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Attraction of fruit-piercing moth *Eudocima phalonia* (Lepidoptera: Noctuidae) to different fruit baits

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Abstract

The adult fruit-piercing moth, *Eudocima* (*fullonia*) *phalonia* (L.) comb. (Lepidoptera: Noctuidae) is a major pest of citrus and numerous other commercial fruit crops. Application of insecticides is undesirable particularly at harvest time in fruit crops. Here we report on the attraction of *E. phalonia* to different fruit baits. *E. phalonia* was significantly attracted to feed more on fruit puree with Agar and Phytogel than on fruit puree with Agarose. Of the 15 fruit baits tested, moths preferred to feed on banana baits more than on any other, followed by guava and orange, which were significantly more attractive than kiwi, apple, pineapple, pear, papaya, mango, grapefruit, tomato or green grape. Star fruit, plum and sour sop fruit baits were the least attractive and were no more attractive than water control treatments. The present study identifies valuable attractants which may be used as part of a lure and kill strategy for this important pest and also form a foundation upon which future bioassay-driven fractionation and chemical structure elucidation can be developed.

Keywords: *Eudocima phalonia*; Lepidoptera; Noctuidae; Attract; Feeding; Fruit baits

1. Introduction

The adult fruit-piercing moth, *Eudocima* (*fullonia*) *phalonia* (L.) comb. (Lepidoptera: Noctuidae) is an important pest of citrus and numerous commercial fruits and vegetables (Baptist, 1944; Cochereau, 1977; Zilli and Hogens, 2002) and it has been listed as one of the 10 most serious pests of the Pacific region (Waterhouse and Norris, 1987). It is also a serious pest in subtropical and tropical Africa, Asia, and Australia (Denton et al., 1999).

Adult moths pierce ripening fruits with their strongly sclerotized probosces, macerate the pulp, and suck the fluid. (Sands and Schotz, 1991) Fruits attacked by these insects become dry and spongy and lose their commercial value. The site of the feeding wound becomes a permanent site for secondary disease infection, causing further injury to damaged fruits. Damaged fruits are unmarketable, and if packed, pose a threat to sound fruits through pathogenic contamination.

Adult *E. phalonia* feeds on fruits of more than 100 plant species (Davis et al., 2005) including several economically important ones such as citrus, apple, pear, star fruit, grape, melon, tomato, banana, mango, papaya, pineapple and strawberry (Muniappan et al., 1995; Muniappan et al., 2002). The larval hosts of *E. phalonia* in Asia, Africa, and Australia are the vines of Menispermaceae (Sands and Chan, 1996). However, the larval host range has extended to *Erythrina* spp. (Fabaceae) in addition to Menispermaceae in the Pacific Islands and Papua New Guinea (Reddy et al., 2005).

An integrated method for management involving biological control, bagging of fruits, netting rows of vegetable crops and netting individual fruit trees has been recommended, but it is not yet economically viable (Fay, 2002; Muniappan et al., 2002). An economically acceptable alternative control strategy for *E. phalonia* would be the use of semiochemicals. In this context, future work on semiochemicals appears imperative (Reddy and Guerrero, 2004) to develop an eco-friendly control method for this moth. Few studies have been carried out on attractants of *E. phalonia*. Fay and Halfpapp (2001) found that

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sugared-agar baits containing highly volatile esters (such as *n*-butyl acetate and methyl butyrate), aldehydes and an alcohol were more attractive to *E. phalonia* compared with baits contained esters only.

To develop a 'lure and kill' method to control of *E. phalonia*, a series of experiments was carried out in field cages and in laboratory to elucidate which fruit baits attract the maximum numbers of adult moths. The following questions were addressed: (1) Can fruit puree solidified with a nutrient medium and enclosed in a sausage casing attract moths? (2) Which medium and fruit puree are effective and able to attract the largest number of moths?

2. Materials and methods

2.1. Preparation of fruit sausage as bait for E. phalonia

Fruits (Table 1) were purchased from a market in Guam. Each fruit was blended using a Waring commercial blender. With the exception of banana, 250 ml of fruit puree was prepared and mixed with 250 ml of tap water in a 1000 ml of Erlenmeyer flask (Pyrex, USA). Due to the pulpy nature of blended banana 150 ml of fruit puree was mixed with 350 ml of tap water.

Each fruit puree was mixed with 7.5 g of Agar (Sigma-Aldrich), 1 g of Phytagel™ (Gellan gum; agar substitute gelling agent; Sigma-Aldrich) or 6 g of Agarose (Type II, Medium EEO; Sigma-Aldrich). The flasks were heated over a hot plate (Corning, NJ) and the mixtures brought to a boiling point. Flasks were then removed from the heat and placed into bowl (20 × 8 cm) containing cool water.

Home-pack sausage casings were purchased from Zach's Spice Company, Deer Park, TX. Before the preparation of fruit sausages, casings were thawed by placing them in a bowl of cold tap water. Casings were cut to lengths of approximately 20 cm, the test solutions were poured into individual sausage casings and the open ends were tied with string. Each casing measured 15 cm in length and 3.5 in diameter. The prepared casings were allowed to solidify at room temperature (24 °C) for 2–3 h prior to use.

2.2. Evaluation of different media for use in sausage casings for E. phalonia

This experiment was conducted in outdoor field cages (1.8 × 1.8 × 1.8 m). In each cage, one of the sausage casings in which fruit puree were combined with Agar, Phytogel or Agarose was hung on a wire at 1.5 m above the ground. In all experiments, baits were placed at 14:00 h. Only banana and orange fruit baits were used in this study. Newly emerged adults of *E. phalonia* ($n = 40$) were released in each of two different field cages at 16:30. The inter cage distance was about 5 m. Each treatment was replicated four times. Observations on the number of moths landing and feeding for a minimum of 5 min on the casings were made physically by the authors' everyday at 20:30 as the moths are known to be active during this time of the day. Baits were replaced once in 3 days. This experiment was continued for 6 days and the generated data were pooled.

2.3. Attraction of E. phalonia to different fruit baits

This experiment was conducted in the laboratory (10 × 6 × 3.5 m). Although fruit puree with Agar and Phytogel were shown to be more effective at attracting moths than the fruit puree with Agarose in the previous experiment, Phytogel was used as medium in the laboratory studies as it is less expensive. Each of the fruit casings (Table 1) were suspended from the ceiling (1.2 m) with

Table 1
Mean number (±SE) of *Eudocima phalonia* moths feeding on sausage casings with different fruit puree in a solidified phytogel

Common name	Scientific name	Family	Number of moths feeding
Banana	*Musa* X *paradisiaca* L.	Musaceae	15.9±0.1[a]
Guava	*Psidium guajava* L.	Myrtaceae	9.3±0.3[b]
Orange	*Citrus* spp.	Rutaceae	9.3±0.2[b]
Kiwi	*Actinidia deliciosa* Chev.	Actinidiaceae	5.3±0.2[c]
Apple	*Malus pumila* P. Mill	Rosaceae	4.9±1.0[c]
Pineapple	*Ananas comosus* (L.) Merr.	Bromeliaceae	5.1±0.1[c]
Pear	*Pyrus communis* L.	Rosaceae	5.0±0.2[c]
Papaya	*Carica papaya* L.	Caricaceae	5.2±0.1[c]
Mango	*Mangifera indica* L.	Anacardiaceae	4.3±0.3[c]
Grapefruit	*Citrus paradisi* M.	Rutaceae	2.4±0.2[d]
Tomato	*Lycopersicum esculentum* Mill.	Solanaceae	2.7±0.2[d]
Green grapes	*Vitis vinifera* L.	Vitaceae	2.5±0.1[d]
Star fruit	*Averrhoa carambola* L.	Oxalidaceae	0.6±0.7[e]
Plum	*Prunus cerasifera* Ehrh. L.	Rosaceae	0.3±0.8[e]
Sour sop	*Annona muricata* L.	Annonaceae	0.5±0.1[e]
Control (water)	—	—	0.0±0.0[e]

Means followed by a different letter in a column are significantly different ($p<0.05$; ANOVA followed by Tukey–Kramer test). Each treatment was replicated four times. Total number of moths released in a test room, $n = 50$. Observations were recorded daily up to 6 days.

string and wire. The height from the ground level was 2.3 m. Casings with tap water served as controls. The baits were placed at 14:00 h. Fifty newly emerged adults of *E. phalonia* were released into the laboratory at 16:30 on the first day. Recordings of the number of moths landing and feeding on each of the casings for 5 min were made physically daily by the authors' at 20:30 for 6 days and data were pooled. Baits were replaced once in 3 days. Five fruit baits and a control were tested at a time, each replicated four times.

2.4. Statistical analysis

Results from the evaluation of different media and attraction of moths to different fruit baits were analyzed using one-way ANOVA (SPSS for windows; SPSS Inc., Chicago, 2003), followed by means separation by Tukey–Kramer test.

3. Results

3.1. Evaluation of different mediums for use in sausage casings for E. phalonia

The average prevailing temperature and relative humidity during the experimental period was 28±2 °C and 80% RH, respectively. *E. phalonia* were attracted and fed significantly ($p<0.05$) more on the fruit puree with Agar and Phytogel than on an Agarose (Fig. 1). However, there was no significant difference ($p>0.05$) between fruit puree with Agar and Phytogel in feeding potential of moths.

3.2. Attraction of E. phalonia to different fruit baits

E. phalonia showed a significant preference for feeding on ($p<0.05$) the baits of banana compared with all other fruit baits tested (Table 1). This was followed by guava and orange, which were significantly ($p<0.05$) preferred to kiwi, apple, pineapple, pear, papaya, mango, and grapefruit, tomato and green grapes. However, baits from star fruit, plum, and soursop were not significantly ($p>0.05$) more attractive than the control (water). Control (water) baits attracted no moths. The prevailing temperature, humidity was 23±1 °C and 70% RH, respectively.

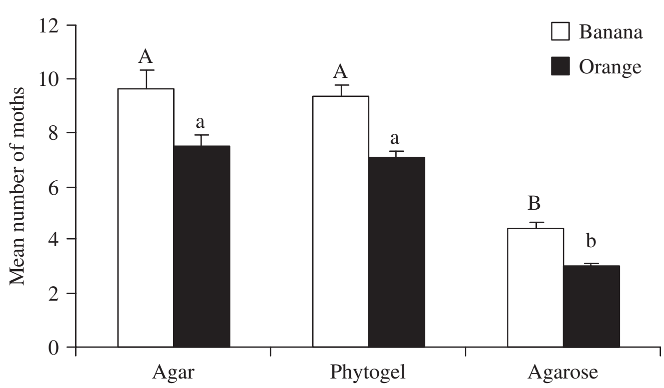

Fig. 1. Mean number (±SE) of *E. phalonia* moths feeding on sausage casings with fruit puree solidified with different mediums. Each treatment was replicated four times. Total number of moths released in a cage, $n=40$. Observations were recorded daily up to 6 days and data pooled. Bars with same lower or upper case letter did not differ significantly ($p<0.05$; ANOVA followed by Tukey–Kramer test).

4. Discussion

Despite the economic significance of *E. phalonia*, effective-sampling tools and attractive semiochemicals are yet to be identified (Davis et al., 2005). The reasons for using the fruits puree in sausage casings were that these baits withstand rain, provide space for adults to land and pierce the casings using proboscis and provide an opportunity for commercial production. Ripe fruits were used as they were known to attract more moths than unripe and over ripe fruits (Fay and Halfpapp, 2001). The results from our study using fruit puree solidified in sausage casings demonstrate that *E. phalonia* shows a significantly stronger feeding response to fruit puree with Agar and Phytogel than to Agarose media with both the fruit baits from banana and/or orange. Consequently, we determined to use Phytogel as medium in our further experiments because this chemical is less expensive than the Agar.

Results from the second part from the study indicate that baits of banana are a significantly stronger attractant than the others tested. Although orange is one of the main hosts for *E. phalonia*, the baits from it and guava attracted significantly fewer moths than banana but a greater number than the other baits tested. Our results corroborate those of Denton et al. (1989) who reported that banana was most preferred to *E. phalonia* over guava, mango, papaya and other fruits. Since control (water) baits attracted no moths, we interpret the sighting of a moth on a sausage as being the result of attraction to the sausage. These findings form a foundation upon which future bioassay-driven fractionation and chemical structure elucidation can be developed.

Sweet/sugar baits are widely used to capture moths and butterflies (Holland, 1903; Sargent, 1976). The ingredients used, although varied, include sugar and sugar-rich materials, as well as fruits and alcoholic beverages (Landolt, 1995). Molasses and sugar syrups have been evaluated as a bait placed in pails for attracting and killing *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae) (Frost, 1926, 1928), *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) (Eyer, 1931; Hern and Dorn, 2004), *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) (Ditman and Cory, 1933; Beerwinkle et al., 1996) and *Mocis latipes* (Lepidoptera: Noctuidae) (Landolt, 1995). Although Fay and Halfpapp (2001) demonstrated for the first time the attractiveness of *E. phalonia* to sugared-agar baits containing volatile fruity esters, our study indicated the definitive attractiveness of fruits baits to this economically important fruit pest.

Additional studies are required to further refine the effect of wind response of male and female moths by observing various characteristics such as bait type, bait contrast, size, height, shape and flight activity. For most insect species, visual and/or volatile plant cues play a role during host location (Prokopy and Owens, 1983; Prokopy et al., 1987). In some cases, attraction is increased many fold when these two host-locating modalities were combined (Wallbank and Wheatley, 1979; Tuttle et al., 1988). Blackmer and Cañas (2005) reported that in nature, these two cues occur together, though they may not be perceived equally well depending on the environmental conditions and habit. Further, the authors mentioned that very little is known about how these two modalities interact during host location. Therefore, research examining the possible effects of physical characteristics on the attraction of the bait is valuable. Additional studies are also required on the addition of pesticides in small quantities to the fruit puree in the baits. The insect is attracted to the bait loaded with the fruit puree and feeds on the poisonous chemical. This will play a role in developing effective monitoring and, attract and kill systems for this important economic pest.

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References

Baptist, B.A., 1944. The fruit-piercing moth (*Othreis fullonia* L.) with special reference to its economic importance. Indian J. Entomol. 6, 1–13.

Beerwinkle, K.R., Shaver, T.N., Lingren, P.D., Raulston, J.R., 1996. Free-choice olfactometer bioassay system for evaluating the attractiveness of plant volatiles to adult *Helicoverpa zea*. Southwest. Entomol. 21, 395–405.

Blackmer, J.L., Cañas, L.A., 2005. Visual cues enhance the response of *Lygus hesperus* (Heteroptera: Miridae) to volatiles from host plants. Environ. Entomol. 34, 1524–1533.

Cochereau, P., 1977. Biology and ecology of populations in New Caledonia of a fruit-piercing moth: *Orthreis fullonia* Clerck (Lepidoptera: Noctuidae, Catocalinae) Travaux et Documents de l'O.R.S. T.O.M., Paris.

Davis, E.E., French, S., Venette, R.C., 2005. Mini Risk Assessment-Fruit Piercing Moth: *Eudocima fullonia* Green (Lepidoptera: Noctuidae), http://www.aphis.usda.gov/ppq/ep/pestdetection/pra/efulloniapra.pdf, USDA-CAPS http://www.aphis.usda.gov/ppq/ep/pestdetection/pra/efulloniapra.pdf.

Denton, G.R.W., Muniappan, R., Austin, L., Diambra, O.H., 1989. Fruit-piercing moths of Micronesia. Agricultural Experiment Station, University of Guam, Technical Report 27, 26p.

Denton, G.R.W., Muniappan, R., Marutani, M., McConnell, J., Lali, T.S., 1999. Biology and natural enemies of the fruit-piercing moth *Othreis fullonia* (Lepidptera: Noctuidae) from Guam. In: ADAP Crop Protection Conference Proceedings, Honolulu, Hawaii, University of Hawaii, pp. 150–154.

Ditman, L.P., Cory, E.N., 1933. The response of corn earworm moths to various sugar solutions. J. Econ. Entomol. 26, 109–115.

Eyer, J.R., 1931. A four year study of codling moth baits in New Mexico. J. Econ. Entomol. 24, 988–1001.

Fay, H.A.C., 2002. Fruitpiercing moths and fruitspotting bugs: Intractable pests of tree fruits in a reduced-insecticide environment. Acta Hort. 575, 485–493.

Fay, H.A.C., Halfpapp, K.H., 2001. Baits for fruitpiercing moths—the state of play? NT Department of Primary Industry and Fisheries Technical Bulletin No 288, pp. 51–57.

Frost, S.W., 1926. Bait pails as a possible control for the oriental fruit moth. J. Econ. Entomol. 19, 441–450.

Frost, S.W., 1928. Continued studies of baits for oriental fruit moth. J. Econ. Entomol. 21, 339–348.

Hern, A., Dorn, S., 2004. A female-specific attractant for the codling moth, *Cydia pomonella*, from apple fruit volatiles. Naturwissenschaften 91, 77–80.

Holland, W.J., 1903. The Moth Book. A Guide to the Moths of North America. Dover Publications Inc., New York, 479p.

Landolt, P.J., 1995. Attraction of *Mocis latipes* (Lepidoptera: Noctuidae) to sweet baits in traps. Fla. Entomol. 78, 523–530.

Muniappan, R., Purea, M., Tarilongi, B., Berukilukilu, L., Bule, S., Reddy, G.V.P., 2002. Fruit piercing moths in Vanuatu and their management. J. South Pac. Agric. 9, 16–27.

Muniappan, R., Silva-Krott, I.U., Lali, T.S., 1995. Distribution of larval host plants of the fruit piercing moth, *Othries fullonia*. Chemoecology 5/6, 75–77.

Prokopy, R.J., Aluja, M., Green, T.A., 1987. Dynamics of host odor and visual stimulus interactions in host finding behavior of apple maggot flies. In: Labeyrie, V., Fabes, G., Lachaise, D. (Eds.), Junk. Dordrecht, Germany, pp. 161–166.

Prokopy, R.J., Owens, E.O., 1983. Visual detection of plants by herbivorous insect. Annu. Rev. Entomol. 28, 337–364.

Reddy, G.V.P., Cruz, Z.T., Bamba, J., Muniappan, R., 2005. Host adaptation of the fruit piercing moth, *Eudocima fullonia*. Physiol. Entomol. 30, 398–401.

Reddy, G.V.P., Guerrero, A., 2004. Interactions of insect pheromones and plant semiochemicals. Trends Plant Sci. 9, 253–261.

Sands, D.P.A., Chan, R.R., 1996. Survivorship of Australian *Othreis fullonia* on *Erythrina variegata*: hypotheses for development of host-plant biotypes in the Pacific. Entomol. Exp. Appl. 80, 145–148.

Sands, D.P.A., Schotz, M., 1991. Ecology of fruit-piercing moths in subtropical Australia. Proceedings of the 11th International Congress Plant Protection, vol. II, pp. 229–232.

Sargent, T.D., 1976. Legion of Night. The Underwing Moths. University of Massachusetts Press, Amherst, MA, 222p.

Tuttle, A.F., Ferro, D.N., Idoine, K., 1988. Role of visual and olfactory stimuli in host finding of adult cabbage root flies, *Delia radicum*. Entomol. Exp. Appl. 47, 37–44.

Wallbank, B.E., Wheatley, G.A., 1979. Some responses of cabbage root fly to allyl isothiocyanate and other volatile constituents of crucifers. Ann. Appl. Biol. 91, 1–12.

Waterhouse, D.F., Norris, K.R., 1987. Biological Control: Pacific Prospects. Inkata Press, Melbourne.

Zilli, A., Hogens, W., 2002. An annotated list of the fruit-piercing moth genus *Eudocima* Billberg, 1920 (sensu Poole with descriptions of our new species (Lepidoptera: Noctuidae, Catocalinae). Quadrifina 5, 153–207.