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Capacity building and validation of integrated parasite management in prime lambs in Western Australia

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Abstract

The project aimed to quantify the potential loss of growth and value in prime lambs in Western Australia due to worm infections, and to develop integrated parasite management based prime-lamb specific control recommendations. The focus of this study was on the worm species which reduce growth rates in prime lambs (non-*Haemonchus* sp.). Observations were conducted over 3 years on 14 properties throughout South-West Western Australia, with worm egg counts and lamb weights measured at intervals from lamb marking for the next 105 days. The results suggest that best-practice worm control over the critical period for prime lamb growth should include: ensuring that growth rates are 240 grams per head per day or greater in the first 14 weeks after the start of lambing; conducting worm egg counts about 10 weeks after the start of lambing; weaning and giving an effective (>98%) drench shortly afterwards if the count is over 250 eggs per gram; and drench onto lower worm burden paddock. All of these practices would be cost effective given the significant economic value to be gained when prime lambs are slaughtered around 28 weeks after the start of lambing and they are also relatively easy to implement.

Executive summary

There are no published reports regarding the impact of worms on prime lamb enterprises in Western Australia. Uncontrolled parasitism is common in Western Australian prime lamb flocks with the potential for lost productivity. This project aimed to quantify the potential loss of growth and value in prime lambs due to worm infections, and to develop recommendations for integrated parasite management. There is a need to ensure that worm-control advice is readily available to WA prime lamb producers, and the project aimed to facilitate the development of an appropriately-skilled network of sheep consultants, and to provide information for websites and other worm control support services.

Seven sheep consultants (3 veterinary, 4 agricultural) agreed to participate in the project. The seven sheep consultants nominated 14 sheep producers to participate in the study. The 14 selected sheep producers were classified as wool and prime lamb enterprises and were located in the medium rainfall and cereal-sheep zones, reflecting the different winter growing conditions in Western Australia. Information was collected from a total of 42 flocks from 2013 to 2015. The design was a case-control, i.e. 50 lambs not drenched ("producer-program" group) were compared with 50 lambs given drenches to suppress worms ("worm suppressed" group). Both groups of lambs grazed together and were part of larger group. Measurements were collected at similar times after the start of lambing on each of the 42 flocks. Data was analysed for the whole period from lamb marking to 22 weeks after the start of lambing (average of 105 days) and to slaughter in 10 flocks.

The focus of this study was on non-*Haemonchus* species, which reduce growth rates in prime lambs. *Nematodirus* spp. was present in all prime lamb flocks, but has a far lower egg output compared to other strongyles. To take into account the mixed infections of worms, a formula [strongyle WEC minus *Haemonchus* + (two times *Nematodirus* WEC)] was used to calculate the weighted average worm egg count for each treatment group per 105 days per flock.

In this study internal parasites had an effect in 86% of prime lamb flocks judged by the higher growth rates in the worm suppressed compared to the producer-program group. Prime lamb flocks with a significantly ($p < 0.05$) higher growth rate in the worm suppressed group when compared to the producer-program group were given a 'worm effect' category. Slaughter information was calculated for five unaffected and five 'worm effect' flocks comprising average carcase weight, fat score and dollar per head per treatment group and yield.

The lamb flocks categorized as 'worm effect' had higher average worm egg counts for the entire period from lamb marking to 22 weeks after the start of lambing. These 'worm effect' flocks had an average worm egg count of 474 eggs per gram compared with 261 eggs per gram in the unaffected flocks ($p=0.005$). Lambs from the worm suppressed group in 'worm effect' flocks gained 19.8 grams per head per day or 2.1 kilograms in total more than the undrenched lambs over an average of 105 days. This represents an 8% advantage in growth rates in worm suppressed groups. The 'worm effect' flocks were located in both medium rainfall and cereal-sheep zones of Western Australia. At slaughter, the difference in liveweight between the two treatment groups had increased, and was estimated on prevailing prices to be worth $5.73 per head. About 70% of this value is attributed to

increased carcase weight gain at slaughter and 30% of the value is due to an increase in the average cents per kilogram per carcase weight price paid for the worm suppressed group. High growth rates from lamb marking to 14 weeks after start of lambing appears to help mitigate some of the effects of higher worm burdens during the ensuing period.

In 2015, the effectiveness of integrated parasite management was evaluated on 14 flocks, following drenching of the ewes with an effective autumn drench (greater than 98% effective) in the first week of April (before break of season) to minimise pasture contamination. While ewes from 8 out 9 flocks received an effective autumn drench, in 13% of flocks this integrated parasite management practice still resulted in a significant ‘worm effect’.

General thresholds beyond which worm-related production loss is expected would be of value as a basis for control recommendations. Correlating the average worm egg count from the whole 105 day period with a single worm egg count at a particular time for which action is required showed the critical single worm egg count to be different for 73, 100, 128 and 156 days after the start of lambing. By sampling at day 73 after the start of lambing we attempted to predict whether pasture contamination from this time would lead to significant reduction in growth rates by slaughter. The increased weighted worm egg count in ‘worm effect’ flocks rose more rapidly than in unaffected flocks and was associated with a lower average liveweight at slaughter.

We conclude that best-practice worm control for prime lambs should include: ensuring growth rates are 240 g/h/d or greater in the first 14 weeks after the start of lambing; conducting worm egg counts at about 10 weeks after the start of lambing and weaning and giving an effective drench shortly afterwards if the egg count at 10 weeks is over 250 epg. Drenching onto a lower worm burden paddock would be advantageous as otherwise worm burdens are likely to be high again within 4 weeks. All of these practices would be cost effective given the significant economic value to be gained when prime lambs are slaughtered around 28 weeks after the start of lambing and they are also relatively easy to implement.

At present, taking worm egg counts at 10 weeks from prime lambs after the start of lambing is not a routine recommendation or commonly practiced by prime lamb producers. A count at this time provides a good index of the need, or otherwise, of a drench soon afterwards and ideally, a move to a less contaminated paddock. The alternative to leaving the treatment to a more usual 17 weeks or later after the start of lambing risks significant productivity and economic loss.

The new information from this project will be of great interest to all sheep advisors in Western Australia – consultants, veterinarians and producer groups. The information provides a new and economically-significant strategy to profit more from prime lambs. Ideally the information should be disseminated within a planned framework but some resources to initiate and develop new communication channels would need to be provided.

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1 Background

Over the past decade, there has been a major change to sheep enterprises in Australia, with a sustained increase in the returns from prime lamb production leading to a sharp increase in its relative importance. In Western Australia, sheep meat production is no longer a minor sector within the sheep industry, now rivalling wool in total value, and is generally more profitable.

While the control of internal parasites is integral to efficient sheep management, the recommendations developed from research over past decades has applied particularly to Merino-dominant enterprises. However, due to differences in the nature of parasitic effects between wool and meat enterprises, observations indicate that the control of worms in prime lambs is less than optimal on many properties in the state. The widespread occurrence of anthelmintic resistance, affecting all except newly-introduced anthelmintic groups and all important nematode species, commonly reduces the effectiveness of control, and provides a further imperative for the use of objectively-developed programs, and of integrated parasite management strategies.

The impact of poor worm control on prime lamb enterprise profitability is likely to be both significant, and disproportionately greater compared to the sheep industry generally. In a survey of disease costs to the Australian livestock industries, Sackett et al (2006) estimated the reduction in income and costs of nematode control in prime lambs at some $8.50 per head, compared with an average of less than half that figure for mostly wool-producing sheep. With higher lamb prices since that estimate, the relative loss will have increased. Given that the effects of worm infections are mostly sub-clinical, it is likely that many lamb producers are unconsciously foregoing significant income, and this may be of greater magnitude than expected when using Merino enterprise costings.

This project aimed to facilitate the development of an appropriately-skilled network of sheep consultants, to investigate the cost of worm infections in prime lambs, and to validate best practice programs, as the basis for promoting the adoption of more effective, sustainable and profitable production systems.

1.1 The impact of worms on sheep meat production

Sheep nematodes have long been recognised as a major cause of reduced lamb growth rates, with abundant evidence from pen studies that characterised the pathophysiological and biochemical mechanisms (reviewed by Coop and Kyriazakis, 1999). Numerous grazing studies investigating the effectiveness of control strategies in Merino sheep confirm the lower bodyweights of lambs (weaners) carrying significant worm burdens, in relation to worm controlled or worm-suppressed sheep (Anderson 1976, Johnston et al 1979, Thompson and Callinan 1981, Barton and Brimblecombe 1983, Beveridge et al 1985, Brown et al 1985, Pullman 1991, Larsen et al 1995).

However, although reports from elsewhere confirm losses due to parasites in meat-breed sheep (McAnulty et al 1982), it appears that until recently, no studies in Australia had specifically investigated the effects of worm infections on prime lamb enterprises. This prompted MLA support for a comprehensive investigation in south-east South Australia and Victoria, with observations from 2004-2007 involving different production systems, mostly on lambs post-weaning (Carmichael, 2009). Efficient worm control programs averted parasitic loss on 27% of properties, but lamb growth rate was reduced on 73% of the properties, with a mean loss of 12% on the 38% most severely affected, predominately in association with *Teladorsagia circumcincta* and *Trichostrongylus* spp. Loss was statistically associated with levels of pasture contamination with nematode infective larvae (L3): a mean loss of over 10 gm/head/day where this exceeded 1500 L3/kg DM, but less than this (or not statistically significant) below 460 L3/kg DM. In general, economic loss was unlikely where pasture contamination was below 1000 L3/kg DM, or scour worm burdens below 5000 worms, provided pasture nutritional quality was high. This study provides useful indications of likely parasitic effects in other environments where these worm species are prevalent, and also provides good information on parasite management practices in prime lamb enterprises, and potential lamb growth rates in relation to nutritional quality.

More recently, single-flock grazing studies with artificially infected prime lambs confirmed the potential for major growth rate reductions in the weeks prior to slaughter. In South Australia, Blackburn et al (2015) found lambs trickle-infected with the especially pathogenic species, *Trichostrongylus vitrinus*, to suffer a loss of 50 gm/head/day, and from a similar experiment with *Trichostrongylus colubriformis* in northern New South Wales, Dever et al (2016) reported a loss of 36 gm/head/day. In both cases, the considerably greater growth rate loss than reported by Carmichael (2009) were associated with much larger worm burdens or worm egg counts, confirming the potential for severe loss where parasites are uncontrolled.

1.2 Prime lamb worm control in Western Australia

Sheep worm control programs in WA are not at present specific to wool or meat-breed enterprises, and farmers have not reported the failure of recommended programs when applied to prime lamb operations. While clinical parasitism occurs occasionally, seen as scouring and ill-thrift, and in lambs responsive to drenching, moderate nematode burdens more typically lead to reduced growth rates, which are evident only by repeated weighing. However, as few farmers routinely weigh lambs until close to anticipated turn-off, significant losses in growth are often likely to escape detection.

There is a need for worm control programs specific to prime lamb enterprises, where rapid growth rate is essential for profitability, which differ from largely Merino enterprises.

<u>Sheep management</u>

Prime lambs are more likely to be born early in the season (April, May, June), than Merinos, where a later lambing (June or July) is usually most profitable. While a late time of lambing provides optimal whole-year pasture utilisation (avoiding heavy stocking rates in late autumn maximises spring plant growth), most prime lamb producers aim to turn off lambs before the pasture dries off and loses quality, and so avoid carry-over of large numbers. Differences in the time of year when worm-susceptible lambs (and per-parturient ewes) are present alter the annual pattern of worm populations, and therefore the nature of optimal control measures. Consequently, it is especially important that worm control recommendations are planned specifically for prime lamb operations.

As a further difference from Merino flock management, prime lambs are frequently not weaned until the first draft of heaviest lambs is sent for slaughter. For early-born lambs especially, this may mean that weaning for the remaining lambs is delayed for some weeks beyond the “typical” (in WA) Merino weaning age of 16-18 weeks (and well beyond the recommended 12-14 weeks). This has potentially major implications: lambs at 3-5 months are usually at the most worm-susceptible stage of life, and delaying drench by some weeks could lead to heavy worm burdens and significant parasitism. (This issue became evident during the course of the project and has led to specific recommendations.)

Breed effects

Although the majority of ewes in WA are still Merino (67%; AWI 2015 figures), most prime lambs are a first-cross with a British breed sire and some are meat-specific breeds (SAMM, Dorpers, etc.). Due to the relatively rapid growth and characteristically heavy build, lower weights or size than should be achieved at a certain time point may not be evident. When compared to Merino lambs, which are usually also present on WA farms, cross-bred or meat breed lambs are likely to appear to be growing at adequate or better rates, but in fact may be suffering an invisible reduction in growth rate due to worms or nutrition. Drenches may be withheld on the incorrect assumption that lambs are growing at optimal rates, when in fact worm infections are imposing an invisible production penalty.

Consequences of scouring

As faecal carcass contamination is a human health issue, it is especially important that lambs presented for slaughter do not carry dags or are actively scouring. While abattoir policy may permit a small degree of breech soiling, there can be significant costs where heavily dagged lambs are drafted off for crutching, or entire consignments rejected. Outbreaks of scouring in pre-slaughter lambs therefore have significant adverse consequences, and as this is (in WA especially), mostly worm-induced, effective control will prevent serious problems.

Restrictions on drenching

Legislated withholding periods for meat products apply to anthelmintics as a human safety concern, and vary from zero for a small number of products to nearly 6 month for some long-acting anthelmintics. Export Slaughter Intervals are often longer. This can be a significant impediment to the use of some commonly-used drenches: the ESI for the most effective single-active anthelmintic monepantel is 115 days, and for Closantel, 60 days. Several external parasite-control products also have long withholding periods.

This can be a particularly difficult problem for prime lamb worm management, as lambs should be sent for slaughter as soon as they reach target weights. IPM principles that reduce the requirement for drenching, and avoid the reliance on those with long ESI periods, are especially applicable in this industry sector.

1.3 The need for investigation in Western Australia

As noted above, in common with most of the Australian sheep flock, wool production was until recently the major enterprise in Western Australia, but this has changed, and prime lamb production is of similar importance, with prospects of an increasing role. Most sheep parasite investigations, and hence recommendations to industry, have previously focused on Merino-based enterprises. There is therefore an obvious need to ensure that worm control recommendations are appropriate for meat-sheep management programs, and the present project aims to provide the basis for this.

Although there are no published reports regarding the impact of worms on prime lamb enterprises in Western Australia, Jacobson et al. (2006) found surprisingly high worm egg counts in lambs sampled in lairage prior to slaughter: a mean worm egg count for scour worms of 1150 eggs per gram (epg), and above 2000 epg in 22% of cases. Even with an allowance for a faecal concentration effect in pre-slaughter sheep, these values are far higher than normally considered indicative of production effects and at the higher end, overt parasitic disease (scouring was present in a small number of lamb lines). Preliminary investigations on 3 farms in the Great Southern also showed high worm egg counts in all prime lamb flocks (> 500 epg) at some time before slaughter (Woodgate 2011, unpublished).

From long experience of laboratory results and clinical investigations, it is obvious that uncontrolled parasitism is common in WA prime lamb flocks, with the obvious potential for (mostly sub-clinical) lost productivity. However, the reasons for differences between properties, years and over time are unknown. This project aimed to quantify the potential loss of animal growth and value due to worm infections, and to develop IPM-based prime-lamb specific control recommendations. These were to be based on the well-understood epidemiology of the major nematode species, modified for meat-sheep management practices, and with the imperative to ensure a minimal impact on lamb growth rates.

A specific issue concerns recommendations for drenching based on worm egg count values, which are basic to present effective and sustainable programs. The poor relationship between WEC and live weight gain or wool growth has been known for some time (Bisset and Morris, 1996; Morris et al., 2001; Doyle et al., 2011), but general thresholds beyond which worm-related production loss is expected would be of particular value. Recommendations for the management of pastures to minimise the challenge to prime lambs during their main periods of growth were also to be investigated. The project was to provide the basis for the demonstration and validation of best practice prime lamb worm control, based on observations over 3 years and across several different environments.

In addition, there was a need to ensure that worm-control advice is readily available to WA prime lamb producers. With the reduction in the extension capacity within DAFWA, it was especially necessary to ensure continued support from advisers with experience in the principles of sustainable, effective prime lamb worm control. This proposal aimed to facilitate the development of an appropriately-skilled network of worm control consultants, and to and to provide information for websites and other worm control support services.

2 Project objectives

The objectives of this project were:

1 To develop a network of at least 7 sheep consultants sufficiently experienced and confident to supply IPM advice for sheep meat production systems in Western Australia

2 To demonstrate the production and economic benefits of IPM on at least 14 prime lamb enterprises in Western Australia by comparing different flocks on each of the enterprises using current and IPM approaches to worm control
3 To develop protocols for drenching decisions and other worm control measures based on assessments of worm burdens and the nutritional status, for Western Australia prime lamb enterprises.

3 Methodology

The methods for each objective were:

3.1 Objective 1: Develop a network of sheep consultants

A list of consultants in Western Australia with regular contact with the sheep producers was compiled as shown in Table 1. The consultants were providing technical advice to sheep producers such as condition scoring, pasture renovation, grazing management, feed budgeting, husbandry or worm control to their clients. Seven sheep consultants (3 veterinary, 4 agricultural) agreed to participate in the project. Their sheep clients were within the medium rainfall (MRZ) and cereal-sheep zones (CSZ) reflecting the different growing conditions in Western Australia. The medium rainfall zone (MRZ) includes the whole south west, from the Perth area in the north, to Albany in the south and has a six month growing season. The cereal sheep zone (CSZ) extends from the Geraldton area in the north-west to the Esperance region in the south east and has a five month growing season. In 2013, a total of 4910 sheep producers with greater than 500 sheep were located in these two zones. Fifty six per cent of Western Australian producers are wool and prime lamb enterprises, 33% wool and 12% prime lamb.

Table 1 List of seven sheep consultants involved in the project from 2013 to 2015

Agricultural consultants		
Ashley Herbert	Perth	Agrarian Management
Edward Riggall	Narrikup	Ed Riggall Consulting
Andrew Ritchie	Darkan	Iconag
Paul Omodei	Manjimup	Planfarm Pty. Ltd.
Veterinary consultants		
Miles Nye-Chart	Mount Barker	Mt Barker Veterinary Hospital
David Swan	Esperance	Swan Veterinary Services
Ray Batey	Perth	Austbreed Consulting

The seven consultants were asked to provide the names of sheep producers whom they have a relationship and had prime lambs production as part of their sheep enterprise. All nominated sheep producers were classified as wool and prime lamb enterprises.

The 14 prime lamb producers selected from this list to participate are shown in Table 2.

Table 2 List of 14 prime lamb producers nominated by the 7 consultants and involved in the project from 2013 to 2015

Producer/year in project/property	Long term winter growing season rainfall (April to October) (mm)	DAFWA Agricultural zone	Total area of property (ha)	Start of lambing (mid-point over 3 years)
Robertson 2013/14/15	255	Medium	4702	April 2
CSouth 2013/14	320	Medium	806	June 15
CSouth 2015	320	Medium	1749	June 15
Pech 2013/14/15	337	Medium	4483	June 3
Sewell 2013/14/15	348	Medium	833	May 11
Bignell 2013/14/15	351	Medium	2143	June 21
Wallace 2013/14/15	396	Medium	1304	May 9
DSouth 2013/14/15	417	High	1570	June 16
House 2013/14/15	422	High	1007	July 5
CBeech 2013/14/15	424	High	868	June 21
Campbell 2014/15*	429	High	834	June 6
Lubcke 2013/14/15	429	High	793	June 19
Quinlivan 2013/14/15	454	High	2134	May 15
SBeech 2013*	477	High	1046	June 30
Norton 2013/14/15	594	High	235	March 31
Rose 2013/14/15	714	Very High	329	May 31

*Withdrawn in 2013 and replaced by Campbell for 2014 and 2015.

A wide variety of worm control programs were in operation across the 14 flocks. In the past some of selected producers had used services for worm egg counts (WECs) and less frequently a worm egg count reduction test (WECRT) for drench resistance. The use of worm egg counting shows an awareness of the need for improved worm control by some of the selected producers. In a 2014 Western Australian sheep producer's survey, only twenty four per cent of sheep producers conducted one or more WECs.

Some consultants requested they attend visits to client properties when observations were planned. Summary information of their clients from the previous year was also provided to some consultants in 2014, 2015 and 2016.

3.2 Objective 2: Production and economic benefits

Background on information on selected flocks

An attempt was made to select sheep producers located in the medium rainfall and cereal-sheep zones reflecting the different winter growing conditions in Western Australia. The winter growing season (WGS) rainfall i.e. rainfall received between April to October was obtained for each property from 2013 to 2015. The average percent of the long term WGS was calculated for each property as shown in Table 3. The median WGS rainfall was 396 mm which represented 102% of the long term average WGS over the 3 years of the study.

The start of lambing (SOL) for the ewes whose progeny participated in the study ranged from March to July. The range in SOL was similar for flocks located in the medium and high rainfall zones of Western Australia.

Table 3 The month lambing commenced, average winter growing season (WGS) rainfall and as a percent of the long term average WGS from 2013 to 2015

Name/years in project	Start of lambing (Month)	Average winter growing season (WGS) rainfall (mm)	Percent of long term WGS
Norton 2013/14/15	March	573	96%
Robertson 2013/14/15	April	286	112%
Wallace 2013/14/15	May	439	111%
Sewell 2013/14/15	May	349	100%
Quinlivan 2013/14/15	May	513	113%
Rose 2013/14/15	May	648	91%
Pech 2013/14/15	June	338	100%
Campbell 2014/15	June	395	92%
CSouth 2013/14/15	June	302	94%

Name/years in project	Start of lambing (Month)	Average winter growing season (WGS) rainfall (mm)	Percent of long term WGS
DSouth 2013/14/15	June	379	91%
Lubcke 2013/14/15	June	395	92%
Bignell 2013/14/15	June	337	96%
CBeech 2013/14/15	June	396	93%
House 2013/14/15	July	431	102%

Growth rates in prime lambs may be influenced by a number of factors including genetic (maternal ewe and terminal sire combination), size of the maternal ewe and birth status of the lamb. Potential growth rates in the prime lamb progeny may differ depending on the maternal ewe and terminal sire combination. The categories of maternal ewes mated to a terminal sire are shown in Table 4. The most common combination of parents of the prime lamb was the result of mating a maternal Merino ewe to a White Suffolk terminal sire.

Table 4 The maternal ewe and terminal sire category

Ewe category	Number of flocks	Percent of total
Merino	23	55%
SAMM	3	7%
Merino – SAMM	5	12%
Merino – Dohne	3	7%
Merino - Border Leicester	8	19%
Terminal sire category	**Number of flocks**	**Percent of total**
White Suffolk	13	31%
Black Suffolk	6	14%
Poll Dorset	9	21%
Dorper	3	7%
SAMM	3	7%
Kelso	3	7%
White & Black Suffolk	5	12%

The size of the maternal ewe may also affect potential growth rates. The standard reference weight (SRW) of the ewe i.e. sheep in condition score 3; fleece free; and weighed 12 hours off feed was calculated. Seventeen percent of ewes had a SRW of less than 57 kg; 42% had a SRW 57 kg to 61 kg; and 42% had a SRW greater than 61 kg.

The birth status of the prime lamb progeny i.e. single or multiple or mixed (single and multiple) born may also influence the potential growth rates. In the study, 18 flocks were single born, 5 flocks multiple born, and 19 flocks were mixed born.

Prime lamb performance

Information was collected from a total of 42 flocks from 2013 to 2015. The design was a case-control i.e. prime lambs not drenched (**producer-program group**) were compared to prime lambs given drenches to suppress worms (**worm suppressed group**). Both groups of lambs grazed the same pastures and were part of a larger group of prime lambs.

Drenches to the control group of prime lambs in each flock were given according to a schedule based on time after the start of lambing (SOL) as shown in Table 5. Each visit to a property was called an event. Event 1 or the first visit to a property was at lamb marking and this time was determined by the producer. This was when the two groups of prime lambs were selected and the first drench treatment was given to the worm suppressed group. Event 1 was an average of 51 days after the start of lambing or SOL. The second property visit was Event 2 (average of 73 days SOL) or 21 days later. The next three property visits (events 3 to 5) were standardised across all 42 flocks. Event 3 was an average of 100 days or 14 weeks SOL; Event 4 was 128 days SOL and Event 5 was 156 days or 22 weeks SOL.

Table 5 The average number of days after the start of lambing when each property visit occurred from 2013 to 2015

Name/years in project	Start of lambing (date)	Event 1or lamb marking (days)	Event 2 (days)	Event 3 (days)	Event 4 (days)	Event 5 (days)
Norton 2013/14/15	March 31	67	85	103	129	157
Robertson 2013/14/15	April 2	65	85	99	127	156
Wallace 2013/14/15	May 9	53	69	98	126	154
Sewell 2013/14/15	May 11	39	63	100	132	156
Quinlivan 2013/14/15	May 15	56	74	98	126	157
Rose 2013/14/15	May 31	51	71	98	126	165
Pech 2013/14/15	June 3	57	79	100	127	157
Campbell	June 6	48	70	97	126	154

Name/years in project	Start of lambing (date)	Event 1or lamb marking (days)	Event 2 (days)	Event 3 (days)	Event 4 (days)	Event 5 (days)
2014/15						
CSouth 2013/14/15	June 15	47	77	98	130	155
DSouth 2013/14/15	June 16	48	70	98	129	157
Lubcke 2013/14/15	June 19	48	69	97	128	152
Bignell 2013/14/15	June 21	52	79	100	128	156
CBeech 2013/14/15	June 21	46	68	99	132	160
House 2013/14/15	July 5	39	66	97	129	155

Standardising the schedule of property visits according to the time since the start of lambing allowed information from different flocks to be combined each year and between years. It also reduced any confounding effects on growth rates and worm egg counts by having excessively variable dates when visiting each property. Measurements on the prime lambs were collected at similar times after the start of lambing on the 42 flocks. The average interval from lambing marking or Event 1 to Event 5 was 105 days. Measurements were collected on some flocks after the final property visit at Event 5 as the project lambs were still within the moxidectin export slaughter interval (ESI) but this information was not included in the analysis.

At lamb marking - two groups of 50 prime lambs were selected and electronically ear tagged. Both treatment groups had 25 male and 25 female lambs and were supplemented with selenium and cobalt at lamb marking and Event 3. The prime lambs in the worm suppressed group were given an injection of long acting moxidectin (ESI of 133 days). Oral moxidectin drench was given to the worm suppressed group at Events 3, 4 and 5. Macrocyclic lactones (ML) resistance was present in all but two flocks, but moxidectin was effective (95% or greater) on 6 out of 13 tested flocks. Consequently, incomplete suppression of *Teladorsagia* sp. may have resulted in higher than expected WEC in the worm suppressed group.

Individual faecal samples from the same 50 prime lambs from the producer-program group (no drench) were taken at events 2 to 5. Twenty individual faecal samples from prime lambs from the worm suppressed group were also taken at each event but not necessarily the same individual lamb. Larval differentiation from a bulk sample of faeces was done for both prime lamb groups for events 1 to 5. *Haemonchus* sp. was detected in the prime lambs from 6 flocks in 2013. As the focus of this study was on non-*Haemonchus* worms which reduce growth rates in prime lambs, it was decided to specifically remove the *Haemonchus* burdens. Consequently in 2014 and 2015, prime lambs from the producer-program group from the 6 flocks were given a closantel drench at lamb marking and Event 3 to remove *Haemonchus* leaving other strongyles and *Nematodirus* worms. In Western Australia there is no recorded resistance to closantel by *Haemonchus* sp. nor was resistance detected following drenching with closantel when conducting the worm egg count reduction test (WECRT).

Every prime lamb was given a visual dag score using a scoring system for dags on unmulesed lambs from event 1 to 5 (AWA and MLA Visual sheep score booklet). A lamb with score 1 has no dags; a score 5 animal has extensive dags not only remaining in the breech area, but extending right down the hind legs to the pasterns.

The 100 selected prime lambs from both treatment groups (producer-program and worm suppressed groups) were weighed at each event. The average growth rate for each treatment group per period per year was calculated. Prime lamb flocks with a significantly higher growth rate ($p < 0.05$) in the worm suppressed group compared with the producer-program group from events 1 and 5 were deemed to have a **'worm effect'**. This was further divided into two categories: events 1 to 3 and events 3 to 5. Information from 39 flocks was used in this analysis. The liveweight in each group per flock was adjusted to all start on 51 day SOL at lamb marking. Similarly the final liveweight was adjusted to 156 days SOL. The difference in adjusted liveweight between the two treatment groups of prime lambs for each flock per event was calculated.

The average group WEC was calculated which included strongyle minus *Haemonchus* and *Nematodirus.* The formula [(strongyle WEC minus *Haemonchus* + (two times *Nematodirus* WEC))] was used to calculate the weighted average WEC for each treatment group per event per flock (due to the far lower egg output for *Nematodirus* spp*.* compared to other strongyles). This allows all worm species from 36 flocks to be included in the analysis. It also minimised differences in average group WEC in flocks located in medium and high rainfall zones.

The average WEC from the whole period from events 2 to 5 was then calculated. The average WEC was adjusted for days between sample events for each flock and if they were drenched during this period. The adjusted difference between WECs of the two treatment groups for each flock from event 2 to 5 was used in the analysis i.e. WEC in the producer-program group minus WEC in worm suppressed over 105 days.

The correlation of worm egg counts (WEC) and growth rates was investigated using a case-control format. Odds ratios were used to investigate which characteristics of these 'worm effect' cases (birth status category; month of lambing category; agricultural zone category; terminal sire or maternal ewe category or year; growth rate to Event 3 or 14 weeks after the SOL category) are risk or protective factors.

An alternative way to create case-control flocks is to use the difference in liveweight gain between the two treatment groups. The 50% percentile was greater or less than 0.71kg difference between the two treatment groups. Prime lamb flocks had a greater than 0.71 kg difference in the worm suppressed group compared to the producer-program group. Some 17, or 47%, of case flocks were considered to have a 'positive worm effect' over an average of 105 days.

Ten flocks provided slaughter information on average carcase weight, fat score and dollar per head per treatment group. The prime lamb treatment groups were weighed on the day before they were sent to slaughter to calculate yield and faecal samples from individual sheep were collected. The prime lambs were sent to slaughter an average of 41 days after Event 5 or 156 days after the SOL.

<u>Integrated parasite management in ewes</u>

Information from the drenched ewes was collected in 2014 and 2015 to access the effectiveness of the integrated parasite management (IPM) programs. In 2015, the only IPM practice evaluated on 14 flocks was drenching the ewes with an effective autumn drench (>98% effective) in the first week of April before break of season to minimise pasture contamination by worm larvae as per DAFWA recommendations.

There were 16 flocks with pre and post WECs and larval differentiation results from the ewes and subsequently from their lambs to Event 3 or 98 days after the start of lambing. Pre-lambing WEC was taken after giving the autumn drench (a standard recommendation in WA, aimed at reducing the development of drench resistance by avoiding drenches in summer in mature sheep). An average of three 3 sampling dates (lambing marking or Event 1 or 50 days SOL, Event 2 or 72 days SOL and Event 3 or 98 days SOL) of post WEC were calculated.

Worm egg count reduction test (WECRT) for drench resistance were undertaken in 13 out of 14 flocks by December 2015. Results for *Teladorsagia* egg count reduction were analyzed to determine what drenches were effective. *Haemonchus* was removed by drenching with closantel in flocks known to have this worm. All producers were sent the results of the WECRT before requesting they drench the project ewes in the first week of April with an effective drench. One flock that commenced lambing in March was given an effective drench before the start of lambing.

Nematodirus spp. was present in all prime lamb flocks. To take into account this mixed infection of worms a formula [(strongyle WEC minus *Haemonchus* + (two times *Nematodirus* WEC))] (as outlined for the lamb results, above) was used to calculate the weighted average WEC for each treatment group per event per flock.

3.3 Objective 3: Protocols for worm control decisions

Individual samples from the same 50 prime lambs from the producer-program group (no drench) were taken over the timeframe of events 2 to 5 (defined in Objective 2), an average interval of 83 days. Twenty individual samples from prime lambs from the worm suppressed group were also taken at each event (not necessarily the same individual lambs). A formula [(strongyle WEC minus *Haemonchus* + (two times *Nematodirus* WEC))] was used to calculate the weighted average WEC for each treatment group per event per flock. The average WEC from the whole period from events 1 to 5 was then calculated. The average WEC was adjusted for the number of days between sampling events in each flock, and if they were drenched during this period. The difference in growth rates between the worm suppressed and producer-program group of lambs was calculated for each event. The correlation between the flock values of differences in WEC and growth rate between the two groups and the dollar cost was calculated. Data from 36 flocks over the 3-year project period were used in this analysis. Strategies for worm control were designed - these aimed for the maximum cost/benefit but also had to be practical.

4 Results

The results for each objective are:

4.1 Objective 1: Develop a network of sheep consultants

Initial presentations to the consultants were made in 2014 to advise then of the project and ensure familiarity with current worm control recommendations. Presentations included “Sheep worm control and program development update”, “Drenches and drench resistance” and “long-acting anthelmintics”, plus a basic introduction to parasite biology where appropriate. In addition to the 7 consultants involved in the project, an additional 7 veterinarians and 2 agricultural consultants participated in the sessions, further extending the expansion of expertise.

In addition to discussion of the project at several field days and worm control updates in 2015 and 2016, sheep health workshops March and April 2017 included key messages from the project. These workshops were held at 5 locations and attracted 119 sheep producers. The majority of people that completed the feedback forms were interested in this topic. Prime lamb worm control was also discussed in a presentation on worm control to the West Midlands Group in March, 2017.

In addition, presentations were made to professional conferences: Australian Sheep Veterinarians (Hobart, February 2015), and the World Association for the Advancement of Veterinary Parasitology (Liverpool, August 2015).

4.2 Objective 2: Production and economic benefits

<u>Prime lamb performance</u>

At each visit, there is a gradual increase in adjusted liveweight of prime lambs in the worm suppressed group compared with the producer-program group (no drench). A 1.1kg difference between treatment groups is evident by Event 5 as shown on Table 6. This is because 86% of flocks recorded a higher growth rate in the worm suppressed prime lamb compared with the producer-program group. One third of the potential loss of 1.1 kg had occurred by Event 3 (100 days or 14 weeks after the start of lambing) increasing to 67% by Event 4.

Table 6 The average adjusted live weight of the producer and worm suppressed groups at Event 1 and Event 5

Adjusted average weight	Producer-program group (kg)	Worm suppressed group (kg)
Event 1 (51 days SOL)	17.4	17.5
Event 5 (156 days SOL)	40.6	41.8

On individual flocks over 3 years, 28% of prime lamb flocks had a ‘worm effect’. These flocks had significantly higher difference in average WEC of 474 epg compared with 261 epg in the unaffected flocks (p=0.005). The increase in growth in prime lambs from the worm suppressed group was 19.8 g/h/d or 2.1 kg in total. This represents an 8% improvement in growth rates in worm suppressed groups over an average of 105 days.

The average WEC of the producer-program group of prime lambs in 'worm effect' flocks had significantly higher strongyle worms (minus *Haemonchus)* as shown in Table 7. The average WEC for *Nematodirus* was higher in the medium compared with the high rainfall zones for both flock categories.

Table 7 The average worm egg counts in the producer-program group in different DAFWA agricultural zones

Agricultural zone	Producer-program group	Average WEC (epg)	Average WEC (epg)	Average WEC (epg)
		Strongyles (minus *Haemonchus*)	*Nematodirus* spp.	*Strongyles + Nematodirus* (x2)
Medium	Worm effect	404[a]	74	551[c]
Medium	Unaffected	158[b]	54	266[d]
High	Worm effect	394[a]	42	477[c]
High	Unaffected	244[b]	29	293[d]

[a] vs [b] p=0.02 and [c] vs [d] p=0.005

No risk factor was associated with 'worm effect' flocks. That is, birth status of lamb category; month of lambing category; agricultural zone category; terminal sire or maternal ewe category or year did not influence 'worm effect' or unaffected flock categories.

However, growth rate of the prime lambs from lamb marking to 14 weeks after SOL was one potential protective factor that appears to help mitigate some of the effects of higher worm burdens as shown in Table 8. Flocks with growth rates of 240 grams per head per day or greater in the producer-program and worm suppressed groups in the first 100 days after the SOL had a reduced risk of being classified as 'worm effect' at the 90% level of confidence.

Table 8 The odds ratio of growth rate mitigating the effects of worms at 90% level of confidence

Estimate	Estimate	Lower 95% limit	Upper 95% limit
Overall proportion of cases	0.29	0.16	0.44
Proportion exposed in cases	0.3	0.09	0.61
Proportion exposed in non-cases	0.64	0.46	0.8
Odds of exposure in cases	0.43		
Odds of exposure in non-cases	1.78		
Odds ratio	**0.24**	**0.06**	**0.91**

The winter growing season (WGS) rainfall in each 'worm effect' property ranged from 230 to 769 mm. The WGS rainfall in 2013 and 2014 was above the long term average on most properties. In 2015, the WGS rainfall ranged from 69% to 106% between properties. The widespread reduction in WGS rainfall in all but 2 flocks resulted in significantly reduced growth rates in both prime lamb groups as shown in Table 9. The drier winter growing season in 2015 also resulted in a non-significant reduction in average WEC i.e. difference between the average WECs of the treatment groups.

Table 9 The annual winter growing season (WGS) and average growth rates in prime lamb flocks on 14 properties

Year	Percent of long term WGS	Average WGS (mm)	Producer program group (g/h/d)	Worm suppressed group (g/h/d)	Average difference in WEC (epg)
2013	106%	443	234[a]	244[c]	339
2014	108%	444	225[a]	234[c]	345
2015	82%	343	203[b]	210[d]	275

[a] vs [b] p=0.048 and [c] vs [d] p=0.025

The percent of 'worm effect' flocks in each year was not significantly different despite the reduction in 2014 and 2015. The reduction in WGS rainfall on most properties and a decrease in WEC in flocks may have also contributed to a reduction in percent of 'worm effect' flocks in 2015 as shown in Table 10.

Table 10 The number and percent of flocks with a 'worm effect' for each year

Year	'Worm effect' flocks	Unaffected flocks	Total	Percent 'worm effect'
2013	5	8	13	38%
2014	4	10	14	29%
2015	2	10	12	17%
Total	11	28	39	28%

In the 17 cases flocks based on 50% percentile, the lambs in the worm suppressed group gained an extra 1.7 kg or 16 g/h/d. The 7% improvement in growth rates by suppressing worms in the case flocks was similar to 'worm effect' flocks. However, the growth rate advantage in the worm suppressed group was only 1.5 g/h/d in the other 19 control flocks. Case flocks with a greater than 0.71 kg difference between treatment groups also had a significantly higher average WEC of 407 epg compared with 252 epg in the unaffected or control flocks (p=0.036).

Information at slaughter was obtained from 10 prime lamb flocks as shown in Table 11.

Table 11 Information on prime lambs at slaughter from the producer-program and worm suppressed groups from 10 flocks

Slaughter information	Average
Producer-program group (PG) – carcase price	$4.45/kg
Worm suppressed group (WSG) – carcase price	$4.48/kg
Producer-program group (PG) – carcase wt.	22.3 kg
Worm suppressed group (WSG) – carcase wt.	22.7 kg
Yield (PG)	44%
Yield (WSG)	44%
18.1–24 kg carcase and fat score 2–4 (PG)	85%
18.1–24 kg carcase and fat score 2–4 (WSG)	83%
Gain by worm suppressed group ($/head)	**$2.70**

Table 11 includes five unaffected flocks with no difference in the average liveweight between treatment groups and consequently carcase weight despite being killed 51 days (average) after Event 5. In comparison, prime lambs from the five 'worm effect' flocks were sent to abattoirs 34 days (average) after Event 5. The difference in average liveweight between the treatment groups increased from 1.7 kg at 156 days after the SOL to 2.9 kg at slaughter. Consequently, the economic gain in the worm suppressed group was $5.73 per head as shown in Table 12. The gain was from increased carcase weight and price per kilogram received.

Table 12 Information at slaughter on prime lambs from the producer-program and worm suppressed groups from 5 'worm effect' flocks

Slaughter information – 'worm effect'	Average
Producer-program group (PG) – carcase price	$4.33/kg
Worm suppressed group (WSG) – carcase price	$4.40/kg
Producer-program group (PG) – carcase wt.	21.2 kg
Worm suppressed group (WSG) – carcase wt.	22.2 kg
Yield (PG)	44%
Yield (WSG)	44%
18.1–24 kg carcase and fat score 2–4 (PG)	87%
18.1–24 kg carcase and fat score 2–4 (WSG)	86%
Gain by worm suppressed group ($/head)	**$5.73**

Twenty eight or 72% of flocks were drenched by producer before Event 5 or 22 weeks after the SOL. The normal practice was to wean and drench their prime lambs at an average of 119 days or 17 weeks after the SOL (range 14 to 22 weeks SOL). None of the prime lambs sent to slaughter were drenched after Event 5. Overall, prime lamb producers in this study have the potential to gain $1.58 per head with improved worm control by slaughter.

Integrated parasite management of the ewes

No evidence of a reduction in drench efficacy was detected for *Trichostrongylus* spp., *Chabertia* sp. or *Nematodirus* spp. worms.

A reduction in WEC by Teladorsagia of 98% or less to macrocyclic lactones (ML) drenches was evident in 8 out of 13 flocks as shown in Table 13. A multi-combination drench was greater than 98% effective in all but 4 flocks. Efficacy of abamectin in these 4 flocks was less than 85%. There was evidence of severe resistance to abamectin (<60% reduction) in 2 flocks and moderate resistance (60% to 90% reduction) in another 5 flocks.

Table 13 Percent reduction in worm egg counts by *Teladorsagia* in 13 flocks (WECRT)

Flock	Year	Combination BZ+LEV	Abamectin	Moxidectin	Triple - ABA+BZ+LEV
Wallace	2013	100%	100%	100%	100%
Pech	2014	54%	100%	100%	100%
Bignell	2013	95%	99%	100%	100%
SouthC	2014	100%	98%	100%	100%
Lubcke	2013.	35%	87%	97%	100%
House	2015	31%	89%	95%	100%
Sewell	2014	38%	97%	93%	100%
Campbell	2014	80%	99%	94%	100%
Quinlivan	2013	49%	87%	94%	99%
SouthD	2014	0%	84%	98%	98%
BeechC	2015	19%	79%	89%	95%
Rose	2013	83%	58%	87%	91%
Norton	2015	-9%	40%	59%	54%

Based on DAFWA recommendations an increasing percentage of participating producers drenched in autumn as shown in Table 14. In 2015, 9 producers drenched around the recommended time (first week of April) and 8 out 9 gave an effective drench (>98%).

Table 14 The number and percentage of flocks that were drenched in autumn from 2013 to 2015

Year	Total flocks	Autumn drench	Precent
2013	14	5	36%
2014	14	7	50%
2015	14	9	64%
Total	42	21	50%

After giving an effective drench in autumn, a pre-lambing WEC was taken and the corrected average WEC is shown on Table 15. Five flocks with a lamb category of 'worm effect' had significantly higher corrected WEC (average of 647 epg) compared with 11 unaffected flocks (average of 254 epg) by Event 3 or day 98 SOL. There were a small number of groups of ewes with a pre-lambing average WEC greater than 100 epg but similar portions in the two ewe-lamb categories.

Table 15 The average pre (minus 25 days before the start of laming) and post lambing (events 1 to 3) WECs for ewes from 16 flocks in 2014 and 2015

Ewes	Pre lambing WEC (epg)	Post lambing WEC (epg)
Ewes with 'worm effect' lambs	47	207
Ewes with unaffected lambs	48	189

The differentiation of strongyle larvae from ewes adjusted for *Nematodirus spp.* is given in Table 16. In ewes, the main strongyle worm present at the pre-lambing sampling following the autumn drench was *Teladorsagia* sp. which is not unexpected.

Table 16 Larval differentiation of strongyles from ewes at pre (minus 25 days before the SOL) and post lambing (events 1 to 3) adjusted for *Nematodirus* spp.

Larval differentiation for ewes	Pre-lambing	Post-lambing
Teladorsagia sp.	80%	51%
Trichostrongylus spp.	13%	37%
Haemonchus sp.	0%	0%
Chabertia sp.	6%	9%
Nematodirus spp.	1%	3%

The differentiation of strongyle larvae from their lambs (average of Event 2 and 3) is shown in Table 17. There was no difference in larvae population between 'worm effect' and unaffected prime lamb flocks, but 'worm effect' flocks had significantly higher all-species

WECs. However, the percent of *Nematodirus* spp. in the prime lambs was much higher compared with their mothers (16% vs 3%). While *Teladorsagia* sp. was the main worm present (70%) most of groups of prime lambs had a mixed infection.

Table 17 Larval differentiation of strongyles from the progeny of the ewes (average from Event 2 and 3) adjusted for *Nematodirus* spp.

Larval differentiation	Prime lambs
Teladorsagia sp.	70%
Trichostrongylus spp.	13%
Haemonchus sp.	0%
Chabertia sp.	1%
Nematodirus spp.	16%

Figure 1 shows the increase in corrected average WEC of the producer-program group (no drench) from Event 1 (lamb marking) to Event 5 or 154 days SOL. After Event 4 or 128 days after SOL, a predicted worm egg count was generated as the majority of producer-program group lambs were drenched. The increase in average corrected WECs on ‘worm effect’ flocks was more rapid compared with unaffected flocks. The predicted average corrected WEC was 1381 epg at Event 5 on ‘worm effect’ flocks compared with average of 688 epg on unaffected flocks.

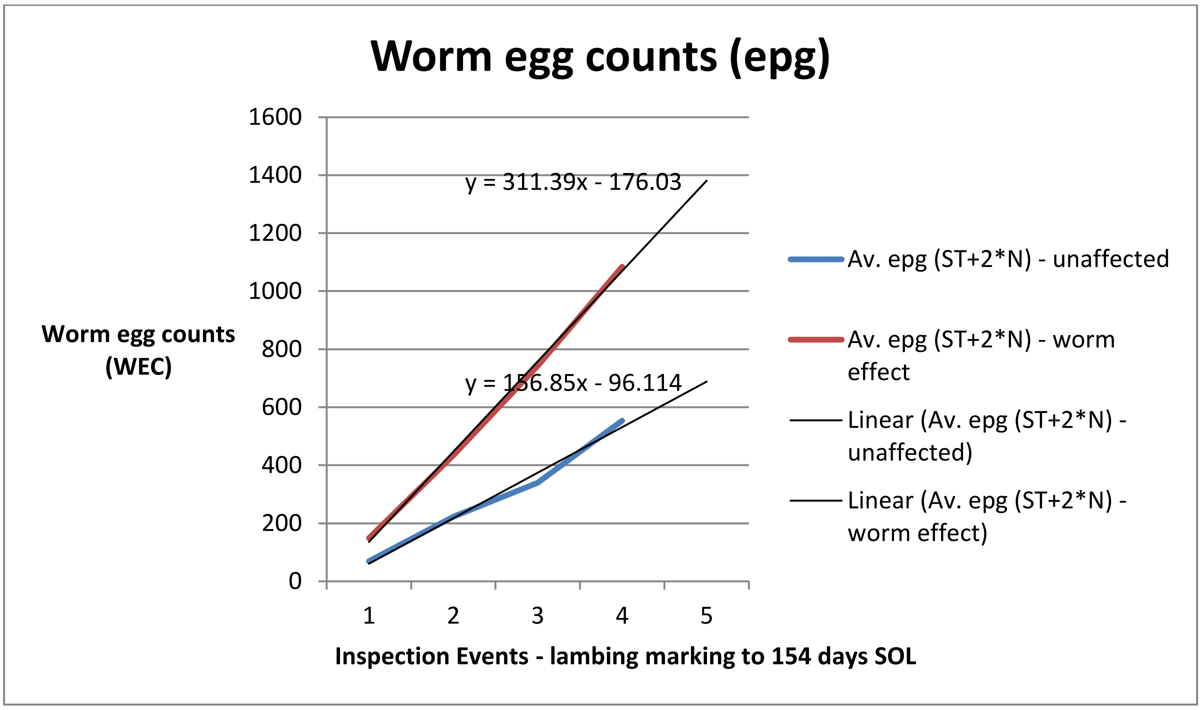

Fig. 1 Increase in the average WEC of the producer-program group from the ‘worm effect’ and unaffected flocks from Event 1 (lamb marking) to Event 5

4.3 Objective 3: Protocols for worm control decisions

Figure 2 shows the impact of WEC on growth rates in the prime lambs, as the difference between worm-suppressed and producer-program groups. The p-value for the linear regression (within intercept) is p=0.001. The intercept is not significantly different to 0 and was omitted from the graph. It indicates a reduction in growth rates as WECs increased across the 36 flocks in this study.

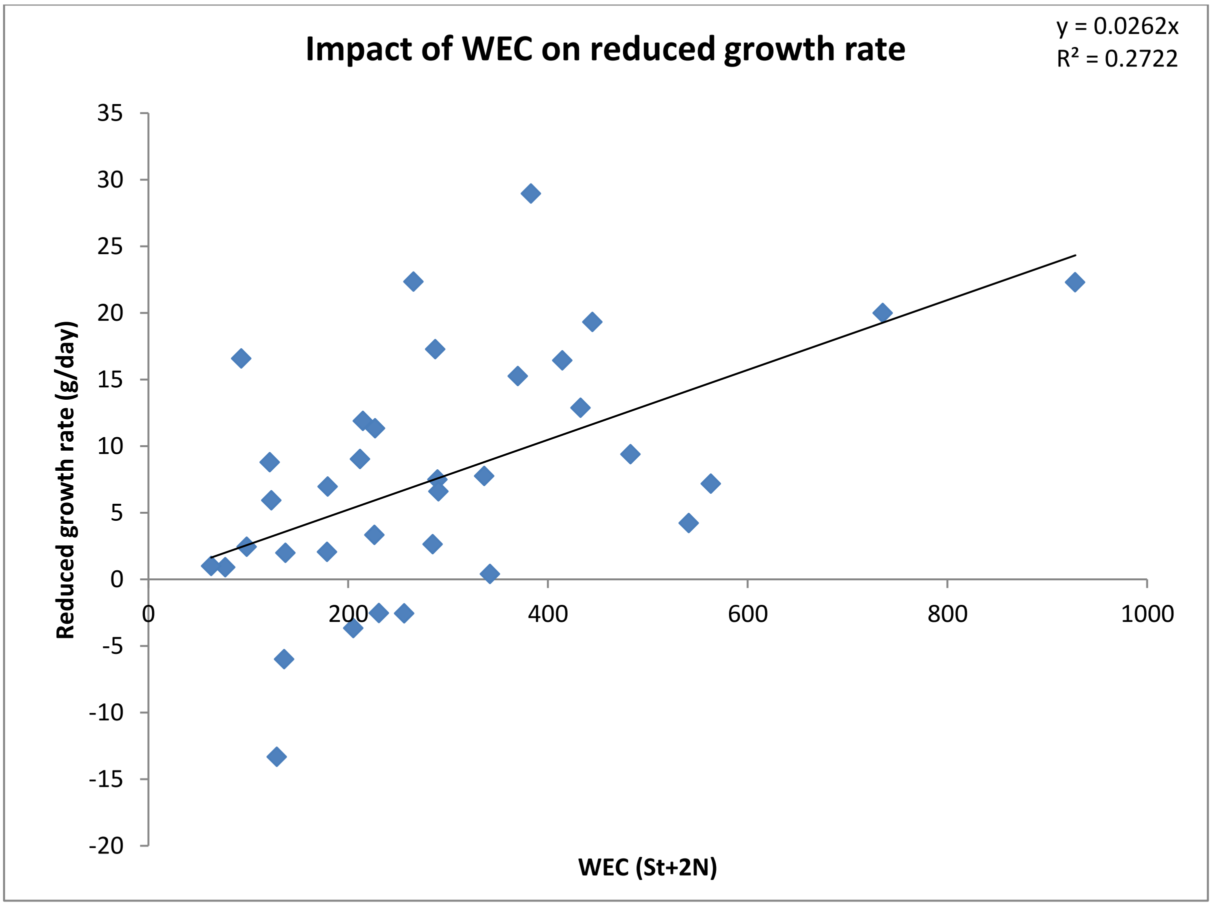

Fig. 2 The impact of WEC on growth rates in the prime lambs

Figure 3 shows the impact of weight gain on price at slaughter. The net increase in weight and price per head per group is presented. It shows what the increase in price can be at slaughter. The prices for the prime lambs sent to WAMMCO (Katanning) or Washes (Bunbury) abattoirs were for the October to February period.

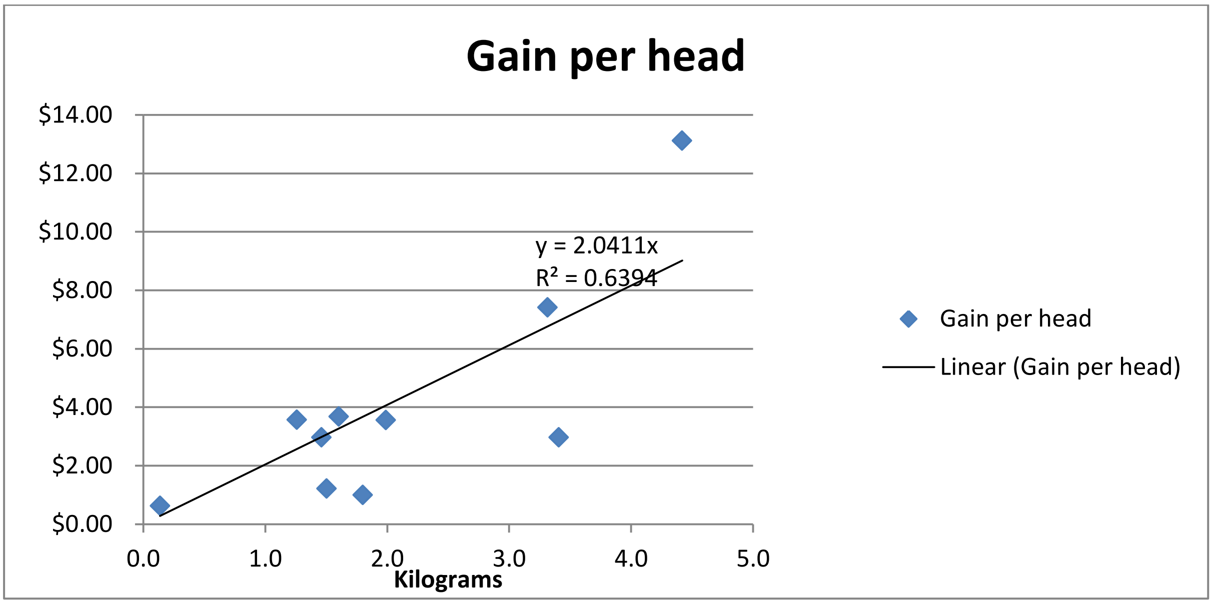

Fig. 3 The impact of weight gain on price at slaughter

A table based on information from these two charts was used to investigate potential cut-off average WEC values associated with a significant economic benefit. The average WECs for three flock categories is shown in Table 18.

Table 18 The average WECs for unaffected and 'worm effect' flocks

Flock category	Unaffected flocks	50% percentile	'Worm effect'*
Average difference WEC (epg) per 105 days	250	407	474
Difference in growth rate (g/h/d) per 105 days	7	11	12
Difference Kg/head per 105 days	0.68	1.12	1.30
$ per head per 105 days	$1.40	$2.28	$2.65

* "Worm effect" refers to a statistically-significant difference in average lamb growth rates between suppressed and producer-program groups over the modelled period of growth, where mean worm egg counts were also significantly different. (See Objective 2 for details)

The average WEC from the whole period from events 2 to 5 of 350 epg is a possible cut-off point when consistent benefit is likely to occur in 95% of flocks. This is when worm control is expected to result in a gain of $2 and rising when slaughtered later.

Converting the average WEC from the whole period to a single WEC at a particular time for which action is required was attempted. The critical single WEC is different for 73, 100, 128 and 156 days after the start of lambing. Sampling requires collection of faeces from 20 individual prime lambs. Sampling at day 73 after the SOL, is an attempt to predict that future worm burden may lead to significant reduction in growth rates by slaughter. If the single WEC (strongyle minus *Haemonchus* + 2x*Nematodirus)* is greater than 250 epg then the prime lambs would require a drench by 14 weeks after the start of lambing. As 84% of the strongyle population in prime lambs is *Teladorsagia* sp. at 14 weeks SOL the drench is required to be greater than 98% effective.

5 Discussion

The discussions for each objective are:

5.1 Objective 1: Develop a network of sheep consultants

Animal health and production communication is currently in a state of flux in Western Australia, with consequences for the efficient dissemination of information from this project to the industry. Until 2016, the Department of Agriculture and Food WA maintained a strong multi-channel extension function, including information to industry professionals as well as producers. However, with recent staff reductions and the termination of most research, development and extension functions, many traditional communication channels no longer exist. The sheep industry has yet to adjust to these changes and to actively seek alternative advisory sources, but it is likely that technical advice will be increasingly provided by private consultants, and more generally through local producer organizations. In this context, the present project provides an opportunity to upskill information providers in parasite management, and specifically in worm control in prime lambs.

It has become obvious that the lack of background of agricultural consultants in animal health reduces the confidence of most in providing detailed advice. Even with information and assistance from DAFWA staff (though there are now no specialist parasitologists), it appears that they will not actively assist clients in planning annual worm control programs. In this situation, the most effective tactic may be to ensure that they are familiar with the key messages from the project, and are able to refer clients to the ParaBoss website and DAFWA webpages (while these exist).

Despite this, the project findings have increased the awareness of the consultants of the economic necessity for effective worm control, particularly in prime lambs, and of the basic elements of control programs. This is likely to provide a positive benefit in promoting more efficient worm control to the local industry, regardless of how specific information is provided.

The veterinarians involved with the project are familiar with worm control recommendations and hence able to add the new findings to their advice programs, but are generally less familiar with sheep nutrition and pasture management than the agricultural consultants. In addition, sheep producers do not at present routinely consult private veterinarians on sheep management, and worm control queries are typically single-issue requests. There is much scope for extending the awareness of producers that veterinarians can assist with planning worm control. The project has extended the awareness of the both the consultants and veterinarians that sheep worm control does not entail only drenching programs, but should be based on IPM principles, which requires an understanding of the role of nutrition, pastures and genetics.

There is also likely to be a significant parasite-management information role for the locally-based producer groups, which typically have up to 200 members, and have expanded their activities in recent years to include small-scale trials and demonstrations as well as information days and on-line newsletters. Examples include: “A-Sheep” (Esperance), “Stirling to Coast” (Albany – Mt Barker), “Southern Dirt”, the Liebe Group and Facey Group (mid-Great Southern), Kondinin Group (especially wheatbelt), and the West Midlands Group (Badgingarra-Dandaragan). Initial contact indicates interest by these groups in including livestock parasite updates, and it should be feasible to secure regular information opportunities. It will be important that the websites that provide basic information (especially ParaBoss) are comprehensive and current, and updating is presently in progress for the WA situation.

The new information from this project will provide a good basis to interest the non-DAFWA advisory sources in WA – consultants, veterinarians, producer groups - in new and economically-significant strategies. However, ideally this would be within a planned framework, and some resources to initiate and develop new communication channels would be provided.

5.2 Objective 2: Production and economic benefits

<u>Prime lamb performance</u>

In this study higher growth rates in the worm suppressed compared to the producer-program group was recorded in 86% of prime lamb flocks. High average WECs (strongyle minus *Haemonchus* and 2x*Nematodirus)* in prime lambs were associated with significantly reduced growth rates from events 1 to 5. The ‘worm affect’ flocks were located in both medium rainfall and cereal-sheep zones of Western Australia. Improved worm control should reduce the potential loss at slaughter of $5.73 per head in this group. About 70% of this value is attributed to increased carcase weight gain at slaughter but 30% of the value is due an increase in the average cents per kilogram per carcase weight price paid for the worm suppressed group

Worms have the potential to reduce growth rates in almost all prime lamb flocks and some economic loss cannot be avoided. An alternative method to categorise flocks into case and controls suggest a small growth rate advantage in the worm suppressed group of 1.5 g/h/d in the 19 flocks classified as unaffected (control). Worm control in prime lambs is about what to do to avoid forgoing dollars by sale or slaughter. That is, the difference in value of lambs from the 17 case flocks with a 7% improvement in growth rates and the 19 control flocks with a 1% improvement in growth rates when suppressing worms by the time of Event 5.

The normal practice was to wean and drench their lambs an average 17 weeks after the start of lambing. This may be the only drench given to the prime lambs before they were sold or sent to slaughter. In some cases the drench was required to treat a significant worm burden and others was to minimise future production loss. However, it was too late in the production cycle as 67% of any potential weight loss had already occurred. Not all producers with a ‘worm effect’ drenched their prime lambs by Event 5. Conversely, owners of flocks that were unaffected did drench their lambs, but were unlikely to retrieve much benefit. Grazing management following weaning was determined by the producer. Depending on the time of lambing, some flocks had to graze pasture paddocks post weaning that were potentially highly contaminated with worm larvae. Grazing of low worm burden paddocks like a standing fodder crop post weaning was only available for those producers that started lambing from late June onwards, and weaned and drenched at least 17 weeks after the start of lambing.

The average liveweight of prime lambs at slaughter was 50.5 kg in the 10 flocks. The prime lambs were sent to the abattoir on average at day 197 or 28 weeks after the start of lambing. The export slaughter interval component of this project may have delayed the slaughter of some prime lambs. However, there is a need for integrated parasite management activities to reduce the effects of worms in prime lambs post drenching. The continual and increasing reduction in growth rates post drenching in the ‘worm effect’ flocks demonstrates the need for such consideration. Importantly, as no worm-risk factors could be discerned (apart from lamb growth rates), the likelihood of a worm-induced profit penalty may occur in any flock where worm populations are not actively managed by IPM and drenching strategies.

<u>Integrated parasite management of the ewes</u>

In 2015, more producers voluntarily drenched their project ewes around the first week of April compared with the previous years. The main difference was the use of an effective drench in 2015, as 8 out 9 flocks received an effective drench (>98%) compared with 1 out 7 flocks in 2014. However, drenching the ewes in autumn with an effective drench did not affect the worm outcome in their progeny. In a normal Western Australian summer with hot and dry weather the vast majority of strongyle worm eggs in sheep faeces on pasture die quickly, and never reach the larval stage that can infect sheep. However in autumn, higher rates of survival of worm larvae in faeces typically occur, leading to increased contamination of new green pasture in the early winter period. The level of pasture contamination in the early winter months (May and June) determines which WEC pathway the prime lamb progeny will take.

Some 36% of flocks from the medium agricultural zone had a ‘worm effect’ compared with 24% of flocks from the high/very high zones. The longer hotter summer did not result in a reduced risk of a ‘worm effect’ in prime lambs in the winter growing season.

Prime lambs from unaffected flocks were predicted to have an average WEC of around 1,000 epg at slaughter if not drenched. However, it is the rate of WEC increase from lamb marking to slaughter that appears to be the key in these flocks (i.e. lower counts for longer are associated with better growth rates).

In addition, the 19 unaffected flocks had higher growth rates in the producer-program group of prime lambs relative to the worm suppressed group. The interaction between the two factors may be one reason why there is only 1.5 g/h/d between the producer and worm suppressed groups in the 19 unaffected flocks.

5.3 Objective 3: Protocols for worm control decisions

The proposed single critical WEC (strongyle minus *Haemonchus* + 2x*Nematodirus*) of 250 epg taken about 10 weeks after the start of lambing should detect 95% of prime lamb flocks that left untreated will continue to have significant loss in weight over the next 10 weeks. A drench within 3 weeks after sampling would provide a significant benefit. However, if the WEC is below 250 epg at 10 weeks after the SOL, then drenching can be delayed until 17 weeks after the start of lambing, as normally practiced by 72% of producers in this study.

For those flocks with greater than 250 epg at 10 weeks after the SOL, this suggests that they are grazing highly contaminated pastures. In addition to the drench by 14 weeks, it would be recommended to wean the lambs at that time. However, this is not a common practice by prime lamb producers, as lambs are often not weaned until some weeks later. Ideally lambs should be weaned onto a lower worm challenge paddock, as otherwise WECs are likely to rebound to previous levels within 4 weeks. No producer in this study consciously prepared a lower worm burden pasture paddock to be available at 14 weeks after the SOL. Consequently, a second WEC at 128 after the SOL is important to assess the contamination of the weaning paddock. Worm burdens above 250 epg at day 128 the SOL require a second drench. To maximise the benefit of drenching for longer it best to graze the prime lamb on a lower worm burden paddock.

At present, taking worm egg counts at 10 weeks after the SOL is not a routine recommendation or commonly practiced by producers. However, the indication that a count at this time provides a good index of the need or otherwise of a drench soon afterwards (and ideally, a move out of the paddock) raises the issue of whether this should become a routine recommendation, as leaving the treatment to a more usual 17 weeks or later after the start of lambing (i.e. the usual time of weaning for prime and Merino lambs) risks significant production loss. Twenty one percent of the potential loss of 1.1 kg to worms in this study had occurred by 10 weeks increasing to 33% over the next 3 weeks or an additional loss of 12%. However, further delaying treatment until 18 weeks after the SOL the potential additional loss in liveweight has now increased to 34%. In the first 22 weeks after the SOL any reduction in growth rates in prime lambs grazing pastures is not compensated by slaughter. The alternative to a worm egg count is to drench as a routine, which is not best practice.

In this study, a higher average growth rate after the start of lambing was identified as a potential factor that may mitigate some of the effects of a worm burden in prime lambs. This suggests that prime lambs are more resilient to worm burdens provided that Feed-On-Offer remains above 2,000 kg/hectare dry matter. This facilitates the maximum intake of pasture and consequently prime lamb growth rates.

It appears that best-practice worm control over the critical period for prime lamb growth should include: conducting worm egg counts about 10 weeks after the SOL; weaning and giving an effective drench shortly afterwards if over 250 epg; drenching onto lower worm burden paddocks; and ensuring that average growth rates are greater than 240 g/h/d in the first 14 weeks after the start of lambing. This would be cost effective and relatively easily-implemented, as there is significant economic value to be gained in prime lambs destined for slaughter at around 28 weeks after the start of lambing.

6 Recommendations

6.1 Carcase Composition

Prime lamb producers in this study have the potential to gain an average of $1.58 per head by following the recommendations for improved worm control before slaughter at 28 weeks after the start of lambing. While the majority of this value is attributed to increased carcase weight gain at slaughter some is also due an increase in the average cents per kilogram per carcase weight price paid for the worm suppressed group. Reasons for this increase in price are unknown but it may be related to carcase composition. The Meat Standards Australia (MSA) model of best practice for prime lamb production includes recommendations for feed management, handling, curfew, slaughter, product aging and retail presentation. The process has been shown to successfully reduce the variation in sheep meat tenderness. However, the role of improved worm control in prime lambs in Western Australia as part of the feed management section of this process should be further investigated.

6.2 Digital record-keeping

A new paradigm is that many sheep enterprises in Western Australia are now composed of multiple and often large properties. All 14 sheep enterprises involved in this study had one to 5 additional properties. Most sheep enterprises have their own transport and movement of sheep between properties occurs regularly. For example, monitoring the same group of ewes over summer resulted in sampling on three different properties. The ewes received their autumn drench on one property and then were subsequently transported to another property for the start of lambing. The producer did not know what other group of sheep had grazed the lambing paddock in the previous 2 months nor what drench treatments they had received. Consequently, preparing a low worm burden paddock for lambing ewes in autumn becomes very difficult. The development of digital record keeping applications (“smart phone farm apps”) that track movements of sheep may offer a solution but while they show the location of sheep in a paddock at one point in time they will need further development to better define the potential worm burden of a lambing paddock. This requires a risk based assessment for a lambing paddock rating its potential worm burden in early winter. This could also be applied to weaning prime lambs onto lower worm burden paddocks during August to November.

7 Key messages

What to do to avoid forgoing dollars in prime lambs at slaughter

- Prime lambs grazing green pastures during the winter growing season (April to October) should not accumulate high scour worm burdens as it reduces:
    1. Liveweight and carcase at slaughter
    2. Dollar value received for the carcase
- Prepare low worm burden paddocks in autumn by:

1. Drenching ewes with an effective drench (>98%) around the first week of April, well before the “break of season” (or is giving a summer drench, leave 10-20% undrenched)
2. Checking worm egg counts of ewes pre-lambing and drench if the average is more than 100 eggs per gram
3. Plan lambing paddocks grazed by other sheep so they also have a low worm level

- Monitor prime lambs about 10 weeks after the start of lambing (collect 20 faecal samples from lambs in each mob):

1. If greater than 250 epg (average), give an effective drench the lambs at 14 weeks after the start of lambing
2. Re-sample 4 weeks later, and if greater than 250 epg – then give another drench
3. If less than 250 epg at 10 weeks, wean and drench as for normal practice

If worm egg counts are not checked, a drench should always be given by 17 weeks at the latest, regardless of how well lambs appears to be growing.

- Ensure average growth rates in lambs are 240 grams per head per day or greater to 14 weeks after the start of lambing to help mitigate some of the effects of scour worms
- Maintain good growth rates in lambs after 14 weeks after the start of lambing – don’t let Feed-On-Offer (FOO) go below 2000 kg/ha.
- Prepare low worm burden paddocks to wean prime lambs onto, as otherwise worm burden are likely to be high within 4 weeks.
- Options for lower worm burden paddocks from August to November include:

1. Paddocks grazed by adult non-pregnant sheep with low WEC for last 2 months
2. Pasture paddocks cut for hay which has not been grazed for last the 2 months
3. Paddocks sown for hay and grazed following the removal of baled hay
4. Standing fodder or cereal crops
5. Spray-topped or hay-freeze pasture paddocks not grazed for the last 2 month
6. Renovated pasture paddocks not grazed for the last 2 months
7. Paddocks grazed by cattle for the last the 2 months

- Stubble paddocks are not generally available until December – given an effective summer drench onto stubbles to any residual prime lambs not sold

8 Bibliography

Carmichael I (2009) Parasite Control in Southern Prime Lamb Production Systems. MLA Report AHW 045.

Coop RL, Kyriazakis I (1999) Nutrition-parasite interactions. Veterinary Parasitology 84, 187–2004.

Dever, M.L., Kahn, L.P., Doyle, E.K. (2015) Persistent challenge with *Trichostrongylus colubriformis* and *Haemonchus contortus* larvae does not affect growth of meat-breed lambs suppressively treated with anthelmintics when grazing. Veterinary Parasitology 209, 76–83.

Dever M.L., Kahn, L.P., Doyle, E.K., Walkden-Brown, S.W. (2016) Immune-mediated responses account for the majority of production loss for grazing meat-breed lambs during *Trichostrongylus colubriformis* infection. Veterinary Parasitology 216, 23–32.

Jacobson C, Bell K and Besier B (2009) Nematode parasites and faecal soiling of sheep in lairage: evidence of widespread potential production losses for the sheep industry. Animal Production Science 49: 326–332.

Jacobson C, Pluske J, Besier RB, Bell K and Pethick D (2009) Associations between nematode larval challenge and gastro-intestinal tract size that affect carcass productivity in sheep. Veterinary Parasitology 161: 248–254.

Larsen JWA, Vizard AL, Anderson N (1995) Production losses in Merino ewes and financial penalties caused by trichostrongylid infections during winter and spring. Australian Veterinary Journal 72, 58–63.

McAnulty RW, Clark VR, Sykes AR (1982) The effect of clean pasture and anthelmintic frequency on growth rates of lambs on irrigated pasture. Proceedings of the New Zealand Society of Animal Production 42,187–188.

Sweeny, J.P.A., Gardner, G.A., Dobson, R.J., Jacobson, C., Bell, K. (2011) Associations between trichostrongylid worm egg count and productivity measures in Dorper lambs. Veterinary Parasitology 180, 307–314.

Steel, J. W., Symons, L. E. A., Jones, W. 0. (1980) Effects of Level of Larval Intake on the Productivity and Physiological and Metabolic Responses of Lambs Infected with Trichostrongylus colubriformis. Aust. J. Agric. Res., 31, 821–38

Steel, J.W., Jones, W.O., Symons, L.E. A. (1982) Effects of a concurrent infection of *Trichostrongylus colubriformis* on the productivity and physiological and metabolic responses of lambs infected with *Ostertagia circumcincta*. Aust. J. Agric. Res., 33, 131–40

Sutherland IA, Shaw J and Shaw RJ (2010) The production costs of anthelmintic resistance in sheep managed within a monthly preventive drench program. Veterinary Parasitology 171: 300–304.

Symons, L. E. A., Steel, J. W., Jones, W.O. (1981) Effects of level of larval intake on the productivity and physiological and metabolic responses of lambs infected with *Ostertagia circumcincta*. Aust. J. Agric. Res., 32, 139–48.

Appendix A: Databases

The excel databases from this project will be available upon request.

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