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RESEARCH ARTICLE

Damage potential of primary fruit-piercing moths *Eudocima* and *Rhytia* spp. (Lepidoptera: Noctuidae) and their biointensive management in guava and mandarin orange

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Abstract

Fruit-piercing moths belongs to the genus *Eudocima* spp. and *Rhytia hypermnestra* (Lepidoptera: Noctuidae) are a major pests of ripening and semi-ripening fruits viz. citrus, guava, pomegranate, grapes, fig, sapota, mango, papaya and tomato in India. The damage potential of fruit-piercing moths (FPM) on number and weight basis revealed that the per cent damage in guava ranged from 0 %-22.64 % and 0 %-20.90 % respectively at Agricultural College and Research Institute (AC & RI), Madurai. In the field I of Palamedu area, per cent damage recorded in guava was 17.90 %-21.91 % (number basis) and 17.89 %-22.22 % (on weight basis) and in field II of Palamedu area, it was ranged from 17.22 %-22.65 % and 15.16 %-20.89 % respectively. Similarly, the mean per cent fruit damage was recorded to range from 13.29 %-24.46 % on number basis in mandarin orange at Lower Palani Hills. To manage the FPM, seven treatments viz. light trap, fruit trap, delta trap, neem oil 3 %, NeemSweet - P 60 EC at 0.24 %, *Opuntia dillenii* including untreated control were evaluated. The mean per cent fruit damage prior to first round of application in all the treatments were 23.89 %-25.91 %. The damage increased to 27.75 % in the untreated check during 14 days after treatment (DAT), however lesser extent of damage was recorded in treated plots. A minimum fruit damage of 15.35 % was recorded in the NeemSweet-P 60 EC-treated plot, followed by neem oil (3 %) with 16.67 % and fruit trap with 17.05 %. Considering the mean per cent reduction after the first round, it was significantly higher in NeemSweet-P 60 EC (44.18 %), neem oil (39.57 %) and fruit traps (38.23 %), as compared to the lesser reduction in *Opuntia dillenii* (13.74 %). Second round application significantly reduced the fruit damage, to an extent of 8.76 % at 7 DAT and 6.20 %-25.20 % at 14 DAT. The cumulative reduction was recorded low in NeemSweet-P 60 EC (11.42 %) and neem oil (13.16 %) whereas it was 30.75 % in the standard check. Corresponding mean per cent reduction over control was high in NeemSweet-P (62.86 %), neem oil (57.20 %) and fruit trap (51.15 %).

Keywords: biointensive; damage potential; *Eudocima;* guava; mandarin orange; *Rhytia*

Introduction

Fruit-piercing moths belongs to the genus *Eudocima* spp. and *Rhytia hypermnestra* (Lepidoptera:Noctuidae) are major pests of ripening and semi-ripening fruits in subtropical and tropical regions such as Africa, South East Asia and Western Pacific countries (1-10). In India, this was first recorded as a serious pest (11). The major primary fruit-piercing moths (FPM) viz. *Eudocima materna* (Linnaeus), *Eudocima phalonia* (Clerck), *Eudocima homaena* (Hübner), *Eudocima salaminia* (Cram.), *Eudocima cajeta* (Cramer) and *Rhytia hypermnestra* (Stoll) were recorded as serious fruit piercers on citrus, guava, pomegranate, grapes, fig, sapota, mango, papaya and tomato in India. These moths can pierce the ripening fruits with the help of thick spines and sclerotised hooks at the tips of proboscis and sucks the juice. The affected fruits show punctured holes of penetration which pave the way for secondary infection by the saprophytic fungi viz. *Oospora* sp. (12, 13), *Fusarium* sp., *Colletotrichum* sp. and certain bacteria (1) resulting in heavy yield loss of more than 50 % (8, 14). However, the symptoms are sometimes mistaken by farmers for fruit fly attack and fruit rot disease as wrong diagnosis. Due to nocturnal habit of larvae and adults of FPM and difference in feeding habits, the management of fruit sucking moth is rather difficult. Considering the seriousness of the problem and scanty information, the present study was undertaken at Agricultural College and Research Institute (AC & RI), Madurai to assess the damage potential of *Eudocima* spp. and its biointensive management.

Materials and Methods

Damage potential of *Eudocima* spp. and *R. hypermnestra*

During the ripening period of guava fruits, the damage caused by the FPMs was assessed in the guava orchard at AC & RI, Madurai, Tamil Nadu, India by recording the damaged and undamaged fruits on the number and weight basis daily for a period of four weeks (Fig. 1). The guava varieties like Smooth Green, Red Fleshed, Lucknow-46,

Primary fruit piercing moth - *Othreis materna*

Secondary fruit piercing moth - *Anua corona*

Fig. 1. Primary and secondary fruit-piercing moths.

Lucknow-49 and Chittidar were observed for damage. Based on the damage percentage the most preferred and least preferred varieties were identified.

Similar studies were also conducted in guava orchard at Palamedu, Madurai district during September-October 2022 and in mandarin orange orchards at Thandikudi of Lower Palani Hills, Dindigul district , during November 2022.

Management of *Eudocima* spp. and *R. hypermnestra*

A field trial was conducted in guava orchard in the field I and II of Palamedu area of Madurai district, Tamil Nadu during September-October months for the management of *Eudocima* spp. and *R. hypermnestra*. The seven different treatments viz. light trap, fruit trap, delta trap, neem oil 3 %, NeemSweet - P 60 EC at 0.24 %, *Opuntia dellinii* including untreated control were evaluated against adults of FPMs (Fig. 2). Each treatment was replicated four times and five guava trees (variety: Lucknow - 49) were taken for observation per replication. The experiment was conducted using a randomized block design (RBD).

The method of preparation and imposing of treatments are as follows: The light trap (T1) was installed in the centre of the selected plants using yellow bulb (200 W) and it was illuminated

Fig. 2. Different types of traps.

from 7.00 PM to 5.00 AM. The fruit trap (T2) was prepared by using guava fruit extract (semi solid - 500 mL prepared by adding sufficient quantity of water), sugar (100 g) and malathion 0.05 % (2 mL). The fruit pulp was kept in a wide mouth plastic container (30 cm x 23 cm) and the mouth was covered by open cone shaped funnel having the diameter of 21 cm x 10 cm which allows the entry of the moths inside the plastic container. The inner surface of the funnel was smeared with grease. The plastic containers were hung at the rate of one per tree. The contents were changed at weekly interval. The hollow triangular delta trap (T3) was prepared by using thick cardboard sheet. The outer surface of the trap was pasted by laminated paper sheet to prevent the trap from settling of moisture, dew etc. The inner surface of the trap was smeared with sticky material. At the bottom of the trap, a plastic plate was firmly attached and a guava fruit was placed to attract the adult moths. This trap was hung at the rate of two per tree. The fruits were replaced daily by fresh ones. Locally available neem oil (T4) was used for the spraying at 3 % concentration along with Teepol at 0.05 %. Two rounds of spray were given at fortnightly interval using a hand operated rocker sprayer. A new neem formulation (T5 - NeemSweet-P 60 EC mixture of oils of *Azadirachta indica* and *Acorus calamus* - patent pending) which was developed at AC & RI, Madurai was tested at 0.24 %. The split opened succulent stems of *O. dillenii* (T6) were hung at a rate of four per tree at four corners of the tree and were replaced once in a week. All the treatments were installed/imposed properly at same day. Without imposing or spraying any treatments, ten trees were kept as control (T7).

Observations and statistical analysis

Five tagged guava trees in each replication were selected to record the percentage of fruit damage caused by the *Eudocima* spp. and *R. hypermnestra*. The percentage of fruit damage was recorded by counting the total number of fruits and infested fruits at each harvest. The observations were taken on a day before spray, 7th and 14th days after spray/installation of treatment. The mean per cent damage was calculated and the data were corrected using the Abbott's formula. The means were separated and compared using Duncan's Multiple Range Test (DMRT).

Results

Damage potential of fruit-piercing moths on guava orchard

The per cent fruit damage was assessed on number as well as weight basis in the guava orchard at AC & RI, Madurai and two fields in Palamedu area of Madurai district, Tamil Nadu. Likewise in lower Palani Hills, the damage potential was assessed in the mandarin orange orchards.

Damage potential on number and weight basis revealed that the per cent damage ranged from 0 %-22.64 % and 0 %-20.90 % respectively at AC & RI Madurai campus (Table 1). The guava varieties viz. Lucknow 49 and Chittidhar were found to be most favoured varieties for the fruit-piercing moths. In the field I of Palamedu area, per cent damage recorded was 17.90 %-21.91 % (number basis) and 17.89 %-22.22 % (on weight basis) and in field II, it was ranged from 17.22 %-22.65 % and 15.16 %-20.89 % respectively (Table 2). In

Table 1. Extent of fruit damage (%) in guava orchard by fruit-piercing moths in Madurai during August, 2022

Guava varieties	Mean in number basis*			Mean in weight basis* (kg)		
	Healthy fruits	Affected fruits	Per cent damage	Healthy fruits	Affected fruits	Per cent damage
Smooth Green	129.20	26.40	16.97 (23.91)^{b}	20.397	4.28	17.35 (24.32)^{b}
Red Fleshed	62.40	16.60	21.01 (27.13)^{c}	5.011	1.08	17.73 (24.86)^{b}
Lucknow-46 (Guja guava)	71.50	0.0	0.0 (0.57)^{a}	5.430	0.0	0.0 (0.57)^{a}
Lucknow-49	117.20	30.50	20.65 (27.02)^{c}	19.03	5.03	20.90 (27.08)^{d}
Chittidhar	137.70	40.30	22.64 (28.46)^{d}	15.871	3.88	19.65 (26.56)^{c}

*Mean of five trees / variety.

Figures in the parenthesis are arc sine transformed values.

Mean followed by the same letter(s) are not significantly different according to DMRT (p = 0.05).

Table 2. Extent of fruit damage (%) in guava orchard by fruit-piercing moths at Palamedu area during September-October, 2022

Date of observation	Field I						Field II					
	Mean in number basis*			Mean in weight basis* (kg)			Mean in number basis*			Mean in weight basis* (kg)		
	Healthy fruits	Affected fruits	Per cent damage	Healthy fruits	Affected fruits	Per cent damage	Healthy fruits	Affected fruits	Per cent damage	Healthy fruits	Affected fruits	Per cent damage
September												
II week	9.12	2.25	19.79 (26.54) ^{ab}	1.44	0.356	19.82 (26.62) ^{ab}	10.33	2.27	18.02 (25.11) ^{a}	1.70	0.340	15.16 (22.91) ^{a}
III week	7.38	1.71	18.81 (25.48) ^{a}	1.16	0.287	19.83 (26.65) ^{ab}	9.76	2.48	20.26 (27.07) ^{b}	1.66	0.397	19.29 (23.06) ^{ab}
IV week	8.13	2.00	19.74 (26.44) ^{ab}	1.28	0.315	19.74 (26.46) ^{ab}	9.56	2.80	22.65 (28.86) ^{bc}	1.53	0.420	20.89 (27.51) ^{bc}
October												
I week	6.88	1.50	17.90 (24.62) ^{a}	1.08	0.247	18.61 (25.49) ^{a}	9.59	2.31	19.41 (26.32) ^{a}	1.39	0.346	20.00 (27.06) ^{b}
II week	7.13	1.86	20.68 (27.28) ^{b}	1.13	0.301	18.05 (25.12) ^{a}	8.99	1.87	17.22 (24.87) ^{a}	1.42	0.283	16.62 (23.93) ^{a}
III week	7.13	2.00	21.91 (29.31) ^{b}	1.12	0.320	22.22 (28.56) ^{c}	8.47	2.06	19.56 (26.46) ^{ab}	1.27	0.310	19.62 (26.27) ^{ab}
IV week	7.12	1.83	20.45 (27.02) ^{b}	1.18	0.296	18.22 (25.07) ^{a}	9.12	1.97	17.76 (25.10) ^{a}	1.35	0.296	17.98 (25.02) ^{ab}
V week	6.13	1.50	19.66 (26.09) ^{ab}	1.06	0.231	17.89 (24.59) ^{a}	7.93	2.00	20.14 (27.17) ^{b}	1.19	0.310	19.68 (23.91) ^{ab}

* Mean of ten trees/field.

Figures in the parenthesis are arc sine transformed values.

Mean followed by the same letter(s) are not significantly different according to DMRT (p = 0.05).

Table 3. Extent of fruit damage (%) in oranges by fruit-piercing moths in Lower Palani Hills during November, 2022

Experimental site	Mean in number basis *		Mean per cent damage
	Healthy fruits	Affected fruits	
Thandigudi	17.6	5.7	24.46 (29.36) ^{d}
Murugan koil	21.3	4.3	16.79 (23.82) ^{b}
Periyamalai	24.8	3.8	13.29 (21.31) ^{a}
Kanalkadu	18.2	4.7	20.52 (25.96) ^{c}
Mangalam kombu	23.3	4.6	16.49 (23.88) ^{b}
Batlan kadu	12.7	3.4	21.12 (27.12) ^{c}
Perum parai	19.8	4.9	19.84 (26.38) ^{c}
Pannai kadu	20.2	3.8	15.83 (23.46) ^{b}

* Mean of ten trees / estate.

Figures in the parenthesis are arc sine transformed values.

Mean followed by the same letter(s) are not significantly different according to DMRT (p = 0.05).

orange fields, the per cent damage was calculated solely on numerical basis, ranged from 13.29 %-24.46 % (Table 3).

Management of fruit-piercing moths

The field experiment on the management of FPMs was conducted in guava orchard at Palamedu area of Madurai district. Six treatments were imposed with four replications.

The mean per cent fruit damage caused by the fruit-piercing moths prior to first round of application in all the treatments were 23.89 %-25.91 %. The damage increased to 27.75 % in the untreated check during 14th DAT, however lesser extent of damage was recorded in treated plots. A minimum of 15.35 % fruit damage was recorded in NeemSweet-P 60 EC treated plot, followed by 16.67 % in neem oil (3 %) and 17.05 % in fruit trap treated plots which were on par with each other when compared to untreated check (Table 4). Similarly, the second round of application significantly reduced the fruit damage, to an extent of 8.76 %-24.46 % at 7 DAT and 6.20 %-25.20 % at 14 DAT. The cumulative reduction was 11.42 % in NeemSweet-P 60 EC and 13.16 % in neem oil, whereas it was 30.75 % in the standard check.

Considering the per cent fruit damage reduction over control after the first round of treatments, it was highest in NeemSweet-P 60 EC (44.18 %) followed by neem oil (39.57 %) and fruit trap (38.23 %) and was lowest in *O. dillenii* (13.74 %). Similarly, the corresponding mean percent reduction over control was highest in NeemSweet-P (62.86 %), followed by neem oil (57.20 %) and fruit trap (51.15 %) (Table 5).

Discussion

Damage potential of fruit-piercing moths in guava and citrus plantations

In the present study the combined fruit damage was 22.64 % on number basis and 19.65 % on weight basis irrespective of varieties in guava orchard.

Table 4. Management of fruit-piercing moths in guava orchard

Treatments	Pre -treatment count	Per cent fruit damage*						Overall mean
		First round of treatments (Days after imposing)			Second round of treatments (Days after imposing)			
		7	14	Mean	7	14	Mean	
Light trap (200 W)	25.91	21.36 (26.76)^{b}	19.31 (25.33)^{c}	20.34 (26.05)^{b}	16.46 (23.66)^{bc}	14.88 (20.71)^{d}	15.67 (22.19)^{d}	18.00 (24.76)^{c}
Fruit trap	23.89	18.10 (25.10)^{a}	16.00 (23.09)^{b}	17.05 (24.09)^{a}	13.76 (21.56)^{b}	12.20 (20.36)^{c}	12.98 (20.96)^{c}	15.02 (23.19)^{b}
Delta trap	24.75	22.55 (27.60)^{b}	20.25 (25.89)^{c}	21.40 (26.75)^{b}	18.91 (25.33)^{cd}	16.75 (23.98)^{e}	17.83 (24.66)^{e}	19.62 (26.72)^{c}
Neem oil (3 %)	24.36	18.00 (25.32)^{a}	15.33 (22.26)^{b}	16.67 (23.79)^{a}	9.46 (18.07)^{a}	9.86 (18.19)^{b}	9.66 (18.13)^{b}	13.16 (21.46)^{a}
NeemSweet-P 60 EC	22.47	17.50 (24.66)^{a}	13.20 (21.80)^{a}	15.35 (23.23)^{a}	8.76 (16.16)^{a}	6.20 (13.58)^{a}	7.48 (14.87)^{a}	11.42 (19.58)^{a}
Opuntia dilleni	25.00	24.00 (29.10)^{c}	23.75 (28.13)^{d}	23.88 (28.62)^{c}	24.46 (36.17)^{e}	25.20 (36.02)^{e}	24.83 (36.09)^{f}	24.35 (36.09)^{d}
Control	23.55	26.40 (30.54)^{d}	29.10 (32.66)^{e}	27.75 (31.60)^{d}	32.42 (33.98)^{f}	35.06 (35.91)^{f}	33.74 (34.95)^{g}	30.75 (33.52)^{e}

* Mean of four replications

Figures in parentheses are arc sine transformed values

Means followed by the same letter (s) are not significantly different according to DMRT (p = 0.05).

Table 5. Effect of implementing various traps in management of fruit piercing moths in guava

Treatments	Per cent reduction over control*						Mean
	First round of application			Second round of application			
	7	14	Mean	7	14	Mean	
Light trap (200 W)	19.09^{c}	33.64^{d}	26.37^{c}	49.23^{c}	57.56^{d}	53.39^{d}	41.46^{d}
Fruit trap	31.44^{b}	45.02^{c}	38.23^{b}	57.56^{b}	65.20^{c}	61.38^{c}	51.15^{c}
Delta trap	14.58^{d}	30.41^{e}	22.49^{d}	41.67^{d}	52.22^{e}	46.95^{e}	36.19^{e}
Neem oil (3 %)	31.82^{b}	47.32^{b}	39.57^{b}	70.82^{a}	71.88^{b}	71.35^{b}	57.20^{b}
NeemSweet-P 60 EC	33.71^{a}	54.64^{a}	44.18^{a}	72.98^{a}	82.32^{a}	77.65^{a}	62.86^{a}
Opuntia dillenii	9.09^{e}	18.38^{f}	13.74^{e}	24.55^{e}	28.12^{f}	26.34^{f}	20.81^{f}

* Mean of four replications

Means followed by the same letter(s) are not significantly different according to DMRT (p = 0.05).

In orange plantations at Lower Palani hill, the per cent damage ranged from 15.83 %- 24.46 % (number basis). A per cent damage up to 8.67 % at Bijapur and up to 33.96 % at Raichur on pomegranate was recorded earlier (15). Also, another study reported a per cent damage of 40 %–50 % in citrus orchards in Punjab, while in the Phillaur and Abohar areas, it was 70 % and 10 % respectively (16). This variation may be due to climate variability.

Management of fruit piercing moths

In the present study, the overall corresponding mean per cent reduction over control was high in NeemSweet-P (62.86 %) followed by neem oil (57.20 %) in guava.

Few studies have been conducted on the management of FPM activity. The use of lanterns and lights to deter the FPM activity (10), but this method was determined to be an impractical means of reducing damage on a small scale trial. This method gave a substantial reduction of moths by 60 % in Japan (17) and and other investigators also was confirmed this method as very effective (18-21).

Further, an earlier study recommended fruit bait containing water (6 pt), fruit pulp (2 pt), crude sugar (½ lb) and sodium silico-fluoride or lead arsenate (1 oz) (10), whereas another study used the poisoned bait to trap FPMs (16). Minimum fruit damage of 35.0 % was observed in the trees covered with nets, followed by the application of horticultural mineral oil (HMO) with Arbofine (36.3 % damage), while Hindustan Petroleum horticultural mineral oil (HP HMO) and Madras Agro Killers horticultural mineral oil (MAK HMO) managed the fruits from FPMs with 38.1 % and 38.4 % damage respectively (22). These findings support the present results, which reveal that oils in general have a repellent effect against FPMs. Olfaction plays the major role in food location by FPMs (23). The use of NeemSweet-P 60 EC and neem oil was effective in reducing fruit damage by repelling the moths and these findings are in accordance with previous results (24) which were reported the effect of neem oil on guava and pomegranate fruits against *E. materna*. The significant decrease in fruit damage (4 %--21 %) by *E. phalonia* was observed when HMO sprayed at 0.35 % in orange orchards at weekly intervals until the fruits were ripe as compared to control with more than 40 % fruit damage (9) . Similarly foliar application of neem oil at 1 % or malathion 50 EC (2 mL) at 10-15 days interval during fruit maturity till harvest provided good result on control of FPMs in citrus (25). Foliar application of neem seed kernel extract (NSKE, 5 %), fish oil rosin soap (2 %), karanj oil (1 %), azadirachtin (1500 ppm) or neem oil (1 %) on trees at fruit maturity was found to be effective against *Eudocima* spp. The above-mentioned findings evidenced the role of olfaction in feeding behaviour of FPMs.

In the present study, keeping light trap in orchard recorded a 41.46 % reduction of FPMs in guava orchard over control. Similarly, the use of UV radiation (blue fluorescent lights, black lights and mercury lamps) attracted nocturnal insects (26). The use of IPM

module i.e poison bait traps, light traps, smoke, weed removal etc. for the management of Eudocima spp. in fruits has also been reported (27).

Conclusion

The present study revealed that, use of NeemSweet-P 60 EC, neem oil was effective in reducing fruit damage by repelling the moths. Being the nocturnal feeding habits of FPMs, management is very difficult. However, integration of above said management practices will yield fruitful results. In addition to that, some of the management methods viz. removal of larval hosts belongs to the family Menispermaceae in and around the fruit orchards, removal of damaged fallen fruits from orchards, keeping light traps, fruit traps and use of smoke during dusk helps to minimize the FPM population.

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Authors' contributions

JR experimented and wrote the original draft. MJ participated in the design of the study and performed the statistical analysis. SM and AV reviewed the content and edited the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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