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Reproductive Biology of *Fopius vandenboschi* (Fullaway) (Hymenoptera: Braconidae) in the Laboratory

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Abstract: *Fopius vandenboschi* (Fullaway) is one of the natural enemies of oriental fruit flies in genus *Bactrocera*. It is a koinobiont solitary endoparasitoid that parasitizes first and second instars of oriental fruit flies. The advantages of this parasitoid are the ability to parasitize several host species and the length of female longevity. Reproductive biology of *F. vandenboschi* in this research showed that it produced average 21.0±13.4 offspring per female, equivalent to net reproductive rate of 8.4 female offspring per generation. The sex ratio is equal to 0.6 : 0.4 (♂ : ♀) and the mean generation time of is 22.5 days. These results can be applied for mass-rearing production of *F. vandenboschi* for inoculative and inundative release to enhance management populations of *Bactrocera* fruit fly pest in Thailand.

Keywords: *Fopius vandenboschi* (Fullaway), *Bactrocera*, reproductive biology, natural enemies, mass-rearing

1. Introduction

Parasitoid is an insect whose larva living, developing, feeding on its host tissue and finally kills the host at eclosion. Although larva of parasitoid is a parasite, adult parasitoid is free-living feeds on honeydew, nectar and pollen (Koul & Dhaliwal, 2003). The categorization of parasitoids can be done in several ways such as classified according to stage of host as egg, larval, pupal or adult parasitoid; classified according to the number of its egg in host as solitary or gregarious parasitoid or may be classified according to its larval feeding behavior as endoparasitoid or ectoparasitoid. Parasitoid is one of the natural enemies that frequently use in biological control program which has been successively researched and developed for more than 100 years. This concept can be used for control or reduce pest populations, in addition it is safe for agriculturists, consumers and environment (Clausen, 1978; Clausen et at., 1965).

In Thailand, tephritid fruit flies in the genus *Bactrocera* are considered as important pests because they can cause serious damage to economic fruits (Plant pathology research group, 2003; Waterhouse, 1993). Moreover, some species such as the oriental fruit fly, *Bactrocera dorsalis* (Hendel) has resistance to pesticides and wide host range (Vontas et al., 2011) that makes it difficult to control. Therefore, the biological control program using parasitoids has been widely used to manage this fruit fly species. The important parasitoid species in Thailand are *Diachasmimorpha longicaudata* (Ashmead), *Fopius arisanus* (Sonan) and *Fopius vandenboschi* (Fullaway) (Hymenoptera: Braconidae) (Vargas et al., 2012). *F. vandenboschi* is a solitary endoparasitic wasp that parasitizes first and second instars (van den Bosch & Haramoto, 1953) of several fruit fly pests (Diptera : Tephritidae) such as, *Ceratitis capitata* (Wiedemann), *Bactrocera cacuminatus* (Héring), *Bactrocera dorsalis* complex, *Bactrocera correcta* (Bezzi), *Bactrocera latifrons* (Hendel), *Bactrocera pedestris* (Bezzi), *Bactrocera tryoni* (Froggatt) and *Carpomya vesuviana* Costa (Chinajariyawong et al., 2000; Wharton & Giltrap, 1983). It distributes in Indo-Pacific region from Pakistan through Taiwan including Thailand (Wharton & Giltrap, 1983). The advantages of *F. vandenboschi* are the ability to parasitize various tephritid fruit fly pest species and the longer female lifespan than any other related parasitoids. Combined with the high capability of female parasitoid in host searching and the ability to survive under unsuitable environmental conditions and high competition with other parasitoids (Ramadan, 2004; Ramadan et al., 1995), *F. vandenboschi* is a remarkable parasitoid for application in biological pest control programs.

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The augmentation is one of the key techniques in the processes of biological control, by increasing in the numbers of natural enemies in agricultural area (Department of Agriculture Thailand, 2003). This strategy enhances the efficacy and achievement of pest control. Augmentation requires understanding the biology of that particular natural enemy especially reproductive biology. Thus, this study was aimed to provide the useful information about the reproductive biology of *F.vandenboschi* in laboratory for mass-rearing production and used in inoculative or inundative release of this parasitoid species which will allow for effective pest control of *Bactrocera* fruit flies in Thailand.

2. Materials and Methods

2.1 Tephritid fruit flies and parasitoids

B. dorsalis were obtained from Plant Pest Management Research Group, Department of Agriculture Thailand and maintained in laboratory at Department of Biology, Faculty of Science, Burapha University, Chon Buri Campus. The adult fruit flies were reared in ventilated plastic container with 26.5 cm diameter and 27 cm high, provided a 10% honey and yeast extract powder as food source.

F. vandenboschi was collected from ripening java apple (*Syzygium samarangense*) infested with tephritid fruit fly larvae from Bangkok, Thailand in 2013. Fruits were placed in containers until larvae developed into puparia and emerged. Adult parasitoids were identified using keys published by Wharton and Giltrap (1983) and reared in ventilated plastic container with 26.5 cm diameter and 27 cm high provided a 10% honey as food source. Both parasitoid and host fly (*B. dorsalis*) were maintained under laboratory condition at 27 ± 2 °C, with 70 ± 10% RH and a photoperiod of 12L:12D. The voucher specimens of parasitoid and host fly were kept at Department of Biology, Faculty of Science, Burapha University, Chon Buri Campus.

2.2 Reproductive biology of *F. vandenboschi*

In order to obtain virgin *F. vandenboschi* of the same age, parasitized *B. dorsalis* puparia were isolated individually in 1.5 ml microtube and examined under stereo microscope few days before parasitoid emergence when parasitoid pupa can be seen inside the host puparium. Paired three days old sexually mature male *F. vandenboschi* (Hagen, 1953) with one day old female in ventilated plastic box (11x11x6.5 cm), allowed to mate for 24 h. The experiments were conducted for 40 pairs. The reproductive biology of *F. vandenboschi* was tested on the first instar *B. dorsalis*. Each pair of mated *F. vandenboschi* was provided with 100 larvae in mashed ripe banana packed in a modified oviposition unit (4.5x5.5x1 cm plastic box with nylon lid). The oviposition unit was exposed to parasitoid for oviposition for three days until the larvae turn into third instar, and then take the oviposition unit out. Replaced with the new unit twice which will be correspond to age at peak oviposition of *F. vandenboschi* (8.4 ± 1.3 days) (Ramadan et al., 1995). The exposed larvae were reared until adult fruit flies and parasitoids emerged, counted the number and calculated as the average number of offspring and net reproductive rate. The date that first female offspring emerged were averaged as the mean generation time of *F. vandenboschi*.

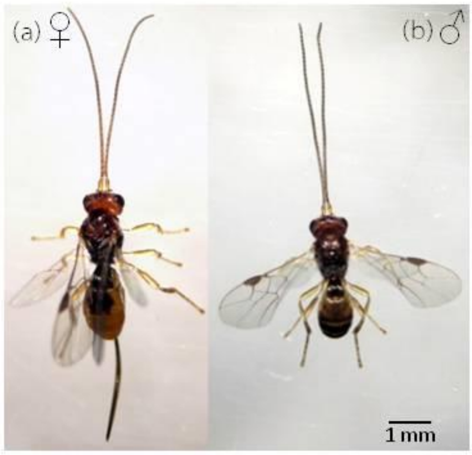

Figure 1. *Fopius vandenboschi* (Fullaway); (a) female, (b) male

3. Results

The reproductive biology of *F. vandenboschi* in laboratory condition examined from 40 pairs of parasitoid was shown in Table 1. The average number of both male and female offspring that female parasitoid produced was 20.1±13.4 offspring. The progeny sex ratio was more biased toward male (502 offspring) than female (337 offspring). The net reproductive rate was 8.4 female offspring per generation and this parasitoid species required 22.5 days for new female offspring production.

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Table 1 . Reproductive parameters of *Fopius vandenboschi*

Average number of offspring produced per female (±SD)	Sex ratio (♂ : ♀)	Mean generation time (days)*	Net reproductive rate (per generation)*
21.0±13.4	0.6 : 0.4	22.5	8.4

* according to Vargas et al. (2002)

4. Discussion and Conclusions

F. vandenboschi is a parasitoid of important tephritid fruit fly species in tropical and subtropical areas (Chinajariyawong et al., 2000; Wharton & Giltrap, 1983). It reproduces by arrhenotokous parthenogenesis (Heimpel & Boer, 2008; Shaw & Huddleston, 1991), which unfertilized eggs (n) develop to males and fertilized eggs (2n) develop to females. Consequently, female parasitoid can specify sex of its offspring as male or female based on the host size at time of oviposition (Godfray, 1994). So, female parasitoid plays a major role in biological control as the parasitized agent. In addition, it also has roles in increasing and maintaining parasitoid population in the level that can effectively control the pest fly (Stouthamer et al., 1992). In this study, *F. vandenboschi* had average parasitization rate of 21.0% similar to the study on mass-rearing of Ramadan (2004) that the parasitization rate was in the range of 14.9-33.6% and occurred at peak rate when female parasitoid was 11 to 15-day-old. Ramadan et al. (1995) and Vargas et al. (2002) also reported that the average total number of eggs laid by female *F. vandenboschi* during lifetime were 33.3-34.2 eggs/female. Therefore, the number of *F. vandenboschi* offspring in this study was lower than the number of its eggs. This may due to the difference in population size between this and those experiments which influence mating behavior of *F. vandenboschi*. In general, insect is a social animal that need social stimulation to increase breeding success which involve population growth (Bompard et al., 2013). Accordingly, the mass production of parasitoid should be reared in large population to increase breeding rate and increase chance to obtain female offspring.

The net reproductive rate of *F. vandenboschi* in this study, which determined from number of female offspring, was consistent with Vargas et al. (2002). Although the reproductive rate of *F. vandenboschi* was the lowest compared to other related fruit fly parasitoids (Vargas et al. 2002), it was found that female longevity of *F. vandenboschi* was the longest (26-30 days) (Ramadan, 2004). In addition, its mean generation time (22.48 days) was shorter than its lifespan. These turned into the advantages of this parasitoid species because the presence of female parasitoid in environment in long period of time will increase chance of parasitism. However, *F. vandenboschi* has a unique reproductive characteristic that is a newly emerged male required a premating period to reach sexual maturity before being ready to mate (Hagen, 1953). Thus, to ensure that male parasitoid will emerge first and mature before female emergence, female *F. vandenboschi* usually laid unfertilized eggs in the early phase of its lifespan and switched to lay more fertilized eggs when it was older (Ramadan et al., 1991). In this experiment, *F. vandenboschi* was allowed to lay egg until it was 11-day-old which Ramadan (2004) reported that it was in the period of the highest oviposition and the highest number of female offspring production. The result in this study then showed the bias sex ratio of offspring toward male (60%) whereas Ramadan (2004) and Vargas et al. (2002) presented the sex ratio in their experiment was bias toward female (56-57%). This indicates the significance of the age interval after the 11-day-old of this parasitoid species that has high impact on the increasing number of female offspring. Consequently, the mass-rearing production of *F. vandenboschi* should be used mated female aged over 11 days (Ramadan, 2004) which will produce more female offspring to use as effective agent in inoculation and inundation biological control.

The research on reproductive biology of *F. vandenboschi* can be further used in mass-rearing production for augmentation in tephritid fruit fly control. In conclusion, selecting appropriate age of the breeders should be done to obtain large number of female offspring. In addition, the application of *F. vandenboschi* with other related parasitoid species such as *D. longicaudata* that attack late instars tephritid fruit fly will establish complex interaction among parasitoids. It will help facilitate the effective and success biological control.

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