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Fruit-piercing moths (Lep., Noctuidae) in Thailand: A general survey and some new perspectives

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86 fruit-piercing moths are listed with collecting and feeding details on some 24 fruit species; 29 represent new world records as fruit-piercers, 29 new Thai species. But 4 species cause alone 60–95% of primary fruit-piercing moth damage to longan and citrus. Actual or potential ability to pierce intact skin of the most important fruits (primary damage), or just the pulp through already damaged skin (secondary damage), has been assessed for all moth species through analysis of their mouth-parts in correlation with piercing behaviour and feeding experiments. 9 species are proved or indicted to cause primary damage to longan, an additional 18 to citrus and a further 59 to soft or very soft fruit. The main larval host plants of the most common fruit-piercer *Othreis fullonia* are 3 *Tinospora* species, a further 25 Menispermaceae being alternate/occasional/possible host plants in nature or experiments. Small to average sized lianas, *Tinospora* spp. are found to have exceptional survival fitness and regeneration potential, and to be most common in disturbed, secondary vegetation biotopes. Thus the increasing frequency and damage by *O. fullonia* to fruit cultivation is blamed on the widespread destruction of forests, protection of which being a measure suggested for improved control of the moth.

Fruit-piercing moths are noctuid Lepidoptera adults which feed upon the sap of a wide variety of fruits by piercing their skin, or at least the pulp, by a specially adapted proboscis. The first report on the moths known to the author appeared in Australia (KÜNCKEL, 1875) and, though subsequently the moths' ability to pierce was doubted for decades, they have now been reported from most tropical and subtropical regions of Africa (e.g. JACK, 1916, 1922; COTTERELL, 1916, 1940), Asia (e.g. SUSAINATHAN, 1924; CLAUSEN, 1927), America (e.g. RAMIREZ, 1920; KING & THOMPSON, 1958); and more recently even from Europe, viz. Italy and Switzerland (BÄNZIGER, 1969 a, b, 1970), Yugoslavia (BÜTTIKER, 1970), Czechoslovakia (SPITZER, 1976), and England (WAAGE, in litt.).

In certain areas and years the moths appear in huge numbers in fruit orchards and then may cause very severe damage, occasionally almost nearly total loss (WHITEHEAD & RUST, 1972 b). The fungi *Oospora* sp. (MULLER, 1939), *Fusarium* sp., *Colletotrichum* sp., and bacteria (HARGREAVES, 1936) gain entrance through the hole pierced by the moths and/or are inoculated by the infected proboscis (DADANT, 1953) causing the fruit to rot.

Most research on the moths deal with the epidemiology and control possibility, especially in Japan (MATSUZAWA, 1961; NOMURA *et. al.* 1965; NOMOURA & HATTORI, 1967), S. Africa (MYBURGH, 1963; WHITEHEAD & RUST, 1967, 1972 a, b), and Zimbabwe (Rhodesia) (BOSCH, 1971), where damages are particularly severe. Mouth-part morphology and feeding mechanisms have also been studied (see

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later), while COCHEREAU (1974, 1977) published literature reviews (although unfortunately many important works mentioned in the text are not listed in his bibliography and so cannot be traced).

Possibly because of the somewhat retiring nocturnal habits of fruit-piercing moths, only little attention was given to them until recently in Thailand and, to our knowledge, no specific study on them has appeared in any scientific journal. They have been mentioned briefly in textbooks (AREEKUL, 1965; CHAROENSOM, 1978), and in lists of pests in reports to the Department of Agriculture (PHOLBOON, 1965; BOONYONG, *et al.*, 1970; THANOMTHIN, 1970).

In more recent years, however, agriculturalists in Thailand have become increasingly aware of fruit-piercing moths. There are several reasons for this: (i) The control of many major pests of fruit is increasingly successful so that fruit-piercing moths, against which at present there is no really effective control, become more evident; (ii) new fruit varieties are imported and local species are more widely and more intensively grown, leading to new, more widespread, and/or heavier attacks; (iii), probably most important, the moths seem to be more common, at least in certain regions on certain fruits and years, and this seems to be due to the increasing destruction of forests, a view which will be discussed in some detail.

This article attempts to lay a foundation upon which agriculturalists can base further research aimed at control of this obdurate pest complex.

SPECIES OF FRUIT-PIERCING MOTHS FOUND IN THAILAND

In the list below are mentioned 86 noctuid species caught and/or studied by the author (with exceptions mentioned) during over a decade of mostly part time night observations in field and laboratory investigations on fruit-piercing moths in Thailand. Of the 86 species 57 were observed piercing intact or wounded fruit, both cultivated and wild, while the remaining 29 - mostly caught with lighttraps - are either well-known fruit-piercing species in other countries, or their proboscis morphology and close relationship with known fruit-piercing species leave little doubt that they do pierce fruit. But a number of species are «marginal» fruit-piercers, assumed to be able to pierce at very best only the very softest fruit.

Only some 15 species (see below No. 2, 10, 14, 20, 33, 34, 35, 37, 44, 48, 55, 58, 66, 77, 86) had been mentioned before in Thailand as fruit-piercers, while some 29 species - and an additional 20 suspected ones - have never before been reported as fruit-piercers from anywhere else. 29 species represent new Thai records, or at least they were not among the identified species in the Thai National Reference Collection (TNRC), Department of Agriculture, Bangkhen, Bangkok.

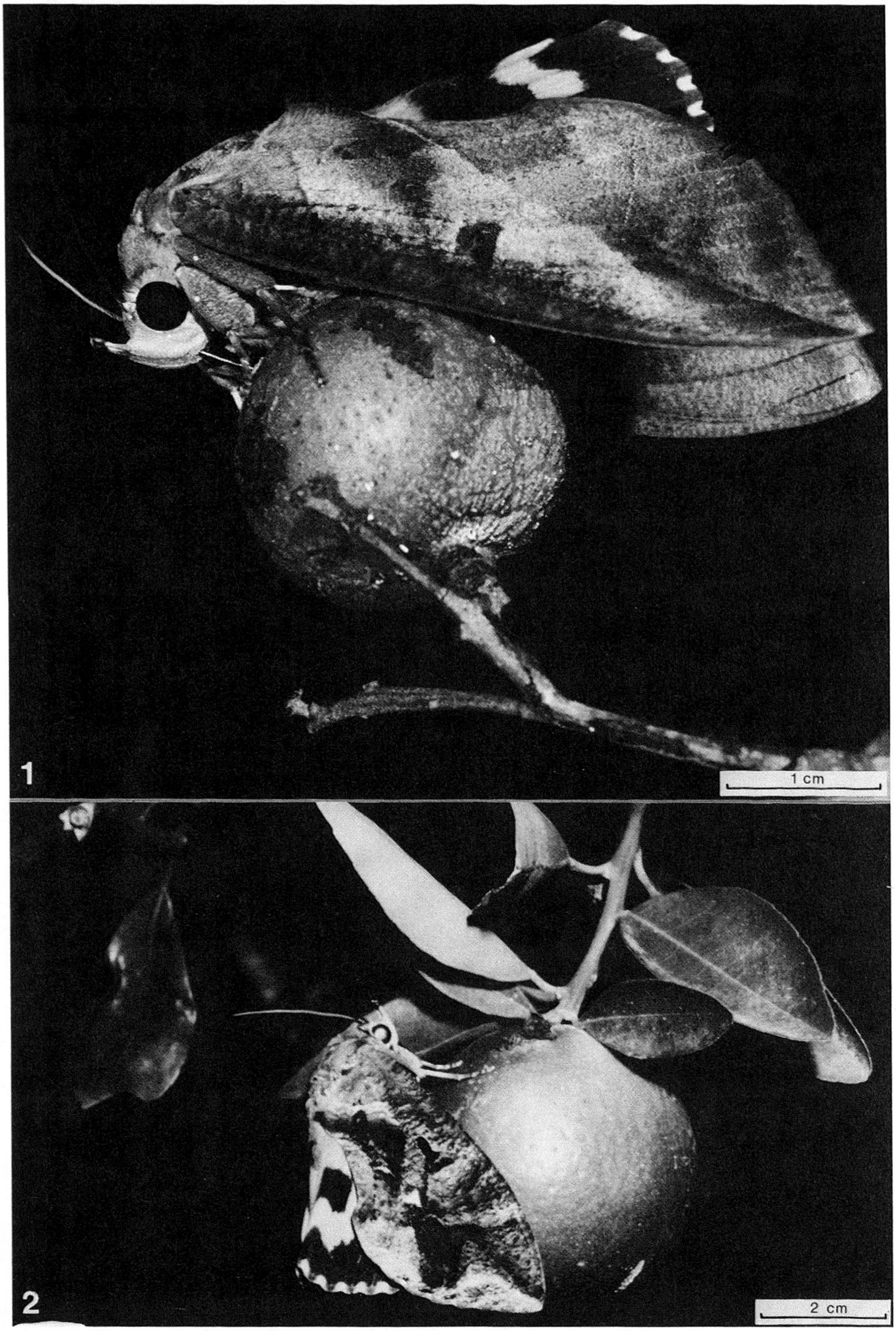
Most of the species have been recently identified by the author at the British Museum (Nat. Hist.), London, with the invaluable help of the specialists there, and the names were updated to their newest stand. However, I am told by Dr. J. D. HOLLOWAY that some genera need taxonomic revision, especially *Parallelia* which is used here in *sensu latu*. Also, according to Mr. M. R. HONEY, *Anomis metaxantha, Parallelia feneratrix, P. onelia, P. rigidistria, Spirama retorta* seem to represent species complexes likely to consist of more than one species.

In the present paper the official classification of the British Museum is followed, as laid down in NYE (1975). Some of the current synonyms have been added.

Ophiderinae

1. *Adris tyrannus* (GUEN.) *(Othreis, Ophideres)*
   1 lighttrap capture; hills of the N[2]. Well-known fruit-piercer in Japan (CLAUSEN, 1927), China (WOO *et al.*, 1975). New Thai record.
2. *Anomis flava* FABR.
   In lighttraps; larvae found as pests of cotton; N and NE. Known to suck fruit in Japan (NOMURA & HATTORI, 1967).
3. *Anomis guttanivis* (WLK.)
   On decomposing organic matter in N, NE and C, uncommon.
4. *Anomis lineosa* (WLK.)
   1 lighttrap capture, hills of the N. New Thai record.
5. *Anomis mesogona* (WLK.)
   In lighttraps; known to suck fruit in Japan (NOMURA & HATTORI, 1967).
6. *Anomis metaxantha* (WLK.)
   On peach *(Prunus persica* BATSCH), mandarin *(Citrus reticulata* BLANCO), longan *(Dimocarpus longan* LOUR.), Panama berry *(Muntinja calabura* L.); N to S, common. First record as fruit-piercer.
7. *Arcte coerula* (GUEN.) *(Cocytodes coerulea, C. caerulea)*
   In lighttraps, hills of the N, scarce. Reported as a fruit-piercer from Japan (NOMURA & HATTORI, 1967).
8. *Arcte nigrescens* BUTL. *(Cocytodes)*
   In lighttraps, hills of the N, scarce. New Thai record.
9. *Ericeia inangulata* (GUEN.)
   On longan, *M. calabura,* not frequent. First record as fruit-sucker.
10. *Eudocima salaminia* (CRAM.) *(Maenas, Eumaenas, Ophideres, Othreis)* (fig. 5)
    On mandarin, longan, papaya *(Carica papaya* L.), guava *(Psidium guajava* L.), *M. calabura, Ficus hispida* L., *F. racemosa* L. N to S, quite common.
11. *Facidina suffumata* (GUEN.)
    On guava, peach, longan, rose-apple *(Eugenia jambos* L.). N, uncommon. New Thai and first record as fruit-piercer.
12. *Focillistis salsoma* (SWINH.)
    On *M. calabura,* N, uncommon. New Thai and first record as fruit-sucker.
13. *Hulodes drylla* GUEN.
    On longan, *M. calabura,* not uncommon. First record as fruit-piercer.
14. *Ischyja manlia* (CRAM.)
    On guava, longan, *Diospyros glandulosa* LACE, *F. racemosa.* N to S, quite common on rotting fruit.
15. *Khadira aurantia* (MOORE) *(Othreis)*
    In lighttraps, NE, scarce. In TNRC, A. SAMRUADKIT, B. LEKAGUL and P. PHOLBOON *leg.* Known to pierce fruit in Sri Lanka (BAPTIST, 1944).
16. *Oraesia argyrosigna* MOORE *(Calpe)*
    1 specimen from NE, P. PHENJIT *leg.,* in the TNRC.
17. *Oraesia emarginata* (FABR.) *(Calpe)*
    On mandarin, longan, guava, *M. calabura, F. racemosa.* N to S, quite common.
18. *Oraesia rectistria* GUEN.
    In lighttraps. N, uncommon. New Thai record.

[2] N, NE, C, S = North, Northeast, Central & South Thailand

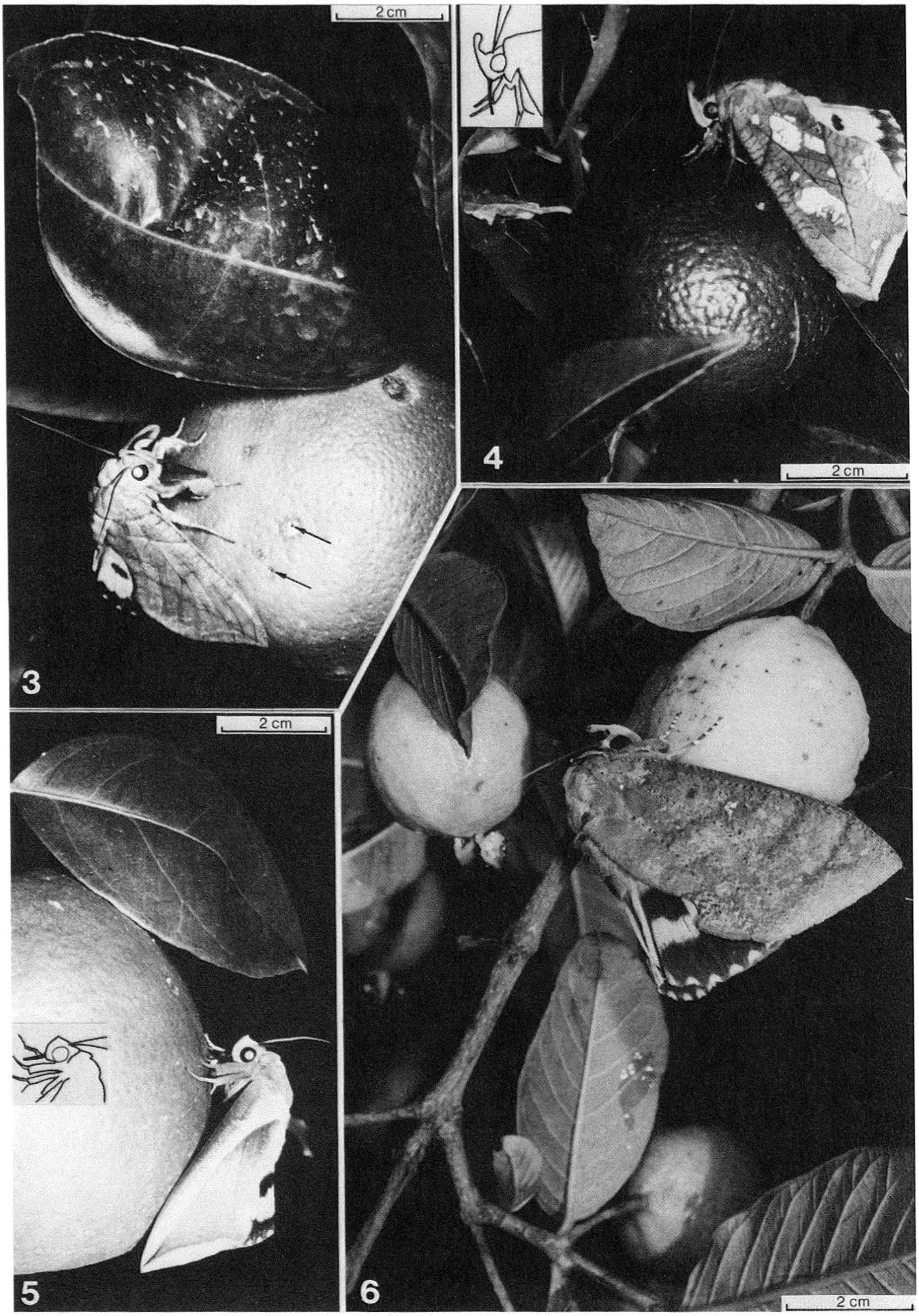


Figs. 1–2. *Othreis fullonia* ♂ piercing an intact longan fruit. Proboscis is easily visible (1). *O. fullonia* ♀ piercing a sound mandarin (2). Both moths are primary fruit-piercing species of these fruits. All photographs of moths in present study were taken under natural conditions in the field at night.

19. *Othreis cajeta* (CRAMER)
I am indebted to Mr. P. SUKUMALANAN for this new Thai record; he caught the species at a lighttrap in the hills of the N.
20. *Othreis fullonia* (CLERCK) *(Ophideres fullonica* L.*)* (fig. 1, 2)
On mandarin, orange *(Citrus sinensis* OSB.), lime *(C. aurantifolia* SWING.), longan, guava, peach, rambutan *(Nephelium lappaceum* L.*), Baccaurea* sp., *Irvingia malayana* OLIV., *Spondias axillaris* BURTT & HILL, *D. glandulosa, Vitex pinnata* L., *Leea indica* MERR.; *Grewia tomentosa* JUSS., *F. racemosa, F. hispida, M. calabura;* in experiments also mangosteen *(Garcinia mangostiana* L.) with a small hole. N to S, very common.
21. *Othreis homaena* HÜBN. *(Ophideres ancilla* CRAM.*)* (fig. 8)
On guava, mainly S, scarce.
22. *Oxyodes scrobiculata* (FABR.) (fig. 13)
On longan, very common, especially N.
23. *Platyja umminia* (CRAM.) *(P. umminea)* (fig. 7)
On mandarin, longan, guava, peach, rose-apple, *F. hispida, M. calabura.* N to S, quite common. First record as fruit-piercer.
24. *Plusiodonta auripicta* MOORE
In lighttraps, N, uncommon. New Thai record.
25. *Plusiodonta chalsytoides* GUEN.
On guava, *D. glandulosa;* N, quite common. New Thai and first record as fruit-piercer.
26. *Plusiodonta* sp.
On guava, N, uncommon. New Thai and first record as fruit-piercer.
27. *Rhytia discrepans* (WLK.) (fig. 6)
On guava, grape *(Vitis vinifera* L.*)* (experiment). N to S, uncommon. First record as fruit-piercer.
28. *Rhytia hypermnestra* (STOLL) *(Othreis)* (fig. 3, 4)
On mandarin, longan, guava, *I. malayana, F. racemosa, Solanum erianthum* D. DON. N to S, common.
29. *Serrodes caesia* WARR.
In lighttraps, hills of the N, scarce. New Thai record.
30. *Serrodes campana* GUEN.
On longan, C, SE, N, scarce.
31. *Serrodes partita* (FABR.) *(S. inara* CRAM.*)*
On longan, *F. racemosa,* unidentified berry. N to S, scarce.
32. *Sphingomorpha chlorea* (CRAMER)
In lighttraps, sucked broken grape in experiments; N, C, NE, uncommon.
33. *Sympis rufibasis* GUEN.
On longan, very common, especially in N.

Catocalinae

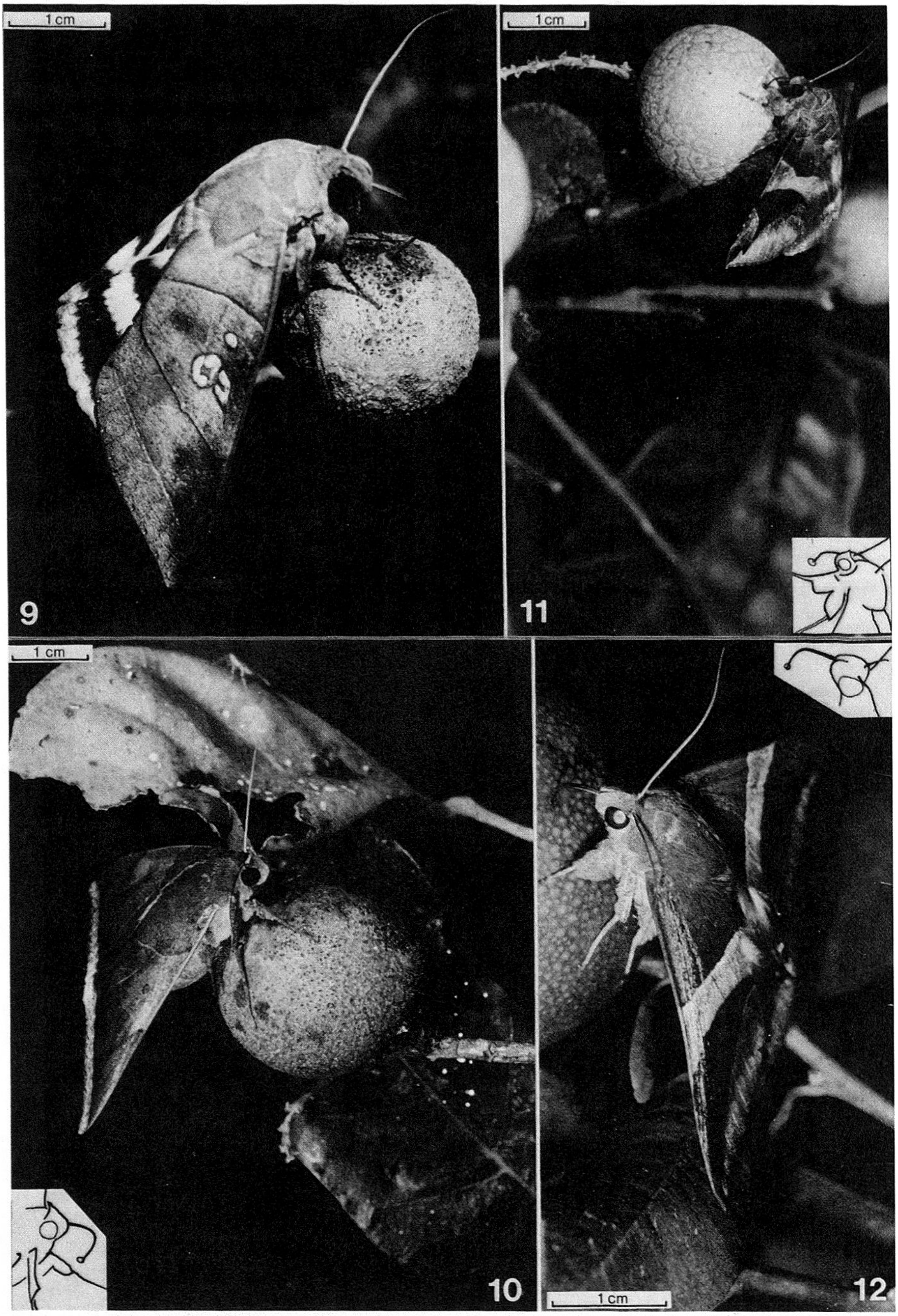
34. *Achaea janata* (L.)
On peach, longan, *M. calabura;* N to S, very common.
35. *Achaea serva* (FABR.)
On *M. calabura,* N to S, scarce.
36. *Anua tumidilinea* (WLK.)
On longan, hills of the N, uncommon. New Thai and first record as fruit-piercer.



Figs. 3–6: *Rhytia hypermnestra* ♂ piercing the skin of a mandarin at an intact spot, not using holes visible near by (arrows) (3). *R. hypermnestra* ♀ (4) and *Eudocima salaminia* (5) piercing intact mandarins. *R. discrepans* ♂ piercing a sound guava (6). The moths are primary fruit-piercing species of these fruits.

37. *Artena dotata* (FABR.) *(Lagoptera, Ophiusa, Thyas)* (fig. 10)
On mandarin, longan, peach, *M. calabura, Ficus* sp. N to S, very common.
38. *Artena lacteicincta* (HMPS.)
In lighttraps, N to S, scarce.
39. *Artena submira* WLK. *(Lagoptera, Ophiusa)*
On mandarin, longan; N, uncommon. New Thai and first record as fruit-piercer.
40. *Ercheia cyllaria* (CRAM.)
On mandarin, longan, peach, *F. hispida, M. calabura;* N, quite common.
41. *Ercheia diversipennis* WLK.
On peach, longan, *M. calabura;* N, common. New Thai and first record as fruit-piercer.
42. *Ercheia pulchrivena* (WLK.)
In lighttraps, hills of the N, uncommon. New Thai record.
43. *Erebus caprimulgus* (FABR.) *(Nyctipao)*
On mandarin, longan; N to S, common. First record as fruit-piercer.
44. *Erebus crepuscularis* (L.) *(Nyctipao)*
On mandarin, longan, rambutan; N to S, quite common.
45. *Erebus gemmans* (GUEN.)
In lighttraps, hills of the N, scarce. New Thai record.
46. *Erebus glaucopis* (WLK.)
In lighttraps, hills of the N, scarce. New Thai record.
47. *Erebus hieroglyphica* (DRURY) *(Nyctipao)*
On longan, N to S, quite common. First record as fruit-piercer.
48. *Eupatula macrops* (L.) *(Erebus, Nyctipao)*
On mandarin, longan, N to S, quite common.
49. *Grammodes geometrica* (FABR.)
On guava, *M. calabura,* N to S, quite common.
50. *Hypopyra unistrigata* (GUEN.)
In lighttraps, hills of the N, uncommon.

Figs. 7–8: *Platyja umminia* ♀ (7) and *Othreis homaena* ♀ (8) as primary fruit-piercing species of guava.



Figs. 9–12: *Ophiusa coronata* (9), *Artena dotata* (10), *Parallelia arcuata* (11) and *P. fulvotaenia* (12) as secondary fruit-piercing species of longan (9–11) and mandarin (12). Holes previously pierced by primary fruit-piercing species are used to introduce the proboscis and pierce the pulp of the fruits. Note discolouration around the holes; they are relatively wide compared to the width of the proboscides.

51. *Hypopyra vespertilio* (FABR.) *(Enmonodia)*
On longan, N, quite common.
52. *Lagoptera juno* (DALM.) *(Dermaleipa)*
In lighttraps, sucked grape in experiments. Hills of the N and C, uncommon. Well-known fruit-piercer in Japan (NOMURA & HATTORI, 1967).
53. *Mocis frugalis* (FABR.)
On longan, N to S, common.
54. *Mocis laxa* (WLK.)
On longan, hills of the N, uncommon. New Thai and first record as fruit-sucker.
55. *Mocis undata* (FABR.)
On guava, longan, N to S, very common.
56. *Ophisma gravata* GUEN.
On longan, N, uncommon. New Thai and first record as fruit-piercer.
57. *Ophiusa circumferens* (WLK.) *(Anua)* (According to Dr. J. D. HOLLOWAY probably conspecific with *O. trapezium.)*
In lighttraps, N to S, uncommon. New Thai record.
58. *Ophiusa coronata* (FABR.) *(Anua)* (fig. 9)
On mandarin, longan, mango *(Mangifera indica* L.*)*, guava, *M. calabura, F. racemosa*. N to S, very common.
59. *Ophiusa indiscriminata* (HMPS.) *(Anua)*
On *M. calabura,* N, uncommon. New Thai and first record as fruit-piercer.
60. *Ophiusa tirhaca* (CRAM.) *(Anua tirhaca, = Pseudophia tirrhaea* TREIT.*)*
On peach, rambutan, longan, *M. calabura, Rubus* sp. N, C, uncommon.
61. *Ophiusa trapezium* (GUEN.) *(Anua)*
In lighttraps; sucked grape in experiments. Hills of the N, uncommon. New Thai and first record as fruit-piercer.
62. *Parallelia amygdalis* (MOORE)
On longan, N, uncommon. New Thai and first record as fruit-piercer.
63. *Parallelia analis* (GUEN.) *(Ophiusa)*
On longan, N, uncommon. New Thai and first record as fruit-piercer.
64. *Parallelia arctotaenia* (GUEN.) *(Ophiusa)*
In lighttraps, N, NE, uncommon. Known to pierce fruit in Japan (NOMURA & HATTORI, 1967).
65. *Parallelia arcuata* (MOORE) *(Ophiusa)* (fig. 11)
On mandarin, N to S, uncommon. First record as fruit-piercer.
66. *Parallelia crameri* (MOORE) *(Ophiusa)*
On mandarin, longan, oriental pear *(Pyrus lindleyi* REHD.*)*. N to S, common.
67. *Parallelia curvata* (LEECH) *(Ophiusa)*
From the vegetation, N, scarce. New Thai record.
68. *Parallelia duplexa* (MOORE)
In lighttraps, uncommon. New Thai record.
69. *Parallelia feneratrix* GUEN.
In lighttraps, hills of the N, uncommon. New Thai record.
70. *Parallelia fulvotaenia* (GUEN.) *(Ophiusa)* (fig. 12)
On mandarin, longan, *M. calabura.* N to S, quite common. First record as fruit-piercer.
71. *Parallelia joviana* (STOLL)
On *M. calabura,* N, common.

72. *Parallelia maturata* (WLK.)
In lighttraps, N to C, uncommon. Known to suck fruit in Japan (NOMURA & HATTORI, 1967).
73. *Parallelia onelia* (GUEN.)
In lighttraps, N to C, uncommon.
74. *Parallelia properata* WLK.
Flying in forest, N, scarce. New Thai record.
75. *Parallelia rigidistria* (GUEN.)
In lighttraps, N to S, scarce. New Thai record.
76. *Parallelia simillima* (GUEN.)
On longan, uncommon. First record as fruit-piercer.
77. *Parallelia stuposa* FABR. *(Dysgonia)*
In lighttraps, hills of the N, uncommon.
78. *Parallelia umbrosa* (WLK.)
On longan, mandarin, N, uncommon. First record as fruit-piercer.
79. *Pericyma cruegeri* (BUTL.)
On *F. racemosa*. N, uncommon. First record as fruit-piercer.
80. *Pericyma glaucinans* (GUEN.)
On peach, N, scarce. First record as fruit-piercer.
81. *Pericyma umbrina* (GUEN.)
On peach, rose-apple, N to S, uncommon. First record as fruit-piercer.
82. *Phyllodes consobrina* WESTW. *(Ischyja)*
On *F. hispida,* N to S, scarce.
83. *Phyllodes eyndhovii* VOLL.
On mandarin, rambutan, N to S, uncommon.
84. *Pindara illibata* (FABR.) *(Parallelia)*
On mandarin, longan, N to S, uncommon. First record as fruit-piercer.
85. *Spirama retorta* (CLERCK)
On longan, *M. calabura,* N to S, common.
86. *Thyas honesta* HUEBN. *(Anua, Lagoptera, Dermaleipa)* (mostly listed as *regia* LUCAS, a Papuan species)
On mandarin, longan, guava; N to S, common.

Species of uncertain feeding habits or distribution in Thailand

Anomis sabulifera (GUEN.), *Artena certior* WLK., *Erebus albicinctus* KOLL., *Parallelia absentimacula* (GUEN.), *P. mediifascia* WILEMAN & SOUTH, *P. palumba* (GUEN.), and *Platyja cyanopasta* (TURN.) all represented in the TNRC, are likely to pierce fruit because of their close relationship with fruit-piercing species; but the author has not yet examined their mouth-parts.

Artena inversa (WLK.), *Saroba albopunctata* (SEMPER), *Platyja sumatrana* (FELDER) have not yet been recorded in Thailand but are likely to occur in the South as the author caught them in N.W. Malaysia; he considers them as fruit-piercers because of their close relationship with such species and because of their typical piercing mouth-parts.

Othreis [Elygea] materna (L.) a common fruit-piercing pest over a very vast area from Africa to India and Sri Lanka, and from Java to Australia and the Pacific, has never been recorded in Thailand and adjacent countries. This is even more astonishing considering the fact that its larval host plants belong to the same group *(Tinospora* sp.) (SUSAINATHAN, 1924) as those of its close relative *Othreis fullonia,* common in Thailand and otherwise sympatric over the rest of its range.

The exceptional feeding habits of the four *Calyptra* species present in Thailand are still being researched but it is clear that they are at least in part fruit-piercing.

PRIMARY AND SECONDARY FRUIT-PIERCING MOTHS

An important aspect for applied research (control) is the distinction between the so-called primary and secondary fruit-piercing moths. In fact, of the many species which may be found feeding upon fruits, only a minority, the primary ones, are actually capable of piercing the sound, intact skin (or at least an intact spot of the skin which may have holes elsewhere) of a fruit like an orange. The secondary ones either use already present holes pierced by the primary species, or use an opening in the skin due to such causes as other insects' (crickets, wasps, beetles) or frugivorous animals' (birds, bats, rodents) bite damage, or cracks in the skin due to disease, weather, etc. These moths introduce the proboscis through such wounds and pierce into the pulp of the fruit. This has been noted already by JACK (1922), and WHITEHEAD & RUST (1972b) used the term «primary» fruit-piercing moths to denote those capable of piercing intact fruit.

For agriculturalists the secondary fruit-piercing moths would seem to be of minor importance, as the damage can only start when a hole is pierced by the primary types. But it must be mentioned that the rot causing pathogens, besides actively growing or accidentally getting through the hole pierced, can be inoculated (DADANT, 1953) by the moths' proboscis, and this is possibly done more efficiently by the secondary ones since they feed on damaged fruit which is likely to be already infected. The role of the secondary fruit-piercing moths in this connection must still be assessed and a study of this is planned.

Furthermore, it must be pointed out - and this has never been done explicitly - that the status of a primary or secondary fruit-piercer is not a fixed characteristic of a moth species but varies according to the fruit type it feeds upon. At least theoretically, any fruit-piercing moth is both a primary as well as a secondary fruit-piercer, this depending on whether the skin of the fruit species the moth feeds upon is soft enough, or too hard, to be pierced. Taking a sequence of fruits with soft to increasingly harder skin, namely blackberry *(Rubus* sp.), Panama berry, peach, longan and mangosteen, the moths *Dysgonia algira, Achaea janata, Ophiusa tirhaca* and *Othreis fullonia* are primary fruit-piercers of the first, the first two, the first three, and the first four fruits, respectively; and the moths are also secondary piercers of the last four, last three, last two and last fruit, respectively.

This is further complicated by the finding that *Ophiusa tirhaca* e. g. is capable of piercing the intact skin of a ripe peach but apparently not that of an unripe one. *Oraesia emarginata* is able to pierce the sound skin of a «Däng Klom» variety longan but apparently not that of a «Chomphoo» variety, as this has a rather tougher skin.

Characterization of a moth as a primary or a secondary piercer should always be done, therefore, with reference to the type of fruit.

While primary fruit-piercing moths can pierce the sound skin and the secondary ones the pulp of a fruit, there are moths of a third group which can do neither. They just lick and imbibe whatever sap is freely available on a damaged fruit, or at very best rasp with the bristles of their proboscis the exposed surface of the fruit's pulp to release some sap from torn superficial cells. Obviously the boundary between this third group and the secondary piercers can be vague because the method of feeding is in part dependent on the hardness of the fruit pulp which is subjected to strong variation during the ripening process. Therefore, for a somewhat improved definition, in the present paper «normally ripe, ready to be eaten» fruit is implied, unless otherwise stated. When longan is considered, *Simplicia* sp., *Dierna strigata* (MOORE) and *Ommatophora luminosa* (CRAMER) are examples of this third group. Except for a number of species with intermediate and thus not clearly definable capabilities (*viz.* species No. 7-9, 12-14, 22, 32, 49-51, 53-55; fig. 13), such non-piercing fruit-sucking moths are not considered further here, as they are not true fruit-piercing species; but it must be kept in mind that they are very numerous and often confused with the damage-causing fruit-piercing moths. They belong to many different lepidopterous families.

The compilation and arrangement of primary and secondary fruit-piercers and the respective fruits is found in Tables 1-3.

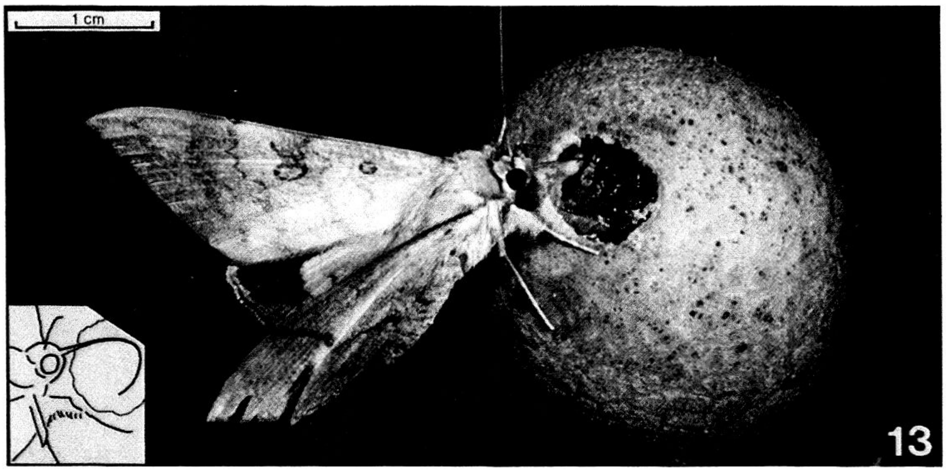


Fig. 13: *Oxyodes scrobiculata* imbibing sap as a non-piercing fruit-sucking moth on a longan which had previously been gnawed by some animal. Note the recurved proboscis laid onto the pulp's surface.

MOUTH-PART MORPHOLOGY AND PIERCING CAPABILITY

In order to assess better whether a moth is a primary or a secondary fruit-piercing species of a particular fruit, microscope mounts of the mouth-parts of all fruit-piercing moths collected were made in addition to, whenever possible, careful observations on the feeding behaviour of the moths both in the field and in captivity.

Although it is not possible to establish definitely from the mouth-part structure alone which types of fruit a moth is capable to pierce, it nevertheless provides important clues. No moth with long, unsclerotized proboscis lacking the armature mentioned below can possibly pierce the tough skin of a longan or that of citrus, the two most important fruit types liable to fruit-piercing moth damage in Thailand.

Studies of mouth-part morphology of these moths were carried out already by KÜNCKEL (1875) while the most recent of numerous later studies is the very good one by JOHANNSMEIER (1976), which also contains a thorough reference review on this subject.

After BÄNZIGER (1970, cf. also fig. 16, 19; 1973, cf. fig. 47–68) the efficiency to pierce depends upon: (i) The rigidity of the proboscis or the ability to transfer a longitudinal stress without bending, i. e. mainly the ratio between its length and thickness together with the degree of sclerotization. (ii) The type of the proboscis armature, i. e. the presence of a sharp tip, of ridges or hooks near the tip to tear the skin, and of erectile barbs (with forward to backward inclination controlled by blood pressure) which aid the piercing of thick skin and enable deep penetration into the pulp, especially if this is hard. Less efficient piercers lack the erectile barbs but have numerous, large, sharp blades. (iii) The ability to perform certain proboscis motions such as the spindle movement (important for the piercing of the skin), the anti-parallel movement (shifting in opposite directions of the stylets), which is important for both the piercing of the skin as well as the penetration into, and the laceration of the pulp, etc. It is likely that some species are capable of twisting the stylets in a to and fro rotary oscillation, with an effect somewhat comparable to a drill as found in the Noctuid *Calyptra eustrigata* HMPS. (BÄNZIGER, 1980).

Most «ordinary» Lepidoptera have only few, small, passively movable bristles, flat or cone-like sensillae, and a blunt tip on the proboscis which tends to be long and bendable, and incapable of the special motions mentioned.

From the behavioural aspect, a moth observed feeding on a fruit in the field was discounted as a primary damage causing species when one or more of the following criteria applied: (i) Proboscis uses an evident wound in the skin (cf. fig. 13). (ii) Proboscis enters through a small round hole but, being slightly wider than the proboscis' diameter, it must have been pierced beforehand by another moth (cf. fig. 9–12). (iii) In spite of the proboscis' size, the hole must have been pierced by another moth some time before as it already smells rotten, and/or shows discolouration in the pulp or the skin around the hole (cf. fig. 9). If none of the criteria apply but there is still doubt about the ability of the proboscis to cause primary damage, the moth was encaged with the same type of fruit it was feeding on but with intact skin, until piercing evidences were found or the moth died. This procedure established the moth as a primary piercing species of that fruit, or indicted it as only secondary.

Besides a number of exceptions, it was found that the Catocalinae are capable of piercing only soft skinned intact fruit, if at all, while the Ophiderinae can pierce these as well as the medium hard to hard skinned intact fruit with varying degrees of success. *Ercheia, Pericyma* and, to a lesser extent, *Phyllodes* species are the only Catocalinae with sclerotized sharp proboscis tip, armed with saw-like ridges or tearing hooks and, at least in *Pericyma,* erectile barbs. They are likely to be able to pierce fruit with skin of intermediate hardness, including mandarin. It is not yet clear whether some *Artena, Anua, Ophiusa, Thyas,* and *Lagoptera* species have barbs which are erectile. The anti-parallel movement enabling piercing of the pulp has been observed in many species. Species No. 49–51 and 53–55 have proboscides only slightly better adapted for piercing than «ordinary» Lepidoptera and are thus incapable of piercing fruit except the very softest, if at all.

Of the Ophiderinae listed only species No. 7–9, 12–14, 22, and 32 lack the mentioned reinforced proboscis and armature. They seem thus capable of piercing at very best only the softest fruits. A special position is taken by *Facidina suffumata, Saroba albopunctata, Platyja umminia,* and *P. sumatrana* which have neither

Table 1: (a) Primary fruit-piercers of hard skinned fruit (longan), as well as of thick, soft and very soft skinned fruit. (b) Primary fruit-piercers of thick skinned fruit (citrus, rambutan), as well as of soft and very soft skinned fruit; secondary piercers of longan.

	longan	mandarin	rambutan	rose-apple	guava**	peach	persimmon	papaya	grape	mango	Panama berry	*Rubus* sp.
a) *A. tyrannus*	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
E. salaminia	pe	pe	p+	p+	pe	p+	p+	pe	p+	p+	p+	p+
F. suffumata	p+	p+	p+	pe	pe	pe	p+	p+	p+	p+	p+	p+
K. aurantia	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
O. cajeta	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
O. fullonia	pe	pe	pe	p+	pe	pe	p+	p+	p+	p+	pe	p+
O. homaena	p+	p+	p+	p+	pe	p+	p+	p+	p+	p+	p+	p+
R. discrepans	p+	p+	p+	p+	pe	p+	p+	p+	pe	p+	p+	p+
R. hypermnestra	pe	pe	p+	p+	pe	p+	p+	p+	p+	p+	p+	p+
b) *A. flava*	s+	px	px	px	px	px	px	px	px	px	p+	p+
A. guttanivis	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
A. lineosa	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
A. mesogona	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
A. metaxantha	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
E. cyllaria	se	p+	p+	p+	p+	pe	p+	p+	p+	p+	pe	p+
E. diversipennis	se	p+	p+	p+	p+	pe	p+	p+	p+	p+	pe	p+
E. pulchrivena	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
O. argyrosigna	s+*	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
O. emarginata	se*	pe	p+	p+	p+	p+	p+	p+	pe	p+	p+	p+
O. rectistria	s+*	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
P. cruegeri	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
P. glaucinans	s+	p+	p+	p+	p+	pe	p+	p+	p+	p+	p+	p+
P. umbrina	s+	p+	p+	pe	p+	pe	p+	p+	p+	p+	p+	p+
P. umminia	se*	pe	p+	pe	pe	pe	p+	p+	p+	p+	p+	p+
S. caesia	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
S. campana	se*	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+
S. partita	se*	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+	p+

pe = established primary; p+ = probable primary; px = possible primary; se = established secondary; s+ = probable secondary; *seem to occasionally pierce intact, soft skinned varieties of longan; **ripe, yellow state.

hooks nor barbs but an extremely thoroughly sclerotized proboscis and a fiercely sharp tip. The anti-parallel motion of the stylets has been observed in most species.

Tables 1–3 indicate which moths are primary or secondary piercers of each type of fruits.

FRUITS ATTACKED

By and large only ripe fruit is attacked, but when this is not available unripe as well as overripe fruit is taken. Also, possibly because of scent emanation and metabolic gas production, «live» fruit, i. e. fruit still on the plant, is very much preferred, especially by the primary species, to fallen, or picked fruit which might, for instance, be hung up as bait in fruit orchards to keep the moths away from the main cultivation. This had already been noted by BAPTIST (1944), NEUBECKER (1966), WHITEHEAD & RUST (1972b). Non-piercing fruit-sucking and some species with little developed fruit-piercing ability might be baited in this way.

But *Ischyja manlia* was exclusively, *Ericeia inangulata* and some other as *Erebus* sp., were occasionally seen feeding on fallen, broken, overripe or rotting fruit, while *Platyja umminia* and *Facidina suffumata* were observed trying to pierce intact, unripe, very hard guava.

Lansa *(Aglaia domestica* PELLEG.*)*, mafai *(Baccaurea ramiflora* LOUR.*)*, pummelo *(Citrus maxima* MERR.*)*, mangosteen, durian *(Durio zibethinus* L.*)* were not seen being attacked by fruit-piercing moths in nature. The first two have a latex (Euphorbiaceae!) in the fruit's skin which might repel the moths. The other have an exceedingly thick or hard skin, the moths' proboscis not being strong or long enough to reach the pulp. Sometimes such unlikely fruits as those of *Solanum erianthum* are pierced, which are smaller than the attacker's *(Rhytia hypermnestra)* proboscis, seedy and bitter.

Table 2: Primary fruit-piercers of soft skinned fruit (rose-apple - mango), as well as of very soft skinned fruit; secondary piercers of hard and thick skinned fruit.

	longan	mandarin	rambutan	rose-apple	guava**	peach	persimmon	papaya	grape	mango	Panama berry	*Rubus* sp.
A. dotata	se	se	s+	p+	p+	pe	p+	p+	p+	px	pe	p+
A. lacteicincta	s+	s+	s+	p+	p+	p+	p+	p+	p+	px	p+	p+
A. submira	se	se	s+	p+	p+	p+	p+	p+	p+	px	p+	p+
L. juno	s+	s+	s+	p+	p+	p+	p+	p+	p+	p-	p+	p+
O. gravata	se	s+	s+	p+	p+	p+	p+	p+	p+	px	p+	p+
O. circumferens	s+	s+	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+
O. coronata	se	se	s+	p+	pe	p+	p+	p+	px	p-	pe	p+
O. indiscriminata	s+	s+	s+	p+	p+	p+	p+	p+	px	p-	pe	p+
O. tirhaca	se	s+	se	p+	p+	pe	p+	p+	px	p-	pe	pe
O. trapezium	s+	s+	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+
P. crameri	se	se	s+	p+	px	px	px	p+	p-	p-	p+	p+
P. fulvotaenia	se	se	s+	p+	px	p+	p+	p+	p-	p-	pe	p+
P. consobrina	s+	s+	s+	p+	p+	p+	p+	p+	p+	px	p+	p+
P. eyndhovii	s+	se	se	p+	p+	p+	p+	p+	p+	px	p+	p+
P. auripicta	s+	s+	s+	p+	p+	p+	p+	p+	p+	p+	p+	p+
P. chalsytoides	s+	s+	s+	p+	pe	p+	pe	p+	p+	p+	p+	p+
Plusiodonta sp.	s+	s+	s+	p+	pe	p+	p+	p+	p+	p+	p+	p+
T. honesta	se	se	s+	p+	pe	p+	p+	p+	px	p-	p+	p+

Abbreviations same as Table 1, with the addition of p- = unlikely primary

Table 3: Primary fruit-piercers of very soft skinned fruit (Panama berry, *Rubus* sp.); secondary piercers of hard, thick, and soft skinned fruit, if at all.

	longan	mandarin	rambutan	rose-apple	guava**	peach	persimmon	papaya	grape	mango	Panama berry	*Rubus* sp.
A. janata	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	pe	p+
A. serva	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	pe	p+
A. tumidilinea	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+	p+
A. coerula	?	?	?	?	?	?	?	?	?	?	sx	p+
A. nigrescens	?	?	?	?	?	?	?	?	?	?	sx	p+
E. caprimulgus	s+	se	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
E. crepuscularis	s+	se	se	s+	s+	s+	s+	s+	s+	s+	px	p+
E. gemmans	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
E. glaucopis	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
E. hieroglyphicus	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
E. inangulata	s+	?	?	?	?	?	?	?	?	?	se	p+
E. macrops	s+	se	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
F. salsoma	s+	?	?	?	?	?	?	?	?	?	s+	p+
G. geometrica	?	?	?	?	s+	?	?	?	?	?	se	p+
H. drylla	s+	?	?	?	?	?	?	?	?	?	se	p+
H. unistrigata	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
H. vespertilio	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
*I. manlia****	sx	?	?	?	s+	?	s+	?	?	?	s+	p+
M. frugalis	sx	sx	sx	sx	sx	sx	sx	sx	sx	sx	s+	p+
M. laxa	sx	sx	sx	sx	sx	sx	sx	sx	sx	sx	s+	p+
M. undata	sx	sx	sx	sx	se	sx	sx	sx	sx	sx	s+	p+
O. scrobiculata	sx	?	?	?	?	?	?	?	?	?	s+	p+
P. amygdalis	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. analis	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. arctotaenia	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. arcuata	s+	se	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
P. curvata	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. duplexa	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. feneratrix	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. joviana	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. maturata	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. onelia	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. properata	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
P. rigidistria	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
P. simillima	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+	p+
P. stuposa	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. umbrosa	se	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
P. illibata	se	se	s+	s+	s+	s+	s+	s+	s+	s+	px	p+
S. chlorea	?	?	?	?	?	?	?	?	?	?	s+	p+
S. retorta	se	s+	s+	s+	s+	s+	s+	s+	s+	s+	s+	p+
S. rufibasis	se	se	s+	s+	s+	s+	s+	s+	s+	s+	p+	p+

Abbreviations as in Table 1, with the addition of sx = possible secondary; ? = so far no assessment possible; *** = on overripe, rotting fruit.

Strawberries *(Fragaria* sp.) and litchi *(Litchi chinensis* SONN.*)*, all eagerly pierced in experiments, escape heavy damage by fruit-piercing moths in Thailand because they ripen before the bulk of these moths start to fly. Peaches suffer little for similar reasons, but especially because they are picked unripe, as are guava and in part mango, to be eaten pickled or raw.

CHAROENSOM (1978) lists over 50 species of fruit *(sensu latu)* grown in Thailand and it is clear that many more cultivated fruit than the ones mentioned in this paper are pierced, to say nothing of wild ones.

Tables 1-3 indicate which fruits suffer primary or secondary damage by what moth species.

At present, fruits of real economic importance in Thailand liable to heavy attack by fruit-piercing moths actually include only longan and citrus (mainly mandarin). As both have hard or thick skin, only relatively few moth species can cause economically serious primary damage (Table 1). Of these *Othreis fullonia* is the paramount culprit responsible for an estimated 70-90% and 50-70% of total primary damage inflicted on longan and citrus by fruit-piercing moths, respectively. Research, therefore, concentrated on this species.

Next to this come *Eudocima salaminia* and *Rhytia hypermnestra* which together cause some 10-25% and 20-40% (latter includes *Oraesia emarginata)* primary damage to longan and citrus, respectively; the rest is caused by the remaining species in Table 1. The softer types of fruit are pierced by many more moth species so that the above-mentioned piercers are much less evident on such fruit.

THE LARVAL HOST PLANTS OF OTHREIS FULLONIA

In the hope of better understanding the yearly population dynamics and especially the overall increased frequency of *O. fullonia,* emphasis was laid in this study on the range of the larval host plants and their ecology.

The larvae were described by BAPTIST (1944) and COMSTOCK (1963), and notes on their parasites given by GAHAN (1922), BEZZI (1925), and COCHEREAU (1977).

The larval food plants of *O. fullonia* have long been established as belonging to several species of Menispermaceae (Table 4) but, interestingly, populations in the area of the Pacific mainly live on several species of the genus *Erythrina* (Leguminosae) (JEPSON, 1917; COCHEREAU, 1977; a. o.). This and the, when compared to Thailand, very different ecosystem prevalent in New Caledonia are the main reasons why the results of the last author's detailed ecological study of *O. fullonia* in that island of the South Pacific is not or only partially applicable to Thailand.

Until FORMAN (1956, 1981, first and latest paper, respectively, in a long series) started to revise Asian Menispermaceae, this plant family was not well known taxonomically, and much less so biologically though some species have long been used in local pharmacopoeiae (BURKILL, 1935). Thus, in collaboration with Mr. L. L. FORMAN, much time had first to be invested in floristic studies of Thai menisperms - which led to the discovery of several new species - and then in ecological studies.

In Thailand the larvae of *O. fullonia* (fig. 14) had been recorded on *Tinospora crispa* (mentioned under the later synonym *T. tuberculata), Tiliacora triandra,* and *Stephania japonica* (PHOLBOON, 1965); an additional plant mentioned, *Tinospora cordifolia* (WILLD.) HOOK. F. & THOMS., must have been misidentified as it is a

Table 4: Already known or suspected larval host plants (Menispermaceae only) of *Othreis fullonia*.

host plant	country	author
tribe *TINOSPOREAE*		
Tinospora smilacina BENTH.	Australia	TRYON, 1924
Tinospora cordifolia (WILLD.) HOOK.f. & THOMS.	India	SONTAKAY, 1944
Tinospora crispa (L.) HOOK.f. & THOMS. *(=T. tuberculata* (LAM.) K. HEYNE)	India Thailand	MARJABANDHU, 1933 PHOLBOON, 1965
**Tinospora tinosporoides* (F. MUELL.) FORMAN *(=Fawcettia tinosporoides* F. MUELL.)	Australia	MOSSE-ROBINSON, 1968
Dioscoreophyllum volkensii ENGL.	Sierra Leone	HARGREAVES, 1936
tribe *MENISPERMEAE*		
Cocculus hirsutus (L.) DIELS	India	SUSAINATHAN, 1924
Hypserpa decumbens (BENTH.) DIELS	Australia	Anonymous in COCHEREAU, 1974
Legnephora moorei (F. MUELL.) MIERS (not synonymous with *Pericampylus incanus* (COLEBR.) MIERS)	Australia	SMITH, 1939 TRYON, 1974
Pericampylus glaucus (LAM.) MERR. *(=P. incanus* (COLEBR.) MIERS)	Australia	TRYON, 1924
**Sarcopetalum harveyanum* F. MUELL.	Australia	MOSSE-ROBINSON, 1968
Stephania aculeata BAILEY	Australia	TRYON, 1924
Stephania dinklagei (ENGL.) DIELS	Sierra Leone	HARGREAVES, 1936
Stephania japonica (THUMB.) MIERS *(=S. hernandifolia* WALP.) *(=S. forsteri* (DC.) A. GRAY)	Australia Thailand New Caledonia	TRYON, 1924 PHOLBOON, 1965 COCHEREAU, 1974
tribe *COSCINIEAE*		
Anamirta cocculus (L.) WIGHT & ARN. *(=Cocculus indicus)*	Sri Lanka Ghana	BAPTIST, 1945 BOX, 1941
tribe *TILIACOREAE*		
Albertisia ferruginea (DIELS) FORMAN *(=Synclisia ferruginea* (DIELS) HUTCH. & DALZ.)	Sierra Leone	HARGREAVES, 1936
**Carronia multisepalea* F. MUELL.	Australia	MOSSE-ROBINSON, 1968
**Pleogyne australis* BENTH. *(=P. cunninghamii* MIERS)	Australia	MOSSE-ROBINSON, 1968
Tiliacora sp. near *dinklagei*	Sierra Leone	HARGREAVES, 1936
Tiliacora triandra (CLEBR.) DIELS	Thailand	PHOLBOON, 1965
Tiliacora funifera (MIERS) OLIV. *(=T. warneckei* DIELS)	Sierra Leone	HARGREAVES, 1936

*suspected host plant only

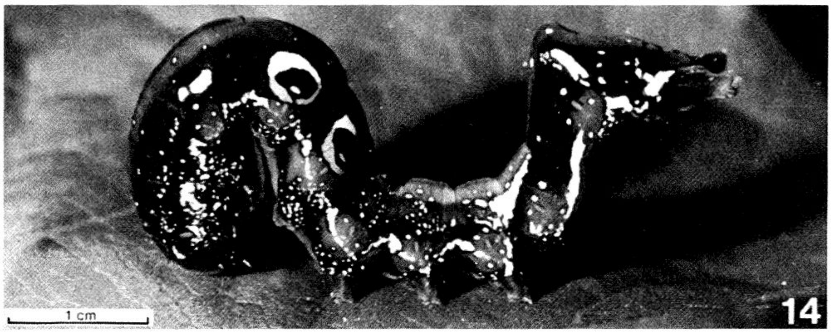


Fig. 14: Last instar larva of *Othreis fullonia* in threat posture.

species of the Indian subcontinent (FORMAN, 1981) not present in Thailand. As summarized in Tables 5 and 6 many more actual or potential host plants were discovered during the present study, both by observation in nature and in the laboratory. Rearing experiments (Table 6) showed that different individuals (populations?) of larvae do not accept a particular species of Menispermaceae to the same extent. Some will die rather than feed on a species such as *S. japonica* which is accepted by other larvae; some develop normally on *T. triandra* which is just nibbled at by some other individuals. Also, early and late instars are less choosy than the middle stages. Less surprisingly, the different species of menisperms are accepted to variable degrees, e. g. the four Thai *Tinospora* species and *Parabaena sagittata* (also a member of the tribe Tinosporeae) were found to be eaten without hesitation, *Arcangelisia flava* and *Tinomiscium petiolare* only if the first mentioned hosts were not present, while the *Cyclea sp.* were only nibbled at, if at all, when nothing else was given, and without the larvae to develop fully.

From the field observations and rearing experiments it can be concluded that the main larval host plants of *O. fullonia* (and of *Rhytia hypermnestra)* belong to *Tinospora sinensis* (fig. 15) and *T. crispa* (fig. 17) all over Thailand, and *T. baenzigeri* (fig. 16) in C., S., and N. E. Thailand. The larvae were found less frequently on *Tiliacora triandra, Anamirta cocculus* and *Parabaena sagittata,* possibly because they are less common plants. The remaining species of Table 5, and probably most of Table 6a, b, can be assumed to be eaten more or less sporadically in nature;

Table 5: Larval host plants of *Othreis fullonia* as found in nature in Thailand (in order of frequency of the larvae) (present study).

frequent	occasional
Tinospora sinensis (LOUR.) MERR.	*Anamirta cocculus* (L.) WIGHT & ARN.
Tinospora baenzigeri FORMAN	*Tiliacora triandra* (COLEBR.) DIELS.
Tinospora crispa (L.) HOOK.f. & THOMS.	*Parabaena sagittata* MIERS.
	**Cocculus laurifolius* DC.
vernacular:	*Pericampylus glaucus* (LAM.) MERR.
บอระเพ็ด boraphet	*Stephania japonica* (THUNB.) MIERS.
จุ่งจะลิง jungjaling	
ชิงช้าชาลี chingchachali	

*observation made in N. India, but this host plant is present also in Thailand

Table 6: Additional menispermaceous plants eaten by larval *Othreis fullonia* as established in experiments in Thailand.

a) fully accepted:

tribe *TINOSPOREAE*
Tinospora sp. aff. *glabra* (BURM.f.) MERRILL

b) generally eaten in absence of "common" hosts, and by certain individuals only:

tribe *COSCINIEAE*	tribe *FIBRAUREAE*
Arcangelisia flava (L.) MERR.	*Fibraurea chloroleuca* MIERS
Coscinium blumeanum MIERS	*Tinomiscium petiolare* MIERS
tribe *MENISPERMEAE*	
Diploclisia glaucescens (BL.)	

c) often only nibbled at; larval development mostly incomplete:

tribe *MENISPERMEAE*	
Cissampelos hispida FORMAN	*Stephania capitata* (BL.) SPRENG.
Cissampelos pareira L.	*Stephania brevipes* CRAIB
Cyclea atjehensis FORMAN	*Stephania elegans* HOOK.f. & THOMS.
Cyclea barbata MIERS	*Stephania glabra* (ROXB.) MIERS
Cyclea polypetala DUNN	*Stephania kerrii* CRAIB
Cyclea varians CRAIB	*Stephania suberosa* FORMAN
	Stephania venosa (BL.) SPRENG.

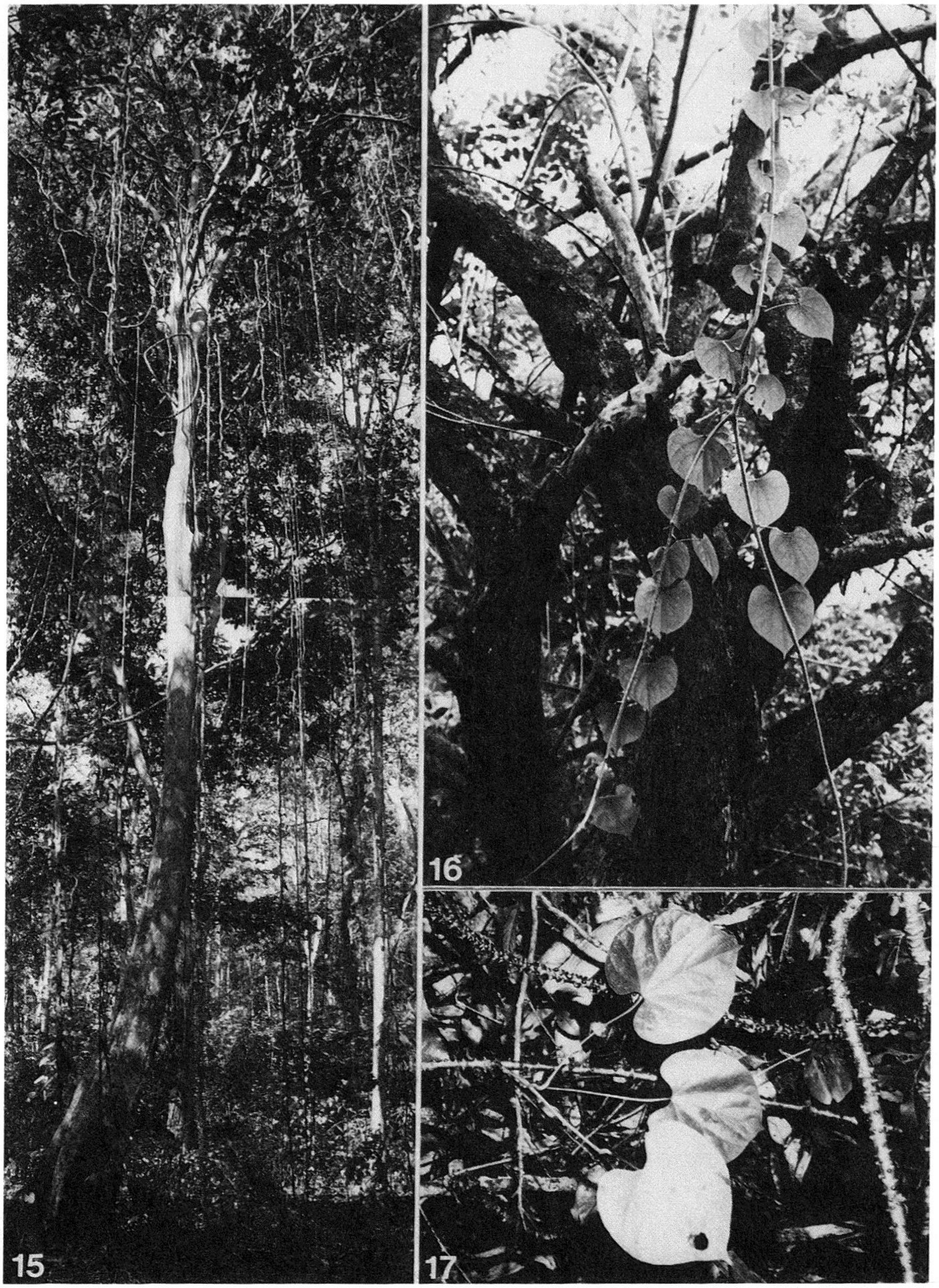
they are likely to play a role as alternate food plants during the period when *Tinospora* spp. are leafless or in areas where these are rare or absent. Though it cannot be excluded that some species of Table 6c may occasionally be eaten by some *O. fullonia* individuals they are unlikely to be consistent host plants in nature in Thailand.

The host preference inconsistency of larval *O. fullonia* could be an expression of a dynamic species adapting to new hosts and habitats; the evolution of ecological races or subspecies might already be in progress.

ECOLOGICAL NOTES ON THE MAIN LARVAL HOST PLANTS OF OTHREIS FULLONIA

Tinospora (fig. 15–17). Morphological and taxonomic description of *T. sinensis, T. crispa,* and *T. baenzigeri* – only recently established as a frequent, separate species from *T. crispa* – is given by Forman (1981) in an excellent revision with keys and illustrations of *Tinospora* in Asia and the Pacific. The first two are distributed all over Thailand from sea level to at least 1200 m in the North (but *T. sinensis,* at least, must go much higher as I found it up to 1350 m in subtropical areas such as the Lesser Himalayas of Uttar Pradesh [N. India] and in mountain areas of Yunnan Province, S. W. China). The third species had been found in all regions of Thailand except the North (i. e. north of Tak), from sea level up to at least 400 m (however, so far I had little opportunity to visit higher areas in C. and S. Thailand).

While the three species may be found in primary forests, evergreen as well as deciduous, the most typical habitats are the borders between primary and secondary forests, in clearings, and especially in the disturbed, deciduous or even



Figs. 15–17: Large, old *Tinospora sinensis*. Note the winding stems in the crown of the tree, and the many adventitious aerial roots hanging down to the ground. (Some of the thicker and twisted cords are actually stems which have fallen from the tree branches.) From the ground other vine species climb the aerial roots (15). Leaves and typically non-warty stems of *T. baenzigeri* hanging down from a *Sesbania* sp. tree (16). Leaves and typically warty stems of *T. crispa* (17).

more open, savannah-like plant associations, as long as there are bushes or trees as a support on which to climb. They may persist on a single big tree in a rice field or in untended town gardens, and on hedges; the warty *T. crispa* is still kept in a semi-wild state in villagers' gardens for medical purposes. Sometimes two or more species live in proximity or even intertwine with each other. Males are always more common than females.

As small lianas with stems of up to 6 cm diameter, mostly only 1-2 cm, they may climb trees to at least 30 m height, though mostly less than 10 and often just a couple of m when young, and tend to spread across and over the crown of one or several bushes or trees. Fallen from a tree, they easily survive on the ground. Compared to other lianas they are not very strong and the bark (outer corky layers of periderm) easily peels off. The total stem length of an average plant may measure many tens of meters with hundreds of leaves of 15-30 cm in diameter.

The roots grow close to the ground surface, often for many meters as a single rod with many small rootlets branching off; neither tubers nor stolons as in other Menispermaceae are formed. The leaves are generally formed on the new growths which develop out of the main trunk mostly in the upper regions of the plant. The plants flower for a few weeks late December to March, i. e. when they are leafless, at least in areas with a dry season. The flowers emit a pleasantly fragrant scent. The fruits are ripe from February to May. The yellow-orange to red drupes of 0.5-20 mm are probably eaten by birds; still slimy, obviously regurgitated, seeds are occasionally found near the plant. New twig and leaf formation starts already in April or May, before the rainy season sets in, and leaves start to drop towards the end of it in late October; single leaves may still be present in January in humid places. In the north where the dry season is more pronounced, they may be leafless for 2-4 months, or even more, while in the more moist south they seem to be leafless for a short time only.

One of the main features of *Tinospora* is the formation of aerial adventitious roots (fig. 15). From a large plant dozens may hang down, up to 15 m long, 1-4 mm thick, as uniform, completely straight when young, smooth, very plyable «threads» which form branched rootlets as soon as they reach the ground. They may grow up to 20-30 cm in length in 24 hours, though usually less, and 0.5 cm in thickness in a year. If damaged, or whenever the connection of the main plant with the ground is cut, a new aerial root is generally formed somewhat proximal to the wound or near the lowest-hanging part of the plant, sometimes within 10 days. As the main plant grows in length and the connection with the ground becomes insufficient for the nutrient supply, more aerial roots are produced. In all these instances the leaves generally do not drop.

The aerial roots give the plant an excellent ability to survive mechanical damage but the plant's survival fitness is enhanced by two other features, i. e. the ability to endure periods of 6-8 months without nutrient or water supply and the regeneration capability from cuttings. During a drought, after a fire or other circumstances when the connection with the ground is severed, the plant may remain in a quiescent state for up to many months before it develops aerial roots. This is also the case when the main plant is torn (e. g. falling branches, trees) or cut by man, sometimes even if the cuttings are as short as 20 cm. A latex-like, utterly bitter, sap will exude from the wound for some time, then will harden and seal the wound against further water loss. The climber's tenacity is exemplified by *T. baenzigeri*'s ability to survive as one of the few wild plants on telegraph posts and wire lines, and walls, in towns where creepers and their supporting trees are generally eradicated.

The implications of the above-mentioned physiological-ecological features are important for larval *O. fullonia* and hence also for the adult as a pest of fruit cultivation (see below).

Other Menispermaceae. Menisperms - actually proved to be eaten by *O. fullonia* caterpillars - are, with exception of *S. japonica,* much less common:

T. sp. aff. glabra and *S. suberosa,* are 2 newly discovered species; *S. elegans,* has only recently been found for the first time in Thailand; *S. venosa, S. kerrii,* and *S. glabra* have a spotted distribution in open forests; *S. brevipes* is a small delicate plant in some humid, shady areas in the hills; *P. glaucus* grows only in humid but sunny habitats of the hills in the north and, as *A. cocculus, A. flava, C. blumeanum, F. chloroleuca,* and *S. capitata,* in certain areas in the south, whereas *P. sagittata, D. glaucescens,* and *T. petiolare,* are found in patches in very humid habitats of the northern hills (latter also

South); *T. triandra*, is possibly more commonly found as semi-wild plant in gardens (used in preparation of curries) than wild in nature. They are all more sensitive to dry climate, much more bound to forest, little adaptable, have no aerial roots nor regenerative capability from cuttings, though some (e. g. *Stephania venosa, S. kerrii, S. glabra, S. suberosa, S. capitata)* have tubers which can survive fire and dry spells or, as the other *Stephania*, have a network of stolons from which new growths may be produced after damage.

YEARLY POPULATION FLUCTUATION AND MASS OUTBREAKS

In N. Thailand adult fruit-piercing moths begin to appear on fruit in May, the population increasing to its first peak in June-July and to its second in October, though the population is generally high throughout the rainy season (June-October), decreasing markedly only thereafter. In January-April they are infrequent. In S. Thailand and Peninsular Malaysia the fluctuation is less pronounced. These data are based both on field observations on the moths piercing fruit as well as on lighttrap captures.

The reason for this population fluctuation is not yet fully understood, no clear correlation to any single external factor being evident. In tropical Thailand there are always some fruits available throughout the year; however, fruiting seems to be somewhat more abundant during the rainy season, thus one would be tempted to correlate fruit-piercing moth populations to this factor. But in a typical case, a population of wild *Ficus racemosa* trees with profuse ripe fruit several times a year and plenty of moths piercing them during the rainy season, had no moths during the abundant dry season fruiting period.

For *O. fullonia,* lack of leaves on *Tinospora* during the dry season would seem to be a main reason for the population decrease during this period, at least in N. Thailand. But in the south the deciduousness of *Tinospora* is short, and there are several evergreen alternate host plants, as there are in the north. However, a large forest population of essentially evergreen *Tiliacora triandra* was without larval *O. fullonia* in mid December, when *Tinospora* were leafless there. *(O. fullonia* is common in the area in the rainy season.) In the case of other fruit-piercing species, the ecology of the larvae and their host plants has not yet been studied. As some will certainly turn out to live on evergreen plants, it is clear that factors other than deciduousness play a role in the population fluctuation of fruit-piercing moths. Leathery texture and the deficiency of certain nutrients in fully grown leaves (occurring toward the end of the rainy season) may impair the development of the larvae. Climatic factors (periods with temperature and humidity extremes during the «cool» season, high temperature, and low humidity during the «hot» season, as compared to the rather even, warm temperature and high humidity of the rainy season) may impair the development and survival of immature as well as adult stages, though this aspect is probably minimal in the rain forest region of the south. Disease, parasites and predators which characteristically lag behind the population increase of the host/prey are likely to have an additional impact. Diapause and aestivation may further regulate the development of the immatures, and possibly adults.

According to Myburgh (1963) there are mass outbreaks of *S. partita* every 5-10 years. For *O. fullonia* they occur every 5 years in New Caledonia following droughts which may produce mass fruiting and hence support large fruit-piercing moth populations (Cochereau, 1977). In Thailand there was very serious fruit-piercing moth damage to longan in the Lamphoon-Chiengmai provinces in 1980, the second of two consecutive very dry years. However, while drought may well be followed by mass outbreaks of fruit-piercing moths, this may not be dependent on mass fruiting which, in its turn, may not necessarily be induced by droughts. For instance, longan had a very large crop in 1981, an unusually wet year with a relatively small fruit-piercing moth population.

Correct understanding of the mechanism behind the population fluctuations and mass outbreaks is very desirable; it would allow early prediction of population size, if perhaps not ways to manipulate it.

CONCLUSIONS AND CONTROL PROSPECTS

From the ecological data presented above it is clear that the main larval host plants of *O. fullonia,* the three *Tinospora* species, must have greatly expanded their populations through the widespread destruction of the forests perpetrated in Thailand with increasing pace. All over the country, but especially in the seasonally dry north, forests and other wild plant associations are deliberately, and occasionally accidentally, put to the torch for a variety of reasons. These range from the passing down from generation to generation of destructive practices which serve no obvious purpose, to the more efficient hunting technique with which game is chased out of thickets by fire, practiced even in Nature Reserves. More «understandable» reasons are clearing for easier passage to collect forest produce, to make space, light or fertilizer (ashes) for wild forest vegetables and mushrooms, to induce certain trees to drop their leaves which are used for thatching, or just for some atavistic fear of the forest innate in people living in or close to it. Besides this illegal destruction, done mainly in protected areas, forests are further destroyed by road construction, enlargement of acreage for agricultural purposes, timber extraction, etc.

With their survival fitness and regeneration capability, the *Tinospora* does not only better withstand and more quickly recover from destruction than other plants but they are also offered the very habitat in which they grow best. With more larval food available it is not surprising that *O. fullonia* has become increasingly common, especially since also the adults' food, fruit, is more widely cultivated.

As already Myburgh (1963) and Neubecker (1966) pointed out, prospects to control fruit-piercing moths have always been slim, as insecticides are not applicable in the immatures' habitat and the adults' diurnal resting sites, both scattered in wide areas of «wastelands» and in or near forests. Neither would they be effective - if applied on fruits - before the adults have inflicted the damage by piercing a hole, since this generally takes less than a few minutes, and is often a matter of seconds. However, the population is likely to be reduced subsequently. At any rate, insecticides should not be used on ripening fruits, the ones preferred by the moths. Possible control methods, reviewed by Baptist (1944), include: 1) attracting and killing of the moths by poisoned baits, 2) smoking of orchards to obscure the fruits' scents which attract the moths, 3) repelling by deterrent sprays, 4) orchard sanitation (destruction of rotting or fallen fruit), 5) early harvest, 6) capture and destruction of the feeding moths by hand or net, 7) bagging or screening of the fruits, and 8) repelling the moths by light.

The first four methods have proved ineffective so far. As stated earlier, for some reason fruit piercers prefer fruits still on the tree to detached fruit used as baits, or to the different attractants (fruit base) (method 1). The spectacular captures of thousands of moths by baits (Brain, 1929; personal communication by farmers) must pertain to non-piercing fruit-sucking moths. No recent author has recommended the method as being useful. But it is conceivable that in the future, once the main attracting principle is known, a technique may be devised to draw moths away from ripening fruit.

I found no recent reference recommending method 2; the effect is probably too localised and laborious, and the smoke must persist all night throughout the ripening period of the fruits. Similarly, for method 3 no substance has yet been found to be effectively repellent without damaging the fruit at the same time. And for method 4 it is questionable that decaying fruit attract primary fruit-piercing moths, since ripe, «living» fruit on trees are more attractive. Though disposing of rotten fruit is likely to be useful (if nothing else at least against other insects) it may nevertheless require too big a work input to be worthwile.

Early harvest (method 5) should be practiced in outbreak years, when damage by moths piercing ripe fruit is so heavy that the reduced value due to picking of not quite ripe but still sound fruit is the lesser evil. Method 6 may be worthwile where labour is cheap and the fruit valuable (this being true also for methods 7 and 8). In cases where fruits are high up in trees, the author has tried with some success to capture the moths by striking them with a kerosene soaked cloth pad fixed at the end of a long stick. But it must be kept in mind that this method, although it will diminish the chances of the moth feeding again and reduce possible subsequent populations, nevertheless works only after first damage has been done.

Enclosing the fruits in a paper bag (method 7) gives best protection but is labour intensive. The repelling of the moths by strong light (method 8) seems to be the most promising method. Baptist (1944) was the first to suggest and try out this method in Sri Lanka, though it was Nomura *et al.* (1965) who first succeded in reducing substantially the moths (by 60%) in Japan, followed by Whitehead & Rust (1967, 1972a, b) (by 80–90%) in S. Africa, and Bosh (1971) in Zimbabwe (Rhodesia) (reduction to 1.5%). For Thailand, where the most heavily infested orchards tend to be in places near forest or wasteland without electricity, kerosene pressure lamps would seem to be the best suited light supply. Whitehead & Rust (1972a) obtained 93% moth reduction (mainly *Serrodes partita* in peach orchard) when placing such lamps at 1.5 m from the ground at intervals of 15–25 m on the downwind edges of the orchard. (Fruit-piercing moths locate fruit orchards by smell and thus will fly against the wind.)

From the results expressed in the present paper two additional ways to reduce damage by fruit-piercing moths, especially *O. fullonia,* are recommended. (i) Eradication of the larval host plants, mainly *Tinospora* and to a lesser extent *Tiliacora,* where they are left growing semi-wild in the above-mentioned habitats. Destruction of *Tinospora* must be thorough, taking care that no part of the plant is left on trees or ground, because of the survival and regeneration potential of the species. The stems should be either thoroughly burnt, poisoned, smashed, sliced longitudinally or cut into very short pieces. Large specimens which cannot be torn down because growing on tall trees should be regularly checked for at least a year that all adventitious roots are consistently cut until the plant starves. (ii) Counter the spread of *Tinospora* by protecting the primary vegetation ecosystems which are all *Tinospora*-poor; reduce forest clearing, especially by fire, as much as possible. Wherever feasible, it is strongly urged to establish new nature and forest reserves, and to afford them better protection.

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ZUSAMMENFASSUNG

Früchtestechende Nachtfalter (Lep., Noctuidae) in Thailand: Allgemeine Übersicht und neue Perspektiven.

Von früchtestechenden, adulten Noctuiden sind 86 Arten mit Sammeldaten und Angaben über ihre Ernährungsweise auf 24 Fruchtarten aufgeführt. Davon sind 29 Arten zum ersten Male als Früchtestecher beobachtet worden, und 29 stellen für Thailand neue Arten dar. Nur 4 Arten verursachen zusammen 60-95% des gesamten auf früchtestechende Noctuiden zurückzuführenden Primärschadens auf Longanfrüchten und Agrumen. Mittels morphologischer Untersuchung des Stechrüssels, des Verhaltens beim Stechakt und/oder mittels Ernährungsversuchen wurden sämtliche Falter auf ihre Fähigkeit geprüft, ob sie das Fruchtfleisch durch einen Stich an einer unversehrten Stelle der Fruchtschale mit dem Rüssel erreichen können (Primärschaden) oder ob sie nur durch eine schon vorhandene Öffnung in der Schale zum Saft gelangen (Sekundärschaden). 9 Arten sind erwiesene/vermutete primäre Stecher von Longan, zusätzliche 18 von Agrumen und weitere 59 von weich- bis sehr weichschaligen Früchten.

Die Hauptwirtpflanzen der Larven des weitaus wichtigsten Früchtestechers *Othreis fullonia* sind 3 *Tinospora*-Arten; weitere 25 Menispermaceen sind als Ersatzwirte bzw. gelegentliche oder potentielle Wirte im Freien oder in Experimenten festgestellt worden.

Die bisher wenig bekannten *Tinospora* haben sich als Pflanzen mit aussergewöhnlicher Überlebens- und Regenerationspotenz herausgestellt. Als kleine bis mittelgrosse Kletterer kommen sie vornehmlich in Biotopen mit stark gestörter, sekundärer Vegetation vor. Somit wird die zunehmende Häufigkeit und der durch *O. fullonia* angerichtete Schaden in Obstgärten auf die zunehmende Zerstörung der Wälder zurückgeführt. Verstärkter Schutz der Wälder ist eine der empfohlenen Massnahmen zur Bekämpfung des Falters.

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After the manuscript had been accepted, *Othreis jordani* HOLL. and *Adris* sp. aff. *tyrannus* (GUEN.), a new species, were caught for the first time in Thailand. Both species should be included in table 1a as probable primary piercers of longan, mandarin and softer fruits.

Larval *Othreis fullonia* have since been found also in nature on *Arcangelisia flava, Coscinium blumeanum, Tinomiscium petiolare* and *Tinospora* sp. nov. aff. *glabra.*