final report

Project code: B.AHE.0228
Prepared by: Maxine Murphy
Date published: December 2013
ISBN: 9781925045819

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

WeanerSafe data reporting

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication

Abstract

The WeanerSafe project was terminated sixteen months early by the then newly elected Queensland State Government and the B.AHE.0055 contract with MLA and AWI cancelled. The anthelmintic resistance survey had been conducted but only baseline data had been collected for the Safe Grazing (time-controlled rotational grazing) trial.

Anthelmintic treatments to control peak infections of the highly pathogenic *Haemonchus contortus* of weaner sheep continue to fail due to parasite resistance. Farm-specific resistance profiles based around the Faecal Egg Count Reduction Test (FECRT) and a short questionnaire were developed for 20 enterprises across southern Queensland. Efficacies of <95% were present on 85% of farms for one or more anthelmintics and on 10% of farms for six anthelmintics. No resistance was identified on three farms. The 4-active combination was effective on 100% of farms (n=4) and naphthalophos on 94% (n=16). High levels of parasite resistance were identified to all other anthelmintics tested. Seventy percent of farms practised 'drench and move', a high-risk strategy for anthelmintic resistance.

Safe Grazing reduces dependence on anthelmintics. Grazing logistics appropriate for the inland south east region were being investigated on farms that rotationally- (n=3) or continuously-grazed (n=3) weaners for meat (n=3) or wool (n=3) production. A pasture 7-day graze followed by a 70-day rest period requires further evaluation for weaner productivity and worm control benefits.

Executive summary

Background

The WeanerSafe project was terminated sixteen months early by the then newly elected Queensland State Government and the B.AHE.0055 contract with MLA and AWI cancelled. Collection of data sets for the anthelmintic resistance survey had been completed but critically, for the Safe Grazing trial only baseline observations had been recorded. The late onset of rains during the second summer season further reduced the data collection period to about 4 weeks. Information collected up to February 2013 is the subject of this report.

Project objectives

The project has two sections, an anthelmintic resistance survey (Part 1) conducted on 20 farms across southern Queensland where *H. contortus* is endemic and the cause of weaner mortalities, and a Safe Grazing (time-controlled rotational grazing) trial (Part 2) conducted on sheep-only enterprises where possible to reduce dependence on anthelmintics for worm control in weaner sheep over hot wet summers. The aim was to demonstrate these technologies on-farm and provide support during the adoption phase.

Significant findings

Part 1 Anthelmintic resistance survey

The Faecal Egg Count Reduction Test (FECRT) was employed to determine resistance profiles on each of 20 farms across inland southern Queensland. *Haemonchus contortus* was the predominant parasite on 19 of the 20 farms. *Trichostrongylus colubriformis* was predominant on one farm only. Single- and multi-active combination anthelmintics, persistent and non-persistent, oral, capsule, pour-on and injectable formulations were tested. Monepantel was not tested. Widespread resistance in *H. contortus* was identified to most of the anthelmintics tested:

- Efficacies of <95% were present on 85% of farms for one or more anthelmintics and on 10% of farms for six anthelmintics. No resistance was identified on three farms.
- The 4-active combination product was 100% efficacious (n=4 farms)
- Naphthalophos resistance was detected on one farm (n=16) only
- High levels of resistance (failure to reduce the worm egg count by ≥95%) were identified to levamisole (42% of farms), moxidectin long acting injection (50% of farms) and the closantel/abamectin combination (67% of farms).

On four farms where populations of *T. colubriformis* were present no resistance was identified to the more potent Macrocyclic Lactone (ML) drench actives. Farmers responded to a short drenching practices questionnaire on Day 0 of the FECRT. Major findings across the region were:

- 55% of farms ran meat breeds of sheep
- 75% are drenching more often than in the last 2-5 years
- 100% used worm testing to determine the timing of treatments
- 85% also drenched on visual signs of worminess if sheep were in the race for other management reasons

- 85% calculated dose rates on the estimated weight of the largest animal in the mob
- 60% intentionally dosed more than the manufacturers recommended dose rate
- 70% always or usually practised a ‘drench and move’ strategy
- 30% used ASBV WEC in a selection index for rams

Part 2 WeanerSafe grazing

A time-controlled rotational grazing trial was conducted on three farms in the Millmerran to Stanthorpe region in inland south east Queensland. Another three continuously-grazed farms in the area were monitored as region typical controls. The late onset of summer storms in the second grazing season further reduced the period available for data collection. A third grazing season would have built on already collected farm- and region-specific data. Findings to date:

- A pasture 7-day graze followed by a 70-day rest period may be appropriate for the region
- Identification of effective drenches by resistance testing was considered by farmers to be the most important outcome of the trial
- Induction of weaners into the grazing system should be linked to the onset of summer storms and new pasture growth
- An understanding of *H. contortus* epidemiology enabled farmers to better tailor the technology to their farms in line with the variations within and between seasons
- Treatment of weaners with highly effective drenches into and out of the rotational system is critically important to avoid escalation of drench resistance and to achieve a reduction in the number of drench treatments applied
- Pasture growth was dominated by seasonal conditions with pastures in both grazing systems responding well to rain events
- No weaner mortalities from uncontrolled worm infections occurred over the period of the grazing trial and from the limited data collected, productivity was not compromised

Communications

Farmer adoption of resistance testing and Safe Grazing was encouraged through on-farm demonstrations of the technologies. About 90 farmers participated in drench resistance webinars or attended workshops conducted at Nindy Gully, Miles and Thallon in the months leading up to the commencement of this project.

Conclusions

Identification of efficacious drench treatments is critical for effective worm control across all grazing systems and has immediate benefits on-farm by reducing drench frequency and deaths of weaner sheep. However, the consensus was that resistance testing procedures were too complex for individual farmers to easily adopt. Safe Grazing practices were well received particularly on farms running meat breeds of sheep as weight gains are closely monitored and quickly jeopardised by parasitic infections. Frequent and marked changes between and within seasons demand flexibility in implementing grazing strategies. If paddock infrastructure is in place grazing can be easily moved from continuous- over hot dry periods if seasonal rains

are delayed, to time-controlled rotational grazing i.e. Safe Grazing when prevailing conditions are hot and wet.

Recommendations for future actions

Supplying resistance testing to farmers through private agricultural services would be a first step in reducing the amount of drench product purchased without prior resistance testing. A strategy utilizing a pasture 7-day graze followed by a 70-day rest period requires further evaluation in terms of benefits for pasture growth, weaner productivity and reduced incidence of weaner mortality through better worm control.

Table of Contents

1. Background

There are two subsections to this project, the anthelmintic resistance survey (Part 1) and the Safe Grazing trial for weaner sheep (Part 2).

Anthelmintic treatments to control peak infections of the highly pathogenic *Haemonchus contortus* of weaner sheep continue to fail due to parasite resistance. Deaths of up to 5% (2-30%) of the weaner mob is not uncommon. Testing for resistance in parasites every two years and providing safe grazing for weaner sheep during hot wet summers are recommendations of www.wormboss.com.au . To date, the uptake of resistance testing has been very poor. Safe Grazing, based on time-controlled rotational grazing to produce low-worm pastures, facilitates better worm control by increasing the time taken for acute infections requiring treatment to develop and therefore reducing the number of treatments dosed. While the methodology for the anthelmintic resistance test is well defined the logistics of pasture ''graze'' and ''rest'' periods for better worm control has not been tested for inland south east Queensland.

Both these technologies are considered important to conserve anthelmintic efficacy, the cornerstone of most worm control programs, and are suitable for on-farm adoption.

While co-operator farms in this project were considered region typical, they were also progressive as worm testing was already part of their management strategies. This group was therefore targeted as ''more likely'' to adopt advanced on-farm technologies.

Communicating outcomes to a wider farmer group and raising awareness of the WormBoss on-line resource were considered integral to this project to support farmer self-sufficiency as agency resources become increasingly curtailed.

2. Project objectives

The project had three objectives

(i) To conduct anthelmintic resistance tests on 20 farms

(ii) To determine region-appropriate logistics of Safe Grazing for weaner sheep on three farms in south east Queensland with continuously grazed farms (n=3) in the region monitored as region-typical controls.

(iii) To support on-farm adoption of these technologies

3. Part 1: Anthelmintic resistance survey

3.1 Introduction

Anthelmintic resistance (AR) is the failure of an anthelmintic drug to reduce a gastrointestinal nematode (GIN) burden of sheep by less than 95%. It is an inevitable consequence of controlling a biological entity (GIN) with a chemical drug treatment. During the very hot wet summers typical of southern inland Queensland failure of drug treatment exposes young susceptible weaner sheep to pathogenic worm burdens.

3.2 Methodology

Co-operator farms

Twenty farms across southern Queensland, in a line from Charleville east to Roma and Warwick, and south to Stanthorpe and the border regions of northern New South Wales were enrolled in resistance testing from October 2011 to February 2013 (Figure 1). All farms regularly used worm testing as part of their management strategy for worm control. Farms were distributed across the 300mm to 750mm annual rainfall zone. Testing commenced when the mob average monitor worm test results were at least 400 eggs per gram (e.p.g.). A short questionnaire was used to gather information about drenching practices at the first farm visit.

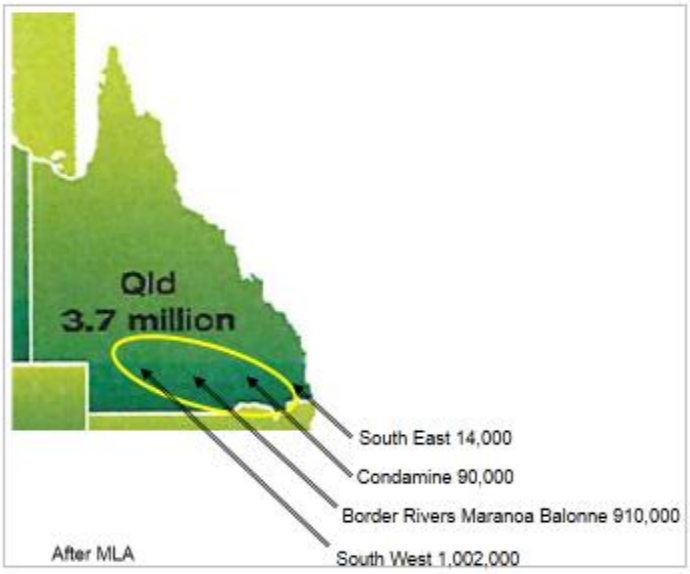

Figure 1 Location of farms enrolled in the anthelmintic resistance survey and sheep numbers in each region. Adapted after MLA 2011.

On-farm testing

The Faecal Egg Count Reduction Test (FECRT) was used to determine anthelmintic resistance (AR). On each farm, groups of 15 sheep were randomised into treatment groups (median=6, ranging from 4 to 7) and a corresponding untreated control group. Randomisation of sheep into groups was facilitated by uniquely numbered and coloured ear tags applied on day 0. Single- and multi-active combinations of narrow-, mid- and broad-spectrum anthelmintic actives were tested as oral, injectable, capsule or pour-on formulations. A group of fifteen sheep were shorn on Day 0 as part of the testing procedure for the off-shears pour-on product. All anthelmintics were dosed at the manufacturers' recommended dose rate. Choice of anthelmintic tested on each farm was determined by farm history of usage and farmer's request to test a particular product. Monepantel was not tested.

Parasitology

In the laboratory, each group of samples (n=15) was sub-divided into three groups of five each with each composite sub-group analysed by the modified McMaster technique. Eggs were enumerated at x40 magnification with 1 egg equivalent to 40 eggs per gram (epg) of faeces. Bulk larval cultures were set-up for each group of 15

samples and incubated for 7 days at 27°C. Differentiations of at least 100 infective larvae were conducted for each bulk culture.

Determination of resistance

Pre- and post-drench differentiated worm egg counts of treatment and untreated groups of sheep were used in the calculation of resistance and also to control for continuous larval development during the test evaluation period. Statistical analysis was carried out using GenStat Release 14 software package with data analysis facilitated in an Excel spreadsheet. The reduction of the worm egg count for each anthelmintic was calculated with the following formula:

%Reduction= 100 [1 – (mt2 * mc1) / (mc2 * mt1)] where:

mc1= mean epg control group pre-drench; mc2 =mean epg control group post-drench, and
mt1= mean epg treatment group pre-drench; mt2 =mean epg treatment group post-drench

Resistance to an anthelmintic was inferred if the reduction in the arithmetic mean from the genera corrected treatment group was <95%, 10-14 days after treatment and the lower 95% confidence limit was less than the 90% reduction level when compared to the control group.

This research was approved by the Eco-Sciences Precinct Animal Ethics Committee.
Approval numbers: SA201202 – 376 Drench Resistance Survey
SA201202 – 377 WeanerSafe time-controlled rotational grazing trial.

3.3 Results for individual farms

Anthelmintic resistance profiles for each of 20 farms and information about drenching practices that may have contributed to the current levels of anthelmintic resistance are tabulated below.

3.3.1 Farm Code 1

This 3500 hectare farm is located east of Inglewood in the 650 mm annual rainfall region. It runs a white Dorper self-replacing flock of about 2000 ewes with lambs, 500 weaners, 500 last year's weaners, 300 dry ewes and 200 rams.

Anthelmintic resistance was detected in *H. contortus* (Table 1a). The closantel (50g/L) plus abamectin combination was effective against *H. contortus* whereas closantel (37.5 g/L) alone was only 67% effective. Moxidectin long acting injection was not effective. In follow-up testing moxidectin oral was only 30% efficient. Levamisole alone or in combination with benzimidazole, or with benzimidazole and abamectin (follow-up testing) was not efficacious. Naphthalophos alone was effective producing a 98% reduction in the worm burden.

Responses to the drenching practices questions are tabulated in Table 1b. This farm is drenching all classes of stock less frequently than 5 years ago and the manager credits this to regular worm testing for informed drench decisions, and rotational grazing.

Table 1a Farm Code 1- Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	1387	1533	
LEV	2867	596	88 (80-93)
NAP	1735	66	98 (87-99)
BZ+LEV	1651	227	89 (0-99)
CLOS	1527	746	67 (42-81)
CLOS+ABA	2017	40	98 (70-99)
MOX long acting injection	1967	777	70 (56-79)

ABA=abamectin BZ= benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 1b Farm Code 1- Responses to drenching practices questions

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	Less often
Are sheep drenched to a regular planned program?	No, use worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rates on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy?	Always, sheep are moved to paddocks recently grazed by adult dry sheep or to irrigated pastures
Is ASBV WEC part of the selection index for rams?	No

3.3.2 Farm Code 2

This farm is located at Ballandean south of Stanthorpe in the 650mm to 700mm annual rainfall zone. The farm runs a self-replacing flock of 700 Corriedale Poll Dorset sheep on 1500 hectares. A beef cattle enterprise on the property turns off weaners as they reach target weights.

Anthelmintic resistance was identified in *H. contortus* (Table 2a). Overall, the closantel (50g/L) abamectin combination and the moxidectin long acting injection were ineffective. The BZ capsule, dosed concurrently with a levamisole drench was effective. All the short acting drenches tested, were effective.

Responses to the drenching practices questions are tabulated in Table 2b. This farm is drenching more often than five years ago due to the series of wet seasons.

Table 2a Farm Code 2 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy(%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	1840	3640	
LEV	2893	53	99 (95-99)
NAP	4133	0	100
BZ+LEV+ABA	1506	0	100
CLOS+ABA	1188	1333	43 (0-70)
MOX long acting injection	3533	907	87 (78-92)
BZ Capsule+LEV	2240	0	100

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 2b Farm Code 2 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Yes
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	N/A
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	No
Do you practice a 'drench and move' strategy?	Sheep are usually moved to paddocks recently grazed by cattle
Is ASBV WEC part of the selection index for rams?	Yes

3.3.3 Farm Code 3

This farm is located in the Maranoa shire south-west of Roma in the 400mm to 500mm annual rainfall zone. The Dorper / Damara enterprise has only been operational for three years. The intention is to run a self-replacing flock in a rotational grazing system based on pasture availability. Fencing is still being erected. The owner participated in the WeanerSafe worm egg counting webinar and follow-up workshop at Nindy Gully in 2011. Monitor and Day 10 worm tests are now conducted on-farm.

Anthelmintic resistance was identified in *H. contortus* (Table 3a). Moxidectin long acting injection, the combination of closantel (50g/L) and abamectin and the BZ capsule dosed concurrently with an abamectin drench, were not efficacious. These results are not region typical. Levamisole and naphthalophos were efficacious.

Table 3a Farm Code 3 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	2787	1357	
LEV	2173	57	95 (32-99)
NAP	1506	0	100
CLOS	640	63	80 (0-98)
CLOS+ABA	960	40	91 (57-98)
MOX long acting injection	1160	420	27 (0-94)
BZ Capsule+ABA	893	330	29 (0-51)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

It is suspected that ML resistant-*H. contortus* were imported with purchased sheep. A quarantine moxidectin long acting injection was dosed at the vendor farm on advice from industry.

Responses to the drenching practices questions are tabulated in Table 3b. The owner is now drenching more frequently than in the past two years due to the wetter than normal seasons and poor drench efficacy.

Table 3b Farm Code 3 - Responses to drenching practices questionnaire

Question	Response
Compared to 2 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Yes
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy?	Where possible, sheep are moved to rested paddocks
Is ASBV WEC part of the selection index for rams?	No

3.3.4 Farm Code 4

This 18000 hectare farm is located in the Paroo shire just east of Charleville in the 300mm annual rainfall zone and runs a self-replacing Merino enterprise with 6798 ewes, 2084 weaners and 393 wethers. General rainfall is very low and extremely variable in amount. Extended periods of dry weather can last for months and years. During periods of extended dry weather the farm is destocked. Sheep for restocking are purchased from the pastoral zone.

Anthelmintic resistance was identified in *H. contortus* (Table 4a). The closantel (50g/L) abamectin combination and moxidectin long acting injection were efficacious on a Day 10 worm test conducted concurrently with the FECRT.

Moxidectin oral failed to give a 95% reduction of the worm burden. The ivermectin capsule was not efficacious. Ivermectin and abamectin were not efficacious. These results are unexpected and not region-typical. This farm has a history of rotating between brands of ML drenches rather than rotating between unrelated drench actives.

Levamisole alone or in combination was not tested. Naphthalophos alone was efficacious.

Responses to drenching practices questions are tabulated in Table 4b. In normal seasons, this pastoral zone farm does not drench. During the current wet season all classes of stock are being drenched three times a year and the owner reports poor response to the anthelmintics dosed.

Table 4a Farm Code 4 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count(epg) Day 0	Average faecal worm egg count(epg) Day 10-14	Efficacy (%)(C.I.)
Control	287	426	
BZ	643	173	82 (58-92)
NAP	756	0	100
IVER concentrate	707	693	34 (0-78)
IVER capsule	360	440	18 (0-68)
ABA pour-on	51	400	48 (0-78)
MOX oral	373	66	88 (73-95)

ABA=abamectin BZ=benzimidazole IVER=ivermectin MOX=moxidectin NAP=naphthalophos

Table 4b Farm Code 4 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Yes
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	N/A
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Average sized
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy?	Sheep are usually moved to rested paddocks
Is ASBV WEC part of the selection index for rams?	No

3.3.5 Farm Code 5

This 1500 hectare farm is located in the Millmerran shire north west of Warwick in the 650mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather. This farm runs a Dorper stud and cropping enterprise.

Anthelmintic resistance was identified in *H. contortus* (Table 5a). The closantel (50g/L) abamectin combination and moxidectin oral failed to give a 95% reduction of the worm burden. The long acting more potent injectable formulation of moxidectin was efficacious. Levamisole alone was ineffective but in combination with benzimidazole alone, or with benzimidazole and abamectin, was effective.

Responses to drenching practices questions are tabulated in Table 5b. This farm has not experienced an increase in drenching compared with five years ago even though the last three summers have been unseasonably wet. Sheep are run under a rotational grazing system incorporating crops with pastures.

Table 5a Farm Code 5 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficiency (%)(C.I.)
Control	977	2683	
LEV	1947	347	92 (84-96)
BZ+LEV	343	43	95 (49-99)
BZ+LEV+ABA	1560	0	100
CLOS+ABA	747	187	90 (52-98)
MOX oral	2520	740	87 (57-96)
MOX long acting injection	1453	107	98 (91-99)

ABA=abamectin BZ= benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin

Table 5b Farm Code 5 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	No change compared to 2 years ago
Are weaners drenched to a regular planned program?	Worm test results
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Not sure
Do you practice a 'drench and move' strategy	Sheep are always moved after drenching to grain stubble or forage crop
Is ASBV WEC part of the selection index for rams?	No

3.3.6 Farm Code 6

This 2000 hectare farm is located in the Goondiwindi region in the 600mm to 650mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather. This farm runs a fat lamb and cropping enterprise.

Anthelmintic resistance was identified in *H. contortus* (Table 6a). The closantel (50g/L) and abamectin combination and the moxidectin long acting injection were not efficacious. Levamisole alone was not giving good control of *H. contortus* but was effective in the 4-active combination. Naphthalophos alone was effective. Copper capsules are being investigated for anthelmintic activity against *H. contortus* and produced a 98% reduction in the worm egg count in concurrent testing.

Responses to drenching practices questions are tabulated in Table 6b. This farm is drenching more frequently than 5 years ago.

Table 6a Farm Code 6 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	7173	1827	
LEV	9573	1173	54 (0-85)
NAP	6507	53	99 (99-99)
BZ+LEV+ABA+CLOS	5073	53	96 (82-99)
CLOS+ABA	5067	80	93 (52-99)
MOX long acting injection	6633	87	88 (50-97)

ABA=abamectin BZ=benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 6b Farm Code 6 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	No
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are always moved to grain stubble or forage crop
Is ASBV WEC part of the selection index for rams?	No

3.3.7 Farm Code 7

This farm is located south east of St George in the 500mm to 600mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather. This farm ran a Merino wool sheep enterprise five years ago and has since changed to Dorper meat sheep. The owner participated in the worm egg counting school at Nindy Gully in 2011 and has since organised local farmers to also use the worm test technology.

Anthelmintic resistance was identified in *H. contortus* (Table 7a). The ivermectin capsule resulted in a 93% reduction of the worm burden. The more potent moxidectin

long acting injection was effective indicating that the ML class of drench actives is losing efficacy on this farm.

Responses to drenching practices questions are tabulated in Table 7b. During the good seasons of the last three years stocking rates have been maximized and paddocks have been set-stocked.

Table 7a Farm code 7 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	427	320	
BZ	1507	13	99 (69-99)
LEV	307	0	100
NAP	600	0	100
IVER capsule	760	40	93
CLOS	307	13	98 (31-99)
CLOS+ABA	2053	0	100
MOX long acting injection	557	40	100

ABA=abamectin BZ= benzimidazole CLOS= closantel IVER=ivermectin LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 7b Farm Code 7 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	No
Do you consider AR still to be of concern?	No
Do you practice a 'drench and move' strategy	No
Is ASBV WEC part of the selection index for rams?	No

3.3.8 Farm Code 8

This farm is located in the Goondiwindi district in the 550mm to 650mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather. It is a self-replacing Merino crossbred flock. Ewes are sometimes purchased and run as a single mob.

Anthelmintic resistance was identified in *H. contortus* (Table 8a). The combination of closantel (50g/L) and abamectin, and the moxidectin long acting injection were not

effective. Levamisole alone, or in combination with benzimidazole was not effective. Levamisole in combination with benzimidazole, abamectin and closantel (4-active combination) was effective. Naphthalophos alone was effective.

Responses to drenching practices questions are tabulated in Table 8b. During the last three wet seasons stocking rates have been maximized but the owner has concerns about the efficacy of the short acting drenches.

Table 8a Farm Code 8 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	2400	2237	
LEV	1400	437	68 (0-95)
NAP	3013	53	99 (92-99)
BZ+LEV	2087	242	87 (32-98)
BZ+LEV+ABA+CLOS	1983	33	98 (84-99)
CLOS+ABA	3200	182	93 (71-98)
MOX long acting injection	733	43	92 (54-98)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 8b Farm Code 8 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are usually moved after drenching to paddocks recently grazed by cattle or dry sheep or to rested paddocks
Is ASBV WEC included in the selection index for rams?	No

3.3.9 Farm Code 9

This farm is located south of Goondiwindi in the 550mm to 650mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather. This sheep enterprise has been developed over the last three years and is

currently running a self-replacing Dorper flock. Weaners are purchased and run as a single mob.

All drenches tested were ineffective against *H. contortus* (Table 9a). Moxidectin long acting injection, the most potent of this class of drench active was not tested. Naphthalophos should be retested to confirm the 'resistant" finding.

The most plausible explanation for this level of drench resistance is that resistant *H. contortus* were imported with sheep purchased in northern New South Wales.

Responses to drenching practices questions are tabulated in Table 9b. Weaner sheep are currently being drenched more often than two years ago.

Table 9a Farm Code 9 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against Haemonchus contortus

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficiency (%) (C.I.)
Control	1280	1307	
LEV	920	493	46 (0-87)
NAP	1267	120	90 (51-98)
BZ+LEV	1000	497	49 (0-80)
BZ+LEV+ABA	1953	280	73 (31-90)
CLOS+ABA	1080	67	94 (65-99)
MOX oral	1347	507	61 (16-82)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 9b Farm Code 9 - Responses to drenching practices questionnaire

Question	Response
Compared to 2 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are usually moved to paddocks recently grazed by cattle
Is ASBV WEC included in the selection index for rams?	No

3.3.10 Farm Code 10

This 1850 hectare farm is located in the Tenterfield district in the 750 annual rainfall zone and runs about 1000 Merino weaners. Monepantel is routinely used as a quarantine drench. Even in low rainfall seasons worms burdens, usually *T. colubriformis* require treatment.

Anthelmintic resistance was identified in *H. contortus* (Table 10a). The combination of closantel (50g/L) with abamectin, and the moxidectin oral were not effective. Moxidectin long acting injection was not tested. Levamisole alone is giving good control but in combination with benzimidazole and abamectin, is inefficient. This is an inconsistent finding. Naphthalophos alone was not tested, but in combination with benzimidazole and levamisole, was effective. This farm prefers to use naphthalophos in combination with benzimidazole or levamisole.

The ML based drenches are giving good control of *T. colubriformis* (Table 10b).

Responses to drenching practice questions are tabulated in Table 10c. This farm is drenching “slightly” more often than five years ago with various weaner mobs drenched up to15 times a year.

Table 10a Farm Code 10 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	1493	1733	
LEV	947	1467	98 (82-990
BZ+LEV+ABA	960	93	0 (0-47)
NAP+BZ	773	813	96 (84-99)
NAP+LEV	507	707	97 (90-99)
CLOS+ABA	427	280	0
MOX oral	1347	80	58 (0-93)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 10b Farm Code 10 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Trichostrongylus colubriformis*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	1493	1733	
LEV	947	1467	0 (0-58)
BZ+LEV+ABA	960	93	99 (99-99)
NAP+BZ	773	813	0 (0-71)
NAP+LEV	507	707	0 (0-38)
CLOS+ABA	427	280	100
MOX oral	1347	80	99 (99-99)

ABA=abamectin BZ= benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 10c Farm Code 10 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Yes and worm testing
If some sheep in the mob are showing visual signs of worms when mustered, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are always moved to paddocks recently grazed by cattle, forage crops or recently established pastures
Is ASBV WEC part of the selection index for rams?	Yes

3.3.11 Farm Code 11

This 1800 hectare farm, located south of Goondiwindi in the 600mm annual rainfall zone runs a mixed merino enterprise managed under a rotational grazing strategy. Paddocks are grazed between 4 and 10 days and rested about 100 days.

All drench actives tested were efficacious against *H. contortus* (Table 11a). Because of previous concerns about moxidectin efficacy, a pyraclophos drench was dosed concurrently with the long acting injectable formulation on the advice of the farm's consultant. This may have masked resistance to the moxidectin long acting injection.

Responses to drenching practices questions are tabulated in Table 11b. This farm is drenching more frequently than five years ago.

Table 11a Farm Code 11 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	507	307	
LEV	1213	0	100
NAP	467	0	100
BZ+LEV	787	0	100
BZ+LEV+ABA	573	0	100
BZ+LEV+ABA+CLOS	973	0	100
CLOS+ABA	293	0	100
MOX long acting injection +PYR	720	0	100

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 11b Farm Code 11 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are usually moved after drenching to paddocks rested paddocks
Is ASBV WEC part of the selection index for rams?	Yes

3.3.12 Farm Code 12

This farm is located in the Tenterfield region in the 700mm annual rainfall zone and runs a self-replacing Merino flock with weaners stocked at 3DSE/hectare. Fifty percent of the farm is stocked with cattle. Currently this farm is purchasing wethers that will be integrated with the home mob on arrival at the farm. General rainfall can be variable in amount and onset. Dry periods usually only extend for a few months.

Anthelmintic resistance was identified in *H. contortus* (Table 12a).The closantel based combination was effective. Moxidectin was not tested. Benzimidazole alone was included at the owner's request and it was ineffective. Levamisole alone was not giving good control of *H. contortus* but when combined in the 4-active short-acting combination, was effective. Naphthalophos alone and in combination with benzimidazole and levamisole was effective.

Responses to drenching practices questions (Table 12b). This farm is drenching more often than five years ago.

Table 12a Farm Code 12 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	2307	2827	
BZ	3667	1557	65 (42-79)
LEV	5960	1187	84 (71-91)
NAP	2173	53	98 (91-99)
NAP+BZ+LEV	2267	133	95 (78-99)
BZ+LEV+ABA+CLOS	2573	133	96 (89-98)
CLOS+ABA	4520	53	99 (70-99)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole NAP=naphthalophos

Table 12b Farm Code 12 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Averaged sized
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are always moved after drenching to paddocks recently grazed by cattle
Is ASBV WEC part of the selection index for rams?	No

3.3.13 Farm Code 13

This pastoral zone farm is south east of Charleville and receives on average 350mm annual rainfall. General rainfall can be variable in amount and onset with dry periods that extend for months and years. Typically the dry weather is followed by a run of very wet seasons during which worm infections cause deaths of weaner mobs. This farm runs a self-replacing Merino flock. Weaners are purchased locally and run as one mob. Ewes with lambs are stocked at 1 sheep to 10 acres as the country has a low carrying capacity. Currently this farm is purchasing weaners to integrate with the home mobs.

Anthelmintic resistance was not identified in *H. contortus* (Table 13a). All drenches tested were efficacious. Naphthalophos was not tested.

Responses to drenching practices questions are tabulated in Table 13b. This farm has reported no change in drenching frequency over the last five years.

Table 13a Farm Code 13 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.) against *Haemonchus contortus*

Anthelmintics tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	3507	2707	
BZ	2747	66	97 (75-99)
LEV	2213	26	98 (91-99)
CLOS+ABA	1867	0	100
MOX long acting injection	2853	13	99 (92-99)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin

Table 13b Farm Code 13 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often you now drench your sheep?	No change
Are weaners drenched to a regular planned program?	Worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	No
Do you practice a ‘drench and move’ strategy	Sheep are usually moved after drenching to rested paddocks or set-stocked for a long acting drench
Is ASBV WEC part of the selection index for rams?	Yes

3.3.14 Farm Code 14

This farm located north east of St George in the 550mm annual rainfall zone runs a self-replacing Merino flock. General rainfall can be variable in amount and onset and dry periods can extend for a few months to years.

Anthelmintic resistance was identified in *H. contortus* (Table 14a). The closantel (50g/L) plus abamectin combination had reduced efficacy. Moxidectin oral was ineffective but the more potent moxidectin long acting injection was efficacious. Levamisole alone and in combination with benzimidazole was efficacious. Naphthalophos alone was efficacious. Responses to drenching practices questions are tabulated in Table 14b. This farm is drenching more frequently than five years ago.

Table 14a Farm Code 14 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) Confidence Intervals (C.I.) against *Haemonchus contortus*

Anthelmintics tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
+Control	1320	+1320	
LEV	663	13	98 (90-99)
NAP	693	0	100
BZ+LEV	736	0	100
CLOS+ABA	1867	187	90 (59-98)
MOX oral	1320	160	88 (79-93)
MOX long acting injection	3467	13	99 (84-99)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos
+control group salvaged drenched on animal welfare grounds before post-drench samples could be collected

Table 14b Farm Code 14 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Some sheep are drenched to a regular planned program Some mobs are worm tested
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are sometimes moved after drenching to rested paddocks or paddocks recently grazed by cattle or dry adult sheep
Is ASBV WEC part of the selection index for rams?	No

3.3.15 Farm Code 15

This 25000 hectare farm is located west of Roma in the 400mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather that can last for months to years. This farm runs a self-replacing Dorper and Damara flock with 13500 ewes, 2500 weaners and 400 rams. This farm participated in the worm egg counting schools run by the WeanerSafe project in 2011. All worm testing is currently conducted on-farm.

Anthelmintic resistance was not identified in *H. contortus* (Table 15a). All drenches tested were effective.

Responses to drenching practices questions are tabulated in Table 15b. This farm is drenching more often than five years ago.

Table 15a Farm Code 15 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy(%) (Confidence Intervals(C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	1213	1560	
LEV	2353	17	99 (96-99)
NAP	1733	27	99 (98-99)
BZ+LEV	2480	13	99 (92-99)
BZ+LEV+ABA	1937	0	100
CLOS+ABA	3880	0	100
MOX long acting injection	2240	67	98 (85-99)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 15b Farm Code 15 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Averaged sized
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	No
Do you consider AR still to be of concern?	No
Do you practice a ‘drench and move’ strategy	No
Is ASBV WEC part of the selection index for rams?	No

3.3.16 Farm Code 16

This 4000 hectare farm is located south of Goondiwindi in the 500mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather that can last for months to years. This farm runs a white Dorper self-replacing flock with 2000 ewes. The farm has only been in sheep for the last two years.

Anthelmintic resistance was identified in *H. contortus* (Table 16a). None of the long acting drenches were efficient. Levamisole and naphthalophos are giving good control.

Responses to drenching practices questions are tabulated in Table 16b. This farm is drenching more often than two years ago.

Table 16a Farm Code 16 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	5213	+5213	
LEV	6480	153	98 (89-99)
NAP	3947	0	100
CLOS	4400	937	79 (40-93)
CLOS+ABA	4733	1090	76 (46-90)
MOX long acting injection	7493	2400	73 (0-98)
Capsule (BZ+ABA)	4880	4870	0 (0-64)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos +control group salvaged drenched on animal welfare grounds before post-drench samples could be collected

Table 16b Farm Code 16 - Responses to drenching practices questionnaire

Question	Response
Compared to 2 years ago, how often do you now drench your sheep?	More often No sheep 2 years ago
Are weaners drenched to a regular planned program?	WormBuster program and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	N/A
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Not at present Will rotate when fencing is completed
Is ASBV WEC part of the selection index for rams?	No

3.3.17 Farm Code 17

This 1800 hectare farm is located east of Inglewood in the 550mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather that can last for months to years. This farm runs a self-replacing Merino flock with about 3000 sheep.

Anthelmintic resistance was identified in *H. contortus* (Table 17a). Against *H. contortus*, neither the closantel based combination nor the moxidectin long acting injection were efficient. Levamisole alone and naphthalophos alone were effective.

Against *T. colubriformis*, moxidectin long acting injection was efficacious whereas the abamectin in combination with closantel was not effective indicating resistance to the less potent drench active in the ML drench class (Table 17b). This result needs further investigation.

Responses to drenching practices questions are tabulated in Table 17c. Sheep are being drenched more often than five years ago. Drenches are dosed at the recommended dose rate. The owner was unaware that poor wool growth could be due to inefficient worm control due to failing anthelmintics.

Table 17a Farm Code 17 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	3347	1750	
LEV	3243	40	97 (89-99)
NAP	4424	70	96 (71-99)
CLOS+ABA	3987	533	73 (59-83)
MOX long acting injection	3350	733	45 (23-61)

ABA=abamectin CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 17b Farm Code 17 - Undifferentiated group mean worm egg counts (eggs per gram(epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Trichostrongylus colubriformis*

Anthelmintics tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%) (C.I.)
Control	3347	1750	
LEV	3243	40	N/A
NAP	4424	70	N/A
CLOS+ABA	3987	533	78(66-86)
MOX long acting injection	3350	733	95 (93-97)

ABA=abamectin CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos
N/A=not applicable due to insufficient *T. colubriformis* larvae in these treatment groups

Table 17c Farm Code 17 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	Yes, only because of resistance testing
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sometimes to paddocks recently grazed by dry adult sheep
When you purchase rams is ASBV WEC part of the selection index?	Yes

3.3.18 Farm Code 18

This 400 hectare farm is located near Stanthorpe in the 750mm annual rainfall zone. General rainfall is variable in amount and onset with periods of dry weather. This farm runs a self-replacing Merino Border Lester cross flock with about 380 ewes, 430 lambs and 60 cattle. Terminal sires are Poll Dorset. Rotational grazing has reduced drench usage by 30% in the last five years. FAMACHA© scoring and Haemonchus Dipstick© testing of individual mobs and individual animals is part of the worm management strategy.

Anthelmintic resistance was identified in *H. contortus* (Table 18b). The closantel based combination (50g/L) was not effective but the moxidectin long acting injection was efficacious. All the short acting drenches tested, were efficacious. The ML drench actives were effective against *T. colubriformis* (Table 18b).

Responses to drenching practices questions are tabulated in Table18c.

Table 18a Farm Code 18 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	107	380	
LEV	640	80	99 (93-99)
NAP	707	27	99(91-100)
BZ+LEV	1200	40	99 (99-100)
BZ+LEV+ABA	667	0	100
CLOS+ABA	200	213	66 (0-98)
MOX long acting injection	1027	27	99 (89-99)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 18b Farm Code 18 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Trichostrongylus colubriformis*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.)
Control	107	380	
LEV	640	80	89 (0-99)
NAP	707	27	62 (0-99)
BZ+LEV	1200	40	74 (0-97)
BZ+LEV+ABA	667	0	100
CLOS+ABA	200	213	97 (46-99)
MOX long acting injection	1027	27	100

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 18c Farm Code 18 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	Less often
Are weaners drenched to a regular planned program?	Rotational grazing and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	Yes
Have you changed drenches in the past because of perceived drench failure?	Yes, only because of resistance testing
Do you consider AR still to be of concern?	No
Do you practice a ‘drench and move’ strategy	Always to paddocks recently grazed by cattle
Is ASBV WEC part of the selection index for rams?	No

3.3.19 Farm Code 19

This 5000 hectare farm is located in the Tenterfield region in the 750mm annual rainfall zone. General rainfall is variable in amount and onset with extended periods of dry weather. The Merino wether flock consists of about 5000 sheep on 850 hectares. Weaners are purchased and run as a single mob.

Anthelmintic resistance was identified in *H. contortus* (Table 19a). Closantel alone and moxidectin long acting injection were efficacious. Levamisole alone, or in combination with benzimidazole did not give good control but in combination with benzimidazole and abamectin, was efficacious. Naphthalophos alone is giving good control.

Responses to drenching practices questions are tabulated in Table 19b. The drenching frequency on this farm is the same as it was five years ago.

Table 19a Farm Code 19 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintics tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%) (C.I.)
Control	1893	2453	
LEV	2133	240	91 (81-96)
NAP	3333	133	97 (89-99)
BZ+LEV	3027	427	89 (63-97)
BZ+LEV+ABA	2521	173	95 (86-98)
CLOS	2773	173	95 (79-99)
MOX long acting injection	2373	40	99 (96-99)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 19b Farm Code 19 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often you now drench your sheep?	No change
Are weaners drenched to a regular planned program?	Sheep are drenched to a planned program along with worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench the whole mob?	Yes
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes, “plus a bit’
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	No
Do you consider AR still to be of concern?	Yes
Do you practice a ‘drench and move’ strategy	Sheep are always to paddocks recently grazed by cattle and rested native pastures
Is ASBV WEC part of the selection index for rams?	No

3.3.20 Farm Code 20

This 500 hectare farm is located in the Tenterfield region in the 750mm annual rainfall zone. The farm runs a fine wool Merino flock of about 500 ewes.

Anthelmintic resistance was identified in *H. contortus* (Table 20a). The long acting drenches are not giving good control of *H. contortus*. Levamisole alone, or in combination with benzimidazole and levamisole is not giving good control. Naphthalophos alone was not tested but naphthalophos in combination with benzimidazole was efficient but inefficient in combination with levamisole. This farm always uses naphthalophos in combination with benzimidazole or levamisole.

The ML class of actives are giving good control *T. colubriformis* (Table 20b). Responses to the drenching practices questions are tabulated in Table 20c. This farm is drenching more frequently than in previous years and doses more that the recommended dose rate.

Table 20a Farm Code 20 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Haemonchus contortus*

Anthelmintic tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%)(C.I.
Control	933	973	
LEV	893	97	94 (80-98)
NAP+BZ	547	13	99 (90-99)
NAP+LEV	893	227	82 (64-91)
BZ+LEV+ABA	680	200	71 (0-93)
CLOS+ABA	1147	173	84 (51-95)
MOX oral	893	200	79 (0-96)

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 20b Farm Code 20 - Undifferentiated group mean worm egg counts (eggs per gram (epg)), and Efficacy (%) (Confidence Intervals (C.I.)) against *Trichostrongylus colubriformis*

Anthelmintics tested	Average faecal worm egg count (epg) Day 0	Average faecal worm egg count (epg) Day 10-14	Efficacy (%) (C.I.)
Control	933	973	
LEV	893	97	0 (0-65)
NAP+BZ	547	13	69 (0-98)
NAP+LEV	893	227	30 (0-65)
BZ+LEV+ABA	680	200	100
CLOS+ABA	1147	173	100
MOX oral	893	200	100

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos

Table 20c Farm Code 20 - Responses to drenching practices questionnaire

Question	Response
Compared to 5 years ago, how often do you now drench your sheep?	More often
Are weaners drenched to a regular planned program?	Yes and worm testing
If some sheep in the mob are showing visual signs of worms when mustered for other reasons, do you drench?	Yes, the whole mob is drenched
When drenching your sheep, do you determine the dose rate on an estimate of the weight of the largest sheep in the mob?	Yes
Is the recommended dose given?	More than
Have you changed drenches in the past because of perceived drench failure?	Yes
Do you consider AR still to be of concern?	Yes
Do you practice a 'drench and move' strategy	Sheep are usually moved to fresh paddocks
Is ASBV WEC part of the selection index for rams?	Yes

4. Part 2: Safe grazing for weaner sheep

4.1 Introduction

Spring lambing is practised by the majority of farms across southern Queensland to take advantage of good pasture growth over summer. The hot moist conditions that ensure grass growth also support outbreaks of haemonchosis.

Grazing weaners on low-worm pastures during hot wet seasons is recommended to maximise productivity and reduce the frequency of drug treatments (www.wormboss.com.au). Low worm pastures are developed using time-controlled rotational grazing strategies and *H. contortus* infections are well managed under this type of system. When moisture is not limiting, temperature determines the rate of egg hatch and length of time worm larvae remain alive on pasture. Worm eggs hatch in 7 days when ambient temperatures are continuously at 27°C. However, the diurnal fluctuations in temperatures change over time, impact the time taken to completion of parasite developmental stages on pastures and affect the logistics of time-controlled rotational strategies.

This trial was designed to determine the logistics of Safe Grazing for weaner sheep on farms in the inland south east Queensland where cattle and crops are not easily integrated into the grazing system. It is envisaged that this technology would be suitable for use in years when moisture is not limiting for parasite development.

4.2 Methodology

Co-operator farms

This project was originally designed to enrol two sheep-only farms into the grazing trial. Each farm was to manage a group of sixty sheep under a time-controlled rotational grazing system and on another part of the farm, a similar group of sheep would be managed under a continuous grazing system. As this arrangement was considered by co-operators to be too disruptive to existing farm management the compromise was to enrol farms in the region already rotationally grazing (n=3) or continuously grazing (n=3) (Table 21).

Farms were located in the Millmerran to Stanthorpe region (Figure 2). Dalveen farm was enrolled in mid-2012 with data collected over one summer period only. In the first grazing season no attempt was made to influence normal farm management. Managers determined when to drench and the class of drench to administer. For the Safe Grazing farms, owners also determined the logistics of their rotation system. In most cases, the drench resistance test had not been conducted prior to the start of the trial.

In the second season the only change to the continuously grazed farm management was the use effective drench treatments in line with animal welfare guidelines and to preserve farm profitability. For the Safe Grazing farms adjustments to the pasture graze and rest times were made as appropriate. Only effective drench treatments were administered. Ultimately, because of the uniqueness of each farm, each one acted as its own control with data to be assessed over three grazing seasons.

Table 21 Profiles of co-operator farms participating in the Safe Grazing trial

Farm	Gore	Dalveen	Ballandean	Inglewood	Millmerran	Stanthorpe
Region	Traprock	Traprock	Granite Belt	Traprock	Darling Downs	Granite Belt
Grazing type	*continuous*	*continuous*	*continuous*	*rotational*	*rotational*	*rotational*
Breed of animal	Merino	Merino	Corriedale	Merino	Dorper	Merino X Border Leister
Origin of sheep	introduced	homebred	homebred	introduced	homebred	homebred
Enterprise type	wool	wool	wool/meat	wool	meat	meat
Pasture type	Blue grass	Blue grass	Blue grass	Blue grass	Rhodes grass	Kikuyu Fescue Clover
Dry matter (DM) yields kilogram (kg) /hectare(ha)	200	156	2006	908	1700	4633
*Average diurnal temperature (^{0} C) range	17-33	17-33	14-27	17-33	17-33	14-27
*Average number of days with temperatures ≥35^0 C	27	27	1.2	27	27	1.2

*Long term averages sourced from www.weatherzone.com.au

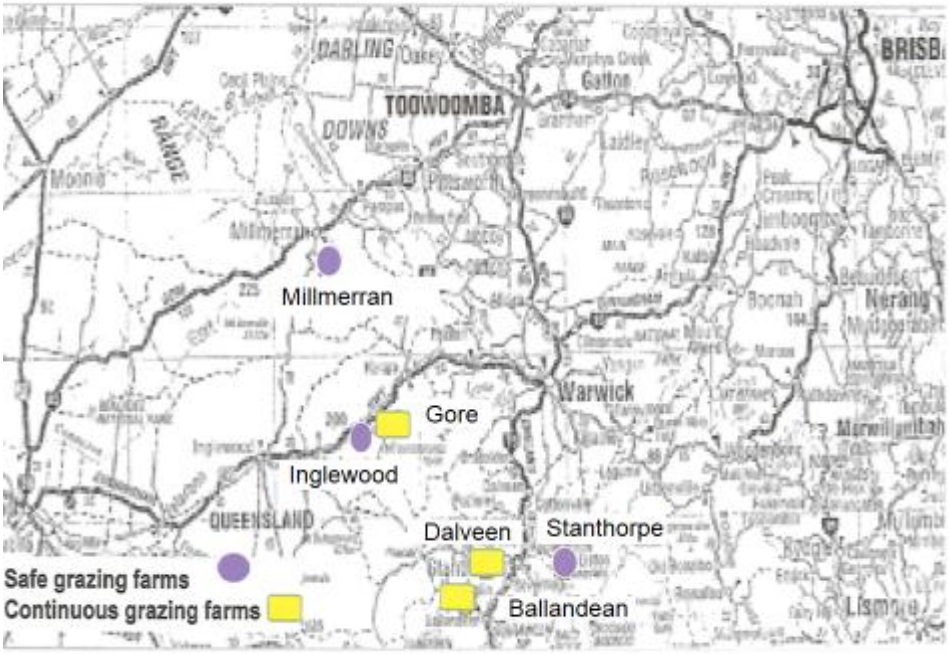

Figure 2 Location of co-operator farms in south east Queensland

On-farm testing

On each farm, 60 sheep were ear tagged and faecal samples collected for individual worm egg counts and larval culture approximately every eight weeks. Live-weights, rainfall readings and pasture data were also collected. Farm managers submitted mob monitor samples for worm egg counting four weeks after each farm visit by project staff. In the second season mob monitor samples for worm egg counts tracked the build-up of infections over the dry months until the break in the season when farm visits by project staff resumed. Drench resistance testing was satisfactorily completed on four farms. Further testing is required on Gore and Inglewood farms.

Data loggers to record temperature (^{0} C) and Relative Humidity (RH) were installed on pastures near sheep camps. Pastures were assessed in terms of per cent perennial, persistent and productive (3P). Quadrant pasture samples were collected for Dry Matter (DM) yields per kilogram (kg) per hectare (ha). Weaner productivity was measured by live-weight gains and wool cut.

Parasitology

Samples were analysed by the modified McMaster technique, either individually or as a composite of five samples. Eggs were enumerated at x40 magnification with a sensitivity of <50 epg (individual) or <40 epg (composite). Bulk larval cultures were set-up and incubated for 7 days at 27°C. Differentiations of at least 100 infective larvae were conducted for each bulk culture.

Communications

Initial discussions were conducted with each owner / manager at the commencement of the project. Information meetings was held in May 2012 (Warwick) and March 2013 (Stanthorpe). Conversations regarding the project were held on-farm with the owners and managers.

4.3 Results for individual farms

4.3.1 Continuously grazed farms

The three continuously grazed farms, Gore, Dalveen and Ballandean were monitored to provide region-typical comparative data for the Safe Grazing farms. Located in south east Queensland approximately 200 km west of Brisbane, Gore and Dalveen are sheep-only Traprock farms. Historically, merino sheep in this region are grazed on unimproved pastures but in the last few years the numbers of farms running meat breeds of sheep have increased. Cattle are run on the better country along creek banks. Average rainfall is about 650mm to 700mm per annum with most rain falling in summer although good falls of rain do occur during the cooler months.

Ballandean is in the transitional zone between the Traprock and the Granite Belt and experiences higher rainfall, fewer days with temperatures over 35^0 C and higher pasture dry matter yields than Gore and Dalveen. High dry matter yields allow Ballandean to rotate cattle though sheep paddocks when necessary.

In normal years worm burdens build after the first summer storms to peak from November to February. This peak coincides with weaning when young stock are most susceptible to heavy infections. Typically two to three drenches are dosed to

prevent stock losses. In 2013, the onset of summer storms was delayed until late December.

4.3.1.1 Continuously grazed farm 1 - Gore

The farm

Gore farm grazes about 17000 fine wool merino sheep across three farms in the region including the Safe Grazing farm at Inglewood. Typically, weaner wethers are sourced from the New England district of New South Wales each September, the mob is then spilt and allocated to farms as appropriate.

Key findings

- Identification of an efficient drench was considered by the owner to be the most important outcome of the trial
- A series of days with temperatures >35^0 C were lethal to pasture larvae. The grass cover on this farm is sparse allowing the drying effects of the sun to be maximised. The region experiences a long term average of 27 days a year with temperatures ≥35^0 C (weatherzone.com.au).
- All drench combinations tested were 'resistant' in a drench test
- As weaners are sourced from regions considered high-risk for drench resistance it is likely that much of the drench resistance on this farm and on the Inglewood farm has been imported
- A stumbling block to adopting Safe Grazing is the concern that Traprock pastures 'sucker' during long rest periods
- Worm egg counts were lower in season two. Only one short acting drench was administered
- Wild dogs are causing significant sheep losses

Observations and measurements

In the first grazing season, 800 weaner wethers, 12 months of age, and in the second grazing season 470 weaner wethers, 17-18 months of age were inducted into the grazing trial. Typically, purchased weaners are quarantine drenched and held until introduced into the grazing system each November and then continuously grazed until May. The weaner paddock is usually sheep-free for 84 days prior to introduction of stock (Table G.1). In second season weaners were inducted on arrival at the farm because of the dry conditions.

Table G.1 Continuous grazing system for weaner sheep on Gore 2011-2013

Logistics of grazing strategy	Grazing season	
	2011-2012	2012-2013
Age at induction (months)	12	17-18
Number of paddocks	1	1
Paddock preparation time (days)	84	0
Pasture graze time (days)	continuous	continuous
Pasture rest time (days)	N/A	N/A

The timing of treatments and treatment types (Table G.2) were at the discretion of the owner. Drench treatments were applied tactically when worm egg counts were between 500epg to 1000epg. Monepantel was the quarantine drench in both seasons.

Table G.2 Dates and drench treatments administered on Gore 2011-2013

Date	Drench treatment	Comments
01/09/2011	MPL	Quarantine drench
15/11/2011	MPL	Entry drench
23/02/2012	CLOS+ABA	
15/05/2012	NAP+LEV	Weaners remained in this paddock until spring and then moved to other paddocks on the farm
24/10/2012	MPL	Entry drench Late on-set of significant rain events

ABA =abamectin CLOS=closantel MPL=monepantel

The dominant pasture was Blue grass (Table G3). Dry matter yields were typically 200DM/kg/ha but measured 44DM/kg/ha at the start of the second season. At the conclusion of the trial in February 2013 the pasture yield was 153DM/kg/ha, the extra growth due to the late onset of summer storms.

Table G.3 Pasture details on Gore 2011-2013

Pastures	Grazing season	
	2011-2012	2012-2013
Grass green an actively growing *on entry*	yes	yes
Grass green an actively growing *on exit*	no	yes
Grass cover	low	moderate
Grazing height (cm)	3	2
% Productivity	30	50
% Perennial	100	100
% Palatable	80	80
% legume or herb	5	5
Actual Dry Matter yields (DM/kg/ha)	200	44

Data logger readings (Figure G.1) in the first season fluctuated between 11^0 C and 43^0 C (Figure G.2). Relative humidity readings were consistently 60-80% or above, a level suitable for the continuation of the worm cycle on pasture.

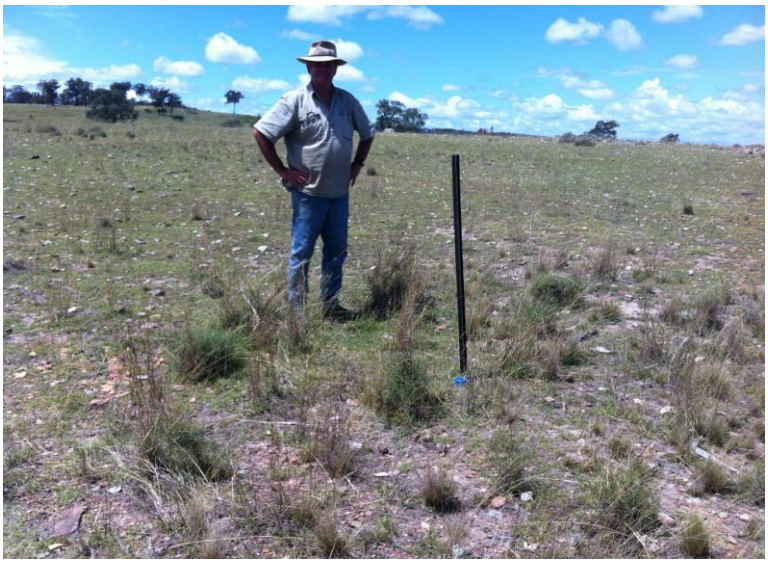

Figure G.1 Pastures and data logger location on Gore February 2012

Total rainfall for the three month period December to February was 221mm in season one and 254mm in season two. Peak rainfall was 111mm (December season one) and 117mm (December season two). The mob average worm egg count in January 2012 was 307epg but only 40epg in January 2013 (Figure G.3). Rainfall totals and incidence were similar in both years.

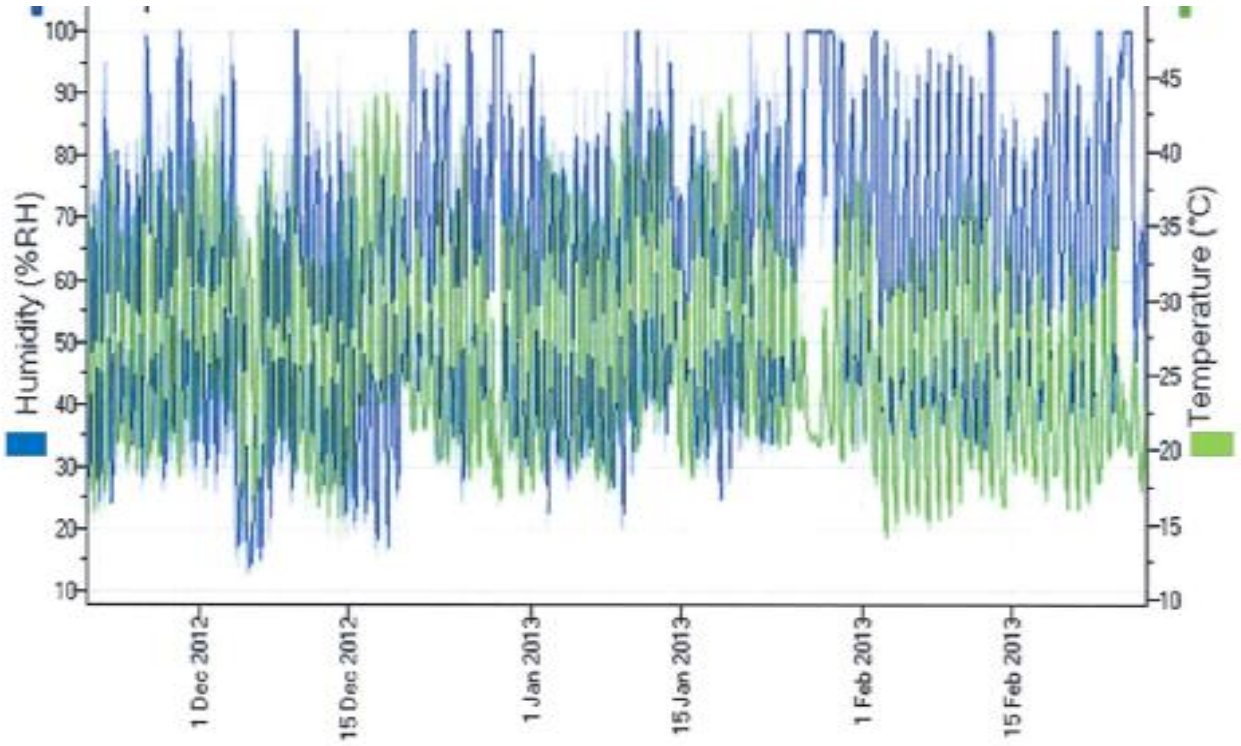

Figure G.2 Temperature (^{0} C) and relative humidity (RH) readings on Gore December 2012-February 2013

Worm egg counts in the first grazing season were controlled with two drenches in addition to the entry drench. Both the end-of season and the May drenches tested "resistant" against *H. contortus* in a drench resistance test conducted by the local reseller in September 2011. The reduced efficacy of both these drenches may explain the continuous low level infections into autumn (Figure G.3) on this farm and on Inglewood. The owner requested that further resistance testing be delayed on Gore and Inglewood until the 2013-2014 grazing season.

H. contortus was the predominant worm population in coproculture but small numbers of *T. colubriformis* populations were also present in some coprocultures. These levels were too low for definitive resistance analysis and results are indicative only. *H. contortus* was resistant to all drench actives tested (Table G.4a). The ML based drench actives alone or in combination were effective against *T. colubriformis* (Table G.4b) except for the 3-way combination drench containing abamectin. Efficacy of abamectin alone against *T. colubriformis* needs to be further investigated.

The use of inefficient drench products on both farms represents poor communication between all parties concerned and underscores the need for better communication of results and an acknowledgement from the farmer that he understands the information being delivered.

In season one, weaners were on average 42kg when purchased and 45kg by the end of grazing. Wool cut 4.2 kg of 16.8 micron wool per head at shearing in August 2012. In the second season, weaners were 33 kg in November 2012 and 45 kg in February 2013. Sheep are shorn in August.

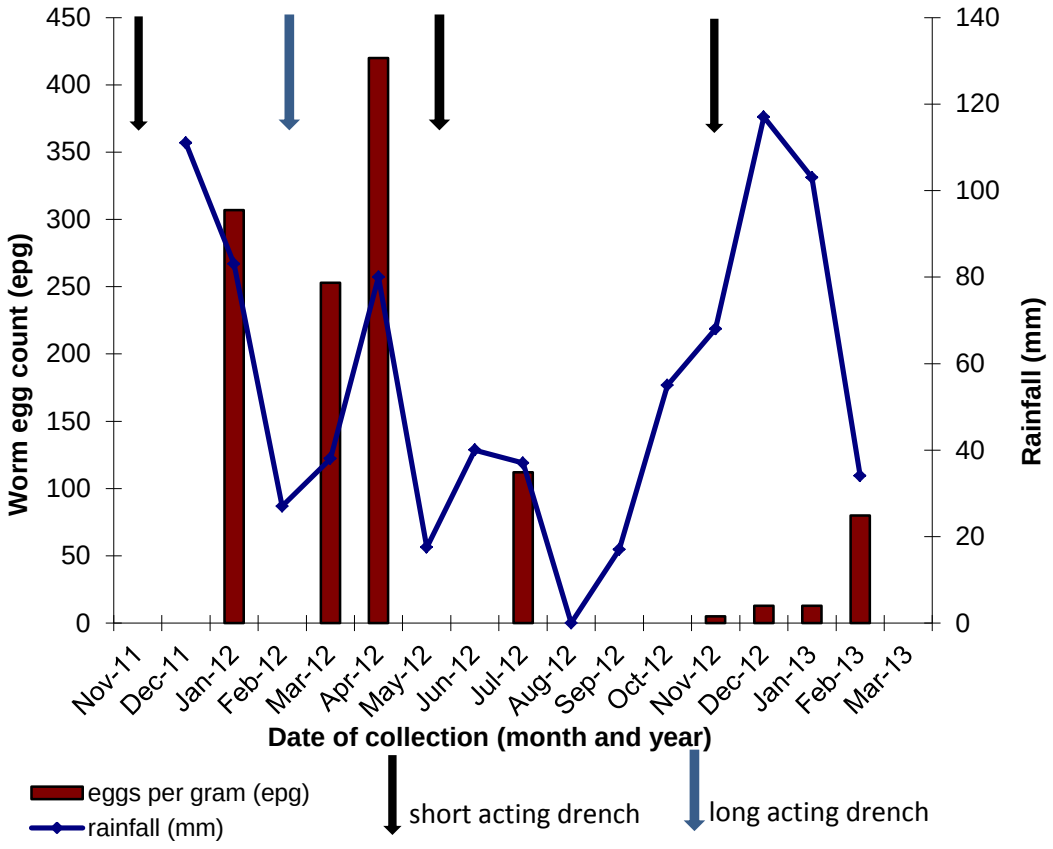

Figure G.3 Worm egg counts (epg), rainfall (mm) and drench treatments on Gore 2011-2013

Table G.4a Efficacy of drench actives against *Haemonchus contortus* on Gore

Drench actives tested	Efficacy (%)	†Resistance status
LEV	85	Resistant
BZ+LEV+ABA	56	Resistant
NAP+LEV	50	Resistant
NAP+BZ+LEV	74	Resistant
CLOS+ABA	78	Resistant
MOX long acting injection	50	Resistant
BZ+ABA Capsule+LEV	20	Resistant

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Table G.4b Efficacy of drench actives against *Trichostrongylus colubriformis* on Gore

Drench actives tested	Efficacy (%)	†Resistance status
LEV	81	Resistant
BZ+LEV+ABA	90	Resistant
CLOS+ABA	100	Non-resistant
MOX long acting injection	100	Non-resistant
BZ+ABA Capsule+LEV	100	Non-resistant

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Owner's responses to questions about worm control on Gore and Inglewood

Worm control on your farm

- *We buy weaner wethers from northern New South Wales every year*
- *With the start of the wet season two years ago stocking rates were increased and worms became a problem. At that time resistance testing showed that what I thought to be a 90% kill was really a 50% kill. That was a big wake-up call.*
- *Pastures are always shorter than 10cm during grazing on Gore*

Cost of production

- *Worm infections are a major cost to production*
- *Drenches cost about $10/ head for labour and product*
- *Drench costs account for 30% of costs/year over my three farms*
- *Deaths due to worms is about 3-4% per annum. We lost 400 weaners out of 16000 two years ago.*

Rotations on Gore

- *Fencing would be a major infrastructure cost*
- *Dust has been an issue but with the increased rainfall over the last few seasons pasture growth has been greater and the dust problem has been less.*

What have you gained from the project?

- *Increased worm testing gives me more information and a better picture of worm infections*

- *I have learnt a lot about the effect of high temperatures on pasture larvae and in turn the effects on worm egg counts. The Granite Belt has cold winters to clean pastures and the Traprock has the high temperatures during summer*
- *Yes, I will continue to test for resistance*
- *Rotations do give better grass cover but this country needs to be run hard to manage regrowth*
- *If I am to control worms better in the future I need to know more about feed quality, drench resistance levels and set stocking*

4.3.1.2 Continuously grazed farm 2 - Dalveen

The farm

This 1800 hectare fine wool merino enterprise is located in the Traprock region and runs 3000 merino sheep as a self-replacing flock producing lambs each September and October. Lambs are marked at 4 weeks of age, drenched and moved onto spelled pastures in spring. During spring and early summer, temperatures are often hot, rainfall low and residual winter pastures senescent. This farm was enrolled in 2012.

Key findings

- The owner considered a 'good' drench to be an important outcome of the trial
- The owner was unaware of drench resistance until it was suggested by a pharmaceutical representative as a reason for the poor wool cuts in the last few years
- By grazing weaners with three year old wethers pasture infectivity was better controlled
- The owner will move into rotational grazing when the wild dog situation is under control
- Pasture quality is poor. The owner has observed that pasture quality improves when sheep are rotationally grazed.
- Wild dogs are constantly a threat and responsible for significant losses of weaner sheep

Observations and measurements

Information was collected for the 2012-2013 grazing season only.

Four hundred homebred mixed sex weaners, 12 months of age were continuously grazed in a 200ha paddock. Preparation time for pastures was reduced to 12 days as sheep were boxed with 3 year old wethers until the wild dog threat had been resolved (Table D.1).

Table D.1 Continuous grazing system for weaner sheep on Dalveen 2012-2013

Logistics of grazing strategy	Grazing season	
	2011-2012	2012-2013
Age of induction (months)	Not enrolled	12 months
Number of paddocks		1
Paddock preparation time (days)		12
Pasture graze time (days)		continuous grazed with wethers
Pasture rest time (days)		N/A

The entry drench was efficacious (Table D.2) and had been chosen by the owner on the results of a previous resistance test conducted by a pharmaceutical representative. Two short acting efficacious drenches were dosed in the 2012-2013 season in addition to a drench in April.

Table D.2 Dates and drench treatments administered on Dalveen 2012-2013

Date	Anthelmintic drenched	Comments
18/04/2012	BZ+LEV+ABA	
14/09/2012	BZ+LEV+ABA	Entry drench
12/03/2013	NAP+BZ+ABA	Exit drench

ABA =abamectin BZ=Benzimidazole LEV=levamisole NAP=naphthalophos

The dominant pasture on the farm was Blue grass (Figure D.1). Dry matter yields of 156 DM/kg/ha reflected the dry spring (Table D.3). Regular worm egg counts were instituted to monitor worm infections and informed drench decisions made by the owner. Weaners were drenched when the mob mean worm egg count was above 500epg.

Table D.3 Pasture details on Dalveen 2012-2013

Pastures	Grazing season	
	2011-2012	2012-2013
Grass green an actively growing *on entry*	Not enrolled	No – some green pick
Grass green an actively growing *on exit*		yes
Grass cover (%)		75
Grazing height (cm)		10
% Productivity		25
% Persistent		20
% Palatable		15
% legume or herb		5
Actual Dry Matter yields (DM/kg/ha)		156

Although reasonable rains (381mm) were received in the November to February period, the soil moisture profile was low after the dry spring. Highest rainfall was 116mm in December. Pastures eventually responded to the series of rain events and by February a humid environment for egg hatch and larval development was operating at the soil/grass interface.

The sudden rise in the mob average worm egg counts from 40epg in February to 1800epg in March illustrates the explosive nature of haemonchosis when pasture conditions become favourable for larval survival (Figure D.2).

Figure D.1 Pastures on Dalveen November 2012

A Safe Grazing drench resistance test was conducted in September 2012. *H. contortus* was the predominant parasite with smaller populations (1-15%) of *T. colubriformis* in some coprocultures.

Only four actives were tested. Levamisole alone and naphthalophos alone were effective against *H. contortus*. The combination of closantel (50g/L) and abamectin, and moxidectin long acting injection were not efficacious (Table D.4a).

Moxidectin long acting injection, the most potent in the ML class of drench actives was efficacious against *T. colubriformis.* The less potent active, abamectin in the combination with closantel, failed to control this parasite (Table D.4b). This result requires further investigation.

Average weight of weaners on induction into the grazing system was 22kg and on exit after summer grazing was 32kg. Weaners usually cut 3kg of 17.5 micron wool per head although measurements from trial weaners were not available for this report.

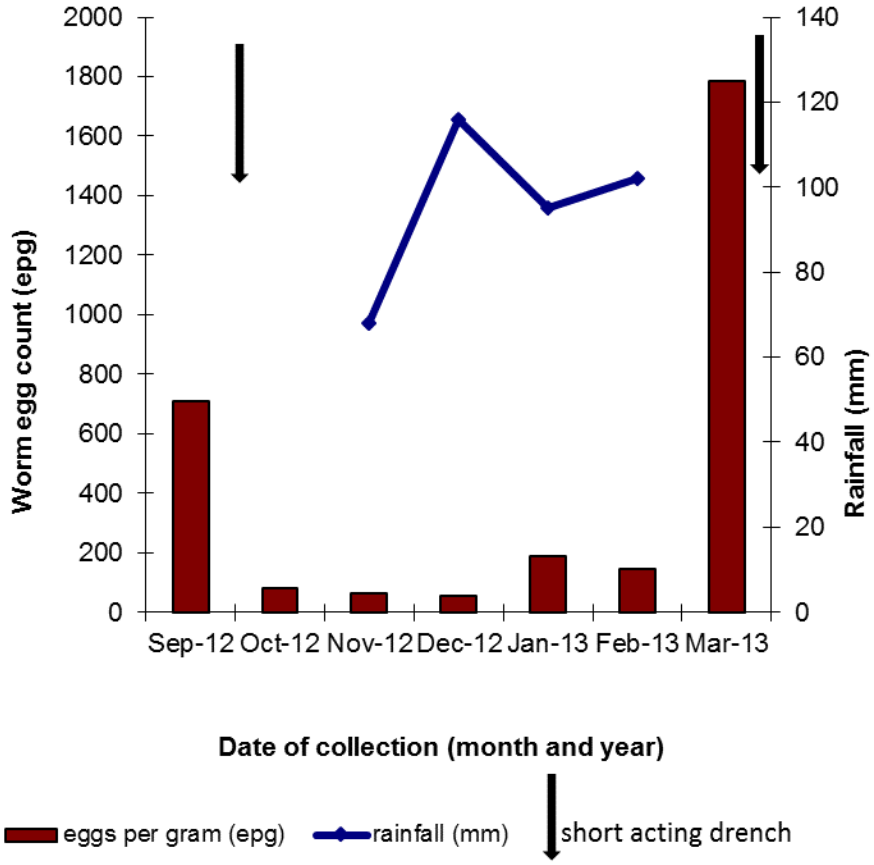

Figure D.2 Worm egg counts (epg), rainfall (mm) and drench treatments on Dalveen 2012-2013

Table D.4a Drench resistance in *Haemonchus contortus* on Dalveen

Anthelmintics tested	Efficacy (%)	†Resistance status
LEV	97	Non-resistant
NAP	96	Non resistant
CLOS+ABA	73	Resistant
MOX long acting injection	45	Resistant

ABA=abamectin CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Table D.4b Drench resistance in *Trichostrongylus colubriformis* on Dalveen

Anthelmintics tested	Efficacy (%)	†Resistance status
CLOS+ABA	78	Resistant
MOX long acting injection	95	Non-resistant

ABA=abamectin CLOS=closantel MOX=moxidectin
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Owner's responses to questions about worm control

Worm control on your farm

- *We don't buy in sheep, we breed replacement stock. We do buy in rams.*
- *We use terminal sires with resistance to worms*
- *Pastures are always (mostly) higher than 10 cm during summer grazing*

Cost of production

- *Drenches cost about $4.00/head. Labour is not included as we use our own labour.*
- *Subclinical losses – not sure*
- *No deaths due to worm this year. Two years ago we had an explosion of worm numbers and lost 5% of weaners. Losses were not as high in the wether flock.*

Rotations

- *We would use rotations if more paddocks were available. Extra fencing would be needed and would add to the cost.*
- *The size of current paddock is too big for available stock. It needs to be under 100ha.*
- *Rotations are not suitable for lambs 5 months of age although pastures are better after a period of spelling*

What have you gained from your limited time in the project?

- *Dry weather helps clean pastures of larvae leading to fewer worms*
- *Testing for worm levels is essential*
- *Feed quality not pasture spelling is the issue on this farm*
- *Will tend to move sheep in the future to improve pasture quality*
- *Will use the day 10 worm test to monitor drenches*

4.3.1.3 Continuously grazed farm 3 - Ballandean

The farm

This 6000 hectare farm located at Ballandean on the western Granite Belt / eastern Traprock region runs a Corriedale / Poll Dorset self-replacing flock of about 700 sheep on 1500 hectares. A beef cattle enterprise on the farm turns off weaners as they reach target weights. Lambing starts in August and is finished by September.

Key findings

- Identification of effective drench treatments was considered by the manager to be the most important outcome of the trial
- Worm egg counts on this farm were the highest and most persistent of all the continuously grazed farms
- Typically, in early spring sheep graze an understory of short green pick protected by taller dry grass that provides a humid environment for worm activity
- Larval survival is most likely longer on this farm as temperatures are often up to 5^0 C cooler than on the other Traprock farms
- The farm has the potential to incorporate cattle into the rotational grazing system
- Wild dogs are taking weaners, possibly up to 4 percent

Observations and measurements

One hundred and fifty-six homebred weaners, seven months of age were inducted into the trial in the first grazing season and 140 homebred hogget ewes, 12 months of age in the second grazing season. Paddocks were rested for 180 days prior to grazing (Table B.1).

Table B.1 Continuous grazing system for weaner sheep on Ballandean 2011-2013

Logistics of grazing strategy	Grazing season	
	2011-2012	2012-2013
Age of induction (months)	7	12
Number of paddocks	1	1
Paddock preparation time (days)	180	180
Pasture graze time (days)	continuous	continuous
Pasture rest time (days)	N/A	N/A

This farm regularly uses worm testing and a mean worm egg count >500epg is the trigger to drench. Two short-acting drenches in addition to the quarantine drench were dosed in each season to control worm infections. Monepantel was the quarantine drench in both seasons (Table B.2).

Table B.2 Date and drench treatments administered on Ballandean 2011-2013

Date	Drench treatment	Comments
22/12/2011	MPL	Entry drench
16/04/2012	NAP	
07/06/2012	BZ+LEV+ABA	
09/10/2012	MPL	Entry drench
24/01/2013	BZ+LEV+ABA	
01/03/2013	BZ+LEV+ABA	

ABA=abamectin BZ= benzimidazole LEV=levamisole MPL=moxidectin NAP=naphthalophos

The dominant pasture on the farm was Blue grass (Figure B.1). In season one, the dry matter yields were 2006 DM/kg/ha and 1861 DM/kg/ha, into and out of the rotations respectively. In season two, yields were 1586 DM/kg/ha on entry and DM/1813kg/ha after grazing. Only 50% of grass on entry to the grazing system in 2012 was “green and actively growing” (Table B.3).

Table B.3 Pasture details on Ballandean 2011-2013

Pastures	Grazing season	
	2011-2012	2012-2013
Grass green an actively growing *on entry*	yes	50%
Grass green an actively growing *on exit*	yes	yes
Grass cover (%)	100	100
Grazing height (cm)	15	12.5
% Productivity	35	35
% Persistent	50	50
% Palatable	60	60
% legume or herb	15	15
Dry Matter yields (DM/kg/ha) in	2006	1586

The wet autumn and early winter in 2012 supported cycling of worm infections until June when maximum temperatures started to fall below 18^0 C, the Dinaburg line for initiation of egg hatch and larval development.
The mob average worm egg count from the first season weaners was 1586epg in June (Figure B.2). These high worm infections during winter prompted the manager to spell the weaner paddock for eight weeks from June 2012 and then graze with cattle for another seven weeks.

Figure B.1 Pastures on Ballandean March 2012

While rainfall totals for the four month period November to February were similar (375mm in 2011-2012 and 380mm in 2012-2013) in both years, the distribution pattern was very different. In December 2011 the on-farm rainfall reading was 80mm contrasted with 170mm in December 2012.

The mob average worm egg counts were similar in both seasons, 1000epg in March 2012 and 893epg March 2013.

A drench resistance test was conducted in March 2012 (Table B.4). The predominant parasite was *H. contortus*. Resistance in *H. contortus* to the closantel (50g/L) plus abamectin combination and the moxidectin long acting injection is of concern on this farm. The BZ capsule, dosed concurrently with levamisole is giving good control but the true efficacy of the capsule may have been masked by the efficacy of levamisole. Levamisole alone, or in combination with benzimidazole and abamectin, was efficacious. Napthalophos alone was efficacious.

Table B.4 Efficacy of drench actives against *Haemonchus contortus* on Ballandean

Anthelmintic tested	Efficacy (%)	†Resistant status
LEV	99.3	Non-resistant
NAP	100	Non-resistant
BZ+LEV+ABA	100	Non-resistant
CLOS+ABA	43	Resistant
MOX long acting injection	87	Resistant
BZ Capsule+LEV	100	Non-resistant

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos †Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Average estimated weight of the seven month old weaners on entry into the rotation was 37kg in 2011, growing out to 45kg, three months later. Twelve month old weaners in 2012 were 50kg, growing out to 55kg by February 2013. Wool cuts were about 5kg per head of 23 to 24 micron wool.

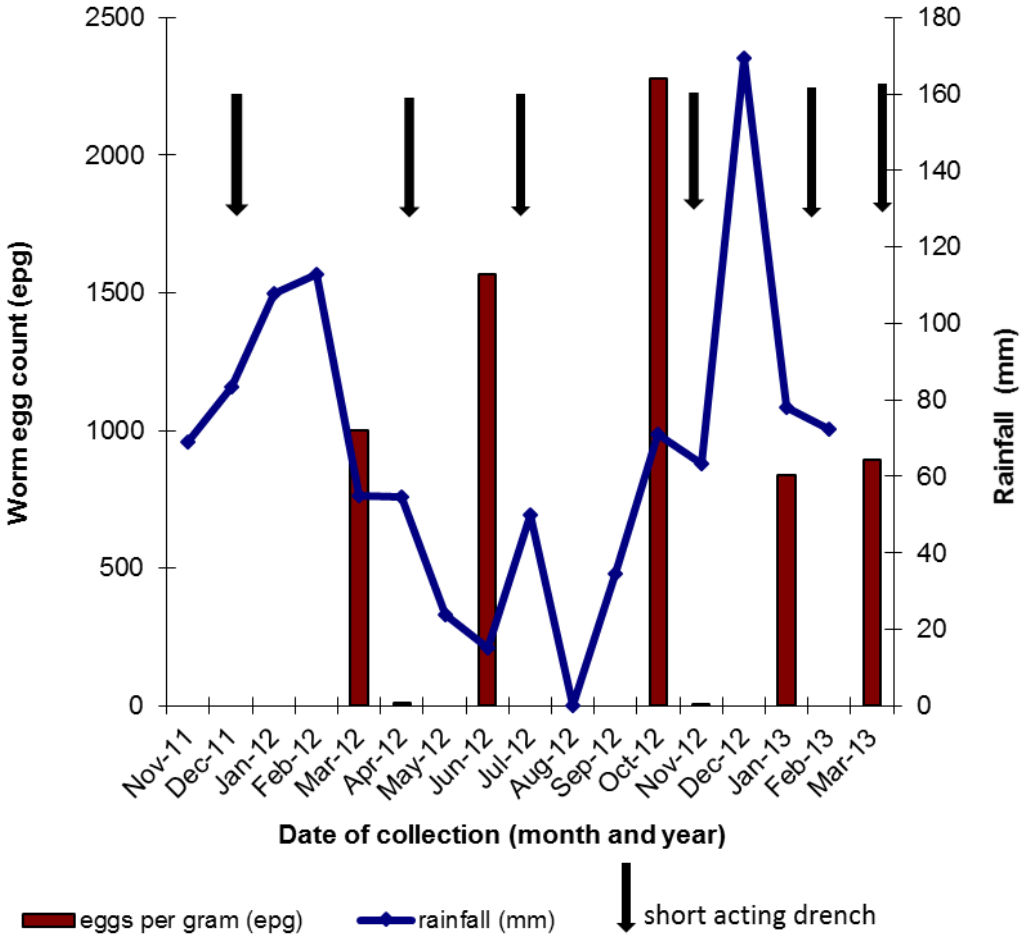

Figure B.2 Worm egg counts (epg), rainfall (mm) and drench treatments on Ballandean 2011-2013

Manager's responses to questions about worm control:

How do you guard against drench resistance on your farm?

- *We don't buy in sheep, they are homebred*
- *We do buy SAM terminal sires. We don't yet use ASBV WEC.*
- *Pastures are mostly grazed higher than 10 cm in summer*
- *We rotate drenches and take care with drench selection*

Cost of production

- *Owner would know drench costs*
- *Labour is an expense*
- *I think worms are causing subclinical losses*
- *Significant losses of weaners are due to wild dogs*

Rotations

- *Would use rotations if the wild dog problem is resolved*
- *Extra fencing would be needed*
- *To increase productivity pastures need to be improved so that ewes have more milk*

What have you gained from your limited time in the project?

- *An understanding that a good drench is most important for worm control*
- *An understanding that a 3 month rest period for paddocks especially during dry weather helps clean pastures of larvae*
- *Testing for worm infections is essential*
- *Feed quality important for ewes to increase conception rates*
- *We will continue to test for resistance*

4.3.2 Safe Grazing farms

The three Safe-Grazing farms, Inglewood, Millmerran and Stanthorpe while in the same general annual rainfall zone of 650mm to 750mm were different in terms of climate and soils. The Inglewood farm is a sheep-only enterprise in the Traprock. Millmerran has a climate similar to Inglewood but integrates crops with pastures for worm-free grazing. Stanthorpe, in the Granite Belt has a slightly wetter and milder climate. On this farm pastures are highly productive and cattle are more easily integrated into the rotations as required.

4.3.2.1 Safe Grazing farm 1 - Inglewood

The farm

This 1200ha farm is located in the Traprock region west of Stanthorpe. It is rotationally grazed and part of the Gore complex of farms. Merino weaner wethers are sourced from the New England of New South Wales each September. The ‘top’ group are run on Gore and the ‘tail’ group allocated to this farm. Drench resistance on this farm is similar to that on Gore and has most likely been imported in sheep from the New England. Weaners are quarantine drenched on arrival and held before being introduced into one of the weaner paddocks.

Key findings

- Identification of effective drenches was considered by the owner and manager to be most important in achieving better worm control
- The previous owner developed the rotational grazing system to better control the continuously high worm infections on this farm. The current owner has continued with this strategy.
- All drench actives tested in the resistance test were ineffective
- In the second grazing season, four paddocks were grazed for no more than 21 days and spelled for 63 days
- The carrying capacity of this farm has not been maximised
- Worm burdens were significantly lower in the second grazing season
- Only one short acting drench was used in the second season

Observations and measurements

Fifteen hundred weaner wethers 12 months of age, and 800 weaner wethers 14 months of age were inducted into the rotational grazing system in the first and second

grazing season respectively. Weaner paddocks were sheep-free for at least 84 days prior to entry of stock.

In the first grazing season, four to five paddocks were grazed between 21 and 28 days depending on pasture availability, and spelled about 70 days. In the second season, dry conditions dictated that weaners be inducted into the rotations on arrival at the farm. Four paddocks were grazed for less than 21 days and spelled for 63 days (Table I.1).

The timing of the graze period was determined by existing farm infrastructure, pasture growth and the local practice of utilizing graze periods of <21 days based on information from industry workshops. Twenty-one days is the pre-patent period of *H. contortus*.

Table I.1 Safe Grazing system on Inglewood 2011-2013

Logistics of grazing strategies	Grazing season	
	2011-2012	2012-2013
Age of induction (months)	12 months	17-18 months
Number of paddocks	4	4
Preparation time prior to entry(days)	84	0
Pasture graze time (days (range))	28 (21-28)	21
Pasture rest time (days)	70	63

Monepantel was the entry drench in the first season, and in the second season monepantel was dosed concurrently with a 3-active primer drench to achieve close to 100% reduction in the worm burden as possible, and to protect against importing resistant worms (Table I.2). Weaners were drenched on average 3 times over the summer period 2011-2012 but only the short acting entry drench was dosed in the 2012-2013 season.

Table I.2 Drench treatments and dates administered on Inglewood in 2011-2013

Date	Drench treatment	Comments
15/11/2011	MPL	Entry drench
23/02/2012	CLOS+ABA	
12/04/2012	NAP+LEV	
20/11/2012	MPL+BZ+LEV+ABA	Entry drench

ABA=abamectin BZ=benzimidazole CLOS=closantel LEV=levamisole MPL=monepantel NAP=naphthalophos

In season one, pastures were dry at the end of the grazing season fuelling concerns about insufficient pastures for the winter period (Table I.3). In season two, fewer sheep were grazed and one paddock was closed to rotation to conserve pastures for winter.

Table I.3 Pasture details on Inglewood 2011-2013

Pastures	2011-2012	2012-2013
Grass green an actively growing *on entry*	yes	yes
Grass green an actively growing *on exit*	no	yes
Grass cover (%)	80	75
Grazing height (cm)	10	5
% Productivity	75	75
% Persistent	90	85
% Palatable	80	80
% legume or herb	10	10
Actual Dry Matter yields (DM/kg/ha)	908	257

Relative Humidity readings from data loggers on pastures (Figure 1.1) were low (45%) during the warmer parts of the day, while readings of >90% were typical of the late evening to early morning (Figure I.2).

Figure I.1 Pastures and data logger location on Inglewood February 2012

In the second grazing season, storm events were delayed until December. Infections were then expected to peak in late February but worm egg counts remained low (Figure I.3). Rainfall in the period December to February was 272mm in 2011-2012 and 210mm in 2012-2013.

The mob average worm egg count was 280epg in January 2012 and 27epg in January 2013.

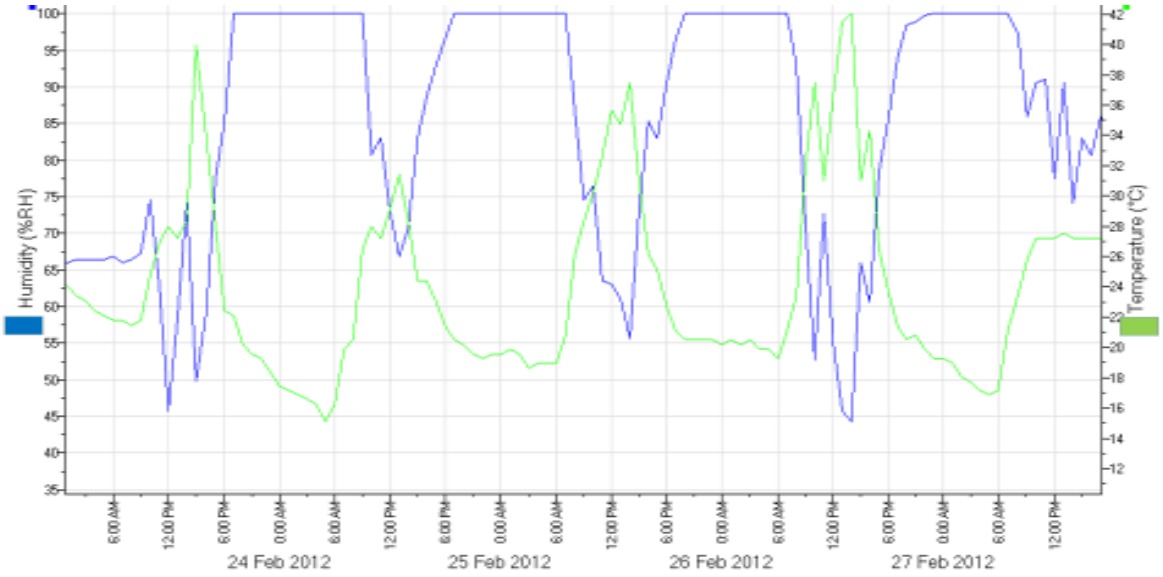

Figure I.2 Temperature (^{0} C) and humidity readings (RH) from data loggers on Inglewood February 2012

The drench resistance test was conducted in September 2011 by the local reseller and results were supplied by the owner who requested that further testing be delayed until the 2013-2014 grazing season. The long-acting closantel (50g/L) and abamectin combination, and the naphthalophos and levamisole mixture were not efficacious and failed to give adequate worm control in season one.

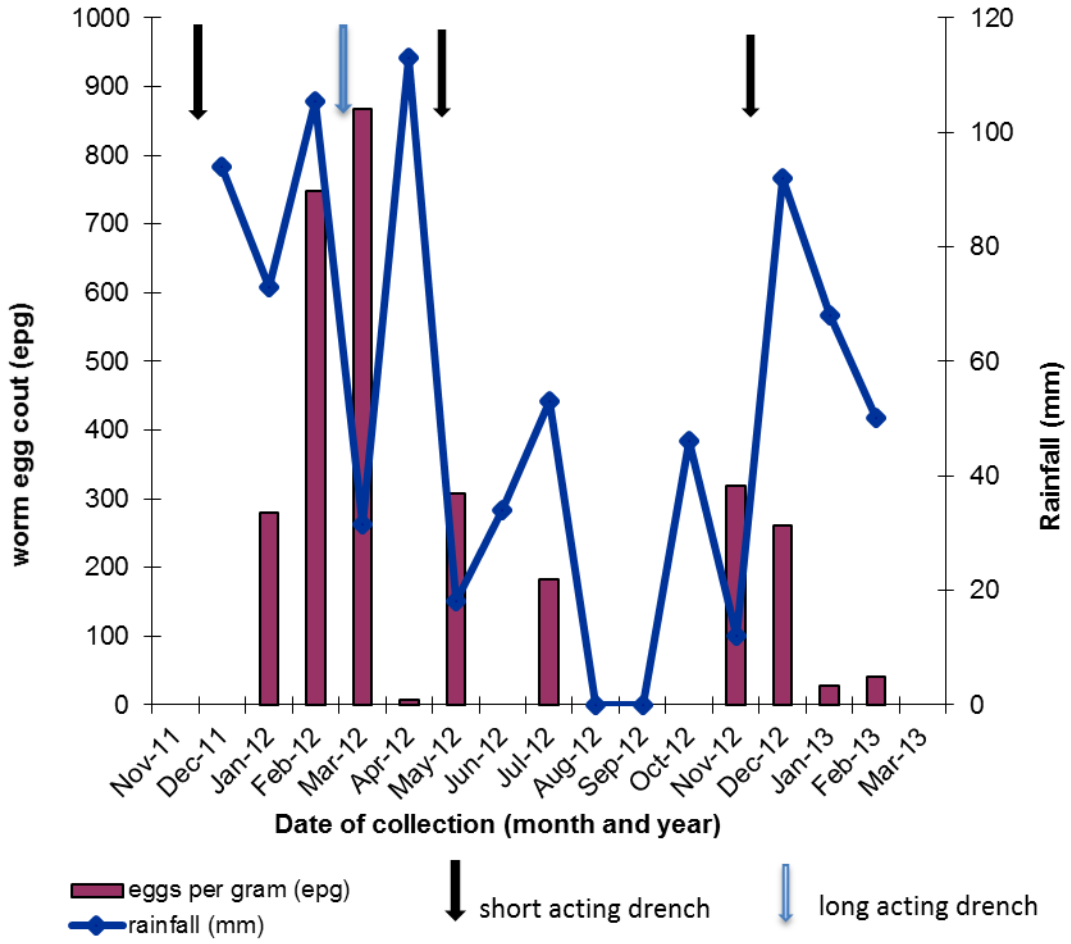

Figure I.3 Worm egg counts (epg), rainfall (mm) and drench treatments Inglewood 2011-2013

Average weight of weaners on entry to the rotations was 32kg, growing to 37.8kg in the first season. Wool production is the primary objective and weaners cut 4.2kg / head of 16.8 micron greasy wool in season one.

For the owner's responses to questions about worm control on Inglewood see page 37.

4.3.2.2 Safe Grazing farm 2 - Millmerran

The farm

This farm is a mixed agricultural enterprise near Millmerran on the western Darling Downs integrating cropping on river flats with prime lamb production. The stud has been developed over the last five years and now runs about 900 Dorper ewes producing 1800 lambs for the meat market each year. Namibian genetics are being introduced to produce a line of consistently productive "top-quality'' stock. Stud management is currently investigating offering ASBV WEC as part of a selection index for rams.

Key findings

- In the second grazing season, 17 paddocks were grazed for <7 days each and rested for 70 days.
- Worm burdens were greatly reduced in the second grazing season
- Levamisole was dosed as the entry and exit drench (owner's choice) in the first grazing season. Subsequent resistance testing identified an efficacy of 92% for this drench.
- In high risk barber's pole seasons a drench that reduces the worm burden by ≥98% is imperative for effective worm control in young susceptible stock
- Worm egg counts were significantly lower in season two
- Only one short acting drench was dosed in the second grazing season. Two short- and two long-acting drenches were dosed in the previous grazing season.

Observations and measurements

In the 2011-2012 season, 250 homebred weaner ewes, seven months of age were managed under Safe Grazing protocols with stock rotated through nine paddocks, each grazed 10-14 days according to feed availability, and rested 80 days. Pre-induction preparation time was also 80 days (Table M.1). Five hundred homebred weaner ewes, two to eight months were inducted into the rotational system in the second summer season.

Early in the 2012-2013 grazing season weather conditions were hot and dry. Pre-induction preparation time was reduced to 42 days and pastures were rested for 70 days. A shorter graze time of <7 days was implemented to minimize autoinfection. More paddocks were added into the rotation.

Table M.1 Safe Grazing system on Millmerran 2011-2013

Logistics of grazing strategy	Grazing season	
	2011-2012	2012-2013
Age of sheep at induction (months)	7	2-8
Number of paddocks	9	17
Paddock preparation time (days)	80	42
Pasture graze times (days (range))	10 (10-14)	<7
Pasture rest time (days)	80	70

In 2011, levamisole was the owner's choice of an entry drench as data collection from the resistance test was not completed (Table M.2). In the second season an entry drench was not indicated as the worm egg counts were <40epg. A tactical 3-way combination drench was administered in late December when the mob average worm burden was 141epg. The owner considered that the dry weather offered an opportunity to 'eradicate' resistant worms.

The farm manager participated in the WeanerSafe worm egg counting webinar and now conducts all worm testing including Day 10 worm tests, on-farm.

Table M.2 Dates and drench treatments administered on Millmerran 2011-2013

Date	Drench	Comments
01/11/2011	LEV	Entry drench
01/12/2011	MOX long acting injection	
01/03/2012	LEV	Exit drench
21/05/2012	MOX long acting injection	
15/11/2012	No drench	No entry drench worm egg counts <40 epg
04/12/2013	BZ+LEV+ABA	Tactical drench

ABA=abamectin BZ=benzimidazole LEV=levamisole MOX=moxidectin

Rhodes grass pastures are dominant on this farm (Figure M.1). Pasture dry matter yields were 1099 DM/kg/ha in November 2012 and 1813 DM/kg/ha after grazing in February 2013 (Table M.3).

Soil moisture was generally low in the 2012 to 2013 season the result of daily temperatures 35°C or higher and high evaporation rates. Pastures were dry and not 'green and actively growing' on entry into the second season rotation but responded to rainfall later in the season.

Table M.3 Pasture details on Millmerran 2011-2013

Pastures	Grazing season	
	2011-2012	2012-2013
Grass green an actively growing *on entry* to the grazing system	Yes November 2011	No (some green pick) December 2012
Grass green an actively growing *on exit* from the grazing system	Yes April 2012	Yes February 2013
Grass cover (%)	80	75
Grazing height (cm)	8	7.5
% Productivity	20	20
% Persistent	20	20
% Palatable	20	15
% legume or herb	5	5
Dry Matter yields actual (DM/kg/ha)	1700	1099

Temperature and RH readings were consistent with those on the Traprock farms with temperatures over 35^0 C on a number of occasion during summer months.

Figure M.1 Pastures on Millmerran February 2012

The predominant internal parasite in coproculture was *Haemonchus contortus*.

Worm infections were significantly reduced in the second grazing season (Figure M.2). On-farm rainfall recordings for the December and January period were 57mm in 2011-2012 and 231 mm in 2012-2013.

The mob average worm egg count in February 2012 was 1806epg and 13epg in February 2013 despite greater overall rainfall in the preceding weeks.

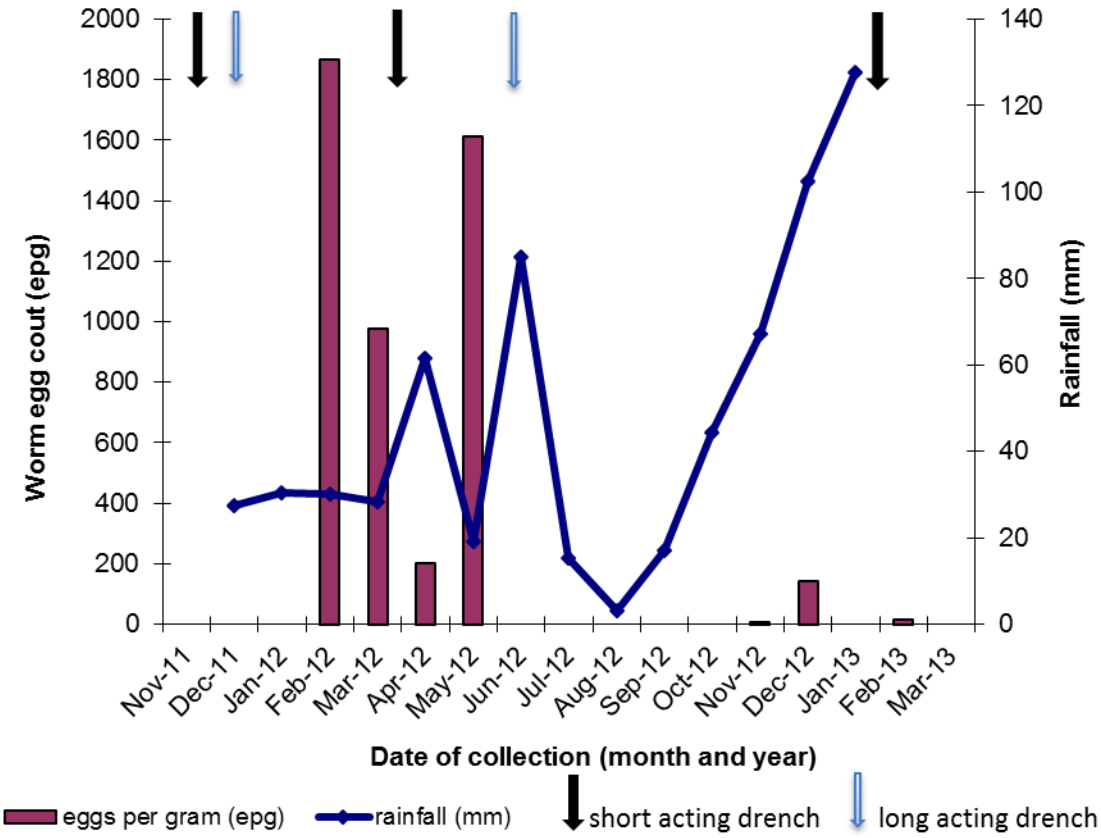

Figure M.2 Worm egg counts (epg), rainfall (mm) and drench treatments on Millmerran 2011-2013

The anthelmintic resistance test was conducted in March 2012 (Table M.4). Moxidectin oral failed to give a 95% reduction of the worm burden but the more potent moxidectin long acting injection was efficacious. The closantel (50g/L) plus abamectin combination was not efficacious. Levamisole alone was not efficacious but in combination with benzimidazole alone, or with benzimidazole and abamectin, was efficacious. Consideration is being given to testing the new formulation of naphthalophos, abamectin and albendazole.

Table M.4 Efficacy of drench actives against *Haemonchus contortus* on Millmerran

Drench actives tested	Efficiency (%)	†Resistance status
LEV	92	Resistant
BZ+LEV	95	Non-resistant
BZ+LEV+ABA	100	Non-resistant
CLOS+ABA	90	Resistant
MOX oral	87	Resistant
MOX long acting injection	98	Non-resistant

ABA=abamectin BZ= benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Average weight of weaners at the start of the first season rotation was 16kg and 45 kg when sold in February 2012. The production objective for this farm is to market all mobs for the domestic market (live weight 44kg) by early January/ February. Batches of lambs are removed for market when they reach target weights.

Owner's responses to questions about worm control:

How do you delay resistance?

- *Don't but in sheep*
- *Use rotations for all classes of sheep*
- *We don't use terminal sires with resistance to worms although it is our intention as a stud to work towards that*
- *Pastures are always (mostly) grazed higher than 10cm in summer*

Pastures

- *Use crop stubbles. Pastures are 70% annuals*

Productivity

- *Meat production meeting targets*
- *Rotations good for controlling worms and short graze gives recovery time for pastures*

Will you continue to test drenches for resistance?

- *yes*

Rotations

- *Necessary*

Do you know the cost of worm infections on your farm?

- *Drenches cost about $2.5/hd per year*
- *Labour costs are about $2.00/ hd per year*
- *Subclinical losses, not sure*
- *Deaths of stock run at about 0.5 % and mostly are orphaned lambs*
- *Good fences make management easy*

What have you gained from the project?

- *Knowledge of what actives are working on sheep*
- *Monitoring saves drench costs by knowing when a drench is needed*

4.3.2.3 Safe Grazing farm 3 - Stanthorpe

The farm

This 400 hectare grazing farm, 12 kilometres south east of Stanthorpe runs a merino wether flock, and a breeding flock of 500 Merino Border Leister cross ewes on separate areas of the farm. In the 2012-2013 season, the farm commenced a transition to a cattle dominant enterprise with a consequent reduction in ewe numbers. Four hundred Angus cattle are now run on the farm.

Key findings

- Rotational grazing was implemented a number of years ago to improve worm control
- Rotations have resulted in a reported 30% reduction in drench usage
- Larval survival times are longer on this farm due to the milder wetter climate
- Worm burdens were not significantly reduced in the second grazing season. Pasture spelling time was 50 days and probably too short for the milder conditions experienced on this farm but forced due to enterprise change
- Productivity was not compromised. These cross-bred sheep appear resilient on indicators such as worm egg counts, Body Condition Scoring, Dipstick® and FAMACHA© scoring
- Only two short acting drenches were dosed in the second grazing season. Three drenches, two of which were long acting were dosed in season one.

Observations and measurements

Two hundred homebred hogget ewes (2011-2012) and 80 weaners (2012-2013) were managed under Safe Grazing. In the first season, pastures were grazed for 7 (4-10) days based on the size of the paddock and availability of pastures, and rested 77 days (Table S.1). Weaners were rotated onto the next paddock when grass height was grazed down to 10cm or when pasture utilization was about 30%.

In the second season, sheep were always grazed less than 7 days to minimise autoinfection. The rest period was also reduced to 50 days in response to changing circumstances on this farm.

Table S.1 Safe Grazing system on Stanthorpe 2011-2013

Logistics of grazing strategy	Grazing season	
	2011-2012	2012-2013
Age of sheep at induction (months)	18	2
Number of paddocks	15	13
Paddock preparation time (days)	82	50
Pasture graze time (days (range))	7 (4-10)	<7
Pasture rest time (days)	77	50

In the first season, three drenches were dosed, two of which were long acting whereas in the second season, only two short acting drenches were administered. In the second grazing season monepantel was dosed concurrently with a 3-active combination drench to ensure high efficacy and to also protect the most active ingredient, monepantel against resistant worms (Table S.2).

Table S.2 Dates and drench treatments administered on Stanthorpe 2011-2013

Date	Drench	Comments
21/10/2011	MOX oral+BZ+LEV	Entry drench
22/12/11	NAP+BZ	
8/03/2012	MOX oral+BZ+LEV	Exit drench
1/11/2012	MPL+BZ+LEV+ABA	Entry drench
5/02/2013	BZ+LEV	

ABA=abamectin BZ=benzimidazole LEV=levamisole MOX=moxidectin MPL=monepantel NAP=naphthalophos

The dominant pasture was naturalised native pastures of Kikuyu and Fesque and in some years there was a high production of sub-clovers. While pastures on this farm were not adversely affected by the drier conditions experienced in the early part of the second grazing season, dry matter yields were much lower than those of the previous year (Table S.3).

Table S.3 Pasture details on Stanthorpe 2011-2013

Pastures	Grazing season	
	2011-2012	2012-2013
Grass green and actively growing *on entry to the grazing system*	Yes November 2011	Yes February 2013
Grass green and actively growing *on exit from the grazing system*	Yes April 2012	Yes March 2013
Grass cover (%)	100	100
Grazing height (cm)	20	15
% Productivity	85	85
% Persistent	30	30
% Palatable	85	80
% legume or herb	20	20
Actual Dry Matter yields (DM/kg/ha)	4633	1351

Temperature readings (Figure S.1) ranged from 4^0 C to 45^0 C on a number of occasions in the period from December 2012 to January 2013 when ambient temperatures were 14^0 C to 27^0 C. Relative Humidity readings were always high, often 100% but on occasions dropping to 20% (Figure S.2).

Figure S.1 Pastures and data logger location on Stanthorpe December 2012

Total rainfall in the November to January period was 406mm in 2011-2012 and 419mm in 2012-2013. Significant rain events dumped 269mm of rain in January 2012 and 279mm in January 2013. While conditions were considered to be dry at the start of season two, the total rainfall and rainfall distribution were similar in both seasons.

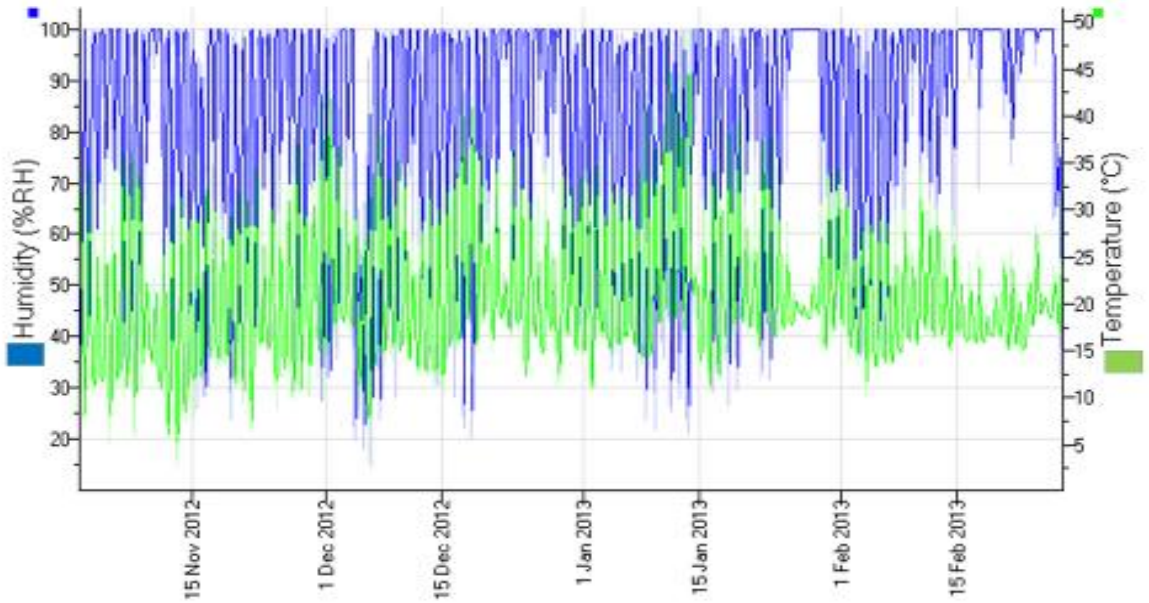

Figure S.2 Temperature (^{0} C) and relative humidity (RH) readings on Stanthorpe 2012 – 2013

H. contortus was the predominant worm population in coproculture. Small numbers (2-26%) of *T. colubriformis,* and up to 2% of *Oespohagostomum* spp most likely *venulosum* were also present in some cultures.

Worm egg counts escalated following rain events in the December period in both seasons (Figure S.3).

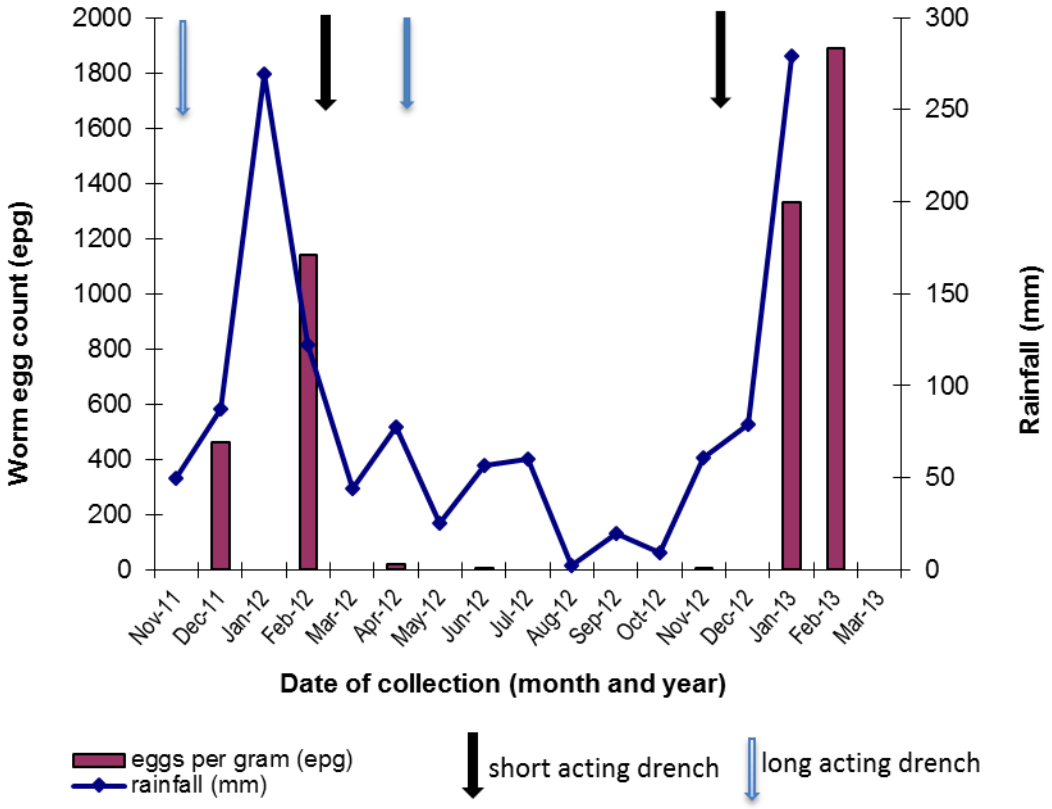

Figure S.3 Worm egg counts (epg), rainfall (mm) and drench treatments on Stanthorpe 2011-2013

The sharp rise in mob average worm egg count to 1889epg in February 2013 from a low base of <40epg in November 2012 was unexpected after the ''dry'' spell. During the similar period in the previous season, the mob average worm egg count was 460epg in December 2011 rising to 1140epg in February 2012.

The resistance test was conducted in March 2012. Moxidectin long acting injection was efficacious against *H. contortus* and further testing 12 months later identified an efficacy of 88% for moxidectin oral (Whitemore personal communication) indicating emerging resistance to the ML class of drench active. The combination of closantel (50g/L) and abamectin was not efficacious (Table S.4a). All the short acting drenches tested were identified as effective.

The ML based drenches were efficacious against *T. colubriformis* (Table S.4b) although the non-ML based drench actives were not effective.

Table S.4a Efficacy of drench actives against *Haemonchus contortus* on Stanthorpe

Drench actives tested	Efficacy (%)	†Resistance Status
LEV	99	Non-resistant
NAP	99	Non-resistant
BZ+LEV	99	Non-resistant
BZ+LEV+ABA	100	Non-resistant
CLOS+ABA	66	Resistant
MOX long acting injection	99	Non-resistant

ABA=abamectin BZ= benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

Table S.4b Efficacy of drench actives against *Trichostrongylus colubriformis* on Stanthorpe

Drench actives tested	Efficacy (%)	†Resistance Status
LEV	89	Resistant
NAP	63	Resistant
BZ+LEV	75	Resistant
BZ+LEV+ABA	100	Non-resistant
CLOS+ABA	97	Non-resistant
MOX long acting injection	100	Non-resistant

ABA=abamectin BZ= benzimidazole CLOS= closantel LEV=levamisole MOX=moxidectin NAP=naphthalophos
†Resistance is declared when the percent reduction in the worm egg count is <95% and LC.I.<90%

The average weight of weaners on entry to the rotational grazing system in 2011 was 19kg and 65kg when sold in June 2012. In the 2012-2013 season entry weights were again on average, 19kg and 38kg by February 2013.

Manager's responses to questions about worm control:

How do you delay resistance?

- *Don't buy in sheep, only some replacement ewes and always use a quarantine drench*
- *Don't use ASBV WEC when purchasing terminal sires*
- *Pastures grazed are always (mostly) higher than 10cm in summer*
- *Always use rotational grazing for all classes of sheep especially weaners over summer*
- *Determine correct drench dose by weighing before drenching*
- *Always rotate drenches*

Pastures

- *very beneficial to keep 1500–2000kg/ha residue for better recovery of grass and with a 50 day spell pastures do well*
- *In future we will keep cattle in front of sheep if pastures are good enough and this will keep worms under control*
- *Rotations benefit pastures and keeps good condition on ewes. We need a condition score of at least 3 and preferably closer to 4 to increase the twinning rate*
- *We want a high twinning rate, about 160% at scanning and 140% at marking*

Productivity

- *Primarily for meat. We sell lambs at 45kg minimum*
- *Wool sales are a side benefit and wool income pays for shearing, labour, jetting and some of fly strike control costs*

What have you gained from the project so far?

- *Multi-active drenches are working better than expected. Cydectin® LA still effective against barber's pole whereas Cydectin® oral is not. Cydectin® is the only drench effective on scour worms*
- *Confidence knowing I am doing the best I can*

How do you rate the value of a good drench?

- *A good drench is the most important outcome of the trial*

Will you continue to test drenches for resistance?

- *If still in sheep this test would be an essential tool*

Rotations

- *Necessary for worm control in this region. Set stocking is a thing of the past*
- *Rotational grazing greatly improves pasture quantity and quality*

5. Discussion and conclusions

- Efficient drenches are the cornerstone of most if not all worm control programs developed on commercial sheep enterprises in inland southern Queensland. In this project widespread anthelmintic resistance was identified on region-typical sheep farms underscoring the need for more rigorous on-farm drench testing and improved grazing practices.

- International standards define resistance in general terms as less than a 95% reduction of the worm egg count. Even an anthelmintic considered to be efficacious can leave a legacy of resistant worms equal to 5% of the infecting burden. This can be significant if the infecting genus has a high biotic potential and weather conditions are suitable for maximum larval survival on pasture. The kill rate of efficient drenches needs to be close to 100% for susceptible weaner sheep in high-risk summer seasons where *H. contortus* is endemic.

- Barger (1996) stated that before implementing any control option, farmers will first consider effectiveness, then cost and ease of application with sustainability being a lower order priority. More complex systems are less likely to be adopted and maintained. Drench resistance testing falls into the ‘’more complex’’ category. Consistent with this sentiment, farmers reported that they would prefer a third party to manage the complex on-farm testing protocols with farm personnel assisting. This may present an opportunity for the agricultural services industry to supply testing as most drenches are still purchased without the benefit of prior resistance testing despite decades of best practice advice to the contrary. Without change, the worm test conducted 10 days after drenching will by default become the test that farmers use to determine drench efficacy. At the very least, farmers will have an indication of the worminess of sheep on return to pasture.

- Safe Grazing strategies are more likely to be practised on farms running meat breeds of sheep. For these breeds weight gains dependent on productive

pastures are closely monitored and quickly jeopardized by parasitic infections. As wool growth is not measured until shearing, the connection between a reduced wool cut and the incidence of a damaging worm infection up to six months earlier becomes difficult to make.

- Farmers assess the pasture quality and carrying capacity of their farms on a daily basis and feel comfortable and competent with the activity. In contrast, resistance testing is conducted once every two years during which time procedures are easily forgotten and competency becomes an issue. Information gathered on this project suggests that there is a heightened awareness about the benefits of time-controlled rotational grazing for worm control and the number of farmers already practising some form of rotational grazing was unexpected but pleasing. While there is little interest in resistance testing per se, drench resistance may be the catalyst that drives adoption of Safe Grazing.

6. Bibliography

Abbott KA, Taylor MA, Stubbings LA, Sustainable control of parasites in Sheep (SCOPS), A Technical Manual for Veterinary Surgeons and Advisors, 3rd edition www.nationalsheep.org.uk (accessed 04.07.2013)

Albers GAA, Gray GD, Le Jambre LF et al., The effect of *Haemonchus contortus* on liveweight gain and wool growth in young Merino sheep. *Aust J Agric Res* 1989;40:491-432.

AWI and MLA*, Making More from Sheep*. Module 11 Healthy and Contented Sheep. Australian Wool Innovation and Meat and Livestock Australia Limited. 2008.

Bailey JN, Kahn LP, Walkden-Brown SW, Availability of gastro-intestinal nematode larvae to sheep following winter contamination of pasture with six nematode species on the Northern Tablelands of New South Wales. *Vet Parasitol* 2009*;*160:89-99.

Bailey JN, Walkden-Brown SW, Kahn LP, Comparison of strategies to provide lambing paddocks of low gastro-intestinal nematode infectivity in a summer rainfall region of Australia. *Vet Parasitol* 2009;161:218-231.

Baker KE, George SD, Stein PA et al., Efficacy of monepantel and anthelmintic combinations against multiple-resistant *Haemonchus contortus* in sheep, including characterisation of the nematode isolate. *Vet Parasitol* 2012;186:513-517.

Banks DJD, Singh R, Barger IA et al., Development and survival of infective larvae of *Haemonchus contortus* and *Trichostrongylus colubriformis* on pasture in a tropical environment. *Int J Parasitol* 1990; 20:155-160.

Baldock FC, Lyndal-Murphy M, Pearse B, An assessment of a composite sampling method for counting strongyle eggs in sheep faeces. *Aust Vet J* 1990;67:165-167.

Barger IA, Prospects for integration of novel parasite control options into grazing systems. *Int J Parasitol* 1996;26:1001-1007.

Barger I, Control by management. *Vet Parasitol* 1997;72:493-506.

Barger IA, The role of epidemiological knowledge and grazing management for helminth control in small ruminants. *Int J Parasitol* 1999;29:41–47.

Barger IA, Siale K, Banks DJD et al., Rotational grazing for control of gastrointestinal nematodes of goats in a wet tropical environment. *Vet Parasitol* 1994;53:109-116.

Besier B, New anthelmintics for livestock: the time is right. *Trends Parasitol* 2007;23:21-24.

Besier RB, Refugia-based strategies for sustainable worm control: Factors affecting the acceptability to sheep and goat owners. *Vet Parasitol 2012;*186:2-9.

Besier RB, Love SCJ, Anthelmintic resistance in sheep nematodes in Australia: The need for new approaches. *Aust J Exp Agric* 2003;43:1383-1391.

Besier B, Love S, Advising on helminth control in sheep: It's the way we tell them. *The Vet J* 2012;193:2-3.

Burke JM, Miller JE, Terrill TH, Impact of rotational grazing on management of gastrointestinal nematodes in weaned lambs. *Vet Parasitol* 2009;163:67-72.

Cheah TS, Rajamanickam C, Epidemiology of gastro-intestinal nematodes of sheep in wet tropical conditions in Malaysia. *Trop Anim Hlth Prod* 1997;29:165-173.

Cobon DH, O'Sullivan BM, Effect of *Haemonchus contortus* on productivity of ewes, lambs and weaners in a sem-arid environment. *J Agric Sci* 1992;118:245-248.

Coles GC, Bauer C, Borgsteede FHM et al., Methods for the detection of anthelmintic resistance in nematodes of veterinary importance. *Vet Parasitol* 1992;44:35-44.

Coles GC, Jackson, F, Pomroy WE et al., The detection of anthelmintic resistance in nematodes of veterinary importance. *Vet Parasitol* 2006;136:167-185.

Colvin AF, Walkden-Brown SW, Knox MR et al., Intensive rotational grazing assists control of gastrointestinal nematodosis of sheep in a cool temperate environment with summer-dominant rainfall. *Vet Parasitol* 2008;153:108-120

Dinaburg AG. Development and survival under outdoor conditions of eggs and larvae of the common ruminant stomach worm, *Haemonchus contortus*. *J Agric Res* 1944; 69:421–33.

Dobson RJ, Le Jambre L, Gill JH, Management of anthelmintic resistance:inheritance of resistance and selection with persistent drugs. *Int J Parasitol* 1996;26:993-1000.

Dobson RJ, Besier RB, Barnes EH et al., Principles for the use of macrocyclic lactones to minimise selection for resistance. *Aust Vet J* 2001;79:756-761.

Dobson RJ, Hosking BC, Besier RB et al., Minimising the development of anthelmintic resistance, and optimising the use of the novel anthelmintic monepantel, for the sustainable control of nematode parasites in Australian sheep grazing systems. *Aust Vet J* 2011;89:160-166.

Dobson RJ, Barnes EH, Tyrrell KL et al., A multi-species model to assess the effect of refugia on worm control and anthelmintic resistance in sheep grazing systems. *Aust Vet J* 2011;89:200-208.

Ehrlich WK, Cowan RT, Lowe KF, Managing Rhodes grass (*Chloris gayana* cv. Callide) to improve diet quaity. 1. Effects of age of regrowth, strip grazing and mulching. *Trop Grasslands* 2003;37:33-44.

Flemming SA, Craig T, Kaplan RM et al., Anthelmintic resistance of gastrointestinal parasites in small ruminants. *J Vet Intern Med* 2006;20:435-444.

GenStat for Windows, Release 14.1. VSN International Ltd., Oxford, 2013.

Green PE, Forsyth BA, Rowan KJ et al., The isolation of a field strain of *Haemonchus contortus* in Queensland showing multiple anthelmintic resistances. *Aust Vet J* 1981;57:79–84.

Healey AF, Hall E, Gaden CA et al., Intensive rotational grazing reduces nematode faecal egg counts in sheep on the Cicerone project. *Anim Prod Aust* 2004;25:85-88.

Hutchinson G, Nematode Parasites of small ruminants, camelids and cattle. Diagnosis with emphasis on anthelmintic efficacy and resistance testing. *Aust NZ Standard Diagnostic Procedures* 2009;pp1-61.

Kahn LP, Woodgate RG, Integrated parasite management: Products for adoption by the Australian sheep industry. *Vet Parasitol* 2012;186:58-64.

Kahn L, Dever M, Bowers S, Lower worm egg counts associated with higher ewe body condition score. 24th International conference of the World Association for the Advancement of Veterinary Parasitology. Perth Western Australia. 2013.

Kaplan RM, Drug resistance in nematodes of veterinary importance: a status report. *Trends Parasitol* 2004*;*20:477-481.

Kaplan RM, Vidyashankar AN, Howell SB et al., A novel approach for combining the use of *in vitro* and *in vivo* data to measure and detect emerging moxidectin resistance in gastrointestinal nematodes of goats. *Int J Parasit* 2007;37:795-804.

Kaplan RM, Vidyashankar AN, An inconvenient truth: Global worming and anthelmintic resistance. *Vet Parasitol* 2012;186:70-78.

Kelly GA, Kahn LP, Walkden-Brown SW, Integrated parasite management for sheep reduces the effects of gastrointestinal nematodes on the Northern Tablelands of New South Wales. *Anim Prod Sci* 2010;50:1043-1052.

Kelly GA, Walkden-Brown SW, Kahn LP, No loss of production due to larval challenge in sheep given continuous anthelmintic treatment via a controlled release capsule. *Vet Parasitol* 2012*;*183:274-283.

Knox M, Lyndal-Murphy M, Kotze A et al., Macrocyclic lactone resistance in an isolate of ovine *Trichostrongylus colubriformis* from North Queensland. 23th International conference of the World Association for the Advancement of Veterinary Parasitology. Buenos Aires. 2011;p46.

Le Jambre LF, Geoghegan J, Lyndal-Murphy M, Characterization of moxidectin resistant *Trichostrongylus colubriformis* and *Haemonchus contortus*. *Vet Parasitol* 2005;128:83–90.

Le Jambre LF, Martin PJ, Johnston A, Efficacy of combination anthelmintics against multiple resistant strains of sheep nematodes. *Anim Prod Sci* 2010;50:946-952.

Levecke B, Dobson RJ, Speybroeck N et al., Novel insights in the faecal egg count reduction test for monitoring drug efficacy against gastrointestinal nematodes of veterinary importance. *Vet Parasitol* 2012;188:391-396.

Love S, Prevalence of anthelmintic resistance in sheep worms in Australia – a thumbnail sketch. *Aust Sheep Vet Conf* Barossa Valley. Adelaide. South Australia. 2011;47-50.

Lyndal-Murphy M, Anthelmintic resistance in sheep. Australian Standard Diagnostic Techniques for Animal Diseases. CSIRO, Melbourne, Australia,1993; pp 1–17.

Lyndal-Murphy M, Pepper P, Swain T, Determining resistance of ovine nematodes to anthelmintic treatments*. Aust Soc Parasitol Conf* Perth, Western Australia, Australia. 2004;59.

Lyndal-Murphy M, Pepper P, Delaney K et al., Determining resistance of ovine nematodes to anthelmintic treatments*. Aust Soc Parasitol Conf* Gold Coast, Queensland Australia. 2006;108-109.

Maxwell D, Love S, Lyndal-Murphy M, 2012. www.wormboss.com.au/programs/slopes-plains.php (accessed 04.10.2013).

McCullagh P, Nelder JA, *Generalized Linear Models.* 2nd ed. Chapman and Hall, London, 1989.

McKenna PB, How do you mean? The case for composite faecal egg counts in testing for drench resistance. *NZ Vet J* 2007;55:100-101.

Miller CM, Waghorn TS, Leathwick DM et al., How repeatable is a faecal egg count reduction test? *NZ Vet J* 2006;54:323-328.

Morgan ER, Cavill L, Curry GE et al., Effects of aggregation and sample size on composite faecal egg counts in sheep. *Vet Parasitol* 2005;131: 79–87.

Nielsen R, Drench resistance of sheep worms – New England region, New South Wales. Novartis Animal Health Update, Armidale. November, 2012.

O'Connor LJ, Walkden-Brown SW, Kahn LP, Ecology of the free-living stages of major trichostrongylid parasites of sheep. *Vet Parasitol* 2006;142:1-15.

O'Connor LJ, Kahn LP, Walkden-Brown SW, The effects of amount, timing and distribution of simulated rainfall on the development of *Haemonchus contortus* to the infective larval stage. *Vet Parasitol* 2007*;*146:90-101.

O'Connor LJ, Kahn LP, Walkden-Brown SW, Moisture requirements for the free-living development of *Haemonchus contortus*: Quantitative and temporal effects under conditions of low evaporation. *Vet Parasitol* 2007;150:128-138.

O'Connor LJ, Kahn LP, Walkden-Brown SW, Interaction between the effects of evaporation rate and amount of simulated rainfall on development of the free-living stages of *Haemonchus contortus*. *Vet Parasitol* 2008*;*155:223-234.

Overend DJ, Phillips ML, Poulton AL et al., Anthelmintic resistance in Australian sheep nematode populations. *Aust Vet J* 1994;71:117-121.

Pepper PM, Swain AJ, Lyndal-Murphy M, Using simulation techniques to investigate methods to determine resistance of helminths to anthelmintic treatment. *Proceed MODSIM 2003 International Congress on Modeling and Simulation* 4 2003;1580-1585.

Pritchard RK, Hall CA, Kelly JD et al., The problem of anthelmintic resistance in nematodes. *Aust Vet J* 1980;56:239-250.

Roberts FHS, O'Sullivan PJ, Methods for egg counts and larval cultures for strongyles infesting the gastro-intestinal tract of cattle. *Aust J Agric Res, 1950;*1:99-102.

Sackett D, Holmes P, Abbott K et al., Assessing the economic cost of endemic disease on the profitability of Australian beef cattle and sheep producers. *Final Report, project AHW-087.* Sydney: Meat and Livestock Australia 2006; pp133.

Sager H, Rolfe P, Strehlau G et al., Quarantine treatment of sheep with monepantel-Rapidity of faecal egg count reduction. *Vet Parasitol* 2010;170:336-339.

Schroder J, Integrated Parasite Management of Sheep. National overview of the need, available tools and the fit with Industry. *Proceed Aust Anim Prod* 2010;28:74-75.

Swan RA, The epizootiology of haemonchosis in sheep. *Aust Vet J* 1970;46:485-492.

Torgerson PR, Schnyder M, Hertzberg H, Detection of anthelmintic resistance: a comparison of mathematical techniques. *Vet Parasitol* 2005;128:291–298.

van Wyk JA, Cabaret J, Morphological identification of nematode larvae of small ruminants and cattle simplified. *Vet Parastiol* 2004;119:277-306.

Walkden-Brown SW, Reeve I, Thompson L-J et al., Project Benchmarking Survey: A national survey of parasite control practices. *Proceed Aust Sheep Vets Conf* 2006;38-47.

Walkden-Brown S, Colvin A, Hall E et al., Gastrointestinal nematode control in sheep under three grazing management systems and factors influencing faecal worm. 24th International conference of the World Association for the Advancement of Veterinary Parasitology. Perth Western Australia.2013.

Walker E, Charman N, Kelly J et al., Anthelmintic resistance survey in the central west LHPA. *Proceedings, 95th District Veterinarian's Conference*, Armidale, NSW 2013;pp18-24.

Woodgate RG, Besier RB, Sustainable use of anthelmintics in an Integrated Parasite Management Program for sheep nematodes. *Anim Prod Sci* 2010;50:440-443.

Woodgate RG, Love S, WormKill to WormBoss. Can we sell sustainable sheep worm control? *Vet Parasitol* 2012;186:51-57.