Agriculture, Ecosystems and Environment 260 (2018) 27–35

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Effect of orchard management, neighbouring land-use and shelterbelt tree composition on the parasitism of pest leafroller (Lepidoptera: Tortricidae) larvae in kiwifruit orchard shelterbelts

Jacqui H. Todd*, Joanne Poulton, Kate Richards, Louise A. Malone

The New Zealand Institute for Plant & Food Research Limited, Private Bag 92169, Auckland 1142, New Zealand

ARTICLE INFO

Keywords:
Organic production
Integrated pest management (IPM)
Natural enemies
Hedges
Margins

ABSTRACT

The parasitoid communities in organic and integrated pest management (IPM) kiwifruit orchards have previously been found to differ significantly, but we do not know if this affects the quality or quantity of biocontrol services. We compared parasitism of two leafroller (Lepidoptera: Tortricidae) pest species, *Ctenopseustis obliquana* (Walker) and *Cnephasia jactatana* (Walker), in the two types of orchard. Within each orchard, we focussed on a large shelterbelt between the kiwifruit vines and an alternative land-use to also investigate whether the shelterbelts and neighbouring habitat were a source of pests or beneficial insects for these orchards. Sentinel larvae were used to determine both parasitoid identity and parasitism rate each month during the kiwifruit growing seasons in 2013/14 (16 orchards) and 2014/15 (12 orchards). The numbers of Tortricidae and parasitoids in the shelterbelt on each orchard in each month was also assessed in 2014/15. Four parasitoid species emerged from the sentinel larvae, although average parasitism rates were very low (1–3%). There were no detectable effects of orchard management, shelterbelt type or neighbouring land-use on parasitism rates. Parasitoid numbers were low in all orchards in 2014/15, although more parasitoids were collected from the IPM orchards than the organic ones. This may have been in response to the increasing numbers of Tortricidae in the shelterbelts on the IPM orchards during the season, a trend that was not observed in the organic orchards. Both shelterbelt composition and neighbouring land-use were found to affect total combined counts of Tortricidae and parasitoids, with higher counts in shelterbelts composed of *Cryptomeria japonica* and where adjacent land contained native bush or tree-based scrub. Each may therefore be a source of both taxa for the orchards. Modifications to the shelterbelts that increase parastoids but not Tortricidae are needed.

1. Introduction

Suppression of pest insects is one of the valuable ecosystem services provided by invertebrates in agricultural systems (Losey and Vaughan, 2006). The populations of invertebrates providing this service can benefit from the presence of varied habitat within the system as well as heterogeneity in the surrounding landscape (Shackelford et al., 2013; Gonzalez et al., 2015; Ramsden et al., 2015). For instance, both adjacent vegetation and land-use have been shown to affect parasitoid abundance within crops (Inclan et al., 2015; Macfadyen and Muller, 2013; Paredes et al., 2013). Within New Zealand kiwifruit orchards, tall shelterbelts of various tree species are grown around and through the orchard to protect the fruit from wind and frost damage. These shelterbelts may provide a habitat for natural enemies but can also be a source of pest insects for the crop (Suckling et al., 1998).

Two of the main economic pests of New Zealand kiwifruit are the highly polyphagous leafrollers (Lepidoptera: Tortricidae), *Ctenopseustis obliquana* (Walker) and *Cnephasia jactatana* (Walker), both native New Zealand species (McKenna and Stevens, 2007; Steven, 1991). In the absence of suitable control measures, feeding damage from these pests can result in the loss of more than 30% of fruit (McKenna et al., 1995; Steven, 1990). In New Zealand, all commercial kiwifruit orchards are either certified organic (http://www.biogro.co.nz), or conventional orchards using an integrated pest management (IPM) programme (Steven and Benge, 2007). A number of management practices differ between these orchards (Todd et al., 2016). For example, to prevent fruit damage from leafrollers, IPM growers usually apply sprays containing emamectin benzoate or methoxyfenozide, one spray immediately pre-blossom and one soon after fruit-set, whilst organic growers apply two or three Bt-based sprays immediately post-blossom, which is when the fruit are most susceptible to leafroller damage (McKenna et al., 1995; Stevens et al., 1995). After this, leafroller

* Corresponding author.
E-mail address: jacqui.todd@plantandfood.co.nz (J.H. Todd).

https://doi.org/10.1016/j.agee.2018.03.016
Received 20 November 2017; Received in revised form 16 March 2018; Accepted 26 March 2018
Available online 31 March 2018
0167-8809/

Table 1
Characteristics of the study site in each orchard. The orchards were managed using either a certified organic programme, or an integrated pest management (IPM) programme. The kiwifruit variety grown in the orchards was either *Actinidia chinensis* var. *deliciosa* 'Hayward' (Green) or *Actinidia chinensis* var. *chinensis* 'Zesy002' (Gold). Each study site focussed on a shelterbelt of trees between the kiwifruit orchard and a neighbouring land-use, with the study conducted on the side facing the kiwifruit vines. The shelterbelts were classified into five types for analysis, and there were six different neighbouring land-uses identified, including steep valleys covered densely in native plants ("native bush").

Orchard No. (management)	Kiwifruit variety	Length of study site (m)	Description of the shelterbelt (code for analysis)	Neighbouring land-use (code for analysis)
1 (IPM)	Green	63	*Pinus radiata* (Type 4)	Native bush (Type 6)
2 (organic)	Green	59	Mostly *Cryptomeria japonica*, some other trees (*Pinus radiata*, *Eucalyptus* spp.) (Type 3)	Scrub, mostly trees (Type 4)
3 (IPM)	Green	135	*Cryptomeria japonica* (Type 1)	Paddock (Type 2)
4 (organic)	Gold	68	Various plants mostly native species[b] (Type 5)	Native bush (Type 6)
5 (IPM)	Green	104	*Casuarina glauca* (Type 2)	Scrub, mostly low bushes (Type 3)
6 (organic)	Green	73	*Cryptomeria japonica* (Type 1)	Scrub, mostly low bushes (Type 3)
7 (IPM)	Green	69	Various plants mostly native species[b] (Type 5)	Native bush (Type 6)
8 (organic)	Green	60	*Cryptomeria japonica* and some *Casuarina glauca* (Type 3)	Native bush (Type 6)
9 (IPM)	Green	75	*Cryptomeria japonica* (Type 1)	Native bush (Type 6)
10 (organic)	Green	78	*Pinus radiata* trees (some native shrubs) (Type 4)	Native bush (Type 6)
11(IPM)	Green	47	Various plants mostly native species[b] (Type 5)	Exotic plantation (*Eucalyptus* spp.) (Type 5)
12 (organic)	Green	86	*Cryptomeria japonica* (Type 1)	Exotic plantation (*Cupressus lusitanica*) (Type 5)
[a]13 (organic)	Green	53	*Cryptomeria japonica* (Type 1)	Native bush (Type 6)
[a]14 (IPM)	Gold	50	Various plants mostly native species[b] (Type 5)	Native bush (Type 6)
[a]15 (organic)	Green	57	*Cryptomeria japonica* (Type 1)	Roadside (Type 1)
[a]16 (IPM)	Green	61	*Cryptomeria japonica* (Type 1)	Roadside (Type 1)

[a] Indicates orchards that were only used in the first year (2013/14).

[b] Species included: *Coprosma* spp. (e.g. karamu), *Pittosporum* spp. (e.g, karo), *Phormium* spp., *Podocarpus* spp. (e.g. totara), *Macropiper excelsum*, *Kunzea* spp., *Leptospermum scoparium*, *Melictyus ramiflorus*, *Myrsine australis*.

populations are monitored on both the organic and IPM orchards, and further sprays are applied only if the crop is shown to be at risk (McKenna, 1998). Consequently, natural enemies may be able to provide a valuable ecosystem service if they are able to suppress the leafroller populations during the growing season, reducing the need for later sprays. The orchard shelterbelts may contribute to this service if they contain natural enemies that suppress tortricid populations in the shelterbelt and disperse into the crop to attack pests there (Garratt et al., 2017).

A previous survey of New Zealand kiwifruit orchards showed that the invertebrate communities differed significantly under the organic and IPM management programmes (Todd et al., 2011). For instance, there were more invertebrate natural enemies (parasitoids, predators and omnivores) in the organic orchards. However, we do not know if the services provided by these functional groups, and the suppression of pest insect populations in particular, differed between the different communities in the organic and IPM orchards (Letourneau and Bothwell, 2008). Here, our aim was to determine the identity of parasitoids and compare the rate at which they were parasitizing *Ct. obliquana* and *Cn. jactatana* in organic and IPM kiwifruit orchards. By focussing our study on the shelterbelts grown between the kiwifruit vines and an alternative neighbouring land-use (e.g., dairy pasture, forest), we were also able to assess the effect of shelterbelt tree species and adjacent land-use on populations of Tortricidae and their parasitoids in this habitat.

2. Materials and methods

This study was conducted over two southern hemisphere kiwifruit production seasons: late spring to autumn in 2013/14 and 2014/15. The orchards used in this study were individually managed to produce fruit for export and were located in the Bay of Plenty region of New Zealand, near the town of Te Puke (37.78° S, 176.32° E). In the first year, we used 16 orchards, 14 of which were planted with *Actinidia chinensis* var. *deliciosa* 'Hayward' (green-fleshed kiwifruit), and the remaining two orchards were planted with *Actinidia chinensis* var. *chinensis* 'Zesy002' (gold-fleshed kiwifruit). Eight of the orchards (including one growing gold-fleshed fruit) were managed using the organic system certified by BioGro NZ Ltd (http://www.biogro.co.nz/) under which only organic agrichemicals may be used, and orchards must have been managed organically for at least three years before they can be certified for export. The remaining eight orchards were managed using the IPM programme (Steven and Benge, 2007) which has been in place on all conventional kiwifruit orchards growing fruit for export from New Zealand since 1997.

In the second year, we repeated the study in 12 of the orchards (six organic and six IPM) that had been used in the first year, with 11 growing 'Hayward' and one organic orchard growing 'Zesy002' kiwifruit. This reduction in orchard numbers occurred because the management of two of the organic orchards was changed to the IPM programme in 2014. Since previous research has shown that the invertebrate fauna in kiwifruit orchards is affected by the different management practices used in the two programmes (Todd et al., 2016), it is likely that this change in management would have had an impact on the results of our study. Consequently, these two previously organic orchards were not included in the 2014/15 season of the study, and two nearby IPM orchards were also removed from the second year of the study to maintain a balanced design.

At each orchard, we selected a single shelterbelt as our study site (Table 1). Ideally, we would have conducted our study both within the shelterbelt and within the kiwifruit vines on each orchard. However, in 2010 the kiwifruit vine disease *Pseudomonas syringae* pv. *actinidiae* (Psa) was detected in New Zealand (Vanneste et al., 2013), and conducting research within the kiwifruit vines on multiple orchards became impossible because of the phytosanitary measures and movement controls that were in place when this study began in 2013 (New Zealand Government, 2013). Consequently, we focussed on a shelterbelt at each orchard because these were not subject to the same Psa controls because they consisted of tree species that were not susceptible to the disease. We selected a shelterbelt that was growing between the kiwifruit vines and an alternative neighbouring land-use (e.g., dairy pasture or forest), taking note of the land-use and shelterbelt composition at each site (Table 1). Kiwifruit orchard shelterbelts are generally grown 2–5 m away from the edge of the vine canopy to facilitate tractor access.