INTEGRATED CONTROL OF INTERNAL PARASITES IN SMALL RUMINANTS

tatiana L. Stanton and Michael L. Thonney
Cornell University
Ithaca, New York, USA

Background

Parasitism by *Haemonchus contortus* (barber pole worm) and other strongyles (nematodes in the family Strongylidae) infecting the digestive system is a major cause of death and poor production in sheep and goats in the United States. However these internal parasites must be managed carefully to avoid developing resistance to the limited classes of available dewormers. In order for chemical dewormers to be effective, the targeted worm population needs to be vulnerable. However as the on-farm worm population is repeatedly exposed to dewormers, natural selection favors the survival of worms that are genetically resistant to the dewormers used.

Dewormer resistance is well documented on U.S. sheep and goat farms (Howell et. al., 2008) and now extends into the Northeast. In early Fall 2007, the Baker Institute for Animal Health in cooperation with the Cornell Department of Animal Science sampled 174 goats from 19 NY and PA goat farms immediately before and 7 to 10 days after deworming with commonly used dewormers. Eighty two percentage of the farms using fenbendazole showed moderate to severe dewormer resistance and 53% of the farms using ivermectin had moderate to severe resistance. More than half the farms tested (11 of 19) exhibited severe resistance to one or more dewormers and another 3 exhibited moderate resistance to one or more dewormers. A follow up study on dewormer resistance in NE US meat goat herds was conducted in Spring 2008 using a more sensitive “larval development assay” test to observe resistance. Pooled samples of feces representing a minimum of 6 goats were collected from 12 farms and tested simultaneously for susceptibility to several different dewormers. Two farms had insufficient worm populations in the spring. Of the remaining 10 farms, severe to moderate resistance to high dosages of thiabendazole, levamisole, thiabendazole X levamisole, or ivermectin was exhibited by 100%, 60%, 60% and 90% of the farms, respectively. All farms showed severe resistance to high dosages of at least one dewormer and three farms showed severe resistance to at least 2 different dewormer treatments.

Even without consideration of dewormer resistance, reliance on chemical dewormers is problematic for pasture based commercial sheep dairies because no dewormers are labeled in the US for use in lactating dairy ewes. The problem is particularly acute for farmers marketing under the organic label where milk products cannot be marketed as organic for 90 days after emergency off-label dewormer use nor lamb marketed as organic meat if lambs are dewormed or receive milk from ewes dewormed during lactation or the last third of pregnancy. Farmers marketing “grass fed” milk and meat are also challenged to achieve good milk production and lamb growth in the face of parasite challenges without concentrate feeding.

To reduce the usage of chemical dewormers and hinder the advance of dewormer resistance, farmers need to adopt integrated parasite management practices that keep parasite loads under manageable levels while insuring the survival of a gene pool of worms that have rarely been exposed to dewormers and are still susceptible, i.e. the "refugia". The following sections describe promising integrated parasite management practices.

Targeted Selective Deworming and Judicious Use of Dewormers

A primary cause of dewormer resistance and destruction of a farm's refugia is deworming the entire flock or herd at the same time. Parasites are not equally distributed across individuals in a flock. Instead, general estimates are that approximately 20 to 30% of the flock harbors 80% of the worm load and are responsible for the buildup of worm populations in pastures over the grazing season. The task of targeted selective deworming is to identify and deworm only those animals in need of deworming and/or shedding large amounts of eggs. Targeted selective deworming (TSD) in small ruminants has been shown to prolong dewormer efficacy (Kenyon and Jackson, 2012). Although, a farmer could implement TSD by fecal sampling their entire flock regularly, this is time consuming and expensive and does not identify animals with low tolerance to worms that are not shedding many eggs, Instead we generally use visual cues, sometimes in combination with production records, to identify the specific individuals requiring deworming.

One valuable tool to identify sheep or goats in need of deworming for barber pole worm (*H. contortus*)is using FAMACHA cards to score animals for anemia based on the color of the membrane of the inside eyelid. Anemia is a typical sign of *H. contortus* infection. It is NOT an accurate indicator of infection for other important parasitic "round worms". These worms often disrupt the digestive system and typically result in diarrhea, weight loss and poor hair/fleece condition. Therefore we often recommend a "5 point check" to monitor small ruminants to determine which individuals to deworm. The checks can be tailored to a farm's specific parasite problems but generally include FAMACHA scoring, body condition scoring or weight monitoring, checking dag scores or for the presence of diarrhea, and examining animals for bottle jaws and/or other danger signs of particular parasites in that flock.

Monitoring practices help retain refugia and reduce pasture contamination only if done frequently enough. This is generally every two weeks during the grazing season and monthly in other seasons. However, monitoring may need to be weekly during peak parasite periods if large number of animals are showing elevated FAMACHA scores. If the worm problem is allowed to persist too long then a large percentage of the flock will need deworming simultaneously, defeating the purpose of selective deworming. These checks help determine animals repeatedly needing deworming and can identify specific management weaknesses. For example, if recently weaned lambs or ewes starting lactation with the highest milk production are most problematic than you may need to re-examine your weaning strategies or lactation diets. However, the genes for building up immunity to worms in small ruminants are often unrelated to milk or growth ability of individual sheep and goats. Therefore, selective deworming can help identify those animals for culling that exhibit poor immunity to worms without having an environmental explanation (nursing large litter, coping with a separate health problem) for their susceptibility. Parasite resistance traits are low to moderately inherited in small ruminants depending on the worm challenge in the environment (Riley and Van Wyk, 2009). Therefore, monitoring can be used to compare lambs or ewes from different sires to identify sires with potential for genetic selection for worm resistance.

Dewormers are highly effective at saving the lives of heavily parasitized animals. To combat resistance, try to avoid giving dewormers by injection or as pour-on. For best effect, dewormers should be given orally far back in the mouth using a drenching gun or syringe extender to help deliver the dewormer to the rumen where it will bind to rumen particulates and exposure will be optimal rather than being delivered directly to the abomasum (simple stomach) where exposure may be too brief. Even when some dewormer resistance has developed, the effectiveness of dewormers in the benzimidazole family (i.e. albendazole, fenbendazole) can be prolonged by fasting animals 12 hours prior to deworming or by repeating the dose 12 hours later. Avoid fasting animals in late pregnancy/early lactation as fasting may result in ketosis. Rotation of dewormer families may actually hasten dewormer resistance. Therefore, continuing to use the same dewormer class until it fails in effectiveness is recommended except when that dewormer is ineffective against the particular stage or type of worm targeted.

Evasive Grazing

Parasitic strongyle worms are basically a pasture problem. They are susceptible to ammonia and do not survive well in the deep bedding pack of most winter barns. In hoop houses or greenhouses with shallow or no bedding, worm larvae survival is also reduced by drying out of the fecal pellets. Instead, worm larvae thrive on pastures and in barnyards where grazing material is present and manure contamination is significant.

Evasive grazing is a term for managing pastures using parasite control as a primary consideration. The goal is to adopt a pasture rotation strategy that 1) moves animals out of a section of pasture fast enough to prevent infection from feces deposited during the current grazing period (autoinfection) and 2) allows a long enough rest period that there is substantial die off of infectious larvae before animals return to that section to graze (Colvin et.al., 2008). Decisions about pasture height, timing of spring entry into pastures, types of animals exposed to pasture (dry stock, lactating females, young stock), management of pasture sections during the rest period and management of small pastures bordering the barn also have a major impact on worm loads in sheep and goats.

Barber pole worm (*H. contortus*) eggs take about 3-5 days to hatch at 77-79˚F and about 15-30 days to hatch at 50–52˚F (Rose, 2016). During the grazing season in the Northeast we generally assume it takes about 5 to 14 days for barber pole worm to mature from an egg to an L3 larva capable of infecting a sheep or goat. Recommendations to avoid autoinfection are to remove sheep and goats from a pasture within 4 days in warmer weather (late spring, summer) and 7 days in cooler seasons (fall). Because most of the worm larvae are located in the bottom 2 inches of forage, animals should be moved earlier if pastures get too short (i.e. 3 -4 inches). Height considerations are probably not as crucial in the first pass through in Spring.

In tropical conditions, populations of *H. contortus* infectious larvae on pasture regrowth in rotational pasture systems appear to peak about 14 days and then decrease substantially by 42 days when animals are moved weekly (Mahieu et al., 2008). However, studies in temperate regions indicated that *H. contortus* L3 populations on pasture regrowth peak later (~6 wks.) and take as much as 13 wks.to decrease substantially on pastures grazed 2 to 4 wks. (Eysker et. al., 2005). Individual larvae can survive for many months on a pasture. However, resting pastures for ≥60 days after removal of small ruminants can drastically reduce exposure to infectious larvae.

To maintain forage quality under these extreme rest periods, pastures may need to be mowed or grazed by an unrelated species between rotations to keep them from becoming too mature. There are additional advantages for parasite control from either mowing the paddocks or grazing them with an unrelated livestock species during the “rest” period. In hot dry weather, close mowing of pastures shortly after removal of the goats or sheep dries out fecal pellets, reducing larvae survival. Harvesting a hay crop from a pasture substantially decreases larvae survival. The specific stomach and intestinal worms infecting sheep and goats generally do not complete their lifecycles in cattle or horses. Therefore, rotating cattle or horses through a pasture between the grazing intervals can help "vacuum up" larvae especially if timed to follow a warm rain.

Studies in Maine have indicated that holding sheep inside and off of pasture until June 15th when compared to May 15th, results in the Spring flush of eggs being shed indoors and substantially reduces fecal contamination of pastures and flock worm loads over the grazing season (Weber, 2016). However, this delay in turn out may not be feasible for many farms.

Barnyard Effect

Most practices to control the barber pole worm and other stomach and intestinal worms center around reducing the concentration of feces in grazing areas or disrupting the life cycle of the worms. To reduce fecal contamination, avoid stockpiling manure in barnyards or areas that readily drain into adjacent pastures. Spreading un-composted manure on pastures and overstocking pastures are two other sources of fecal contamination.

Heavily used barnyards and pastures adjacent to barns are a major source of worm infection. Insuring that these pastures are rested is extremely important especially in situations where they serve as lambing or kidding paddocks. Rotational grazing early in the grazing period can help reduce the buildup of worms by forcing animals to graze in outlying areas. In the summer of 2005, the Cornell Department of Animal Science with funding from the Northeast Sustainable Agriculture Research and Education Program (NE SARE) compared worm counts for different types of pasture management systems at three meat goat farms in Vermont and three meat goat farms in New York. In each region, a farm that did not rotate pastures but instead continuously grazed on large parcels surrounding barn areas was compared to two similar farms (does with nursing kids) practicing pasture rotation in the spring and early summer. Farm managers observed that suckling kids grazed close to the barns where fecal contamination was intense if pasture rotation was not practiced. Worm counts were far higher for the two farms that did not rotate and kid loss to worms and coccidia were observed at both these farms by July (Figure 1).

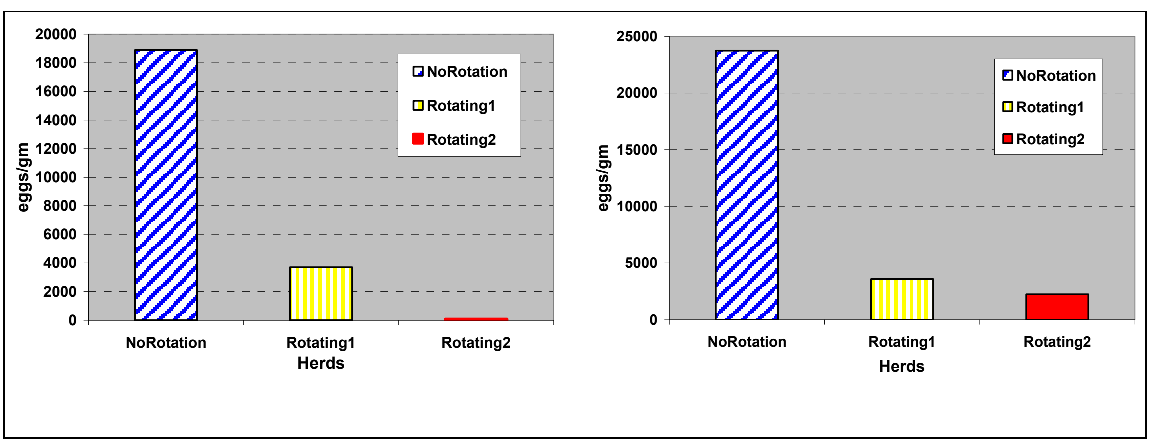

Figure 1. Comparisons of worm egg counts per gram of feces in goat kids in early July in two herds that rotated versus a similar herd that did not in two different regions of the Northeast US.

This barnyard effect can be reduced by 1) resting barnyard pastures; 2) graveling barnyards, treating them with herbicides, or making them small enough that grazing material does not survive in them; 3) eliminating barnyards by using lanes to move animals from barn to pasture or leaving animals in pasture 24 -7 or closing them in barns or dry lots at night.

Please note that certain management systems are inherently less likely to be impacted by worms. Evasive grazing practices may not be necessary in flocks and herds that wean young stock prior to the grazing season to market or raise off pasture and only manage dry ewes or does (whose immune systems should be fully functional) on pasture.

Use of Copper Oxide Wire Particles in IPM

Several studies particularly in the Southeast US have indicated that dosing sheep and goats with copper oxide wire particles (COWP) can reduce barber pole worm infections (Burke et.al., 2013). Sheep unlike goats are ten times more susceptible to copper toxicity than cattle. Copper is an important livestock nutrient deficient in many soils. Copper oxide wire particles were developed as a slow release form of copper to address these copper deficiencies. They are administered orally with the goal that they will lodge in the true stomach (abomasum) long enough to permit acid solubilization of the copper for absorption in the small intestine. Because much of their action takes place in the abomasum, they target primarily *H. contortus* rather than other parasitic strongyle worms. The pH of the true stomach is crucial to their effectiveness. Infection with brown stomach worm (*Teladorsagia circumcincta*) damages the gastric glands, thus increasing the pH of the abomasum and the chyme (partly digested food expelled from the abomasum into the small intestine), and preventing release of copper from the COWP (Bang et.al., 1990). When this occurs, the effectiveness of COWP for either copper supplementation and/or parasite control is drastically impaired.

From 2012 until 2017, the Cornell Sheep and Goat Program conducted numerous on-farm trials looking at the effect of COWP dosing on *H. contortus* infection on NY sheep and goat farms. Funding for these studies was provided by the Northeast Sustainable Agriculture Research and Education Program (NESARE) and the Federal Capacity Fund. The effect of oral dosing with copper oxide wire particles (COWP) on gastrointestinal nematode infections in lactating dairy goats and sheep is not well documented. Additionally, some farms worry about copper residues in the milk or poor curd formation after COWP dosing. Therefore one study was conducted at a commercial goat dairy in Northern NY. Sixteen, 15, and 15 lactating does were given HCOWP (1 g/10 kg live weight), MCOWP (2 g/head), or LCOWP (1 g/head), respectively. Individual fecal samples were collected and FAMACHA scores were recorded on days 0, 14, 28, and 42 after dosing. Individual milk samples were analyzed for copper concentrations on days 0, 14, and 42. Individual blood samples were collected on day 42 to measure aspartate aminotransferase (AST), an indicator of copper toxicity. No long term effect of COWP level on either overall strongyle or *H. contortus* fecal populations was observed. However, *H. contortus* eggs per gram (epg) decreased similarly for HCOWP and MCOWP from 0 to 14 days; changes were -1153 ± 469.4 and -1226 ± 484.8 epg, respectively, while *H. contortus* eggs increased by 107 ± 484.8 epg for LCOWP ($P = 0.036$ vs MCOWP and HCOWP). Curd formation for 4 cheese types remained consistent the week following COWP treatment. Milk copper increased slightly between day 0 (0.131 ppm) and day 14 (0.174 ppm) but individual values were all within the pre-treatment range and highest levels of copper recorded were below maximum allowable levels. Changes in milk copper concentration from 0 to 42 days were not significant. However, in separate paired t tests, copper concentrations increased significantly (P = 0.003) from 0.105 ± 0.019 to 0.171 ± 0.019 ppm from 0 to 14 days for HCOWP but not for MCOWP (P = 0.12) or LCOWP (P = 0.14). Copper toxicity elicits AST activity of >300 ppm. Plasma AST concentrations on day 42 were 118 ± 6.9, 121 ± 7.2, and 113 ± 7.2 ppm for HCOWP, MCOWP and LCOWP, respectively, and did not differ significantly. In this study, dosing dairy does with 2 g COWP/head as compared to 1 g/10 kg live weight caused similar reductions in *H. contortus* epg and significantly lower increases in milk copper concentrations from Day 0 to Day 14 with only 25% (small does) to 50% (large does) as much COWP.

The results of our Northeast studies on COWP dosing are very variable. Dosing with COWP at 0.5 g/head and 1.0 g/head was very effective at reducing *H. contortus* egg counts in weaned lambs during the grazing season at the St. Lawrence County Cornell Cooperative Extension Learning Farm from 2012 to 2015. This farm historically provided no supplemental copper to their flock. However results on other farms indicated only short term reductions in *H. Contortus* egg counts from dosing or no significant difference in worm loads between treated and control animals.

Southeast researchers recommend using COWP as part of a FAMACHA program where animals scoring 3 receive COWP dosing (0.5 to 1.0 g per lamb, 1 to 2 g per ewe) and animals scoring higher receive an effective dewormer. They caution that farmers should verify that COWP is working in their flock and consult with their veterinarians about risks of copper toxicity.

Use of High Tannin Forage Legumes in IPM

In the Southeast US, consumption of Lespedeza (*Sericea lespedeza)*, a forage legume containing condensed tannins, has reliably reduced parasitic strongyle infections in sheep and goats (Lange et al., 2006; Shaik et al., 2006). However, Lespedeza is not winter hardy in Northeast climates. Condensed tannins in numerous forages may suppress strongyle infections through direct effects on worms and/or improved immune response in the host because of improved protein nutrition (Min and Hart, 2003). Birdsfoot trefoil (*Lotus corniculatus L.*), is a forage legume containing condensed tannins that IS well adapted the Northeast. In preliminary studies, it has shown some anti-parasite effects in small ruminants (Heckendorn et al., 2007; Marley et. al., 2003).

Cornell University as part of a USDA Organic Research and Extension Initiative project with several other universities has solicited Northeast sheep and goat farmers to establish 1-to 3-acre fields of Birdsfoot Trefoil (BFT) under organic practices and conduct grazing trials the following year to compare the worm loads of lambs and kids grazing BFT versus conventional pastures. Preliminary results from some of these grazing trials follows.

In one study at a commercial sheep dairy, lambs born the last 3 weeks of April were raised on dairy dams until June 1st and then put to pasture with yearling ewes. As part of the farm's worm prevention, lambs had received a "once in their life" dose of COWP at 2 g/head. Farm policy was to graze lambs and yearlings for as long as possible on land not used for the dairy flock. This necessitated using low fertility fields owned by other land owners. A low Phosphorous (2 lb/acre), acidic (soil pH 5.3) field was dedicated to the grazing trial with part of it planted in Bruce BFT. Fences were moved daily but animals could backtrack for 3 days. Lambs on conventional pasture (CP) and BFT received ~273 and 197 sq. ft./head/day of new pasture respectively because of differences in forage production. The BFT group averaged better

FAMACHA scores in wk. 4 and 6 (1.6 vs. 2.5, and 1.1vs 2.0). Fecal egg counts were similar fo both groups until wk. 6 when average egg counts were 1488 epg and 1062 epg for the BFT and CP lambs respectively. Larval cultures at the beginning and end of the 6 wk. grazing trial indicated that nodular worm (*Oesophagostomum columbianum)* was the primary worm represented with only a low percentage of *H. contortus.* Daily weight gains averaged 0.33lb/head and 0.12 lb/head for lambs grazing BFT and CP respectively.

In contrast, a similar study was done in a flock of Dorset/Icelandic lambs where *H. contortus* was the primary parasitic worm and field fertility was substantially better. The 6 wk. grazing trial started immediately after weaning. Fecal egg counts for both groups rose sharply after weaning but were similar for both groups until wk. 6 when average egg counts were 4550 epg and 6955 epg for the BFT and CP lambs respectively. Average FAMACHA scores were similar for both groups until wk. 6 when the BFT group averaged better FAMACHA scores (1.9 vs. 3.1). Daily weight gains averaged 0.48 lb/head and 0.36 lb/head for BFT and CP grazed lambs respectively.

<u>Trial combining Birdsfoot trefoil (BFT) grazing with COWP dosing</u>

In this study strongyles infections were compared for lambs receiving 3 different nutritional treatments for 8 weeks after weaning in combination with or without COWP (1 g bolus) dosing two weeks pre-weaning. Eight lambs each were assigned to each of the following treatments: BFT + COWP, BFT alone, Conventional pasture (CP) + COWP, CP alone, or Hay/Grain (HG) + COWP. Pastured lambs were moved ~ every 5 days and drylot lambs were fed second cut grass-hay ad lib (13.5% crude protein, 64% total digestible nutrients on dry matter basis) and approximately one pound/head/day of concentrate feed (15.4% CP, 77%TDN as dm).

All lambs receiving COWP 2 weeks pre-weaning appeared to have lower round worm egg counts and more desirable FAMACHA scores for 8 weeks post weaning as compared to the group of lambs on BFT pasture alone and especially lambs on CP alone. These changes in roundworm egg counts resulted almost entirely from changes in the *H. contortus* worm egg population. In addition, no lambs on the BFT pasture alone, the BFT + COWP or the CP + COWP treatments had to be dewormed over the 70-day study. In contrast, 2 lambs required deworming on the HG + COWP treatment, and 4 of 8 lambs on CP alone had to be dewormed based on severe anemia and weakness. Daily weight gains over the 70 d study averaged 0.3 lb, 0.25 lb, 0.22 lb, 0.18 lb, and 0.16 lb for BFT + COWP, HG + COWP, BFT, CP + COWP and CP treatments, respectively. Dewormed lambs were included in these weight averages. Weight gains for HG + COWP and CP alone would probably have been worse if the heavily parasitized lambs requiring deworming in these two treatments had not been dewormed. In this study, lambs given both COWP and BFT appeared to outperform lambs receiving both COWP and Hay/Grain. The good growth of lambs on BFT despite the absence of concentrates has important implications for lambs managed as “grass fed” as well as for organic and conventional farmers raising weaned lambs on pasture.

Conclusion

There are several management strategies sheep and goat farmers can adopt to reduce dependency on chemical dewormers and mitigate some of the potential consequences of dewormer resistance. Targeted selective deworming and evasive grazing are two effective management practices. However, they require serious planning and labor commitments. The jury is still out on the effectiveness of COWP dosing and BFT grazing to combat worm loads in vulnerable animals such as growing lambs and kids. However, the good growth of lambs on BFT in combination with COWP dosing despite the absence of concentrates has important implications for lambs managed as "grass fed" as well as for organic and conventional farmers raising weaned lambs on pasture.

References

Bang K.S., A.S. Familton, A.R. Sykes. 1990. Effect of ostertagiasis on copper status in sheep: A study involving use of copper oxide wire particles. Res Vet Sci. 49:306–314.

Burke, J.M, J.E. Miller, and T.H. Terrill. 2013. Copper Oxide Wire Particle to Control *Haemonchus contortus* in Sheep and Goats. in 10th Anniversary Conference of the American Consortium for Small Ruminant Parasite Control (May 2013).

Colvin, A.F., S.W. Walkden-Brown, M.R. Knox, J.M. Scott. 2008. Intensive rotational grazing assists control of gastrointestinal nematodosis of sheep in a cool temperate environment with summer-dominant rainfall. Veterinary Parasitology 153: 108–120.

Eysker, M., N. Bakker, F.N. Kooyman, H.W. Ploeger. 2005. The possibilities and limitations of evasive grazing as a control measure for parasitic gastroenteritis in small ruminants in temperate climates. Vet. Parasitology 129: 95–104.

Heckendorn, F., D.A. Haring, V. Maurer, M. Senn, and H. Hertzberg. 2007. Individual administration of three tanniferous forage plants to lambs artificially infected with Haemonchus contortus and Cooperia curticei. Veterinary Parasitology 146:123-134

Howell, S.B., J.M. Burke, J.E. Miller, T.H. Terrill, E. Valencia, M.J. Williams, L.H. Williamson, A.M. Zajac, R.M Kaplan.2008. Anthelmintic resistance on sheep and goat farms in the southeastern United States. J. Am. Vet. Med. Assoc. 233: 1913-1919.

Kenyon F. and F. Jackson. 2012. Targeted flock/herd and individual ruminant treatment approaches. Vet. Parasitology.186: 10-17.

Lange, K., D.D. Olcott, J.E. Miller, J.A. Mosjidis, T.H. Terrill, J.M. Burke and M.T. Kearney. 2006. Effect of sericea lespedeza (*Lespedeza cuneata*) fed as hay, on natural and experimaental *Haemonchus contortus* infections in lambs. Vet. Parasitology 141:273-278.

Mahieu, M.K., H. Archimede, J. Fleury, N. Mandonnet and G. Alexandre. 2008. Intensive grazing system for small ruminants in the Tropics: The French West Indies experience and perspectives. Small Ruminant Res 77: 195–207.

Marley, C., R. Cook, R. Keatinge, J. Barrett, N. Lampkin. 2003. The effect of birdsfoot trefoil (*Lotus corniculatus*) and chicory (*Cichorium intybus*) on parasite intensities and performance of lambs naturally infected with helminth parasites. Vet. Parasitology 112:147-155.

Min, B. R., and S. P. Hart. 2003. Tannins for suppression of internal parasites. Journal of Animal Science 81(E.Supple.2):E102-E109.

Riley, D.G. and J.A. Van Wyk. 2009. Genetic parameters for FAMACHA score and related traits for host resistance/resilience and production at differing severities of worm challenge in a Merino flock in South Africa. Vet. Parasitology. 164: 44-52.

Rose, J.H., 1963. Observations on the free-living stages of the stomach worm Haemonchus contortus. Parasitology 53: 469–481.

Shaik, S.A., T.H. Terrill, J.E. Miller, B. Kouakou, G. Kannan, R. M. Kaplan, J.M. Burke, and J. Mosjidis. 2006. Sericea lespedeza hay as a natural deworming agent against Haemonchus contortus infection in goats. Vet. Parasitology 139:150–157.

Weber, J. Personal communication. June 10, 2016.