

A preliminary study on some ecological aspects of the fruit piercing moths in Songkhla Province of Southern Thailand

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Abstract

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A preliminary study on some ecological aspects of fruit piercing moths (FPM) in Songkhla province of southern Thailand was conducted from December 2003 to November 2004. The objectives of this study were to determine species diversity, the seasonal abundance of the major moth species occurring in longkong (*Aglaiia dookkoo* Griff.), citrus (*Citrus reticulata* Blanco) and pomelo (*C. maxima* Merr.) as well as to assess yield losses due to these insects in citrus cropping systems. Twenty-four species of FPM were collected from these crops. The greatest species richness and relative abundance were observed in citrus, covering 23 species from 452 individuals trapped. In pomelo, 20 different species were found among the 142 individuals trapped. In the longkong system, there were 13 species found among the 100 individuals trapped. The three most dominant species collected at the longkong site were *Erebus ephesperis* (Hübner), *E. hieroglyphica* (Drury) and *Ophiusa coronata* (Fabricius). From the citrus site the most common species trapped were *O. coronata*

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(Fabricius), *E. ephesperis* (Hübner) and *Othreis fullonia* (Clerck). The most abundant species from the pomelo site were *Trigonodes hyppasia* (Cramer), *Mocis undata* (Fabricius) and *E. ephesperis* (Hübner). Simpson's indices of diversity were 0.79, 0.89 and 0.88 in longkong, citrus and pomelo, respectively. Moth population levels peaked in July and November in citrus, and in June in both longkong and pomelo. These peak occurrences were directly synchronized with the ripening stage of the fruit or at the harvest periods. Fruit losses due to FPM in citrus were 24.8% and 22.7% in the 1st harvest season (July-August 2004) and the 2nd harvest season (November-December 2004), respectively.

Key words : fruit piercing moth, citrus, longkong, pomelo, population

บทคัดย่อ

อรัญ งามผ่องใส¹ บรูซซ์ บาร์เรตต์² สุไรกร เพิ่มคำ¹ นิรมล สุธาประดิษฐ์¹ และ รัชณี นิลละอ¹
การศึกษาเบื้องต้นนิเวศวิทยาบางประการของผีเสื้อมวนหวานในจังหวัดสงขลา
ภาคใต้ของประเทศไทย

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ศึกษาเบื้องต้นผีเสื้อมวนหวานในจังหวัดสงขลาในระหว่างเดือนธันวาคม พ.ศ. 2546 ถึงเดือนพฤศจิกายน พ.ศ. 2547 โดยมีวัตถุประสงค์เพื่อศึกษาชนิดและปริมาณของแมลงดังกล่าวในลองกอง ส้มโชกุน และส้มโอ และประเมินความเสียหายของส้มโชกุนที่เกิดจากการเข้าทำลายของผีเสื้อมวนหวานในสภาพไร่ ผลการศึกษาสำรวจพบผีเสื้อมวนหวานจากพืชทั้ง 3 ชนิดดังกล่าวจำนวน 24 ชนิด พบชนิดและปริมาณผีเสื้อมวนหวานมากที่สุดในส้มโชกุนจำนวน 23 ชนิด ปริมาณ 452 ตัว รองลงมา ได้แก่ ส้มโอจำนวน 20 ชนิด ปริมาณ 142 ตัว และลองกองจำนวน 13 ชนิด ปริมาณ 100 ตัว ตามลำดับ 3 ชนิดแรกที่พบมากที่สุดในลองกองได้แก่ *Erebus ephesperis* (Hübner), *E. hieroglyphica* (Drury) และ *Ophiusa coronata* (Fabricius) ในส้มโชกุนได้แก่ *O. coronata* (Fabricius), *E. ephesperis* (Hübner) และ *Othreis fullonia* (Clerck) และในส้มโอได้แก่ *Trigonodes hyppasia* (Cramer), *Mocis undata* (Fabricius) และ *E. ephesperis* (Hübner) ค่าดัชนีความหลากหลายโดยวิธีการของซิมป์สัน (Simpson's index of diversity) ในลองกอง ส้มโชกุน และส้มโอ เท่ากับ 0.79, 0.89 และ 0.88 ตามลำดับ ในส้มโชกุนพบประชากรผีเสื้อมวนหวานมากที่สุดในเดือนกรกฎาคมและพฤศจิกายน ส่วนในลองกองและส้มโอพบประชากรผีเสื้อมวนหวานในเดือนมิถุนายน ซึ่งในช่วงดังกล่าวเป็นฤดูเก็บเกี่ยวผลผลิต ความเสียหายของผลส้มโชกุนจากการเข้าทำลายของผีเสื้อมวนหวานในฤดูเก็บเกี่ยวครั้งแรก (ก.ค. - ส.ค. 2547) และครั้งที่ 2 (พ.ย. - ธ.ค. 2547) คิดเป็น 24.8% และ 22.7% ตามลำดับ

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Thailand produces a variety of economically important fruits such as citrus, lychee, longan, mango, grape, pomelo, mangosteen and durian. Most of the fruit producing regions are located in the northern, eastern and southern regions of the country. Thailand's exports of fresh fruits to world markets have sharply increased over the past several years (Office of Agricultural Economics, 2003).

Climatic conditions and insect pests are considered to be the most important factors caus-

ing loss in fruit yield. The fruit piercing moth (FPM) complex is one of the most important insect groups attacking many kinds of fruits in Thailand and worldwide (Jumroenma *et al.*, 1998; Waterhouse and Norris, 1987). FPMs have been recorded attacking over 40 different species of tropical and subtropical fruit in the Pacific region. Citrus varieties, mango, papaya, lychee, stone fruit, carambola, kiwi fruit, capsicum and tomatoes are all particularly susceptible. Both male and female adult moths will attack green and ripe fruits, but

most damage is caused when the moths puncture mature fruit with their well-developed proboscis and feed on the fruit's juices (Lubulwa and McMeniman, 1997; Sands *et al.*, 1996). The larvae of FPM usually feed on weeds and non-fruit plants (Evans and Crossley, 2002).

Fruit damaged by FPM becomes soft and mushy, differing from the type of damage caused by fruit flies where the fruit is more liquified (Heu *et al.*, 1985 cited by Kessing and Mau, 1993). FPM moths are also vectors of fruit rot diseases including *Oospora citri*, *Fusarium* sp., *Colletotrichum* sp. (Banziger, 1982), and several types of bacteria (Hargreaves, 1936). For example, when moths attack green fruit the site of the feeding puncture on the fruit's surface will become discolored, and in a short time fungi will develop at the site and spread throughout the fruit causing it to drop prematurely (Comstock, 1963; Kumar and Lal, 1983; Waterhouse and Norris, 1987).

Previous studies dealing with FPMs in Thailand have been projects primarily confined to the eastern, northern and central regions of the country (Banziger, 1982; Boonyarat *et al.*, 1986; Jumroenma, 1999; Jumroenma *et al.*, 1998). Very little research has been conducted on FPM abundance and impact from southern Thailand, a region where many important tropical fruits are grown in abundance. In addition, the seasonal and climatic conditions influencing outbreaks of FPMs in southern Thailand are very different from the northern regions of the country. Consequently, a preliminary study of the FPMs in southern Thailand was conducted.

The objectives of the study were to determine species diversity and seasonal abundance of FPMs attacking important fruit crops in southern Thailand. Fruit losses of citrus due to FPM damage were investigated during two seasons.

Materials and Methods

1. Site descriptions

This study was conducted in the Songkhla Province of southern Thailand, between November 2003 and December 2004. The fruit plantings

included longkong (*Aglaia dookkoo* Griff.), citrus (*Citrus reticulata* Blanco) and pomelo (*C. maxima* Merr.).

The citrus site was a 5-year old planting of approximately 15 rai (2.4 ha.) in size and surrounded by rubber trees. The pomelo planting was a 8-year old site and 5 rai (0.8 ha) in size. The 8-year old longkong plants were part of an intercropping system with banana (Figure 1B). This planting size was approximately 10 rai (1.6 ha).

During the length of the study, no insecticides or fungicides were applied in the plantings. Previous to the study, foliage sprays on the citrus were usually applied on a 10-15 day interval, and consisted of abamectin, chlorpyrifos or cypermethrin for controlling citrus leaf miner, thrips, aphids and scale insects. The acaricide, dicofol, was applied for red mite control. Fungicides applied were carbendazim, benomyl and copper hydroxide. There were no insecticide applications during harvest. Naphthalene balls were also hung on the citrus shoots to repel FPMs during the harvest periods (Figure 1A).

2. Species diversity study

A study was conducted at the site as mentioned in previous section where FPM diversity were examined in the fruit hosts of longkong, citrus and pomelo between November 2003 and December 2004. The characteristics of each crop, as well as crop management practices, were collected from the farmers.

Both sexes of adult FPMs were trapped in four cages at each location. Cage size was 40 cm x 40 cm x 40 cm. To attract the adult moths, a piece of ripe pineapple was hung as a bait inside the cage. The cages were either hung outside (citrus bush) or under the plant canopy (longkong and pomelo) at a height of 0.6 m. above the ground surface (Figure 2). Each week the pineapple baits were replaced and the adult moths collected from each cage were taken back to the laboratory for identification. Collected FPM specimens were identified to species using keys and descriptions published by Kuroko and Lewvanich (1993) and Lewvanich (2001). The number of individuals per



Figure 1. Napthalene in plastic bag hanging on citrus shoot (A) and longkong plantation (B).



Figure 2. Insect cages for trapping the FPMs in citrus (A) and in longkong (B).

FPM species were recorded, and their diversity was calculated with Simpson's index (D_s):

$$D_s = 1 - \sum_i [n_i^*(n_i-1)]/[N*(N-1)]$$

Where n_i = the number of individuals in the i^{th} species collected, and N = the total number of organisms in the sample.

A two-tailed correlation between the number of the FPMs in different locations and climatic factors including temperature, relative humidity and rainfall at each experimental site was determined according to Pearson's method. The stages of fruit development were recorded during the study. Diversity of species and abundance of the FPMs were compared among locations.

2. Fruit damage study

An assessment of FPM damage to citrus was investigated at a single site (4-5 year old trees) for two seasons. The first harvest assessment was

conducted during June-July 2004, and the second was done during November-December 2004. Damage evaluations were conducted in three different sized plots, 10 rai (Plot no.1), 4 rai (Plot no. 2) and 2.5 rai (Plot no. 3), within the same orchard. Two and three plants/row of 10 plants/plot were sampled for fruit assessment. Prior to harvest, the total number of almost ripe fruit was counted. In addition, the number of dropped fruit with the FPMs damage symptoms was counted once a week. Percentages of fruit losses were evaluated and compared between 2 harvest seasons.

Results and Discussion

1. Species diversity of fruit piercing moths

Table 1 shows the Simpson's index (D_s) value and number of individuals per fruit piercing moth (FMP) species collected from the longkong, citrus and pomelo plantations. The lowest D value,

Table 1. Simpson's index (D_s) and the number of individuals per FPM species collected from the longkong, citrus and pomelo plantations during December 2003 - November 2004.

Species of fruit piercing moths (no. of individuals)		
Longkong (<i>A. dookoo</i> Griff.)	Citrus (<i>C. reticulata</i> Blanco)	Pomelo (<i>C. maxima</i> Merr.)
<i>Anisoneura aluco</i> (Fabricius) (1)	<i>Achaea janata</i> (Linnaeus) (9)	<i>Achaea janata</i> (Linnaeus) (2)
<i>Anomis guttanivis</i> (Walker) (3)	<i>Anisoneura aluco</i> (Fabricius) (2)	<i>Achaea serva</i> (Fabricius) (2)
<i>Artena dotata</i> (Fabricius) (2)	<i>Anomis guttanivis</i> (Walker) (21)	<i>Anomis guttanivis</i> (Walker) (11)
<i>Ercheia cyllaria</i> (Cramer) (1)	<i>Artena dotata</i> (Fabricius) (6)	<i>Artena dotata</i> (Fabricius) (1)
<i>Erebus caprimulgus</i> (Fabricius) (2)	<i>Chalciope mygdon</i> (Cramer) (11)	<i>Ercheia cyllaria</i> (Cramer) (1)
<i>E. ephesperis</i> (Hubner) (40)	<i>Erebus caprimulgus</i> (Fabricius) (1)	<i>Erebus caprimulgus</i> (Fabricius) (1)
<i>E. hieroglyphica</i> (Drury) (14)	<i>E. ephesperis</i> (Hubner) (66)	<i>E. ephesperis</i> (Hübner) (16)
<i>Mocis undata</i> (Fabricius) (1)	<i>E. hieroglyphica</i> (Drury) (8)	<i>E. hieroglyphica</i> (Drury) (3)
<i>Ophiusa coronata</i> (Fabricius) (10)	<i>Eudocima salamina</i> (Cramer) (5)	<i>Eudocima salamina</i> (Cramer) (3)
<i>Othreis fullonia</i> (Clerck) (9)	<i>Eupatula macrops</i> (Linnaeus) (2)	<i>Eupatula macrops</i> (Linnaeus) (1)
<i>Spirama retorta</i> (Bangalore) (1)	<i>Grammodes geometrica</i> (Fabricius) (14)	<i>Grammodes geometrica</i> (Fabricius) (3)
<i>Thyas honesta</i> (Hubner) (6)	<i>Hulodes drylla</i> (Guenee) (3)	<i>Mocis frugalis</i> (Fabricius) (6)
<i>Trigonodes hyppasia</i> (Cramer) (10)	<i>Ischyja manlia</i> (Cramer) (1)	<i>M. undata</i> (Fabricius) (21)
Total =100	<i>Mocis frugalis</i> (Fabricius) (48)	<i>O. coronata</i> (Fabricius) (12)
$D_s = 0.79$	<i>M. undata</i> (Fabricius) (48)	<i>O. fullonia</i> (Clerck) (1)
	<i>Ophiusa coronata</i> (Fabricius) (86)	<i>Parallelia joviana</i> (Stoll) (2)
	<i>Othreis fullonia</i> (Clerck) (49)	<i>Sphingomorpha chlorea</i> (Cramer) (8)
	<i>Parallelia joviana</i> (Stoll) (3)	<i>Spirama retorta</i> (Bangalore) (14)
	<i>Parallelia</i> sp. (1)	<i>Thyas honesta</i> (Hübner) (1)
	<i>Sphingomorpha chlorea</i> (Cramer) (20)	<i>Trigonodes hyppasia</i> (Cramer) (33)
	<i>Spirama retorta</i> (Bangalore) (5)	Total 142
	<i>Thyas honesta</i> (Hubner) (9)	$D_s = 0.88$
	<i>Trigonodes hyppasia</i> (Cramer) (34)	
	Total 452	
	$D_s = 0.89$	

or dominance measure, was 0.79 from the longkong plantation. In the citrus and pomelo plantings, the D values were 0.89 and 0.88, respectively. These data indicate that the citrus site had the greatest level of FPM diversity among the three plantings. However, in terms of species richness, 23 species of FPM were sampled from the citrus plantings where 20 species and 13 species were obtained from the pomelo and longkong plantings, respectively. These results are supported by the report of Fay (2004) that over 40 different fruit hosts have been recorded as being attacked by the fruit piercing moth, but various citrus are amongst the most preferred.

The richness of the FPMs in citrus (Table 1) was higher than that previously reported for mangosteen planting areas in Chumporn province

located in northernmost South of Thailand. The seven species of FPMs collected from the mangosteen plantation are *Achaea serva* Fabricius, *Erebus ephesperis* Hübner, *Eudocima salamina* Cramer, *Mocis undata* Fabricius, *Ophiusa coronata* Fabricius, *Othreis fullonia* Clerck and *Thyas honesta* Hübner (Jumroenma, 1999). All of these species but *A. serva* had been found in the citrus sampling.

The relative abundance of all fruit piercing moth species continued to be the highest in citrus throughout the year compared with longkong and pomelo (Figure 3). The total number of individuals collected during December 2003-November 2004 were 100, 452 and 142 in the longkong, citrus and pomelo planting areas, respectively (Table 1). There are two important characteristics found in citrus

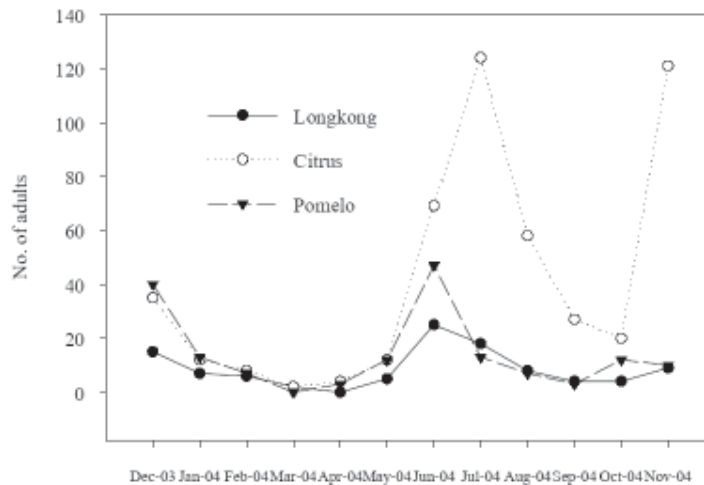


Figure 3. Fluctuations of the FPMs adults in longkong, citrus and pomelo plantations during December 2003 - November 2004 in Songkhla province of southern Thailand.

that may help explain its attractiveness to FPMs. The first is the long harvest period of citrus, lasting about 7 weeks, as compared to the longkong harvest of only a 2 week duration (Tables 4 and 5). Secondly, citrus has a relatively soft skin and compared to the hard and thick skin of pomelo. These two conditions, a long harvest period and a soft fruit skin, may help explain the greater number of FPM species collected in citrus.

2. Seasonal abundance of fruit piercing moths

The seasonal abundance of trapped adult FPM (all species) among the fruit plantings is illustrated in Figure 3. Despite the differences in numbers of trapped moths, two general annual periods of adult activity are apparent. Subsequent samples taken after December 2003 show a decline in moth activity from the end of the year peak. The next peak of moth activity started to occur in April. In the longkong and pomelo plantings the moth flight began to decline in July, whereas in citrus moth activity dropped in August and September. Between October and November the number of moths trapped started to increase again. This increase was much more pronounced in the citrus planting.

The reason for these outbreaks are likely associated with stage of fruit development. Fay

(2004) noted that the wide range of fruit crops have increased the quantity and length of time fruit is available for FPM attack and oviposition. As shown in Table 2, harvesting periods of longkong and pomelo were June-July 2004, and those of citrus were June-August and November-December 2004. Waterhouse and Norris (1987) revealed that most fruit piercing moths likely preferred to attack fruits that were ripe or nearly ripe. Similarly, Jumroenma *et al.* (1998) reported on some FPM outbreaks occurring in the northern, eastern and southern regions of Thailand in 1998. In these regions, the harvest season was in progress, ending, or just beginning, respectively. FPM adult abundance was also reported by Boonyarat *et al.* (1986) for the Chinat province of central Thailand. They reported a large number of the FPM species, *O. coronata*, collected during mid-July to early September, but no mention was made of two periods of moth activity as in our study.

Besides the occurrence of maturing fruits, climatic factors such as temperature, relative humidity (RH) and rainfall can influence the abundance FPM outbreaks. For example, Schreiner (n.d.) reported that *O. fullonia* moth populations in Guam are generally higher during the rainy season. In our study, such climatic factors did not appear to significantly affect the number of moth

Table 2. Climate data (monthly average) and ripe fruit stage appearance of longkong, citrus and pomelo during December 2003-November 2004 in Songkhla province of southern Thailand.

	Fruit stage appearance											
	12/03	1/04	2/04	3/04	4/04	5/04	6/04	7/04	8/04	9/04	10/04	11/04
Longkong	0	0	0	0	0	0	1	2	3	3	0	0
Citrus	3	1	1	2	2	2	3	3	1,3	1	2	3
Pomelo	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Temp. (°C)	26.6	27.6	25.7	27.6	28.2	27.9	27.6	28.4	27.8	27.0	26.2	26.8
RH (%)	85.6	95.3	78.9	76.6	79.1	80.8	81.7	82.8	80.2	83.8	86.9	84.3
Rainfall (mm.)	213.3	30.2	113.4	121.4	112.6	328.8	201.4	58.6	80.3	162.3	261.9	119.6

0 = no fruit

1 = young fruit

2 = nearly ripe fruit (yellow green fruit skin and nearly harvest)

3 = ripe fruit (yellow fruit skin and harvest)

Table 3. Pearson's correlation index between the number of fruit piercing moth adults collected from three cropping systems and temperature, relative humidity (RH) and rain fall.

	Longkong	Citrus	Pomelo	Temp. (°C)	RH (%)	Rainfall (mm.)
Longkong		.63*	.83**	.14	.12	.00
Citrus			.24	.24	.05	-.25
Pomelo				-.07	.22	.32
Temp. (°C)					-.26	-.16
RH (%)						-.14
Rainfall (mm.)						

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

individuals trapped (Table 3). However, another indirect factor to consider would be the availability of host vines. Such soft new growth of host vines is essential to the survival and development of newly hatched FPM caterpillars. Intense early summer rain after a long dry season seems to support vigorous growth in host plants. Fay (2004) reported that such host vine growth in Queensland, Australia, results in large FPM moth numbers occurring in January/February with mating peaking in February, March and April. In our study the occurrence of the large moth numbers in June-July (Figure 1) was likely attributed to the rainy season (May-June) followed by the dry season (January-April) (Table 2). In addition, the declining rainfall

in July that resulted in reducing host plant growth effected a decrease in moth population.

3. Host preferences of fruit piercing moths

In the citrus plantation, the five most abundant species made up over 65% of the moths trapped. They were *O. coronata* (19%), *E. ephesperis* (14.6%), *O. fullonia* (10.8%), *M. frugalis* (10.6%) and *M. undata* (10.6%). In the pomelo plantation, the five most abundant species made up over 67% of the moths trapped and consisted of *T. hyppasia* (23.2%), *M. undata* (14.7%), *E. ephesperis* (11.2%), *S. retorta* (9.8%), and *O. coronata* (8.4%). In the longkong plantation, the five most abundant species that made up 83% of

the moths trapped were *E. ephesperis* (40%), *E. hieroglyphica* (14%), *T. hyppasia* (10%), *O. coronata* (10%), and *O. fullonia* (9%). Some of the most abundant FPM species found among the fruit plantings were the same species. For example, *E. ephesperis* and *O. coronata* were two species found in relative abundance at all three fruit sites, and *T. hyppasia*, *O. fullonia*, and *M. undata* were species found in relative abundance in two of the three fruit plantings (Table 1).

The seasonal occurrence of these most abundant species, based on trap catches, display similar patterns among the three fruit plantings (Figure 3 and 4). For example, the FPM population dramatically increased during May-July in citrus. Thereafter the moth populations sharply decreased. However, a small, but different pattern in longkong was observed with the most dominant species, *E.*

ephesperis, which attained the highest density in July. Conversely, the highest point of abundance for the other species was found in June (Figure 4).

The number of dominant species of FPMs differed markedly among fruit crops. For example, a single dominant species occurred in longkong and pomelo, whereas four species showed relative dominance in citrus (Figure 4). In addition, the occurrence of outbreaks among the different dominant species in citrus was somewhat distinguished. In early June, outbreaks of *O. coronata* and *E. ephesperis* occurred; in mid-July, *O. coronata* and *M. frugalis* were most abundant; and in August, *M. undata* was the dominant species (Figure 4). It is assumed that the more evenness in each dominant species the more peaks of outbreaks possibly was observed due to competition and coexistence of organisms in the ecosystem.

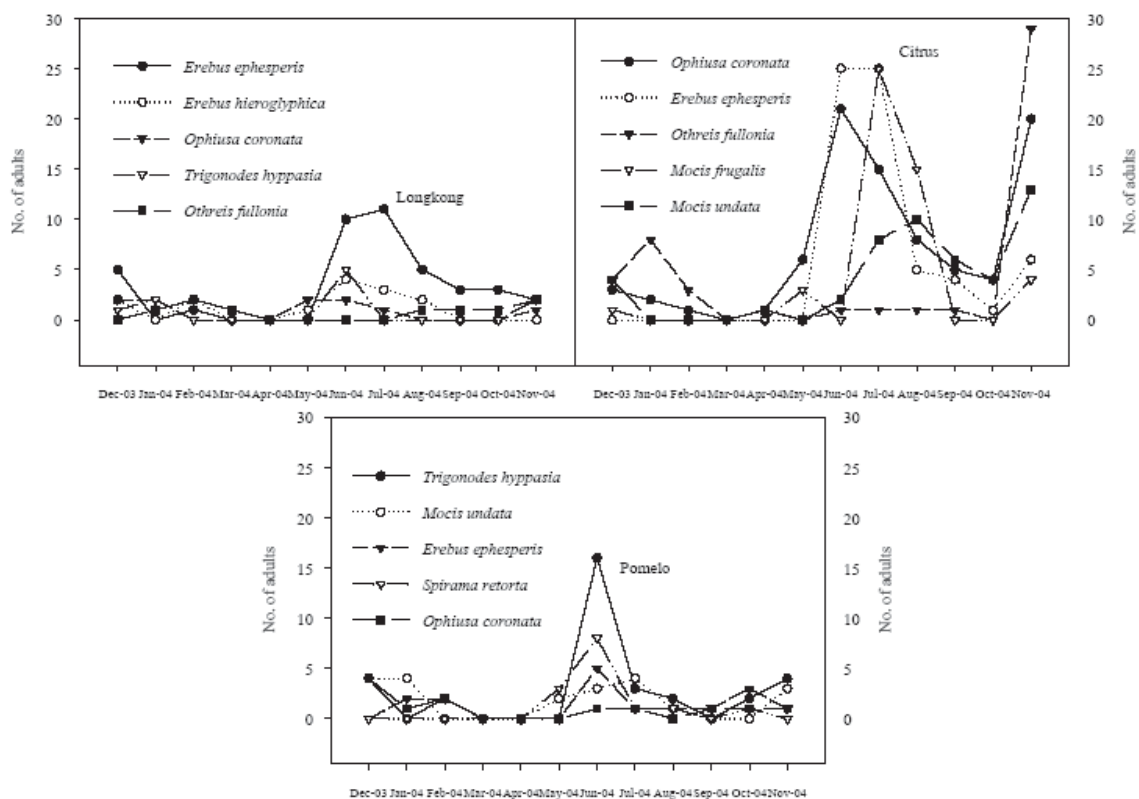


Figure 4. Dominant species of fruit piercing moths in longkong (a), citrus (b) and pomelo (c) plantations during December 2003 - November 2004 in Songkhla province of southern Thailand.



Figure 5. A) Damage symptoms caused by the FPMs in citrus (arrow). B) Damaged fruits fall down under the bush (arrow).

Table 4. Percentages of dropped fruits caused by the FPMs in the 1st season during June-August 2004 in Songkhla province of southern Thailand.

Plot no.	% Damaged Fruit caused by the FPMs (Means±SE) ^{1/}								
	14/6/04	21/6/04	28/6/04	5/7/04	12/7/04	19/7/04	29/7/04	9/8/04	Total
1	1.9±0.6	2.2±0.7	2.4±0.5	2.1±0.5	7.4±2.3	9.8±3.3	6.7±1.5	3.3±0.9	35.8
2	1.9±0.6	1.6±0.4	0.3±0.1	2.0±0.8	3.3±1.1	5.5±1.3	2.4±0.8	1.3±0.4	18.3
3	2.2±0.6	3.2±1.1	0.9±0.2	1.9±0.7	3.5±0.7	5.2±1.2	1.6±0.6	1.5±0.6	20.0
Mean	2.0±0.3	2.3±0.4	1.2±0.2	2.0±0.4	4.7±0.9	6.8±1.2	3.6±0.7	2.0±0.4	24.8

^{1/} Averaged from 10 replications

Table 5. Percentages of dropped fruits caused by the FPMs in the 2nd season during November-December 2004 in Songkhla province of southern Thailand.

Plot no.	% Damaged fruit caused by the FPMs (Means±SE) ^{1/}								
	3/11/04	10/11/04	17/11/04	24/11/04	1/12/04	8/12/04	15/12/04	22/12/04	Total
1	2.0±0.5	3.0±0.9	2.6±0.6	1.8±0.6	2.5±0.7	1.5±0.6	4.4±1.9	3.2±1.2	21.0
2	2.2±0.8	0.8±0.2	0.7±0.3	0.7±0.2	1.4±0.3	1.5±0.6	1.9±0.6	1.7±0.6	10.9
3	4.6±1.3	3.4±0.9	5.0±1.6	4.9±1.9	4.6±1.5	4.6±1.3	4.8±1.5	4.4±1.1	36.3
Mean	2.9±0.5	2.4±0.4	2.8±0.6	2.5±0.7	2.8±0.6	2.5±0.5	3.7±0.8	3.1±0.6	22.7

^{1/} Averaged from 10 replications

4. Fruit damage study

When moths attack ripening fruit the site of the feeding puncture on the citrus fruit's surface will become discolored, and in a short time fungi will develop at the site and spread outward on the surface and throughout the fruit (Figure 5A), often resulting in the fruit dropping prematurely (Figure 5B).

As expected, levels of seasonal fruit damage occurred during periods of high moth activity. For example, the highest fruit losses occurred in July of the 1st harvest season (Table 4). These numbers correspond with the high population numbers of adult moths found in citrus plantation (see Figure 3).

The mean percent total from all three fruit

plantations was 24.8% (Table 4). This translates into a severe economic impact for growers. For example, if the total number of fruits harvested per tree averaged 169 during the first harvest season, and if the mean weight of each fruit would be about 10 fruits per kg (a typical measure), then each tree would produce about 16.9 kg of fruit. If the average price of citrus was 30 Baht/kg, the loss due to FPM damage would be 125.7 Baht/tree (24.8% of 507 Baht/tree) for the first harvest. If the tree density was 70 plants/rai, the market loss would be 8,799.0 Baht/rai (or 54,993.8 Baht/ha) in this harvest season.

The levels of fruit damage during the second harvest were slightly lower than those in previous season (Table 5). Study on fruit losses due to FPMs damage during this harvest period have been rarely reported. However, fruit losses caused by *O. fullonia* has been estimated about 4% in an orchard of mandarin tree in low population year, but in an outbreak year, losses could reach up to 42% (Cochereau, 1972).

Conclusions

The successful production of citrus in Songkhla province of southern Thailand is dependent on the infestation levels of the fruit piercing moths. This is attributed not only to the richness of three dominant species attacking the fruits in two harvest seasons, but also to the high losses in terms of market value in this crop. The current control tactic used by most farmers, that of using naphthalene as a repellent during harvesting period, seems to be ineffective because fruit losses remain at a high level. Climatic factors including temperature, relative humidity and rainfall did not show direct effect on fruit moth population, but they might directly affect the host plants used by the larval stages. Factors influencing all stages of the FPM development should be further studied, particularly in the three most commonly occurring species found in citrus (*O. coronata*, *E. ephesperis* and *M. frugalis*). The development of an integrated pest management (IPM) approach for FPM in citrus occurring in southern Thailand is needed.

Such a management practice is only possible with the appropriate biological and ecological data of the key pest species.

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