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Nematode Parasites and Grazing Research

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1.0 Introduction

Parasitism, and gastrointestinal nematode parasitism in particular, is arguably the most serious constraint affecting ruminant production world-wide. Economic losses are caused by decreased production, cost of prophylaxis, cost of treatment, and the death of infected animals. It is difficult by any form of major survey or other estimation to establish precise figures on losses incurred in production from infection and disease. Even minimal accuracy of loss estimates is difficult because production diseases or disorders may result from interaction with nutritional and environmental stresses, management methods, concurrent diseases, genetic predispositions, or other factors. Periodic reports on such losses from governmental agencies and others, always range into millions of dollars per year and include all phases of production. Problems with nematode parasitism are often classified as production disease (i.e. chronic subclinical condition affecting productivity such as weight loss, reduced weight gain, reproductive inefficiency, etc.). The unique thing about nematode parasitism, compared to other infectious diseases, is that the host is almost always associated with some level of infection year round whereas other infectious diseases usually come and go. Therefore, nematode parasitism continually affects production, and other infectious diseases affect production sporadically. Because nematode parasites are associated with all grazing animals, it is important to understand the parasites involved, how infection might affect results and how to control parasites to minimize parasite effects on grazing research. For an overview of these parasites, appropriate sections in well recognized and used textbooks can be referenced (Dunn, 1980; Urquhart et al., 1996; Bowman and Georgi, 2002).

2.0 Importance of nematode parasites in grazing ruminants

The incidence of nematode parasitism in the southeast is considered to be relatively high compared to the rest of the US, primarily due to the favorable environment conditions for development and survival year round. This presents potentially more production problems that producers in this region have to deal with.

It has been suggested that nematode parasitism could be divided into three categories (subclinical, economic and clinical), based on their effects on the host. Subclinical is the presence of parasites, but for whatever reason, there are no measurable adverse effects. Economic is the level that prevents the host from reaching its genetic potential for production. Clinical occurs when the balance between the host and the parasites is such that the parasites cause abnormal signs including anemia, diarrhea, anorexia, rough hair coat, etc. Both economic and clinical parasitism would result in economic losses.

There are a number of factors that may influence the impact of parasites and assessment of that impact can be difficult, particularly subclinical parasitism. Such factors may include: host nutritional stress, climate, pasture and animal management, concurrent diseases, class of animal and others. The impact of economic parasitism can be evaluated by deworming and then measuring the response criteria used to assess performance or production. It has been well established that deworming young animals results in improved weight gains and better condition. Adult animals, depending on the livestock species, can harbor few to many worms and getting rid of them may or may not be worth the effort. Any advantage in deworming adult cattle has been variable from essentially nothing to modest effects. On then other hand, the advantage in deworming adult small ruminants can be major. Some of these effects include increased conception rates, reduced time to first conception (heifers, ewe lambs and doelings) and increased milk production. The fact that dewormed adult animals maintain or gain some weight probably accounts for these effects as they have more body reserves to accommodate the physiologic (particularly energy, for times of the year when nutrition is poor) demand. However, what infection they do have continuously contributes to pasture contamination which ultimately is reflected in whatever animals are exposed to the infection resulting from that contamination. Generally, if it is young animals, they will experience the most adverse effects.

3.0 Nematodes involved in ruminant parasitism

The four major nematode parasites of ruminants across the SE from Texas to Florida, in order of prevalence, are *Ostertagia (Telodorsagia)*, *Haemonchus*, *Cooperia* and *Trichostrongylus*. However, the relative proportions of these nematodes will vary from location to location. Other minor nematodes present, in relative order of importance, include: *Nematodirus*, *Oesophagostomum*, *Strongyloides*, *Trichuris* and *Bunostomum*. *Ostertagia* and *Haemonchus* are by far the most pathogenic in cattle and small ruminants, respectively, and essentially all control measures are directed at these parasites. Scientific and vernacular names of common nematode parasites as well as their relative pathogenicity are presented in Table 1.

4.0 Effect of nematode parasites on the host

Although much progress has been made in studying the physiologic mechanisms by which nematode parasites adversely affect animal performance, there are many unknowns, particularly when dealing with subclinical parasitism, i.e., those infections that do not result in overt clinical signs.

Ostertagia (in cattle) and *Telodorsagia* (in small ruminants) are the most important and well-studied species in temperate regions. Effects of infective larvae occur within hours after ingestion. The larvae enter gastric glands of the abomasum, resulting in 1) decreased acid production due to loss of parietal cell function; 2) absence of proteolytic pepsin because, as stomach pH rises, pepsinogen is not activated; and 3) movement of serum protein, particularly albumin, and sodium from circulating

blood into the lumen of the abomasum, thus leading to fluid dumping and diarrhea. Larvae and adults of other species contribute to pathology by causing abomasitis and enteritis which further interferes with nutrient absorption.
Haemonchus is the most important and well-studied species in subtropical and tropical regions. Because it is a blood feeder primarily, anemia results and death may ensue. Of particular note is that *Haemonchus*, although not that prevalent in cattle, can under certain conditions become a major player.

The major physiologic change resulting from a combination of infection with all species is loss of appetite. Although reduced appetite may be a major factor resulting in reduced performance, infected animals have a reduced ability to utilize nutrients. Although decreased digestibility and utilization of dietary energy and protein has been documented, it is felt that post-absorptive protein metabolism rather than an impairment of protein digestion and absorption is more important.

5.0 Epidemiology of nematode parasites

Understanding the epidemiology, i.e., the factors that influence the interaction between parasite, host and environment, is necessary before efficient control mechanisms can be developed. It is not practical here to address a full discussion of the epidemiology, so for additional information, a number of old but still relevant reviews are available (Kelly, 1973; Michel, 1976; Armour, 1980; Thomas, 1982; Williams, 1986). Some aspects are also covered in the texts cited above.

To start with, the parasite has to develop and survive in the host. After ingestion, infective larvae invade the mucosa (lining) of the abomasum, small intestine or large intestine depending on what worm is involved. While in the mucosa, larvae develop to the next larval stage and then return to the surface of the gut mucosa where they become adult worms. The major host defense mechanism is immunity. When an infectious agent enters the body, the immune system reacts through a series of activities that mobilize various components (antibodies, killer cells, etc.) that then attack and kill the invaders. These components act on the larval stages in the mucosa and the adults. How strong the immune response is depends on several factors. The immune system has to mature with age, therefore, young animals are relatively susceptible to infection and become more resistant with age. So, young animals usually harbor the heaviest infection levels and suffer the most severe consequences. Adult animals have developed stronger immunity and harbor low infection levels. One way infection level is measured is by quantifying the number of eggs being passed in the feces. So, relatively high and low egg counts are usually seen in young and adult animals, respectively. Young animals are more subject to clinical disease where signs of infection (diarrhea, rough hair coat, anemia, weigh loss, bottle jaw, death, etc.) are seen. In older animals, infection becomes more subclinical where the only subtle sign may be reduced weight gain in cattle, but serious clinical signs can occur in small ruminants. However, nutrition (as mentioned above) and/or stress can alter a host's immune competence. Under poor nutrition and/or stressful conditions, the immune system is compromised and can not respond adequately. Therefore, no matter what the age of the animal, the effects of infection will become worse. The prepatent period of most worms is about 3 weeks, but this period can be extended for worms that have the capability to enter a period of delayed development called hypobiosis. This occurs during the season of the year when the environmental conditions are unfavorable for development and survival of the free-living larval stages. Depending on the worm, this happens either during summer or winter. In cattle, *Ostertagia* undergoes hypobiosis in the summer in southern/hot regions and in the winter in northern/cold regions. In small ruminants, *Haemonchus* appears not to undergo hypobiosis in southern/hot regions, but does in northern/cold regions. *Telodorsagia* is rare or non-existent in southern/hot regions and undergoes hypobiosis in the winter in northern/cold regions.

It is important not only to consider the worms present in the host, but also to understand the importance of what happens during the free-living phase on pasture. Nematode parasites do not multiply within the animal. One infective larvae ingested results in the potential for one worm to develop to the adult stage. The life cycle patterns are similar for all gastrointestinal nematodes. Eggs are passed in feces and time to hatch is variable depending primarily on temperature. The warmer it is the faster the first stage larvae develops and hatches from the eggs (as short as 24 hrs), and as the temperature get colder, development and hatch takes longer (up to 3-4 weeks). The first-stage larva molts to a second-stage which then molts to become the third-stage (infective - L_3) larvae, all taking place in the feces. Time from egg hatch to L_3 ranges from about one week to several weeks depending on moisture and temperature. Development and survival to the L_3 varies greatly depending upon seasonal conditions and weather patterns. In the South, development and survival is usually greater from autumn to late spring than during hot and/or dry conditions of late spring and summer. L_3 may survive for many months depending upon ecological conditions. L_3 have limited ability to move or migrate. In any event, once the L_3 stage is reached, moisture is needed to leave the feces unless distributed by external forces such as hooves, rainfall, farm equipment or other physical means.

Once on pasture, L_3 can migrate laterally and vertically, however, not by much. Migration is usually only a meter or two laterally and 5-6 cm vertically on forage. This migration relies on adequate moisture, which is for the most part regulated by air temperature. When air temperature increases, larval recoveries are diminished because drier conditions prevail and vice versa. However, L_3 can survive a long time when protected by the microclimate at the forage/ground interface which can be much different that the macroclimate above ground.

The grazing behavior (grazer/browser) of ruminants and stocking rate play important roles in the number of L_3 ingested. For example, higher/lower stocking rates may mean less/greater availability of forage which in turn could mean that more/fewer larvae would be ingested during grazing. Even this relationship is not simple because animals practice selective grazing and the morphology of the plant may influence movement of the larvae. In general, as stocking rate increases, worm burdens also increase. The foregoing emphasizes the importance of conditions outside the animal which may influence animal parasitism.

Conditions such as climate, plant morphology and grazing management, e.g., stocking rate, rotational grazing, etc. are important when assessing the potential for parasitism or the need for treatment.

6.0 Monitoring or predicting parasite burdens of ruminants and/or pastures

The most absolute and direct method for documenting the number of worms present in an animal is to slaughter the animal, collect, identify, and count the numbers present. This is an expensive procedure because the animal is lost and must be removed from the experiment, and special training is needed to identify and count the worms. In addition, enough animals must be slaughtered in each treatment group in order to precisely identify and estimate burdens associated with various treatments under study. Unfortunately, monitoring of worms without slaughtering the animal is not easy or absolute. Therefore, the common methodologies employed to indirectly evaluate infection level are the fecal egg count (FEC), blood packed cell volume (PCV), fecal culture and pasture forage sampling.

6.1 FEC (eggs per gram, epg, of feces)

The FEC is exactly that, a method to evaluate the number of parasite eggs excreted per gram of feces (epg). There are several difficulties associated with measurement of FEC including: egg production does not always reflect the number of worms present, eggs cannot be completely identified to species, i.e., they may be grouped in various categories but not absolutely identified. The number of eggs present may be influenced by factors such as ovipositing, i.e., egg laying efficiency, diarrhea, and some methodologies used for epg determination may be less precise than others.

Research with sheep indicates that FEC for the most part reflects the animals' worm burden and also serves as an indicator of seasonal changes in level of infection. For cattle, FEC is not as reliable for measuring worm burden in individual animals However, trends in FEC over time can be seen, thus reflecting the relative direction of infection levels within and between experimental groups. Inefficiencies associated with single egg counts can be reduced by increasing the number of animals sampled per experimental unit and by serial (repeated) sampling.

6.2 PCV

Nematode parasites can affect an animals' ability to maintain erythropoesis. All nematode parasites can result in chronic anemia where red blood cells are not being made fast enough to keep up with demand. Of special note, *Haemonchus* feeds on blood directly and if large numbers are present, blood loss can be acute leading to death. Fortunately, this is not as common in cattle as it is in small ruminants. However, serious problems can occur with *Haemonchus* in nursing calves during summer grazing. PCV values have been used to support other response criteria, and is not necessarily used as a "stand-by-themselves" diagnostic tool.

6.3 Fecal culture

In order to identify the worms present, eggs in feces can be cultured to L_3 which have distinguishable characteristics for each genus. Of most importance is the population distribution and any changes over the duration of an experiment. Larval differential counts obtained from culture have been relatively highly correlated (0.40-0.65) with the composition of the worm burden.

6.4 Pasture larval counts

There are two ways to evaluate pasture larval counts, one is direct and the other is indirect. The direct way is to collect forage and recover and identify the larvae. The indirect way is to recover worms from parasite naive animals (tracers) that have grazed the pasture. The advantages of collecting forage are it is less time consuming and relatively inexpensive. The main disadvantage is that the whole pasture area is evaluated and knowing that animals can be selective in their grazing area(s), the count only reflects how many larvae are available overall and not necessarily what is actually available during consumption. The main advantage of tracers is that it reflects how many larvae the animals consumed regardless of grazing, and this is really more important. The disadvantages are that it is very time consuming and relatively expensive. Also, the minimum number of tracer animals needed depends on the variability of infection level between treatment groups. Many studies have used only 2-3 animals per treatment group and this may not be adequate to truly reflect differences.

7.0 Precision of assessing pasture or animal worm burdens

In most grazing experiments, the pasture is the experimental unit even though multiple animal units are used per pasture to improve the precision of estimating treatment effects. If a grazing experiment involves monitoring pasture infectivity or animal worm burden, the experimental unit is the pasture. This is because the treatment (regardless of what it may be) is randomly applied to the unit of land. Nematode parasites have free-living stages that are very important relative to ultimate parasitism in animals. Thus, factors that influence both the free-living stages and those associated with the host ultimately reflect parasite effects. Consequently, response criteria used to assess the level of parasitism and its influence on animal performance result from both factors influencing the free-living stages as well as those associated with the host/parasite relationship.

Often the total worm burden or the burden of specific species is not normally distributed. A test for homogeniety of variance is recommended before proceeding with further statistical analyses. If variances are not similar, a data transformation is necessary. In order to adequately assess treatment differences, as reflected by differences in parasite numbers, one needs to determine the importance of individual species for a given experiment (Table 1).

8.0 Summary

The impact of nematode parasites on ruminant production is dependent upon many factors including host nutritional and environmental stresses, climate, pasture and animal management, concurrent diseases, and class of animal. Generally, young nonsuckling animals experience the most adverse effects from parasitism. The major physiologic change resulting from most gastrointestinal nematodes, with the possible exception of *Haemonchus* is loss of appetite. Although reduced appetite is probably a major factor resulting in reduced performance, there are additional factors including protein or nitrogen metabolism, water balance, and unknown physiologic changes that could reduce host performance.

An understanding of the epidemiology, i.e., the factors that influence the number of parasites within the host and in the free-living state on pastures, is important before efficient control mechanisms can be developed. Factors influencing the number of free-living larvae include moisture, temperature, herbage available, morphology of the plants as well as grazing management. Researchers involved in grazing studies should carefully consider the importance of the need to control or monitor the parasite burdens on pastures or in animals. It could be very important if the experimental results are confounded by the parasite load of the cattle and/or pastures.
Unfortunately, monitoring or predicting the parasite burden of cattle and/or pastures is not simple.

Site	Nematodes: Scientific name	Nematodes: Vernacular name	Relative pathogenicity.
Abomasum			
	Haemonchus	Barber's pole worm	+ + ++
	Ostertagia/Telodorsagia	Brown stomach worm	++ +
	Trichostrongylus	Bankrupt worm or stomach hair worm	+ +
Small intestine			
	Cooperia	Cooperids or Bankrupt worm	+
	Trichostrongylus	Intestinal hair worm	+ +
	Bunostumum	Hook worm	+ +
	Nematodirus	Thread-necked worm	+ +
	Strongyloides	Thread worm	+
Large intestine			
	Oesophagostomum	Nodular worm	+ + +
	Trichuris	Whip worm	+