WAARD Project

Wales Against Anthelmintic Resistance Development

Prosiect CYYG

Cymru'n Ymladd Ymwrthedd Gwrthlyngyrol

Final Project Report

Date: September 2015

Report prepared by the WAARD project consortium.

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
The European Agricultural Fund for Rural Development: Europe Investing in Rural Areas

Llywodraeth Cymru
Welsh Government

Cyllidwyd y prosiect hwn drwy Gynllun Datblygu Gwledig Cymru 2007 - 2013 a ariennir gan Lywodraeth Cymru a'r Undeb Ewropeaidd.

This project has received funding through the Rural Development Plan for Wales 2007 - 2013 which is funded by the Welsh Government and the European Union.

Contents

Glossary

Term	Definition
AR	Anthelmintic Resistance
BZ or 1-BZ	Benzimidazole group of anthelmintics
EBV	Estimated Breeding Values
EHT	Egg Hatch Test
FEC	Faecal Egg Count
FECR	Faecal Egg Count Reduction
FECRT	Faecal Egg Count Reduction Test
KT	Knowledge Transfer
L3	3rd Stage roundworm larvae
LV or 2-LV	Levamisole group of anthelmintics
ML or 3-ML	Macrocyclic-Lactone group of anthelmintics
Triple Resistance plus Moxidectin	A term used in this report to describe farms that showed lack of efficacy to all 4 anthelmintic treatments tested. See page 6 for full explanation.
TST	Targeted Selective Treatment
TT	Targeted Treatment

1. Background

Project Overview

In 2014 Hybu Cig Cymru – Meat Promotion Wales (HCC) commissioned the WAARD (Wales Against Anthelmintic Resistance Development) project to investigate the current levels of anthelmintic resistance (AR) on sheep farms in Wales. The project was funded through the Rural Development Plan for Wales 2007-13; Supply Chain Efficiencies Scheme, for Animal Health activities.

The project is led by Techion UK Ltd, supported by Bristol University, RVC Welsh Regional Veterinary Centre as well as 5 Veterinary Practices located throughout Wales (see Appendix 2 for Project Consortium members).

For roundworm resistance the three older anthelmintic groups (1-BZ, 2-LV and 3-ML) were tested as well as a separate test on Moxidectin (a member of the 3-ML group with persistent action), to see how effective they were on the farms sampled. It has been shown previously that where resistance to the 3ML group was present, Moxidectin was still fully effective, even though it does belong to that same anthelmintic group. Recent reports have identified the first cases of Moxidectin resistance in the UK. There are concerns regarding resistance to this group of anthelmintic as many farmers have turned to depend on Moxidectin due to its prolonged efficacy and its use in ectoparasite treatments hence its inclusion in the survey. Testing for Triclabendazole resistant fluke was undertaken by WRVC as part of the project and this was also carried out by Faecal Egg Count Reduction Test (FECRT).

Sampling was not random; farms were selected purposely based on likely engagement and compliance. The aim was to provide a general indication of levels of resistance, and also to refine and demonstrate a Faecal Egg Count Reduction (FECR) system based on current veterinary practices and accessible to farmers as part of routine flock health management.

To determine resistance levels in sheep roundworms the consortium used the DrenchSmart® service, which is a Techion product that has globally recognised procedures for undertaking FECRT (See Appendix 2 for full protocols). Each veterinary partner used the FECPAK system (both 1st and 2nd generation FECPAK systems) to carry out Faecal Egg Counts (FEC) within the practice and some samples were analysed in Techion's UK laboratory. Roundworm eggs were cultured to the third larval stage (L3) and identified to genus level to estimate the species composition of pre-treatment and post-treatment samples, and thereby indicate taxa that survived treatment. Egg hatch tests (EHT) were conducted using Thiabendazole to provide a measure of Benzimidazole anthelmintic efficacy independent of the FECRT.

A total of 61 farm tests were completed for roundworm resistance. Of these, 3 sets of data were rejected due to low confidence, leaving 58 farm tests with valid results. Of these, 28 tests were carried out in the autumn/winter (Oct 2014 – Jan 2015) and 30 were carried out in spring/summer (May 2015 – Jul 2015). Testing was repeated in spring/summer on 11 farms that were tested in autumn/winter to ascertain if season and species present had an influence on anthelmintic efficacy. Therefore, resistance data is available for 47 unique farms.

The authors of this report on behalf of the consortium are Eurion Thomas (Techion UK), Dr Eric Morgan (Bristol University) and Dr Neil Paton (WRVC), with technical input from the partner veterinarians.

Summary of results

Figure 1 demonstrates the overall results of the 47 farms tested for roundworm resistance in 2014 and 2015.

Farms were determined as being resistant to an anthelmintic when the FECRT was less than 95%. For the 11 farms that were tested twice in different seasons we selected the data set that demonstrated the most resistance for this overall summary.

The results indicate 94% of farms have evidence of resistance to Benzimidazole (1-BZ), while 68% of farms have resistance to Levamisole (2-LV) drenches. Resistance was also detected for 51% of farms to Ivermectin (3-ML) drench and 19% of farms tested demonstrated evidence of resistance to Moxidectin (3-ML).

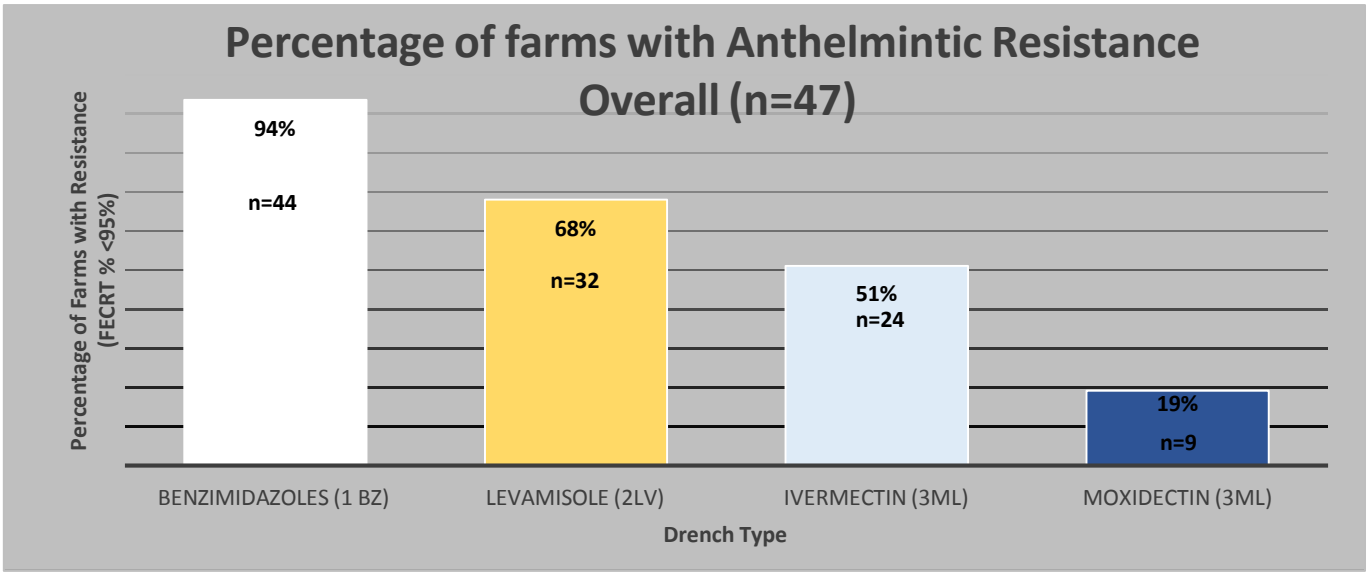

Figure 1. The percentage of Welsh farms with resistance (FECR <95%) to Benzimidazole, Levamisole, Ivermectin and Moxidectin drenches.

Figure 2 shows the number of farms that show resistance to multiple actives. A worrying 43% of farms examined demonstrate triple wormer resistance, some including Moxidectin. Please note the term 'triple resistance plus Moxidectin' will be used here to describe farms that showed lack of efficacy to all 4 anthelmintic treatments tested. It is well documented that having 3-ML resistance does not necessarily mean that Moxidectin is ineffective so in terms of resistance it does not strictly have the same properties as other anthelmintics in the 3-ML group. This term will be used throughout the remainder of this report.

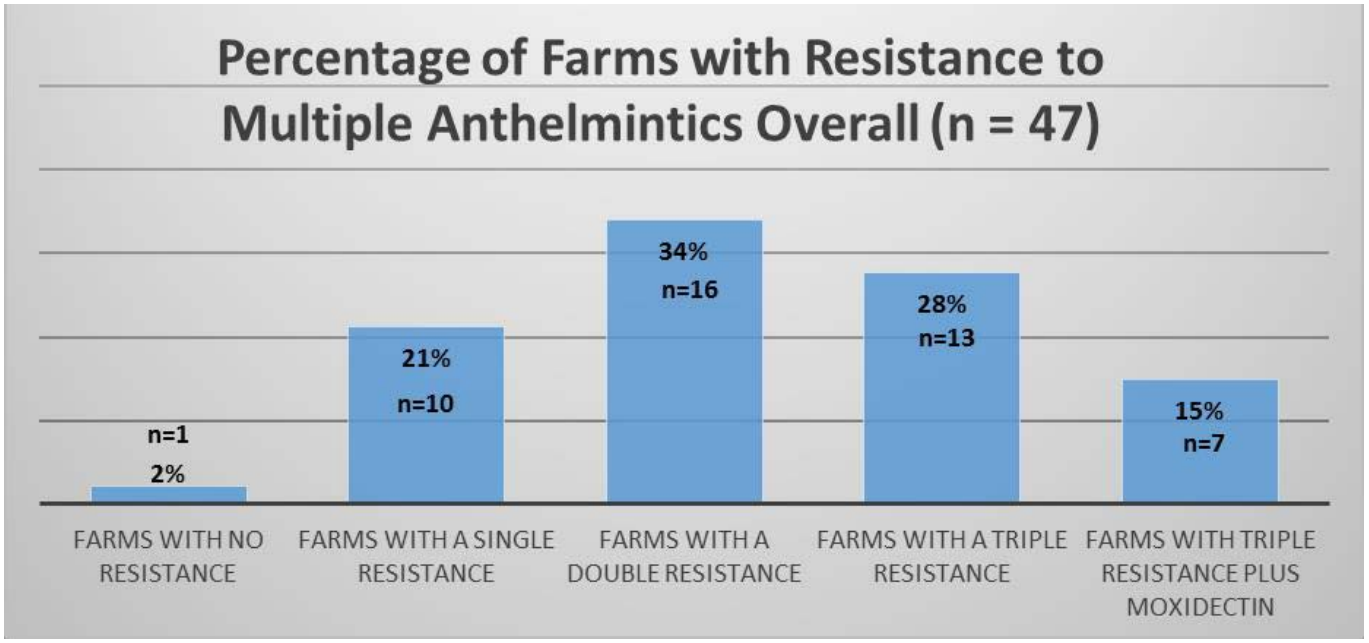

Figure 2. The percentage of Welsh farms with resistance to multiple anthelmintics. Sample sizes are shown for each category.

For the flukicide resistance testing a total of 40 farms were screened for fluke eggs. Unfortunately due to the seasonal conditions encountered during the study period, only two farms had fluke egg counts high enough to be able to continue with the fluke egg reduction test. On both of these farms, resistance to Triclabendazole was detected. It was unfortunate that the project period coincided with a year that was unusually low for fluke infectivity.

2. Anthelmintic Resistance – Roundworms in Sheep

Comment on roundworm infection levels

One of the challenges encountered during this project was finding sufficient worm burdens on farms to enable the start of the testing. The DrenchSmart® protocols state that the strongyle egg count of 500epg or higher is necessary before the project is undertaken. For this project, it was difficult to find FEC levels this high on recruited farms, especially in spring/summer. Leaving strongyle FEC levels to increase to high enough levels in spring/summer was further complicated by the presence of *Nematodirus* eggs in the monitoring egg count and often lambs had to be wormed for *Nematodirus* when strongyle FEC was too low to start testing and there was then a 3 week delay before monitoring could start again. It was decided late in both seasons that the consortium would look outside the original recruited list of farmers to ensure enough farms were tested.

The fact that strongyle burdens in both seasons was low is an interesting outcome in itself although not a required project outcome at the outset. Many participating farmers have commented how useful it had been to monitor worm burdens before visits as without it they would have normally wormed those lambs sooner. In spring/summer several project farmers only gave one treatment for *Nematodirus* between lambing and the end of July, whereas in normal seasons they would have received one, if not two additional treatments.

The consortium members have also been surprised at how low the worm challenge has been in early 2015 and this has generated lots of discussions amongst us as to the contributing factors. This may include environmental conditions with unusually cold conditions in late spring and early summer delaying egg hatching and larval development. The low burdens seen at the end of 2014 is another potential factor as this may result in less overwintering of worm burdens both on pasture and also within adult ewes.

Roundworms Prevalence and distribution of resistance

Figures 3 & 4 demonstrate the percentages of farms that showed resistance to each of the four anthelmintics in autumn/winter 2014 and spring/summer 2015. See Appendix 3 for the FECRT results of each anthelmintic for each farm.

When looking at each farm's individual FECR there is a large variation in the reduction rates from 0% reduction to 94% reduction and this is true for all four anthelmintics that were tested (note: negative reductions were converted to 0% for farmer reports to avoid confusion). When reporting results to farmers, reductions between 90% and 94% were reported as 'resistance suspected' as this is the first evidence of resistance, whereas reductions of 90% or less were reported as 'resistance confirmed'. For reductions of 80% or more, it can be argued that, from an animal performance perspective, farmers may still see a positive effect of using those anthelmintics if animals were suffering from a roundworm infection. However, if farmers continued using anthelmintics at these levels they won't be as effective as FECR above 95%. Furthermore, the subsequent pasture contamination will only be from resistant roundworms (for a 3 week period following anthelmintic activity period), which will increase the prevalence of resistant roundworms on that farm. The majority of these farms (57% of all tests that were defined as resistant) showed very poor efficacy (<80% FECR), and are likely to result in reduced animal performance.

The high prevalence of reduced anthelmintic efficacy observed here is in line with the results of previous surveys in the rest of the UK for 1-BZ and 2-LV. There has, however, been a significant increase in levamisole (2-LV) resistance since the last time a large scale survey of this kind was commissioned in Wales. Under the 2006 Worm Watch Project, surveillance results showed 78% of farms were resistant to group 1-BZ and 34% were resistant to group 2-LV (McLean et al Worm Watch Report, 2006).

The relatively high prevalence of reduced 3-ML efficacy (including Moxidectin) indicates a worsening of resistance to this group. Although testing for 3-ML resistance was only carried out on one farm in the Worm Watch Project it was widely regarded that 3-ML resistance was at very low levels in Wales 10 years ago with only a handful of farms where 3-ML resistance had been confirmed. In 2012 a report on a small survey of 11 farms in Powys and Herefordshire found evidence of lack of efficacy in the 3-ML group on 55% of those farms (Jones et al, Veterinary Record correspondence Jan 14, 2012). This project confirms the increase in 3-ML resistance with 70% of farms showing failed treatments with Ivermectin and 30% of farms showing failed treatments with Moxidectin in spring/summer (Figure 4).

It is interesting to note that the results appear to be considerably worse in the spring/summer period than in the autumn/winter period, especially for the 3-ML Group (Ivermectin and Moxidectin). The reason for the difference could well be down to the presence of more *Teladorsagia* in the spring/summer period which may have developed more 3-ML resistance than *Trichostrongylus*. We were unable to differentiate between *Teladorsagia* and *Trichostrongylus* in the larval culture work

done in the autumn period. However it's interesting to note that the spring/summer speciation work does show a lack of efficacy of 3-ML against *Trichostrongylus* on most farms.

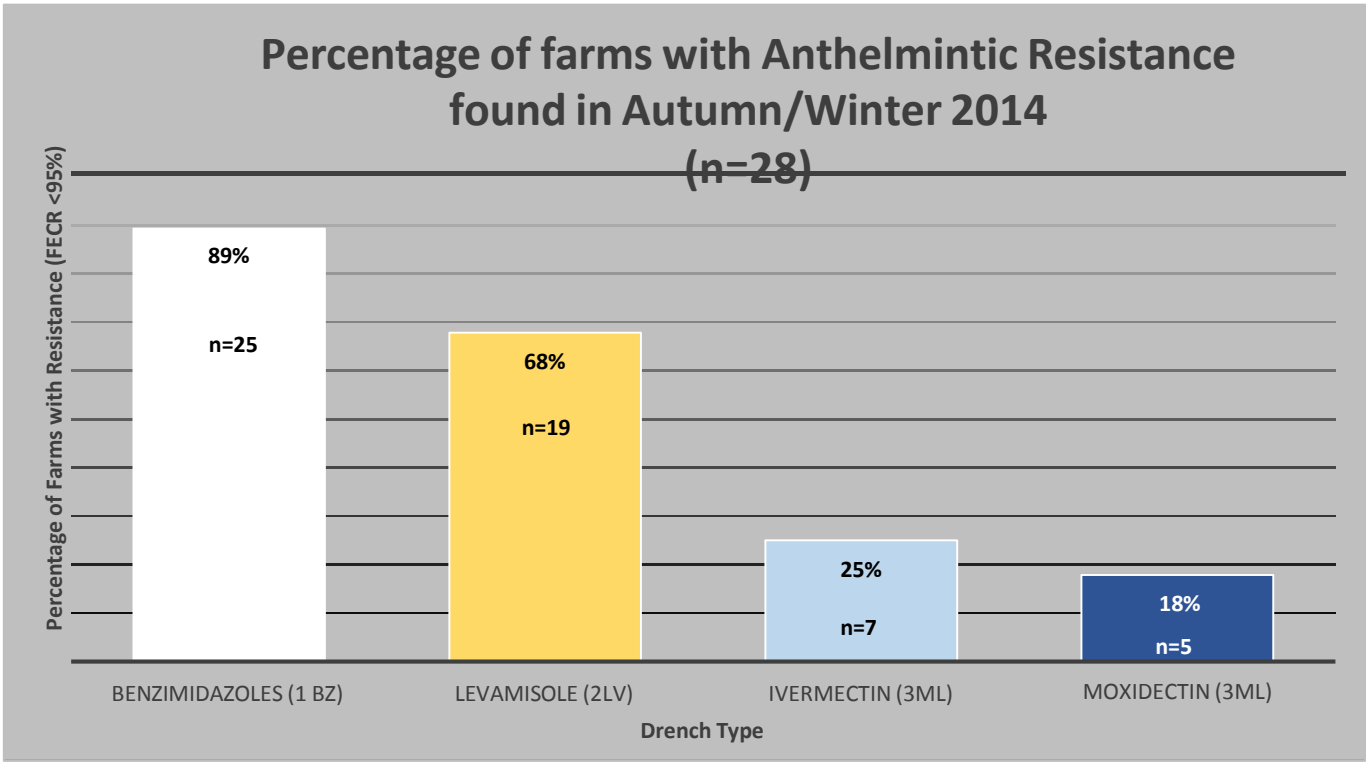

Figure 3. The percentage of Welsh farms with resistance (a FECR <95%) to Benzimidazole, Levamisole, Ivermectin and Moxidectin drenches in Autumn/Winter 2014.

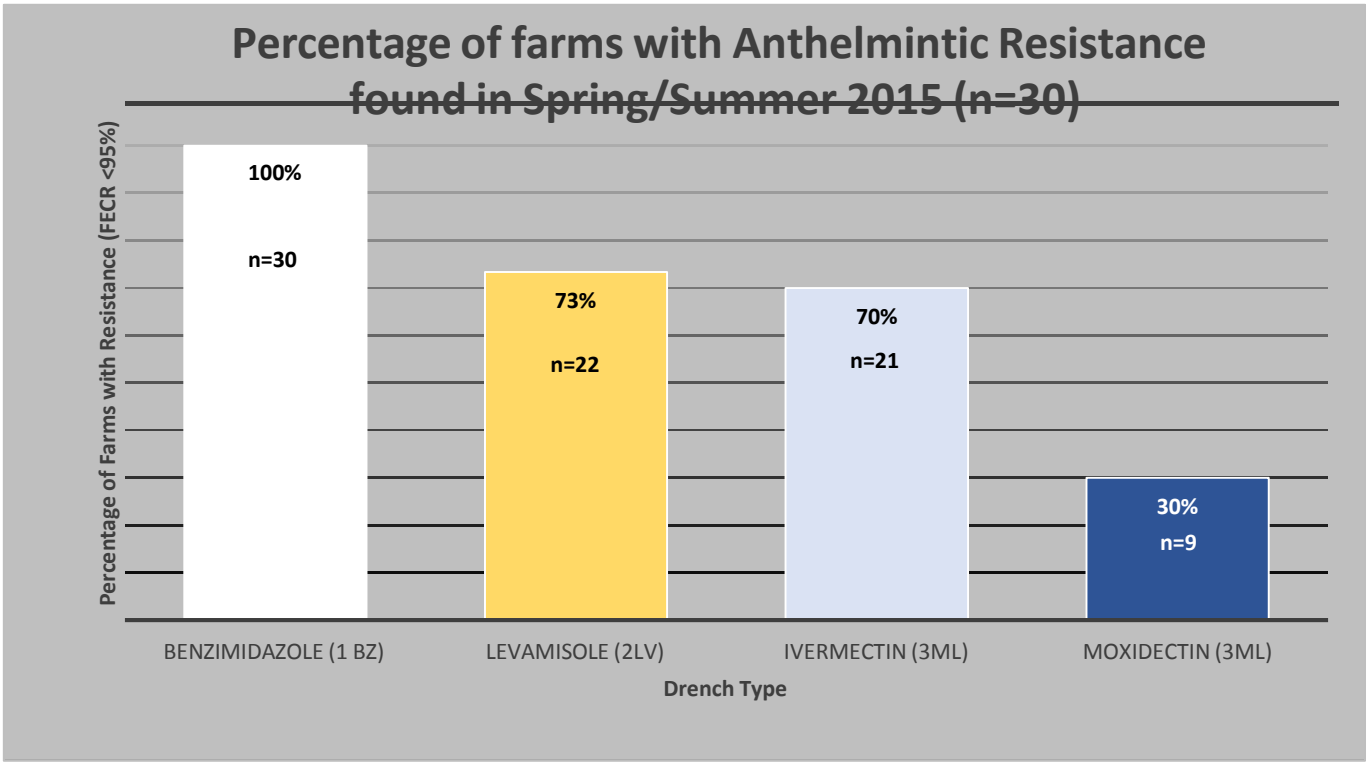

Figure 4. The percentage of Welsh farms with resistance (a FECR <95%) to Benzimidazole, Levamisole, Ivermectin and Moxidectin drenches in Spring/Summer 2015.

Caution needs to be exercised when interpreting actual FECR figures from spring/summer, as some Day 1 starting strongyle FEC's on some farms were very low. This may have a potential effect on biasing percentage reductions towards lower percentages. As discussed later in this report the parasite burdens across Wales were very low in the early part of 2015 and in order to complete testing by the deadline date the ideal starting FEC threshold that would normally be used under the

protocol had to be reduced. This does not alter our confidence in the fact that resistance was detected as positive egg counts post treatment were evident. It only, therefore, affects confidence in the extent of resistance in those cases.

Figures 5 & 6 demonstrate the percentage of farms with multiple resistance during the two testing periods. The results from the spring/summer period are a major concern to future parasite control with the older anthelmintics which are used in Wales (Figure 6). In spring/summer 60% of farms had either triple (n=11) or triple resistance plus Moxidectin (n=7) resistance. As a result only two new actives are available to these farmers that are fully effective in controlling strongyle worms: Monepantel (4-AD) or Derquantel-Abamectin (5-SI).

Of the 28 farms tested in the autumn/winter period, only one farm had full efficacy from all the anthelmintics that were tested (Figure 5). The encouraging point here is that this farm was very aware of the SCOPS principles and the partner vet who carried out the work on this farm believed that they had implemented many of the principles over the last 10 years which may explain why resistance hadn't developed. This also showed up in the questionnaire analysis where this farms scored highly in best worm management practices (see comment on farm H8 in 'Farmer Practices' section).

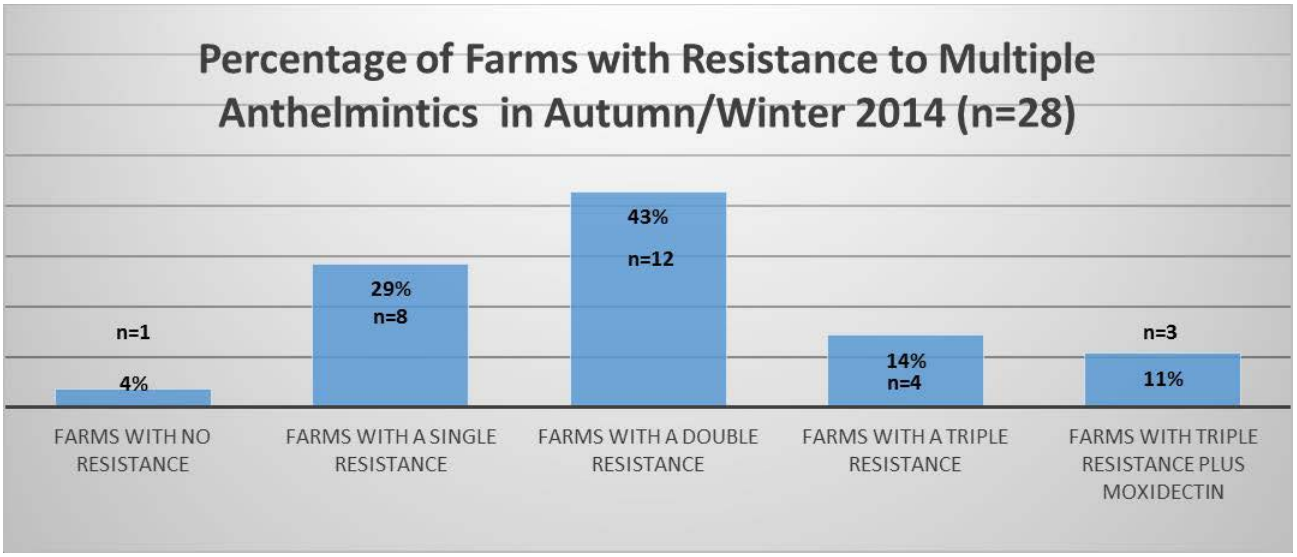

Figure 5. The percentage of Welsh farms with resistance to multiple anthelmintics in Autumn/Winter 2014. Sample sizes are shown for each category.

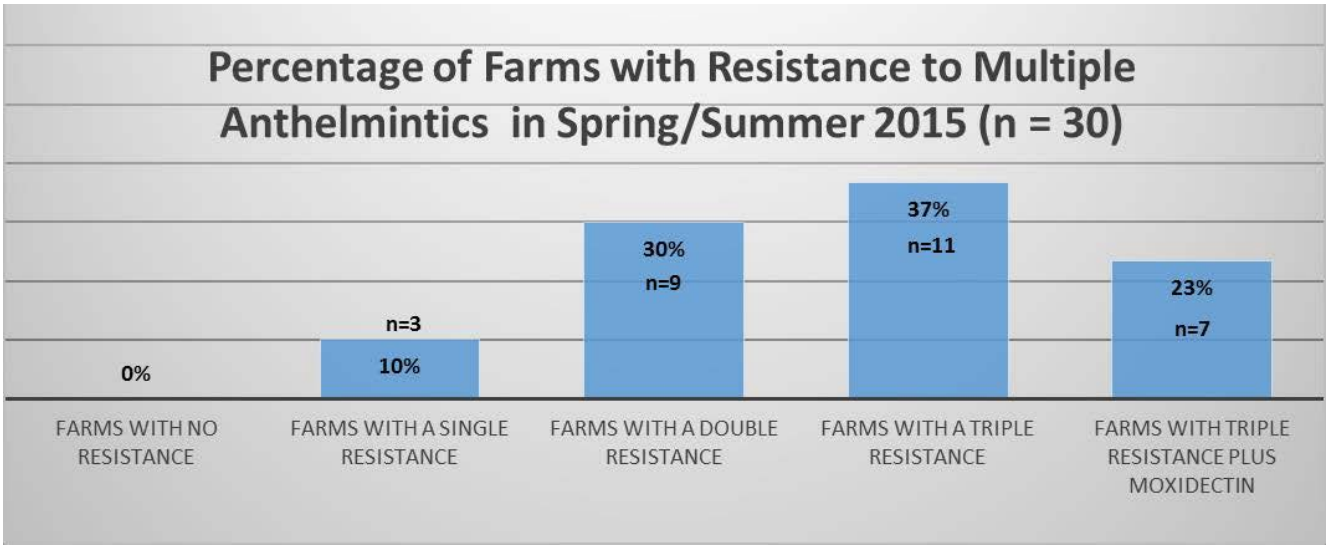

Figure 6. The percentage of Welsh farms with resistance to multiple anthelmintics in Spring/Summer 2015. Sample sizes are shown for each category.

Where multiple resistance was found, the results have come as a major surprise to the majority of farmers involved. Most farmers were suspicious that they had resistance to Benzimidazole (1-BZ) and a few farmers were wary of resistance to Levamisole (2-LV). One farmer reported concerns of lack of performance in lambs after treatment with Moxidectin (3-ML). These results highlight the importance of testing for resistance, as most farmers assume the wormer treatments they are using are fully effective.

Influence of season and parasite species on apparent resistance

Parasite species surviving treatments

It is worth noting here that all FECR data presented are based on strongyle egg counts only. As Nematodirus eggs can be easily distinguished from strongyle eggs the FECR for Nematodirus and strongyle were calculated separately. In most farms tested in spring/summer Nematodirus was present, however, there was no evidence of resistance against any of the anthelmintics tested. Having a 100% FECR for Nematodirus provides us with confidence in strongyle resistance results as they show that positive post treatment FEC's aren't due to misadministration of the anthelmintic treatment. As Nematodirus FECR showed 100% efficacy for each farm, the results aren't reported anywhere in this report (see Appendix 4 for larval culture reports). Each individual farm report did however show this.

Faecal samples were sent to Bristol University for culturing and speciation to determine which strongyle worm species were resistant. It is widely believed in New Zealand and Australia that resistance on a property is often single species rather than multi species and the pattern in the UK would be for resistance to commonly develop first in a single species with continued use potentially leading to resistance in multiple species.

The results of which species are surviving treatment are illustrated in Figures 7 and 8 below.

There are, however, difficulties involved with an egg hatching procedure and as a result it is not always possible to identify the species present. This was true for several samples from farms tested in the autumn as is explained below.

Autumn/winter sampling

On farms surveyed in autumn 2014 (n=28), pre-treatment cultures were successful on 14 farms (50%). Most failures were due to a combination of postal delays and faecal consistency. Delays were not a serious issue for pelleted faeces since eggs are able to hatch and commence development through the larval stages during transit; however, faeces with higher water content are more typical later in the year and anaerobic conditions can be generated in this material, which over a week or more can reduce egg viability and make cultures unreliable. Future surveys outside the usual summer season should make allowance for softer faeces, for example by mixing samples with vermiculite prior to transit or to ensure rapid dispatch to the laboratory.

Larval identification focused on distinguishing pathogenic from less pathogenic genera. Thus, a perceived limitation of the study was that sampling in autumn is not optimal for highly pathogenic species such as *Teladorsagia circumcincta* and *Haemonchus contortus*, whose egg counts peak earlier in the season. A survey based on FECR alone could therefore preferentially detect AR in less pathogenic genera such as *Cooperia*, *Chabertia*, *Bunostomum* and *Oesophagotomum*, whose eggs are indistinguishable from those of other *Trichostrongylids*. As well as being relatively common outside the summer season, these species are often dose-limiting for anthelmintics and might be expected to develop resistance first (for example, *Cooperia oncophora* in cattle). The implications of FECR results, unsupported by larval culture and identification, would therefore be highly uncertain in terms of potential impacts on production and comparability with other surveys. For the autumn survey, larval identification was limited to differentiating morphologically distinct groups, in order to determine whether limited FECR were due to 'core' pathogenic taxa or 'fringe' less-pathogenic taxa. Groups were *Teladorsagia/Trichostrongylus*, *Haemonchus*, *Cooperia* and 'others', comprising long-tailed L3 mainly belonging to the less pathogenic genera listed above. The genus *Trichostrongylus* contains several species, which may be more or less common in summer and autumn, but all are considered pathogenic. Time pressures on EHTs (which must be conducted on fresh material), meant that larvae were preserved for identification. As differentiation of *Trichostrongylus* from *Teladorsagia* was difficult on preserved larvae, these genera were grouped together.

Prior to anthelmintic treatment, the proportions of L3 of different groups, averaged by farm, were: *Teladorsagia/Trichostrongylus* 80%, *Haemonchus* 16%, *Cooperia* 5%, and other 15%. After BZ treatment, they were 97%, 11%, 14% and 3%, respectively. Of samples that contained eggs following LV treatment, all larvae cultured were *Teladorsagia/Trichostrongylus*. Results by farm are shown in Figure 7. Of eight samples that were cultured following identification of eggs after Ivermectin or Moxidectin treatment, only one yielded L3, all of which were identified as *Teladorsagia/Trichostrongylus*.

Results clearly indicate that *Teladorsagia/Trichostrongylus* dominated pre-treatment FEC, and were preferentially selected by anthelmintic treatment. The less pathogenic long-tailed larvae were rarer than expected and almost completely absent following treatment. Therefore, AR detected by FECR in the autumn survey pertains to pathogenic nematode species and should be of significant concern for sustainable production. Differentiation of *Teladorsagia* from *Trichostrongylus* was not

possible morphologically, but material has been retained where possible, and could be examined by PCR in future. *Haemonchus* was rare and only occasionally found after Benzimidazole treatment. The frequent failure of cultures after IVM/MOX treatment is a cause for concern, and might be caused by low egg numbers in combination with small sample volume, sub-optimal culture conditions, or non-lethal effects of treatment on egg viability. There is a previous paper (Tyrell et al: The effects of Ivermectin and Moxidectin on egg viability 2002) that found an inhibitory effect on larval development with Ivermectin, but this was with the capsule formulation and not oral. Refinements to culture methods and larval identification protocol were made for the spring sample, in order to address these questions and to further build laboratory capacity for follow-on and future AR surveys in Wales.

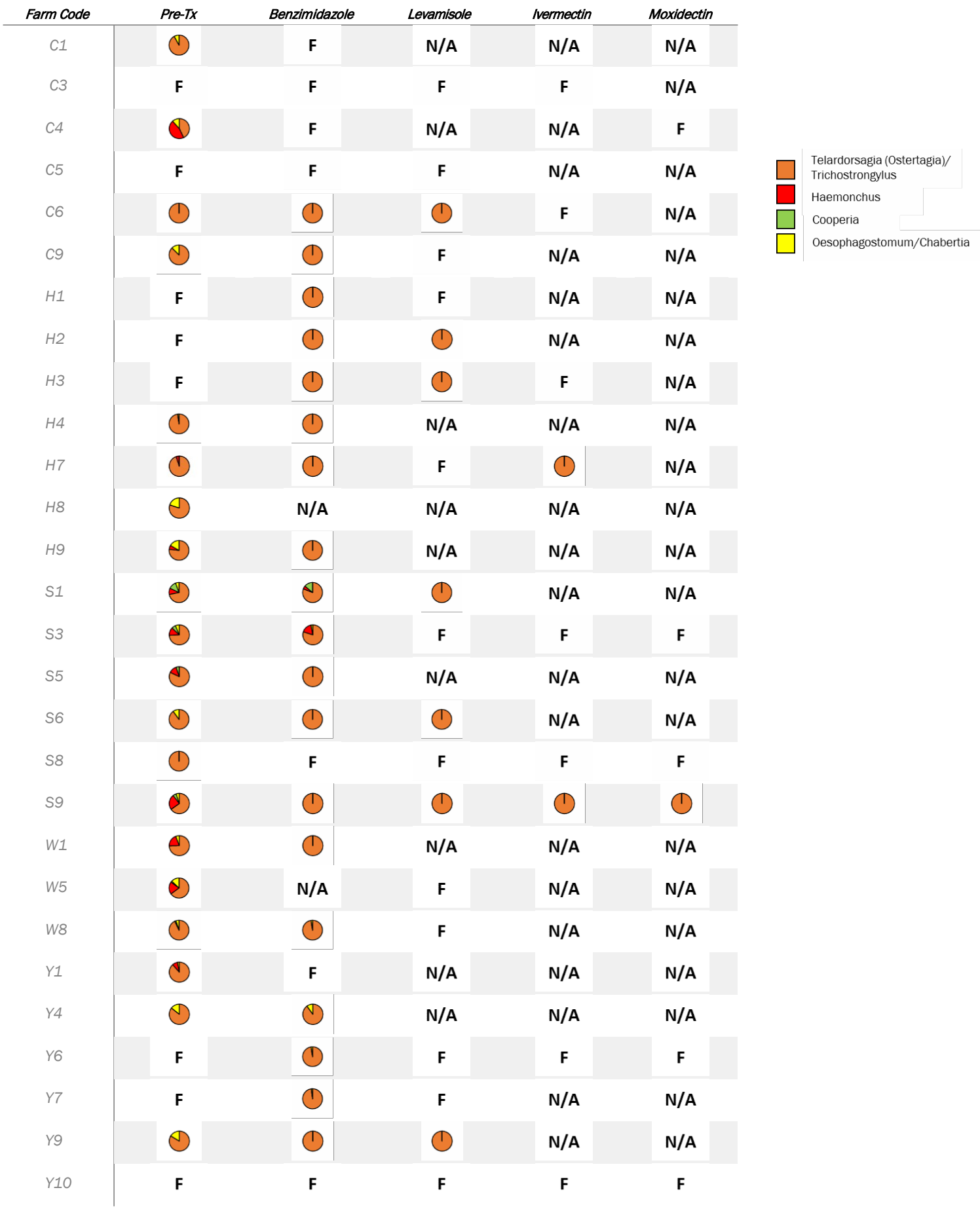

Figure 7. The proportions of L3 stage larvae cultured before treatment (Pre-Tx) and after treatment with Benzimidazole (1-BZ, 14 days post-treatment), Levamisole (2-LV, 7 days post-treatment), Ivermectin (3-ML, 14 days post-treatment) and Moxidectin (3-ML, 14 days post-treatment) for farms surveyed in autumn/winter 2014. Post-treatment cultures were conducted only when eggs were noted in the FECR (<95%). Failed larval cultures are denoted by 'F'; while larval cultures were not performed when FECR >95% and these are denoted by 'N/A'.

Spring / summer sampling.

The vast majority of larvae recovered in spring / summer were identified as *Trichostrongylus* and *Teladorsagia* species, with the genera differentiated in these samples (see Figure 8). In pre-treatment pooled samples, the genera were evenly mixed, with an average of 53% by farm identified as *Trichostrongylus* spp. and 45% by farm *Teladorsagia* spp. Both genera were also commonly recovered from culture of pooled faecal samples after treatment (Table 1). Overall, the proportion of *Trichostrongylus* decreased following treatment, while the proportion of *Teladorsagia* increased. This indicates that resistance was more common or stronger in *Teladorsagia* across all drug groups. However, *Trichostrongylus* was also recovered from almost all cultures post-treatment. These results suggest that multi-species resistance is the norm on sampled farms for which FECR was <95%. This is in line with findings elsewhere, although a new finding for the UK, in which resistance was previously thought to be more concentrated in *Teladorsagia*. Given the local novelty of the result, and the subtle morphological differences between L3 of these genera, it is advisable to confirm this finding by PCR of larval DNA. Larvae have been preserved for this purpose and a cross-section of samples will be sent to Biobest for testing after all cultures have been completed, with results expected in November / December 2015.

The key outcome from both autumn and spring/summer larval cultures is that the pathogenic genera *Trichostrongylus* and *Teladorsagia* dominated FEC both before and after treatment, across drug groups. Failed FECRT therefore are not associated with the 'lesser' species, but rather with core pathogenic worm species. Implications are that the FECRT data presented in this report show a failure of treatment against worm taxa that are likely to cause reduced performance on the farms, and that this should be taken very seriously.

Table 1. Genus composition before and after treatment, from culture of pooled faecal samples. Averages are by farm and do not necessarily sum to 100%.

Group	% *Trichostrongylus*	% *Teladorsagia*	% *change in proportion Trichostrongylus*	% *change in proportion Teladorsagia*
Pre-treatment	53	45		
Post-BZ	48	52	-7	+10
Post-LV	41	59	-8	+8
Post-IVM	38	62	-16	+19
Post-MOX	35	65	-15	+15

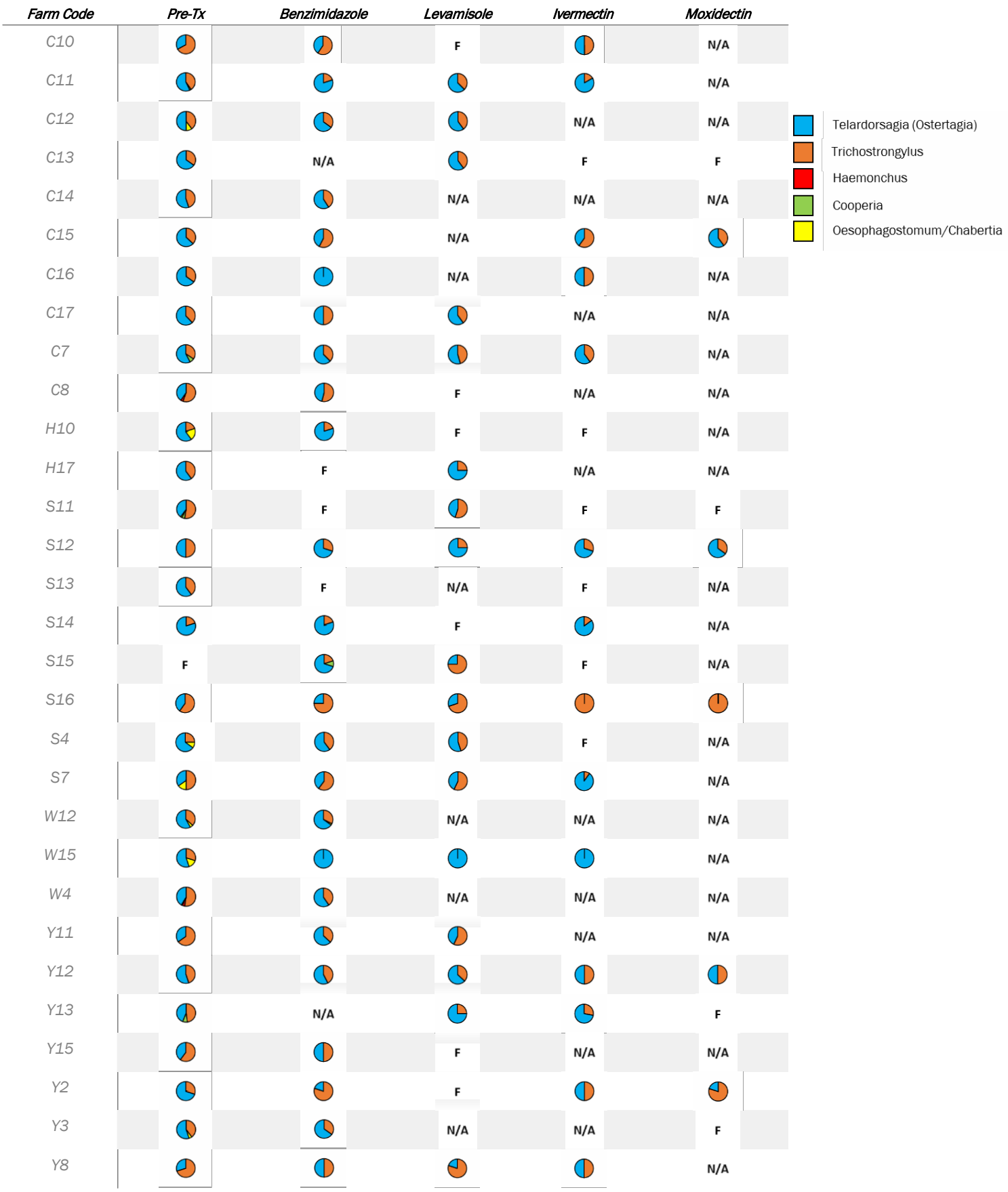

Figure 8. The proportions of L3 stage larvae cultured before treatment (Pre-Tx) and after treatment with Benzimidazole (1-BZ), Ivermectin and Moxidectin (3ML) 14 days post-treatment and Levamisole (2-LV), 7 days post-treatment, for farms surveyed in spring/summer 2015. Post-treatment cultures were conducted only when eggs were noted in the FECR (<95%). Failed larval cultures are denoted by 'F'; while larval cultures were not performed when FECR >95% and these are denoted by 'N/A'

Analysis of farms that were tested twice in different seasons

One of the project objectives was to retest five of the farms tested in autumn/winter (2014) in the following spring/summer (2015) to observe any differences in results and provide more evidence if season and species present had an influence on resistance status as discussed above. In the end, the project was extended and a total of 11 farms were tested in both periods.

Table 2 shows the two sets of FECR results for each farm. Each farms results are grouped together with the autumn/winter results appearing first, followed by the spring/summer results. An indication of whether a result has changed between periods is shown in the last column.

Table 2. The comparison between the FECR results of farms tested in autumn/winter 2014 and in spring/summer 2015. The FECR results for each drench active, the number of drenches each farm is resistant to, and a comparison of the autumn/winter and spring/summer resistance statuses are shown.

Farm Code	Original code if retested	Date Treated	FECRT % Benzimidazoles (1 BZ)	FECRT % Levamisole (2 LV)	FECRT % Ivermectin (3 ML)	FECRT % Moxidectin (3 ML)	No. Drenches with Resistance	Different Resistance Status?
C4		05/11/2014	86%	98%	97%	86%	2	
C12	C4	08/07/2015	68%	86%	99%	99%	2	Yes
C6		08/10/2014	58%	90%	86%	100%	3	
C8	C6	03/07/2015	40%	94%	94%	99%	3	No
C9		12/11/2014	54%	91%	98%	100%	2	
C11	C9	10/07/2015	80%	91%	91%	99%	3	Yes
S1		22/10/2014	23%	94%	100%	100%	2	
S15	S1	10/07/2015	-232%	49%	75%	95%	3	Yes
S3		17/11/2014	81%	65%	96%	57%	3	
S11	S3	18/06/2015	72%	90%	80%	86%	4	Yes
S8		04/11/2014	6%	88%	71%	59%	4	
S16	S8	08/07/2015	-22%	67%	70%	89%	4	No
S9		17/11/2014	28%	78%	38%	84%	4	
S12	S9	20/07/2015	-14%	66%	1%	-8%	4	No
Y1		28/10/2014	94%	99%	99%	99%	1	
Y11	Y1	24/06/2015	50%	63%	100%	97%	2	Yes
Y4		07/11/2014	89%	93%	97%	97%	2	
Y12	Y4	24/07/2015	88%	43%	72%	93%	4	Yes
Y6		20/11/2014	88%	94%	94%	31%	4	
Y13	Y6	15/06/2015	-173%	50%	58%	94%	4	No
Y9		26/11/2014	68%	53%	99%	96%	2	
Y15	Y9	25/06/2015	67%	78%	98%	100%	2	No

Of the 11 farms that were repeat tested, resistance status changed for six farms (Table 2). For five of these farms the resistance status was worse in spring/summer and one of the farms changed from a double to a triple resistance plus Moxidectin. One of the farms that changed had Levamisole FECR change from not resistant to resistant and Moxidectin changing from resistant to not resistance status.

The change in status on these farms could be associated with an increase in the proportion of *Teladorsagia* and *Trichostrongylus* compared with the autumn tests, in which other species were common. Although most often present in minor proportions, these other species were rarely found in post-treatment cultures (see Fig. 7), indicating general susceptibility to treatment. Their almost universal absence in pre-treatment cultures in spring and summer means that FECRT were dominated

by *Teladorsagia* and *Trichostrongylus*, which were more likely to be resistant, hence making FECR < 95% more likely. For all farms that showed a change in resistance status an analysis of results was done to see if the raw data for FEC and species presence could add more details to help explain the change in status. The findings for the 6 farms are listed below.

- **Farm C4 – C12.** , Although the autumn result for 2LV was 98%, there were positive FEC's in 6 out of 12 lambs post treatment which suggested the presence of resistance and there was a fairly high FEC at day one (1750epg) which may be due to the *Haemonchus* that was present which biased the FECR to a better result. The summer results confirms resistance and both *Teladorsagia* and *Trichostrongylus* appear to survive. For Moxidectin the explanation isn't as easy as larval cultures failed for this group in the autumn but the reduced efficacy in the autumn may just be down to *Haemonchus* which was present then at day one but not in the summer.
- **Farm C9 – C11**, For Ivermectin resistance the reduced efficacy seen in the summer period was all down to *Teladorsagia* which may not be present in the autumn test which explains the changes in status.
- **Farm S1 – S15**, Summer results for larval culture were not returned by time report written.
- **Farm S3 – S11.** Although the autumn result for Ivermectin (3ML) was 96%, there were positive FEC's in 8 out of 12 lambs post treatment and also a high FEC at day one biasing FECRT. There was debate on classifying this farm as resistant in the autumn. The summer results confirms this 3ML resistance.
- **Farm Y1 – Y11**, Although the autumn result for 2LV was 100%, there were positive FEC's in 4 out of 12 lambs post treatment which suggested the presence of resistance and there was an extremely high FEC at day one (3650epg) which may be due to the Haemonchus that was present which biased the FECR to a better result. The summer results confirms this and both *Teladorsagia* and *Trichostrongylus* appear to survive although *Teladorsagia* had poorer efficacy than *Trichostrongylus* and there may be no *Teladorsagia* present in the autumn which may explain the difference.
- **Farm Y4 – Y12.** Both Ivermectin and Moxidectin changed from not resistant to resistant. Although the autumn result for both was 97%, there were positive FEC's in 5 out of 12 lambs post treatment for ivermectin and 4 out of 12 for Moxidectin. The summer results show that both *Teladorsagia* and *Trichostrongylus* appear to survive treatments so the change is not explained by presence of different species.

This highlights the importance of testing over seasons. These results clearly demonstrate that it is possible to get different results across seasons, and that some anthelmintics can be more effective in one season compared to another. It is also important to speciate worms when carrying out FECRTs to identify which species are present as this will help determine what species are being killed and which species are surviving. The ideal time to carry out a FECRT would be when there are most likely a mixed population of the most important worm species as if there are enough of the different species present at the same time, this may negate the requirement for repeat testing in a different season.

Farmer practices

Information on management factors thought to be relevant to the development of AR was collected by questionnaires administered by the visiting veterinarian. The questionnaire consisted of three sections: (1) background information on farm type and production, (2) worm control procedures, and (3) qualitative assessment by the veterinary surgeon of the extent to which the farmer was following SCOPS principles. The aims were: (1) to identify any links between farm practices and observed resistance or susceptibility to anthelmintics, and (2) to annotate practices on the study farms in relation to best practice recommendations.

For analysis, answers to individual questions on worm control were aggregated into scores representing compliance with best practice on specific practices, and compared with observed drench efficacy (Table 3). The AR status was summarised using a points system, with one point for resistance to each of the four groups (FECR <95%), two points for FECR <80%, and three points for FECR <40%. Points were summed across groups to give an AR score, by which farms were ranked. DrenchSmart® FECR results were used to categorise AR.

Table 3. Scores for farm worm management practices. Scores were compiled based on best practice (SCOPS) recommendations and scaled to 100, with high scores indicating good practice. Anthelmintic resistance (AR) was also scored and results are shown for the top and bottom five scoring farms.

	AR	Quarantine	Dosage Accuracy	Drench Frequency	T(S)T	Dose & move	Breeding	Overall SCOPS	Vet score	Time
Mean	36	34	60	37	26	50	14	37	48	37
Range	0-100	0-100	0-85	0-62	0-83	0-100	0-100	14-60	20-90	10-80
Best five	8	32	63	43	23	80	3	40	58	45
Worst five	73	44	57	30	23	60	23	38	46	25

The vet score was significantly correlated with overall composite score for best practice (Spearman rho=0.50, p=0.01), indicating that participating vets were able to efficiently assess compliance with best practice.

There was no significant difference in overall scores or in individual components between farms ranking low (below median or lowest five farms) or high (above median or highest five farms) for AR. Further, a binary logistical regression did not reveal meaningful relationships between farm characteristics and practices and the presence of resistance to individual drug classes. Overall SCOPS score and having previously conducted drench efficacy checks were both positively related to the chance of finding 3-ML resistance in the present survey. The presence of triple resistance was also more likely in farms having previously conducted drench efficacy checks. These paradoxical results could be explained by recruitment bias, i.e. farmers having realised that they have a problem being more likely to participate. Moreover, farms with an acknowledged AR problem could be more likely to change practices and therefore score highly on best practice scores. This would confound the statistical analysis above. The question on the duration for which farmers had followed best practice recommendations was answered by only 13 of the 28 farmers, too few to allow statistical analysis. Overall sample size is low and limits the power of analyses attempting to relate AR to observed practices. Analysis will be repeated with the whole cohort after the summer test questionnaires are added to the data set. These were not returned in time for this report but will be published in a separate paper.

One farm (H8) showed good drug efficacy across all active groups. This farm scored above the median for all categories in Table 3 above, and among the highest overall scores – the highest when duration for which practices had been applied was taken into account. It is possible that good drug efficacy on this farm was related to exemplary adherence to SCOPS recommendations, and this farm could be used to demonstrate these principles in future.

A wide range of practices were observed, and are summarised below:

Quarantine: Most of the farmers (17/28) reported using quarantine for bought-in stock. However, only one conducted quarantine properly, i.e. obtained a perfect score for reported practice. A perfect score required the use of Moxidectin plus

either Monepantel or Derquantel-Abamectin, yarding for at least 24 hours and turning out onto contaminated rather than clean pasture. The most common failing was use of an inappropriate drug (16/17), with eight farmers using whichever anthelmintic was to hand, five using a combination of BZ and LV, and one of each using only BZ, LV or Monepantel. Many farmers also turned sheep out onto pasture too soon after quarantine treatment (7/17), with five not yarding at all following quarantine treatment. The practise of turning out onto contaminated pasture was widely reported (15/17).

Dosing accuracy: None of the farmers weighed all animals before drenching, though 18/28 weighed some in order to get an idea of weights in the group. Anthelmintic dose was set to the weight of the heaviest individual by 18/27 farmers who answered this question, with nine dosing to average weight.

FECRT: Only 5/28 farmers had previously submitted to anthelmintic efficacy testing, with all of those being a full FECRT, and none reporting only a simple post-drench FEC. Of the five reporting a FECRT, three stated that it did not show AR, and two were uncertain. In fact, all five of those farms had some level of AR in the present study. Anthelmintic resistance was found on all 11 farms on which the farmers suspected it to be present, and clearly found on 4/8 on which they considered resistant roundworms not to be present (a further three were marginal).

Drenching frequency: Farmers reported treating ewes for roundworms at tupping (15/27), at lambing (17/27) and/or at other times (10/27). Lambs were reported to be treated on average 3.7 times per year (median: 3.5, range: 2-6).

T(S)T: Uptake of strategies for targeted treatment at group level (TT) and targeted selective treatment of individual animals (TST) appeared to be limited overall, with farms scoring an average of 1.5 out of 6 possible points using the scoring system (range 0-5). Targeted treatment seemed more widely applied than TST. Individual farmers often used several triggers for treatment, with just 4/28 following a fixed schedule only, and a further five following a fixed schedule as well as treatment triggered by other factors. Triggers used were poor growth rate (2), high FEC (6), or 'looking like they need it' (21), with five farmers using more than one indicator. None of the TT approaches were associated with a marked reduction in the number of annual lamb treatments. Regarding TST, only 4/28 farmers reported leaving some animals in the group untreated. Of these, one left up to half untreated on the basis of good growth (by eye and weighed) and lack of scour, and the rest leaving up to 10% untreated on the basis of good performance (by eye).

Dose and move: Moving animals to clean pasture after anthelmintic treatment was reported by 10/27 farmers. A modified dose-and-move system was widely used, consisting of treating a couple of days before the move (10/13) or moving then dosing a while later (3/13).

Breeding: Few farmers appeared to be actively seeking improved genetics for resistance to worm infection, with 3/28 having bought a ram with low estimated breeding value (EBV) for FEC. However, 6/26 were more likely to preferentially keep ewe lambs for breeding if they needed less worming, i.e. to select for resilience in the female line. Farmers using selective breeding did not obviously treat ewes or lambs less than their peers, although sample size was small.

Duration: Of 13 farms assessed by vets to be following good practice, and for which the duration of such practices was recorded, only one had these in place for more than the last five years, nine had introduced them in the past 3-5 years, and three only in the past year or two.

Overall: Using the weighted scoring system, farmers scored on average 16 out of a possible 43 points, with the best farm scoring 26 and the worst six. There was no statistically significant correlation between current practices and AR score (see analysis above). The very high compliance with individual recommendations above, but low overall maximum score, suggests that farmers are selective in their application of SCOPS recommendations.

General comments on farmer practice survey

The lack of a statistically significant relationship between current practices and observed AR could be due to low sample size, biased recruitment, and could be confounded by recent changes in practices. It is also possible - though perhaps less plausible - that best practice recommendations have limited impact on the development of AR, and that other unmeasured factors are more important.

Wide uptake of recommendations for sustainable control practices (based on expectations from previous surveys and those in other countries) were observed for avoiding dose inaccuracies and move to clean pasture, targeting treatment of groups according to performance (TT), and keeping on resilient ewe lambs for breeding. Targeted treatment was guided by subjective criteria more than objective performance recording, and was not associated with reduced treatment frequency. Steps were

taken to dose accurately by the majority of farmers, though not all. Poor compliance was observed for quarantine treatments, and farmers had not widely chosen to apply recommendations on selecting resistant rams or avoiding dosing ewes at tupping.

While limited uptake of some recommendations could be due to unsurmountable barriers (e.g. FEC EBV are not available for all breeds), in other cases a lack of knowledge transfer (KT) appears to be at fault. For example, a majority of farmers carried out quarantine drenching for incoming stock, but very few did so correctly, suggesting that some key messages are not getting through widely or clearly enough. Other recommendations appear to have been taken up to significantly change practices, e.g. modification of dose-and-move.

Evaluation of methods for future adoption

Egg hatch test

Egg hatch tests (EHT) were conducted on samples collected on day zero, in order to (1) provide added confidence in the classification of farms as BZ-resistant for FECR, and (2) evaluate the EHT as a convenient screening test for BZ-resistance in future.

An aliquot was taken from the pooled faecal sample (for larval cultures, above), preserved anaerobically, and sent to the laboratory. Eggs were extracted and placed in water (3 replicates), with 0.1µg/ml Thiabendazole (3 replicates) and 0.25µg/ml Thiabendazole (3 replicates). The number of eggs and hatched (L1 stage) larvae were counted after 24 hours of incubation and compared with the proportions expected based on the control replicates in water. The statistical significance of deviations above 50% expected hatch at the critical concentration of 0.1µg/ml was assessed by Chi-squared test.

Samples were received from 20/28 farms sampled in autumn, with others either yielding too few eggs or arriving in poor condition due to postal delays.

The corrected proportion of eggs hatching at a Thiabendazole concentration of 0.1µg/ml was significantly correlated with FECR after treatment with Benzimidazole (r=-0.65, p=0.001; Figure 9). The critical concentration EHT accurately predicted the four farms tested that reported FECR >95%, while the two samples with EHT >0.5 were from farms reporting FECR <95%. The proportion of eggs hatching was higher in samples from farms with FECR <95% (mean 0.26) than from farms with FECR >95% (mean 0.13). However, across the entire range of farms, the threshold of 50% egg hatch was poorly predictive of FECR, with only 2/16 farms with FECR <95% testing resistant on EHT, and 1/4 farms with FECR <50%.

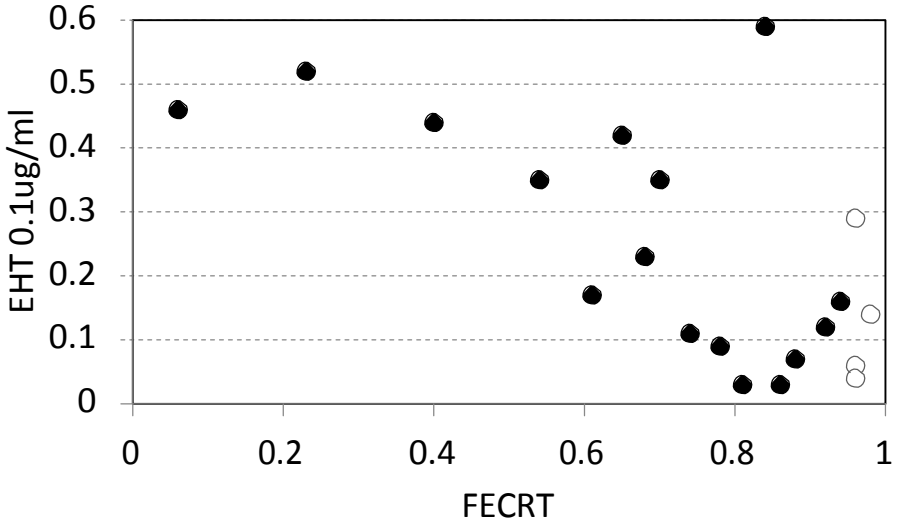

Figure 9. The proportion of eggs hatching in a concentration of 0.1µg/ml Thiabendazole, adjusted for that hatching in water (Egg Hatch Test; EHT 0.1ug/ml), compared with the proportional faecal egg count reduction (FECR). Black circles = FECR <95%; open circles = FECR >95%. Half the eggs are expected to hatch at this concentration, and thus proportions >0.5 are normally taken to indicate *in vitro* resistance to Benzimidazoles.

At the higher concentration of 0.25µg/ml, 27% and 52% of eggs hatched from samples showing >0.5 hatch at the lower concentration, confirming lack of Thiabendazole efficacy *in vitro* in those samples. The proportion of eggs hatching was also higher in samples from farms with FECR <95% (mean 0.11) than from farms with FECR >95% (mean 0.03). However, across the full range of farms, there was no significant correlation between the proportion of eggs hatching and FECR (r=-0.30, p=0.12; Figure 10).

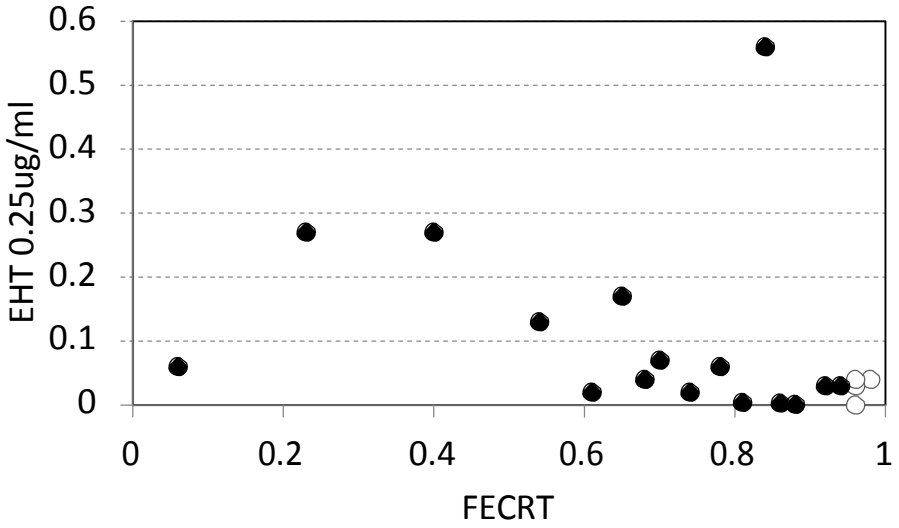

Figure 10. The proportion of eggs hatching in a concentration of 0.25µg/ml Thiabendazole, adjusted for that hatching in water (Egg Hatch Test; EHT 0.25ug/ml), compared with the proportional FECR. Black circles = FECR <95%; open circles = FECR >95%.

In summary, EHT results were a poor match for FECR results, categorising the majority of farms with FECR <95% after treatment with BZ as susceptible to BZ *in vitro*. Both samples deemed resistant on EHT were from farms testing <95% on FECR. The EHT might, therefore, have value as a confirmatory test for resistance in the field. However, only two of 18 farms with FECR <95% were confirmed resistant on EHT. Since no gold standard for AR was available in the current survey, it is possible that this is a true result and that FECR vastly over-estimated the prevalence of AR on the study farms. This seems unlikely, however, given previous surveys and the current state of knowledge on the prevalence of BZ- resistance. Increased sensitivity of the EHT could be achieved by lowering the critical threshold for proportion of eggs hatching, but only at the cost of decreased specificity, i.e. increased chance of falsely identifying susceptible nematode populations as resistant.

There are several possible explanations for the apparently poor performance of the EHT, besides misclassification of resistance using the FECRT. The EHT was conducted on an aliquot of pooled faeces, and if not well mixed the egg population tested might not be fully representative of that subjected to FECRT. Furthermore, nematode species composition could affect EHT, such that resistance in a more prolific species within a mixed population would be underestimated relative to FECRT. The concentration of Thiabendazole *in vitro* is critical to test outcome, and if inaccurate would affect classification, although this cannot explain the mismatch with FECRT given the lack of separation of farms with FECR <>95% on any EHT threshold. We conclude that in its current state, the EHT would be a poor tool with which to screen farms for BZ-resistance, because of poor sensitivity relative to FECR.

FECRT methodology

In the absence of a gold standard for anthelmintic efficacy on the study farms, the Bayesian Markov-Chain Monte Carlo approach of Torgerson et al. (Int. J. Parasitol. 2104, 44, 299) was used to provide the most accurate possible classification of drug efficacy (hereafter referred to as the Zurich method). The 14-day individual counts in the untreated control group were used as the reference sample (since individual samples were not taken on day zero), and the mean percentage reduction and 95% confidence intervals (CI) were calculated using the freely available application (http://www.math.uzh.ch/as/index.php?id=256). Outcomes were classified as effective if FECR and the lower CI were both ≥95%; resistant if FECR and the upper CI were both <95%; and doubtful if the confidence bounds crossed 95% FECR.

Results of the Zurich method were compared with those from Drenchsmart for the first 32 tests conducted. The Drenchsmart criteria were based on arithmetic FECR using the single FEC value from pooled day zero samples and the mean of the post-treatment individual FEC for each drug group, without reference to the untreated control group. The result was expressed as a simple FECR%, and test outcomes classified as follows: ≥95% = effective (green); 90-95% = borderline (amber); <90% = resistant (red).

Firstly, the number of tests classifying treatment as effective was compared with those classifying treatment as ineffective or doubtful (Table 4).

Table 4. Classification of FECRT outcome using the Zurich and Drenchsmart methods, grouping test outcomes as effective or not/doubtful.

	Zurich method	
Drenchsmart method	Effective	Ineffective or doubtful
Effective	14	1
Ineffective or doubtful	0	17

Results showed excellent agreement between tests. Out of 32 tests used in this analysis, 31 (97%) showed complete agreement, while a single test categorised as effective by Drenchsmart (moxidectin, 99% FECR) was considered doubtful by Zurich (97.3% FECR, CI 92.4-99.3). On no occasion was a test considered effective by the Zurich method classified as ineffective or doubtful by Drenchsmart.

Secondly, the number of tests classifying treatment as definitely ineffective was compared with those classifying treatment as effective or doubtful (Table 5).

Table 5. Classification of FECRT outcome using the Zurich and Drenchsmart methods, grouping test outcomes as effective/doubtful or ineffective.

	Zurich method	
Drenchsmart method	Effective or doubtful	Ineffective
Effective or doubtful	17	4
Ineffective	0	11

Results again showed very good agreement between tests. Out of 32 tests used in this analysis, 28 (88%) showed complete agreement. This time, four test results disagreed. In all cases, Drenchsmart returned a borderline (90-95%, amber) result, while the Zurich method considered the drug used definitely ineffective (FECR<95% with upper CI also <95%). The FECR figure returned by Drenchsmart in each case, with the Zurich result in brackets, was: LV 94(90); BZ 92(74); LV 94(79); LV 91(92). There were no cases of tests considered effective by the Zurich method but ineffective or doubtful by Drenchsmart.

Taken together, these results show a high degree of reliability when classifying drug effectiveness using the simple FECR method within Drenchsmart, when compared with the more sophisticated Zurich method, which takes account of variation in individual FEC in the treated and control groups. Some disagreement in FECR is expected between methods since the reference value for Drenchsmart is the day zero pooled FEC value for the group treated by each drug, while the Zurich method compares individual FEC in the treated and control groups at the post-treatment visit. Misclassifications were mainly recorded for tests that considered drugs ineffective by the Zurich method but borderline (FECR 90-95%) by Drenchsmart. This is already dealt with by the advice returned with a borderline result that there might be an issue with drug effectiveness. There were no cases in which a drug was deemed ineffective by the Zurich method but effective by Drenchsmart, or vice versa.

Further accuracy could in principle be added to Drenchsmart results by more fully utilising data on individual post-treatment counts, in treated and control groups. At present this is not used in the core result, but rather as a source of additional information for test interpretation. Monte Carlo simulation was used to investigate this for the same 32 tests. From each series of individual FEC, values were resampled with replacement, and %FECR calculated. This was repeated 10,000 times to return a mean FECR and bootstrap 95% CI. Two separate FECR were returned: in relation to the pooled day zero FEC, and in relation to the individual counts in the untreated control group. Classification followed the rules for thresholds and CI stated for the Zurich method above. Cases for which Drenchsmart (basic form) and Zurich results disagreed were reviewed.

For the single case in which Drenchsmart judged treatment to be effective and the Zurich method returned a doubtful classification, bootstrapping from the control group agreed with the Zurich test, but bootstrapping form the pooled day zero sample agreed with the Drenchsmart result. This might be expected, since the comparator FEC used to calculate FECR was aligned in that manner for each bootstrap method. For the four cases of disagreement between doubtful and ineffective classes, two were resolved in favour of the Zurich result by bootstrapping (from both bootstrap methods). This suggests that bootstrapping might be used to reinforce Drenshsmart results by adding explicit bounds of uncertainty to the basic %FECR result. This could be built into future refinements of the Drenchsmart system. However, even without them, misclassifications were few in the present study and this strongly supports the conclusions reached on drug effectiveness on the farms tested.

The FECR data provided during the WAARD study represent an important resource for further examining the influence of factors such as pooling, dilution factor, and pre-treatment FEC thresholds, in the design and interpretation of FECRT. These studies are important in order to evaluate the performance of field drench testing for the detection and management of AR. The analyses required are complex and will continue beyond the end date of the project. A supplement to this report will summarise outcomes.

3. Anthelmintic Resistance – Fluke in sheep (Triclabendazole resistance).

FECRT status

The FECRT was carried out using the method previously outlined by Daniel et al in previous studies on resistance. Briefly a pooled sample of faeces from the farm are washed through a series of filters with the fluke eggs collecting in the final filter. The eggs (if present) are washed off the final filter. This wash is repeatedly sedimented to concentrate the *Fasciola* eggs and the sediment is poured onto a petri dish, counter-stained with methylene blue and counted under a stereomicroscope.

A total of 40 farms were visited to screen for liver fluke presence and half were visited in the autumn/winter period and the other half in the spring/summer period. Using this technique it was found that only two of the farms (5%) had sufficient eggs to diagnose a fluke infection (Figure 11) and therefore treated with Triclabendazole. These were then repeat visited at a 21 day interval to determine if the recommended Triclabendazole treatment was effective. Both of these farms were determined to have resistance issues.

As no other farms studied had a positive result it is likely that the positive results on these farms are largely due to the presence of resistance on these farms. Without this the fluke issues on both of these farms may have been reduced or non-existent in the study period.

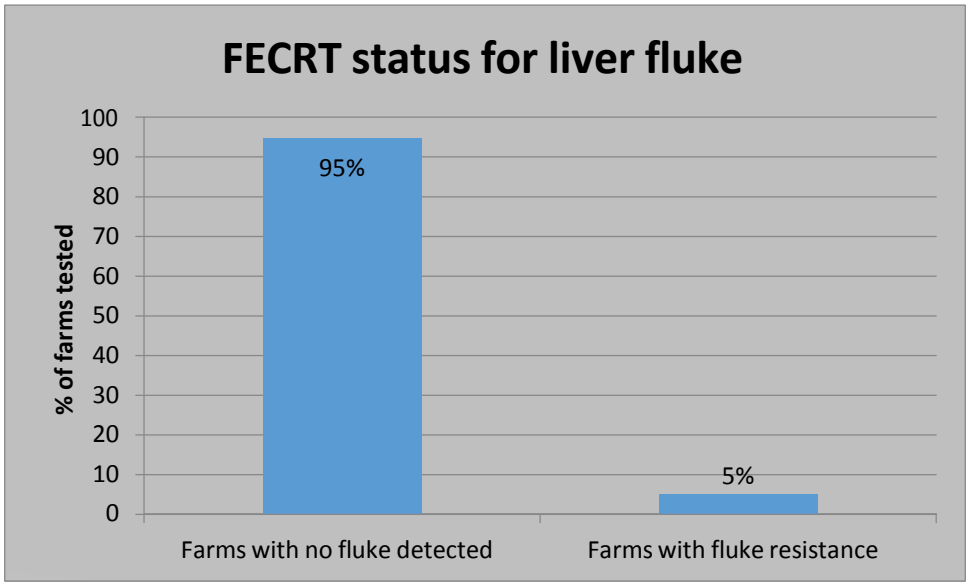

Figure 11. The percentage of Welsh farms with Faecal Egg Count Reduction Tests revealing liver fluke resistance in sheep.

Questionnaire analysis

Triclabendazole remains the mainstay of fluke control on farms, and 1/3 of farms will use Triclabendazole in single agent formulations (Figure 12). The remainder used a combination drug despite the advice in the literature to avoid this treatment.

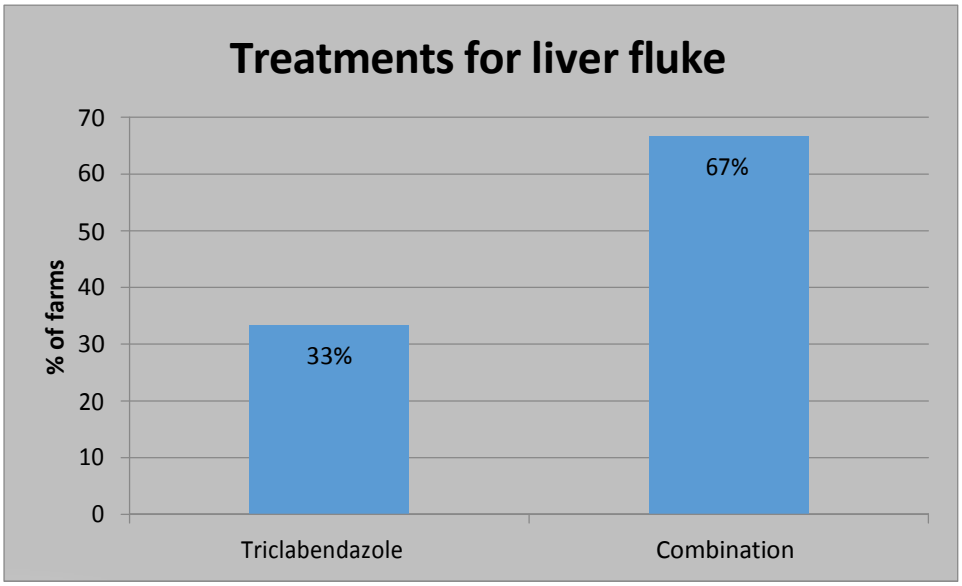

Figure 82. The percentage of Welsh farms that use Triclabendazole or a Combination treatment to control liver fluke in sheep.

The decision to treat for liver fluke can be critical to the success of any control of *Fasciola hepatica* infestation in flocks.

Of the farms examined, 33% of farmers had taken abattoir returns into account when deciding if or when to treat, other farmers were also a source of information (Figure 13). Veterinary surgeons were another source of information and it is to be presumed that they are using the NADIS parasite forecast to guide their clients. The same farmers that discussed with their Veterinary Surgeon were also using some form of testing to determine if treating was required.

More concerning however was there were 22% of the farmers that have not used any external source of information to determine the need for treatment. The farmers on this study chose to be involved and therefore have some interest in improving *Fasciola hepatica* control. This number is likely to be underrepresented in the study farms and in the wider population of farms there will be a much larger proportion who will decide on treatment based on possibly inappropriate information that may be inapplicable to the particular farm and season.

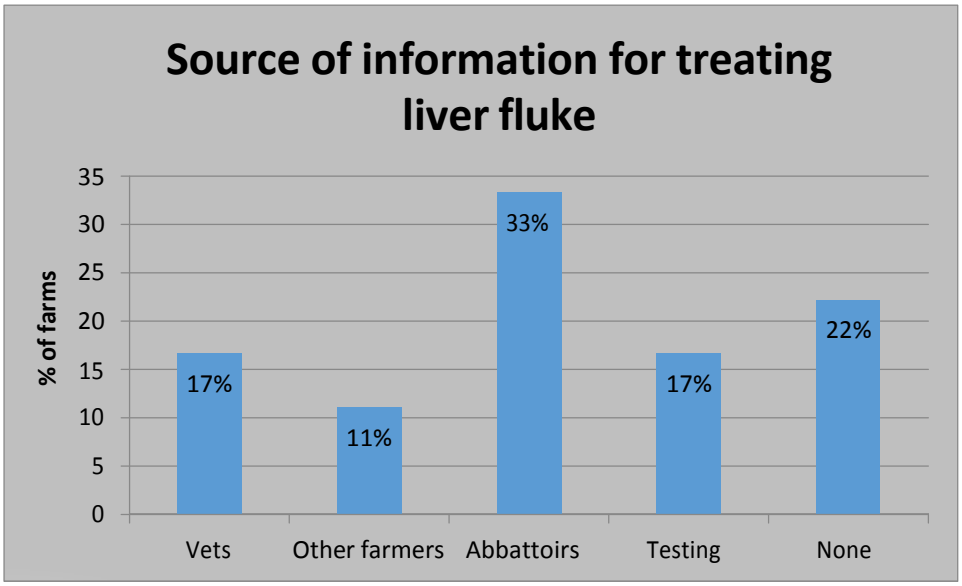

Figure 93. The percentage of Welsh farms that use Vets, other farmers, abattoirs, testing or no information (none) as their source of information for the treatment of liver fluke in sheep.

Treatment can be reduced by avoiding exposure to the pathogen. In the case of *Fasciola hepatica* this is done by avoiding snail friendly pasture at times when there is a high risk of infection. The snail (*Galba truncatula*) requires a warm (above 10˚C) and moist environment (above 70%) to thrive and act as intermediate hosts for the *Fasciola* parasite. Only 14% of farmers surveyed would take fluke risk into account when moving their flock (Figure 14). This may be as it is perceived that Wales has a wet environment where there is no escape from the exposure. This is a misconception that needs to be addressed.

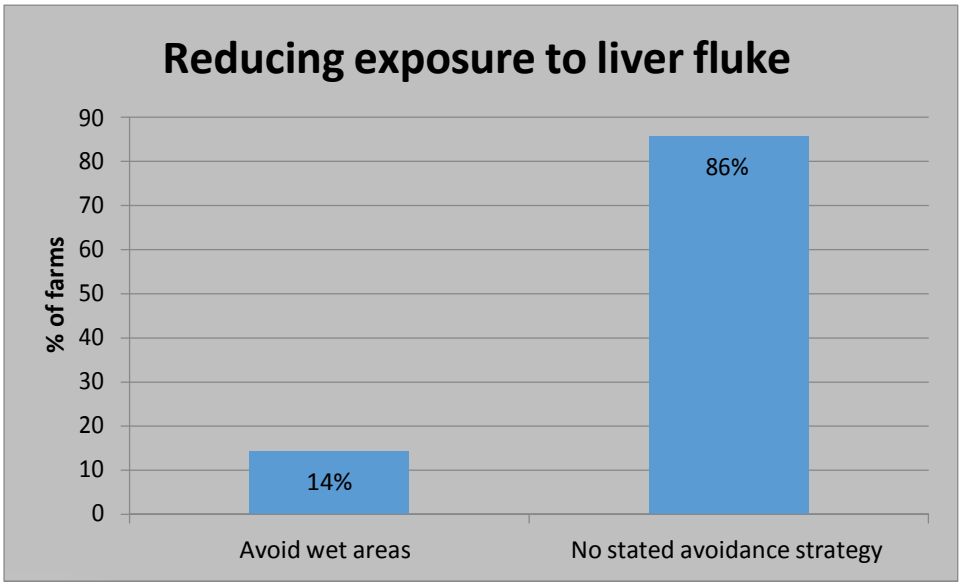

Figure 14. The percentage of Welsh farms that take fluke risk into account to reduce exposure when deciding to move their flocks.

The number of treatments can also be reduced by avoiding the introduction of the parasite where it doesn't occur and it can prevent parasites that are resistant to current flukicides. The use of quarantine procedures is shown in Figure 15, quarantine protocols were carried out on 81% of farms, while 5% of farms had no protocol and 14% of farms were closed flocks. This is encouraging as it suggests that a majority of farmers are aware that they should protect themselves from disease introduction.

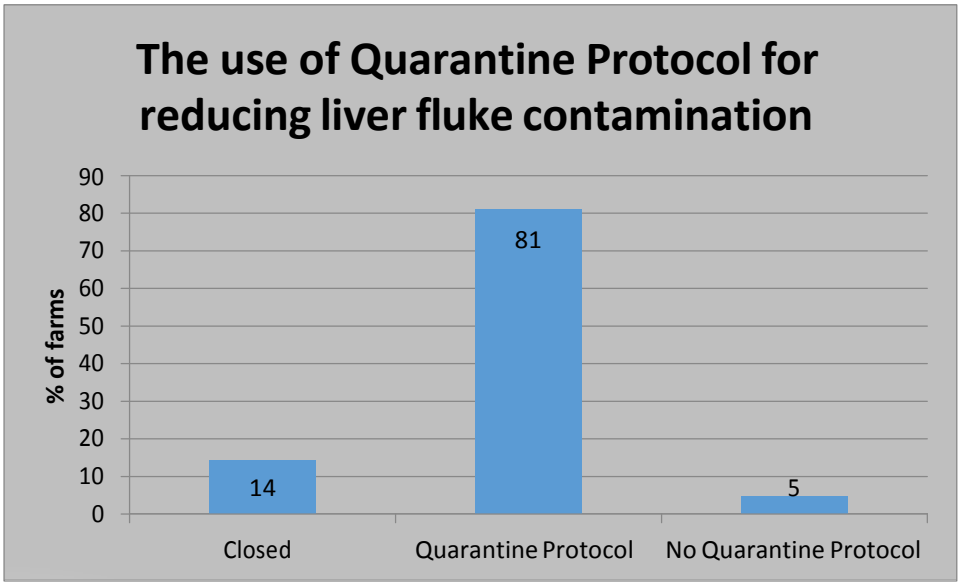

Figure 15. The percentage of Welsh farms that use Quarantine Protocols to reduce liver fluke contamination.

The actual quarantine protocol for *Fasciola hepatica* is complex and changes between farms depending on the circumstances of both the farm where the stock originated and destination farm. One part of the procedure that remains consistent is the length of the quarantine period for *Fasciola hepatica*. SCOPS recommendations suggest that four weeks is a minimum period to ensure that eggs remaining in the gut are shed in areas where there are no snails.

The length of quarantine can be used as a crude proxy for the overall quality of the quarantine protocol. No farmer was keeping the bought in sheep in quarantine for 4 weeks though 24% suggested that they would quarantine for 3-4 weeks (Figure 16). Others would quarantine for 1-2 weeks, while 52% did not define the time period. This finding suggests that the proper quarantine protocol is not well understood or known, and farmers may have a false sense of security about liver fluke resistance issues.

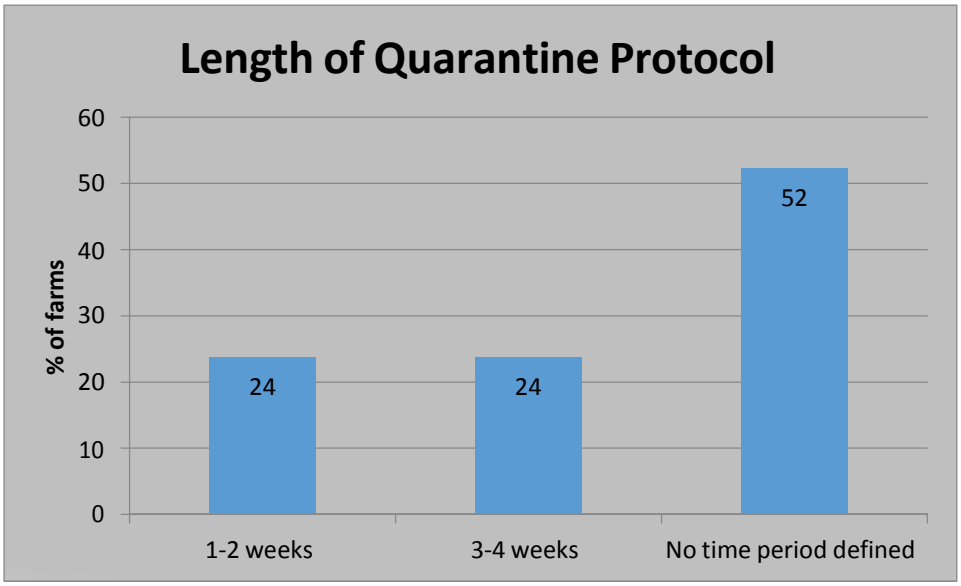

Figure 16. The percentage of Welsh farms that utilize a 1-2 week, 3-4 week or have no defined Quarantine Protocol for controlling liver fluke infections in sheep.

4. Knowledge Transfer

The consortium undertook several KT activities to disseminate the results of the project and it is envisaged that this will continue following the end of the project using the final results.

Activities:

- Five meetings were arranged in the spring to publicise the preliminary results from the autumn/winter testing period. Presentations were carried out by Eurion Thomas (Techion UK) on roundworm resistance, Neil Paton (WRVC) on flukicide resistance and the partner vets which represented each area.

	Date	Time	Venue
1.	Tuesday 28 April 2015	6.00pm -	Lampeter Rugby Club, SA48 7JA
2.	Wednesday 29 April 2015	2.00pm -	Conrah Hotel, Aberystwyth, SY23 4DF
3.	Tuesday 5 May 2015	6.00pm -	Castle Hotel, Brecon, LD3 9DB
4.	Wednesday 6 May 2015	2.00pm -	Welshpool Livestock Market, SY21 8SR
5.	Wednesday 13 May 2015	2.00pm -	Eagles Hotel Llanrwst, LL26 0LG

- Presentation or preliminary results at NSA Welsh Sheep Event Seminar, Newtown – 19th May 2015
- Presented preliminary results to HCC Wales Parasitology Steering Committee – 17th March 2015
- Presented preliminary results to SCOPS Committee – 17th March 2015
- Presentation of preliminary results by Techion UK at five meetings for Sainsbury's/Dunbia lamb producers in June 2015
- Results disseminated to partner vets clients through various local meetings and newsletters.

Planned Future Activities:

- Poster Presentation at British Cattle Vets Association congress in October 2015.
- Summary of results to be included in Techion Newsletters to FECPAK^{G2} clients and prospects.
- Various members of the consortium are actively involved in KT activities around this subject and these results will be incorporated in to various meetings and material.

5. Project recommendations and outcomes

Participating farms

Each participating farmer received a full report explaining the results of roundworm resistance, and offering advice and recommendations to alter parasite control policy where required (see Appendix 5 for an example of a farmer report). The reports are designed so that the first 4/5 pages are the most important for a farmer to read and then all other technical material and data that is of more importance to an advisor or veterinarian are in Appendices at the end of the report.

The recommendations included:

- **Adopting SCOPS Principles.** Especially highlighting quarantine treatments and FEC monitoring.
- **Advising which wormers can be used in future e.g.:**
    - If efficacy were >80% it was advised that those wormer's could still be used on occasion to help reduce pressure on other anthelmintic groups, but to be aware that continued use will further reduce efficacy's.
    - Where multiple resistance was present that sequential treatment of 2 wormers that had fairly good efficacy could be tried with a warning to always use a post treatment drench check to ensure it was effective.
    - Incorporating the careful use of the 2 new wormers Zolvix (4AD) and Startect (5SI).
- **Alternative Control Strategies** – e.g. grazing management and contamination mapping.

Farms that participated in the Fluke testing part of the project were able to access testing that avoided unnecessary flukicide treatment and were given guidance on strategies that could be used to optimise management of liver fluke on their farms.

Welsh livestock industry

This section focuses on recommendations to industry stakeholders and policy makers in terms of reviewing current advice and protocols for parasite control, use and availability of anthelmintics and any future research needed.

Roundworms

Uptake of SCOPS recommendations. The last 10 years has seen numerous activities throughout Wales to spread the SCOPS (Sustainable Control of Parasites in Sheep) messages and many farmers will be aware of these. It is however evident from the questionnaire analysis that not all recommendations are implemented by farmers and often where farmers think they are applying the principles they are not doing so correctly. It is therefore important that activities to promote the correct implementation of SCOPS recommendations continue within Wales and to explore new methods of KT in this area. It is also evident that a proportion of farm veterinarians and SQP's aren't well versed in the updated recommendations and it is suggested that a CPD program should be rolled out for both veterinarians and SQP's. It is also recommended that a review is done of all literature and online material that is available to the industry to ensure they are up to date as there is evidence of some key organisations having old recommendations (one example where advice for quarantine treatment is at least five years out of date).

One of the main recommendations for farmers to focus on is to find out their Drench Resistance Status as it is evident that most farmers will not know if the wormer products they are purchasing are effective on their farms. If a farmer has a known resistance status then this needs to be made available to those advising them and to those who sell them wormer products.

There also needs to be a concerted effort for the industry to make more use of the new actives (4-AD & 5-SI) as these are currently hugely underutilised and farmers need to be educated on the benefits and reasoning behind why they need to start integrating them into their control policy. This is particularly the case in quarantine treatments where it is apparent that farmers are using inappropriate wormers or not even having a quarantine protocol at all.

Licencing dual active anthelmintics. It is evident that many farms only have two anthelmintic groups that will be fully effective (Groups 4-AD and 5-SI) and there will be increasing pressure on development of resistance to these groups in the future if farmers have to rely on them for effective worm control. In the Southern Hemisphere most sheep wormers are now dual or triple actives where two or more anthelmintics from separate groups are provided in the same wormer. There is only one dual active wormer that has been licenced for use in Europe (Startect 5-SI). For farms where multiple resistance is present the use of dual active products may be useful to first of all help achieve good parasite control and secondly reduce resistance

selection pressure on the 4th and 5th groups of anthelmintics. The outcomes of this project could be used as evidence to support the case for the licencing of veterinary worming medicines in Europe which are already licenced in other parts of the world. This consortium does recommend that in the event that more multi active wormers are licenced their sale and use needs to be restricted to farmers who have evidence of multiple resistance and the need for treatment.

Sequential Treatment with wormers from two different groups. As the dual actives mentioned above are not available in the UK an alternative is for multiple resistant farms to be able to administer two different anthelmintics sequentially (e.g. administer a 1BZ drench and then administer a separate 2LV drench). If this is advised on some farms then how the message is conveyed to the industry has to be handled carefully as it shouldn't become the norm for farmers to carry this out on their own accord. The use of sequential treatment needs to be restricted the same as for dual active wormers above, The effectiveness of this approach will also need to be monitored through post drench checks.

Quarantine Recommendations. The current SCOPS recommendations are to treat with either Zolvix (4-AD) or Startect (5-SI) and a Moxidectin product (3-ML). The consortium agrees that there is no need to change these recommendations at the moment but does suggest that the situation with Moxidectin resistance needs to be monitored carefully as this may affect the effectiveness of this quarantine protocol in the future.

Further Research. The consortium suggest that more research is needed on how Welsh sheep farmers can control internal parasites where multiple resistance is present.

Research is needed to determine if using dual active wormers or sequentially treating with two different wormers (as mentioned above) are lowering parasite burdens in multiple resistant farms. In New Zealand it is uncommon for a worm species to be resistant to different anthelmintic groups and often different species are resistant to different anthelmintic groups, which is why dual active wormers will provide good efficacy. The tests in spring/summer for this project suggest that individual worm species populations are resistant to multiple anthelmintic groups which may question how effective dual active wormers or sequential treatments would be on multi resistant farms.

Research also need to be carried out on alternative approaches to roundworm control and reducing the reliance on anthelmintics. These would include using grazing management, alternative forages, sheep bred for resistance against worms and would involve careful monitoring and data collection to help manage the situation. Disease models have been developed under the EU funded GLOWORM project and on farm validation of these models would test their suitability as real tools that Welsh farmers can use to manage roundworms.

It would also be of interest to determine the cost of resistance on individual farms and to the industry as a whole. At some of the efficacy levels reported here there must be a significant impact on lamb performance, especially in a season which is favourable to roundworm infections. A suggestion would be to carry out some follow on work on some of the worst affected farms to try and evaluate if changing to effective wormer treatments increases performance.

Fluke

The industry should be encouraged to undertake a more intensive fluke testing regime for farms – possibly linked with the current parasite forecasting models to target testing and treatment as effectively as possible. This will require targeted education campaign in parasite control and is likely to be most successful in conjunction with literature that is aimed at controlling roundworms.

In this project faecal testing was used due to the ability to quantify egg numbers, but for treatment decisions this is not required. This increases the range of tests that would be suitable. Suggested criteria for a test should be discussed; such criteria could include the ability to carry out an on-farm, quick, test that requires a non-invasive sample, is adaptable to individual and group situations and uses a sample that is easy to acquire such as faeces or saliva.

Particular areas of KT include quarantine, testing options, sources of information and appropriate use of the various active ingredients available for fluke control. SCOPS have a wealth of information in the technical manual but for farmers this information may be relatively inaccessible and poorly laid out in comparison to the work on the nematode species. Improving the presentation of the information and disseminating the information more widely will assist better KT.

The use of combination drugs should be discouraged and possibly the sale of these should be stopped. Lobbying the pharmaceutical industry and the regulators is a possible approach to this issue.

6. Conclusions

The level of AR in Wales has appeared to increase considerably over the last 10 years with the failure of the 3-ML group (both Ivermectin and Moxidectin) being of specific concern as it is still believed that these are effective on most farms. The increase in 3-ML resistance is especially worrying because one of the objectives of the SCOPS group when they formed in 2003 was to 'sustain the effectiveness of the 3-ML group on the majority of sheep farms for some years to come'. Although SCOPS have made considerable inroads in engaging with farmers about the new messages around roundworm control it is apparent that the majority of Welsh farmers haven't implemented these principles on farm or certainly haven't done so correctly.

A positive outcome from the project for farmers is that if they know the resistance status of their farm they can act to try and maintain a good level of animal performance. Even when farms show triple resistance with or without Moxidectin there are still actions that can be taken to manage worm infections in this situation. The implementation of SCOPS principles need to be introduced across many more farms and for some, a more detailed integrated parasite management system will benefit how we manage this situation. Integrated parasite management systems involve using management to help combat worms with less reliance on wormers through the use of sheep bred for resistance, novel forages, contamination mapping and grazing management. Most farmers are still unaware of which wormers work on their farm and testing for resistance should be the first action we as an industry need to encourage. Any follow-on help and advice will develop from this first vital piece of information. Farmers should be encouraged to seek veterinary advice to help with this subject.

To help engage farmers in changing their attitudes to roundworm control a demonstration and realisation of the true cost of resistance would be of great benefit. It is difficult to get farmers to change just for the good of industry but if there was a real and significant financial gain seen from doing so adoption will be much easier. It has been shown that the improved lamb value that can be attributed to using an effective wormer versus and ineffective wormer is between £7 and £18 per lamb *(Miller et al 'The production cost of anthelmintic resistance in sheep', 2012 and Sutherland et al 'The production costs of anthelmintic resistance in sheep within a monthly preventive drench program, 2010)*. Using the result from the spring/summer that showed 60% of farms are triple resistant, sometimes including Moxidectin we can make the assumption that 60% (2.9million) of the 4.8million lambs produced in Wales annually (Little Book of Meat Facts, HCC 2014), are potentially treated with an anthelmintic with reduced efficacy. If this was the case the potential loss to the sheep industry in Wales through poorer lamb performance may be between £20 million and £53 million. These losses would be most realistic in years when conditions favour roundworm activity and the value will be influenced by market prices, but it's obvious that wormer resistance is potentially a significant cost to the red meat industry in Wales and something that needs to be addressed.

For fully effective control many farmers will also need to turn to the new wormer groups Zolvix (4-AD) and Startect (5-SI). If these actives are more heavily relied on in the future then there will be increasing pressure on resistance development which the industry has to be proactive in trying to delay for as long as possible.

It is interesting to note that the spring/summer results show that for the majority of farms, failure to a particular anthelmintic is multi-species with *Teladorsagia* and *Trichostrongylus* being the two species commonly failing. These results need to be confirmed as it is unusual to regularly see cross resistance between worm species on a particular property. If it is confirmed then this raises doubts about the effectiveness of any new sequential or dual action treatment strategies that may be implemented in the future.

With respect to *Fasciola hepatica* (liver fluke) control there is a large amount of KT that needs to occur. We do not know the actual prevalence of Triclabendazole resistance in Wales nor is there evidence for resistance to the other flukicides in the Welsh livestock industry and intervention at this stage might prevent or slow the spread of resistance in Wales. The control of trematodes is as complex as controlling nematodes, and is furthermore complicated by the multiple species that can act as hosts for the parasite. Control must take all susceptible species into consideration, cattle, sheep, deer or goats that may be present on the farm.

Treatment of stock appears to be a reflex action in a manner reminiscent of the historical attitude to anthelmintic administration. The project identified that many farms did not have a fluke burden at the time of testing but would have been treated had the project team not reported a negative result.

The choice of treatment is predominately Triclabendazole. The project did not ascertain the beliefs of the farmers in choosing products as this would have been more appropriate for a market research project but anecdotally the project team believe that this active ingredient is perceived as the best in the beef and sheep industry. This over reliance on a single active ingredient risks increasing the prevalence of resistance within Wales. Knowledge transfer regarding the use of other products

alongside the avoidance of combination products (as opposed to dual active products) in the treatment of animals for liver fluke is needed.

The prevalence of resistance to Triclabendazole by *Fasciola hepatica* on Welsh Farms remains unknown and should be the focus of further surveillance work. This may need to be carried out over multiple years as the prevalence of liver fluke infestation is even more variable than anticipated.

However, our understanding of liver fluke control appears to be poor and there may be opportunities to intervene and slow if not prevent the spread of resistance and particularly multiple resistance by educating farmers.

7. ACKNOWLEDGEMENTS

Thanks go to the Welsh Government and European Union who funded this project commissioned by Hybu Cig Cymru (HCC) under the Rural Development Plan for Wales 2007.

Thanks to Lynfa Davies and John Richards from HCC for their help and guidance in setting up this project.

Thanks to all project consortium members (listed in Appendix 2) who worked hard at making this project a success and helping pull this report together, and to Helen and Sophie from Techion for data presentation and proofing.

And finally a special thanks to all the 49 farmers who volunteered to take part in this project and helping out with the on farm work and allowing us to use their data.

Appendix 1 – Consortium members details

The WAARD project consortium is managed by Techion Group and includes the following partners:

- Techion Group Ltd, Peithyll, Capel Dewi, Aberystwyth, Eurion Thomas, Mared Owen and Sarah Buttery, with support from Greg Mirams, Helen Manly, Sophie Gibson-Pinn in New Zealand.
- Bristol University, Dr Eric Morgan, Dr Gerald Coles, Katie Bull
- Welsh Regional Veterinary Centre, Gelli Aur, Llandeilo Carmarthenshire (WRVC), Dr. Neil Paton
- Steffan Veterinary Services Ltd, 5 High Street, Lampeter, Ceredigion Dr. Jim Hopkins BVetMed MRCVS
- Ystwyth Veterinary Practice Ltd, Llanbadarn Fawr, Aberystwyth. Dafydd Jones, MRCVS
- Camlas Farm Vets LLP, Waterloo Place, Salop Rd, Welshpool. Iolo White BVSc. MRCVS
- Milfeddygfa'r Wern Vets, Station Road, Llanrwst. Eilidh Hawkins BVM&S MSc MRCVS
- Kate Hovers, BVSc CertSHP MRCVS – Independent Veterinary Consultant, Cwmhydfer, Trecastle, Brecon, Powys,

Appendix 2 – DrenchSmart® Protocol

DrenchSmart® is a faecal egg count reduction test that assesses drench efficacy and was developed by Techion Group Ltd. in New Zealand. DrenchSmart® adheres to global FECRT standards and analysis of the data is supported by utilising the latest FECRT statistical analysis software.

DrenchSmart® is already widely used in New Zealand and provides information which is used for:

- Property valuation
- The development of effective quarantine protocols
- Increasing performance and profitability of sheep enterprises
- Removing the guesswork by knowing which drenches work on farm
- Ensuring longevity of drenches by protecting the drugs that are working

For more information on DrenchSmart® visit www.techiongroup.co.nz/product_pages/drenchsmart.aspx

DrenchSmart® was used to test for resistance to the following anthelmintics:

ANTHELMINTIC TYPE	WORMER PRODUCT NAME	ACTIVE INGREDIENT
Benzimidazoles (1 BZ)	Rycoben SC 2.5% (oral)	Ricobendazole
Levamisoles (2 LV)	Levacide 3% (oral)	Lavamisole
Ivermectin (3 ML)	Oramec (oral)	Ivermectin
Moxidectin (3 ML)	Cydectin 0.1% drench (oral)	Moxidectin

Procedure

- Mob counts to be monitored on each farm to ensure sufficient challenge before initial vet visit.
- Strongyle egg counts needs to be 500epg or higher before a visit is undertaken.
- When average counts are high enough a Vet (or vet supervised technician) will visit each farm. At each farm visit the vet will:
    - Split lambs to 5 groups of 15 lambs (4 x treatments and 1 x Control) – 75 lambs total
    - Tag and treat the animals in each group accordingly. Colour coded tags will be provided that relate to each group (e.g. White tag = Benzimidazole group).
    - Collect mob faecal samples from each group by following the recommended protocols (12 animals pooled in 1 sample bag).
    - Collect 1 overall mob faecal samples for larval culture using supplied pots and following recommended protocols.
    - 12 animals to be sampled per drench group (15 treated to give 3 spares for no samples / losses etc.).
- Individual samples to be collected from the same animals each time, ear tagged for each drench group.
- Technician to carry out post treatment visit to collect further faecal samples from the animals as follows:
    - 7 days later for Levamisole (2-LV).
    - 14 days for other 3 treatment groups and control.
    - 12 individual samples to be collected from each group. Colour coded bags correspond to the ear tag colour.
    - 1 mob sample per treatment and control group is collected for larval culture using supplied pots and following recommended protocols.

- FEC counts to be undertaken on all samples by partner vets using FECPAK^{G2} system. Pooled samples will be carried out pre-treatment with individuals done on post-treatments samples.
- Larval culture and speciation to be carried out on samples collected before treatment and from groups where a drench failure is detected (Bristol University).
- All veterinary partners who are carrying out sampling and testing in the field will be provided with:
    - Ear tags.
    - Drenching syringes.
    - Colour coded bottles of wormer for each anthelmintic group.
    - Labels with batch no. expiry date, wormer brand name, date treated for farmer to include in medicine book.
    - Colour coded sample bags.
    - Colour coded pots for larval culture.
    - Full SOP's.
    - Weight to dose rate charts for each anthelmintic group.
- Data will be analysed and a report will be sent to the farmer and his veterinarian which would include:
    - Actual data - individual FEC count results and larval culture results.
    - Recommendations –interpretation of the results will be provided.
    - Parasite species identification - where possible resistant parasite species will be identified.

Appendix 3 – Data Summary FECRT Results

Autumn/Winter 2014 FEC reduction results by Drench and Farm

Table 6. The FECRT results for the 28 farms in the WAARD Project for autumn/winter 2014. The FECR results for Benzimidazole, Levamisole, Ivermectin, Moxidectin and the number of drenches with resistance are shown.

Farm Code	Date Treated	FECRT % Benzimidazole	FECRT % Levamisole	FECRT % Ivermectin	FECRT % Moxidectin	No. Drenches with Resistance
		(1 BZ)	(2 LV)	(3 ML)		
C1	12/11/2014	98%	94%	99%	99%	1
C3	08/01/2015	70%	42%	92%	99%	3
C4	05/11/2014	86%	98%	97%	86%	2
C5	08/01/2015	92%	94%	100%	99%	2
C6	08/10/2014	58%	90%	86%	100%	3
C9	12/11/2014	54%	91%	98%	100%	2
H1	04/11/2014	74%	87%	99%	99%	2
H2	04/12/2014	61%	89%	98%	100%	2
H3	31/10/2014	40%	0%	85%	100%	3
H4	30/10/2014	65%	98%	98%	100%	1
H7	06/11/2014	80%	96%	68%	97%	2
H8	21/10/2014	98%	99%	98%	100%	0
H9	30/10/2014	64%	99%	99%	100%	1
S1	22/10/2014	23%	94%	100%	100%	2
S3	17/11/2014	81%	65%	96%	57%	3
S5	21/10/2014	84%	98%	97%	97%	1
S6	17/10/2014	79%	93%	96%	100%	2
S8	04/11/2014	6%	88%	71%	59%	4
S9	17/11/2014	28%	78%	38%	84%	4
W1	09/10/2014	87%	98%	100%	100%	1
W5	18/11/2014	96%	86%	100%	100%	1
W8	17/12/2014	91%	60%	99%	99%	2
Y1	28/10/2014	94%	99%	99%	99%	1
Y10	02/01/2015	91%	97%	97%	99%	1
Y4	07/11/2014	89%	93%	97%	97%	2
Y6	20/11/2014	88%	94%	94%	31%	4
Y7	06/11/2014	0%	91%	99%	100%	2
Y9	26/11/2014	68%	53%	99%	96%	2

Spring/Summer 2015 FECRT results by Drench and Farm

Table 7. The FECRT results for the 30 farms in the WAARD Project for spring/summer 2015. Eleven of the 30 farms were repeat test from farms tested in autumn/winter 2014. The FECR results for Benzimidazole, Levamisole, Ivermectin, Moxidectin and the number of drenches with resistance are shown.

Farm Code	Original code if retested	Date Treated	FECRT % Benzimidazoles (1 BZ)	FECRT % Levamisole (2 LV)	FECRT % Ivermectin (3 ML)	FECRT % Moxidectin (3 ML)	No. Drenches with Resistance
C10		26/06/2015	41%	78%	39%	100%	3
C11	C9	10/07/2015	80%	91%	91%	99%	3
C12	C4	08/07/2015	68%	86%	99%	99%	2
C13		15/07/2015	57%	78%	83%	68%	4
C14		09/06/2015	71%	99%	96%	100%	1
C15		13/07/2015	67%	99%	11%	62%	3
C16		31/07/2015	48%	96%	69%	99%	2
C17		15/07/2015	59%	85%	100%	100%	2
C7		18/06/2015	40%	82%	86%	100%	3
C8	C6	03/07/2015	40%	94%	94%	99%	3
H10		31/07/2015	40%	99%	94%	98%	2
H17		31/07/2015	72%	87%	96%	100%	2
S11	S3	18/06/2015	72%	90%	80%	86%	4
S12	S9	20/07/2015	-14%	66%	1%	-8%	4
S13		13/07/2015	37%	90%	67%	98%	3
S14		30/07/2015	44%	27%	25%	99%	3
S15	S1	10/07/2015	-232%	49%	75%	95%	3
S16	S8	08/07/2015	-22%	67%	70%	89%	4
S4		20/07/2015	51%	98%	86%	100%	2
S7		24/07/2015	37%	83%	83%	97%	3
W12		31/07/2015	52%	100%	97%	100%	1
W15		31/07/2015	88%	92%	54%	98%	3
W4		16/06/2015	82%	100%	95%	100%	1
Y11	Y1	24/06/2015	50%	63%	100%	97%	2
Y12	Y4	24/07/2015	88%	43%	72%	93%	4
Y13	Y6	15/06/2015	-173%	50%	58%	94%	4
Y15	Y9	25/06/2015	67%	78%	98%	100%	2
Y2		02/07/2015	64%	93%	46%	80%	4
Y3		31/07/2015	78%	99%	98%	90%	2
Y8		15/06/2015	-317%	63%	83%	95%	3

Appendix 4 - Data Summary of all larval culture results

Table 8. Larval Culture results for farms in autumn/winter 2014 and spring/summer 2015. Percentage reductions and sample validity are shown for each of the main nematode parasite species.
See table footnote for notes and code explanation.

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
C1_2014	12/11/2014		Benzimidazoles	**98%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
C1_2014	12/11/2014		Levamisole	**94%**			UNKNOWN	N	N/A	N	N/A	N	UNKNOWN	N	N/A	N
C1_2014	12/11/2014		Ivermectin	**100%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
C1_2014	12/11/2014		Moxidectin	**100%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
C3_2014	8/01/2015		Benzimidazoles	**70%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
C3_2014	8/01/2015		Levamisole	**42%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C3_2014	8/01/2015		Ivermectin	**92%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C3_2014	8/01/2015		Moxidectin	**99%**			100%	N	100%	N	100%	N	100%	N	N/A	N
C4_2014	5/11/2014		Benzimidazoles	**86%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
C4_2014	5/11/2014		Levamisole	**98%**			100%	Y	100%	Y	N/A	N	100%	Y	N/A	N
C4_2014	5/11/2014		Ivermectin	**97%**			100%	Y	100%	Y	N/A	N	100%	Y	N/A	N
C4_2014	5/11/2014		Moxidectin	**86%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
C5_2014	8/01/2015		Benzimidazoles	**92%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C5_2014	8/01/2015		Levamisole	**94%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C5_2014	8/01/2015		Ivermectin	**100%**			100%	N	100%	N	100%	N	100%	N	100%	Y
C5_2014	8/01/2015		Moxidectin	**99%**			100%	N	100%	N	100%	N	100%	N	100%	Y
C6_2014	8/10/2014		Benzimidazoles	**58%**			58%	Y	100%	N	100%	N	100%	N	100%	N
C6_2014	8/10/2014		Levamisole	**90%**			91%	Y	100%	N	100%	N	100%	N	100%	N
C6_2014	8/10/2014		Ivermectin	**86%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
C6_2014	8/10/2014		Moxidectin	**100%**			100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C9_2014	12/11/2014		Benzimidazoles	**54%**			47%	Y	100%	N	100%	N	100%	Y	100%	Y
C9_2014	12/11/2014		Levamisole	**91%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
C9_2014	12/11/2014		Ivermectin	**98%**			100%	Y	N/A	N	N/A	N	100%	Y	N/A	N
C9_2014	12/11/2014		Moxidectin	**100%**			100%	Y	N/A	N	N/A	N	100%	Y	N/A	N

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
H1_2014	4/11/2014		Benzimidazoles	**74%**			UNKNOWN	Y	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
H1_2014	4/11/2014		Levamisole	**70%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
H1_2014	4/11/2014		Ivermectin	**99%**			100%	N	100%	N	100%	N	100%	N	N/A	N
H1_2014	4/11/2014		Moxidectin	**100%**			100%	N	100%	N	100%	N	100%	N	N/A	N
H2_2014	4/12/2014		Benzimidazoles	**61%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
H2_2014	4/12/2014		Levamisole	**89%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
H2_2014	4/12/2014		Ivermectin	**98%**			100%	N	100%	N	100%	N	100%	N	N/A	N
H2_2014	4/12/2014		Moxidectin	**100%**			100%	N	100%	N	100%	N	100%	N	100%	N
H3_2014	31/10/2014		Benzimidazoles	**40%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	92%	Y
H3_2014	31/10/2014		Levamisole	**-27%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
H3_2014	31/10/2014		Ivermectin	**85%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
H3_2014	31/10/2014		Moxidectin	**100%**			100%	N	100%	N	100%	N	100%	N	100%	Y
H4_2014	30/10/2014		Benzimidazoles	**65%**			65%	Y	100%	N	100%	N	100%	N	100%	N
H4_2014	30/10/2014		Levamisole	**98%**			100%	Y	N/A	N	N/A	N	100%	N	100%	Y
H4_2014	30/10/2014		Ivermectin	**98%**			100%	Y	N/A	N	N/A	N	100%	N	100%	Y
H4_2014	30/10/2014		Moxidectin	**100%**			100%	Y	N/A	N	N/A	N	100%	N	100%	Y
H7_2014	6/11/2014		Benzimidazoles	**80%**			79%	Y	100%	N	100%	N	100%	N	100%	Y
H7_2014	6/11/2014		Levamisole	**96%**			100%	Y	100%	N	N/A	N	N/A	N	100%	Y
H7_2014	6/11/2014		Ivermectin	**68%**			67%	Y	100%	N	100%	N	100%	N	100%	N
H7_2014	6/11/2014		Moxidectin	**97%**			100%	Y	100%	Y	N/A	N	N/A	N	100%	N
H8_2014	21/10/2014		Benzimidazoles	**98%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
H8_2014	21/10/2014		Levamisole	**99%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
H8_2014	21/10/2014		Ivermectin	**98%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
H8_2014	21/10/2014		Moxidectin	**100%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
H9_2014	30/10/2014		Benzimidazoles	**64%**			53%	Y	100%	Y	100%	N	100%	Y	100%	Y
H9_2014	30/10/2014		Levamisole	**99%**			100%	Y	100%	Y	N/A	N	100%	Y	100%	Y

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
H9_2014	30/10/2014		Ivermectin	**99%**			100%	Y	100%	Y	N/A	N	100%	Y	100%	Y
H9_2014	30/10/2014		Moxidectin	**100%**			100%	Y	100%	Y	N/A	N	100%	Y	100%	Y
S1_2014	23/10/2014		Benzimidazoles	**23%**			13%	Y	62%	Y	13%	Y	100%	Y	N/A	N
S1_2014	23/10/2014		Levamisole	**94%**			92%	Y	100%	N	100%	N	100%	N	N/A	N
S1_2014	23/10/2014		Ivermectin	**100%**			100%	Y	100%	Y	100%	Y	100%	N	N/A	N
S1_2014	23/10/2014		Moxidectin	**100%**			100%	Y	100%	Y	100%	Y	100%	N	100%	N
S3_2014	17/11/2014		Benzimidazoles	**81%**			80%	Y	68%	Y	100%	N	89%	N	N/A	N
S3_2014	17/11/2014		Levamisole	**65%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
S3_2014	17/11/2014		Ivermectin	**96%**			100%	Y	100%	Y	100%	Y	100%	Y	N/A	N
S3_2014	17/11/2014		Moxidectin	**57%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
S5_2014	21/10/2014		Benzimidazoles	**84%**			81%	Y	100%	Y	100%	Y	100%	N	N/A	N
S5_2014	21/10/2014		Levamisole	**99%**			100%	Y	100%	Y	100%	Y	N/A	N	N/A	N
S5_2014	21/10/2014		Ivermectin	**97%**			100%	Y	100%	Y	100%	Y	N/A	N	N/A	N
S5_2014	21/10/2014		Moxidectin	**97%**			100%	Y	100%	N	100%	N	N/A	N	100%	Y
S6_2014	17/10/2014		Benzimidazoles	**79%**			76%	Y	N/A	N	N/A	N	100%	N	N/A	N
S6_2014	17/10/2014		Levamisole	**93%**			92%	Y	N/A	N	N/A	N	100%	Y	N/A	N
S6_2014	17/10/2014		Ivermectin	**96%**			100%	Y	N/A	N	N/A	N	100%	N	N/A	N
S6_2014	17/10/2014		Moxidectin	**100%**			100%	Y	N/A	N	N/A	N	100%	N	N/A	N
S8_2014	4/11/2014		Benzimidazoles	**6%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
S8_2014	4/11/2014		Levamisole	**88%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
S8_2014	4/11/2014		Ivermectin	**71%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
S8_2014	4/11/2014		Moxidectin	**59%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
S9_2014	17/11/2014		Benzimidazoles	**28%**			-10%	Y	100%	Y	100%	Y	100%	Y	N/A	N
S9_2014	17/11/2014		Levamisole	**78%**			66%	Y	100%	Y	100%	Y	100%	Y	100%	Y
S9_2014	17/11/2014		Ivermectin	**36%**			2%	Y	100%	Y	100%	Y	100%	Y	100%	N
S9_2014	17/11/2014		Moxidectin	**84%**			75%	Y	100%	Y	100%	Y	100%	Y	100%	Y

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
W1_2014	9/10/2014		Benzimidazoles	**87%**			82%	Y	100%	Y	100%	N	100%	N	100%	Y
W1_2014	9/10/2014		Levamisole	**98%**			100%	Y	100%	N	N/A	N	100%	N	N/A	N
W1_2014	9/10/2014		Ivermectin	**100%**			100%	Y	100%	Y	N/A	N	100%	N	99%	Y
W1_2014	9/10/2014		Moxidectin	**100%**			100%	Y	100%	Y	N/A	N	100%	N	100%	Y
W5_2014	18/11/2014		Benzimidazoles	**96%**			100%	Y	100%	Y	100%	N	100%	Y	100%	N
W5_2014	18/11/2014		Levamisole	**86%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	94%	Y
W5_2014	18/11/2014		Ivermectin	**100%**			100%	Y	100%	Y	100%	N	100%	Y	N/A	N
W5_2014	18/11/2014		Moxidectin	**100%**			100%	Y	100%	Y	100%	N	100%	Y	100%	N
W8_2014	17/12/2014		Benzimidazoles	**91%**			90%	Y	100%	N	100%	N	95%	Y	N/A	N
W8_2014	17/12/2014		Levamisole	**60%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
W8_2014	17/12/2014		Ivermectin	**99%**			100%	Y	N/A	N	100%	N	100%	N	100%	N
W8_2014	17/12/2014		Moxidectin	**99%**			100%	Y	N/A	N	100%	N	100%	N	100%	Y
Y1_2014	28/10/2014		Benzimidazoles	**94%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
Y1_2014	28/10/2014		Levamisole	**99%**			100%	Y	100%	Y	N/A	N	100%	N	100%	N
Y1_2014	28/10/2014		Ivermectin	**99%**			100%	Y	100%	Y	N/A	N	100%	N	N/A	N
Y1_2014	28/10/2014		Moxidectin	**99%**			100%	Y	100%	Y	N/A	N	100%	N	100%	Y
Y4_2014	7/11/2014		Benzimidazoles	**89%**			88%	Y	100%	N	100%	N	92%	N	100%	Y
Y4_2014	7/11/2014		Levamisole	**93%**			UNKNOWN	N	N/A	N	N/A	N	UNKNOWN	N	N/A	N
Y4_2014	7/11/2014		Ivermectin	**97%**			100%	Y	N/A	N	N/A	N	100%	Y	N/A	N
Y4_2014	7/11/2014		Moxidectin	**97%**			100%	Y	N/A	N	N/A	N	100%	Y	N/A	N
Y6_2014	20/11/2014		Benzimidazoles	**88%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
Y6_2014	20/11/2014		Levamisole	**94%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
Y6_2014	20/11/2014		Ivermectin	**94%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	80%	N
Y6_2014	20/11/2014		Moxidectin	**31%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
Y7_2014	6/11/2014		Benzimidazoles	**-40%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
Y7_2014	6/11/2014		Levamisole	**91%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
Y7_2014	6/11/2014		Ivermectin	**98%**			100%	N	100%	N	100%	N	100%	N	N/A	N
Y7_2014	6/11/2014		Moxidectin	**100%**			100%	N	100%	N	100%	N	100%	N	N/A	N
Y9_2014	26/11/2014		Benzimidazoles	**68%**			61%	Y	100%	N	100%	N	100%	Y	100%	N
Y9_2014	26/11/2014		Levamisole	**53%**			44%	Y	100%	N	100%	N	100%	Y	60%	N
Y9_2014	26/11/2014		Ivermectin	**99%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	Y
Y9_2014	26/11/2014		Moxidectin	**96%**			100%	Y	N/A	N	N/A	N	100%	Y	100%	N
Y10_2014	2/01/2015		Benzimidazoles	**91%**			UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
Y10_2014	2/01/2015		Levamisole	**97%**			100%	N	100%	N	100%	N	100%	N	N/A	N
Y10_2014	2/01/2015		Ivermectin	**97%**			100%	N	100%	N	100%	N	100%	N	N/A	N
Y10_2014	2/01/2015		Moxidectin	**99%**			100%	N	100%	N	100%	N	100%	N	N/A	N
C7	24/06/2015		Benzimidazoles	**40%**	35%	Y	35%	Y	100%	N	100%	N	100%	N	100%	Y
C7	24/06/2015		Levamisole	**82%**	83%	Y	77%	Y	100%	N	100%	N	100%	N	96%	Y
C7	24/06/2015		Ivermectin	**86%**	86%	Y	84%	Y	100%	N	100%	N	100%	N	100%	Y
C7	24/06/2015		Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	100%	N	N/A	N	#N/A	Y
C8	9/06/2015	C6	Benzimidazoles	**40%**	32%	Y	42%	Y	100%	N	100%	N	100%	N	100%	Y
C8	9/06/2015	C6	Levamisole	**94%**	100%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
C8	9/06/2015	C6	Ivermectin	**94%**	100%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
C8	9/06/2015	C6	Moxidectin	**99%**	100%	Y	100%	Y	100%	N	N/A	N	N/A	N	#N/A	Y
C10	28/05/2015		Benzimidazoles	**41%**	27%	Y	47%	Y	100%	N	100%	N	100%	N	100%	Y
C10	28/05/2015		Levamisole	**78%**	100%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
C10	28/05/2015		Ivermectin	**39%**	7%	Y	54%	Y	100%	N	100%	N	100%	N	100%	Y
C10	28/05/2015		Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C11	10/07/2015	C9	Benzimidazoles	**80%**	72%	Y	90%	Y	100%	N	100%	N	100%	N	100%	Y
C11	10/07/2015	C9	Levamisole	**91%**	90%	Y	92%	Y	100%	N	100%	N	100%	N	100%	Y
C11	10/07/2015	C9	Ivermectin	**91%**	87%	Y	96%	Y	100%	N	100%	N	100%	N	100%	Y
C11	10/07/2015	C9	Moxidectin	**99%**	100%	Y	100%	Y	N/A	N	100%	N	N/A	N	100%	Y

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
C12	8/07/2015	C4	Benzimidazoles	**68%**	59%	Y	72%	Y	100%	N	100%	N	100%	Y	100%	Y
C12	8/07/2015	C4	Levamisole	**86%**	84%	Y	87%	Y	100%	N	100%	N	100%	Y	100%	Y
C12	8/07/2015	C4	Ivermectin	**99%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	Y
C12	8/07/2015	C4	Moxidectin	**99%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	Y
C13	15/07/2015		Benzimidazoles	**57%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C13	15/07/2015		Levamisole	**78%**	79%	Y	74%	Y	100%	N	100%	N	100%	N	100%	N
C13	15/07/2015		Ivermectin	**83%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C13	15/07/2015		Moxidectin	**68%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
C14	17/07/2015		Benzimidazoles	**71%**	69%	Y	74%	Y	100%	N	100%	N	100%	N	100%	Y
C14	17/07/2015		Levamisole	**99%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C14	17/07/2015		Ivermectin	**96%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	N
C14	17/07/2015		Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C15	21/07/2015		Benzimidazoles	**67%**	78%	Y	49%	Y	100%	N	100%	N	100%	N	100%	N
C15	21/07/2015		Levamisole	**99%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	N
C15	21/07/2015		Ivermectin	**11%**	44%	Y	-44%	Y	100%	N	100%	N	100%	N	100%	N
C15	21/07/2015		Moxidectin	**62%**	63%	Y	58%	Y	100%	N	100%	N	100%	N	100%	N
C16	21/07/2015		Benzimidazoles	**48%**	21%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
C16	21/07/2015		Levamisole	**96%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C16	21/07/2015		Ivermectin	**69%**	76%	Y	56%	Y	100%	N	100%	N	100%	N	100%	Y
C16	21/07/2015		Moxidectin	**99%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C17	30/07/2015		Benzimidazoles	**59%**	67%	Y	46%	Y	100%	N	100%	N	100%	N	100%	Y
C17	30/07/2015		Levamisole	**85%**	86%	Y	85%	Y	100%	N	100%	N	100%	N	95%	Y
C17	30/07/2015		Ivermectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
C17	30/07/2015		Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
H10	31/07/2015		Benzimidazoles	**40%**	20%	Y	40%	N	N/A	N	N/A	N	N/A	N	100%	Y
H10	31/07/2015		Levamisole	**99%**	UNKNOWN	Y	UNKNOWN	Y	UNKNOWN	N	UNKNOWN	N	UNKNOWN	Y	100%	Y

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
H10	31/07/2015		Ivermectin	**94%**	UNKNOWN	Y	UNKNOWN	Y	UNKNOWN	N	UNKNOWN	N	UNKNOWN	Y	100%	Y
H10	31/07/2015		Moxidectin	**99%**	UNKNOWN	Y	UNKNOWN	Y	UNKNOWN	N	UNKNOWN	N	UNKNOWN	Y	100%	Y
H17	31/07/2015		Benzimidazoles	**72%**	UNKNOWN	N	UNKNOWN	N	N/A	N	N/A	N	N/A	N	100.00%	Y
H17	31/07/2015		Levamisole	**87%**	83.70%	Y	91.90%	Y	N/A	N	N/A	N	N/A	N	100.00%	N
H17	31/07/2015		Ivermectin	**96%**	100.00%	Y	100.00%	Y	N/A	N	N/A	N	N/A	N	98.00%	Y
H17	31/07/2015		Moxidectin	**100%**	100.00%	Y	100.00%	Y	N/A	N	N/A	N	N/A	N	100.00%	Y
S4	23/07/2015		Benzimidazoles	**51%**	55%	Y	22%	Y	100%	N	100%	N	100%	Y	100%	Y
S4	23/07/2015		Levamisole	**98%**	98%	Y	97%	Y	100%	N	100%	N	100%	Y	100%	Y
S4	23/07/2015		Ivermectin	**86%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
S4	23/07/2015		Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	Y	100%	Y
S7	24/07/2015		Benzimidazoles	**37%**	28%	Y	25%	Y	100%	N	100%	N	100%	Y	91%	N
S7	24/07/2015		Levamisole	**83%**	79%	Y	80%	Y	100%	N	100%	N	100%	Y	N/A	N
S7	24/07/2015		Ivermectin	**83%**	55%	Y	97%	Y	100%	N	100%	N	100%	N	97%	Y
S7	24/07/2015		Moxidectin	**97%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	Y	100%	N
S11	18/06/2015	S3	Benzimidazoles	**72%**	100%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
S11	18/06/2015	S3	Levamisole	**90%**	89%	Y	90%	Y	100%	N	100%	N	100%	N	100%	Y
S11	18/06/2015	S3	Ivermectin	**80%**	100%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
S11	18/06/2015	S3	Moxidectin	**86%**	100%	Y	100%	Y	100%	N	100%	N	100%	N	100%	Y
S12	20/07/2015	S9	Benzimidazoles	**-14%**	-60%	Y	32%	Y	100%	N	100%	N	100%	N	100%	Y
S12	20/07/2015	S9	Levamisole	**66%**	50%	Y	83%	Y	100%	N	100%	N	100%	N	100%	Y
S12	20/07/2015	S9	Ivermectin	**1%**	-39%	Y	40%	Y	100%	N	100%	N	100%	N	100%	Y
S12	20/07/2015	S9	Moxidectin	**-8%**	-40%	Y	25%	Y	100%	N	100%	N	100%	N	100%	Y
S13	13/07/2015		Benzimidazoles	**37%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
S13	13/07/2015		Levamisole	**90%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
S13	13/07/2015		Ivermectin	**67%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
S13	13/07/2015		Moxidectin	**98%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
S14	30/07/2015		Benzimidazoles	**44%**	44.40%	Y	44.40%	Y	N/A	N	N/A	N	N/A	N	100.00%	Y
S14	30/07/2015		Levamisole	**28%**	UNKNOWN	N	UNKNOWN	N	N/A	N	N/A	N	N/A	N	100.00%	Y
S14	30/07/2015		Ivermectin	**25%**	19.80%	Y	43.40%	Y	N/A	N	N/A	N	N/A	N	100.00%	Y
S14	30/07/2015		Moxidectin	**99%**	100.00%	Y	100.00%	Y	N/A	N	N/A	N	N/A	N	100.00%	Y
S15	31/07/2015	S1	Benzimidazoles	**0%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
S15	31/07/2015	S1	Levamisole	**49%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
S15	31/07/2015	S1	Ivermectin	**75%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
S15	31/07/2015	S1	Moxidectin	**96%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	N
S16	26/06/2015	S8	Benzimidazoles	**-22%**	24%	Y	-53%	Y	100%	N	100%	N	100%	N	100%	Y
S16	26/06/2015	S8	Levamisole	**67%**	75%	Y	61%	Y	100%	N	100%	N	100%	N	100%	Y
S16	26/06/2015	S8	Ivermectin	**70%**	100%	Y	50%	Y	100%	N	100%	N	100%	N	100%	Y
S16	26/06/2015	S8	Moxidectin	**89%**	100%	Y	82%	Y	100%	N	100%	N	100%	N	100%	Y
W4	16/06/2015		Benzimidazoles	**82%**	75%	Y	86%	Y	100%	N	100%	N	100%	N	100%	Y
W4	16/06/2015		Levamisole	**100%**	100%	Y	100%	Y	100%	N	100%	N	N/A	N	#N/A	Y
W4	16/06/2015		Ivermectin	**95%**	100%	Y	100%	Y	100%	N	100%	N	N/A	N	#N/A	Y
W4	16/06/2015		Moxidectin	**100%**	100%	Y	100%	Y	100%	N	100%	N	N/A	N	#N/A	Y
W12	31/07/2015		Benzimidazoles	**52%**	46%	Y	58%	Y	100%	N	100%	N	76%	N	100%	Y
W12	31/07/2015		Levamisole	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	N
W12	31/07/2015		Ivermectin	**97%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	Y
W12	31/07/2015		Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	N	N/A	N
W15	31/07/2015		Benzimidazoles	**88%**	79%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	N
W15	31/07/2015		Levamisole	**92%**	86%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	N
W15	31/07/2015		Ivermectin	**54%**	16%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	Y
W15	31/07/2015		Moxidectin	**98%**	100%	Y	100%	Y	N/A	N	N/A	N	100%	N	100%	N
Y2	2/07/2015		Benzimidazoles	**64%**	90%	Y	3%	Y	100%	N	100%	N	100%	N	100%	Y
Y2	2/07/2015		Levamisole	**93%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y

Farm Code	Date Tested	Original Code if Re-tested	Drench Type	**Strongyle Reduction %**	*Ostertagia/Telardorsagia*		*Trichostrongylus**		*Haemonchus*		*Cooperia*		*Other less pathogenic***		*Nematodirus*	
					Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity	Reduction %	Validity
Y2	2/07/2015		Ivermectin	**46%**	61%	Y	10%	Y	100%	N	100%	N	100%	N	100%	Y
Y2	2/07/2015		Moxidectin	**80%**	94%	Y	47%	Y	100%	N	100%	N	100%	N	100%	Y
Y3	31/07/2015		Benzimidazoles	**78%**	73.70%	N	80.60%	N	N/A	N	N/A	N	100%	N	100%	N
Y3	31/07/2015		Levamisole	**99%**	100%	Y	100%	N	N/A	N	N/A	N	100%	N	100%	Y
Y3	31/07/2015		Ivermectin	**98%**	100%	Y	100%	N	N/A	N	N/A	N	100%	N	N/A	N
Y3	31/07/2015		Moxidectin	**90%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	N/A	N
Y8	15/06/2015		Benzimidazoles	**-317%**	-594%	N	-198%	N	100%	N	100%	N	100%	N	99%	Y
Y8	15/06/2015		Levamisole	**63%**	75%	N	57%	Y	100%	N	100%	N	100%	N	100%	Y
Y8	15/06/2015		Ivermectin	**83%**	72%	N	88%	Y	100%	N	100%	N	100%	N	99%	Y
Y8	15/06/2015		Moxidectin	**95%**	100%	N	100%	Y	N/A	N	N/A	N	N/A	N	#N/A	Y
Y11	24/06/2015	Y1	Benzimidazoles	**50%**	10%	N	72%	Y	100%	N	100%	N	100%	N	100%	Y
Y11	24/06/2015	Y1	Levamisole	**63%**	54%	Y	67%	Y	100%	N	100%	N	100%	N	100%	Y
Y11	24/06/2015	Y1	Ivermectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	#N/A	Y
Y11	24/06/2015	Y1	Moxidectin	**97%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	#N/A	Y
Y12	25/06/2015	Y4	Benzimidazoles	**88%**	88%	Y	89%	Y	100%	N	100%	N	100%	N	98%	Y
Y12	25/06/2015	Y4	Levamisole	**43%**	34%	Y	53%	Y	100%	N	100%	N	100%	N	98%	Y
Y12	25/06/2015	Y4	Ivermectin	**72%**	75%	Y	69%	Y	100%	N	100%	N	100%	N	100%	Y
Y12	25/06/2015	Y4	Moxidectin	**93%**	94%	Y	92%	Y	100%	N	100%	N	100%	N	100%	Y
Y13	3/07/2015	Y6	Benzimidazoles	**-173%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	97%	Y
Y13	3/07/2015	Y6	Levamisole	**50%**	15%	Y	74%	Y	100%	N	100%	N	100%	N	100%	Y
Y13	3/07/2015	Y6	Ivermectin	**58%**	31%	Y	75%	Y	100%	N	100%	N	100%	N	100%	Y
Y13	3/07/2015	Y6	Moxidectin	**94%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	100%	Y
Y15	30/07/2015	Y9	Benzimidazoles	**67%**	59%	Y	73%	Y	N/A	N	N/A	N	N/A	N	99%	Y
Y15	30/07/2015	Y9	Levamisole	**78%**	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	UNKNOWN	N	99%	Y
Y15	30/07/2015	Y9	Ivermectin	**98%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y
Y15	30/07/2015	Y9	Moxidectin	**100%**	100%	Y	100%	Y	N/A	N	N/A	N	N/A	N	100%	Y

Please Note:

- The egg counts of each worm type are extrapolated from the larval culture results, this is an indicator of trends only, not an absolute result.
- * Ostertagia and Trichostrongylus results are combined for Autumn/Winter 2014
- **Other non-pathogenic include Chabertia, Oesophagotomum and Butosonun

Chart Codes

Reduction % Key: 95% and Above – Drench is effective against this species

90% - 94% (inclusive) – Resistance is developing against this species.

89% and below – Drench is NOT effective against this species as resistance has been confirmed

UNKNOWN: Larval culture failed so information on worm species cannot be determined.

Test Validity: Y = Pre-test worm species present at more than 50epg

N = Pre-test worm species present at less than 50epg

"Where a pre-test/pre-drench worm species is present at less than 50epg for that species – then no validity should be attributed to that result."

Source :www.wormwise.co.nz

DrenchSmart®

WAARD Project

Wales Against Anthelmintic Resistance Development

Prosiect CYYG

Cymru'n Ymladd Ymwrthedd Gwrthlyngyrol

S9: XXXX, XXXXXXXXX

Report

Report Date: April 2015

Contents

Techion Group Ltd TECHNOLOGY IN ACTION

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart®

Drench Summary

Drench Active	Quick Drench Selection	Species	Starting FEC	Percentage Reduction	Resistance Status	Test Confidence
Benzimidazoles (1BZ)	✗	Strongyle	990	28%	Resistance Confirmed	High
	NA	Nematodirus	0	NA	NA	NA
Levamisoles (2LV)	✗	Strongyle	1140	78%	Resistance Confirmed	High
	✓	Nematodirus	60	100%	No Resistance detected	Low
Ivermectin (3ML)	✗	Strongyle	1200	36%	Resistance Confirmed	High
	✓	Nematodirus	30	100%	No Resistance detected	Low
Moxidectin (3ML)	✗	Strongyle	1860	84%	Resistance Confirmed	High
	✓	Nematodirus	60	100%	No Resistance detected	Low

Availability Legend

✓ Available for Use – this active has not demonstrated resistance at this point in time. Adopt SCOPS* guidelines to maintain this status.

? Use Cautiously – this active may be developing resistance. Adoption of SCOPS* guidelines can maintain this as a useful group – seek advice.

✗ This active is not working effectively on this property. Advice required regarding the role for this group on the farm in the future

For more detailed explanations on drench use please refer to the recommendations section of this report

*SCOPS – Sustainable Control of Parasites in Sheep.

For the latest SCOPS guidelines please see the HCC Booklet – 'Are you winning the war on worms?' or visit the SCOPS website www.scops.org.uk

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart®

Results Interpretation and Recommendations

The interpretation and recommendations have been compiled by Eurion Thomas of Techion and Jim Hopkins, BVetMed MRCVS, Steffan Veterinary Services Ltd, Lampeter

Overall Summary

The results show that none of the wormers that were tested worked at full efficacy which is of real concern. However all is not lost, and the aim of this section is to firstly explain what the results mean but also an action plan of what you need to do to deal with the situation. By following these recommendations and working closely with your vet then you should be able to improve the control of parasites on your farm which should hopefully reflect in better stock performance. There are now only the two new wormer groups (4AD & 5 SI) which are fully effective on your farm, so the goal from now is to protect these two group from resistance development.

On the subject of performance you mentioned that your early lambing flock shows good performance but the fact that they are creep fed is likely to mask any worm issues. The later lambing flock where lambs are finished on grass alone are not performing satisfactorily, especially in wet seasons and it is highly likely that failure to control worms effectively is a large contributor to this drop in performance. Wet and warm periods are ideal situations for heavy parasite burdens on pasture and resistance is more likely to be reflected through poor performance during these periods. Even on the creep fed lambs inadequate worm control may be influencing feed conversion ratios and resulting in higher creep intakes and higher costs.

Which worms survived the treatment?

- Initial faecal egg counts for *Nematodirus* eggs were not adequate to get a meaningful result although the results do show a 100% kill but we can't rely on that. However there is no evidence of extensive resistance in *Nematodirus* worms in the UK so it's of less concern.
- The Day 1 larval culture showed the sheep had a mixed infection dominated by *Trichostrongylus* and also the presence of *Haemonchus, Cooperia,* and *Oesophagostomum /Chabertia*. The latter three worm species aren't important in sheep so we can ignore these.
- Of the important worms the good news is that *Haemonchus* (Barbers Pole Worm) is susceptible to all 4 wormers. This species is rarely found in West Wales but is obviously present so its good news that you can control it.
- For all four wormers the species that survived was *Trichostrongylus* and these are probably the most important and common worms in your area in the late summer and autumn.
- Because *Telodorsagia* was not present in the sample at all at the time of testing we can't determine the status for this species. *Telodorsagia* is an important and common species and tends to be present in spring and summer. If we carried out this test at those times we may get different results.

RECOMMENDATIONS

Adopting SCOPS guidelines (Sustainable Control of Parasites in Sheep)

The full SCOPS guidelines were given to you in the HCC Booklet – 'Are you winning the war on worms?' or otherwise visit the SCOPS website www.scops.org.uk

We will focus on 2 of the main guidelines here but please read the book for other important information.

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

Quarantine Treatments

One of the likely causes for resistance development across all 4 wormers is bringing the problem on to the farm through the purchase of store lambs. Although quarantine protocols have been tighter in the last year, historically this hasn't been the case.

All incoming stock should be:-

- Double treated with either 4AD (Zolvix) **OR** 5SI (Startect) **AND** Moxidectin (e.g. Cydectin / Zermex)
- Using Moxidectin in injectable form will also deal with any threat of scab
- Kept off pasture for 24 – 48 hrs
- Then turn out to 'dirty pastures'

FEC Monitoring

With limited choice of wormers available to you there is pressure that these aren't overused and targeting treatments to only when needed is essential to help prolong their use. Monitoring will be key to managing the situation.

Lambs:-

- FEC can be carried out from 6 weeks of age but be wary of Nematodirus issues for young lambs early in the season as Nematodirus can cause issues without being picked up on a FEC count.
- If decision is made to treat then you don't need to monitor that group for another 3 or 4 weeks (unless you are checking that the treatment has worked).
- If decision is made not to treat then another FEC test should be done in 10 to 14 days' time. Any longer and you may miss a significant burden that can cause performance loss.
- Each group of animals should be tested separately (where feasible) as each group will have different challenges based on age, litter size, grazing history.

Ewes:-

- The only time of year ewes may need worming is around the lambing period when a drop in the ewes immunity causes a rise in worm burden and egg output.
- The main reason for worming ewes at this time is to avoid contaminating the pasture.
- Getting the timing of this dose correct is important as we often don't worm at the most effective time.
- Not all your sheep succumb to the worm challenge as bad as others do and ewes in good condition and on a good diet are less affected.
- Monitoring FEC will help determine which groups of ewes need to be wormed and when that wormer is needed (if any at all).
- Avoid repeatedly using long acting wormers such as Moxidectin on ewes at this time of year.

When treating ewes or lambs try and leave at least 10% of the group untreated.

Which wormers to use?

When you have determined that you need to use a wormer what should you go for in light of these results?

Zolvix (4AD) and Startect (5SI)

- You will need to start integrating these two new wormer groups in to the worming plan for good parasite control
- But we also need to be wary of not over relying on them and developing resistance.
- Although they are more expensive than other wormers they will be more cost effective than cheaper wormers that don't work.
- Use on lambs in mid-season / autumn.

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

- Avoid using in ewes around lambing.

Levamisole and Moxidectin on their own

- Although there is clear resistance to these two, they still reduced egg counts by 78% and 84% respectively and you are likely to still see a clinical effect of using them.
- Using these occasionally will help reduce the pressure on the other wormers.
- However they will have a very short shelf life on the farm as every time they are used the resistance levels will increase (this is more so with Moxidectin due to its long acting nature).
- As these aren't 100% effective you could consider using when FEC show moderate worm burdens and used the other treatment options listed here when there is a considerable infection.
- **ALWAYS do a drench check** when you used these wormers to see how effective they actually were.
- The reductions with white drenches and Ivermectin were so poor that there is no value of using these with the exception of using white drench (1BZ) to control Nematodirus early in the season.

Using two wormers sequentially

- When we have 2 worms that have fairly good kill rates then we can use both of them together and we should be able to improve treatment efficacy close to that of the new wormers.
- In your case we would possibly look at using Levamisole (2LV) and Ivermectin (3ML) at the same time.
- Do not mix – administer both wormers separately.
- Using this on occasions will again relieve pressure on the new wormer classes and get good performance.
- Consider this treatment for any ewes you decide to treat in the spring.
- **ALWAYS do a drench check** when you use this sequential treatment to see how effective it actually was.

Avoid combination products

E.g. Fluke and worm or injectable scab treatment's that also treat roundworms:

- If Fluke control is needed then use a flukicide on its own.
- If Scab needs to be controlled consider dipping instead of injectable products.

Remember that we don't know for sure the resistance status for Telodorsagia so the tested wormer's COULD still be used early in the summer.

Grazing Management

New control strategies show that reducing the parasite burden on pasture is just as if not more effective than regular wormer treatments. Discuss with your vet / advisor on how you can use some of the following tools:-

- Contamination mapping. Use FEC data to help detect your worm 'hotspots' and avoid grazing with fat lambs.
- Reducing burden in the 'hotspots' – cross grazing with cattle / dry ewes in summer, reseeding, use of clover and novel forages such as chicory and plantain.
- Reducing contamination of pastures – Targeting spring ewe treatments, using sheep bred so they carry less worms.

It is recommended that a detailed 'Flock Health Plan', incorporating some of the above points is drafted in association with the local veterinarian.

We would also encourage you to discuss this with your animal health distributor (SQP) if you use one as they should be aware of the issues when they sell wormers to you in the future.

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

Appendix 1. General Information

Customer Details

Farmer Name:	XXXX
Phone:	XXXX
Fax:	
Email:	
Address:	XXXXXXXX

Collection Details

Farm Code:	S9
Day One Collection Date:	17.11.2014
Day 7 Collection Date:	24/11/2014
Day 14 Collection Date:	01/12/2014
Starting FEC:	660 epg
Age of Animals:	Lambs
Last Treatment Date:	
Drench Used:	

Contractor Details

Contractor Name:	Dr. Jim Hookins. BVetMed MRCVS, Steffan Veterinary Services Ltd.
Phone:	01570 422322
Mobile:	
Email:	Jim.Hopkins@Steffanvets.co.uk

Drench Selection

- Benzimidazole (1 BZ), Levamisole (2LV), Ivermectin (3ML), Moxidectin (3ML)

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

Appendix 2. DrenchSmart Protocol Information

Protocols

- Starting FEC must be a minimum of 500epg, although recommendation is levels of 700-800epg.
- A sensitivity of 30epg is used for all FEC tests
- All drenches used in trial are within the listed expiry period and batch numbers are provided
- A measured composite mob sample of 12 animals pre drench is used and then 12 individual samples post-drench.
- All treatments are administered orally
- All animals involved in the trial are ear tagged – no exceptions

Drench Resistance – A Definition

"Resistance is the heritable ability of the parasite to tolerate a normally effective dose of the anthelmintic."

Source: www.scops.org.uk

Detecting drench resistance

The test used to determine the drench resistance status for sheep drenches on your property is called a Faecal Egg Count Reduction Test (FECRT). This test is based around the fact that when parasites are first ingested by grazing animals, it will take 18 - 21 days before it is able to produce eggs and betray its presence. Put another way, if a fully effective drench treatment has been administered, the earliest we would expect to see eggs in faecal samples is 18 - 21 days later. If we drench accurately and see eggs in samples 7 or 14 days post-treatment (depending on which active is used), this is normally accepted as evidence that some worms have survived the treatment, i.e. the drench is not working properly.

FECRT tests are normally expressed as the percentage reduction in eggs counted between the pre and post-drench (7 or 14 days) periods. A treatment that is 100% successful would result in all worms being killed and egg counts at day 7 or 14 would be 0. In this case, the reduction would be 100%. In other words the higher the percentage (%) figure the better the drug is performing.

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart – Resistance Levels

Reduction %	*sistance Status*	Action
95% and Above	No Resistance Detected – treatment was fully effective	Adopt SCOPS guidelines to maintain this status.
90% - 94%	Resistance Suspected – Treatment less than fully effective. This result suggests that some resistant worms are present.	Adoption of SCOPS guidelines can maintain this as a useful group – seek advice.
89% and Below	Resistance Confirmed	Advice required regarding the role for this group on the farm in the future

General notes on testing for drench resistance

- Because sheep and cattle do not generally share the same worms, a drench type that is failing to control sheep worms may still work effectively on cattle worms. I.e. don't extrapolate sheep results to cattle and vice versa.

- There are many different parasite species on each farm and the mix of these species is likely to change through the season. Often when resistance is detected it is to an individual species only. By identifying the times of the year that the species is not present or stock classes the species does not affect, then the use of the drug may still be possible at these times.

- Because DrenchSmart tests work on measuring a percentage reduction, result accuracy is improved when we have a high starting FEC. If the starting FEC is less than 500 eggs per gram (epg) we need to be much more conservative when interpreting results. Sample size is also important. The more valid results we have the more confident we can be with our results.

- A combination of issues such as starting FEC, sample size and other factors are used to assign a level of test confidence.

Confidence Level	*erpretation*
HIGH	Can be very confident in results
MEDIUM	Results are good and unlikely to change if we re-tested
LOW	Would need to see a very poor reduction before resistance was declared with confidence. Results indicative only.

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

FECRT Limitations

1. The DrenchSmart protocol for the starting FEC is a minimum of 500epg, with a preferred starting FEC of 700-800epg. While all endeavors are made to have all animals involved with the evaluation at 500epg or higher, due to natural composite mob FEC distribution some animals or treatment groups may have FEC's lower than the optimal 500epg minimum. A starting FEC of 500epg or higher is required to be able to deliver the DrenchSmart Reduction Results with a high level of confidence.
2. A Larval Culture involves the hatching of parasite eggs in a sample to identify parasite species present. Intentions are to always identify species where resistance has occurred, however there can be difficulties involved with an egg hatching procedure. As a result it is not always possible to identify the species present.
3. Sample collection protocols and equipment have been designed to protect the sample from degradation during collection and transportation. Where equipment or procedures have not been followed, or events beyond the parties control occur, no responsibility can be taken for the sample quality prior to reaching the Techion Laboratory.
4. All results are based on the conditions and species present at the time of collection. This evaluation will produce a 'moment in time' interpretation. Recommendations are that regular monitoring be an integral part of an ongoing parasite management programme.
5. The views and interpretations expressed in the DrenchSmart Report are that of the WAARD Project Consortium and are not claimed to be the only interpretation.

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

Appendix 3. Data Records

DrenchSmart®

Pre-FECRT Larval Culture Results - Day One

STRONGYLE GROUP OF PARASITES					
Scientific Name	**Common Name**	**Site**	**Importance**	**Percentage Composition**	**Comments**
Haemonchus contortus	Barbers pole worm	Abomasum	Rare in Wales but important if present	23%	
Telodorsagia (Ostertagia) spp	Small brown stomach worm	Abomasum	Important in spring and summer	0	
Trichostrongylus axei	Stomach hair worm	Abomasum	Important in late summer and autumn	62%	
Trichostrongylus spp	Black scour worm	Small intestine	Important in late summer and autumn		
Cooperia spp	Small intestinal worm	Small intestine	Common in autumn but rarely important	5%	
Strongyloides papillosus	Threadworm	Small intestine	Common in autumn but rarely important		
Bunostomum trigonocephalum	Hookworm	Small intestine	Rarely important	5%	
Oesophagostomum / Chabertia	Nodule worm	Large intestine			
	Large mouth bowel worm	Large intestine			
Trichuris ovis	Whipworm	Large intestine			
Nematodirus	Thin neck intestinal worm	Small intestine	Important in early spring through autumn	5%	

Total %	100

Techion Group Ltd TECHNOLOGY IN ACTION

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart®

Species Resistance Summary Chart**

Parasite Species

	*Telodorsagia (Ostertagia) spp		*Trichostrongylus		*Haemonchus		Cooperia		Oesophagostomum / Chabertia		Other		*Nematodirus	
	Reduc %	Validity	Reduc %	Validity	Reduc %	Validity	Reduc %	Validity	Reduc %	Validity	Reduc %	Validity	Reduc %	Validity
Benzimidazoles (1 BZ)	N/A	N	-16.5	Y	100.0	Y	100.0	N	100.0	N			N/A	N
Levamisole (2 LV)	N/A	N	64.3	Y	100.0	Y	100.0	Y	100.0	Y			100.0	N
Ivermectin (3 ML)	N/A	N	-2.8	Y	100.0	Y	100.0	Y	100.0	Y			100.0	N
Moxidectin (3 ML)	N/A	N	74.0	Y	100.0	Y	100.0	Y	100.0	Y			100.0	N

* Species of most significance, ** Please Note: The egg counts of each worm type are extrapolated from the larval culture results, this is an indicator of trends only, not an absolute result. Nematodirus is not included in the main data table as its susceptibility or resistance is evident form the FEC data.

Chart Codes

Reduction % Key: 95% and Above – Drench is effective against this species

90% - 94% (inclusive) – Resistance is developing

89% and below – Drench is NOT effective against this species as resistance has been confirmed

Test Validity: Y = Pre-test worm species present at more than 50epg

N = Pre-test worm species present at less than 50epg

"Where a pre-test/pre-drench worm species is present at less than 50epg for that species – then no validity should be attributed to that result."

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart®

Source :www.wormwise.co.n

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart – Results

Drench tested: Benzimidizoles (1 BZ)

Day One Result

	Strongyle	Nematodirus	Total	EPG
G1	33	0	33	990

Starting Average FEC's:

Strongyle	Nematodirus
990	0

Day 14 Results

	Strongyle	Nematodirus	Total	EPG
G1	10	0	10	300
	20	0	20	600
	22	0	22	660
	12	0	12	360
	75	0	75	2250
	7	0	7	210
	45	1	46	1380
	46	0	46	1380
	27	0	27	810
	9	0	9	270
	11	0	11	330
	2	0	2	60
TOTAL	286	1	287	8610

Number of Day 14 Samples Collected: 12

**IMPORTANT That multiplier is changed to match the number of samples collected*

Day 14 Average FEC's:

Strongyle	Nematodirus	Total
715	3	717.50

REDUCTION PERCENTAGES:

Strongyle	Nematodirus	Combined Reduction percentage
28%	-150%	28%

Larval Culture Results - Day 14

Comments: 0

Species	*Reduction Percentage (%)*	*Valid Result*
Haemonchus	100.0	Y
Ostertagia /Teladorsagia	N/A	N
Trichostrongylus	-16.5	Y
Cooperia	100.0	N
Chabertia / Oesophagostomum	100.0	N
Other Nematodirus	N/A	N

DrenchSmart®

Drench tested: Levamisoles (2 LV)

Day One Result

	Strongyle	Nematodirus	Total	EPG
G1	38	2	40	1200

Starting Average FEC's:	Strongyle	Nematodirus
	1140	60

Day 7 Results

	Strongyle	Nematodirus	Total	EPG
G1	8	0	8	240
	33	0	33	990
	0	0	0	0
	5	0	5	150
	9	0	9	270
	7	0	7	210
	3	0	3	90
	1	0	1	30
	8	0	8	240
	16	0	16	480
	4	0	4	120
	7	0	7	210
TOTAL	101	0	101	3030

Number of Day 7 Samples Collected: 12

**IMPORTANT That multiplier is changed to match the number of samples collected*

Day 7 Average FEC's:	Strongyle	Nematodirus	Total
	253	0	252.50

REDUCTION PERCENTAGES:	Strongyle	Nematodirus	Combined Reduction percentage
	78%	100%	79%

Larval Culture Results - Day 7

Comments: 0

Species	*Reduction Percentage (%)*	*Valid Result*
Haemonchus	100.0	Y
Ostertagia/Teladorsagia	N/A	N
Trichostrongylus	64.3	Y
Cooperia	100.0	Y
Chabertia / Oesophagostomum	100.0	Y
Other	0.0	0.0
Nematodirus	100.0	N

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart – Results

DrenchSmart®

Drench tested: Ivermectin (3 ML)

Day One Result

	Strongyle	Nematodirus	Total	EPG
G1	40	1	41	1230

Starting Average FEC's:

Strongyle	Nematodirus
1200	30

Day 14 Results

	Strongyle	Nematodirus	Total	EPG
G1	12	0	12	360
	31	0	31	930
	39	0	39	1170
	5	0	5	150
	29	0	29	870
	15	0	15	450
	8	0	8	240
	89	0	89	2670
	8	0	8	240
	28	0	28	840
	15	0	15	450
	27	0	27	810
TOTAL	306	0	306	9180

Number of Day 14 Samples Collected: 12

**IMPORTANT That multiplier is changed to match the number of samples collected*

Day 14 Average FEC's:

Strongyle	Nematodirus	Total
765	0	765.00

REDUCTION PERCENTAGES:

Strongyle	Nematodirus	Combined Reduction percentage
36%	100%	38%

Larval Culture Results - Day 14

Comments: 0

Species	Reduction Percentage (%)	Valid Result
Haemonchus	100.0	Y
Ostertagia/Teladorsagia	N/A	N
Trichostrongylus	-2.8	Y
Cooperia	100.0	Y
Chabertia / Oesophagostomum	100.0	Y
Other	0.0	0
Nematodirus	100.0	N

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

Drench tested: Moxidectin (3 ML)

Day One Result

	Strongyle	Nematodirus	Total	EPG
G1	62	2	64	1920

Starting Average FEC's:

Strongyle	Nematodirus
1860	60

Day 14 Results

	Strongyle	Nematodirus	Total	EPG
G1	2	0	2	60
	8	0	8	240
	11	0	11	330
	5	0	5	150
	15	0	15	450
	10	0	10	300
	11	0	11	330
	1	0	1	30
	10	0	10	300
	7	0	7	210
	31	0	31	930
	9	0	9	270
TOTAL	120	0	120	3600

Number of Day 14 Samples Collected: 12

**IMPORTANT That multiplier is changed to match the number of samples collected*

Day 14 Average FEC's:

Strongyle	Nematodirus
300	0

Total
300.00

Combined Reduction percentage

REDUCTION PERCENTAGES:

Strongyle	Nematodirus
84%	100%

Combined Reduction percentage
84%

Larval Culture Results - Day 14

Comments: 0

Species	*Reduction Percentage (%)*	*Valid Result*
Haemonchus	100.0	Y
Ostertagia/Teladorsagia	N/A	N
Trichostrongylus	74.0	Y
Cooperia	100.0	Y
Chabertia / Oesophagostomum	100.0	Y
Other	0.0	0
Nematodirus	100.0	N

Techion Group Ltd TECHNOLOGY IN ACTION

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart®

Drench tested: Control

Day One Result

	Strongyle	Nematodirus	Total	EPG
G1	73	1	74	2220

Starting Average FEC's:

Strongyle	Nematodirus
2190	30

Day 14 Results

	Strongyle	Nematodirus	Total	EPG
G1	44	0	44	1320
	50	0	50	1500
	135	5	140	4200
	46	1	47	1410
	35	1	36	1080
	134	1	135	4050
	222	2	224	6720
	49	0	49	1470
	47	0	47	1410
	47	0	47	1410
	18	0	18	540
	56	1	57	1710
TOTAL	883	11	894	26820

Number of Day 14 Samples Collected: 12

**IMPORTANT That multiplier is changed to match the number of samples collected*

Day 14 Average FEC's:

Strongyle	Nematodirus	Total
2208	28	2235.00

REDUCTION PERCENTAGES:

Strongyle	Nematodirus	Combined Reduction percentage
-1%	8%	-1%

Techion Group Ltd
TECHNOLOGY IN ACTION

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited

DrenchSmart®

Appendix 4. Project Background

WAARD Project

Wales Against Anthelmintic Resistance Development

Prosiect CYYG

Cymru'n Ymladd Ymwrthedd Gwrthlyngyrol

This project into anthelmintic resistance in Wales is overseen by Hybu Cig Cymru – Meat Promotion Wales and funded by the Rural Development Plan for Wales. The project started in September 2014 and finishes in July 2015

The WAARD project consortium is managed by Techion Group and includes the following partners:

- Techion Group Ltd, Mr Eurion Thomas and Mr Greg Mirams
- Bristol University, Dr Eric Morgan and Dr Gerald Coles.
- Welsh Regional Veterinary Centre, Gelli Aur (WRVC), Dr. Neil Paton
- Steffan Veterinary Services Ltd, Lampeter
- Ystwyth Veterinary Practice Ltd, Aberystwyth
- Camlas Farm Vets LLP, Welshpool
- Wern Vets, Llanrwst
- Kate Hovers – Independent Veterinary Consultant

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
The European Agricultural Fund for Rural Development: Europe Investing in Rural Areas

Llywodraeth Cymru
Welsh Government

Cyllidwyd y prosiect hwn drwy Gynllun Datblygu Gwledig Cymru 2007 - 2013 a ariennir gan Lywodraeth Cymru a'r Undeb Ewropeaidd.

This project has received funding through the Rural Development Plan for Wales 2007 - 2013 which is funded by the Welsh Government and the European Union.

Techion Group Ltd
TECHNOLOGY IN ACTION

Disclaimer: The views and interpretations expressed in this report are that of Techion Group Limited. It is not claimed to be the only interpretation. Any questions in relation to the conclusions contained in this report can be directed to Techion Group Limited

© Techion Group Limited