GASTROINTESTINAL PARASITES: A FREQUENTLY UNDERESTIMATED CONSTRAINT ON PRODUCTION OF GRAZING ANIMALS

D.I. Bransby
Department of Agronomy and Soils, Auburn University, AL 36849, USA

ABSTRACT
A knowledge of parasitism in grazing animals is needed to properly understand and manage grazed ecosystems. This paper focuses on effects of gastrointestinal (GI) parasites in beef cattle. These parasites have both clinical and subclinical effects on animals. Cattle between the age of 5 and 15 months are affected most, and deworming typically increases weight gain in these animals by 0.1 to 0.2 kg/ day. Results from deworming studies with cows and calves have been inconsistent. Parasite control in commercial livestock operations is dependent mainly on use of chemotherapy, although biological control could be effective. Grazing management variables such as stocking rate, method of grazing (rotational vs. continuous) and supplementation appear to have little effect on the need to deworm cattle. Future research should include work on improving the understanding of parasite life cycles and ecology, the inconsistency of results from deworming cows and calves, and improving experimental procedures.

KEYWORDS
worms, cattle, grazing methods, stocking rate, parasites, animal constraint

INTRODUCTION
Without knowledge of parasitism in grazing animals it is not possible to properly understand and manage grazing ecosystems. There are several reasons for this contention. First, animal parasites are an integral component of grazing ecosystems. Secondly, many gastrointestinal (GI) parasites depend on the presence of grassland plants to complete their life cycle: without these plants they cannot survive. Thirdly, effects of parasitism in grazing animals may often interact with grassland conditions and grassland management variables. Therefore, a poor understanding of the effects of parasitism on grazing animals by those interested in the effects of grassland ecology or grassland management variables on parasitism and/or animal production can lead to erroneous conclusions from grazing experiments. Finally, evidence in the literature suggests that this may have happened many times without scientists being aware of it.

In view of this, the objectives of this paper are to a) review the current state of knowledge on effects of GI parasites on grazing animals, b) identify and clarify some misperceptions, c) identify future research needs, and d) encourage traditional grazing research specialists to participate in this research. The discussion is focused primarily on GI parasites (and more specifically, on nematodes) in beef cattle. Reasons for limiting this focus are to allow reasonable depth in the analysis (inclusion of ectoparasites and other parasites could be covered only in a superficial review within specified page limitation), and because GI parasites strongly affect production of grazing animals, these effects depending heavily on pasture and range conditions. Furthermore, many of the principles discussed apply to other ruminants, but validity of extrapolating from research on cattle to other animals should not be assumed.

PARASITE LIFE CYCLE
Grazing animals ingest gastrointestinal parasites while grazing pastures. These parasitic nematodes cause an estimated $300 million loss annually in the United States alone (Tindall and Olentine, 1983). The economically important nematodes (commonly known as worms) found in cattle are the trichostrongyle type, which are part of a larger group called helminths. Geographic distribution of different worm species is influenced largely by climatic conditions (Levine, 1963). Important genera of trichostrongyles found in the southeastern region of the United States are Haemonchus, Ostertagia, Trychostrongylus, Cooperia and Nematodirus spp. All are nematodes of the abomasum and small intestine.

The generalized life cycle of the trichostrongyles begins with an unembryonated egg produced by the L5 (adult) nematode in the lumen of the intestine. These eggs are passed out of the animal in the feces, and the number of eggs varies widely with time, and among nematode species. Unfortunately, this often renders traditional fecal egg counts a poor indicator of worm burdens in the animal. In the fecal pat, embryonation occurs, and then the egg hatches into an L1 larva. This larva then progresses through the L2 stage, to become an L3 larva. In this form, larvae leave the fecal pat and move, mainly through films of moisture resulting from precipitation, to adjacent plants. They usually move no more than 15 to 45 cm from the pat, unless washed further by heavy rain (Armour, 1970). Ruminants then ingest the L3 larvae by grazing the plants on which they are located. Since these larvae are concentrated close to fecal pats and in the lower canopy of the pasture, cattle are likely to ingest more if they are forced to consume forage close to feces, or close to the soil surface. The L3 larvae pass from the rumen to the abomasum gastric gland and molt, to become the L4 larvae. These molt once again to become the L5 adult. Under favorable pasture conditions, L3 larvae live about three weeks, and then die if they are not ingested by a host. However, Reinemeyer (1994) indicates that "infective larvae routinely survive through winter and can endure drought conditions if sheltered within desiccated feces."

Ostertagia ostertagi is considered the most pathogenic and economically important GI nematode that affects beef cattle in temperate regions of the world (Armour, 1970). This species has an arrested development period that is called larval inhibition, which occurs when the L3 larvae enter the gastric gland and stay in the gland after molting to an L4. Inhibition, or arrested development, occurs when the environmental conditions in the pasture become unfavorable for L3 survival (winter in the northern United States, and summer in the South): the L3 enters the gastric gland and after molting to an L4, remains there until pasture conditions become more favorable for L3 survival. The mechanism by which pasture environmental conditions initiate and terminate inhibition are not properly understood. However, during the period of inhibition no eggs are shed, which means that infection cannot be detected by the traditional method of fecal egg counts.

PATHOGENIC EFFECTS ON ANIMALS
Since *O. ostertagi* is considered the most economically important worm in temperate regions of the world, pathogenicity of this species will be the main focus of the following discussion. The L3 larvae invade the mucosa of the abomasum and impair the function of this vital digestive organ. Clinical signs are poor weight gain, weight loss, diarrhea, a rough hair coat, and sometimes fluid accumulation under the jaw. Production losses occur through reduced weight gain, reduced milk production, increased susceptibility to other diseases and, in severe cases, death (Johnstone, 1985). These production losses are related largely to reduced feed intake, reduced nutrient digestibility due to an elevated abomasal pH, and decreased

absorption of nutrients in the small intestine (Sykes, 1987).

Once larvae enter the gastric gland and growth begins, cellular changes occur in the parasitized glands. Primary lesions develop as microscopic, white, raised, umbilicate nodules on the surface of the abomasum. Under normal conditions, L5 adults emerge from the gastric glands in 18 to 20 days, and further cellular changes occur. There is visual evidence of hyperplasia, and loss of cellular differentiation, especially in parietal HCl-producing cells in both parasitized and unparasitized surrounding glands. Damaged cells are replaced with undifferentiated cells, giving the abomasum a cobblestone appearance (Myers, 1984).

In severe cases of ostertagiosis, the pH of abomasal contents may rise from a normal level of 2 to 3, to as high as 7. The maximum pH for normal digestion is 4.5. A pH above this level interfers with the activation of the pro-enzyme pepsinogen (a precursor of pepsin, which is responsible for the initial breakdown of proteins into polypeptides) and the number of bacteria in the GI tract. Reduced HCl resulting from destruction of parietal cells associated with infection, reduces digestion because HCl is responsible for some acid hydrolysis of carbohydrates and proteins, and activation of pepsinogen to pepsin (Jennings et al., 1996). The mechanism by which worms reduce the appetite of animals is poorly understood, but in many cases this could be the major cause of production losses. In addition, this reduced intake caused by infection with GI parasites has important implications relative to potential interactions between GI parasites and grazing management variables (Bransby, 1993).

Clinical and subclinical effects of trichostrongylid infections are greatest in beef animals between the ages of 5 and 15 months. Typically, beef calves acquire nematode infections during the second month of life, but worm numbers do not increase dramatically until just prior to weaning. The animals most at risk from parasitism are stockers, because of high stocking rates and constant residence on infective pasture before immunity develops. This applies especially during winter, when poor forage growth concentrates available larvae, and animals are also exposed to climatic and nutritional stresses. Most cattle typically develop acquired immunity against reinfection and clinical disease during the second grazing season. Generally, cattle greater than 18 months old harbour small numbers of endemic worms and have persistent low egg counts in feces (Reinemeyer, 1994).

Therefore, especially with stockers, in which effects of parasitism are likely to be most severe, results of deworming studies indicate mostly that treating cattle will be economically beneficial. Weight gain responses to deworming typically range from 0.1 to 0.2 kg/day, or about 10 to 20 kg over a 100-day growing period, with occasional observations of responses as high as 0.4 kg/day (Bransby, 1997). However, even with stockers, cases in which no response to deworming occurs are observed.

Benefits from deworming beef cows have been less consistent, and are well summarized by Reinemeyer (1992):

- "Most beef cows are infected by small numbers of worms that do not cause obvious signs of disease.
- Beef cows are not a major source of parasitic infection for their calves.
- In numerous studies, anthelmintic treatment of beef cows has been reported to increase weaning weights of calves and conception rates of cows.
- Performance parameters of treated cows and control cows were not significantly different in most deworming trials, and many studies had flawed experimental designs.
- The parasitologic necessity and economic justification for anthelmintic treatment of beef cows remain controversial."

CONTROL METHODS

In general, the strategy to control effects of trichostrongylid parasites best is to limit accumulation of large numbers of infective larvae on pasture, primarily by reducing contamination of the environment with nematode eggs (Williams and Knox, 1976). Reduced contamination of the environment can be achieved by suppressive treatment, which entails treating cattle frequently to keep worm egg production at virtually zero. An alternative option is integrated treatment, which combines drug administration with management practices, such as movement of cattle to less contaminated pastures. Finally, strategic treatment provides long-term protection from reinfection by synchronizing anthelmintic treatment with climatic changes that result in natural decreases in larval contamination of pastures.

Suppressive treatment is the least desirable option, because it is expensive and may result in development of resistance of parasites to anthelmintics. Unfortunately, anthelmintic treatment of cattle is often administered only when animals have been mustered for other management procedures. This often does not optimize timing of treatment and reduces the risk of reinfection from contaminated pastures, and may be economically inefficient (Reinemeyer, 1994).

Many approved compounds and formulations are effective against adult trichostrongylids, and it is simple to treat cattle with clinical disease and to temporarily disrupt environmental contamination from egg production. Certain drugs or regimens are effective against larvae in the stage of arrested development in the host, and can be used strategically to postpone the onset of environmental contamination subsequent o larval maturation. Sustained release formulations are a recent advance that can provide prolonged prevention of environmental contamination.

Besides use of chemicals, biological control methods could also be used to reduce parasite burdens on grasslands. Perhaps the best known of these is to increase the number and diversity of dung beetle populations: by burying manure which contains worm eggs these insects reduce the number of L3 infective larvae in the pasture. For example, Fincher (1975) showed that tracer calves grazing a pasture with a reduced dung beetle population (achieved by screening and trapping), acquired four times more worms than calves on pastures with an increased dung beetle population, and similar results have been shown by others (Bergstrom et al., 1976; Bryan 1973; Bryan, 1976; Grenvold et al., 1992). Unfortunately, increased use of pesticides seems to have devastated dung beetle populations in certain parts of the world. However, the relatively greater economic benefit from pesticide use, compared to elimination of beneficial organisms, seems to cause authorities to turn a blind eye to this negative side-effect. For example, in the USA, pesticides used for cotton production and use of anthelmintics could have eliminated most of the native dung beetle populations, and research on the use of dung beetles to control internal parasites in the USA has all but ceased. The logic behind this could be that pesticides for cotton and anthelmintics for cattle are of greater economic value to society than any benefits from dung beetles. Therefore, the strategy behind the USDA policy could be to prevent information on this reaching environmental activists, thus protecting pesticide and anthelmintic companies, and the perceived general economic interests of society at large. On the other hand, if use of pesticides which destroyed beneficial organisms like dung beetles were prohibited, there would be greater incentive for governments and industry to develop more environmentally friendly procedures for controlling pests. In fact, the USA government is continually increasing emphasis on Integrated Pest Management (IPM).

INTERACTIONS BETWEEN WORMS AND GRAZING CONDITIONS

Factors such as stocking rate, method of grazing (rotation of livestock through several subdivisions, or continuous within a single fenced area), supplemental feeding, and pasture species can strongly affect the weight gain of beef cattle. Effects of these factors can be both direct, through nutrition, and indirect, through their influence on parasitism. However, reports in the literature on the interaction between parasitism and pasture conditions are often conflicting or inconclusive. Therefore, to identify general principles is very difficult.

Stocking rate and supplementation. Animal weight gain of dewormed cattle usually decreases with increased stocking rate because of a corresponding decrease in nutritional status (Hart, 1972; Jones and Sandland, 1974; Bransby et al., 1988). A review article by the American Association of Veterinary Parasitologists (1983) states that "... serious helminth parasite problems seldom occur when pastured cattle are on a good plane of nutrition", and "in the southeastern U.S., the well-known synergism of poor nutrition and parasitism becomes most prominent in winter months". Such statements seem to encompass a general principle which would have implications for many pasture-related factors as they influence animal weight gain. For example, it could be assumed that the principle implies that cattle weight gain response to deworming is likely to be greater at high stocking rates (a poor plane of nutrition) than at low stocking rates (a good plane of nutrition), or for supplemented cattle compared to unsupplemented cattle. However, most studies which have addressed these issues did not reveal such an interaction for animal production: several stocking rate studies have revealed similar weight gain responses to deworming across all stocking rates (Roe et al., 1959; Southcott et al., 1967; Brown et al., 1985; Kunkel and Murphy, 1988; Kee, 1994). Kee et al. (1994) also found that weight gain responses for supplemented and non-supplemented animals were similar across several stocking rates.

Method of grazing. Sometimes claims are made that rotational grazing reduces the need for treating livestock for worms, relative to continuous grazing. This suggestion originates largely from the notion that temporary removal of animals from a grazing area for several weeks will break the life cycle of parasites (Ciordia et al., 1964). However, limited research conducted on this issue does not consistently support the theory. Ciordia et al. (1964) and Kunkel and Murphy (1988) actually showed increased parasite loads for rotational grazing compared to continuous grazing. This was reflected in reduced weight gain in animals under rotational grazing in the study by Ciordia et al., but not that of Kunkel and Murphy. Other studies (Roe et al., 1959; Mooso et al., 1989) showed no difference in parasitism or weight gain between rotational and continuous grazing, while studies in Cuba showed an advantage for rotational grazing (Mendez et al., 1983; Saaverda et al., 1983a, b). Due to confounding across these studies, explanation of these inconsistencies is not possible.

Several observations suggest that rotational grazing without chemotherapy often will not improve parasite control relative to continuous grazing. First, many parasites can survive in a pasture or in the inhibited phase for 3 to 5 months. Secondly, larvae can feasibly be washed from one subdivision in a rotational grazing scheme to another by runoff from heavy rain. Thirdly, high stocking densities associated with rotational grazing are likely to cause animals to graze closer to the ground and to manure (where L3 larvae are concentrated), and to spread manure containing eggs more with their hooves than under continuous grazing. Finally, conditions in the pasture canopy between grazing periods in a rotational scheme are probably more favorable (more moist and not too hot) for parasite survival than under continuous grazing. All these observations suggest that in some cases reinfection with worms could be even higher under rotational grazing than under continuous grazing. Therefore, cattle in rotational grazing schemes should probably be treated for worms at least as frequently as those under continuous grazing to ensure similar levels of worm control.

Pasture species. Because pasture canopy environment is likely to vary among forage species, larval survival and animal infection is also likely to be influenced by different forages. However, very little research has been conducted to determine these effects. Bransby (1997) recently showed that weight gain of cattle grazing tall fescue (*Festuca arundinaceae*) infected with the endophtic fungus, *Neotyphodium coenophialum*, which causes fescue toxicity, increased considerably more when animals were dewormed with ivermectin that cattle grazing fungus-free fescue pastures. This suggests that there could be an interaction between fescue toxicity and the effect of worms on cattle or perhaps, different worm burdens in infected and fungus-free fescue. However, more definitive experiments are needed to verify this possibility.

FUTURE RESEARCH

Trends in the literature suggest that research on parasitism in livestock is decreasing at public institutions such as universities, and in government agencies. The reason for this is not entirely clear, but the consequences could be serious. For example, the focus of research could tend strongly toward development and testing of new drugs by industry, with little attention on potential negative effects of these drugs, and at the expense of urgently needed research on options such as biological control and the possibility of vaccination as a preventive measure.

Without questions, a greater understanding of the ecology of parasites in grazed ecosystems is badly needed. The inconsistency of results from deworming studies with cows and calves makes this a high priority for future research. However, in order to be of value to livestock producers results of such studies need to measure effects of worms on reproductive performance as well as weight gain. Clearly, this requires large numbers of animals and large areas of land which, in turn, make experiments costly and both logistics and control of experimental error difficult. Despite these problems, it would be extremely useful if conditions under which no production responses to deworming cows and calves occur could be identified and explained.

In a general context, further work is needed to better understand the life cycle of parasites, and how this is affected by environmental and management factors. Without this fundamental research the livestock industry will remain heavily dependent on chemotherapy for parasite control, and the potential of developing methods of biological control or management options to reduce parasites will remain largely unexplored. The breadth of knowledge and expertise required to do such studies effectively is substantial. Therefore, teams of scientists, including specialists such as parasitologists, animal physiologists and grassland ecologists are needed.

Research methodology seems to be another major constraint to progress in the field of parasitism in grazed ecosystems. In particular, current sampling and laboratory procedures for quantifying parasite loads in both animals and pastures have severe limitations and often result in high experimental error and the associated difficulty in identifying statistical differences among treatments. Consequently, improved experimental procedures should also be a high research priority.

CONCLUSIONS

To properly understand and manage grazing ecosystems, a knowledge of parasitism in grazing animals is necessary. Effects of GI parasites are greatest in beef cattle between the ages of 5 and 15 months. Cattle older than 18 months generally develop some immunity to parasites. Although parasite burden in animals increases with increased stocking rate, weight gain responses to deworming across several stocking rates have often been similar. Furthermore, greater weight gain responses to deworming have seldom been observed for grazing animals without supplementation compared to animals with supplementation. These results tend to refute the general notion that effects of parasites are seldom serious if grazing animals are on a good plane of nutrition.

Because some parasites can survive for extended periods, either in the fecal pat or in the animal, rotational grazing is not likely to eliminate parasites from a grazing ecosystem. Several factors suggest that the necessity for parasite control for cattle under rotational grazing would be at least equal to that for animals under continuous grazing.

Future research on parasitism in grazing animals would be improved if conducted by research teams instead of specialists in a given area. Priorities for such research should include more work on parasite life cycles ane ecology, reasons for inconsistency among experiments on deworming cows and calves, and improved experimental procedures.

REFERENCES

American Association of Veterinary Parasitologists. 1983. Research needs and priorities for ruminant internal parasites in the United States. Am. J. Vet. Res. **44**: 1836-1847.

Armour, J. 1970. Bovine ostertagiosis: A review. Vet. Res. **86**: 184-190.

Bergstrom, R.C., L.R. Maki and B.A. Werner. 1976. Small dung studies of beetle action on trichostrongylid eggs in sheep and cattle feces. Proc. Helminthol. Soc. Wash. **43**: 171-174.

Bransby, D.I. 1993. Effect of grazing management practices on parasite load and weight gain of beef cattle. Vet. Parasitol. **46**: 215-221.

Bransby, D.I. 1997. Steer weight gain responses to ivermectin when grazing fescue. Large Animal Practice **18(3)**: 16-19.

Bransby, D.I., B.E. Conrad, H.M. Dicks and J.W. Drane. 1988. Justification for grazing intensity experiments: Analyzing and interpreting data. J. Range Mgmt. **41**: 274-279.

Brown, T.H., G.E. Ford, D.W. Miller and I. Beveridge. 1985. Effect of anthelmintic dosing and stocking rate on the productivity of weaner sheep in a Mediterranean climate environment. Aust. J. Agric. Res. **36**: 845-855.

Bryan, R.P. 1973. The effects of dung beetle activity on the number of parasitic gastrointestinal helminth larvae recovered from pasture samples. Aust. J. Agric. Res. **24**: 161-168.

Bryan, R.P. 1976. The effect of the dung beetle *Onthophagus gazella*, on the ecology of the infective larvae of gastrointestinal nematodes of cattle. Aust. J. Agric. Res. **27**: 567-574.

Ciordia, H., W.E. Brizzell, D.M. Baird, H.C. McCampbell and P.E. White. 1964. Effect of rotational grazing systems on gastrointestinal nematodes in beef yearlings. Am. J. Vet. Res. **25**: 1473-1478.

Fincher, G.T. 1975. Effect of dung beetle activity on the number of nematode parasites acquired by grazing cattle. J. Parasitol. **61**: 759-762.

Grenvold, J., C. Summer, P. Holter and P. Nansen. 1992. Reduced splash dispersal of bovine parasitic nematodes from cow pats by the dung beetle *Diastellipalpus quinquedens*. J. Parasitol. **78**: 845-848.

Hart, R.H. 1972. Forage yield, stocking rate, and beef gains on pasture. Herb. Abstr. **42**: 345-353.

Jennings, F.W., J. Armour, D.D. Lawson and R. Roberts. 1966. Experimental *Ostertagia ostertagi* infections in calves: Studies with abomasal cannulas. Amer. J. Vet. Res. **27**: 1249-1257.

Johnstone, I.L. 1985. Dairy cattle and their worms. Anim. Nutr. And Health **40(3)**: 25-31.

Jones, R.J. and R.L. Sandland. 1974. The relation between animal gain and stocking rate. J. Agric. Sci. **83**: 606-611.

Kee, D.D. 1994. Steers and sward response to stocking rate, deworming, supplementation and stocking methods on bermuda and bahiagrass. PhD Diss. Auburn University, Auburn, AL.

Kunkel, J.R. and W.M. Murphy. 1988. Effect of stocking rate, grazing system and fenbendazole treatment on subclinical parasitism in dairy heifers. Am. J. Vet. Res. **49**: 724-727.

Levine, N.D. 1963. Weather, climate, and the bionomics of ruminant nematode larvae. Advances in Vet. Sci. **8**: 215.

Mendez, M., T. Orta, M. Fadrage, A. Delgado and A. Venereo. 1983. The influence of two rotational grazing systems on the parasitic infections of pastures. Helminth. Abstr. Ser. A. **52(8)**: 445.

Mooso, G.D., D.G. Morrison, C.C. Willis and J.E. Miller. 1989. Short duration grazing versus continuous grazing for stocker beef animals. LA Agric. **32(3)**: 8-10.

Myers, G.M. 1983. Internal parasites of food animals. Anim. Nutr. And Health **39(2)**: 34-44.

Reinemeyer, C.R. 1992. The effects of anthelmintic treatment of beef cows on parasitologic and performance parameters. Compendium on Continuing Education for the Practicing Veterinarian **14(5)**: 678-685.

Reinemeyer, C.R. 1994. Parasitism of dairy and beef cattle in the United States. J. Am. Vet. Med. Assoc. **205(5)**: 670-680.

Roe, R., W.H. Southcott and N.H. Turner. 1959. Grazing management of native pastures in the New England region of New South Wales. I. Pastures and sheep production with special reference to systems of grazing and internal parasites. Aust. J. Agric. Res. **10**: 530-534.

Saaverda, L., I. Ferber, J. Rodriquez and M. Alarcon. 1983a. Comparative study of gastrointestinal nematode infection in Holstein calves reared under linear and radial systems of pasture. Helminth. Abstr. Ser. A. **52(6)**: 329-330.

Saaverda, L., Rodriquex-Diego and J. Agarte. 1983b. Variations of the system of pasture rotation for the control of gastrointestinal nematodes in Holstein calves during the rainy season in Cuba. Helminth. Abstr. Ser. A. **52(12)**: 623.

Southcott, W.H., D.D. Heath and J.P. Langland. 1967. Relationship of nematode infestation to efficiency of wool production. J. Br. Grassl. Soc. **22**: 117-120.

Sykes, A.R. 1987. Endoparasites and herbivore nutrition. Pages 211-232 in J.B. Hacker and J.H. Ternouth, Ed. The nutrition of herbivores. Academic Press. Sydney, Australia.

Tindall, W. and C. Olentine. 1983. Parasites: Evaluating the problem. Anim. Nutr. and Health **39(2)**: 24-32.

Williams, J.C. and J.W. Knox. 1976. Effect of nematode parasite infection on the performance of stocker cattle at high stocking rates on 'Coastal' bermudagrass pastures. Amer. J. Vet. Res. **37**: 453-464.