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Targeted treatment as a strategy for managing sheep parasites
Review conducted for Sheep CRC
2009

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Terms of Reference

1. Assess progress of Project 1.3.1 against the following specific objective stated in the Sheep CRC Operational Plan 2008-09, and provide relevant advice:
   To develop for different environments the "targeted treatment" concept of ensuring a sustainable basis to routine worm control recommendations by limiting drenching to animals identified as likely to benefit from treatment, so that a source of non-anthelmintic resistant worms (in "refugia") is continually present on sheep properties.

2. Provide a summary of the scientific literature on "targeted treatment" as a parasite management strategy and show how Project 1.3.1 advances scientific knowledge and/or practical implementation in this context.

3. Provide an assessment on whether "targeted treatment" parasite management is likely to be:

   (a) efficacious
   (b) cost-effective and practical to implement
   (c) acceptable on animal welfare grounds.

4. Provide an assessment of the time-scale and resources required to successfully complete the Project.

1. Progress

Assessment of progress is based mainly on draft milestone reports received from each of the three research groups addressing activity R3.1.2.2 - *Termination of Year 1 trials in WA and NSW and preliminary report on Year 1 results* – together with briefings given to me at a Project Meeting held on 10th March 2009 in Sydney during which progress on each of the NSW, WA and SA elements of the project was presented in detail and discussed. Other discussions have taken place with Dr Brown Besier by phone and email over the past 4-5 months from which I have been able to clarify various issues related to project design and progress. As the project has been undertaken in three distinct environments, namely Summer, Winter and Mediterranean rainfall zones, each requiring a different approach to worm control, it is appropriate first to summarise progress on each individually and then finally to draw some overall conclusions.

Northern Tablelands, NSW- Summer Rainfall Zone

This Northern Sub-Project builds upon the findings of the AWI-funded Integrated Parasite Management-Sheep (IPM-s) project which demonstrated that tactical chemical control based on treatments determined by a structured Drench Decision Support Tool (DDST) could greatly reduce or eliminate production loss from worms in the New England environment. By elimination of unnecessary drenches, this approach could be viewed as targeted treatment on a flock basis.

The present project compares IPM-s worm control with typical (non-IPM-s) control methods used on commercial properties in this summer rainfall region where *Haemonchus contortus* is the most significant worm species in terms of rapid onset of high levels of acute mortality. The aims of the Northern Sub-Project, as stated in the original protocol, are:

1. To quantify production loss associated with “conventional” parasite control in the New England and compare this to production loss on farms implementing IPM-s including use of a drench decision aid.
2. To further evaluate and if necessary, optimise, the use of a drench decision aid to reduce unnecessary drenches and increase drenching trigger thresholds, ie. to rely to a greater extent on resilience of sheep to manage worm infections.
3. To broadly determine the economics of IPM worm control incorporating targeted flock treatment against more laissez faire “typical” approaches.
4. To investigate and validate measures of resilience to worm infection in a region dominated by *H. contortus*.

The project was implemented in accordance with the original protocol and Year 1 data from shearing in July-Oct 2007 to shearing 2008 has been collected and analysed from 6 private properties, 3 practising IPM-s and 3 practising conventional (“Typical”) parasite control. Data collection is currently mid-way through Year 2.

Selection of “Typical “ properties was based on (1) geographical proximity to one of the selected “IPM-s” properties, (2) having more than 1500 breeding ewes and reasonable match with regional averages for property type and parasite control, and (3) limited use of IPM-s strategies for parasite control (grazing management, worm egg count (WEC) monitoring, and drench resistance testing).

Owners of Typical properties receive no feedback on the measurements made other than an annual summary of fleece and bodyweight data on their property, and all management and worm control decisions are left to their discretion. IPM-s property owners receive feedback on WEC and other measurements made; drench control decisions are made in conjunction with Dr Lewis Kahn utilising the DDST which takes account of a combination of fat score, WEC thresholds and green herbage mass availability to inform the decision on whether to drench the flock (see Table 1).

Table 1. *Haemonchus contortus* worm egg count (epg) thresholds

(at least 60% barbers pole)

Fat Score	Green Herbage Mass Available (kg DM/ha)		
	400	**800**	**1200**
2.0	800	1000	1100
2.5	900	1200	1300
3.0	1100	1300	1500

In summary, the experimental design is a 3x2 factorial over 2 successive years with crossover at the end of Year 1:

- 2 treatment approaches (IPM-s, Typical); 3 replicates (farms) per treatment
- 2 Levels of worm challenge (Natural, Capsule/low challenge); Capsule sheep are maintained worm-free using albendazole capsules and combination

drench at 70-80 day intervals. In Year 2 there is a crossover of worm challenge treatments.
- 2 Classes of stock (Yearling ewes, Mixed aged ewes)
- 2 mobs (>300) per property (yearling, mixed age)
- 120 sheep tagged/mob; 60 Capsule (shearing to shearing), 60 Natural

The following measurements are being made:
- Fleece weight and wool test at each shearing
- WEC, fat score and bodyweight
- PCV and haematology
- Faecal egg count reduction test - in Year 2

Derived variables are:
- Cost of worms (based on production loss determined by comparison of Capsule vs Natural in each treatment system)
- Resilience – assessed in Year 2 from growth and PCV

Benefits of targeted treatment are assessed in terms of performance, parasitological variables, drench frequency and cost/benefit analysis.

In summary, Year 1 results show:
- Greasy fleece weight was reduced by worm infection on both IPM-s and Typical properties but to a lesser degree on the former treatment
- Liveweight gain was reduced by worm infection on both IPM-s and Typical properties but to a lesser degree on the latter treatment
- Markedly higher worm-related mortality rates were associated with Typical compared with IPM-s treatment in both yearling (+6.1 vs +1.6%)% and mixed age (+14.4 vs +3.2%) ewes.
- Yearly average WEC were greater on Typical compared to IPM-s properties in yearling (2294 vs 370 epg) and mixed age (1013 vs 610 epg) ewes.
- Typical properties had more anthelmintic treatments than IPM-s (5.2 vs 3.9) with a greater use of persistent anthelmintics (37% vs 13% of treatments).
- Based on estimated costs associated with mortality, fertility, wool loss, liveweight change, treatment and monitoring, the total annual cost of worms was greater on Typical compared to IPM-s properties by approximately $3 in yearling ewes and by approximately $9.50 in mixed age ewes.

Year 2 of the project has been initiated as planned during which potential indicators of resilience to worm infection are being evaluated. No data from Year 2 has been made available to the reviewer.

Conclusion: The sub-project has been successfully implemented as planned and is progressing well. There is clear evidence from the first year’s data that an IPM-based, targeted flock treatment approach can achieve superior management of worm infections together with reduced drench usage and less reliance on sustained activity formulations. These latter effects on drenching practice, achieved by use of a decision support tool, would be expected to reduce selection for anthelmintic resistance in *H. contortus* and other worm species in this environment. These outcomes were obtained without significant additional losses in productive performance and with a marked benefit in animal welfare in terms of reduced mortality, which was the principal factor contributing to the large economic advantage of the targeted flock treatment.

Southern Coastal Region, WA – Mediterranean Rainfall Zone

The WA Sub-Project is focused on investigation of the effectiveness and practicality of a targeted treatment strategy for control of "scour worms", mainly *Teladorsagia* and *Trichostrongylus* spp., in a Mediterranean environment. Flocks treated according to an index that indicates the proportion of animals likely to benefit from treatment are being compared with flocks treated according to "normal" drenching programs.

The trial design builds on earlier studies of targeted treatment in hogget-age sheep which showed that this was not an ideal strategy for this age group because of their inability to combat worms without a growth penalty. The earlier work also showed that diarrhoea was not a useful index of the need for treatment, logical decisions could not be made without worm egg counts to indicate the level of parasitism, and short-interval weight changes were not a practical index for treatment decisions.

On this basis the current project adopted the following over-arching considerations:

- Restriction of targeted treatment to adult sheep over 18 months of age
- Drench decisions to be made when farmers normally do routine treatments or when WEC are recommended, and should not involve additional monitoring or yarding
- Proportion of sheep to be drenched according to need to (1) maintain pasture contamination with worm eggs at a minimum level or (2) maintain flock productivity in the face of worm challenge using an index based on mean flock WEC and body condition score.
- Individuals which are visually poorest on body condition score/ size/ apparent health (i.e. "tail" of flock) to be chosen for treatment.

The stated aims of the WA Sub-Project are:

- 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 animals 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 those individuals which should receive treatments when only a proportion of a flock is to be drenched
- To investigate the relationship between worm egg count and sheep weight change in adult Merino ewes.

The project was implemented in accordance with the original protocol and observations commenced in January-February 2008 enabling collection and analysis of data for Year 1 in three flocks of ewes at two sites. The essential features of the trial design were as follows:

- Flocks 1 and 2 were Merino ewes run at Mt Barker Research Station and Flock 3 were Merino-Dohne crosses run on a commercial property near Albany. Lambing was in July.
- Each flock was divided into 2 groups of approximately 150-200 individually identified sheep: a Targeted group, in which a proportion only were treated, and a Normal group, in which all were treated when drenches were given.
- The two groups were run in separate paddocks which were formed from one original paddock to ensure similar sheep nutrition and worm larval availability.

- Both groups in each flock contained a sub-group of 25-40 worm-suppressed sheep to enable adjustments to be made for differences in nutrition in analysis of growth differences between treatments.
- Drench treatment was based on WEC on 30 faecal samples collected from non-worm suppressed sheep in each treatment group
- Normal groups were drenched according to the following times and criteria:
  - December: if mean WEC > 200 epg
  - Early April: if mean WEC > 200 epg
  - From June at 4-6 weekly intervals: if WEC > 300epg and scouring or 500 epg and no scouring
  - Pre-lambing: maximum WEC of 200epg
- Targeted groups were drenched as follows:
  - December, April and pre-lambing: to maintain desired mean WEC a proportion was treated to reflect this
  - Proportion drenched based on prototype index with increasing proportion treated as WEC increased and condition score changed as shown in Table 2.
  - A "farmer assessment" visual index of the poorest-performing sheep was used to indicate the individuals in the relevant proportion for treatment – usually readily apparent as the "tail" of the flock on the basis of size and condition score.

Table 2. Prototype drench index for Mediterranean rainfall zone

Worm Egg Count	Proportion drenched	
	Av. condition score <3.0	Av. condition score > 3.0
Below 100 epg	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%

The following measurements are being made:

- Greasy wool weight at shearing
- WEC, bodyweight, condition score
- Lambing performance – pregnancy, marking and weaning percentages, weaning weights, WEC
- Pasture nutrition levels

In summary, across the three flocks Year 1 results showed:

- Number of drenches per ewe in the Targeted group was reduced to between 60% and 75% (Mean 65%) of those given to the Normal group
- No uniform indication of a bodyweight difference between Targeted and Normal treatments over the year – in Flocks 1 and 2 Normal groups were slightly heavier (not statistically significant); in Flock 3 the Targeted group was 2.5 kg heavier (statistically significant).
- No indication of a substantial difference in wool weights between Targeted and Normal groups – in Flocks 1 and 2, Normal groups produced 0.26 and 0.29kg, respectively, more greasy wool (not statistically different), and in Flock 3 wool weights were identical in each group.
- No adverse effects detected on lambing performance attributable to the reduced level of drenching in the Targeted groups.
- No worm-related disease occurred.
- Based on egg deposition, strong indication that targeted treatment delivered substantial benefit on refugia for non-resistant worms during the critical period for worm egg development from late February to end of March.
- The targeted treatment index was appropriate for determining the percentage of sheep to be drenched judging by the absence of significant production loss and disease.
- Identification of sheep performing less well on a visual basis proved both simple to apply and accurate in apportioning sheep to be drenched in the Targeted group.

The second year of the evaluation of the targeted treatment strategy using the prototype index is in progress with similar trials being conducted on three sites including two commercial properties.

Conclusion: The WA sub-project has been successfully implemented as planned and is progressing well. There is clear evidence from the first year's data that a targeted treatment approach in the Mediterranean rainfall zone can achieve effective management of scour worm infections in ewes with an overall reduction in drench usage and without significant additional losses in productive performance or worm-related disease. The prototype index, which uses worm egg count and condition score to inform the decision on what proportion of sheep in the flock require to be drenched, has been shown to be appropriate and readily applied. Potential longer-term benefits of targeted treatment in terms of non-resistant worms in refugia appear to be supported by the overall increase in egg deposition which occurred from non-drenched sheep on this treatment during the critical summer months. This effect would be expected to reduce selection for anthelmintic resistance in scour worms, mainly *Teladorsagia* and *Trichostrongylus* spp, in this environment.

Naracoorte, SA – Winter Rainfall Zone

The SA Sub-Project is focused on investigation of the effectiveness and practicality of a targeted treatment strategy for control of "scour worms", mainly *Teladorsagia* and *Trichostrongylus* spp., in a Winter Rainfall environment. Drought and staff issues prevented implementation of the project until August 2008 when a trial was initiated at Struan Research Centre.

In broad terms this trial addresses similar aims to those of the WA trial, namely:

- To investigate the effects on sheep health and production of leaving a proportion of sheep undrenched when the remainder of a flock are treated.
- To test a drenching matrix based on WEC for the determination of the proportion of a flock which should be drenched
- To test the practical use of a visual assessment of the condition score of sheep to indicate those individuals which should receive treatment.

The trial has been established in a single flock of 500 first cross Border Leicester / Merino ewes of mixed age; 250 were allocated to a Control group subjected to normal farm treatment practice and 250 were allocated to a Targeted treatment group. Both groups graze concurrently on the same dryland pastures, rotated according to feed availability. The following measurements are being made:

- Bodyweight, condition score, dag score and WEC
- Pasture contamination with worm larvae
- Pasture quality

Established critical times for drenching decisions at Struan are late December (first summer drench), late February (second summer drench) and mid May (pre-lambing). Based on experience, there are certain critical WEC associated with each of the seasonal decisions on whether to drench or not, as follows:

- First summer drench, 100 epg;
- Second summer drench 80 epg;
- Pre-lambing drench 150 epg;
- Spring drenches, 200 epg.

Under the trial design, the research flock comprises equal numbers of ewes given either the normal drenching program or targeted treatment. The objective at each drench decision point is to reduce the overall flock WEC below the critical level, described above. Should the overall flock WEC be below the critical level, no sheep are drenched and the proportion of sheep drenched is increased as the flock WEC rises, as exemplified for Spring in Table 3:

Table 3. Drenching matrix for targeted treatment in Spring – Winter rainfall zone

Worm egg count (epg)	**Percentage to be drenched[#]**
200	20
250	35
350	60
450	80
550	100

[#] Percentage to be drenched calculated after (not including) provision for scouring animals

Once a decision to drench is made, 50% of the flock are automatically drenched and the balance, if required, is provided by Targeted treatment animals chosen for drenching. The required proportion of sheep for drenching is then enrolled from the cohorts of lowest body condition score upwards, making allowance for any scouring animals, which are always drenched.

To date, two drench treatments have been given; in December all Control and 20% of Targeted animals were drenched and in February all Control and 29% of Targeted animals were drenched. This represented 60 and 65% of the total flock at the first and second summer drench, respectively. Prior to the first treatment ewe growth rates were similar but, following the first summer drench, Targeted ewe growth rates were 23 g/day less than Controls before again increasing to be only 4g/day lower than Controls over the January-February period. The first and second summer treatments achieved the objective of reducing average WEC of the flock to below the target level of 100 and 80 epg, respectively. Dag scores were low and similar in both groups and condition scores remained similar in both groups throughout.

Conclusion: The SA trial has been implemented successfully and, although the early stages are demonstrating promising results, it is too premature to draw firm conclusions about the success of the targeted treatment strategy in this environment.

Overall Conclusions and Recommendations

The trials that are currently in progress in NSW, WA and SA have been appropriately designed to develop and evaluate the concept of targeted treatment of ewe flocks within the context of presently accepted routine worm control schemes which have been established specifically for sheep production systems in the Summer, Mediterranean and Winter rainfall zones, respectively.

Examination of these trials shows that each is clearly focused on testing the application of a decision tool, or matrix, designed to be relevant to existing treatment and management practices of farmers in a particular region and to be readily useable under normal field conditions on-farm. If proven to be robust by experience and further data collection, these decision tools should enable farmers to make an incremental change in their management of worms towards making informed judgements on what proportion of the flock to treat, taking into account infection level (WEC), condition of the animals and feed availability. Appropriately, the criteria of success include: (1) no detrimental impact on sheep welfare, in terms of ability to control worm-related disease, and (2) no significant negative effect on productive performance, in terms of bodyweight, wool growth and quality, and lambing performance.

Notwithstanding that trials in each zone are at different stages, analysis of the Year 1 data that is currently available shows that the targeted treatment concept has the capacity to both significantly reduce the overall level of drenching of ewes and to meet the prescribed welfare and production criteria in all three environments. However, these observations need to be confirmed by completion of studies over 2 years in each region. Similarly, the limited data that is available on the impact of targeted treatment on egg deposition on pasture is suggestive of a positive effect in terms of maintaining a source of worms in refugia that have not been exposed to drench, but further observations are required together with testing of the resistant status of these populations in Year 2. Such information will be a critical indicator of the sustainability of targeted treatment as a strategy to minimise development of anthelmintic resistance in worm populations.

The NSW trial is scheduled to be completed by late 2009 and, if the Year 2 observations essentially confirm the Year 1 results thereby establishing proof of concept, this sub-project could move immediately into an early adoption phase for IPM-s during 2009-10. It is recommended that an effective communication and training package be developed and used to initiate a beta-trial of the commercial prototype of the DDST with several farmers in the Summer rainfall zone supported with appropriate mentoring by consultants.

The WA sub-project is scheduled to complete studies at 3 sites by December 2009 to confirm whether the current prototype matrix can adequately support targeted treatment decisions in the Mediterranean rainfall zone. It is recommended that the project then proceed to the development of a commercial index in consultation with farmer groups and consultants in readiness for on-farm beta-testing of the matrix in an early adoption phase in 2010-11.

The SA sub-project is effectively at a preliminary stage with targeted treatment of only one flock being evaluated on a research farm and still only halfway through the first year. There is a need to expand research activity in the Winter rainfall zone to at least two additional sites under commercial conditions in the 2009-10 period to establish proof of concept for the prototype drenching matrix being proposed for this region.

2. Summary of Scientific Literature

Progressive escalation of resistance to anthelmintics in gastrointestinal nematodes of small ruminants has stimulated much research globally over the past 30 years aimed at an understanding both of the genetic mechanisms and population dynamics influencing resistance development in worm parasites, and of those management practices which accelerate its emergence on-farm and jeopardise animal production and welfare.

The term “refugia” refers to the proportion of a given parasite population that escapes exposure to any control measure - for example free-living stages on pasture (the suprapopulation) when the hosts are treated with an anthelmintic, or worms in untreated animals (the infrapopulation) – and are hence available to dilute resistant parasites which survive treatment. Although the concept of refugia has been understood for many years as a potential factor in the selection for anthelmintic resistant parasites (Martin et al., 1984; Martin, 1985; Michel, 1985), it is only relatively recently that attention has been directed toward devising methods of maintaining a nematode population in refugia in an effort to maintain susceptibility within the suprapopulation (Van Wyk, 2001; Besier and Love, 2003).

In temperate areas, the majority of the parasite population is usually found on pasture, and therefore, provides a relatively large reservoir of susceptibility. In tropical areas, this may not always be the case, since the extreme heat desiccates the free living worm stages on pasture within as short a period as four weeks. There are a range of environmental and climatic factors which influence egg and larval development and survival and have the potential to skew the genetic structure of surviving infective larval populations, for example, hot and dry or drought conditions can increase mortality amongst the free living stages thus reducing the proportion of the parasite population in refugia. Species differences in fecundity, development and survival rates of the major sheep parasites influences their epidemiology and relative abundance in refugia in different environments. Furthermore there are host-associated factors, such as the level of resilience to parasitic infection and the extent of expression of immunity, which can influence the relative proportions of parasites in refugia by affecting the contribution of parasite eggs to pasture contamination.

Through interaction with these environmental, parasitological and host factors, management practices can have an impact on the maintenance of refugia. It is now well understood that frequency of exposure to anthelmintic together with the timing of drenching in relation to the relative proportions of the total worm population residing on pasture or within the host are major factors contributing to refugia. Considerable international research effort has therefore been directed towards development and evaluation of worm management techniques which reduce the frequency of treatment and at the same time restrict it to those animals that necessitate treatment in order to maintain production at an acceptable level together with preventing worm-related disease. (see reviews by van Wyk et al., 2006; Besier, 2008; Jackson & Waller, 2008; Kenyon et al., 2009). This approach has been termed “targeted treatment”, when given on a whole flock basis at the most appropriate time bearing in mind the need to maintain refugia, or “targeted selective treatment” when selective treatment is given only to those animals that will benefit most from treatment, leaving the remainder of the flock untreated (Kenyon et al., 2009).

The complexity of the interactions outlined above exemplifies the necessity of tailoring targeted treatment strategies to particular environments and production systems. However, a common element is the need to develop an indicator on which to base the selection of particular animals for treatment which is cost-effective, simple to use, requires minimal operator training and can be applied alongside the sheep. A number of methods, ranging from visual identification to performance-based, parasite-based or pathophysiological markers, have been or are currently being evaluated in various production systems around the world including South Africa, USA, Kenya, Guadaloupe, France, Scotland, New Zealand and Australia (see Besier, 2008; Kenyon et al., 2009).

Originally developed in South Africa (see van Wyk el., 2006) and since extended to several other countries, application of a method (FAMACHA) based on the categorisation in the ocular membranes of the degree of anaemia caused by *H.contortus* has enabled treatment to be restricted to those individuals most at risk and lead to substantial reduction in the number of animals being drenched. However, FAMACHA requires a considerable labour and time input for the frequent yarding of flocks, individual animal restraint and inspection, and is therefore practical only where either labour is relatively inexpensive or flock sizes are small. In *H.contortus* endemic zones in Australia where large flocks and small labour forces are the norm, it is impractical to implement FAMACHA. Accordingly, through Project 1.3.1 it has been necessary to develop an index based on worm egg count, condition score and herbage availability for the Summer rainfall zone of Northern NSW, where ewe flocks are at risk from haemonchosis and a source of refugia for non-resistant worms is provided in the flocks judged as not requiring treatment under the IPM-s strategy.

The development and evaluation of a suitable indicator of parasitism with non-haematophagous nematodes in individual animals is a significant challenge which is currently under investigation particularly in the UK/Europe and Australasia. The main indices that are being pursued are focused on identifying those individuals which fail to achieve acceptable production levels in comparison to others in the flock.

In New Zealand, Leathwick et al. (2006a) examined the effect of leaving the heaviest 15 % of lambs untreated at each of 6 suppressive treatments throughout the grazing season in New Zealand and found that there was a slower development of resistance in *Teladorsagia* spp. in the targeted group. In another study where the heaviest 10 % of the flock remained untreated, no significant differences were found in liveweight gain, compared to a flock where all animals were suppressively treated, and increased numbers of worms were found on pasture (Leathwick et al., 2006b).

A more refined decision support tool has been recently developed and evaluated in field trials in Scotland. This tool used estimation of energy deposition, based on liveweight gain, and of metabolisable energy intake, based on assessment of herbage availability and quality, to calculate the efficiency of energy utilisation in individual lambs (Greer et al., 2009). A threshold efficiency value was used below which lambs received anthelmintic treatment. Compared to suppressively treated animals, no reduction in cumulative liveweight gain was observed in the targeted treatment lambs, and there was a slight reduction in the number of anthelmintic treatments required compared to strategically treated lambs. Importantly, 87% of the lambs that had a pre-treatment efficiency of nutrient utilisation lower than the suggested threshold responded positively to treatment.

When compared to the research being undertaken overseas it is apparent that Project 1.3.1 is at the leading edge of defining and evaluating indices which can be used practically and readily by sheep producers for targeted treatment of ewe flocks in various Australian environments. The prototype indices combine the essential parasitological, animal condition and nutritional elements necessary for an informed decision on which animals within the flock require treatment and will benefit most.

3. Assessment of Likely Success of Targeted Treatment.

Success of this project will be ultimately measured by the level of adoption of the targeted treatment concept in ewe flocks by farmers throughout the major sheep producing regions of the Summer, Winter and Mediterranean rainfall zones. At this stage of the project it is clearly difficult to be prescriptive about the likelihood of overall success because of the different stages of evaluation that have currently been attained in each of these zones. However, reasonably informed judgements can be made on the basis of the first year's data, particularly from the NSW and WA elements of the project.

Application of the targeted treatment approach to parasite management is likely to be highly efficacious in ewe flocks when applied both within an IPM-s strategy to control *H.contortus* in a summer rainfall environment and within the accepted worm management routine in a Mediterranean environment to control scour worms of *Teladorsagia* and *Trichostrongylus* species. This is evident from the data in terms of regulating WEC and worm-related disease, including mortality, together with the absence of production penalties when compared with typical treatment regimes in these environments.

Development and testing of the targeted treatment concept has paid much attention to producing an outcome that can be readily applied in a practical fashion in commercial, on-farm situations without adding significantly to cost or complexity of worm management decisions. This appears to be achievable in all three climatic zones because proposed targeted treatment decisions have been incorporated into the normal annual cycle of worm treatments. At the heart of the decision-making lies the application of a readily understandable decision support tool, index or matrix, which has common elements for each zone, namely, level of infection (WEC), animal condition and pasture quality. These elements do not extend the understanding or application of principles much beyond what is currently being used by leading producers and, given the development of appropriate communication and extension packages, should be readily transferable to the sheep industry as a whole.

Convincing evidence of the cost – effectiveness and reliability of targeted treatment will be crucial to the acceptability of the concept to farmers. Early economic data, particularly from the NSW trial, looks very promising in this regard. However, in all zones it will be important to generate acceptability by demonstrating on selected farms that the application of targeted treatment, utilising the appropriate decision support tool for that region, generates a profitable outcome by reducing drench frequency without compromising production or susceptibility to worm-related disease. The additional benefit of prolonging the useful life of anthelmintic classes by maintaining a level of susceptible worms in refugia will be a harder message on which to promote the concept; it will be a secondary consideration to most sheep producers, even though there is a high awareness in the industry of the problems and risks of anthelmintic resistance.

Given that targeted treatment involves reducing the frequency of worm treatment, it is not surprising that an immediate response to the idea might be that animal welfare will be compromised. Evidence from these trials indicates that adherence to the principle of treating those animals most at risk to parasitic disease by application of the decision matrix is unlikely to compromise animal welfare. In fact, the early results from farms in northern NSW on which *H.contortus* is endemic provide convincing evidence of substantially reduced mortality rates in ewe flocks on targeted treatment compared to the worm treatment protocols typically applied in this region. Despite this optimism, it will be important to generate further data to convince producers in all regions that reduced frequency of drenching on a flock basis is acceptable on animal welfare grounds.

4. Time–scale and resources for project completion

As indicated above it is essential that the field evaluations currently in progress in NSW, WA and SA collect data over 2 full year cycles to enable proof of concept of targeted treatment. This will necessitate that the present allocation of resources for this research be maintained until that timepoint is reached for each of the trials in turn.

At the conclusion of the field evaluation phase during late 2009 into late 2010, resources should be progressively moved into the development of communication, information and training programs specifically tailored for commercial implementation of a packaged product centred on a decision tool or index appropriate for each region. Sheep management consultants and others with particular expertise in delivering regional worm control programs should be engaged in this exercise.

Early phase adoption through late 2010 and 2011 should be undertaken on several “demonstration properties” in each of the three regions, on which farmers who have been trained in the targeted treatment concept apply the principles to their worm management practice in ewes over a 12-month period, ideally from one shearing to the next. Data should be collected on production and lambing performance together with the WEC, condition scoring and nutritional information on which drench decisions were based. During this phase it would be essential to maintain a high level communication exercise to the industry as a whole so that farmers were made aware of the existence and progress of the trials and had the opportunity to visit these properties on field days held at appropriate intervals.

The final phase of the project, commencing in 2011-2012, should entail full scale promulgation of targeted treatment within worm management programs tailored for ewe flocks in the Summer, Winter and Mediterranean rainfall zones.

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