Australian Government

Rural Industries Research and Development Corporation

Development of a Range of Pesticides for use in Coffee

Generating insecticide efficacy and residue data to support registration of selected pesticides in coffee

A report for the Rural Industries Research and Development Corporation

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April 2007

RIRDC Publication No 07/061
RIRDC Project No SAG 5A

ISBN 1 74151 458 4
ISSN 1440-6845

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Published in April 2007
Printed on environmentally friendly paper by Canprint

Foreword

Coffee growing is a small but viable industry in Australia. Approximately 30 growers in Queensland and 170 growers in NSW produce some 1220 ha of crop, and this is projected to grow substantially.

To date the industry has relied on obtaining APVMA (Australian Pesticides and Veterinary Medicines Authority) permits for the use of various pesticides to control insects, weeds and fungal diseases in coffee. Such permits remain valid for a limited period, and must be renewed from time to time to enable the continued legal use of these pesticides. During any permitted use period, the APVMA may specify that certain data relating to the efficacy, crop safety and residue profiles of particular pesticides should be collected and documented before renewal of permits can be approved.

On commencing this project, all permits for pesticide use in coffee had expired, and there were no pesticides fully registered for use in this crop. Furthermore, data requested by the APVMA had not been provided, and there was thus some reluctance on the part of the authority to renew permits in the absence of supporting data. It thus became necessary to address the need to develop and standardise a range of pesticides for use in Australian grown coffee, and to provide the necessary supporting data enabling registration or ongoing permit use of these.

As a result of work conducted under this project, coffee growers now have access to a range of registered or permitted pesticides for use in this crop. Growers are now able to better manage coffee crops using selected pesticides (including insecticides, herbicides and fungicides) chosen for their suitability for use within integrated pest management systems.

This project was funded from RIRDC Core Funds which are provided by the Australian Government. This was part of the RIRDC New Plant Products program.

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Peter O'Brien
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Acknowledgments

The authors would like to acknowledge the valuable assistance and advice provided by Alan Norden of the Australian Pesticides and Veterinary Medicines Authority (APVMA).

Contents

Executive Summary

What the report is about

This report describes the methodology used, results obtained and outcomes achieved in providing a complete data package to the relevant parties to enable Australian coffee growers' access to the legal use of a range of pesticides in this crop.

Who the report targeted at

The report is targeted at growers, regulators and any other parties interested in the production of coffee in Australia.

Background

Coffee growing is a small but viable industry in Australia comprising 30 growers in Queensland (700 ha), and 170 growers in NSW producing 500 ha of crop. The current crop is thus 1220 ha and is projected to grow substantially. Approximately 50% of total production is exported, and growers actively promote their product overseas. Australian coffee enjoys a reputation for being "clean and green" and for being of very high quality.

To date, the industry has relied on obtaining APVMA (Australian Pesticides and Veterinary Medicines Authority) permits for the use of various pesticides to control insects, weeds and fungal diseases. On commencing this project, all permits for pesticide use in coffee had expired, and there were no pesticides fully registered or permitted for use in this crop. Furthermore, many of the previously permitted insecticides were of the broad spectrum organophosphate type, and were not suited for use in modern integrated pest management systems.

There was thus a need to urgently pursue pesticide registration for key insecticides, herbicides and fungicides to enable coffee growers to manage pest situations in a legal and environmentally responsible manner.

Aims and objectives

The objectives of this research was to generate data to support the registration and/or ongoing permit use for a range of pesticides for use by coffee growers with an emphasis on the development of modern products suitable for inclusion in integrated pest management systems.

Methods used

The methodology adopted to achieve the aims of this project was to firstly identify those pesticides that were suitable for use in coffee, and to obtain advice from the APVMA regarding the precise data requirements necessary to support registration and/or ongoing permit use for each of these. Where pesticides were currently registered for use on other crops, and whose properties were well known, limited data was required. Usually, scientific argument for efficacy and crop safety, together with grower testimonials of safe and successful use under permit over two seasons or more, was sufficient to enable future renewal of such permits. This information was gathered and provided to the APVMA.

For newer chemistry pesticides, replicated trial work was necessary to prove efficacy and crop safety and these trials were conducted during the course of the project. In addition, detailed residue trials were conducted under GLP (good laboratory practice) protocols to determine maximum residue limits

(MRLs) in consumable produce. This data was provided to the relevant chemical companies for inclusion in their registration submissions to the APVMA.

The Australian Coffee Growers Association was informed regarding the outcomes of this project.

Results

As a result of this work, a number of permits allowing the use of various pesticides in coffee were reissued, and data to support the registration and/or further renewal of permits were submitted to the APVMA and to chemical companies.

At the conclusion of the project, and as a result of the work conducted, most of the pesticides for which use in coffee was sought were either currently permitted for use in the crop or were under consideration for inclusion as registered pesticides on labels to be finalised in 2007. The current status for each of the pesticides considered in the project is summarised below:

1. <u>Insecticides</u>

a) Success 120 SC (120 g/L spinosad) - Now fully registered for the control of avocado leaf roller in coffee.

b) Admiral 100 EC (100 g/L pyriproxyfen) - Efficacy and residue data to support the use of this product to control scale insects in coffee was provided to Sumitomo Chemical Australia Pty Ltd. That organisation has subsequently included the data in a submission to the APVMA with the view to gaining full registration of this product for use in coffee in 2007.

c) Prodigy 240 SC (240 g/L methoxyfenozide) - Efficacy and residue data to support the use of this product to control avocado leaf roller in coffee was provided to Dow AgroSciences. That organisation has included this data in a submission to the APVMA with the view to gaining full registration of this product for the use in coffee in 2007.

d) Applaud 440 SC (440 g/L buprofezin) - Efficacy and residue data to support the use of this product to control mealy bug in coffee was provided to Dow AgroSciences. At this stage Dow AgroSciences do not intend to apply for registration of this product to be included on their label for use in coffee. This is because they only recently updated the Applaud label, and the data provided was too late for inclusion in the previous submission. Despite this, they have indicated that it will be included when they next update their label. In the interim period we have submitted a permit application for Applaud in coffee and this is under consideration by the APVMA.

e) Lorsban 500 EC (500 g/L Chlorpyrifos) - Permit No 8387 allowing the use of Chlorpyrifos for the control of green coffee scale at a rate of 100 mL/100L was obtained during the course of this project, and is valid until 30/9/2009. Efficacy, crop safety data, grower testimonials and scientific argument have been submitted to APVMA to support continued permit use for the control of scale insects and mealy bug with this product in coffee.

f) D-C-Tron Plus petroleum oil - Permit No 7314 allowing the use of Ampol D-C-Tron Plus for the control of green coffee scale at a rate of 1.25 L/100L was obtained during the course of this project and is valid until 31/12/2010. Efficacy, crop safety data, grower testimonials and scientific argument has been submitted to APVMA to support continued permit use for the control of scale insects and mealy bug with this product in coffee

g) Mimic 700 WP (700 g/kg tebufenozide) - Permit No 7313 allowing the use of Mimic for the control of avocado leaf roller at a rate of 86 g/1000L was obtained during the course of this project, and is valid until 31/12/2007. As this product will be replaced by Prodigy, no further permit renewal will be required.

h) Supracide 400 EC (400 g/L methidathion) - Permit No 7312 allowing the use of Supracide for the control of green coffee scale and mealy bug at a rate of 125 mL/100L was obtained during the course of this project, and is valid until 31/12/2007. As this product is under review by the APVMA and may be deregistered for use in any crop at a later date, no further permit renewal will be required.

2. Herbicides

a) Glyphosate - Permit No 7315 allowing the use of Glyphosate 360 for the control of annual and perennial weeds at a rate of 1.0 - 1.5 L/ha was obtained during the course of this project and is valid until 6/12/2007. Grower testimonials and scientific argument have been submitted to APVMA to support continued permit use of glyphosate in coffee.

b) Basta - Permit No 7316 allowing the use of Basta for the control of broadleaf and grass weeds at a rate of 2.0 - 4.0 L/ha was obtained during the course of this project and is valid until 6/12/2007. Grower testimonials and scientific argument has been submitted to APVMA to support continued permit use of Basta in coffee.

c) Stomp (pendimethalin) - Permit No 8388 allowing the use of pendimethalin as a pre emergent herbicide in seedling coffee at a rate of 2.0 - 3.0 L/ha was obtained during the course of this project and is valid until 28/11/2010. Grower testimonials and scientific argument has been submitted to APVMA to support continued permit use of pendimethalin in coffee.

3. Fungicides

Copper - Permit No 7322 allowing the use of copper containing fungicides was obtained during the course of this project and is valid until 16/12/2010. Grower testimonials and scientific argument have been submitted to APVMA to support continued permit use of copper fungicides in coffee.

As a result of work conducted under this project, coffee growers now have access to a range of registered or permitted pesticides for use in this crop. Growers are now able to better manage coffee crops using selected pesticides (including insecticides, herbicides and fungicides) chosen for their suitability for use within integrated pest management systems. This should encourage the trend toward integrated pest management and enhance the industries sustainability and environmentally responsible image.

Implications

For growers this project will be of great benefit in removing the confusion about which pesticides may or may not be used in their production systems. In addition, the products selected will enable growers to use modern pesticides more suited to integrated pest management systems and which are less hazardous to both users and the environment.

The use of safer pesticides will benefit the community in general and will enhance the image of the coffee growing industry.

Introduction

In comparison with coffee growing areas overseas, there are relatively few serious insect pests of coffee in Australia. This reduces the industry's reliance on chemical control, which helps sustain its environmentally responsible image, and contributes to its economic competitiveness. However, outbreaks of certain pests do occur with some frequency. Of particular importance are avocado leaf rollers (*Homona spargotis*), scale insects, principally green coffee scale (*Coccus viridus*), hemispherical scale (*Saissetia coffeae*), and mealy bugs (HEMI:Pseudococcidae). Leaf rollers most commonly cause damage to young leaves in periods of leaf flush but may also cause reduced fruit set through their feeding activity on flowers and pin head fruits. Scale insects rapidly build up in coffee foliage and stems, while mealy bugs most frequently inhabit the base of fruit clusters and can be found infesting young leaves and shoots. Heavy infestations of these pests can significantly reduce the vigour of plants through directly drawing on the plants resources and through interference of photosynthesis by facilitating the development of sooty mould. The feeding activity of mealy bugs may also reduce the quality of the coffee bean.

These pests lend themselves comparatively well to successful control with selective insecticides and biological control agents within an integrated pest management (IPM) system. However, to date, the industry has relied on obtaining permits for control of insect pests. Many of these permits have expired and, in any case, some of the chemicals previously permitted have not been suitable for use in IPM systems. It therefore became necessary to seriously address the need to develop and standardise a range of pesticides for use in coffee that would provide growers with the means to control key pests in a way that would not detract from the environmentally responsible image of the industry. Development of these products helps ensure that Australian coffee continues to be regarded as a superior product sought after by international buyers. This enhances the economic value of the crop and contributes to the attractiveness of the industry to prospective new growers. The use of "soft" products for insect control promotes the environmental sustainability of the coffee industry as a whole, and encourages an integrated pest management approach in dealing with coffee pests.

The purpose of this research was to conduct replicated small plot trials and to generate residue and efficacy data to enable the registration or permit use of selected pesticides in coffee.

Objectives

- To generate data to support the registration and/or permit use of insecticides for the control of avocado leaf roller caterpillar in coffee.

- To generate data to support the registration and/or permit use of insecticides for the control of scale insects in coffee.

- To generate data to support the registration and/or permit use of insecticides for control of mealy bug in coffee.

- To generate residue data under GLP protocols to support the registration and/or permit use of insecticides in coffee.

- To obtain permits for the use of various herbicides, insecticides and copper containing fungicides for use in coffee, and to collect anecdotal and scientific evidence to support renewal of these, upon expiry of currently valid permits.

Chapter 1: Avocado leaf roller

Introduction

Avocado leaf roller (*Homona spargotis*) and related species (LEPI:tortricidae) are significant pests in many crops grown in North Queensland. In coffee, the pest is most common in periods of leaf flush and flowering, but infestations can occur at any time. Larvae construct protective retreats by webbing together leaves, flowers and fruit in which to feed and pupate. Feeding activity results in reduced tree vigour through the loss of leaves, and may result in direct crop loss by damaging fruit and reducing fruit set on infested trees. Although broad spectrum organophosphate insecticides have been regularly used to control leaf roller, successful control of this pest by certain 'soft' chemicals, such as Success (spinosad) and Mimic (tebufenozide), has been demonstrated in other crops. Success has shown highly specific action towards thrips and larval lepidoptera, with a low toxicity to beneficial insect species. Mimic is an insect growth regulator that is highly selective for larval lepidoptera and safe for a range of beneficial insects.

Prodigy (methoxyfenozide) is a later generation insect growth regulator recently being explored for use against lepidopteran larvae, and similarly exhibits a low toxicity on non-target organisms. Insecticides capable of effectively controlling leaf roller larvae, with minimal detrimental effects on naturally occurring beneficial insect species, is a desirable option in integrated pest management systems.

The aim of a series of trials conducted in the 2004 and 2005 seasons was to demonstrate the efficacy of the above mentioned insecticides for the control of avocado leaf roller in coffee so as to provide growers with more environmentally safe options for controlling this pest in integrated pest management systems.

Avocado leaf roller larva infesting coffee

Healthy coffee terminal

Coffee terminals infested with avocado leaf roller

Typical avocado leaf roller retreat in coffee

Avocado leaf roller trial 2004 season: Mimic and Success

Methodology

The trial was located at an established coffee plantation at Mareeba, North Queensland, during the 2004 season. The crop was approximately eight years old with a crop spacing of 1.5 metres between plants and 3.5 metres between adjacent rows. The trial was a randomised complete block design with four replicates. Each plot was comprised of six plants with additional plants at either end of each plot to reduce spray drift between plots. Treatments were Success 120 SC at 2.4, 4.8 and 9.6 g ai/100L and Mimic 700 WP at 3.0, 6.0 and 9.0 g ai/100L. These were compared to Lorsban 500 EC at 50.0 g ai/100L, Supracide 400 EC at 50.0 g ai/100L and to an untreated control. Treatments were applied using a motorised backpack sprayer and lance fitted with two Spraying Systems TX 6 hollow cone nozzles. Trees were sprayed to point of run off. A preliminary assessment of the pest population was conducted immediately prior to insecticide application by counting the number of larvae in each size class on one side of one tree at 11 randomly selected locations within the trial area. Larvae were categorised into three size classes, small (1^{st} and 2^{nd} instar larvae), medium (3^{rd} and 4^{th} instar larvae) and large (5^{th} and 6^{th} instar larvae). Efficacy assessments were conducted at one, three and seven days after application, and were comprised of counts of the number of larvae in each size class on one side of one plant per plot.

Data from all assessments were analysed for equality of variance and normal distribution. After appropriate transformation (if required), a general linear model analysis of variance was used to determine significance at the $P = 0.05$ level. Treatment means were separated using the protected LSD technique at 95% confidence limits. Results are presented as the untransformed equivalents.

Results

Table 1 – Preliminary assessment of pest population at trial site

Location	Mean number of leaf roller on one tree			
	Small	Medium	Large	Total
1	1	2	3	6
2	3	6	3	12
3	3	3	2	8
4	2	7	1	10
5	2	1	2	5
6	1	4	0	5
7	5	5	2	12
8	6	1	2	9
9	5	7	1	13
10	4	8	4	16
11	6	5	1	12
Mean	**3.5**	**4.5**	**1.9**	**9.8**
Std. Dev.	1.9	2.5	1.1	3.6

At the preliminary assessment, there was an average of 10 live larvae found on one side of each tree sampled. There was some natural variation between samples, but the population of larvae appeared to be evenly distributed throughout the trial site. The majority of the leaf roller larvae found at the site were of the small or medium sized category although there were moderate numbers of large larvae present.

Table 2 – Mean number of leaf roller larvae on one side of one tree - 1 DAA

Treatment		Rate (g ai/100L)	Mean number of leaf roller on one side of one tree			
			Small	Medium	Large	Total
1	Untreated control	Nil	4.0 bcd	4.3 c	1.8 c	10.0 b
2	Success 120 SC	2.4	1.8 ab	2.5 abc	2.0 c	6.3 ab
3	Success 120 SC	4.8	1.0 a	1.3 ab	0.3 ab	2.5 a
4	Success 120 SC	9.6	1.8 ab	0.8 a	0.0 a	2.5 a
5	Mimic 700 WP	3.0	4.8 cd	3.8 c	1.3 bc	9.8 b
6	Mimic 700 WP	6.0	6.0 d	3.5 bc	0.3 ab	9.8 b
7	Mimic 700 WP	9.0	4.3 cd	3.3 bc	1.0 abc	8.5 b
8	Lorsban 500 EC	50.0	1.3 a	0.8 a	0.3 ab	2.3 a
9	Supracide 400 EC	50.0	2.5 abc	3.8 bc	1.0 bc	7.3 b
P Value			0.0023	0.0173	0.0042	0.0007
LSD			2.5	n/a*	n/a*	4.2

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
* n/a = Log transformation used.

At 1 DAA, there were significantly fewer small larvae in Success at 4.8 g ai/100L and in Lorsban compared with the untreated control. No other insecticide treatment significantly reduced the number of small larvae compared with the untreated control at 1 DAA. All the Success treatments, and Lorsban, had significantly fewer small larvae compared with Mimic treatments.

Success at 4.8 and 9.6 g ai/100L had significantly fewer medium and large larvae compared with the untreated control, while Mimic at 6.0 g ai/100L had significantly fewer large larvae compared with the untreated control at 1 DAA. Success at 9.6 g ai/100L, and Lorsban, had significantly fewer medium larvae compared with all Mimic treatments and Supracide. Success at 4.8 g ai/100L also had significantly fewer medium larvae compared with Mimic at 3.0 g ai/100L but did not differ in comparison with other insecticide treatments. With the exception of Success at 9.6 g ai/100L having fewer large larvae than Mimic at 3.0 g ai/100L and Supracide, there were no significant differences between insecticide treatments for large larvae.

There were significantly fewer total larvae in Success at 4.8 and 9.6 g ai/100L and in Lorsban compared with the untreated control, Mimic treatments and Supracide at 1 DAA. There were no other differences between insecticide treatments at this time.

Table 3 – Mean number of leaf roller larvae on one side of one tree - 3 DAA

Treatment		Rate (g ai/100L)	Mean number of leaf roller on one side of one tree			
			Small	Medium	Large	Total
1	Untreated control	Nil	4.8 c	5.3 c	2.5 b	12.5 e
2	Success 120 SC	2.4	1.5 ab	3.0 bc	0.3 a	4.8 bcd
3	Success 120 SC	4.8	0.5 a	0.8 ab	0.0 a	1.3 ab
4	Success 120 SC	9.6	0.3 a	0.3 a	0.0 a	0.5 a
5	Mimic 700 WP	3.0	2.5 bc	1.3 ab	0.5 a	4.3 cd
6	Mimic 700 WP	6.0	3.3 c	1.0 ab	0.3 a	4.5 cd
7	Mimic 700 WP	9.0	0.5 a	1.3 ab	0.0 a	1.8 abc
8	Lorsban 500 EC	50.0	0.0 a	1.0 ab	0.0 a	1.0 a
9	Supracide 400 EC	50.0	3.8 bc	2.8 b	2.3 b	8.8 de
P Value			0.0002	0.0067	0.0000	0.0007
LSD			n/a*	2.4	n/a*	n/a*

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
* n/a = Log transformation used.

At 3 DAA, all insecticide treatments except Mimic at 3.0 and 6.0 g ai/100L, and Supracide, had significantly fewer small larvae compared with the untreated control. Success at 4.8 and 9.6 g ai/100L, Mimic at 9.0 g ai/100L and Lorsban also had fewer small larvae compared with Supracide and Mimic at 3.0 and 6.0 g ai/100L.

All insecticide treatments except Success at 2.4 g ai/100L had significantly fewer medium larvae compared with the untreated control at 3 DAA. Success at 9.6 g ai/100L also had fewer medium larvae compared with Success at 2.4 g ai/100L and Supracide at this time. All Success and Mimic treatments, and Lorsban, had significantly fewer large larvae compared with both Supracide and the untreated control.

There was no difference for the total number of larvae between Supracide and the untreated control at 3 DAA. All other insecticide treatments had a significantly lower mean number of total larvae compared with the untreated control but only Success at 4.8 and 9.6 g ai/100L, Mimic at 9.0 g ai/100L and Lorsban had significantly fewer total larvae compared with Supracide. Lorsban and Success at 4.8 and 9.6 g ai/100L also had a significantly lower mean number of total larvae compared with Mimic at 3.0 and 6.0 g ai/100L.

Table 4 – Mean number of leaf roller larvae on one side of one tree - 7 DAA

Treatment		Rate (g ai/100L)	Mean number of leaf roller on one side of one tree			
			Small	Medium	Large	Total
1	Untreated control	Nil	5.0 c	4.0 b	1.3	10.3 c
2	Success 120 SC	2.4	0.5 a	0.8 a	0.5	1.8 b
3	Success 120 SC	4.8	0.0 a	0.3 a	0.0	0.3 a
4	Success 120 SC	9.6	0.3 a	0.8 a	0.3	1.3 ab
5	Mimic 700 WP	3.0	0.8 ab	0.0 a	0.3	1.0 ab
6	Mimic 700 WP	6.0	0.3 a	0.3 a	0.0	0.5 ab
7	Mimic 700 WP	9.0	0.3 a	0.0 a	0.0	0.3 a
8	Lorsban 500 EC	50.0	0.8 a	0.8 a	0.8	2.3 b
9	Supracide 400 EC	50.0	2.5 b	2.8 b	1.0	6.3 c
P Value			0.0001	0.0000	0.0771	0.0001
LSD			n/a*	n/a*	n/a*	n/a

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
*n/a = Log transformation used.

All insecticide treatments had a significantly lower mean number of small larvae compared with the untreated control at 7 DAA. Lorsban, all Success treatments and Mimic at 6.0 and 9.0 g ai/100L had significantly fewer small larvae compared with Supracide.

With the exception of Supracide, all insecticide treatments were comparable and had significantly fewer medium larvae compared with the untreated control. There was no significant difference for the number of medium larvae between Supracide and the untreated control at 7 DAA.

There was no significant difference for the mean number of large larvae between treatments at 7 DAA. However, there was a tendency towards greater numbers of larvae in the untreated control and Supracide and lower numbers of large larvae in other insecticide treatments.

Success, Mimic and Lorsban treatments all had significantly fewer total larvae compared with the untreated control and Supracide at 7 DAA. Mimic and Success at 9.0 g ai/100L had significantly lower number of total larvae compared with Lorsban and Success at 2.4 g ai/100L.

Discussion

All insecticide treatments except Supracide achieved effective control of leaf rollers in coffee. Supracide variously reduced the number of small and medium larvae to a modest degree but this treatment was largely ineffective against this pest. Lorsban was highly effective for control of leaf roller in coffee but, as it is a broad spectrum insecticide, its use may be disruptive to predators and parasites of leaf roller and other coffee pests. For this reason, its use should be limited in IPM systems.

All Success and Mimic treatments achieved comparable results to Lorsban by 7 DAA but there were differences in the rate of knockdown between these and between rates of Success and Mimic. In this regard, Mimic was notably slower acting compared with Success. This was not unexpected due to the growth regulant mode of action of the former resulting in a lower acute toxicity to the target species in comparison to the latter product. Mimic did not appear to be effective until 3 DAA but feeding by larvae may have ceased prior to this.

Success at 4.8 and 9.6 g ai/100L were highly effective of controlling leaf rollers of all size classes throughout the trial. However, the lowest rate of Success used was less effective than Lorsban at 1 and 3 DAA, especially for control of large larvae. Therefore, Success applied at 4.8 and particularly 9.6 g ai/100L may be preferable under conditions of high pest pressure or where more rapid control is required. The recommended rate of Success for control of leaf roller in other crops is 4.8 g ai/100L and these results suggest a comparable rate should be used in coffee.

Avocado leaf roller trial 2005 season: Prodigy, Mimic and Success

Methodology

The trial was located at an established coffee plantation at Mareeba, North Queensland, during the 2005 season. The crop used in the trial was approximately 2.5 metres tall, five years old and had not been ratooned. The planting distance was 0.75 metres between plants and three metres between adjacent rows. The crop had just begun to set fruit and a new leaf flush had recently occurred. The trial was a randomised complete block design with four replications. Plot size was ten metres of row comprising approximately 12 trees. A space of two to three plants at either end of each plot was used to reduce spray drift between plots and replicates were separated by at least one row of untreated coffee. Treatments were Prodigy (methoxyfenozide) 240 SC at 30.0, 40.8 and 60.0 g ai/100L, Mimic (tebufenozide) 700 WP at 6.0 g ai/100L and Success (spinosad) at 4.8 g ai/100L. All insecticide treatments were applied with Agral® non ionic wetter at 10 mL/100L. Insecticide treatments were compared to an untreated control. Treatments were applied using a motorised backpack sprayer and high volume spray gun through a single D2 full cone nozzle with trees sprayed to run off. Prior to insecticide application, a preliminary assessment was conducted using eight non-treatment trees randomly selected from within the trial area. Efficacy assessments were conducted at one, three, eight and fifteen days after application (DAA). At each assessment, the number of larvae in ten randomly selected retreats were counted. Retreats were selected on the basis of being 'apparently infested'. As larvae die or vacate retreats they may quickly fall into disrepair, especially if formed from young leaves that have not yet fully expanded. Thus retreats were only selected if they appeared to be in relatively good condition with a strong likelihood of harbouring an active larva. Larvae were categorised as small (1^{st} and 2^{nd} instar larvae), medium (3^{rd} and 4^{th} instar larvae) and large (5^{th} and 6^{th} instar larvae). At the preliminary assessment, and at fifteen DAA, counts of the number of apparently infested retreats were conducted on five plants per plot to obtain an indication of the level of pest pressure in the crop before and after treatment.

Data from all assessments were analysed for equality of variance and a normal distribution. After appropriate transformation (if required), a general linear model analysis of variance was used to determine significance at the P = 0.05 level. Treatment means were separated using the protected LSD technique at 95% confidence limits. Results are presented as the untransformed equivalents.

Results

Table 1 – Preliminary assessment of percentage of retreats occupied by live leaf roller larvae at the trial site (n=10)

Location	Percentage of retreats occupied by larvae			
	Small	Medium	Large	Total
1	20	50	30	100
2	30	30	20	80
3	10	30	40	80
4	20	40	20	80
5	40	20	20	80
6	40	20	40	100
7	20	50	10	80
8	10	30	50	90
Mean	23.8	33.8	28.8	86.3
Std.Dev.	11.9	11.9	13.6	9.2

A significant infestation of leaf roller larvae was observed at the site at the preliminary assessment. The distribution of larval size classes indicated that the population was well established. There were subtle variations in the distribution of size classes across the site but these appeared to be random and did not occur in any recognizable gradients. An average of 86.3 % of suspected inhabited retreats were infested by live larvae. Retreats that were empty had either been vacated or contained larvae killed by naturally occurring predators or parasites.

Table 2 – Mean percentage of apparently infested retreats occupied by small larvae (n=10)

Treatment		Rate (g ai/100L)	1 DAA	3 DAA	8 DAA	15 DAA
1	Untreated control	Nil	22.5 abc	27.5 b	7.5 b	15.0 b
2	Prodigy 240 SC	30.0	25.0 bc	0.0 a	0.0 a	0.0 a
3	Prodigy 240 SC	40.8	20.0 ab	2.5 a	0.0 a	0.0 a
4	Prodigy 240 SC	60.0	40.0 c	2.5 a	0.0 a	0.0 a
5	Mimic 700 WP	6.0	27.5 bc	5.0 a	0.0 a	5.0 ab
6	Success 120 SC	4.8	5.0 a	2.5 a	0.0 a	5.0 ab
P Value			0.0230	0.0004	0.0004	0.0167
LSD			17.2	10.3	n/a*	n/a*

Means within columns followed by a common letter are not significantly different ($P \geq 0.05$).
DAA = days after application
n/a* = Log transformation used.

At 1 DAA, there were significantly fewer retreats infested by small larvae in Success compared with Mimic and Prodigy at 30 and 60 g ai/100L. No insecticide treatments had significantly fewer small larvae compared with the untreated control.

All insecticide treatments had significantly fewer retreats occupied by small larvae compared with the untreated control at 3 and 8 DAA and there were no significant differences between insecticide treatments.

By 15 DAA, the percentage of retreats occupied by small larvae was significantly lower in all Prodigy treatments compared with the untreated control, but there were no significant differences between Success or Mimic and the untreated control. Despite this, both Success and Mimic did show a noticeable tendency towards reduced numbers of small larvae compared to the untreated control.

Table 3 – Mean percentage of apparently infested retreats occupied by medium larvae (n=10)

Treatment		Rate (g ai/100L)	1 DAA	3 DAA	8 DAA	15 DAA
1	Untreated control	Nil	25.0 b	35.0 c	30.0 b	22.5 b
2	Prodigy 240 SC	30.0	40.0 b	12.5 ab	0.0 a	0.0 a
3	Prodigy 240 SC	40.8	37.5 b	2.5 a	0.0 a	0.0 a
4	Prodigy 240 SC	60.0	27.5 b	2.5 a	0.0 a	0.0 a
5	Mimic 700 WP	6.0	37.5 b	17.5 b	2.5 a	2.5 ab
6	Success 120 SC	4.8	2.5 a	2.5 a	0.0 a	2.5 ab
P Value			0.0000	0.0002	0.0000	0.0000
LSD			n/a*	12.1	n/a*	n/a*

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
*n/a = Log transformation used.

At 1 DAA, Success exhibited a significantly lower percentage of retreats occupied by medium sized larvae compared with all other treatments. There were no significant differences between the other insecticide treatments and the untreated control.

By 3 DAA, all insecticide treatments had significantly fewer retreats infested by medium larvae compared with the untreated control. Prodigy at 40.8 and 60 g ai/100L and Success had significantly fewer infested retreats compared with Mimic.

There were a significantly greater percentage of retreats occupied by medium larvae in the untreated control compared with all insecticide treatments at 8 DAA.

By 15 DAA, the percentage of retreats occupied by medium larvae was significantly lower in all Prodigy treatments compared with the untreated control, but there were no significant differences between Success or Mimic and the untreated control at this time. However, both Success and Mimic did show a strong tendency towards reduced numbers of medium larvae compared to the untreated control.

Table 4 – Mean percentage of apparently infested retreats occupied by large larvae (n=10)

Treatment		Rate (g ai/100L)	1 DAA	3 DAA	8 DAA	15 DAA
1	Untreated control	Nil	30.0 c	27.5 c	25.0 b	17.5 b
2	Prodigy 240 SC	30.0	2.5 a	0.0 a	0.0 a	0.0 a
3	Prodigy 240 SC	40.8	12.5 ab	0.0 a	0.0 a	0.0 a
4	Prodigy 240 SC	60.0	5.0 ab	0.0 a	0.0 a	0.0 a
5	Mimic 700 WP	6.0	20.0 bc	5.0 b	0.0 a	2.5 a
6	Success 120 SC	4.8	10.0 ab	0.0 a	0.0 a	5.0 a
P Value			0.0286	0.0000	0.0006	0.0030
LSD			16.6	5.0	n/a*	8.4

Means within followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
n/a* = Log transformation used.

All insecticide treatments except Mimic recorded a significantly lower percentage of retreats occupied by large larvae compared with the untreated control at 1 DAA. Prodigy at 30 g ai/100L had significantly fewer large larvae compared with Mimic, but there were no other differences among insecticide treatments.

At 3 DAA all insecticide treatments had significantly fewer retreats infested by large larvae compared with the untreated control. Mimic recorded significantly higher numbers of large larvae compared with Success and all Prodigy treatments.

At 8 DAA the percentage of retreats occupied y large larvae was significantly greater in the untreated control compared with all insecticide treatments.

There were significantly fewer retreats infested by large larvae in all insecticide treatments compared with the untreated control at 15 DAA. There were no significant differences among insecticide treatments at this time.

Table 5 – Mean percentage of apparently infested retreats occupied by live larvae of all size categories (n=10)

	Treatment	Rate (g ai/100L)	1 DAA	3 DAA	8 DAA *	15 DAA
1	Untreated control	Nil	77.5 b	90.0 c	62.5 b	55.0 c
2	Prodigy 240 SC	30.0	67.5 b	12.5 a	0.0 a	0.0 a
3	Prodigy 240 SC	40.8	70.0 b	5.0 a	0.0 a	0.0 a
4	Prodigy 240 SC	60.0	72.5 b	5.0 a	0.0 a	0.0 a
5	Mimic 700 WP	6.0	85.0 b	27.5 b	2.5 a	10.0 b
6	Success 120 SC	4.8	17.5 a	5.0 a	0.0 a	12.5 b
P Value			0.0001	0.0000	0.0000	0.0000
LSD			20.7	14.2	*n/a	7.1

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
n/a* = Log transformation used

There were a significantly lower percentage of retreats infested by leaf roller larvae in Success compared with all other treatments at 1 DAA. There were no other significant differences between treatments for the percentage of occupied retreats at 1 DAA.

The untreated control had significantly greater percentage of infested retreats compared with all insecticide treatments at 3 DAA. Success and Prodigy at 40.8 and 60 g ai/100L had a significantly lower number of infested retreats compared with Mimic.

At 8 DAA the percentage of retreats occupied by live larvae was significantly greater in the untreated control compared with all insecticide treatments.

At 15 DAA, all insecticide treatments had a significantly lower level of infestation compared with the untreated control, and all Prodigy treatments had fewer infested retreats compared with both Mimic and Success.

Table 6 – Mean number of apparently infested retreats per tree (n= 5 trees /plot)

Treatment		Rate (g ai/100L)	Mean number of apparently infested retreats per plant	
			Preliminary assessment	15 DAA
1	Untreated control	Nil	5.9	2.8 b
2	Prodigy 240 SC	30.0	6.7	1.0 a
3	Prodigy 240 SC	40.8	6.8	1.1 a
4	Prodigy 240 SC	60.0	4.7	0.4 a
5	Mimic 700 WP	6.0	9.6	1.0 a
6	Success 120 SC	4.8	4.1	0.6 a
P Value			0.0609	0.0192
LSD			n/a	n/a*

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
DAA = days after application
*n/a = Log transformation used.

The mean number of apparently infested retreats per tree was moderately high in all treatments prior to treatment application. By 15 DAA, the mean number of retreats per tree had declined in all plots but remained significantly higher in the untreated control compared with all insecticide treatments. There was no difference between insecticide treatments although there was a slight tendency towards lower numbers of retreats in Prodigy at 60 g ai/100L and Success compared with other treatments.

Discussion

There was a significant infestation of leaf roller larvae present at the site at the time of insecticide application. An average of 80% of apparently active retreats contained live larvae with approximately equal proportions of the three larvae size classes represented. This indicated that the population was maturing at the time of the preliminary assessment. A natural decline in the number of leaf roller retreats per plant, and a decline in the percentage of apparently active retreats containing live larvae occurred over the trial period, most likely due to the progression of larvae to adults in the absence of new recruitment of young larvae into the population. Despite this decline, clear treatment effects were observed.

All insecticide treatments except Mimic successfully reduced the percentage of large larvae in retreats at one day after application, but only Success significantly reduced medium and small larvae at this time. This result was expected as Success is a contact and stomach poison whereas Prodigy and Mimic are insect growth regulators requiring slightly longer periods to kill larvae. Prodigy at 40.8 and 60.0 g ai/100L appeared to act more rapidly than Mimic, significantly reducing the percentage of live medium, large and total larvae compared to Mimic at 3 DAA. Mimic interferes with the moulting process and, although insects may stop feeding shortly after application, larvae are known to survive for up to 7 days. This is consistent with results at 8 DAA, at which stage all insecticide treatments were equally effective and provided a high level of control of leaf roller larvae in all size classes. No larvae were observed in any Prodigy treatments at 15 DAA. There were a significantly higher percentage of live larvae in Success and Mimic compared with all Prodigy treatments at 15 DAA. This suggested a slightly greater period of residual activity for Prodigy at all rates applied. Despite this difference the level of control achieved for all insecticide treatments was very high.

Coffee leaf roller trials 2006 season: Prodigy, Mimic and Lorsban

Introduction

During the 2005 season, Prodigy 240 SC was assessed for the control of avocado leaf roller in coffee at rates of 30 - 60 g ai/100L. The rates used in these trials were subsequently found to be above those recommended by the manufacturer for the control of this pest in avocado. In avocado, the recommended rate of application for Prodigy is 6 gai/100L, and two further trials were thus conducted during the 2006 season to justify the use of this rate of application for the control of avocado leaf roller in coffee.

Methodology

The trials were located at Walkamin, North Queensland, during the 2006 season. At commencement of the trials, the crop was bearing young "pinhead" fruit with some late flowers still present. Row spacing was 2.5 m with trees grown as a hedgerow 1.4 m high. There was abundant new vegetative growth flush and the crop was heavily infested with the target pest.

Trials were designed as randomised complete blocks with four replications. Plot size was ten metres of row comprising approximately 12 trees. A space of two to three plants at either end of each plot was used to reduce spray drift between plots and replicates were separated by two rows of untreated coffee.

Treatments applied were Prodigy 240 SC at 6 g ai/100L and Lorsban 500 EC at 50 g ai/100L in trial 1, and both Prodigy and Mimic 700 WP at 6 g ai/100L in trial 2. A single spray application was made for both trials using a Solo backpack mister with spray mix applied to run off. Prior to application, the pest infestation was assessed by opening ten leaf roller retreats in each plot and recording the number and size category of all larvae found. Larvae were categorised as small (1^{st} and 2^{nd} instar larvae), medium (3^{rd} and 4^{th} instar larvae) and large (5^{th} and 6^{th} instar larvae). Only retreats which appeared to be in good condition, with a strong likelihood of holding live larvae, were inspected. Efficacy assessments were similarly conducted at four, seven and 14 days after application (DAA).

Data from all assessments were analysed for equality of variance and a normal distribution. After appropriate transformation (if required), a general linear model analysis of variance was used to determine significance at the P = 0.05 level. Treatment means were separated using the protected LSD technique at 95% confidence limits. Results are presented as the untransformed equivalents.

Results – Trial 1 – Prodigy vs. Lorsban

Table 1 – Pre Spray assessment - 23/11/06 - Mean number of live leaf rollers occupying 10 retreats per plot

Treatment	Product Rate (mL/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	2.8	4.0	2.5	9.3
2. Prodigy	25	6	2.8	3.3	2.8	8.8
3. Lorsban	100	50	4.0	2.5	2.5	9.0
P Value			0.4383	0.3331	0.9434	0.8477
LSD (Pr=0.05)			N/A	N/A	N/A	N/A

N/A = Log transformation or Pr>0.05

Prior to insecticide application there were no significant differences for the mean number of live larvae in any size category occupying 10 retreats per plot. Similarly, there were no significant differences between treatments for the total number of larvae in 10 retreats.

Table 2 – Mean number of live leaf rollers occupying 10 retreats per plot - 4 DAA

Treatment	Product Rate (mL/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	3.8 b	2.3 b	2.0	8.0 b
2. Prodigy	25	6	0.0 a	0.8 ab	0.0	0.8 a
3. Lorsban	100	50	0.0 a	0.3 a	0.8	1.0 a
P Value			0.0024	0.0485	0.0730	0.0000
LSD (Pr=0.05)			1.7	N/A	N/A	1.4

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

At 4 DAA, The mean number of small larvae found in 10 retreats per plot was significantly lower in both insecticide treatments compared with untreated control. There were significantly lower mean numbers of medium larvae in Lorsban compared with the untreated control at 4 DAA. For Prodigy, the mean number of medium larvae was lower in comparison with untreated control, but was not significantly different at 95% confidence limits. There were no significant treatment effects for large larvae, although numbers were markedly lower in both insecticide treatments. For total larvae, the mean number found in 10 retreats per plot was significantly lower for both insecticide treatments in comparison with the untreated control. Both insecticides performed similarly at 4 DAA.

Table 3 – Mean number of live leaf rollers occupying 10 retreats per plot - 7 DAA

Treatment	Product Rate (mL/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	2.5 b	2.8 b	3.3 b	8.0 b
2. Prodigy	25	6	0.0 a	0.0 a	0.0 a	0.0 a
3. Lorsban	100	50	0.3 a	0.3 a	0.5 a	1.0 a
P Value			0.0066	0.0287	0.0218	0.0000
LSD (Pr=0.05)			1.3	2.0	2.2	1.3

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

At 7 DAA, the mean number of larvae in all size categories, and the total number of larvae occupying 10 retreats per plot, was significantly lower for both insecticide treatments in comparison to the untreated control.

Table 4 – Mean number of live leaf rollers occupying 10 retreats per plot - 14 DAA

Treatment	Product Rate (mL/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	2.5 b	3.3 b	3.0 b	9.3 c
2. Prodigy	25	6	0.0 a	0.0 a	0.0 a	0.0 a
3. Lorsban	100	50	0.3 a	1.3 a	0.8 a	2.5 b
P Value			0.0007	0.0190	0.0006	0.0000
LSD (Pr=0.05)			1.0	2.0	1.0	1.4

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

At 14 DAA, the mean numbers of larvae in small, medium and large categories were significantly lower in both insecticide treatments compared with the untreated control. Prodigy exhibited complete control of the pest at this time, whilst low numbers of larvae in all size categories were found in Lorsban. As a result, the total number of larvae in Lorsban was significantly greater in comparison with Prodigy at this time, but numbers remained significantly lower in this treatment in comparison with the untreated control.

Table 5 – Mean percentage of retreats occupied by live larvae

Treatment	Product Rate (mL/100L)	Active Rate (g ai/100L)	0 DAA	4 DAA	7 DAA	14 DAA
1. Untreated	Nil	Nil	92.5	80.0 b	85.0 b	92.5 c
2. Prodigy	25	6	87.5	7.5 a	0.0 a	0.0 a
3. Lorsban	100	50	90.0	10.0 a	10.0 a	25.0 b
P Value			0.8477	0.0000	0.0000	0.000
LSD (Pr=0.05)			N/A	13.8	12.9	14.4

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

There were no significant differences for the mean percentage of retreats occupied by live larvae for any treatment prior to insecticide application.

At 4 and 7 DAA, the mean percentage of retreats occupied by live larvae was significantly lower in both insecticide treatments compared with the untreated control. At 14 DAA, Lorsban recorded a significantly higher mean number of retreats with live larvae compared with Prodigy, but a significantly lower percentage in comparison with the untreated control.

Results – Trial 2 – Prodigy vs. Mimic

Table 1 – Pre Spray assessment - 27/11/06 - Mean number of live leaf rollers occupying 10 retreats per plot

Treatment	Product Rate (mL or g/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	2.5	3.8	2.3	8.5
2. Prodigy	25 mL	6	1.8	3.8	2.5	8.0
3. Mimic	8.6 g	6	3.8	2.5	1.8	8.0
P Value			0.1021	0.1985	0.7484	0.5120
LSD (Pr=0.05)			N/A	N/A	N/A	N/A

N/A = Log transformation or Pr>0.05

There were no significant differences for the mean number of larvae in any size category or for the total number of larvae occupying 10 retreats per plot for any treatment prior to insecticide application.

Table 2 – Mean number of live leaf rollers occupying 10 retreats per plot - 4 DAA

Treatment	Product Rate (mL or g/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	3.5 b	3.3 b	2.0 b	8.8 b
2. Prodigy	25 mL	6	0.0 a	0.3 a	0.3 a	0.5 a
3. Mimic	8.6 g	6	1.0 a	0.0 a	0.3 a	1.3 a
P Value			0.0106	0.0001	0.0062	0.0001
LSD (Pr=0.05)			1.9	0.8	1.0	2.0

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

At 4 DAA, the mean numbers of larvae in all size categories, and total larvae were significantly lower in both insecticide treatments compared with the untreated control. Differences for Prodigy and Mimic were not significant.

Table 3 – Mean number of live leaf rollers occupying 10 retreats per plot - 7 DAA

Treatment	Product Rate (mL or g/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	2.0	5.0 b	2.3 b	9.3 b
2. Prodigy	25 mL	6	0.3	0.0 a	0.0 a	0.3 a
3. Mimic	8.6 g	6	0.8	0.0 a	0.0 a	0.8 a
P Value			0.0776	0.0002	0.0017	0.0000
LSD (Pr=0.05)			N/A	1.4	1.0	1.4

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

At 7 DAA, both Prodigy and Mimic significantly controlled leaf roller and only very few live larvae were found in these. In contrast there were significantly higher numbers of medium, large and total larvae in the untreated control with markedly higher numbers noted for small larvae in comparison with insecticide treatments.

Table 4 – Mean number of live leaf rollers occupying 10 retreats per plot - 14 DAA

Treatment	Product Rate (mL or g/100L)	Active Rate (g ai/100L)	Small	Medium	Large	Total
1. Untreated	Nil	Nil	2.8	4.0 b	2.5 b	9.3 c
2. Prodigy	25 mL	6	0.8	0.0 a	0.0 a	0.8 a
3. Mimic	8.6 g	6	2.8	0.5 a	0.0 a	3.3 b
P Value			0.2267	0.0025	0.0001	0.0002
LSD (Pr=0.05)			N/A	1.7	0.6	2.2

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

At 14 DAA, the mean numbers of medium and large larvae in both insecticide treatments were significantly lower compared with the untreated control. There were no significant treatment effects for small larvae, but numbers were noticeably lower in Prodigy compared with Mimic and the untreated control. For total larvae, both insecticide treatments recorded a significantly lower mean number in 10 retreats compared with the untreated control, but numbers were significantly lower with Prodigy compared with Mimic.

Table 5 – Mean percentage of retreats occupied by live larvae

Treatment	Product Rate (mL or g/100L)	Active Rate (g ai/100L)	0 DAA	4 DAA	7 DAA	14 DAA
1. Untreated	Nil	Nil	85.0	87.5 b	92.5 b	92.5 c
2. Prodigy	25 mL	6	80.0	5.0 a	2.5 a	7.5 a
3. Mimic	8.6 g	6	80.0	12.5 a	7.5 a	32.5 b
P Value			0.5120	0.0001	0.000	0.0002
LSD (Pr=0.05)			N/A	20.2	14.1	22.3

Means within columns followed by a common letter are not significantly different (Pr=0.05)
N/A = Log transformation or Pr>0.05

There were no significant differences for the mean percentage of retreats occupied by live larvae for any treatment prior to insecticide application,

The mean percentage of retreats occupied by live larvae was significantly lower for both insecticide treatments at all post application assessments, but Prodigy had a significantly lower mean number of retreats occupied compared with Mimic at 14 DAA.

Discussion

The crop was heavily infested with avocado leaf roller prior to insecticide application. All insecticides applied were very efficacious for controlling the pest, particularly Prodigy. In this respect, there were more larvae surviving in Lorsban at 7 and 14 DAA compared with Prodigy. Similarly there were higher numbers of small larvae found in Mimic compared with Prodigy at 14 DAA. In both Prodigy and Mimic treatments, at 4 DAA, a small number of large larvae appeared to have died very recently indicating that the full effect of these products probably occurred some days after application. Examples showing the appearance of these severely intoxicated larvae at 4 DAA are shown below.

From 4 DAA, it was clear that retreats in all insecticide treatments, in both trials, were not being maintained, and some had begun to come apart as leaves expanded. By 7 DAA retreats appearing to be in good condition were scarce in insecticide treatments, and there was little sign of re-infestation particularly with Prodigy and Mimic.

The site appeared to be under ongoing pressure from leaf roller as shown by the presence of relatively constant numbers of small larvae found in the untreated control at all assessments. There was some evidence that Prodigy may have a longer residual activity compared with both Lorsban and Mimic, as there were significantly higher numbers of total larvae at 14 DAA after application in these treatments, in comparison with Prodigy. This difference was mainly due to the presence of higher numbers of small larvae in Mimic compared with Prodigy at 14 DAA, perhaps indicating that the insecticide residue had depleted to a greater extent in the former compared with the latter.

There were no phytotoxic effects on the crop resulting from the application of the insecticides

Conclusions

1. A single application of Lorsban 500 EC at 50 g ai/100L, and both Mimic 700 WP and Prodigy 240 SC at 6 g ai/100L, significantly controlled a heavy infestation of avocado leaf roller in coffee.

2. Larvae in all size categories were controlled.

3. Under conditions of sustained pressure from avocado leaf roller, Prodigy appeared to possess a longer residual activity compared with Lorsban and Mimic.

Chapter 2: Hemispherical scale

Introduction

Scale insects (HEMI: coccidae) and mealy bugs (HEMI: pseudococcidae) are common pests in a wide range of fruit crops in North Queensland. In coffee, mealy bugs are found within clusters of developing and mature berries. Scale insects, in particular hemispherical scale, (*Saissetia coffeae*), are commonly found infesting fruit clusters, but also infest flowers, leaves and young stems. The feeding activity of these pests may reduce plant vigour and the production of copious amounts of honeydew provides a substrate for the development of sooty mould. The presence of honeydew attracts ants that attempt to protect the resource by defending scale insects and mealy bugs from predators and parasitoids that play an important role in the natural control of scale insects and mealy bugs in coffee crops.

Where dense populations of scale insects or mealy bugs have developed, the application of insecticides may be necessary. In order to preserve the population of beneficial insects selective insecticides that have minimal impact on these are preferred.

Buprofezin (Applaud®) and pyriproxyfen (Admiral®) are insect growth regulator insecticides with activity against scale insects. Applaud is also known to be effective for the control of mealy bug. The development of these products for use by coffee growers would fulfil the need for IPM compatible insecticides in this crop, and would provide a more environmentally safe alternative to the broad spectrum organo phosphate insecticides generally used for the control of these pests.

The aim of two trials conducted in North Queensland during the 2005 and 2006 seasons was to develop two insect growth regulator insecticides, buprofezin and pyriproxyfen, for use in integrated pest management systems in coffee.

Hemispherical scale insect trial 2005 season: Admiral and Applaud

Methodology

The trial was located at an established coffee (cv. Catuai) plantation at Mareeba, North Queensland, during the 2005 season. The crop was eight years old with tree height ranging from 2 to 2.5 metres. Crop spacing was one metre between plants at a row spacing of four metres. At trial commencement, the crop was actively producing new leaves, and flower buds were beginning to emerge in leaf axils.

The trial was a randomised complete block design with four replicates. Each plot was comprised of four trees. A space of two or three trees at either end of each plot was used to reduce spray drift between plots, and replicates were separated by at least one row of untreated coffee trees. Insecticide treatments were Admiral (pyriproxyfen) 100 EC at 2.5 and 5.0 g ai/100L and Applaud (buprofezin) 440 SC at 13.2 and 26.4 g ai/100L. Insecticide treatments were compared with an untreated control. Insecticides were applied using a motorised backpack mister and D2 full cone nozzle with spray mix applied to point of run off.

A preliminary assessment of the pest population was conducted immediately prior to application. Insecticide efficacy assessments were conducted at two, five and eight weeks after application (WAA). At each assessment, 20 terminals per plot were randomly selected, and the presence or absence of a scale insect infestation was recorded. In addition, five infested terminals in each plot were collected, and the number of scale insects nymphs, healthy mature scale insects and dead mature scale insects on these were counted. A terminal was defined as a vegetative stem (crop was not bearing fruit) from tip to leaf axil of the third pair of fully mature leaves.

Data from all assessments were analysed for equality of variance and a normal distribution. After appropriate transformation (if required), a general linear model analysis of variance was used to determine significance at the P = 0.05 level. Treatment means were separated using the protected LSD technique at 95% confidence limits. Results are presented as the untransformed equivalents.

Results

Table 1 – Mean number of live hemispherical scale insects (nymphs and adults) per terminal based on 5 terminals per plot.

Treatment		Rate (g ai/100L)	Preliminary	2 WAA	5 WAA	8 WAA
1	Untreated control	Nil	62.0	100.6	81.7 c	8.0
2	Admiral 100 EC	2.5	42.7	17.4	4.5 a	12.4
3	Admiral 100 EC	5.0	35.4	26.6	15.1 ab	21.7
4	Applaud 440 SC	13.2	10.8	46.3	8.4 a	11.4
5	Applaud 440 SC	26.4	32.8	26.2	38.1 bc	15.3
P Value			0.3915	0.1671	0.0126	0.6929
LSD (Pr = 0.05)			*n/a	*n/a	*n/a	*n/a

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
WAA = weeks after application
*n/a = Log transformation used.

There were no significant treatment effects for the mean number of live scale insects of any life stage at the preliminary assessment.

At 2 WAA, there were no significant treatment effects for the mean number of scale insects per terminal, although there were markedly greater numbers of scale insects in the untreated control compared with all insecticide treatments. Slightly higher numbers of scale insects were observed in Applaud at 13.2 g ai/100L compared with other insecticide treatments.

At 5 WAA, there were significantly greater numbers of scale insects in the untreated control compared with all insecticide treatments with the exception of Applaud at 26.4 g ai/100L. Despite this, numbers were markedly lower in this treatment compared with the untreated control. Admiral at 2.5 g ai/100L and Applaud at 13.2 g ai/100L had significantly fewer live scale insects per terminal compared with Applaud at 26.4 g ai/100L.

There were no significant treatment effects for the mean number of scale insects per terminal at 8 WAA.

Table 2 – Mean number of hemispherical scale insect nymphs per terminal based on 5 terminals per plot.

Treatment		Rate (g ai/100L)	Preliminary	2 WAA	5 WAA	8 WAA
1	Untreated control	Nil	56.3	95.7	80.6 c	7.9
2	Admiral 100 SC	2.5	36.0	16.1	4.1 a	12.4
3	Admiral 100 SC	5.0	29.5	20.1	15.0 ab	21.6
4	Applaud 440 SC	13.2	8.3	39.4	7.6 a	11.4
5	Applaud 440 SC	26.4	26.2	22.0	36.2 bc	15.3
P Value			0.3818	0.1575	0.0116	0.6715
LSD (Pr = 0.05)			*n/a	*n/a	*n/a	n/a (pr > 0.05)

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
WAA = weeks after application
*n/a = Log transformation used.

There were no significant differences for the mean number scale insect nymphs per terminal at the preliminary assessment, despite a tendency towards fewer of nymphs in Applaud at 13.2 g ai/100L.

Although there was a markedly greater mean numbers of scale insect nymphs per terminal in the untreated control compared with all insecticide treatments, differences were not significant at 2 WAA.

At 5 WAA, there were significantly greater numbers of scale insect nymphs in the untreated control compared with all insecticide treatments, with the exception of Applaud at 26.4 g ai/100L. Admiral and Applaud at 2.5 and 13.2 g ai/100L respectively had significantly lower mean numbers of nymphs per terminal compared with Applaud at 26.4 g ai/100L.

There were no significant treatment effects for the mean number of scale insect nymphs per terminal at 8 WAA.

Table 3 – Mean number of live mature hemispherical scale insects per terminal based on 5 terminals per plot.

Treatment		Rate (g ai/100L)	Preliminary	2 WAA	5 WAA	8 WAA
1	Untreated control	Nil	5.7	4.9	1.2 bc	0.1
2	Admiral 100 SC	2.5	6.8	1.3	0.4 ab	0.0
3	Admiral 100 SC	5.0	5.9	6.5	0.1 a	0.2
4	Applaud 440 SC	13.2	2.5	7.0	0.9 abc	0.0
5	Applaud 440 SC	26.4	6.7	4.2	1.9 c	0.0
P Value			0.6378	0.3163	0.0234	n/a
LSD (Pr = 0.05)			*n/a	*n/a	*n/a	n/a (pr > 0.05)

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
WAA = weeks after application
*n/a = Log transformation used.

The numbers of live mature scale insects on terminals was broadly similar between treatments at the preliminary assessment, although Applaud at 13.2 g ai/100L showed slightly lower numbers of mature scale insects per terminal compared with other treatments.

There were no significant treatment effects for the mean number of live mature scale insects per terminal at 2 WAA.

At 5 WAA, only Admiral at 5.0 g ai/100L recorded significantly fewer live mature scale insects per terminal compared with the untreated control. Admiral at both 2.5 g ai/100L and 5.0 g ai/100L had significantly lower mean numbers of live mature scale insects per terminal in comparison to Applaud at 26.4 g ai/100L and had fewer mature scale insects per terminal compared with Applaud at 13.2 g ai/100L.

The numbers of live mature scale insects was too low to enable comparison between treatments at 8 WAA.

Table 4 – Mean percentage of live mature hemispherical scale insects tests based on the total number of tests on 5 terminals per plot.

Treatment		Rate (g ai/100L)	Preliminary	2 WAA	5 WAA	8 WAA
1	Untreated control	Nil	91.4	69.7	25.3 c	1.8
2	Admiral 100 SC	2.5	91.2	65.6	9.4 b	0.0
3	Admiral 100 SC	5.0	84.0	66.2	0.6 a	7.5
4	Applaud 440 SC	13.2	81.7	67.8	23.1 c	0.0
5	Applaud 440 SC	26.4	84.9	75.1	13.1 bc	0.0
P Value			0.6866	0.8433	0.0003	0.2265
LSD (Pr = 0.05)			n/a (pr > 0.05)	n/a (pr > 0.05)	n/a*	n/a*

Means within columns followed by a common letter are not significantly different (P≥ 0.05).
WAA = weeks after application
n/a* = Log transformation used.

Eighty to ninety percent of mature scale insects were alive at the preliminary assessment with no significant differences between treatments.

At 2 WAA, there were no significant treatment effects for the percentage of live mature scale insects comprising the population. All treatments showed a decline in the percentage of live scale insects compared with values obtained at the preliminary assessment.

The percentage of live scale insects in the pest population declined considerably in all treatments from 2 - 5 WAA. The percentage of live mature scale insects was significantly lower in Admiral at 2.5 and 5.0 g ai/100L compared with the untreated control. There were no significant differences between Applaud treatments and the untreated control. Admiral at 2.5 g ai/100L had a significantly a lower percentage of live mature scale insects compared with Applaud at 13.2 g ai/100L but not compared to Applaud at 26.4 g ai/100L. Admiral at 5.0 g ai/100L recorded a significantly lower percentage of live mature scale insects compared with all other insecticide treatments.

At 8 WAA, there were virtually no live adult scale insects present at the site and there were no discernable treatment effects.

Table 5 – Percentage of terminals infested with hemispherical scale insects of any life stage based on 20 terminals per plot.

Treatment		Rate (g ai/100L)	Preliminary	2 WAA	5 WAA	8 WAA
1	Untreated control	Nil	53.8	55.0	45.0	23.8
2	Admiral 100 SC	2.5	40.0	41.3	26.3	8.8
3	Admiral 100 SC	5.0	66.3	60.0	40.0	23.8
4	Applaud 440 SC	13.2	61.3	60.0	33.8	13.8
5	Applaud 440 SC	26.4	67.5	58.8	40.0	22.5
P Value			0.2260	0.6467	0.5203	0.5064
LSD (Pr = 0.05)			n/a (pr > 0.05)	n/a (pr > 0.05)	n/a (pr > 0.05)	n/a (pr > 0.05)

WAA = weeks after application
* = Log transformation used.

There were no significant differences between treatments for the percentage of terminals infested by hemispherical scale insects at the preliminary assessment. There were no significant treatment effects for the mean percentage of terminals infested by scale insects at 2, 5 or 8 WAA.

The percentage of terminals infested with scale insects of any life stage at 2 WAA remained broadly similar to levels observed during the preliminary assessment. By 5 WAA, the percentage of terminals infested had declined in all treatments, and by 8 WAA, only a low level of infestation was observed throughout.

None of the treatments applied were phytotoxic to the crop.

Discussion

At the preliminary assessment, there was a significant infestation of hemispherical scale insects in the crop, and approximately 60 % of new leaf terminals were infested throughout the site. Although the percentage of terminals infested was relatively uniform, there was some natural variation between treatments for the mean number of live scale insects per terminal, most notably, a weaker infestation in Applaud at 13.2 g ai/100L. The lower mean number of live scale insects observed in this treatment in the preliminary assessment was attributed to the chance occurrence of unusually poor infestations in two replicates. Overall, most variability of this nature was successfully accommodated by the careful blocking of replicates. Additionally, there was considerable variation in the numbers of live scale insects within plots.

Despite variation of scale insect numbers within and between treatments, some evidence of treatment effects were noted from 2 WAA when it was observed that in that the mean number of live scale insect nymphs per terminal had increased considerably in the untreated control but not in insecticide treatments. This suggested that the insecticides applied were principally active against the immature life stages rather than adults. This effect was not unexpected, as both Admiral and Applaud are insect growth regulators interfering with the moulting process of juvenile life stages of insects.

By 5 WAA, all insecticide treatments, except Applaud at 26.4 g ai/100L, reduced the total number of live scale insects (nymphs and adults) compared with the untreated control. There was some tendency towards greater efficacy in Admiral treatments compared to Applaud, but reliable comparisons were difficult due to increasing variability between plots. For this reason, the percentage of live mature scale insects comprising the population was analysed in order to reduce the effect of natural variation in the number of scale insects between terminals. Results indicated that, not only was Applaud at 13.2 g ai/100L less effective than both Admiral treatments, but that both rates of Applaud were not significantly different in comparison with the untreated control. Applaud at 26.2 g ai/100L was most comparable to Admiral at 2.5 g ai/100L whilst Admiral at 5.0 g ai/100L was more effective in reducing the percentage of live mature scale insects compared with all other insecticide treatments. The results more clearly showed that both Admiral treatments had resulted in significantly reduced viability of the adult scale insect population by 5 WAA. Applaud at 26.4 g ai/100L had achieved an acceptable level of control of adults by 5 WAA but Applaud at 13.2 g ai/100L had not significantly affected the mature scale insect population at that time.

The number of live scale insects in the untreated control had declined slightly by 5 WAA and, by 8 WAA, scale insect numbers were very low. Virtually no live adults were observed in any treatment at this time, and no significant differences were detected between treatments. Aside from the role of insecticide treatments, the decline of the adults in the crop was most likely due to the activity of parasitoids, predators and pathogenic fungi that were regularly observed in all treatments.

Hemispherical scale insect and mealy bug trial 2006 season: Admiral, Applaud, Lorsban and D-C-Tron Plus

Methodology

The trial was located at an established coffee (cv. Catuai) plantation at Mareeba, North Queensland, during the 2006 season. The crop was four years old, varying in height from 1.5 to 2 metres. Planting distance was 1.5 metres between plants at a row spacing of 2.5 metres. At application, the crop was nearing harvest, and most plants possessed bright red and near ripe berries. Hard green berries were still found on some trees, particularly on lower laterals of dense bushes.

The trial was a randomised complete block design with four replicates. Each plot comprised eight trees with plots separated by at least two trees to reduce spray drift between plots. Treated rows were separated by a single guard row of untreated crop. Insecticide treatments applied were Admiral 100 EC at 5.0 g ai/100L, Applaud 440 SC at 26.4 g ai/100L, Lorsban 500 EC at 50 g ai/100L and D-C - Tron Plus petroleum oil at 1.25 L/100L compared with an untreated control. Treatments were applied using a motorised backpack sprayer with a high volume Hardi spray gun and full cone D2 nozzle. Trees were sprayed to point of run off, using approximately four litres of spray mixture per plot.

A preliminary assessment comprising counts of hemispherical scale insects nymphs and adults and the numbers of mealy bugs on 12 berry clusters at each of six locations within the trial area was conducted prior to insecticide application. Assessments of insecticide effects were conducted at one, three and five weeks after application (WAA). At each assessment, the number of hemispherical scale insects nymphs and adults and the numbers of mealy bugs on 12 randomly selected berry clusters per plot were counted. A berry cluster was defined as all berries and stems arising from paired leaf nodes on a coffee stem. Typically, there were four main fruit stems for each pair of leaves, each bearing from one to many berries. Only clusters of berries that were comparatively dense (numbering greater than sixteen berries) were considered suitable sampling sites for hemispherical scale insects and mealy bugs.

Data from all assessments were analysed for equality of variance and a normal distribution. After appropriate transformation (if required), a general linear model analysis of variance was used to determine significance at the $P = 0.05$ level. Treatment means were separated using the protected LSD technique at 95% confidence limits. Results are presented as the untransformed equivalents.

Results

Table 1 – Preliminary assessment of pest population (n=12 fruit clusters)

Location	Mean level of infestation per berry cluster					
	Mean number of scale insects nymphs	% clusters infested by scale insect nymphs	Mean number of scale insect adults	% clusters infested by scale insect adults	Mean number of mealy bugs	% clusters infested by live mealy bugs
1	3.3	58.3	0.1	8.3	0.8	50.0
2	13.4	75.0	1.4	33.3	10.3	33.3
3	45.8	75.0	0.4	25.0	27.1	66.7
4	26.1	75.0	0.5	25.0	3.2	50.0
5	9.3	83.3	0.2	8.3	12.3	50.0
6	33.3	58.3	0.3	16.7	1.3	16.7
Trial Mean	21.9	70.8	0.5	19.4	9.2	44.4
Trial St Dev	16.1	10.2	0.5	10.1	10.0	17.2

WAA = weeks after application

The majority of the scale insect population at the site was comprised of nymphs. Adult scale insects were only present in very low numbers. The mean number of adults per cluster was broadly similar throughout the crop but the mean number of live scale insects nymphs varied considerably. Despite this variation, the percentage of clusters that were infested by scale insects was relatively consistent. The number of mealy bugs present in coffee clusters also varied throughout the site. The percentage of clusters infested by mealy bugs was generally lower than that of scale insects and slightly more variable.

Table 2 – Mean number of hemispherical scale insect nymphs per cluster (n=12)

Treatment		Rate (g ai/100L)	1 WAA	3 WAA	5 WAA
1	Untreated control	Nil	24.7 b	26.5	10.6
2	Admiral 100 EC	5.0	9.3 a	5.6	7.5
3	Applaud 440 SC	26.4	10.9 a	14.2	6.4
4	Lorsban 500 EC	50.0	14.0 ab	12.0	13.1
5	D-C-Tron Plus	1.25 L	5.1 a	11.1	5.3
P Value			0.0463	0.0725	0.8084
LSD (Pr = 0.05)			12.4	n/a (pr > 0.05)	n/a (pr > 0.05)

Means followed by a common letter are not significantly different (P≥ 0.05).
WAA = weeks after application

At 1 WAA, there were significantly greater numbers of live hemispherical scale insects nymphs in the untreated control compared with Admiral, Applaud and D-C-Tron Plus. There was no significant difference in the number of nymphs between the untreated control and Lorsban although the infestation was lower in the latter. The mean number of scale insect nymphs for Lorsban did not differ significantly in comparison to other insecticide treatments.

At 3 WAA, all treatments exhibited notably lower mean numbers of scale insect nymphs per cluster compared with the untreated control although differences were not significant at the p=0.05 level. Admiral recorded a lower mean value for the number of nymphs per terminal in comparison to other insecticide treatments.

There were no significant treatment effects for the mean number of hemispherical scale insect nymphs per terminal at 5 WAA.

Table 3 – Mean number of live mature hemispherical scale insects per cluster (n=12)

Treatment		Rate (g ai/100L)	1 WAA	3 WAA	5 WAA
1	Untreated control	Nil	0.8	1.0	0.6
2	Admiral 100 EC	5.0	0.6	0.5	0.3
3	Applaud 440 SC	26.4	1.1	1.0	1.0
4	Lorsban 500 EC	50.0	1.4	2.9	2.9
5	D-C-Tron Plus	1.25 L	0.4	0.5	0.9
P Value			0.8159	0.1969	0.5680
LSD (Pr = 0.05)			n/a*	n/a (pr > 0.05)	n/a*

WAA = weeks after application
* = Log transformation used.

There were no significant treatment effects for the mean number of live hemispherical scale insects adults at 1, 3 or 5 WAA.

Table 4 – Mean percentage of clusters infested with hemispherical scale insect nymphs

Treatment		Rate (g ai/100L)	1 WAA	3 WAA	5 WAA
1	Untreated control	Nil	77.1	70.8	66.7
2	Admiral 100 EC	5.0	50.0	54.2	52.1
3	Applaud 440 SC	26.4	56.3	50.0	39.6
4	Lorsban 500 EC	50.0	50.0	60.4	77.1
5	D-C-Tron Plus	1.25 L	50.0	68.8	50.0
P Value			0.1326 (pr > 0.05)	0.5111 (pr > 0.05)	0.2427 (pr > 0.05)
LSD (Pr = 0.05)			n/a	n/a	n/a

WAA = weeks after application

There were no significant treatment effects for the percentage of clusters infested by scale insects nymphs at 1 WAA. Despite this, there was a noticeable tendency towards a greater percentage of infested clusters in the untreated control compared with insecticide treatments.

There were no significant treatment effects for mean percentage of fruit clusters infested with hemispherical scale insects nymphs at 3 WAA, but the lowest percentage of infested clusters was seen in Applaud and Admiral treatments.

There were no significant treatment effects for the mean percentage of fruit clusters infested with scale insect nymphs at 5 WAA.

Table 5 – Mean percentage of clusters infested with live hemispherical scale insect adults

Treatment		Rate (g ai/100L)	1 WAA	3 WAA	5 WAA
1	Untreated control	Nil	18.8	27.1	22.9
2	Admiral 100 EC	5.0	14.6	14.6	10.4
3	Applaud 440 SC	26.4	25.0	18.8	25.0
4	Lorsban 500 EC	50.0	31.3	25.0	33.3
5	D-C-Tron Plus	1.25 L	14.6	14.6	18.8
P Value			0.6679	0.2281	0.7052
LSD (Pr = 0.05)			n/a (pr > 0.05)	n/a (pr > 0.05)	*n/a

WAA = weeks after application
* = Log transformation used.

There were no significant treatment effects for the percentage of clusters infested by scale insects adults at 1, 3 or 5 WAA. Admiral recorded the lowest percentage of clusters infested by scale insect adults at 5 WAA.

Table 6 – Mean number of live mealy bugs per fruit cluster (n=12)

Treatment		Rate (g ai/100L)	1 WAA	3 WAA	5 WAA
1	Untreated control	Nil	6.6	3.0 b	3.5
2	Admiral 100 EC	5.0	4.6	3.2 b	2.6
3	Applaud 440 SC	26.4	1.4	1.5 a	2.6
4	Lorsban 500 EC	50.0	1.3	1.2 a	1.3
5	D-C-Tron Plus	1.25 L	3.8	4.0 b	0.6
P Value			0.1946	0.0283	0.0926
LSD (Pr = 0.05)			n/a*	n/a*	n/a*

Means within columns followed by a common letter are not significantly different ($P \geq 0.05$).
WAA = weeks after application
* = Log transformation used.

At 1 WAA, there were no significant treatment effects for the mean number of mealy bugs per fruit cluster. There was a tendency towards greater numbers of mealy bugs in the untreated control compared with insecticide treatments and for lower numbers of mealy bugs in Lorsban and Applaud compared with other insecticide treatments.

By 3 WAA, there were significantly fewer mealy bugs in Applaud and Lorsban compared with other treatments.

There were no significant treatment effects for the mean number of mealy bugs per fruit cluster at 5 WAA although there was a tendency towards lower numbers of mealy bugs in Lorsban and D-C-Tron Plus compared with other treatments.

Table 7 – Mean percentage of clusters infested with live mealy bugs

Treatment		Rate (g ai/100L)	1 WAA	3 WAA	5 WAA
1	Untreated control	Nil	58.3 c	54.2 b	64.6 b
2	Admiral 100 EC	5.0	50.0 bc	52.1 b	50.0 ab
3	Applaud 440 SC	26.4	31.3 ab	31.3 a	39.6 a
4	Lorsban 500 EC	50.0	25.0 a	27.1 a	29.2 a
5	D-C-Tron Plus	1.25 L	56.3 c	37.5 ab	29.2 a
P Value			0.0081	0.0224	0.0383
LSD (Pr = 0.05)			19.5	18.2	24.5

Means followed by a common letter are not significantly different (P≥ 0.05).
WAA = weeks after application

There were a significantly lower percentage of clusters infested with mealy bugs in Applaud and Lorsban compared with the untreated control and D-C-Tron Plus at 1 WAA. Lorsban had a significantly lower percentage of infested fruit clusters compared with Admiral but Applaud did not.

At 3 WAA, Lorsban and Applaud had a significantly lower percentage of infested clusters compared with Admiral and the untreated control. D-C-Tron Plus was intermediate in effect and was not significantly different compared with other insecticide treatments or the untreated control.

There were a significantly greater percentage of fruit clusters infested by mealy bugs in the untreated control compared with all insecticide treatments except Admiral at 5 WAA. There were no significant differences between insecticide treatments.

Discussion

There was a moderate infestation of mealy bugs and hemispherical scale insects at the site with an average of 44.4 and 70.8% of coffee berry clusters infested respectively prior to treatment application. The majority of the scale insect population was comprised of nymphs. Although the number of hemispherical scale insect adults within clusters was relatively uniform between samples, the number of scale insect nymphs and mealy bugs varied considerably. The trial site was blocked and samples were standardised in an attempt to reduce some of this variation but large differences between berry clusters within plots still occurred. This variation limited the ability to distinguish treatment effects, especially for hemispherical scale insects. A natural reduction in the number of scale insect nymphs was also evident in the untreated control over the duration of the trial. Observations in the field indicated that actively growing berries (those that are still unripe) tended to attract greater populations of scale insects. Therefore, the observed decline in the pest population may be related to berry maturity near harvest.

All insecticide treatments except Lorsban significantly reduced the number of hemispherical scale insect nymphs by 1 WAA. There was a slight tendency towards further reduction in nymphs in Admiral at 3 WAA but, by 5 WAA, the population of nymphs was relatively consistent across all treatments. No significant changes in the number of adults or in the percentage of berry clusters infested by scale insect nymphs or adults was observed. A slight reduction over time in the percentage of clusters infested by scale insect adults was observed for Admiral and a slight reduction in the percentage of clusters infested by scale insect adults was observed for Applaud. For the remaining insecticide treatments, numbers of nymphs and mature scale remained relatively constant or showed an increase in the percentage of clusters infested over the duration of trial.

These tendencies may reflect the different mechanisms by which Admiral and Applaud regulate insect populations. Admiral interrupts insect metamorphosis, and so would be expected to manifest itself as a reduction in the number of adults over time. Applaud interferes with reproductive activity and so might be expected to reduce the number of nymphs. However, no significant differences were observed between these treatments and interpretation of tendencies within the data must be viewed with caution. Even taking into account the natural variability inherent in the pest population, it appeared that only limited control of hemispherical scale insects was occurring by 5 WAA. It was suspected that inadequate penetration of the insecticide treatments could be a significant factor in the control of scale insects and mealy bug populations in mature crops. Both hemispherical scale insects and mealy bugs appeared to favour the densest clusters of berries in which to settle. This may have offered some protection from insecticide sprays. In addition, the habit of scale insects and mealy nurturing eggs within protected cavities under the scale insects or in dense masses of mealy material and mould may also contribute to the survival of populations following an insecticidal spray.

Despite these factors, some insecticide treatments successfully reduced the mealy bug infestation at the site. Lorsban and Applaud achieved a rapid reduction in the percentage of clusters infested by mealy bugs compared with the untreated control and maintained a significantly lower level of infestation for up to 5 WAA. At no time did Admiral appear to exert a significant level of control of the mealy bug population. The percentage of clusters infested by mealy bugs declined in D-C-Tron Plus by 3 WAA and was significantly lower than the untreated control by 5 WAA. Why D-C-Tron Plus should take so long to exert control over mealy bug populations is uncertain.

Hemispherical scale insect and mealy bug observational trial 2006 season: Lorsban 500 EC

Methodology

On 1/7/06, at Walkamin, North Queensland, Lorsban 500 EC was sprayed at a rate of 100 mL/100L on a small area of coffee bushes infested with hemispherical scale insects and mealy bug. The trees were bearing for the first time and were approximately 1.5 m in height. Vegetative growth was dense, and trees were planted to form a hedgerow. At application, temperature was moderate at 21^{0}C with a relative humidity of 70%.

Prior to application, eight infested terminals bearing mature (red and dark red) cherry, within the area to be treated with Lorsban were marked as permanent monitoring sites. The activity of target pests was compared to that in an adjacent unsprayed area.

The crop was sprayed using a motorised backpack mister with spray mix applied to the point of run off. Marked terminals were inspected prior to insecticide application, soon after insecticide had dried, and at one and two weeks after application.

Observations

Prior to application there were low numbers of adult hemispherical scale and crawlers found irregularly on marked terminals. All marked terminals had significant infestations of mealy bug and all appeared to be healthy. Mealy bug colonies were invariably attended by ants which were present in significant numbers.

Observations within the sprayed area at 45 minutes after application were aimed to document the insecticidal effect on ants. It was observed that, in all cases, ant activity had virtually ceased at that time and only very few obviously intoxicated specimens were observed. As expected, ant activity in the untreated area remained high.

At 1 week after application the following notes were made regarding insect activity on sprayed terminals:

<u>Mealy bug</u>

Terminal 1: Population of mealy bug much reduced but, in recesses covered by mould and mealy wax, a few large mealy bugs, several small bugs and healthy egg masses remained.

Terminal 2: High mortality, associated with more open terminal? Only 1 or 2 large mealy bugs remaining.

Terminal 3: High mortality with low numbers of small mealy bugs remaining, some healthy egg masses but no adults.

Terminal 4: High mortality, no live adults or egg masses seen.

Terminal 5: Smaller colony, low numbers of all sizes still alive, little mould and still attended by ants.

Terminal 6: Medium colony, many still alive but no ants.

Terminal 7: Large open colony, all dead, one healthy egg mass seen.

Terminal 8: Small colony in middle of bush, high mortality but a few small mealy bugs persisting and one apparently healthy egg mass observed.

Overall, high mortality, ant activity generally stopped on most terminals, some mealy bugs that remained looked alive but were discoloured or did not move much.

Hemispherical scale: Difficult to distinguish alive from dead, some large nymphs apparently still alive, large numbers of first instar crawlers dead though one live one was spotted. Adults impossible to tell but eggs appeared very healthy. No ant activity at all.

Within the untreated area, mealy bug activity remained high and ants were present in considerable numbers. There was a general increase in hemispherical scale activity and crawlers were seen in higher numbers compared with observations one week previously.

At 2 weeks after application, observations within the sprayed area were as follows:

Mealy bug:

Terminal 1: Some egg masses remained and three unhealthy adults (dead?) seen. No crawlers sighted. No ants.

Terminal 2: No live mealy bug or crawlers seen. No ants.

Terminal 3: One live adult and several egg masses remained. No ants.

Terminal 4: No live mealy bug or crawlers seen, few eggs. No ants.

Terminal 5: One adult mealy bug observed and some eggs, low ant activity.

Terminal 6: Many mealy bugs, many ants and eggs – healthy population. Low level of ants.

Terminal 7: Some adults and eggs remained low level of ants.

Terminal 8: Some adults and eggs remained low level of ants.

Within the unsprayed area, many healthy colonies of mealy bug were found and these were invariably attended by ants.

Hemispherical scale: Still large numbers of dead first instar nymphs but a few healthy older nymphs seen. A few adults with eggs found, but no crawlers seen. Within the unsprayed area, the hemispherical scale population appeared healthy. Moderate numbers of adult and nymph stages were found. Crawlers frequently seen.

Conclusions

It was concluded that a single application of Lorsban 500 EC at 100 mL/100L effectively controlled mealy bug and hemispherical scale in mature coffee. There were no phytotoxic effects on the crop.

D-C-Tron Plus phytotoxicity observational trial 2006 season:

On 1/7/06, at Walkamin, North Queensland, D-C-Tron Plus petroleum oil was sprayed at a rate of 2.0 L/100L on mature coffee (cv. Catuai). The crop was ready for harvest with most cherry being red or dark red. The trees were bearing for the first time and were approximately 1.5 m in height. Vegetative growth was dense, and trees were planted to form a hedgerow. At application, temperature was moderate at 21^{0}C with a relative humidity of 70%. Application was made using a Solo backpack mister to runoff.

The crop was inspected for phytotoxic effects at three, seven and 10 days after application. No signs of phytotoxicity were found over this period. Weather conditions were moderate as tabled below. Weather data was recorded at Walkamin research station, 1.5 km from the site.

Date	Day	Temps		Rain	Evap	Sun	9 am				
		Min	Max				Temp	RH	Cld	Dir	Spd
		°C	°C	mm	mm	hours	°C	%	8th	km/h	
1	Sa	14.5	22.5	0	4.2	9.4	18.0	77	3	SE	15
2	Su	11.5	24.2	0	4.0	9.7	17.3	73	2	SSE	19
3	Mo	10.7	25.0	0	3.8	9.9	16.8	72	0	SE	2
4	Tu	10.9	21.4	0	3.6	10.0	15.5	55	0	ESE	7
5	We	7.7	20.2	0	4.0	9.2	14.5	78	4	SE	19
6	Th	11.3	21.5	0	4.0	5.9	15.7	82	3	ESE	13
7	Fr	14.5	21.7	0	3.8	10.0	16.8	72	2	ESE	28
8	Sa	13.3	21.0	0	5.6	8.9	16.4	71	1	ESE	28
9	Su	14.2	21.0	0	4.2	6.9	17.5	77	4	SE	19
10	Mo	16.3	22.5	0	3.8	2.8	19.0	84	5	ESE	6
11	Tu	17.5	24.8	0	2.6	1.8	21.0	78	7	ESE	15

General Conclusions

The insecticide efficacy trials conducted in this project generated useful information relating to their effectiveness, appropriate rates of application and duration of control for leaf roller, hemispherical scale and mealy bugs in coffee.

Most insecticides tested were effective at controlling leaf roller larvae on coffee leaves. The only exception was Supracide, a widely used organophosphate compound. Although some activity was observed for smaller leaf roller larvae, Supracide was largely unsuitable for use on leaf rollers in coffee. Other insecticide treatments appeared equally effective, but differed in the length of time required to achieve control of this pest. Success and Lorsban, which are contact and stomach poisons, both exhibited very rapid action against leaf roller larvae with significant reductions in the pest population within one day of application. Mimic and Prodigy are insect growth regulators, and as such, required slightly longer periods to exert the same level of control on the pest population. Of the two, Prodigy reduced the insect population more rapidly in comparison to Mimic, when the former was used at high rates of application. At a rate of 6 g ai/100L, both products performed similarly, and Prodigy was equally effective at this rate compared to the higher rates applied in some trials. Insects affected by both Mimic and Prodigy reportedly cease feeding shortly after ingesting insecticide and therefore may not result in greater damage to the crop compared with more rapidly acting insecticides.

There were some subtle variations in residual activity between insecticide treatments for the control of leaf roller in coffee. In this respect, there was a tendency for the total number of larvae present at seven and 14 DAA to be greater in Lorsban compared with Success, Prodigy and Mimic. This suggested that Lorsban might be slightly less effective over longer periods of time compared with these. When applied at 6 g ai/100L, Prodigy appeared to possess a slightly longer residual effect compared with Mimic.

Insecticide trials were conducted against hemispherical scale populations infesting coffee at different stages in the crop. One trial compared insecticide treatments for scale populations infesting coffee terminals during periods of new vegetative growth, and the other during the fruiting period. Mealy bugs are generally only present in significant numbers during fruiting and so were not included in the first trial.

The highly variable nature of scale populations in space and time, reduced the precision at which differences between insecticide treatments could be distinguished. Despite this, some strong tendencies and some significant differences between insecticide treatments and the untreated controls were observed, particularly for hemispherical scale nymphs. Admiral, Applaud, Lorsban and D-C-Tron Plus petroleum oil all appeared to reduce the population of scale nymphs shortly after application compared with the untreated control. Often there were no clear distinctions in efficacy between insecticide treatments for control of hemispherical scale. However, there were some strong indications that Admiral may have been more effective than Applaud, Lorsban and D-C- Tron Plus, particularly for control of adult scales. Analyses of the percentage of live adult scale on leaf terminals also indicated a strong rate related effect for Admiral and Applaud but this was not observed at any other time. The efficacy of insecticide treatments was more unambiguous for Mealy bugs which showed a rapid reduction and excellent control by Lorsban and Applaud up to three weeks after application. Admiral and D-C- Tron Plus appeared largely ineffective against mealy bugs although there was some indication of late control by D-C-Tron Plus.

In most instances, the effectiveness of insecticide treatments for the control of hemispherical scale declined steadily over time. There were no clear differences observed between treatments by eight weeks after application for infestations in leaf terminals and by five weeks after application for infestations in fruit clusters. Two factors may have influenced this. Firstly, populations of hemispherical scale tend to reach a peak and crash naturally through the interaction of host quality and beneficial organisms. Secondly, some individuals seemed able to survive insecticide applications and rapidly re-infest sites. This factor may have been especially important in fruit clusters that may offer a greater level of protection from exposure compared with infestations on leaf terminals. This may also explain why there were no longer obvious differences between treatments at five weeks for protected berry clusters compared with eight weeks for exposed leaf terminals, although berry maturity was also certainly a contributing factor. That there were seldom clear differences between the percentages of terminals or fruit clusters infested also suggested that survival of scale after insecticide applications is common. The most likely avenue for survival is through the protection of scale eggs in a cavity underneath the scale test. Field observations also indicated that mealy bug eggs might be protected within the waxy egg mass. None of the insecticide treatments appeared to have a direct effect on eggs protected in this way. Thus, some newly hatched crawlers would be capable of re-infesting the crop following a spray. A second application of insecticides may be necessary to reduce the survival of crawlers.

All of these insecticides applied in the reported trials should have a role in managing insect pests in coffee. Success, Prodigy, Mimic, Applaud, Admiral and D-C- Tron Plus are especially useful within an integrated pest management system. Pests such as hemispherical scale and mealy bugs can be effectively controlled by the activity of predators and parasitoids naturally occurring within coffee crops, and insecticides that operate without disrupting such populations are highly desirable. An effectively managed system, utilising such selective insecticides in preference to broad spectrum chemicals should require less intensive management as healthy populations of beneficial organisms reduce the necessity for insecticidal sprays.

All of the insecticides used in the reported trials were safe for use on coffee.

Implications

The data these trials will support the registration and/or continued permit use of insecticides for managing insect pests in coffee. Without regulation of the types of chemicals used, reliable data on efficacy or chemical residues there has been the risk that the Australian coffee industry may be perceived as lacking necessary safeguards for public health and failing to prevent the possibility of excessive or ineffectual use of insecticides and unnecessary environmental disruption. By enabling the registration of a range of selective, ‘soft’ insecticides, capable of being incorporated in to an integrated pest management programme, the Australian coffee growing industry will be able to sustain its reputation for producing a clean, green, high quality product. It also enables growers to make informed decisions on which chemicals they use and the limitations and success they are likely to achieve.