Evaluation of lambdacyhalothrin and deltamethrin trunk treatments for control of Fuller's rose weevil, *Asynonychus cervinus* (Boheman) (Coleoptera: Curculionidae), on Citrus

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Summary
Lambdacyhalothrin, sticky polybutenes and deltamethrin applied as trunk treatments controlled Fuller's rose weevil (FRW), *Asynonychus cervinus* populations in citrus tree canopies. Lambdacyhalothrin (0.075% a.i.) suppressed FRW over a period of three months with a single application. Trunk sprays of lambdacyhalothrin and deltamethrin at various concentrations did not result in detectable residues in fruit two days after application. Foliar sprays of both compounds resulted in detectable residues in fruit which did not decline significantly over a 56 day period. Lambdacyhalothrin is a suitable candidate for registration as a trunk treatment for control of FRW in export citrus groves, as it is effective and persistent without causing fruit residues. In comparison, polybutene bands are also effective for FRW control, however they are expensive to apply, both in terms of labour and material costs.

Introduction
Fullers' rose weevil (FRW) (also known as Fuller rose beetle, *Asynonychus godami* (Crotch), in the United States) is a major quarantine pest of export citrus to Japan. FRW lays its eggs in crevices such as underneath the calyx of fruit (Morse *et al.* 1987). Japan has a nil tolerance for FRW and detection of viable egg masses in fruit by quarantine authorities results in fumigation which is expensive and may result in quality loss (Anon 1988). In recent years, various trunk treatments have proved to be successful in excluding weevils from trees and reducing FRW egg masses in fruit. The effectiveness of sticky polybutene bands in excluding FRW from citrus canopies has been well documented (James 1991, Magarey *et al.* 1992). Polybutene bands, however, are susceptible to contamination by debris, are labour intensive to apply, and may also be phytotoxic (Haney and Morse 1988). As an alternative to sticky bands, insecticide trunk treatments whilst not excluding FRW from the canopy, can kill weevils that do access the tree. Two pyrethroid insecticides, lambdacyhalothrin and to a lesser extent deltamethrin, have performed consistently well in previous field trials in comparison with polybutene bands, however only multiple applications and high rates were applied (Magarey *et al.* 1992). This paper reports on a series of follow-up trials. The first investigated the efficacy of a range of treatments. For possible registration purposes, two additional trials were conducted to:

i. determine suitable minimum rates of lambdacyhalothrin and
ii. determine the residues of lambdacyhalothrin and deltamethrin in fruit when used as trunk and foliar sprays.

Materials and methods

Efficacy trial
A grove of Navel oranges (cv Lane's Late) located at Colignan, Victoria and heavily infested with FRW was chosen for the trial. This grove was planted as a double hedgerow (rows 1.3 m apart and double rows 5.4 m apart) and watered by drip irrigation. To prevent foliage from coming into contact with the ground, trees were skirted and weeds touching the canopies were removed. The trial tested the efficacy of three pyrethroid insecticides; lamb-dacyhalothrin[A], deltamethrin[B] and bio-resmethrin[C] each applied at two rates and a sticky polybutene[D] trunk band. The experimental design contained eight replicates of eight treatments (Table 1) arranged in an 8 × 8 Latin square design with plots of nine trees. Since canopies in the hedgerow touched, weevils could crawl from one tree to another. To allow for this, the four end trees in the plot were used as buffers. Each tree trunk was sprayed with 250 mL of insecticide (approximately 300 mm above the ground) using a handline sprayer with four nozzles on a U-shaped wand designed to encircle the trunk. In the first year of the trial, because of the unknown efficacy of the chemicals, three applications of insecticides were made; on 27 March, 8 May and 19 June 1990. The polybutene material was applied with a trowel on 27 March to a width of approximately 10 cm.

Table 1. Effect of seven insecticidal trunk treatments on the number of FRW adults in citrus canopies. Treatments were applied in March, May and June 1990 and in February 1991. Mean number of weevils collected in a 0.28 m^2 tray at four sampling dates. Transformed data $\log_e (x+1)$. Retransformed means are presented in parenthesis.

Treatment	rate (% a.i.)	2/3/90[A,B]	1/5/90[B]	11/2/91[C]	9/4/91
lambdacyhalothrin	0.3	3.36 (28.8)	0.48 (0.62)	1.05 (1.86)	0.09 (0.09)
lambdacyhalothrin	0.6	2.92 (18.5)	0.48 (0.62)	0.35 (0.42)	0.00 *
deltamethrin	0.06	2.87 (17.6)	1.34 (2.82)	1.68 (4.37)	0.00 *
deltamethrin	0.12	2.97 (19.5)	1.56 (3.76)	0.90 (1.46)	0.00 *
bioresmethrin	0.06	3.10 (22.4)	2.66 (13.3)	1.85 (5.36)	1.12 (2.06)
bioresmethrin	0.12	2.69 (14.7)	1.55 (3.71)	1.74 (4.70)	0.87 (1.39)
polybutene		3.22 (25.0)	1.24 (2.46)	0.49 (0.63)	0.00 *
untreated		3.00 (20.0)	2.12 (7.30)	1.94 (5.96)	1.44 (3.22)
LSD (P = 0.05)		0.57	0.79	0.27	0.20

[A] Pre-treatment assessment 1990
[B] Full results for weevil counts in 1990 have been previously published (Magarey *et al.* 1992)
[C] Pre-treatment assessment 1991
* Treatment was omitted from the analysis as all replicates had zero counts.

Footnote:
[A] Karate® EC insecticide. 50 g L^{-1} lambdacyhalothrin. ICI Australia, P.O. Box 4311, Melbourne, Victoria 3001, Australia.
[B] Cislin® SC insecticide 10 g L^{-1} deltamethrin. Wellcome Australia, P.O. Box 12, Concord, NSW 2137, Australia.
[C] BRM® SC insecticide 50 g L^{-1} bioresmethrin. Wellcome Australia, P.O. Box 12, Concord, NSW 2137, Australia.
[D] Tac-gel® Formula 3 polybutene. Rentokil Pty Ltd, 554 Pacific Highway, Chatswood, NSW 2067, Australia.

Table 2. Effect of four different rates and two application programs of lambdacyhalothrin on the mean number of FRW adults in citrus canopies. Treatments were applied on 20 February and 10 April 1991. Mean number of weevils collected in a 0.28 m² tray.

Rate of lambdacyhalothrin (% a.i.)	Application dates	Mean weevil counts		
		19/2/91[A]	9/4/91[B]	21/5/91
0.60	Feb	7.4	0.0*	0.0*
0.60	Feb and Apr	8.2	0.2	0.0*
0.30	Feb	8.3	1.0	0.5
0.30	Feb and Apr	13.3	0.0*	0.0*
0.15	Feb	7.8	0.0*	0.0*
0.15	Feb and Apr	12.7	0.0*	+
0.075	Feb	12.5	0.0*	0.3
0.075	Feb and Apr	7.7	0.0*	+
0.0	–	14.8	5.0	9.8

[A] Pre-treatment assessment
[B] Assessment prior to second treatment
* Treatment was omitted from the analysis as all replicates had zero counts.
\+ Missing data. Due to equipment malfunction lambdacyhalothrin 0.075 and 0.15 % a.i. were sprayed with incorrect rate in the second application.

In 1991, the polybutene band was scraped to remove debris and the insecticide treatments were re-applied on 13 February.

The population density of adult weevils in the citrus canopies was assessed by jarring 10 limbs per plot (two limbs on each of five trees) five times with a rubber mallet and counting the number of weevils collected in a 0.28 m^2 tray. Numbers of adults were assessed on the following dates: 2 March and 1 May 1990. In 1991, FRW numbers were assessed on 2 February and 9 April. Data were analysed by ANOVA with a $\log_e$ transformation ($\ln(x+1)$) to stabilize the residual variance.

Lambdacyhalothrin efficacy trial

Four rates of lambdacyhalothrin (0.6%, 0.3%, 0.15% and 0.075% a.i.) were applied as trunk treatments to trees in rows adjacent to the efficacy trial in a single and double application program. The plots used were identical in design to the efficacy trial. The first spray was applied on 20 February and the second on 10 April 1991. All treatments had six replicates and the untreated control had four replicates. These were allocated to a row column design with the rows corresponding to four hedgerows and the 13 columns corresponding to plots across the hedgerows.

Weevil numbers were assessed in the same way as in the initial efficacy trial on the following dates: 19 February (as a pre-treatment covariate), 9 April (just prior to the second treatment) and on 21 May 1991. Due to the low numbers of FRW, the data were analysed using a generalized linear model with a Poisson distribution and a log link function (Payne *et al.* 1987). Treatments with all replicates having zero weevils were excluded from the analysis.

Residue trial

Insecticides were applied as trunk and foliar sprays to single citrus trees (cv Lane's Late) grown at the Sunraysia Horticultural Centre, Irymple. Samples of the insecticide formulations and tank mixes were diluted with acetone/hexane (60/40 v/v) and analysed by gas-liquid chromatography (GLC). Four trunk treatments with concentrations as determined by GLC, lambdacyhalothrin (0.15% a.i., 0.39% a.i.) and deltamethrin (0.07% a.i., 0.15% a.i.) and two foliar treatments lambdacyhalothrin (0.15% a.i.) and deltamethrin (0.07% a.i.) were applied on 17 April 1991. Trunk treatments were applied as described previously, whilst the foliar sprays were applied to run off with a handline sprayer. The trial was a randomized complete block design of seven treatments (including an untreated control), each replicated four times.

Five fruit samples were taken from each plot by removing at least one fruit from each of four aspects. Samples were taken as soon as the sprays had dried and at 2, 7, 14, 28 and 56 days after treatment. Fruit was kept at -10°C prior to analysis by GLC. The five fruits comprising each sample were chopped and homogenized in a food processor. A representative sample (50 g) was extracted with acetone (150 mL) in a blender for three minutes. The mixture was filtered through a glass fibre filter paper under vacuum. The blender and filter cake were washed with acetone and the washings added to the sample extract in a 1 L separating funnel. Water (600 mL) was added to the separating funnel and the mixture twice extracted with dichloromethane (75 mL, 50 mL). The combined dichloromethane extracts were dried by passing through a column of anhydrous sodium sulphate (10 g). The dried extract was concentrated in a Kuderna-Danish evaporator, with inversion into hexane, to a final volume of approximately 2 mL. The extract was added to a column containing activated florisil (5 g) which had been prewashed with hexane (15 mL). The column was eluted with 25 mL dichloromethane/hexane/acetonitrile (50/49.25/0.75, v/v/v). The eluate was concentrated in a Kuderna-Danish evaporator, with inversion into hexane, to a final volume of 5.0 mL, in readiness for analysis by GLC with electron capture detection. The GLC column was packed OV210/OV101 for analysis and OV225 for confirmation. GLC temperatures were column 240°C, detector 350°C and injector 250°C. Nitrogen was used as the carrier gas at 30 mL min^{-1}. For both insecticides, the limit of detection was 0.01 mg kg^{-1} on a whole fruit basis. Analysis commenced on 20

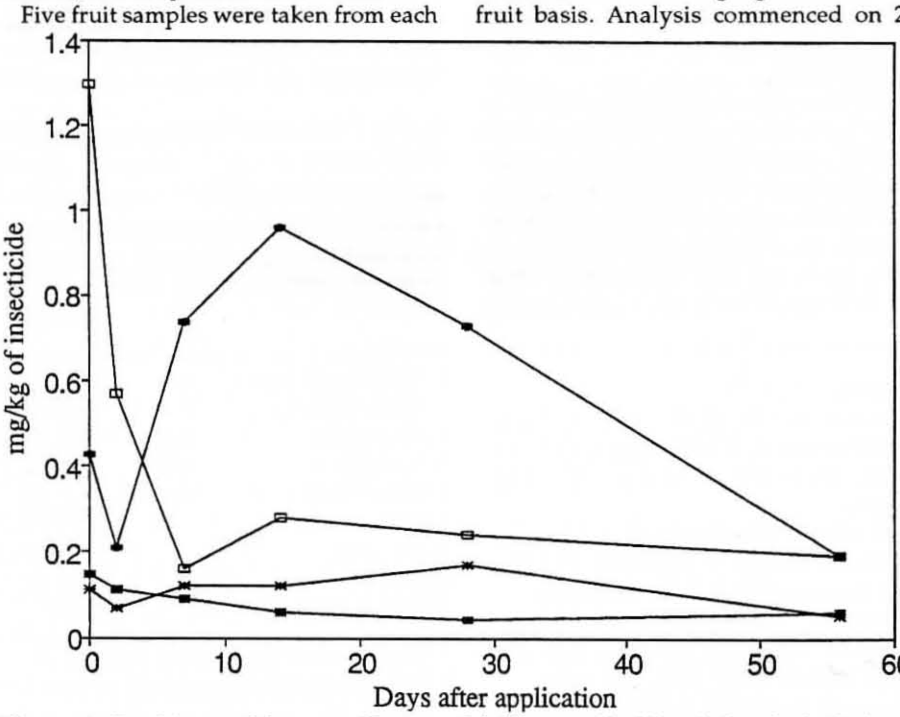

Figure 1. Residues of four replicates of foliar applied lambdacyhalothrin (0.15% a.i.) in citrus fruits 0, 7, 14, 28 and 56 days after treatment.

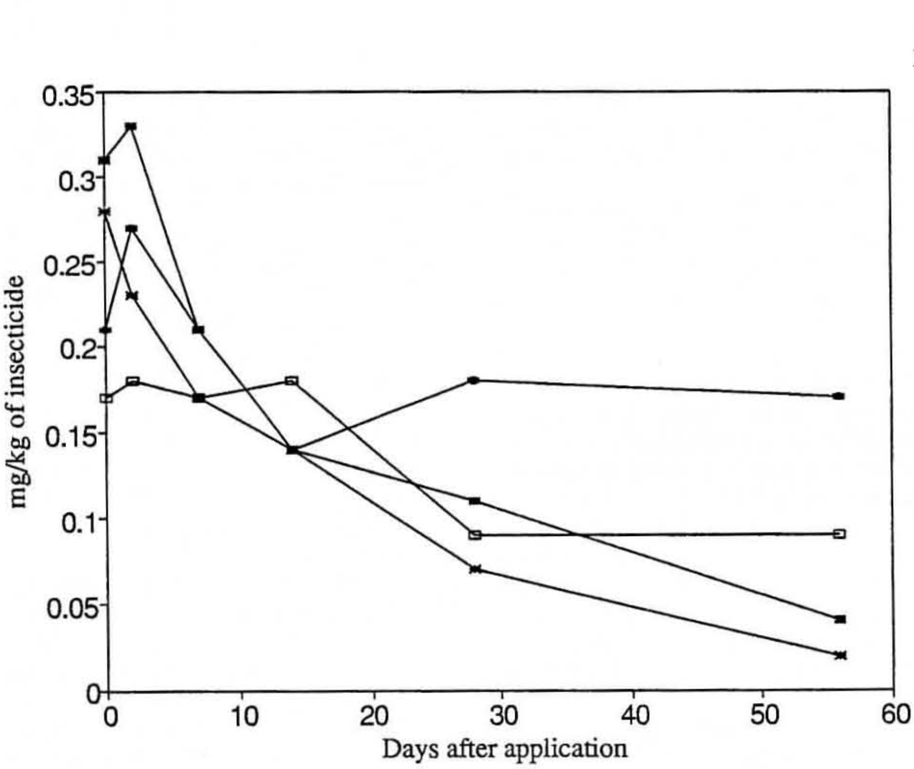

Figure 2. Residues of four replicates of foliar applied deltamethrin (0.07% a.i.) in citrus fruits 0, 7, 14, 28 and 56 days after treatment.

May 1991 and was completed on 31 July 1991. Data were analysed statistically by ANOVA.

Results

Efficacy trial

Results of counts of FRW adults and egg masses in 1990 for this trial have been previously published (Magarey *et al.* 1992). Trunk treatments of lambdacyhalothrin and polybutene gave consistent suppression of FRW in both years (Table 1). Deltamethrin was less effective whilst bioresmethrin was not significantly different ($P > 0.05$) from the control. Deltamethrin at 0.12% a.i. was as effective as lambdacyhalothrin (0.6% a.i.) in 1991, but not in 1990. Lambdacyhalothrin at both rates, deltamethrin 0.12% a.i. and polybutene all gave at least six months suppression of adult numbers in the canopy, being significantly different ($P < 0.05$) from the control on 11 February 1991 prior to treatment that year.

Lambdacyhalothrin efficacy trial

All lambdacyhalothrin treatments resulted in mean weevil counts of one or fewer adults per plot (Table 2). The untreated control had significantly more weevils ($P < 0.05$) than all other treatments.

Residue trial

Both formulations were found to contain the active ingredient in the concentration as stated on the pesticide label and both tank mixes of deltamethrin were found to contain lambdacyhalothrin in concentrations approaching that of deltamethrin. No deltamethrin was detected in the lambdacyhalothrin tank mix, but all samples from foliar treatments contained residues of both analytes (insecticides). The tank mix was sampled early in the spraying operation and it is likely that cross contamination occurred later. The presence of two insecticides in some samples did not affect the accuracy of the analysis. Cross contamination probably occurred during the spraying operation, when tank valves are opened or closed. Smaller volumes of insecticide were used in the residue trial than in the efficacy trial, making serious cross contamination more likely.

All trunk sprays produced no detectable residues in fruit samples two days after treatment. However, two samples from the deltamethrin 0.06% a.i. trunk treatment contained 0.01 and 0.02 mg kg^{-1}. No other samples from trunk treatments produced detectable residues. Both foliar sprays produced detectable residues in every sample. Residues from foliar applied lambdacyhalothrin (0.15% a.i.) in fruit declined from a mean of 0.5 mg kg^{-1} on day zero to 0.13 mg kg^{-1} by day 56 (Figure 1). Residues of foliar applied deltamethrin (0.07% a.i.) declined from a mean of 0.25 mg kg^{-1} on day zero to 0.08 mg kg^{-1} by day 56 (Figure 2). For both treatments a linear decline in the level of residues was not statistically significant at $P > 0.05$.

Discussion

FRW populations in citrus canopies peak each year in March/May and decline to low levels by November/December (Madge *et al.* 1992). Single applications of lambdacyhalothrin (0.15–0.6% a.i.) controlled populations of FRW in canopies for up to three months. In the efficacy trial lambdacyhalothrin (0.6% a.i.) performed as effectively as the polybutene band. Lambdacyhalothrin (0.3% a.i.) was as effective as the polybutene band in controlling FRW over a two to three, but not a six month interval between treatment. Due to the seasonal decline in weevil numbers it is difficult to determine the duration of effective control. Suppression lasts at least six months since on 11 February 1991 the population was suppressed in both the lambdacyhalothrin and one of the deltamethrin treatments that had not been sprayed since June 1990. FRW populations declined in all treatments, including the control over the 13 months of the efficacy trial. However, in plots of the lambdacyhalothrin trial in rows adjacent to the efficacy trial, initial 1991 populations were high with 7–14 weevils per plot. A fortnightly sample of weevil populations in an untreated section of the grove over a three year period revealed that populations in February 1991 were comparable to those of March in the previous year (Magarey unpublished). Therefore it is likely the low 1991 counts recorded in the efficacy trial were due to a reduction caused by the combined treatment effects rather due to a natural population decline.

One management option for FRW is to apply treatments over several seasons during or just prior to the period of peak weevil activity in order to reduce the grove population. Since Japan has a nil tolerance for FRW, suppression is inadequate and FRW must be prevented from surviving in the canopy. In some instances, insecticide application every three months may be necessary. A second management option is to withhold treatment, thus allowing some weevils to enter the canopy, but only whilst their eggs will hatch well before harvest. A day degree model for egg hatch could be used to time insecticide treatment based on an anticipated harvest date (Morse and Laking 1987). Under California conditions, this period may vary from three weeks in summer to three and a half months in winter.

Trunk sprays do not result in significant crop residues if a withholding period of two days is observed. Both compounds are highly stable on fruit as can be seen from the results of the foliar sprays. The fact that there is no significant decline in residues of either compound after 56 days is a good indication of their persistence. Decay of lambdacyhalothrin appears to be slower in oranges than other crops. Residues of lambdacyhalothrin declined from day zero to day 21 by 46% (Figure 1) compared to a fall of 79% in soy beans, 55% in lupins and 86% in canola over the same period (J. Lydiate, ICI Australia, personal communication). The slow rate of decay means that caution should be observed in application of trunk treatments to minimize spray drift onto fruit.

Trunk treatment with lambdacyhalothrin can provide effective control of FRW provided it is timed effectively. At a rate of 0.15% a.i. and the spray volumes used in this trial and based on a cost of \$80 per litre of Karate® (50 g L^{-1} lambdacyhalothrin), the estimated material cost is 48 cents per tree. Trunk application of lambdacyhalothrin is therefore a cheap, effective and low residue method for control of FRW in export citrus groves. An effective alternative to insecticide trunk treatment is the use of polybutene bands. To apply a 10 cm polybutene band approximately 200–250 g of polybutene is required per tree. Based on a cost of \$14 kg^{-1} for Tac-gel® Formula 3 polybutene, the material cost is approximately \$1.50 per tree. Polybutene bands have the additional disadvantage in being labour intensive to apply.

Acknowledgments
Brian Wilkins is thanked for his expert technical assistance. The State Chemistry Laboratory performed all chemical residue analyses. The Horticultural Research and Development Corporation is gratefully acknowledged for financial support. Mark Welsh assisted with treatment application and Megan Edwards is thanked for reviewing the manuscript.

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