Research reports

Potential for reduced-dose of synthetic aggregation pheromone of *Carpophilus* spp. for an attract and kill strategy in stone fruit orchards

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Summary
High costs of standard-doses of synthetic aggregation pheromone of *Carpophilus* spp. may limit commercial acceptance of an attract and kill strategy to manage *Carpophilus* spp. damage in stone fruit orchards. Pheromone rates one sixth of the standard-dose performed statistically equivalent to the standard-dose in peach orchards in the Goulburn Valley, Victoria, Australia. Data supported the use of reduced-dose of pheromone in combination with ripe fruit and fermented fruit juice as a co-attractant.

Keywords: Synthetic aggregation pheromone, attract and kill, reduced-dose of pheromone, *Carpophilus* spp., stone fruit.

Introduction
In southern Australia, three species of *Carpophilus* (Coleoptera: Nitidulidae): *C. davidsoni* Dobson, *C. mutilatus* Erichson and *C. hemipterus* (L) are major pests of ripening stone fruit (James *et al*. 1995, 1997). Economic losses up to 30% have been reported at fruit harvest due to *Carpophilus* spp. damage (Hossain *et al*. 2000). Until recently, no pesticides were registered to control *Carpophilus* spp. on stone fruit in Australia, so growers relied on the use of broad-spectrum sprays applied against other pests, such as *Grapholita molesta* Busck (Lepidoptera: Tortricidae), to control *Carpophilus* spp. This often did not give satisfactory control of *Carpophilus* spp.

An important development in *Carpophilus* spp. management came with the identification and synthesis of the male produced aggregation pheromones of *C. hemipterus* (Bartelt *et al*. 1990), *C. mutilatus* (Bartelt *et al.* 1993) and *C. davidsoni* (Bartelt and James 1994). Field trials in the USA and Australia indicated the potential use of synthetic aggregation pheromones and ripening fruit as a co-attractant, to control *Carpophilus* spp. in stone fruit (Bartelt *et al*. 1992, 1994a, 1994b, James *et al*. 1994, 2000a, 2001).

Our research into the use of pheromone and co-attractant in attract and kill stations identified the high cost of standard-dose of pheromone as a limiting factor for acceptance and use of the system to reduce *Carpophilus* spp. populations in orchards before fruit ripened and were damaged by the beetles.

This paper provides results from field experiments evaluating the use of a reduced-dose of pheromone in an attract and kill system.

Materials and methods
Experimental sites
The experiments were conducted in northern Victoria in eight T204 peach orchard blocks in similar microclimates from November 5, 2001 to February 14, 2002. All blocks were as similar as possible, in terms of the tree age (7–12 years), irrigation (micro jet) and tree training (vase shaped). Three treatments (standard-dose pheromone, reduced-dose = one sixth of the standard-dose, and no pheromone – 'untreated' control) were distributed randomly among the eight orchard blocks. Two of the blocks were treated with standard-dose pheromone, three with reduced-dose pheromone, and the remaining three were 'untreated' controls. To minimize the influence of pheromones, especially on the untreated blocks, a minimum of 2 km distance was maintained between the experimental blocks. The treated blocks did not receive any insecticides whereas one half of each untreated blocks received one insecticide spray during late December or early January as a compromise to satisfy grower's concern.

Attract and kill stations
Five mg of each of *C. davidsoni, C. hemipterus* and *C. mutilatus* aggregation pheromones per septum were absorbed into rubber septa (red-rubber, Aldrich Chemical Co., Milwaukee, Wisconsin, USA). The standard-dose treatment involved six septa per station and the reduced dose treatment used one septum per station. Septa in stations were replaced fortnightly. A total of 45 mg and 270 mg of *Carpophilus* spp. pheromone was deployed each fortnight in reduced and standard-doses, respectively. The septa were suspended over polystyrene boxes (each box was 19 cm deep × 34 cm wide × 48 cm long) containing ripening peaches and 600 mL of fermented peach juice. The fermented peach juice was prepared by dissolving 3 g of dry yeast in 600 mL of peach juice, which was then absorbed into 30 g of polyacrylamide granules (Water Wise, Arthur Yates and Co. Ltd., Milperra, New South Wales) and placed in a one litre plastic container. This container was covered with fine mosquito mesh, secured with a rubber band to prevent *Carpophilus* spp. entering the container and then placed in the bottom of a polystyrene box.

The ripening peaches were placed around and on top of the juice container in the box. The fruit and fermented juice were sprayed with fipronil (0.1 g a.i L^{-1}) to kill landing *Carpophilus* spp. Five boxes were used for each attract and kill station. To improve dispersion of the pheromone and volatiles from the co-attractant, the five polystyrene boxes were placed on top of a 75 cm deep upturned wooden fruit bin. The co-attractant was replaced in all attract and kill stations weekly. Three attract and kill stations were placed about 50 m apart and 12–15 m away from the orchard trees in the north west corner of each treated block. North west corners were considered to be upwind with respect to prevailing winds. Attract and kill stations were deployed on December 11, 2001 and continued until February 7, 2002.

Estimation of Carpophilus spp. numbers
Each week the *Carpophilus* spp. on top of the juice container were collected and placed into a graduated cylinder to volumetrically estimate the population size. All fruit in the polystyrene boxes were removed individually, opened for inspection and to count *Carpophilus* spp. Any *Carpophilus* spp. left in the boxes after fruit removal were added to the graduated cylinder.

Species composition
All *Carpophilus* spp. were transported back to the laboratory and the first 500 beetles from each attract and kill station were identified to species using the descriptions by Dobson (1954, 1964). The results were used to estimate species composition.

Monitoring of Carpophilus spp. populations
A diagonal transect of six traps was established in each block, starting from the north west corner, to estimate *Carpophilus* spp. abundance in the orchards. The first trap was placed approximately 20 m from the north west corner of the block with the remaining five traps placed 20 m apart. The trap positions were numbered consecutively along the transects with the one nearest the north west corner of the block being assigned number one. Traps were Magnet™ funnel traps (23 cm × 17 cm) containing fermented apple juice (FAJ) (Mansfield and Hossain 2004). All *Carpophilus* spp. collected in the traps were transported to the laboratory for counting and species identification.

Fruit damage assessment
Most of the blocks were picked twice. Assessment of fruit damage was conducted in each block during the major fruit pick. Five thousand four hundred fruit were inspected from each block. Three hundred fruit from each of three trees at each of the six monitoring trap locations were randomly picked and inspected for sign of *Carpophilus* spp. damage. *Carpophilus* spp. often make very small holes at the stem end of the fruit.

Statistical analysis
Counts of *Carpophilus* spp. in the attract and kill stations were analysed by fitting a linear mixed power model with time as a co-ordinate. Counts of *C. davidsoni* in the monitoring traps and damaged fruit were either analysed using a Generalised Linear Mixed Model with Poisson errors or counts were $\log_e$ transformed and analysed by fitting a Linear Mixed Model with normal errors, depending on goodness of fit. Statistical analysis was performed using Genstat 5.42 (Genstat Committee 2002).

Results
The majority of *Carpophilus* spp. (>95%) caught in monitoring traps were *C. davidsoni* with *C. hemipterus* making up the remainder except for one week when small numbers of *C. humeralis* were caught in control blocks. Populations of *C. davidsoni* declined after placement of attract and kill stations (Figure 1), but no significant differences were observed due to pheromone treatment (P >0.05).

Large numbers of *Carpophilus* spp. were caught in the attract and kill stations in both standard (270 mg) and reduced-dose (45 mg) blocks especially immediately after placement of the stations (Figure 2), but there were no significant differences between the pheromone treatments.

Fruit damage in the control blocks (12.23%) was significantly higher (P <0.001) than in blocks treated with standard (2.78%) and reduced-dose (2.54%) of aggregation pheromone. No significant differences were observed between reduced and standard-dose blocks (P >0.05).

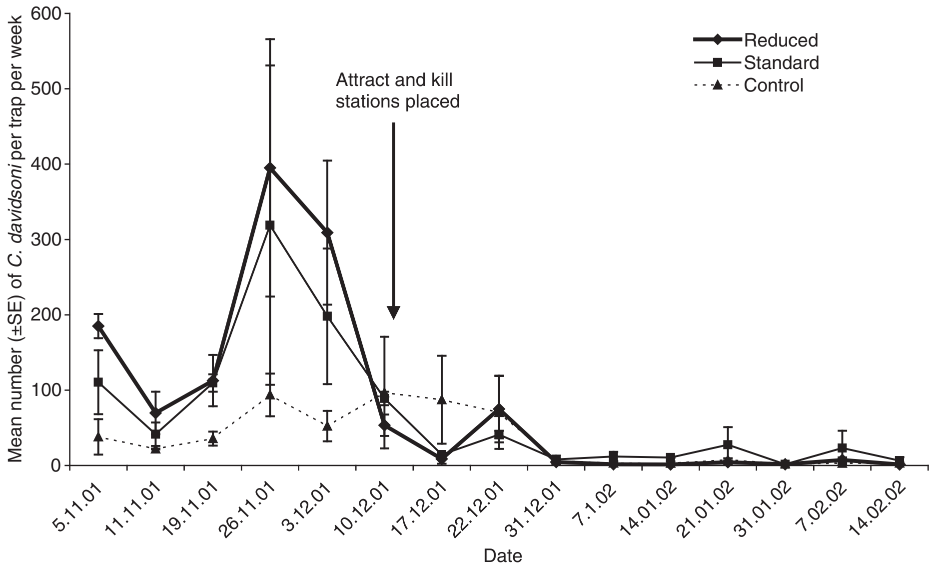

Figure 1. Mean number (±SE) of *C. davidsoni* caught in fermented apple juice baited monitoring traps in control, reduced-dose and standard-dose of pheromone treated blocks in the Goulburn Valley in 2001/2002.

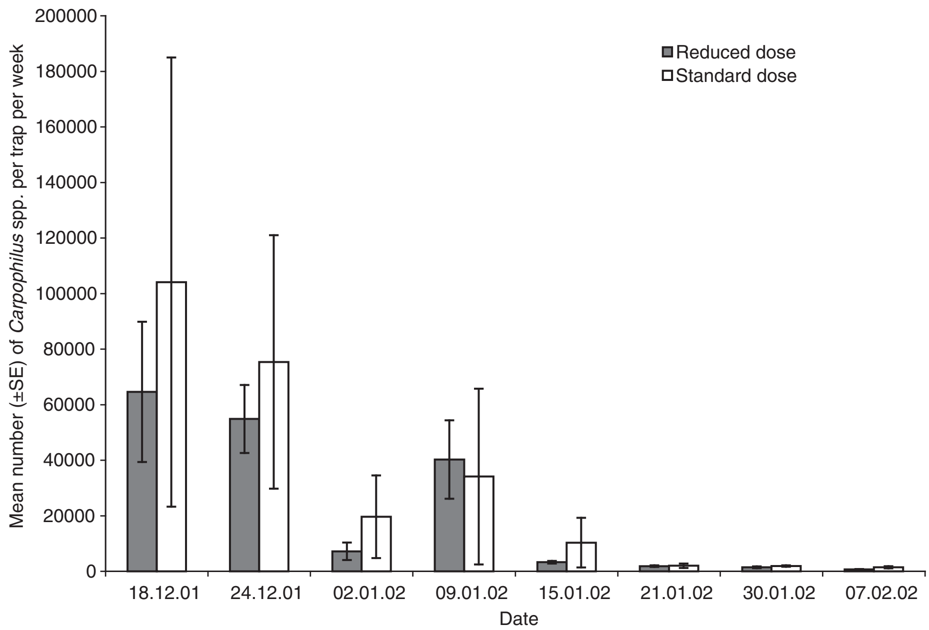

Figure 2. Mean number (±SE) of *Carpophilus* spp. caught in attract and kill stations with reduced-dose and standard-dose of pheromones in the Goulburn Valley in 2001/2002.

Discussion
Since there were no significant differences in damage between the two pheromone doses, the results clearly demonstrate that there is scope to reduce the pheromone dose without reducing the efficacy of the attract and kill stations.

The three-species mixture of pheromones was used because these species are recorded as major pests (James *et al.* 1997) and a system that controlled all three species would have wider applicability and commercial potential.

Species composition of the *Carpophilus* spp. populations indicated that *C. davidsoni* was most prevalent throughout the experiment. *C. hemipterus* was a minor component but *C. humeralis* and *C. mutilatus* were virtually absent. This suggests that further cost reductions could be obtained through omitting the *C. mutilatus* pheromone. Such action could present a risk if the population being treated contained significant number of *C. mutilatus*. This risk could be managed by assessing species composition in each fruit-growing district where *Carpophilus* spp. cause damage to fruit. James *et al*. (2000b) demonstrated that, although there is cross attraction to *C. davidsoni* pheromone by *C. mutilatus,* significantly fewer *C. mutilatus* were caught in traps baited only with *C. davidsoni* pheromone compared to traps baited with either a combination of *C. davidsoni* plus *C. mutilatus* or *C. davidsoni* plus *C. mutilatus* plus *C. hemipterus* pheromones.

Further work is required to determine if the *C. davidsoni* plus *C. hemipterus* pheromones mix will attract sufficient *C. mutilatus* to be effective in areas where *C. mutilatus* is present.

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