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# Relative resistance of Dorper crossbred ewes to gastrointestinal nematode infection compared with St. Croix and Katahdin ewes in the southeastern United States

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## Abstract

A study was conducted to evaluate relative resistance of Dorper crossbred (DO), Katahdin (KA), St. Croix (SC), and Hampshire (HA) ewes to natural and experimental gastro-intestinal (GI) nematode infection over a 20-month period. The objective of Experiment 1 was to evaluate breeds for resistance to infection acquired naturally from mixed grass pastures. In Year 1 (May–December 2000) de-worming of ewes occurred during wet, hot conditions in July and during late pregnancy in December. In Year 2 (January–December 2001), ewes were de-wormed after fecal egg count (FEC) for a breed group rose above 1000 eggs per gram (epg) or after blood packed cell volume (PCV) of an individual ewe fell below 20. FEC was determined every 28 days and PCV every 14–28 days. In both the years, ewes were pastured together, except during the 28-days breeding periods, on tall fescue, bermudagrass, or ryegrass, and rotated among pastures dependent on forage availability. Ewes were in good or excellent condition (body condition score of 3–4 out of 5) throughout the study. The objective of Experiment 2 was to evaluate the breeds for relative resistance to an experimental infection with *Haemonchus contortus* infective larvae. Both PCV and FEC were determined every 7 days from 14 to 42 days after inoculation with 30,000 infective larvae per ewe. In Experiment 1, Year 1, FEC was slightly greater and PCV was lower from July to September in DO ewes (breed  $\times$  time,  $P < 0.001$ ). In Year 2, de-worming occurred 14 days later in DO ewes compared with other breed types. Otherwise PCV and FEC were similar among the hair breeds and higher and lower, respectively, compared with HA ewes (breed  $\times$  time,  $P < 0.001$ ). In Experiment 2,

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FEC and PCV were similar among hair breeds; FEC was lower and PCV higher in hair breeds compared with that of HA ewes ( $P < 0.01$ ). Relative resistance of mature Dorper crossbred ewes was comparable to that of Katahdin and St. Croix ewes and superior to that of Hampshire ewes. Published by Elsevier Science B.V.

*Keywords:* Hair breeds; Nematode resistance; Sheep

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## 1. Introduction

Hair sheep fit well into small- to mid-size sustainable production systems in the southeastern US because they do not require shearing, present a means of forage management, may be tolerant to the harsh summer climate, and may be more resistant to gastro-intestinal (GI) nematode parasite infection than most wool breeds (Courtney et al., 1985; Zajac et al., 1990; Gamble and Zajac, 1992; Wildeus, 1997). Hair sheep in the US include St. Croix (SC), Katahdin (KA), and Dorper (DO) breeds. St. Croix sheep were imported to the mainland US from the Virgin Islands in 1960. The Katahdin breed was developed in Maine in the 1950s from St. Croix crossed with a variety of wool sheep, including Suffolk and Wiltshire Horn. The Dorper breed was introduced to the US in 1995 from South Africa. The Dorper originated from crosses of Dorset Horn and Blackhead Persian.

Resistance to GI nematode infection has been documented in St. Croix (Courtney et al., 1985; Zajac et al., 1990; Gamble and Zajac, 1992) and Katahdin sheep (Presson, 1986). The Dorper breed has not been evaluated for parasite resistance under southeastern US conditions compared with other hair breeds. Therefore, the objective of the current study was to evaluate Dorper crossbred ewes, compared with St. Croix, Katahdin, and Hampshire (HA) ewes for indications of relative resistance to GI nematode infection under natural grazing conditions and under an experimental infection with *Haemonchus contortus*. The Hampshire breed has been determined to be susceptible to infection (Preston and Allonby, 1979).

## 2. Materials and methods

All experimental procedures were reviewed and accepted by the Agricultural Research Service Animal Care and Use Committee in accordance with the NIH guide for the Care and Use of Laboratory Animals. Pain and stress to animals was minimized throughout the experimental period.

### 2.1. Experiment 1

The objective of Experiment 1 was to evaluate breed types for relative resistance to nematode infection under natural pasture grazing conditions. Year 1 was considered from May to December 2000 and Year 2 was considered from January to December 2001. In both the years, ewes had access to 27 ha of grass pastures of either tall fescue, bermudagrass, or ryegrass, with the exception of not more than 30 days during lambing in which they were supplemented with bermudagrass hay and a mixed ration. Ewes were rotated among

Table 1

Numbers of Dorper crossbred (DO), Hampshire (HA), Katahdin (KA), and St. Croix (SC) ewes used in Experiment 1

	Year 1 (2000)		Year 2 (2001)	
	May–August	September–December	January–April	May–December
DO, yearling	13	13	5	13
DO, 2–5 year	0	7	12	7
HA, yearling	0	0	12	19
KA, yearling	20	19	10	10
KA, 2–5 year	0	0	1	14
SC, yearling	15	14	0	0
SC, 2–5 year	0	6	18	22

pastures dependent on forage availability. Average size of individual fenced pastures was 2.7 ha. Stocking rate of all pastures was approximately 5.5 ewes with lambs per hectare. Hampshire ewes used in this study were barren and did not lamb in autumn months. Previous exposure of these pastures with sheep dates back more than 10 years. Ewes were supplemented with a mixed ration (up to 1.5 kg per ewe of 42.3% alfalfa pellets, 34.6% cracked corn, 19.7% soybean meal, 44% and, 3.1% cane molasses, and 0.17% dicalcium phosphate) for approximately 30 days before and after lambing. From November 2000 to February 2001 ewes were supplemented with bermudagrass hay when forage was limiting. Supplementation was not necessary in fall 2001. Ewes had access to free choice of minerals.

Breeds used were Katahdin (KA), St. Croix (SC), Hampshire (HA; Year 2 only), and percentage Dorper (DO; Table 1). The Dorper crossbred ewes in Year 1 were Dorper × Romanov or Dorper × Romanov × St. Croix and, in Year 2 also included yearling 75% Dorper and 25% Romanov. Changes in animals during the study represented availability and culling for reproductive reasons after lambs were weaned. In addition, six ewes died during Years 1 and 2 for unknown reasons (three DO ewes and three SC ewes), and one KA ewe died from dystocia and another died after being lodged in a feeder. In Year 1, de-worming occurred during summer (July; Ivomec Sheep Drench<sup>®</sup>, 0.2 mg/kg) and winter (December; Cydectin<sup>®</sup>, 0.2 mg/kg), typical to past management for de-worming. In Year 2, de-worming (Cydectin<sup>®</sup>, 0.2 mg/kg) of individual ewes occurred when blood packed cell volume (PCV) was <20, or all ewes of a breed type were de-wormed when the average fecal egg count (FEC) was >1000 eggs per gram (epg). In Year 2, from October to December, FEC for breed types was allowed to peak to detect breed differences to a heavier challenge. For both the years, ewes were pastured as a single group except during a 30 day breeding period in May and September 2000, and May and August 2001, when they were grouped according to breed. During breeding, ewes were rotated approximately every 10 days among the four pastures being used so that each breed had access to similar quality forage and conditions during the 30-days period. Pregnant ewes were vaccinated against *Clostridium chauvoei*, *C. septicum*, *C. novyi* Type B, *C. haemolyticum*, *C. tetani*, and *C. perfringens* Types C and D (Covexin 8<sup>®</sup>) 14 days before lambing. Existence of a peri-parturient effect was examined for FEC and PCV determined within 30 days of lambing.

Body condition scores (BCS; 1 = emaciated; 5 = obese), body weight, and FEC were determined every 28 days and PCV determined every 14–28 days, depending on the level of infection. Individual FEC were determined by a modified McMaster's technique (Whitlock, 1948) with a sensitivity of 50 epg.

## 2.2. Experiment 2

The objective of Experiment 2 was to examine the relative resistance of hair breeds compared with HA ewes to an experimental infection of *H. contortus*. Breeds used were HA ( $n = 12$ ), 3/4 or 7/8 Dorper (DO;  $n = 11$ ), and KA ( $n = 8$ ) and all ewes were between 2 and 3 years of age. Ewes were housed on concrete with free choice access to bermudagrass hay, mineral mix, and supplemented with 115 g corn/soybean meal mix. Ewes were de-wormed (Tramisole soluble drench powder<sup>®</sup>; 8.0 mg/kg) and 6 days later FEC were determined to be  $\leq 50$  epg. Two weeks after de-worming (January 2002), ewes were challenged orally with 30,000 *H. contortus* infective larvae (L3). Initial and final body weight were determined along with FEC and PCV every 7 day until 6 weeks after inoculation.

## 2.3. Statistical analysis

Body weight (Experiment 2) was analyzed using the general linear model procedures of SAS (1996). FEC, PCV, and body weight (Experiment 1) were analyzed using the mixed procedure of SAS (1996). The mathematical model that was used to analyze PCV, FEC, body weight and BCS included breed with a repeated statement for date of collection (Littell et al., 1996). In Experiment 1, Years 1 and 2 were analyzed together. FEC was logarithm transformed using  $\log_{10}(\text{FEC} + 1)$  to stabilize the variance. Data are reported as back-transformed least squares means  $\pm$  S.E.M.

To test the peri-parturient effect on PCV and FEC (log transformed) determined within 30 days of lambing in fall of both the years, the discrete variable (whether ewes had lambed or not) was included in the mathematical model with breed and the interaction. Data (PCV, body weight, BCS, back-transformed FEC) are presented as least squares means  $\pm$  S.E.M. These means are corrected for variables in the model.

## 3. Results

### 3.1. Experiment 1

The PCV was somewhat lower and FEC greater in DO ewes during the warmer months (from July to September) in 2000 compared with the other hair breeds (breed  $\times$  time,  $P < 0.001$ ; Fig. 1). For most of Year 2, PCV was lower for the HA ewes compared with that of other breeds. Between September 2000 and July 2001, FEC were similar among breeds except for increased values in November and December in SC ewes. In July 2001, unadjusted mean FEC was  $>1000$  epg for SC, KA, and HA ewes, necessitating de-worming. De-worming occurred 2 weeks later for the DO breed. After October 2001, FEC increased

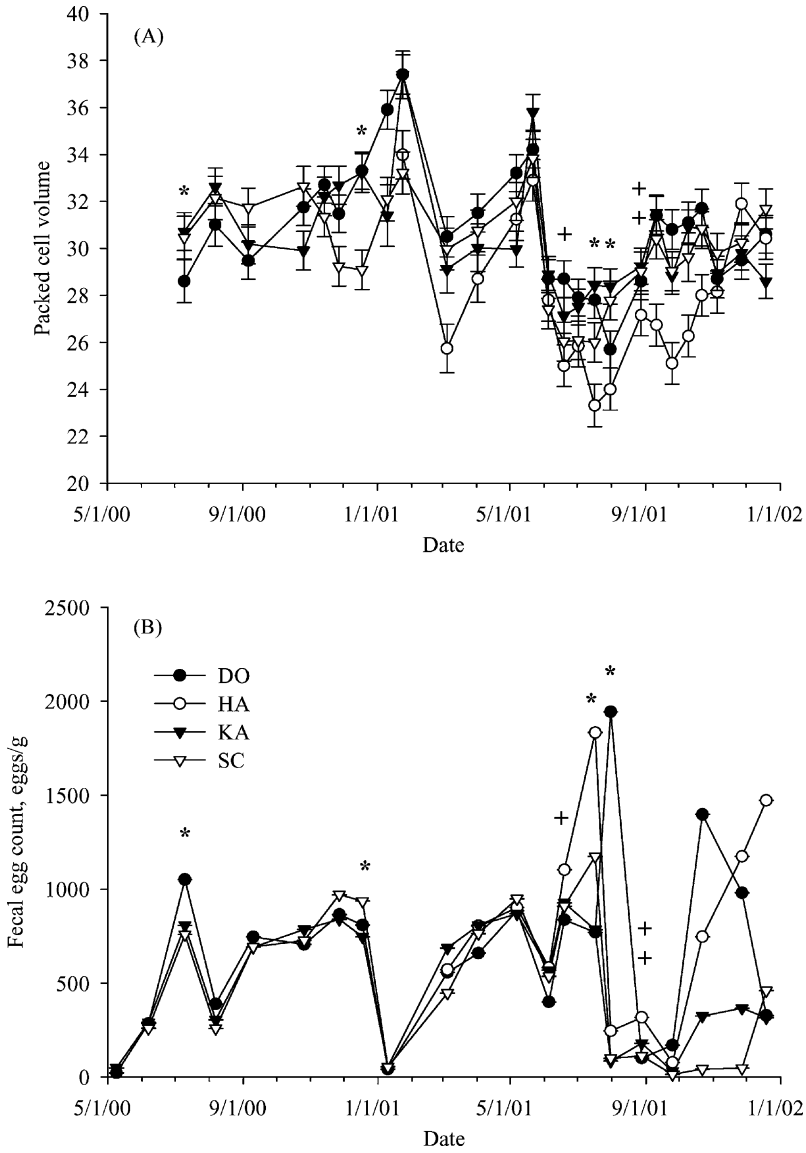


Fig. 1. Least squares means and standard errors of blood packed cell volume (A) and back-transformed fecal egg counts (B) in Dorper crossbred (DO; closed circle), Hampshire (HA; open circle), Katahdin (KA; closed triangle), and St. Croix ewes (SC; open triangle). A breed  $\times$  time interaction was detected for both variables ( $P < 0.001$ ). An asterisk indicates de-worming for a breed group and a plus sign indicates de-worming for individual ewes (HA6134, June 2001; HA6134, HA6161, September 2001).

Table 2

Least squares means and standard errors (number of ewes in parenthesis) of PCV and FEC within 30 days of lambing in Fall 2001, to discern peri-parturient effect among Dorper crossbred (DO), Katahdin (KA), and St. Croix (SC) ewes

	Ewes not lambing			Ewes lambing		
	DO (7)	KA (14)	SC (6)	DO (11)	KA (10)	SC (13)
PCV (late gestation/ early lactation) <sup>a</sup>	29.7 ± 1.3	29.1 ± 0.9	26.3 ± 1.4	33.0 ± 1.1	29.2 ± 1.1	30.2 ± 0.9
FEC (egg, late gestation/ early lactation) <sup>b</sup>	168.2 ± 1.6	15.3 ± 1.0	1.1 ± 1.6	169.6 ± 1.0	68.2 ± 1.1	35.6 ± 0.9
PCV (mid to late lactation) <sup>c</sup>	34.6 ± 1.4	33.3 ± 1.0	30.3 ± 1.5	31.2 ± 1.1	27.7 ± 1.2	31.2 ± 1.0
FEC (mid to late lactation) <sup>d</sup>	977.4 ± 1.2	269.3 ± 0.8	102.7 ± 1.5	1794.6 ± 0.9	426.1 ± 0.1	27.8 ± 0.9

<sup>a</sup> Peri-parturient effect,  $P < 0.02$ ; breed effect,  $P < 0.01$ .

<sup>b</sup> Breed,  $P < 0.002$ ; lactation,  $P < 0.03$ .

<sup>c</sup> Breed × lactation,  $P < 0.03$ .

<sup>d</sup> Breed effect,  $P < 0.001$ .

in DO and HA ewes compared with SC and KA ewes and was not associated with a decline in PCV. De-worming occurred twice for HA ewe (6134) and once for HA ewe (6161) in Year 2.

To discern peri-parturient effects, the PCV tended to decrease during early lactation ( $n = 22$ ) for all breeds compared with those ewes that had not lambed in fall 2000 ( $n = 37$ ;  $28.2 \pm 1.9$  versus  $31.8 \pm 1.0$ ;  $P < 0.10$ ), but there was no effect on FEC at that time (no lambs,  $741.7 \pm 0.4$  versus lambs,  $677.1 \pm 0.7$ ). In fall 2001, during late gestation/early lactation, PCV was similar or greater compared with non-pregnant ewes ( $P < 0.02$ ; Table 2). Twenty-eight days later (mid to late lactation), PCV was reduced in lactating DO and KA ewes, but not SC ewes (breed × lactation,  $P < 0.03$ ; Table 2). There was a slight increase in FEC measured during late gestation/early lactation compared with non-pregnant KA and SC ewes, but a decrease in that of DO ewes (breed,  $P < 0.002$ ; lactation,  $P < 0.03$ ). There was no peri-parturient effect on FEC 28-days later (mid to late lactation).

In Year 1, body weights of KA ewes were lower than those of SC and DO ewes. Body weight of DO ewes was greater than that of KA or SC ewes throughout the trial. After March, body weight of SC < KA < DO < HA ewes (breed × time,  $P < 0.001$ ; Fig. 2A). Body condition scores of KA ewes was always greater than that of SC ewes (breed × time,  $P < 0.001$ ; Fig. 2B). Body condition scores of DO and HA was more variable throughout the experiment.

### 3.2. Experiment 2

PCV was lower ( $P < 0.02$ ) in HA ewes compared with the hair breeds and FEC were similar among breeds (Fig. 3). PCV was similar between DO and KA ewes and there was little change over time. Hampshire ewes were heavier in body weight than the hair breeds (HA,  $73.1 \pm 3.2$  kg; DO,  $55.1 \pm 3.3$  kg; KA,  $59.9 \pm 3.9$  kg;  $P < 0.002$ ) and did not change 42 days after inoculation.

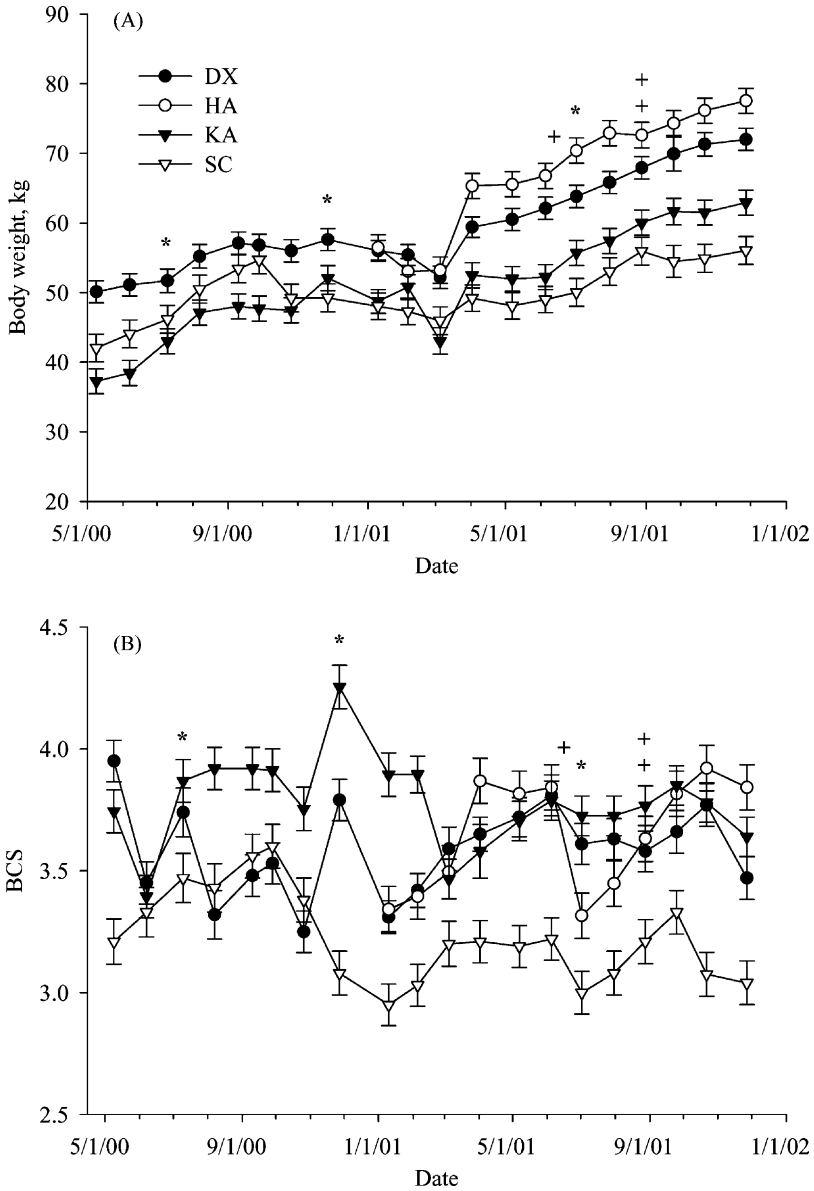


Fig. 2. Least squares means and standard errors of body weight (A) and body condition scores (BCS; B) of Dorper crossbred (DO; closed circle), Hampshire (HA; open circle), Katahdin (KA; closed triangle), and St. Croix ewes (SC; open triangle). A breed × time interaction was detected for both variables ( $P < 0.001$ ). An asterisk indicates de-worming for a breed group and a plus sign indicates de-worming for individual ewes (HA6134, June 2001; HA6134, HA6161, September 2001).

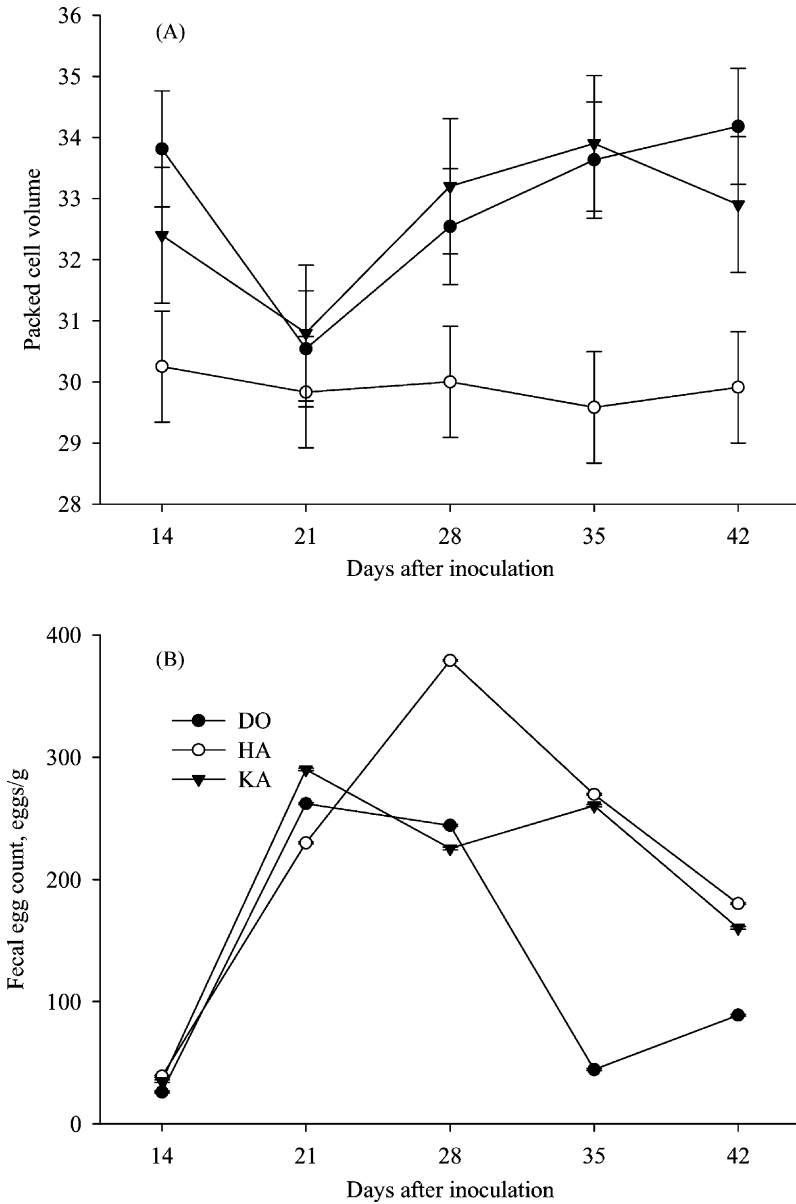


Fig. 3. Least squares means and standard errors of blood packed cell volume (A) and back-transformed fecal egg counts (B) in Dorper crossbred (DO; closed circle), Hampshire (HA; open circle), and Katahdin ewes (KS; closed triangle). A breed effect was detected for packed cell volume ( $P < 0.01$ ).

#### 4. Discussion

Determination of the resistance of breed types to GI nematode infections is imperative because of the crisis of the sheep and goat industry threatened by strains of GI nematodes that are resistant to available anthelmintics. The resistance of Caribbean derived breeds of sheep is well-recognized. Under South African conditions, the Dorper breed has been determined to be more resistant than the Hampshire sheep, but much less resistant than the Red Massai, an East African hair breed (Preston and Allonby, 1979). Similarly, in the current study, Dorper ewes were more resistant than the Hampshire ewes. In contrast, Dorper resistance was similar to that of the hair breeds during most of Experiment 1 and all of Experiment 2, although the challenge was low to moderate based on FEC response compared with the South African study (Preston and Allonby, 1979). Dorper ewes were slightly more susceptible to pasture infection in summer of 2000 compared with the other hair breeds. This could be because the immune response to GI nematode infection may have been delayed and became functional as the animals matured (Gamble and Zajac, 1992; Schallig, 2000). Indeed, as the Dorper ewes matured, PCV was comparable to other hair breeds in Experiments 1 and 2 and FEC were similar to hair breeds in the induced infection in Experiment 2. In summer 2001, the average FEC increased in the St. Croix, Katahdin, and Hampshire ewes above 1000 epg. Interestingly, this rise occurred 14 days later in the Dorper ewes, which delayed anthelmintic treatment.

The hybrid vigor of Dorper  $\times$  Romanov or Dorper  $\times$  Romanov  $\times$  St. Croix ewes could have offered some nematode resistance. However, Gruner et al. (1986, 1992) reported that the Romanov breed appeared to be susceptible to parasite infection compared with Lacaune sheep. Studies have demonstrated that F1 crosses of a resistant and susceptible breed display an intermediate response to infection (Amarante et al., 1999a; Li et al., 2001), suggesting some resistance could have been gained with St. Croix crossbreeding. On the other hand, Amarante et al. (1999b) reported similar resistance of F1 and resistant (Florida Native) ewes compared with the susceptible (Rambouillet) breed, suggesting that maturity of animals used in the latter study was involved in resistance.

During November and December 2001, FEC escalated in the Dorper and Hampshire ewes, but was not associated with decreased PCV. The increased FEC were likely due to an infection of GI nematodes other than *H. contortus*, as PCV did not decline typical of haemonchosis. Good nutrition or forage quality may have also offset the detrimental effects of the infection so that PCV was not affected.

Levels of parasitism did not appear to be higher in the Hampshire ewes for a substantial part of the study. De-worming occurred at a similar rate to other breeds with the exception of two additional treatments given to the most susceptible individuals. The apparent resistance displayed by Hampshire ewes in this study may simply be a reflection of the extent of challenge from pasture. Previous studies (Barger et al., 1994) have shown that under tropical conditions, where larval survival is limited, a short-term rotational strategy (28 days) can be used to reduce the challenge from pasture. Maximum resting period was 60–90 days for most of the pastures used in the current study. In addition, the reduced contribution to pasture contamination made by the more resistant hair breeds used in this study should also have resulted in reduced pasture larval populations. This concept has been reported previously where pastures grazed by resistant Gulf Coast Native ewes showed continually

reduced infection levels over a 3-year period compared to no change in infection level on pastures grazed by Suffolk ewes (Miller et al., 1998). Hair sheep have predominantly grazed these pastures for more than 10 years. Grazing behavior appeared similar among the breeds. There was no other fresh forage available other than the infective grass and ewes appeared to graze as a single group, independent of breed type. In addition, all ewes had the potential to develop an induced and innate immunity to GI nematode infection before this study was initiated (Gamble and Zajac, 1992; Schallig, 2000). However, previous studies demonstrated that natural immunity in the more susceptible wool breeds should not preclude them from becoming infected with high levels of nematodes (more than 2500 epg; Gamble and Zajac, 1992). Finally, the level of stress incurred by the Hampshire ewes was low compared with other breeds because they were not pregnant or lactating throughout the study. Even with this potentially confounding effect in Experiment 1, FEC of these ewes increased above 2000 epg in October 2001, indicating increased susceptibility to GI nematode infection compared with St. Croix and Katahdin ewes.

A peri-parturient effect on FEC was detected only in St. Croix and Katahdin, but not Dorper crossbred ewes, in fall 2001, but not in fall 2000. Decreased PCV in pregnant/lactating ewes in fall 2000 (all breeds examined) and 2001 (Dorper and Katahdin in mid to late lactation) suggests that these ewes may have been more sensitive to nematode infection. Certainly, conditions (warm temperatures and adequate rainfall) for development of *H. contortus* larvae were still favorable in the fall supporting increased infection levels in the animal. The supplemental feed before lambing could contribute to the increased PCV before ewes became sensitive to the peri-parturient effect.

Ewes were in good or excellent condition throughout the study. Average mature body weights were typical for respective breeds (ASIA, 1996). The lighter body weight of Katahdin compared with St. Croix ewes in Year 1 reflects the younger age of Katahdin ewes (a difference of 6 months). Decreased body weight of St. Croix ewes in October 2000 may be associated with a larger number of these ewes that lambed at this time compared with other breeds. Body weight of ewes did not change after lambing in October 2001 as ewes were more mature at this time compared with the previous year. The gradual increase in body weight among all breeds reflects ewes approaching their mature weight as the study progressed.

Decreased body weight observed in all hair breeds in March 2001 was associated with decreased PCV and increased FEC. A more variable BCS in Dorper and Hampshire ewes may reflect a greater sensitivity of these breeds to the environment and perhaps parasite infection. After ewes were de-wormed, BCS improved.

## 5. Conclusion

The Dorper ewes appeared to be nearly as resistant to infection as the Katahdin and St. Croix breeds and more resistant than the Hampshire ewes when the challenge was low to moderate. Under southeastern conditions in the current study, Dorper crossbred ewes maintained good or excellent body condition and demonstrated relative resistance to natural or experimental infection.

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## References

- Amarante, A.F.T., Craig, T.M., Ramsey, W.S., Davis, S.K., Bazer, F.W., 1999a. Nematode burdens and cellular responses in the abomasal mucosa and blood of Florida Native, Rambouillet and crossbred lambs. *Vet. Parasitol.* 80, 311–324.
- Amarante, A.F.T., Craig, T.M., Ramsey, W.S., El-Sayed, N.M., Desouki, A.Y., Bazer, F.W., 1999b. Comparison of naturally acquired parasite burdens among Florida Native, Rambouillet and crossbred ewes. *Vet. Parasitol.* 85, 61–69.
- American Sheep Industry Association (ASIA), 1996. *Sheep Production Handbook*. Denver, CO, pp. 33–38.
- Barger, I.A., Siale, K., Banks, D.J., Le Jambre, L.F., 1994. Rotational grazing for control of gastrointestinal nematodes of goats in a wet tropical environment. *Vet. Parasitol.* 53, 109–116.
- Courtney, C.H., Parker, C.F., McClure, K.E., Herd, R.P., 1985. Resistance of exotic and domestic lambs to experimental infections with *Haemonchus contortus*. *Int. J. Parasitol.* 15, 101–109.
- Gamble, H.R., Zajac, A.M., 1992. Resistance of St. Croix lambs to *Haemonchus contortus* in experimentally and naturally acquired infections. *Vet. Parasitol.* 41, 211–225.
- Gruner, L., Cabaret, J., Sauve, C., Pailhories, R., 1986. Comparative susceptibility of Romanov and Lacaune sheep to gastrointestinal nematodes and small lungworms. *Vet. Parasitol.* 19, 85–93.
- Gruner, L., Gouix, J., Cabaret, J., Boulard, C., Cortet, J., Sauve, C., Molenat, G., Calamel, M., 1992. Effect of genetic type, lactation and management on helminth infection of ewes in an intensive grazing system on irrigated pasture. *Int. J. Parasitol.* 22, 919–925.
- Li, Y., Miller, J.E., Franke, D.E., 2001. Epidemiological observations and heterosis analysis of gastrointestinal nematode parasitism in Suffolk, Gulf Coast Native, and crossbred lambs. *Vet. Parasitol.* 98, 273–283.
- Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., 1996. *SAS System for Mixed Models*. Cary, NC, SAS Institute Inc., 656 pp.
- Miller, J.E., Bahirathan, M., Lemarie, S.L., Hembry, F.G., Kearney, M.T., Barras, S.R., 1998. Epidemiology of gastrointestinal nematode parasitism in Suffolk and Gulf Coast Native sheep with special emphasis on relative susceptibility to *Haemonchus contortus* infection. *Vet. Parasitol.* 74, 55–74.
- Presson, B.L., 1986. Initial investigation into the level and substance of breed dependent resistance of sheep to prevalent gastrointestinal nematode. PhD dissertation. University of AR, DAI, 47-05B, 118 pp.
- Preston, J.M., Allonby, E.W., 1979. The influence of breed on the susceptibility of sheep to *Haemonchus contortus* infection in Kenya. *Res. Vet. Sci.* 26, 134–139.
- SAS/STAT<sup>®</sup> Software: Changes and Enhancements through Release 6.11, 1996. SAS Inst. Inc., Cary, NC.
- Schallig, H.D., 2000. Immunological responses of sheep to *Haemonchus contortus*. *Parasitology* 120, S63–72.
- Whitlock, H.V., 1948. Some modifications of the McMaster helminth egg-counting technique apparatus. *J. Coun. Sci. Ind. Res.* 21, 177–180.
- Wildeus, S., 1997. Hair sheep genetic resources and their contribution to diversified small ruminant production in the United States. *J. Anim. Sci.* 75, 630–640.
- Zajac, A.M., Krakowka, S., Herd, R.P., McClure, K.E., 1990. Experimental *Haemonchus contortus* infection in three breeds of sheep. *Vet. Parasitol.* 36, 221–235.