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How can New Zealand sheep farmers survive drench resistance?

Kellogg Rural Leadership Programme

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I would like to thank the Kellogg Programme Investing Partners for their continued support.



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Executive Summary

Background: For generations New Zealand sheep farmers have been world leaders in the production of high-quality protein from pasture raised sheep, livestock raised with animal welfare at the forefront of their minds. For sheep to meet production targets, farmers have used anthelmintics (anti worm drench) for 60 years as a tool to control worms in sheep. However due to various management practices on farm, many drenches have lost effectiveness and now drench resistance is becoming more and more common on New Zealand farms.

Currently 27% of New Zealand sheep farmers have triple drench resistance. With only two more drench options on the market, being Zolvix and Startect, farmers are now at risk of developing resistances to these final options. Worldwide consumers demand sheep to be raised in a clean green environment with high animal welfare standards. It is critical that farmers use every tool possible to mitigate the risk of drench resistance and continue to farm sheep in a sustainable way while meeting consumer demands. As well as animal welfare and the threat to market concerns, drench resistance presents significant financial implications to farmers. Trial work has shown a 14% reduction in potential carcass weight for sheep experiencing drench resistance. For a property marketing 4000 lambs annually, this equates to a \$81,200 reduction in gross farm income from undetected drench resistance.

Methodology: The methodology comprises of a literature review to provide insight into the current state of drench resistance on sheep farming in New Zealand. This aimed to provide a clearer understanding of what drench resistance is, what causes it and what can be recommended to farmers to mitigate the risk or how farmers can farm with it. Semi structured interviews were used to gain insights and findings from farmers and industry professionals as to what causes drench resistance and what management practices can be used to mitigate the threat or to farm with it.

Findings:

- Generally, farmers don't invest their time into understanding drench resistance until they discover it, 90% of those interviewed didn't understand drench resistance until it occurred on farm.
- Regardless of farming system, topography and climatic challenges, there is many different management practices that can be used to mitigate the threat of developing drench resistance or to successfully farm with it.
- As drench resistance is a scientific area, a key finding was that farmers need multiple experts such as consultants and advisors involved in the business, although this can create inconsistent advice.

Recommendations:

1. Farmers must carry out FECRT, Pre and Post drench checks to identify current worm challenge and to assess efficacy of drench.
2. Farmers need to engage support into their farming businesses from external advisors who specialize in the field of drench resistance, ideally using more than one from different companies.
3. Farmers need to implement changes to their farming system where appropriate to enable a sustainable farming business.
4. Industry professionals must drive the movement of developing more effective on farm testing for faecal egg count reduction tests, larvae culture testing, and larvae level testing in pasture.

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1.0 Introduction

Over the last 60 years anthelmintic drenches have allowed sheep farmers in New Zealand to rapidly increase productivity while making continuous strides in animal welfare. However, with the increase in anthelmintic drench resistance, questions are now arising around the long-term sustainability of the industry and whether New Zealand can maintain its position as a world leader in sheep production (Leathwick et al., 2011).

Following the identification of resistance to single acting anthelmintic drenches, a dual combination was developed. When resistance to dual combination became an issue, a triple combination was developed. Currently 27% of sheep farmers in New Zealand have reported resistance to triple drenches (Scott. A., 2023). It is becoming clear the previous approach to simply drench out resistance is no longer viable. Currently there is no indication a new novel drench will be developed.

Anthelmintic resistance threatens the economic viability of the sector, as well as farmers ability to farm in an environmentally and ethically sustainable manner. Anthelmintic resistance affects a farm's productivity. Studies have shown that sheep resistant to drench can have a 14% reduction in carcass weight potential (Dowling, 2023). From an environmental perspective, the ideal sheep producer has a small carbon footprint, growing sheep quickly and without production limitation. Traditionally, anthelmintics were critical in the farmers toolkit. With the limiting efficacy of anthelmintics, new approaches are now required to address parasites. Finally, the day-to-day quality of life and health of livestock is affected. Studies have suggested that parasites contribute to mortality in malnourished sheep (Gulland, 2009).

New Zealand is a world leader in the export of mutton and lamb, currently exporting 94% of its product ("Beef and Lamb New Zealand", 2022). Given the economic significance of the industry, it's imperative that farmers continue to produce sheep meat to the standards demanded by increasingly conscious consumers. This is a complicated problem that needs to be faced head on. VetNews (2023) reported that only 15% of their clients have up to date knowledge of their drench status. This is even though half of faecal egg count reduction tests (FECRT's) carried out have indicated significant drench resistance (VetNews, 2023). It is more important than ever that farmers understand they can't manage this problem if they don't measure it.

This report is split into two parts and investigates the current practices that have driven drench resistance and how farmers can change systems to combat the threat of anthelmintic drench resistance while remaining viable. The first part will canvass the existing literature on this issue. Part two considers the views of farmers on the ground as well as industry professionals.

The findings from this report will help farmers and industry professionals consider how they can mitigate the impacts of drench resistance with examples of practical management tools for various farming systems and locations.

2.0 Literature review

2.1 Drench Resistance in Sheep in New Zealand: An overview.

Drench resistance is defined as a drench that is killing less than 95% of the parasites present (Hamilton, 2021). Anthelmintics have for many years provided farmers with a safe, cheap, and highly effective method of controlling parasite infection in grazing livestock (Heuer et al., 2006). Thanks to

the use of anthelmintics like Thiabendazole in 1964 and Levamisole in the 1970's farmers experienced significant increases in productivity.

These drenches at their inception eliminated parasites and produced significant livestock production gains such as lifting hogget weights in the autumn by 10kg. Previously 90% lambing from 45kg ewes was the norm but anthelmintic use lifted this to 129% from 56kg ewe in 2006. (Clark, 2008). From the 80's macrocyclic lactone drenches like Ivermectin were introduced. Ivermectin, Moxidectin and Abamectin forged a path for sheep farmers to control worms and it became common practices to drench sheep every month of the year. Robertson (2023), suggests that the three traditional ivermectin, moxidectin and abamectin drench families looked after farmers well for 40 years are now costing in on farm production as efficacy is dropping. Robertson (2023), also mentioned that "triple drench resistance in various shapes and forms is now commonplace".

Anthelmintic resistance was initially identified in New Zealand in 1979, and over the years, it has unfortunately become widespread. According to research by Leathwick (2001), it is now a prevalent issue, with over 50% of sheep farms in the country showing detectable levels of resistance to one or more chemical classes of anthelmintics. (Dodunski, 2023), pointed out that in 1995 when she was first working in a vet clinic, she found very little leakage when carrying out a 10 day drench check, indicating the drench was highly effective. Leakage is when drench used isn't 95% effective at removing worms from the sheep and therefore resistant worms leak from the sheep post drenching. This compared to 2021 "I see plenty of drench checks which contain a good sprinkling of positive counts". Latest national data from 2022 regarding drench resistance in sheep shows 48% of farms tested had resistance to *Trichostrongylus* worms when a triple drench was used in the North Island and 31% in the South Island (Riddy, 2022). Scott (2023), suggests that triple drench when used for controlling nematodes in sheep are not effective on 27% of New Zealand sheep farms. This is shown in the below table 1 where 20% of North Island farmers are experiencing triple drench resistance according to Gribbles Veterinary data from 2016/2017.

Considerable effort has been invested in understanding management practices on and off farm which increase anthelmintic resistance and how these might be managed (Leathwick et al., 2011). Unfortunately, the uptake of management practices to mitigate the risk of drench resistance has been poor by farmers. (Miller et al., 2012), suggests that this is largely due to a lack of clear economic data illustrating the cost of drench resistance and the confusion around what constitutes resistance management. This article also explained that providing a general measure of the impact of anthelmintic resistance on animal productivity is difficult because there are invariably differences in all farming systems and animal genetics. Waghorn et al. (2006), described that the way in which anthelmintic drenches previously controlled parasitism from 1980 to 2006 contributed to the development of resistance. The journal (Waghorn et al., 2006) also mentioned that the level of resistance increased due to the use of long-acting controlled use capsules. This is due to capsules being slow releasing over 90-120 days period and therefore sheep only excrete out resistant worms over that period and create contaminated pastures of resistant worms.

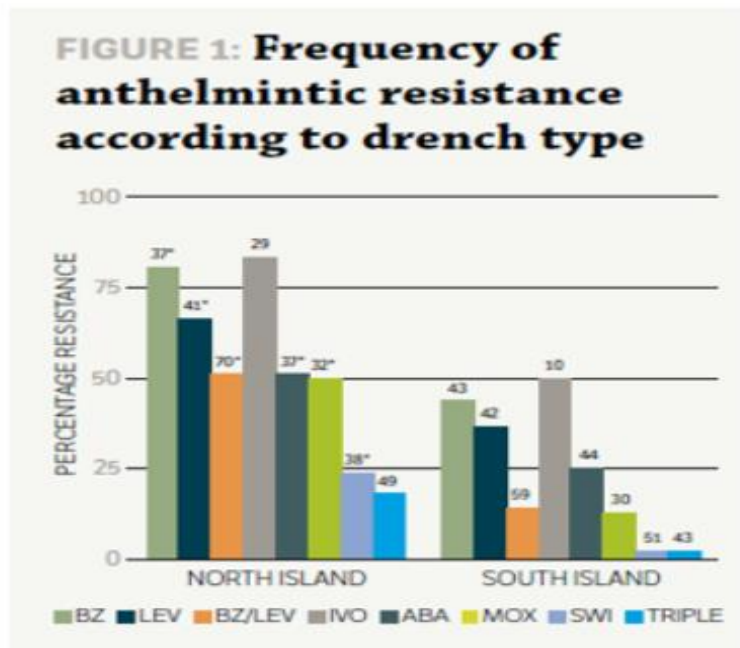


Figure 1: Frequency of Anthelmintic resistance according to drench type (2016-2017 national FECRT data. (Gribbles Veterinary Laboratories, 2021)

2.2 Implications: financial and production

Parasitism within sheep is a major limitation on sheep productivity worldwide (Sutherland et al., 2010). Using ineffective drenching comes at a large financial cost as production is estimated to drop by 33% (Lawrence et al. 2007). Trial work completed has shown there is potential to have a 14% loss in carcass weight potential in lambs over 4 months of age (Dowling, 2023) when sheep have triple drench resistance. The New Zealand average lamb carcass weight in 2020 was 19kg and the price per kg forecast for 2023 is \$7.60. (*Beef and Lamb*, 2021). This equates to 2.6kg carcass weight loss and \$19.75 less per lamb sold compared to the New Zealand average. This is a significant lost financial opportunity.

Another study, Miller et al. (2012), illustrated the financial impact when there was a reduction in carcass weight by 2.8kg, significant increase in dags, and a significant reduction in body condition score. A beef and lamb interview with Graham Fergus (*Beef and Lamb*, 2021) reports that when drench resistance was detected on his property liveweight gains per day decreased, and the number of days required to get his lambs to weight for processing increased. For Graham Fergus this means returns per kg of dry matter consumed decreased too. As a result, feed becomes significantly more expensive. This was further illustrated when Graham Fergus experienced a 34% increase in number of grazing days and 38% decrease in average liveweight of lambs over a three year period with drench resistance. This is shown in figure 3 below where those lambs treated DQL-ABA reached the target weight of 38kg's 17 days quicker than those lambs drenched with Albendazole. DQL-ABA which is Startect is a new quarantine drench whereas Albendazole is part of the early developed benzimidazoles Miller et al., 2012). The same journal (Miller et al. (2012), carried out their trial "The production cost of anthelmintic resistance in lambs". It found that using an ineffective drench on a proportion of the lambs had 9kg less liveweight gain per lamb compared to those who were treated with an effective drench. Figure 2 below shows that when DQL-ABA Startect was used on 50% of the sample, lambs had 100% drench effectiveness and the carcass weight of the lambs was 23.36kg. The

other 50% of the trial lambs were drenched with Albendazole Arrest HI. Mineral and had effectiveness of 70% and 30%. The carcass weight for these lambs was 18.64kg. This is a difference of 4.72kg carcass weight which is a significant production difference which drives financial performance. From a New Zealand farmers outlook Scott (2023), suggests that for a property producing 4000 lambs annually, undetected drench resistance could reduce gross farm income by an estimated \$81,200 per annum. The same article also explained that from a national perspective just under 18 million lambs were processed at the works for 2022/23 season. On these figures drench resistance could be costing New Zealand as much as \$98 million per annum.

Mean values for production and parasite factors for each treatment with their associated P values.

Parameter	DQL-ABA	Albendazole	P value
Mean faecal egg counts (epg)	199.4	660.0	0.001
Overall liveweight gain (kg)	25.43	16.43	0.001
Fleece weights (kg)	2.02	1.66	0.001
Carcass weight (kg)	23.36	18.64	0.001
Carcass value (NZ\$)	111.60	100.04	0.001
Fat depth (mm)	11.35	7.78	0.001
Condition score at 3rd treatment	2.7	2.3	0.026
Final condition score	3.41	2.44	0.001
Faecal soiling score at 3rd treatment	0.72	1.804	0.002
Final faecal soiling score	1.387	1.528	0.010

Figure 2: Sheep production values from two different anthelmintic treatments (Veterinary Parasitology, 2012).

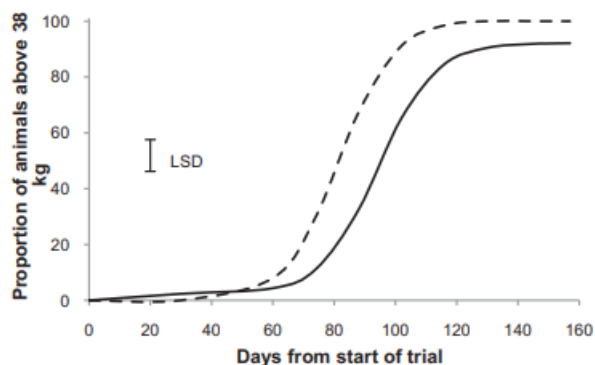


Figure 3: Numbers of days required for sheep required to get to the target weight of 38kg when two groups of lambs were given different anthelmintic treatments (Veterinary Parasitology, 2012).

2.3 Consumer expectations and animal welfare

Cecchini et al (2017) explained that consumer concerns about the environment are driving demand for sustainable food products with transparent production processes. In the context of New Zealand’s export market for sheep meat, it is critical that consumer markets such as China understand our “Clean green image”.

Tait et al., (2016) conducted studies on lamb and dairy product choices, assessing willingness to pay for environmental sustainability, animal welfare and food safety in these countries. The results revealed that although environmental sustainability is important, both Chinese and Indian consumers place a higher value on farm animal welfare and food safety. 53% of New Zealand export lamb was sold to China in the period from 2018-2022 (Shohet, 2023). On this basis it is important farmers maintain high animal welfare standards to meet consumer expectations, alongside sustainability and food safety considerations. Sheep that are carrying high numbers of parasites also produce less wool, less milk and poorer liveweight gains as a result of poorer feed intake and efficiency of feed intake (Grant et al., 2020). The same journal also mentioned aside from the production effects mentioned earlier, parasites also pose health and welfare concerns for sheep contributing to scouring (diarrhea), anemia, loss of body condition and, in severe untreated cases, death.

Figure 4 below illustrates sheep suffering from worm challenge compared to figure 5 which is healthy sheep grazing the hill country of New Zealand. Figure 5 illustrates the clean green image New Zealand farmers portray although the ongoing development of drench resistance could pose serious threat to New Zealand export market if livestock are suffering as in figure 3.



Figure 4: Sheep suffering from worm challenge with severe scouring/dags.



Figure 5: Healthy sheep happily grazing on New Zealand pasture.

2.4 International case study: Comparing drench resistance in the United Kingdom to New Zealand

A farm survey of 600 sheep farmers was completed in Great Britain and Ireland to gauge the levels of anthelmintic resistance and the control practices used (Morgan et al., 2012). Like New Zealand the United Kingdom is experiencing increased numbers of anthelmintic resistance in sheep.

According to McMahon et al (2013), 81% of farmers in Northern Ireland have experienced anthelmintic resistance to various treatment types. Bull et al. (2022) suggests that the amount of drench resistance found in flocks in Southern England in 2016 is significantly higher than it was in 2013. Keegan et al. (2017), made similar findings in Ireland where a sample of 10% of farmers had an efficiency rate of 50% when using anthelmintics to treat lambs.

The increase in drench resistance in the United Kingdom and Ireland is despite farmers being strongly advised to implement sustainable management practices of parasites (McMahon et al., 2013).

'Scops' (Sustainable Control of Parasites in Sheep) was formed in 2003 in the United Kingdom and Northern Ireland with the purpose of providing and promoting practical guidelines around sustainable anthelmintics use (McMahon et al., 2012). Similar to Wormwise in New Zealand. In the United Kingdom, like New Zealand, certain management practices have more negative impacts on drench efficacy than others. Morgan et al., (2012), explained that 93% of farmers surveyed routinely treat their sheep with anthelmintics and ewes are drenched on average 2.35 times per annum. 92% of farmers planned their own drenching strategies with only 7% using veterinary advice. The same survey showed that only 19% of farmers knew their drench efficacy as they had undertaken a recent FECRT although 51% believed they had fully effective anthelmintic drenches.

Like many other countries there is very little quantitative data published on how sheep farmers in Great Britain and Ireland can control anthelmintic resistance (Morgan et al., 2012). McMahon et al. (2013), suggests the following as appropriate management tools to farm with or prevent drench resistance:

- Appropriate dosing equipment calibration. Only 25.7% calibrate the equipment before treatment.
- Disciplined quarantine protocol. In particular post treatment, sheep should be held off feed for 24 - 48 hours.
- Having a proportion of sheep not treated (Refugia). Farmers surveyed who leave a proportion of ewes undrenched increased from 1.2% to 6.3% from 2005-2011.
- Co grazing sheep with cattle. This practice has increased 11.3% from 2005-2011 as cattle consume larvae on contaminated pastures.

2.5 Management tools

Various on farm management practices have been trialed and implemented on farms in New Zealand to minimize and farm with drench resistance. Pomroy (2006), suggests that management of anthelmintic resistance is a complex issue with contradictions in the advice for farmers. A variety of approaches that do not include the use of anthelmintics have been suggested to assist with parasite control in sheep and cattle. Operational practices for managing anthelmintic resistance will almost certainly vary between countries and climatic zones, (Leathwick et al., 2011). Something effective on the East Coast of the North Island may be vastly different to that recommended in Central Otago. This journal explained that some farming practices are likely to be significantly more selective for anthelmintic resistance than others.

The following section will consider:

- The removal of high-risk drenching
- Faecal egg count reduction tests,
- The use of forage crops and new grass
- Cross grazing/Refugia, and
- Quarantine protocols.

2.5.1 Removing high risk drenching

Anthelmintic treatment of adult sheep around lambing has been a common practice in New Zealand for many years. In a study of 103 farmers, only 11 farms surveyed had not been using pre-lambing anthelmintic treatments in the proceeding 5 years (Lawrence et al., (2011). Modelling showed that an anthelmintic treatment administered to adult ewes at docking time could contribute to resistance as it created a pre-selected larval challenge to lambs and removed a source of refugia (Leathwick et al, 2011).

According to Leathwick et al. (2011), long-acting products can influence anthelmintic resistance through either head selection, tail selection or a combination of both. Head selection is the selective removal of worms present at the time of drenching. Tail selection occurs when the drugs continued activity prevents susceptible third stage larvae from establishing within the drenched animal. This has the negative effect of screening the population of worms for resistance. Robertson (2023), suggests that the mundane truth is that better fed ewes in better condition don't suffer the effects of parasitism the same. This finding suggests that well fed adult sheep can handle being exposed to parasites and continue to be productive.

2.5.2 Faecal Egg Count Reduction Tests (FECRT)

FECRT is a common tool to measure the efficacy of the anthelmintic being used. The test involves counting the quantity of strongylid eggs within fecal samples both prior to and after giving anthelmintic to sheep. By analyzing the results, it can determine the effectiveness of the drench based on the decrease strongylid eggs per gram after the treatment. This reduction percentage serves as an indicator of the susceptibility or resistance of the nematode population to a specific compound. If the reduction falls below 95%, it is indicative of a population of worms that displays resistance to the treatment.

“Turning around triple drench resistance is possible” (2021), explains that information generated from the FECRT informs the farmer about which drenches are working on their property. This is invaluable information. Having a FECRT means that for a lamb finisher buying lambs off the breeding farm, he can have confidence in what quarantine drench is required to be effective. In the same article Andrew Dowling said, “ineffective drenching costs money in lost production and time”.

2.5.3 Using forage crops & new grass

Farmers have relied on forage crops for generations for a number of different uses. In addition to breaking in soil, providing drought feed, and crops rotations, farmers are now turning their attention to the use of forage crops as a tool for managing worm larvae intake in sheep. Beef & Lamb New Zealand (2013) explained that feed crops with new grasses have a lower worm level. For forage crops the larvae can't climb up the stems and therefore when the sheep eat the forage, they aren't ingesting larvae at the same rate. Pomroy (2011) mentioned that many of the crops used for worm management have a growth form which is not conducive for infective larvae to be present for a sheep to ingest, which implies that certain forage crops allow little exposure of larvae to sheep.

Beef & Lamb New Zealand (2013) mention that 95% of the worm population live outside the sheep so utilizing crops and new grasses can be a management strategy to minimize lambs from ingesting contaminated larvae. Leathwick et al. (2011) explained that utilizing low contaminated pastures is an effective management tool that can be used to prevent anthelmintic resistance. Pasture contamination can be managed via pasture renewal or grazing with alternative stock. For example running cows behind trade lambs. Drought can also cause this to naturally occur.

This report suggested that the use of forage crops can have a positive effect on worm control as they minimize the exposure of vulnerable stock (generally lambs) to a parasite larvae challenge, resulting in a much slower rate of reinfection after drenching which drives significant production benefits (see figure 4). According to Mollan (1999), forages that contain condensed tannins (CT) such as Lotus and Sulla have been shown to increase growth rates in lambs with a high worm burden compared to lambs not eating forages containing CT, in the absence of anthelmintics. The report also found that lambs had significantly lower faecal egg counts and lower intestinal worm challenge when fed Sulla compared to the other trial lambs who were fed traditional forages without CT.

Effect of daily intake of *Ostertagia* larvae and anthelmintic on growth of young lambs (adapted from Coop et al 1982)

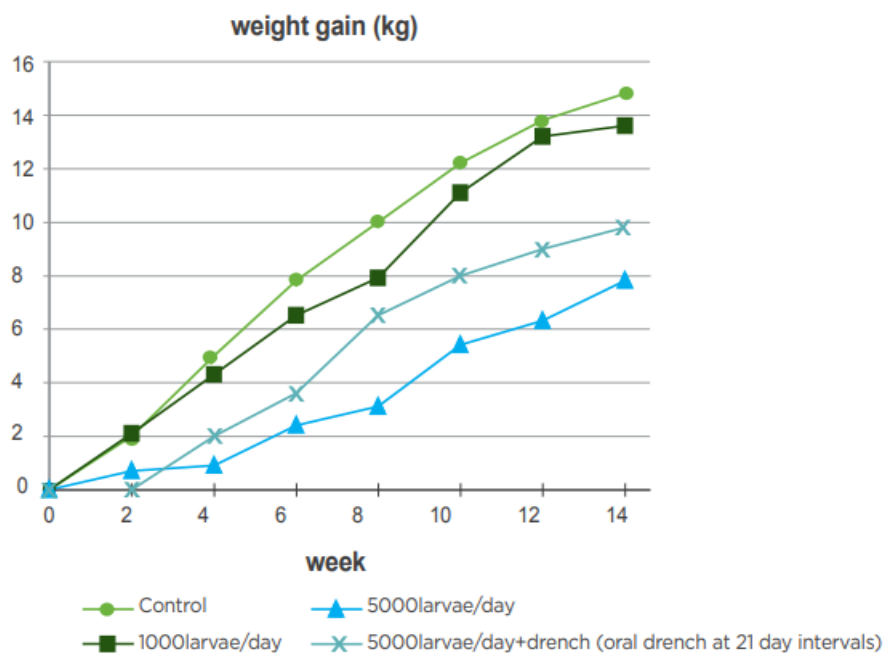


Figure 6: Effect of daily intake of *ostertagia* larvae and anthelmintic on growth of young lambs (Beef and Lamb, 2013).

Figure 6 provides an understanding from the lamb production point of view when comparing lambs that are experiencing a high level of worm challenge on contaminated pasture and those with a low worm burden. When lambs are fully controlled their weight gain is 15kg over 14 weeks. Those lambs experiencing 5000 larvae/day due to contaminated pasture have weight gains of 8kg over the same period of 14 weeks. This graph illustrated the value in having low contaminated pastures to boost lamb production.

2.5.4 Cross grazing/Refugia

Much of the focus on resistance to worms worldwide is on the retention of susceptible genotypes in refugia (Leathwick et al., (2011). Beef and Lamb New Zealand (2013) describes Refugia as the practice of ensuring there are susceptible worms inside the animal to reproduce, with the idea being that this creates a reservoir of non-resistant worms in the population base. This reservoir for susceptible larvae on the pasture would ideally outnumber the resistant larvae on the pasture. Then when the worms breed in the animal, the gene frequency for resistance will be diluted.

Kenyon et al. (2009), explains the same concept of maintaining a reservoir of susceptible worms on pasture, has been advised as one of the management tools to mitigate the risk of resistance. A common practice on New Zealand farms is to wean lambs at 80-120 days. Traditionally the lambs are then given the best feed available, while being run by themselves, in order to get them to saleable weights the quickest. As the lambs graze by themselves this runs a monoculture of young stock, which are normally treated with anthelmintics every 21-28 days. (Lawrence et al., 2011). Leathwick et al. (2011), suggested that this practice, i.e., grazing treated lambs and untreated ewes on separate parts over the summer and autumn, was likely to significantly accelerate the development of resistance on the area grazed by lambs. This is because under this management style you are removing the ewes to a separate area of the farm so there is no source of unselected parasites/refugia.

Beef and Lamb New Zealand (2013) advise there are different ways to achieving refugia. A few key practices are being used by some New Zealand farmers. For example, leaving all or part of the ewe flock undrenched, or to follow drenched lambs with undrenched ewes. A more recent suggestion for creating refugia is to leave a percentage of lambs un drenched at each drenching. Another way is to drench the mob and return them to the same infected pasture for a week or so before they go onto clean pasture. This ensures that susceptible worms have already been deposited on the pasture. This is very different approach as traditionally it was recommended to drench onto clean pastures.

Drafting undrenched tail end- two tooth ewes and grazing them with lambs has been chosen by farmers recently as a source of refugia. The two tooth benefit from better feed (without drenching) and no lambs need to be left undrenched to create refugia (Beef and Lamb, 2022). Hilson (n.d.) suggested this by providing refugia through ewes at weaning/shearing. Hilson adds 8-10% of ewes to each mob of lambs post weaning/shearing. He explains that this makes lamb mobs easier to move, rapidly improves ewe condition and hopefully provides significant refugia. According to Rural News (2021), Andrew Dowling suggests that maintaining a population of drench susceptible parasites is vital to the continued preservation of drench efficacy in any farmers system.

2.5.5 Quarantine Protocols

Farmers who purchase sheep off other farmers can control the entry of parasites to their properties by appropriately administering anthelmintics on entry to remove all worms. It is important for purchasers of sheep to know the status of the drench efficacy from who they are buying from. Pomroy (2011), found that data from a national survey showed that sheep bought from properties who did not know their drench status were highly likely to be carrying drench resistance. The same survey also found that, of those surveyed, 65% of farmers used quarantine drenching on arrival.

According to Leathwick et al. (2011) many sheep are purchased onto properties in New Zealand and worldwide that have no anthelmintic quarantine policy in place. This failure to adequately quarantine sheep when purchased is responsible for causing many farmers to acquire drench resistance. Pomroy

(2011) explained that although quarantine drenching has been recommended by industry professionals for several years, the levels of adoption has been slow. The similar practices are shown by Deuss (1991), who suggests that stopping the spread of resistant parasites from entering a property can be done with treating sheep with appropriate anthelmintics on entry.

3.0 Methodology and limitations

A range of opinions and perspectives have been canvassed using semi structured interviews with a group of farmers and industry professionals to gather data on a qualitative basis. Most existing data is historical. Six farmers were interviewed with five from the North Island and one from the South Island. These farmers operate a range of different farm systems, with varying size and topography. The interview questions (Appendix 10.1) varied depending on whether the farmers already had drench resistance or were actively preventing the risk.

It was important to understand the impact drench resistance has had on the farm financially and socially, and what risks are associated with it. It was equally important to understand which management practices have been implemented to navigate through or to avoid drench resistance depending on the drench status of the farm, and what the impact and feasibility of these management changes were.

In addition to the farmers, seven industry professionals were interviewed including vets, scientists, and farm consultants. This provided an understanding of drench resistance from outside the farm gate as well as an indication of whether levels of research and development in this space are appropriate and gauging where future research is required. Industry professionals were also able to shed light on farmers perceived knowledge of drench resistance, and how this could be further developed.

All farmer interviews were conducted online using Microsoft Teams which took 1.5 hours. Interviews were then analyzed using thematic analysis which is a method used for identifying, analyzing and describing themes within gathered data (Braun & Clarke, 2006). Following on from thematic analysis a mind map (Figure 7) has been developed to show the themes derived from the interviews. Key themes were compared, contrasted, and evaluated which has allowed recommendations for industry to be formed.

4.0 Limitations

The six farmers who were willing to be interviewed generally only represented one side of the industry. All farmers interviewed were highly driven, innovative, and aware so this does not represent the whole of the industry. Also, both farmer and professional interviewees had limited financial data on the impact of drench resistance. Literature reviewed had limitations as finding data from studies was limited certainly in the space of animal welfare impacts and financial impacts of drench resistance.

5.0 Key Themes

5.1 Interview Mind Map



Figure 7: Key themes arising in relation to drench resistance taken from interviews.

Key themes were derived from conducting interviews with farmers and industry professionals. Although I interviewed farmers with different farming practices, locations and climate challenges, there was common themes drawn from them. Industry professionals were also interviewed which was a mixture of vets, consultants, and anthelmintic suppliers. Like farmers there was common themes taken from the interview process.

Common responses and themes from interviews.

- “My stock all looked good, so I didn’t think I had drench resistance until this one day”.
- There is a lack of understanding of what drench resistance is by farmers.
- Conflicting advice from different anthelmintics companies.
- Vets have had a significant role in the development of drench resistance in New Zealand.
- There is a lack of technology for carrying out larvae testing on pasture quickly and efficiently.
- Quicker and easier FECRT testing technology needed.
- Farmers don’t take drench resistance seriously until they discover it.
- A full farm system change is not required although changes to aspects of the farm is crucial.
- Farmers generally assign poor sheep production to factors such as grass type, weather, wool length rather than towards efficacy of anthelmintics.
- Monoculture systems are the most at risk.
- Multiple easily incorporated practices available for farmers to use.

5.2 Six key themes taken from Interviews.

Through the interview process, six key themes became apparent:

- Industry advice is inconsistent.
- Making change is crucial but a slow approach is most effective for long term sustainability.
- Opportunities for change are available but uptake on advice is poor.
- A variety of management practices are available for all farmers regardless of topography and climate.
- A lack of data around financial implications of drench resistance is clear.
- There are questions around the efficiency of FECRTs

5.2.1 Industry advice is inconsistent.

Farmers have been using anthelmintics as a way of controlling worms in sheep for 60 years. All farmers interviewed purchased anthelmintics from vet clinics or rural supply businesses such as Farmlands. It was clear that farmers put their trust in veterinary and technical field reps to advise what anthelmintics are best suited for their situation. All of those interviewed had expert reps involved in their business and it was common that there was more than one. Anthelmintics is a very broad and difficult topic where research is ongoing.

From the interviews conducted it was clear that there is no silver bullet for anthelmintic drench resistance. As a result, advice can be inconsistent between anthelmintics suppliers, and even more concerningly within them. This was a source of significant frustration for those interviewed, and a consistent theme. A common response was that advice “depends what colored shirt they have on”.

Respondents noted that it is important to understand that anthelmintic suppliers are sales driven. As a result, advice is not always genuine and ulterior motives are common.

Some of the key areas that farmers found to be particularly inconsistent were:

- **Pre lamb ewe treatments.** A common response was that capsules were recommended from one anthelmintic supplier due to proven data of higher lamb weaning weights and lambs that don't have dags. However another vet would recommend that ewes do not need a pre lamb treatment and that the use of capsules speeds up the risk of drench resistance. Farmers are in business for a multitude of reasons, but economic drivers are often high on the priority list so therefore decisions are often made around financial reward such as capsule use.
- **Quarantine practice.** Another common theme was the inconsistency in advice around how long lambs should be housed off feed for post quarantine drenching. Some farmers surveyed have been told to quarantine for 24 hours, others have been advised 48 hours, and one recommended at 72 hours. Some received feedback that 95% of worms will have exited the sheep at 48 hours whereas another was told 72 hours is required to have 95% clean out. To quote one farmer *"I was told it takes 72 hours by one vet and another 24 hours, but that long becomes an animal welfare problem so 24 is what I go with."* With quarantine practices playing a vital role in intercepting resistant worms from entering a property, the various responses showed not only a clear inconsistency in advice, but also the rationale behind it.
- **Knowing when to drench.** Various farmers mentioned their trigger point for drenching varied from season to season. The key theme is that they were all different. Some drenched at FECRT's of 80 and higher, another at 200 and one was just told every 28 days. It is important to note that at different times of the year, different weighted sheep and different aged sheep can be left undrenched at higher FECRT results. Although the above trigger point numbers were from farmers who all ran the same system which is winter lamb finishing.

"I go every 28 days since it's been bloody wet, and the vet said keep on top of them". Farmer
"Not sure why 200, just what the vet said when I dropped in FEC's last week". Farmer

5.2.2 Making change is crucial but a slow approach is most effective for long term sustainability.

When a farmer has identified drench resistance or wants to eliminate the threat, it is a clear theme that making changes to farm management and policies is crucial. All farmers and industry professionals interviewed were very clear that a slow approach is the best approach. Many of those interviewed who had farmed with drench resistance explained that they tried to change too much too quick, to their detriment.

It was clear that farmers and industry professionals perceived that drastic decision making can create major unrest with all involved in the farm and can also have significant financial implications. It was clear in the interviews that not only do a lot of decisions need to be made over time but with the right people around you.

“You’re very vulnerable, you don’t need to change everything overnight”. Farmer

“Tried to change everything too quick at the start, made changes that worked with the system, but it took years”. Farmer

“Discovering drench resistance is a shot across the bows, changes are absolutely required but not everything and not by yesterday”. Industry Professional

“Best response is a slow response”. Industry Professional

“Get the little wins first, start by adding a few ewes with finishing lambs this summer for refugia. Next year we’ll try removing capsules from the old ewes and hopefully in two years no ewes get anything”. Industry Professional

“My client went against what his rep suggested which was scare mongering him, and as it transpired, we made the right call to not overreact”. Industry Professional.

From the above responses from interviews, it became clear that those interviewed recommended that a slow approach is the most effective approach.

5.2.3 Opportunities for change are available but uptake on advice is poor.

Of the farmers who have experienced drench resistance, none of them had measures in place to mitigate the risk and have only made changes since discovering the resistance. It is a common theme that farmers only make changes once they have discovered drench resistance. Industry professionals commented that very few of their clients are actively mitigating risk, and that much of their time is spent working with affected farmers. So why do farmers not actively mitigate the threat? Those surveyed alluded to blaming poor livestock performance on everything except worms, such as feed quality, facial eczema, bad batch of lambs etc. One industry professional mentioned that many farmers have had a touch of drench resistance for many years simmering away leading to production slowly dropping.

“If your sheep are killing out at 10-14% less of the carcass weight potential but you have never experienced receiving the 10-14%, you never know what its like to have the extra money in the bank. As you’ve never had it you don’t consider there being a problem and wait until there’s a train wreck when drench efficacy drops below 50%”. Industry Professional.

“farmers judge on what they can see, you can’t tell you have drench resistance until drench is less than 50% effective, there are so many out there with the writing on the wall”. Industry Professional

“I normally get a wound up farmer when the lambs are dying, reality is I have been harping on to him for three years that his system is unsustainable’. Industry Professional.

Extension work has been present in the drench resistance space for many years. An example of this is Wormwise which is a solely funded program through Beef and Lamb New Zealand which provides farmers with the latest tools to minimize drench resistance. Of those farmers interviewed there was a clear theme that although they had heard of work being done by Beef and Lamb, it wasn’t until drench resistance was present that the use of resources like Wormwise were utilised.

“It annoys me that stuff like Wormwise isn’t in your face as much because once I went looking there was definitely stuff that would have helped me avoid this mess”. Farmer

“As a levy payer and have been for 30 years I am quite cynical with industry bodies, this has been talked about for years becoming the problem but what have they done about it”. Farmer

While interviewing two rural professionals from within a levy paying organization it was explained that their allocation of resources towards research and development and farmer extension is driven by levy payer’s needs.

“Research and development basically are driven by where our levy payers tell us we need to sort something”. Industry Professional.

“It’s really only been in the last five years that drench resistance has been brought up and we have been asked to do anything about it, this probably shows its getting serious but is disappointing that Wormwise has been going since 2005 but hasn’t flowed through to farmers until more recently”. Industry Professional.

5.2.4 A variety of management practices are available for all farmers regardless of topography and climate.

Every interview I conducted emphasized the need for change regarding farm management practices. It must be noted that the interviewed were from various locations in New Zealand, various on farm systems, from intensive lamb finishing to hill country breeding properties, those who farm with high sheep to cattle ratio’s, and those with very few cattle integrated, those in high rainfall areas and those in low. One farmer interviewed in a finishing system said “you need to earn the right to farm winter lambs”. What he was alluding to is that to continue operating your system you need to be disciplined with worm management and have the right protocols set up. It is important to mention that although all farmers had similar themes, they all have different drivers for their business and different passions which effected what changes they implemented.

Farmer interviews brought out key themes regarding what management practices have been utilised, all of which required some change but none of which came with significant burden or significant financial expense.

- **Lamb days (number of days lamb are on farm).** All farmers interviewed had a clear and disciplined approach to minimizing the number of days lambs were on farm. The consensus was that lambs needed to be grown as fast as possible and have the least drenches as possible, thus reducing the risk of resistant worms contaminating the pastures.

“Lamb arrives from wherever and get Zolvix, that’s the only drench they get and are gone in 40-50 days, I buy heavier lambs so I can do this. Works well as the farms never getting contaminated. Shepherd loves it too as our drenching have dropped hugely from our old system”. Farmer, Finishing.

“We sell every store lamb produced at weaning in the first week of November, it allows us to take advantage of the strong early store market but also mitigates the risk of potentially holding lambs for

months that require far too many drenches, the problem becomes someone else's". Farmer, Breeder and Finisher.

"If lambs are carried late we still make sure everything is gone by 1st April, as we only lamb in October our lambs are late born. I reckon if they're gone by April 1st it allows the farm to have a spell until October" Farmer, Breeder.

"If the lambs are on budget they go, I don't care how small they are, but I do need to get the balance right with making money, we are in a tricky spot here as we wean when the store market is at its lowest". Farmer, Breeder.

"We have a supply agreement with a finishing farm, and he takes every lamb on one day, its great for us, money in the bank and the drench guns go away". Farmer Breeder.

"Farmers must reduce the number of days lambs are on farm, the old school way of parking up lambs all winter with subpar growth and killing them late on high schedules are gone. These lambs are getting eight triple drenches that aren't effective and just build a pot of resistant worms. The worst thing that happened was a \$9 lamb schedule as financial incentives were too tempting". Industry Professional.

It became very clear through the interview process that reducing lamb days was a vital tool in the farmers toolbox for reducing the contamination of larvae on pastures and reducing drenching costs.

- **Refugia.** Refugia was recommended by all industry professionals and used by all farmers interviewed. All farmers interviewed were using refugia via undrenched ewes rather than leaving a proportion of lambs undrenched. This was due to the perceived lamb production cost of leaving 10-20% of lambs undrenched. It was interesting to note that two lamb finishers already had ewes in their system before drench resistance was discovered but due to capsule and long-acting drenching use at pre lamb to 100% of ewes, refugia was not effective. All farmers interviewed had a no drenching policy for adult sheep except for one who would very rarely drench young ewes if there was a drought or hoggets hadn't been grown out well enough for mating. Industry professionals explained that refugia was the easiest of the practices to implement, as they all had the same view that adult sheep should not be drenched due to their ability to withstand high worm challenges compared to lambs. A common theme between both farmers and industry professionals was there was no known quantity of ewes needed to be effective for refugia. Although all farmers interviewed had ewe flocks of over 600 head and would rotate these around behind lambs or amongst lambs. Ewe numbers used for refugia varied from 10 ewes per 100 lambs in a paddock to 2000 ewes being grazed directly behind lambs.

"Farmers continue to run monocultures of young stock, you must introduce refugia as part of your tool box if you want to take this seriously. It's simple and easy to do and it works". Industry Professional.

"Although refugia has limited data, my anecdotal experience is that it worked time and time again. Farmers find it user friendly, but I recommend using ewes to do it not undrenched lambs. I have had backlash from clients who have tried with lambs, and I get the blame the lambs haven't grown". Industry Professional.

“Lambs are a worm factory so having ewes work, but they must not be treated ever”. Industry professional.

“Breeding farms who treat multiple bearing ewes often think they are doing refugia by leaving some of their ewes undrenched such as their singles. The issue is that they are lambing them on a separate part of the farm to the multiples so in fact there refugia is not being done properly, we need better education around this”. Industry Professional.

“When we discovered drench resistance the first thing I was encouraged to do was introduce worms from another farm. I went to my ram breeder who breeds rams for FEC and bought some dry hogget’s off them. As these had a good status, I brought them home and didn’t quarantine drench them. I then put a few in each paddock with my ewes to create refugia, I reckon it worked bloody well”. Farmer.

“I now intentionally buy in lamb ewes in May and June and leave them undrenched and rotate these around the farm. I am disciplined on where I source these from and will only buy if a recent FECRT has been done by the vendor”. Farmer.

“Cropping is taking care of the worms on the flats but on the hill country I have adopted a 5-year ewes system for financial reasons but also in the face of drench resistance as multiple people told me I need refugia”. Farmer.

“I came back from a professional career in a different industry and just did whatever dad had done for years. We drenched every ewe three times a year as it’s what we’d always done and I didn’t know better, what a disaster. I now only drench very light two tooth ewes and leave the old ewes undrenched. It works but it just means a lot of crutching. I don’t have exact rotations of undrenched ewes following lambs, but I just make sure that I shuffle ewes around at different times”. Farmer.

All farmers interviewed believed refugia had played a significant role in their drench resistance journey and found implementation simple and easy.

- **Cattle integration.** Cattle were part of all systems on the farms surveyed at percentages to sheep ratios. One breeding property ran 90% sheep 10% cattle, while generally the others were 60% sheep and 40% cattle. It must be noted that on many of the winter lamb finishing systems I interviewed, the ratio could be rather skewed as that was taken over the whole year, whereas on farm numbers will fluctuate throughout the year. For example, 90% lambs through the winter and then 90% cattle over the late spring summer period when no lambs are farmed. Although type, breed, and system were all different on every farm interviewed, the common theme was that cattle were integrated with sheep as a pasture control tool but also with heavy weighting toward worm management. The key rationale was around using them as vacuums on the contaminated pastures post grazing with lambs.

“I don’t really have any set number I put in every rotation, just run my feed budget, and coming into October work out the grasses growth and set stock them accordingly with trade lambs. Works bloody well, you don’t even really notice the cattle in there, they have grown bloody well as well as soaking up parasites. This starts our 6-month set up for next autumn”. Farmer.

“We have bull calves we rear right through to kill at 18 months, so they flick round soaking up worms when they’re old enough but also have some flex in this policy, we’ll buy dry cows or older steers as well to mop up worms through the season behind lambs. Another one of those things that’s hard to measure and to know how many you need but I think it works”. Farmer.

Cattle integration was a practice heavily recommended by Industry professionals also. All of those interviewed perceived a balanced livestock system was the best approach and the risk of monocultures, especially of young stock like lambs and calves are extremely risky for drench resistance.

“I went into a place that had lost a lot of money from drench resistance, we straight away changed the stocking ratio and lifted cattle numbers up from 30% to 50%. The cattle are working well soaking up worms but also pasture quality benefits. When clients are at the start of the journey post discovery cattle are vital, farmers can’t stop farming for years to break the cycle so they need systems that can still make them money, I think cattle are perfect for this”. Industry Professional.

“Cattle integration is key, they come in eat the larvae, those larvae die and reduce the worm burden. They’re a win as they make money as well”. Industry Professional.

- **Forage Crops.** A key theme that came from the interviews was that the use of forage crops is a valuable tool. It was made clear that it doesn’t work for everyone due to topography, soil type and climatic conditions but like all the approaches, for those farmers with the right conditions, it can have significant benefits. A consistent response from farmers was that they found brassica such as kale and rape to be the most effective although some had been using herb mixes also with a mixed response. Farmer interviewees perceived that although plantain/clover/chicory starts off with a low worm burden it can very quickly build, as new lambs are always being added to it as others are killed off. Kale and rape were generally used as single graze or a two-graze system where there was a light graze in the summer and again in winter. Due to the time from planting to grazing being from 4 months up to 9 months, the crop is extremely clean when stock enter it, so worm challenge was generally low which boosted lamb growth rates. Both groups interviewed also concluded that brassica and herbs such as plantain have the correct plant leaf and stem structure so that larvae are minimal, therefore lambs ingest little larvae compared to traditional ryegrass clover where plant structure is vastly different.

“I use rape to push and pull feed at various times of the season when it comes to store lamb purchases, it allows me to enter the market when no one else will but have confidence that the lambs will meet target growth rates without worms affecting them. Every trade I do it is calculated on a cent per kg of dry matter basis so although people say cropping is too expensive, it can be done. It works great for our business overall in terms of the cropping rotation, but the added benefits of the low worm challenge are seriously beneficial to us”. Farmer.

“I use forage crops in the summer for lamb finishing and graze it again in the winter with cattle. This works well for our lamb system as the crop has a higher grazing residual and the establishment of the crop breaks the worms’ cycle”. Farmer.

“Lambs just don’t do in the summer here on grass even though it looks good, my summer trade is often a very slim margin anyway, so I need them growing every day I have them. They just seem to grow on the chicory”. Farmer

One of the breeding properties used it as a tool to avoid selling store lambs on the bottom of the market although mentioned “it only takes one failed crop to make that a bad decision”. The same farmer emphasized the importance of having a cropping specialist involved that understands your business. “We didn’t know what we were doing as the sales rep recommended us these crops that

had maturity dates very different to when we needed the feed. A disaster and spent \$17000 more on cropping but still dumped lambs on the weak store market”.

All rural professionals interviewed shared the same themes as farmers around the importance of the use of crops on lowering the worm challenge. I found a common theme that although this is a recommended practice, none of them had any data on the benefits of cropping. Lamb days was mentioned by half of the interviewees in regard to crops allowing lamb growth rates to be increased dramatically, therefore reducing lamb days compared to traditional rye grass finishing, especially over the summer months.

“Crops absolutely work but you need to grow the right one, from what I am seeing it needs to be brassica like kale or raphno brassica”. Industry Professional.

“You can’t take drench off lambs unless you feed them clean, uncontaminated high value feed, this is where plantain clover works a treat, they grow like mushrooms”. Industry Professional.

Two of the industry professionals interviewed had experience in trial work with plants that have high levels of condensed tannins such as Sulla and Lotus. Going forward these types of crops could be beneficial for farmers as the data suggests that lambs with higher FEC’s that were fed crops containing condensed tannins grew faster than those fed traditional crops or grass with no condensed tannins, in the absence of drench.

“CT forages are bit fussier to grow and maintain than ryegrass and clover – or we are simply more experienced at growing grass clover and so it seems easier. There was an extension programme some years ago called “The Goldie Bloom” which tried to encourage farmers to use more lotus – didn’t work very well and I heard farmers say there was no real advantage for the effort, but that was in the days when drench resistance wasn’t a problem (yet) so I’m guessing that the benefits today may well justify the extra effort”. Industry Professional.

“The trial work is slightly outdated now but I have been harping on about Sulla for years and have little buy in, be good to have some trial work done on it now to get some farmers doing it on scale, if you can grow lucerne you can grow Sulla easy as”.

- **Genetics.** Genetics was a management tool more favoured by industry professionals although two of my farmers interviewed were also utilizing this tool. Breeding for resilience or resistance to parasites was viewed differently by many. Some thought breeding for your resilience is a way of contaminating your farm very quickly and having poor stock as you are putting parasite pressure on the sheep as a selection tool. Whereas breeding for resistance means sheep can be exposed to worm pressure and still perform. This was the preferred practice and is becoming more common by ram breeders in New Zealand. One of my interviewees purchases rams from studs who are breeding rams with a key focus on parasite management, and one was a ram breeder focused on resilience.

“Why wouldn’t you buy rams from someone front footing this situation, we know the sheep look like Romneys, have good growth, feet are good, so the drench work is a no brainer. It amazes me why so few farmers are chasing it, everyone seems to take the facial eczema thing way more serious but worms the same I reckon”. Farmer

“We breed rams here for resilience and have done since the early 90’s. The reason more people aren’t doing it is it can be on livestock at times but my philosophy is someone’s got to do it cause its bloody important going forward”. Farmer

“Genetics, it’s a simple tool, many of my clients do it with facial eczema ram’s genetics but only recently the discussions around resistance rams have begun. With this wave of triple drench resistance every ram breeder is going to say they have been breeding for worms for years so buyers will need to be careful”. Industry Professional.

5.2.5 A lack of data around financial implications of drench resistance is clear.

When I interviewed farmers and industry professionals it became very apparent that evaluating the financial implications of drench resistance is carried out poorly and inconsistently. Only one farmer interviewee had financial data on the impact to their business.

“The year leading up to discovering drench resistance our lambs weaned 33kg, ewes scanned 201%, ewes lambed 154% and our gross farm revenue per hectare was \$1350. The year we discovered everything dropped at a rate of knots, lambs weaned 26kg, ewes scanned 180%, ewes lambed 125% and gross farm revenue dropped to \$980 per hectare”. Farmer

It must be noted that although drench resistance likely had a major role in the drop in financial performance, it cannot be all attributed to drench resistance as various other factors such as feed quality, ewe condition, store lamb market, and prime lamb market, all have direct impacts on farm financial performance. When most farmers were questioned on this topic a theme emerged which was generally anecdotal as the true effects hadn’t been measured or costs associated with drench resistance.

“Probably not too bad given we caught it within 6 months of it developing and early in the worm season so to speak. We were able to get back on track quickly but the major cost for us was going from a relatively cheap drench to having to use Startect which is approximately double the cost per head”. Farmer

“We seemed to lose a lot more lamb that we were trading in the summer, not sure if worms had a part to play in that but it definitely cost us money”. Farmer

“It’s a hard topic to evaluate except for areas such as carcass weight potential which we have done some work on. There is work being done now but isn’t released yet around reducing drench inputs into lambs which hopefully will show a positive financial response. As I say it is difficult to put direct costs and financial performance down to solely drench resistance when many other factors are at play”. Industry professional.

“Had a client who quit all his breeding ewes and went trading. Gross farm revenue lifted by \$400 per hectare due to the system change but then drench resistance hit with a vengeance. We probably dropped back to levels where we were with the ewe breeding system, but its climbing back up now slowly, entered a few ewes again and some cropping and seem to be back on track”. Industry Professional.

5.2.6 There are questions around the efficiency of FECRTs

Many farmers interviewed used pre drench faecal testing and 10 days post drench checks as a tool to identify when to drench and whether it had been effective. Some of the interviewees, especially who

have a good pool of owner bred lambs, would conduct a full FECRT every 2-3 years. There was a general theme that farmers undertook very little testing until they discovered drench resistance. The general perception from industry professionals was that testing is not done well or anywhere near the level it needed to be. They appreciated that the technology needed to be developed to make this change.

“I just thought it was working, sheep looked healthy and easy to move, wasn’t until we had it and I started doing some reading, a vet from Massey said you can’t see it until drench is less than 50% effective. It bloody easy doing those checks, we bought our own kit and I taught myself, so we don’t have to wait for vets. My biggest frustration is around when I have a bad FECRT that needs culturing. This takes two weeks to get back to me. By this time if I don’t treat them they could be dying, so I go back to old bad habits. We really need a quicker way of knowing exactly what worm is guilty”.

Farmer.

“I find I do all this work through the summer with my cattle and ewes getting my autumn pastures all set up for the first lamb trade, I then see opportunity to buy lambs but I can’t guarantee my pastures is ready for it cause we cant test for larvae on pasture, well you can but no one does as it costs heaps and takes ages. As a result, I end up generally taking the punt and buying lambs as I feel I’ve done everything right. Surely the scientist can find something”. Farmer

“We need a better tool for telling farmers when to drench, FECRT’s work ok but is 10 individual samples of ones bulk out of a mob of 1000 really enough of a guide? The other part to this testing issue is that we can FEC them and put them back onto a dirty paddock but where’s their next shift? We need tools to test larvae contamination on pastures to determine safe zones, I reckon this would be extremely powerful”. Industry Professional.

“Farmers need better tech to get cultures back quicker, two weeks is too long when the animal’s welfare is at stake”. Industry Professional.

6.0 Findings and discussion

Drench resistance is currently being discovered on more and more of New Zealand’s sheep farms. The traditional method of controlling worms in sheep through a drum of drench has run its course. The continuation of carrying on the same management practices on farm and the lack of engagement with industry professionals has sped up this \$98 million per annum problem (Scott 2023). Farmers need to develop new tools and management techniques for their businesses to remain sustainable.

It became very apparent from the literature and the interview process that most farmers don’t know their drench status. Vet News (2023) suggests that only 15% of their clients knew their drench status despite 50% of FEC’s carried out showing levels of resistance. This was in line with findings in the United Kingdom where only 19% of farmers surveyed knew their drench efficacy (Morgan et al., 2012).

90% of the farmers interviewed for this study hadn’t measured their drench status until drench resistance was discovered. This theme was apparent from industry professionals who generally explained that it wasn’t until post drench resistance discovery that their clients wanted to know the status. Generally, this was because farmers believed they could visually assess if their drench wasn’t

effective. In fact drench resistance is only visible when it is already below 50% efficacy (Leathwick et al., 2011).

From the literature and farmers/industry professionals interviewed the lack of data on the financial cost of drench resistance was very clear. Although one farmer interviewee had financial and production loss data on the cost of drench resistance, he was the only one. It was clear that those farmers knew it had cost them in terms of production and financial results, but it was unclear by how much.

Both the literature and interviews with industry professionals agreed that gathering data on drench resistance is very difficult and poorly done. The technology is outdated, testing tools are poor, and farmers mindsets are often a challenge. For many farmers there are simply more pressing matters. One farmer interviewed mentioned gross farm income dropped from \$1350/ha down to \$980/ha the year drench resistance was discovered. There was a common theme in the literature and by industry professionals around the production cost of using ineffective drench. The same farmer had some data on weaning weights of lambs dropping by 7kg over the same period. Similar findings were reflected in the literature. For example, a recorded 14% carcass weight potential loss when an ineffective triple drench is used (Dowling 2023).

The lack of financial and production data is clearly a handbrake for the industry regarding front footing the drench resistance outbreak. Farmers generally assign other factors for drench resistance such as feed quality, time of year, age of sheep, as inhibitors for sheep production. This is largely due to the lack of testing that is carried out by farmers who therefore don't know the effectiveness of the drench they're using. It is a commonly held theme that if farmers don't measure it, they can't manage it. Therefore this report illustrates that if farmers want to remain sustainable into the future, better financial and production analysis needs to be carried out both on farm and through extension work.

On farm changes are required but it is clear that change must not be rushed but should rather be considered carefully with consideration to farm limitations such as topography, climate, raising capital and farmer values. A "slowly slowly" approach has been the most effective and was recommended by all research completed in this report. Some of those interviewed had been involved in situations where poor processes had been rushed, resulting in poor production and financial results. It is very clear that farmers must make changes to areas which their property allows. For example, a high-country property with zero cultivatable land cannot utilize forage crops but instead could implement refugia, genetics or cross grazing with cattle. It was very clear that there is a large pool of management practices that can be implemented depending on farm limitations.

Throughout the literature review and interview process another clear theme emerged. That there are management practices that are highly effective for farmers experiencing drench resistance or those farmers who are wanting to mitigate the risk. Carrying out FECRT, pre and post drench checks, refugia by minimizing monoculture systems, forage crops, removing high risk drenching such as capsules and long-acting drenches in adult sheep, use of genetics for either resilience or resistance, minimizing lamb days, cross grazing with cattle, are all management strategies for use on farm to create a sustainable farming business. These practices are published on various platforms such as Beef and Lamb, Wormwise and the New Zealand Veterinary journal. It appears from the investigation in this report from both literature and interviews that farmer uptake of the advice is poor. Farmers who actively farm to mitigate the threat of drench resistance are a small proportion and rather on farm change generally occurs after the drench resistance is diagnosed.

Interestingly animal welfare was very rarely mentioned in interviews except when I questioned either farmers or industry professionals. Production effects were perceived to be more important than animal welfare. This theme was also concluded from the literature review as there is very little literature on the topic of animal welfare regarding sheep suffering from worm challenge. With markets such as China demanding animal welfare being one of the highest priorities when purchasing products such as sheep meat, Tait et al., (2016). It was concerning that very little had been done in this space and something that needs further research going forward.

7.0 Recommendations

- 1) Farmers must carry out FECRT, Pre and Post drench checks to identify current worm challenge and to assess efficacy of drench.
- 2) Farmers need to engage support into their farming businesses from external advisors who specialize in the field of drench resistance. Ideally using more than one from different companies.
- 3) Farmers need to implement changes to their farming system where appropriate to enable a sustainable farming business.
- 4) Industry professionals must drive the movement of developing more effective on farm testing for faecal egg count reduction tests, larvae culture testing and larvae level testing in pasture.

8.0 Conclusions

In a time of uncertainty around agriculture regarding consumer demands, animal welfare, production targets, and land use, it is imperative that farmers control farm production with these factors at the forefront of their minds.

One major production limitation for sheep farms is the use of ineffective drenches which is caused by resistance. For a 4000 sheep property this could potentially cost \$81,200 per year. From the literature review and interviews conducted it has become clear that farmers can remain sustainable when farming with drench resistance. It must be noted that for farmers to remain sustainable changes to farm management must be implemented, but this doesn't require a full farm system change. It is recommended that changes are made to what is appropriate for the farm, with consideration given to topography, climate, and farmer values.

Farmers must front foot the situation facing their businesses and implement changes where they are available. This will be a shift from the current majority who are not actively mitigating the risk. It is imperative that farmers get anthelmintic experts and advisers involved in their business as this topic is very scientific which many farmers struggle with. It is clear from this report that those who have successfully managed their way through drench resistance have multiple industry experts involved in their business. Through more powerful extension work by through organisations like Ag Research, Beef & Lamb New Zealand, Wormwise, Massey University and Lincoln University the message needs to reach more New Zealand sheep farmers. Farmers are not utilizing the resources available and are waiting until drench resistance is present before making changes. This needs to improve or the 27% of farmers currently suffering triple drench resistance will significantly grow. Industry leaders need to develop better testing technology for worm diagnostics to speed up testing and invest in more benchmarking tools to evaluate the financial impacts to businesses of farming with drench resistance.

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10.0 Appendices

10.1 Appendix One: Farmer Interview Questions

Section One: Farm overview.

1. What region are you farming in?
2. What is your effective farming area?
3. What is your current farming system?
4. Is drench resistance currently present in your sheep?
 - a. If not, has it been present in your sheep in the past?
5. How do you measure drench effectiveness?

Section Two: Livestock management while farming without drench resistance.

1. How do you think drench resistance is a risk to your business and why?
2. How is sheep production measured on your farm.
 - a. If so what KPI's do you use and why?
3. Describe what methods are used on farm for measuring worms in sheep?
 - a. How regularly is this carried out.
4. Is farm financial performance analysed on a yearly basis and describe how this is done?
5. What is your historical death rate in sheep?
6. Describe what management practices you use to eliminate drench resistance on your property?
7. Describe why are these chosen practices used?
8. How did you find implementing these changes?
 - a. Describe what ones you found difficult and why?
9. Do you have someone involved in your business solely for the purpose of drench advice?
 - a. If so, describe how has this benefitted your farming system?
 - b. Describe the changes they advised you to implement.

Section Three: Livestock management on farm while farming with drench resistance.

1. How is sheep production measured on your farm?
 - a. If so what KPI's do you use and why?
2. Describe what methods are used on farm for measuring worms in sheep?
 - a. How regularly is this carried out?
3. How did drench resistance effect your sheep performance?
4. What is your historical death rate in sheep?
5. Describe how you discovered drench resistance?
6. Describe what management practices caused drench resistance?
7. How did drench resistance impact the farm financially?
8. Describe what management practices have you adopted to farm with drench resistance?
9. Why are these chosen practices used?
10. How did you find implementing these changes?
 - a. Describe what ones you found easy and why?
 - b. Describe what ones you found difficult and why?
11. Do you have someone involved in your business solely for the purpose of drench advice?
 - a. If so, describe how this benefitted your farming business?
 - b. Describe the changes they advised you to implement?

10.2 Appendix two: Industry Professional Interviews.

1. Describe if you think the level of research and development currently being undertaken in New Zealand for drench resistance is appropriate?
 - a. If not, describe what areas you think need further research and development?
2. From the outside looking in, describe what are the key management practices being used to cause drench resistance to enter farms?
3. Describe what you believe are the key management practices that can be used to farm with drench resistance in sheep.
4. Have you been involved in a full farm system change due to the discovery of drench resistance?
 - a. Describe what system you changed to?
 - b. How come this system was chosen compared to others?
5. Describe if this was successful in terms of removing drench resistance in sheep on the property?
6. Describe what were the implications of this system change both positive and negative, including financial performance?
7. Was this business benchmarked with other properties pre and post system change?
 - a. How was this benchmarking completed?

10.3 Appendix three: Question Tree

