Formosan Entomologist
Journal Homepage: entsocjournal.yabee.com.tw

Life History of Ganaspidium utilis (Beardsley) (Hymenoptera: Eucoilidae) in Taiwan 【Research report】

非洲菊斑潛蠅寄生蜂 (Ganaspidium utilis) (膜翅目：隆盾癭蜂科) 之生活史【研究報告】

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Received: 2005/03/26 Accepted: 2005/06/08 Available online: 2005/06/01

Abstract

This study was conducted to determine the life history of a solitary, larval-pupal endoparasitoid, Ganaspidium utilis (Beardsley), of Liriomyza trifolii (Burgess) at 25 ± 2oC. The female of G. utilis deposits its eggs in the larvae of L. trifolii. There are four larval instars, which began to develop after L. trifolii pupated. The mean number of progeny produced per G. utilis female was 66.7 ± 18.4 individuals. The sex ratio of the offspring of G. utilis was 1 male: 1.4 females when 50 leafminer larvae were provided daily for parasitization. No significant difference was observed in the mean number of male and female progeny produced.

摘要

本實驗探討在 25 ± 2oC 溫度下，非洲菊斑潛蠅 (Liriomyza trifolii) (Burguess) 寄生蜂 (Ganaspidium utilis) (Beardsley)自幼蟲期到蛹期之寄生現象。雌寄生蜂產卵在非洲菊斑潛蠅幼蟲體內，在斑潛蠅進入蛹期時，G. utilis 便開始孵化及發育，幼蟲期可分辨出四個齡期。雌寄生蜂所產平均子代數為66.7 ± 18.4隻。本實驗中每日提供50隻L. trifolii幼蟲為寄主，結果顯示其寄生蜂子代雄蜂及雌蜂的性別比例是1比1.4。比較子代雌雄平均數之結果顯示兩者無顯著差異。

Key words: Life history, Ganaspidium utilis, Liriomyza trifolii
關鍵詞: 生活史、Ganaspidium utilis、非洲菊斑潛蠅

Full Text: PDF(0.29 MB)

台灣昆蟲 25: 87-94 (2005)
Formosan Entomol. 25: 87-94 (2005)

Life History of *Ganaspidium utilis* (Beardsley) (Hymenoptera: Eucoilidae) in Taiwan

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ABSTRACT

This study was conducted to determine the life history of a solitary, larval-pupal endoparasitoid, *Ganaspidium utilis* (Beardsley), of *Liriomyza trifolii* (Burgess) at 25 ± 2°C. The female of *G. utilis* deposits its eggs in the larvae of *L. trifolii*. There are four larval instars, which began to develop after *L. trifolii* pupated. The mean number of progeny produced per *G. utilis* female was 66.7 ± 18.4 individuals. The sex ratio of the offspring of *G. utilis* was 1 male: 1.4 females when 50 leafminer larvae were provided daily for parasitization. No significant difference was observed in the mean number of male and female progeny produced.

Key words: Life history, *Ganaspidium utilis*, *Liriomyza trifolii*

Introduction

Liriomyza sativae (Blanchard), *L. trifolii* (Burgess), *L. huidobrensis* (Blanchard), *L. bryoniae* (Kaltenbach), and *L. strigata* (Meigen) are economically important leafminers (Spencer, 1973). Chien (1997) reported that *L. trifolii*, *L. bryoniae*, and *L. sativae* caused serious damage to ornamentals and vegetables between 1984 and 1995 in Taiwan. The wide geographical distribution of leafminers can be attributed to a number of factors including: insecticide resistance, increase in monoculture of horticultural crops, increase in horticultural trade among countries, a lack of international quarantine, and their cold-hardiness (Murphy and LaSalle, 1999; Zhao and Kang, 2000; Chen and Kang, 2002; Chen and Kang, 2004).

Resurgences of secondary pest outbreaks involving *Liriomyza* species have been reported throughout the world's agroecosystems, primarily due to indiscriminate use of pesticides incompatible with parasitoid activity (Johnson, 1993; Saito *et al.*, 1996). Development of alternative methods to pesticides is urgently needed to sustain the economic viability of horticultural crop production. One of the best alternatives to pesticides

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is the use of biological control agents in managing leafminers (Johnson and Mau, 1986; Johnson, 1987). *Liriomyza* species are known to be regulated by many natural enemies in their native ranges (Murphy and LaSalle, 1999). For example, in Taiwan, *Hemiptarsenus varicornis* (Girault), *Neochrysocharis formosa* (Westwood), *Chrysocharis pentheus* (Walker) and *Chrysonotomyia okazakii* (Kamijo) are reported to be native parasitoid species (Chien and Ku, 2001a). Out of those 4 parasitoids, *H. varicornis* and *N. formosa* are the most dominant (Chien and Ku, 2002).

Ganaspidium utilis is a larva-pupal endoparasitoid that was introduced into Hawaii from the Weslaco area of Texas for the control of *L. trifolii* and *L. sativae* (Nakao and Funasaki, 1979). It successfully became established in Hawaii, the Marianas, Tonga, and Guam and has become an important natural enemy of *Liriomyza* spp. (Lai and Funasaki, 1986; Greathead and Greathead, 1992; Johnson, 1993).

In 2003, *G. utilis* was introduced to Taiwan from Hawaii. Upon arrival, the parasitoids were isolated in the quarantine laboratory of National Pingtung University of Science and Technology (NPUST) and were kept under observation to study their biology and parasitism. Previous studies described the biology of *G. utilis* using *L. sativae* as a host (Petcharat and Johnson, 1988). A cost effective method for the mass production of *G. utilis* was also developed (Rathman *et al*., 1991). However, a detailed description of the biology of this parasitoid has not been reported previously in Taiwan. Therefore, the objective of this study was to describe the biology of *G. utilis* and to determine its developmental time, fecunddity, longevity, and sex ratio under laboratory conditions using *L. trifolii* as the host.

Materials and Methods

Using *L. trifolii* larvae as test insects

Throughout this study, the same procedures were followed to obtain the late 2nd or early 3rd instar *L. trifolii* larvae as test insects. Six pairs of *Phaseolus* Henderson lima bean plants (2 leaves each) were placed for 6 hours in a screened cage containing 50-60 *L. trifolii* adults. After 6 hours, the bean plants were removed from the cage and were held for 5 days to allow the *L. trifolii* eggs to hatch and develop until they reached the late 2nd or early 3rd instar.

Rearing of *G. utilis*

Ganaspidium utilis parasitoids used in this study were obtained from a laboratory culture using *L. trifolii* as the host insect. The *L. trifolii* colony was maintained in the laboratory using methods described by Rathman *et al.* (1991). *G. utilis* was reared using methods described by Petcharat and Johnson (1988). Stems of *L. trifolii* infested bean plants (2 leaves each) were cut immediately above the roots and placed in a 200 ml flask filled with water. A honey-water solution (25%) was sprayed on the lima bean leaves as a food source for the adult parasitoids. Plants were exposed to *G. utilis* for 24 hours and then removed. The leaves were cut at the base and kept in closed plastic containers to allow the *L. trifolii* larvae to pupate. Leafminer puparia were collected and held in a petri dish (9 cm diameter) until the *G. utilis* adults emerged. Parasitoid adults were returned to the oviposition cages for either culture maintenance or were used in subsequent studies.

Immature stages of *G. utilis*

Immature stages of *G. utilis* were examined by exposing 12 pairs of lima bean plants (2 leaves each) infested with late 2nd or early 3rd instar *L. trifolii* larvae. The four larval instars were morphologically distinguished by the head capsule size of the larvae as described by

Table 1. Mean size and developmental time of immature stages of *G. utilis* at 25 ± 2°C

Stage	No.	Length (mm) (mean ± SE)	Width (mm) (mean ± SE)	Developmental time (d) (mean ± SE)
Egg	27	0.30 ± 0.03	0.14 ± 0.01	2.33 ± 1.02
1st instar	12	0.40 ± 0.08	0.19 ± 0.01	1.55 ± 0.46
2nd instar	12	0.90 ± 0.08	0.26 ± 0.01	1.40 ± 0.46
3rd instar	9	1.03 ± 0.11	0.42 ± 0.15	1.30 ± 0.40
4th instar	9	1.10 ± 0.05	0.68 ± 0.02	1.50 ± 0.40
Prepupa	52	1.26 ± 0.16	0.52 ± 0.02	2.33 ± 0.18
Pupa	84	1.63 ± 0.18	0.75 ± 0.08	7.67 ± 3.26
Male	21			18.83 ± 1.59a [1)]
Female	21			17.33 ± 1.26a
Av.				18.08 ± 0.16

[1)] Means in the same column followed by the same letter do not significantly differ at the 5% level by the *t*- test.

Petcharat (1987). Each pair of lima bean plants was grown in a container and then placed in a parasitoid oviposition cage, containing 10 pairs of parasitoids. Plants were held in the cage for 6 hours to allow the parasitoids to lay their eggs in the leafminer larvae. Six hours after the plants were removed from the oviposition cage, four parasitized leafminer larvae or pupae were randomly selected and dissected daily under a dissecting microscope until the parasitoid adults emerged from the leafminer puparia. This study was replicated four times.

Longevity of *G. utilis*

Two leaves containing about 50 late 2nd or early 3rd instar leafminer larvae were used. Leaves were placed in a cage, and newly emerged male and female parasitoids were paired and released into the cage. After 24 hours, exposed leaves were removed, and 50 new late 2nd or early 3rd instar leafminer larvae were added. This was done daily until the female parasitoid died. A honey-water solution (25%) was provided to the males until they died. The numbers of days that males and females lived were recorded. This study was replicated four times.

Fecundity and Sex ratio of *G. utilis*

Using leaves exposed during the experiment on the longevity of parasitoids, the fecundity and sex ratio were determined. The exposed leaves were held in a petri dish (9 cm diameter) until the leafminer larvae pupated. The puparia were collected and held until adult parasitoids or leafminers emerged. The number of *G. utilis* emerging and the sex ratio were recorded daily. The emerging parasitoids were sexed under a microscope using antennal characteristics as described in Beardsley (1988). This study was replicated four times.

All experiments were conducted in a laboratory at 25 ± 2°C and 50 ± 10% RH with a photoperiod of 14L: 10D. Means were compared by using the *t*-test from SAS (2003).

Results

Immature stages of *G. utilis*

Generally, only one egg was laid by a *G. utilis* female per host. Eggs were stalked (Fig. la). The average length of eggs was 0.3 ± 0.03 mm (Table 1). First instar *G. utilis* larvae hatched after the *L. trifolii* larvae had pupated. The mean body lengths of the larvae were 0.40 ±

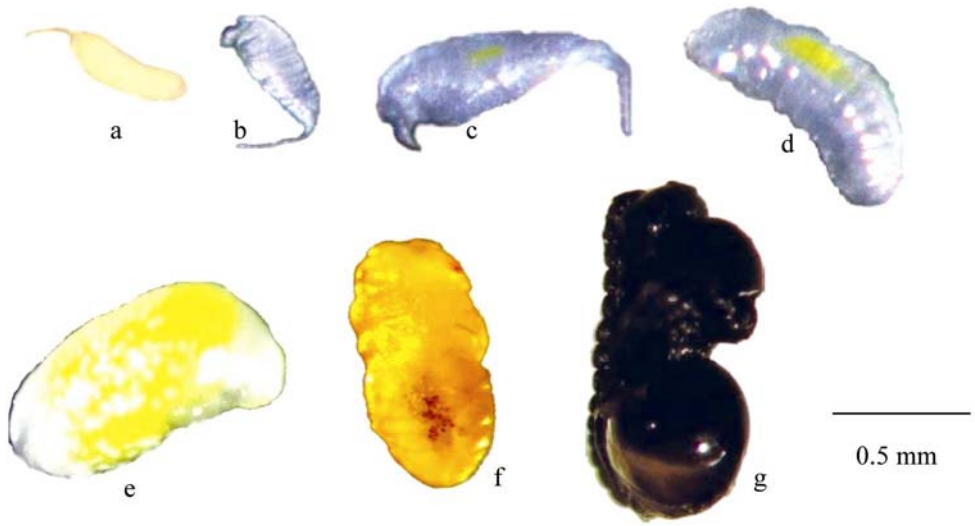

Fig. 1. *Ganaspidium utilis* egg (a), larvae; 1st (b), 2nd (c), 3rd (d), and 4th (e) instar, pre-pupa (f), and pupa (g).

0.08, 0.90 ± 0.08, 1.03 ± 0.11, and 1.1 ± 0.05 mm for the 1st, 2nd, 3rd, and 4th instars, respectively (Table 1). The first instar was eucoliform (Fig. 1b). Small sclerites were distinguishable in the area of the buccal cavity but no mandibles were present in the 1st, 2nd, or 3rd instars, which entirely fed hemolymphagously (Petcharat and Johnson, 1988). Second and 3rd instars (Fig. 1c, d) were similar in form, differing only in size (Table 1). Third instars were visibly attached to the exterior of the leafminer within the puparium. A tail was observed on the 1st and 2nd larval instars. Fourth instars (Fig. 1e) developed within the puparium, and mandibles were found (Petcharat and Johnson, 1988). The three body regions (head, thorax, and abdomen) were clearly identifiable in the prepupal stage (Fig. 1f). Following the pupation of *G. utilis*, the remnants of the leafminer disappeared. Pupae were exarate naked as the hymenopterous type (Fig. 1g).

Developmental time of *G. utilis*

Only one egg was laid by a *G. utilis* female per host. First instar *G. utilis* hatched in 2.33 ± 1.02 days after egg deposition within the leafminer puparium. The total developmental times for males (18.83 ± 1.59 days) and females (17.33 ± 1.26 days) did not significantly differ (Table 1).

Longevity of *G. utilis*

Adult parasitoids emerged in 18.08 ± 0.16 days after egg deposition. The average longevity observed was 14.83 ± 0.70 days. No significant difference was observed in longevity between males (14.33 ± 3.67 days) and females (15.33 ± 0.46 days) (t = 6.58, $p > 0.05$).

Fecundity and sex ratio of *G. utilis*

Ganaspidium utilis females laid eggs throughout their lifespan. This species displays arrhenotokous reproduction with unmated females producing only male progeny (Petcharat and Johnson, 1988). The total number of progeny produced was 66.7 ± 18.40 individuals per female. No significant difference was observed in male (27.79 ± 10.23) and female (38.87 ±

10.61) progeny production by a *G. utilis* female (t = 23.45, P > 0.05).

The sex ratio of *G. utilis* observed was 1 male: 1.4 females. Approximately 65% of eggs were laid within 1 week after adult emergence. Host feeding behavior was not observed.

Discussion

Chien and Ku (2001b, c) reported that the longevities of *H. varicornis* were 22.4 ± 0.6 (female) and 14.5 ± 1 days (male), and for *N. formosa* were 22.3 ± 1.2 (female) and 7.5 days (male) at 25ºC. Similarly, Lopez *et al.* (2004) reported that the longevities of *Halticoptera circulus* (Walker), an imported parasitoid form Hawaii to Taiwan, were 34.25 ± 4.92 (female) and 14.25 ± 2.36 days (male) at 26ºC. Petcharat and Johnson (1988) also observed longevities of 8.9 ± 1.4 (male) and 8.8 ± 2 days (female) for *G. utilis* at 26ºC. The longevity of females observed in this study was higher than that reported by Petcharat and Johnson (1988) but lower than the rest of the other parasitoids mentioned above at both temperatures.

Developmental times varied between *H. varicornis* (11.1 ± 0.1 days) and *N. formosa* (14.4 ± 0.2 days) at 25ºC (Chien and Ku 2001b, c), and *H. circulus* (31.57 ± 4.49 days) and *G. utilis* (25.9 ± 1.4 days) at 26ºC (Petcharat and Johnson, 1988; Lopez *et al.*, 2004). The developmental time observed in this study was lower than that of *G. utilis* observed by Petcharat and Johnson (1988) and *H. circulus* by Lopez *et al.* (2004), but was similar to or higher than those of *H. varicornis* and *N. formosa* (Chien and Ku 2001b, c).

The mean number of progeny produced per female also varied with the parasitoid species at 204 ± 22 (*H. varicornis*) and 202 ± 18 (*N. formosa*) at 25ºC (Chien and Ku, 2001b, c), and 145.25 ± 0.67 (*H. circulus*) and 51.4 ± 13.8 (*G. utilis)* at 26ºC (Petcharat and Johnson, 1988; Lopez *et al.*, 2004). In comparison with other parasitoids, the progeny production observed in this study was higher than that reported by Petcharat and Johnson (1988) and lower than the other reports at both temperatures.

The female sex ratios were reported to be 0.62 (*H. varicornis*) and 0.54 (*N. formosa)* at 25ºC (Chien and Ku, 2001b, c), and 0.67 (*H. circulus)* and 0.58 (*G. utilis*) at 26ºC (Petcharat and Johnson, 1988; Lopez *et al.*, 2004). The female sex ratio of *G. utilis* observed in this study (0.58) was similar to that observed by Petcharat and Johnson (1988), but higher than that of *N. formosa* at 25 ± 2ºC (Chien and Ku, 2001c).

Because of the shorter developmental time, *G. utilis* can multiply faster than can the other parasitoids mentioned above. *G. utilis* laid approximately 65% of the eggs in half of its adult life, and the longevity of *G. utilis* was also shorter than those of other parasitoids reported by other researchers. Due to the shorter longevity and developmental time, several generations of *G. utilis* can overlap in a population. This attribute may be beneficial for the control of *L. trifolii*, as its population is also known to overlap in the field. The lower female sex ratio than other parasitoids mentioned above necessitates more *G. utilis* adults being released in the field to achieve significant control of *Liriomyza* leafminers.

Ganaspidium utilis can successfully control leafminers at a temperature of 25 ± 2ºC. Based on the results observed in this study, *G. utilis* may be a good candidate for the control of *Liriomyza* leafminers. However, further studies are needed to discern additional attributes of *G. utilis,* including its search efficiency, mutual interference, functional response, search behavior, and dispersal characterristics at different temperatures. These attributes are of critical importance to the

determination of the effectiveness of *G. utilis* against *Liriomyza* leafminers on commercial crops in Taiwan.

Acknowledgments

The authors would like to express their thanks to Dr. Ethel M. Vilalobos and Dr. Larry Nakahara for providing and hand-carrying the culture of the parasitoids from Hawaii to Taiwan. Thanks are also due to the National Pingtung University of Science and Technology for offering a scholarship and other supportive facilitates for this study in Taiwan.

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Received: March 26, 2005
Accepted: June 8, 2005

非洲菊斑潛蠅寄生蜂 (*Ganaspidium utilis*) (膜翅目：隆盾癭蜂科) 之生活史

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摘 要

本實驗探討在 25 ± 2ºC 溫度下，非洲菊斑潛蠅 (*Liriomyza trifolii*) (Burguess) 寄生蜂 (*Ganaspidium utilis*) (Beardsley) 自幼蟲期到蛹期之寄生現象。雌寄生蜂產卵在非洲菊斑潛蠅幼蟲體內，在斑潛蠅進入蛹期時，*G. utilis* 便開始孵化及發育，幼蟲期可分辨出四個齡期。雌寄生蜂所產平均子代數爲 66.7 ± 18.4 隻。本實驗中每日提供 50 隻 *L. trifolii* 幼蟲爲寄主，結果顯示其寄生蜂子代雄蜂及雌蜂的性別比例是 1 比 1.4。比較子代雌雄平均數之結果顯示兩者無顯著差異。

關鍵詞：生活史、*Ganaspidium utilis*、非洲菊斑潛蠅。