PREDOMINANT *CARPOPHILUS* SPP. (COLEOPTERA: NITIDULIDAE) ASSOCIATED WITH DAMAGED APRICOT FRUIT ON TREES

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Summary

During the growing season of 2006/07, a study was conducted in apricot blocks (*Prunus armeniaca* cv. Moorpark) in Loxton, South Australia to investigate the importance of various *Carpophilus* species in relation to fruit damage on the trees. Although monitoring traps, baited with fermented apple juice, caught large numbers of *C. hemipterus,* the beetles found inside the fruit were mostly *C. davidsoni*. Significantly more fruit at a late stage of maturity were infested by *C. davidsoni* than fruit at an early stage of maturity. More study is required to determine *Carpophilus* species composition on other apricot cultivars and other fruit types .

Keywords: insect population monitoring, fruit damage

INTRODUCTION

Nitidulid beetles (primarily *Carpophilus* spp.) are serious pests of ripening stone fruit in southern Australia (e.g. James *et al*. 1997, Hossain *et al*. 2007). *Carpophilus davidsoni* Dobson, *C. mutilatus* Erichson and *C. hemipterus* (L) are attracted to, and penetrate ripening fruit, causing rapid breakdown (Hely *et al*. 1982), which can result in substantial fruit losses (James *et al*. 1997). The beetles are vectors of Brown rot (*Monilinia* spp.), which frequently develops at the sites of beetle entry (Kable 1969). The importance of *Carpophilus* spp. in stone fruit production has increased considerably in recent years. Mass-trapping was developed to effectively reduce the population of *Carpophilus* spp. before the fruit ripened and became attractive to beetles (Hossain *et al*. 2006).

Although *Carpophilus* spp. are pests of a wide variety of crops and commodities, some species are especially attracted to plant materials that are damaged, fermenting or otherwise decomposing (Nout and Bartelt 1998). *C. hemipterus*, *C. mutilatus*, *C. freemani* Dobson and *C. obsoletus* Erichson are known to attack fruit in Southern California (Bartelt 1999) and *C. davidsoni, C. hemipterus* and *C. mutilatus* attack fruit in Australia (James *et al*. 1997, Hossain *et al*. 2007). *C. davidsoni* is an Australian species and dominant in Australian stone fruit orchards (Hossain *et al*. 2007). Most of the published literature reports that *C. hemipterus* are predominantly found in damaged/rotten fruit on the ground. It was also occasionally found in damaged sweet corn ears, over-ripe melons etc. (Pena 1991).

Hossain and Williams (2003) reported that *C. hemipterus* were attracted to decomposing fruit in fruit dumps but that *C. davidsoni* was not. Smilanick (1979) reported that colonization by *C. mutilatus* decreased with advancing ripeness of figs, whereas *C. hemipterus* appeared to increase. All these support the idea that each *Carpophilus* spp. could respond differently to different fruit ripening states or fermentation stages. When we conducted fruit damage assessment both in the trees and in fruit on the ground, it was very obvious that most of the *Carpophilus* observed in the fruit on trees were *C. davidsoni*. However, for fruit on the ground, including apricot, especially in late ripe-, or rotting stage, the dominant (>80%) species was *C. hemipterus* (Hossain unpubl. data).

This study was designed to understand the importance of various *Carpophilus* species in relation to damage of apricot fruit on the tree.

MATERIALS AND METHODS

The study was conducted during the growing season of 2006/07 in two apricot, *Prunus armeniaca* cv. Moorpark, blocks on the Loxton Centre, Loxton, South Australia. The blocks, each approximately 0.5 ha in size, had a previous history of high damage due to *Carpophilus* spp. The two blocks were located 300 m apart, separated by open ground. Block 1, trained as free-standing open-vase trees, carried a light crop. Block 2, trained as central-leader tree, carried a heavy crop. The blocks did not receive any insecticide treatments. Monitoring traps were installed in the blocks on 8th November 2006 and continued until late-January 2007. According to standard practice (Hossain *et al*. 2006) funnel traps (Magnet™; 15 cm x 16 cm) containing fermented apple juice were used to monitor the beetle populations. Two traps located 20 m from the north-eastern and south-western corners of the blocks were placed in each of the two blocks.

Each week for 11 weeks the *Carpophilus* spp. collected in traps were transported to the laboratory for counting and species identification using the methods of Hossain and Williams (2005).

Fruit harvesting was carried out at each trap location when at least one third of fruit had reached a maturity suitable for drying. Block 1 was harvested on the 28th December 2006 and Block 2 on the 3rd January 2007. At each trap location a minimum of 500 fruit were picked from trees adjacent to the trap. All fruit sampled was within the range of maturity at which Moorpark cultivar apricots are commercially harvested for drying, that is, from half-coloured through to fully-coloured fruit. Approximately half the number of fruit sampled was at a maturity towards the lower limit of this range and the other half towards the upper limit of this range. Fruit was harvested directly into zip-lock plastic bags which were immediately sealed so that the *Carpophilus* could not escape. No beetles were observed escaping from the individual fruit being harvested during bagging. The bags were labelled with trap location of fruit harvested. All bags with fruit were placed in a cool store at 2°C after harvesting, to slow down *Carpophilus* spp. activity. On removal from the cool store fruit were separated into un-infested and infested fruit. Infested fruit were classified as: early stage of ripening plus *Carpophilus* damage hole; early stage of ripening plus early stage of rot; late stage of ripening plus damage hole; or, late stage ripening plus early stage of rot. Beetles from each infested fruit were transferred into separate labelled sample tubes, and placed in a freezer for three days before being counted and identified to species.

Species composition data collected weekly were analysed using linear regression to determine if the numbers per trap of the three species changed over time. A model that included the 3-way interactions and all 2-way interactions between blocks, species and collection date was used. The data was transformed on the logarithmic scale to satisfy the assumptions of the analysis, i.e. the data is normally distributed with constant variance. Means were compared using least significant differences (LSD) values at the 5% significance level.

To account for differences in numbers of fruit assessed at each maturity and trap location the data relating to type of damage and frequency of fruit damage caused by *C. davidsoni* in apricot collected from trees at different stages of maturity was arranged in four contingency tables (one for each trap). A log-linear model was then fitted to determine if there is an interaction between maturity and type of damage, while allowing for information relating to the four traps. Each term of the model was tested against a chi-square distribution. Means were compared using LSD values at the 5% significance level.

Data relating to the number of beetles per infested fruit was analysed using analysis of variance. The variability between blocks was allowed for in the model that included interaction between maturity and type of damage.

RESULTS

Carpophilus spp. in the orchard

The seasonal fluctuations of *Carpophilus* spp. during the study period are shown in Figure 1. *C. davidsoni*, *C. hemipterus* and *C. humeralis* were trapped during the study period. A single specimen of *C. mutilatus* was trapped on only two occasions (data not presented). The dominant species differed between the two blocks ($p=0.004$), with the mean log-count of *C. hemipterus* trapped in Block 1 being significantly higher than that of *C. davidsoni*, while in Block 2 the mean log count of *C. davidsoni* trapped was significantly higher than that of *C. hemipterus* (Table 1). *C. humeralis* occurred in similar numbers, on average, in both blocks over the monitoring period but the numbers were significantly lower compared to the other two species.

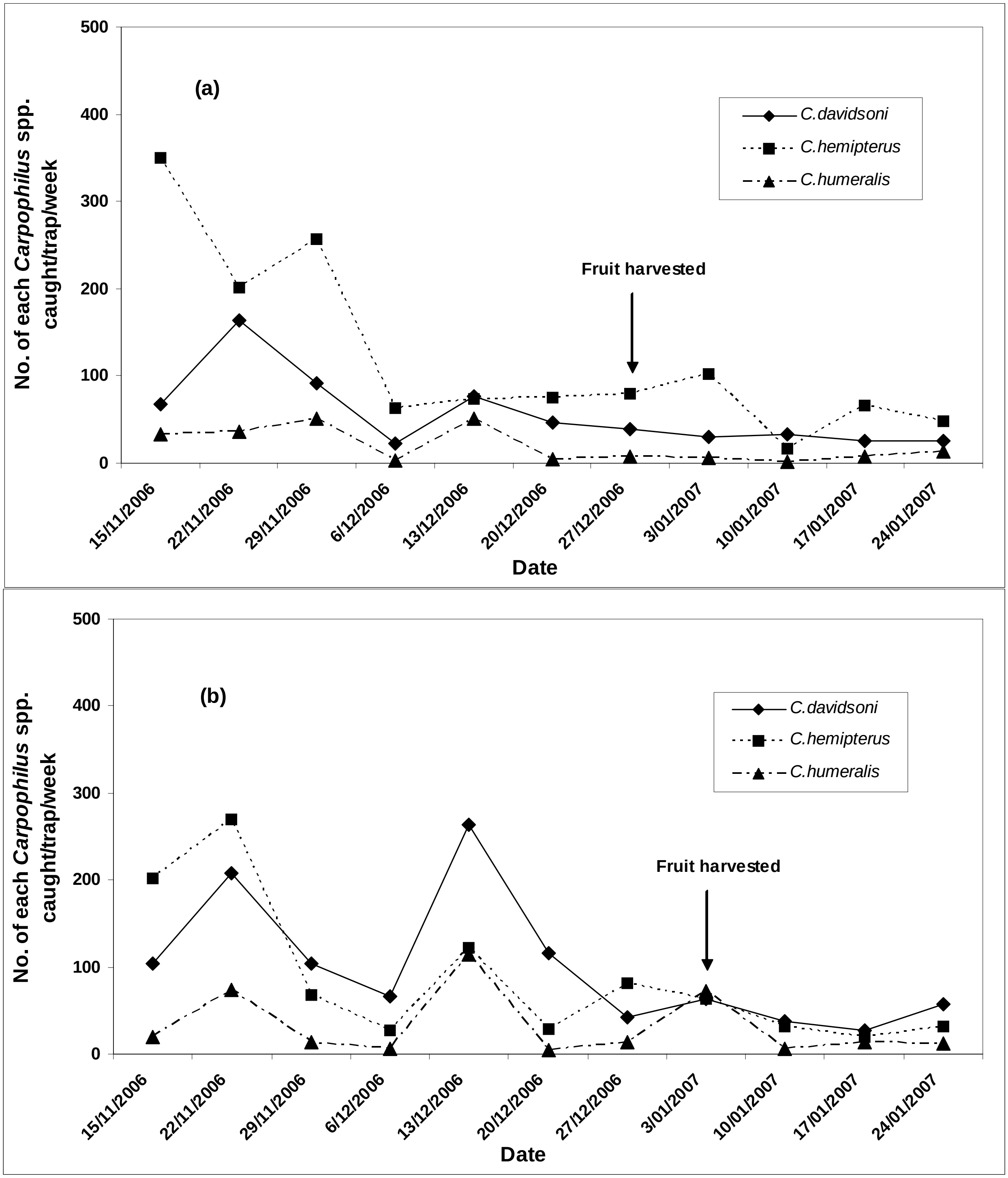
Independent of the block or the species, numbers of *Carpophilus* trapped significantly ($p<0.001$) reduced over the monitoring interval (Table 2). Number of beetles trapped of all three species was generally low during the fruit ripening and post-harvest stages. In Block

Table 1. Mean (log) weekly count *Carpophilus* spp. (and back transformed means in parentheses) caught in monitoring traps over the 11 week monitoring period (from 15/11/06 to 24/01/07) in two apricot blocks at Loxton, South Australia.

Block number	Mean (log) count (beetles/trap/week)		
	C. davidsoni	*C. hemipterus*	*C. humeralis*
1	3.77 (42.4)	4.40 (80.5)	2.43 (10.4)
2	4.18 (64.4)	3.54 (33.5)	2.84 (16.1)

LSD ($p=0.05$) for comparison between species within each block or between blocks within each species = 0.58

Figure 1. Average number of *Carpophilus* spp. caught in monitoring traps in appricot Block 1 (a) and Block 2 (b) during 2006/07 growing season at Loxton, South Australia.



1 highest numbers of *C. hemipterus* were trapped in the first week of monitoring and the number dropped sharply within four weeks (Figure 1a). After that, the number was low, never exceeding 100 beetles/trap/week. The highest number of *C. davidsoni* was trapped in the second week of monitoring. *C. davidsoni* populations then dropped and stayed below 70 beetles/trap/week for the rest of the season (Figure 1a). In Block 2, where *C. davidsoni* was more predominant than *C. hemipterus* the highest number of *C. davidsoni* was trapped only two weeks before fruit harvest (Figure 1b). However, the number of *C. davidsoni* being trapped dropped sharply by the time of fruit harvest, with numbers trapped then remaining less than 70

Table 2. Mean (log) weekly count *Carpophilus* spp. (and back transformed means in parentheses) caught in four monitoring traps in apricot blocks during the 2006/07 growing season at Loxton, South Australia.

Week ending	Mean (log) count (beetles/trap/week)
15/11/2006	4.19 (65.0)
22/11/2006	4.54 (92.7)
29/11/2006	4.04 (55.8)
6/12/2006	2.87 (16.6)
13/12/2006	4.51 (89.9)
20/12/2006	3.14 (22.1)
27/12/2006	3.17 (22.8)
3/01/2007	3.52 (32.8)
10/01/2007	2.51 (11.3)
17/01/2007	3.09 (21.0)
24/01/2007	3.26 (25.0)
LSD (p=0.05)	0.79

Table 3. Predicted mean (log scale) number of fruit (and back transformed means in parentheses) infested by *C. davidsoni* at each combination of fruit maturity and condition from apricot orchards in Loxton, South Australia (fruit harvested in Block 1 on 28/12/06 and in Block 2 on 03/01/07).

Fruit maturity	Predicted mean (log scale) number of fruit					
	Condition of fruit					
	Beetle hole damage		Beetle hole damage + early stage of rot		Uninfested fruit	
Early stage	2.14	(8.5)	0.22	(1.3)	5.46	(234.0)
Late stage	3.37	(29.0)	2.40	(11.0)	5.42	(226.3)

Approximate LSD (p=0.05)) for comparison between condition of fruit within each fruit maturity or between fruit maturity within each condition of fruit = 1.02

beetles/trap/week. The *C. hemipterus* in Block 2 followed a similar trend to Block 1 with numbers remaining low just prior to, and throughout the harvest period (Figure 1b).

Carpophilus spp. inside the fruit

Beetles found inside the fruit were mostly *C. davidsoni*. Only two *C. hemipterus* were observed in a fruit which was ripe and early stage of rotting (data not presented). The majority of the fruit assessed was not infested with *Carpophilus* spp. (Table 3). Level of infestation and fruit condition were significantly influenced by the stage of fruit maturity ($p<0.001$), with significantly more fruit at a late stage of maturity being infested than fruit at an early stage of maturity (Table 3). Likewise, the proportion of infested fruit that had started to rot was significantly higher in fruit at a late stage of maturity compared with fruit at an early stage of maturity.

Although the number of fruit that were infested with *C. davidsoni* was higher at a late stage of maturity than at an early stage of maturity, the number of beetles found per infested fruit did not significantly differ between the two maturities (p=0.13). However, significantly more *C. davidsoni* were found per infested fruit that had developed an early stage of rot (2.66) compared with infested fruit that had a damage hole only (1.73), irrespective of stage of maturity (p=0.008).

Neither the number of fruit infested with *C. davidsoni* nor the number of *C. davidsoni* per infested fruit differed significantly between the two blocks.

DISCUSSION

In our current study we observed *C. davidsoni* in almost all fruit infested with beetles. *C. davidsoni* show a clear preference to colonize fruit on the tree as opposed to fallen fruit. Only two *C. hemipterus* were observed in fruit on a tree and that fruit was in the early stage of rotting. This was despite *C. hemipterus* being the dominant species caught in monitoring traps in Block 1 and a significant proportion of the population trapped in Block 2. The dominance of *C. davidsoni* and absence of *C. hemipterus* infesting sound fruit on the tree in this study adds to the findings of Hossain and Williams (2003) that *C. hemipterus* were attracted to decomposing fruit in fruit dumps whereas *C. davidsoni* was not. Smilanick (1979) also reported that colonization by *C. mutilatus* decreased with advancing ripeness of figs, whereas *C. hemipterus* appeared to increase. Both of these two studies support the findings that *C. hemipterus* might be less attracted to sound fruit compared to *C. davidsoni* or *C. mutilatus*. It is possible that damage done by *C. davidsoni* creates conditions suitable for colonization by *C. hemipterus*.

James *et al.* (1995) reported that *C. davidsoni* was the dominant species in most of the Australian stone fruit growing regions, including the Riverland of South Australia where the trial site is located, although *C. hemipterus* was also common in the Riverland. The current study also confirmed high numbers of *C. hemipterus* in the monitored blocks but they were not found infesting fruit on the tree. We have observed that *C. hemipterus* are more active and can escape very easily, while they are being handled in the laboratory. We took particular care when collecting fruit and we did not observe the escape of any beetles from the individual fruit being harvested.

Although the aroma of ripening apricot might reduce the effectiveness of monitoring traps there was no evidence from the fruit damage assessments that *C. hemipterus* had moved from fruit on the ground to fruit on the tree. *C. hemipterus* was the predomonant species caught in the traps in Block 1 but was not found in damaged fruit on the trees in that block, whereas *C. davidsoni* was the predominant species in the damaged fruit on the trees. If *C. hemipterus* was the most damaging species it would be expected that Block 1 would have experienced more *C. hemipterus* in the maturing fruit but this was not so. This reinforces our conclusion that *C. davidsoni* is the major pest species. Early studies possibly implicated *C. hemipterus* as the damaging species because they would have been present in fruit at very advanced stages of damage or ripening. Orchard hygiene practices that remove fallen fruit have been recommended to fresh market peach and nectarine growers to prevent build up of *Carpophilus* spp. before harvest. The use of '*attract and kill*' to reduce populations of both *C. davidsoni* and *C. hemipterus* before fruit begins to ripen has also been successful in preventing damage (Hossain *et al.* 2006).

Bartelt *et al*. (1994) showed greater numbers of *C. humeralis* were caught when traps were placed near to the ground. In addition *C. humeralis* is reported mostly to be a pest of fruit such as pineapple that grow at or near ground level (Schmidt 1935). Since our traps were approximately 1.5 m from the ground and the experiment was conducted in a stone fruit growing district, the low number of *C. humeralis* in the traps was not unexpected.

'*Attract and kill'* traps used to control *Carpophilus* spp. are baited with tri-species pheromone and synthetic food-attractant. Cost of the pheromone is very high. It may be possible to reduce the cost if only *C. davidsoni* is causing the damage to fruit on the tree. The *C. davidsoni* pheromone also has some attraction to other *Carpophilus* species (Bartelt and James 1994). Although our study concluded that *C. davidsoni* is the dominant species infesting ripening apricot fruit on the trees, this was based on observation of only one cultivar of apricot. More study is required to determine *Carpophilus* species composition on other cultivars or other fruit types.

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