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Distribution of the oriental fruit moth *Grapholita molesta* Busck (Lep., Tortricidae) infestation on newly planted peaches before and during 2 years of mating disruption

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Abstract: Oriental fruit moth (OFM) *Grapholita molesta* Busck (Lep., Tortricidae) is one of the most important pests of commercial stone fruit orchards in the Goulburn-Murray Valley region of Victoria, Australia. OFM populations have been successfully controlled by the use of the mating disruption (MD) technique for many years, but damage to shoot tips and fruit has now started to increase. The most severe damage under MD is found at the edge of peach blocks, adjacent to the pear blocks under insecticide treatment. In 1997–98, OFM infestation levels were examined in a newly planted peach block surrounded by older peaches, pears, apples and pasture. The infestation distribution was followed up for four consecutive years. No treatments were used against OFM for the first 2 years in the newly planted peaches, but in years 3 and 4 the whole block was treated with MD. At the end of year 2, shoot tip damage was randomly distributed throughout the newly planted peach block with no 'edge effect'. After MD was applied in year 3, the damage was confined to the edges of the block adjacent to insecticide-sprayed apples and pears. No 'edge effect' was detected along the border with an older peach block treated with MD or on the border with pasture. Extending the MD treated area for 25–30 m into the neighbouring apples and pears in year 4 reduced the 'edge effect'.

Key words: *Grapholita molesta*, edge effect, mating disruption, oriental fruit moth, peach shoot tip damage

1 Introduction

Mating disruption (MD), as a major technique in integrated pest management (IPM), is widely used in Australian stone fruit orchards to combat the oriental fruit moth (OFM) (*Grapholita molesta* Busck, Lep., Tortricidae). MD has been used for many years in Victoria to control OFM but some orchardists have reported an increase in shoot tip and fruit damage on the border of peach blocks treated with MD adjacent to fruit blocks where insecticide treatments were used. This pattern of damage is known as the 'edge effect'. Similar patterns of damage in MD-treated orchards were associated with MD treatments inside the orchard rather than with insecticide treatments in adjacent orchards (Gut and Brunner, 1998). Il'ichev et al. (1998) suggested that damage in the edge of MD peach blocks adjacent to insecticide-treated pear blocks could result from migration of mated OFM females from the pear blocks to the peach MD blocks. Pears are not usually treated for OFM by MD or insecticides. OFM has only recently been recognized as a problem in pears since growers reduced their spraying against codling moth [*Cydia pomonella* L. (Lep., Tortricidae)] (Il'ichev et al., 1999). Volatiles from peach shoot tips and fruit could attract mated females from pears to the adjacent peach block for oviposition (Sexton and Il'ichev, 2000).

Barnes and Blomefield (1997) successfully prevented OFM damage to peaches and nectarines in South Africa by expanding MD into the first five rows of the neighbouring blocks. They suggested that success of the area-wide MD treatment depended on effective management of the borders of MD orchards and blocks, but edge damage effects were not mentioned in their research. Border treatments were considered important because of the decrease in concentration of pheromone at the edges of MD blocks caused by wind (Suckling and Karg, 1997), and because of possible migration of mated females from non-MD blocks into adjacent MD areas (Barnes and Blomefield, 1996).

The 'edge effect' of OFM, particularly under MD treatment, has not been described in the literature. However, similar distributions of damage concentrated at the edges of vineyards caused by other tortricids have been investigated (Trimble, 1993; Louis et al., 1997).

Geier (1963) recorded a higher codling moth (*C. pomonella*) infestation along the margins than in the interior of a discrete isolated apple orchard in the Australian Capital Territory. He suggested that border zones with lower temperatures, or more likely greater exposure to wind in marginal areas, could restrict the mobility of females. However, Van Leeuwen (1940) demonstrated with recapture of marked-released moths that increased infestation along orchard margins was mostly because of moth migration from outside sources.

In each of the examples given above, the orchards or vineyards were well established prior to the observations. In 1997, the development of an infestation was observed in newly planted peaches surrounded by productive blocks of peach, pear, apple and pasture.

This paper reports observations on changes in distribution of shoot tip damage in a newly planted peach study block during four consecutive seasons (1997–2001) with and without MD treatments applied to the whole study block and along its borders.

2 Material and methods

2.1 Description of the study area

The study area was a newly planted peach block in East Shepparton, Victoria, Australia. Peach trees (c.v. Tatura 204) were planted in August 1997 in a block that had been vacant for 2 years. This study block was about 6.5 ha in area and contained 4233 trees planted at 3.1 m gaps within rows. Rows were 5.1 m apart and orientated in the north–south direction. The study block was surrounded by a pasture (block 1) to the north, a peach block (c.v. Noon) (block 5) under first year of MD treatment for OFM control, apple block (c.v. Granny Smith) (block 6) and pears [c.v. William Bon Chretien (WBC)] (block 7) under insecticide treatment to the south. Apples (c.v. Granny Smith) (block 8) and WBC pears (block 9) under insecticide treatment were to the west. Apples (c.v. Granny Smith) (block 2 and block 3) and WBC pears (block 4), also under insecticide treatment, were located to the east (fig. 1). The study block was subdivided by an orchard track, forming two plots P1 (2333 trees) and P2 (1900 trees). There was no initial OFM infestation in the study block because fruit trees had not previously been planted on the block. Therefore, the OFM infestation that would occur in the study block must be due to OFM migration from adjacent fruit blocks.

There were no insecticide treatments or MD application used against pests in the study block during the first two seasons (1997–98 and 1998–99). In August 1999, MD was applied to reduce the OFM infestation, which had damaged about 70% of peach shoot tips by the end of the 1998–99 season. The study block was treated with 'Isomate OFM Rosso' (Shin-Etsu Chemical Co. Ltd, Tokyo, Japan for Biocontrol Ltd., Australia) at the recommended rate of 500 dispensers per hectare. During the 1998–99 season, a 25–30-m wide MD barrier was established on the WBC pear (block 9) and Granny Smith apple blocks (block 8) on the west side adjacent to the study block. The Noon peach block (block 5) on the south side remained under MD treatment. The neighbouring Granny Smith apple block (block 6) on the south side was under insecticide treatment for OFM control.

2.2 Monitoring of OFM population

Food traps were used for monitoring the OFM population in the study block and surrounding fruit blocks in 1997–98. These food traps are not specific to OFM, but are commonly used to indicate the level of OFM population under different treatments, including MD when sex pheromone traps are not effective. Each trap (Efecto-fly trap, Avond Pty Ltd, Narrogin, Australia) was filled with 1 l of 10% brown sugar solution and 12 drops of terpinyl acetate solution (48.5 ml of terpinyl acetate with 1.5 ml of non-ionic wetting agent and 50 ml of warm water).

A set of three food traps was placed in each of the surrounding fruit blocks near the border with the study

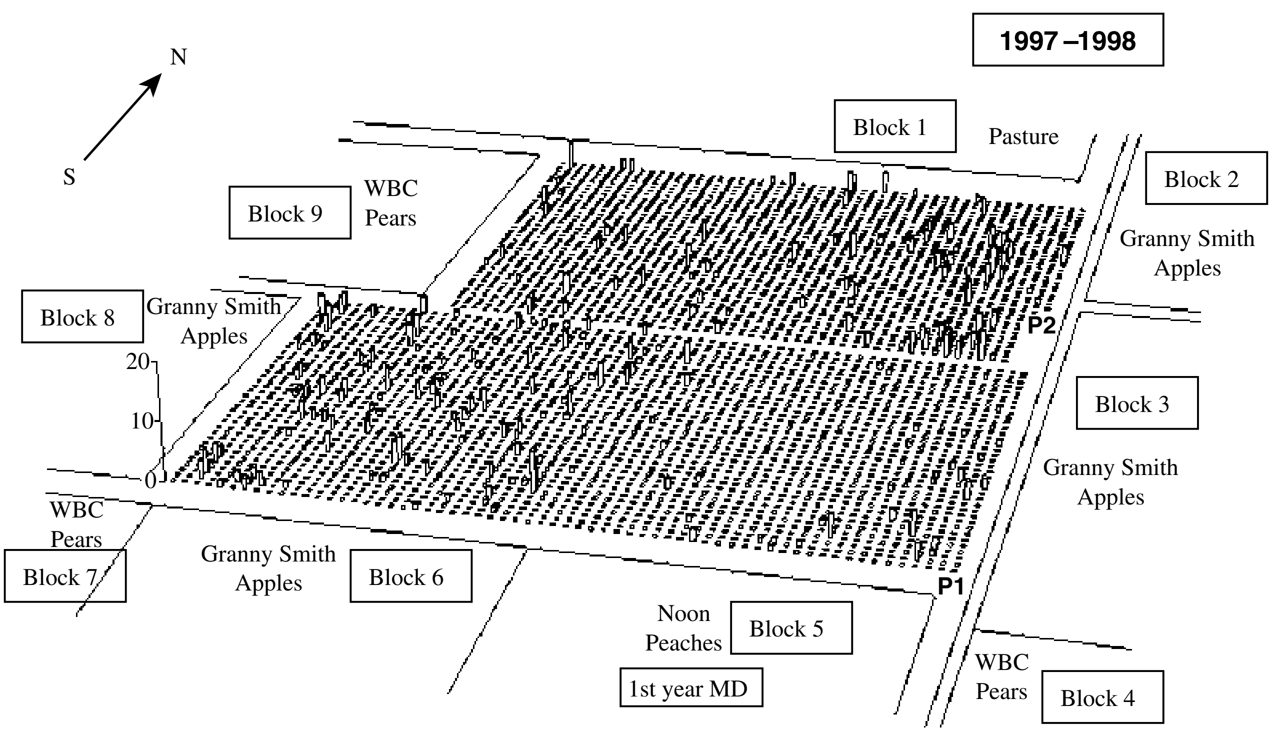

Fig. 1. *Distribution of shoot tip damage on a study block of newly planted peaches during the 1997–98 season. Bars indicate the number of damaged shoot tips per tree*

block. Each set consisted of a trap on the first tree of the row and the other two traps five trees apart down the row. Similar sets of three food traps were placed in the study block, opposite each surrounding fruit block. The food traps were monitored weekly by collecting moths and changing the sugar and terpinyl acetate solutions from the beginning of September 1997 to the end of February 1998.

2.3 Shoot tip damage assessments

Mated OFM females very often oviposit on fresh shoots of stone fruit trees, laying eggs near the tip. Hatched OFM larvae enter twigs, usually near the tip, and tunnel into the shoot for 8–10 cm. This causes the tip to die or wilt.

In the 1997–98 and 1998–99 seasons, every damaged shoot tip was counted from each of the 4233 peach trees in the study block in late November–December. In the 1999–2000 season, the damaged shoot tips were counted on all trees within five trees from the borders of plots P1 (2333 trees) and P2 (1900 trees), and on every second tree inside the plots. For the season 2000–2001, damaged shoot tips were counted in every fifth tree in every fourth row of trees. The numbers of damaged shoot tips were recorded and the data then graphically presented for distribution analysis.

2.4 Statistics and analysis

To analyse distribution of the shoot tip damage within the block, the spatial trend in counts of damaged shoot tips was determined by fitting a generalized linear mixed model with Poisson errors. Models were fitted using GENSTAT 5 release 4.2, Lawes Agricultural Trust, Rothamsted Experimental Station. The spatial autocorrelation between neighbouring damaged trees in the combined plots P1 and P2 was determined using SPLUS SpatialStats (MathSoft Inc., Seattle, WA, USA).

3 Results

3.1 The OFM population

The food trap monitoring data in 1997–98 indicated the presence of OFM infestation in the fruit blocks south of the study block. During the first OFM flight, 17.3 OFM per trap were caught in the Noon peach block 5 under MD, 6.0 OFM per trap in the Granny Smith apple block 8, and 2.0 OFM per trap in the WBC pear block 9. The traps in the study block indicated the beginning of the OFM infestation with an average catch of 1.1 OFM per trap. During the 1997–98 season, the average number of OFM caught per trap was 66.3, 13.3 and 23.7 on Noon peach block 5, Granny Smith apple block 8 and WBC pear block 9, respectively. The OFM infestation also increased later in the season in the study block, where the average catch during the season was 5.6 OFM per trap. No OFM were caught in food traps placed near the pasture (block 1). The monitoring data indicated that the OFM population was highest in the Noon peach block 5.

3.2 Shoot tip damage

The shoot tip infestation in the study block started in the middle of November 1997. The distribution of shoot tip damage throughout the interface of the study block (assessment from 27 to 29 November 1997) is shown in fig. 1. Although damage appeared higher in the south-west corner of P1 and the east side of P2, the distribution of damaged trees was too sparse for a statistical pattern to be determined. In general, the number of damaged shoot tips fluctuated from one to five per tree.

In the second season (1998–99), the damaged shoot tips were counted from 21 to 23 December 1998. The damage increased throughout the study block compared with the previous year, but was distributed throughout the whole block of peaches without any detectable edge concentration (fig. 2).

In the third season (1999–2000), after MD application, the damage (assessment from 7 to 9 December 1999) decreased throughout the middle of the study block. There was no edge effect between the study block and the Noon peach block 5 both under MD, but a high number of damaged shoot tips were detected on the peach trees along the east and west edges of the study block. The level of damage observed along both the east and west edges of the study block was similar despite the use of the five tree-wide (about 25–30 m) MD barriers placed along the WBC pear block 9 and Granny Smith apple block 8 on the west side (fig. 3).

In the fourth season (2000–2001), after the continued use of MD, the number of damaged shoot tips (assessment from 13 to 14 January 2001) remained at comparatively low levels in the middle of the block. There was a decrease in the number of damaged shoot tips in the trees in the P1 and P2 plots adjacent to MD barriers on the west side. This decrease was especially noticeable along the rows of trees sampled immediately adjacent to the Granny Smith apple block 8 on the west side (fig. 4). These findings were in complete contrast to the 'edge effect' observed on the east side of the study block, adjacent to Granny Smith apple blocks 2 and 3, which were still being treated by insecticides, with no MD barriers in place.

The damage was very low and the distribution of damaged shoot tips per tree in 1997–98 was sparse (fig. 1). The number of damaged shoot tips per tree had generally increased in 1998–99 (fig. 2). There was a negative exponential trend in counts of shoot tip damage per tree in 1998–99 in the five trees of each row from the south-east corner and in the first five rows of the trees from the east side of the plot P1 ($P \leq 0.01$). A similar trend was observed in the last five rows at the west side of the plot P2 ($P = 0.01$). In 1999–2000, the shoot tip damage per tree was higher near the west and east edges of each plot (fig. 3) with a negative exponential trend in the five rows from the east and west sides of the plots P1 and P2 ($P < 0.001$). There was a similar significant trend in the five trees in the north side of the plot P1, and in the five trees in the south and north of the plot P2 ($P \leq 0.05$). This demonstrated that the 'edge effect' occurred after MD application in the study block in 1999–2000. In general, shoot tip damage decreased throughout the whole study block in 1999–2000 compared with 1998–99.

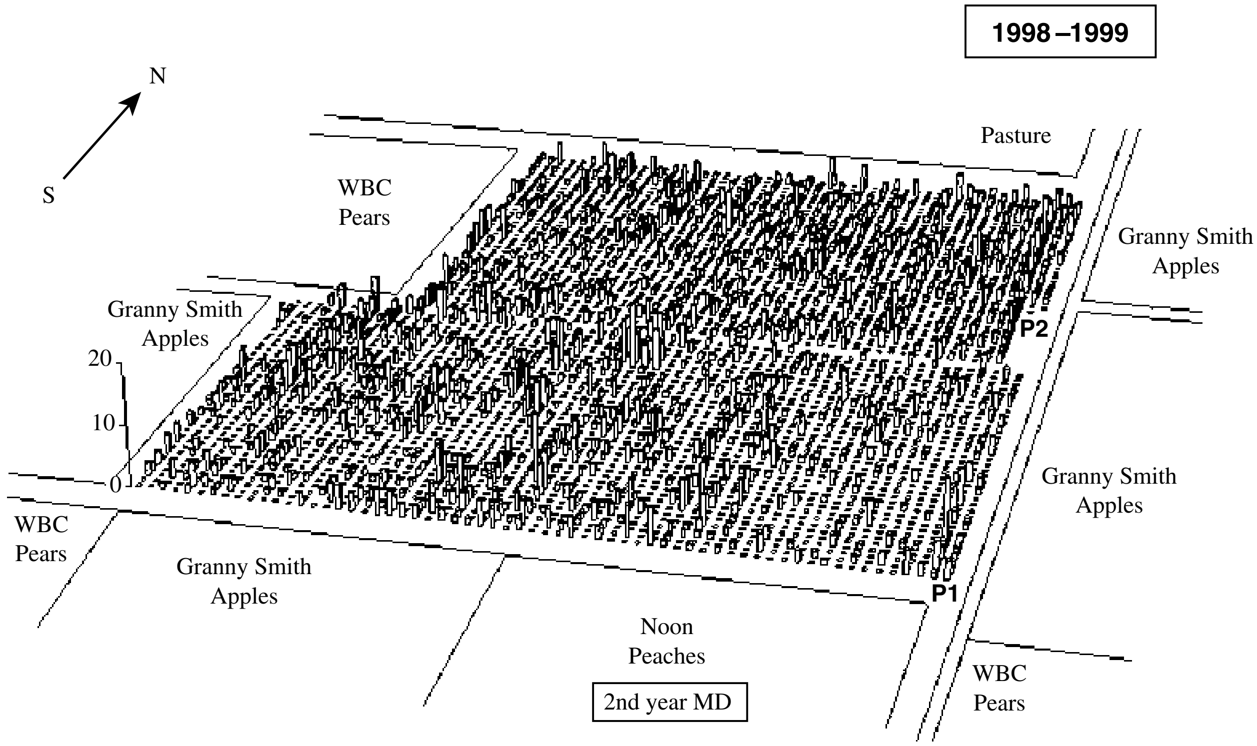

Fig. 2. *Distribution of shoot tip damage on the study block during the second season after planting (1998–99). Bars indicate the number of damaged shoot tips per tree*

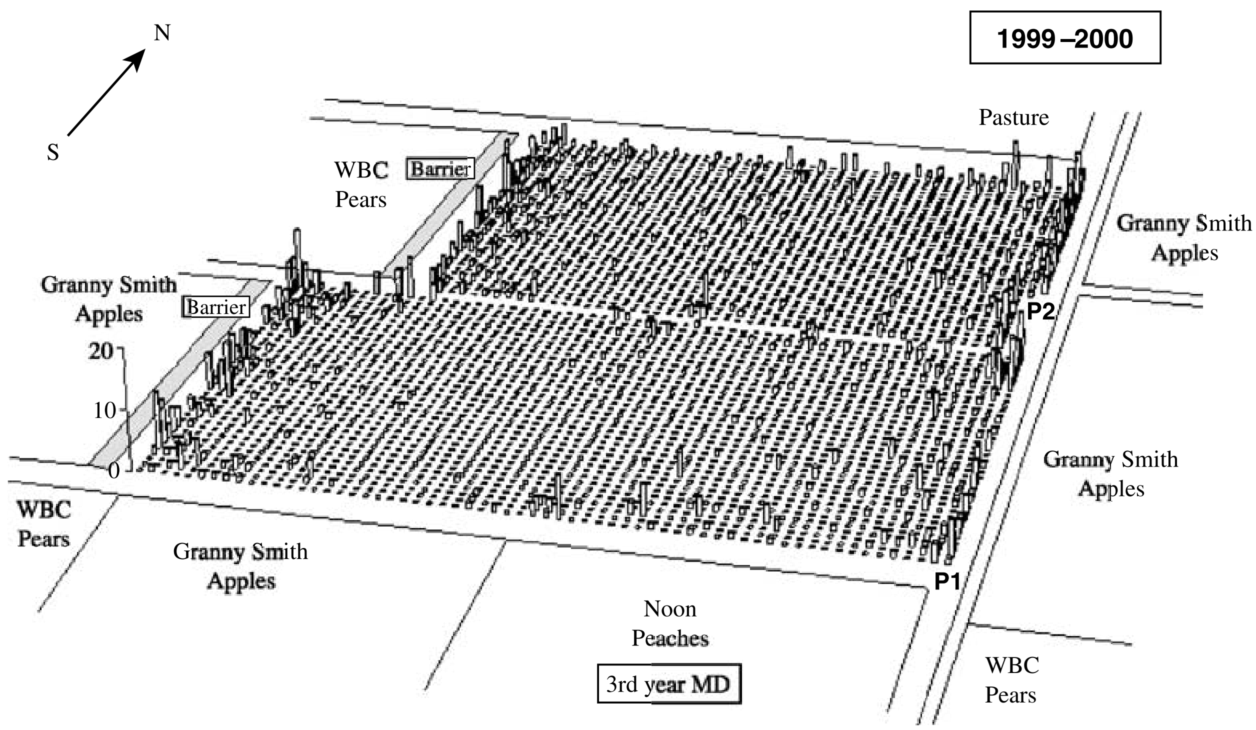

Fig. 3. *Distribution of shoot tip damage on the study block after the first season of mating disruption and barrier treatments (1999–2000). Bars indicate the number of damaged shoot tips per tree*

Over the combined plots there was no significant positive autocorrelation between neighbouring trees, indicating no positive spread from tree to tree. In fact, in 1998–99 and 1999–2000, there was a very small significant negative autocorrelation, indicating perhaps that OFM were drawn to more severely affected trees from neighbouring trees. During the 2000–2001 season, there was a significant negative exponential trend in numbers of damaged shoot tips on the east edge of both the P1 and P2 plots ($P < 0.05$). On the

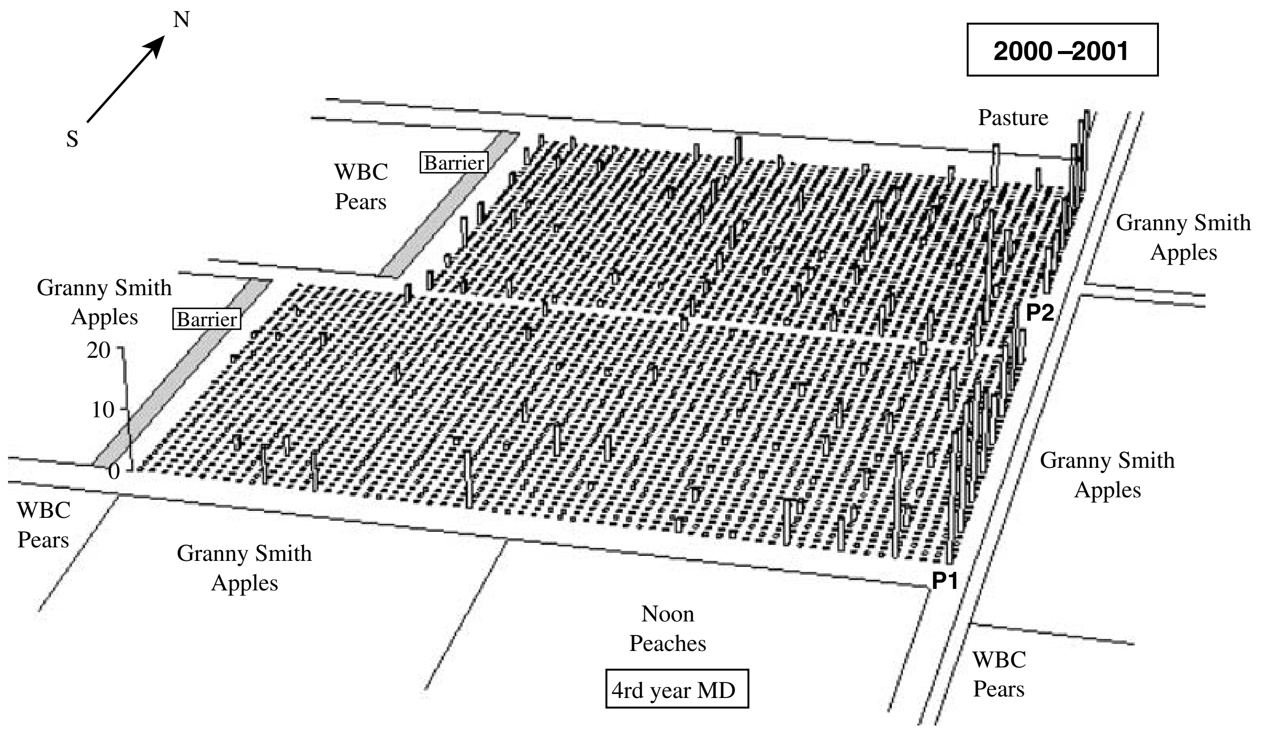

Fig. 4. *Distribution of shoot tip damage on the study block after the second season of mating disruption and barrier treatments (2000–2001). Bars indicate the number of damaged shoot tips per tree*

west side of the study block, where MD barriers had been established, there was a significant negative exponential trend in damaged shoot tip counts from the edge of the P2 plot ($P < 0.001$), but not along the edge of the P1 plot ($P = 0.24$). In contrast to the previous two seasons, there was a significant ($P < 0.001$), but weak ($r = 0.18$) spatial autocorrelation between neighbouring trees, indicating a positive spread from tree to tree throughout both the P1 and P2 plots in the study block.

4 Discussion

The number of moths caught by food traps during the first year of investigation indicated that OFM existed mainly in the Noon peach block 5, where MD was applied during the first season (1997–98). Migration of mated OFM females from surrounding blocks under different treatments to the study block without any treatments, may have caused the infestation in the study block. Pears are known to provide a reservoir of OFM (Il'ichev et al., 2002).

Fruit growers in the Goulburn-Murray Valley region of Victoria do not usually control OFM on newly planted stone fruit blocks because young trees have no fruit. This study indicated that untreated, newly planted stone fruit blocks can be quickly infested and constitute a nursery for OFM. Such blocks require special attention, as they could provide OFM that migrate to neighbouring MD blocks and orchards as mated females.

No 'edge effect' was detected between study block and Noon peach block 5 both treated with MD, but an 'edge effect' was detected along areas of the study block adjacent to apples and pears under insecticide treatments. For example, the level of damage along the east and west edges of the study block was similar, in spite of the five-tree MD barriers on adjacent WBC pears and Granny Smith apples along the west side. There was also no 'edge effect' on the study block immediately adjacent to the pasture. If the 'edge effect' is related to the decrease in concentration of MD pheromone at the block edges caused by wind, as Suckling and Karg (1997) have previously suggested, then we would expect to see an 'edge effect' alongside the pasture. As this was not evident we suggest that 'edge effect' is more related to the fruit variety and the food source preferences of OFM females that mated outside the MD areas. The occurrence of 'edge effect' along the border with apples and pears, but not with pasture, provides circumstantial evidence of mated OFM females that may be migrating into the peaches from other fruit. They could be very sensitive to their preferred host plant volatile, which would be their oviposition attractant at this stage of the life cycle, and migrate back into the peaches to oviposit.

The MD barrier of five trees on adjacent fruit blocks was not large enough and overall not effective in protecting peaches against the OFM 'edge effect' during its first season of use. However, during its second season of use, there was very little shoot tip damage observed along the edge of the P2 plot adjacent to WBC pears, and virtually no damage was recorded along the P1 plot adjacent to Granny Smith apples (fig. 4).

Dorn et al. (1999) suggested that insecticide treatments applied to neighbouring plots should be checked for their impact on pest behaviour. They cited unpublished data indicating that sublethal doses of azinphosmethyl increased the frequency of copulation, altered oviposition sites, and increased short-term egg deposition for codling moth *C. pomonella*.

If the insecticide treatments applied to the plots alongside the newly planted peaches in this study resulted in behavioural changes that led to the 'edge effects', then we would have expected the 'edge effects' to always be present alongside the insecticide-treated plots. As there were no 'edge effects' alongside the WBC pears (block 9) and Granny Smith apples (block 8) where MD barriers were applied, it is unlikely that the 'edge effect' is due to insecticide-induced behavioural changes.

On the east side of the study block the 'edge effect' was still apparent along areas adjacent to Granny Smith apples where no MD barriers were used. This study indicates that the control of an established OFM population by MD could take two to three seasons. The MD treatment should be extended beyond the boundaries of the MD block into neighbouring blocks to prevent 'edge effect'.

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References

Barnes, B. N.; Blomefield, T. L., 1996: Mating disruption manual for codling moth and oriental fruit moth. Stellenbosch, South Africa: Infruitec: Stellenbosch Institute for Fruit Technology.

Barnes, B. N.; Blomefield, T. L., 1997: Goading growers towards mating disruption: the South African experience with *Grapholita molesta* and *Cydia pomonella* (Lepidoptera, Tortricidae). IOBC/wprs Bulletin **20,** 45–56.

Dorn, S.; Schmacher, P.; Abivardi, C.; Meyhofer, R., 1999: Global and regional pest insects and their antagonists in orchards: spatial dynamics. Agric. Ecosyst. Environ. **73,** 111–118.

Geier, P. W., 1963: The life history of codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae), in the Australian Capital Territory. Austral. J. Zool. **11,** 323–367.

Gut, L. J.; Brunner, J. F., 1998: Pheromone-based management of codling moth (Lepidoptera: Tortricidae) in Washington apple orchards. J. Agric. Entomol. **15,** 387–406.

Il'ichev, A. L.; Jerie, P. H.; Hossain, M. S., 1998: Wide area mating disruption of oriental fruit moth *Grapholita molesta* Busck (Lepidoptera: Tortricidae) in Victoria. In: Pest Management—Future Challenges. Ed. by Zalucki, M. P.; Drew, R. A. I.; White, G. G. Brisbane, The Univ. of Queensland Printery, 348–355.

Il'ichev, A. L.; Hossain, M. S.; Jerie, P. H., 1999: Migration of oriental fruit moth *Grapholita molesta* Busck (Lepidoptera: Tortricidae) under wide area mating disruption in Victoria, Australia. IOBC/wprs Bulletin **22,** 53–62.

Il'ichev, A. L.; Gut, L. J.; Williams, D. G.; Hossain, M. S.; Jerie, P. H., 2002: Area-wide approach for improved control of oriental fruit moth *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae) by mating disruption. Gen. Appl. Ent. **31,** 7–15.

Louis, F.; Schirra, K.-J.; Feldhege, M., 1997: Mating disruption in vineyards: determination of population densities and effects on beneficials. IOBC/wprs Bulletin **20,** 95–99.

Sexton, S. B.; Il'ichev, A. L., 2000: Pheromone mating disruption with reference to oriental fruit moth *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae). Gen. Appl. Ent. **29,** 63–68.

Suckling, D. M.; Karg, G., 1997: The role of foliage in mating disruption in apple orchards. IOBC/wprs Bulletin **20,** 169–173.

Trimble, R. M., 1993: Efficacy of mating disruption for controlling the grape berry moth, *Endopiza viteana* (Clemens) (Lepidoptera: Tortricidae), a case study over three consecutive growing seasons. Can. Entomol. **125,** 1–9.

Van Leeuwen, E. R., 1940: The activity of adult codling moths as indicated by captures of marked moths. J. Econ. Entomol. **33,** 162–166.

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