Trap Design Effect on Capture of *Carpophilus* spp. (Coleoptera: Nitidulidae) Using Synthetic Aggregation Pheromones and a Coattractant

DAVID G. JAMES, ROBERT J. BARTELT, and CHRISTOPHER J. MOORE

Yanco Agricultural Institute, NSW Agriculture, PMB Yanco, New South Wales 2703 Australia

ECOLOGY AND BEHAVIOR

ABSTRACT In a series of experiments conducted in stone fruit orchards in southern Australia, water-based funnel-type traps baited with synthetic aggregation pheromone and fermenting bread dough, trapped 3- to 7-fold as many *Carpophilus* beetles (primarily *C. davidsoni*) than wind-oriented pipe traps or dry funnel traps. The efficacy of dry funnel traps but not pipe traps, appeared to be improved by using water-filled collecting bottles. The potential for using water-based funnel traps in population suppression of *Carpophilus* spp. in stone fruit orchards through mass trapping is discussed.

KEY WORDS Nutidulid beetles, trap design, aggregation pheromone

NITIDULID BEETLES of the genus *Carpophilus* are serious pests of ripening stone fruit in southern Australia, particularly apricots, peaches, and nectarines in the inland irrigated horticultural regions of New South Wales, Victoria, and South Australia (Gaven 1964, Helv et al. 1982). *Carpophilus* spp. (primarily *C. hemipterus* (L.), *C. mutilatus* Erichson, and *C. davidsoni* Dobson) (James et al. 1995) cause damage in these regions by penetrating ripening fruit resulting in rapid breakdown. They often enter at sites of mechanical damage or at the stem end and also serve as vectors of brown rot (Kable 1969, Tate and Ogawa 1975). Major damage can occur within a few days of beetle attack and losses of entire crops have been reported.

Current control measures consist of multiple ground or foliar applications of organophosphate insecticides in the month or so before harvest. However, control is often unsatisfactory and short-lived because of difficulties in targetting beetles and beetle immigration into treated blocks from surrounding areas. In addition, the use of organophosphates in stone fruit invariably results in outbreaks of twospotted spider mite, *Tetranychus urticae* Koch, which is otherwise controlled by natural enemies (James 1990). Some of these materials have preharvest intervals of 7–14 d during which time *Carpophilus* beetles can cause serious damage.

The use of synthetic aggregation pheromones to monitor or mass-trap *Carpophilus* spp. has considerable potential for management of these pests. Male-produced aggregation pheromones have been identified and synthesized for a number of *Carpophilus* spp. including *C. hemipterus* (Bartelt et al. 1992a), *C. mutilatus* (Bartelt et al. 1993), and *C. davidsoni* (Bartelt and James 1994). Research conducted in the United States (Bartelt et al. 1992b, 1993, 1994a), Israel (Blumberg et al. 1993) and Australia (James et al. 1993, 1994) has demonstrated these pheromones to be highly potent attractants for *Carpophilus* spp. when synergized by food volatiles. Wind-oriented pipe traps (Dowd et al. 1992) baited with synthetic pheromone and fermenting bread dough, can attract thousands of beetles weekly (James et al. 1995) or daily (Bartelt et al. 1994a, b). To evaluate the potential of mass trapping as a management option for *Carpophilus* spp., it is important to determine the most effective trap design for maximum beetle captures. Peng and Williams (1991) compared 9 trap designs for nitidulids and showed 5 funnel-type traps were equally efficient in trapping dusky sap beetles, *Carpophilus lugubris* Murray, Williams et al. (1993) showed a simple funnel-type trap (NIT trap) was more effective than the wind-oriented pipe trap (Dowd et al. 1992) for 3 nitidulid species including *C. lugubris*.

Here, we report on the efficiency of 5 trap types (and modifications to 3 of them) for capturing *Carpophilus* spp. in stone fruit orchards in the Murumbidgee Irrigation Area of southern New South Wales, using synthetic aggregation pheromones and a co-attractant.

Materials and Methods

Synthetic Pheromones. Pheromone trapping prior to these experiments indicated *Carpophilus*
populations in Murrumbidgee Irrigation Area stone
fruit orchards were dominated by *C. davidsoni* and
the pheromone for this species was therefore used
in experiments 1 and 2. The pheromone for *C. davidsoni* consisted of a 100:8:31:160 blend of
(2E,4E,6E,8E)-5-ethyl-3-methyl-2,4,6-nonatriene,
(3E,5E,7E)-6-ethyl-4-methyl-3,5,7-decatriene,
(2E,4E,6E,8E)-3,5,7-trimethyl-2,4,6,8-decatetraene,
and (2E,4E,6E,8E)-7-ethyl-3,5-dimethyl-2,4,
6,8-decatetraene (Bartelt and James 1994). In ex­periments 3 and 4 the pheromone for *C. mutilatus*
was also used. The pheromone for *C. mutilatus*
consisted of a 100:7 blend of (3E,5E,7E)-5-ethyl-7-
methyl-3,5,7-decatriene and (3E,5E,7E)-6-ethyl-4-
methyl-3,5,7-decatrene (Bartelt et al. 1993). The
pheromone for *C. hemipterus* was used in species
reference traps employed in experiment 3 and con­sisted of a 100:31:11:8 blend of (2E,4E,6E,8E)-
3,5,7-trimethyl-2,4,6,8-decatetraene, (2E,4E,6E,8E)
-3,5,7-trimethyl-2,4,6,8-decatetraene, and
(2E,4E,6E,8E)-7-ethyl-3,5-dimethyl-2,4,6,8-decat­
etraene and (2E,4E,6E,8E)-7-ethyl-3,5-dimethyl-
2,4,6,8-decatetraene (Bartelt et al. 1992b). The
synthetic pheromones were purified only by distil­lation and open column chromatography on silica
gel. These procedures did not remove the small
amounts of Z isomers produced in the syntheses
(Bartelt et al. 1990) but there is no evidence that
these (presently unavoidable) impurities are detri­mental to pheromone activity (Bartelt et al. 1992b).

Pheromones were diluted appropriately with
hexane and stored in a freezer until needed. Con­centrations of components were determined by gas
chromatography on diluted aliquots (instrumenta­tion as described by Bartelt and James 1994). Phero­mone solutions were applied to rubber septa
(11 by 20 mm, red rubber, Aldrich, Milwaukee,
WI) followed by 300 µg of methylene chloride.
Once the liquid had soaked into the septa, they
were aired in a fume hood for 1 h and stored in a
freezer in tightly closed bottles until needed. Septa
in experiments 1 and 2 were prepared with 500 µg
of *C. davidsoni* pheromone per septum. Septa in
experiments 3 and 4 were prepared with 5,000 µg
each of *C. davidsoni* and *C. mutilatus* pheromone
per septum. For the species reference traps in ex­periment 3 septa were prepared with 5,000 µg
each of *C. davidsoni*, *C. mutilatus* and *C. hemipterus*
pheromone per septum.

**Contrastant Baits and Traps.** Fermenting
whole-wheat bread dough was used as the phero­mone synergist (=10 ml per trap) held in a 20-ml
glass tube with a fine gauze lid. Five trap types (3
commercially available and 2 experimental) were
evaluated for their performance in trapping *Car­tophilus* spp. (Fig. 1). The effect of modifications
to 3 of them was also evaluated.

**Wind-Oriented Pipe Trap.** This was based on
the design of Dowd et al. (1992) and has been used in
most of the field studies conducted to date by the
authors (e.g., Bartelt et al. 1994a, b; James et al.
1994). This trap was constructed from white poly­
vinyl chloride (PVC) piping and assembled in the
form of a T. Beetles entered the trap through a
cone-shaped piece of screen and ended up in a
plastic 140-ml gauze-bottomed bottle attached to
the bottom of the trunk pipe. The trap design in­corporates a 'fin' that enables orientation with the
wind so that the trap entrance is always accessible
to beetles approaching the trap from downwind.

No killing agent was used as beetles are unable to
find their way out and rapidly die from dessication.
During experiment 1 this trap was modified by using
a solid-bottomed plastic collecting bottle half­
filled with water.

**Upturned McPhail Trap.** A plastic version of this
commonly used trap for fruit flies (Trappit Dome
Trap, Agrisense, Pontypridd, Glamorgan, UK) was
used in an upturned position, so that beetles could
enter from above. Preliminary studies indicated 2-­to 3-fold as many *Carphophilus* spp. were trapped in
upturned McPhail traps as in correctly posi­tioned
ones (D.C.J., unpublished data). Water was
used in this trap to prevent beetles escaping. The
pheromone septum and cocontrant were placed in
a plastic holder screwed to the bottom of the
trap and positioned above the water level. The en­trance part of the trap was yellow and the lower,
water-filled part clear.

**Lucitrap.** This trap was a simple clear plastic
bucket-type trap (6 liters) with a yellow lid con­taining =60 separate entrance cones (cone base, 1
cm diameter) and 2 covered compartments for
placement of lures. The trap was designed for trap­ping the Australian sheep blowfly *Lucilia cuprina*
(Wiedemann) using chemical lures that mimic
odors of fly food sources (Miazma. Warwick,
Queensland, Australia). For trapping *Carphophilus* spp. the Lucitrap was filled with water to a depth
of 2–4 cm and the pheromone septum and co­contrant placed in 1 of the lure compartments. In
experiment 3 this trap was modified by sealing up
all entrance cones and opening up one of the lure
compartments. This provided a single 4-cm-diam­eter exit for volatiles and entrance for beetles.
Unreplicated observations indicated *Carphophilus* spp.
were more readily trapped using a single entrance.

**Faulder Funnel.** Designed for this experiment,
this was a simple funnel trap constructed from
white PVC piping. The body of the trap was a 23-
cm piece of pipe (11 cm diameter) with red plastic
funnels fitted at either end. The base of the top
funnel (4 cm diameter) was covered with nitidulid­proof gauze except for a central opening. The bot­tom funnel was screwed onto the pipe with a
flange and led into a 140-ml gauze-bottomed plas­tic collecting bottle. As with the pipe trap, once
beetles entered the collecting bottle they were un­able to escape. The pheromone septum and co­contrant were taped to the inside of the pipe. Dur­ing experiment 1 and in experiment 2 this trap was
modified by using solid-bottomed collecting bottles
half-filled with water.
Fig. 1. The 5 trap types used in this study were (1) Magnet Funnel trap, (2) Faulder Funnel trap, (3) Upturned McPhail trap, (4) Lucitrap, and (5) wind-oriented pipe trap.

**Magnet Funnel Trap.** This dark green trap (23 by 17 cm) obtained from Agrisense (Pontypridd) is a simple funnel design used primarily for trapping moths. For trapping *Carpophilus* spp., we filled the trap with water to a depth of 2–4 cm. The pheromone septum and co-attractant were taped to the inside of the downward projecting funnel. All traps except Lucitraps were suspended from tree branches at =1.5 m above the ground. Lucitraps were nailed or tied to tree trunks at the same height. Traps were examined weekly, beetles collected, and fluff replaced. Pheromone septa were replaced every 2 wk.

**Sites and Experimental Design.** Three experiments were conducted in 3 stone fruit orchards near Leeton in the Murrumbidgee Irrigation Area in southern New South Wales during 1994 and 1995. No insecticides were used in any of the orchards during the experiments. Experiment 1 was conducted during a 12-wk period (26 October–18 January) in a 0.25-ha peach orchard at the Yanco Agricultural Institute. Four trap types (Pipe, Lucitrap, upturned McPhail, Faulder Funnel) each replicated 4 times, were evaluated. Treatments were randomized although missing trees prevented the use of a uniform grid. Trees were spaced at 5-m intervals and the orchard was flood-irrigated. Beetles were counted and identified (using Dobson 1952, 1954) in the laboratory. During 30 November to 18 January the collecting bottles of pipe and Faulder Funnel traps were half filled with water. Experiment 2 was conducted in a 1-ha apricot orchard during fruit ripening from 7 December to 4 January. A pipe trap (dry collecting bottle) and a Faulder Funnel trap (water-filled collecting bottle) were placed in each perimeter tree (n = 54). Trees were spaced at 5-m intervals and traps placed on the outside edges of tree canopies. Beetles were counted in the laboratory and those caught in reference pipe traps in the center of the orchard provided data on species composition. Experiment 3 was conducted in a 0.5-ha apricot orchard during 18 January to 1 March. Four trap types (Pipe, upturned McPhail, Magnet Funnel, Lucitrap) and a modified (single opening) Lucitrap were evaluated. Each trap type was replicated 3 times in a randomized complete block design with a 6.5-m tree spacing. Beetles were counted in the laboratory. The rapid decomposition of the large numbers of beetles caught in water-based traps in this and the preceding experiment prevented species identification. Only beetles caught in the dry pipe traps in experiment 3 were identified. Trapping data for all experiments were transformed to the log (x + 1) scale and subjected to analysis of variance and least significant difference procedures.

**Results**

**Experiment 1.** The water-based upturned McPhail and Lucitraps caught significantly greate
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Table 1. Mean captures (±SE) of Carpophillus spp. in 4 trap types in a southern New South Wales peach orchard during 26 October 1994–18 January 1995 (experiment 1)

<table>
<thead>
<tr>
<th>Trap type</th>
<th>Total No. of captures</th>
<th>Catch per week per trap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C. davidsi</td>
<td>C. mutilatus</td>
</tr>
<tr>
<td></td>
<td>per trap</td>
<td>per trap</td>
</tr>
<tr>
<td></td>
<td>26 October–30 November</td>
<td></td>
</tr>
<tr>
<td>Upturned McPhail (with water)</td>
<td>416 ± 17</td>
<td>5</td>
</tr>
<tr>
<td>Lucitraps (with water)</td>
<td>237 ± 22</td>
<td>6</td>
</tr>
<tr>
<td>Pipe (without water)</td>
<td>57 ± 3</td>
<td>4</td>
</tr>
<tr>
<td>Faulder funnel (without water)</td>
<td>39 ± 7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 November–18 January</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upturned McPhail (with water)</td>
<td>292 ± 70</td>
<td>21</td>
</tr>
<tr>
<td>Lucitraps (with water)</td>
<td>233 ± 80</td>
<td>18</td>
</tr>
<tr>
<td>Pipe (with water)</td>
<td>40 ± 7</td>
<td>5</td>
</tr>
<tr>
<td>Faulder funnel (with water)</td>
<td>225 ± 85</td>
<td>30</td>
</tr>
</tbody>
</table>

All trap types were replicated 4 times and baited with synthetic pheromone for C. davidsi (500 µg) and fermenting bread dough. Analysis in log10 scale. Means in columns followed by the same letter are not significantly different (P > 0.05).

Discussion

The results from this study indicate that water-based funnel traps are highly effective in capturing large numbers of Carpophillus spp. Although Carpophillus populations during these experiments were dominated by C. davidsi, enough data were collected to suggest that C. hemipterus and C. mutilatus respond similarly to the trap types tested. Peng and Williams (1991) evaluated a more extensive range of trap types (all with water) baited with fermenting bread dough only and also found funnel-type traps to be the most efficient for capturing Carpophillus lugubris Murray. During the current experiments, upturned McPhail traps, Lucitraps, and Magnet Funnel traps caught 3- to 7-fold as many beetles as the dry, wind-oriented pipe trap of Dowd et al. (1992). In experiment 3, when numbers of Carpophillus spp. were at their highest, this difference was 4- to 5-fold, similar to the dif-
Table 3. Mean captures (±SE) of C. hemipterus, C. mutilatus and C. davidsoni in four trap types and a modified (single-opening) version of the Lucitrap in a southern New South Wales apricot orchard during 18 January–1 March 1995

<table>
<thead>
<tr>
<th>Trap type</th>
<th>Overall total (all species)</th>
<th>Captures per week per trap (all species)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upturned McPhail</td>
<td>13.789</td>
<td>786 ± 303a</td>
</tr>
<tr>
<td>with water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnet trap</td>
<td>11.749</td>
<td>653 ± 148a</td>
</tr>
<tr>
<td>with water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lucitrap</td>
<td>10.566</td>
<td>587 ± 118a</td>
</tr>
<tr>
<td>with water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Lucitrap</td>
<td>10.136</td>
<td>566 ± 164a</td>
</tr>
<tr>
<td>with water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe</td>
<td>1.947</td>
<td>154 ± 321b</td>
</tr>
<tr>
<td>without water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All traps replicated 3 times and baited with synthetic pheromones for C. davidsoni (5,000 µg) and C. mutilatus (5,000 µg) and fermenting bread dough. Analysis in logx + 1) scale. Of the 1,947 beetles caught in the pipe traps, 71% were C. davidsoni, 29% were C. mutilatus and 1% were C. hemipterus. Means followed by the same letter not significantly different (P > 0.001).

The difference shown by Williams et al. (1993) for pheromone/coattractant baited simple, dry funnel traps compared to pipe traps. Pipe traps have been used extensively for pheromone/coattractant trapping of Carpophilus spp. in recent years (e.g., Bartelt et al. 1992a, James et al. 1994) and can trap considerable numbers of beetles when large populations occur. For example, single traps in Australian stone fruit orchards have caught up to 20,000 C. davidsoni per week (D.G.J., unpublished data) and single traps in a California date garden caught up to 63,500 C. mutilatus per week (Bartelt et al. 1994a).

From the results of this study we could perhaps speculate a 4- to 5-fold increase in these catches if water-based funnel traps were used. The pipe trap was designed as an efficient research tool for comparing attractants/pheromones for Carpophilus spp., and with its wind orientation is probably very effective in sampling beetle populations within a defined area; however, it clearly lacks the potential of funnel traps.

The effect of water in enhancing trap captures was indicated in experiment 1. The poor performance of the Faulder Funnel trap in the 1st part of the experiment was improved significantly in the 2nd part, to the level of upturned McPhail and Lucitraps, by using collection bottles half-filled with water. In experiment 2, the use of water in Faulder Funnel traps more than doubled beetle captures compared with dry pipe traps, whereas the pipe trap captured double the number of beetles when both were used without water. The addition of water to pipe traps in experiment 1, however, did not improve their efficacy. This was possibly the result of the limited space of water vapor in these traps because of the small (5 mm) upper opening of the collection bottle. In the Faulder Funnel traps, water vapor escaped through a 12-mm opening. Two species of Carpophilus (C. hemipterus, C. dimidiatus) were shown to respond to humidity gradients: Amos and Waterhouse 1967. Amos 1989: choosing moister environments over dry environments. Dowd and Bartelt (1991) also showed C. hemipterus was attracted to water and that water acted as an effective pheromone synergist. Increased attractiveness of pheromone/coattractant volatiles when carried by air currents with a high moisture content is therefore not unexpected.

The commercially available Magnet funnel trap and Lucitrap are both used dry for trapping moths and blowflies, respectively. However, they can be converted easily for use with water by sealing the drainage holes. The large numbers of openings in the Lucitrap (optimal for blowfly trapping) did not alter the effectiveness of the trap for Carpophilus spp. compared to a single opening. The Magnet trap plus water was also evaluated by Peng and Williams (1991) (referred to as the 'Unitrap' or 'Moth trap') and found to be very effective for trapping C. lugubris, although it was less effective for other nitrilids in the genus Gischothris. Dry Magnet traps baited with synthetic pheromone and coattractant were also effective for trapping C. hemipterus and C. mutilatus in date plantations in Israel (Blumberg et al. 1993). One problem in using water in Carpophilus traps during summer is the rapid decomposition of beetles and resultant putrefaction. In this study, traps were emptied weekly and this problem did not become excessive. However, if such traps are used by orchardists in mass trapping Carpophilus spp., weekly servicing would be a disadvantage. The effect (if any) of putrefaction or continued attraction by beetles to pheromone/coattractant baits should be investigated.

It is still unknown what percentage of the beetle population in a finite area the above described traps are capable of capturing. This fundamental question must be answered before an assessment can be made of the potential mass trapping has as a management tool for Carpophilus spp., in stone fruit or cherries. The effective trapping range provided by the traps and different pheromone doses (Bartelt et al. 1994b, James et al. 1994) must also be determined. The economic effect of Carpophilus spp. in stone fruit orchards derives from their propensity to develop enormous populations under favorable conditions. Observational and anecdotal evidence suggests that damage to ripening fruit on trees occur only when extremely large populations are present. Smaller populations tend to confine themselves to fallen fruit. Very high levels of mass trapping may therefore not be necessary to achieve economic control of Carpophilus spp. in stone fruit orchards.

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