

**Research Article**

**Biology and ecology of fruit piercing moth *Eudocima phalonia* (L.) in a citrus orchard in Sarawak, Malaysia**

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**ABSTRACT.** The fruit piercing moth (FPM), *Eudocima phalonia*, is a major citrus pest. Alternation of host plant capability increase their survival and cause insecticides to become ineffective. There is lack of information on the biological and ecological aspect of FPM in Malaysia. This study reports some aspects of the biology and ecology which cover the seasonal population and life cycle of FPM in citrus orchard and in an adjacent secondary forest in the Kuching Division, Sarawak in Malaysia. Cages (0.6 x 0.6 x 0.6 m) with fresh banana bait were hung in both citrus and secondary forest stands to monitor seasonal population while sleeve cages (0.2 x 0.3 m) were used to study its life cycle on an alternate host plant, Bandicoot Berry (*Leea indica*). Most of the moth was found in the citrus orchard (67%) as compared to the secondary forest (37%). The moth was detected throughout the year with its activity lowest during the wet months (September-March) when fruits were still available, while the highest activity was recorded during the dry months (May-June) which also coincided with the main fruiting season. The alternate host Bandicoot Berry (*Leea indica*) provided food for the larvae of the FPM in the secondary forest areas. The FPM had four developmental stages on bandicoot berry which included eggs ( $3.0 \pm 0.1$  days), larvae ( $20.8 \pm 1.0$  days) and pupal ( $15.8 \pm 0.5$  days). The life cycle from eggs to adult emergence took  $39.6 \pm 2.2$  days.

**Keywords:** Fruit piercing moth, life cycle, seasonal moth population, *Leea indica*.

**INTRODUCTION**

The *Eudocima phalonia* (Lepidoptera: Erebidae) (Holloway, 2011; Zahiri *et al.*, 2012) or fruit piercing moth (FPM) is a native in the Indo-Malaysia region. These large noctuid moths are adult pests of a range of commercial fruits with at least 40 different species of tropical and subtropical fruits including citrus, carambola, guava, mango, papaya, banana, fig, persimmon, longan, eggplant, tomato, melon and pineapple. This moth causes severe damage to fruits throughout the tropical and subtropical belt from Africa to Southeast Asia and Australia and to Pacific islands (Waterhouse & Norris, 1987; Jumroenma *et al.*, 1998; Ngampongsai *et al.*, 2005).

Compared to other moths, the FPM moth is unique in a way that the adult moth with a strong proboscis is more damaging than when it is at the caterpillar stage. Both sexes of adult moths puncture mature fruit with their well-developed proboscis and feed on the fruit's juices (Lubulwa & McMeniman, 1997; Sands *et al.*, 1996) and cause crop losses of more than 50% (Sands *et al.*, 1993). Fruits that are damaged become soft and mushy, differing from the type of damage caused by fruit flies where the fruit is more liquified (Kessing &

Mau, 1993), and lose their market value. Damaged fruits are unmarketable and if packed or sold, pose a threat to sound fruit through pathogenic contamination (Reddy *et al.*, 2007). In addition, the preliminary wound serves as a permanent access point for secondary infection organisms, which can cause further spoilage (Reddy *et al.*, 2005).

The perseverance and survival of *E. phalonia* are dependent on its ability to host on both wild and indigenous plants. The larvae tend to feed on foliage of wild hosts, typically trees, shrubs and vines within the families of Menispermaceae and Fabaceae (Kumar & Lal, 1983; Kessing & Mau, 1993; Muniappan *et al.*, 1994-1995; Reddy *et al.*, 2005). There are records showing that fruit piercing moths feed on plants from the family Lardizabalaceae, Amaranthaceae, Berberidaceae, Sterculiaceae and Leeaceae. This capability of host plant alternation makes application of insecticide ineffective. An integrated method for management involving biological control, bagging of fruits, netting rows of vegetable crops and netting individual fruit trees has been recommended but it is not yet economically viable (Fay, 2002; Muniappan *et al.*, 2002).

In Sarawak, citrus is a major fruit crop and covers an area of 3,135 hectares (Sarawak Agriculture Department, 2007a) with an export value of RM83,024.00 or US\$27,675 in 2005 (1 US\$ = RM 3) (Sarawak Agriculture Department, 2007b). FPM infestation and attacks can cause substantial economic losses to citrus growers. In Malaysia, limited information and research has been conducted on FPM particularly in regards to its biology and ecology. This study on the biological and ecological niche of this species can lead to a better understanding on effective and integrated pest management approaches. This paper reports some aspects of the biology and ecology which cover the seasonal population and life cycle of the FPM on the citrus orchard and alternate host in the Kuching Division in Sarawak, Malaysia.

## MATERIALS AND METHODS

### Study sites

The experiment was conducted in a two hectare six-year-old honey mandarin (*Citrus reticulata* Blanco) citrus orchard in Tondong, Kuching Division in Sarawak, Malaysia from January 2008 to June 2009. It comprised of 200 stands of healthy and well maintained marcotted trees that were planted in January 2002. During the length of the study, no insecticides or fungicides were applied on the citrus stands. The experiment consisted of studying the seasonal FPM population pattern throughout the citrus growing season and the life cycle of the moth on the host plant in the adjacent secondary forest. Peel colour was used as an indicator of fruit maturity and is one of the easiest means to judge ripeness without destructive sampling in the field (Liu *et al.*, 2001; Ying *et al.*, 2004).

### Seasonal moth population pattern

The seasonal FPM population pattern was monitored weekly by trapping throughout the citrus growing seasons from January 2008 to June 2009. Four cages (0.6 m x 0.6 m x 0.6 m) were randomly placed in the citrus orchard and secondary forest areas. Ripe bananas were used as food bait. The cages were hung at 1.5 m above the ground. Fresh ripe bananas were replaced once in three days to ensure the freshness of the baits and moths caught were recorded in both sites on the same day. The mean number of caught moths were combined and expressed on a monthly basis.

### Life cycle of the moth in secondary forest

The experiment was conducted in a secondary forest adjacent to the citrus orchard. Plots of 20 x 20 m were established with an interval of five metres along an established baseline. Weekly sampling was conducted from January 2008 to June 2009. At the start of the experiment, trees and shrubs were examined for the presence of larvae. Plants that showed the potential as hosts

were identified and a sleeve cage (0.2 m x 0.3 m) was used for life cycle study. Field observations were made for eggs and larvae on leaves of the alternate host, Bandicoot Berry at a two-day interval during the study period to record the developmental period of eggs, larvae, pupal and the adult.

**Data Analysis**

Data was subjected to Student’s t-test using SPSS software for Window version 16.01 to analyse the differences in mean adult FPM population pattern in the citrus orchard and secondary forest.

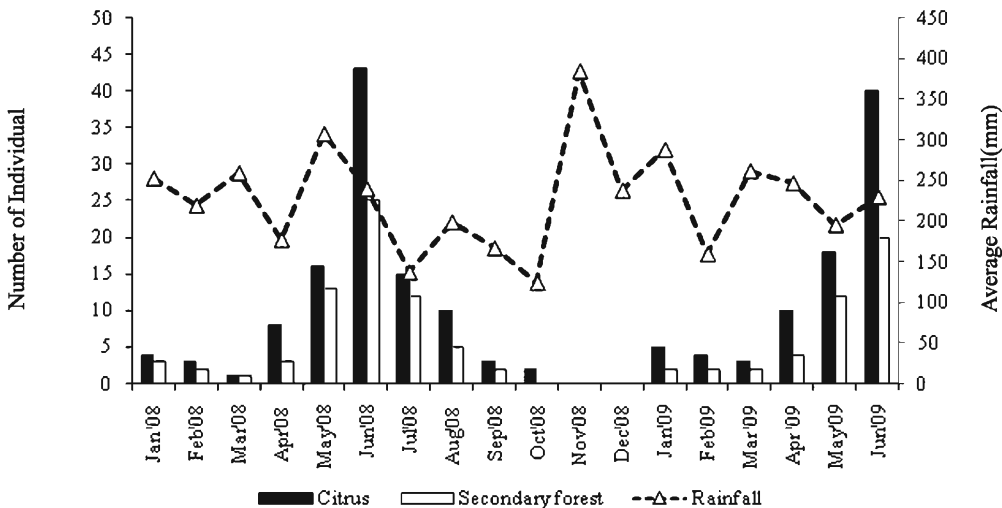
**RESULTS AND DISCUSSION**

**Seasonal moth population pattern**

Generally, the annual moth population density varied with a peak in June 2008 and 2009. The moth activity started to increase after March and began to decline after July onwards with the lowest activity recorded between September to March (Figure 1). There were

293 individual FPM caught in the cage traps with 63% found in the citrus orchard and 37% in the secondary forest. The FPM occurrence in the citrus orchard was significantly higher ( $p \leq 0.05$ ) than the secondary forest with a mean of  $10.3 \pm 2.9$  (mean individual  $\pm$  standard error) and  $6.0 \pm 1.7$ , respectively. This reflects the preference of the FPM to feed on mature citrus fruit instead of wild hosts (Figure 2; 3). This is one feature characters of the FPM where the adult feeds on a wide variety of commercial fruits including citrus (Waterhouse & Norris, 1987; Jumroenma *et al.*, 1998). In a report by Ngampongsai *et al.* (2005), they found a higher occurrence of FPM in citrus orchards due to the long harvest period and softer fruit skin.

Ngampongsai *et al.* (2005) reported that *O. fullonia* populations in Guam are generally higher during the rainy season in contrast to this study where the FPM population was reported lower during the rainy season. Boonyarat *et al.* (1986) reported that a large number of FPM species, *O. coronata*, were collected in mid-July to early September in China, while in the present study, a majority of the moths were



**Figure 1.** Fluctuations of the adult *Eudocima* moth in citrus orchard and secondary forest during January 2008 – June 2009.



**Figure 2.** Adult moth feeding on citrus fruit.

trapped between April and June. Fay (2004) reported that a large FPM population occurred in January/February in summer in Queensland, Australia.

Low activity in this study may be due to abiotic factors (such as annual rainfall, humidity and temperature). Data obtained from the Kuching Meteorological Station showed that the average rainfall began to peak in October and started to decline towards March. The adult moth population recorded in this study was low between September and March during the wet season (October-March), increased in April and peaked in June during the dry season (April-September) (Figure 3). Ngampongsai *et al.* (2005) suggested that apart from maturing fruits, climatic factors such as temperature, relative humidity and rainfall can influence the abundance of fruit piercing moth outbreaks in addition to the minimal breeding and feeding during wet season.

The wide range of fruit crops has increased the quantity, and length of time fruit is available for FPM attack and oviposition (Fay, 2004). He further reported that moth populations were higher in citrus orchards than the secondary forest which may be due to the feeding habitat of the adult moths as they were attracted to feed on mature and ripened citrus fruits instead of on wild hosts. In this study, the moth numbers were found relatively higher in the citrus orchard than in the nearby forest throughout the year, and this also implies that



**Figure 3.** Puncture wounds on fruits and premature fruits.

adult moths are alternating between the citrus orchard and the nearby forest. It is thought that after feeding in the fruit orchard, they immediately return to their breeding site in the forest which coincides with the main citrus fruiting season during the month of April to June, before declining. The increase in adult moth population may be associated to the stage of fruit development. Waterhouse & Norris (1987), Ngampongsai *et al.* (2005) and Fay & Halfpapp (2006) indicated that these peaks and low occurrence are influenced by the ripening or near ripening of citrus.

### Life cycle

In this study, larvae of *E. phalonia* was found to feed on leaves of a wild shrub, *Leea indica* or locally known as Kemali, or Bandicoot Berry from the family of Leeaceae. It is a small multistem shrub with medicinal value and can



**Figure 4.** Mature larvae on the Bandicoot Berry foliage.

grow up to 10 m (Burkill, 1966; Chatterjee & Prakashi, 1994; Lattif *et al.* 1984; Prajapati *et al.*, 2003; Varadarajan *et al.*, 2008). In Australia, larvae often feed preferentially on foliage of certain *Tinospora* spp. (family Menispermaceae). Around 60% of the Australia menisperm species are now known to support fruit piercing moth larvae. Despite the reports of host plants being predominantly vines and lianas in the family of Menispermaceae (Banziger, 1982; Robinson *et al.*, 2001; Reddy *et al.*, 2005), there are also records on non-menispermaceous such as on coral trees (*Erythrina* spp. of Leguminosae) in New Guinea and the Pacific Island (Muniappan *et al.*, 1994-1995; Cochereau, 1972; Fay, 1996; Reddy *et al.*, 2007) and Bandiroot Berry (*Leea indica* of Leeaceae) in Thailand (Banziger, 1982).

Life cycle of *E. phalonia* was monitored on five individual moths in a sleeve cage. The moth would complete its life cycle on the Bandicoot Berry. *Eudocima phalonia* has four developmental stages ranging from the egg to five larval instars to pupa before becoming an adult (Table 1). In the field, with air temperature of between  $28.0-32.0 \pm 1.0^\circ\text{C}$ , the average egg incubation period was  $3.0 \pm 0.1$  days while the mean larval developmental period was  $20.8 \pm 1.0$  days (Figure 4) and the mean pupal period was  $15.8 \pm 0.5$  days. The life cycle from eggs to adult emergence took  $39.6 \pm 2.2$  days.

Eggs hatch within three to four days as reported by Waterhouse & Norris (1987) while larva lasts for about 21 days as reported by

Kumar & Lal (1983). Reddy *et al.* (2005) found that the larval development stage on *Tinospora homosepala* and *Erythrina variegata* in Guam ranged from 17.5–25.1 days. The pupal period was at an average of 12.5-17.8 days as reported by Kumar & Lal (1983) and Waterhouse & Norris (1987). Reared on Bandicoot Berry, the total life cycle required 39.6 days compared with 43 days and 31.5 days in Fiji and New Calidonia (Cochereau, 1977; Kumar & Lal, 1983; Waterhouse & Norris, 1987).

The separation of resources between larvae and adults provided the *Eudocima* spp. an extension in its reproduction period and in maintaining population density, even during unfavourable climatic conditions and shortage of food resources (Fay & Halfpapp, 1993). Despite their widespread occurrence and the severe damage they cause, it is difficult to control the moth with insecticide as they spend only a short time on citrus fruits and do not breed on the affected crops. Bagging fruits or netting trees in a big orchard is neither practical nor cost effective. A study by Leong & Roland (2011) showed that citrus fruit damage can be substantially reduced (4-16% fruit damage) using horticultural mineral oils (HMOs). The potential of using HMO can be incorporated in the Integrated Pest Management programme while potential bio-control agents should also be explored particularly in the secondary forest area.

## CONCLUSION

Moth activities are largely affected by seasonal weather, fruiting pattern and also host alternation capabilities. The capability of

**Table 1.** Stage of development of *E. phalonia* reared on Bandicoot Berry (*Leea indica*) foliage at  $28.0-32.0 \pm 1.0^\circ\text{C}$ .

Development Stage	Average No (days $\pm$ S.E.)
Egg incubation	$3.0 \pm 0.10$
Larval period	$20.8 \pm 1.00$
Pupal period	$15.8 \pm 0.52$
Egg laying to adult emergence	$39.6 \pm 2.17$

Note: S.E. means standard error

alternate hosts increases its survival. Factors influencing all stages in fruit piercing moth (FPM) development should be further studied. Their short stay at fruits and decision to breed on the host plant in the secondary forest makes the use of insecticide ineffective. The development of an integrated pest management (IPM) for FPM in citrus is needed in view of the low success rate in controlling this pest. Therefore, understanding the biological and ecological aspects of the FPM is essential in the formulation of such management practice.

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