Aromatic fruits as baits for the management of fruit-piercing moths in pomegranate: exploiting olfaction

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'Baits' are substances that attract, trap and kill pests. In horticultural practice, baits are used to trap insect pests, thereby diverting them from cultivated crops. An important insect pest that can be managed using baits is the fruit-piercing moth (FPM), *Eudocima* species. These frugivorous moths are distributed throughout India and inflict serious damage to a wide range of cultivated fruits. In southern India, pomegranate cultivation is escalating and so is the fruit damage caused by FPM. The damage by FPM alone sums up to 40% of the production, thus causing heavy loss to farmers. However, existing control measures are ineffective in reducing damage caused by the moths. In the present communication, we study the feeding preference of FPM to banana, guava, tomato and molasses in multiple and limited-choice field experiments. The results indicate that the moths are attracted to bait fruits, viz. banana, guava compared to the main crop, pomegranate. We conclude that using these aromatic fruits as baits, we can divert the moths from the main crop, which will serve as an economically viable control measure.

Keywords: Aromatic fruits, baits, fruit-piercing moths, olfaction, pomegranate.

BAITS are luring substances that can be used to trap an organism if appropriately deployed. Baits work on the principle of exploiting olfactory response of the target organism, to lure and trap them. In insects, 'olfaction' plays an important role in locating food, mates and oviposition sites. Olfaction is the ability of insects to perceive and distinguish odours that are mediated through sensory neurons and the brain, leading to a critical and specific behaviour. Exploiting this mechanism, several trapping methods based on pheromones and kairomones are already in use for managing insect pests. Food-based baits are an effective method for insect control. They consist of an attractive feeding substance along with a toxicant that works by deceiving insects into a trap. Such baits if selective to target pests are environmentally safe.

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Fruit-piercing moths (FPMs) (*Eudocima* [=*Othreis*] *materna* (Linnaeus), *Eudocima fullonia* (Clerck), *Eudocima homaena* Hubner) belong to the Noctuidae family of the order Lepidoptera. They are serious pests of fruit crops in the tropical and subtropical belts spanning from Africa to the Pacific Islands[1]. Unlike other lepidopteran moths where the detrimental life stages that cause economic loss are always larvae, here the adult stage is more injurious causing huge damage to fruits, including citrus, guava, mango, papaya, banana, pomegranate, etc. FPMs are nocturnal feeders. They penetrate their proboscis into the rind of fruit and suck the juice[2] (Figure 1). The internal injury consists of a bruised area beneath the rind augmenting secondary rots[3]. Such rot leads to fermentation of the fruit and attracts secondary moth feeders that take advantage of the access hole drilled by moths of the *Eudocima* spp. A solitary moth would generally attack many fruits on a single night making them unmarketable and leading to huge economic losses. Surveys to pomegranate-growing areas of Chitradurga, Karnataka by the present authors have revealed loss ranging from 20% to 40% by FPM. Fruit loss up to 57% was reported earlier in pomegranate at Rahuri, Maharashtra with maximum damage to ripe fruits (21.06–47.62%) than unripe fruits (2.86–13.86%)[4]. Another study reported fruit damage in the range 0.00–8.67% at Bijapur and 18.45–33.9% at Raichur[5]. This is high considering the farm gate price fluctuations of Rs 60–110 per kg of harvested fruit.

The female moths oviposit on creepers of the Menispermaceae family that grow in forests and wastelands. The hatched larvae complete their life cycles on the host plants, thus making control of immature stages difficult as spraying larval hosts is not feasible[6]. Management of this pest using insecticides has not been an option because of inadequate contact of the moth with the fruit; only ripe fruits are attacked on which insecticides cannot be sprayed due to pesticide residue issues. As economic value of pomegranate is high, farmers usually deploy watch and ward with torches to swat the moths alighting on the fruit. This is far from efficacious as swarms can never be fully deterred from attacking fruits. The fact that the moths are nocturnal renders vigil impractical. Other methods of management like fruit-bagging, netting trees/orchards, hand collection of moths, light traps, advancing/delaying the cropping have their own limitations and flaws[2]. However, management of *Eudocima* species in the field through baits is less explored[2,7,8]. Several studies established the feeding preference of these moths to aromatic fruits, viz. banana, guava and tomato at laboratory level. Nevertheless, the efficacy of these bait fruits in attracting the moths in the field was not explored. Though the laboratory experiments are ideal to understand the feeding preferences of moths, the repeatability of these results in the field is fraught with several difficulties and uncertainties like huge experimental area, aroma from main crop may mask the bait odour thereby

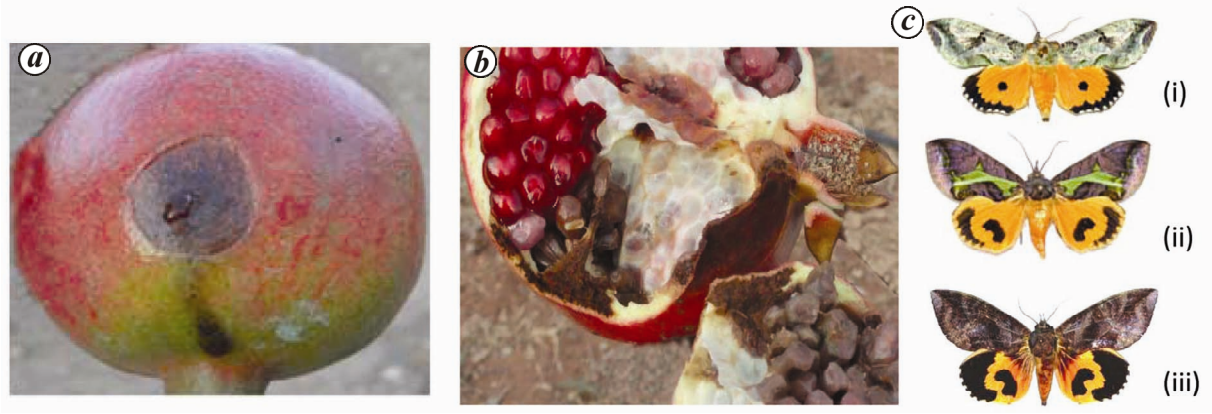

Figure 1. ***a***, Damage by fruit-piercing moth (FPM) on mature pomegranate fruit showing the pin-size feeding hole with surrounding browning. ***b***, Damaged fruit cut open showing the internal injury. ***c***, Different FPM species that attack pomegranate. (i) *Eudocima materna*; (ii) *E. homaena* and (iii) *E. fullonia*.

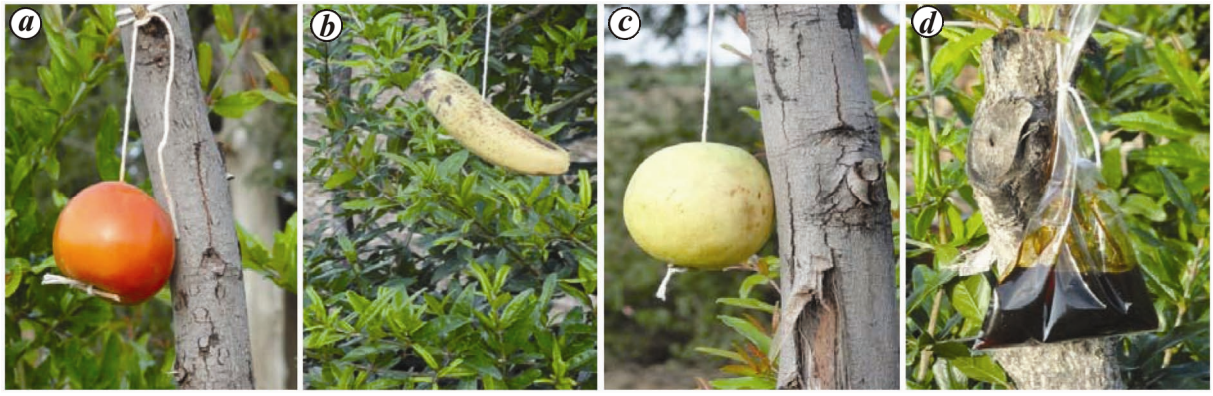

Figure 2. Different baits tied in the pomegranate field to attract FPMs. ***a***, Ripe fruits of tomato; ***b***, banana; ***c***, guava; ***d***, sachet with molasses.

influencing the orientation of target insect, etc. Therefore, the present study was taken up to explore the feasibility of bait fruits application for the management of FPMs.

In this study, we evaluated the efficiency of 'fruit baits' in trapping FPMs in multiple as well as limited-choice field experiments. The study was carried out in a pomegranate field at Hiriyur (13.95°N, 76.62°E), Chitradurga district, Karnataka, India. The trials were conducted in two different orchards located 3 km from each other. The cultivated variety of pomegranate was cv. Bhagwa. The plants were 4 years old raised by following standard agronomic practices. The bait treatments were conceived at fruit maturity. In the multiple-choice field experiment all the treatments, viz. banana, guava, tomato, molasses were screened to identify the potential attractants for FPMs. In the limited-choice field experiment only the selected treatments from the multiple-choice field experiment were further tested in an open field to establish the efficacy of the potential fruit baits in attracting moths. The experimental procedure for both multiple-choice and limited-choice field experiments is the same, but the number of treatments evaluated differs.

The baits, banana (cv. Robusta), guava (cv. Allahabad Safed), tomato (cv. Local red) and molasses were evaluated for their efficacy in attracting FPMs in the preliminary open-field choice experiment. These baits were selected based on findings from previous studies[2,5,7–10]. In the case of banana, over-ripened whole fruits having bright yellow rind with brown 'sugar spots' were selected for the study. Similarly, in the case of guava, over-ripened whole fruits with uniform yellow rind and good aroma were used. In the case of tomato, ripened whole fruits with bright uniform red colour were chosen for the study. The baits, viz. banana, guava, tomato and molasses (15 ml sealed in 50 gauge polythene sachet of 13 × 10 cm dimension) were fastened using a thread (Figure 2) to randomly erected wooden poles (placed at a distance of 10′) in the borders of the field @ 40 units per hectare in all directions. The baits were tied at the crop canopy level (~5′–6′). According to previous studies, moth visits were reported between 19:30 and 23:30 h with a peak at 23:00 h in the fields[5]. In the present study, the baits were not poisoned as there is a possibility for accidental ingestion by non-target organisms; instead, continuous scouting was carried out from 19:00 to 24:00 h to monitor the feeding activity of moths on baits. The number of moths visiting the baits and feeding punctures per fruit/sachet were recorded. Further, the moths that were feeding on

Figure 3. Feeding of FPMs on bait fruits in the pomegranate field. Active feeding postures of (***a***, ***c***) *E. materna* on guava and (***b***) *E. fullonia* on banana bait fruits during night hours.

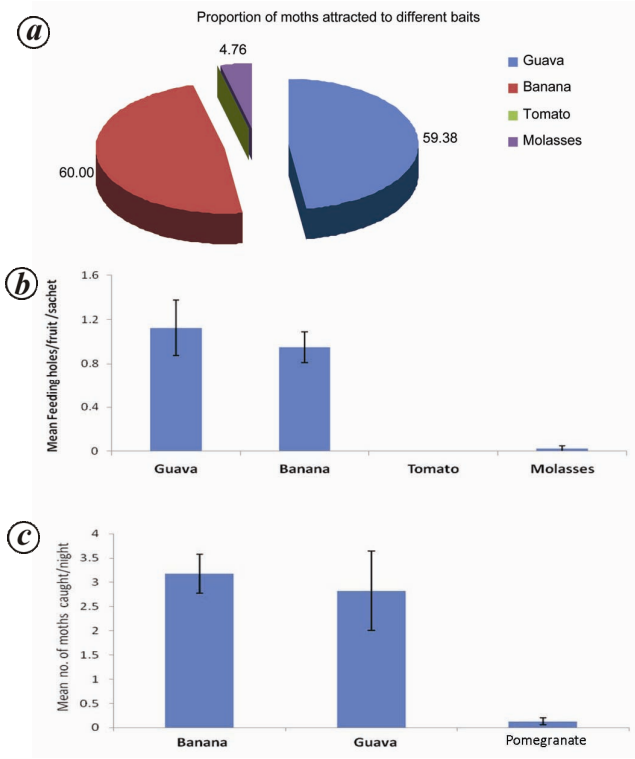

Figure 4. Food bait preferences (with error bars) of FPMs exhibited in (***a***, ***b***) multiple-choice open field experiment and (***c***) limited-choice open field experiment.

the fruits were caught using aerial insect nets and observations were taken on total moths trapped. Similarly, in the second limited-choice confirmatory trial, the selected treatments, viz. banana, guava were tried and data recording was carried out as explained above. Both the experiments were continued for two weeks without changing the baits. The data were pooled and subjected to statistical analysis using ANOVA[11].

The results of multiple-choice experiments indicated that the moths preferred certain fruits that were aromatic (Figure 2). We found *E. materna*, *E. fullonia* and *E. homaena* feeding on bait fruits (Figure 3). Guava and banana were equally attractive with 59.38% of moths visiting guava and 60% visiting banana (Figure 4 *a*). The moths did not visit tomato, revealing their non-preference. However, previous studies conducted to understand the adult feeding preferences of FPMs under laboratory conditions revealed that freshly emerged moths of *E. materna*, *E. fullonia* and *E. homaena* preferred to feed on guava followed by tomato and banana. The reported preference index was highest for guava (323.09), followed by tomato (199.29) and banana (195.51)[5]. In the present multiple-choice open field study, the moths exhibited high preference for guava and banana compared to tomato, indicating the possibility of using these fruits as baits to attract moths. In the case of molasses, only 4.76% of moths visited the sachets. Earlier studies reported molasses as the most preferred attractant, which may serve as an useful ingredient of bait formulations against *E. materna*[2]. However, molasses exhibited weak attraction compared to banana or guava fruit baits.

The mean feeding punctures among the treatments were significantly different ($F = 17.16$, $df = 156$, $P < 0.001$). The fruit baits that exhibited high attraction for FPMs (banana and guava) also recorded significantly ($P = 0.05$) more feeding punctures compared to the other treatments (Figure 4 *b*). Earlier studies reported that *E. fullonia* prefers sweet, aromatic fruit (e.g. banana or guava) to those with low sugar content (e.g. tomato or bell pepper)[12]. Cherian and Sundaram[13] observed no damage to orange fruits when ripened tomato was available in the fruit orchard. The moths attacked oranges immediately after the removal of tomato crop. The authors suggested that tomato could act as a trap crop to attract the moths. However, in the present study, FPMs did not show any preference for tomato under field conditions. Perhaps, between orange and tomato, the latter may be a more preferred host.

In the limited-choice open field experiment, maximum number of moths was found feeding on banana (36.5 ± 8.5) followed by guava (32.5 ± 0.5), confirming their potential as bait fruits (Figure 5). The number of moths feeding on the main crop, pomegranate, was comparatively less (1.5 ± 0.5) (Figure 5). Denton *et al.*[14] quantified fruit preferences of *E. fullonia* and found that the preference index was very high for banana (100) followed by guava (89), with pomegranate being the least (0). Several other laboratory studies also found that pomegranate was least preferred with cumulative preference

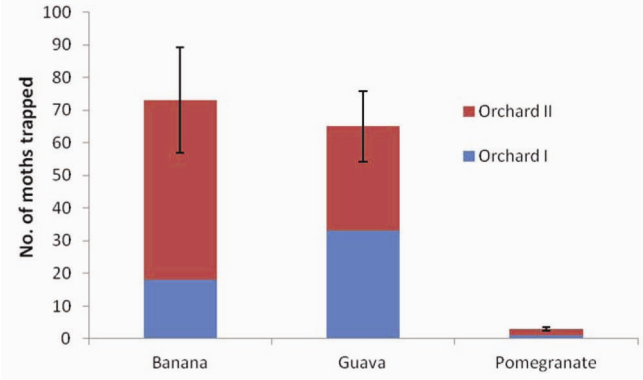

Figure 5. Total FPM catches (with error bars) on bait fruits compared to pomegranate fruits (main crop) during fortnight experimental period.

index of 3.22 as against guava and banana[2,7,9]. This clearly showed that the FPMs can be lured from the main crop to bait fruits such as banana and guava. Hanging of ripe banana fruits in orange orchards to reduce moth damage on oranges was also suggested earlier, as moths preferred banana over orange[10]. However, the present study establishes the feasibility and efficacy of bait fruit approach in the pomegranate field and validates the FPM feeding preference to over ripe banana and guava fruits.

Olfaction is the ability of an organism to detect and discriminate odours in the environment. Insects rely mainly on olfaction to locate their food[15]. The antennal structures in insects are the functional equivalent of the human nose, enabling them to detect specific olfactory information in a complicated malodorous environment[16]. In a nocturnal lepidopteran like the FPMs, olfaction is one of the major means to locate food[17]. In the present study, the olfactory preferences of FPMs towards certain preferred fruits like banana and guava[2,7,9] were manipulated using them as baits in the pomegranate orchard to lure them away from the main crop. Using bait fruits like banana and guava (40 fruits per hectare) helped in trapping 138 FPMs over a period of two weeks (Figure 5) that otherwise might have caused enormous damage to pomegranate fruits. Watch and ward easily swatted/caught moths while they are feeding on bait fruits. This obviated the need to add toxicants to bait fruits. Further, it not only makes this approach pesticide-free, but renders the baits safe to non-target organisms like bats, birds and even humans. Thus, the present study clearly establishes that the feeding preferences of FPMs to certain fruits can be exploited for their management in the field. Further, chemical identification of potential odours (that are implicated in luring the FPMs) from these bait fruits through in depth studies, viz. head space analysis, GC-MS, GC-EAD will enable formulation of synthetic baits that will disrupt the FPM olfactory orientation in the field. Such studies not only help to fine-tune the present FPM management strategies, but make them more robust and sustainable in the long run.

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