Managing internal parasites in organic livestock production systems

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Introduction

Worms (internal parasites) in livestock can significantly affect animal welfare as well as economic outcomes for farmers.

In Australia, worms are the number one health problem for sheep, with costs estimated to be

$369 million (Sackett and others, 2006).

Internal parasites are also a major health issue for cattle, costing an estimated $38 million a year in lost production and control costs (Sackett and others, 2006).

To sell livestock as 'organic', producers are not allowed to treat livestock with veterinary chemicals (anthelmintics) to control internal parasites. There is also mounting pressure in conventional livestock systems to reduce reliance on anthelmintics because of the increasing prevalence of drug-resistant worms and because of consumer concerns over chemical residues.

The 'invisibility' of internal parasites

Worms and their effects are more or less invisible. Even on post-mortem examination, many internal parasites are hard to see. As to their effects, about 80% of the costs of internal parasites are due to production losses which often are subtle, but nonetheless significant.

Also, signs consistent with 'worminess', such as anaemia, scouring or ill thrift, can be due to other causes, such as bacteria, viruses or poor nutrition.

Assessing worm burdens

Because worms and their effects are often more or less invisible, objective measurements should be used to assess the impact of worms. These include:

- Faecal worm egg counting (WEC) and 'worm-typing' (larval differentiation).
- Measurements of productivity e.g. growth rates, milk yields etc.
- Visual assessment, including body condition, behaviour, and signs suggesting disease, for example anaemia, 'bottle jaw' (submandibular oedema) and scouring (diarrhoea).

Key worm species and their impact on livestock productivity

The first step in good worm control is to identify which worms are present, their lifecycles, what conditions favour their survival, and how they affect host animals.

Detailed information about important worms and specific control methods can be found on:

NSW DPI website, www.dpi.nsw.gov.au/agriculture/livestock/sheep/health and,

WormBoss website http://www.wormboss.com.au/worms.php

The key worms affecting livestock are listed in Table 1. Note there are other worms including lungworms, other scour worms, and other parasites, such as coccidia, but those listed in Table 1 are usually the most important in temperate regions of Australia.

Table 1 Most important worms of ruminants in Australia

Common Name	Scientific Name	Location of adult worms	Effects

Common Name	Scientific Name	Location of adult worms	Effects
Barber's pole worm	*Haemonchus contortus* (mainly sheep, goats); *H. placei* (mainly calves)	Abomasum (4th stomach)	Blood-suckers, causing pallor / anaemia, exercise intolerance, loss of protein. Sometimes sudden death.
Liver fluke	*Fasciola hepatica* (many warm-blooded final hosts)	Liver	
Small brown stomach worm	*Teladorsagia (Ostertagia) circumcincta (sheep, goats); Ostertagia ostertagi (cattle)*	Abomasum	Grazes on mucosa (stomach or intestinal lining): loss of protein, malabsorption, loss of appetite, scouring
Black scour worms	*Trichostrongylu- s* (various species)	Mostly in small intestine	

Assessing worm burdens

Faecal worm egg counts (WECs) are a simple but very important tool for assessing worm burdens. Worm-typing (larval differentiation) is often done to determine which species of worm are present.

Some benefits of WECs:

- Better measure of worm burdens than visual assessment alone
- Gives early warning of burdens that could become a problem
- Prevents unnecessary treatments
- Helps to differentiate from other causes of disease or ill thrift
- Can be used after treatment (often10 days after) to test efficacy of the treatment
- Objective and regular measurements such as WECs give producers peace of mind
- When combined with worm-typing, WECs can lead to better treatment choices (different worms might require different control measures).

WormTest is another name for WECs that are done to monitor roundworm egg counts (and worm-type) and fluke (stomach and liver fluke) egg counts in livestock, including cattle, sheep, goats, alpacas, pigs and horses. Egg counts are done on dung samples submitted to the laboratory in a WormTest collection kit. Note that the laboratory method for round worm egg counts is different to that for flukes: be sure to specify on the lab submission form which tests you require. WormTest kits, which include packaging suitable for mailing to the lab of your choice, are available from Local Lands Services (LLS), NSW DPI offices and rural suppliers. Tests can be done at NSW DPI or private parasitology labs.

WECs need to be interpreted along with other factors, such as the species, age and condition of the animal, the types of worm present, and various management factors. For example, weaners might be treated at a lower egg count than non-lactating adults in good condition.

Also note that WECs do not correlate as well with worm burdens in cattle as they do with small ruminants and alpacas. For example it is possible to have significant production losses and even clinical parasitism in cattle with low worm egg counts. If in doubt, check this using a 'diagnostic treatment', i.e. identify and treat a proportion of the affected mob and assess any responses to treatment, preferably using objective measurements (e.g. growth rate) as well as visual assessment.

All tests and methods have their shortcomings. Despite this, WECs are a most important and cost-effective tool. Unfortunately, WECs are used somewhat less than they should be.

For more information on faecal worm egg counts and WormTest, as well as the most significant internal parasites affecting sheep, goats and cattle see NSW DPI website: www.dpi.nsw.gov.au/agriculture/vetmanual/specimens-by-disease-syndrome/diseases_of_livestock/internal_parasites

Also see: http://www.wormboss.com.au/tests-tools.php

Other tests

Haemonchus Dipstick Test

This test detects occult (hidden) blood in the faeces which can serve as an early warning of problems from barber's pole worm in sheep, even earlier than with WECs. It is most useful in areas and seasons where disease from barber's pole worm (haemonchosis) is a serious problem.

More information: http://www.wormboss.com.au/tests-tools/tests/assessing-worms.php

Other lab tests

Field and laboratory vets may employ other tests, such as pepsinogen estimation (if ostertagiosis in cattle is suspected), liver function tests, or haematology (blood counts), to help diagnose disease due to parasites or other causes. Dung samples may be tested for coccidia, or viruses or bacteria that may cause scouring.

Visual assessment of livestock

Visual signs such as loss of condition, lethargy or scouring may indicate a significant worm burden.

Various visual assessment tools have been developed to help producers identify and treat those animals in a herd most severely affected by internal parasites.

Body condition scoring (BODCON) is a field based method of scoring the tissue over the lumbar vertebrae of goats. Scour worms such as *Trichostrongylus* spp. and *Teladorsagia* sp. can cause reduced appetite, scouring and weight loss that is easily detected by this method (MLA, 2007). Condition or fat scoring is also used in sheep and cattle. (See NSW DPI website).

FAMACHA© is an on-farm method of grading the colour of the conjunctiva the lower inner eyelid of individual goats and sheep against a simple colour chart (Figure 1). Pallor indicates anaemia which is commonly caused by the blood sucking nematode *Haemonchus contortus* (barber's pole worm). Other causes include liver fluke infections and ovine mycoplasmosis (formerly known as eperythrozoonosis). FAMACHA is used to detect haemonchosis-affected sheep and goats for treatment and, in the case of repeatedly affected animals, culling.

Figure 1 FAMACHA© eye colour chart assesses level of anaemia (an indicator of barber's pole worm infestation) in sheep and goats.

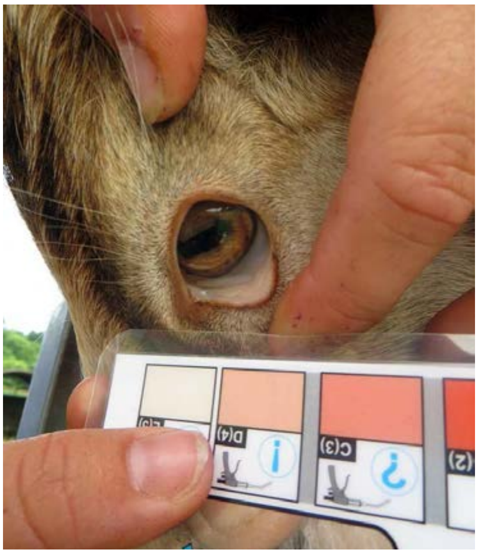
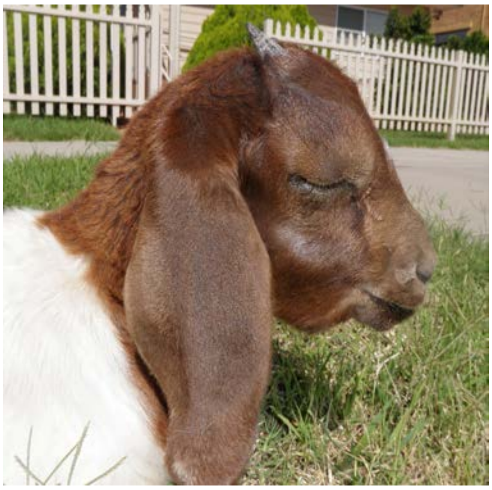


Photo credit: Susan Schoenian, 'Baalands'. www.flickr.com/photos/baalands/9263070823/sizes/c/in/photostream/

Due to the frequent testing required (all individuals in a mob are tested and recorded every 1–2 weeks during the worm season), MLA considers FAMACHA to be largely unsuitable in Australian commercial flocks. However, there may be a role for it in small hobby flocks (under 50 sheep) where frequent monitoring is possible (MLA, 2007: http://www.wormboss.com.au/tests-tools/tests/assessing-worms.php).

Another easily recognised symptom of worm infection is bottle jaw or sub-mandibular oedema (Figure 2). The swelling under the jaw can result from both severe barber's pole worm and liver fluke infections; but may also be caused by other factors such as a severe lack of protein in sheep.

Figure 2 . Bottle jaw (sub-mandibular oedema) can indicate severe infection by both barber's pole worm and liver fluke.



Dr Libby Guest

Sheep that lag (a tail in the mob) or lie down during mustering can also indicate a significant worm infection.

Although labour- and time-intensive, these tools can help with selection of animals that are more resilient to worms, whereas WECs, for example, detect those with greater host resistance to worms (MLA, 2007).

More information: Tools and tests:

http://www.wormboss.com.au/tests-

tools/tests/assessing-worms.php

Resilience vs resistance:
http://www.wormboss.com.au/tests-tools/management-tools/breeding.php

Visual signs of worms:

http://www.wormboss.com.au/worms/roundworms/signs-of-worms.php

Factors affecting parasitism

To effectively control internal parasites in organic livestock systems you must know and manage the relevant risk factors. These include:

- Location – Local climatic and environmental conditions strongly influence which parasites are present and in what numbers. Warm and moist conditions generally increase the risk of significant infections.
- Livestock susceptibility - Breed and genetic selection, age, and stressors such as poor nutrition, pregnancy, birthing and weaning, can increase susceptibility to parasitism.
- Livestock management – This includes grazing management (quality and quantity of feed) and stocking rates, pasture species selection and soil health.

Location of the livestock enterprise

Controlling worms organically is often more challenging in the high rainfall areas of southeastern Australia. This is particularly the case in coastal areas where higher rainfall and humidity create moist conditions which favour free-living stages (eggs, larvae) of worms on pasture.

This doesn't mean that organic livestock production in wetter regions should be avoided. Rather it means that greater diligence is required to maintain livestock health and to strategically prevent the build-up of parasites under favorable conditions.

Which worms infect livestock largely depends on climatic conditions. For example, liver fluke (*Fasciola hepatica*) is an important parasite of livestock in wetter zones which favour the intermediate host, an aquatic snail. So, liver fluke is more common in the eastern third of NSW, but also may occur in some western irrigation areas.

There are websites which identify appropriate management options (including non-chemical) for the major internal parasites according to specific regions. For sheep, WormBoss is the national repository of information on sheep worm control in general, as well as providing more specific guidance for worm control in specific regions around Australia: www.wormboss.com.au/programs.php. The general principles enunciated in WormBoss also apply to other livestock.

For cattle, the MLA's 'atlas' of parasite control in cattle identifies major control regions and management options. See: www.mla.com.au/Livestock-production/Animal-health-welfare-and-biosecurity/Parasites/Cattle-parasite-atlas

Also check information on state government websites, for example, NSW DPI: http://www.dpi.nsw.gov.au/agriculture/livestock/health

Local environmental conditions can also play a role in livestock susceptibility. For example, under dry conditions when liver fluke may not be considered an issue, livestock tend to congregate in areas such as soaks and water courses where green pasture persists, and where fluke are more prevalent. So, fluke infections can be higher during dry spells than in good seasons when livestock are dispersed over a greater area.

Some strategies to minimise fluke infection are exclusion of stock from, or draining, these persistently damp areas. There are also management, water quality and environmental advantages to permanently fencing off swamps, creeks, dams, and using only troughs to supply stock water.

Drought and floods may also play a role because they affect the quantity and quality of forage.

Poorer nutrition can reduce the resistance and resilience of livestock with respect to internal parasites.

Livestock susceptibility factors

The susceptibility of livestock to internal parasitic infestations is often referred to in terms of their resistance or resilience to infection. Resistance is the animal's ability to withstand infection by parasites; resilience is the ability to cope with the effects of parasites once infection has occurred.

Livestock nutrition

The development and maintenance of immunity requires protein, energy and minerals in balanced proportions. Poor nutrition increases vulnerability, (reduces resilience and resistance), to pests and diseases.

Providing browse or browse paddocks is a good worm control option for goats (MLA, 2007).

Browse may improve nutrition as well as reducing exposure to infective worm larvae on pasture.

Breeding worm resistant livestock

Host resistance to worms is a heritable trait in sheep and other livestock. The heritability is sufficiently high in sheep to allow for significant increases in the resistance of a flock of sheep over time by using rams that have favourable Australian Sheep Breeding Values for worm egg count (ASBV-WEC) as well as other desirable traits.

Resilience is also heritable, and is independent of resistance. The resilience of a flock can be improved by selecting rams with favourable ASBVs for various production traits.

The emphasis placed on various traits in breeding programs depends on the particular issues faced by producers and what their goals are.

Walkden-Brown et al. (2008) found that selection for resistance to worm infection in goats is likely to result in slow genetic progress but with no evidence of negative correlations with production traits.

More information:
http://www.wormboss.com.au/tests-tools/management-tools/breeding.php

Culling susceptible livestock

Some individuals in a herd or flock are significantly less resistant and/or resilient to internal parasites than the average. Once identified as 'repeat offenders', these should be removed from the flock.

Breed selection

As well as genetic variation within any flock or herd, there are some livestock breeds that have genes which make them somewhat more resistant or more resilient to internal parasites than other breeds.

For example, the Red Maasai, a breed of sheep kept by Maasai pastoralists in East Africa's Great Rift Valley, have been found to be genetically resistant to intestinal worm parasites. Geneticists working at the International Livestock Research Institute (ILRI), in Nairobi, Kenya are investigating which genes may be conferring worm resistance in this breed. The St Croix is another native or indigenous breed of sheep which shows strong resistance to some worms.

Other sheep breeds may be more resilient to parasites. Whilst breeds such as Dorpers may appear to suffer less from worms than other breeds in some environments (eg. rangelands), this could also be due to their propensity to browse more than other sheep breeds, resulting in a lower intake of worm larvae.

Goats are more susceptible to parasite infection than sheep. Boer, Nubian, Angoras and Swiss Dairy seem to be particularly vulnerable whilst Kiko, Spanish and Myotonic have been reported as being more resistant (Schoenian, S. and Semler, J. 2013).

Livestock age

Young livestock are more susceptible to parasites than adults. With maturity, their immune response and resilience to parasitic infections strengthens.

By two years of age most cattle have strong immunity to roundworms; accordingly, adult cattle require less frequent treatment, unless liver fluke is an issue.

Sheep less than 12 months of age are most susceptible to the harmful effects of internal parasites. Dry adult sheep usually have lower worm burdens and shed significantly fewer worm eggs in their faeces compared to lambs and weaners. They are also much less likely to suffer production losses due to internal parasite infection because of greater immunity and resilience (MLA, 2007). Grazing management can exploit this by having older, less susceptible stock grazing wormier pastures before young stock, or have a higher number of less susceptible livestock together with young stock.

Goats are particularly slow to develop immunity to internal parasites. Goats of any age have little natural resistance or resilience to parasitic infection.

Stress and physiological state

Stress weakens immunity and increases vulnerability to worms.

Late pregnancy, early lactation and weaning are times when animals' resistance to worms may be low. Good management including good nutrition is critical at these times.

Poor nutrition is a very common stressor, especially during droughts, and markedly increases susceptibility to parasitism and other diseases.

Good nutrition and managing exposure to worms through grazing rotations assists in developing and maintaining resistance and resilience. Good management optimizes nutrition by giving access to quality pasture, and providing quality supplementary feed under adverse conditions such as drought or flooding.

Minimising livestock stress from poor handling procedures or lack of shelter is also a priority.

Livestock management and internal parasites

Good worm management consists of a number of strategies, both short and long term. An integrated approach to parasite management is essential if it is to be effective and sustainable.

Impact of pasture management on worms

Pastures are often utilised by organic mixed livestock and cropping enterprises as a stage in a cropping rotation. The pasture phase is used to provide livestock nutrition, improve soil structure, create fertility for crops, and to break weed, pest and disease lifecycles. In order to maximise these benefits, rotations should be the right length and should include appropriate pastures and crops.

For example, in a mixed legume and grass based pasture, a pasture phase that is too long can cause a decline in nutritional value, and an increase in parasite load. Additionally, with the pasture becoming grass dominant over time there may be less nitrogen that is fixed and available for crops succeeding in the rotation.

Moving livestock to a new grazing environment can increase the risk of worm infections.

Livestock newly introduced to an organic enterprise should first be placed in a quarantine paddock and checked for worms. If treatment is required, do this prior to mixing new livestock with the organic herd. This prevents unnecessary contamination of clean pastures with parasites as well as allowing for contaminants such as weed seeds to be passed through the gut and confined to the non-organic area.

Note that newly introduced non-organic livestock may be carrying worms with some degree of drench resistance to one or more drench groups, so if chemical drenching is required then it is important to consider quarantine protocols to keep these drug resistant worms out of the system. There is a recommended protocol for this (which includes using anthelmintics) See: http://www.wormboss.com.au/news/articles/drenches/quarantine-drenching-getting-it-right.php

If anthelmintic treatments are used, the treated livestock must be quarantined from organic livestock for a period equivalent to three times the withholding period specified on the product label, or three weeks, whichever is longer. There are restrictions on selling these livestock as 'Organic'. See section on 'Chemical Treatments' in this Primefact and also: www.dpi.nsw.gov.au/agriculture/farm/organic/livestock-vaccinations

Pasture selection

When selecting pasture species in organic systems, consider nutritional and health benefits for livestock, nutritional inputs for subsequent crops (e.g., nitrogen fixation); soil improvement benefits (e.g. tap rooted species help recycle nutrients and improve soil structure); persistence of species under different grazing regimes, and competitiveness against weeds, pests and diseases.

Pasture species with anthelmintic properties

Some bioactive forages show potential for worm control in sheep and goats, partly at least by improving resilience against parasites.

Research shows that some leguminous pasture species containing condensed tannins (CT) can reduce worm burdens and WECs in sheep and goats, although why this happens is not always clear.

The CT content of some forage species is shown in Table 2.

Table 2 Condensed tannin (CT) content in different forage species.*

Forage	CT g/kg of DM
Birdsfoot trefoil (*Lotus corniculatus*)	48
Big trefoil	77
Sanfoin	29
Sulla	51-84
Lucerne	0.5
Sericea lespedeza	46-152
Perennial ryegrass	1.8
Chicory	3.1
Crabgrass/tall fescue mixture	3.2

*The standard used for analysis will affect the results. For these studies, a Quebracho (a tannin containing South American hard wood tree species) standard was used. Source: ATTRA 2007. Tools for Managing Internal Parasites in Small Ruminants: Sericea Lespedeza

However, finding the tannin producing species with the 'right' combination of nutritional benefits and 'anti-worm' effects is not easy.

According to Min et al. (2003), low concentrations of CT (20-45 g CT/kg DM) are helpful to animals, whereas high forage CT concentrations (55 to

106 g of CT/kg of DM) have been shown to reduce productivity, (Barry and Manley, 1984). If CT levels are too high, palatability can be a major issue, resulting in lower animal productivity.

Results vary according to CT concentration and type, and the species of animal grazing the forage.

A number of species have been investigated for their effectiveness in controlling internal parasites.

Forage chicory is known to improve the live weight gain in lambs and to lead to lower pasture contamination because “larval survival on chicory is lower than on grasses” (Rattray, 2003).

Research indicates that chicory can reduce adult worm burdens in sheep but not WECs or the establishment of ingested infective larvae.

Grazing chicory may reduce worm impacts in infected animals and improve immunity, but doesn’t appear to decrease pasture infectivity or protect sheep from further infection (Rahmann and Seip, 2006).

Lotus corniculatus has been shown to reduce dagginess and flystrike in lambs (Leathwick and Atkinson, 1995), this possibly being related to reduced levels of internal parasites in sheep (Niezen et al. 1996).

Sericea lespedeza tannins have also been shown to be effective in controlling coccidiosis and reducing methane emission.

Research on lambs infected with barber’s pole worm (*H. contortus*) grazing Sulla, a short lived highly productive perennial legume originating from the Western Mediterranean and Northern Africa, showed reduced WECs and worm burdens (Niezen et al. 2002a; Hoste et al.

2005b). However, Sulla was not effective against black scour worm (*T. colubriformis).* (Molan et al. 2000a; Niezen et al. 2002a). Other research (Athanasiadou et al. 2005; Tzamaloukas et al.

2005; and Pomroy and Adlington, 2006) indicates that feeding Sulla has no effect in the short term but, if fed for longer, may reduce WECs and improve animal performance.

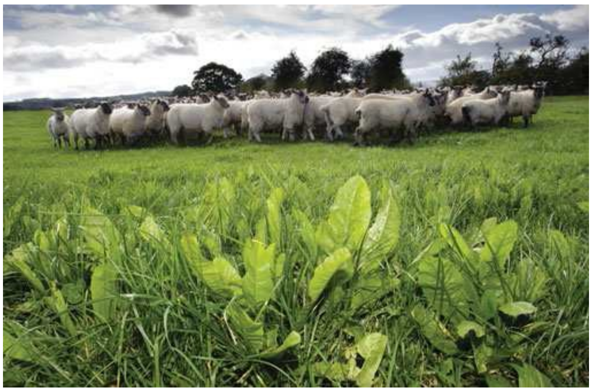
This has implications for grazing management, particularly as Sulla is difficult to manage agronomically, being susceptible to competition by weeds at establishment, as well as after cutting. Also it is not suitable for intensive grazing (Frame, 2005).

The tannin content of plants varies considerably between plant species and genotype. It may also depend on stage of plant growth, and can vary with plant part (leaf, stem, inflorescence, and seed), season of growth and factors such as temperature, rainfall, cutting and defoliation by grazing herbivores and insects.

More research is required to better understand these influences on tannin content and how to manipulate tannins to maximise nutritive value for animals.

Several options for feeding tanniferous plants have been reported, including cultivation of arable crops and inclusion in the normal rotation (Niezen et al., 1998). These can then be used as ‘de-worming paddocks’, or the plants can be harvested and fed as hay or silage at a later date.

Figure 3 Sheep grazing chickory



www.fwi.co.uk/articles/17/06/2013/139532/sheep-grazed-on-chicory-show-reduced-worm- count.htm

Grazing management strategies

Grazing management is very important in managing parasites. Producers should use strategies which optimise livestock nutrition and minimise numbers of worm eggs and larvae on pasture.

During grazing, pasture height should ideally be kept above 10cm as most of the infective worm larvae - which move within thin films of water on plants - are within the first 10cm above ground. However, some livestock may preferentially close graze pasture regardless of pasture height.

The terms ‘safe’, ‘clean’ or ‘low-risk’ – all relative terms - are often used in relation to pasture and parasite load. The main function of any grazing system is to limit exposure of animals to worm larvae as well as providing a good quantity of quality forage for grazing animals.

Free-living stages (eggs and infective larvae) of worms have certain weaknesses, and grazing management seeks to exploit these.

For example, barber’s pole worm eggs are only viable for 7 days after deposition on pasture, and must receive adequate warmth and moisture in this time if the eggs are to produce larvae. The infective larval stages of round worms are unable to feed and have limited energy reserves. Their life is thus limited, with death occurring faster under warmer conditions because larval motility is increased and energy reserves are depleted faster. Larvae are also susceptible to heat and desiccation. Also, many roundworms have distinct preferences for different animal species, so grazing with one species (e.g. cattle) can reduce pasture infectivity for another (e.g. sheep).

WormBoss provides grazing management options to provide low-risk worm paddocks for sheep in different regions: www.wormboss.com.au/programs.php

Rahmann and Seip (2006) describe three grazing management strategies as measures to minimize new and re-infection of gastro-intestinal nematodes in sheep and goats: 'preventive strategies', 'evasive strategies' and 'diluting strategies'. These are summarised in Table 3.

Table 3 Overview of different grazing management strategies in sheep and goats (Rahmann and Seip, 2006)

Preventive strategies	Evasive strategies	Diluting strategies
Turning out parasite free animals on clean pastures	***Worm challenge is evaded by moving animals from contaminated to clean pasture***	***Worm challenge is relieved by diluting pasture infectivity***
• Delayed turnout • Changing pastures between seasons • Moving at weaning • Late lambing • Grass re-seeds • Cultivation of annual forage crops • Silage/ hay aftermaths • Alternation of different host species	• Moving to safe pastures within the same season • Alternate grazing of different species • Hay/silage aftermaths • New grass reseeds • Cultivation of annual forage crops	• Avoid stocking rates close to carrying capacity of plant production • Reduction of the general stocking rate • Mixed grazing with other host species • Alternate grazing with other host species • Mixed grazing with other age groups

Spelling pastures

Giving pastures a spell from grazing can break parasite lifecycles, providing cleaner pastures for livestock in the future. The length of spelling should be enough to allow a sizeable majority of the free living stages of worms on pasture to die.

For most of the important worms of livestock, the infective larval stages live much longer than the eggs from which they come. So, the infective stage depends on how long it takes most larvae to die. This is very much dependent on temperature and could range from 2-3 weeks (hot summer, western plains of NSW) to 6-8 weeks (summer, NSW North Coast), to 5-6 months (colder months, NSW tablelands). A rule of thumb for the temperate eastern third of NSW: 2-3 months in summer, and double that in winter.

If timed correctly, spelling pastures may have additional benefits. For example, removing livestock during the wetter times of the year reduces soil compaction. Also, spelling paddocks aids pasture replenishment when they are re-seeding.

There are challenges, however when you need to spell pasture for as long as 5-6 months to produce low-worm-risk pastures. A problem may develop where pastures become rank and animal production could suffer; but the aim is to minimise the deposition on pasture of worm eggs during times when conditions (warmth/moisture) allow these eggs to develop and produce larvae. When preparing a paddock for spring lambing in the Northern Tablelands of NSW, for example, this means that sheep and goats should not graze the paddock in March and April, and possibly part of May if the weather is mild. However the paddock can be grazed in the colder months leading up to lambing because the problem worm in that region, barber's pole worm, cannot complete its lifecycle when daily maxima are consistently below 18 degrees C. If the paddock is being prepared for sheep or goats, it can still be grazed with cattle to prevent feed from becoming tall and rank.

Conventional or traditional farmers have the option of 'smart grazing', which involves grazing sheep within 0-21 days after a highly effective drench. This can be done because no or few worm eggs will be passed in the dung within approximately 3 weeks of a highly effective drench.

Integrated grazing

Older, less susceptible stock grazing 'wormy' pastures can reduce worm exposure for young stock that follow.

A variation is to have a higher number of less susceptible livestock together with young stock.

Alternate or cross grazing is another form of integrated grazing. For example, grazing cattle before sheep improves worm control in both species as they generally carry different species of worms. Preceding or following cattle or sheep in a grazing rotation with free-ranging chickens can help also as chickens break-up manure piles.

Ducks grazing wet areas can consume snails (*Lymnaea* spp.), the intermediate host for liver fluke (*Fasciola hepatica*). For more information on identification of liver fluke snails see: http://www.dpi.nsw.gov.au/agriculture/livestock/sheep/health/liver-fluke-snails

Another method is to graze different species together, which 'dilutes' the parasite load. This also has weed control benefits as different grazing habits do not allow domination of any one weed species.

Niezen et al. (1996) states that in order for a successful sheep-cattle integrated grazing management system to be implemented, the ratio of sheep to cattle stock units[1] should approach 50:50; with any increase above 65:35 (sheep:cattle) making such a system less effective.

[1] Dry Sheep Equivalents or DSE is a standard unit frequently used to compare the feed requirements of different classes of stock or to assess the carrying capacity and potential productivity of a given farm or area of grazing land. For more information see: http://www.agronomy.com.au/download/dseratings.pdf

Not all species are appropriate for alternate grazing. For example, because goats are more likely to carry 'cattle' worms than say sheep, and because they also carry all 'sheep' worms, they are less effective as a means of reducing worm risk for other host species. In addition, goats generally develop less host resistance to worms compared to cattle (especially) or sheep, so tend to shed more worm eggs in their faeces.

Alpacas carry both sheep and cattle worms, as well as their own 'special' (camelid) worms (in their countries of origin). However, this does not usually present a great problem for sheep when used in small numbers as guard animals. Also alpacas use 'latrines', not widely dispersing their faeces like grazing ruminants.

Liver fluke infects a wide range of warm-blooded animals (including humans and wild animals), which has implications for grazing management and liver fluke control, except that adult beef cattle are less vulnerable to liver fluke (and shed fewer eggs) than say young cattle, small ruminants or alpacas.

Cultivation and intermediate cropping

This system curtails a build-up of insects, parasites or other disease agents and therefore promotes cleaner pastures. Sowing mustard and ploughing it in as a green manure has been shown to clean a pasture (Belstead and Belstead, 1992).

Rotational and strip grazing

Old, stale and overgrazed pastures are less nutritious and less digestible, and may have a higher parasite load. Other problems with overgrazing include soil compaction and invasion by non-palatable weed species.

Rotational grazing involves moving livestock strategically onto fresh pasture, or partitioned pasture areas, to allow vegetation in previously grazed pastures to regenerate. Other names include cell grazing and controlled grazing.

The time livestock are grazed on a particular paddock before being 'rotated' and then returned to that area generally depends on stocking rate and pasture growth rate. The latter depends on species, pasture nutritional status and climatic factors. Brief grazing periods (less than 4–7 days depending on temperature) avoids continuous infection ('auto-infection') by parasites.

Management of parasites to coincide with the duration of pasture rotations depend on the lifecycle of the particular parasite species, longevity of larvae as well as the length of time and conditions under which eggs take to hatch. For more detail relating to sheep worms, see the appendices in 'Your Program' in WormBoss, e.g. http://tinyurl.com/factors-pdk-contam-wboss

Strip grazing involves back-fencing stock to match larvae development so that stock are not re-infected ('auto-infected') by infective larvae produced by worm eggs they have recently deposited on pasture.

Optimising pasture management for livestock health

Good pasture management uses strategies to create good quality pastures. Achieve this by adopting practices which promote optimum soil health and pasture nutrition, combined with appropriate grazing strategies.

PROGraze is a series of workshops designed for producers to better manage their pastures and optimise livestock production and to develop pasture and livestock management plans. For more information see:

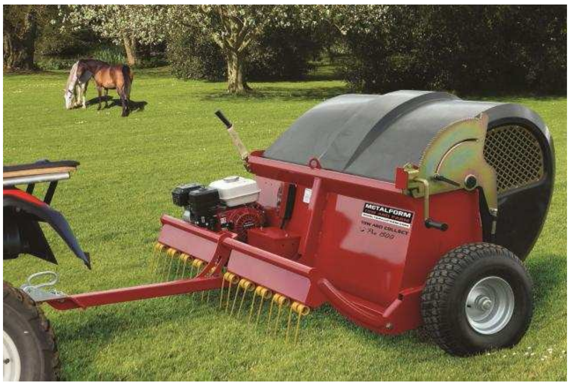
www.dpi.nsw.gov.au/agriculture/profarm/courses/prograze

Manure management

Manure, especially cattle manure, provides a warm and moist environment which favours the survival of worm eggs and larvae.

Ideally, manure should be collected, composted and spread onto spelled pastures; however this is mostly impractical, especially in large scale operations. Specialist pasture 'sweepers' and 'vacuums' are available for this purpose (Figure 4).

Figure 4 A pasture 'sweep and collect' manure collector



http://www.towandfarm.com.au/collect-1500-p- 215.html

How fast manure decomposes is affected by environmental factors (rainfall, temperature) and the activity of decomposers such as earthworms, fungi, bacteria and arthropods, such as dung beetles. This can be helped by mechanical methods such as harrowing and slashing.

Dung beetles

Adult dung beetles shape dung into balls which are used to nourish its larvae. The dung is buried under the dung pat, where the female beetle lays a single egg in each dung ball. The larva hatches a few days later and feeds on dung. Larva quickly break up and bury manure pats, causing them to dry out. This restricts the development of fly and worm larvae, allows more rapid recycling of nutrients from the manure to the pasture and decreases the occurrence of rank, innutritious pasture.

Dung beetles may establish naturally in areas of high rainfall or where pastures are irrigated. If dung beetles are not already established they can be obtained from people on properties where they already exist.

Cell grazing or planned grazing can increase dung beetle populations by concentrating the manure in smaller areas, reducing the time beetles spend searching for food. Grazing cycles that match the beetles' reproductive cycle (around 3-4 weeks in summer) are good, since livestock are likely to return to a paddock at the same time that new adult beetles are emerging from the soil (Coldham, 2011).

The effectiveness of dung beetles may be less in warm moist environments where the free- stage (egg to infective larvae) of worm lifecycles are shorter.

Research into dung beetle activity and their effects on reducing parasite larvae has shown mixed results. Some showed that burial of dung helped larvae to live longer and that protection from extreme climatic conditions favoured larval development (Rahmann and Seip, 2006).

Harrowing and slashing

Harrowing or slashing paddocks are options to break up livestock manure where parasites can thrive. This spreads the manure thinly and evenly, aiding drying and increasing exposure to UV light. In addition, slashing improves the digestibility of pasture by removing tall, rank plants.

Harrowing should generally occur at the beginning of a dry period just prior to spelling a pasture.

Organically acceptable treatments for the control of internal parasites

The Australian National Standard for Organic and Biodynamic Produce lists the materials which are currently permitted for use in organic farming systems for the control of pests and diseases in livestock (See:

http://www.daff.gov.au/ data/assets/pdf_file/0018/126261/national-standard-2013.pdf. Annex D, p. 56).

The selection of organic treatments should be based on need (worm type, and level of worm burden) and as part of an integrated approach to the management of livestock pests and diseases.

Note that not all these materials are suitable for parasite control and that State or Federal regulations may restrict or prevent the use of those that are suitable. In such cases, these regulations override organic standards and must be complied with.

A few of the options for control of internal parasites are discussed below.

Biological control agents

All gastro-intestinal nematodes of livestock have a life-cycle which involves a free-living or pre-parasitic stage on pasture. These pre-parasitic stages are vulnerable to attack by biological control agents.

Some organisms that feed on free-living stages of parasites may be commercialised in the near future. These include micro-arthropods, protozoa, predacious nematodes, viruses, bacteria and fungi. The most promising are fungi.

Among the fungi, *Duddingtonia flagrans*is superior at surviving passage through the gut of animals as well as destroying worm larvae in faecal pats (Larsen, 2002). *D. flagrans* produces trapping nets, induced by the presence of nematodes, these traps lasting for about 2-3 weeks. (Gronvold et. al.,1996).

CSIRO field trials with *D. flagrans* have shown that fungal treatment of young weaners in autumn resulted in lower worm egg counts and greater live weight gains over the following winter and spring. CSIRO collaborated with a commercial partner in scaling up production of fungal material to commercial levels and developing delivery systems of fungal spores to animals (sheep, beef, dairy, goat and horses) through addition grain supplements, lick blocks or controlled-release devices.

Commercial launch of a product in Australia may not be too far way.

Strains of the bacteria *Bacillus thuringiensis* (B.t.) that kill larval and adult worms have shown promise in research studies. (see Kotze et al., 2007). B.t. is registered in Australia for insect control on plants but not for application to animals.

Phytotherapeutic, marine derived, and homeopathic treatments

The use of veterinary medicines including phytotherapeutic, marine derived and homeopathic substances is administered by the Australian Pesticide and Veterinary Medicines Authority (APVMA). APVMA registration of some products may be required before these can be legally administered. For more information see the APVMA publication - Complementary animal health products: guidelines for veterinary herbal and marine-derived remedies (see: http://new.apvma.gov.au/node/490).

Phytotherapeutic treatments

Phytotherapeutic treatments are those products which are derived from plants with minimal processing.

Organic phytotherapeutic treatments include drenches made from a mixture of natural products such as garlic, molasses, vegetable oil and cider vinegar, seaweed products and tree products.

Rahmann and Seip (2006) provide an overview of herbs and preparations that have either proved to have an anthelmintic efficacy (scientifically tested) or that are traditionally used to help control internal parasites: http://orgprints.org/12976/1/181_Endoparasiten_Artikel_no_2_von_Rahmann_und_Seip.pdf

Administer preparations derived from plants with caution. While often thought to be harmless, plants and their extracts if applied inappropriately can cause severe harm, even death.

Diatomaceous earth (DE)

Diatomaceous earth (DE) is often promoted as a natural de-wormer. DE comprises the remnants of tiny fossilised diatoms, which now occur as mine deposits in various parts of the world. DE is registered as a food additive in many countries.

It is sometimes said that the sharp edges of diatoms kill worms and insects by damaging their outer protective cuticle or coating.

Some studies have shown that continual ingestion of diatomite by animals can damage the intestinal lining, causing malabsorption and impairing gut defences through increased permeability (King, C. 2006).

Homeopathic treatments

Homoeopathy works on the principle that: “Substances usually in extreme dilutions, which when given to healthy individuals, produce the same symptoms as the disease being treated....the whole organism is treated in an attempt to raise its levels of resistance and stimulate its ability to throw off disease”. (MacLeod, 1981).

Whilst there is little scientific evidence supporting the effectiveness of homoeopathy it is widely used in organic dairy farming.

Mineral licks

It has been suggested that adding minerals and clays such as bentonite[2], (a very fine clay containing up to 70% silicates) to the livestock’s diet in the form of freely available mineral licks or blocks, might also help as a de-wormer.

[2] Note that bentonite should not be used for more than 8 weeks or problems may develop in the rumen.

Mineral licks ideally are formulated based on an assessment of local soils and plants for deficiencies. A nutritionally balanced diet, which includes correction of mineral deficiencies, will improve resilience of animals to parasites.

Trengove (2001) examined the impact of commercially available multi-mineral mixes on worm burdens and found no effect against *Trichostrongylus* spp. or *Teladorsagia* sp. in sheep. However, long-term studies are being considered as they may more accurately assess the nutritional effects of minerals (MLA, 2007).

Copper

Copper (Cu) is important for immune function in livestock. Cu at the right therapeutic dose is known to be effective against certain internal parasites, notably barber's pole worm (*Haemonchus contortus*). However, the margin between the therapeutic amount of Cu, given by mouth as a single dose, and levels that are toxic for sheep, is relatively small. Great care should be taken when mixing sheep rations or feeding this mineral, especially in areas where plants containing pyrrolizidine alkaloids are endemic and likely to be grazed. These include *Echium* (Paterson's Curse), *Heliotropium* and *Senecio* (fireweed) species. Toxins in these plants can cause copper accumulation and chronic copper poisoning in some livestock. See also: www.dpi.nsw.gov.au/agriculture/livestock/nutrition/problems

Copper sulphate (CuSO4)

Copper sulphate ($CuSO_4$) or 'bluestone' has been shown to be effective against barber's pole worm and its use is often advocated in organic farming. As noted above, carefully avoid overdosing livestock, which can cause severe illness and even death.

Copper oxide wire particles (COWP) bolus

Boluses of copper oxide wire particles (COWP) given orally are a much safer form of copper supplementation. The boluses lodge within the forestomachs and release needle-like particles of copper oxide that move with the ingesta to the abomasum. The low pH here facilitates release of soluble copper (Bang 1990). Note that COWPs have been found to be effective against barber's pole worm but not intestinal worms. Also, they may not be registered for this use.

Use of Vaccines

Boosting host immunity with a vaccine is another way of managing internal parasites.

Field trials in Western Australia and New South Wales have shown that a vaccine developed by the Moredun Institute in Scotland for barber's pole worm, could produce up to 90% protection in a flock. (Besier, 2012).

The vaccine, known as BarberVax®[3], is not yet registered for use in sheep or goats in Australia. The product is currently (2014) undergoing registration with the Australian Pesticides and Veterinary Medicines Authority (APVMA). More recently, Meat & Livestock Australia (MLA) and the Goat Industry Council of Australia (GICA) have joined forces with Moredun Research Institute to enable use of BarberVax® in goats.

[3] Producers should gain written permission from their certifier prior to the use of this and other vaccines

Unlike most bacterial and viral vaccines, which often employ a primer dose followed by a booster, Barbervax® will require (several) repeat doses through a barber's pole worm season. This is because the vaccine employs 'hidden' antigens, from the worm's gut, and this is not boosted by natural infection from barber's pole worm as the animal's immune system can't 'see' these antigens unless separated from the worms.

Organic standards classify the use of vaccines as 'restricted'. Accordingly their routine use is discouraged and is only permitted when the organic farmer demonstrates that a specific disease is endemic in the region or on the organic farm, or where their use is required by law or, in proven cases, where such a disease cannot be effectively controlled by other management practices.

Organic certifiers require written verification from a veterinarian to confirm the presence or threat of disease prior to approving the application of the treatment. In addition, the vaccines must not contain genetically modified ingredients or by-products.

The use of vaccines under these circumstances will not prejudice certification and does not require quarantine procedures. Full records of all treatments must be kept.

For more information on the use of vaccinations and other veterinary treatments in organic farming see: www.dpi.nsw.gov.au/__data/assets/pdf_file/0013/213601/Use-of-vaccinations-in-organic-farming.pdf

Chemical treatments

Animal welfare is a prime concern in organic standards and severe parasitism should never be allowed to develop. However if an animal is severely parasitised, chemical control may be the only humane option. Furthermore, if treatment is mandated by Commonwealth, State or Territory legislation, then this has precedence over organic standards and the specified control must be undertaken.

If treatment is required, the Australian National Standard for Organic and Bio-dynamic Produce (OISCC, 2013) states that treatment should consist of:

3.15.4

a. In the first instance, the provision of phytotherapeutic (e.g. plant extracts/essences etc.) or homeopathic products (e.g. plant, animal or mineral substances), or

b. If the above products are not successful and are unlikely to become effective in combating illness or injury and further treatment is essential to avoid suffering or distress to the animal, allopathic[4] veterinary drugs or antibiotics may be used in accordance with veterinary direction.

[4] The Oxford English Dictionary defines allopathy as: the treatment of diseases by conventional means, i.e. with drugs having effects opposite to the symptoms; often contrasted with homeopathy.

Where specific disease or health problems occur and no alternative permissible treatment or management practice exists (under the Standard), or where treatment is required by law; the following applies:

a. Therapeutic use of allopathic veterinary drugs or antibiotics is permitted. After such treatment, livestock cannot be sold as organic or bio-dynamic. Their products and/or progeny can be marketed as organic or bio-dynamic after a minimum management period…'

Prior to administering any non-permitted treatment, the animal should be removed from the organic management system and placed in a specially allocated (non-certified) quarantine area.

Following treatment, livestock should then either be permanently removed from the enterprise or if being returned to the organic unit, held in the quarantine area for a period equivalent to at least three times the withholding period specified on the product label, or three weeks, whichever is longer.

Organic standards state that if the treated animal is to be returned to the organic production unit there are conditions pertaining to the sale of products or progeny derived from the animal (see Table 4).

Table 4 The minimum management period livestock products and/or progeny can be marketed as organic, bio-dynamic or in-conversion. Source: OIECC, 2009.

Produce	Requirements for organic
Wool	From 18 months after entering the
Milk	From 180 days after entering the
Eggs	From chicks up to 2 days old entering the
Poultry & meat from game birds	From chicks up to 2 days old entering the
Ruminant and mono-gastric animals for meat	From last trimester (excludes embryo
Aquaculture	From fingerling form

Conclusion

Control of internal parasites in organic farming systems is achieved by an integrated approach to livestock management.

Management strategies include:

- Regular monitoring of livestock for signs of infection using tests and visual tools.
- Genetic selection of resistant breeds and improving in-flock resilience by culling susceptible livestock and using sires with favourable breeding values.
- Managing exposure to worms by providing low-risk pastures; achieved by rotational grazing, grazing with alternate species, spelling pastures, removal / spreading of manure etc.
- Providing good, balanced nutrition, through good quality pastures, supplementary feeding if required, and mineral licks where deficiencies have been identified.
- Using biological controls such as dung beetles and, when available, predacious fungi, to reduce pasture contamination.

To manage animals' existing worm burdens:

- Use of vaccinations when available

- Careful use of alternative treatments and therapies, and monitoring their efficacy. These include herbs such as garlic, slippery elm and plantain, minerals including copper, dolomite and seaweed meal, and homeopathic remedies.
- Animal welfare is a prime concern in organic standards and severe parasitism should never be allowed to develop even if it means compromising the livestock's organic status.

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WormBoss. www.wormboss.com.au

For a comprehensive range of Primefacts on internal (and external) parasites of sheep and cattle, see the NSW DPI web sites: www.dpi.nsw.gov.au/agriculture/livestock/sheep/health; and www.dpi.nsw.gov.au/agriculture/livestock/health/specific/cattle

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