Unpublished Report

Document ID:	SheepCRC_3_22
Title:	Targeted Treatment Strategies For Sustainable Worm Control In Sheep In Western Australia: Trials In 2008/10 & 2009/10
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Key words:	sheep; parasite; treatment; targeted treatment; field trials

This report was prepared as part of the Sheep CRC Program 2007-2014. It is not a refereed publication. If the report is quoted it should be cited as:

Sheep CRC Report 3_22

SHEEP CRC/ DAFWA RESEARCH PROJECT REPORT:

Targeted Treatment Strategies For Sustainable Worm Control In Sheep In Western Australia: Trials In 2008/10 & 2009/10

(CRC Project 1.3)

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(December 2010)

CONTENTS

SUMMARY

This Report outlines investigations into the implementation of the "targeted treatment" concept for anthelmintic resistance management, as the basis for practical and relatively simple strategies that do not entail reduced sheep production. "Targeted treatment" incorporates the "refugia" concept for resistance management, which requires that sufficient non-resistant worms remain within the worm population on a property to dilute resistant types surviving drenches, which is considered the fundamental basis for strategies to combat anthelmintic resistance.

The research reported was aimed specifically at non-*Haemonchus contortus* species (especially *Teladorsagia* and *Trichostrongylus*), and utilised a 2-stage targeted treatment index: an initial flock worm egg count to determine the level of parasitism and hence the proportion of a flock that required drenching at a particular time, then an individual-animal body condition score assessment to identify those in lower scores and most likely to benefit from treatment. Trials involved 5 flocks in southwest Western Australia over 2 trial years (using different trial designs), and followed early investigations that indicated the targeted treatment approach to be effective provided an appropriate index for application could be developed, but that bodyweight change over time was too labour-intensive for general application.

Year 1, 2008/09: A 2-paddock design compared a "normally-treated" (whole flock drenched) group with a "targeted treatment" group on three properties (2 at Mt Barker, one near Albany). This enabled comparisons of the effects of the treatments on worm populations in relation to different levels of pasture contamination with worm eggs; initial pasture larval levels were equivalent, and nutritional effects on sheep production were removed in the analysis through the inclusion of a worm-suppressed group in each treatment flock. Drenches were given only in late summer (according to a routine "summer drenching" program), and the 3 flocks received 60%, 53% and 73%, respectively, of the number of drenches administered to the normal-treatment groups, in which all sheep were drenched. No clinical signs of parasitism or adverse effects on reproductive indices occurred in the TST groups, and no consistent or statistically significantly bodyweight gain and wool weight differences occurred in relation to treatment. Although bodyweights were approximately 2 kg lower and wool growth 0.3 kg less in two of the TST groups than in the normal treatment groups, there was a slight advantage to the targeted group in one trial. The greatest indication of a production disadvantage to the targeted treatment group was in a maiden ewe flock, which also received the fewest drenches compared to the normal group. In all cases, body condition scores of the TST groups were consistently greater than optimal production recommendations. The body condition score index for selection of sheep for drenching in the targeted groups proved easy to apply, as operators moving along the race were able to rapidly indentify sheep in lower condition score.

Year 2, 2009/10: A one-paddock design was used to test an easily-implemented comparison of treatments, as although the long-term effects of different levels of worm egg deposition onto pastures could not be compared, the treatment groups were subjected to identical larval intake and nutrition. At 2 sites, a "normal" (whole-group drenched) and "targeted" (part-group drenched) was compared in mature Merino ewes (one near Albany, one near Arthur River), with a worm-suppressed group to indicate

the maximum production potential. As with the previous trial, drenching decisions were made according to flock worm egg counts and individual-sheep body condition scores. (A third site was commenced but yielded no useful information as worm egg counts were too low.) In each flock, 70% of the targeted groups were drenched in April or May (following the presently-recommended "summer-autumn drenching" program), with moderate to high worm egg count challenge over the trial year. Although good production levels were achieved in comparison to the worm-suppressed groups, no differences in weight or body condition score change or wool weights were found at either site, and no signs of ill-health occurred at any time. As with the earlier trials, the sheep selected for drenching in the targeted group were easily identified as an operator moved along the race, and the targeted treatment operation took less time than did the whole-flock drenching process.

Although changes in the level of drench resistance was not measured in either trial year (due to the short timeframe, and difficulty of demonstrating changes when drenches are highly effective), the basis of the refugia effect is apparent from the ratio of worm eggs produced from worms in sheep either drenched or left untreated. A substantial dilution effect of resistant worms is therefore expected, and computer modelling of similar scenarios has indicated a significant reduction in the rate of development of resistance.

Conclusions: It was concluded that the TST concept when applied in mature sheep has potential as an easily-implemented approach to sustainable drench management, and would reduce the cost and labour associated with worm control. Although the new strategy requires the survival of a larger worm population than with "normal" control programs, no signs of parasitic disease were seen and no statistically significantly loss of sheep production occurred. In some trials there was some (non-significant) reduction in bodyweights or wool production, but this was occurred where considerably larger proportions of sheep were left undrenched than modelling studies indicate are necessary to provide an effective refugia effect. Implementation in practice is likely to result in a smaller production effect, but still provide a significant impact on anthelmintic resistance development. Importantly, the identification of sheep in lower condition score, as the core of the worm resilience- based strategy, proved easy to implement and required less time than the normal drenching operation.

Further work: These investigations have been conducted mostly in a Mediterranean climate, and although trial work in South Australia has confirmed that a targeted treatment approach worm based flock egg counts resulted in no sheep production loss, demonstrations are needed in other environments. Research to extend the concept is in progress in South Australia and Western Victoria (a total of 8 properties between those States), but the approach is also expected to be relevant in other non-*Haemonchus* dominant regions of Victoria, and in New South Wales.

Although the studies have involved a specific targeted treatment strategy (flock worm egg counts and individual body condition score drenching decisions), there is considerable potential to develop alterative implementation strategies. These could include the deliberate avoiding of drenching of a fixed percentage of a flock at a critical point in an annual control program, or as an ad hoc tactic whereby any sheep considered to be in good body condition are not drenched when a flock treatment is given. A number of high resistance-selection situations in addition to "summer drenching” can be identified, including drenching sheep as they move to a “worm safe pasture”, and where long-acting anthelmintics are used.

Computer modelling studies are essential to indicate likely roles for targeted treatment strategies in different environments and at various drench-decision points. Modelling has been used extensively in Australia for some years, and successful simulations of field trial results provides confidence that treatment options can be appropriately compared. Numerous simulation studies in recent years have suggested that in all environments, the tactic of leaving a small percentage of a flock undrenched at epidemiologically-important times provides a major refugia benefit and will delay the development of resistance substantially with minimal increase in worm burdens over time. Model predictions will be important tools in the development of demonstration plans.

However, it must be acknowledged that the notion that some sheep should be left undrenched as a routine worm control measure will be challenging to many sheep producers, even though it is common practice on many farms in Western Australia. Acceptance of the change will require, firstly, that advisers and producers in different regions are convinced of the threat due to anthelmintic resistance, and that worm control programs must include resistance management strategies. Local demonstrations will then be necessary to show that the new approach is simple to apply and does not prejudice sheep production. Encouragingly, it appears likely that a major impact on the development of drench resistance can be achieved where considerably lower proportions of flock are left untreated compared with those used in the experiments detailed in this Report.

1. INTRODUCTION

Resistance in sheep worms to anthelmintics continues to increase in both prevalence and severity throughout Australia (Besier and Love 2003), and by mid 2010, only a combination of all available anthelmintic classes remained effective on some sheep properties. Although a new anthelmintic class introduced to Australia in 2010 (the Amino-Acetonitrile Derivatives; specifically, monepantel (Hosking *et al* 2009)) has since provided useful relief, it is essential that drench use practices minimise the development of resistance to this and preserve the remaining effectiveness of the older classes.

The major conceptual basis of strategies aimed at reducing anthelmintic resistance is to ensure that sufficient non-resistant parasites *in refugia* from anthelmintics are present to dilute numbers of resistant parasites (van Wyk 2001, Besier 2008; Jackson and Waller 2008). Sources of worms in refugia are either as infective larvae on pasture where environment conditions permit their survival, or as adult worms in undrenched sheep during periods when larvae cannot survive on the pasture due to adverse environmental conditions. Sustainable worm control recommendations depend on a balance between the proportions of the total worm population on a property in different refugia niches, in comparison to resistant populations which remain after drench treatments.

Refugia strategies

In temperate environments such as New Zealand and Europe, infective larvae typically survive on pasture year-round except where there are extremes of cold, and although anthelmintic resistance is common it occurs at a lower prevalence than in Australia (Kaplan 2004, Waghorn *et al* 2008). The major causal factors for resistance are believed to be an excessive drench frequency, and pasture management routines based on “worm-safe” pastures (Leathwick *et al* 2009, Leathwick and Besier 2010).

In contrast, in strongly seasonal climates such as the Mediterranean climate zone of Western Australia, routine treatments during the hot, dry summer period have been shown to increase resistance levels to anthelmintics even though they effectively control worm burdens (Besier 2001; Besier *et al.* 2001). Investigations into modifications to the “summer drenching” program indicated that avoiding drenching of adult sheep during summer provides effective refugia without risking production loss (Woodgate and Besier 2010), and this is now the routine recommendation for this environment (Woodgate and Besier 2009).

In the *Haemonchus contortus*–dominant environment of northern NSW, where excessive drenching is associated with high levels of anthelmintic resistance, recent investigations have led to the development of more sustainable recommendations based on pasture movements to reduce infection risk and worm egg count monitoring to indicate which flocks require drench treatments (Kelly *et al* 2010).

However, in other regions of Australia, there has been less progress towards modifications to drenching programs to reduce the resistance selection pressure. While pasture larval survival is considerably greater than in Mediterranean climatic zones, providing some potential for refugia management, the greater risk of worm infections to sheep production has resulted in a cautious approach to modifications to strategic drenching recommendations. Worm egg counts are advocated used to indicate whether specific treatments can be avoided, but major structural changes to worm control programs have not been investigated.

A concern of advisers to sheep farmers regarding refugia-based strategies is the potential risk of helminth disease or sheep production loss, and the perception that they are complex and may not be appropriately implemented. Recent investigations have therefore centred on the development of relatively simple approaches to providing refugia for non-resistant worms, and the demonstration that with effective monitoring, these entail minimal risk to the sheep enterprise.

Targeted treatment strategies

The "targeted treatment" concept involves leaving a proportion of a flock undrenched when a routine treatment is given (van Wyk *et al* 2006, Besier 2008, Kenyon *et al* 2009), and aims to provide a relatively simple strategy that ensures some refugia, without the need for complicated planning or changes to worm control routines. It is also intended to increase the efficiency of anthelmintic treatments, in terms of time and cost. The fundamental basis of targeted treatment approaches is the identification of individual animal which may be safely left untreated when others in the flock are drenched.

Under traditional programs, when a flock is judged to be wormy all sheep are routinely treated on the justified grounds that leaving any untreated may lead to some sub-clinical production loss. However, data from numerous parasite control experiments indicates that the effects of worms on a flock are far from evenly distributed, with many tolerating worm burdens and gaining weight when others are showing obvious signs of parasitism (ie, "resilient" to the effects of worm burdens) . The concept has been successfully developed as the FAMACHA system for indentifying individual sheep suffering from haemonchosis (van Wyk and Bath 2002), and has been widely adopted around the world in most major *Haemonchus* zones (van Wyk *et al*, *Veterinary Parasitology* manuscript in preparation). However, this system requires the frequent inspection of individual animals (7-10 days apart in risk periods), and even where this is feasible, it is specific to *Haemonchus contortus*. For this reason, new approaches under development in Australia are based on whole-flock treatments, confined to specific flocks on the basis of worm egg counts (Kelly *et al* 2010).

For the non-*H.contortus* species ("scour worms", especially *Teladorsagia* (*Ostertagia*) *circumcincta* and *Trichostrongylus* spp), investigations in Western Australia (Besier 1999, 2001) and New Zealand (Leathwick *et al* 2008) have demonstrated major reductions in the rate of drench resistance development where a proportion of a flock was deliberately left undrenched. Computer modelling studies confirm substantial reductions in the rate of resistance development where relatively small proportions of a flock are left untreated (Barnes *et al* 1995, Dobson *et al* in press). However, easily-exploited indicators of which individuals should remain untreated are less specific to parasitism for the "scour worms" than for *H.contortus*. Studies have considered weight gain (Greer *et al* 2009) and sheep milk production (Kenyon *et al*, *Veterinary Parasitology* manuscript in preparation), but these require more time and effort than is likely to be feasible in most Australian situations. Surprisingly, there has been little international attention to body condition score as an indicator of relative thrift. Although this is affected chiefly by nutritional conditions, that point applies to all production-based indices, and it appears that the subjective nature of condition score may have limited its appeal.

However, the recent wide promotion of LifeTime Ewe guidelines for nutritional management, based on condition score targets throughout the year, are expected to increase the use of condition score and expertise of assessment. Sheep CRC research into "targeted treatment" strategies for non-*Haemonchus* species has therefore focused on the use of body condition scores to indicate which individuals are most likely to benefit from worm treatment, after an assessment of flock worm status indicates the likely level of parasitic effect. Results discussed in this report have been recently reported (Besier *et al* 2010), and indicate that body condition score can be an effective indicator for targeted treatment drenching decisions.

Potential efficiency gains
As a targeted treatment approach reduces the total number of drench treatments given, the cost is reduced, and the labour effort required is potentially decreased. Cost savings will become especially relevant as more worm populations are resistant to most anthelmintics: in 2010, on a 50 kg sheep basis, the macrocylic lactone (ML) products retailed at approximately $0.20 – 0.25; the "triple combinations" at $0.40-50; and the newly-introduced product, "Zolvix" (monepantel) at around $1.20 - 1.30 per head.

The reduction in drenching effort will be largely dependant on the input required to identify individuals for treatment. If approached as a normal drenching task in a race, and minimal time is taken to decide whether a particular animal is drenched or left untreated, it is possible to move along the race more quickly than when al are drenched. However, if excessive time is taken by assigning a condition score, more time may be required.

Previous research conclusions
Trials in Western Australia in 2006/07 focused on short-term weight change as an index of the effects of "scour worms" on individual sheep. The possibility of preferentially targeting the "better-doers" under parasite challenge (worm resilient animals) has been investigated at Mt Barker Research Station, where over the course of a year, some 12% of sheep at Mount Barker Research Station did not require treatment at any time on the basis of good weight gains, when the mean number of treatments was approximately 2 and some sheep received 4 or 5 (Besier, 2007).

This trial also indicated some limitations of the targeted treatment strategy, which suggest some modifications if it is to be practical and "safe" (not lead to worm control disasters). These have been central to the current trial design and include:

1. It appears that targeted treatment strategies are not ideal in hogget-age sheep. At each point when the "normally-treated" sheep were drenched but the "targeted group" were not, the former gained significantly more weight, to end the trial a mean of some 5% heavier. Sheep of this age (12 months at commencement) were apparently not able to combat worms without a growth penalty. (It should be noted, that some compensatory gain subsequently occurred in the targeted group sheep.)

2. Diarrhoea was not a useful index for the need for treatment. In the young sheep, most sheep eventually scoured and there was no gain in treating individuals only when the sign appeared.
3. Worm egg counts to indicate the level of parasitism are an appropriate basis for decisions regarding the proportion of a flock to be treated.
4. Short-interval weight changes are not a practicable index for treatment decisions. Although it was never envisaged that 2-weekly weighing would be undertaken by farmers, this interval was too short to objectively indicate the less resilient sheep, possibly due to gut-fill and other transient effects.

Present research directions

On the basis of this previous research, present directions are:

- To restrict the targeted treatment concept to adult sheep (at least 2 years of age).

- Decisions on whether or which proportion of sheep will be drenched should be made when farmers would normally do this. This is either when routine treatments are due, or when worm egg counts are recommended to be taken, and should not involve additional monitoring or yarding.

- The proportion of sheep to be drenched will be decided according to the reason for treatment. This is to either maintain pasture contamination with worm eggs at a minimum level, or to maintain flock productivity in the face of worm challenge.

- The individuals chosen for treatment will be those that are visually poorest, on body condition score or comparative thrift.

HYPOTHESIS

That leaving a proportion of the better performing sheep in a flock untreated when a drench treatment is indicated, with untreated individuals identified using guidelines based on worm egg counts and visual sheep assessment, will reduce the development of anthelmintic resistance without a significant reduction in flock productivity.

AIMS

- To investigate the effects of leaving a proportion of sheep undrenched when the remainder of a flock are treated, in terms of sheep health and production relative to the present strategy of treating all in a flock

-To test a prototype index for the determination of the proportion of a flock that should remain undrenched in different situations

- To test the use of a visual assessment of sheep to indicate which individuals should receive treatments when only a proportion of a flock is to be drenched

2. TRIALS, 2008-2009 & 2009-2010

Published trial reports
- Report to Sheep CRC: "Decision rules for targeted worm treatment of sheep in Western Australia: Year 1 (2008/09)"
- Journal Article: Besier R.B., Love R.A., Lyon J., van Burgel A.J. (2010) A targeted selective treatment approach for effective and sustainable sheep worm management: investigations in Western Australia. *Animal Production Science* 50, 1034-1042

Trial designs
The targeted treatment concept outlined in Introduction was tested over 2 years using different trial designs.

-**1. 2008/09**: Separate treatment paddocks were used to compare "normally treated" (whole flock drenched) and "targeted treated" groups, linked by worm-suppressed groups (with long-acting drenches) to indicate between-paddock nutritional effects in the analysis. This design tests the epidemiological effect of different levels of pasture contamination with worm eggs after treatments were given, and not only immediate treatment effects. However, the design assumes that the initial level of pasture contamination with worm larvae, and pasture environmental effects on subsequent larval development, was equivalent between paddocks. For this reason, paddocks were chosen and fenced on the basis of topography and, pasture type and density, and an assessment of initial worm larval levels was attempted where feasible.

- **2. 2009/10:** A single paddock was used for both "normal" and "targeted" treatment groups (with a worm-suppressed group to indicate potential production without worm effects). This approach ensures that sheep are exposed to identical worm challenge, and receive identical nutrition. The observation of differential treatment worm control effect is confined to the immediate post-treatment period, and no epidemiological effect is indicated, although the long-term effects of continued worm challenge on sheep not treated is also indicated.

- **Treatment decision basis**: The flock worm status was assessed using a matrix of worm egg count (prior to treatment) and mean body condition score, to indicate the proportion of the flock which should be treated. This maintained counts at below approximately 200 eggs per gram for a flock in score 3.0, and below approximately 300 epg for mean scores above 3.0. The sheep treated were those judged subjectively to be in the lowest condition score for the proportion indicated by the matrix.

DAFWA Trial Committee / Animal Ethic Approval numbers

1. Flock 1 (2008):
DAFWA Number 05AL21 Animal Ethics Committee 4-05-31
2. Flocks 2, 3 (2008)
DAFWA Number 07AL19, Animal Ethics Committee 6-07-50
3. Flocks 4, 5, 6 (2009)
DAFWA Number 09AL06, Animal Ethics Committee 1-09011

2A: TRIALS, 2008/10

Aims

- To investigate the effects of leaving a proportion of sheep undrenched when the remainder of a flock are treated, in terms of the development of anthelmintic resistance and production relative to the present strategy of treating all in a flock

- To test a prototype index for the determination of the proportion of a flock which should remain undrenched in different situations

- To test the use of a visual assessment of sheep to indicate which individuals which should receive treatments when only a proportion of a flock is to be drenched, and to investigate whether this is more effective than a random selection of individuals

- To observe the effect of drenching only a proportion of a flock on the whole-flock worm egg count and subsequent levels of worm larvae on the pasture.

Trial sites:

- Flock 1: Mt Barker Research Station (60 km NE of Albany); mature Merino ewes, (total, 290)

- Flock 2: Mt Barker Research Station; first-lamb Merino ewes, (total, 315)

- Flock 3: Property of Mr A.Evans, Kalgan River (25 km E of Albany); mature Merino Dohne cross ewes, (total, 316).

Materials and Methods
(Summary, see published reports for details)

Three flocks of ewes (at 2 sites) were each divided into 2 groups of approximately 150 -200 individually-identified sheep: a “normal group” (all treated when drenches were given) and a “targeted group” (a proportion only treated). The proportion treated varied according to an index based on previous experience, and incorporating flock worm egg counts and mean body condition score. The individuals selected for treatment were those assessed visually as the poorer performers. In each treatment group, a sub-group of 40 sheep was maintained worm-free to allow statistical adjustment of nutritional differences between paddocks. All sheep were weighed every 4 weeks (except from lambing to weaning), and worm egg counts were monitored. Fleece weights were obtained for 10 (Trials 1 and 2) or 12-month (Trial 3) wool growth periods, and reproductive indices (lambing, marking and weaning percentages) were measured.

(It should be noted that *Haemonchus contortus* was removed from the worm populations encountered at all trial sites by use of closantel at intervals. The trial was specifically aimed at environments where the scour worms, especially *Teladorsagia* (*Ostertagia*) and *Trichostrongylus* are major causes of parasitic loss.)

Treatment index

	Av. condition score <3.0	**Av. condition score > 3.0**
Below 100 eggs per gram	0	0
100-250 epg	20%	10%
250-500 epg	50%	25%
500-750 epg	80%	60%
750-1000 epg	100%	75%
Above 1000 epg	100%	100%

Results

The trial provided a realistic basis for evaluating the TST concept, as worm egg counts in the normal-treatment sub-groups indicated that there was effective worm control over the year in all three trials and there was minimal reduction in sheep production in comparison with the worm-suppressed groups (which maintained zero or negligible worm egg counts). It is unlikely that nutrition limited sheep production, as the mean body condition scores of the worm-suppressed control groups were relatively high (3.5 for Trials 1 and 3, and 3.0 for the younger sheep in Trial 2).

Worm egg counts and drench treatments (Figures 2, 4 and 6)

The egg counts of the normal-treatment groups (in which all sheep were drenched) at the Mt Barker location (Trials 1 and 2; Figs. 2 and 4) were typical of those of adult sheep in Western Australia (initially low counts in summer, dropping further after the single "summer drench" in February) and remained low throughout the trial period. In Trial 3 (Fig. 6), a second treatment was required in April, presumably reflecting the more favourable environment for development of worm larvae.

In the TST groups, drenches were indicated in February on the basis of the treatment criteria as required by approximately 10%, 10% and 50% of the animals in Trials 1, 2 and 3, respectively. Additional drenches were indicated as needed by approximately 50% of the sheep in Trials 1 and 2, and to 100% of the animals in Trial 3 in April. Counts then remained relatively low and were not different from those of the normal-treatment groups for the remainder of the trials, except for one instance in Trial 3. The total number of drenches actually administered to the TST groups over the two treatment dates was 60%, 53% and 73% of those administered to the normal-treatment groups in Trials 1, 2 and 3, respectively.

Differentiation of larvae in faecal samples indicated that *Teladorsagia* (*Ostertagia*) comprised 57%, 74% and 54% of the genera present in Trials 1, 2, and 3, respectively, and *Trichostrongylus* comprised 21%, 14% and 28% of the genera present in Trials 1, 2, and 3, respectively.

Weight changes (Table 1 and Figures 1, 3 and 5)
To adjust for differences in weight change between paddocks, data were adjusted according to the weight change of the worm-suppressed sheep and expressed as the difference between the TST groups and the normal treatment groups (expected to have the highest weight gain) (Table 1).

Over the course of the trial, sheep in Trial 1 lost weight, but this was from a high level (condition scores were higher than usual for breeding ewes). Sheep in the other two trials gained weight, which was expected for the younger ewes. Treatment comparisons indicated that the normal-treatment groups in Trials 1 and 2 gained 1.6 kg and 2.00 kg, respectively, more weight than the TST groups over the course of the trial, or approximately 3%. In contrast, the weight change advantage in Trial 3 was 2 kg in favour of the TST group. No weight changes were statistically significant (Trial 2, $P \sim 0.10$).

Dag scores were negligible in all cases and never exceeded a score of 2 (lightly dagged), except for a single sheep in Trial 2. No other signs of ill health or and no mortalities related to worm infections were observed.

Body condition scores (Table 2)
The condition scores over the course of the trial indicate that the sheep were in sound nutritional condition (Table 2); in Trials 1 and 3, condition scores considerably exceeded LifeTime Wool guideline. Over all trials, body condition scores of individual sheep fell below a score of 2.0 on only 15 occasions, in Trials 1 and 2 during the lactation period, but the mean scores remained well within the guidelines. Condition scores of all groups of sheep in Trials 2 and 3 increased over the course of the trial, and those of sheep in Trial 1 decreased slightly. However, all groups had similar mean scores at the end of the trial. There were no significant differences in the change in mean scores over the trial period between the TST and normal-treatment groups for Trials 1 and 3. For Trial 2, final scores were not available for the TST group, but at the September assessment there was a statistically-significant advantage to the normal group of 0.3 score units.

Wool weights (Table 1)
Fleece weights of the TST sheep in Trials 1 and 2, adjusted for paddock effects, reflected the body weight trends and were 0.26 kg and 0.29 kg (greasy) less than those of the normally-treatment groups. Fleece weight in the TST group in Trial 3 also followed the same trend as weight change and was almost identical to that of the normal treatment group (Table 1). No wool weight differences were statistically significant, but for Trial 2, the p-value was approximately 0.1.

Reproductive performance (Table 3)
Ultrasound scanning indicated that pregnancy rates were high in all trials (92–98%; Table 3). Birth and survival rates were high for Merino sheep, with virtually no lamb losses between marking and weaning. The weaning rates for the Mt Barker trials (109–123%) were very good, especially those for the maiden ewes in Trial 2. Weaning rates were lower in Trial 3 (94–100%) but are still high compared with industry averages. Reproductive performance was similar between treatment groups in Trials 1 and 2, and when weaning rates were adjusted for pregnancy rates, there was no treatment effect in Trial 3.

Discussion
(See the publications listed above for more detailed Discussion of the results.)

No significant production loss occurred where a substantial proportion of a flock was left undrenched when the majority in the flock were treated, in the 2 trials involving mature sheep in good nutritional condition. A reduction in wool growth, with non-significant weight gains, occurred in the trial which used young ewes, suggesting that resources used for growth were diverted to cope with worm burdens. No differences in reproductive occurred, and no signs of worm-related disease were evident at any time.

It is likely that a useful refugia benefit was obtained, although changes in anthelmintic resistance were not measured because incremental changes over short periods are rarely detectable when efficacy of the anthelmintic is high. However, the treatment benefits in respect of anthelmintic resistance can be inferred from the relative proportions of worm eggs deposited onto the pasture from drenched vs undrenched sheep. The greater output of eggs from worms in undrenched sheep would have provided high levels of dilution of resistant worms, especially as the treatments were applied during the summer and autumn periods, which are most selective for anthelmintic resistance when all animals are drenched.

Results from earlier trials in Western Australia and New Zealand, where a pre-determined proportion of a flock was left undrenched at a single critical point, support these inferences. These trials indicated a significant reduction in the development of drench resistance, although only 10% of a flock was left undrenched. Computer modelling studies further indicate that a useful level of refugia with minimal risk to sheep production can be accomplished by leaving 4–less than10% of a flock untreated (Dobson *et al.* 2010). In the present trials, a considerably higher proportion of sheep were left untreated because adult sheep generally have greater tolerance of worm burdens than lambs, and because the potential reduction in the costs of drenches and labour were also a factor in the investigation.

Implementation of the treatment decision index proved to be effective and practicable. The worm egg count values used to determine the proportion of sheep to be treated in the TST groups were based on threshold values used for diagnostic purposes in this laboratory (excluding *H. contortus*). In adult sheep, counts below a flock mean of 200 epg in well-nourished sheep are considered unlikely to affect sheep production, and above 500 epg, treatment would usually be justified. Selecting sheep on the basis of body condition score also proved to be effective. For non-*Haemonchus* species, this relies on the assumption that sheep that are less resilient to parasitism will be in lower bodily condition or will exhibit a low growth rate. A weight-change index is likely to be feasible only for intensive sheep production enterprises, but in these trials, selection of sheep for drenching took less time than normal drenching. Once a threshold condition score level for treatment was established, most sheep could be differentiated on visual appearance (especially if they had short wool) or on a cursory condition score judgement. The consequences of misallocating some sheep or treating more than the indicated percentage are not likely to be serious, and the time needed for a rigorous assessment would not be justified.

A major potential benefit of the TST approach is that it reduces the complexity of refugia-based drench-resistance management recommendations. Less than maximal worm control may be counter-intuitive, but it is essential to ensure that some worms survive to dilute the number of resistant worms. The TST approach, when optimised for a particular situation, is a relatively simple method of ensuring that refugia is provided, and is easily applied in large sheep flocks. It is also robust regarding the proportion of a flock left undrenched, which is especially important when worm status (worm burdens in sheep and infective larvae on pasture) cannot be easily estimated.

As an additional benefit, restricting treatment to a proportion of the flock will reduce the time and effort of drenching and will save on chemical costs. This may become an attractive option should new and more expensive anthelmintics become available.

However, it is essential that TST strategies are validated for specific environments and sheep management systems before they are widely recommended. The trial model outlined in the second series of trials in this Report (follows below) involves a relatively simple format that can be used for low-cost evaluations of the strategy on commercial properties, and adapted to require minimal monitoring and laboratory work.

2B. TRIALS, 2009/10

Introduction

As detailed for trials in 2008/09, research in the recent past years has sought both to provide additional "refugia" opportunities, and also to reduce the labour effort and cost associated with drenching, by limiting treatment to sheep judged to be unaffected by worm burdens. This "targeted treatment" approach seeks to identify individual animals exhibiting signs of sub-clinical parasitism (relatively poorer weight gains or body condition score), so that drenches can be given specifically to these, hence reducing the proportion of a worm population exposed to a drench (Besier 2008). Recent investigations in the south coast region have confirmed the feasibility of the targeted treatment approach, with a minimal reduction in production performance in mature animals despite a drop by up to 50% in the number of drenches given (Besier 2007; Appendix 1).

In practice, for ewes the opportunities for drenching in association with routine management operations (ie, when they are yarded) include: ram removal, marking, weaning, crutching (often pre-lambing) and shearing. Apart from summer drenches, farmers typically drench either according to a routine (eg, always at shearing, whether or not there is evidence of worms), or when signs indicate the need (lower than expected body condition for the available nutrition, or scouring). However, there is often no need for treatment (especially if according to a management routine), or more likely, a small number in the flock will warrant treatment but many or most do not.

It is recognised that worm effects alone do not explain lower condition scores in some ewes compared to others, but worms are almost always present at some level on green pasture. Whether or not ewes in acceptable condition score and good health have a worm burden, there is little point in drenching (except to possibly increase wool production), but the poorer condition of other sheep is likely to at least partly reflect the effects of worms. The results will add to earlier information, and also demonstrate the applicability of a trial model involving a single flock only, hence requiring a lower resource and labour input compared to the 2-flock design used previously.

Trial design basis

For these trials, demonstration flocks contained 2 treatment groups running together: one given drenches "as normal" (all drenched, in early April and at other times on the basis of signs or flock condition score), and a "targeted treatment" group (a proportion drenched in April (WEC/condition score-based.

A criticism is that effect on worm levels later in the year due to pasture worm egg contamination differences after treatment cannot be measured. However:

- A major advantage is that all sheep are exposed to the same level of pasture nutrition, which is of particular importance in a demonstration where body condition scores are the basis of treatment decisions. Replicated designs are expensive and two-flock designs also require more effort and cost to ensure nutritional equivalence.
- In practice, sheep are always faced with some worm larvae on pasture (here, drenches will be given only during the green-pasture period), especially when no summer drenches are given (current recommendations). In well-nourished, adult worm-immune sheep differences in larval intake has minimal effect regarding differences in worm burden.
- Although the "normal" sheep may at time be exposed to more worm larvae than if in a separate paddock, we have abundant information on the epidemiological effect from 2-flock comparisons and can interpret results in this light. Importantly, both groups of sheep are exposed to the same larval intake at the start of observations, as they are for nutrition.
- The simple design allows repetition in a wide range of situations, hence maximising experience with the targeted treatment concept in practice.

Aims

- To demonstrate under practical management circumstances the effectiveness of worm control in ewe flocks using a targeted treatment strategy based on a single worm egg count and body condition scores, when integrated into the "modified summer drenching" program now recommended in Western Australia
- To confirm that leaving a proportion of ewe flocks undrenched when the entire flock would normally be treated provides sound worm control based on production and health parameters.

Trial sites:

- Flock 1: Mt Barker Research Station (60 km NE of Albany); mature Merino ewes, (total, 290). (NB: did not continue due to low worm egg counts.)
- Flock 2: Property of Messrs. Tony and Tim Scott, Dellyanine Road, Arthur River (10 km SW of Arthur River), mature Merino ewes, (total, 410)
- Flock 3: Property of Mr A.Evans, Kalgan River (25 km E of Albany); mature Merino Dohne cross ewes, (total, 316).

Materials and Methods

At each site, a flock of mature ewes due to lamb in 2009 was split into 3 groups, which were given different worm control treatments. The general basis for drench treatments was the "summer-autumn drenching" protocol, which is recommended in WA in place of "summer drenching", as a drench resistance management measure. This involved an initial treatment in April or May, with any Albany additional treatments according to owner policy or where worm egg counts indicated.

Groups:

- "Normal" drench treatments (all group drenched)
- "Targeted treatment" (a proportion of the group drenched according to the worm egg count-body condition score matrix, aiming to keep worm egg counts below 200 eggs per gram;
- "Worm-suppressed" (treated with a long-acting anthelmintic to prevent worm infection during the course of the trials), to provide an estimate of the relative worm effect at each later treatments.

Group sizes were: targeted treatment and normal, 190 and 144 (Flocks 2 and 3, respectively), and 30 (worm suppressed).

Proportions treated: The drench decision matrix used in the 2008/09 trials (indicated in report above) was used; basically this aims to maintain worm egg counts at about 200 eggs per gram, or higher for flocks with a mean condition score above 3.0. In both Flocks 2 and 3, 70% of the targeted treatment group of ewes were drenched in April (Flock 2) or May (Flock 3) (no other treatments were indicated). The sheep left untreated were those in better body condition at the time.

Measurements/ Analyses: Worm egg counts were measured in a proportion of the groups (usually N = 50 per group), and weights and body condition score of all sheep were measured at a minimum at every yarding (at treatment (April.May); lamb marking (July); weaning (October) and shearing (December 2009, Flock 2; March 2010, Flock 3). (Additional observations were made in some cases.) Analyses are essentially comparisons of means between treatments when taken at trial commencement and conclusion.

Results

Flock 1: No useful information resulted from the Mt Barker Research Station flock, as due to high counts in both sub-groups in early 2009, all sheep were drenched, and counts never returned to levels adequate for trial purposes.

Flock 2 (West Arthur) (Table 4, Figures 7 and 8):
The sheep gained considerable weight over the course of the trial: by 8.15 kg for the worm-suppressed (mean commencement weight for all groups: ~ 60 kg), which was significantly different from the ~ 4 kg of the normal and targeted groups (not statistically significantly different). Similarly, body condition score increased by 0.3 from an initial mean of 3.0 in the worm-suppressed group, but there was no real change in either of the other groups (increase of 0.05-0.1). Mean wool weights were

marginally, but not quite significantly ($p = 0.13$), higher in the worm-suppressed group (4.45 kg) compared with 4.34 kg for both other groups.

Worm egg counts (Fig. 8) at trial start indicated the need for treatment (means, approximately 250 epg). After treatment in April, counts were different between the normal and targeted groups when measured one month later: 135 eggs per gram vs. 5 epg. At later observations (July and December) there was no difference related to treatments, and little likely effect of worms on sheep production (mean of ~ 130 epg).

Flock 3 (Kalgan River) (Table 5, Figures 9 and 10):
No between-group differences were found, as the worm-suppressed sheep showed only marginally and not significantly greater weight and condition score changes. In comparison to Flock 2, these sheep had initially lower mean weights but higher mean condition scores (56 kg and score 3.4), and lost a mean 0.4 in condition score. Similarly, no differences in wool weights were found, and the worm-suppressed group produced marginally less wool than the other groups (5.16 kg, vs 5.21 and 5.24 kg).

Worm egg counts (Fig. 10) post-treatment were measured only June (when very low in both normally-treated and the targeted group; less than 20 epg), and December, when they were both very low (less than 100 epg).

Discussion

The results confirm the indications from the trials in 2008/09, that in mature adult sheep in good nutritional condition (mean score 3 and above), leaving a substantial proportion of the flock undrenched when routine treatments are given did not adversely affect sheep production performance.

The design used here differed from that of the earlier trials, in that both the normally- and target-treated groups ran together. While this ensures that all sheep are exposed to identical worm intake, it prevents expression of differences over time due to the deposition of different numbers of worm eggs. However, differences in weight and condition score did not differ between groups in the weeks after initial treatments (or other times), when any differential effect due to the different proportions treated would be most likely to be evident. This adds confidence to the observation that no between-treatment effects occurred. However, no observations regarding reproductive performance can be made, as lambs cannot easily be identified to ewes.

Of interest, the mean weight increase of the non-drenched sheep was greater than the drenched sheep in the targeted group (by 2 -3 kg). Although these sheep did not reach the mean weights of the non-drenched sheep, this suggests that they responded to a greater degree than those in better condition. However, the non-drenched sheep were of equivalent (or greater) mean weight than that of the normally-treated group, further indicating that no performance disadvantage occurred where a drench was withheld.

Although the selection of sheep for drenching within the targeted treatment group was “by eye”, ie, they were not objectively condition scored at the time (later conducted by a separate operator), the mean weights of this group were approximately 5 and 7.5 kg (Flocks 2 and 3) lower than those not drenched; this indicates that the rapid assessment technique was appropriate.

As in the earlier trials, no objective assessment of changes in anthelmintic resistance levels was made, as this is not feasible for trials of such short duration, due to the lack of precision of presently-available tests (periods of 3-5 years are usual for this). Later computer modelling studies will evaluate the benefits of the targeted treatment strategy regarding the development of resistance, but from general principles, the levels of worm egg deposition in periods critical for worm development can be made. The significantly greater deposition in the targeted treatment group in Flock 2 over autumn is likely to provide substantially more pasture contamination with worm larvae deriving from worms not exposed to drenches; this was not evident in Flock 3 (worm egg counts were abnormally and inexplicably low in the targeted group), but as a similar proportion of sheep remained untreated, an effect similar to that in the other flock is likely.

Further demonstrations of the targeted treatment effect will be necessary in a range of environments, and this model provides an easily implemented format for commercial properties. Relatively little change from normal practice is necessary, and worm egg counts taken from the flock as a whole will indicate whether any group is likely to be suffering excessive parasitism. A minimal observation frequency is necessary, as provided groups are formed at random, the figures of interest are the differences between treatments at trial end.

3. CONCLUSIONS

The results from the 5 field trials reported here, and indications from 3 earlier trials, clearly indicate that as a strategy against non *Haemonchus* worm species, and in mature sheep in good body condition, targeted drenching treatment can be a safe, effective and simple approach to anthelmintic resistance management.

- Sheep production: The sole indication from experimental work in WA of a reduction in production performance was in one flock in the 2008/09 series, where a targeted treatment group produced nearly 0.3 kg less wool. However, this was in maiden ewes, given only 50% of the drenches given to the normally-treated group. By treating sheep in lower condition score – normally below CS 3.0- it appears that only animals that could "afford" to lose body condition remained undrenched. No effects on reproduction – the primary aim for ewe flocks – have been noted, even at positive but statistically non-significant levels. As the proportions of sheep left undrenched are well above those likely to be chosen in commercial situations, it is reasonable to expect that in flocks run to Lifetime Wool guidelines (as used for these experiments), targeted treatment does not constitute a sheep proportion risk. While it is yet to be determined whether there is a differentially greater benefit associated with drenching lower condition score sheep, those in better condition are less likely to suffer appreciable production or reproductive effects.

- Anthelmintic resistance effect: The effect of targeted treatment compared to whole-flock drenching practices is not possible to objectively assess in short-term trials. However, the deposition of worm eggs in the faeces of undrenched sheep at critical times for worm larval development has been shown to lead to a significant reduction in drench resistance development in trials in New Zealand and WA, where resistance status was measured. In the current series, the levels of worm excretion observed from non-drenched sheep during autumn, when the population composition for the winter worm-risk period is determined, is likely to have a major effect on the level of anthelmintic resistance. Computer simulation modelling strongly supports this strategy, and using data from earlier WA trials, a 25% reduction in drenching led to a reduction in drench resistance development of 50-100%. Of particular note, modelling projections indicate that where anthelmintics are highly effective (99+%), leaving a small proportion of a flock untreated (4 - 10 %) can provide a major reduction in drench resistance development (Dobson *et al*, in press). Targeted treatment has also been shown to provide a significant refugia benefit in numerous field trials in other countries (Kenyon *et al* 2009, Besier 2010).

- Drenching efficiency: While sheep producers rarely ascribe a cost to the labour input required for drenching, the technique used in these trials for sheep drenching decisions reduced the total drenching time, and significantly, the physical effort required to treat adult animals. The cost of drench product is considerably lower in Australia than in many other countries, and is comparatively minor in relation to total production inputs. However, the recent release of a new anthelmintic (monepantel) at some 5 times the cost presently-effective products may alter this - especially as existing options continue to fail as resistance levels increase.

- Practicality of implementation:

- <u>Determination of proportion of a flock to drench</u>: The present trials required a worm egg count to assess the relative “worminess” of each flock, to indicate the proportion of sheep to remain undrenched. Worm egg count is strongly recommended as the basis for worm control decisions and is used extensively by the most technically-aware sheep producers (“Innovators” and “Early Adopters”). In WA, monitoring in autumn is a recommendation for “summer-autumn drenching”, and worm egg counting is important for reducing the excessive use of anthelmintics. However, in situations where no worm egg count is available but signs of parasitism are not evident, experience indicates it will be possible to safely leave a small proportion of a flock undrenched. Local investigations to determine appropriate worm egg count levels and “rules” for such decisions are obviously necessary.

- <u>Selection of sheep</u>**:** Of the various indices proposed for determining the proportion of a flock that should remain undrenched under a targeted treatment strategy, body condition score offers the only rapidly-implemented approach for the typical Australian circumstances of large flocks and limited labour availability. The technique used in the recent trial series was to move along a race as if for drenching, with a rapid subjective assessment of whether an individual sheep was above or below the condition score level that described the proportion it as decide to drench. This proved to take less time than drenching the entire flock, and selected the appropriate part of the group (as seen by the relative condition score of drenched and non-drenched groups). The technique is robust, in that incorrectly assigning a small number of sheep will make minimal difference to the mean result, allowing rapid movement along the race. This is likely to be seen as easy to implement as sheep producers become increasingly familiar with condition score assessment (eg, through LifeTime Wool courses) increases.

It must be noted that the present trials were intended chiefly to confirm the principles of targeted treatment, especially in terms of the likelihood of production loss or worm disease risk, and practicality of application. Further, the work has been mostly in a Mediterranean climate, although trial work in South Australia has confirmed that on a worm egg count decision basis, a targeted treatment approach resulted in no sheep production loss. Work in progress in South Australia and Western Victoria will extend these demonstrations onto a total of 8 properties. It is essential that further demonstrations are conducted in regions not yet involved but were the concept is expected to be applicable, such as in other parts of Victoria, and in New South Wales.

However, it is considered that the CRC-funded investigations now have sufficient strength to provide the basis for an implementation phase, aimed at embedding the targeted treatment concept into general sheep worm control recommendations across southern (non-*Haemonchus* dominant) Australia. Whether as an annual strategy based on worm egg counts to determine the proportion of a flock to remain undrenched, or an ad hoc tactic whereby any sheep considered to be in good body condition are not drenched when a flock treatment is given, the targeted treatment approach can ensure that some refugia for non-resistant worms is available, without the need for complex changes to existing worm control programs.

4. CONCEPT IMPLEMENTATION

Key requirements for the acceptance and further development of the targeted treatment concept are seen as firstly, convincing the industry (advisers and producers) of the importance of anthelmintic resistance and the need to include resistance management into worm control programs, and the demonstration of targeted treatment strategies in a range of sheep raising systems and environments.

As a basis, several targeted treatment “models” can be identified, and are susceptible to computer simulation modelling:

1. Treatment situation

- <u>Strategic treatments in winter rainfall regions</u>: a percentage of an (adult) flock is left undrenched in summer (temperate environments) or autumn (Mediterranean environments). These are identified high-selection risk situations (varying with summer climatic conditions), which also have major implications for the relative level of worm infections for the entire year.

<u>- High selection situations outside strategic periods</u>: where drenches are given as sheep move onto clean pastures, or where a long-acting product is to be used. Although worm larvae may survive for a period sufficient to render many “safe pastures” less than absolute (compared with Mediterranean summer pastures), these practices are increasingly considered to exacerbate resistance development, and given the relative short-term requirement of their benefit, leaving part of the flock undrenched is unlikely to greatly compromise its effectiveness.

- <u>Tactical treatments</u>: ad hoc decisions made when routine drenches are given to adult sheep flocks, so that sheep in high body condition score (eg, 3.5 and above) may be left undrenched (on basis that worms are not evidently affecting these individuals).

This will typically be 5 - 25 % of a commercially-run flock, and is easy to implement as these sheep are very obvious within a flock.

2. Flock treatment proportion

The body condition score basis for selecting individual sheep which may remain undrenched proved effective and efficient. It is not certain that sheep in lower body condition are will necessarily respond to drenching, on the basis that a reason for their lower condition rank reflects a lower resilience to worms, and early indications from 2010 investigations suggest that sheep may respond to an equivalent degree across a condition score range. This is currently being pursued, including as the main basis for a post-graduate thesis by Meghan Cornelius.

However, regardless of the relative response to treatment, it can be assumed that sheep in better condition score are best able to “afford” to lose condition without an appreciable effect on overall productivity. The recommendation that sheep drenching decisions is made on a condition score basis is therefore expected to remain.

One element in a treatment decision not so far considered is the worm control effectiveness of the drench. The size of the non-resistant worm population required to dilute resistant genotypes will obviously increase as the proportion of resistance increases. New Zealand estimates indicate that where an anthelmintic was 99.9% effective (which may be achieved with newly-introduced groups), only 1% of animals need be left undrenched to provide a 10-fold dilution of resistant survivors; however, a 95%-effective anthelmintic would require 34% of the flock to remain untreated for a similar effect Leathwick (2008). In the Australian situation where anthelmintic resistance affects every sheep farm and every anthelmintic type, it is important that the resistance status is known, or the effectiveness of any refugia strategy will be reduced.

5. FURTHER WORK

The present studies confirm that the targeted treatment concept has potential, and the actual drench decision basis used in these trials could be safely implemented in WA and similar environments. However, some additional information and local demonstrations are required before large-scale adoption campaigns can be commenced. These include:

- **Modelling to indicate the most appropriate targeted treatment programs** for other regions, and the extent of the refugia benefit. While empirical field evidence may be seen as the “gold standard”, changes in drench resistance status are incremental and difficult to detect over short time periods (such as one year). Computer simulation modelling has therefore been used extensively to explore worm control options, especially in relation to anthelmintic resistance management (Barnes *et al* 1990, Smith 1990, Leathwick *et al* 1995, Learmount *et al* 2006). Encouragingly, modelling studies indicate that leaving even relatively low percentages of a flock undrenched can provide large reductions in the rate of drench resistance development (Barnes *et al* 1995, Dobson *et al* in press). Modelling will have a major role in indicating likely appropriate strategies for demonstration in different environments. Discussions have been held with Dr Robert Dobson (Murdoch University), who developed and now operates the WormWorld model (Barnes *et al* 1990, 1995), and an extensive series of studies will explore regionally-appropriate scenarios during autumn 2011.

- **Drench decision worm egg count indices**: it is likely that specific WEC values in relation to targeted treatment percentages will vary between environments, and investigations over the past 2 years in South Australia have utilised lower levels than in WA. These studies are continuing in 2011(with additional MLA support) and will underpin the development of WEC matrices for other regions.

- **The basis of the body condition score index**: while it has been postulated that poor-condition sheep are likely to best respond to drenching, this is not certain. It is feasible that a similar response in terms of production gain may occur regardless of initial body condition status, and preliminary information from CRC-funded studies in 2010 (post-graduate project for M.Cornelius) suggests there may be no advantage to those in poorest condition. If these findings are confirmed, flock productivity would be less impacted where "incorrect" decisions were made regarding which individual sheep were drenched. Although it is not likely that changes would be made to the basic recommendation that these sheep are preferentially selected for treatment, the importance of identifying poor-condition sheep would be reduced, with consequent savings in time and effort. This will be pursued in field studies during 2011.

- **Adoption planning:** given the conceptual challenge evident regarding the notion that sheep should be left undrenched, it is considered critical that sheep advisers (consultants, DPI advisers, private veterinarians) provide firm support for the need and format of targeted treatment strategies before wider communication efforts to producers are made. Failure to ensure this support is likely to see targeted treatment dismissed as a "crackpot" theory, and is the greatest risk outside WA.

Steps envisaged (and to be debated within Project 1.3) are likely to include:

- A planned campaign to convince to "next users" that: current recommendations do not provide adequate refugia; that targeted treatment is a viable option; and the demonstration that specific local recommendations (developed in association with regionally-based consultants) do not reduce sheep health or productivity. This will involve scientific levels (conference presentations /scientific articles); meetings with adviser to discuss the concept, experimental results and modelling studies; and personal approaches to key consultants and DPI staff. Following this, a large number of monitored demonstration studies are envisaged, coordinated by local advisers. A difficulty will be the belief by many advisers that their current recommendations provide sufficient refugia or other resistance management measures, although this is not necessarily correct when considered objectively.

Of relevance, there is little need to convince the parasitology sector of the importance of the refugia concept, as this has been fundamental to accepted resistance management theory for some years. There is an expanding volume of literature on targeted treatment research, and support by this sector will assist in transferring the ideas to industry advisers.

- Wider industry support sector discussions: the next level of influence is the product manufacturers and retailers, who are traditionally difficult to convince except where there is a clear and immediate commercial advantage. Some support is likely from manufacturers of new anthelmintics, as the high cost of flock treatment will be reduced by a targeted treatment approach, but at a minimum it will be important that this sector is aware of the concept and able to direct enquiries to advisers (or to WormBoss).

- “Early-stage adopters”: given the relative novelty of the targeted treatment idea, it will be important to have district experience with the concept: this may initially involve a number of farmers leaving 5% of good-condition adult ewes undrenched whenever drenches are given, and observing them over the following months. Although most in this industry sector will be generally aware of current worm control recommendations and in some cases of the refugia theory, the active support and cooperation by local advisers will be essential.

- General industry: a key requirement will be that a producer is convinced that firstly, drench resistance is a potentially costly problem, and secondly that it is an issue warranting action on a particular farm. This has been a key extension message for many years and will continue through CRC activities, including WormBoss and Managing Sheep Worms workshops, but must be accepted before refugia and targeted treatment concepts are likely to be of interest. A simple message may be: “don’t drench sheep that don’t need it: save money and effort, and fight drench resistance at the same time.”

6. ACKNOWLEDGEMENTS

The research reported was largely funded by the Sheep CRC, with DAFWA in-kind support. The willing cooperation of the property owners, Mr Alan Evans and Tony and Tim Scott, and of Mt Barker research station staff, is gratefully acknowledged. The expert assistance of DAFWA technical officers in the field (Bob Love, Darren Michael, Brian Taylor, Josh Bunn,) and laboratory (Jill Lyon, Heide Guetlich, Jo Hislop, Esther Spence and Andrea Butler) was essential to the success of the project. Numerous scientific colleagues in Australia and internationally contributed to the development of the concept.

In particular, this work is a memorial to the expertise and hard work of the late Bob Love, who supervised field operations for the parasitology group for many years.

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8. TABLES & FIGURES

Table 1. Year 1, 2008/09: Body weight changes and fleece weights for normal-treatment (Normal) and targeted selective treatment (TST) groups. "Control" indicates worm-suppressed groups.

Trial / Group	Treatment	Body weight (kg)				Fleece weight (kg)	
		Initial weight	Final weight	Change	SE	Weight	SE
Trial 1		**3/01/08**	**22/12/08**			**Shorn 8/12/08 [A]**	
Normal	**Control**	66.7	64.2	-2.5	0.9	5.12	0.13
	Treatment	62.3	59.9	–2.4	0.4	4.83	0.06
TST	**Control**	70.0	67.1	–3.0	1.0	5.07	0.22
	Treatment	62.7	58.2	–4.5	0.4	4.51	0.06
Difference Normal – TST				1.6	1.5 (ns)	0.26	0.21 (ns)
Trial 2		**14/02/08**	**18/12/08**			**Shorn 8/12/08 [A]**	
Normal	**Control**	54.6	59.7	5.1	0.6	4.55	0.11
	Treatment	55.4	59.6	4.2	0.5	4.46	0.06
TST	**Control**	55.2	59.7	4.5	0.8	4.64	0.11
	Treatment	55.2	56.8	1.6	0.4	4.26	0.07
Difference Normal – TST				2.0	1.2 (*P* ~ 0.1)	0.29	0.18 (*P* ~ 0.1)
Trial 3		**18/01/08**	**14/01/09**			**Shorn 18/03/09**	
Normal	**Control**	63.4	72.6	8.8	1.3	6.16	0.15
	Treatment	62.8	68.4	5.7	0.6	5.80	0.07
TST	**Control**	61.7	70.8	9.1	1.3	6.08	0.11
	Treatment	63.8	71.3	8.1	0.7	5.75	0.07
Difference Normal – TST				–2.1	2.0 (ns)	0.04	0.42 (ns)

[A] Wool weights are for a 10-month growth period for Trials 1 and 2.

Table 2. Year 1, 2008/09: Body condition scores for normal-treatment (Normal) and targeted selective treatment (TST) groups. "Control" indicates worm-suppressed groups.

Trial/ Group	Treatment	Body condition score			
		Initial	Final	Change	SE
Trial 1		**3/01/08**	**22/12/08**		
Normal	**Control**	3.83	3.83	0.00	0.09
	Treatment	3.68	3.55	–0.13	0.04
TST	**Control**	4.11	3.69	–0.42	0.10
	Treatment	3.93	3.34	–0.59	0.14
Difference Normal – TST				0.03	0.15 (ns)
		14/02/08	**08/09/208**		
Trial 2					
Normal	**Control**	2.89	2.83	–0.06	0.07
	Treatment	2.86	2.82	–0.04	0.04
TST	**Control**	2.94	2.82	–0.13	0.10
	Treatment	2.94	2.53	–0.41	0.05
Difference Normal – treatment				0.30	0.14 ($P <$ 0.05)
		18/01/08	**05/12/08**		
Trial 3					
Normal	**Control**	3.03	3.86	0.83	0.09
	Treatment	3.06	3.74	0.67	0.05
TST	**Control**	2.96	3.88	0.93	0.09
	Treatment	3.02	3.85	0.83	0.04
Difference Normal – treatment				–0.06	0.14 (ns)

[A] Final observation when all groups were assessed

Table 3. Year 1, 2008/09: Pregnancy, lamb marking and weaning indices for normal-treatment (Normal) and targeted selective treatment (TST) groups. "Control" indicates worm-suppressed groups.

Trial	Treatment group	Pregnancy scanning (pregnant/total)	Lambs marked (lambs/ ewes)	Lambs weaned (lambs/ ewes)
Trial 1	**Control**	141/146 (97%)	160/146 (110%)	159/146 (109%)
	Treatment	139/145 (96%)	160/145 (110%)	160/145 (110%)
Trial 2	**Control**	153/156 (98%)	187/157 (119%)	186/157 (118%)
	Treatment	147/155 (95%)	194/158 (123%)	194/158 (123%)
Trial 3	**Control**	145/155 (94%)	N/A	151/151 (100%)
	Treatment	142/155 (92%)		142/151 (94%)

Table 4. Year 2, 2009/10: Body weight and body condition score changes and wool production for normal-treatment (Normal) and targeted selective treatment (Targeted) groups, on Flock 2. "Control" indicates worm-suppressed groups.

Flock 2	Start	End	Difference	LSD N v TT	Sig. ?
	Bodyweight				
Control	59.47	67.64	8.17		
				1.13	
Normal	59.47	63.57	4.1		NSD
Targeted	59.47	64.06	4.59		NSD
	Condition score				
Control	2.98	3.3	0.32		
				0.07	
Normal	2.98	2.99	0.01		NSD
Targeted	2.98	3.03	0.05		NSD
	Wool				
Control		4.45			NSD
Normal		4.34		0.13	NSD
Targeted		4.34			

Table 5. Year 2, 2009/10: Body weight and body condition score changes and wool production for normal-treatment (Normal) and targeted selective treatment (Targeted) groups, Flock 3. "Control" indicates worm-suppressed groups.

Flock 3	Start	End	Difference	LSD N v TT	Sig. ?
	Bodyweight				
Control	**56.25**	**58.21**	**1.96**		
Normal	**56.25**	**56.65**	**0.4**		NSD
Targeted	**56.25**	**56.45**	**0.2**	**1.25**	NSD
	Condition score				
Control	**3.39**	**3.02**	**-0.38**		
Normal	**3.39**	**2.89**	**-0.5**		NSD
Targeted	**3.39**	**2.94**	**-0.45**	**0.1**	NSD
	Wool				
Control		**5.16**			
Normal		**5.12**	**0.17**		NSD
Targeted		**5.24**			

Figure 1: Year 1, 2008/09, Flock 1: Relative bodyweight differences between treatments (adjusted as if same weight at start of 2008 observations)

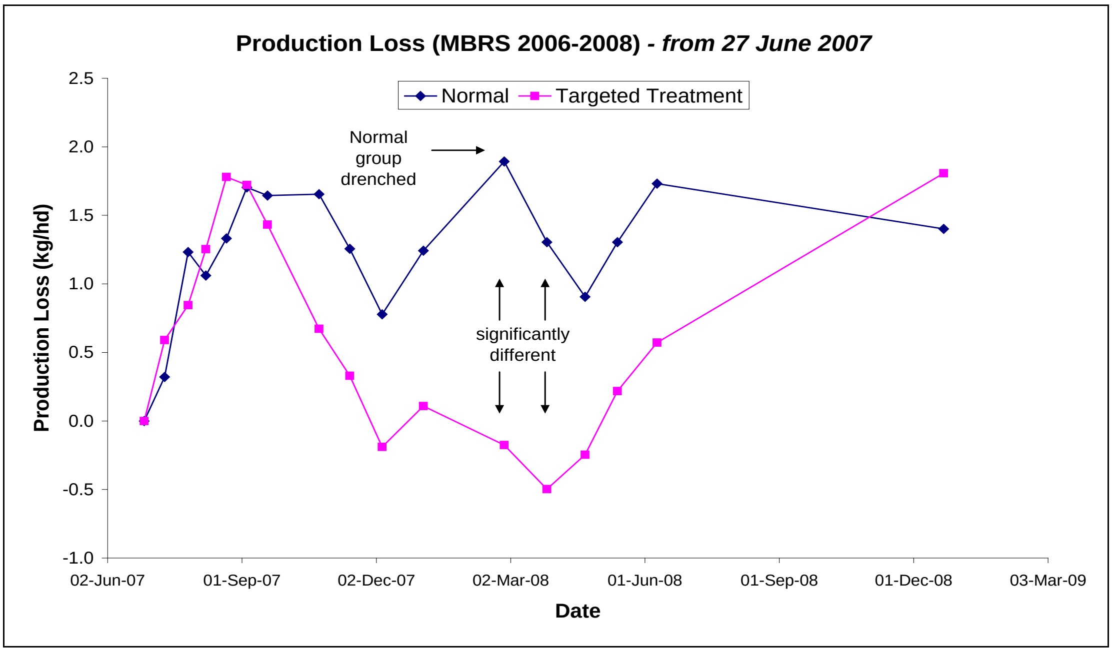

Figure 2. Year 1, 2008/09, Flock 1: Worm egg counts of normal-treatment (Normal) and targeted selective treatment (TST) groups and the percentage of sheep drenched on each treatment date. Statistically significant counts are indicated by *

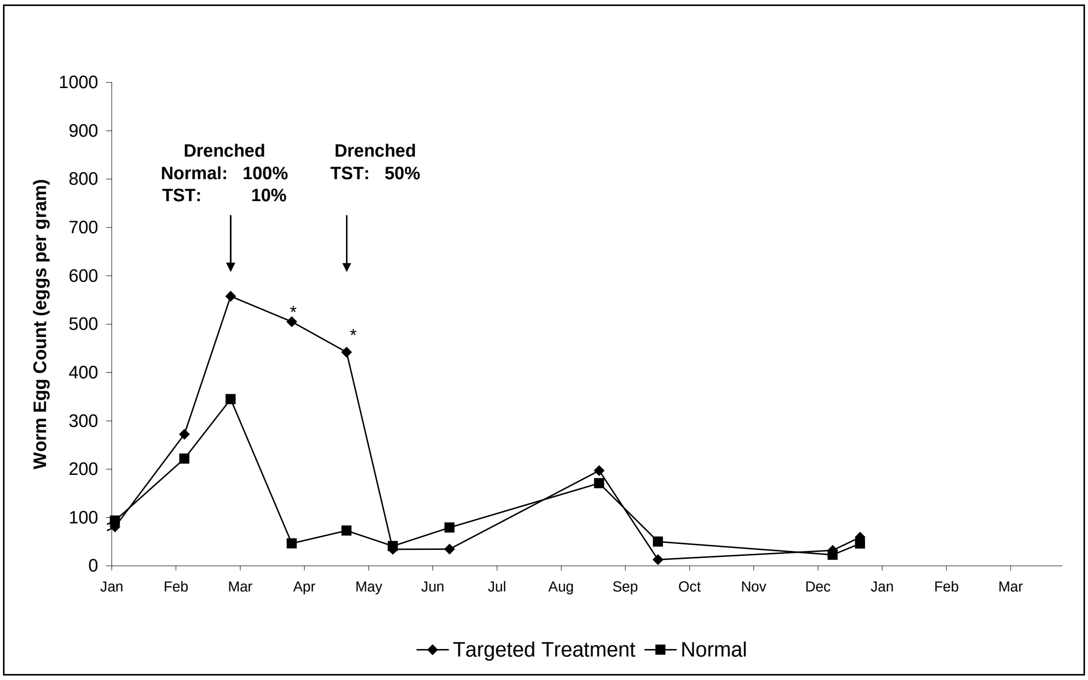

Figure 3: Year 1, 2008/09, Flock 2: Relative bodyweight differences between treatments (adjusted as if same weight at start of 2008 observations).

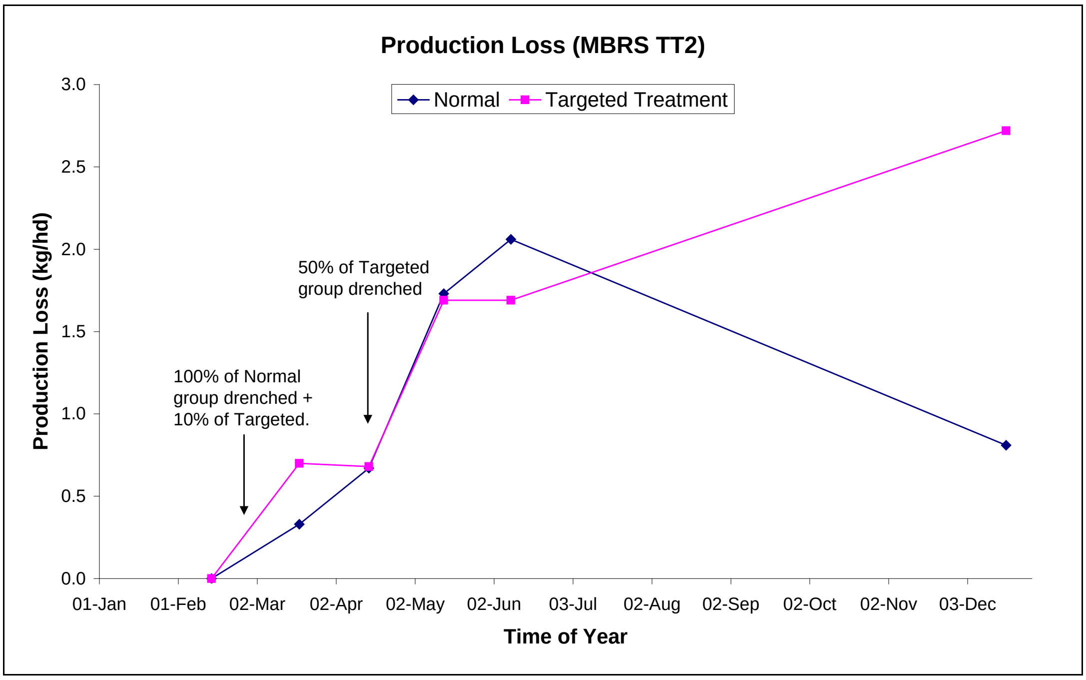

Figure 4. Year 1, 2008/09, Flock 2: Worm egg counts of normal-treatment (Normal) and targeted selective treatment (TST) groups and the percentage of sheep drenched on each treatment date. Statistically significant counts are indicated by *

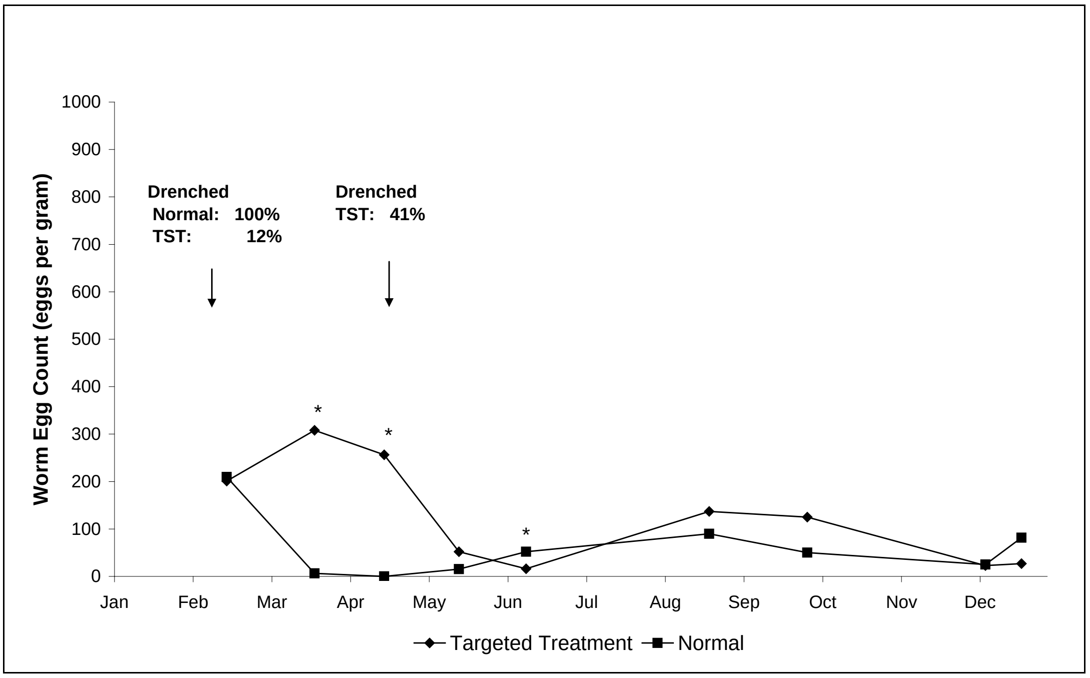

Figure 5: Year 1, 2008/09, Flock 3: Relative bodyweight differences between treatments (adjusted as if same weight at start of 2008 observations).

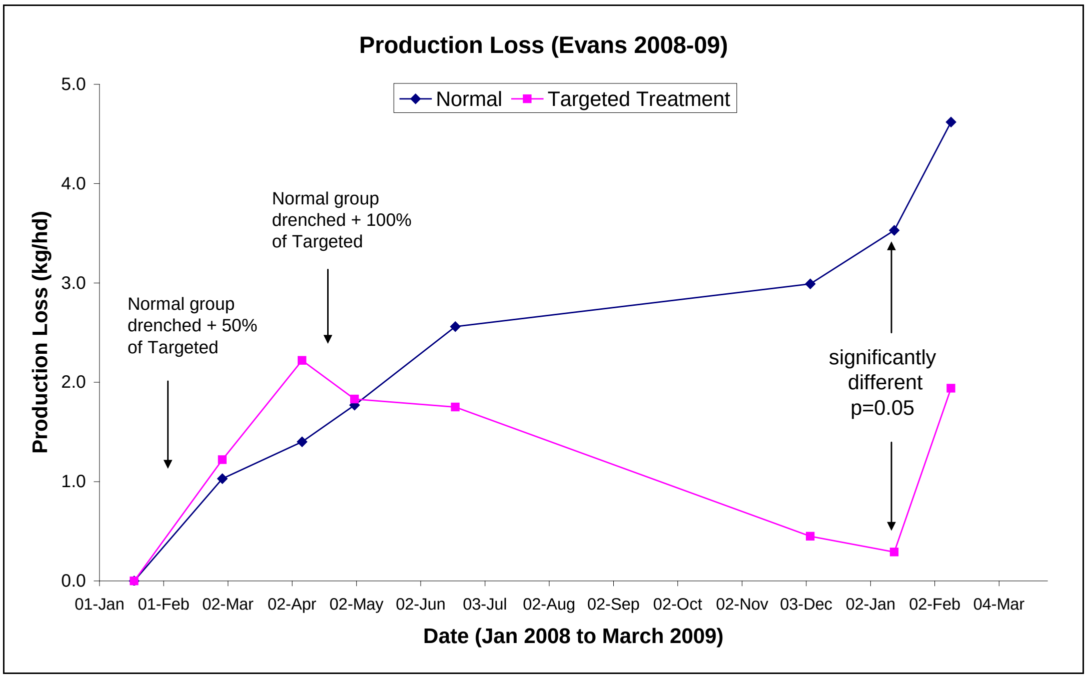

Figure 6. Year 1, 2008/09, Flock 3:Worm egg counts of normal-treatment (Normal) and targeted selective treatment (TST) groups and the percentage of sheep drenched on each treatment date. Statistically significant counts are indicated by *

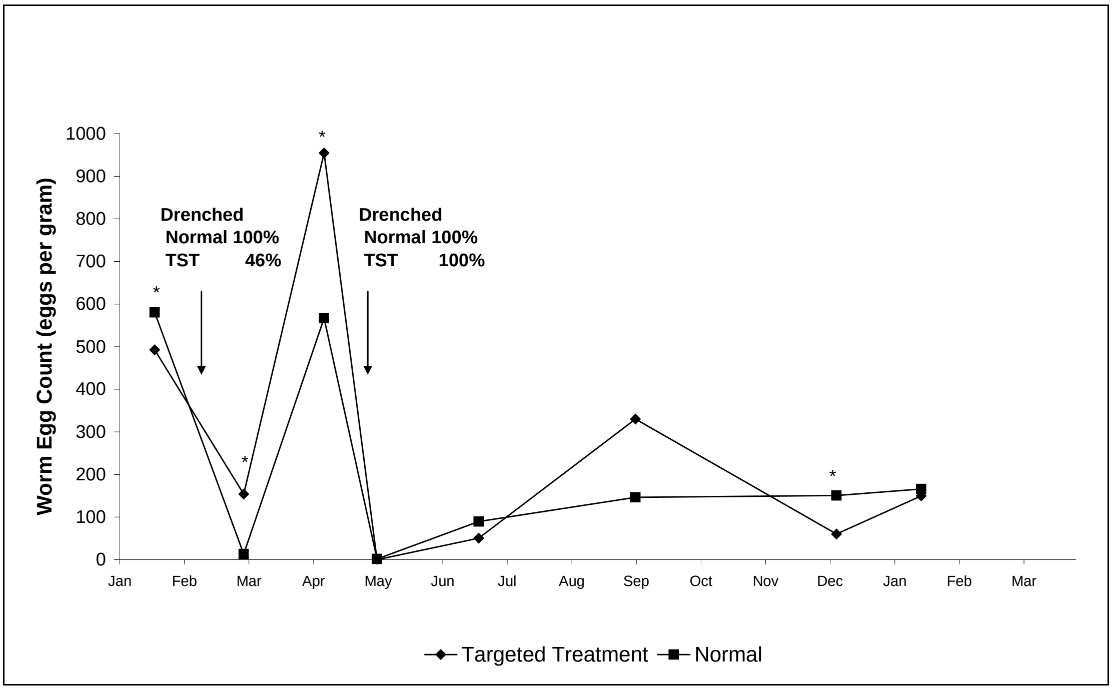

Figure 7. Year 2, 2009/10: Flock 2: Bodyweights (kg) of sheep in worm-suppressed control (C), normally-treated (N) and targeted treatment (T) groups, 2009/10.

Figure 8. Year 2, 2009/10: Flock 2: Worm egg counts (eggs per gram) of sheep in normally-treated (N) and targeted treatment (T) groups, 2009/10.

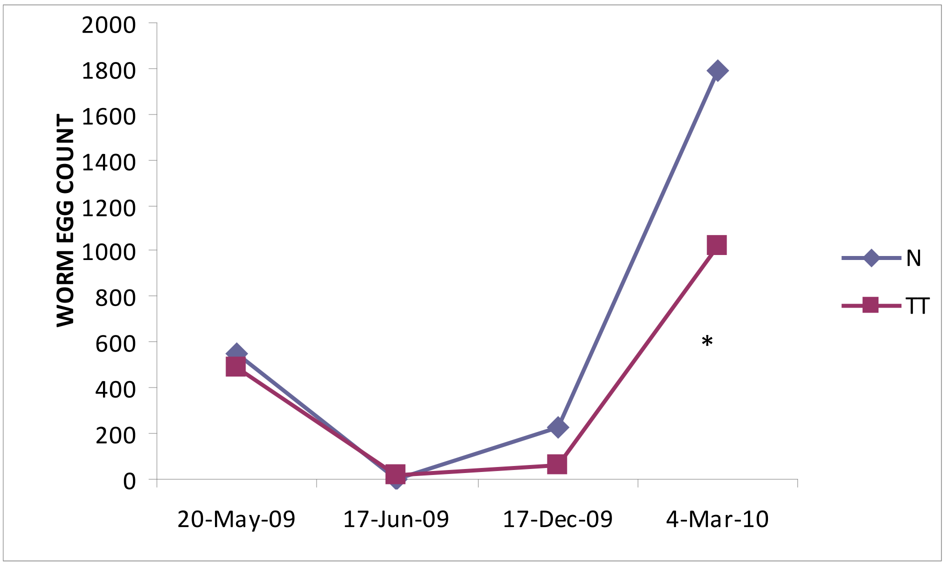

Figure 9. Year 2, 2009/10: Flock 3: Bodyweights (kg) of sheep in worm-suppressed control (C), normally-treated (N) and targeted treatment (T) groups, 2009.

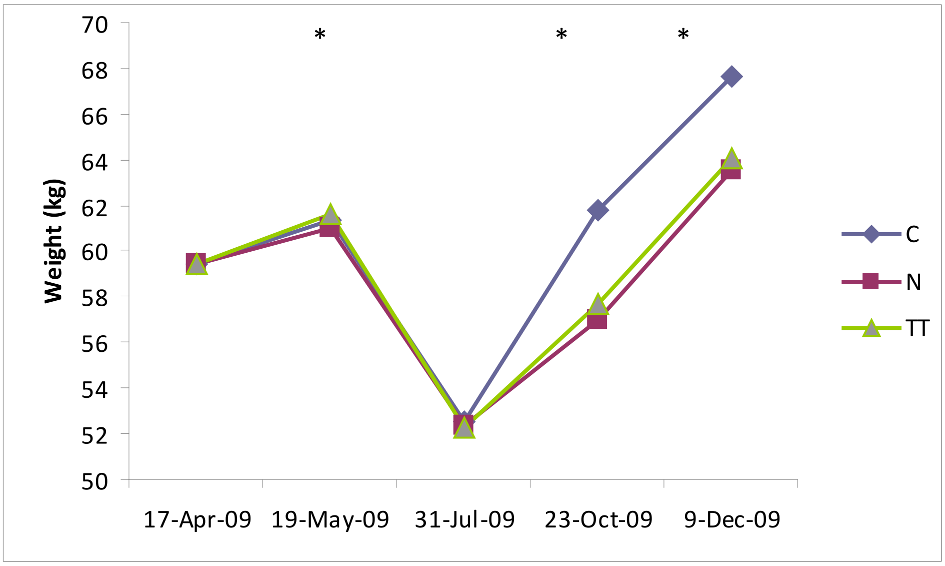

Figure 10. Year 2, 2009/10: Flock 3: Worm egg counts (eggs per gram) of sheep in normally-treated (N) and targeted treatment (T) groups, 2009.