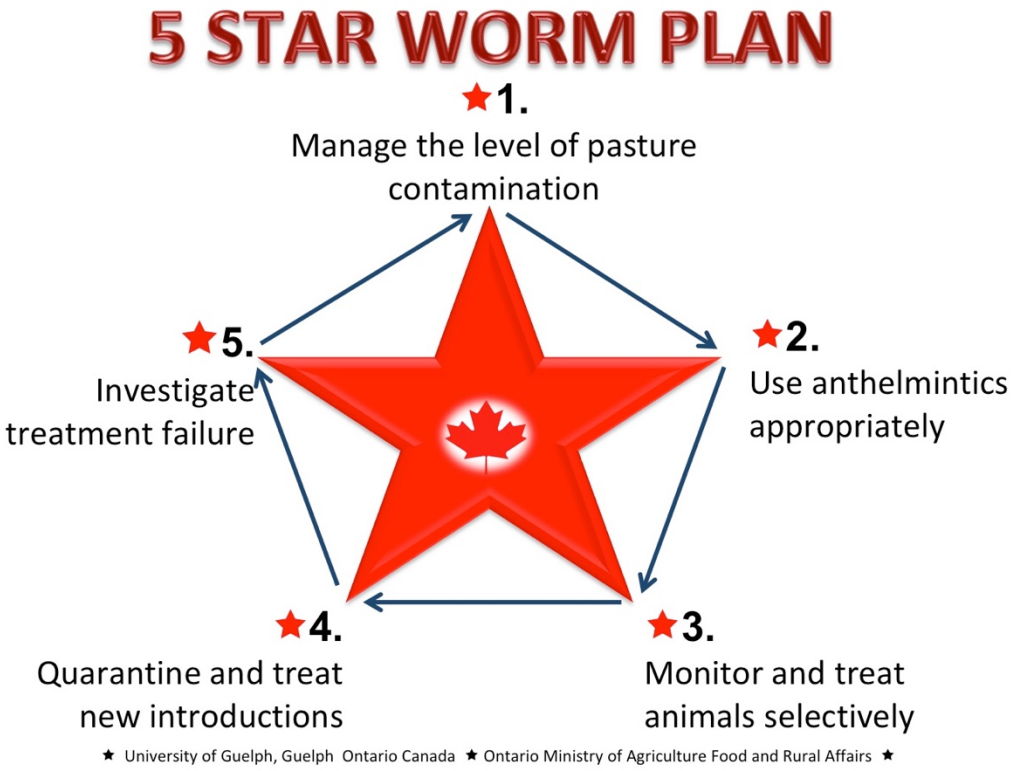
The goal of a parasite control program is to control the level of parasites on the farm to a level that has minimal effect on animal health and productivity, without allowing the development of anthelmintic resistance.

THE 5 STAR WORM PLAN

This is known as sustainable Integrated Parasite Management or sIPM. Gastrointestinal parasites do not need to be an issue on a small ruminant farm, if sound principles and an understanding of the epidemiology are used in developing a suitable control program. We present the main points here. The program is called "5 STAR WORM PLAN". Use this program with your veterinarian to develop a health management approach that is correct for your farm.



★ 1. MANAGE THE LEVEL OF PASTURE CONTAMINATION

There are many methods available to reduce the level of parasite contamination of pastures. None in of themselves are 100% effective, but together they are very important in any sustainable integrated parasite management program and will make the difference between success and failure. The goal is to have all pastures as "safe" pastures; there are many methods to achieve this.

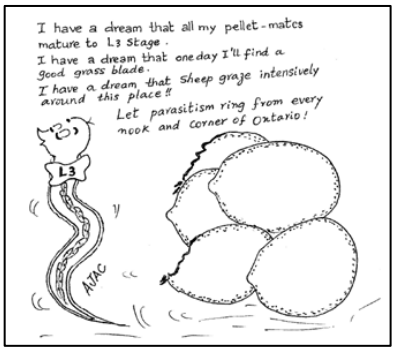
1.1 MANAGE THE BIGGEST SOURCES OF PASTURE CONTAMINATION

The two biggest sources and times of pasture contamination with GIN eggs are: 1) lambs and kids by mid to late grazing season (e.g. late July / August) and 2) adult females in late gestation and lactation (the periparturient egg rise) – usually in the spring at turnout. To manage the contamination by youngstock, monitor frequently and treat when needed– particularly from mid-grazing season (e.g. early to mid-July). To manage the contamination from the PPER, treat adults selectively before putting to pasture (see below). Managing parasitism in farms which practice pasture-based lambing /

kidding is more difficult because of the risk of mismothering if ewes / does need to be gathered up to treat at or soon after giving birth. In that case, treatment may need to be delayed but it is important to include a method of monitoring the adults and treating when needed. Young, nursing lambs and kids don't tend to pick up parasites in the first few weeks of life because they are not grazing as much, but the parasites deposited by the adults will wait for them.

1.2 USE OUR UNDERSTANDING OF THE BEHAVIOUR OF THE FREE-LIVING STAGES

By understanding where the infective L3 are in the pasture, we can modify grazing management to try to reduce exposure of the sheep / goats to them.



1.2.1 Break up the faecal pellet

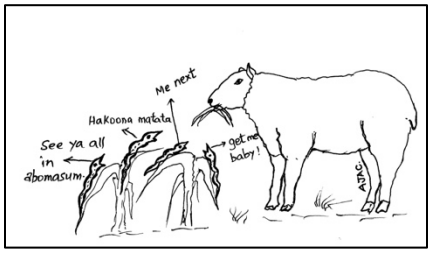
Remember that L1 and L2 stages live inside the faecal pellet. If the pellet is exposed to moisture or is broken up by earthworms, dung beetles or by mechanical means (e.g. harrowing), the L1 & L2 are then exposed to the environment where adverse temperatures, sunlight or dry conditions can kill them more rapidly. Unfortunately, this also facilitates release of L3 from the pellets.

1.2.2 Modify grazing based on temperature and humidity

L3 dislike dryness so they will migrate down to the soil during hot days but migrate up when the dew is on the grass. Waiting until the dew is off the grass to graze short pastures is often not practical. Exposing the ground to sunlight may have some benefits as it gives the L3 less place to hide and exposes them to heat and drying. This can be done by either de-thatching using a harrow, or routinely planting new pastures and ploughing in old pastures.

1.2.3 Modify grazing based on sward height

The L3 are restricted on how high they can climb (usually not higher than 5 cm or 2 inches), so long grass pastures may be safer than short grass. However, sheep and goats are able to more selectively graze than cattle and will avoid long grasses with higher lignin content in favour of the new shoots close to the ground. Overgrazing pastures will increase the infection rate by forcing the livestock to graze close to the soil.



1.2.4 Eliminate areas of the pasture that favour L3 survival

Areas of the pasture that are wetter, such as low lying areas or around water troughs, may have greener grass and attract sheep and goats to graze but also favour survival of L3. If practical, eliminate these areas for grazing either by fencing off or gravelling (e.g. around water troughs). If there are bedded areas on pasture (e.g. around round bales), these will become heavily contaminated.

1.3 ROTATE PASTURES WITH OTHER LIVESTOCK SPECIES

While cattle share some parasites with sheep and goats (e.g. *Trichostrongylus axei*), rotation with this species has been shown to lower pasture infectivity to sheep and goats. Horses will also work but not llamas as they share parasites. Co-grazing (grazing at the same time) with cattle is less effective but may help.

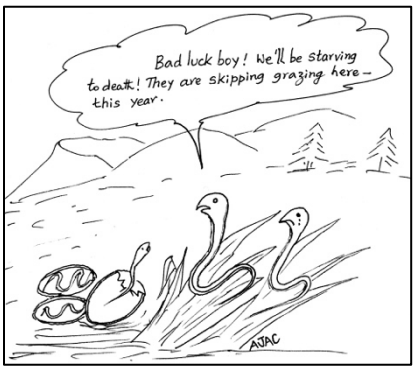
As with all methods of lowering pasture contamination, if deworming is done so there are few parasites in refugia, this practice will increase the risk of development with AR.

1.4 AVOID GRAZING SHEEP AND GOATS TOGETHER

Sheep and goats share the same parasites. Because adult goats do not develop immunity to parasites they will be a more important source of pasture contamination than adult sheep. Additionally, they metabolize anthelmintics more rapidly than sheep, require higher dosages than sheep and because of that are at risk of developing AR more rapidly than sheep.

1.5 REST PASTURES THAT ARE HEAVILY CONTAMINATED

If a pasture was particularly heavily infected at the end of the previous grazing season, select it for ploughing, reseeding, haying and / or grazing with another species.



1.6 BE AWARE OF RISKS OF CONTAMINATION FROM STORED MANURE

Although it is unlikely that infective larvae will survive in well-composted manure that has heated properly, fresh manure can be a source of parasites. A particular risk may occur in the spring when bedding packs are cleaned from the barn and spread directly to fields intended for grazing or hay production. Thus, it is safer to spread manure onto fields prior to ploughing for crops.

Often manure is seasonally stored on a cement or gravel yard. Make sure that the animals have no access to this pile and additionally make sure that runoff from the manure pile doesn't enter any place where livestock are maintained. This includes yards and pastures. This should be included in any farm's nutrient management plan.

1.7 USE LOW-RISK PASTURES FOR THE MOST SUSCEPTIBLE ANIMALS

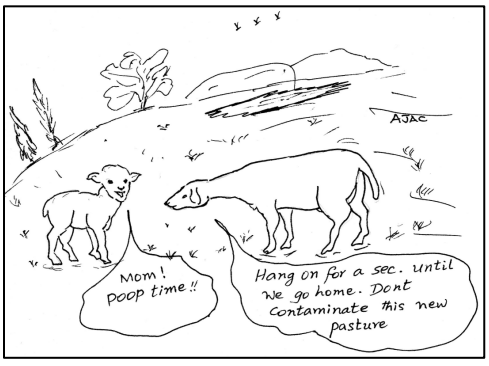
Graze weaned lambs/kids on newly seeded / rested pasture or hay fields. Annual pastures (e.g. turnips) that are ploughed in at the end of the season are also low risk.

1.8 "DOSE AND MOVE" VERSUS DELAYED "DOSE AND MOVE"

If the entire flock is to be treated, there are techniques explained in Figures 3 that allow a susceptible refugia to be maintained – ideally, dose and delay moving for a few days is preferred to ensure animals become infected with a low dose of susceptible parasites.

1.9 REDUCE THE CONTAMINATION OF A PASTURE BY USING PASTURE ROTATION

Firstly, understand that L3 can survive for weeks to months on pasture if the environment is moist and temperate, and that the L3 of most species (except *Haemonchus contortus* that does not survive < 0° C.) can survive over winter. This makes it very difficult to accurately predict when a pasture is finally "safe" in a pasture rotation system. Most pasture rotation systems require that the flock return repeatedly to the same pasture in a grazing season. Unless the frequency of rotation is < 7 days (*Haemonchus*) or < 14 days (*Teladorsagia* and *Trichostrongylus*), eggs deposited when grazed previously will likely be hatched and developed to L3 – just waiting to infect the returning livestock. Additionally, those L3, under the right weather conditions (e.g. temperate and moist), will survive for months. The following are some suggestions that will help with using pasture rotation to control parasites:



1.9.1 Evasive Grazing

This technique of grazing pastures when the risk of parasites is lowest requires knowledge regarding the speed of larval development given local conditions. Models have been developed that take geography, weather and management practices into account to predict when pastures might

be becoming dangerous. These are used in countries such as Australia, New Zealand and the UK (http://www.nadis.org.uk/parasite-forecast/). It should be remembered that during the summer, pastures can remain very infective for months, making evasive grazing impractical if used as the sole method for parasite control.

1.9.2 Intensive Rotational Grazing

This is a form of evasive grazing and is relatively safe if the following hold true:

1. Animals are moved from the strip before eggs hatch and the larvae develop to the L3 stage (variable depending on weather; longer in cool weather but shorter in warm weather); AND
2. Animals do not return to the strip until the L3 have died (variable depending on weather and moisture but may be up to several months if temperate and humid). Most producers cannot afford to do this.

On average, the worst time period between grazing sessions is 2 to 3 weeks - the most likely time that the eggs have hatched and developed to L3. While short-term grazing will limit pasture contamination, returning to the strip several times in a season will result in the build-up of L3 - just as if the pasture was set stocked (i.e. animals put to the same pasture for the entire grazing season). While it may be prudent to intensively rotationally graze in order to make optimal use of the pasture, monitor FEC closely.

1.10 IF HEAVILY CONTAMINATED PASTURES MUST BE GRAZED

Often, the producer has only heavily contaminated pastures available for grazing. The following strategies may help to lower risk in the face of grazing heavily contaminated pastures.

1.10.1 Rotate weaned youngstock ahead of adults

After weaning, lambs or kids should have "first access" to safe pastures. This way there is less risk from exposure to contaminated pastures. Adults are better able to tolerate heavily contaminated pastures.

1.10.2 Use adults to graze heavily contaminated pastures

If pastures are heavily contaminated and safe pastures are in short-supply, non-lactating ewes or does not in late pregnancy can be grazed more safely than youngstock on these pastures. If the adults have good immunity, this may help to lower the infectivity by grazing off L3 but not recontaminating the pasture with fresh eggs. This should be done while monitoring FEC.

1.10.3 Don't graze nursing lambs / kids

It is more difficult to manage the parasite exposure of lambs / kids when grazing with their dams. If only heavily contaminated pastures are available, try to avoid grazing nursing lambs/kids. If possible, practice early weaning (e.g. 60 days) so their exposure can be better managed. If not, increase the frequency of FEC monitoring. At weaning, lambs / kids should be moved to pasture with the lowest level of contamination.

1.10.4 Lower stocking densities

Because of the nature of faecal consistency in small ruminants (pellets as opposed to soft patties), sheep and goats often do not have the option of grazing away from faeces, as cattle do so controlling stocking density becomes more important with these species. By lowering stocking densities, there will be less pasture contamination with feces. Recommendations vary but keeping set stocking densities < 6 to 8 sheep/goats per acre is often mentioned. With rapid pasture rotation, these densities can be increased. But FEC monitoring must also be done regardless of stocking density.

1.11 RECORD PASTURE USE AND TREATMENTS.

Appendix 3 is an example form that can be used for this purpose

★ 2. USE ANTHELMINTICS APPROPRIATELY

2.1 TREAT APPROPRIATELY TO AVOID TREATMENT FAILURE AND DEVELOPMENT OF AR

- Weigh the sheep/goats. Dose for the heaviest in the group
- Use only dewormers with a Drug Identification Number (DIN) to assure quality of the product.
- Dose correctly by reading the label and calculating based on the weight of the animals to be treated.
  - If not labelled for sheep or if using in goats, obtain the correct dosage from your vet.
  - Goats are generally treated at 2X sheep dose (BZ) or 1.5X sheep dose (ML)
- To increase effectiveness of a drug when AR is suspected
  - Do not double the recommended dosage but rather give the recommended dosage twice 12 hr. apart (BZ and ML only).
  - Holding the sheep/goats off-feed for 12 to 24 hr. before treatment with a BZ can increase the length of time that the anthelmintic is effective.
- Calibrate the drench gun or automatic syringe frequently.
- Drench correctly by depositing the entire dose over the tongue, at the back of the throat.
- Oral drenches should be used instead of injectable products.
- Use the correct route of administration for the product. Do not use a cattle pour-on.

2.2 Rotate anthelmintic classes slowly

Consensus suggests to not rotate anthelmintic drug classes more frequently than annually. Rapid rotation is thought to lead to multiple class AR. Do not use an anthelmintic until it doesn't work anymore due to anthelmintic resistance. This will mean the loss of that drug class permanently for that flock.

2.3 Using combination dewormers

If resistance is present for a drug class on a farm, sometimes combining it with another drug class will increase its efficacy – at least for a while. In Canada, a combination dewormer is licensed for use in sheep (Startect, Zoetis Canada), the only one licensed in North America. This dewormer can be used for quarantine drenching to prevent introduction of resistant parasites (see ★4). It can also be used judiciously when resistance to BZ or ML is present on a farm or to lower the risk of AR developing. It can't be used on goats, however.

There is evidence that when using a novel-to-the farm anthelmintic in combination with another class, the development of AR is very delayed. If the decision is made to use two anthelmintic classes at the same time (with the exception of Startect), do not combine in the same drench gun but give separately in sequence at a full dose for each product, i.e. drench the sheep with drug class A (e.g. ivermectin) and using a different drench gun, drench with drug class B (e.g. fenbendazole). Do this only on the advice of your flock veterinarian, including calculation of a proper meat withdrawal period since combining deworming treatment constitutes extra-label drug use (ELDU) and may extend meat withdrawal times. Do this while also re-evaluating your farm's parasite control program so that further development of AR is avoided.

★ 3. MONITOR AND TREAT ANIMALS SELECTIVELY

3.1 TARGETED TREATMENTS (TT)

This means to treat sheep or goats **only when the group needs it**. This is done by monitoring FEC (usually pooled samples) and clinical evidence of disease and then treating the group. Record all FEC results (example form provided in Appendix 4). Increasing the interval between anthelmintic treatments reduces the development of AR. Times to monitor (and possibly treat):

3.1.1 Ewes / does prior to lambing / kidding

This is to eliminate or reduce the PPER, which is considered one of the most important early sources of pasture contamination for lambs and kids. Monitor ewes and does at lambing or early lactation. Ewes / does with a significant PPER will contaminate the spring pasture with eggs starting a few weeks prior to lambing / kidding and continuing through to about 6-8 weeks into lactation depending on nutritional management. Youngstock will be very susceptible to infection from any overwintered L3 on pasture.

Ewes may suffer disease or decreased productivity if not dewormed in the face of a high FEC. Does may also be more prone to disease as immunity in this species is poor for parasites. However, treatment of the entire group or when treatment is not needed may hasten development of AR on a farm – particularly for *Haemonchus*. This is because there are not sufficient parasites in refugia (in the case of *Haemonchus*, no L3 refugia on pasture in the spring) to prevent development of AR. Under some management conditions, e.g. if ewes lamb and nurse lambs indoors, it may not be necessary to deworm at this time because they are not contaminating pasture – as long as the females appear healthy.

For these reasons, it is important to make the decision on whether or not to deworm prior to lambing / kidding with your flock/herd veterinarian and to always monitor faecal egg counts in nursing adults.

3.1.2 Lambs/ kids at mid-summer

The exact date to start taking faecal samples will vary depending on the previous parasite history of that farm, the warmth and humidity of the summer and how warm weather arrives on that farm. Generally, early to mid-July is the earliest that we routinely see clinical evidence of parasitism. Mostly it is slightly later - late July to August, which appears to be the highest risk period in our climate for haemonchosis. However, there is tremendous variation in the start of warm weather in Canada and veterinarians and producers should be ready to make adjustments to these dates.

GI parasitism can be controlled if animal infection is routinely monitored. This is done by checking FECs in the youngstock (and adults if grazing together) in early to mid-July, and treating only when high counts are found (or in the case of haemonchosis, evidence of anaemia can also be used, i.e. FAMACHA© scoring). If the FEC is negative, but animals are showing severe clinical signs of parasitism, consult your flock/herd veterinarian to determine if another disease is present (e.g. coccidiosis). Alternatively, the prepatent period for the parasite may not have been reached yet.

Occasionally, if the spring pasture is heavily contaminated from the previous grazing season with over-wintered L3 (usually *Teladorsagia* but not *Haemonchus*), parasitism can occur earlier. Lambs / kids on these pastures may encounter such a severe infection by grazing these overwintered L3 that they become clinically ill (diarrhea, off-feed, depressed) from the immature parasites before eggs are present in their feces. Any youngstock that die should be necropsied by a veterinarian to determine if this is the cause of death. Never assume death is due to worms (or that it isn't!).

3.1.3 Repeat monitoring in the grazing season

Monitor frequently at the times of highest risk, i.e. mid-summer to early fall. If when the lambs/kids are monitored, the FEC is below the cut-point to treat, resample in mid-summer at least every 3-4 weeks and more frequently, particularly if *Haemonchus* is known to be a problem in the past or the FEC is borderline. On farms with a history with *Haemonchus*, it may be necessary to monitor as frequently as every 10 days.

3.1.4 Monitor after treatment

Routine faecal egg counts should be done every 4 to 6 weeks after treatment (shorter periods if a less persistent anthelmintic is used) although this can be done more frequently if pastures have significant contamination and no safe pastures exist on a farm. If the animals with signs of parasitism do not rapidly improve after treatment, it is strongly recommended to resample at 14 days to determine if treatment failure occurred (see above). Keep in mind there are several reasons for treatment failure beyond anthelmintic resistance so also review all your protocols for administering a dewormer.

3.1.5 Monitor according to farm history

By knowing the farm history, the time of monitoring can be adjusted. For example, if the previous summer, lambs had elevated FEC in the first week of July, then monitoring should be started in mid-June.

3.1.6 Monitor in the autumn?

By October there is less reason to use FECs to determine infection. Although the animals may be parasitized, most of the development is now to the arrested stage (L4), which do not feed or produce eggs. Although there is variation, adult parasites naturally die off in the autumn with only a few surviving into the winter and those do not produce many eggs. Performing FECs at this time will not properly estimate the level of infection present in the animal. However, if there is concern because of clinical evidence of disease or there were problems in previous years, a FEC can be done; a high count is significant but a low count doesn't mean the animals are not parasitized, just not with egg-producing adults. Similarly, FAMACHA© score can be used to augment FEC to determine level of *Haemonchus* infection.

3.1.7 Treatment of breeding animals at housing?

Treatment in the autumn may reduce the arrested L4 that overwinter in the animal, and thus may lower the level of PPER the next spring in pregnant ewes and does. But we need to be assured that the treatment is both necessary and actually works at this time of year. Treating the entire flock may lead to AR in *Haemonchus* because of lack of parasites in refugia. For this reason, it is strongly recommended to only selectively treat animals at this time.

3.1.8 Treatment pre-breeding?

The recommendation to treat pre-breeding should only be done if monitoring or poor condition suggests that the adults are parasitized. Usually adults will not show signs of parasitism unless periparturient or debilitated with another disease or poor nutrition. Treatment when not necessary will contribute to the development of AR.

3.2 TARGETED SELECTIVE TREATMENTS (TST)

This means treating **only those individual animals that need it when they need it** and is based on the knowledge that in any given population, only a proportion actually requires deworming. The challenge is to correctly identify the animals that need treating and those that don't. The development of AR can be slowed or prevented if about 1/3 (30%) of animals are NOT treated. This proportion can be lower if no AR is present but if AR is already present, then 30% is the minimum proportion that should be untreated. This approach leaves a susceptible parasite population in refugia – both on the pasture and in the untreated animals and is critical to the success of any sustainable integrated parasite control program. The producer has only a few options to be able to do this effectively and economically.

3.2.1 Using faecal egg counts

Unless the flock size is very small, it is not economical to perform individual FEC on all animals in order to detect the "big shedders", i.e. those 30% of animals that shed 70% of the eggs. There is no method of determining parasite egg load in faeces other than using a laboratory based-test. Some producers wish to perform their own FECs. If this is the case, they must be well trained and focus their labour on performing FECs when the most information can be gained.

3.2.2 Using the FAMACHA© system

The FAMACHA© system can be used very effectively to select individual animals for treatment of haemonchosis - but is not effective at detecting infection of other GIN species. It could be used on farms that know when *Haemonchus* becomes a problem (e.g. starting late July, early August) but **must** be combined with pooled FEC to rule out other causes of parasitism. Producers should be properly trained (see above) before undertaking this procedure. Fatal errors (not treating an animal that is anaemic because it was scored incorrectly) can be reduced with proper training.

Sheep or goats that score 4 or 5 require treatment (3s too if a large part of the flock is anaemic) and then everybody monitored every 2 to 3 weeks during the high-risk period. FAMACHA© cards must be used in good light, and replaced annually as the colour may fade with time. Because there are other causes of anaemia, it is important to investigate treatment failure. Use the provided record to track FAMACHA© treatment results.

3.2.3 Using evidence of diarrhea

Dag scores indicating diarrhea may be helpful when the producer can eliminate other reasons for scouring (e.g. coccidiosis or lush pasture) and may work best when combined with monitoring weight gains. However some research suggests that by the time the lambs or kids have diarrhea, significant clinical disease is occurring - i.e. waiting until they have diarrhea is too late. Additionally, haemonchosis can be severe without signs of diarrhea.

3.2.4 Using weight gains

Routine weighing of lambs or kids (e.g. every 3 weeks) can identify those animals that are not gaining as fast as their cohorts, one reason for which may be GIN parasitism. One method of using this information is to only deworm the lighter animals and leave the heavier ones untreated. Expected ADGs will vary depending on the breed, sex and age of the animal and the pasture being grazed. A producer may get a feel for what growth should be expected from the youngstock on a particular type and growth of pasture. That may be more useful than a scientific formula.

For those using RFID and automated weighing systems, it is possible for producers to select poor gaining animals for treatment on a relatively frequent basis. The same type of system is used frequently for lambs in feedlots. That way, changes in the individual animal's weight can be tracked and individuals that fail to gain would be treated. Pooled FEC should also be done to verify that parasitism is the cause of the poor growth and not poor nutrition or other disease such as coccidiosis or pneumonia.

Body condition score was not found to be helpful of predicting FECs in a recent Canadian study. It may be that it is not sensitive enough to pick up early parasitism. By the time the animals are thin, parasites have taken a severe toll. That being said, very thin animals should be treated but also monitored for response to treatment as many other diseases can be responsible for animals with a BCS of < 2, e.g. Johne's disease (paratuberculosis), maedi visna, chronic pneumonia, dental disease and internal abscesses plus many more.

3.2.5 Using milk production in grazing dairy small ruminants

Dairy goats in their first lactation may benefit from deworming in terms of improved milk production if they have a history of grazing as youngstock. While there is evidence that deworming will improve milk production in dairy ewes and dairy does, keep in mind that no anthelmintic is approved for use in lactating dairy small ruminants. If deworming is done, it should be an evidence-based decision, e.g. elevated FEC. The producer and veterinarian are responsible for ensuring that chemical residues are not present in milk sold for human consumption.

Use of an anthelmintic approved in lactating dairy cows in lactating dairy sheep or goats, is not a guarantee that violable residues will not be detected in the milk. This is for several reasons: dose is often higher in goats; anthelmintics are metabolized differently in sheep and in goats than in cows and so excretion may be longer; there is no maximum residue limit (MRL) established for drugs not licensed for lactating dairy sheep / goats so if the test can detect it – even at a level lower than is acceptable for cows, it is in violation. As previously mentioned, have the veterinarian submit a request to CgFARAD to obtain proper guidance.

3.2.6 Using number of lambs / kids nursing

There is evidence that ewes or does nursing multiples shed more eggs than ewes or does nursing singles. This is likely due to differences in nutritional stresses between the two groups. Deworming only females with multiples - either before parturition based on pregnancy scanning, or after based on number nursing - is one way to target those animals that likely have the highest PPER.

3.2.7 Using FAMACHA© scoring at lambing / early lactation

Research performed on Ontario flocks found that the criteria for selection of treatment (*Haemonchus* specific) in the period around lambing and early lactation, should be FAMACHA© score 3, 4 or 5. If a thin ewe has a normal FAMACHA score, then it may also be advised to treat. It is critical to also perform pooled FECs to make sure that other parasites are not also an issue.

3.3 USING THE "5 POINT CHECK" CRITERIA FOR TREATMENT

This system identifies sheep and goats that may require deworming and was developed in South Africa. It includes infection from a variety of parasites – not just GIN and embraces the concept of targeted selective treatment or "*Leave the best and treat the rest*".

1. The nose is checked for discharge that indicates nasal bots (*Oestrus ovis*)
2. The eyes are checked for anaemia, indicating blood-sucking worms
3. The jaw is checked for submandibular oedema that also accompanies anaemia and protein-losing infections cause by parasites such as *Haemonchus* and liver fluke (see below)
4. The back is checked for body condition score indicating possible infection by internal parasites like *Teladorsagia* and *Trichostrongylus* species.
5. The tail is checked for signs of diarrhea, indicating mainly worms that also cause loss in body condition score.

This approach is still being refined and requires FEC monitoring. Remember that by the time an animal shows signs of parasitism such as in points 2, 3, 4 and 5 – it is already very ill. This system requires that you also work hard to reduce exposure to parasites on pasture (under ★ 1 of the 5 STAR WORM PLAN).

3.4 ALTERNATIVE METHODS OF CONTROL TO REDUCE RELIANCE ON CHEMICAL ANTHELMINTICS

To reduce the use of chemical anthelmintics, some of the following methods have been used to augment targeted selective treatment. Regardless of what methods are employed, make sure they are science-based and can work on your farm. A recent analysis of the published literature in this area found that genetic selection and some nutritional methods were the only scientifically proven means to alternatively control GIN parasitism. The abstract of the publication is presented in Appendix 5.

3.4.1 Genetic selection

The breeding of resistant sheep or goats can be done by selecting a breed (e.g. some tropical hair breeds) or selecting individuals within a breed - usually rams that have lower FEC or other measures when compared to other rams in the group. However, it is important to make sure if "resistant" breeds are selected that one does not sacrifice important economic traits such as prolificacy, milk production, growth and carcass characteristics.

Gene marker tests in some countries will help identify sheep that will have lower FEC although are breed dependent. There is much research ongoing in the use of genomics to identify these animals more accurately. Selecting animals based on their ability to mount an immune response is promising. The CarLA® saliva test (Carbohydrate Larval Antigen) developed in New Zealand

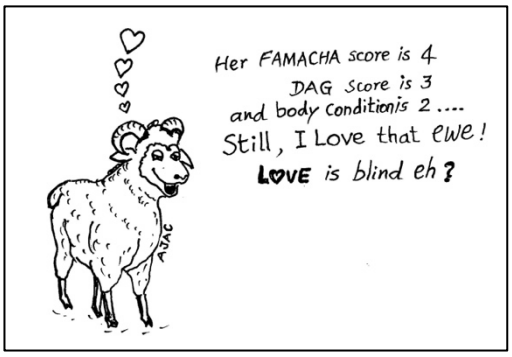
(AgResearch) measures antibodies to the L3 stage of GIN and can help to select sheep that develop immunity more rapidly or to cull animals that do not. Recently completed research at the University of Guelph is evaluating its utility under Ontario conditions. From this work (thesis in preparation) it appears that the CarLA® saliva test performed in youngstock in October, can predict which animals have lower FECs and higher CarLA antibodies the following grazing season when those ewe lambs give birth and raise their own lambs. This is very promising and requires more research to determine how heritable this trait is in Ontario breeds and grazing conditions.

Remember that immunity is acquired and resistant animals still need to be infected with parasites to develop this immunity. Heritability for this trait is moderate (h^2 is 0.25 to 0.3), so a producer could use FEC in ram lambs or buck kids (comparison within a group) as a criteria for selecting a replacement male, and marketing those that have high FECs. But because heritability is only moderate, genetic progress within a flock may take up to 5 years to see an impact on flock levels of parasitism. To properly select parasite-resistant males, it is important to have a large enough group to accurately find the resistant animals without sacrificing important genetic traits of production.

Remember that goats in general do not develop immunity as well as sheep. Much less research has been done with goats on selecting for genetic resistance and so the following strategy covered in the next paragraph may work better for this species.

Culling the "worm magnets"

Rather than selecting resistant animals, it is easier to identify and cull parasitized adults that are slow to develop immunity to parasites. This can be done by culling those with a high FEC, repeatedly have scores 4 or 5 on the FAMACHA© chart or require repeated deworming treatments, AKA "worm magnets". These adults should be removed from the breeding flock and lambs/kids from these animals should be sent to market rather than retained as replacements. Additionally, lambs or kids that need repeated treatments should not be retained as replacements as they are also more likely to give birth to offspring with less ability to develop immunity to parasites.



Resilient animals

Resilient sheep/goats will be infected and will contaminate a pasture with eggs, but will not have as significant production losses. There is differing opinion about whether these animals should be kept. Regardless, within a population, there will be resilient and susceptible sheep so that selection must be done by using good records, measures of anaemia, FEC and growth monitoring in order to avoid losses and to select the correct animals.

It is important to remember that using clinical parameters alone, will not allow identification and treatment of these high egg producing resilient animals. This is another reason why it is important to use FEC to monitor infection.

3.4.2 Pasture plants containing condensed tannins

Grazing pastures containing a large proportion of plants with high levels of condensed tannins (CT), has variably been shown to reduce shedding of eggs in the faeces. In North America, most research has been published on the legume *Sericae lespedeza* (SL), a warm climate plant. The mechanism appears to be 2-fold. While there is a direct effect by CT on the ability of the adult parasite to produce eggs and for those eggs to develop to infective larvae in the feces, at least some of the effect is from the elevated levels of by-pass protein available to the animal. Animals fed SL also have an improved immune response over animals on a control diet.

Low levels of CT in the diet have been shown to increase reproductive performance and wool growth independent of parasite load. However, CT can be toxic to the animal if too high; high levels in the diet decrease feed consumption and have a negative effect on performance.

Two temperate climate plants with some potential benefits are Bird's Foot trefoil (*Lotus corniculatus*) and Sulla (*Hedysarum coronarium*). Experimentally, sainfoin (*Onobrychis coronarium*) has been reported as both beneficial and of no benefit. There are other CT plants and tree extracts (Quebracho extract for example) that are promising and may be a helpful adjunct to other control measures. Research on varieties of Bird's Foot trefoil are beginning at the University of Guelph to determine tannin content at different times of the year and at different cutting stages. The next step will be to evaluate palatability and treatment effect in both cattle and sheep.

3.4.3 Nematophagus fungi

A fungus, *Duddingtonia flagrans*, grows in faeces - sending out hyphae that trap and kill the free-living forms of GIN in faecal pellets. While these fungi occur naturally, in order to get them into the faeces in sufficient quantity to be effective, the spores must be fed to grazing livestock daily for a minimum of 60 days. The intent is to feed at turn-out for a period of time to disrupt the build-up of L3 on pasture until the season is advanced enough that disease will not occur in that grazing season. Research has focussed on feeding ewes during the PPER - the major source of spring pasture contamination, which should then spare the lambs. At this point, daily dosing is the only option for grazing sheep and goats. It is commercially available from BioWorma (International Animal Health Products) in the USA and New Zealand but not yet in Canada. A bolus that will deliver spores over a longer term would be preferred.

3.4.4 Copper oxide

Copper oxide wire particles were first developed to supplement sheep and goats in areas of the world with copper deficiency. It appears effective in temporarily reducing infections due to *Haemonchus contortus*. It does not appear to improve weight gains (over controls). It does elevate liver copper levels in sheep. Given the copper status of sheep in central Canada where copper toxicosis is already an issue, use of copper oxide wire particles is not advised without monitoring of copper status of the flock. It is also critical to realize that copper sulphate (bluestone) should NEVER EVER be fed to sheep or goats. There have been several cases in Canada of copper toxicity in both sheep and goats related to producers feeding copper sulphate in the mistaken belief it will control parasites.

3.4.5 Vaccination

A commercial vaccine is available in Australia, New Zealand and the UK to control *Haemonchus contortus* (Barbervax). The Moredun Research Institute, a UK-based animal health charity owned by farmers, developed Barbervax in partnership with the Department of Agriculture and Food, Western Australia, with support from Meat and Livestock Australia. All profits are invested in further research projects aimed at reducing livestock disease e.g. a vaccine for scour worms. It is not yet licensed in North America.

The vaccine is killed and is made from whole *Haemonchus* parasites harvested from purposely infected lambs at slaughter. By stimulating immunity, the egg count and number of parasites is reduced, thus lowering pasture contamination. The vaccine requires three priming doses to be administered before the height of *Haemonchus* season. This is followed by two or three additional vaccinations during the grazing season for a total of five to six vaccine doses. Please keep in mind that the research was done in Australia where the grazing season is year round. While 5-6 vaccinations sounds like a lot, in that country it is common that each lamb is drenched with a dewormer 5-6 X per year. Use of this vaccine will reduce greatly the amount of chemical dewormers needed by reducing pasture contamination and enhancing immunity. Research is ongoing to develop vaccines against the "scour worm" parasites, i.e. *Teladorsagia* and *Trichostrongylus*.

3.4.6 Alternative Dewormers

There have been many alternative or natural deworming products recommended over the years. Some are toxic to sheep and goats as well as the parasites (e.g. nicotine). Some do not work in controlled, peer-reviewed studies (garlic, papaya seeds, diatomaceous earth). Diatomaceous earth may be useful for control of external parasites but more research needs to be done to show sufficient efficacy and safety. It is dangerous for humans to inhale. There are other herbal plants that have been hypothesized to be effective parasiticides, (e.g. Neem oil) but at this time there is insufficient supportive scientific evidence for this claim, and safety for both animals and humans has not been demonstrated.

The purpose of "natural" deworming products is to reduce the use of chemical anthelmintics. While this is a laudable goal, these products – in the absence of proof of efficacy (or safety) – may pose a threat to the welfare of the animals. The goal of the 5 STAR program is to reduce the use of anthelmintics and should be implemented with the objective of greatly reducing chemical use but not allowing for animals to suffer from the effects of parasitism.

★ 4. QUARANTINE AND TREAT NEW INTRODUCTIONS

Purchased sheep or goats may introduce parasites, and possibly AR. While performing a FEC may determine if infection is present, it may be more prudent to effectively treat the animal(s) while in isolation and then expose the animal to the farm parasites prior to mixing. Because these recommendations are very farm specific, you must involve your flock veterinarian in developing this protocol. Below are suggestions as to how this may be done.

4.1 TREAT ALL NEW INTRODUCTIONS WHILE IN ISOLATION

Purchased sheep and goats should not be turned out with your flock or onto pastures grazed by your flock until the possibility of AR parasites has been minimized.

4.1.1 Unknown history of AR in the farm of origin

Startect™ (Zoetis Canada Ltd) is licensed for sheep and should be the treatment of choice for a quarantine treatment in that species. It should not be used in goats, as there is no safety or efficacy data in that species. To treat any animal, they should be weighed first and dosed to body weight or slightly higher to assure there is no risk of under treatment.

For goats, treat with ivermectin drench (not injection) at 1.5 X the sheep dose. After the animal has swallowed the anthelmintic, follow-up this treatment with a BZ anthelmintic (don't mix together) - either fenbendazole or albendazole (not in does that may be in their first 30 days of pregnancy) at 10 mg/kg bw (double the sheep dosage). The BZ treatment can be repeated in 12 hours on the advice of the flock veterinarian.

4.1.2 Resistance to both ML & BZ dewormers is present in the farm of origin – goats only

If the parasite of concern is *Haemonchus*, then closantel (Flukiver™, Elanco Canada Ltd) will likely be very effective, as resistance has not yet been reported to this anthelmintic, although this product is not approved for goats in Canada. In Canada, the vast majority of AR has been identified in that parasite and not in *Teladorsagia* or *Trichostrongylus*. Use of ivermectin or a BZ (not both) in combination with closantel as described in 4.1.1 will most likely eliminate those parasites.

4.2 HOLD TREATED ANIMALS OFF PASTURE

The sheep / goats should be held off pasture and ideally in a drylot for at least 48 hours to allow passage of any parasite eggs. Manure from this holding time needs to be properly composted so that the resistant eggs and larvae are killed.

4.3 TURN ANIMALS ONTO A CONTAMINATED PASTURE

If the new introductions are still infected with GIN, they will be very resistant! This means it is important to dilute any eggs they may still be passing with "farm" parasites, which is accomplished by turning them onto contaminated pasture, ideally one which has a high level of refugia.

4.3.1 When no contaminated pasture is available

Keep the treated animal(s) in isolation. During the grazing season, have a FEC performed 14 days after treatment. If more than 10 animals, samples can be pooled from 10 randomly selected animals. If fewer, do individual samples. If still positive, consult your flock veterinarian on other available treatments. If the animals are purchased during the winter months, FEC may not be useful as the parasites are hypobiotic (arrested). A FEC should be done in the spring prior to turnout to assess if they are still infected with resistant GIN.

★ 5. INVESTIGATE TREATMENT FAILURE

5.1 IS IT PARASITES THAT ARE MAKING THE ANIMALS SICK?

If the sheep/goats appear not to respond to treatment or are showing signs of parasitism despite deworming recently, the reason for this must be investigated. Other diseases may be the cause of poor growth or diarrhea, or even sudden death. Poor growth can be nutritional in origin (e.g. poor pasture, selenium deficiency). Diarrhea can be due to coccidiosis. Pulpy kidney (*Clostridium perfringens* type D) can be the cause of sudden death on lush, green pasture. Anaemia may be due to liver flukes (*Fasciola hepatica*) although at this time in Canada, this parasite is not common.

Have FECs performed (if ML, CL or Startect were used, 14 days after treatment; if BZ was used 10 to 14 days after treatment). If animals have died, have your veterinarian or local diagnostic laboratory perform a necropsy and abomasal worm count. Just seeing a few worms in the stomach is not "proof positive" that they killed the animals; they need to be measured and counted as described previously.

5.2 TESTING FOR PRESENCE OF ANTHELMINTIC RESISTANCE

If the FEC is still high, perform a drench response test as described previously. Make sure you are delivering a sufficient dose of the dewormer. If the treatment fails to reduce the FEC, you and your veterinarian need to discuss if you should pursue a faecal egg count reduction test. If AR is confirmed, review this document, and with your flock veterinarian develop a plan for managing parasites.

5.3 RE-ESTABLISHING A SUSCEPTIBLE PARASITE REFUGIA – CAN IT BE DONE?

If AR has been identified on a sheep property, is it possible to re-establish susceptible refugia? The jury is still out on this one. The following has been recommended: 1) the refugia is reduced through either leaving the pasture fallow for a long period of time, grazing with another species such as cattle or horses (not goats or sheep), or ploughing and reseeding; 2) lambs or kids that have been purposely infected with susceptible GIN are then introduced to seed the pasture with susceptible L3; 3) then the flock of that farm is grazed on these pastures and the new infection will dilute the level of resistant parasites carried by those animals. Difficulties with this approach are to first invest in reducing the refugia and then to locate lambs or kids with heavy loads of susceptible GIN.

Next section is "Parasite control on organic sheep and goat farms"