CARPOPHILUS SPP. (COLEOPTERA: NITIDULIDAE) RESPONSES TO AGGREGATION PHEROMONE PLUS DECOMPOSED FRUIT AS CO-ATTRACTANT IN STONE FRUIT ORCHARDS IN SOUTHERN AUSTRALIA

M.S. Hossain[1], D.G. Williams[1] and A. D. Milner[2]

[1]Department of Primary Industries, Private Bag 1, Tatura Victoria 3616, Australia.
[2]Centre for Biostatistics & Clinical Trials, Peter MacCallum Cancer Centre, Locked Bag 1, A'Beckett St, Victoria 8006, Australia
Email: Mofakhar.Hossain@dpi.vic.gov.au

Summary

The response of *Carpophilus* spp. to 'attract and kill' stations that used aggregation pheromone plus fruit, which was progressively decomposed, as co-attractant was examined in Summer Fire Nectarine orchards. In the 1999/00 season, *C. davidsoni* was the dominant species (>90%) in the 'attract and kill' stations, whereas in 2000/01 *C. hemipterus* was dominant. In 1999/00, rotten fruit in the stations was replaced each week whereas in 2000/01 fruit was added to, instead of replacing, the rotten fruit. Although there were no significant differences in levels of damage, this work suggests that the quality of co-attractant had an important impact on the composition of species captured in the 'attract and kill' stations and the efficacy of the 'attract and kill' stations.

Keywords: Aggregation pheromone, *Carpophilus* spp. co-attractant, 'attract and kill' stations, stone fruit.

INTRODUCTION

Three species of the genus *Carpophilus* (Coleoptera: Nitidulidae), *C. davidsoni* Dobson, *C. mutilatus* Erichson and *C. hemipterus* (L.) are major pests in stone fruit in southern Australia (James *et al.* 1995, 1997). Growers have reported crop losses of 30% (Hossain *et al.* 2000).

Following 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) a new and environmentally friendly way of controlling *Carpophilus* spp. became possible. Bartelt *et al.* (1992) observed that the effect of the *Carpophilus* spp. aggregation pheromone was synergised by a food attractant and recommended its use as a co-attractant. Fig juice (Bartelt *et al*. 1990, 1992), rotting grapefruit (Blumberg *et al.* 1993), whole-wheat bread dough (Bartelt 1997), blends of synthetic compounds typical of yeast fermentation (Bartelt *et al.* 1992), and fermented apple juice (FAJ) (James *et al.* 1998) have been used as co-attractants with *Carpophilus* spp. aggregation pheromones. Field trials demonstrated the potential for combinations of aggregation pheromones and food-based co-attractants in mass-trapping programs (Bartelt *et al.* 1992, 1994a, 1994b, James *et al.* 1994, 2000, Hossain *et al.* 2001).

James *et al*. (2001) used decomposed stone fruit as co-attractant with aggregation pheromones in 'attract and kill' stations placed in an open area in the centre of an orchard. This experiment was set up when *Carpophilus* spp. were already damaging the fruit on the trees and, although it was too late to control the damage, the percentage of damaged fruit was significantly greater within 200m of the pheromone source than in trees located further away from the pheromone source. Hossain *et al*. (unpublished data) demonstrated effective management of *Carpophilus* spp. by using 'attract and kill' stations containing ripening stone fruit as co-attractant with aggregation pheromones placed 12 – 15m away from orchard trees on the upwind side of the orchards. However, inconsistency in results between two different experiments in two different districts prompted an analysis of the response of different *Carpophilus* spp. to the decomposing fruit used in this experiment as a co-attractant.

This paper describes the population trends of *Carpophilus* spp. observed during 'attract and kill' trials in which the fruit used as the co-attractant progressively decomposed. The relevance of the responses to effective *Carpophilus* spp. management is discussed.

MATERIALS AND METHODS

Experimental Sites

Data from experiments conducted during two growing seasons in commercial fresh stone fruit orchards in Swan Hill, Northern Victoria, to investigate the cost-effective use of aggregation pheromone plus co-attractant to control *Carpophilus* spp. in fresh market stone fruit, were re-assessed to explain variations in the results. We stress that the experiments were not designed to compare co-attractants.

Six commercial nectarines, CV Summer Fire, orchard blocks were used for this experiment. Three blocks were treated with 'attract and kill' stations and three control blocks contained no 'attract and kill' stations. In the 1999/00 fruit season all blocks were sprayed with parathion-methyl against *Carpophilus* spp. whereas in 2000/01 only the control blocks were sprayed with parathion-methyl for *Carpophilus* spp. Growers used their own orchard sprayers to apply the pesticide. In both seasons parathion-methyl was applied in late December or early January. Only one application was made against *Carpophilus* spp.

'Attract and kill' stations

In 1999/00, each 'attract and kill' station consisted of three polystyrene boxes (19 cm deep by 34 cm wide by 48 cm long) containing ripening peaches as co-attractant. Peaches were sprayed with Fipronil (0.1 g a.i L^{-1}) to kill landing *Carpophilus* spp. Two pheromone septa were hung over each polystyrene box and were shielded from direct sunlight by a paper plate suspended above the pheromone septa (Figure 1a). Synthetic aggregation pheromones (5 mg of each of *C. davidsoni, C. hemipterus* and *C. mutilatus* pheromones per septum), produced under contract by CSIRO, Melbourne, were used in this experiment. Septa were replaced with new ones every fortnight. A total of 18 septa (270 mg of *Carpophilus* spp. pheromone) were deployed per treated block in each fortnight. The co-attractant was replaced in all 'attract and kill' stations weekly. Three 'attract and kill' stations were placed about 50 m apart in the upwind (northwest) corner of each treated block. 'Attract and kill' stations were placed 12 - 15 m away from the orchard trees of each treated block. 'Attract and kill' stations were deployed on 30 December 1999 and removed on 31 January 2000.

The design of the 'attract and kill' stations was modified for 2000/01 to reduce labour costs and a different layout was used. Each 'attract and kill' station consisted of one industrial half-bin containing ripening peaches sprayed with Fipronil (0.1g a.i L^{-1}). Five pheromone septa were hung over each bin. The septa were shielded from direct sunlight by a paper plate suspended above the pheromone septa (Figure 1b). Instead of replacing all fruit each week, new fruit was added weekly to the fruit already in the bin. Within three-four weeks the 'attract and kill' stations became very messy and were difficult to handle. On 17 January 2001, we removed almost 80% of the rotten fruit from each of the stations and fresh fruit was added. Pheromone septa were replaced fortnightly. A total of 20 pheromone septa (300 mg of *Carpophilus* spp. pheromone) were deployed each fortnight in each treated block. One 'attract and kill' station was placed in each corner of each treated block. The 'attract and kill' stations were deployed on 8 December 2000 and removed on 31 January 2001.

Beetle number and species composition in the 'attract and kill' stations

In the 1999/00 season, *Carpophilus* spp. numbers were estimated each week by inspection of both the inside and outside of the fruit in the stations. In addition, all *Carpophilus* spp. in the bottom of the polystyrene boxes were collected and spread on a sheet of paper. Five hundred beetles were counted and identified to species using the keys of Dobson (1954, 1964). The results were used to ascertain species composition and to estimate the number of the beetles left on that sheet of paper. In 2000/01, *Carpophilus* spp. numbers were again estimated weekly but the nature of the co-attractant made it difficult to handle rotten fruit from the bin. A 2L plastic bucket (50 cm long x 21cm deep x 19 cm wide) with a handle was placed within the bin and beetle numbers in the bucket were estimated each week (Figure 1b). All fruit in the bucket was also inspected externally and internally for *Carpophilus* spp. From each bucket 500 beetles were counted and identified to species. The results were used to estimate species composition and the number of beetles in the 'attract and kill' station.

Monitoring of *Carpophilus* spp. populations

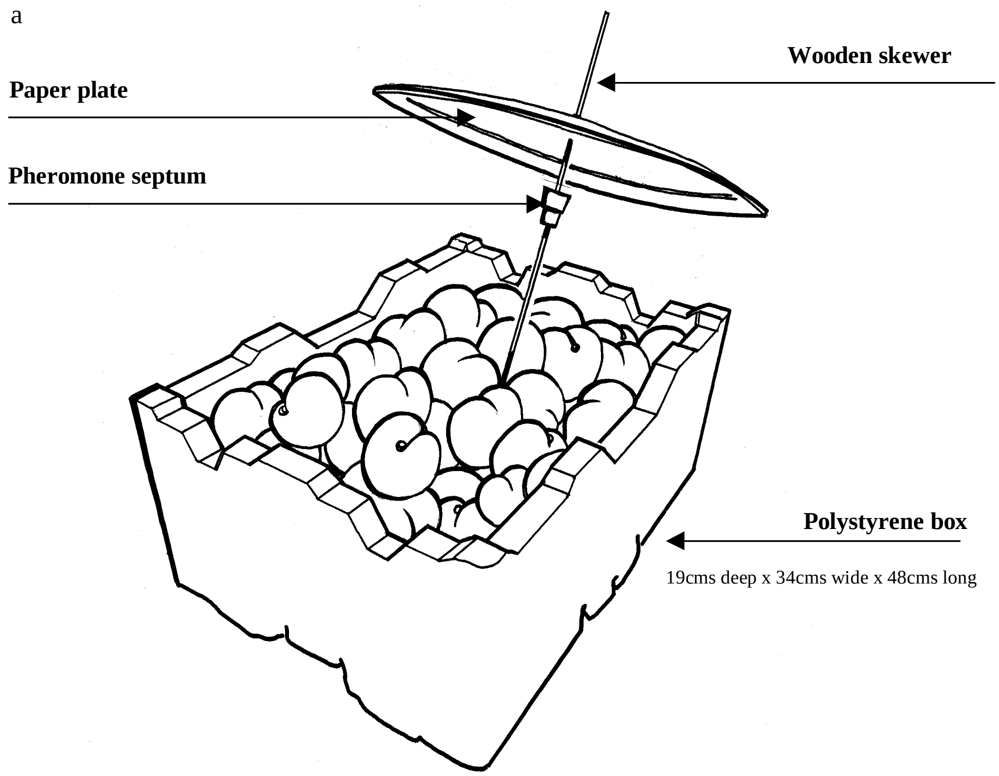
Monitoring traps consisting of Magnet™ funnel traps (23 cm x 17 cm) containing FAJ were used to monitor *Carpophilus* spp. populations in each block. This is a standard practice in Australia and details are described in Mansfield and Hossain (2004). In 1999/00 a diagonal transect of six traps was established in each block, starting 35 m from the north west corner, with the remaining five traps about 20 m apart. In 2000/01 a trap was placed on the diagonal 35 m from each corner and the remaining two traps were placed about 20 m apart in the centre of each block. In both seasons monitoring of *Carpophilus* spp. activity began at least two weeks before deployment of the 'attract and kill' stations and continued for at least a week after the final fruit harvest.

Fruit damage assessment

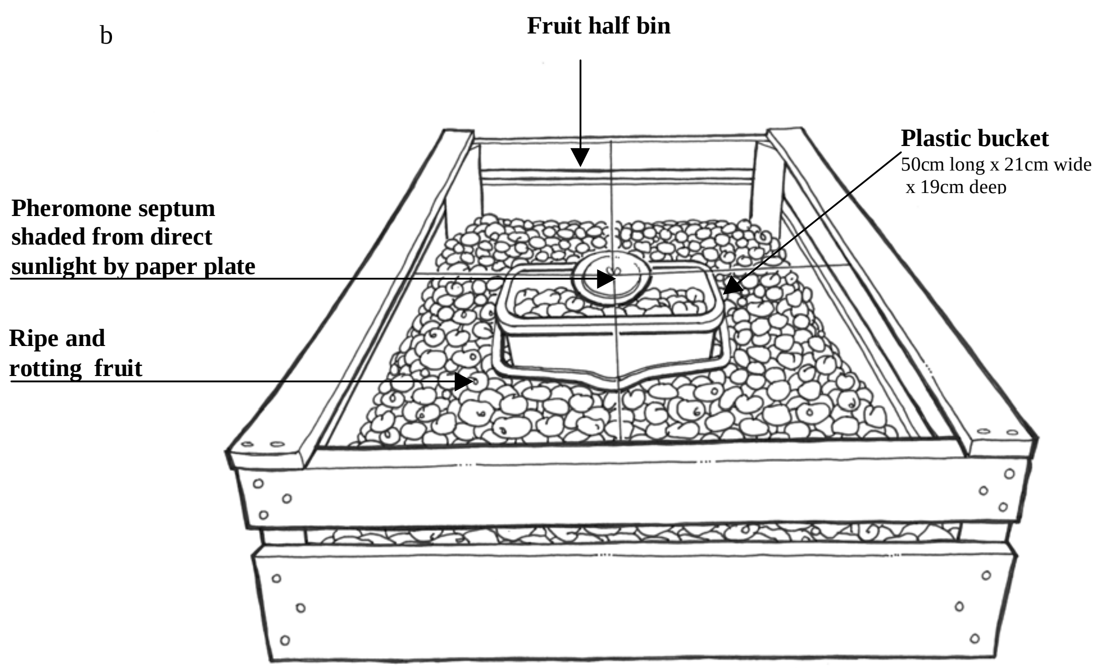
In 1999/00 five hundred fruit were randomly picked from three trees around each trap location along the transect. A total of 3000 fruit was checked for *Carpophilus* spp. damage from each block and the

Figure 1. a) Polystyrene box contains ripening peaches and pheromone septum supported over polystyrene box. The septum was shielded from direct sun light by a paper plate.
b) Half bin containing rotting fruit. Pheromone septum suspended over the fruit and shaded from direct sunlight by a paper plate.

a



b



percentage of damage was calculated. A larger sample was used in 2000/01 for fruit damage assessment in each of the six blocks. Nine hundred fruit were randomly picked from three trees around each trap location. A total of 5400 fruit were checked for *Carpophilus* spp. damage from each block and the percentage of damage was calculated.

Statistical analysis

In both 1999/00 and 2000/01 weekly counts of *Carpophilus* spp. in the 'attract and kill' stations from the three blocks were analysed using a linear mixed auto-regressive model, after $\log_e$-transformation, to determine if station position and week of assessment had significant effects on the number of *Carpophilus* spp. caught. Total counts of *C. davidsoni* in the monitoring traps over each season were $\log_e$-transformed and then underwent analysis of variance. Damaged fruit were analysed using a generalised linear mixed model with binomial errors and a logit link function. All statistical analyses were performed using Genstat for Windows, 6th edition (Genstat Committee 2002).

RESULTS

Effectiveness of 'attract and kill' stations

Numbers of *Carpophilus* spp. caught in the 'attract and kill' stations in 1999/00 and 2000/01 seasons were not significantly different (P=0.88 for 1999/00 and P=0.32 for 2000/01) between the station positions. This allowed us to use the total numbers of *Carpophilus* spp. caught in all stations at each block in further analyses. In both seasons week of assessment had a significant effect on station catch (P<0.001, both seasons) with maximum catch during week 2 in the 1999/00 season and during week 7 in the 2000/01 season.

In 1999/00, the average number of *Carpophilus* spp. caught in 'attract and kill' stations during the first week was 3233 per treated block with a range of 2800 - 3600. The average number was more than double, 6733 per treated block with a range of 2000 – 12600, in the second week. *Carpophilus* spp. numbers decreased to 3083 per treated block with a range of 2300 – 4100 in the third week and continued low throughout the harvest period (Figure 2a). *C. davidsoni* was the dominant species (>90%).

In 2000/01, there were less than 20000 *Carpophilus* spp. caught per treated block in the 'attract and kill' stations during the first two weeks of deployment. The number declined to less than 5000 in the following week. Although the numbers remained low (5000 - 15000 per treated block per week) up to 17 January, they slowly increased and on 24 January, there was a sharp increase in numbers (average 45000 per treated block per week; range 23010 to 65372 per treated block per week). The following week, numbers dropped below 15000 per treated block per week (Figure 2a). Significantly higher numbers of *Carpophilus* spp. (P<0.01) were caught on 24 January 2001 and significantly lower numbers (P<0.001) were caught on 27 December 2000 as compared to all other sampling days.

Unlike the 1999/00 season, the dominant species caught in the 'attract and kill' stations was not *C. davidsoni*. However, only a week after the placement of 'attract and kill' stations *C. davidsoni* population was higher than that of the other two species. After that the population of *C. hemipterus* was always higher than *C. davidsoni* (Figure 2b). The average total catch per week of *C. hemipterus* was significantly higher (P<0.01) than either *C. davidsoni* or *C. humeralis*, but there were no significant differences (P>0.05) between the latter two.

Monitoring of *Carpophilus* spp. populations

In 1999/00 the numbers of *Carpophilus* spp. caught in the monitoring traps were very low during the first two sampling days in control and treated blocks but the numbers of *C. davidsoni* then increased. *C. davidsoni* numbers rose steadily in the control blocks until the end of harvest (Figure 3a) but numbers in the treated blocks remained relatively constant after the third sample day (6 January 2000) (Figure 3b). Numbers of *C. hemipterus* and *C. humeralis* remained low throughout the experiment (Figures 3a, b).

In 2000/01 the numbers of *C. hemipterus* and *C. humeralis* caught in the monitoring traps in both control and treated blocks declined rapidly at the end of November and remained very low until harvest. *C. hemipterus* numbers increased during the end of harvest. *C davidsoni* numbers remained high in the control blocks until the end of November, then steadily reduced in the first two weeks of December and remained low (Figure 3c). The *C. davidsoni* numbers caught in the treated blocks drastically declined before 'attract and kill' stations were deployed and remained low until the start of harvest (Figure 3d).

In each season total trap catch was analysed to understand whether pheromone had some impact, especially on the *C. davidsoni* populations. In both

Figure 2. a) Average number of *Carpophilus* spp. caught in 'attract and kill' stations in 1999/00 and 2000/01 seasons. Average was calculated using data from 4 blocks in 1999/00 and 3 blocks in 2000/01.
b) Species composition, represented by average number of *C. davidsoni*, *C. hemipterus* and *C. humeralis*, caught per block in 'attract and kill' stations in 2000/01.

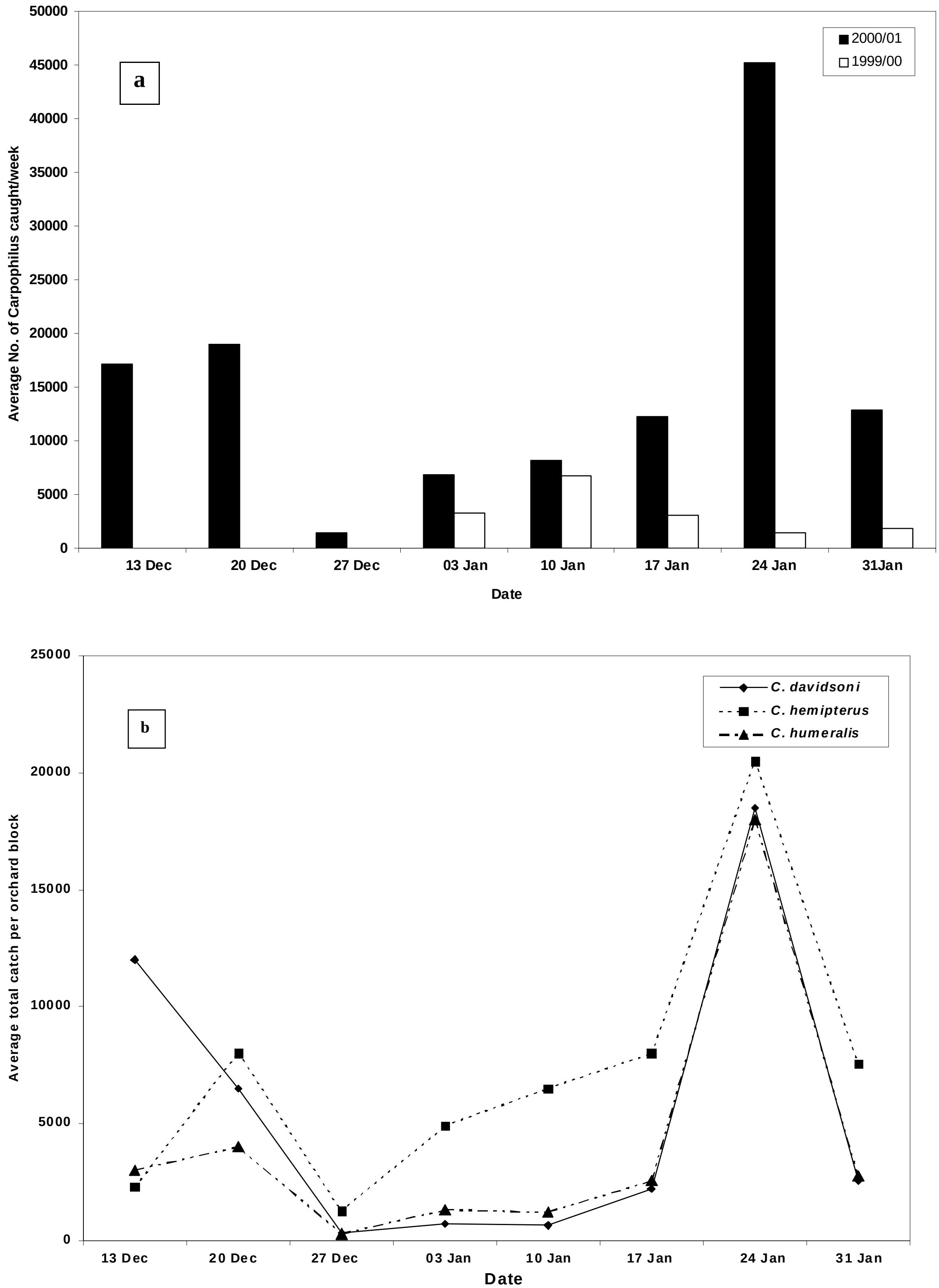
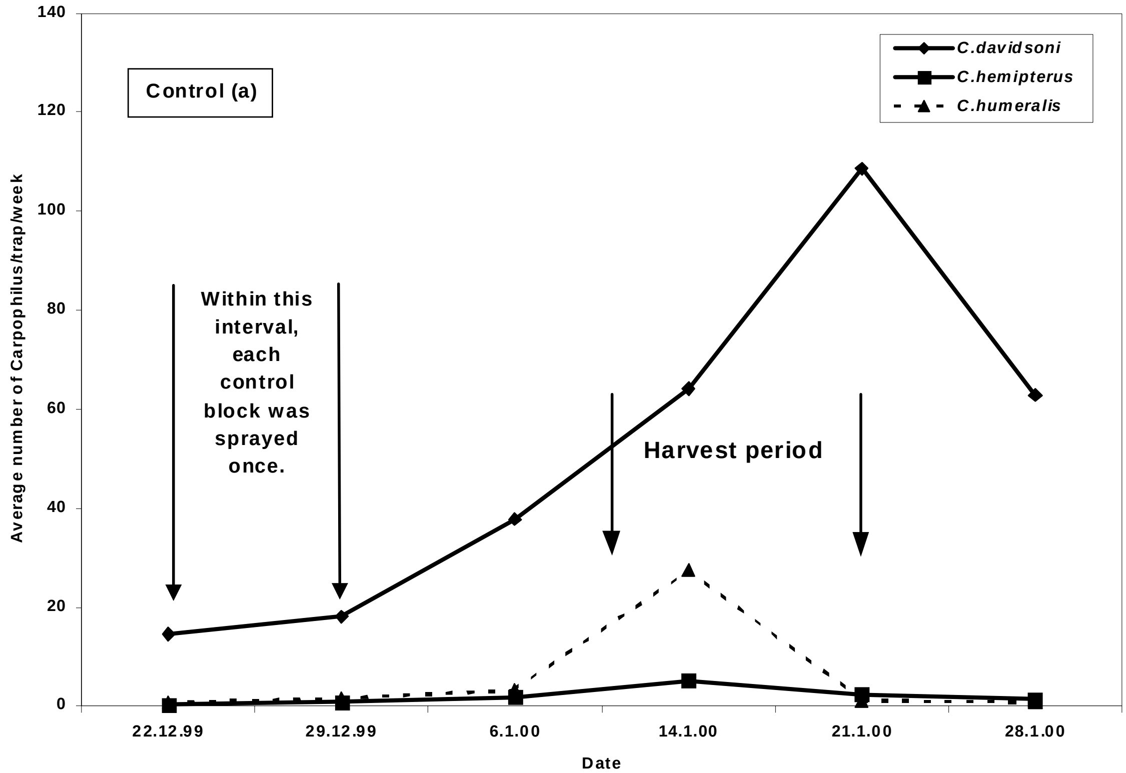


Figure 3. Average number of *C. davidsoni*, *C. hemipterus* and *C. humeralis* caught in fermented apple juice baited monitoring traps in control and treated blocks in 1999/00 (a and b) and 2000/2001 (c and d) seasons.



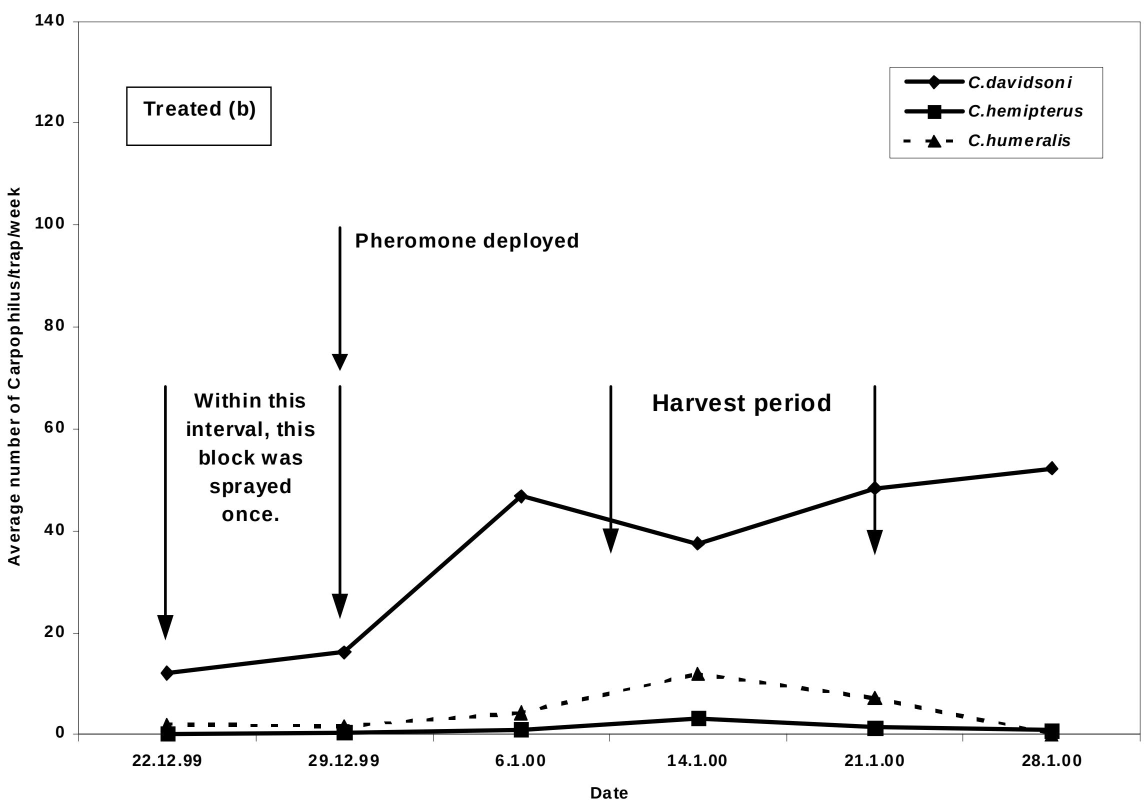
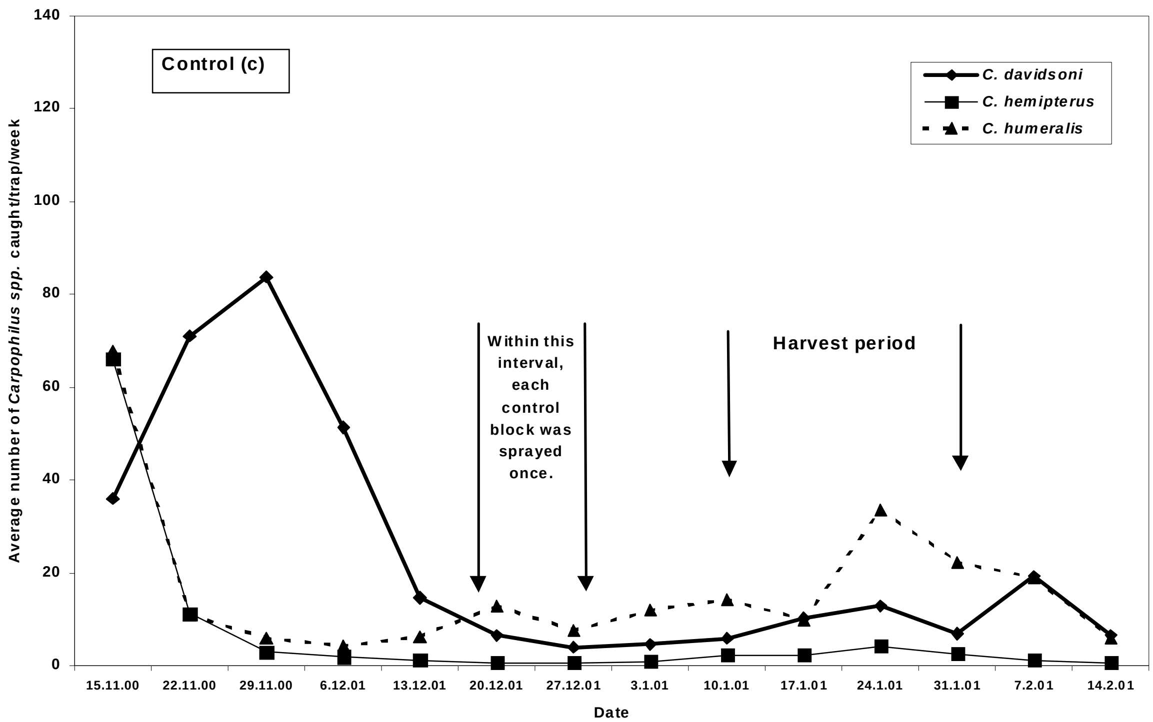


Figure 3 cont. Average number of *C. davidsoni*, *C. hemipterus* and *C. humeralis* caught in fermented apple juice baited monitoring traps in control and treated blocks in 1999/00 (a and b) and 2000/2001 (c and d) seasons



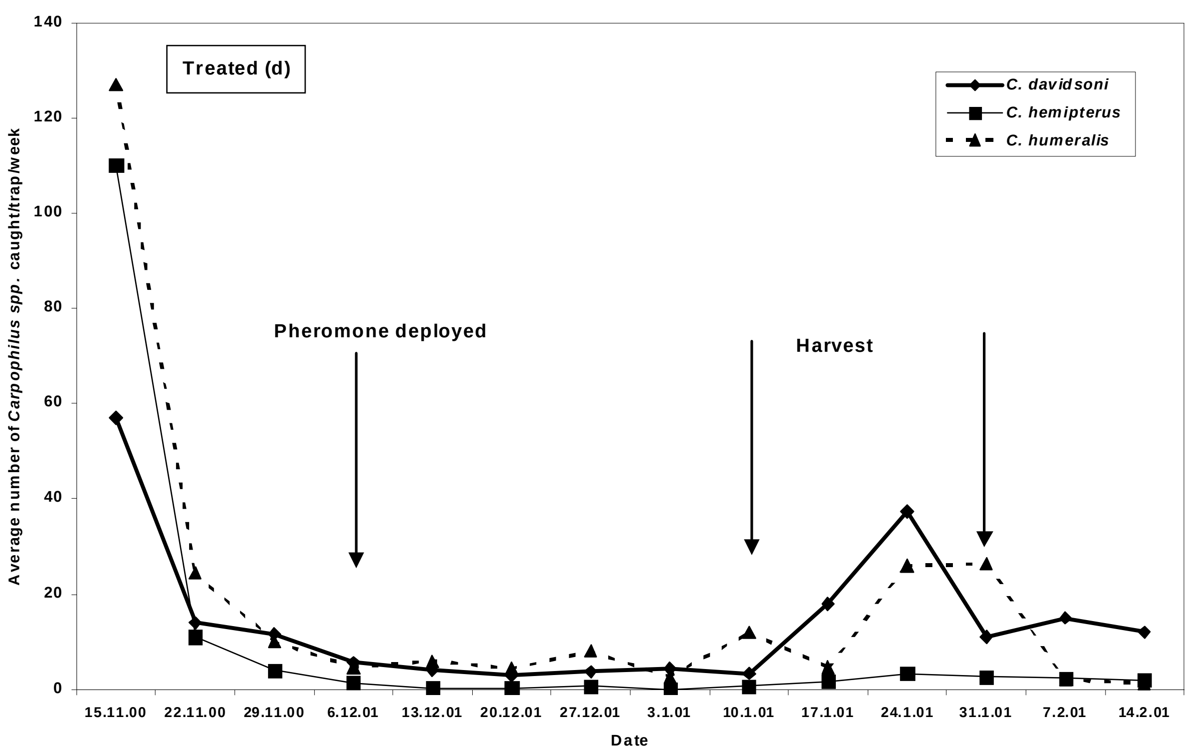


Table 1. Treatment means for total catch in monitoring traps over two seasons.

Treatment	Mean no. of beetles caught			
	1999/2000		2000/2001	
	$\log_e$*	b-t+	$\log_e$*	b-t+
Control	5.635[a]	280.059	5.294[a]	199.138
Treated	5.031[a]	153.086	5.023[a]	151.023
sed	0.534	-	0.695	-

*$\log_e$-transformed mean
+back-transformed mean
sed - standard error of difference between two means
In each column means followed by the same letter were not significantly different from each other

seasons, there was no evidence of significant reductions in trap catches from the pheromone treatment (P>0.05). Log_e-transformed and back-transformed means are shown in Table 1.

Fruit damage assessment

In the 1999/00 season, fruit damage by *Carpophilus* spp. in control blocks averaged 3.9% (range 2.55% - 5.26%) but in treated blocks averaged 2.4% (range 1.6% - 3.45%). In 2000/01 the percentage of damaged fruit was higher in the treated blocks (average 2.43%, range 1.5% – 3.86%) compared to that of control blocks (average 1.49%, range 0.34% - 1.85%). However, there was no significant difference (P>0.05) between control and treated blocks in either season.

DISCUSSION

Experiments in the 1999/00 and 2000/01 seasons aimed to find out the best possible location for, and to reduce the cost of labour and materials of the 'attract and kill' stations.

Although James *et al.* (2001) reported unacceptable damage within 200 m of the pheromone sources during their attempt to control *Carpophilus* spp. with the 'attract and kill' strategy, we considered it would be impracticable to separate the 'attract and kill' stations from the orchards by more than 12 - 15 m. This would allow for easy access to the stations and not compromise other orchards in the vicinity. Previous studies from Australia (James *et al*. 1994) and the United States (Bartelt *et al.* 1992) indicated that the aggregation pheromones were more effective early in the season when flight activity was high but food supplies were low. We were concerned that the cost of implementing 'attract and kill' would be prohibitive if season-long deployment was used. In 1999/00 the 'attract and kill' stations were deployed approximately two weeks prior to commencement of fruit harvest. Fruit damage in all treatments was not commercially acceptable. Although the data from monitoring traps (Figures 3a and b) and the damage assessments suggested that the 'attract and kill' stations had reduced the *Carpophilus* spp. populations, there were no significant differences between the treated and control blocks. Lack of significance was most likely the result of the unpredictably high degree of variability between populations in the blocks during the 1999/00 season.

In 2000/01 the 'attract and kill' stations were deployed five to six weeks before fruit colour change was expected (ie. six to eight weeks before harvest). Peaches and nectarines undergo a colour change as they mature. Onset of colour change occurs one - two weeks before harvesting starts. In 1999/00 the 'attract and kill' stations used fresh ripening peaches. The peaches were changed every week. This involved considerable handling of fruit. The fruit being removed was often rotten and messy. This increased the cost and inconvenience of the 'attract and kill' stations. In 2000/01 we modified the 'attract and kill' stations used by adding fresh fruit to the stations each week instead of replacing the rotten fruit. This may have affected the ability of the 'attract and kill' stations to draw *Carpophilus* spp. to the stations from inside the block. Leaving the decomposing fruit in the stations might create a problem. The smell, as detected by our noses at least, was different to that of the 'attract and kill' stations in the Goulburn Valley (GV), northern Victoria, where the co-attractant (fruit plus fermented peach juice) was changed every week (Hossain (unpublished data). Hossain and Williams (2003) reported that *C. hemipterus* were attracted to decomposing fruit in fruit dumps but *C. davidsoni* was not. Smilanick (1979) reported that colonisation by *C. mutilatus* decreased with advancing ripeness of figs, whereas *C. hemipterus* appeared to increase with advancing ripeness of figs. All these support the idea that each *Carpophilus* species could respond differently to fruit ripening stages and/or fermenting stages.

Carpophilus spp. numbers in monitoring traps and ‘attract and kill’ stations increased considerably over the harvest period. *C. davidsoni* numbers caught in the ‘attract and kill’ stations exceeded the other two species only on the week immediately after the placement of stations. The rest of the season *C. hemipterus* was dominant. Hossain (unpubl. data) reported that *C. davidsoni* was always dominant (>95%) in the ‘attract and kill’ stations in the GV, where co-attractant was replaced every week. James *et al*. (2000) also reported that *C. davidsoni* is the dominant species in most of the Australian stone fruit growing regions including Swan Hill. However, *C. hemipterus* was common in Swan Hill. The number of *Carpophilus* spp. killed in the ‘attract and kill’ stations on January 24 2001 was the highest in either season. Although *C. davidsoni* numbers on January 24 were lower than that of *C. hemipterus*, the numbers were comparable (Figure 2b). When we replaced almost 80% of rotting fruit with fresh fruit in the ‘attract and kill’ stations on January 17, we may have improved the quality of the co-attractant and thereby increased the close range stimuli for *Carpophilus* spp. to enter the stations. Although the highest number of *Carpophilus* spp. was caught in the ‘attract and kill’ stations on 24 January when fruit was being harvested, it was probably too late to protect the ripening crop. There was also a high number of *Carpophilus* spp. in monitoring traps and an unacceptable level of fruit damage. This failure to protect the ripening crop, even after catching so many *Carpophilus* spp., might be due to failure to ‘attract and kill’ *C. davidsoni* early in the season and then maintaining a low population before fruit colour. When there is a pheromone source in the area, *Carpophilus* spp. will still land very readily on any other “host odour site” such as “coloured/ripening fruit” in the general area even if this does not have pheromone (Bartelt, R.J. personal communication). We suggest that the volatiles from the rotting fruit were not an effective co-attractant for *C. davidsoni.* Unlike *C. hemipterus, C. davidsoni* is not generally found in fruit dumps (Hossain and Williams 2003). *C. hemipterus* numbers in the ‘attract and kill’ stations were always higher than *C. davidsoni* but the monitoring traps indicated that *C. davidsoni* was more numerous than *C. hemipterus* in the block. This could be the main reason for the high level of fruit damage. *C. davidsoni* may have been attracted to the vicinity of the ‘attract and kill’ stations but did not enter the stations. Moreover the ‘attract and kill’ stations were very sloppy with all the rotten fruit and this may have reduced the effectiveness of the insecticide used as the killing agent, either by diluting its concentration or by enhancing its degradation.

Unfortunately for the experiment, but probably fortunate for the co-operating growers, the control blocks were sprayed with parathion-methyl when *Carpophilus* spp. numbers rose and we lost the ability to compare the pheromone treated blocks with the control blocks.

In 2000/01 the average damage level in the pheromone treated blocks appeared higher than that for the control blocks. If we omit one control block, as that block had zero damage, the damage levels in both control and treated blocks were not significantly different. ‘Attract and kill’ appears to be as effective as spraying with pesticide to control *Carpophilus* spp. However, the work presented here suggests that the quality of co-attractant has an important impact on the composition of species captured in the ‘attract and kill’ stations. Use of a synthetic co-attractant may overcome this problem.

ACKNOWLEDGMENTS

We thank Cathy Mansfield for constructive review of the manuscript. Thanks are due to Avtar Saini and Bob Bennett for their technical assistance during this work. This work was conducted as part of project FR-99031, “Integrated Pest Management Strategy using the pheromone for control of Oriental Fruit Moth and *Carpophilus* beetle in orchards.” managed by Alex Il’ichev. We greatly appreciate the co-operation of the orchardists who kindly allowed us to use their orchards for this trial work. Horticulture Australia Ltd. and the Department of Primary Industries provided the financial support for this work.

REFERENCES

Bartelt, R.J. (1997). Aggregation pheromones of *Carpophilus* spp. (Coleoptera: Nitidulidae) Review of chemistry and biology. *Recent Research Developments in Entomology* **1**: 115-129.

Bartelt, R.J., Carlsen, D.G., Vetter, R.S. and Baker, T.C. (1993). Male-produced aggregation pheromone of *Carpophilus mutilatus*. (Coleoptera: Nitidulidae). *Journal of Chemical Ecology* **19**: 107-118.

Bartelt, R.J., Dowd, P.F., Plattner, R.D. and Weisleder, D. (1990). Aggregation pheromone of dried fruit beetle, *Carpophilus hemipterus*. Wind-tunnel bioassay and identification of two novel Tetraene Hydrocarbons. *Journal of Chemical Ecology* **16**: 1015-1039.

Bartelt, R.J., Dowd, P.F., Vetter, R.S., Shorey, H.H. and Baker, T.C. (1992). Responses of *Carpophilus hemipterus* (Coleoptera: Nitidulidae) and other sap beetles to the pheromone of *C. hemipterus* and host-related co-attractants in California field tests. *Environmental Entomology* **21**: 1143-1153.

Bartelt, R.J. and James, D.G. (1994). Aggregation pheromone of Australian sap beetle, *Carpophilus davidsoni* (Coleoptera: Nitidulidae). *Journal of Chemical Ecology* **20:** 3207-3219.

Bartelt, R.J., Vetter, R.S., Carlson, D.G. and Baker, T.C. (1994a). Responses to aggregation pheromones for five *Carpophilus* species (Coleoptera: Nitidulidae) in a California date garden. *Environmental Entomology* **23**: 1534-1543.

Bartelt, R.J., Vetter, R.S., Carlson, D.G. and Baker, T.C. (1994b). Influence of pheromone dose, trap height, and septum age effectiveness of pheromone for *Carpophilus mutilatus* and *C. hemipterus* (Coleoptera: Nitidulidae) in a California date garden. *Journal of Economic Entomology* **87**: 667-675.

Blumberg, D., Kehat, M., Goldberg, S., Bartelt, R.J. and Williams, R.N. (1993). Responses to synthetic aggregation pheromones, host-related volatiles and their combinations by *Carpophilus* spp. (Coleoptera: Nitidulidae) in laboratory and field tests. *Environmental Entomology* **22**: 837-842.

Dobson, R.M. (1954). The species of *Carpophilus* Stephens (Coleoptera: Nitidulidae) associated with stored products. *Bulletin of Entomological Research* **45**: 389-402.

Dobson, R.M. (1964). A new species of *Carpophilus* Stephens (Coleoptera: Nitidulidae) from Australia. *Proceedings of the Royal Entomological Society of London* pp. 71-72.

Genstat Committee (2002). *Genstat for windows, 6th edition*. VSN International Ltd. Oxford.

Hossain, M.S. and Williams, D.G. (2003). Phenology of *Carpophilus* beetle populations (Coleoptera: Nitidulidae, *Carpophilus* spp.) in a fruit dump in northern Victoria. *Australian Journal of Experimental Agriculture* **43**: 1275-1279.

Hossain, M.S., Brown, C., Mansfield, C. and Il'ichev, A. (2001). Attract and kill strategy to control *Carpophilus* beetle. *Proceedings of the Australian Fresh Stone Fruit Growers 7th National Conference,* Hobart, Tasmania, Australia pp 5-7.

Hossain, M.S. Mansfield, C. and Brown, C. (2000). Control of *Carpophilus* spp. by using an aggregation pheromone. *Australian Fresh Stone Fruit Quarterly* **2**: 13-14.

James, D.G., Bartelt, R.J. and Faulder, R.J. (1994). Attraction of *Carpophilus* spp. (Coleoptera: Nitidulidae) to synthetic aggregation pheromones and host-related co-attractants in Australian stone fruit orchards: beetle phenology and pheromone dose studies. *Journal of Chemical Ecology* **20**: 2805-2819.

James, D.G., Faulder, R.J. and Bartelt, R.J. (1995). Faunal and seasonal abundance of *Carpophilus* spp. (Coleoptera: Nitidulidae) in four stone fruit growing regions of south-eastern Australia as determined by pheromone trapping. *Journal of the Australian Entomological Society* **34**: 327-333.

James, D.G., Faulder, R.J., Vogele, B., Bartelt, R.J. and Moore, C.J. (1997). Phenology of *Carpophilus* spp. (Coleoptera: Nitidulidae) in stone fruit orchards as determined by pheromone trapping: Implications for prediction of crop damage. *Australian Journal of Entomology* **36**: 165-173.

James, D.G., Moore, C.J., Faulder, R.J. and Vogele, B. (1998). An approved co-attractant for pheromone trapping of *Carpophilus* spp. (Coleoptera: Nitidulidae). *Australian Journal of Entomology* **37**: 357-361.

James, D. G., Vogele, B., Faulder, R.J. and Moore, C.J. (2000). Efficacy of multispecies pheromone lures for *Carpophilus davidsoni* Dobson and *C. mutilatus* Erichson (Coleoptera: Nitidulidae). *Australian Journal of Entomology* **39**: 83-85.

James, D.G., Vogele, B., Faulder, R.J., Bartelt, R.J. and Moore, C.J. (2001). Pheromone-mediated mass trapping and population diversion as strategies for suppressing *Carpophilus* spp. (Coleoptera Nitidulidae) in Australian stone fruit orchards. *Agriculture and Forest Entomology* **3**: 41-47.

Mansfield, C.M. and Hossain, M.S. (2004). The attractiveness of different fermenting food odours to *Carpophilus* spp. (Coleoptera: Nitidulidae). *General and Applied Entomology* **33:** 41-44.

Smilanick, J.M. (1979). Colonisation of ripening figs by *Carpophilus* spp. *Journal of Economic Entomology* **72**: 557-558.