INTERNATIONAL JOURNAL OF PEST MANAGEMENT, 1996, **42**(2) 107–112

# An ecological study of the damage done to avocado fruits by citrus leafhopper *Penthimiola bella* (Cicadellidae) and coconut bug *Pseudotheraptus wayi* (Coreidae) in South Africa

(*Keywords: Persea americana*, South Africa, *Penthimiola bella, Pseudotheraptus wayi*)

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**Abstract.** Feeding on young avocado fruit by citrus leafhopper *Penthimiola bella* (Stål) (Homoptera: Cicadellidae) causes protrusions on the surfaces of the maturing fruits, rendering them unacceptable for export. In the present study it was found that the incidence of protrusions on Hass avocados (10%) was five times greater than on Fuerte (2%) avocados. The damage was inflicted during early fruit development and did not increase above 11% (average 9%) during the study period. Protrusions were distributed throughout the study site with no edge effect. Feeding was strongly linearly density-dependent, and fruits with protrusions were not aborted (i.e. the trees utilize resources to mature fruit that are lost to the grower). A technique for monitoring the incidence of fruit bearing protrusions is described. In contrast, feeding by coconut bug *Pseudotheraptus wayi* (Brown) (Heteroptera: Coreidae) was exponentially density-dependent, but did enhance fruit drop. The mass of indented fruit was 28% lower than that of healthy fruit and those bearing protrusions, indicating that these fruits are less energy-expensive than those bearing protrusions whose mass did not differ from that of healthy fruits.

## 1. Introduction

The avocado, *Persea americana* (Lauraceae), was introduced into South Africa during the Dutch colonization of the eighteenth century but it only began to be cultivated as a crop between 1920 and 1930 (Durand, 1990). Until recently, there have been few and relatively unimportant avocado pests (Annecke and Moran, 1982). However, during the last decade there has been a three-fold increase in the number of insect pest taxa damaging avocado fruits, and this has been attributed to the recent expansion (>25% per annum) in the avocado industry (Dennill and Erasmus, 1992).

During the last 3 years, avocado fruits have been increasingly attacked by Hemiptera that induce protrusions on the fruit surface. The damage, described and illustrated by Dennill and Erasmus (1991), was originally attributed to stinkbugs (including *Nezara viridula* (L.) (Heteroptera: Pentatomidae)) by various researchers and consultants (see Dennill and Erasmus, 1991), but has recently been found to be caused by the citrus leafhopper *Penthimiola bella* (Stål) (Cicadellidae) (Du Toit *et al.*, 1993). In the centre of the protrusions just below the fruit surface, the feeding hole where the insect inserted its mouthparts is clearly demarcated by an elongated (1–3 mm) rod-like scar of dead, black tissue. This scar is surrounded by corky, orange-coloured tissue.

Packhouse surveys of insect damage to avocado fruits in the Nelspruit–Hazyview region of South Africa revealed that during 1990 this damage was the fourth most important and that during 1991 it was the most important cause of damage to the crops, causing losses of 1·8% and 3·1% of the fruits, respectively (Dennill and Erasmus, 1991; Erichsen and Schoeman, 1992). During the 1991 and 1992 seasons, there has been a sudden increase in the incidence of this damage where some farmers claim to have lost up to 30% of their crop (R 5850-00/ha (13 tons/ha at R 1500/ton)) (W. Vos, personal communication). The damage is also becoming more widespread, being reported from the Tzaneen and Natal avocado-growing regions during 1991 and 1992 (C. J. Partridge, personal communication).

Indentations in the fruit surface are caused by coconut bug, *Pseudotheraptus wayi* (Brown) (Coreidae), feeding on young fruits (Viljoen, 1986; de Villiers, 1990; du Toit and de Villiers, 1990; van der Meulen, personal communication). Within the flesh of the fruit below these indentations are feeding marks and scar tissue similar to those occurring immediately below the protrusions caused by Pentatomidae. The damaged part of the developing fruit does not grow normally while the healthy surrounding tissue does, resulting in an indentation where the damage was done. In the above-mentioned packhouse surveys of insect damage to avocado fruits during 1990 and 1991, this damage was most important and second most important, causing losses of 4·7% and 2·8% of the fruits respectively (Dennill and Erasmus, 1991; Erichsen and Schoeman, 1992).

The aims of the present study were to determine: (1) the incidence of protrusions on the two main cultivars (Hass and Fuerte); (2) whether there is an increase in the incidence of this damage over time (to determine whether the damage was inflicted only during the early stages of fruit development between September and December); (3) the distribution of the protrusions within an orchard (some insects are more damaging on the periphery); (4) the distribution of the protrusions and indentations within trees regarding height and aspect (some insects, e.g. citrus thrips *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae), are more damaging on the warmer northern aspects of their host plants at higher southern African latitudes (Grout and Richards, 1990)); (5) whether feeding by *P. bella* and *P. wayi* is density-dependent; (6) whether the two kinds of feeding enhance fruit drop and/or affect fruit mass, and (7) a practical technique for monitoring the damage caused by *P. bella*.

## 2. Materials and methods

The study was undertaken in the Nelspruit–Hazyview

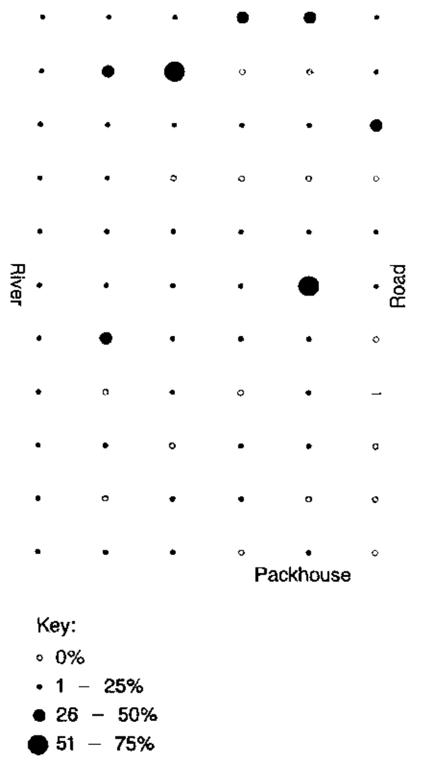


*Figure 1. The pattern of distribution of damage (protrusions) within the study orchard.*

region of South Africa, which appeared to be most severely affected. The orchard selected consists of 2374 trees of cultivars Hass and Fuerte planted in alternating sets of three rows of each. The study site within this orchard consisted of 41 rows with a maximum of 26 trees per row, being bordered on the eastern side by a riverine habitat containing indigenous vegetation invaded by weeds, e.g. bugweed (*Solanum mauritianum* Scop.) and on the western side by a dust road beyond which the orchard continues (Figure 1). The study began on 9 December 1991 immediately after the farmers in the Hazyview area had alerted the South African Avocado Growers' Association to the problem. At this stage the width of the healthy developing fruits was that of a golf ball (mean mass = 46 g). Examination of the study orchard revealed that there were also many fruits displaying indentations caused by *P. wayi*. The only other insect damage observed could be ascribed to loopers (Geometridae) (de Villiers and van den Berg, 1987), and was minimal (three fruits damaged).

## 2.1. *Levels of damage (protrusions) on different cultivars*

Between 9 and 13 December 1991, 11 pairs of contiguous rows of Hass and Fuerte trees (rows three and four, and thereafter every second and third row) were selected. In each set of rows every fifth pair of trees (one of each cultivar) was selected, and the damaged and undamaged fruits at head height were counted on each tree. Since the rows in the study area consist of about 30 trees each, six pairs of trees should have been sampled per row, yielding a total of 66 trees of each cultivar. However, since some trees had died or been removed, a total of 65 Hass and 59 Fuerte trees were sampled in order to determine whether there was a difference in the incidence of damage between these cultivars.

## 2.2. *Incidence of damage (protrusions) over time*

In order to determine whether there was an increase in the incidence of damage over time, a random sample of Hass trees in the same orchard was selected monthly from December 1991 to June 1992. On each tree, the fruit at head height were examined for damage as described above. Only Hass trees were used since the results indicated that Fuerte trees suffered only mild damage (2%) compared with Hass trees which were five times more severely affected (10%).

## 2.3. *Distribution of damage (protrusions) within the orchard*

The 65 Hass trees samples according to the method described above were scored from 1 to 5 according to the percentage of fruits that were damaged (0%, 1–25%, 26–50%, 51–75% and 76–100%, respectively). In this way the distribution of the damage in the orchard could be mapped.

## 2.4. *Density-dependence: distribution of feeding (protrusions and indentations) within trees*

Eleven Hass trees were randomly selected within the study area. Each tree was divided into horizontal 1-m strata and each stratum into four aspects (north, east, south and west). The fruits in each 1-m segment were picked and the damaged fruit (bearing protrusions or indentations) and undamaged fruit were counted. In this manner, the proportion of damaged fruits in each height class and aspect could be determined and compared with the proportion of fruit (both damaged and undamaged) to investigate whether feeding was density-dependent. Again only Hass trees were used.

## 2.5. *Enhancement of fruit drop (protrusions and indentations)*

Damaged and undamaged fruits lying on the ground underneath each of the 11 Hass trees described above were counted. The relationship between the percentage of fruits dropped and percentage of damaged fruits among the dropped fruits could thus be investigated to determine whether damaged fruits are shed.

## 2.6. *Development of a technique for monitoring damage caused by* P. bella *(protrusions)*

In order to devise a practical method for assessing losses caused by fruits bearing protrusions, quick counts of damaged and undamaged fruits at head height were compared with the actual incidence of damage for 20 Hass trees. In addition, the percentage of damaged fruit in the 1–2 m stratum, which is easily accessible, was compared with the actual incidence of damage on the 11 Hass trees described above.

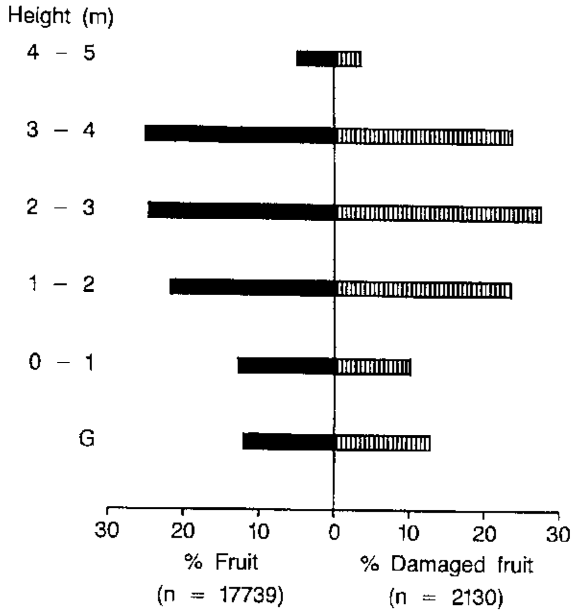


*Figure 2. Diagrammatic comparison of the vertical distribution of damaged fruit (protrusions) with the general vertical distribution of fruit on Hass avocado trees.*

*Table 1. A comparison of the incidence (%) of damage (protrusions) on Hass and Fuerte avocados*

| Cultivar | % fruit damaged | Sample size | |
|---|---|---|---|
| | | No. of fruit | No. of trees |
| Hass | 9·8 | 3256 | 65 |
| Fuerte | 2·1 | 2566 | 59 |

*Table 2. The incidence (%) of damage (protrusions) on Hass avocados from December 1991 until June 1992*

| Date | % fruit damaged | Sample size | |
|---|---|---|---|
| | | No. of fruit | No. of trees |
| 09–13 December 1991 | 9·8 | 3526 | 65 |
| 16–20 December 1991 | 11·1 | 1000 | 20 |
| 27–31 January 1992 | 8·6 | 1000 | 20 |
| 17–21 February 1992 | 8·0 | 1000 | 20 |
| 23–27 March 1992 | 9·6 | 2400 | 50 |
| 20–24 April 92 | 9·0 | 2285 | 50 |
| 18–22 May 92 | 8·1 | 2371 | 50 |
| 22–26 June 92 | 8·0 | 2337 | 50 |

## 3. Results

### 3.1. *Levels of damage (protrusions) on different cultivars*

The percentage of Hass avocados displaying protrusions (9·8%) was five times that of Fuerte avocados (2·1%) (Table 1).

### 3.2. *Incidence of damage (protrusions) over time*

There was no increase in the incidence of damage to Hass fruits during the study period (Table 2). Data collection was terminated at the end of June just prior to harvest.

### 3.3. *Distribution of damage (protrusions) within the orchard*

The damage was distributed throughout the study area; fruit on 75% of the trees were damaged and the median score for damage was 2 (i.e. 1–25%) (Figure 1). Trees displaying highest levels of damage (25–75%) were scattered and did not occur on the borders of the study area (Figure 1).

### 3.4. *Spatial distribution of feeding (protrusions and indentations) within trees*

The vertical distribution of fruit bearing protrusions was similar to that of the distribution of fruits on the trees (Figure 2). The vertical distribution of fruits with indentations

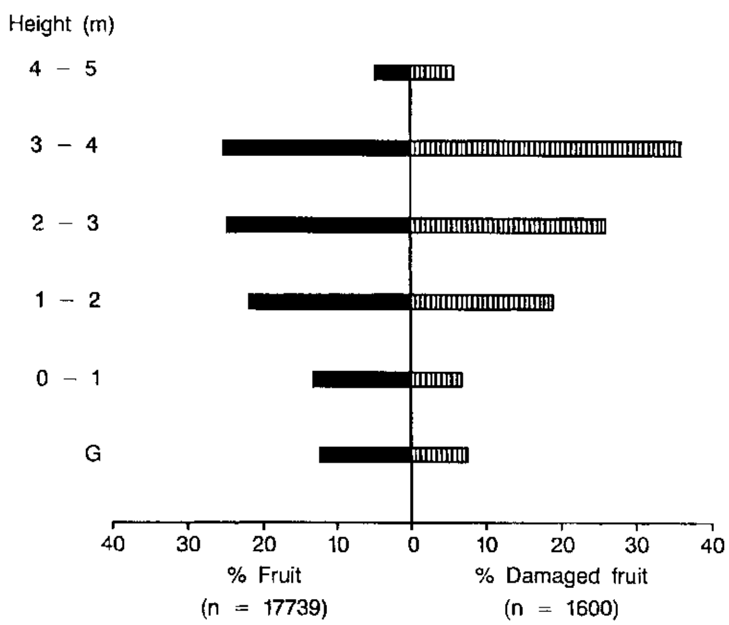


*Figure 3. Diagrammatic comparison of the vertical distribution of damaged fruit (indentations) with the general vertical distribution of fruit on Hass avocado trees.*

*Table 3. A comparison of the incidence (xa) and distribution (xb) of damaged fruits (protrusions only), and the distribution of fruits (damaged and undamaged) (xc) in each of the four aspects of 11 Hass avocado trees. Weighted ANOVAs were performed on the data that were tested for normality (transformations were not required)*

| Aspect | % damaged fruit *xa* (s.e.) | % damaged fruit *xb* (s.e.) | % fruit in each aspect (s.e.) |
|---|---|---|---|
| W | 28·17 (2·761) | 11·86 (1·911) | 28·50 (1·755) |
| N | 27·47 (2·761) | 13·36 (2·058) | 24·64 (1·755) |
| E | 26·88 (2·761) | 12·09 (1·979) | 26·59 (1·755) |
| S | 17·38 (2·761) | 10·26 (2·267) | 20·26 (1·755) |
| LSD[a] | 10·46 | – | 6·650 |
| *P* | 0·027 | 0·794 | 0·013 |

[a]Tukey's multiple comparison LSD at $P = 0{\cdot}05$.
s.e., standard error of the mean.

*Table 4. A comparison of the incidence (xa) and distribution (xb) of damaged fruits (indentations only) in each of the four aspects of 11 Hass avocado trees. Weighted ANOVAs were performed on the data that were tested for normality (transformations were not required)*

| Aspect | % damaged fruit *xa* (s.e.) | % damaged fruit *xb* (s.e.) |
|---|---|---|
| W | 10·29 (1·588) | 30·86 (3·294) |
| N | 7·37 (1·708) | 19·11 (3·294) |
| E | 9·10 (1·644) | 25·46 (3·294) |
| S | 11·78 (1·844) | 24·58 (3·294) |
| *P* | 0·357 | 0·111 |

s.e., standard error of mean.

followed a similar trend except in the higher 3–4 m stratum where there was a relatively greater incidence of damage (Figure 3).

Regarding both protrusions and indentations, there was no difference in incidence of damage (= proportion of damaged fruit out of the total number of fruit) within each aspect of the 11 trees (Tables 3 and 4). However, a comparison of the distribution of damaged fruits within the trees showed that there were significantly lower proportions of damaged fruit on the southern aspects of the trees (Table 3). The distribution of fruits (both damaged and undamaged) on the trees followed the same trend, with significantly lower proportions of fruit on the southern aspects of the trees (Table 3).

### 3.5. *Density-dependence of feeding damage*

The relationship between the percentage of the total number of fruit and the percentage of fruit bearing protrusions in each stratum was linear with a positive slope of approximately 1 (Figure 4). This indicates linear density-dependence. In contrast, the relationship between the total number of fruit and the percentage of fruit with indentations in

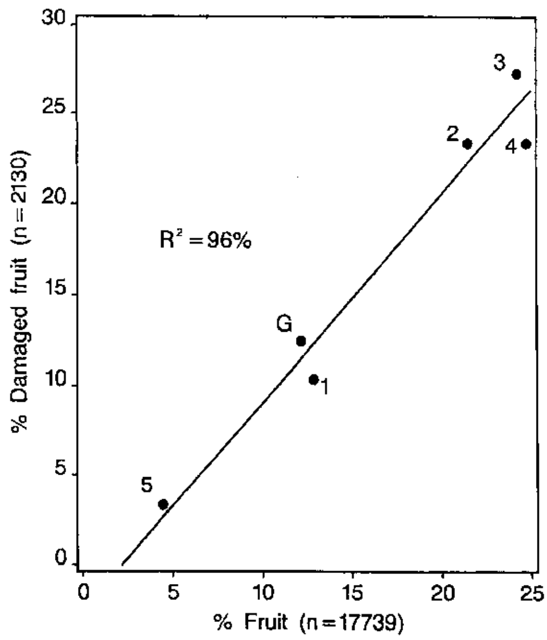


*Figure 4. The relationship between the total number of fruit and the percentage of damaged fruit bearing protrusions on the ground and in vertical 1-m strata into which 11 Hass trees were divided ($y = -2{\cdot}23 + 1{\cdot}13x$). (G, fruit lying on ground; 1, fruit in 0–1 m stratum; 2, fruit in 1–2 m stratum, etc.)*

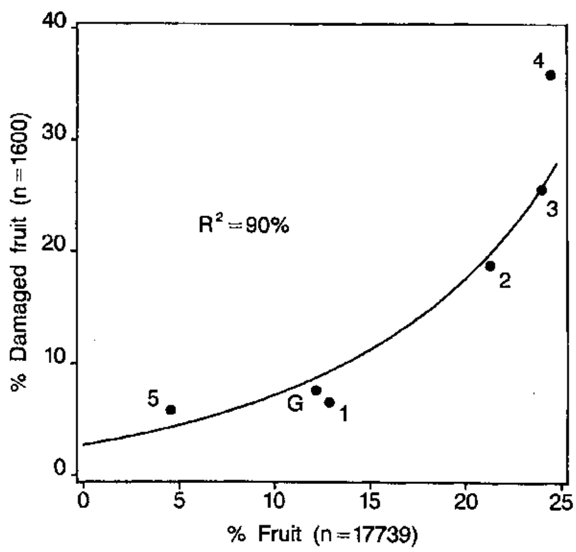


*Figure 5. The relationship between the total number of fruit and the percentage of damaged fruit with indentations on the ground and in vertical 1-m strata into which 11 Hass trees were divided ($y = e^{(1{\cdot}03 + 0{\cdot}0092x)}$). (G, fruit lying on ground; 1, fruit in 0–1 m stratum; 2, fruit in 1–2 m stratum, etc.)*

each stratum was exponentially density-dependent (Figure 5) although a straight line also fitted the data ($y = -6{\cdot}02 + 1{\cdot}36x$; $R^2 = 80\%$; $n = 6$).

### 3.6. *Enhancement of fruit drop (protrusions and indentations)*

There was no relationship between the percentage of fruit dropped and the percentage of fruit bearing protrusions

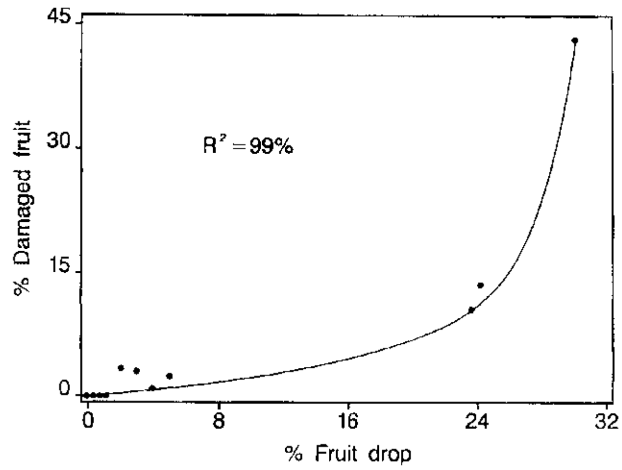


*Figure 6. The relationship between the percentage of fruit dropped and the percentage of fruit with indentations among the dropped fruit* ($y = -2{\cdot}76 + 3{\cdot}78/1\text{-}0{\cdot}0319x$).

among those that had dropped ($R^2 = 17{\cdot}15\%$; $n = 11$). However, there was a strong rectangular hyperbolic relationship ($R^2 = 99\%$) between the percentage of fruit dropped and the percentage of fruit with indentations among those that had been dropped (Figure 6). This indicates that trees with a higher percentage fruit drop shed a higher proportion of damaged (indented) fruits, the proportion of damaged fruit dropped increasing dramatically when the percentage fruit drop exceeds about 24%.

### 3.7. *Development of a technique for monitoring damage caused by* P. bella *(protrusions)*

Head-height counts of damaged fruits were an unreliable index of the actual levels of damage on the trees ($y = 6{\cdot}808 + 0{\cdot}730x$; $R^2 = 24\%$; $P = 0{\cdot}029$; $n = 20$). However, the percentage of damaged fruit in the 1–2 m stratum is a reliable index of the actual fruit loss ($y = 3{\cdot}255 + 0{\cdot}791x$; $R^2 = 88\%$; $P = 0{\cdot}00002$; $n = 11$).

## 4. Discussion

The large number of fruit sampled to compare damage on Hass and Fuerte cultivars clearly indicated that losses were, significantly, five times greater on Hass. The low variation (8–11%) in the percentage of Hass fruit with protrusions over eight sampling dates (from December 1991 to June 1992) indicates that (a) the incidence of damage remained fairly constant, and that 10% is probably a reliable estimate of fruit loss, and (b) that this damage was done during the earlier stages of fruit development (September to November). The early infliction of damage to the fruits has subsequently been confirmed by du Toit *et al.* (1993).

The incidence of fruit with protrusions was not greater along the borders of the orchard, but was fairly evenly distributed throughout the study site. Trees with the highest levels of damage occurred in the centre of the study site, indicating the high mobility of *P. bella*. A less mobile pest would probably produce a 'typical' edge effect, or a wave of damage advancing from a particular point of infestation within the orchard. The pests currently causing lesions on avocado fruit in South Africa, including *P. bella*, are all sporadic because they are polyphages whose mobility enables them to exploit a range of crops (Dennill and Erasmus, 1992).

The distribution of fruit bearing protrusions within the trees indicates clearly that feeding by the pest is density-dependent in regard to height and aspect. The proportion of damaged fruits was significantly lower on the southern sides of the trees, but this occurred only because there were less fruit on the southern aspects (it is commonly known that the shadier sides of trees bear less fruit (Jackson, 1986; Hartmann *et al.*, 1988).

There was no enhancement of fruit drop by *P. bella*. This means that the trees utilize resources to mature fruit that are lost to the grower. In contrast, feeding by coconut bug does enhance fruit drop. The indentations are attributed to feeding by coconut bug at an early stage of fruit development in September–October when fruit abortion occurs (Viljoen, 1986; de Villiers, 1990; du Toit and de Villiers, 1990; van der Meulen, personal communication).

The biomass of fruit with protrusions is similar to that of healthy fruit, which implies that the damaged fruit are as demanding of resources to the plant as healthy fruit.

Although sampling the incidence of protrusions at head height was not an accurate assessment of actual fruit loss, counts of the fruit in the 1–2 m stratum were, in contrast, very accurate. This is to be expected since the proportion of fruit in the 1–2 m stratum is high (21%). These results indicate that only the 1–2 m stratum need be counted in order to monitor the actual crop loss caused by this pest.

## Acknowledgements

We thank Mr C. J. Partridge for alerting us to this problem, the South African Avocado Growers' Association for financially supporting this research, Mrs M. F. Smith and Dr S. L. Chown for assistance with statistics, Ms L. Croukamp for providing horticultural information and Mr W. Vos for being willing to sacrifice so much of his produce in pursuit of knowledge.

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