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Impact of rotational grazing on management of gastrointestinal nematodes in weaned lambs

J.M. Burke [a,*], J.E. Miller [b], T.H. Terrill [c]

[a] Dale Bumpers Small Farms Research Center, USDA, ARS, Booneville, AR 72927, USA
[b] Department of Pathobiological Sciences, School of Veterinary Medicine and Departments of Animal Science and Veterinary Science, Louisiana State University, Baton Rouge, LA 70803, USA
[c] Fort Valley State University, Fort Valley, GA 31030, USA

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ABSTRACT

Gastrointestinal nematode (GIN) control for 'natural' or organic lamb production is needed, especially where *Haemonchus contortus* is prevalent. The objective was to determine the impact of rotational grazing on GIN infection of weaned lambs. In year 1, naturally infected Katahdin lambs (120 days of age) were randomly assigned to graze (1) continuous bermudagrass (CB; $n = 14$), (2) rotational bermudagrass moved every 3.5 days and returned to original plot 35 days later for three rotations (RB; $n = 14$), or (3) rotational bermudagrass rotated when forage height fell below 10 cm (RBH; $n = 7$) where first day of grazing = Day 0. In late summer, all lambs were supplemented with 500 g corn/SBM because of poor condition. The following year, similar animals were used and included the CB ($n = 18$) and the RB ($n = 36$) groups only. In both years, fecal egg counts (FECs) and blood packed cell volume (PCV) were determined every 7–14 days and body weight every 28 days. Individuals were dewormed with 0.5 g copper oxide wire particles (COWP) when FAMACHA score increased to 3 or more. Between 0 and 3 deworming treatments per lamb were necessary and there tended to be fewer RB than CB lambs dewormed by Day 84 for both years combined ($P < 0.001$). Worm free tracer lambs were introduced to CB ($n = 6$) and RB ($n = 8$) plots following the last rotation during the first year to determine worm burdens after 20 days of grazing. Abomasal worm burden tended to be greater in RB than CB or RBH tracer lambs ($P < 0.10$), but intestinal worm numbers were similar. Differences may be due to differences in grazing patterns among groups. Body weight gains were similar between CB and RB groups. Economic value between the CB and RB lambs was similar based on number of lambs that could have been marketed as organic. For both years, lambs relied exclusively on COWP for GIN control with the exception of one lamb. In summary, while there was a reduced incidence of deworming in the RB compared with the CB group of lambs, estimated economic value of these systems was similar.

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1. Introduction

Production of small ruminants is an important industry in the southeastern US because of the abundance of forages. Organic small ruminant products can be sold for a premium due to consumer demand of natural products free of chemical or antibiotic residues and environmental sustainability (Robinson, 2004). However, organic lamb production in the southern US is limited because of the challenge of gastrointestinal nematode (GIN) control, particularly *Haemonchus contortus*, without chemical intervention. Accepted methods of control for *H. contortus* in organic production are good nutrition, rotational grazing, multi-species grazing, and use of resistant breeds

* Corresponding author. Tel.: +1 479 675 3834; fax: +1 479 675 2940.
E-mail address: joan.burke@ars.usda.gov (J.M. Burke).

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(NCAT, 2004). However, these methods may not always be practical. For example, good nutrition helps decrease the level of GIN infection (Coop and Holmes, 1996; Coop and Kyriazakis, 1999), so use of supplements is often necessary in animals grazing poorer quality forages or during seasons when forage growth is limited. However, organic supplements can be costly and difficult to find in remote areas. Also, producers limited by handling facilities may not be able to accommodate larger livestock for multi-species grazing, and even the most resistant breeds may be challenged by GIN during production phases such as lambing/kidding, lactation, and growth. Finally, rotational grazing management promotes shorter forage (not overgrazed) that is more vegetative and nutritious, but the lower forage canopy exposes the animal to more infectious larvae. Because *H. contortus* can live on pastures for several weeks (Donald, 1968), rotational grazing may not be adequate for control. Studies that have examined rotational grazing strategies for sheep and goats have practiced strategic deworming where animals were dewormed at the start of the study (Barger et al., 1994; Chandrawathani et al., 2004).

Emergency treatment with ivermectin to preserve animal welfare is acceptable, but any dewormed livestock cannot be sold as organic under the U.S. National Organic Program standards (2007). To complicate the issue, there is increasing resistance of worms to all classes of dewormers (Miller and Craig, 1996; Zajac and Gipson, 2000; Terrill et al., 2001; Mortensen et al., 2003) so that treatment is often ineffective. In Georgia, over 90% of goat farms had high levels of GIN resistance to ivermectin (Terrill et al., 2001). Therefore, more sustainable options of control of *H. contortus* are necessary for the viability of organic and conventional production of small ruminants in the southeastern US and other regions of the US and world.

The objective of this research was to determine the influence of pasture management on GIN infection, number of anthelmintic treatments needed during the study, and weight gain in weaned Katahdin lambs.

2. Materials and methods

2.1. Animals and procedures

The USDA, ARS Dale Bumpers Small Farms Research Station Institutional Animal Care and Use Committee (Booneville, AR, USA) reviewed and approved all husbandry practices and experimental procedures used in this study.

Naturally infected Katahdin lambs of mixed gender were weaned May 1, 2006 (90 days of age), blocked by gender and sire, and randomly assigned to graze (1) continuous bermudagrass (CB; *Cynodon dactylon*; $n = 14$ in two replicates), (2) rotational bermudagrass moved every 3.5 days through 10 sub-plots and returned to original plot 35 days later for three rotations (RB; $n = 14$ in two replicates), or (3) rotational bermudagrass rotated among 10 sub-plots when forage height fell below 10 cm (RBH; $n = 7$). All five plots were 0.4 ha and had not been grazed 6 months before the study was initiated. Lambs were supplemented with 500 g corn/soybean meal per head daily during the period of the last rotation because of declining body condition at that time. Lambs were offered free choice trace mineralized salt (Land O'Lakes Sheep and Goat Mineral, Shoreview, MN, USA) and water throughout the study period.

For the first year, tracer lambs were used to assess differential level of pasture infectivity among the CB, RB, and RBH grazing treatments. These lambs were dewormed to remove existing nematode infections. Fourteen days post-treatment fecal egg counts (FEC; modified McMaster technique with a sensitivity of 50 eggs/g; Whitlock, 1948) were <100 eggs/g. Tracers then were placed on CB plots ($n = 6$ in two replicates) with experimental animals or RB ($n = 8$ in two replicates) and RBH ($n = 4$) plots that had been grazed for three rotations on the 18th day of the third rotation (Day 88). After 20 days of grazing, tracers were removed and maintained on concrete for 21 days to allow infections to mature and to prevent further infection. The tracers were then humanely slaughtered for necropsy and adult worms in the abomasum and small and large intestine recovered and counted.

In the second year, starting in mid-May 2007, lambs similar to those described for the first year were randomly assigned to two replicates each of (1) CB, (2) RB in four subsections moved every 7 days and returned to original plot 28 days later for three rotations (84 days), and (3) RB as described, but treated with 0.5 g copper oxide wire particles (COWP; Copasure; Animax Veterinary Technology, UK) on Day 0 ($n = 18$/forage treatment in two replicates each). A shorter rotation period with fewer plots would require less labor, but may expose lambs to more larvae. No supplement was fed in 2007.

For both years, FAMACHA scores (on a scale of 1–5 with 1 = red or healthy and 5 = severely anemic) were recorded by examining ocular mucous membranes (Kaplan et al., 2004). Feces were collected directly from the rectum to determine FEC and blood from the jugular vein was collected to determine blood packed cell volume (PCV) every 7 days during the first year and every 7 days if FAMACHA was 3 or greater in a majority of lambs (between May 15 and June 13) or every 14 days (after June 13) during the second year. Body weight was determined every 28 days. Lambs were administered 0.5 g COWP in a gelatin capsule (Burke et al., 2004; Burke and Miller, 2006) if FAMACHA score was 3 or above (Burke et al., 2007a,b). If lambs did not respond to COWP with a reduction in FEC then moxidectin (0.2 mg/kg oral drench; Cydectin®, Fort Dodge Animal Health, Fort Dodge, IA, USA) was administered.

2.2. Pastures and forages

Forage height for the RBH plot in 2006 was measured every 7 days with a disk meter, using 15 measurements per plot. Forage height was determined on final day of grazing for other plots. All plots were mowed to 25 cm in mid-June 2006 so that forages remained vegetative. The bermudagrass plots were primarily bermudagrass with some johnsongrass (*Sorghum halepense*), barnyard grass (*Echinochloa crus-galli*) and other forbs. None of the plots were fertilized to simulate organic principles. Rainfall was recorded during both years of the experiment (Fig. 1).

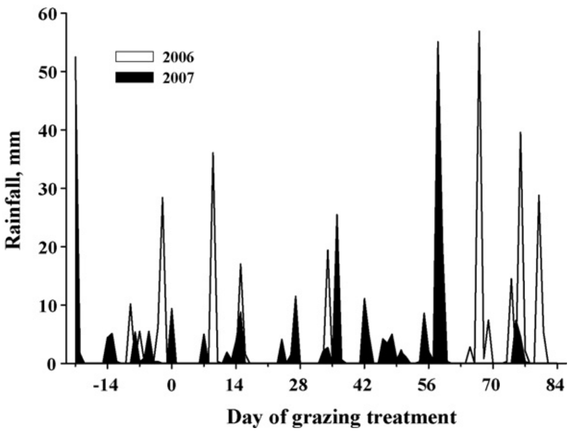

Fig. 1. Rainfall data collected at the ARS station between Days −21 and 84 of grazing treatment are represented for 2006 (white area under curve) and 2007 (black area under curve).

2.3. Economics

Estimation of economic value between CB and RB grazing systems considered whether an animal required deworming and body weight on Day 84. At the time of this study, estimated cost of COWP was $0.10/dose. It was assumed that the US market value of conventional lambs was $2.20/kg live body weight and lambs marketed in the organic market captured a premium of $6.61/kg. Economic value between the CB and RB grazing system plots was considered to be similar, with the exception of required portable fencing and time required to move fencing twice weekly. Because of the nominal cost of COWP, cost of required deworming was ignored. Estimated economic value between grazing systems ignored labor and fencing and considered only the potential to market lambs conventionally or organically.

2.4. Statistical analysis

Data were analyzed using the mixed models procedure of SAS (1996). The mathematical model for FEC, PCV, and body weight included grazing system, gender, sire (two of the same sires were used each year), day, the interactions, and a repeated statement for day of measurement. Means between replicates (CB and RB) within a grazing system were similar and were pooled. The CB and RB systems for 2006 and 2007 were examined in the same model and included year as a variable. Values determined every 14 days were used. The combined data set included the equivalent of three rotations used in 2007; however, the rotation period was slightly longer during the first year extending to Day 105. Differences between years would determine a difference in the RB grazing system between the 28- and 35-day rotation period. The COWP administered to the second RB group did not lead to a reduction in FEC, so data from these four replicates were considered as one forage treatment (RB). The failed treatment was not deemed a deworming event. Contrasts were determined using the PDIFF option (all probability values for the hypothesis) in SAS when probability was <0.05%. The FEC data were log transformed: ln(FEC + 1). Statistical inferences were made on transformed data and untransformed least squares means were presented. General linear models and chi-squared analyses using Proc CATMOD in SAS were used to determine differences between grazing systems for number of dewormings required per system and percentage of the group that remained untreated.

The general linear models procedure was used to examine differences between average daily gain among grazing systems and included treatment, gender, sire, and year (CB vs. RB). This same model was used to compare abomasal and intestinal worm numbers in tracer lambs and included only grazing system as a variable. Worm numbers were log transformed to determine statistical differences between systems and untransformed means are presented. The general linear models procedure was used to examine differences in forage height among grazing systems and means were separated using PDIFF.

In 2006, one lamb remained anemic after administration of COWP and was treated with moxidectin. In 2007, two CB lambs died from undetermined causes within 14 days of initiating grazing treatment, one RB lamb died from apparent haemonchosis by Day 14 and one RB lamb became lodged in a fence, became sick and was removed from the study by Day 14. Available data for all original study animals were included in the analyses. St. Croix lambs replaced dead/removed lambs to maintain stocking rates, but no data was collected from the replacement lambs.

A general linear models procedure (SAS) was used to determine differences in economic value between CB and RB groups of lambs after 84 days of grazing. Sire, gender, and year were included in the model.

3. Results

In 2006, the number of dewormings (0–3 treatments/lamb) required during the 105-day grazing period was similar among grazing groups (CB, 1.60 ± 0.28; RB, 1.23 ± 0.27; RBH, 1.10 ± 0.41). All but one lamb responded to COWP with a reduction in FEC. At least one lamb per group was dewormed on Day 0 and percentage dewormed per group for each sampling day ranged from 0 to 35% (Fig. 2A). FEC peaked between Days 0 and 14 (day, $P < 0.001$; Fig. 2B). The PCV of RBH lambs was lowest between Days 35 and 49 and fluctuated according to incidence of deworming (grazing system × day, $P < 0.001$; Fig. 2C).

The only worm species found in the abomasum of tracer lambs was *H. contortus*. Abomasal worm burden tended to be greater in RB than CB or RBH tracer lambs (8537 > 2925 or 2468 worms/100 ml, respectively; $P < 0.10$). *Trichostrongylus* (CB, 875; RB, 1525; RBH, 912 worms/100 ml) and *Nematodirus* (CB, 208; RB, 225; RBH, 150 worms/100 ml) were found in the small intestine and numbers were not different among treatment groups. Only one lamb in the CB grazing system had *Trichuris*.

When combining years for the CB and RB forage systems, number of required deworming was less for the RB than CB groups ($0.96 \pm 0.14 < 1.65 \pm 0.17$ treatments/lamb; $P < 0.02$) and no year effect was detected. However, percentage of lambs that remained untreated was similar

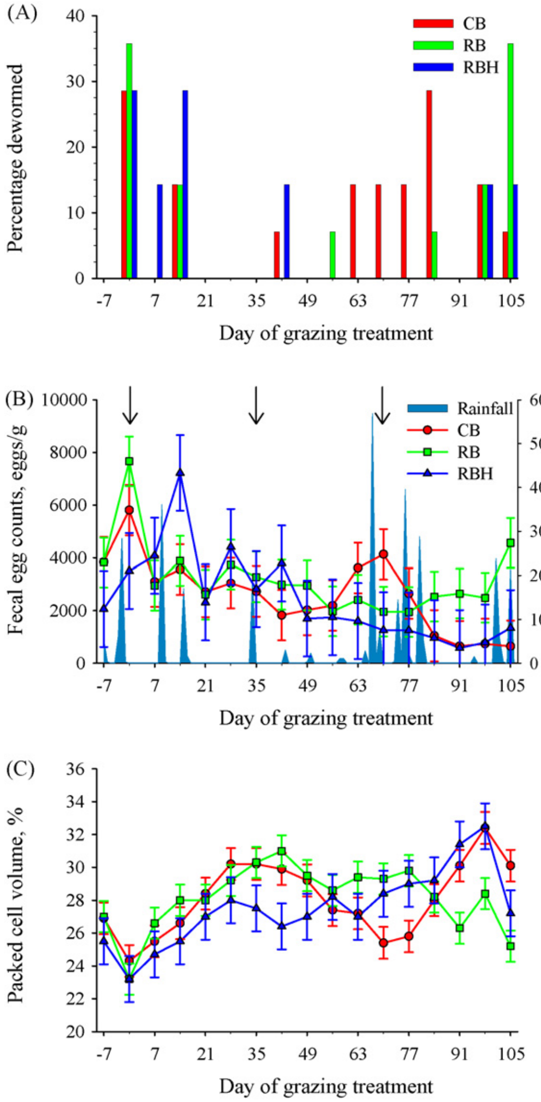

Fig. 2. Actual percentage of lambs within each grazing system, continuous bermudagrass (CB; red circles; $n = 14$), rotational bermudagrass (RB; green squares; $n = 14$), or RB rotated according to height of forage (RBH; blue triangles; $n = 7$), dewormed each week is presented in graph A. Effect of the grazing systems on fecal egg counts (FEC; B) and packed cell volume (PCV; C) in Katahdin lambs during summer 2006. Rainfall (blue area plot) is presented in right axis of Graph B. Arrows indicate day that the RH groups started grazing the first plot of the rotation. Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

(CB, 21.9% and RB, 30.0%). Mean FEC was greater in 2006 than 2007 during the first rotation period (grazing system × day × year, $P < 0.02$; Fig. 3A). By Day 84, FEC for the CB group was similar between years, but FEC for the RB group was greater in 2006 than 2007 ($P < 0.05$). Mean PCV was greater during the first 14 days of grazing in 2007 than 2006 for both grazing system groups and similar between Days 28 and 84 between years (grazing system × day × year, $P < 0.001$; Fig. 3B). Also, PCV for the RB group was greater

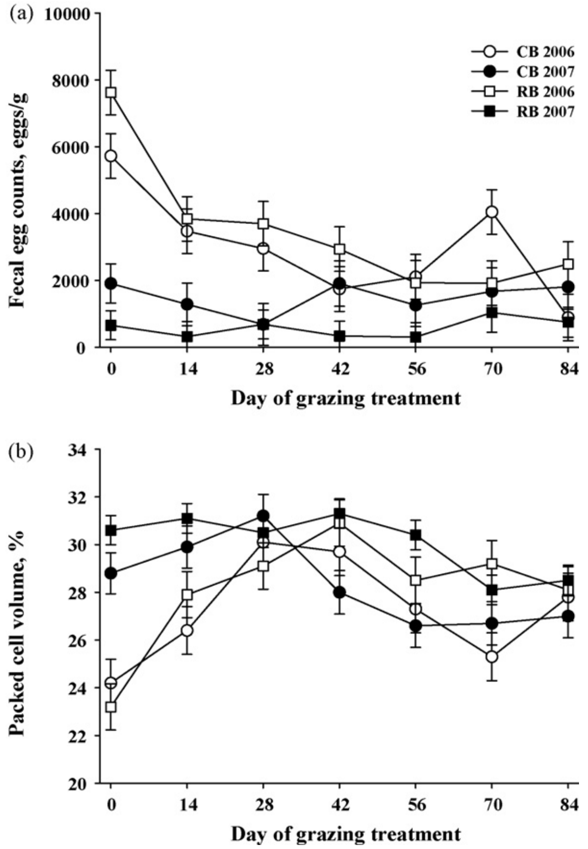

Fig. 3. Effect of the grazing systems, continuous bermudagrass (CB; circles; $n = 14$ in 2006; $n = 18$ in 2007) or rotational bermudagrass (RB; squares; $n = 14$ in 2006; $n = 36$ in 2007) on fecal egg counts (FEC; A) and packed cell volume (PCV; B) in Katahdin lambs during summer 2006 (open symbols) and 2007 (closed symbols). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

than the CB group on Day 70 in 2006 and on Days 42 and 56 in 2007 ($P < 0.05$).

Two sires produced lambs for both years of this study. Lambs from one sire required more deworming (2006: $1.79 \pm 0.20 > 0.86 \pm 0.20$ treatments/lamb; $P < 0.001$), tended to have greater FEC ($3618 > 1808$ eggs/g; $P < 0.08$), and had lower PCV ($24.8 \pm 0.51 < 29.3 \pm 0.42\%$; $P < 0.001$). However, weight gains were similar between sire groups.

In 2006, the RBH lambs gained no weight during the first 28 days and body weight was less than that of other groups after Day 0 (grazing treatment × day, $P < 0.001$; Fig. 4). No weight gains were apparent between Days 56 and 84 for all groups. When combining years, RB lambs in 2007 grew more slowly during the first 28 days than other groups in either year, but weights of all groups were similar by Day 84 (grazing system × day × year, $P < 0.001$; Fig. 5).

After lambs were removed from plots in 2006, forage height was greater in the RB than CB or RBH plots ($18.93 \pm 1.18 > 13.45 \pm 0.83$ or 12.80 ± 1.67 cm, respectively; $P < 0.001$).

The economic value of lambs between the CB and RB grazing systems was similar (CB, \$114.81 ± 14.42; RB,

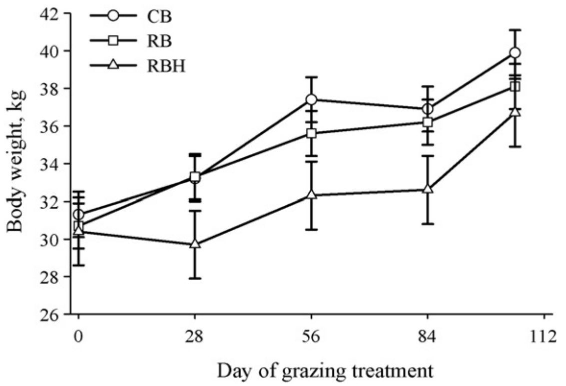

Fig. 4. Effect of the grazing systems, continuous bermudagrass (CB; circles; $n = 14$), rotational bermudagrass (RB; squares; $n = 14$), or RB rotated according to height of forage (RBH; triangles; $n = 7$) on least squares means and standard errors of body weight in Katahdin lambs during summer 2006.

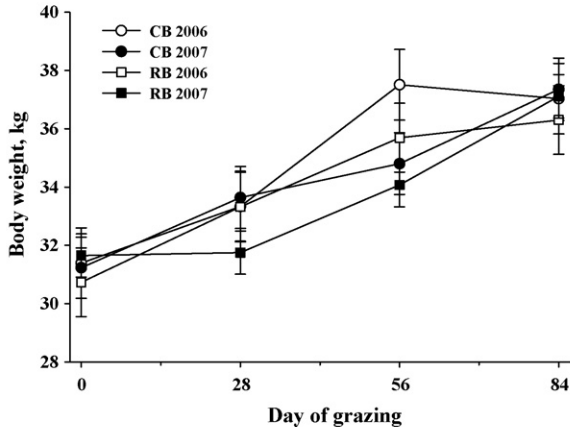

Fig. 5. Effect of the grazing systems, continuous bermudagrass (CB; circles; $n = 14$ in 2006; $n = 18$ in 2007) or rotational bermudagrass (RB; squares; $n = 14$ in 2006; $n = 36$ in 2007) on least squares means and standard errors of body weight in Katahdin lambs during summer of 2006 and 2007.

\$129.57 ± 11.78/lamb). There tended to be a difference between sire groups (\$104.17 ± 14.58/lamb vs. \$140.22 ± 11.76/lamb; $P < 0.06$), but values between years were similar.

4. Discussion

In both years there were fewer occurrences of deworming in lambs from the RB grazing strategy compared with lambs from the CB group. However, percentage of lambs that remained untreated between the two groups was similar. This means that a similar number of lambs could have been marketed as organic based on number of lambs that did not require anthelmintic. Or, if COWP were to be allowed by the US National Organic Program (2007) all but one lamb could have been marketed as organic lamb. In addition, lamb losses were similar between grazing strategies in 2007 and totalled 7.4%, while no lambs died in 2006. There were differences in number of lambs that required deworming between sires, suggesting a greater resistance or resilience to GIN in those not dewormed. This led to a tendency for differences in economic value between sire groups.

The decision to deworm was based on the FAMACHA system using the most liberal criteria of treating scores of 3 or greater (Kaplan et al., 2004; Burke et al., 2007a,b). Susceptibility to GIN increases post-weaning, especially when rainfall and moisture on pastures is adequate for larval survival as occurs in the southeastern US (Burke and Miller, 2006). Katahdin lambs are somewhat more tolerant to GIN than other breeds of sheep, but remain susceptible for several weeks after weaning (Burke and Miller, 2004). If a more conservative approach had been taken for treatment of GIN more lambs would have remained untreated and been available for the organic market; however, more losses to haemonchosis could have occurred. Estimated actual need for deworming based on PCV approaching 20% or less and a FEC >5000 eggs/g was necessary in <9% of RB lambs and <23% of CB lambs in 2007 and approximately 50% in both groups in 2006 (data not shown). Genetics were similar between years so that moisture on pasture could have accounted for differences between years.

Weight gains were similar between the CB and RB grazing systems with the exception of a lag period during the first 28 days for the RB group in 2007. Forage availability was never limiting between these two groups, and forage quality between the two systems was likely similar. Quality of warm season grasses typically wane by mid- to late-summer (Ball et al., 1996) and cannot meet nutritional demands of growing lambs (NRC, 2007). Because body weights were similar after 84 days of grazing and percentage of lambs that remained untreated was also similar, economic value between the CB and RB grazing systems did not differ. However, there was more forage mass after three rotations on the RB system than the CB system determined in 2006, but quality was low based on poor weight gains.

The RBH group of lambs likely did not gain well because lambs were forced to consume lower quality forage before moving to the next plot in sequence. Required deworming was similar to the RB group. Both the RB and RBH groups may have been exposed to fewer larvae than the CB group as those lambs may have concentrated their time near the water trough or bedded down in the same area nightly, picking up more larvae from these short grazed areas. It is not clear why there would be more abomasal worms in the RB compared to RBH or CB tracer lambs, other than a difference in susceptibility due to genetics among this small group of lambs.

FEC and PCV data are difficult to interpret in this study because individual lambs were dewormed as needed. Generalizations can be made on the intensity of GIN infection early in 2006 based on overall high FEC, but otherwise there are fluctuations in FEC and PCV among grazing management groups dependent on number of animals dewormed per sampling period. Others that have examined rotational grazing management in sheep or goats have strategically dewormed grazing groups and began studies with low FEC (Barger et al., 1994; Chandrawathani et al., 2004). This is the first report on grazing strategies for lambs that had not all been dewormed and that examined number of deworming treatments per group based on FAMACHA.

In summary, managing a rotational plot based on forage height could lead to poor weight gains if animals are forced to graze poorer quality forages. Weight gains were similar between CB and RB groups of lambs, but CB lambs required more deworming. The economic value between the CB and RB management systems was similar under the conditions of this study, but somewhat greater in lambs from the resistant/resilient sire. Further work on rotational grazing systems with higher forage quality is needed.

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