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SYNTHETIC FRUITPIERCING MOTH ATTRACTANT

An insect attractant formulation comprising: i) one or more straight chain and/or branched chain C_2-C_{12} aliphatic primary, secondary or tertiary esters and all isomers thereof; and ii) one or more saturated or unsaturated C_2-C_{12} aliphatic aldehydes and all isomers thereof; and/or iii) one or more saturated or unsaturated C_1-C_2 aliphatic primary, secondary or tertiary alcohols and all isomers thereof. The insect attractant formulation used to attract and/or control insects, in particular the fruitpiercing moth, in the vicinity of fruit crops. Also provided is a synthetic fruitpiercing moth attractant comprising two or more straight chain and/or branched chain C_2-C_{12} aliphatic primary, secondary or tertiary esters and all isomers thereof, and a method of attracting and/or controlling fruitpiercing moths by use of two or more straight chain and/or branched chain C_2-C_{12} aliphatic primary, secondary or tertiary esters and all isomers thereof, on or in the vicinity of a fruit crop.
TITLE
"SYNTHETIC FRUITPIERCING MOTH ATTRACTANT"

FIELD OF INVENTION
THIS INVENTION relates to a synthetic fruitpiercing moth attractant.

BACKGROUND ART
Fruitpiercing moths, sometimes referred to as fruitsucking moths, belong to the genus *Eudocima*, which formerly included the genera *Othreis*, *Rhytia*, *Khadira* and *Adris*. They cause damage to around 50 different commercial fruit species resulting in substantial losses to growers through spoilt fruit. The adult moth penetrates the skin or rind of fruit with a barbed proboscis and the extensive probing for juice destroys a large area of tissue beneath the surface. Fruitpiercing moths begin entering fruit crops to feed as soon as the first fruits ripen, as reported in Fay and Halfpapp, *Australian Journal of Experimental Agriculture*, 1993, 33, 327-331. The numbers of moths increase as the proportion of ripening fruit rises. Most damage to crops occurs just prior to harvest when sugar levels in the fruit approach their peak.

There are seven species of *Eudocima* in Australia, including *Eudocima fullonia*, *Eudocima salaminia*, *Eudocima materna*, *Eudocima jordani*, *Eudocima cocalus*, *Eudocima aurantia* and *Eudocima iridescens*, as reported in Nielsen et al., *Checklist of the Lepidoptera of Australia*, 1996. The genus *Eudocima* occurs throughout most of the Pacific (excluding New Zealand), Papua New Guinea, South-East Asia, parts of China, Korea, Japan, the Indian sub-continent and most of sub-Saharan Africa, as reported in International Institute of Entomology: Pest Distribution Maps, 1977. *Eudocima fullonia* is the most prevalent species throughout these regions. *Eudocima materna* also occurs in parts of the Caribbean and northern South America, as reported in Zaggatti, *et al.*, *Catalogue of the Lepidoptera of the French Antilles*, 1995.
In Australia, fruitpiercing moths breed on menisperm vines, which occur in vast tracks of forest and savannah land across the north of the continent. Direct control of the immature stages of these moths is generally impossible. Attempts to moderate the effects of fruitpiercing moths have therefore concentrated on the adult moths in the orchard environment.

To date the most effective methods to control fruitpiercing moths have been covering trees with nets or enclosing fruit in bags. These techniques are principally used in high value crops, such as lychees, longans and persimmons, due to losses occurring from flying foxes and parrots, in addition to fruitpiercing moths and other insect pests. These measures are expensive, especially in crops where vertebrate pests, such as flying foxes and parrots, are not a problem. In addition, where large numbers of trees need to be protected, the cost is prohibitive.

Orchard lighting systems, which employ green-yellow lights (550 – 580 µm), can suppress moth feeding. Tests in Australia, of such systems, have measured a 60-70% reduction in moth activity for medium to low population levels. Such systems require considerable investment in electrical infrastructure, in part due to the mandatory safety requirements imposed by energy authorities. These lighting systems do not control any additional pests from entering the area. For those regions where fruitpiercing moths are an irregular problem, such a technique is prohibitively expensive.

Insecticidal cover sprays have never been widely employed against fruitpiercing moths, due to their lack of efficacy, problems with chemical residues arising from the lateness of application relative to crop harvest, and potential interference with the ongoing development of Integrated Pest Management (IPM), which is now well advanced in some crops. Carbaryl, used on citrus crops, is the only insecticide registered for use against fruitpiercing moths in Australia (as reported in QDPI: INFOPEST Vers.2.5-Pest).
Management Information System, 2000). However, carbaryl has little efficacy against these moths. Zhou Xiao Yin, et al., *South China Fruits*, 1997, 26, 13-14 reported adequate control of the fruitpiercing moth *Oraesia emarginata* with the synthetic pyrethroid, cyfluthrin. However, no successful insecticide trials have been reported for *Eudocima* species. In crops, such as citrus, where IPM depends on the discrete and limited use of broad-spectrum insecticides, it is unlikely that insecticidal sprays for fruitpiercing moths could be introduced without seriously disrupting a finely-tuned pest management system. Unless a suitable narrow-spectrum insecticide can be found with activity against fruitpiercing moths, cover sprays will never offer a sustainable approach to managing these pests.

Baiting based on organic feeding attractants has long been used as a control method against fruitpiercing moths, but they have not provided sufficient mortality rates for use in commercial crops. A number of reports, namely Hargreaves, *Bulletin of Entomological Research* 1936, 27, 589-605; Baptist, *Indian Journal of Entomology*, 1944, 6, 1-13; Yoon and Kim, *Korean Journal of Plant Protection*, 1977, 16, 127-131; Dodia et al., *Gujarat Agricultural University Research Journal*, 1986, 11, 72-73, disclose the use of feeding attractants, which have included brown sugar, fruit (particularly overripe banana), fruit pulp or fruit juice, honey and beer (or other beverages). Vock, *Country Mail*, QLD, 1990, reported the use of these attractants in traps, but more often they are used in conjunction with a toxicant in an open-access bait. Organic feeding attractants have several inadequacies, in that they do not compete well with the odours released by fruit crops, they do not provide a consistent general odour and they attract many non-target or secondary moth species.

Synthetic attractants for insects based on the components of fruit odour have mainly been investigated for tephritid fruit flies.
Zhang et al., *Journal of Chemical Ecology*, 1999, 25, 1221-1232, reported the use of seven volatile compounds for use as an attractant for the apple maggot, *Rhagoletis pomonella*. The compounds identified by Zhang were all fruity esters, predominantly hexyl acetate (35%) and butyl hexanoate (28%). Zhang also reported a refined five-component mixture containing predominantly butyl hexanoate (37%) and hexyl butanoate (28%). Robacker and Heath, *Journal of Chemical Ecology*, 1997, 23, 1253-1262, reported a fruit-mimicking attractant for the Mexican fruit fly, *Anastrepha ludens*, which included the monoterpene 1,8 cineole, the esters ethyl hexanoate and ethyl octanoate, and the alcohol hexanol, in a ratio of 10:1:50:1.

Plant-derived attractants for adult moths are extensively referred to in the literature. Most relate to species, which are attracted to flowers, such as *Gaura* spp., which attract *Heliothis virescens*, as reported in Lingren et al., *Southwestern Entomologist*, 1998, No. 21. The ketone, cis-jasmone from Japanese honeysuckle, attracts a range of adult Lepidoptera, as reported by US Patent 5,665,344 filed in the name of Pair and Horvat, but these are unrelated to fruit-feeding groups such as the *Eudocima*. Landolt, *Journal of Economic Entomology*, 1991, 84, 1344-1347, developed a lure and toxicant system for cabbage looper (*Trichoplusia ni*) adults based on the floral compound phenylacetaldehyde. For fruitpiercing moths, the only reference in the literature, known to the applicants, directed to synthetic feeding attractants is Bosch, *Rhodesian Agricultural Journal*, 1971, 68, 2-4, who commented that moths (species not mentioned) were attracted to amyl or butyl acetate in the laboratory. Bosch makes no reference to how this attraction is made or how the odours were presented.

The use of sex attractants or pheromones have been investigated for fruitpiercing moths, but none has yet been
identified for a *Eudocima* sp. Sex pheromones are generally species specific and so do not have the broad applicability of general feeding attractants. For *Oraesia excavata*, a fruitpiercing moth in Japan, a female-produced sex pheromone was identified by Ohmasa, *Applied Entomology and Zoology*, 1991, 26, 55-62, which consisted of cis-9,10-epoxy-(Z)-6-heneicosene, as the major component, and cis-9,10-epoxy-(3Z,6Z)-3,6-heneicosadiene, as the minor component. There are no reports of a synthetic version of this pheromone being commercially available.

All the currently available methods of attracting and/or controlling fruitpiercing moths are either expensive and/or ineffective.

**SUMMARY OF THE INVENTION**

In one form of the invention, although it need not be the broadest form, the invention provides a synthetic fruitpiercing moth attractant formulation comprising:

(i) one or more straight chain and/or branched chain \( \text{C}_2-\text{C}_{12} \) aliphatic primary, secondary or tertiary esters and all isomers thereof; and

(ii) one or more saturated or unsaturated \( \text{C}_2-\text{C}_{12} \) aliphatic aldehydes and all isomers thereof; and/or

(iii) one or more saturated or unsaturated \( \text{C}_1-\text{C}_{12} \) aliphatic primary, secondary or tertiary alcohols and all isomers thereof.

Component (i) may be selected from one or more of amyl acetate, ethyl acetate, \( \text{n-butyl acetate} \), hexyl acetate, methyl butyrate, ethyl butyrate, methyl caprylate, ethyl caproate, ethyl sorbate, and methyl anthranilate. A preferable example of component (i) is methyl butanoate (CH\(_3\)CH\(_2\)CH\(_2\)CO\(_2\)CH\(_3\)).

Component (ii) may be selected from one or more of acetaldehyde, hexanal and trans-2-hexanal. A preferable example of component (ii) is trans-2-hexenal (CH\(_3\)CH\(_2\)CH\(_2\)CH=CHCHO).
Component (iii) may be selected from one or more of ethanol, 1-hexanol, cis-3-hexanol and 1-butanol. A preferable example of component (iii) is 1-hexanol [CH₃(CH₂)₅OH].

Preferably the moth attractant formulation ranges comprise the following proportions of each of components (i) to (iii);

(a) 20% to 99.9% of component (i); and
(b) 0.1% to 50% of component (ii); and/or
(c) 0.1% to 50% of component (iii);

whereby in each case the components (i), (ii) and (iii) add up to 100% or 100g of mixture on a weight/weight basis wherein each of the components are expressed in grams.

More preferably the proportions of the abovementioned components (i), (ii) and (iii) are as follows:

(a) 55-90% of component (i); and
(b) 10-45% of component (ii); and/or
(c) 0.1-45% of component (iii).

Most preferably the proportion of the abovementioned components (i), (ii) and (iii) are as follows:

(a) 75-80% of component (i); and
(b) 15-25% of component (ii); and/or
(c) 1-25% of component (iii).

The moth attractant formulation may further comprise one or more aromatic compounds, such as d-limonene.

It will be appreciated by and apparent to the person skilled in the art that the above concentrations of components (i), (ii) and (iii) are calculated on a dry weight basis without taking into consideration the amount of any solvent that may be used. The solvents may include acetone, ethanol, hexane or pentane.

The word formulation as used herein refers to an admixture of one or more or the components (i) and (ii) and/or (iii) or where one or more of the components (i) and (ii) and/or (iii) are individually contained in separate areas or components of a bait so as in use to
provide a volatile admixture of the components (i) and (ii) and/or (iii).

In another form of the invention, there is provided a method of use of the above moth attractant formulation to attract and control fruitpiercing moths.

In another form of the invention, there is provided a synthetic fruitpiercing moth attractant formulation comprising, one or more straight chain and/or branched chain \( C_2-C_{12} \) aliphatic primary, secondary or tertiary esters and all isomers thereof.

In yet another form of the invention, there is provided a method of attracting and/or controlling fruitpiercing moths by use of two or more straight chain and/or branched chain \( C_2-C_{12} \) aliphatic primary, secondary or tertiary esters and all isomers thereof, on or in the vicinity of a fruit crop.

In another form of the invention, there is provided a method of attracting and/or controlling insects by use of one of the above moth attractant formulations as a bait, trap or lure for fruitpiercing moths in the vicinity of a fruit crop.

Preferably the moth attractant formulations of the invention further includes a toxicant, chemosterilant, growth regulator or pathogen.

The moth attractant formulations when it is a bait may incorporate the moth attractant formulation as an admixture or having one or more of the components (i) and/or (ii) and/or (iii) individually contained within separate compartments or areas of the bait.

The moth lure may be a coated-gel, which incorporates the moth attractant formulation. The gel may contain a preservative, such as sodium benzoate, and/or 0 - 10% sucrose, as a feeding stimulant. The gel might be used in a trap or as a free-access bait containing a toxicant, chemosterilant, growth regulator, or pathogen. A preferable example of a toxicant is beta cyfluthrin,
imidacloprid, or the like. A preferable example of a chemosterilant
is triethylenephosphoramide (TEPA), hexamethylphosphoric
triamide (HEMPA), or the like. A preferable example of a growth
regulator is tebufenozide, fenoxycarb, or the like. A preferable
e Example of a pathogen is metarhizium, Nuclear Polyhedrosis Virus
(NPV), or the like.

There is a range of possible methods for releasing the
attractant mixtures into the atmosphere other than from a gel
mixture. These might include cotton wicks, sachet dispensers, and

BRIEF DESCRIPTION OF DRAWINGS

FIG 1: illustrates the differential responses by two fruitpiercing
moth species to a range of individual volatile compounds
known to occur in fruit odours, as recorded on an
electroantennogram (EAG).

FIG 2: shows the differences in the observed EAG responses of
E. fullonia to combinations of volatiles to expected EAG
responses as a proportion to the same compounds offered
singly.

FIG 3: compares the numbers of fruitpiercing moths on different
bait compositions.

DETAILED DESCRIPTION

In order to enable the invention to be fully understood, a
number of preferred embodiments will now be described which are
contained in the following Examples.

EXAMPLE 1

The responses of immature unfed and mature fed E. fullonia
and E. materna to a number of different chemical compounds were
assessed by electroantennogram in a laboratory study. The fruit
volatiles included;

- six (6) examples of component (i) being five ‘general’ fruity
  esters (amyl acetate, n-butyl acetate, ethyl butyrate, methyl
butyrate and ethyl acetate), one 'specific' fruity ester (methyl anthranilate);
- three examples of component (ii), acetaldehyde, hexanal, trans-2-hexanal;
- four examples of component (iii), ethanol, 1-hexanol, cis-3-hexanol and 1-butanol,
- an aromatic, d-limonene; and
- a terpene hydrocarbon, eugenol.

The volatiles were prepared in quantities of 0.025 and 2.5 μl in paraffin oil, before being infused individually as a single pulse into a continuous airstream passing over a moth antenna. The electrical response from the antenna was amplified en route to a digital storage oscilloscope. FIG 1 provides a summary of the responses in millivolts of mature fed *E. fullonia* and *E. materna* to 2.5 μl of each compound.

The 'general' fruity esters (n-butyl acetate and methyl butyrate) elicited the greatest response, while the 'green leaf' alcohols (e.g. 1-hexanol) and aldehydes (e.g. trans-2-hexenal) produced intermediate reactions. Similar trends were recorded for immature and unfed moths of both species. Methyl anthranilate, a specific ester responsible for much of the characteristic odour of certain grape varieties, mandarins and carambolas, generated little antennal response in comparison to the 'general' fruity esters (which averaged 3.75x higher).

**EXAMPLE 2**

The electroantennogram responses of *E. fullonia* to simple combinations of different compounds were measured following the procedures in Example 1, to determine whether mixtures of volatiles from different chemical component groups produced responses greater than expected from that observed to the compounds offered singly. The compounds chosen were n-butyl acetate, methyl butyrate, and 1-hexanol.
Irrespective of the chemical mixture, responses were greater than expected (FIG 2). In particular, where a higher proportion of 1-hexanol was represented in the mixture with an ester, the observed response was substantially higher than expected from the proportional response to the chemicals offered singly. This suggested that volatile compounds from different chemical groups are probably involved in the attraction of fruitpiercing moths to suitable fruit, and that they may have a synergistic effect on one another in the attraction process.

EXAMPLE 3

A series of experiments was undertaken in a large flight cage (2x3x2m) in a glasshouse to ascertain how moths responded to different combinations of volatile compounds presented in 'artificial' fruits. The 'artificial' fruits contained 1.75% agar and 10% wt./vol. of sugar in solution, into which 25μl of volatiles per 25ml bait had been infused. These 'fruits' were produced in such a way that they could be hung from the ceiling of the cage, providing moths with free access to them to feed. In Example 3, 'artificial' fruits were prepared to simulate the odours produced from 'mature', 'ripe' and 'very ripe' fruit, based on Carlos, M. and Jenning, W. G., J. Agric. Food Chem., 1987, 35, 845-848; Bartley, J. P. and Schwede, A. M., J. Agric. Food Chem., 1989, 37, 1023-1025; Morales, A. L. and Duque, C., J. Agric. Food Chem., 1987, 35, 538-540; and Wilson, C. et al., J. Agric. Food Chem., 1985, 33, 199-201, which report the composition of volatiles given off by bananas, ripened kiwi fruit, mountain papaya and carambola, respectively. All 'artificial' fruits contained the same seven volatile components, but the proportion of each varied according to the stage of ripeness. For ease of description the 'artificial fruits' will subsequently be referred to as 'fruits'.

Table 1 summarises the attractant formulations used in this example. There were four 'fruits' of a single type for each test,
which included a control treatment with no volatiles added. Tests were conducted through a single night, and replicated on seven separate occasions. The percentage of each fruit type attacked was recorded for each occasion and the results analysed by ANOVAR and LSD(T) tests of means. 'Ripe' fruit were preferred, but not statistically more than the 'very ripe' type (Table 1). However, 'fruits' which contained a high proportion of the non-ester components were far less attractive.

**TABLE 1:** Flight cage experiment

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Mature</th>
<th>Ripe</th>
<th>Very Ripe</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(%) in fruit</td>
<td>(%) in fruit</td>
<td>(%) in fruit</td>
<td>(sugar only)</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>1.5</td>
<td>6.8</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Methyl butyrate</td>
<td>2.0</td>
<td>25.4</td>
<td>11.1</td>
<td>-</td>
</tr>
<tr>
<td>Hexanal</td>
<td>6.2</td>
<td>0.9</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>0.6</td>
<td>14.2</td>
<td>69.4</td>
<td>-</td>
</tr>
<tr>
<td>Trans-2-hexenal</td>
<td>76.1</td>
<td>25.5</td>
<td>7.1</td>
<td>-</td>
</tr>
<tr>
<td>1-Hexanol</td>
<td>0.4</td>
<td>2.0</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>n-Butyl acetate</td>
<td>2.9</td>
<td>9.5</td>
<td>6.1</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>89.7</td>
<td>84.3</td>
<td>94.2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Esters (%)</strong></td>
<td>6.1</td>
<td>58.2</td>
<td>91.9</td>
<td>0</td>
</tr>
<tr>
<td><strong>Bioassay response (%)</strong></td>
<td>25.0</td>
<td>68.8</td>
<td>43.8</td>
<td>6.3</td>
</tr>
</tbody>
</table>

![](https://i.imgur.com/4Q5Q5Q5.png)

**EXAMPLE 4**

In a similar experiment to that of Example 3, the proportions of the specific esters (methyl butyrate, ethyl butyrate and n-butyl acetate) were varied among the three attractant formulations. The aldehyde and alcohol components were held in the same proportions for each treatment. Table 2 summarises the formulations used in this example. The experiment was again conducted over a single night and replicated on separate occasions. Irrespective of the proportions of the individual esters in the 'fruits' there was no statistical difference in their attractancy to the moths at P=0.05.
TABLE 2: Flight cage experiment

<table>
<thead>
<tr>
<th>Chemicals (%)</th>
<th>Ethyl butyrate</th>
<th>Methyl butyrate</th>
<th>n-Butyl acetate</th>
<th>Control (sugar only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>2.9</td>
<td>2.9</td>
<td>2.9</td>
<td>-</td>
</tr>
<tr>
<td>Methyl butyrate</td>
<td>24.5</td>
<td>44.0</td>
<td>24.5</td>
<td>-</td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>44.0</td>
<td>24.5</td>
<td>16.5</td>
<td>-</td>
</tr>
<tr>
<td>Trans-2-hexenal</td>
<td>10.8</td>
<td>10.8</td>
<td>10.8</td>
<td>-</td>
</tr>
<tr>
<td>1-Hexanol</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>n-Butyl acetate</td>
<td>16.5</td>
<td>16.5</td>
<td>44.0</td>
<td>-</td>
</tr>
<tr>
<td>Bioassay response (%)</td>
<td>43.8</td>
<td>56.3</td>
<td>50.0</td>
<td>6.2</td>
</tr>
</tbody>
</table>

F$_{3,12}$ = 2.72  P = 0.0911  LSD(T) = 41.92

EXAMPLE 5

In a follow-on experiment to Example 4, the type and proportions of some of the non-ester components in the 'fruits' were varied, such as the alcohol or aldehyde, to ascertain whether particular kinds of 'green leaf' volatiles were more important in the attractancy process than others. The variable components included trans-2-hexenal, cis-3-hexen-1-ol and 1-hexanol. Only two (2) of these compounds were included in any one treatment at any time. The details of each formulation and its respective bioassay response are summarised in Table 3. Acetaldehyde and hexanal were the other 2 non-ester components, used in standard proportion in each treatment. There was a substantially greater response (55.0%) by moths to the treatment which contained 10.8% trans-2-hexenal and 0.9% 1-hexanol than to the other treatments, although it did not quite exceed the response (30.0%) to the treatment with 10.8% cis-3-hexen-1-ol and 0.9% 1-hexanol by a statistical margin.
TABLE 3: Formulation details and respective bioassay responses

<table>
<thead>
<tr>
<th>Chemicals (%)</th>
<th>Major non-esters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trans-2hexanal</td>
<td>Cis-3-hexen-1-ol</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Methyl butyrate</td>
<td>28.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>28.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Trans-2-hexanal</td>
<td>10.8</td>
<td>-</td>
</tr>
<tr>
<td>Cis-3-hexan-1-ol</td>
<td>-</td>
<td>10.8</td>
</tr>
<tr>
<td>1-hexanol</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>n-butyl acetate</td>
<td>28.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Bioassay response (%)</td>
<td>55.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>

* sugar $F_{3,16} = 4.15P = 0.0236 \text{LSD(T)} = 27.538$

EXAMPLE 6

In a similar manner to the examples above a number of baits were prepared to compare the attraction of a control, single ester and a combination of esters only. The results are summarised below in Table 4. The proportions of each ester used in the combination formulation are equal, with the total quantity of combined ester making up a volume of 25µl/bait.

There was significantly greater number of moth attacks on the baits that contained the combination of esters than on those that contained a single ester.

TABLE 4: Comparison of the attractancy of a single ester against a combination of three esters when presented to Eudocima fullonia in a flight cage

<table>
<thead>
<tr>
<th>Replications</th>
<th>% of baits attacked</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control (sugar only)</td>
<td>n-butyl acetate only</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean</td>
<td>0a</td>
<td>12.5a</td>
</tr>
</tbody>
</table>

$F_{2,9} = 10.50 \quad P = 0.0044 \quad \text{LSD(T)} = 32.651$
EXAMPLE 7

A replicated experiment was undertaken in the flight cage in which the concentration of volatiles in the artificial 'fruits' was varied. Each treatment contained the same seven volatile constituents, and in the same proportions as used for the methyl butyrate treatment in Example 4, with the total concentration of volatiles per 'fruit' being 0, 5, 25 and 100µl per 25ml 'fruit'. The formulations used and their respective bioassay response rates are summarised in Table 5. There were no statistical differences in the mean proportions of 'fruits' attacked where they contained volatiles, although the 25µl/fruit concentration had the highest proportion of attacks. This concentration was therefore retained as the standard for the subsequent field trials.

<table>
<thead>
<tr>
<th>Chemicals (%)</th>
<th>Volatile concentration per bait</th>
<th>5 µl</th>
<th>25 µl</th>
<th>100 µl</th>
<th>Control* (0 µl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl butyrate</td>
<td></td>
<td>44.0</td>
<td>44.0</td>
<td>44.0</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td></td>
<td>24.5</td>
<td>24.5</td>
<td>24.5</td>
<td>-</td>
</tr>
<tr>
<td>n-Butyl acetate</td>
<td></td>
<td>16.5</td>
<td>16.5</td>
<td>16.5</td>
<td>-</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td></td>
<td>2.9</td>
<td>2.9</td>
<td>2.9</td>
<td>-</td>
</tr>
<tr>
<td>Trans-2-hexenal</td>
<td></td>
<td>10.8</td>
<td>10.8</td>
<td>10.8</td>
<td>-</td>
</tr>
<tr>
<td>Hexanal</td>
<td></td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>1-Hexanol</td>
<td></td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>Bioassay response (%)</td>
<td></td>
<td>21.43</td>
<td>28.57</td>
<td>25.00</td>
<td>3.57</td>
</tr>
</tbody>
</table>

sugar only F_{3,24} = 2.72 P = 0.213 LSD(T) = 25.53

EXAMPLE 8

A series of field trials was conducted over a number of years in a citrus crop in which *E. fullonia*, *E. materna* and *E. salaminia* were predominantly the active species. Experiments were conducted from the mature fruit to fully ripe stage of each crop, with fruit numbers averaging around 300 per tree. The citrus crop contained Clementine and hybrid mandarins, all of which were
highly attractive to fruitpiercing moths. The artificial 'fruits' or baits (without insecticide) were generally placed at a height of 2m in some trees, numbering 2-4 baits per tree. Unbaited trees were used as controls. Baits and fruit were observed for moth activity for approximately 90 minutes on the first night of exposure, and often again several nights later. Baits containing only esters (5 or 6 esters per bait) were compared against those that contained 80% esters (3 esters per bait) plus aldehydes and an alcohol in the citrus crop several times through a season. Table 6 summarises the formulation details for each bait used on each occasion.

The average % of baits attacked by *Eudocima* spp. was recorded. On 3 occasions represented by an increasing proportion of ripe fruit, the respective percentages of baits attacked for the ester only and ester + aldehyde + alcohol treatments were: 40:60, 20:45 and 0:20. This obvious difference between bait types is only a statistical one (at P=0.05) if some data for the ester only combination, which dominate one particular date, are excluded from the first occasion.

**TABLE 6: Formulation details for baits**

<table>
<thead>
<tr>
<th>Chemicals (%)</th>
<th>1st occasion</th>
<th>2nd occasion</th>
<th>3rd occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>n-butyl acetate</td>
<td>30</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Methyl butyrate</td>
<td>25</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>20</td>
<td>20</td>
<td>23.1</td>
</tr>
<tr>
<td>Hexyl acetate</td>
<td>15</td>
<td>10</td>
<td>13.3</td>
</tr>
<tr>
<td>Amyl acetate</td>
<td>10</td>
<td>13.3</td>
<td>13.3</td>
</tr>
<tr>
<td>Ethyl caproate</td>
<td>13.3</td>
<td>13.3</td>
<td>10.7</td>
</tr>
<tr>
<td>Ethyl sorbate</td>
<td>13.3</td>
<td>13.3</td>
<td>10.7</td>
</tr>
<tr>
<td>Methyl caprylate</td>
<td>13.3</td>
<td>10</td>
<td>3.9</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Hexanal</td>
<td>14.5</td>
<td>14.5</td>
<td>14.5</td>
</tr>
<tr>
<td>Trans-2-hexenal</td>
<td>15</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>d-limonene</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
EXAMPLE 9

In this example, baits were placed in the citrus crop once a week in a six-week period. Baits contained 80% esters (of 2-3 types), 15-18.9% aldehydes (of 1-3 types) and 1.1-5.0% alcohols (1 type). The commonest volatile components in the baits were n-butyl acetate, methyl butyrate, trans-2-hexenal and 1-hexanol. Table 7 summarises the formulation details for each bait type used. There were equal numbers of baited and unbaited trees, and 2 baits of any treatment in any tree. Moth activity was observed in baited and unbaited trees for 2h after dark. *E. fullonia* was the dominant species active during the first half of the season and *E. materna* during the remainder.

FIG 3 compares the number of moths observed on baits with the number of moths observed on fruit on baited trees for a) all *Eudocima* spp., and b) all *Eudocima* excluding *E. materna*. There was no difference (F=0.68, d.f.=1.13 P=0.427) in the numbers of moths on baits and fruit through the season when all species were included in the data, but when *E. materna* was excluded, significantly more moths (75%) were recorded on the baits (F=5.76, d.f.=1,13 P=0.037). *E. materna* were excluded for statistical purposes because they occur in lower numbers on the east coast of Australia. Irrespective of moth species, during the first 3 weeks of the trial, 85% of moths occurred on baits and only 15% on fruit on baited trees.

Bait Type 1 used in this example became the standard bait composition used in later examples.
TABLE 7: Formulation details for baits

<table>
<thead>
<tr>
<th>Chemicals (%)</th>
<th>Bait type 1</th>
<th>Bait type 2</th>
<th>Bait type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-butyl acetate</td>
<td>15.5</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Methyl butyrate</td>
<td>41.4</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Ethyl butyrate</td>
<td>23.1</td>
<td></td>
<td>15.5</td>
</tr>
<tr>
<td>Methyl caprylate</td>
<td></td>
<td></td>
<td>23.1</td>
</tr>
<tr>
<td>Ethyl sorbate</td>
<td></td>
<td></td>
<td>41.1</td>
</tr>
<tr>
<td>Ethyl caproate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>3.9</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>Hexanal</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Trans-2-hexenal</td>
<td>14.5</td>
<td>15</td>
<td>14.5</td>
</tr>
<tr>
<td>1-hexanol</td>
<td>1.1</td>
<td>5</td>
<td>1.1</td>
</tr>
</tbody>
</table>

EXAMPLE 10

In a further field experiment in a citrus crop, a comparison was undertaken of the attractancy of standard baits (bait type 1, from example 9) against others with a waxed coating, to see whether the latter could extend bait field life. Both standard and waxed bait types contained the seven volatile components and in the same proportions as used in bait type 1 of example 9. The standard baits contain 25µl of the attractant formulation and 25 ml of a sugared-gel (10% sugar, 1.75% agar and water). To form a waxed bait some standard baits had a wax coating applied.

The number of baits attacked was recorded after the first night and the numbers of moths on baits and fruit recorded on the third night of exposure. After the initial night’s exposure, 30% of the standard baits had been attacked by fruitpiercing moths compared to 40% of the waxed baits. On the third night, 5 moths (all E. fullonia) were observed on the waxed baits and none on the standard ones, and one (1) E. fullonia was recorded on fruit on baited trees. After 3 nights, 90% of the waxed baits were found to be pierced compared to 50% of the standard baits.

EXAMPLE 11

This experiment is similar to Example 10, except in that 2% glycerine and 2% paraffin oil was incorporated into the agar baits.
before waxing. The glycerine and paraffin oil are used as extenders in the baits, i.e. they slow the release of the attractant. There were 10 baits of each treatment, and 10 trees with the 3 treatments represented on each. No standard baits were damaged on nights 1 and 2. Of the waxed baits, 20% (of those without glycerine/paraffin) and 30% (of those with glycerine/paraffin) were attacked on night 1, and 40% of both types had been attacked after night 2. On the third night, there were no moths on fruit on baited trees, 1 on a waxed bait (without glycerine/paraffin) and 3 on waxed baits (with glycerine/paraffin). The moths observed on the baits were *E. fullonia* and *E. salaminia*.

Based on the experiments carried out to date it has been found that a fruitpiercing moth attractant formulation comprising; two or more of component (i) [ester], components (i) and (ii) [ester and aldehyde], components (i) and (iii) [ester and alcohol] and a formulation having a number of components (i), (ii) and (iii) are all efficacious in attracting fruitpiercing moths.

It will be appreciated by a person skilled in the art that the fruitpiercing moth attractant formulation comprising of a single component (i), (ii) and (iii) would be efficacious in attracting and controlling fruitpiercing moths.

Throughout the specification the aim has been to describe the preferred embodiments of the invention without limiting the invention to any one embodiment or specific collection of features.
CLAIMS

1) A synthetic fruitpiercing moth attractant formulation comprising;
   i) 20% to 99.9% one or more straight chain and/or branched
      chain C<sub>2</sub>-C<sub>12</sub> aliphatic primary, secondary or tertiary esters
      and all isomers thereof; and
   ii) 0.1% to 50% one or more saturated or unsaturated C<sub>2</sub>-C<sub>12</sub>
      aliphatic aldehydes and all isomers thereof; and/or
   iii) 0.1% to 50% one or more saturated or unsaturated C<sub>1</sub>-C<sub>12</sub>
      aliphatic primary, secondary or tertiary alcohols and all
      isomers thereof;

   whereby in each case the components (i), (ii) and (iii) add up
   to 100% or 100g of mixture on a weight/weight basis wherein
   each of the components are expressed in grams.

2) The synthetic fruitpiercing moth attractant formulation of
   claim 1 wherein component (i) is selected from one or more of
   amyl acetate, ethyl acetate, n-butyl acetate, hexyl acetate, methyl
   butyrate, ethyl butyrate, methyl caprylate, ethyl caproate, ethyl sorbate,
   and methyl anthranilate.

3) The synthetic fruitpiercing moth attractant formulation of
   claim 1 wherein component (ii) is selected from one or more of
   acetaldehyde, hexanal and trans-2-hexanal.

4) The moth attractant formulation of claim 1 wherein component
   (iii) is selected from one or more of ethanol, 1-hexanol, cis-3-hexanol
   and 1-butanol.

5) The synthetic fruitpiercing moth attractant formulation of
   claim 1, comprises:
   (a) 55-90% of component (i); and
   (b) 10-45% of component (ii); and/or
   (c) 0.1-45% of component (iii).

6) The synthetic fruitpiercing moth attractant formulation of
   claim 1, comprises:
(a) 75-80% of component (i); and
(b) 15-25% of component (ii); and/or
(c) 1-25% of component (iii).

7) The synthetic fruitpiercing moth attractant formulation of claim 1, further comprising one or more aromatic compounds, such as d-limonene.

8) The synthetic fruitpiercing moth attractant formulation of claim 1 further comprising a toxicant, chemosterilant, growth regulator and/or pathogen.

9) The synthetic fruitpiercing moth attractant formulation of claim 8 wherein the toxicant is selected from beta cyfluthrin, imidacloprid, and the like.

10) The synthetic fruitpiercing moth attractant formulation of claim 8 wherein the chemosterilant is selected from triethylenephosphoramide (TEPA), hexamethylphosphoric triamide (HEMPA), and the like.

11) The synthetic fruitpiercing moth attractant formulation of claim 8 wherein the growth regulator is selected from tebufenozide, fenoxy carb, and the like.

12) The synthetic fruitpiercing moth attractant formulation of claim 8 wherein the pathogen is selected from metarhizium, Nuclear Polyhedrosis Virus (NPV), and the like.

13) The synthetic fruitpiercing moth attractant formulation of claim 8, further comprising a gel containing a preservative, such as sodium benzoate, and/or 0 - 10% sucrose as a feeding stimulant.

14) A synthetic fruitpiercing moth attractant formulation comprising two or more straight chain and/or branched chain C_{2-12} aliphatic primary, secondary or tertiary esters and all isomers thereof.
15) The synthetic fruitpiercing moth attractant formulation of claim 14 wherein the esters are selected from n-butyl acetate, methyl butyrate and ethyl butyrate.

16) The use of the synthetic fruitpiercing moth attractant formulation of claim 1 to attract and control fruitpiercing moths.

17) The use of the synthetic fruitpiercing moth attractant formulation of claim 14 to attract and control fruitpiercing moths.

18) A bait incorporating the synthetic fruitpiercing moth attractant formulation of claim 1 for use in attracting and/or controlling fruitpiercing moths in the vicinity of a fruit crop.

19) The bait of claim 18 wherein the synthetic fruitpiercing moth attractant formulation is incorporated as an admixture or having one or more of the components (i) and (ii) and/or (iii) individually contained within separate compartments or areas of the bait.

20) A lure incorporating the synthetic fruitpiercing moth attractant formulation of claim 1 for use in attracting and/or controlling fruitpiercing moths in the vicinity of a fruit crop.

21) The insect lure of claim 20 wherein the synthetic fruitpiercing moth attractant formulation is incorporated in a gel coating.

22) The insect lure of claim 20 wherein the gel contains a preservative, such as sodium benzoate, and/or 0 - 10% sucrose, as a feeding stimulant.

23) A bait incorporating the synthetic fruitpiercing moth attractant formulation of claim 14 for use in attracting and/or controlling fruitpiercing moths in the vicinity of a fruit crop.

24) The bait of claim 23 wherein the synthetic fruitpiercing moth attractant formulation is incorporated as an admixture or having one or more of the components (i) and (ii) and/or (iii)
individually contained within separate compartments or areas of the bait.

25) A lure incorporating the synthetic fruitpiercing moth attractant formulation of claim 14 for use in attracting and/or controlling fruitpiercing moths in the vicinity of a fruit crop.

26) The insect lure of claim 25 wherein the synthetic fruitpiercing moth attractant formulation is incorporated in a gel coating.

27) The insect lure of claim 25 where in the gel contains a preservative, such as sodium benzoate, and/or 0 - 10% sucrose, as a feeding stimulant.
Amyl acetate
n-butyl acetate
Ethyl butyrate
Methyl butyrate
Ethyl acetate
Methyl anthranilate
Ethanol
1-hexanol
cis-3-hexenol
1-butanol
Acetaldehyde
Hexanal
trans-2-hexenal
d-limonene
Eugenol
Value relative to standard

Amyl acetate (2.5)*
n-butyl acetate (Ba)(2.5)
Methyl butyrate (Mb)(2.5)
1-hexanol (H)(2.5)
Ba(1.5)+ Mb(1.0)
Ba(1.0)+ Mb(1.5)
Ba(1.5)+ H(1.0)
Ba(1.0)+ H(1.5)
Mb(1.5)+ H(1.0)
Mb(1.0)+ H(1.5)
Ba(1.5)+ Mb(0.5)+ H(0.5)
Mb(1.5)+ Ba(0.5)+ H(0.5)
H(1.5)+ Ba(0.5)+ Mb(0.5)
FIG. 3

E. materna included

Period in which harvest would normally occur

No. of moths observed

E. materna excluded

Period in which harvest would normally occur

No. of moths observed

Week 1  Week 2  Week 3  Week 4  Week 5  Week 6  Week 7

Moths on baits  Moths on fruit (bailed trees)  Remaining fruit showing colour

Remaining fruit showing colour (%)