A Handbook of
Sustainable Worm Management for Livestock Farmers

wormwise
national worm management strategy
WHAT IS WORMWISE?

Farmers have identified the sustainable management of worms as one of the biggest challenges they currently face.

They have asked for a consistent message from those advising them on testing, drench selection, grazing management and genetic solutions to worm problems.

In May 2005, Meat & Wool New Zealand and MAF Sustainable Farming Fund initiated the development of a national worm management strategy involving all stakeholders. In December 2005 all of the participants signed off in support of the strategy.

As representatives of that group, Agcarm, ARPPA, New Zealand Veterinary Association, MAF Sustainable Farming Fund and Meat & Wool New Zealand Ltd have agreed to lead and resource the implementation of this strategy.

A series of workshops for farmers is part of the strategy. The aim of the workshops is to help farmers with the practical application of the information in this Handbook.

Farmers should apply to be registered on the database to receive regular Wormwise newsletters and research updates: email wormwise@meatandwoolnz.com or freephone 0800 696 328.

For more information see the Wormwise website www.wormwise.co.nz and www.wormboss.com.au
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Why this handbook?

This handbook for New Zealand farmers is produced as part of the Wormwise initiative that identified the need for an independent and central source of information about the principles and strategies for sustainable worm management.

In essence the principles themselves are quite straightforward. It is their practical application that is more complicated. Farming systems vary tremendously and what works for one may not be practical for another. For this reason it is impossible to develop a set of “rules”. Instead farmers should seek to understand the principles and then make their own decisions on how they might be applied on their farm. This book is designed to help develop that understanding.

A successful worm management plan should be designed in close cooperation with your animal health adviser.

Why sustainable worm management?

Being able to farm efficiently and sustainably in the years ahead requires examining, if what we do now will make sense in the future. The accelerating development of drench resistance means many current worm control practices are not sustainable.

No drench or drenching programme can offer total freedom from the effects of worms, so having other ways to minimise those effects will improve production and profitability.

Added to this are the costs of drenching both in time and money. Without a sound drenching strategy, which is part of an overall worm management plan, much of this expense and effort can be wasted.

Drench resistance is also a cost to production. Drench failure begins to cost the moment drench effectiveness begins to decline. The point at which this decline in efficacy becomes economically significant occurs long before there is visible evidence of drench failure.

To appreciate the benefits of adopting sustainable worm management principles it is first necessary to have an understanding of how worms affect production. This is the subject of the first chapter, which should stimulate an interest in learning more about worms and their management which is covered in the subsequent chapters.
1. What effects do worms have and how do they limit production?

CHAPTER OVERVIEW
After reading this chapter you will have an understanding of how worms impact animal production. There are worm management approaches aimed at maximising profitability.

- Larval challenge occurs whenever animals graze on pasture contaminated with infective L3 larvae. Infection causes appetite suppression and changed grazing behaviour as well as demanding an immune response, which is a cost to production.

- All animals grazing pasture in New Zealand will be exposed to larval challenge.

- Production loss due to worms is of greatest importance in young stock.

- Physical signs represent the end stage of a complex and progressive disease process. Their appearance represents failure of your worm management strategies.

- Young stock are a fertile breeding ground for the multiplication of worm populations and can become a major source of pasture contamination.

- No drench can completely eliminate the effects of larval challenge.

- Successful worm management strategies should aim to minimise larval challenge at critical points in your farming operation.
What effects do worms have and how do they limit production?

As livestock farmers know, worms are one of the main threats to stock health and production and impact the viability of their farming operations. After reading this chapter you will have an understanding of the ways in which worms exert their effects on animal production and how this affects different stock classes throughout the year. You will also appreciate how this understanding can assist in your farm management profitability.

Two popular concepts of how worms affect livestock are they compete for nutrition with the animals they infect, and cause damage to the gut leading to inefficient feed utilisation and scouring.

Both of these are true, although for the most part even large numbers of worms do not “rob” animals of nutrition. The exceptions to this are the blood sucking parasites such as Haemonchus species (Barber’s Pole worm).

The impact of worms on animal production begins the minute animals are exposed to worm larvae on pasture. These effects may be viewed as a continuum from no exposure to worms, and therefore no impact, to the presence of heavy burdens of worms in animals leading to disease and even death.

The point at which these effects become visible either through stock weight loss, or body condition, or through physical symptoms such as scouring, is called clinical parasitism. Before this point is reached the unseen but important effects, from a productivity point of view, are called subclinical. In today’s modern livestock farming operations minimising these subclinical effects can mean the difference between profit and loss.

This diagram illustrates that long before clinical (visible) signs of worms infection occur, there can be significant production loss.
Subclinical effects

The process begins with animals picking up infective L3 worm larvae when grazing contaminated pasture. This is known as larval challenge. These larvae are foreign to the animal in a similar way to bacteria or viruses and have two major effects.

The first is appetite suppression and changed grazing behaviour. This occurs even at very low levels of larval challenge resulting in reduced food intake. The second effect is the generation of an immune response to the incoming larvae. The immune response requires energy and protein. Both of these needs are met at a cost to production whether it be for body weight gain or maintenance, wool growth or milk production.

There are numerous studies that demonstrate these effects. Two of these are summarised below: one in lambs and a series of trials in cattle.

As long as there are larvae in the pasture that animals are grazing these effects will be continuous. It is safe to say all grazing animals in New Zealand will be exposed to worms on pasture. The level of impact will depend on the amount of pasture contamination, but it is the constant nature of the exposure that results in accumulated productivity loss.

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

The graph shows the growth rates of previously worm free lambs dosed with different levels of infective L3 (larval challenge). The control animals received no larvae. The animals were housed and fed a dry ration. Growth rates and feed intake were monitored.

It can be seen that the challenge with L3 reduced growth rates occurs immediately. The effect was increased with increasing challenge. The depression of feed intake of both drenched and undrenched groups receiving 5,000 larvae per day was the same. At slaughter the drenched group had no resident worms, from which we can deduce that establishing worms were removed at each drench. None of the animals in this trial showed clinical signs of parasitism.

This trial demonstrates the subclinical effects of larval challenge. Regular drenching to remove any established worms has minimal impact. In other words no drench on its own can eliminate the effects of worms.
Recent work has looked at the effects of grazing behaviour in both young and adult cattle using sensors attached to the animals’ jaws. Animals were either treated with long-acting drenches or allowed to become naturally infected by grazing contaminated pasture. The trials showed exposure to worms reduced productive grazing behaviour. Consequently there were reductions in weight gain in young cattle and in milk production in adult dairy cows. The graph shows the differences in behaviour between two groups of adult cows in one of these trials.

Cows exposed to worms spent less time grazing and ruminating and more time in non-productive behaviour (idling). Cows were either allowed to become exposed to natural infection (controls) or treated with a long-acting anthelmintic both to remove resident worms and negate the effects of larval challenge. The observations were made over a 28 day period. Milk production, weight and body condition were all reduced in the non-treated (infected) group.

None of the animals in either of these trials showed clinical signs at any stage. The trials demonstrate the subclinical effects of worm exposure and their impact on productivity. It appears that the suppression in appetite is involved in the immune response to challenge. Other trials involving animals whose immune system has been artificially suppressed have found no or minimal effects in terms of productivity when these animals are challenged with worm larvae.

**Clinical effects**

The clinical effects of worms on animals, are really a progression from the subclinical effects, as worms become established in the body. The distinction between clinical and subclinical is an arbitrary one and may depend on how hard you are looking. Generally speaking at the clinical stage there are visible signs in the animal. The major physical signs are weight loss, scouring and dehydration. Whilst worms cause varying amounts of direct damage to host tissues by their activities of feeding on the gut lining or sucking blood, most effects leading to clinical disease are due to the host reaction to the presence of the worms. The inflammation resulting from physical damage can lead to secondary bacterial infection and ulcers. Worm larvae invade glands in the gut lining and, whilst some adult worms burrow into the lining, many simply reside in the surface mucous layer. The host’s defensive inflammatory response causes changes in the structure and physiology of the gut leading to disturbances in normal gut function. The gut lining may thicken or nodules may form. Abnormal acid or hormone production may occur and the gut becomes “leaky”. The end result may be loss of fluid and protein. Feed conversion efficiency suffers resulting in weight loss, and diarrhoea (scouring) may occur. If these changes are sufficiently severe, death results. In the case of *Haemonchus*, death can also result from blood loss.

At this point the physical symptoms of worm infection are apparent, such as weight loss and diarrhoea which represent the end stage of a complex and progressive disease process. It could be said that the appearance of these signs represents failure of your worm management strategies.
Age effects and immunity

Young animals first encounter worms when they start grazing and at this point they have no specific immunity to them. This means it is easy for worms to establish themselves and become "residents", and reproduce relatively freely. The result is that young stock are a fertile breeding ground for the multiplication of worm populations and can become a major source of pasture contamination.

Because young animals are utilizing large amounts of energy and protein to grow, they are highly susceptible to the effects of parasites. Production loss due to worms is therefore of greatest importance in young stock. Both cattle and sheep generally develop full immunity to worms by 18 to 20 months of age. It is often mentioned that continual exposure to worms is important for the development of good immunity. On New Zealand farms it is extremely likely there will be sufficient worm numbers on pasture for animals to develop immunity.

A successful worm management programme should aim at minimising exposure of young stock to worms. The immune system is energy and protein hungry and depressed by the physiological response to stress, so good nutrition and minimising stress are important management considerations.

Healthy adult animals generally cope much better with worm challenge as their immunity is fully developed and they are not growing. However the comments above regarding nutrition and stress still apply. Remembering the demand for an immune response is responsible for subclinical production loss, there are times when the impact of worms on the productivity of older animals will be important. Around lambing and calving times animals are under stress and there can be a decrease in immunity. This can lead to higher burdens of worms and higher faecal egg outputs as the immune relaxation allows them to reproduce more freely.

Ewes and cows in lactation have high energy and protein demand, so the effects of worm challenge will have a higher impact on productivity. Your worm management strategy should aim to minimise exposure of these animals to a worm challenge.

Rams and bulls at mating time are another example of when attention to these principles is important.
This chapter should have convinced you the subclinical effects of worms can have a major impact on profitability. It has attempted to show you how, by giving some thought to when each stock class is likely to suffer productivity losses from worm challenge, these losses can be minimised. Successful worm management strategies should aim to minimise exposure at these critical points in your farming operation. The rest of this book is aimed at providing the knowledge required to develop these strategies and put them into action.

Remember the whole area of worm management is extremely complex, far from fully understood and unexpected things will happen. Forming a partnership with your animal health adviser will greatly increase your chances of success.

**Take away messages**

1. **If you are seeing clinical signs, your worm management is not working and you may be losing money.**
2. **By minimising worm exposure at critical times, production may be increased.**

**Bibliography**

- M&WNZ R&D Brief 1 The effect of pasture species on lamb parasitism.
- M&WNZ R&D Brief 67 Sustainable internal parasite control for sheep.
- M&WNZ R&D Brief 115 Managing worms.
- M&WNZ R&D Brief 124 Ill Thrift


Coop R L et al. 1982 The effects of three levels of intake of Ostertagia circumcinta larvae on growth rate, food intake and body composition of growing lambs. Journal of Agricultural Science (Cambridge), 98, 255.

2. Worm biology

CHAPTER OVERVIEW
This chapter is devoted to important aspects of worm biology as they impact on worm management. After reading this you will understand the reasons behind some of the principles as well as some of the difficulties. It should also help you see why there is no one single solution.

- Sheep and cattle in New Zealand get infected by a variety of different worm types. Worm eggs pass out in the animal’s dung onto pasture, and animals get infected when they swallow infective (L3) larvae that have developed in the dung and get onto that pasture.

- The numbers of larvae on pasture are affected by weather. Warm moist conditions speed up larvae development resulting in greater numbers of eggs developing to infective larvae.

- It takes around 21-28 days from when an animal eats a worm larva to when worm eggs appear in dung samples.

- The whole-life cycle may be completed in four weeks and in special cases even less.

- The numbers of eggs and larvae present on pasture are much higher than the number of worms inside animals. Therefore effective worm management requires more than simply killing worms in the animal. It should minimise exposure of animals to worms at crucial times.

- Most larvae are found in the first 2cm of pasture height or in the first 1cm of soil.

- Intensive grazing exposes animals to a higher level of larval intake compared to animals lightly grazing the same pasture.
What should you know about the important worms in New Zealand sheep and cattle?

Several different types of worms live inside sheep and cattle. This Handbook focuses on round worms (also called nematodes) that live in the gut and will be referred to as “worms”. Flukes and tapeworms are commonly found and are discussed briefly.

The worms of most importance in New Zealand livestock live in the animal’s gut (stomach and intestine). Although this book refers to worms as if they are all the same, there are actually several different types. These may vary in size, where they live in the animal, and in their life cycles.

Worms strains that infect cattle do not usually infect sheep and vice versa though they might have the same species name. Some worms live only in the stomach (abomasum), others only in the small intestine, and *Trichostrongylus* species can be found in both.

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Scientists have told us recently that the correct name for what we have traditionally called *Ostertagia* in sheep is now *Teladorsagia*. However, in this book we continue to use the name *Ostertagia* as this is what most people know it as. The worm families/types listed are those that cause the most problems in sheep and cattle. There are others that are less common or cause little problem: *Strongyloides, Bunostomum, Oesophagostomum, Chabertia* and *Trichuris*.

Although worms are often referred to by their scientific name, some have common names as well. For example, another name for *Haemonchus* is the Barber’s Pole.

Lungworms are another type of round worm that live in the lungs. They are less important for animal health than those in the gut, but can be a problem in young stock particularly cattle.
Geographic variations

Most of the worms listed occur and cause problems in all areas of New Zealand. However, two – Haemonchus and Cooperia – are more of a problem in the warmer areas of the north because they require a higher temperature range for development. Nematodirus causes more problems in the colder south as it is adapted to cool short summers and its larvae survive cold winters on pasture. Ostertagia and Trichostrongylus occur in all areas.

Once in the gut L3 larvae moult to L4 (immature worms) which finally mature into adult worms.

- Female worms are sexually mature and start laying eggs on average around 21 days after being eaten.
- The eggs pass out in the dung.
- The infective larvae migrate onto the herbage to be eaten by grazing animals.
- In the dung pat larvae hatch from the egg and go through 2 moults to become infective L3 larvae (egg → L1 → L2 → L3 = 1-10 weeks depending on environmental conditions).
- L3 larvae may survive for long periods, sometimes even longer than a year.
The life cycle of round worms

The common round worms of sheep and cattle have three stages in their life cycle: egg, larva and adult. The adult stage is the worm that lives in the gut of the animal. You may see them when you cut open the stomach (abomasum) or small intestine of a sheep.

The immature worm hatches out from an egg in the dung pat. At hatching it is called a larva and for most worm species it will go through four larval stages. The first three stages of development take place in the dung pat and the fourth one inside the animal.

The third larval stage (often referred to as L3) is the infective stage. Infective larvae migrate out of the dung onto soil, or onto the grass where they can be eaten by a grazing animal.

Under ideal environmental conditions, development from egg to L3 takes around seven days, but can be as long as five to ten weeks depending on warmth and moisture. Heavy dews and rain release the L3 from the dung pellet onto the pasture. L3 larvae increase their chance of being eaten by responding to light and temperature. As the pasture is warmed by sunlight and in the presence of moisture (dew/rain) the L3 migrate up the grass blades where they are most likely to be eaten. When the L3 are eaten by an animal they undergo another moult to become an immature worm (L4 larva) which then molts once more and matures into an adult worm.

The female worm mates inside the host animal and produces eggs in about 21 days. The eggs pass out in the dung and the life cycle begins again.

Female worms produce large numbers of eggs over their lifetime and the population of eggs and larvae on pasture is huge.

*Nematodirus* has a life cycle which is slightly different from the other common worms. The larvae develop inside the egg in the dung pat and it is the infective third stage larva that hatches from the egg. Because the larvae are protected inside the egg, they can survive over winter to hatch in the warmer spring or summer weather. From then on they behave like other types of round worms.

Eggs of *Haemonchus/Barbers Pole* are different from other worm eggs in that they require a relatively higher temperature to complete their development. This is why *Haemonchus* is more of a problem in the warmer north and eastern parts of the country.

**Lungworm**

Of the three species of lungworms that can infect ruminants in New Zealand, the most common is *Dictyocaulus*. In the mature form *Dictyocaulus* lives in the airways of the lungs, where it causes irritation and inflammation. Animals severely affected with lungworm may cough and have difficulty breathing. They often have mucus discharge from the nose.
Survival of eggs and larvae

The development of the worms from egg through the larval stages requires a moist environment and occurs at different rates at different temperatures. At low temperatures development is slow, whereas in warmer temperatures it is faster. Temperatures of 20-25°C are optimal for larvae as they die at higher temperatures, due to desiccation (loss of moisture or dehydration).

Most developing eggs and larvae are killed by hot dry weather. Most eggs on pasture die during cold weather (average air temperature less than 10°C). Some larvae survive through winter, also known as "overwintering" and together with new eggs shed by animals in early spring, this initiates the build up in worm numbers.

Infective larvae (L3) are relatively hardy. Once the larva has reached the infective third stage (L3), temperature and moisture will determine how long it survives.

Infective larvae on pasture eventually die as they cannot feed and have to survive on stored energy. In cooler temperatures larvae can survive for up to eight months and in some cases for more than a year. In warmer temperatures larvae may survive only two or three months. Naturally, the longer pasture is left or spelled, without grazing animals the fewer infective larvae it will have. The length of time this takes will vary, as it depends on climatic factors.

The type of pasture can also affect the rate at which dung pats dry out and eggs and larvae die. Some open sward pasture species provide a less suitable environment for larval survival than those with a dense thatch. Refer to M&WNZ R&D Brief 1. The effect of pasture species on lamb parasitism.

Most larvae are found in the first 2 cm of pasture height or in the first 1 cm of soil. When animals graze pasture with longer grass they are likely to be taking in fewer worm larvae than when they graze pasture with shorter cover.

Intensive grazing exposes animals to a higher level of larval intake than animals lightly grazing the same pasture. Amounts and patterns of dung deposition and therefore numbers and distribution of parasites on pasture will vary with type of grazing management.
The prepatent period

Typically it takes around 21-28 days from when a sheep ingests a worm larva to when worm eggs appear in dung samples. This is called the prepatent period.

It is important for two reasons:
- The commonly recommended interval of 28 days between drenches in young stock is aimed at minimising pasture contamination with worm eggs.
- Worm egg counts are at best a picture of the levels of larval challenge on pasture three weeks ago. You may think sheep are free from worms but under the right conditions, they could have picked up a considerable burden. Naturally, if a sustained action drench was used, the period from drench to eggs in the dung is longer, being the length of action plus the 21-28 days.

Seasonal patterns of larvae on pasture

Larval numbers on pasture are generally highest in late spring and autumn. This is because worms complete their life cycle fastest in warm wet conditions. Many developing eggs and larvae are killed by hot dry summer weather and fewer eggs develop in the colder temperatures of the winter months. The mild moist conditions of spring and early summer are ideal conditions for larvae so their numbers on pasture increase. Therefore numbers build up through summer and early autumn but drop if hot dry weather occurs.

Danger periods extend from spring to early winter with extreme danger from March to July. This will vary across the country according to the climatic conditions.

The numbers of eggs and larvae present on pasture are much higher than the number of worms inside animals. Generally, when conditions are favourable, 85 - 95% of the worm population will be found in the pasture. It is very important to remember this when planning worm management. Simply killing worms in the animal is only a part of the overall strategy to minimise exposure of animals to worms at crucial times.
Seasonal pattern of worm burdens in sheep

The seasonal pattern of worm burdens in sheep reflects the levels of pasture larvae they are eating. The numbers of worm eggs in faeces are measured by faecal egg counts, and these typically reach the highest levels in autumn.

Numbers of larvae on pasture are related to the numbers of eggs passed out by the grazing animals. In general, young infected animals will pass much larger numbers of eggs than older animals. As animals mature they develop an immunity to worms, and so carry fewer numbers and pass fewer worm eggs onto the pasture.

However, during late pregnancy and in early lactation, most ewes have a temporary drop in immunity and consequently pass more worm eggs in their faeces. This is the cause of the peri-partum rise in egg counts (PPR) that occurs usually about mid-lactation. By the time of weaning, the ewe's immune response has recovered and egg counts return to normal.

Because of the peri-partum rise in eggs produced, there is a corresponding increase in numbers of larvae on pasture so that when the lambs start grazing there is a new generation of infective larvae on the pasture ready to infect them.

The PPR is greater for ewes with multiple lambs and young ewes having their first lamb.

Different types of worms have different yearly patterns of prevalence. The most common worm in ewes during the PPR is Ostertagia yet this is much less common by the autumn.
Seasonal pattern in cattle

The seasonal pattern in cattle is similar to that of sheep though generally the autumn peak is a little later and possibly not quite as dramatic.

Calves born in spring get infected as soon as they start nibbling pasture. Larvae on the pasture at this time of year have survived over winter. These mature inside the calf and produce eggs which contaminate the pasture in spring and early summer. Therefore by early summer larval numbers on pasture have built up and the calves get re-infected. This results in an even heavier burden for the calf. The eggs from these worms cause a large peak of larvae on pasture in May/June.

As the calves mature they start to develop some resistance to worms and the faecal egg counts start to fall. With the lower egg counts and cooler weather, the larval numbers on pasture are lower in winter. The growth of grass in spring means the larvae are spread over more pasture so are diluted.

Calves have their greatest burden of Ostertagia and Cooperia in their first winter. By the time they are a year old they have normally developed resistance to Cooperia, and levels of Ostertagia. However, peak numbers of Trichostrongylus axei (both larvae on pasture and as worms in the abomasum) occur later in about October, and drop off soon after. So it’s not until cattle are about 18-20 months of age that they have significant levels of resistance to all three major species found in cattle.

Calves in their first year are the main source of pasture contamination with larvae.

Climatics in different parts of the country have some effect on the patterns. Larval development on pasture is more rapid and continues for longer through the year in warmer areas.

Infective larvae can survive for long periods in undisturbed dung pats.
Specific worm types

**Haemonchus**
Called Barber’s Pole worm because of its Barber’s Pole appearance.
Blood-sucking.
Lives in abomasum (4th stomach).
Quite large (20-30 mm).
Female Barber’s Pole worms are prodigious egg layers and can lay up to 10,000 eggs per day.
The danger period for Haemonchus is in late summer and autumn.
The numbers of Haemonchus can build up rapidly, leading to sudden and severe illness in lambs. Haemonchus is a blood-sucking worm which can cause lamb deaths from anaemia and blood loss. It can affect two tooth ewes but less commonly causes serious illness in older sheep.

**Ostertagia also known as Teladorsagia in sheep**
Called brown stomach worm
Female worm lays 50-100 eggs per day.
Lives in abomasum (4th stomach)
Quite small (~10 mm)
The L3 larvae of Ostertagia are resilient and able to survive freezing on the pasture and dry conditions. In the sheep, adults can become arrested or inhibited for varying periods. They resume activity when environmental conditions become more favourable.
Ostertagia has a characteristic not shared by other worm types; the larvae can embed themselves in the wall of the abomasum in small nodules and remain dormant there for several months without maturing. When ready, they emerge from the wall of the abomasum as adult worms and lay eggs.
Ostertagia is the most significant worm for New Zealand cattle. The disease Ostertagia causes can occur in two forms: Type I and Type II. Type I Ostertagiasis is the typical scouring and weight loss associated with other worm infestations in calves. The larvae mature normally and the effect of them and adult worms in the stomach cause loss of appetite, poor feed conversion and weight loss. Type I Ostertagiasis is of most importance in summer and autumn.

Type II results when the inhibited larvae in the stomach wall mature and break out of the mucosa causing damage to the stomach lining. In some situations large numbers emerge at the same time and can cause sudden and severe illness, and even sudden death. This mass emergence usually occurs in the spring in animals of 9-12 months or older. Because it is the maturing larvae that cause the damage, not the adult worms, their presence will not be detected by faecal egg counts (FEC).
**Trichostrongylus**

Called black scour worm.

Adult female worms lay 100-200 eggs per day. There are two common strains of Trichostrongylus. Adult *Trichostrongylus axei* worms (also called stomach hair worm) live in the abomasum, and *Trichostrongylus colubriformis* (black scour worm) live in the small intestine. Both cause damage to the lining of the gut.

The main danger period for *Trichostrongylus* is in winter as the infective larvae are very resistant to cold and desiccation and their numbers can reach high levels in the cooler months. The effects of *Trichostrongylus* in cattle are intermediate between *Ostertagia* and *Cooperia*.

However, *Trichostrongylus* worms can be very damaging in sheep.

**Nematodirus**

Called the thin necked intestinal worm.

The female worm in the small intestine lays 25-30 eggs per day. These pass out in the dung.

The larvae develop to 3rd stage (L3) in the egg shell over a period of two months or more. The combination of egg shell and L3 sheath make it able to survive desiccation and cold. It survives winter in large numbers. This overwintering means the pattern of infection for *Nematodirus* can differ from other worms in that transmission can occur directly (via pasture) from one season’s lambs to the next. Sudden outbreaks of clinical disease can occur in lambs before weaning. *Nematodirus* is of most importance in early spring and throughout the summer.

**Cooperia**

Called small intestinal worm

Small intestinal worm is 10-15 mm long and is found coiled close to the wall of the small intestine.

*Cooperia* is most common in autumn but is rarely important.

In cattle the parasitic effects of *Cooperia* are significantly less than those of *Ostertagia* but they can lay large numbers of eggs and large populations can develop, making *Cooperia* a significant worm in intensive cattle farming systems.

**Lungworms**

The major lungworm in New Zealand is *Dictyocaulus* (D. *filaria* in sheep and D. *viviparous* in cattle). *Dictyocaulus* worms are white, long (several centimetres) and thin with few identifying features. They are commonly found in frothy material in the airways in the lung.

The life cycle of *Dictyocaulus* is similar to that of intestinal worms. Adult females lay eggs containing larvae. After hatching, the larvae wriggle into the animal’s throat, are swallowed, and are passed out in the faeces. They develop on pasture and are eaten by the animals. Larvae travel from the gut through the tissues to the lungs.
Cooperia
Nematodirus
Ostertagia
Haemonchus
Trichostrongylus
Liverfluke

The adult liver fluke (*Fasciola hepatica*) is a flat leaf-shaped parasite (about 20 mm x 10 mm) that lives in the bile ducts of sheep, cattle and other animals.

The life cycle of the liver fluke involves a small freshwater snail. For animals to get infected they must graze damp areas where the snail lives.

Eggs from the adult fluke pass out in the faeces onto pasture where they can get eaten by the snail host. After going through several developmental stages inside the snail and on the pasture, the infective stage (called metacercariae) on the pasture is ready to infect a grazing animal. Inside the animal, the young fluke finds its way to the bile ducts of the liver where it matures and produces eggs, completing the life cycle.

The numbers of metacercariae on the pasture build up from late spring until late autumn when temperatures drop. In areas where the average temperature is higher than 10°C, they can be present all year round.

The signs of fluke infestation in an animal can vary from sudden death (which is rare) to reduced growth rate and production.

Tapeworm

The tapeworm (*Moniezia expansa*) is the largest internal parasite of sheep in New Zealand. Tapeworms are common in young animals, and the tapeworm segments can often be seen in their faeces. Usually by about eight months of age, animals spontaneously lose their tapeworm burden.

The tapeworm segments passed in the faeces contain eggs, which develop inside a small pasture mite. The animal becomes infected when it eats the mite on the pasture it is grazing.

There is little evidence that tapeworms have a significant detrimental effect on lamb growth rate.
3. Principles of worm management

CHAPTER OVERVIEW
After reading this chapter you will understand how to apply the knowledge gained from chapters 1 and 2. The principles of worm management are derived from this understanding as well as from many research studies and the experience of researchers, vets and farmers.

When implementing the principles outlined in this chapter the issue of drench resistance must be kept in mind. This is discussed separately in chapters 3 and 4, which presents ways of reducing the risks of drench resistance development. At times this will involve compromise so the two chapters should be read in conjunction.

- The purpose of any worm management programme is to maintain or enhance profitability by:
  - minimising contamination of pasture with infective worm larvae.
  - minimising uptake of infective larvae by susceptible stock,
  - monitoring the success of the worm management strategies.

- The main focus is to reduce exposure, especially of young animals, to worms by limiting the number of infective larvae on pasture.

- Many tools are available but the mix will vary from farm to farm. Every farmer should carefully consider all the available options for worm management and how best to integrate them on their property.

- A key factor in implementing any strategy is knowing what is happening with worms on your farm. Right now the key tools to determine this are, faecal egg counts (FEC) and the identification of worms present using faecal larval cultures. Monitoring production measures such as weight gain can tell you about the effects of worms on stock.

Worm management strategies may include:
- manipulation of pasture and stock management plans to reduce exposure of animals to worms at key times
- ensuring animals are well fed and have adequate mineral status
- minimising stress and attending to disease prevention
- breeding resistant/resilient animals
- appropriate drenching strategies
Principles of worm management

The basis of a successful worm management strategy is to prevent their negative effects on animal health and production by:

- reducing the contamination of pasture with worms eggs shed by infected stock
- restricting the exposure of susceptible stock to infective larvae.

Many tools are available but the mix will vary from farm to farm depending on what is most appropriate. Remember the situation is not static and your strategies need to be reviewed frequently to take advantage of changes in farm conditions and new control technologies. Farmers should consult with your veterinarian, or other animal health adviser.

A key factor in implementing a strategy is knowing what is happening with worms on your farm. Currently the key tools to determine the situation are faecal egg counts (FEC), and faecal larval cultures to identify the actual species present. Monitoring production such as weight gain and body condition score (BCS) are also important tools to monitor the effects on your stock. Remember there can be other causes of reduced production.

Each farmer needs to consider the options available for worm management and how they can best be integrated on their farm. Various tools are discussed briefly below. The benefits from some may be small but the overall benefit is the sum of all the parts. New developments will continue to appear and should be incorporated into the management strategy. Some possible future developments are discussed at the end of this section.

It is advisable to develop the farm programme in consultation with your animal health adviser.

The strategy requires planning effort but should result in a more efficient, cost-effective and productive farming. As experience develops it becomes easier. The strategy can be fine tuned for changing conditions.
Key factors for a worm management programme

Worm location
At any one time the vast majority of the worm population is on the pasture, rather than inside the gut of the host animal. Therefore, effective controls will minimise pasture contamination with eggs and minimise the exposure of susceptible stock to contaminated pasture. Keeping the worm challenge low by keeping low larval levels on pasture results in healthier more productive stock.

Worm numbers
Worm numbers in pastures vary throughout the year, with peaks in spring and autumn, when the climate favours worm development and young stock are present.

Larval removal
It is difficult to remove larvae without removing the affected herbage e.g. by cutting for hay or grazing with non-susceptible animals.

Spelling period
Spelling pasture for short periods (less than three months) will not reduce numbers of infective larvae sufficiently. Larvae can survive for many months even years on pasture. Cold weather slows their development but does not kill them. Exposure to direct sunlight will dry out and kill some eggs and larvae. Worms can survive and develop in the moisture of a cow pat even in drought conditions.

Immunity
Sheep and cattle (but not goats) develop a level of natural immunity to worms. Sheep begin to develop an effective immunity at around eight to nine months, while cattle over 18 months do not usually develop obvious signs of worms infestation. Therefore, it is important to avoid exposing young stock to high levels of infective larvae.

Nutrition
Animals under stress are less able to counter the effects of a parasite challenge. It is vital to maintain good levels of nutrition to meet the seasonal needs of the animal. Remember adult stock under stress, animals suffering a mineral deficiency and stock that have recently calved or lambed may also release more worms eggs onto the pasture.

Scouring
Although worms can cause animals to scour, there are other causes of scouring that are unrelated to worms.
Tools for worm management

The main focus of any worm management programme is to reduce animals’ exposure, by limiting the number of infective larvae on pasture. If young animals get wormy use drenches to kill the worms. The main aim of a management programme should be to limit the development of larvae on pasture.

To achieve this farmers need to:
- investigate all options available,
- not be afraid to seek advice,
- watch out for new developments.

Keeping stock healthy is important to reduce the effects of worms. Minimising stress and paying attention to disease prevention will mean stock are better able to deal with worm infestations, and will deposit fewer eggs on pasture.

The tools available for you to use any control programme include: farmer knowledge, pasture management, stock management, on-farm diversification, drenching and the use of genetics.

Knowledge

Here are some of the things you need to know.
- What worms are prevalent in your area?
- How do they affect sheep and cattle?
- What are their life cycles?
- When are they important?
- What factors favour larval challenge?

Pasture management

- Pasture length: keep covers long – most worm larvae are in the bottom 2cm of pasture.
- Pasture species: tannin rich pasture species may decrease the rate of larval establishment.
- Hay and silage aftermaths (preferably closed up for three months or longer): most worm eggs and larvae will not survive.
- Fodder crops and new pasture will be free of worm eggs and larvae.
- Spelling pasture (preferably for three months or longer) will reduce the level of eggs and larvae.
- Use of rotation or set stocking will depend on individual circumstances.
Stock management

- Stocking rate: the size of the worm problem largely depends on grazing animal density. The higher the stocking rate for a particular stock class, the higher the potential for worm problems.
- Graze young ahead of older stock.
- Inter species grazing: grazing interchange systems incorporate cattle, deer and adult non-lactating sheep. Pasture can be pre-grazed with resistant stock (for example cattle can be used to prepare pasture for lambs). It may take 4-16 or more weeks depending on initial contamination levels of grazing to make a pasture safe for the next stock class. Goats cannot be used to clean pasture for sheep because they share the same worm species.
- Alternation of species: any age class of cattle can prepare safer pasture for lambs. Any age class of sheep can prepare safer pasture for cattle.
- Use immune stock e.g. older animals that have developed age resistance to worms to prepare pasture for young stock. Below are some general guidelines based on pasture and stock management principles. These are examples of worm management strategies but this is not an exhaustive list or designed to apply to all farms.

Sheep

- Shift lambs off weaning areas for autumn.
- Avoid or minimise grazing lambs on lambing areas in autumn.
- Renew pastures after two years on summer/autumn lamb systems.
- Summer crops create cleaner grazing.

Cattle

- Shift weaners off spring areas for summer and off summer areas for autumn.
- Avoid grazing weaners in autumn where they will spend winter.
- Create new grazing for younger cattle (new grass, crops).

On-farm diversification

- Use other species of animals: diversification into other types such as cattle and deer can effectively reduce the stocking rate of each species.
- Cropping or including grapes and flowers.
Drenching

The different drenches are discussed in detail in the next chapter. Here discussion is restricted to drenching programmes.

Drenching sheep

Preventative drenching is a programme of four or five drenches given to lambs at four-weekly intervals starting at weaning. An additional drench about three weeks before weaning may be needed on farms that have problems with Nematodirus. Additional drenches may be needed in the autumn if climatic conditions favour larval development on pasture. The effect of this preventative programme on the build up of infective larvae on pasture is shown in the graph opposite. The advantage of preventative drenching is, it is an easy programme to follow, but it may not always be the most effective use of drench.

The alternative is to monitor and treat. Use faecal eggs counts (FEC), body condition, live weight, pasture length - quality, and larval contamination of pasture to decide when to drench lambs. The higher the FEC of the grazing stock, the higher the pasture contamination with larvae. Consider past experience of worm biology, which involves more work but can be effective for some farmers. As a general rule, ewes should not need drenching, but there are circumstances when drenching ewes may bring production or animal health and welfare benefits.

Drenching cattle

Young cattle are susceptible to the production limiting effects of worms. The need for drenching is related to the intensity of the farming operation. Calves raised intensively on centre pivot irrigated pasture are likely to be more highly challenged by worms than calves grazed more extensively. The principles of preventative drenching outlined for sheep also apply to young cattle.

Factors to consider when drenching sheep or cattle

- Adult stock should not require routine drenching.
- Worms are only one reason stock may be thin or scouring – make sure you know what you are treating.
- Drenching intervals should seldom be less than 28 days (except in the case of Haemonchus outbreaks).
- Aim to keep drenching to a minimum.
- Consider stock age/class, condition, feeding levels, stress.
- Drenching needs to be combined with appropriate grazing management.
- Drenching plays a valuable role in animal health. It needs strategic decision-making and should be part of a worm management plan. Get advice from your animal health adviser.
Quarantine drenching
All new stock both sheep and cattle, brought onto a farm should be quarantine drenched. A drench check by faecal egg counting is advised 10 days later (see next chapter).

Genetics
There are differences between individual animals, and also between breeds in their susceptibility, or tolerance of, worms. For example, Merinos are generally more susceptible to worms than the downland Romney or Composite breeds of sheep. These differences are inherited and can be selected.

Research on breeding and selection for resistant or tolerant animals has identified sires that will produce progeny more resistant or tolerant to worms. Although much progress has been made in breeding resistant or resilient stock, the focus of this Handbook is on management principles and genetic selection discussion is outside the scope of this handbook.

“Tail end” selection is practised by many farmers when they remove the more susceptible animals from their breeding programmes.

Other ideas, developments and research
- Maintaining susceptible worms in refugia (see next chapter).
- Different delivery systems are being developed for the administration of anthelmintics or drench and new combinations of anthelmintics. Boluses (capsules) are the most recent introduction to the market.
- Better or cheaper diagnostic tests for identifying worms.
- Better or cheaper diagnostic tests for drench resistance.
- Vaccination: currently there are no commercially available vaccines that are effective against worms in ruminants.
- Integrated use of anthelmintics with vaccines.
- Nematode trapping fungi: these fungi have been trialled and could be effective as a slow release device if the technology can be made to work.
- Feed-lots: bringing the feed to the animals rather than taking the animals to the feed can avoid infection with worms.
- New methods for assisting genetic selection for resistance, including gene markers.
- New chemical families of drenches.

Organic production
This can incorporate any of the tools listed above except drenching. There are some so-called organic drenches but little is known about their efficacy.
Monitoring the success of the management programme

There is a saying: “If you can’t measure it, you can’t manage it”. Monitoring is an important part of any management programme.

The specific tests used in monitoring are:
- Faecal egg counts (FEC) including DrenchCheck
- Faecal egg count reduction test (FECRT), or DrenchTest
- Worm counts
- Faecal larval culture and identification

The key tools are trend information around faecal egg counts and faecal larval cultures. These diagnostic tests will tell you how successful are your management strategies. Unfortunately there are no reliable methods to diagnostically measure infective larvae on pasture.

The emphasis here is on the specific diagnostic tests for worms but also important are:
- Good observational skills, and
- Regular weighing of stock or indicator mobs and herds.

Faecal egg counts

Faecal egg counts estimate the worm burdens of sheep or cattle. For flock examinations, faecal samples from a minimum of 10 animals are required because of the way worms are distributed in a sheep population.

However, faecal egg counting has limitations:
- Only mature adult worms lay eggs, so immature worms are not detected.
- Identification of worms is limited because the eggs of several species are indistinguishable.

Faecal larval cultures

Larval cultures involve hatching the eggs in faeces, growing the worms to the infective stage in the laboratory, and identifying them. This is the only way to identify the worms present in an animal without killing it. Although the eggs of Nematodirus are distinctive, the eggs of the other economically important worms e.g. Ostertagia, Trichostrongylus, Cooperia and Haemonchus are virtually identical and are reported in faecal egg counts as Strongylate eggs. Only when the identity of resistant worms and their seasonal pattern is known, can a farm-specific sustainable control programme be designed.

Surplus faecal egg count material from several animals in a mob is usually pooled for a larval culture, so this test cannot give a measure of the worms burden.

A limitation of faecal larval culture examination is that it takes about ten days.
When to use faecal egg counts and larval cultures

**Testing drench effectiveness (DrenchCheck)**
Collect ten fresh faecal samples off the ground seven to twelve days after drenching with an oral drench (preferably the lamb weaning drench).

If eggs are found by FEC, then either the drench is not being administered correctly or drench-resistant worms are present. A positive test should be followed by a DrenchTest.

**Investigating suspected drench failure (DrenchTest FECRT)**
Use this test:
- if eggs are present following DrenchCheck,
- if drench resistance is suspected at any time,
- to check the effectiveness of a particular drench, or
- to look at the extent of drench resistance on a property.

This test is also known as Faecal Egg Count Reduction Test (FECRT) and should be conducted by an appropriate adviser to ensure faulty drenching practices are not the cause of the problem. Divide animals into groups of ten to fifteen individually identified animals. Check FEC test to ensure that egg counts are sufficiently high to give a meaningful result. Weigh animals and drench individually at the recommended dose rate for the drench(es) being evaluated. Collect faecal samples, (from the rectum of each participating animal and conduct a FEC). Seven to twelve days later for orally drenched lambs, or twelve to fourteen days later for calves treated with pour-ons.

Larval culture will tell which worms are present and therefore resistant to the drench(es) used.

**Monitoring drench programme effectiveness**
Use the FEC test to determine the effectiveness of a worm control programme and/or whether a drench is needed. Larval culture will identify which worms are present.

**Deciding whether adult sheep need drenching**
Once over a year old sheep can usually resist the establishment of large worm burdens, and should not need drenching. However, this resistance drops if the sheep are stressed, for example in ewes at lambing. If you believe adult sheep do need drenching, conduct a FEC first to confirm the need.
Health check
Worms can cause Ill-Thrift and/or scouring in stock but these signs can be caused by other things. Determine the cause of the problem before spending money on drenches.

When animals exhibit Ill Thrift or scouring discuss the problem with your veterinary adviser. A FEC may be part of the investigation. Refer M&WNZ R&D Brief 124 Ill Thrift: Identifying the causes and measuring their effects.

Who does faecal egg counts?
There are lots of ways of getting faecal egg counts done - ask your animal health adviser, or you could learn to do them yourself. However, as with any other technical service, the quality and value of the results is only as good as the skill and experience of the person doing the count.

Collecting faecal samples
Collecting faecal samples is easy. Clean impervious containers such as plastic freezer bags or plastic pottles are ideal, or you may have been given a faecal sampling kit.

Some points to note:
- Only one sample per container (approximately one heaped teaspoon).
- Faeces must be fresh when collected (still warm).
- At least ten samples are needed to give a meaningful result for a mob.
- Keep samples in a cool place. If they cannot be examined on the day they are collected, store them in a cool places e.g. fridge, not the freezer.
Keeping records
Moving from a reliance on drenching alone for control to sustainable internal parasite control requires more record keeping and forward planning. The photocopy/master sheets on the following pages can help with both.

Farmers may wish to consult with an animal health adviser when they start using these record sheets.

Faecal Egg Count Summary Sheet
Use this sheet to summarise the results of faecal egg counts. How this is used will depend on the nature of the farm and the numbers of stock. All stock classes could be recorded on the one sheet, or it may be more appropriate to use a separate sheet for each age class.

Drench Effectiveness Status Sheet
This sheet is designed to record information about the drench efficacy status of a farm. Whenever resistance to a drench family appears and if the identity of the resistant worms are known, this information can be recorded.

Pasture Use Planning Sheet
This sheet may be easier to use if it is enlarged to A3 size. More than one sheet may be needed, depending on the size of the working blocks of land. Use pencil to fill it in so changes can be made during the year.

Identify land blocks down the left hand side of the planning sheet. Start by identifying blocks that are going to be spelled say for hay, crop and when this is going to occur. Then plan stock movements. Be sure to include all stock classes and land uses. (This sheet is modified from one produced for the New Zealand Meat Research and Development Council funded by the Parasite Action Group Project [91MT34/1.1].)

Bibliography

M&WNZ R&D Brief 115 Managing worms
M&WNZ R&D Brief 124 Ill Thrift: Identifying the causes and measuring their effects.


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<th>Date Sampled</th>
<th>Age/Mob</th>
<th>Days since last drench</th>
<th>Strongylate *epg mean (range)</th>
<th>Nematodirus *epg mean (range)</th>
<th>Other findings</th>
<th>Comments</th>
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* epg = eggs per gram
# Drench Effectiveness Status

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<th>Farm:</th>
<th>Host species:</th>
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<th>Drench Type</th>
<th>BZ (White)</th>
<th>Levamisole (Clear)</th>
<th>Dual Combination</th>
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Record the percent efficacy for each drench against each species where available from your FECRT results.
Pasture Use Planning Sheet

- minimise the contamination of pasture with worm eggs shed by infected stock
- minimise the exposure of susceptible stock to infective larvae

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This chart is designed to help you plan land use. Fill out in pencil so changes can be made during the year if conditions change. Make sure all species and classes of stock are included and all other types of land use (e.g. closing up pasture for hay making, winter feed) are included.
4. Drenches and drench resistance

**CHAPTER OVERVIEW**

After reading this chapter you will understand the basis of drench resistance and the concept of using refugia and other management practices to reduce the risk of drench resistance developing. You will also learn about the situations that pose most risk for drench resistance development so that you can take measures to reduce that risk. The last part of the chapter explains the different drench families and the importance of correct administration.

- Drench resistance to all drench families is increasing.
- The risk of drench resistance development can be evaluated and steps can be taken to minimise it.
- The concept of refugia refers to a worm population not exposed to drenching.
- Using undrenched animals to create a refugia population will ensure there are still non-resistant worms around and this can be a useful tool in delaying resistance.
- Balancing the need to reduce the risk of drench resistance and yet manage worms so that production and animal welfare do not suffer involves compromise.
- Use the concepts introduced in chapter 3 to work out ways to find a balance.
- Drenching should be just one part of an overall management plan.
- Knowing the drench efficacy status on your farm is essential
  - poor efficacy means lost productivity,
  - continued use of an ineffective drench carries a high risk of accelerating drench resistance development.
- Drench resistance could be a bigger long-term cost than short-term lower production.
What is drench resistance?

Drench resistance is present when previously susceptible worm populations in the animal survive a correctly applied, standard dose of anthelmintic or drench. The resistant worms do not die but carry onto breed. There will always be some worms with the genetic make-up to be resistant to a particular type of drench. Over time resistant worms will breed and pass on their resistance genes to their offspring, while non resistant worms are killed. This means resistant worms make up an increasing proportion of the worm population on the farm.

Recent surveys indicate drench resistance has increased for both sheep and cattle (see diagram).

Worms resistant to one drench in an action family will be resistant, to a greater or lesser extent, to all other drenches in the same action family - this is called “side resistance". Worms may be resistant to more than one action family - this is “multiple resistance". Drench resistance is usually permanent, so reversion to susceptibility is not a usable option.

Prevalence of drench resistant worms in New Zealand

The December 2006 issue of the New Zealand Veterinary Journal presented the results of two drench resistance surveys, one for sheep and the other for beef cattle.

Sheep drench resistance survey

- Survey involved eighty randomly selected farms from North and South Islands.
- Drenches tested: Ivermectin (full dose), Ivermectin (half dose), Levamisole (clear), Albendazole (white), and Levamisole + Albendazole combination; plus untreated control group.
- 36% of farms showed no evidence of drench resistant worms.
- Resistance to the half dose of Ivermectin occurred on 36% of farms, and to full dose of Ivermectin on 25%. Resistance was dominated by Ostertagia; although Cooperia, Nematodirus and Trichostrongylus were also implicated.
- Resistance to Levamisole occurred on 24% of farms and involved Nematodirus, Ostertagia and Trichostrongylus.
- Resistance to Albendazole occurred on 41% of farms and involved all the main parasitic worms.
- Resistance to Levamisole + Albendazole combination occurred on 8% of farms and involved Nematodirus, Ostertagia and Trichostrongylus.
Beef cattle drench resistance survey

- Survey involved sixty two randomly selected farms in the North Island.
- Drenches tested: Ivermectin, Levamisole (clear) and Albendazole (white) given orally, plus untreated control group.
- 7% of farms showed no evidence of drench resistant worms.
- Resistance to Ivermectin occurred on 92% of farms.
- Resistance to Albendazole occurred on 76% of farms.
- Resistance to both Ivermectin and Albendazole occurred on 74% of farms.
- Resistance to Levamisole occurred on 6% of farms.
- The worms most prevalent in drench resistant populations were Cooperia spp.
- On 75% of farms Cooperia were resistant to both Ivermectin and Albendazole. No Cooperia resistant to Levamisole were seen.
- Ostertagia resistant to Ivermectin were found on four farms, to Albendazole on fifteen farms, and to Levamisole on four farms.

Tools to delay drench resistance

Refugia

Refugia, when put into practice, involves making sure there are some drench-susceptible worms available to reproduce. The idea is to create a “refuge” for worms so that non-resistant (susceptible) worms still remain in the population base. The aim is to ensure this reservoir of drench susceptible larvae significantly out numbers drench resistant larvae on the pasture.

When worms breed in the animal, the gene frequency for drench resistance will be diluted.

Three methods to achieve refugia

One way to achieve refugia is by not drenching all the animals in a mob every time.

Another method is to put undrenched ewes on pasture previously grazed by drenched lambs. The susceptible worms shed by the ewes “dilute” the population of resistant larvae left behind by the lambs.

A third way is to drench the mob and return them to the same infective pasture for a week or so before or after they go onto “clean” pasture. This ensures that unselected worms have already been deposited on that pasture. Farmers can think of other ways to create situations of refugia on their own farm.
How do we know this refugia practice will work?
A field trial funded by Meat & Wool New Zealand showed that leaving 10% or 20% of lambs undrenched resulted in a significantly lower level of drench resistance in the worms on pasture, when compared with all animals being drenched.

This is the first research in the world to show that using refugia as a management tool can dilute resistant worms on pasture.

The biggest negative around leaving some stock undrenched was the level of larvae on the pasture increased in the trial. Remember some increase has to happen for refugia to work.

The essence is to allow enough worms through to dilute the drench resistant ones without significantly compromising animal productivity.

Putting refugia into practice
Exact recommendations on how to create refugia will vary between farms. For example, when is it best to leave stock undrenched, what proportion to leave undrenched and what implications there might be for production.

The challenge ahead is to find ways to maintain low levels of pasture infestation yet retain a useful pool of susceptible worms.

It is suggested farmers develop a plan with their animal health advisor on how refugia could be used. This could be based on: the drench resistance status of the worms on the farm, sheep/cattle ratio, stocking rate, other farm enterprises, climate effects on the worm life cycle, key risk periods to stock from parasitism (i.e. when is it best for some stock to go undrenched), current ewe drenching policy (i.e. can undrenched ewes shedding susceptible larvae be grazed after newly drenched lambs), feed quantity and quality.

The Wormwise Technical Advisory Group (made up of New Zealand experts) believes there are general principles, to be followed for mobs of weaned lambs or hoggets when deciding to leave some animals undrenched.

- If feed supplies are low or poor quality, there is a greater risk that parasitism in undrenched stock will impact on production. However, if feed quality and quantity is good and lambs are up to target weights and pasture is “clean”, then it would be an ideal time to leave some lambs undrenched.

- The benefit of leaving some lambs undrenched (and a refugia of susceptible worms) is greatest when lambs are going onto “clean” pasture.
Start conservatively i.e. start by leaving no more than 5% of lambs undrenched rather than 20%. Leaving too many animals undrenched may create a problem later in the season with accumulated parasites contaminating the pastures.

A maximum of 10% undrenched may be adequate (the trial showed the same good impact on resistant worms whether 10% or 20% of lambs were left undrenched).

Choose the best conditioned animals to remain undrenched each time. The heaviest animals are doing well so if they take a check from being left undrenched they will slip back into the “drenched” portion of the mob next time round.

It does not matter if the same animals are excluded at each drenching, as long as their condition is okay. Both animal welfare and animal production losses must be considered.

A comprehensive drench test (FECRT faecal egg count reduction test and cultures) should be carried out regularly, with frequency depending on drench resistance risk factors on each farm.

Even if a test shows that worms on your farm are not resistant to any of the three main drench families, it would be beneficial to create refugia. This is because resistant genes are likely to be present on every farm and keeping them diluted is the best long-term option to retain the efficacy of your drenches.

Cattle and refugia
Employing the concept of refugia in cattle farming will reduce the proportion of resistant worms on the pasture.

Finding a balance
Leaving a few animals undrenched can add to pasture contamination but it is likely that acceptable productivity will continue.

Drench resistance could be a bigger long-term cost than short-term lower production.

The cost of lower production from leaving some young stock undrenched is going to seem more acceptable as resistance to drenches becomes more widespread. For example, lower production in the short term may be worth it, to delay the onset of a situation where 100% of a hogget mob is 5kg lighter because of widespread drench resistance on a farm.

Quarantine drenching
One of the most likely ways to get drench resistant worms on your farm is through introduced stock. A quarantine drenching policy must be part of your worm management plan. Apply the quarantine drenching policy to all new stock brought onto the farm, including rams. It doesn’t matter how long the animals will stay on the farm – it takes less than a day to deposit resistant worms on pasture.
Other practices to reduce or delay worm resistance to drenches

Some things you can do:
- Avoid drenching lambs onto “clean” pasture unless you have a plan to introduce/maintain refugia e.g. leave a proportion undrenched or follow with undrenched ewes.
- Avoid drenching more frequently than every 28 days unless there is a special need.
- Avoid treating the whole flock pre-lambing with a long-acting drench.
- Use effective combination drenches, even if drench resistance has not been identified on your farm.
- Weigh animals so they are not under-dosed.
- Apply the correct dose using correct technique as per the label instructions.

Risk factors for drench resistance and their management

This section identifies the risk factors for the development of drench resistance in sheep, and the actions you can take to reduce them.

Similar principles apply for cattle although at present specific recommendations are still being worked on upon.

Risk factors involving ewes
In general, you should avoid routine drenching of ewes in your farming system. Maintaining a healthy undrenched proportion of the ewe flock is highly desirable to minimise the selection for drench resistance, as this helps maintain a population of unselected worms.

Using long-acting products pre-lambing
Risk factor: high

The treatment of the whole flock of ewes before lambing with long-acting products is an important risk factor and selects for drench resistance. This is supported by trials, the nation-wide survey along with modelling data.

Post lambing (docking) treatment of ewes
Risk factor: moderate

Trials show that drenching ewes at docking time with an oral drench accelerates the development of drench resistance, compared with not drenching them. In New Zealand farming systems, ewes usually gain immunity to worms by docking time. Not drenching them at this time will ensure that eggs from a mixture of susceptible and resistant worms is deposited on pasture, but should not result in production losses if animals are well fed.
**Ewe drenching at other times**
Ewe treatments at other times of the year, such as before mating or mid-winter, may increase selection for drench resistance.

**Risk reduction:**
Consider whether drenching ewes at a particular time of year is necessary (e.g. not all farmers pre-lamb drench) and whether other management practices can improve ewe condition without the need to drench. Alternatively, consider treating only part of a flock. The decision on whether to treat each group of ewes should be based on an analysis of all subsets of the flock and their management and potential productivity. This could include pregnancy rank selectives (triplets vs. twins vs. singles), age (hoggets, two-tooths, mixed age) or condition score.

Treating part of each mob will ensure that some susceptible worms remain in the system and reduce selection for resistant worms.

In some districts, clinical Haemonchosis (Barber’s Pole) can occur in ewes (usually 2-tooths) over summer, requiring prompt action. The strategic use of narrow spectrum products, e.g. Closantel, may be warranted. Consult your animal health adviser.

Older sheep are generally more immune to worms. Well fed ewes run in a balanced farming system (with cattle and with adequate control of worms in young sheep), do not require routine treatment.

Remember if feed supplies are low or poor quality, or around lambing time there is a risk that parasitism in undrenched ewes may impact on production and animal welfare. Farmers must be vigilant and discuss options with their veterinarian or adviser and treat ewes where necessary.

**Risk factors involving lambs**
Preventative drenching of lambs remains the basis of worm control on New Zealand sheep farms. The aim of this system is to reduce the amount of pasture contamination by treating the most susceptible age group to prevent production limiting parasitism and minimise the worm challenge to all sheep in autumn.

**Preventative drenching (5-6) from weaning**
**Risk factor: low to high, depending on drenching policy and grazing management.**

Simply counting the number of drenches used is not necessarily a good measure of selection for drench resistance.

**Risk reduction:**
Consider the interval between drenches – 28 days is preferable to 21 days, as 21 days is very close to the time it takes for new infections to establish and develop and begin to produce eggs.
If lambs are drenched every 21 days then any eggs being shed will generally be coming from worms that have survived the drench. A 28-day interval allows time for susceptible worms to re-infect the host and produce eggs, therefore ensuring that a mixture of susceptible and drench resistant eggs is deposited onto pasture.

Rather than having a lamb-only block (or lambs plus cattle), if you integrate an area with ewes this is beneficial because eggs coming from the ewes are not likely to be drench resistant if ewes are not being drenched.

While drenching lambs “on demand” based on FEC is likely to reduce selection for drench resistance, unless monitoring is performed very carefully it is likely to result in increased larval challenge and lowered animal performance.

**Low contaminated pasture**

**Risk factor: high**

Low contaminated pasture includes newly sown pasture, crops, cattle areas and “drench and move”. Drenching sheep onto “clean” pasture can select strongly for drench resistance. The main way to slow drench resistance is to ensure the number of susceptible worms on pasture vastly out numbers the resistant ones.

**Risk reduction:**

Consider leaving a small proportion of the heaviest lambs undrenched or follow the lambs with undrenched older sheep, or drench a few days before the lambs go onto “clean” pasture. This will allow the lambs to ingest some susceptible larvae after drenching and therefore increase the proportion of susceptible eggs deposited onto the “clean” pasture.

Where lambs are grazing “cleaner” pasture the drenching interval may be extended. Remember to monitor using FEC.

Note giving fewer drenches on “clean” pastures may be just as selective for drench resistance, as giving more on “dirtier” pastures. If lambs are shifted immediately after drenching, it is preferable to choose paddocks previously grazed, or to be grazed soon after by undrenched ewes. This will reduce the selection for drench resistance.

**General risk factors**

**Buying resistant worms**

**Risk factor: high**

Trading of sheep must be considered a high risk factor, as more than 60% of sheep farms in New Zealand have drench resistant worms of some sort. This is especially so if large numbers of sheep are introduced compared with a few rams.
**Risk reduction:**
The risk can be minimised by buying stock from farms able to document a low drench resistance status. Similarly by following a quarantine procedure for all incoming sheep using a triple combination product and holding off pasture for 24 hours. Try to avoid putting the bought in animals out to “clean” pasture.

**Using a single active**

**Risk factor: moderate to high**

Using single active drenches will always be more selective for drench resistance than using combination with another effective drench family.

By far the best time to use combination drenches is when they are still effective on their own, i.e. when drench resistance genes are rare in the worm population. **"Saving" combination drenches until you need them is NOT the right approach.**

**Risk reduction:**

Regular drench resistance testing will tell you the resistance status on your farm and whether it is changing. All the evidence available indicates that combination drenches are better for slowing the development of resistance.

Triple active drenches will be better than double actives, but will also be more expensive. The best time to use combinations is when resistance is rare (i.e. when single active drenches are still working). The extra expense is insurance against the future development of resistance. The continuous use of combination drenches needs to be accompanied by routine drench testing of all single active drenches to monitor whether the resistance status of the farm is changing.

**Continued use of ineffective product**

**Risk factor: high**

Where drench resistance is established on a farm, then continued use of an ineffective product can rapidly increase the gene frequency of drench resistant worms.

**Risk reduction:**

Use regular drench checks (at least once a year) and drench tests to determine drench efficacy on farms.

*A list of references is available in Wormwise Newsletter 4. Refugia*  
*Refer also Wormwise Newsletter 3. Drenching Decisions*
Drenches

There is a wide variety of drenches on the market with a bewildering array of different brand names. You need to know a little about the different sorts to help you choose appropriately. By understanding the different categories described below and reading the product label you will know quite a lot about the product.

Drench is another name for anthelmintic – a substance that kills target worms when administered to the animal.

Once the animal has absorbed the drench from the gut or injection site (or through the skin for pour-ons) the chemical gets into the blood stream and is circulated around the body. It affects the worms when they pass through the gut of the animal.

Drenches can be divided into their chemical families or “action groups” – each having a different action on the worm.

They can also be classified according to how many worm types they target (broad spectrum or narrow spectrum) and whether they are short or long-acting (persistent).

Broad spectrum drenches are effective against a wide range of different internal parasites; whereas narrow spectrum drenches kill only a limited range of parasites.

**Broad spectrum drenches** fall into one of three “action groups”: Benzimidazoles, Levamisole/Morantel or Macrocyclic Lactones (MLs).

**Benzimidazoles** or BZs are sometimes called “white” drenches (although not all are white). They act by preventing the worm from absorbing nutrients, causing it to starve to death.

The BZs generally have broad spectrum activity against most important worms of sheep and cattle though activity against lungworm and inhibited worm larval stages may not be as good as the MLs (see later). Albendazole also has some activity against liver fluke while triclabendazole is only effective against liver fluke. The other BZs have no fluke activity.

**Levamisole and Morantel** are sometimes called “clear” drenches (although, again, not all are clear). They affect the worm’s nervous system and paralyse it. Levamisole is effective against most worms with the exception of inhibited L4 larvae of Ostertagia in cattle. This is a consideration in the prevention of Type II Ostertagia in cattle (refer chapter 2). However, activity against inhibited Ostertagia (Teladorsagia) larvae in sheep is satisfactory. Morantel has a similar spectrum to Levamisole.
**Macrocyclic Lactones** or MLs include avermectins and milbemycins. They are sometimes called endectocides as they have activity against both internal and external parasites. They work by paralysing the worm but through a different mechanism from the clear drenches. They are highly effective against worms including lungworm and inhibited larval stages in both sheep and cattle.

**Combination drenches** contain mixtures of different action groups formulated to contain an effective concentration of each component in a stable suspension. Combination drenches were developed because of the emergence of drench resistance. Where there is drench resistance to a single active on its own, a combination drench will be more effective. This is because worms resistant to one active will generally be killed by the other. Combinations of two or three broad spectrum action groups are now available as oral drenches, and ML/Levamisole combinations are available as pour-ons for cattle.

**Narrow spectrum drenches** include Clorsulon, Closantel and Praziquantel, which are used for killing specific worms such as liver fluke or tapeworms. Closantel has persistent activity against *Haemonchus* (Barber’s Pole worm).

### Drench groups and their active ingredients

<table>
<thead>
<tr>
<th>Drench family</th>
<th>Active ingredients of group</th>
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<tr>
<td><strong>Broad spectrum</strong></td>
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<tr>
<td>Benzimidazoles</td>
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<td>Milbemycin</td>
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**Narrow spectrum**

- clorsulon
- closantel
- niclosamide
- nitroxynil
- oxychlozanide
- praziquantel
- triclabendazole
Formulations

Drenches can be administered to sheep and cattle by a variety of different methods. Drench formulation and method of administration can make a difference to drench efficacy and length of activity against different worm species as well as the withholding period. For this reason it is important to read the label carefully and to follow the specific recommendations for each particular product.

Drench administration

If a drench is to be effective it has to be administered correctly. This is discussed in detail in Wormwise Newsletter 3.

Key points are:

- Do not under-dose. Weigh representative stock to check.
- Ensure your drench gun receives regular maintenance.
- Read drench labels carefully.
- Select a dose volume based on the bodyweight of the largest animals in the group. Don’t guess - weigh them.
- Set and check the reliability of the drench gun by squirting several doses into an accurate measuring vessel.
- Re-check the dose delivery each day the gun is used or after every 200 doses, whichever comes first.

Read drench labels carefully

Important points to check

- Active ingredients
- Dose rate (ml/kg LW kilogram live weight)
- Withholding period
- Safety precautions for operators
- Storage and handling e.g. shake well before use
- Expiry date
- Storage conditions
Wormwise agreed principles

- Healthy animals harbour worms and always will - eradication is neither an appropriate goal nor achievable.
- Well fed animals are less affected by worms than those under nutritional stress.
- Older animals are generally less susceptible to worms than younger ones, and at times, can be used to reduce the number of infective larvae on pastures.
- Animals vary in their susceptibility to worms (genetic variability).
- Animals can be selectively bred for resistance or resilience to round worms.
- When breeding for a characteristic, intensive selection pressure will result in more rapid change being made (applies both to livestock and worms).
- Breeding for a single trait leads to a more rapid change than breeding for a combination of traits.
- Most of the year there are more worms, in the various life stages, on pasture than inside the animals.
- Anthelmintic or drench is a finite resource and should be used to achieve the greatest sustainable benefits for the farmer.
- The way in which you use drenches and manage worms can change the rate at which you select for resistant worms.
- Each farm is a unique ecosystem and effective worm management is dependent on the knowledge of the round worms present and their anthelmintic or drench resistance status.
- Some drench formulations, by their very nature, are long-acting and may hasten the development of drench resistance if they deliver a sub-optimal level of active ingredient for an extended period.
- Once present on a farm, worm resistance to anthelmintics is permanent.

Key points

- Parasitism is a major cause of loss of production in livestock.
- Based on current information, many New Zealand farmers are using anthelmintics in a manner which will result in drench resistant worms and drench failure.

August 2007
Glossary

Abomasum
The fourth stomach of a ruminant

Anthelmintic
Also known as a drench. A drug used to kill internal parasites. Some are also effective against various external parasites

Benzimidazole
A group of anthelmintics; also called the white drenches, or BZs

Broad spectrum
A term used to describe the drenches that control a large number of internal parasites

Cestode
The scientific classification for tapeworms

Challenge
Exposure to parasites, either by artificial (experimental) infection or from grazing worm-contaminated pastures

Clear drench
A common name for the levamisole drenches

Clinical parasitism
The visible effects of worms such as scouring or weight loss, or reduced weight gain

Combination drench
A specially formulated mixture of two or more anthelmintics

CRC
Controlled release capsule

DrenchCheck
A check on drenching efficacy by doing a faecal egg count after drenching

DrenchTest
A test for drench-resistant parasites. Faecal egg counts are done before and after drenching

Epg
Eggs per gram of faeces

FEC
Faecal egg count; a measurement of round worm eggs in faeces, expressed as eggs per gram (epg)

Host resistance
The varying ability of a host animal to resist infection by a disease producing organism such as a round worm

Immunity
The ability to resist and overcome infection by, for example, round worms

Larva
An immature or juvenile stage (plural: larvae)

Larval culture
A laboratory procedure in which worm eggs in faeces are incubated until they develop into the infective larval stage, at which time they can be identified

Levamisole
A group of anthelmintics that includes levamisole and morantel; also called clear drenches

Macrocyclic lactones
A group of anthelmintics that includes the avermectins and milbemycins; often referred to as MLs

Narrow spectrum
A term used to describe the drenches that control only a small number of internal parasites

Nematode
The scientific classification for the round worms

Peri-partum rise
An increase in worm egg output by adult ewes that occurs around lambing time

Prepatent period
The time from when a sheep ingests a worm larva to when worm eggs appear in the dung

Refugia
A worm population not exposed to drenching. Using some undrenched animals to create a refugia will result in non-resistant worms remaining in the population, and this can be a useful tool in delaying resistance

Subclinical parasitism
The unseen effects of worm infection, which can reduce weight gain and suppress appetite

Susceptible
An animal or parasites lacking resistance i.e. animals that are readily infected by parasites, or parasites that can be killed by a drench

Trematode
The scientific classification for flukes

White drench
A common name for the benzimidazole group of anthelmintics

Worms
Round worms
A Handbook of
Sustainable Worm Management for Livestock Farmers

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