THE EFFECT OF MULCHING ON ADULT EMERGENCE OF KELLY'S CITRUS THRIPS (*PEZOTHRIPS KELLYANUS*)

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ABSTRACT

Kelly's citrus thrips (*Pezothrips kellyanus*) (KCT) is a key pest of citrus in New Zealand. Many insecticides used to control KCT cause outbreaks of secondary pests or market restrictions due to chemical residues. Effective control of KCT is likely to consist of integrating a variety of approaches. Increasing mortality of the soil-dwelling pupal stages by using organic mulches to increase the biological activity in the soil is one approach. A field trial compared compost/woody mulch under lemon trees with normal weedy ground cover. Significantly fewer ($P<0.001$) adult KCT emerged under trees with mulch (3.5 thrips in February) compared to trees that had not received mulch (22.7 thrips in February). The organic mulch beneath citrus trees increased the number predatory mites in the soil. There were 5-8 different species of soil mites that could potentially feed on KCT pupae. The physical environment of the mulch may also contribute to reduced emergence of adult thrips.

Keywords: Kelly's citrus thrips, *Pezothrips kellyanus*, mulching, soil predators.

INTRODUCTION

Kelly's citrus thrips (*Pezothrips kellyanus*) (KCT) is a key pest of citrus in New Zealand (Pyle & Stevens 2004), Australia (Baker et al. 2001) and Sicily (Conti et al. 2002). Adults are found within citrus flowers where they feed on pollen and lay eggs. Both the adults and larvae feed on the surface of citrus fruit causing scarring, which can render fruit unacceptable for export or even local markets. Pupation occurs in the soil or litter beneath trees. KCT has proven to be very difficult to control and is the key driver of insecticide use in citrus. Many of the potential insecticides for control of KCT have significant drawbacks, including a risk of causing outbreaks of secondary pests (e.g. citrus red mite and scale insects) or market restrictions as a result of persistent chemical residues (Stevens et al. 2004). Effective control of KCT is likely to consist of integrating a variety of approaches including biological control. No specific parasitoids are known for KCT in New Zealand (Gibb et al. 2003) and none are known from Australia (Baker et al. 2001), but it may be possible to enhance natural enemies of soil-dwelling pupae by using organic mulches under trees. Compost/woody mulches may increase the activity of predators or entomopathogenic fungi in the soil and increase the mortality of the soil-dwelling pupal stage of KCT.

The aim of this trial was to determine the effect of an organic mulch on KCT adult emergence from the soil beneath citrus trees and to identify soil-dwelling mites that might contribute to the biological control of KCT.

METHODS

The trial was established as a randomised complete block design in a Meyer lemon orchard at Mercer, Auckland. Each treatment plot consisted of four trees in a row (10 years old). Treatments applied to each plot were either mulch or no mulch (control). Each treatment was replicated five times.

Mulch

Mulch was sourced from Living Earth, Pikes Point, Onehunga, Auckland. It contained 20-25% compost and 75-80% woody plant material. A 10 cm layer of mulch was placed under the canopy up to ca 1 m from the trunk of each tree within each mulch plot. Placing the 15 m^3 of mulch required for the trial took 2 days and was carried out on 13 and 17 December 2004. The ground beneath trees had been treated with herbicide prior to the trial, therefore plots with no mulch were soil with dead weedy material. No herbicides were applied during the trial and the control plots were weedy by the end of the trial.

Falling emergence traps

Falling/emergence traps designed to trap thrips larvae falling from the canopy and adults emerging from the soil on a sticky surface were made from 10 litre black plastic buckets. A hole (14 cm diameter) was made in the base of each bucket and two sheets of transparent acetate coated with Tanglefoot™ were pinned over the hole. One acetate was placed sticky side down to trap the adults emerging from the soil and the other transparency was sticky side up to trap the larvae dropping from the tree to pupate. Each acetate was marked with a 3 × 3 cm grid enabling easier counting of thrips at assessment time. The traps were set up on 13 January 2005, one month after the mulch was laid. Acetates were changed monthly on 13 February, 16 March and 13 April 2005. Acetates were stored at 8°C in Zip® Lock plastic bags until assessment when each was examined under a microscope and the number of KCT larvae, adults and predators were recorded. Three traps were placed within each four-tree plot. Each time the acetates were changed, the traps were moved to a new site.

Soil samples

Soil samples were collected on four occasions between December 2004 and April 2005. Approximately 500 g soil or a soil-mulch mix was removed from an area of 20 × 20 cm to a depth of 20 cm beneath the canopy at ca 0.5 m from the trunk of three random trees within each treatment and collected into a plastic sealable Minigrip™ bag on each occasion. Soil samples were placed at 8°C until 'Berlese' extraction was made.

For the 'Berlese' extraction each 500 g soil sample was placed in a 1.5 litre (23 cm diameter) plastic funnel supported by cotton mesh material with 3 x 3 mm holes and a lamp placed over the funnel for 72 h. The mobile organisms in the soil moved away from the light/heat source down the neck of the funnel and into a 60 ml specimen jar with 30 ml of 75% ethanol where they were preserved for identification. All arthropods were sorted and counted and a subsample of each 'type' of mite was sent to Landcare Research to be identified.

Fruit damage

On 13 April, 20 lemons on each tree (four trees per plot) were examined and the percentage of rind with KCT damage was assessed (percentages ranged from 0-80%, where 5% was damage part way around stem, 10% was damage all the way around stem and >10% damage around stem and side of fruit).

Statistical analysis

Generalized Linear Models (GLMs) (Chambers & Hastie 1992) were fitted in R (R Development Core Team 2005) to data representing the numbers of larvae or adults captured. The quasipoisson family was used to ameliorate the effect of overdispersion of the data. Analysis of the deviances associated with the models determined the significance of mulch and dates of samples. The mean percentage of rind with KCT damage for each tree was calculated and angular transformed. Angular transformed KCT damage data and numbers of predatory mites were compared amongst treatments using a randomised block design analysis of variance (ANOVA). Least significant differences (LSDs) were calculated to separate treatments if the ANOVA was significant ($P<0.05$). The analysis was performed using the statistics programme Genstat (Release 7.2). Original untransformed percentages are presented in figures.

RESULTS

Falling/emergence trapping

There was no significant effect associated with the treatment (P=0.076) on the number of larvae dropping on to the trap (Table 1). Even though the difference in February appeared more marked, analysing that month alone showed no treatment effect (P=0.10). Thus it was assumed that the numbers of larvae dropping from the trees were the same in both the control and the mulched plots and that the difference between the numbers of emerging adults from the soil could be attributed to treatment effects.

The difference between the numbers of adults emerging from the soil in the two treatments was significant (P<0.001) (Table 1). The average number of adults trapped under the trees with mulch in February and March was 3.5 and 2.8, respectively, compared with 22.7 and 16.0 adults trapped in the control plots, respectively (Table 1).

Predators trapped on both top and bottom acetates were mites (mainly whirlygig mite, *Anystis* sp.), spiders, predatory thrips and earwigs. The abundance of these predators did not differ between treatments at any time (Table 1, P>0.05).

TABLE 1: The average number of KCT larvae and adults, and predators, caught on traps each month from 13 January 2005 until 13 April 2005.

Sample (trapping period)	Treatment	No. larvae dropping (mean ± SEM)	No. adults emerging (mean ± SEM)	No. predators emerging (mean ± SEM)
February	Mulch	14.5 ± 3.0	3.5 ± 0.8	1.5 ± 0.4
(13.1.05 - 13.2.05)	Control	23.7 ± 3.1	22.7 ± 3.1	2.7 ± 0.8
P-value		ns	<0.001	ns
March	Mulch	18.8 ± 3.8	2.8 ± 0.8	1.0 ± 0.7
(13.2.05 – 16.3.05)	Control	22.3 ± 3.0	16.0 ± 2.6	0.9 ± 0.5
P-value		ns	<0.001	ns
April	Mulch	0.1 ± 0.1	0.6 ± 0.2	1.9 ± 0.6
(16.3.05 – 13.4.05)	Control	0.6 ± 0.2	1.9 ± 0.7	0.3 ± 0.2
P-value		ns	ns	ns

Fruit damage

There was no significant difference between treatments in the incidence or severity of KCT damage in April (P>0.05) (Table 2). The extremely high level of damage indicates that the trial was carried out in a block with extremely high thrips populations.

TABLE 2: Proportion of lemons with KCT damage (incidence) and proportion of rind on each lemon (severity) with KCT damage from trees with and without (control) mulch.

Treatment	Mean % of lemons with KCT damage	Mean % of lemons with severe[1] KCT damage	Mean % of rind with KCT damage
Mulch	92.3 ± 3.4	53.3 ± 6.4	16.2 ± 1.6
Control	97.3 ± 1.0	61.0 ± 4.7	19.9 ± 1.7
P-value	ns	ns	ns

[1]Severe damage is defined as >10% of rind damaged (usually all the way around stem and extending down the side of the fruit).

Soil samples

There were significantly more predatory mites in soil samples collected from mulched plots than from the unmulched plots (90 and 44 respectively, P<0.05).

Five different species of predatory mites were found from soil samples and three species of mites whose feeding habits are largely unknown. Details of these mites are shown in Table 3. Other potential predators of KCT found in the soil samples from both treatments included unidentified beetle larvae and adults, millipedes and earwigs.

TABLE 3: Species of mites found in soil samples that may be predators of thrips pupae.

Species (Family)	Comments	Treatments where found
Predators		
Blattisocius dentriticus (Ascidae)	Predator. Smaller than Parasitidae and bigger than Phytoseiid.	Mulch
Neocunaxoides sp. (Cunaxidae)	Predator. Large orange.	Mulch
Macrocheles scutatus (Macrochelidae)	Predator. Large brown – similar to Parasitidae. Feeds on eggs, small insects/mites.	No mulch & Mulch
Undescribed species (Mesostigmata)	Predator. Usually brownish colour.	No mulch & Mulch
Undescribed species (Parasitidae)	Predator. Feeds on insects and mites, including their eggs, and on nematodes. Brown.	No mulch & Mulch
Unknown Feeding Habits		
Eupodes sp. (Eupodidae)	Possibly predatory – spider mite size.	No mulch
Linopodus sp. (Eupodidae)	Possibly predatory – spider mite size.	Mulch
Undescribed species (Penthalodidae)	Feeding behaviour unknown. Looks like Eupodidae except bigger and may have some colour. Similar to earth mites.	No mulch

DISCUSSION

Applying mulch (10 cm deep, 25% compost and 75% woody tree parts) beneath lemon trees encouraged more predatory mites and reduced the survival of KCT pupae in the soil compared with unmulched trees. A range of potential predators of KCT pupae was also present but the feeding preferences of these arthropods for KCT pupae in the soil are unknown. The incidence of fungal pathogens was not specifically measured in this study.

Mulches have been used as an aid to pest control in several situations. Coarse composted mulch and straw mulch were investigated for their ability to increase the effectiveness of natural enemies of pupating thrips in avocado and onion cropping systems (Hoddle et al. 2002; Jensen et al. 2003). Coarse composted mulch beneath avocado trees in California reduced peak emergence rates of adult avocado thrips (*Scirtothrips perseae*) by approximately 50% compared with normal leaf duff (Hoddle et al. 2002). Thrips survival in sterilised mulch did not differ significantly from thrips survival in sterilised mulch with natural enemies (predatory mite, entomopathogen, nematode alone and combined), although survival of thrips was far greater in avocado leaf controls

(M. Hoddle, pers. comm.). This suggests that natural enemies may not be the key agents in suppressing thrips survival in the soil, but rather some physical or chemical property of the mulch also contributes to thrips mortality. Regardless of its mode of action, mulching coupled with the development of "soft" insecticides leads to improved thrips control, higher yields and greater gross return in onions (Jensen et al. 2003).

The use of organic mulches has been adopted as a practical management tool in some horticultural sectors. For example, in many New Zealand vineyards mulch made up of grape prunings, grape marc, greenwaste and bark is used to suppress weeds, increase nutrients, increase soil moisture retention and increase beneficial organisms in the soil (Agnew et al. 2002). However, the economic viability of using organic mulch within the citrus management system has not been evaluated in detail.

In this trial using mulch did not reduce the amount of KCT damage to lemons over a five-month period. Mulching for longer may reduce thrips populations and give a significant reduction in KCT damage on lemons. Californian research suggests that mulch should be applied initially twice at a 6- month interval and then annually after that, and a reduction in fruit damage may not be seen for at least one year after initial application (Hoddle et al. 2002). The plot size used in the present work may have been too small because adult KCTs are very mobile and most likely moved between the mulch and control trees to feed. Trials using larger plots are needed to demonstrate a reduction of fruit damage associated with the reduction of adult emergence shown in this study.

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