STUDIES ON FRUIT SUCKING MOTHS WITH SPECIAL REFERENCE TO TEST LIGHT AND FOOD ATTRACTANTS FOR MOTHS OF *Othreis materna* Linn.

By

Malakappa Kallappa Pujari
(Reg.No. 06/095)

A Thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA**

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
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2008

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part there of has not been submitted by me or other person to any other University or Institute for a Degree or Diploma

Place : M.P.K.V., Rahuri

(M.K. Pujari)

Dated : 04/ 06 /2008

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Associate Professor (CAS)
Department of Agril. Entomology,
College of Agriculture, Pune

CERTIFICATE

This is to certify that the thesis entitled, **"STUDIES ON FRUIT SUCKING MOTHS WITH SPECIAL REFERENCE TO TEST LIGHT AND FOOD ATTRACTANTS FOR MOTHS OF *Othreis materna* Linn."** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of *bona fide* research work carried out by **Mr. MALAKAPPA KALLAPPA PUJARI,** under my guidance and supervision and that no part of the thesis has been submitted to any other University for Degree or Diploma or publication.

The assistance and help rendered during the course of this investigation have been duly acknowledged.

Place : College of Agril., Pune
Dated : 04/06/2008.

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Associate Dean,
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Mahatma Phule Krishi Vidyapeeth,
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Maharashtra State (INDIA)

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Place : M.P.K.V., Rahuri
Dated : 4 / 6 /2008.

(R.S. Patil)

ACKNOWLEDGEMENT

It is a great pleasure to express my whole hearted sense of gratitude to my research guide and chairman of advisory committee, Dr. G.R. Lolage, Associate Professor (CAS) of Entomology, College of Agriculture, Pune for his valuable inspiration, scholastic guidance, constructive criticism, prompt suggestions, constant encouragement and sympathetic attitude right from the inception of research project till the final shaping of this manuscript in the present form. I am fortunate to work under the guidance of such an adept, adorable and dynamic personality.

Grateful thanks are also to Dr. A.S. Jadhav, Dean, Faculty of Agriculture, M.P.K.V., Rahuri and Dr. R.S.Patil, Associate Dean, PGI, M.P.K.V., Rahuri for giving permission and providing necessary facilities for the research work.

I express my sincere thanks to Dr. A.G. Chandele, Head, Department of Agricultural Entomology, M.P.K.V., Rahuri for his valuable suggestions during this research work and helping me in understanding the finer aspects of the subjects, thereby imbibing in me an element of scientific thinking.

I wish to express my profound sense of gratitude to the members of advisory committee Dr. J.R. Kadam, Professor, Department of Agricultural Entomology, Prof. S.R. Kulkarni, Assistant Professor, Dr. S.D. Masalkar, Associate Professor, Department of Horticulture for their valuable suggestions, encouragement and co-operation during the period of this investigation.

My cordial thanks to Dr. B.P. Chavan, Dr. A.B. Tambe, Dr. R.V. Nakat, Dr. D.S. Pokharkar, Dr. C.S.Patil, Dr. V.D. Kale, Dr. S.S. Kulkarni, Assistant Professor of Horticulture for the co-operation that I have received during my post graduate programme.

I am very much thankful to Dr. S.B. Jagginavar, Associate Professor of Entomology, College of Agriculture, Bijapur, UAS, Dharwad for his constant inspiration, encouragement and providing me the related references.

Special thanks to Shri. Gangurde, Shri. Khalekar, Shri. Patil, Shri. Shelar, Shri. Lande and other non teaching staff members of the Department of Agricultural Entomology, Post Graduate Institute, Rahuri.

I am thankful to my friends Arun, Kondhalkar, Gosavi, Kale, Tadavi, Rajput, Shrikant, Sanjay, Vivek, Vijay, Jaydev,Desai, Prashant, Ningu, Chikka, Rohan and Mahantesh, my senior friends Rahul, Mahesh, Sandeep, Vijay and Prajeet, my junior friends Sanjay, Srinivas and Rajshekhar for their co-operation and friendly attitude towards me.

It is extremely difficult to get appropriate words to pen down my feelings of gratitude towards my parents, brothers and members of the family who have done for me and who stood like a leader of my success, good will, constant inspiration, throughout my educational career.

I am also thankful to Shri. Vishwanath Kadam 'Suyog Computers' for typing manuscript of this thesis.

Finally my special thanks to the driving force behind all this work the Indian Council of Agricultural Research for providing Junior Research Fellowship during my postgraduate programme.

Place : M.P.K.V., Rahuri

Dated :04/06/2008

(M.K. Pujari)

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ABSTRACT

STUDIES ON FRUIT SUCKING MOTHS WITH SPECIAL REFERENCE TO TEST LIGHT AND FOOD ATTRACTANTS FOR MOTHS OF *Othreis materna* Linn.

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Research Guide	: Dr. G.R. Lolage
Department	: Agricultural Entomology

The research work on "Studies on fruit sucking moths with special reference to test light and food attractants for moths of *Othreis materna* Linn." was carried out during the year 2007 at Post Graduate Institute, Department of Entomology, M.P.K.V., Rahuri.

Eleven different species of fruit sucking moths were recorded in the region and were classified as primary and secondary fruit sucking moths on the basis of their feeding habit. Among them, *Othreis materna* Linn. and *Othreis fullonia* Clerck were the predominant primary piercers whereas, *Achaea janata* Linn was the important secondary piercer.

Abstract contd..... **M.K. Pujari**

The larvae of *Othries materna* could feed and complete development only on *Tinospora cardifolia*. Nearly thirteen fruits were tested as adult host plants. All the fruits *viz.*, sapota, pomegranate, apple, brinjal, aonla, banana, custard apple, guava, papaya, sweet orange, tomato, pineapple and grape were found damaged by the adults of *Othries materna* Linn. in the laboratory.

The life history of *Othreis materna* was studied in the laboratory. The average egg, larval and pupal period was 2.5, 14 and 12.5 days, respectively. The larva completed six instars with an average of 2, 1.5, 2, 3, 3 and 2 days, respectively. The average longevity of male and female moth was 28.5 and 31.5 days, respectively. The total life period occupied 58.5 days for male and 62 days for female.

Seven type of food attractants were prepared by using different fruits (natural and artificial essence of fruits). Among the attractants of natural fruit juice, banana (60 %) juice was more attractive followed by sweet orange (40 %) and guava (40 %). Among the attractants of artificial essence, orange flavour (60 %) was more effective followed by vanilla flavour (50 %).

The six different coloured light sources were studied as light attractants. It was observed that the moths were not attracted towards any of these light sources.

INTRODUCTION

1. INTRODUCTION

Fruits have perhaps been known to human beings from the days of Adam and Eve as they are believed to have eaten the 'forbidden apple'. They have gained a commercial importance all over the world contributing significantly to the economy of the many countries including India. India with its diverse soil and climate offers ideal conditions for growing several different fruit crops. India ranks second in fruits with an annual production of 52.84 million tonnes, accounting for about 10.3 per cent of the total world's fruit production from an area of 53.46 million ha. (Anonymous, 2006). Since time immemorial, fruits have been the source of food for human beings, as they are richest source of minerals and vitamins. Fresh fruits contain sugars (predominantly fructose) that provide energy without too rapid rise in blood sugar levels, which is a cause for diabetes. The total availability of fruits per head per day is only 76.15 g, which is very less than the recommended level of 125 g per head per day by Indian Council of Medical Research, India (Anonymous, 2004).

The cultivation of fruits has been considered a highly profitable enterprise in recent years, as it fetches attractive monetary returns. Among the dry land fruits, pomegranate and sweet orange are gaining popularity. The pomegranate is commercially grown for its sweet acidic taste. It is extensively grown in countries like Spain, Morocco, Egypt, Iran, Afghanistan and India. In India, Maharashtra occupies maximum area

followed by Gujarat, Rajasthan, Andhra Pradesh, Karnataka and Tamil Nadu (Patil and Karale, 1990). Sweet orange is a Tropical and Sub-tropical fruit crop, commonly known as *mosambi*, malta and *sathgudi*. In India it is commercially grown in Maharashtra, Punjab, Rajasthan and Andhra Pradesh (Singh, 1999).

Of the various constraints in the production of fruits, insect pests are of prime in importance. It is well known that fruit trees of different kinds all over the world are attacked by caterpillars of numerous moths in different categories, such as leaf and flower eaters and bud, bark, stem and fruit borers. But so far, we know of very few examples of Lepidoptera causing direct damage to cultivated crops in the adult stage as butterflies or moths. The fruit sucking moth was first recorded in 1869 by the French botanist, Thozet, as injuring orange fruits at Rockhampton in Australia (Baptist, 1944). Later this was confirmed by the observation of Kunckel in 1875 in Australia. It is described by Moore (1887) in his "Lepidoptera of Ceylon" and subsequently by Hampson (1892) in the Fauna of British India.

Fruit sucking moths attained the importance and significance as pests in various countries according to the development and degree of introduced fruit cultivation, particularly of citrus and pomegranate. Thus in India, fruit sucking moths were first recorded as a serious pest by Lefroy and Hawlett (1909).

Fruit sucking moths belong to the family Noctuidae, and subfamily Ophiderinae cause severe damage to fruits and vegetables by piercing and sucking the juice. The tip of the

proboscis of these moths (primary pierces) is armed with chitinised teeth capable of drilling a hole through the skin of pomegranate, a fruit having a very thick and hard rind. Other species of moths use the hole made by the primary piercers and suck the juice (secondary feeders). The secondary feeders appear to be more harmful than primary piercers as they feed on spoiled fruits and pick up fungi and bacteria responsible for rotting and spread the infection to fruits fed by the primary piercers. The immature stages (caterpillar) of these insects are never found feeding on any of the fruit crops but they found feeding on the leaves of unrelated trees, shrubs and vines often located well away from the adult feeding places (Denton *et al.,* 1989). These plants are mostly belonging to the family Menispermaceae. *Othreis fullonia, Othreis materna, Othreis homaena* and *Othreis cajeta* and others are known to occur in India (Susainathan, 1924a, 1924b and Ayyar, 1944). Even though these moths cause serious damage to tropical and subtropical fruits, very little research has been done in India, especially on the primary fruit piercers, adult and larval food preference, biology, natural enemies and the effect of light and food attractants of the moths. The nocturnal activity of the larvae and adults, lack of knowledge on larval food plants, breeding areas and possible migratory habits of larvae and adults might be some of the factors responsible for very little contribution on fruit sucking moths by an Indian entomologists.

Recent increase in area under cultivation of horticultural crops such as pomegranate, orange, guava, custard

apple, mango and tomato in peninsular India has resulted in realizing heavy losses caused by fruit sucking moths by the farmers. As little work has been done on fruit sucking moths in India and it was thought appropriate to study the pest in various ways which would help to evolve a suitable management strategy. Hence, the studies on various aspects of fruit sucking moths were undertaken with the following objectives,

1. Survey of the species of fruit sucking moths.
2. Survey of larval and adult host plants.
3. To study the biology of *Othreis materna* Linn.
4. To study the attraction of moths to various coloured lights.
5. To study various food attractants for moths of *Othreis materna* Linn. in the laboratory.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The fruit sucking moths belong to the family Noctuidae (Lepidoptera), which pierce the rind of a wide variety of fruits by specially adopted proboscis and suck the juice. Literature pertaining to most of the information on fruit sucking moths in relation to survey of the species, larval host plants, adult food plants, biology, natural enemies, use of light and food attractants in attraction of moths, were reviewed and summarized under the following headings.

2.1 Survey and record of the species of fruit sucking moths

Susainathan (1924 a, 1924 b) listed 17 species of fruit sucking moths of which *Othreis materna, Othreis fullonia* and *Anua caronata* Fabricius were reported as a main cause for heavy fruit fall in pomegranate, sweet orange and sweet lime during July to August from certain Tahsils of Krishna district in Andhra Pradesh.

Hargreaves (1936) listed 46 species of fruit sucking noctuids from Sierra Leone (West Africa). The most important among them were from the genera *Achaea, Anua, Hypocala, Othreis* and *Serrodes,* where as Cotterell (1940) reported 27 species from Gold coast. Box (1941) added another 88 species from Gold coast.

Ayyar (1944) reported 20 species of fruit sucking moths from South India, of which four species of *Othreis*, two species of *Achaea* and two species of *Lagoptera* were important.

Baptist (1944) reported that the genus *Othreis* comprises 6 species in Sri Lanka of which important are in the order of *O. fullonia, O. ancilla, O. salaminia, O. materna, O. hypermnestra* and *O. aurantia.*

Golding (1945) enlisted 24 species of fruit sucking moths from Nigeria. Thirumala Rao (1954) reported two main species of fruit sucking moths, *O. fullonia* and *O. materna* as largely responsible for the damage of citrus fruits from Andhra Pradesh.

Bindra (1969) from Madhya Pradesh listed 25 species of fruit sucking moths belonging to seven different genera of which *O. fullonia, O. materna* and *O. ancilla* were stated to be the most serious.

Fruit sucking moths were serious in Africa, South America, South-East Asia and Australia as reported by Hattori (1969) and observed 120 species of moths in orchards and divided these moths in two groups *viz.,* those which had the ability to pierce or bore the fruits (primary fruit sucking moth) and the second group, which fed only on the juice of damaged fruits (secondary fruit sucking moth).

Sandhu *et al.* (1980) reported five species of fruit sucking moths from Punjab.

Banziger (1982) noticed 86 noctuid species of fruit sucking moths from Thailand. But, four species acted as primary

piercers and caused 60-90 per cent of the total damage on longan and citrus crops. Dodia *et al.* (1986) reported *O. fullonia* in Gujarat on citrus.

Banziger (1987) noticed 24 species of fruit sucking moths near Kathmandu in Nepal. Atachi *et al.* (1989) reported seven species of fruit sucking moths previously unknown in Benin and identified as an important citrus pests.

Mote *et al.* (1991) reported *Achaea janata* as a major pest damaging pomegranate in Sangola whereas, at Rahuri (Maharashtra) it was *O. materna* and which was predominant in this region.

Muniappan *et al.* (1993) reported that the fruit sucking moths distributed throughout the world. The genus *Othreis* in Africa, Asia, Australia and Pacific, *Eudocima* in Australia and New Caledonia, *Pericyma, Ercheia* and *Platyia* in Asia and Micronesia, *Caple* in Asia, *Calyptra* and *Ovaesia* in Japan, *Gonodonata* in America and Scolypteryx, *Ophiusa* and *Dysgonia* in Europe.

Fay and Halfpapp (1999) recorded six species of fruit sucking moths in North Queensland and are *Eudocima fullonia* Clerck, *Eudocima jordani* Holland, *Eudocima materna* Linn., *Eudocima salaminia* Cramer, *Eudocima aurantia* Moore and *Eudocima cocalus* Cramer.

Bhumannavar and Viraktamath (2001b) reported twenty-nine species of noctuids on ripened guava at Dharwad and on pomegranate at Raichur and Bijapur at night, of these nine species belongs to subfamily *Ophiderinae*, 19 species to

catacalinae and one species to *Amphipyrinae.* They also classified them into primary piercers of hard skinned fruits (e.g. pomegranate), primary piercers of soft thick skinned fruits (e.g. Matured unripe guava), primary piercers of soft thin skinned fruits (e.g. tomato) and secondary fruit feeders.

2.2 Host plants

Almost all the species of fruit sucking moths have different larval and adult host plants.

2.2.1 Larval host plants

Susainathan (1924 a) reported that the larval host plants of *Othreis* spp. belongs to several species of Menispermaceae like *Tinospora* and *Cocculus* sp.

Ayyar (1944) reported that the larvae of *Othreis fullonia* feed on leaves of *Tinospora cardifolia* and *Cocculus hirsutus.*

Atwal (1963) reported number of wild plants and weeds as a larval hosts of fruit sucking moths. It includes *Tinospora smilacina* Benth, *Cocculus hirsutus* L., *Cissampelos pareira* L., *Convolvulus arvensis, Triclisia pattens* Oliv. and *Pericampylus glaucus* Blatter in Punjab.

Comstock (1963) observed that at least 30 species of the family Menispermaceae serve as larval hosts, though the species vary from country to country, they belong to the genera *Anamirta, Cocculus, Hypserpa, Pericampylus, Stephania, Tinospora* and *Triclisia.*

Cochereau (1977) found that the larvae of *Othreis fullonia* were feed on coral trees of the genus *Erythrina* (Fabaceae) and on the creeper, *Stephania japonica* (Thumb) Miers a native plant in New Caledonia.

Sands and Schotz (1987) reported 8 species of family Menispermaceae as natural larval hosts of fruit sucking moths by the field observations.

Muniappan *et al.* (1993 and 1995) reported that the larvae of *O. fullonia* feeds on various plants of the family Menispermaceae (in Asia) in contrast to the pacific region, where they feed on leaves of almost exclusively on certain trees of *Erythrina* sp.

Bhumannavar and Viraktmath (2001a) reported that the larvae of *O. materna* could feed and complete development only on species of *Tinospora cardifolia* and *Tinospora sinensis*

Bhumannavar and Viraktmath (2001c) reported that the larvae of *O. homaena* were observed on *Cocculus hirsutus* Diels, *Diploclisia glaucescens* Diels and *Cissampelos pareira* Linn. They also reported that the larvae grew faster and healthier on *Tiliacora acuminata* and slower and weaker on *Cocculus pareira.*

Mohite *et al.* (2004) noticed the larvae of fruit sucking moths feed selectively on the leaves of *'gulvel', Tinospora cardifolia.* They showed cannibalistic behaviour in the absence of food.

2.2.2 Influence of chemical constituents on larval preference

The preference of *Erythrina* and Menispermaceae was thought to be due to similar alkaloids they possess (Thomber, 1970). In this regard, Cochereau (1977) speculated that the occurrence of the alkaloid cocculobidine in both the plants of Menispermaceae and *Erythrina* spp. was largely responsible for the oviposition and larval feeding behaviour of *Othreis* spp. However, Amar *et al.* (1991) identified over 90 closely related alkaloids in *Cocculus* sp. and *Erythrina* and suggested that more than one chemical might be involved in providing stimulus for oviposition and larval feeding. They also pointed out that these structurally similar tetracyclic alkaloids were confined exclusively to species of *Erythrina* and representatives of the Menispermaceae, which indeed lent weight to the idea of *O. fullonia* homing on host plants along specific chemical concentration gradient. It might be further speculated that *O. fullonia* was more strongly attracted to the tetracyclic erythrina type alkaloids present in Menispermaceae plants than those in *Erythrina* species. This could explain why the former were preferentially selected when representatives of both the genera were present.

2.2.3 Adult host plants

Hargreaves (1936) reported that in Sierra Leone (West Africa) fruit sucking Lepidoptera attracted on grape fruit, orange, manderine, tangerine, sweet lime, cashew, mango, bread fruit

and jack fruit, while in other countries apple, apricot, fig, banana, guava, grape, litchi, nectarine, peach, pear and pomegranate have been recorded as other adult food plants.

Ayyar (1944) reported that the fruit sucking moths have been noted on varieties of citrus such as orange, pommelo, sweet lemon, naval orange and also on pomegranate, guava peach, nectarines and even mango in some parts of India.

Besides citrus, the moths also attack mango, grape, pomegranate, apple, pear, peach, plum and other sweet and juicy fruits (Bindra, 1969).

Yadav (1969) observed that except 'Khatta' lime nearly all the citrus varieties like samtara, kazilemon, orange, sweet lime were heavily attacked by fruit sucking moths. The most preferred varieties were sweet lime and Hazara. Apart from citrus, the moths were also reported on guava and banana.

The fruit sucking moths attack almost all known sweet fruit picked when close to ripening including citrus, litchi, peach, mango, paw paw and chinese gooseberry, as well as other fruit with a much lower sugar content such as tomatoes and capsicum (Sands and Schotz, 1987).

The pacific fruit sucking moths attacked many fruit and vegetable crops. Fruit crops attacked as includes apple, apricot, banana, bread fruit, coffee, fig, grape fruit, guava, kiwifruit, litchi, longan, mandarin, mango, nectarine, orange (especially navels), papaya, passion fruit, peach, persimmon, pineapple, plum and star fruit. Vegetable crops attacked has includes, the tomato and melon (Waterhouse and Norries, 1987).

Denton *et al.* (1989) reported the following plants as adult food plants of fruit sucking moths,

Apple	Coffee	Lemon	Passion fruit
Apricot	Custard apple	Litchi	Peach
Banana	Egg plant	Longan	Pineapple
Bell pepper	Fig	Mandarin	Plum
Bread fruit	Grape	Mango	Pommelo
Cactus	Guava	Nectarine	Tangerine
Carambola	Jack fruit	Orange	Tomato
Cashew nut	Kiwi fruit	Papaya	

Fay (2005) reported that fruit sucking moths are known to attack more than 40 different types of fruits. The main crops affected in Queenland include citrus, guava, mango, paw paw, carambola, kiwifruit, litchi and persimmon.

2.2.4 Adult fruit preference

Fruit sucking moths preferred sweet and aromatic fruits (e.g. banana, guava) over those with a low sugar content (e.g. tomato, bell pepper) (Sands and Schotz, 1989). Denton *et al.* (1989) confirmed this and further mentioned that ripe fruits were preferred than unripe fruits. They also used the following formula to work out the preference index,

$$\text{Preference index} = \frac{\text{Mean No. of penetrations in test Fruit/moth/24 hr.}}{\text{Mean No. of penetrations in most preferred fruit/moth/24 hr.}} \times 100$$

According to Denton *et al.* (1989), the descending order of fruit preference was banana (100), guava (89), mango (54), papaya (45), tomato (31), pear (30), black Plum (13), naval orange (10), red apple (10), egg plant (0), plum (0) and pomegranate (0).

Bhumannavar and Viraktamath (2001a) reported that the freshly emerged *O. materna* adults preferred to feed on tomato, followed by banana. The feeding preference in descending order during 1998 was tomato > banana > guava > brinjal > pomegranate > orange > mosambi. During 1999, the preference in descending order was guava > tomato > banana > pomegranate > orange > mosambi > brinjal.

Bhumannavar and Viraktamath (2001c) reported that *O. homaena* preferred to feed on guava followed by tomato. The descending order of feeding preference was guava > tomato > banana > pomegranate > orange > mosambi > brinjal.

2.3 Biology of *Othreis materna*

Hargreaves (1936) described the life history of *O. materna*. The duration of larval and pupal stages of *O. materna* were 16-17 days and 11-12 days, respectively.

The durations of egg, larval and pupal stages of *O. materna* reared on *T. cardifolia* were 8-10 days, 28-35 days and 14-18 days, respectively (Ayyar, 1944).

Srivastava and Bogawat (1968) studied the biology of *O. materna* and reported that the eggs were deposited singly and hatched after 3-4 days. Each female laid 200-400 eggs with five larval instars of 2-3, 3-4, 4-5, 3-4 and 4-7 days duration,

respectively. The mean body length of I, II, III, IV and V instars was 5.5, 10.1, 20.2, 38.0 and 53.2 mm, respectively. The pupal case was constructed using pieces of leaves glued together with silken thread and pupal period lasted for 10-13 days. Under the laboratory conditions, oviposition period lasted for 8-10 days and moths were survived for 25-30 days.

Bhumannavar and Viraktamath (2001a) studied the biology of *O. materna*. They reported that at 25 ± 1°C, the incubation period was 3.5-4 days. *O. materna* generally had five and rarely six larval instars. The duration of larval instars was 13.08 ± 0.73 days. The pupal period varied from 12.5 to 14 days. The length and width of grown up larva were 75 mm and 10 mm, respectively. *O. materna* completed development from egg to adult stages on *T. cordifolia* in 32.42 to 34.25 days with majority of larvae under going five larval instars.

Mohite *et al.* (2004) noticed the complete period of life history of *O. materna* from eggs to the death of adult was 35-52 days, with an average 46.12 ± 5.34 days in case of males and 35-56 days with an average of 48.97 ± 6.06 days in females. The average life span of egg, I instar, II instar, III instar, IV instar, V instar larva, pupa and adult period was 3-4, 3, 3, 3, 4, 4.75, 14.16 and 14-16 days, respectively.

Patel and Patel (2006) studied the biology of fruit sucking moth, *Othreis materna* L. on sweet orange and reported that the average diameter of egg was 0.98 ± 0.03 mm. The average incubation period was 2.35 ± 0.59 days and hatching percentage was 89.00 ± 11.00. The larval stage passed through

five instars. The average development period of first, second, third, fourth and fifth larval instars were 2.1 ± 0.31, 1.35 ± 0.49, 2.5 ± 0.51, 3.55 ± 0.51 and 3.85 ± 0.37 days, respectively. Total larval period was 13.25 ± 1.25 days. The pupal period was 12.85 ± 1.09 days. The average longevity of male and female was 28.8 ± 3.85 and 31.1 ± 1.66 days, respectively. The total life period occupied 58.0 ± 3.97 days for male and 59 ± 3.16 days for female.

2.4 Natural enemies

Literature pertaining to this aspect is very scanty in India. Most of the available literature revealed only the studies on the natural enemies which are presented here.

2.4.1 Natural enemies on egg stage

Hargreaves (1936) obtained four parasitoids from the eggs of *O. fullonia* in Sierra Leone (West Africa) but he did not identify them.

Except preying mantids and spiders, no natural enemies of importance were observed to attack on *O. fullonia,* although numerous parasitoids were obtained from these Noctuids (Box, 1941).

Ayyar (1944) reported one or two chalcid parasitoid on eggs of both *Othreis* and *Achaea.*

Baptist (1944) in Sri Lanka reported two unidentified parasitoid, a braconid larval parasite and chalcid egg parasitoid.

Sontakay (1944) recorded 30 per cent egg parasitization by chalcid parasitoid at Nagpur (Maharashtra).

Maddison (1982) reported that the eggs of *Othreis* sp. were parasitized by *Ooencyrtus* sp., *Telenomus* sp. and *Trichogramma* sp. Further, *Chrysopa* sp., *Lageid* sp. and ants were found feeding on the eggs in New Zealand as predators.

Kumar and Lal (1983) recorded a hymenopteran parasitoid, *Trichogramma papilionis* parasitising the eggs of *O. fullonia* to the extent of 7.7-50.5 per cent from Fiji.

Dodia *et al.* (1986) demonstrated the successful parasitisation of the eggs of *O. fullonia* using the egg parasite wasp, *Trichrogramma chilonis* Ishii and also suggested the possibility of utilizing the *Trichogramma* for the control of the pest.

Sands and Schotz (1989) from South East Qeensland observed three hymenopteran parasitoids from the eggs of *Eudocima* (= *Othreis*) *Salaminia.* But the extent of parasitization did not exceed 11 per cent.

Denton *et al.* (1991) from the American Pacific Islands identified the microhymenopteran egg parasitoids *viz., Telenomus* sp., *Oenocyrtus* sp. and *Trichogramma* sp. of which *Telenomus* sp. was dominant. They reported the relative importance of the three egg parasitoids which varied in different American Pacific Island in 1992. The extent of parasitization by all the three parasitoids was 71.8 per cent and 87.5 per cent on single egg collections and egg masses, respectively.

Muniappan *et al.* (1993) from Guam Island reported that the populations of egg parasitoids of *O. fullonia* included *Telenomus* sp. and *Ooencyrtus* sp. and were density dependent.

The parasitism increased with increase in density of *O. fullonia* eggs. On the other hand another important egg parasitoid *Trichogramma* sp. was density independent.

2.4.2 Natural enemies on larval stage

Ayyar (1944) observed the larval parasitoid *Tetrastichus ophiusae* Cr. on both *Ophideres* and *Achaea.*

Bhatnagar (1957) described a eulophid, *Euplectus maternus* Bhatnagar on *O. fullonia* and *O. materna* from Uttar Pradesh (India).

Cochereau (1977) has reported *Winthemia caledoniae* Mesnil, a tachinid fly as the key larval parasitoid, accounting 25-46 per cent parasitisation in New caledonia.

Maddison (1982) reported a tachinid fly, *Winthemia caledoniae* as an important larval parasitoid of *O. fullonia* from New Caledonia. The fly usually laid its eggs on the fifth instar larvae and the eggs hatched in 3-3.5 days. The maggots penetrated in to the body of *O. fullonia* caterpillar and fed inside on the body fluids until the caterpillar pupated.

Kumar and Lal (1983) successfully mass multiplied and released the tachinid larval parasitoid (*Winthemia caledoniae*) in the field for the control of *O. fullonia* pest in Fiji.

Waterhouse and Norries (1987) were of the opinion that the egg parasitoids especially *Ooencyrtus* sp. were worth serious consideration for introduction elsewhere. According to them another egg parasitoid, *Trichogramma astriniae* occurring in Hawaii needs further exploitation. They also felt that natural

enemies of species of *Othreis* from its presumed area of origin, namely Indo-Malaysian origin might be of great value.

Chinniah and Mohan sundaram (1995) reported *Blattisocius othreisae* Chinniah and Mohansundaram (Acari) on *Othreis* sp. from Tamil Nadu.

Sands (1996) considered that *Euplectus maternus* Bhatnagar, from India, might be a valuable candidate for introduction into countries where species of *Othreis* were pests, since this parasitoid had only been recorded from larvae of *O. materna* and *O. fullonia.*

Jones and Sands (1999) reported that the *Euplectus melanocephalus* was a gregarious, primary ectoparasitoid of larvae of the fruit sucking moth genus, *Eudocima* (Noctuidae : Catocalinae). They also reported that when parasitising *Eudocima materna,* eggs of *Euplectus melanocephalus* were deposited dorsolaterally on one of the first five abdominal segments of second and third instar larva.

2.5 Nature of damage

Baptist (1944) described that the fruit sucking moths were nocturnal in habit and attacks the fruit during the hours of darkness only, sheltering during the day in the jungle or any densely undisturbed vegetation in the vicinity of the orchards.

Golding (1945) reported that the moths piercing activity on fruits observed from 7.00 pm to 11 pm and again in the morning between 4 am to 6 am.

Rakshpal (1945) described the damage caused to ripening fruits of citrus, other than lemon, in Gwalior region in

India. Injury in the ripening oranges was initially a simple puncture, which may not be apparent unless the fruit was squeezed to force drops of juice through puncture in the rind. But, on pomegranate fruit, a puncture was clearly visible. Damaged fruits began to rot near the puncture and thus a brown, roughly a circular area surrounding the puncture was formed. Injured fruits fell down within a week after damage.

Bajpai (1955) reported that the citrus varieties, orange (mandarin) suffered more damage by the feeding activity of fruit sucking moths as compared to other fruits and the loss ranged from 20 per cent to 80 per cent in different years in Nagpur (India).

Ramachandrachari and Padmanabham (1960b) reported that the damage was 3.8 per cent to 9.8 per cent on 'mosambi' in Cuddapah district (Andhra Pradesh).

Baghel *et al.* (1987) recorded that the damage was up to 90 per cent on 'mosambi' in Madhya Pradesh.

Atachi *et al.* (1989) studied seven species of Noctuids, including *Othreis* and found that the adults has a well developed proboscis with a dentate tip which they use to pierce the rind and pulp of the ripening fruit to suck the juice. The punctured region easily became infected with bacteria or fungi that caused the damaged fruit to drop prematurely or rot.

Mote *et al.* (1991) reported the damage upto 57 per cent done by *Othreis* and *Achaea* to pomegranate fruit in Maharashtra. They also reported that the damage was maximum

on ripe pomegranate fruits (42.8 to 92.85 %) than on unripe fruits (2.86 to 13.86 %) at Rahuri (Maharashtra).

Fay and Halfpapp (1993a) recorded that there are highly significant differences in fruit weight, colour, brix and pH between damaged and undamaged Litchi and Crambola. The rate of infested fruits was 40-60 per cent causing 20-30 per cent decrease in yield.

Bhumannavar and Viraktamath (2001b) reported that the damage ranged from 0 to 8.67 per cent at Bijapur and 18.45 to 33.9 per cent at Raichur during 1999 by fruit sucking moths on pomegranate. They also observed that the area surrounding the feeding hole changed to brown as the tissue rotted. The feeding hole measured 0.8 mm in diameter. It was clearly visible on guava and brinjal with powdery material, but it was partly closed without any powdery material on orange and mosambi due to presence of oily glands in the rind.

2.6 Use of light to attract moths

Baptist (1944) showed that the orchard in which a light trap was used, the fruits of trees illuminated by the light suffered less from moth attack than those in complete darkness, thus suggesting the moths have habit of repelling away from light.

Nomura *et al.* (1965) in Japan reported 60 per cent reduction in moths attack due to illumination of light in the orchard.

Bindra (1969) observed that the use of light traps for the control of fruit sucking moths has not proved effective.

The fruit sucking moths were attracted by ultraviolet light and repelled by white light (Bosch, 1971). If, exposed to green-yellow light of mercury lamps, they adapt to the light and assume their resting day light behavior (Bosch, 1971).

White head and Rust (1976) observed the reduction of moths up to 93 per cent in peach orchard by placing kerosene pressure lamps at a height of 1.5 m from ground with an interval of 15-20 m between lamps on the down wind edges of the orchard (Because fruit sucking moths locate fruit orchard by smell and thus fly against wind).

Fay (2005) reported that lights emitting yellow-green wavelength suppressed moth feeding by about 70 per cent at moderate population level.

2.7 Food attractants for fruit sucking moth

Baptist (1944) suggested the utilization of baits to attract the moths and traps in the jars hanged on the branches of the tree. He also suggested that there was no need of addition of poison to the bait as the moths trap within jars. He suggested replacing the bait at least once in a week.

Baiting formula:

Water	-	6 pints (3 litre)
Fruit pulp or extract	-	2 pints (960 g)
Crude sugar	-	½ lb (226.8 g)
Sodium silicofluoride		
or	-	If necessary 10z (30 g)
Lead arsenate		

Golding (1945) observed that the most effective means of killing the moths was to use pieces of mangoes that had been soaked for one hour in 1.25 per cent solution of sodium arsenite in water.

Bajpai (1955) reported in the studies that 211 moths of *O. fullonia,* 72 moths of *O. materna* and 119 moths of *A. janata* were attracted and killed during the period of 40 days where poison bait was used with following composition.

Molasses	-	½ lb (226.8 g)
Vinegar	-	Few drops as flavor
Lead arsenite	-	¼ 0z. (7.087 g)
Water	-	10 Lb.

Fruit sucking moth, *Achaea janata* prefer slices prepared from fruits damaged due to moth attack. A number of moths attacked fruits were cut in to a large number of slices to increase the surface area and exposed in different places in the orchard before dusk. During night, it was found that most of the moths were feeding on the slices and the fruits on the tree were remained almost free from the pest (Ramachandrachari and Padmanabham, 1960b)

Bindra (1969) reported that the use of some attractant poison baits have proved quite useful. He prepared the bait by mixing ½ 0z (226.8 g) of lead arsenate, 1 lb (0.4536 kg) of molasses, one gallon (4.5 litre) of water and a little vinegar was added to it.

Sandhu *et al.* (1980) observed that the poison bait control measures against fruit sucking moths proved only partially effective in Punjab. They used following bait,

Citrus fruit extract	-	4 liters
Gur	-	1 kg
Malathion	-	250 ml
Water	-	10 liters

Fay (2005) reported that Volatile compounds particularly some aldehydes and alcohols were important in the attraction of moths. This combination of attractants incorporated in to sugared baits, which also contained toxicant to kill the moths.

Reddy *et al.* (2007) reported that fruit sucking moth *Eudocima phalonia* was significantly attracted to feed more on fruit puree with Agar and phytogel than on fruit puree with Agarose. They tested 15 fruit baits, of those, moths preferred to feed on banana baits more than any other, followed by guava and orange, which were significantly more attractive than kiwi, apple, pineapple, pear, papaya, mango, grape fruit and tomato.

MATERIAL AND METHODS

3. MATERIAL AND METHODS

The material used and methods followed on the investigations on various aspects of fruit sucking moths envisaged in the introductory chapter were carried out at the Department of Agricultural Entomology, Post Graduate Institute, MPKV, Rahuri during the year 2007-2008 and presented in this chapter.

3.1 Experimental site

The experiment was conducted in the laboratory of Department of Agricultural Entomology, Post Graduate Institute, MPKV, Rahuri, Dist. Ahmednagar (M.S.) during the year 2007. The study was undertaken on the various aspects of *O. materna.*

3.1.1 Collection of moths

Field survey was carried out in the villages of Rahuri Tahsil (*viz.*, Loni, Nimgao Jali and Digras), pomegranate orchard of Department of Irrigation and Water Management (MPKV) and Citrus orchard of Department of Horticulture (MPKV) to collect the moths. The moths were collected during the night at 18.00 pm to 24.00 pm with the help of torches and insect collecting nets.

The orchards were visited during peak fruiting season (September to October). The ripened fruits were carefully observed with the help of torch light. A beam of torch light was focused on to the plants. Moths feeding on the fruits were collected with the help of hand net and released in the plastic bags. To avoid injuries to the moths, special type of big sized

Plate 1

A. Collected moths of *O.materna*

B. Rearing of *O.materna* in laboratory

cloth bags were stitched and round sheet of thermo Cole was placed at the base of each bag so that moth got sufficient space for the movement.

3.1.2 Rearing of moths

The collected moths were released in rearing cages (1m x 1m x 1m). These cages were made up of black cloth (Plate 1A). Both males and females were released in each cage. The cages were tied to the bamboo which was hanged horizontally in the laboratory, to prevent from the ant attack (plate 1B). The different fruits were kept in the different cages for testing the adult food plants. The fruits were regularly replenished.

The eggs were collected from the cage daily and kept them in the petri plates for hatching. After hatching, the neonate larvae were reared on leaves of *Tinospora cardifolia* in bowls (size 10 x 25 cm).

3.1.3 Primary and secondary species of fruit sucking moths

The species of fruit sucking moth which were collected during survey were classified into two groups based on their piercing ability. The moths which have long pointed serrated proboscis used to pierce hard skinned fruits like pomegranate were grouped in to primary fruit sucking moths while, moths which have long simple tube like proboscis unable to pierce into hard skinned fruit but feed through the punctures already made by primary fruit sucking moths were grouped into secondary fruit sucking moths. Each species of moths were kept in different cages separately. The fresh fruits were kept in the cages as a

food and were observed daily. Observations on the length of proboscis of primary fruit sucking moths were also taken.

3.2 Host plants of *O. materna*

3.2.1 Larval host plants

For testing the larval host plants of *O. materna*, the leaves of different plants mostly belonged to the family menispermaceae were collected and tested. These plants includes 'Kakamari', *Anamirta cocculus*, 'Paharvel', *Cissampelos pariera*; *Coscinium fenestratum*' 'Vatoli', *Diploclisa glaucescens, Febraureu tinctoria, Pachygone ovata, Tiliacora acuminate,* 'gulvel' *Tinospora cardifolia* and *Erythrina* species. The leaves of all these plants were provided to the larvae for feeding. The plants on which all larval instars were completed by feeding were recorded as larval host plants.

3.2.2 Adult host plants

Various fruits available in the market were tested as food plants of *O. materna.* The fruits of pomegranate, sapota, apple, banana, tomato, sweet orange, guava, custard apple, papaya, aonla and brinjal were tested. The fruits were kept in cages of *O. materna* and the punctures made by the moths were observed next day morning. The damaged fruits were cut opened and observed the internal damage. The damaged fruits were recorded as adult host plants.

3.3 Biology of *Othreis materna*

The biology of *O. materna* was studied on *Tinospora cardifolia*(('gulvel') under laboratory conditions.

3.3.1 Egg

The efforts were made to collect eggs and larval stages on plants of the family menispermaceae during the survey. But did not found any of them in the field. Therefore, moths were collected from the field during night and released them in adult rearing cages. These cages were prepared by using round iron skeleton covered with black muslin cloth. A pomegranate fruit was kept hanging in the cage as a food to these moths. Egg laying was observed on the muslin cloth. These eggs were collected in the morning with the help of moist camel hairbrush. They were kept in the petri plates (10 x 1.5 cm) having moist blotting paper at the base. Ten eggs were kept for hatching in each petri plates. The eggs were frequently observed under microscope for any change in colour and shape.

3.3.2 Larva

After hatching, the first instar larvae were transferred to plastic bowls (25 x 10 cm). These bowls were covered with muslin cloth with the help of rubber band. They were provided with leaves of *T. cardifolia* daily in the morning. The excreta were removed from the bowls to hygienic conditions.

A larva was kept singly in separate wide mouth plastic bottle and the bottle was covered with muslin cloth with the help of rubber band for the study of larval instars. The larvae were observed daily for moulting, which was determined by the presence of exuvia and moulted head capsule. The duration of each larval instar was recorded.

After each moult, ten larvae were taken for morphological observations and killed them with chloroform for taking observations on length, breadth and weight. The length and breadth were recorded by using vernier calliper and weights by using electronic balance.

3.3.3 Pupa

The fully developed last instar larvae were allowed to pupate by providing leaves of 'gulvel' in the same container. The bottles were kept undisturbed up to the adult emergence for recording the pupal duration. Pupal weight was recorded one day after pupation.

Morphological observations were taken under the microscope and sexes were identified based on the genital openings. In case of female, genital opening was situated on the eighth abdominal segment which was away from the anal slit, while in case of male, the genital slit was situated on the ninth segment which was smaller and close to the anal slit. Pupal period was worked out for both male and female.

3.3.4 Adult moth

After the emergence of moth from pupae, a pair of male and female moths were released in adult rearing cage. Both male and female moths were critically observed for their morphological characters. Maximum wing expansion of moth was recorded in both sexes by millimeter scale.

3.3.5 Pre-ovipositional period

The observations on pre-oviposition period were taken and recorded.

3.3.6 Oviposition period

The observations on duration of egg laying period were recorded.

3.3.7 Fecundity

The total number of eggs laid were counted daily from five different adult rearing cages, having a pair of male and female in each cage. Observations were recorded from the day on which the female moth started to lay eggs until the egg laying was stopped. The average fecundity was calculated from these observations.

3.3.8 Adult longevity

Observations on adult longevity were recorded in both the sexes.

3.3.9 Hatching percentage

Ten petri plates, each having 10 freshly laid eggs were used for taking observations on percentage of hatching. The observations were taken everyday.

3.4 Study of various coloured lights for attraction of moths

The different sources of coloured lights *viz.*, red, yellow, blue, green, milky white and ultraviolet were tested in the laboratory. The (15w) bulbs each of these lights were installed in a separate room and ten numbers of moths were released during night at 7.30pm. Observations on number of moths attracted towards the light were taken up to 12.00pm.

3.5 Study of various food attractants for moths of *O. materna* Linn.

A laboratory study was conducted to find out the attraction of moths of *O. materna* towards various food attractants prepared by natural fruit juice and artificial flavours (essence) of fruits.

3.5.1 Food attractants made of natural fruit juice

The food attractants of natural fruits were prepared by using various fruits *viz.,* orange, pineapple, sweet orange, banana, pomegranate, guava and sapota with the aid of mixer grinder. The quantity of 2 ml molasses was added to the juice. This food attractant was filled in bowls and petri plates were covered by nylon net. Everyday one type of food attractant was prepared and tested in the laboratory. These petri plates and bowls were kept hanging with the help of thread. Ten numbers of newly emerged moths were released in the laboratory during night at 7.30 and kept a watch on them up to 12.00 pm. The number of moths visited for feeding to attractants was recorded. At last a preference test was also conducted by putting all the food attractants together at a time. Observations on number of moths feeding on particular food attractants were recorded.

3.5.2 Food attractants made of artificial flavours (essence)

The food attractants were prepared by using different flavours of fruits available in the market *viz.,* vanilla, orange, mango, lemon, pineapple and strawberry. The food attractants

contained 25ml sugar solution + 2-3 drops of essence. Cotton plug dipped in food attractant was kept in the petri dish and this was covered by nylon net to avoid direct contact of moth. The procedure mentioned under 3.5.1 was followed to test the food attractants made of artificial flavours.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results of the studies made on fruit sucking moths especially on survey of fruit sucking moths, larval host plants, adult host plants, biology, attraction of moths to different coloured lights and to various attractants of *Othreis materna* are presented in this chapter.

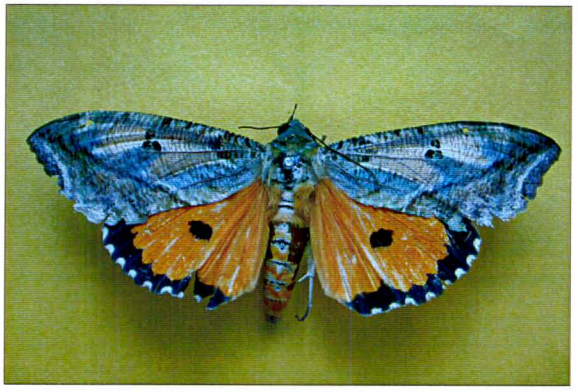
4.1 Survey and record of the species of fruit sucking moths

During the survey of fruit sucking moths in 2007 eleven (11) species of noctuids were caught feeding on pomegranate during night. Of these, four species belonged to subfamily ophiderinae and seven species to catocalinae (table1).

Table1. Species of fruit sucking moths collected during 2007

Sr. No.	Species	Family	Sub family
1.	*Othreis materna* Linn.	Noctuidae	Ophiderinae
2.	*Othreis fullonia* Clerck	Noctuidae	Ophiderinae
3.	*Othreis homaena* Hubn.	Noctuidae	Ophiderinae
4.	*Achaea janata* Linn.	Noctuidae	Catocalinae
5.	*Anomis flava* Fabr.	Noctuidae	Ophiderinae
6.	*Ophiusa caronata* Fabr.	Noctuidae	Catocalinae
7.	*Ophiusa tirhaca* Cram.	Noctuidae	Catocalinae
8.	*Moics frugalis* Fabr.	Noctuidae	Catocalinae
9.	*Remigia archesia* Cram	Noctuidae	Catocalinae
10.	*Paralellia algira* Linn.	Noctuidae	Catocalinae
11.	*Achaea serva*	Noctuidae	Catocalinae

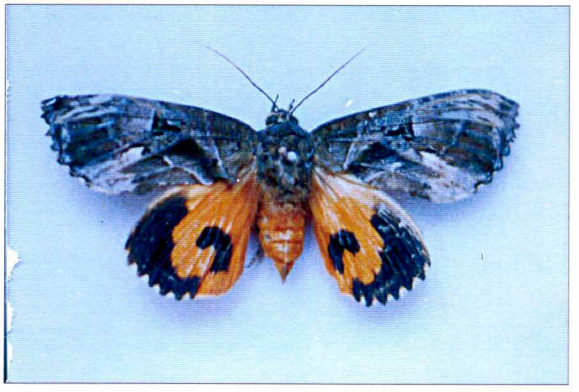
Plate 2



A. *O.materna* (Male)

B. *O.materna* (Female)

C. *O. fullonia* (Male)



D. *O. fullonia* (Female)

E. *O. homaena* (Male)

F. *O. homaena* (Female)

Primary species of fruit sucking moths

4.1.1 Primary fruit sucking moths

The primary species of fruit sucking moths were able to puncture hard skinned fruit with the help of their strong sclerotised proboscis. The microscopic examination of dissected proboscis revealed the presence of scleretised blades, erectile barbs, serrations and tip of proboscis was sharply pointed (plate 3). The proboscis of female moth was longer (14.1 mm) than male (13.22 mm) of *Othreis materna.* The moths drilled a hole through the hard skin of pomegranate with a forward to backward motion. It was observed that the moth took more than 30 minutes during single feeding. The primary fruit sucking moths along with their proboscis length were listed in table 2 and depicted in the plate 2.

Table 2. Primary fruit sucking moths with proboscis length

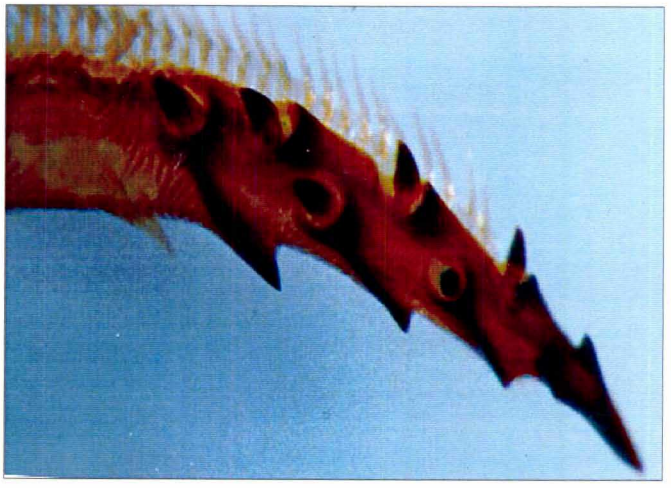
Sr. No.	Species	Average length of proboscis of five individual moths (mm)	
		Male	Female
1.	*Othreis materna* Linn.	13.22	14.10
2.	*O. fullonia* Clerck.	15.13	16.20
3.	*O. homaena* Hubn.	13.42	14.40

4.1.2 Secondary fruit sucking moths

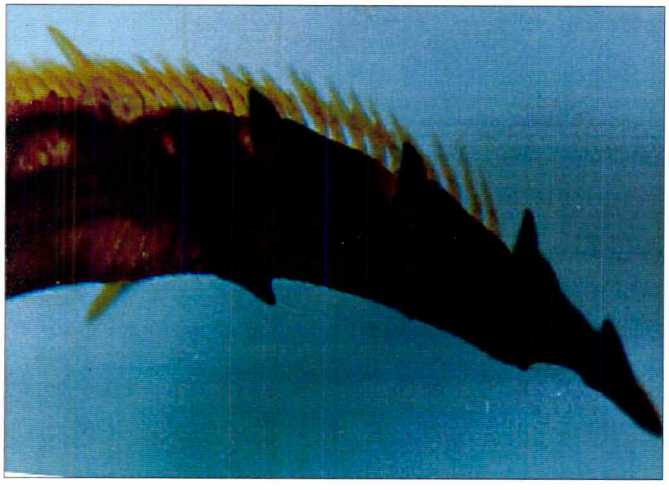
The moths which were unable to pierce in to the hard skinned fruits were classified as secondary fruit sucking moths (table 3). The proboscis of these moths was blunt and soft, permitted feeding only on wounded (damaged by primary moths) and rotten fruits. All the moths under this group used the

Plate 3

A. Proboscis of *O. materna*



B. Dissected proboscis of *O. materna* (Male)



C. Dissected proboscis of *O. materna* (Female)

feeding holes made by the moths of primary piercing group. These moths were shown in plate 4.

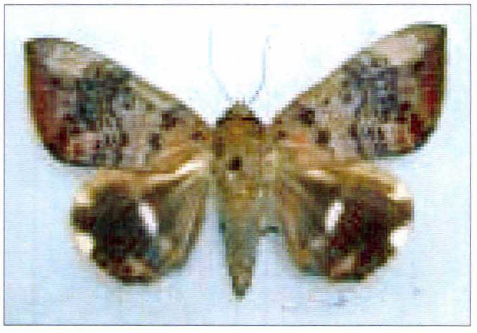
. Table 3. Secondary fruit sucking moths

Sr. No.	Species
1.	*Achaea janata* Linn.
2.	*Anomis flava* Fabr.
3.	*Ophiusa caronata* Fabr.
4.	*Ophiusa tirhaca* Cram.
5.	*Parallelia algira* Linn.
6.	*Mocis frugalis* Fabr.
7.	*Remigia archesia*
9.	*Achaea serva*

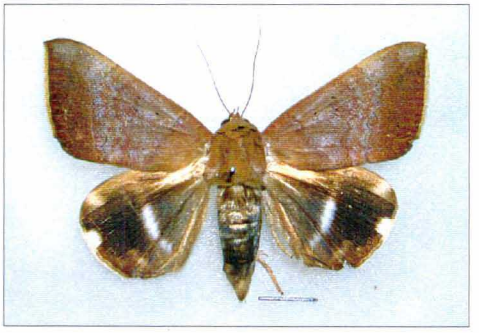
Eleven species of noctuids were caught while feeding on pomegranate and sweet orange during the present investigation. Susainathan (1924a, 1924b) listed seventeen species of fruit sucking moths of which *O. materna, O. fullonia* and *Anua caronata* were important. Ayyar (1940) reported 11 types of fruit sucking moths of which, four species of *Othreis*, two species of *Achaea* and two species of *Lagoptera* were recorded as important piercers in South India.

In India, two species appear to be very common *viz., O. fullonica* Clerck and *O. materna* L., including these, twenty moths were listed from South India (Ayyar, 1944). All the primary species and a secondary species reported during present investigations were also reported by Ayyar, 1944.

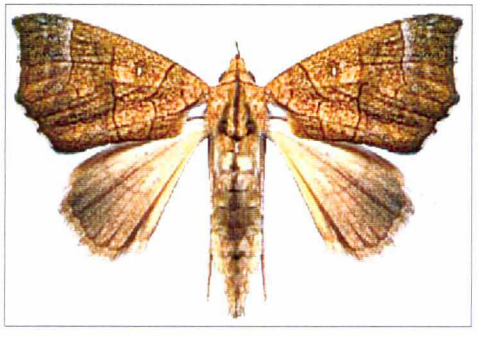
Plate 4



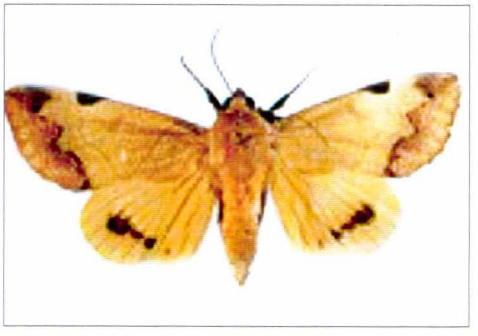
A. *Achaea janata*



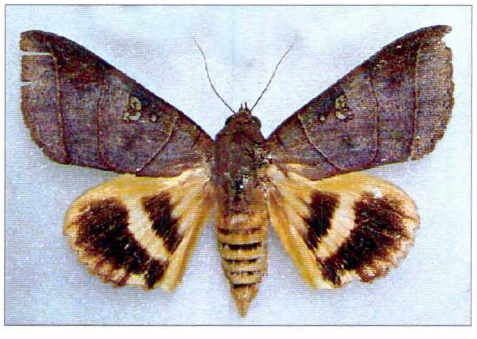
B. *Achaea serva*



C. *Anomis flava*



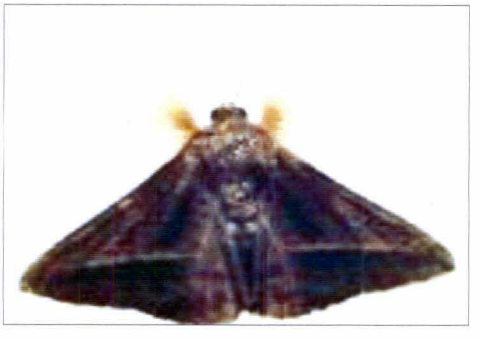
D. *Ophiusa tirhaca*



E. *Ophiusa caronata*

F. *Remigia archesia*

G. *Paralellia algira*



H. *Mocis frugalis*

Secondary species of fruit sucking moths

Baptist (1944) reported six species of fruit sucking moths of genus *Othreis* in Sri Lanka. They were *O. fullonia* Clerck, *O. ancilla* Cramer, *O. materna* Linn., *O. salaminia* Fabricius, *O. hypermnestra Cramer* and *O. aurantia* Moore.

Bindra (1957 and 1969) reported 25 species of fruit sucking moth, of which *O. materna, O. fullonia* and *O. ancilla* were stated as more serious pests in Madhya Pradesh. Ramachandrachari and Padmanabham (1960a) observed ten different fruit sucking moths on sweet orange in Andhra Pradesh. Among them *Othreis fullonia* as the most predominant with maximum frequency of 69.1 per cent appearance in the total composite population of fruit sucking moth.

Dodia *et al.* (1986) reported *O. fullonia* in Gujarat while Banziger (1987) reported twenty four species of fruit sucking moths near Katmandu in Nepal. Out of these 6 species were reported during present investigation *viz., O. fullonia* Clerk, *O. materna* Linn., *Ophiusa coronata* Fabricius, *Achaea janata* Linn., *Paralellia* sp., *Anomis flava* Fabricius.

Mote *et al.* (1991) recorded *O. fullonia, O. materna, O. ancilla* and *Achaea janata* attacking pomegranate in Sangola and Rahuri (Maharashtra). Among these *O. materna* was found predominant species in this region. Similar observations were recorded during the present study.

4.2 Host plants of *O. materna*

The larval and adult host plants of fruit sucking moths are different. The adult stage is destroying most of the

Plate 5

A. ' Gulvel ' *(Tinospora cardifolia)* : Larval host plant of *O. materna*

B. Larvae feeding on *T.cardifolia*

C. Moths of *O.materna* feeding on different fruits in the laboratory

fruits where as larva feeds on uncultivated plants of menispermaceae.

4.2.1 Larval host plants of *O. materna*

The data recorded on larval host plants of *O. materna* are presented in table 4.

Table 4. Survival of larvae of *O. materna* Linn on different plants

Sr. No.	Host plant	Number of larvae studied	Number of survival of larvae	Per cent of survival larvae
1.	*Anamirta cocculus*	10	0	0
2.	*Cocculus hirsutus*	10	0	0
3.	*Cissampelos pareira*	10	0	0
4.	*Diploclisia glaucescens*	10	0	0
5.	*Tiliacora acuminate*	10	0	0
6.	*Tinospora cardifolia*	10	10	100
7.	*Erythrina indica*	10	0	0

It indicates that the larvae of *O. materna* survive and complete its development only on *T. cardifolia* (plate 5B). They did not feed even on tender leaves of other Menispermaceae and *Erythrina* under no choice tests.

The results of the present investigations were in agreement with the findings of Susainathan (1924a), Ayyar (1944), Srivastava and Bogawat (1968) and Mohite *et al.* (2004).

In Australia, larvae of *O. materna* fed on *T. smilacina*, another species of Tinospora (Fay and Halfapp, 1993[b]). This may be due to climatic and regional variation.

Bhumannavar and Viraktamath (2001[a]) reported that the larvae of *O. materna* found only on leaves of *Tinospora cardifolia* in Bangalore, Raichur, Bijapur, Dharwad, Chettalli, Pune and Tirupati. They also reported that under no choice test, the larvae fed on *T. sinensis*.

4.2.2 Adult host plants of *O. materna*

The fruits which were tested as adult food are presented in Table 5.

Table 5. Fruits tested as adult hosts of *Othreis materna*

Sr. No.	Common name	Scientific name	Test results
1.	Apple	*Pyrus malus*	Punctured
2.	Aonla	*Phyllanthus emblica*	Punctured
3.	Banana	*Musa paradisiacal*	Punctured
4.	Custard apple	*Annona squamosa*	Punctured
5.	Sapota	*Achras sapota*	Punctured
6.	Guava	*Psidium gujava* L.	Punctured
7.	Papaya	*Carica papaya* L.	Punctured
8.	Pomegrnaate	*Punica granatum* L.	Punctured
9.	Sweet orange	*Citrus sinensis*	Punctured
10.	Tomato	*Lycopersicon esculentum*	Punctured
11.	Pineapple	*Ananas comsus* L.	Punctured
12.	Grape	*Vitis vinifera* L.	Punctured
13.	Brinjal	*Solanum melongena*	Punctured

Plate 6

A. *O.materna* feeding on pomegranate fruit

B. *O.materna* feeding on 'mosambi' fruit in field

C. *O.materna* feeding on orange fruit in field

The data revealed that all the fruits *viz.*, apple, aonla, brinjal, banana, custard apple, sapota, guava, papaya, pomegranate, sweet orange, tomato, pine apple and grape tested during the study were attacked by the adults of *O. materna* (Plate 5C).

Besides these fruits, the moths also attack on mango, pear, peach, plum and other sweet and juicy fruits (Bindra, 1969).

Yadav (1969) reported the citrus varieties like Samatora, Kazilemon, orange and sweet orange were heavily attacked. Apart from citrus, the moths were also reported on guava and banana.

Denton *et al.* (1989) recorded 36 fruits which were attacked by adults of *O. materna.* Fay (2005) reported fruit sucking moths are known to attack more than 40 different types of fruit in Queensland. Present results are in agreement with the findings of these workers.

4.3 Biology of *O. materna*

The biology of fruit sucking moths, of *Othreis materna* was studied on *Tinospora cardifolia* under laboratory conditions at Department of Entomology, Post Graduate Institute, MPKV, Rahuri. The results are presented here under,

4.3.1 Emergence

The emergence of adults of *O. materna* from pupae was started in the rainy season in the month of August 2007. The emergence of adults started at 19.30 hours after sunset. Freshly emerged moths were getting attracted by strong aroma

emitted by the ripened fruits of pomegranate and sweet orange. The adult moths were strong fliers; they can fly over long distances in search of fruits. Earlier workers reported the emergence of *O. materna* during night after the rains in the month of August and September (Baptist, 1944; Ayyar, 1944 and Mote *et al.*, 1991).

The moths on emergence fly to the nearby orchards for feeding on fruit juice. The moths started coming at dusk and the activity reached to peak from 20 to 23 hours at night. Baptist (1944) reported that the moths were most active in the earlier part of the night. Mote *et al.* (1991) reported that the fruit sucking moths visited pomegranate orchard at night and they left the orchard before sunrise. The moths started coming at dusk and the activity was at peak from 19.00 to 23.00 hours. Again moths were observed from 4.00 to 6.00 hours. Bhumannavar and Viraktamath (2001a) reported that the adult moth activity started around 20.30 hours during September and reached peak at 23.00 hours and declined thereafter. The activity of moths would not affected by heavy spell of rain. Similar observations were reported during present investigations.

Efforts were made to locate the activity of moths during day time in the orchard but not a single moth was observed flying in the orchard. Baptist (1944) reported that the moths shelter in the jungle or any dense undisturbed vegetation in the vicinity of orchards during day time. Similar observations were reported by Ayyar (1944), Atwal (1963) and Garg (1978).

Bhumannavar and Viraktamath (2001a) reported that in captivity *O. materna* did not lay eggs on vines of *Tinospora cardifolia* but oviposited on the nylon net and other surfaces including the fruits on which they were feeding. Similar observations were recorded during present investigation.

Mohite *et al.* (2004) reported that the eggs were deposited on the sides of the cage and very rarely on the bottom or top. The eggs were laid singly.

Patel and Patel (2006) reported that the egg laying was on leaves of *Gulvel* and on iron wire net and covering cloth of cages. All the above findings are in agreement with present investigation.

4.4 Fecundity

It was found that the egg laying capacity of *O. materna* ranged from 800 to 950 per female in the laboratory during the entire life span. The average egg laying capacity was 840 eggs per female.

Srivastava and Bogawat (1969) reported that the females of *O. materna* laid 200-400 eggs during her life span. However, Lolage and Khaire (1998) reported the average fecundity of *O. materna* as 850 eggs per female. Present findings are inconformity with the findings of these workers.

4.4.1 Egg

The egg was hemi-spherical and flattened at base. The freshly laid egg was pale white in colour (Plate 7A).The colour of egg changed to light brown on 2nd day and then dark brown before hatching. The mandibles of embryo were seen

through egg shell when observed under microscope. The complete head capsule and the setae were visible through egg shell under microscope at the time of hatching.

The measurements on eggs are presented in table 6.

Table 6. Measurement on eggs

Sr. No.	Occular micrometer reading	Diameter (mm)
1.	86 - 20 = 66 x 0.015	0.990
2.	85 – 20 = 65 x 0.015	0.975
3.	87 – 20 = 67 x 0.015	1.005
4.	84 – 20 = 64 x 0.015	0.960
5.	87 – 20 = 67 x 0.015	1.005
6.	86 – 20 = 66 x 0.015	0.950
7.	86 – 20 = 66 x 0.015	0.950
8.	85 – 20 = 65 x 0.015	0.975
9.	82 – 20 = 62 x 0.015	0.930
10.	83 – 20 = 63 x 0.015	0.945
	Mean	0.976

Range = 0.930 to 1.005 mm
Average weight of 10 eggs = 0.0042 g

The diameter of an egg ranged from 0.930 to 1.005 mm. The average diameter of an egg was 0.976 mm, while average weight of ten eggs was 0.0042 g.

Ayyar (1944) reported that the eggs of *O. materna* were oval soft and shining pale green. Atwal (1963) reported that the eggs were round transluscent measuring about one millimeter in diameter. Srivastava and Bogawat (1969) observed that the eggs were creamy white, becoming light yellow at

Plate 7

A. Eggs of *O.materna*

B. First instar larva of *O.materna*

C. Sixth instar larva of *O.materna*

D. Pupae of *O.materna*

maturity, hemispherical with concave ventral surface, diameter 0.95-1.05 mm, chorion thick and hard.

Bhumannavar and Virktamath (2001a) found that the eggs were hemispherical with a flat bottom and measured 0.86-0.94 mm in diameter and never crossed 1 mm width. They also reported that the freshly laid eggs were creamy white and turned light yellow with brown markings before hatching. The chorion was thick and hard.

The freshly laid eggs were translucent creamy white but after 12 hrs they became yellowish and turned light brown before hatching. They were semicircular with flattened ventral surface and measured about 0.92 to 1 mm in diameter (Mohite *et al,* 2004 and patel and patel 2006). Similar findings were obtained during present investigation.

4.4.2 Incubation period and hatching

The observations on incubation period and percentage of hatching are presented in table 7.

Table 7. Incubation period and hatching percentage of *O. materna*

Sr. No.	Date of eggs kept	Number of eggs kept	Number of eggs hatched				Total eggs hatched	Percent-age of hatching
			1 day	2 day	3 day	4 day		
1.	2.10.2007	10	-	6	3	-	9	90
2.	2.10.2007	10	-	4	6	-	10	100
3.	3.10.2007	10	-	5	4	-	9	90
4.	3.10.2007	10	-	7	3	-	10	100
5.	4.10.2007	10	-	5	5	-	10	100

Average incubation period = 2.5 days
Range of incubation period = 2-3 days
Hatching percentage = 96 per cent

The incubation period ranged from 2-3 days with mean of 2.5 days and 96 per cent of eggs were hatched. Earlier workers reported the incubation period as 2-4 days and average hatching percentage of egg was 89 percent (Baptist, 1944; Shrivastav and Bogawat, 1969, Lolage and Khaire, 1998, Bhumannavar and Viraktamath, 2001a, Mohite *et al,* 2004 and Patel and Patel, 2006). The results of present investigation are in agreement with the findings of all these workers.

4.5 Larval stage

Investigations were made on the biology of *O. materna* under laboratory conditions revealed that the insect had six larval instars. The details of each larval instar are presented here under.

4.5.1 First instar larva

The first instar larva came out from the egg by making a small hole in to the egg shell. The newly hatched larva, a semilooper, was very active, restless and searched the tender leaves traveling long distances. The body was transparent and pale yellow in colour. The colour of larva changed to green soon after few minutes when it started feeding on the tender leaves of *Tinospora cardifolia.* Initially the larva scraped the surface of the leaf while feeding and later on started cutting the leaves from margins. Body had a few short black setae. Microscopic hairs sparsely distributed all over the body. The colour of the head capsule was light brown with six prominent ocellion on either side. Thorax possesses well developed pair of legs on each segment. A pair of prolegs was present on each fourth, fifth,

sixth and tenth abdominal segments. The pair of prolegs on third abdominal segment was rudimentary and not used in walking. A hump like structure was present on eighth abdominal segment. The larva held the post abdominal segments upward like tail during resting condition. Last abdominal segment was having a pair of leg like structure used to support the abdomen while walking; however, it was held upwards like two fingers at rest (Plate 7B).

The present observations are in accordance with earlier workers, Ayyar (1944), Baptist (1944), Srivastava and Bogawat (1969), Lolage and Khaire (1998), Bhumannavar and Viraktamath (2001a), Mohite *et al.* (2004) and Patel and Patel (2006).

The measurements of newly hatched first instar larvae are presented in table 8.

Table 8. Measurements on first instar larva of *O. materna*

Sr. No.	Length (mm)	Breadth (mm)	Head capsule width (mm)	Weight (g)
1	3.8	0.8	0.4	0.0008
2.	3.6	0.9	0.5	0.0011
3.	3.8	0.7	0.3	0.0010
4.	4.0	0.7	0.6	0.0009
5.	3.9	0.8	0.4	0.0008
6.	3.8	0.9	0.4	0.0012
7.	4.2	0.6	0.3	0.0009
8.	4.5	0.8	0.5	0.0012
9.	4.8	0.8	0.6	0.0009
10.	4.9	0.9	0.5	0.0011

Mean length = 4.13 mm
Mean breadth = 0.79 mm
Mean head capsule width = 0.45 mm
Mean weight = 0.001 g

The average length and breadth of larvae were 4.13 mm and 0.79 mm, respectively. The average head capsule width was 0.45 mm and the average weight of larva was 0.001 g. The mean duration of the first instar was found to be 2 days.

The first instar larva became sluggish and inactive at the time of the first moult. At the beginning of moulting process, the larva started to pull out its thorax and abdomen from the old cuticle. As soon thorax and abdomen became free from old cuticle, the head capsule separated from the body. Baptist (1944) and Mohite *et. al.* (2004) recorded first instar larval duration as 3 days.

Lolage and Khaire (1998) reported that the first instar larval duration was 2 days, while Bhumannavar and Viraktamath (2001a) reported 3-4 days.

Patel and Patel (2006) reported that the average length and breadth of first insatar larva were 4.32 $\pm$ 0.42 mm and 0.86 $\pm$ 0.05 mm, respectively. The average development period of first instar larva was 2.10 $\pm$ 0.31 days. These findings are more or less similar to present investigations.

4.5.2 Second instar larva

The second instar larva was greenish black when freshly moulted and changed to brownish black after few hours of moulting. The colour of the head capsule was brown. Body was smooth with three orange spots subdorsally on second, third and fourth abdominal segments. Anal hump on eighth abdominal segment became prominent in this instar. Four white

spots were present on both dorsolateral sides of the hump. The measurements on second instar larva are presented in table 9.

Table 9. Measurements on second instar larva

Sr. No.	Length (mm)	Breadth (mm)	Head capsule width (mm)	Weight (g)
1	11.8	1.1	0.7	0.0018
2.	11.9	1.0	0.6	0.0020
3.	12.5	1.3	0.8	0.0012
4.	12.6	1.1	0.7	0.0024
5.	11.9	1.4	0.9	0.0021
6.	12.2	1.2	0.8	0.0019
7.	12.0	1.2	0.9	0.0022
8.	11.8	1.0	0.9	0.0023
9.	11.9	1.1	0.8	0.0021
10.	12.1	1.3	0.7	0.0020

Mean length = 12.05 mm
Mean breadth = 1.17 mm
Mean head capsule width = 0.78 mm
Mean weight = 0.002 g

The mean duration of second instar larva was 1.5 days and was measured on an average of 12.05 mm in length and 1.17 mm in breadth. The average head capsule width of second instar larva was 0.78 mm and weight 0.002 g.

The second instar larva was dark in colour but no distinct markings were present and the period occupied by 3

days (Hargreaves 1936 and Baptist, 1944). The results of present investigation are in agreement with Lolage and Khaire (1998), Bhumannavar and Viraktamath (2001a) and Mohite *et al.* (2004).

Patel and Patel (2006) reported that the average length and breadth of second instar larva were 11.81 ± 0.44 mm and 1.26 ± 0.15 mm respectively. The average development period of second instar larva was 1.35 ± 0.49 days. These findings are more or less similar to present investigations.

4.5.3 Third instar larva

Body and head capsule of the third instar larva were black in colour (with two faint black lines running parallel to each other on dorsal side of the abdomen). The partial eyespots appeared on second and third abdominal segments. This eye spot was yellowish at the lower side and slightly whitish coloured towards upper side. The central portion of the eye spot was completely black. Nine pairs of spiracles were visible of that one pair on prothorax and eight pairs on abdominal segments. The spiracles were surrounded by whitish blue spots. The sixth abdominal segment was found with big white irregular spot on lateral sides. The prolegs were well developed and black in colour.

The measurements on third instar larvae were presented in table 10.

Table 10. Measurements on third instar larva

Sr. No.	Length (mm)	Breadth (mm)	Head capsule width (mm)	Weight (g)
1	20.8	2.1	1.4	0.0782
2.	19.6	2.5	1.5	0.0913
3.	19.5	2.2	1.3	0.1220
4.	21.2	2.3	1.5	0.0985
5.	22.1	2.0	1.4	0.0990
6.	20.9	1.9	1.6	0.1120
7.	22.0	1.8	1.5	0.0950
8.	19.8	2.0	1.4	0.0880
9.	20.6	1.9	1.5	0.0918
10.	21.4	2.0	1.5	0.0890

Mean length = 20.79 mm
Mean breadth = 2.07 mm
Mean head capsule width = 1.4 mm
Mean weight = 0.09648 g

The mean length and breadth of third instar larva were 20.79 mm and 2.07 mm, respectively. The mean head capsule width of the larvae measured 1.4 mm and average weight was 0.09648 g. The third instar larval duration was lasted for 2 days.

Baptist (1944) recorded larval period of 4 days. Lolage and Khaire (1938) reported the larval period of third instar was 2-3 days. Bhumannavar and Viraktamath (2001a) reported the

duration of this instar as 2-2.5 days. Mohite *et al.* (2004) reported that the average duration of third instar larva was 3 days.

Patel and Patel (2006) reported that the average length and breadth of third instar larva were 18.8 ± 1.28 mm and 2.58 ± 0.33 mm respectively. The average development period of third instar larva was 2.50 ± 0.51 days.

4.5.4 Fourth instar larva

The colour of the body and head capsule of the fourth instar larva was black. Two parallel lines of gray colour were running dorsally towards posterior side of the abdomen from the fourth segment. Three white spots were present on these lines on each segment. Hump had reddish colour on the top and single vertical white streak at lateral sides. The second and third abdominal segments had prominent eyespots. Each eyespot consisted of two rings, inner ring was completely black and the space between two rings was yellow coloured dorsally and orange ventrally. The last segment had very well developed pair of anal legs. Pair of legs was present on each third, fourth, fifth and sixth abdominal segments. First pair of proleg was not well developed and not used for walking. The spiracles were surrounded by reddish colour with four blue spots.

The measurements on the fourth instar larva were presented in table 11.

Table 11. Measurements on fourth instar larva

Sr. No.	Length (mm)	Breadth (mm)	Head capsule width (mm)	Weight (g)
1	28.2	4.0	2.2	0.4950
2.	30.4	4.0	2.0	0.4420
3.	34.5	4.2	1.9	0.4180
4.	32.6	4.1	2.1	0.3960
5.	30.9	4.1	2.2	0.4250
6.	29.6	3.9	1.9	0.3885
7.	29.8	4.2	2.3	0.4050
8.	28.8	4.0	2.2	0.4125
9.	30.2	3.9	2.1	0.4100
10.	31.2	3.9	2.2	0.3900

Mean length = 30.52 mm
Mean breadth = 4.03 mm
Mean head capsule width = 2.11 mm
Mean weight = 0.4182 g

The average duration of the fourth instar larva was 3 days. The mean length, breadth, weight and head capsule width of fourth instar larva were 30.52 mm, 4.03 mm, 0.4182 g and 2.11 mm, respectively. Earlier workers reported the mean duration of this instar as 3-4 days (Baptist, 1944; Srivastava and Bogawat, 1968, Lolage and Khaire, 1998, Bhumannavar and Viraktamath, 2001a, Mohite *et al.,* 2004 and Patel and Patel, 2006). However, the mean body length, breadth and head

capsule width were reported as 35-45 mm, 4.15 mm and 2.7 mm, respectively (Srivastava and Bogawat, 1969 and Patel and Patel, 2006). The present findings were in agreement with the reports of these workers.

4.5.5 Fifth instar larva

The colour was similar to that of the fourth instar larva. Thoracic segments with deep blue and orange spots. Eye spots present on second and third abdominal segments were large and attractive. The colour of the hump was grayish red. Whenever the feeding larva was disturbed, it exhibited threat posture, the head arched under thoracic segments making the eyespots brighter and large and the caudal areas was elevated.

The measurements on fifth instar larvae were presented in table 12.

Table 12. Measurements on fifth instar larva

Sr. No.	Length (mm)	Breadth (mm)	Head capsule width (mm)	Weight (g)
1	48.6	8.5	4.1	1.2340
2.	49.2	8.2	4.0	1.3940
3.	50.3	8.3	3.8	1.4160
4.	47.7	7.9	3.9	1.1058
5.	48.5	8.2	4.2	1.2050
6.	50.2	8.4	3.9	1.2560
7.	46.8	8.3	3.9	1.3980
8.	48.2	8.4	4.1	1.2560
9.	48.5	8.0	4.0	1.4275
10.	48.3	8.1	4.0	1.4155

Mean length = 48.43 mm
Mean breadth = 8.23 mm
Mean head capsule width = 3.99 mm
Mean weight = 1.3107 g

The average length, breadth and head capsule width were 48.43 mm, 8.23 mm and 3.99 mm, respectively. The mean weight of the larva was 1.3107 g. The average duration of fifth instar was 3 days.

Baptist (1944) reported that the fifth instar larval duration was 4 days. Srivastava and Bogawat (1969) reported 4-7 days larval duration and the length of larva was 45-62 mm. Bhumannavar and Viraktamath (2001a) reported the duration of this instar varied from 3-4 days in population with 5 instars and 2-3 days in isolation with 6 instars. Mohite *et al.* (2004) reported the larval duration as 4-5 days.

Patel and Patel (2006) reported that the average length and breadth of fifth instar larva were 65.33 $\pm$ 0.51 mm and 8.83 $\pm$ 0.14 mm respectively. The average development period of fifth instar larva was 3.85 $\pm$ 0.37 days. The present findings were in agreement with the reports of these workers.

4.5.6 Sixth instar larva

The gray coloured lines were present on the abdomen of sixth instar larva and the lateral sides were transformed into red. The gray coloured regions which were present in fourth and fifth instars were transformed into red colour. The prolegs were also became red colour. The head and thoracic legs were black. The hump on eighth segment also became red in colour. Three irregular white patches were present on both the lateral sides of sixth, eighth and anal segments. Two gray spots appeared laterally just above the spiracles on fourth and sixth abdominal segments. Three to four blue coloured spots were present

surrounding the spiracles on the body. The size of eye spots was increased and colour became bright (plate 7C).

The measurements on sixth instar larva were presented in Table 13.

Table 13. Measurements on sixth instar larvae

Sr. No.	Length (mm)	Breadth (mm)	Head capsule width (mm)	Weight (g)
1	55.8	9.0	4.6	2.3600
2.	56.2	8.9	4.4	2.2085
3.	54.9	8.7	4.7	2.4058
4.	55.1	8.8	4.7	2.3060
5.	55.2	8.8	4.5	2.3075
6.	55.8	8.9	4.4	2.1949
7.	56.3	8.7	4.6	2.2184
8.	57.7	8.8	4.5	2.3025
9.	57.3	8.9	4.3	2.2075
10.	56.9	8.8	4.4	2.3110

Mean length = 56.12 mm
Mean breadth = 8.83 mm
Mean head capsule width = 4.51 mm
Mean weight = 2.262 g

The average length, breadth, weight and head capsule width were 56.12 mm, 8.83 mm, 2.262 g and 4.51 mm, respectively. The larval duration was 2 days.

Baptist (1944) reported that the colour of last instar larva was brown with black markings. Bhumannavar and Viraktamath (2001a) reported the duration of 6th instar larva as 4 days. The present findings were in agreement with the reports of these workers.

4.5.7 Total larval period

The total larval duration ranged from 12 to 14 days with an average of 13 days under laboratory conditions.

Ayyar (1944) reported that the larval period lasts from 4-5 weeks. While Bhumannar and Viraktamath (2001a) reported that the larval duration was 13.08 ± 0.73 days.

Patel and Patel (2006) reported that the total larval period was 13.25 ± 1.25 days.

4.6 Pupation

The last instar larva ceased feeding and movement. The pupatiohn took place in a cocoon made up of white silk spun between dried leaves of *T. cardifolia.* After formation of cocoon the larva was undergone for pupation within 12 to 24 hours. The pupa was obtect type, dark brown in colour, anterior end was blunt and posterior end was conical.

The male and female pupae were differentiated by observing under microscope. In male pupa, vertical slit surrounded by swollen circle was present ventrally at the centre on ninth abdominal segment while in female pupa; vertical slit was present at the junction of eighth and ninth abdominal segment in the middle of ventral side (plate 7D).

The average pupal period was lasted from 10-15 days. The pupal duration was 10-15 days in males and 11-15 days in females.

The measurements of pupae of both the sexes are presented in table 14.

Table 14. Measurements on pupa

Sr. No.	Male pupa			Female pupa		
	Length (mm)	Breadth (mm)	Weight (g)	Length (mm)	Breadth (mm)	Weight (g)
1.	24.6	8.5	1.2538	27.0	10	1.4893
2.	27.4	9.1	1.4710	26.9	10	1.4260
3.	27.1	9.8	1.3942	26.9	10	1.4561
4.	25.0	9.2	1.1572	28.4	9.9	1.5640
5.	26.8	9.9	1.4988	28.9	11	1.5906
6.	25.7	9.3	1.4368	26.0	9.5	1.2938
7.	26.5	9.9	1.2930	27.3	9.1	1.4810
8.	26.2	8.7	1.1189	24.5	9.1	1.3195
9.	25.0	8.7	1.0027	26.0	8.9	1.1031
10.	2.3	8.1	0.7569	24.5	8.4	0.8904

		Male pupa	Female pupa
Mean length	=	25.60 mm	26.64 mm
Mean breadth	=	9.12 mm	9.59 mm
Mean weight	=	1.2383 g	1.208 g

Average length, breadth and weight of male pupa were 25.60 mm, 9.12 mm and 1.2383 g, respectively. The average

length, breadth and weight of female pupa were 26.64 mm, 9.59 mm and 1.208 g, respectively.

According to Ayyar (1944) the pupal period was 14-18 days and length of pupa was 20 mm. Baptist (1944) reported 14-16 days of pupal period. Atwal (1963) reported that the pupal period lasted for 2 weeks. Srivastava and Bogawat (1969) reported the length and breadth of pupa were 22-27 mm and 7-9 mm, respectively. Bhumannavar and Viraktamath (2001a) reported the pupal period was 12-14 days and Mohite *et al.* (2004) reported 8-10 days.

Patel and Patel (2006) reported that the average length and breadth of pupal stage was 25.04 ± 1.11 mm and 8.95 ± 0.59, respectively in case of male and 26.16 ± 1.72 and 9.45 ± 0.53 mm, respectively in case of female. The pupal period was 12.85 ± 1.09 days. The present findings were in agreement with the reports of these workers.

4.7 Adult stage

Adult moths were large in size and stoutly built. They were nocturnal in habit and emerged at night during monsoon season. Sexual dimorphism was seen by the pattern of the forewings. However, they could be easily identified by the coloration of forewings. The wing venation was similar in both the sexes.

Male

Head and thorax of male moth was greenish gray; abdomen orange, forewing greenish gray with numerous faint striated reddish lines; three rufous spots at end of cell; a dark

oblique line from near apex to centre of inner margin, a silvery patch on vein 1 and another below lower angle of cell; a marginal black band with crenulated inner edge; a series of white cilial spots. Underside orange; Costa and apical area blotched with rufous; oblique post medial and sub apical black bands. Inner margin appeared serrated with a perceptible angel at ¼ the length near base. Hind wings with the apical area blotched with rufous, a black spot on costa; another beyond lower angle of a cell; a marginal black band from vein 5 to anal angle. Apical margin with eight half moon shaped white spots (Plate 2A). The moth measured about 29.82 mm in length with mean wing expanse 66.67 mm (table 15).

Patel and Patel (2006) reported that the average length of male month was 29.84 ± 0.94 mm and breadth with expanded wing of male moth was 76.07 ± 1.82 mm.

Female

The colouration of female moth was as in male but with the following difference. Forewing more prominently striated with rufous, the silvery patches below and beyond cell, very large and conjoined, crossed by white streaks above vein 2 and beyond cell. Inner margin like in male with the angle less prominent (Plate 2B). The moth measured about 28.62 mm in length and mean wing expanse was 66.12 mm (table 15).

Patel and Patel (2006) reported that the average length of female month was 30.36 ± 1.47 mm and breadth with expanded wing of female moth was 76.54 ± 1.46 mm.

Table 15. Measurements on adult moths

Sr. No.	Male			Female		
	Length (mm)	Breadth (mm)	Weight (g)	Length (mm)	Breadth (mm)	Weight (g)
1.	30.0	65.0	21.2	28.7	65.5	18.5
2.	30.5	66.0	22.0	28.5	65.4	19.6
3.	28.5	62.8	20.2	28.7	68.7	19.6
4.	28.9	68.0	19.2	28.5	67.0	19.8
5.	29.3	64.2	18.9	30.8	68.7	18.8
6.	31.5	69.4	18.8	31.9	65.4	14.8
7.	29.7	66.7	20.3	32.2	64.0	19.8
8.	30.6	64.9	19.1	31.9	65.4	18.8
9.	29.7	67.5	19.8	30.8	65.4	19.2
10.	29.5	66.9	20.0	28.7	68.7	19.4

		Male	Female
Average length	=	29.82 mm	28.62 mm
Average wing expanse	=	66.67 mm	66.12 mm
Average wing folded	=	19.95 mm	18.30 mm

4.7.1 Adult longevity

The longevity of adult male and female moth of *O. materna* ranged from 27 to 30 days with an average of 28.5 days and 30 to 33 with an average 31.5 days, respectively. Similar results were obtained by Patel and Patel (2006).

4.7.2 Total life cycle of *O. materna*

The duration on total life cycle of *O. materna* was presented in table 16.

Table 16. Duration on life stages of *O. materna*

Stage		Duration (days)	
		Range	Mean
Egg		2-3	2.5
Larva		14-16	14
First instar		2	2
Second Instar		1-2	1.5
Third instar		2	2
Fourth instar		3	3
Fifth instar		3	3
Sixth instar		2	2
Pupa	Male	10-15	12.5
	Female	11-15	13
Adult	Male	27-30	28.5
	Female	30-33	31.5
Total life cycle	Male	53-64	58.5
	Female	57-67	62

The total life period of male varied from 53 days to 64 days with an average of 58.5 days. While in female, it ranged from 57 to 67 days with an average of 62 days.

Baptist (1944) reported the total life cycle of *O. materna* ranged from 5 to 6 weeks. Srivastava and Bogawat

(1969) reported that the total life cycle was 25-30 days under laboratory condition at Udaipur. Bhumannavar and Viraktamath (2001a) reported that *O. materna* completed development from egg to adult stage in 32.42 to 34.25 days. Mohite *et al.* (2004) reported that the life history of *O. materna* from egg to death of adult was 44 to 54 days in males and 49 to 60 days in females.

Patel and Patel (2006) reported that total life period was 49 to 62 days for male and 55 to 66 days for female of *O. materna.*

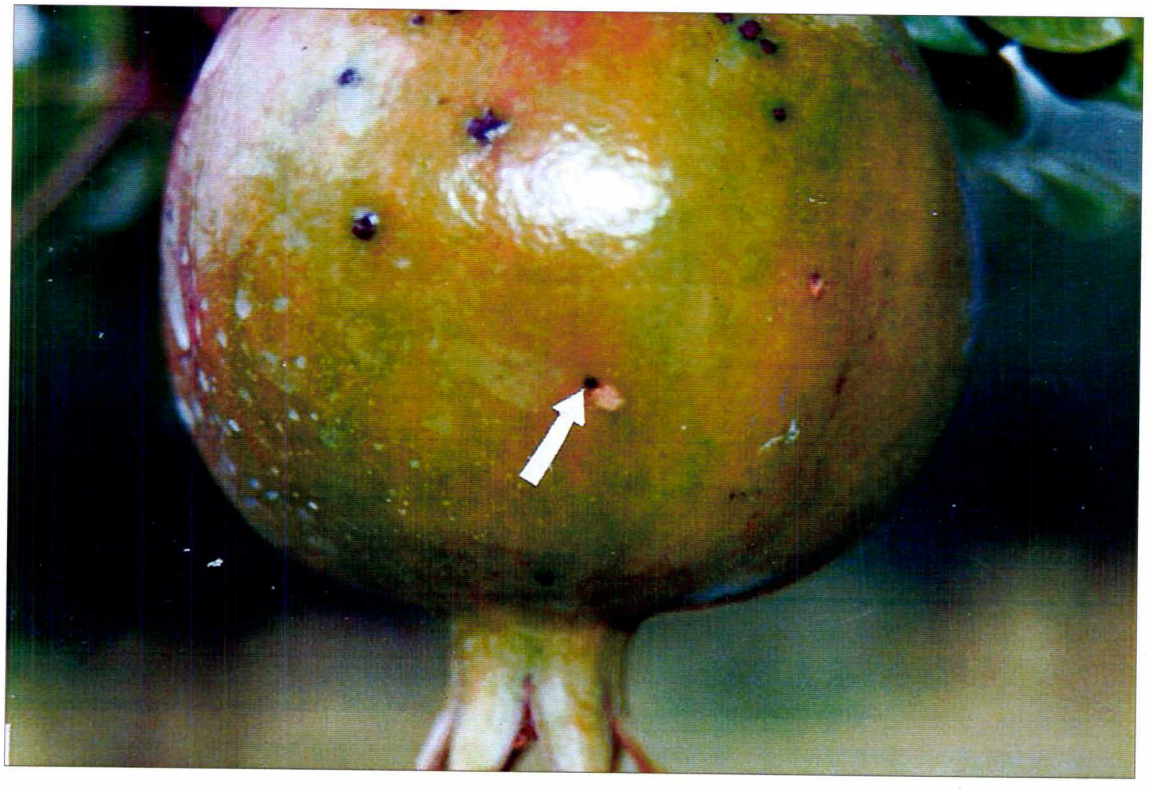
4.8 Nature of damage

Only the adult stage alone was responsible for damaging the fruits. The moths were nocturnal in habit and came to orchards at dusk. They were attracted by the strong aroma of ripening fruits. In the process of feeding, the moth alighted and settled on the fruit and then they searched the surface with the apex of its proboscis, driven in the rind of the fruit with a slow drilling action. The piercing normally completed in less than a minute and then sucking began.

As the juice becomes exhausted at a particular site the proboscis was thrusted deeper until all the juice sucked in the direct path of the proboscis. The area surrounding the feeding hole became soft, fungal and bacterial entry could took place at the site of attack. The puncture changed to brown as the tissue rotted. The rotten area spreads further and fruit became unfit for consumption (Plate 8B).

Baptist (1944) recorded similar observations. He observed that the path of the proboscis was always in a direct

Plate 8



A. Damaged fruit (Fresh feeding hole)

B. Rotting of infested fruit

straight line. If, no satisfactory site is reached by the first insertion, the proboscis was completely withdrawn and inserted at a fresh site once again. As many as eight to ten punctures were reported on a single fruit in the present investigation. Hargreaves (1936) reported 10 such punctures on a single fruit. Yadava (1969) recorded 50 punctures on a single fruit.

4.9 Use of lights to attract the moths

The attraction of moths of *O. materna* to different coloured lights and ultraviolet light were studied in the laboratory during the year 2007. The result was negative. Not a single moths were attracted to any of the lights, which were used in the study *viz.*, red, yellow, blue, green, milky white and ultraviolet light. The results were presented in table 17.

Table 17. Attraction of moths to different coloured light

Sr. No.	Light colour	Number of moths released	Number of moths attracted	Percentage attraction
1.	Red	10	0	0
2.	Yellow	10	0	0
3.	Blue	10	0	0
4.	Green	10	0	0
5.	Milky white	10	0	0
6.	Ultraviolet	20	0	0

Baptist (1944) reported that the trees illuminated by light were less infested by moths compared to trees in the darkness. Nomura *et al.* (1965) in Japan reported that 60 per cent reduction in activity of moths in the orchards. This

indicated that moths were repelled by light. Present investigation confirmed that this moth was negatively phototrophic in nature.

These moths were attracted by ultraviolet light and repelled by white light (Bosch, 1971). If exposed to green-yellow light of mercury lamps, they adopt to the light and assume their resting day light behaviour (Bosch, 1971).

White head and Rust (1976) reported that the moths activity reduced by 93 per cent in peach orchard by placing Kerosene pressure lamps. Fay (2005) reported that lights emitting yellow-green wavelength suppress moth feeding by 70 per cent at moderate population level.

4.10 Food attractants for fruit sucking moth

The results on food attractants of fruit sucking moth were presented here.

4.10.1 Attractants of natural fruit juice

The observations noted on number of moths attracted for attractants prepared by natural fruit juice has been presented in table18.

Table 18. Attraction of moths to different natural fruit attractants

Sr. No.	Fruit attractants	Number of moths released	Number of moths attracted	Percentage attraction
1.	Banana	10	6	60
2.	Guava	10	4	40
3.	Orange	10	3	30
4.	Pineapple	10	2	20
5.	Pomegranate	10	3	30
6.	Sapota	10	2	20
7.	Sweet orange	10	4	40

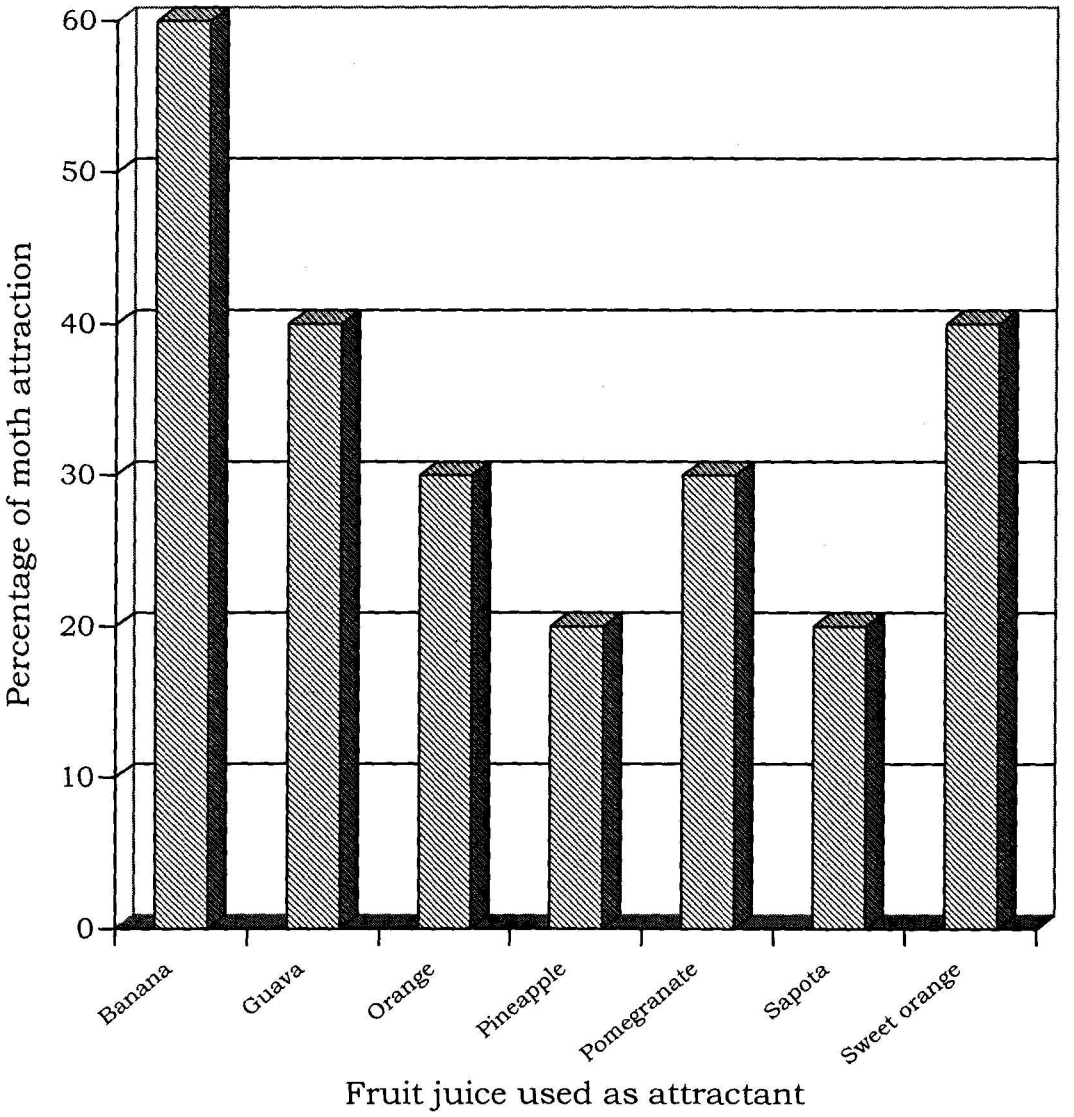


Fig. 1. Extent of moth attraction to different natural fruit attractants

The results indicated that the maximum number of moths (6) were attracted for attractants prepared by banana juice (60 %) followed by attractants of sweet orange (40 %) and guava (40 %). The least number of moths (2) were attracted for attractants of pineapple and sapota juice (20 %). The attractants prepared by orange and pomegranate juice were attracted by 3 moths each (30 %).

Bajpai (1955) reported that about 211 moths of *O. fullonia,* 72 of *O. materna* and 119 of *Achaea janata* were attracted to the attractants during the period of 30th July 1952 to 16th September, 1952 in the field condition.

Reddy *et al.* (2007) reported that the *Eudocima phalonia* moths were preferred to feed on banana attractants more than any other, followed by guava and orange. During present investigation it was found that the *O. materna* moths were more attracted to banana attractants followed by sweet orange and guava.

4.10.2 Attractants of artificial essence (flavours)

The observations on moths attracted for attractants of artificial essence were presented in table 19.

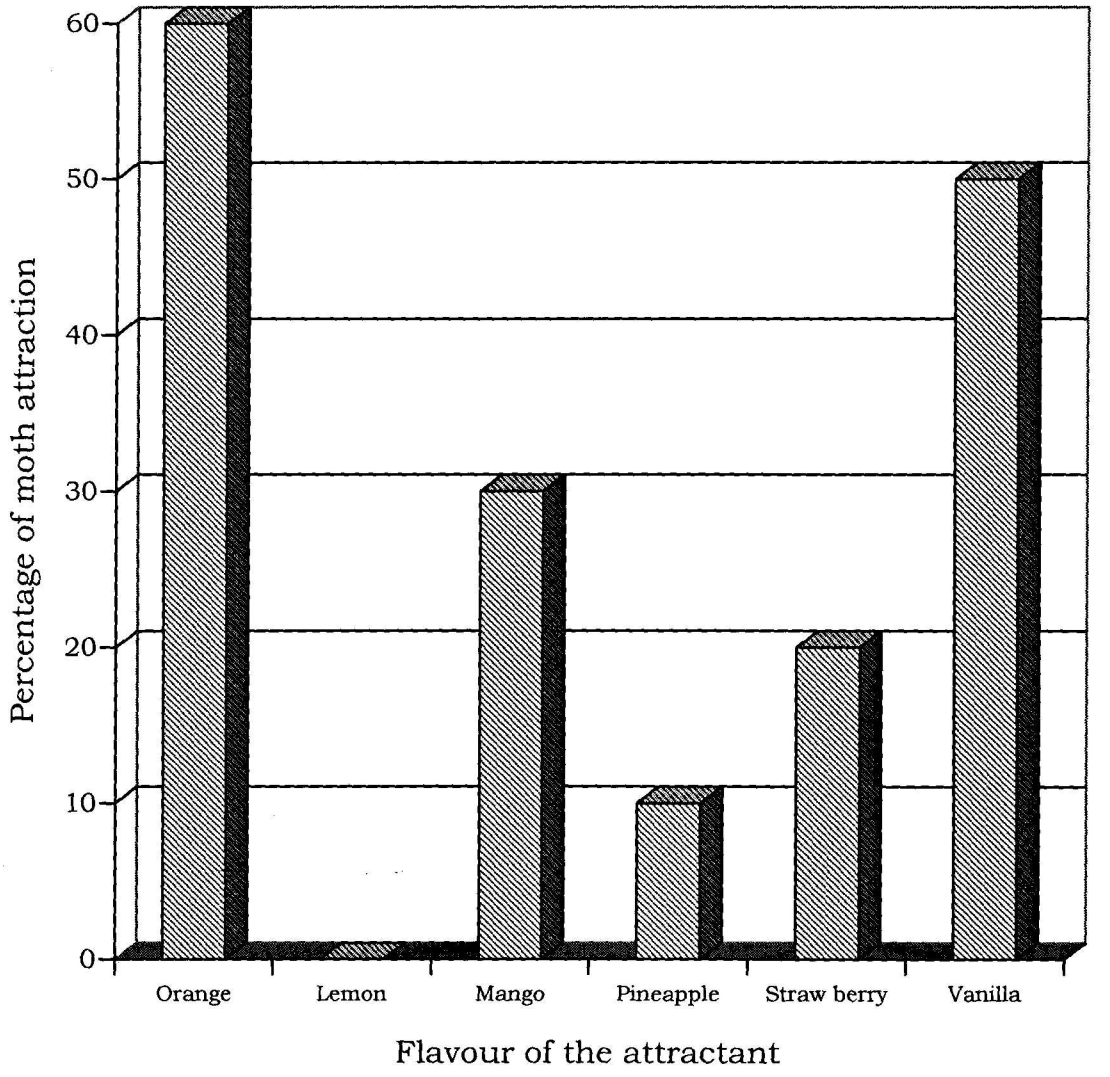


Fig. 2. Extent of moth attraction to different attractants of artificial essence (flavours)

Table 19. Attraction of moths to different attractants prepared by artificial flavours

Sr. No.	Flavour used as an attractant	Number of moths released	Number of moths attracted	Percentage attraction
1.	Orange	10	6	60
2.	Lemon	10	0	0
3.	Mango	10	3	30
4.	Pineapple	10	1	10
5.	Straw berry	10	2	20
6.	Vanilla	10	5	50

The results indicated that more number of moths (6 out of 10) were attracted for attractants of orange flavour (60 %) followed by attractants of vanilla flavour (50 %). None of the moths were attracted for attractants of lemon flavour, however, only one moth (10 %) was noticed on pineapple flavour, while 2 moths (20 %) on attractants of straw berry flavour and 3 moths (30 %) on attractants prepared by mango flavour. During present study it was noticed that the moths were more attracted immediately after release from the cage. They were not settled for more than two minutes except on attractants of orange and vanilla where moths were settled up to five minutes.

SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSION

Investigations on the species of fruit sucking moths, larval and adult host plants, biology of *O. materna*, use of light and food attractants in attraction of moths were undertaken in the laboratory of Department of Entomology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar during the year 2007. The results of the investigations are summarized below.

5.1 Species of fruit sucking moths

Eleven different species of fruit sucking moths were recorded feeding on fruits of pomegranate and citrus in orchards located around the vicinity of University Campus and near by villages. Among them three were of primary fruit sucking moths *viz.,, Othreis fullonia* Clerck, *Othreis materna* Linn., *Othreis homaena* Cramer and eight were secondary fruit sucking moths *viz.,, Achaea janata* Linn., *Ophiusa coronata* Fabricius, *Ophiusa tirhaca* Cramer, *Paralellia algira* L., *Remigia archesia* Cramer, *Anomis flava* Fab., *Mocis frugalis,* and *Achaea serva.*

5.2 Host plants of *O. materna*

The larval and adult host plants were studied in the laboratory. Seven different plants of menispermaceae were tested as larval hosts. The larva of *O. materna* could feed and complete development only on *Tinospora cardifolia.*

Thirteen different fruits were tested as an adult hosts which includes pomegranate, sapota, apple, banana, tomato,

aonla, brinjal, sweet orange, guava, papaya, custard apple, pineapple and grape. All these were found damaged by the moths of *O. materna.*

5.3 Biology of *O. materna*

The life cycle of *O. materna* was studied under laboratory condition during 2007. The moths were collected from orchards of pomegranate and citrus during night hours for initial culture. The adults were reared in cages by providing pomegranate and mandarin fruits as a food. The female moths laid eggs singly on the cloths of cages and also loosely in the cages. The egg laying capacity of female was 800-950 per female. The average incubation period was 2.5 days. Six larval instars were reported with an average of 2, 1.5, 2, 3, 3 and 2 days, respectively. The total larval period ranged from 13-15 days with an average of 14 days. The length of larva increased from 4 mm to 55 mm and weight increases from 0.0009 to 2.30 g during the entire larval period. The average pupal period of male and female was 12.5 and 13 days, respectively. The average longevity of male and female moth was 28.5 days and 31.5days, respectively. The total life period of male varied from 53 days to 64 days with an average of 58.5 days. While in female, it ranged from 57 to 67 days with an average of 62 days.

5.4 Use of light to attract moths

The attractions of moths of *O. materna* to different coloured lights were studied in the laboratory. Five coloured lights and ultraviolet lights were studied, but no moths were attracted to any of the coloured light.

5.5 Food attractants of *O. materna*

The attraction of *Othreis materna* to different fruit attractants and artificial essence (flavours) was studied in the laboratory. Seven natural fruit attractants and six attractants of artificial flavours were studied.

Of the seven fruit attractants tested, moths of *O. materna* preferred to feed on banana (60%) attractants more than on any other, followed by sweet orange (40%) and guava (40%) attractants. Pineapple and sapota attractants were least attractive. The attraction of moths to attractants prepared by orange (30 %) and pomegranate (20 %) were substantial. Among the attractants of artificial flavours the moths were preferred to feed on attractants of orange flavour (60 %) followed by attractants of vanilla flavour (50 %). The attractants prepared by lemon flavour was least attractive. The attraction of moths to attractants prepared by mango (30 %), pineapple (20 %) and strawberry flavours (20 %) were substantial. The moths were settled maximum time on natural fruit attractants than on the artificial attractants.

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*** Originals are not seen**

VITA

7. VITA

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of

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in

AGRICULTURAL ENTOMOLOGY

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