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Anthelmintic resistance (AR):

Mitigation strategies to tackle current and future AR challenges learned from abroad.

By Perry Parkinson

1. Abstract

The overall aim of this trip to New Zealand was to gain a better understanding of not only the level at which resistance is present over there, but to understand how it got to that stage and how its currently affecting sheep farming. Speaking with the likes of Techion and New Zealand Beef & Lamb, you got a sense of the severity of the situation, especially when farmers are being faced with resistance even in triple drenches. The fact that a total of nine different anthelmintic combinations are currently being tested in the 2024 season is alarming to say the least.

The problems I investigated consisted of three main factors. One being the climate, the second being advice and the third and final one being the overall mindset of a lot of farmers. On one hand you have a lot of forward thinking farmers who are planting different cropping varieties and regularly faecal egg count (FEC) testing in order to try and reduce their worm burden and resistance levels, whereas on the other hand you've got the farmers who are using their triple wormers time and time again on the advice of their vets while still running high stocking densities on tired paddocks which have a huge build-up of resistant parasites present. New Zealand isn't that dissimilar to parts of the UK but climate is the ultimate difference. For the most part it provides the perfect habitat for parasites, especially haemonchus, which is why it's such a problem over there. With an ever-increasing climate, the UK is starting to see its fair share, which is worrying.

My overall understanding is it has never been more important for us farmers here in the UK to look at what happened over in New Zealand and learn from it. I've seen a rise in the number of farmers starting to at least recognise FEC testing as an almost normal part of the farming routine, however we have a long way to go before that's the case. Like I mentioned above, the overall mindset of farmers both here and across the world needs to become more aware of the future problems were inevitably going to face. White wormers (Group 1-BZ) being a perfect example, displaying just how quickly a once effective product can become almost useless due to resistance. We can also learn to adapt to our surroundings, and those surroundings being climate. We've proven already how versatile we are at working with the weather, we just need to learn how to recognise patterns and the problems that come along with it. If we start with this, the other management practices such as correct dosing weights, refugia, clean pasture and so on will follow, allowing for us to hopefully reduce the rate at which anthelmintic resistance progresses, while becoming more efficient at the same time.

2. Contents

3. Acknowledgements

Firstly, I'd like to thank Elanco UK for their help throughout the project. Initial discussions were useful to help set the scene and learn more about the status of the UK before embarking on my travels abroad. Colin Mckay – Elanco NZ - in particular helped by putting me in contact with a multitude of influential and immensely insightful people which all play a pivotal part in some way or other when it comes to researching or working alongside worm resistance in New Zealand.

Techion, both in the UK and New Zealand were also extremely helpful in adding to my initial research finding activities. They also helped me identify host farmers to visit both in the UK and in NZ to learn more about my chosen subject area. They also allowed me to come to their main offices and labs in Dunedin, South Island, meeting the team and showing me what goes on in the labs once my samples have been sent off into the cloud. Tracy Hutchinson of Techion for allowing me to stay with her family and introducing me to very switched on and progressive New Zealand farmers who are clearly making it one of their sole focuses to help try and reduce resistance levels in both the North and South Island.

Andrew Dowling of PGG Wrightson for putting me in contact with people, as well as taking the time to explain certain protocols.

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4. Introduction

Before we delve into the world of Anthelmintic resistance, we should be able to understand what it means. Anthelmintic resistance is the *"Heritable reduction in the sensitivity of a parasite population to the action of an anthelmintic"*[1]. Resistance is a problem within the UK sheep sector as it's been shown to result in significant production losses, as well as increased animal welfare issues. A project ran by Sainsburys and Techion showed that UK farms were losing an average of £12,037 through low weight gain due to receiving ineffective drench. NZ farms were losing an average of $74,974 in comparison due to higher stocking numbers[2].

With worm resistance becoming noticeably more prevalent here in the UK, it's important that we, as producers, act fast to help reduce the rate at which it increases. In 2014, Hybu Cig Cymru-meat promotion Wales, rolled out a project in which Anthelmintic Resistance levels in Wales were investigated[3]. This is one of the most recent and accurate research studies out there in the UK, which gives some alarming evidence. For a drench to be classed as ineffective or resistance present to that specific active, anything under 95% efficacy is classed as having resistance. In a very eye opening and not very surprising display of results, 94% of farms tested had resistance to Group 1 active 'Benzimidazoles'. Group 2 'Levamisole' was resistant on 68% of farms, with group 3 'Ivermectin' sat at 51% and surprisingly moxidectin at 19% despite being part of group 3 drenches.

A total of 34% farms that were tested had double resistance, with a following 28% having triple resistance. This displays how much pressure really has been put on anthelmintics on farms within the UK and how quick worm/anthelmintic resistance takes charge when given the chance.

If we then look at New Zealand, Techion are now testing nine combinations in the 2024 worm season . This puts it into perspective how bad worm resistance is becoming and why we need to be acting now to prevent the UK falling into the same position as New Zealand when it comes to anthelmintic resistance.

Table 1 is an example of a drench smart test carried out by Techion that shows the faecal egg count reduction (FECRT) of each test carried out.

[1] SCOPS (unknown). Chapter 3. Internal parasites & diseases. Section 3.2 Diseases. [Online]. Available at: https://www.scops.org.uk/workspace/pdfs/3-2-disease-presentations.pdf. Accessed 29th July 2024.
2 Sainsbury (2017). [Online]. Available at: Sainsburys-Report-2017-Final-V6.0.pdf (fecpakg2.com). Accessed 29th July 2024.

Table 1. The Techion Sainsburys project

Drench active	Percentage reduction
Benzimidazole (BZ)	74.7%
Levamisole (Lev)	67.8%
Combination (BZ & Lev)	82.6%
Abamectin (Aba)	79.1%
Moxidectin	84.9%
Combination (Lev & Aba)	80.8%
Combination (BZ, Lev & Aba)	87.0%

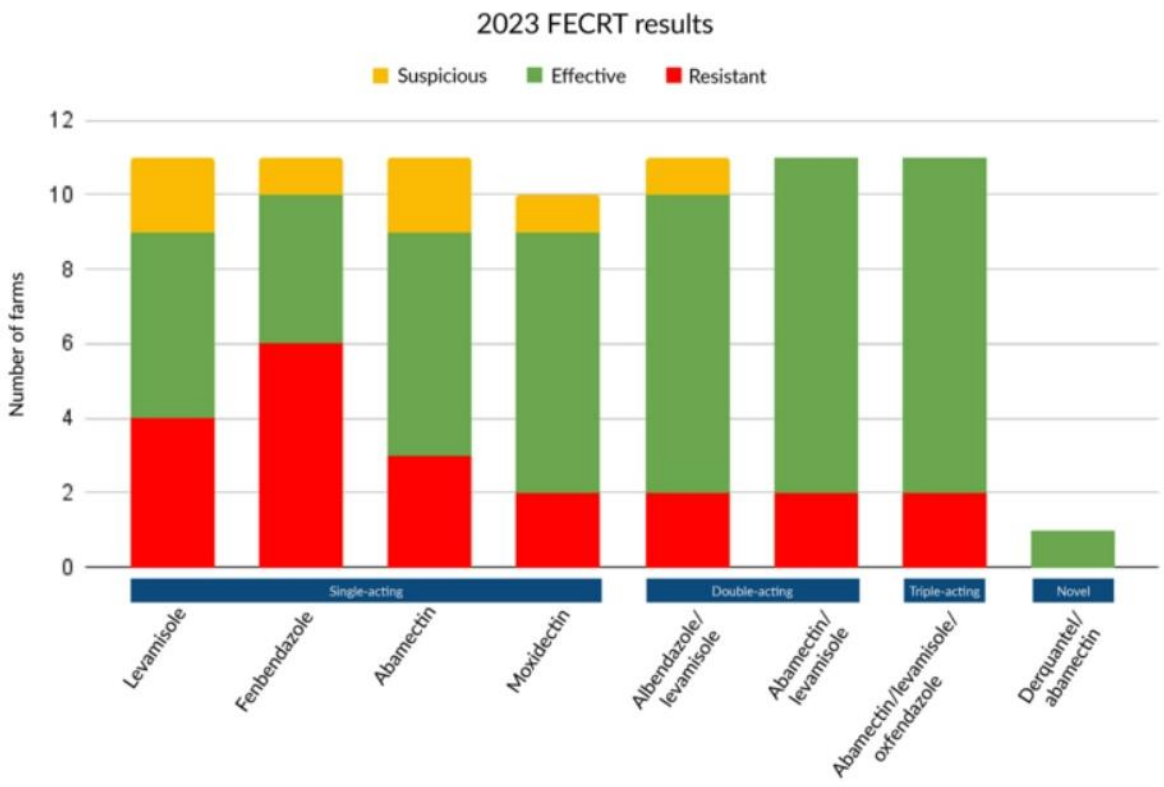
Table 1. shows seven different drenches including combinations used in this on farm test, giving an overall reduction percentage. Anything below 95% is deemed resistant, so in this instance, none of these seven drenches/combi-drenches are truly effective in killing worms within this flock.

The main aim of my project was to travel out to New Zealand to see for myself what worm resistance looks like and if it really is as bad as people say. Being directly in the field and having the opportunity to speak to farmers and industry leaders reiterated how much of a challenge they're up against. Advice seemed to differ quite significantly depending on who you spoke to which inevitably was quite challenging, not only for myself but for the farmers who are amid all of this. From vet groups giving out gift incentives, to old time farmers not believing in resistance, to advisory groups having different views on certain protocols, it seems like there's no set structure or plan for farmers to follow to help prevent resistance on their farm, which is evidently the biggest challenge they face.

Just like some farms here in the UK, a lot of stations were worming their lambs every 28-30 days, which seemed to be normal protocol for them. A lot of them were switching up the groups they were using, which was a positive sight, however with the frequency at which they're administering I couldn't help but think the rotation of drenches would be somewhat useless. Some farmers were using an orange (group 4-AD) wormer in the back end to help eradicate any resistant worms so there is some strategic minds out there, however a lot of farmers would be using an orange wormer in early spring when there wasn't as much of a burden due to the worm seasons only just starting. Unlike the UK, the only single active which is still sold is moxidectin, with double and triple combinations as well as novel being the 'go to' options. The reason for this is because of the higher efficacy provided by these drenches, with us here in the UK still being able to rely on some single actives to provide a high enough kill rate of worms to be classed as effective. ***Figure 1*** *shows a bar chart from Vet South, displaying the FECRT results from 12 farms in the South Island demonstrating the level of resistance detected against each single or combination drench, with Novel being the only one without resistance as of yet (see*

Figure 2). Alongside this, 88 drenches were tested, with a fail rate of 47% detected in single acting drenches, 33% in double and 11% in triples, which demonstrates why New Zealand is using these double and triple actives (see Figure 1).

Figure 1. Taken from Vet South (2023) displaying the FECRT results from different farms[4].



[4] VetSouth (2023). Triple drench resistance remains high. [Online]. Available at: https://www.vetsouth.co.nz/blog/post/105068/triple-drench-resistance-remains-high/. Accessed 10th April 2024.

Figure 2. Taken from Vet South (2023) showing efficacy of different drenches in New Zealand[4].

Drench type	Drench	Resistance	Suspicious	Effective	% Fail*
Single-acting	Levamisole	6	1	5	58%
	Fenbendazole	7	0	5	58%
	Moxidectin	2	2	5	44%
	Abamectin/ Ivomectin	3	0	9	25%
SINGLE-ACTING FAIL RATE = 47%					

Drench type	Drench	Resistance	Suspicious	Effective	% Fail*
Double-acting	Albendazole & Levamisole	4	0	8	33%
	Abamectin & Levamisole	4	0	8	33%
DOUBLE-ACTING FAIL RATE = 33%					

Drench type	Drench	Resistance	Suspicious	Effective	% Fail*
Triple-acting/ novel	Abamectin Levamisole Oxfendazole	2	0	9	17%
	Derquantel & Abamectin	0	0	6	0%
	Monepantel	0	0	2	0%
TRIPLE-ACTING/NOVEL FAIL RATE = 11%					

	Resistance	Suspicious	Effective	% Fail*
TOTAL: 88 drench checks	28	3	57	35%

As an overall comparison between New Zealand and the UK, I think most of the problem in New Zealand comes from the high stocking densities when compared with the UK. A lot of worm resistance we see in the UK comes from lowland finishing farms when compared with hill farms, running over thousands of acres which makes sense. The climate can be somewhat similar to ours here in the UK, as well as the mentality on worming and FECs. It's something that really needs to change and I fear that the UK will reach the same situation as New Zealand before farmers start taking note and action.

One thing that probably didn't help New Zealand was the bionic capsules, which seemed to be extremely popular across both islands until being banned in 2023. The bionic capsule was a combination capsule (bolus) containing both an anthelmintic as well as a mineral dose. It boasted a whopping 100-day protection window which helped sell the product. The major problem which arose with this product was irregular and sub-par levels of actual anthelmintic. which not only meant that worms weren't being adequately killed, but the level of resistance to that active increased due to the low levels of exposure the bolus provided to the worms. The other major implication of this irregular release was the inaccurate withdrawal periods provided for human consumption, which was evidently one of the biggest drivers to take it off the market. Therefore, you could argue that this helped increase anthelmintic resistant on specific farms, making it harder to eradicate or reduce in the future.

Because of the UK's small level of dependence on orange wormers, accessibility is still strong. But over in New Zealand, they went through a massive dry period where farmers and vets really struggled to get hold of the drug, meaning more pressure was put back on triples and purple wormers. Not only did farmers turn to more combinations and purple wormers they started incorporating organophosphates (OP) which is the chemical we use over in the UK to dip sheep. It's a product from Australia which is extremely potent, which will clearly come with its own problems with regards to sheep health, as well as human consumption worries.

5. The Study Research

By visiting New Zealand I aimed to learn more about coping strategies to the level of anthelmintic resistance being experienced. By understanding these management strategies and challenges to adoption/uptake I hoped to highlight the importance of UK farmers doing everything they can now to slow down anthelmintic resistance here.

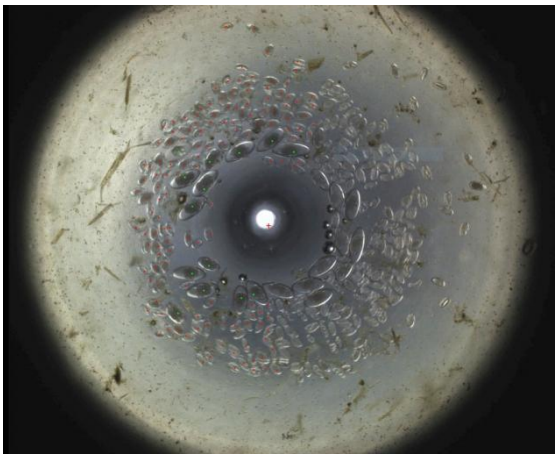
While in New Zealand I visited a the Techion laboratory and a range of farms, from studs to commercial farms, which were all practicing a wide range of worm management techniques, from breeding strategies, grazing management, FECs, FECRT's. I have summarised them as short case studies, highlighting the main area of learnings, both good and bad.

Case study one – Techion – Learning about the technology available: The first stop in my journey was with Techion, based in Dunedin, South Island. I was able to speak to staff as well as tour the laboratory where they aim to develop new and improved ways of testing egg counts and controlling parasites. This can be anything ranging from genotyping of worm eggs, testing of fluke, testing of coccidiosis, as well as using artificial intelligence (AI) to analyse customer samples. AI was used to analyse sample instead of people in the lab.

As it stands, their AI model can instantly detect egg counts of 700epg and above and send results across to clients in a couple of minutes, with staff in the lab doing counts under 700epg. It was interesting to also look back at how far Techion have come with their first ever test kit compared to now. It was a real testament to their dedication towards research. Once I'd been round the lab, Tracy McHutchon of Techion introduced me to a couple of farmers local to Tapanui, West Otago, South Island, who were actively aiming to reduce on-farm worm burdens and in their stock. Naturally it was lambs suffering the most with the high worm counts, however adult stock were also affected due to the level of resistance in the surrounding area. Upon gaining a better understanding of what technology was currently available, I visited a number of farms to understand what techniques were being adopted, if any, the problems or constraints they were facing on the ground and to get a better understanding of the overall opinion they have on managing parasites within their own flocks.

Figure 3 is an image from the FECPAKG2 showing a mass count of strongyle eggs, with nematodirus also present. This is a perfect representation of possible haemonchus with the extreme level of eggs present in the one sample.

Figure 3. Image showing a mass count of strongyle eggs, with nematodirus present (FECPAKG2)



Case study two – Wilden station – Not utilising monitoring effectively: One station, running 8,000 ewes, 2,100 hoggs and 325 cows was testing regularly with the aid of a FECPAKG2, which proved beneficial in the correct dosing times for his lamb's pre and post weaning. With extensively high ground, and a lot of it, rotational grazing as well as mixed livestock grazing was feasible, however no real crop other than grass was applied to help reduce or prevent upcoming worm burdens.

Pete Adam has been growing some winter crops for both cattle and lambs as a tool to help try and relieve grazing pressure but also finish the slower more smaller lambs on the farm. He typically grows 148 acres (60ha) of swedes, 86 acres (35ha) of kale as well as 40 acres (16ha) of fodder beet. From a management/welfare perspective, lambs are given a 5 in 1 vaccine for clostridial diseases as well as a wormer prior to turning onto the brassicas. He says that even though the crop is theoretically clean, the gullies still seem to pose a slight threat with higher worm burdens, which can't necessarily be avoided as such. Being up in the high country, climate played a big role in the establishment and utilisation of certain crops, making it more difficult to grow a herbal ley for example, when compared to lowland stations. They said they believed that testing regularly and staying ahead of the spikes was key to being able to help manage worms on farm. This doesn't necessarily help mitigate against resistance, however, creates a vast understanding of where each farm may be at and with the aid of field mapping, you can alternate adult stock or cattle onto higher burden pasture to 'clean up' allowing weaned lambs on to follow with less risk of parasite infections. Like most store/finishing lamb stations in New Zealand, regular dosing every 30 days was a common etiquette, however with the aid of regular FECs, even reducing this by one dose, would save a lot of time, money and effort which still doesn't seem attractive to most farmers.

Because of the high numbers of stock in the majority of New Zealand farms, a lot of sheep farmers have good, automated weighing systems. Unlike here in the UK, tracking growth rates didn't seem to be as common, nor popular, however when dealing with thousands upon thousands of lambs you can see how tracking weights would add to time constraints. Tracking lamb growth rates can be just as effective as FECs, allowing you to notice potential parasite problems before they cause too much damage. A worm or parasite within a lamb can reduce

growth rates by 50% before showing any symptoms which shows the need for weighing along side regular FEC tests. The general consensus is its easier to just gather the lambs in and drench them in case they have worms, instead of finding out whether that's the actual case. This is the mentality in both New Zealand and the UK, which is the biggest challenge we are facing right now. At least by carrying out a FECRT you can understand if you've got anthelmintic resistance on farm and if so, what active its resistant to.

Figure 4. Me and Peter Adam at Wilden station on a day tailing lambs.

Case study three – Viewfield, Waikoikoi, Otago - New Zealand – Using genetics and monitoring sucessfully: The second farm we visited was a family-owned farm, run by father and son. They were keeping around 3,000 Kelso ewes and, breeding their own replacements with the remainder going to a commercial tup for finishing lambs. The duo had tried every crop under the sun to help reduce their worm burden to no avail. By sticking with the same genetics over time combined with shifting stock and rotating grazing species (grazing lambs after cattle had been in) they seemed to reduce burdens. The most beneficial change they made on farm is by listening to monitoring technology providers when it comes to regular testing. This allowed them to not only track their FECs on farm but by carrying out combination reduction drench tests alongside to check the efficacy of the products typically being used has resulted in a more efficient parasite management - being able to detect what's working for them and what's not. This has saved them time, money and in essence, their stocks lives.

With the son now taking on the majority of the day-to-day activities, it was great to see how willing the father was in allowing his son to implement these methods, knowing that something had to change if they were going to be able to keep farming productively among this ever-growing threat of higher worm resistance.

Figure 5. View down the valley into the Cutha river.

Case study four – Will Duncan, Taihape, Rangitikei District of the North Island - Utilising FECRT: The third farm I visited was run by Will Duncan in Taihape in the Rangitikei district. Will was running 2,200 ewes and 600-700 replacements hoggs over 590 effective (grazeable) acres (420ha). The breed they're running on farm was Romney and the Kelso which, like mentioned above is a popular composite breed found on many farms in New Zealand. Previously, like a lot of farms in New Zealand, Will used to use the capsules designed to provide 100-day cover. Since the product ban Will has resorted to using combination drenches. From a drench management point of view, usually the season will start at docking time, with lambs around 3-4 weeks of age receiving their first dose of lamb first, a double active comprising of levamisole and praziquantel. Once dosed, it would generally follow suit that every 30 days the lambs will be dosed again. By weaning time, the lambs will have been drenched three times. Once drenched with lamb first for the first two drenches, he'll go onto a product called Switch, a triple active containing ivermectin, levamisole and praziquantel. For the fourth dose (30 days after the previous) they'll change to matrix, another triple active containing abamectin, levamisole and oxfendazole. As you can see, levamisole is a commonly occurring active within all these drenches, encouraging resistant worms. Ideally this wouldn't be used for the rest of the season to reduce the chance of those worms on farm becoming resistant to it.

Thankfully, due to Will's forward-thinking nature, he did a combination drench reduction test to find out how effective his drenches were. The five drenches they tested were three triple actives, startect (group 5SI - purple) and a control. These were matrix, boss, startect and a combination of all actives from the other drenches. They individually sampled 55 hoggs to be as accurate as possible. The results they received from the reduction test showed there was a 68% reduction rate across all three triple active drenches, and 100% effective reduction rates when using startect which was expected at the time due to its limited use in New Zealand at that point in time. Since then, Will has reduced worming down to only one drench pre weaning instead of three which is good, with triple drenches being used through the rest of the season

unless using exodus which is a single active containing moxidectin. This is used to treat for haemonchus (barbers pole worm) which doesn't tend to be too much of a problem on Will's farm thankfully. Drenching lambs at three to four weeks isn't going to be effective, with most lambs not really starting to eat grass (and risk ingesting parasite larva) until at least six weeks and more, which is why it's positive to see Will doing away with this practice. Before this change Will would have dosed his lambs nine times by the time they reached a year old, which just shows why there's a potential to have severe resistance.

Will's new routine is now once the lambs have had their first two drenches by January/February time, a FEC will be done 10 days post dosing to see if eggs are still present or not. If eggs are still present, they'll be drenched with a purple or orange wormer because of their 100% effectiveness on farm. This will get rid of all susceptible and resistant worms, allowing him to then go back in with matrix triple next time for the months of March and April. Another FEC will be done, and like before, a purple or orange wormer will be used to clear out resistant worms again before carrying on with triples until end of the season.

The last management tool Will utilises on his farm is using cattle within grazing rotations. He tends to mob stock high risk paddocks with steers to hoover up any worm eggs present to reduce the worm burden his ewes and lambs will ultimately face when entering specific paddocks. He admits there is more to learn and more he can be doing but is slowly starting to make positive changes.

In summary, the use of FECs and the combination reduction tests, allow him to make correct management decisions specific to his farm and his stock, allowing him to at least, for now, clear up and kill resistant worms. But, like he says himself, it's only a matter of time before worms become resistant to purple and orange wormers. Because he's limiting their uses to only twice a year, he's prolonging their efficacy, but this could ideally be dropped to once a year in the middle/back end of worm season if he was able to reduce the worm burdens lambs are facing from February onwards. Will is definitely on the right path and it just shows how beneficial having a forward-thinking attitude is.

Figure 6. Team of working essential dogs owned by William Duncan.

6. Discussion

I think UK farmers have a lot to learn from New Zealand, not only as a preventive measure to show us what will happen if we carry on the way we are, but to also to demonstrate the value of control, testing and monitoring methods such as FECRT and FECs, breeding against anthelmintic resistance and being able to farm more efficiently in conjunction with the alternating climate, while remaining productive.

The biggest eye opener for me while traveling was the nine combinations they're currently testing each season. The scary thing is this number has been increasing year on year with no real sign of them slowing down. With the introduction of both orange and purple wormers, it has taken the pressure off the ever popular double and triple combinations, yet as we carry out more FECRTS, we'll keep seeing that efficacy percentage depreciating. If you refer to **Table 1**, you'll see how the seven actives/combinations range in efficacy percentages, effectiveness essentially. This will vary on every farm and can be caused by attributes such as climate, historical drenching policies (for example the type of wormer used, how often it was used), pasture rotations, crops grazed and grown, mixed livestock grazing and so much more. I understand that in some respects we can't compare the UK to New Zealand because of the majority of their ground being high country and a good majority of UK sheep farmland being lowland with massive differences in stocking density, crops or quality of grass grown and number of farms adopting mixed stocking. But we can still use New Zealand to cherry pick ideas from when thinking about how we can better our farms and our stock by limiting the level of anthelmintic resistance we tolerate and help breed.

There are many things that can be done in New Zealand and here in the UK to help slow down resistance. In the UK were very lucky to have access to SCOPS (sustainable control of parasites in sheep), which provide principles designed to help slow down the development of worm resistance on UK sheep farms and offer best practice guidance on parasite control in sheep. The principles are based on three main drivers for resistance:

1. The frequency of which anthelmintics are used.
2. The efficacy of each treatment given.
3. The actual proportion of total worm population present at the time of treatment.

The four principles of SCOPS are:

1. Always make sure any parasite treatment you give is fully effective.
2. Reduce reliance on parasite treatment through management, monitoring and diagnosis.
3. Avoid bringing in resistant parasites by following a robust quarantine routine.
4. Minimise selection for parasites that are resistant to treatment.

These are simple steps, which if followed correctly can quickly give you a good chance of reducing both the risk and speed of which resistance may take hold on your farm.

Role of effective monitoring:

The biggest and most effective tool in the fight against resistance is faecal egg counts (FECs) and drench resistance tests. The fact there is now nine combination drenches being tested in New Zealand for the 2024 season shows you the severity of the problem compared to the UK who are thankfully still only using single actives, however startect (our group 5 purple wormer) recently coming onto the scene has now given farmers a chance to use a dual active. It begs the question whether we should be selling this to UK farmers only once they've done post reduction tests to prove their farm is in a vulnerable enough state to warrant the use of dual active anthelmintics. Like New Zealand, faecal egg testing is becoming more popular here in the UK in the last few years with many vet practices and merchants now supplying testing kits. In the UK companies such as Techion have invested in new technologies in this area rolling out the FECPACKG2, a micro imaging device, capable to taking digital microscopic images of a sample and sending it off to techs through the cloud, allowing for very quick result turnaround times, aiding in better and quicker management decisions to be made depending on results. Other companies such as Micron Agritech and Ovacyte have produced very similar products, with digital imaging also being at the forefront of their device. Parasight, yet again another similar product using flotation to then take digital images of the parasite eggs is used a bit more frequently over in New Zealand and Australia but is available in the USA also. Many vet practices will still use their own in-house staff and microscopes, using the standard 'McMaster' test but there is definitely a market for on farm testing and this is where the new generation technology in this area should help farmers get quicker, real-time results to aid improved management practices.

Regular FEC testing should be a common practice on every livestock farm. Winter isn't necessarily a high-risk period for worm burdens; however, we've seen firsthand how the more commonly known mild winters are bringing nematodirus back with it. Spring see's the start of the expected nematodirus hatches, which unfortunately coincide with lambs starting to consume larger quantities of grass, putting them at risk, especially when they haven't had previous exposure. A white wormer, although over 90% resistant to other worms, still is the most effective drench to use against nematodirus in lambs. By using FECs in conjunction with the SCOPS nematodirus forecast (a tool used to predict hatches based on weather readings), you're able to quickly build up a picture of the level of risk they pose on your farm at any given time. Field mapping is a great tool to build up using the data from your FECs. Because nematodirus and other worms hatch at different rates depending on the climate/temperature, certain fields may hatch earlier than others. By field mapping, you can over time, predict which fields will have the first or higher burdens, which you can graze with adult dry stock or cattle, 'hoovering' up a lot of the eggs, making it safer and more tolerable for naïve young lambs.

Selecting the appropriate treatment:

Another important step is selecting the right anthelmintic. Some anthelmintic products on the market are classed as narrow spectrum meaning they only target a specific parasite species, which, unless you've speciated/cultured the specific worm your stock is infected with, it may not be effective in clearing your burden up. Carrying out larval cultures in conjunction with FEC

tests or even FECRTs is the best way of being certain of what you're up against. Haemonchus or 'barbers pole worm' is a great example of this. With haemonchus being shown as a strongyle within FEC's, the only way you really know if you're up against it rather than a typical round worm is the rate at which it infects the animal. It's common to see counts in the thousands only a couple of weeks after a relatively low count. This is the only indication before the anaemic symptoms start to appear, followed by sudden death. This is a perfect example of why regular FEC testing is paramount, however larval cultures are the best way of determining this which will then allow you to apply the correct treatment. The problem with cultures is the fact they'll take 14 days to run. By day 14 after a high count, lambs will either be dead or severely slow going, causing animal welfare concerns, which no farmer ever wants, not to mention the rapid reduction in daily live weight gain.

Checking treatments are effective:

Checking to make sure you're using the correct treatment is paramount for not only effectively killing the worms which are present but also in making sure that you're not over using a certain active, indirectly increasing the chances of resistance or reducing the efficacy percentage which seems all too common on a lot of farms. A perfect example of this is nematodirus season. Although FEC tests shouldn't be the only deciding factor on when to dose for nematodirus due to adults already being present within the lamb for eggs to be visible, FEC testing allows you to see if strongyles are present also. This allows for a yellow or clear wormer to be used to target both worms instead of typically going in with your white wormer. Although white wormers are very effective in killing nematodirus, it will struggle to be effective against any existing strongyle worms. This may lead to a continued parasite burden affecting the daily live weigh gains of your lambs and further problems down the line.

The next step is equipment calibration. By calibrating your dosing gun and being 100% confident you're dosing your sheep with the correct quantity you're not running the risk of under dosing, which inevitably leads to worms becoming increasingly resistant to that specific active due to the mild exposure the worms will encounter.

Quarantining new animals and any incoming to the farm should be an unconscious effort, which a lot of farmers will be guilty of not doing. Not only is this essential in trying to prevent anthelmintic resistance being introduced to your farm, but other costly infections and diseases such as sheep scab, iceberg diseases, footrot, CODD and so on. With known widespread resistance to groups 1, 2 and 3, using an orange wormer is essential in being able to effectively clear out any worm burdens in incoming stock, whether they're resistant or not. Its highly advised that a FECRT is carried out post worming, however I'm aware it's not always so easy with space and time constraints often being common problems on farm. A FECRT or 'Faecal egg count reduction test' is a test in which individual samples are taken from random lambs or ewes, they're then given a specific anthelmintic i.e. white, yellow, clear and then tested again either seven days later (yellow group 2) or 14 days (any other wormer) to accurately get a clear percentage in reduction or efficacy, allowing the farmer to see if resistance is present on farm and if so, to what level.

When using wormers, you need to also think about preserving susceptible worms leading to two options:

1. Move and then dose: moving untreated sheep to a cleaner (low contamination) pasture a few days before treatment allowing them to contaminate the pasture with a susceptible (unselected) population of worms before being treated.
2. Dose, delay and then move: allows the treated flock to become 'lightly' reinfected before allowing them access to a low contamination (clean) pasture.

I always find it amazing how many farmers will worm all their stock and move them to a fresh and albeit clean field. Although this seems like the right thing to do, by dosing your animals and moving them straight away can increase anthelmintic resistance as the remaining worms expelled onto the new pasture are more likely to be resistant to the wormer just used. Adopting the dose, delay and move tactic – dose, put them back to the field they came from post worming, leave for 3-7 days and then move to a clean field – delays anthelmintic resistance. The problem we'll always be up against is ultimately spreading the resistant worms onto clean pasture. This is why we also need to preserve susceptible worms – known as 'refugia' - in the pasture for them to dilute resistant genetic in the worm population.

Education:

The second biggest tool we need to implement is education. It seems to be a never-ending battle trying to convince farmers of the benefits to testing. Whether it's because they don't feel they have the technical knowledge to understand or carry out the testing, whether its solely down to financial circumstances or just that old school mindset of we've never tested before so why start now. Thankfully in the UK we have suitably qualified persons (SQPs) and vets who will offer advice depending on your individual situation before selling wormers. This provides an easy alternative for farmers to go out and trust they're using the right product. However, without the right information, such as recent FECs, no one can be 100% certain they are suggesting the correct active to use to be fully effective. This is where your drench smart style tests and testing reduction percentage post drenching will come in handy. Looking at the data available in **Table 1**, you can see how this type of testing (and information) would allow a farmer and their adviser to make a well-informed decision on what active and therefore which product would be best to use to target the specific parasite challenge on that specific farm.

The biggest challenge I found out in New Zealand was not only the monumental level of resistance, but farmers loyalty to their vets and their advice. Unlike the UK, the vets out in New Zealand give annual freebies when purchasing drench. Hampers and big legs of ham are a common occurrence when it comes to purchasing 10L drums of wormer from vets in New Zealand. Not only this, but current advice across both North and South Island seems to be 'triple drench, then triple drench again 24 hours later'. You don't have to be a parasitologist to realise that something in that seems a bit unnecessary. Instead of this advice, why don't we look back to the FECRT tests I mentioned earlier. Surely, by carrying out FECRT tests, you'll be able to not only see what level of resistance you have on your own farm, but find out what you're actually resistant to, and what group wormer/active is going to give you the best chance of improving your stocks welfare and prevent the spread of resistant worms? A bit like us here

in Scotland, the climate is forever changing, with favourable conditions for worms such as nematodirus and haemonchus, being able to prevent or track them is proving more and more difficult. This is why being on top of your game not only with FEC testing, but correct grazing management and worming policies is paramount.

Like mentioned above, here in the UK we're really fortunate to have to likes of SCOPS, who provide excellent resources, through podcasts, seminars, worming principles, nematodirus forecast and much more. SCOPS work alongside the National sheep association and other leading bodies, ensure everyone in the UK is reading from the same handbook when it comes to the correct way to deal with worms on farm and know the correct procedures to take to help slow down resistance not only on their own farm but in the UK as a whole. The SCOPS nematodirus forecast is a great tool which I use myself every year. From my own experience I know how accurate and beneficial this tool is. By taking test results from vets and the likes of Techion, they're able to build up a real time picture of nematodirus in the UK, which generally see's it starting in the warmer south and slowly tracking its way up north through early spring. By watching this forecast, you get a sense of when you need to start FEC testing your lambs, being able to worm them accordingly depending on when nematodirus is present. Don't get me wrong, once you see eggs in your samples, the nematodirus is already present and working on your lambs growth rates, however if you're testing weekly and get that first 35EPG (eggs per gram) sample like I usually do, applying a group 1 white wormer soon nips that in the bud, allowing your lambs to carry on thriving before symptoms would most likely start to show.

Future strategies:

Reducing the dependency on anthelmintic usage is naturally the most effective strategy to utilise on farm. Between genetics, pasture-based selection and management, mixed stocking, grazing strategies, testing and so on, there are multiple ways in which we as farmers can prevent or certainly reduce the rate at which anthelmintic resistance develops on farm. Breeding will be at the forefront of these future strategies. By breeding a naturally more tolerant sheep who can deal with higher burdens of parasites, you're ultimately reducing the need for anthelmintics, therefore slowing down the rate at which anthelmintic resistance develops. Breeding management can be relatively simple, with replacement female lambs or ram lambs only being kept if they show they can deal with a certain level of worms, while still being able to perform, and the same being said for the dams. If an animal needs to be wormed in order for it to overcome a parasitic burden, have it as part of a 'B' flock, where a commercial sire will be used to breed fat lambs for the food chain instead of breeding replacements which will in turn come back into your system and aid in the acceleration of anthelmintic resistance. Tests such as the 'phenR' tests, carried out by Techion are a great way to supply buyers with a score alongside the estimated breeding value (EBV) in order for them to pretty much rank each sire from most naturally resistant to the least. This in itself is a great starting point for someone breeding their own replacements, however this isn't a quick fix and will easily come undone if other management practices aren't carried out in conjunction.

Secondly, grazing strategies for the future can be based off things such as reseed structures on farm. Having a set plan or rotation so there's always 'clean' pasture for susceptible young lambs

to graze on is a great way of ensuring you give them a good start. By FEC testing on a regular basis you can 'field map' your farm, allowing you to quickly build up a picture, season by season, of the fields which hatch out the likes of nematodirus the earliest, allowing you to avoid grazing young lambs until they've built up some natural immunity first. Grazing this off with hoggets or cattle is the best way to 'hoover' up some of the burden, making It safer for lambs. It'll expose them to nematodirus or other parasites but on a reduced scale, allowing them to naturally deal with them. The use of herbal leys is also another great way to combat anthelmintic resistance. Due to certain species of plant/grass having hairy stalks/stems, it stops the parasite from being able to climb up that specific plant and make its way up to grazing height where it would inevitably be ingested by its unsuspecting host. Taking stock off before grazing gets to 4cm in length reinforces this strategy[5]. By combining all of these grazing practices alongside the above breeding strategies, you stand a very good chance of being able to slow down the level at which resistance will develop on your farm and in your sheep.

Nutritional aspects come hand in hand with the grazing strategy also. The likes of chicory and bird foot trefoil have natural antiparasitic properties due to the condensed tannins and lactones which aid in minimising internal parasites within both sheep and goats[6].

Other parasites:

Like I've mentioned above in this report, there's a good number of parasites which cause welfare and management problems to sheep farmers across the world, with the big three being nematodirus, strongyles such as round worms and lastly, haemonchus concortus (barber's pole worm) mainly. Haemonchus is a massive problem over in both New Zealand and Australia, it is only really just starting to become more common or apparent in the UK. We've been lucky enough so far not to have to deal with this parasite on a large scale, however with increasing climate change challenges comes more problems, with haemonchus being one of them. With the blood sucking parasite thriving in warm and damp conditions, in the months leading up to autumn is generally when you'll come across it. With adults laying up to 5,000 eggs quite quickly, its common to find extremely high FEC counts when testing. Due to the parasite sitting in the abomasum and sucking the blood, animals can quickly start to deteriorate, with anaemia, bottle jaw and lethargic animals being common symptoms. Regular FEC testing throughout the worm season will help keep on top of potential outbreaks, with strict quarantine rules on farm being imperative. Dr Hannah Rose Vineer, from the University of Liverpool undertook a research study which showed that at 10 degrees an egg will take a month to reach infectious stage. At 15 degrees this decreases to only two weeks, with temperatures over 15 degrees showing a

[5] AHDB. (2023). [Online]. Available at: https://ahdb.org.uk/news/grazing-strategies-for-worm-control#:~:text=Maintain%20optimum%20sward%20heights%20and,move%20lambs%20onto%20post%2Dweaning. Accessed 27th July 2024.

[6] By Linda Coffey, Margo Hale, Tom Terrill, Jorge Mosjidis, Jim Miller, and Joan B. (2007). TOOLS FOR MANAGING INTERNAL PARASITES IN SMALL RUM. [Online]. NCAT. Available at: https://attra.ncat.org/publication/tools-for-managing-internal-parasites-in-small-ruminants-sericea-lespedeza/ [Accessed 9 June 2024].

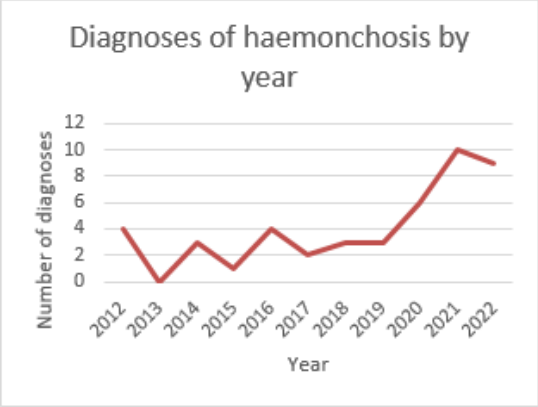
rapid change in egg to infectious stage only taking a week[7]. The problem we face with haemonchus is the fact that it can change its pattern and habits depending on the weather. When it faces adverse weather conditions it can take itself down into the soil where it can reside for a long time, almost hibernating, climbing back up into the grass when faced with more desirable conditions. Because it needs moisture to be passed out of the host via the dung, high worm counts are often found when rainfall has occurred after prolonged dry periods, making autumn the time of year when high counts may be more common. Like when dealing with the other parasites we've already mentioned, the same management practices apply, with regular FEC testing being at the forefront of this fight against parasites and being able to get ahead of it before it poses a larger threat to your stocks wellbeing.

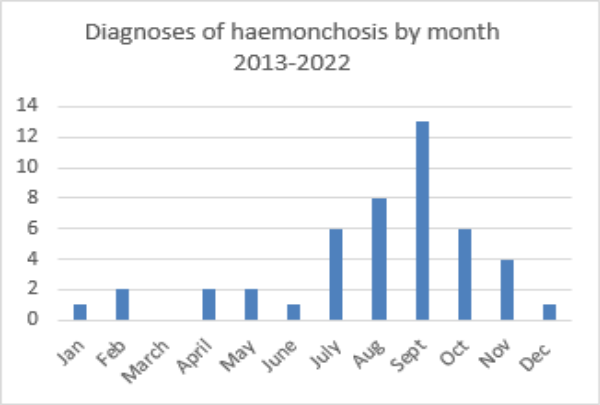
Of course, forever changing climate also poses a haemonchus threat in New Zealand, with barbers pole worm becoming more prevalent in the North Islands ever increasing drier climate. Here in the UK, we've even seen a multitude of cases in the south of England, with it slowly working its way up north which is worrying (**Figure 7**). The more farmers in the UK using FECs, the more we'll know about haemonchus and how prevalent it's really becoming here in the UK. Like I've mentioned already, to distinguish haemonchus over other strongyles we have to speciate, however the number of eggs present is the main indicator when using FECS.

Figure 7 is a graph published by SRUC which shows the slowly increasing rate at which positive haemonchus diagnosis are being made on Scottish holdings. A total of 46 cases have been recorded however the amount of haemonchus outbreaks that will go undiscovered will be drastic. Because we need to speciate in order to tell if we've been plagued with barbers pole or not, one of the main tell tail signs its haemonchus rather than round worm for example is the shear speed at which eggs hatch and become present within the animal. If we're regularly testing with counts under 300-450 and then all of a sudden we've got a count of thousands, you can be pretty sure it's the dreaded haemonchus. But use this alongside history and other clinical signs before making a decision. The reason this goes undetected is because we're lucky in the sense that most anthelmintic groups available to us will eliminate haemonchus. For all those farmers who are routinely worming their lambs every three weeks you might not ever notice it's there. That sounds like a positive however the downside is the more frequently we administer drenches the quicker that parasite will develop resistance to that anthelmintic so it really is swings and roundabouts. By utilising all the control methods above in conjunction with routine FEC testing, we'll be sure to be at a reduced risk of being hit hard by it.

Figure 7. SRUC veterinary blog – haemonchus diagnosis and burdens.

[7] Charlotte Cunningham. (2019). What is haemonchus and how to prevent and treat it. [Online]. Farmers weekly. Available at: https://www.fwi.co.uk/livestock/health-welfare/livestock-diseases/q-and-a-what-is-haemonchus-and-how-to-prevent-and-trea [Accessed 07/07/2024].





Other strongyles follow a similar type of pattern, mainly running its course from late spring through to winter, but depending on the area can vary massively. When most farmers talk or think about worms in sheep or lambs, its usually your typical strongyle. Invading the abomasum and/or intestines of grazing species, it doesn't take long for strongyles to start causing problems if left untreated. Unlike haemonchus, symptoms typically present in the form of weight loss, wool quality diminishing and dirty back ends. A lot less harsh compared with haemonchus some would say yet still just as devastating to an animal if left untreated. Strongyles are generally the worst parasite for anthelmintic resistance with them being so common and so exposed to worming and poor practices. At the start of the sheep season or spring as it were, lambs will tend to be hit with nematodirus first, then swiftly followed by strongyles such as roundworm.

Theres an age old debate between some sheep farmers and scientists which pose the question 'do you want to breed for resistance or resilience' to which I can quite easily see the argument for both. An animal who's in good condition should always be able to fight off worm burdens/parasites, however that can massively depend on the genetic makeup of that parasite, genetics of that animal as well as its surroundings – for example the crop its eating, the level of worm burden on that specific farm and so on. Genetics are by far one of the most valuable assets any sheep farmer can use or utilise if done properly however the problem with the resilience debate is the fact that yes, an animal can still thrive with over 300g per day with a count of 700egp however they're still going to be putting those eggs out onto the pasture which means you're always going to have a burden present. Having that burden present doesn't mean a lot for the ones that are thriving but you'll may have animals under stress/a poor immune system and year on year we see a change in climate, which can end up meaning a lack of winter feed, dry summers leading up to tupping time and so on meaning the overall condition of lambs and ewes on farm can be a lot poorer, thus allowing that 'high' burden you've allowed to reside in your swards to take hold and causes major upset in your stock. By breeding for both resilience as well as resistance and working them in conjunction with each other, as a sheep farmer you're going to have a lot less heart ache in the future. By having an animal that's naturally more resilient to parasites grazing on a farm with carefully thought out crop species and rotations, being managed by a shepherd who's routinely FEC testing and takes care while dosing, they should see a positive increase in average growth rates as well as over

all health and welfare of their sheep. Not only to mention the reduction in fly strike cases due to a reduction in soiled fleeces which is a whole other topic we could get into.

Overall, no matter what the worm or parasite , a lot of them will be following the same pattern throughout the season with some presenting earlier or later than others but all being able to be managed or eliminated through the same strategic principles laid out above. It's a mindset more than anything that's the starting block to reducing anthelmintic resistance on farm.

7. Conclusion

From when I first applied for this travel bursary, I knew exactly what I wanted to research, yet didn't know exactly what I'd find along the way. After carrying out regular FEC testing myself the three years leading up to this trip, I knew the power it gave me on farm when making certain management decisions for the better of my sheep. Because of these regular FEC tests, it allowed me to completely get away from using anthelmintics on half of my flock, providing me with fortnightly to monthly reports, showing that my sheep were in fact, managing just fine on their own without any anthelmintic intervention. Not only was this saving me time and money but gave me the confidence to carry on doing what I was doing, knowing that I was heading towards something great, while reducing the level of resistance along the way. Before going out to New Zealand, I'd heard plenty of horror stories which both scared and intrigued me at the same time. I personally know a lot of New Zealand farmers and there's not a single one that isn't extremely switched on and up to date with current anthelmintic resistance affairs. When I went out there, I was pleasantly surprised at how knowledgeable a lot of sheep farmers were on the matter, but not only that, how much they cared about what they were doing on their farm, trying to protect it for their future selves or their children. It wasn't a personal or greedy way of looking at it, it's for the good of New Zealand sheep farmers as a whole, not just for their individual business. The level of anthelmintic resistance out in New Zealand is quite frankly shocking. We've mentioned above the level of resistance they face and how many combinations they're now having to test in order to find an effective drench. The benefit to that is us Brits can look at that and use that as a focal point or evidence to show us what state the UK sheep farming sector will be in if we don't start acting on it now. Don't get me wrong, there's a lot of farmers in the UK who are regularly using FECs, however there are still a monumental amount that either don't know it exists or don't want to accept the fact that it's the new way of doing things. Between the likes of stud farms breeding for naturally immune or tolerant animals, to the number of grazing strategies sheep and cattle farmers are implementing on farm, to the number of farmers regularly FECs alongside target selective treatments, a lot of them are actively doing something in order to either try and slow down or prevent anthelmintic resistance from being a problem on their farm. New Zealand farmers have an extremely long battle ahead of them to try and slow the rate of resistance. The sad fact is resistance is there to stay. It's just a case of how much they can slow it down before they run out of truly effective anthelmintics. With resistance to group four already existing out in New Zealand, as well as over 30% of FECRT tested farms being resistant to triple actives, it really makes you realise how close they're coming to an almost unimaginable event.

For anyone who's been out to New Zealand, you will know how similar it is to some parts of the UK. This means the outcome can quite easily be the same when it comes to anthelmintic resistance. We're already seeing firsthand how the ever-changing climate is affecting sheep farming in the UK, from fly strike season almost being year-round, to nematodirus hatching months earlier, to haemonchus making its way up north and becoming a lot more common in general. Without all of the above strategies and protocols, it won't take long for the UK to be following in New Zealand's footsteps. From my personal experience and what I found both here in the UK and over in New

Zealand, a combination of FEs, correct grazing management, selective breeding and a general knowledge/knowhow on how to correctly administer anthelmintics is only going to work for us UK farmers, providing we actually care enough to do it in the first place. All of the strategies will be pointless if it falls on deaf ears, which a lot of it seems to be doing currently. There seems to be a requirement for nationwide teaching not only make farmers aware of the imposing threat facing our sheep, but to be able to show them how simple a couple of changes in management can be and how it can positively affect change within quite a short period. With the average age of UK farmers being 65, soon there will be an influx of the next generation of sheep farmers. With an influx of younger generational farmers slowly starting to take over the reins, this is a great opportunity to educate and put anthelmintic resistance is at the forefront of their minds, overcoming the attitude of 'I've always routinely used wormers, like my dad, grandad etc'. The sooner we change this out-dated attitude towards parasite control the better. Not all farmers can be tarred with the same brush though, I've met some great farmers from the older generations who are aware they need to change, or at least look into it which is a massive step in the right direction, and with money and labour becoming harder and harder to find, surely FEC sampling to potentially reduce that need is a positive, right?

Overall, I think the biggest take home from any of this research trip is the fact that farmers, whether they be here in the UK, over in New Zealand or anywhere in the world, need to face the fact that we have resistance. It's here and it's here to stay, unless we do something drastic about it. A lot of UK farmers may look at it as a problem the other side of the globe and we aren't going to get to that position. But we can use the situation in New Zealand as a tool in order to see what's going to happen to us over here in the UK if we don't change the way were dealing with parasites.

New Zealand is not past the point of no return in a sense that the only way they can really carry on farming productively and effectively is by utilising good management practices on farm, using diagnostic tests to monitor and test on farm and integrating breeding and genetics for resilience and resistance. Like I've mentioned time and time again throughout this report, it's the changing of a farmers mindset which is the biggest driver for change. The rate at which you could see improvements on your farm by adopting the principles and at least 'hearing us worm guys out' is massive.

All it takes is for a farmer to hold off dosing until he's ran a quick FEC sample and then see the benefits that brings and build from there. Yes, it may be a lot to change in the first year or two with regards to cropping choices, rotations etc, however if thought out properly it can all run holistically, making the transition a lot easier. It's not about one farmer being better than the other, which is a common challenge we face on a day to day basis, but all of us doing our part in slowing down resistance. A lot of UK farmers I speak to think its fine because someone will create a new wormer but that's not the

case unfortunately. New orange and purple wormers are a perfect example. They are great tools to use when needed, however we know only too well how easy it is to contract resistance. For a simple little worm, they're extremely good when it comes to evolving and adapting. Incentivising testing and monitoring parasites would increase the uptake of the diagnostic tools in our armoury. It's a sad reality that this is probably true, yet we need to do something before it's all too late.