larvae were approximately 10.0%. *L. lateralis* in the indoor rearing shows the mortalities with 14.7% dur-

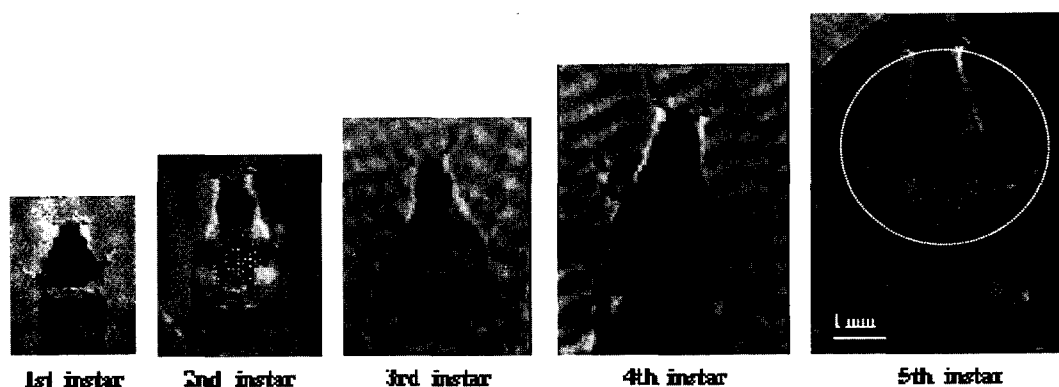


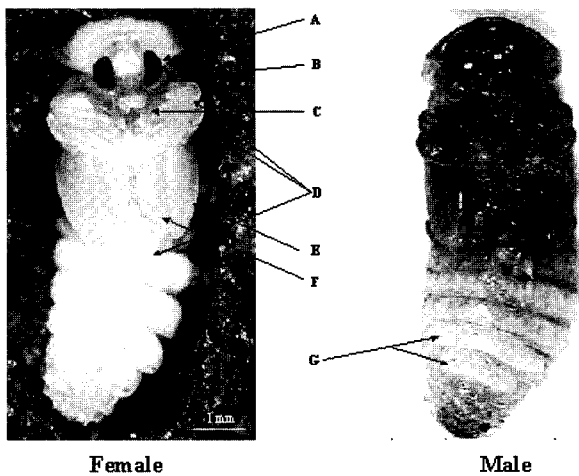
Fig. 6. Change of the larval marking during each instar of *L. lateralis* larva. Larval marking is indicated by circle.

Table 3. Larval period of each instar of *L. lateralis*

Duration of each instar (days)				
1st	2nd	3rd	4th <sup>a</sup>	5th <sup>b</sup>
11.8 ± 1.8	13.0 ± 2.2	20.1 ± 4.0	30.9 ± 12.5	195.9 ± 32.3

<sup>a</sup>The period was arbitrarily decided by counting of duration when 80% of the larvae in the stage of 4th instar became 5th instar.

<sup>b</sup>The period was contained the duration for the induction and break of diapause.



**Fig. 8.** External morphology of *L. lateralis* pupae. A, compound eye; B, antenna; C, mouth parts; D, legs; E, fore wing; F, hind wing; G, light organ.

ing the larval stage and with 9.0% during the pupal stage. Regarding sexual difference in the body size of pupae, the body length of female was larger than that of male. According to the measurements, the average length of female and male pupae was 9.0 mm and 7.5 mm, respectively (Table 5).

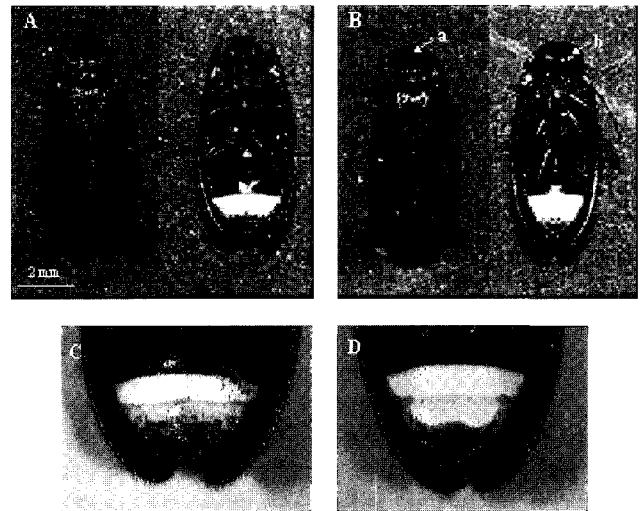
The external morphology of the pupae was shown in Fig. 8. The color of just-pupated pupae was yellow white, changing into thick brown before emergence. At 4 to 5 days after pupation, the color of compound eyes was changed into thick brown and then the color of wing parts was sequentially changed into thick brown at 2 to 3 days after color changing of compound eyes.

#### Adult

The body length of female and male adults was 9.4 mm and 7.6 mm, respectively (Table 5). The body size of female adult was larger than that of male (Fig. 9). The thorax color was mostly orange, and the thick black vertical line, which is a characteristic of *L. lateralis* adult, was obvious in the middle of thorax. The abdomen of adult consists of 8 segments, and the light organ for female and male was observed in the 6<sup>th</sup> segment and 6<sup>th</sup> to 7<sup>th</sup> segments, respectively. The color of light organ was milky white. The adult firefly emits flashes with species-specific

**Table 5.** Body length of the pupa and adult of *L. lateralis*

Pupa (mm)		Adult (mm)	
Female	Male	Female	Male
9.0 ± 1.4	7.5 ± 1.2	9.4 ± 0.4	7.6 ± 0.3



**Fig. 9.** External morphology of *L. lateralis* adults. A, female; B, male; C, female light organ; D, male light organ; a, specific marking of *L. lateralis* adult; b, compound eye.

duration and frequency as signals for mating (Lloyd, 1983).

#### Life history

Life history of *L. lateralis* is composed of distinct four developmental stages of egg, larva, pupa and adult (Fig. 10). Life cycle during two successive generations of *L. lateralis* at 23°C under a natural photoperiod was described in Fig. 11. Egg period was June to August. Larval period was from July in this year to May in the next year, but larvae with a generation in two years were observed from May to July. The total periods of larval stage covered usually more than 10 months in one year in terms of life span, indicating that most of its life cycle consists of larval stage. Pupal period was April to June and adult period was May to July.

This study elucidated the developmental characteristics and life cycle of *L. lateralis* for two generations. These

**Table 4.** Pupation rate, emergence rate and mortality of *L. lateralis* in indoor rearing

Pupation rate (%)	Pupal period (days)	Emergence rate (days)	Mortality (%)		Rate of non-pupated larvae (%)
			Larvae	Pupae	
75.3	28.7 ± 5.1	66.3	14.7	9.0	10.0

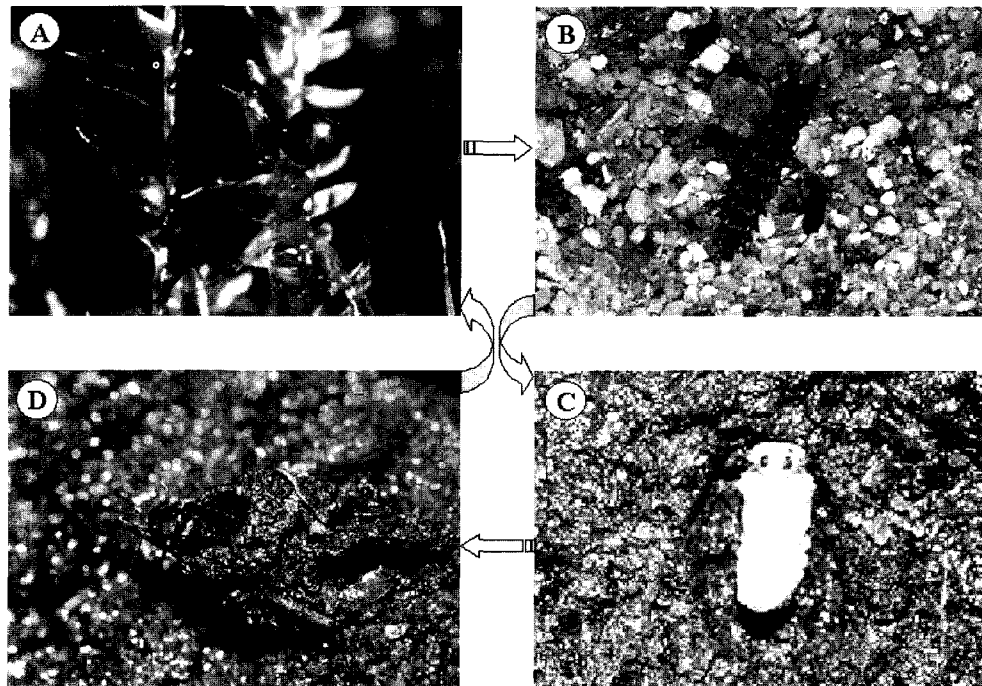


Fig. 10. Life cycle of the firefly, *L. lateralis*. A, egg; B, larva; C, pupa; D, adult.

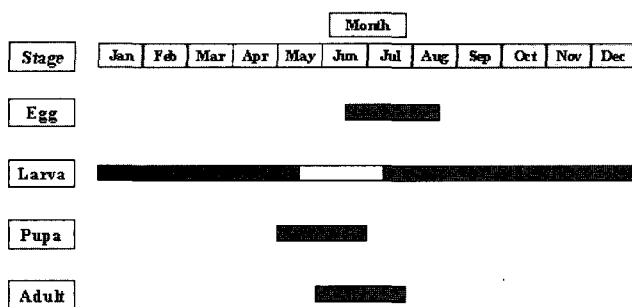


Fig. 11. Mode of monthly occurrence of the firefly, *L. lateralis*. Solid bar indicates occurrence of each stage. Open bar in the larval stage indicates the larval period of the firefly with two-year cycle.

results have shown that the indoor rearing of *L. lateralis* is possible. An increased understanding of development and life history of *L. lateralis* should provide further information for the ecological and physiological study.

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