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Genetic Evaluation of Weaning Weight and the Probability of Lambing at 1 Year of Age in Targhee Lambs

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Summary

The objective of this study was to investigate genetic control of 120-d weaning weight and the probability of lambing at 1 yr of age in Targhee ewe lambs. Records of 5,967 ewe lambs born from 1989 to 2012 and first exposed to rams for breeding at approximately 7 mo of age were analyzed. Records included lamb birth dates, sire, dam, type of birth and rearing, dam age, and weaning weight and, for ewe lambs, the breeding pen and subsequent lambing data. Weaning weight was evaluated as a continuous variable, and lambing data were recorded as a binomial trait, but both traits were analyzed as continuous variables. Full-term lambs (either born alive or stillborn) were recorded as a lambing success (i.e., 1); failure to produce a full-term lamb was indicated with a 0. The relationship matrix included 14,041 animals and at least four generations of pedigree information, with more generations included for animals born in later years of the study. Heritability estimates were 0.14 ± 0.02 for 120-d weaning weight and 0.15 ± 0.04 for probability of lambing. Phenotypic and genetic correlations between the two traits were 0.18 ± 0.02 and -0.23 ± 0.18, respectively. Weaning weight and the probability of lambing at 1 yr of age are thus expected to respond to selection. Ewe lambs with heavier weaning weights were more likely to lamb at 1 yr of age, but this is an environmental, rather than genetic relationship, and selection for ability to lamb at 1 yr of age may result in a small decrease in genetic merit for weaning weight.

Key Words: Sheep, Genetics, Growth, Reproduction, Weaning

Introduction

Dickerson (1970) stated that costs of livestock products depend on the efficiency of reproduction, female production, and growth of offspring and concluded that the major opportunity to improve efficiency in sheep production is to increase rate of reproduction. One method to improve reproductive efficiency is to increase the probability that ewes will lamb at 1 yr of age. Breeding ewes to lamb at 1 yr of age has been proposed for several decades (Briggs, 1936; Hume, 1939; Spencer et al., 1942; Cannon and Bath, 1969; Southam et al., 1971) as a means to increase lifetime productivity (Dyrmundsson, 1973, 1981; Levine et al., 1978; Fogarty et al., 2007), but with the caveat that ewe lambs must be properly developed before breeding (Hume, 1939; Spencer et al., 1942). Lifetime-lamb production is greater for ewes that lamb as yearlings than for ewes that lamb for the first time at 2 yr of age (Bowstead, 1930; Spencer et al., 1942; Hulet et al., 1969; Baker et al., 1978; Levine et al., 1978; Fogarty et al., 2007).

When compared with ewes that did not lamb at 1 yr of age, body weights of ewes that lambed at 1 yr of age were less at lambing (Cannon and Bath, 1969), at the end of the first lactation (Griswold, 1932), and at 18 mo of age (Spencer et al., 1942). Body weights did not differ at maturity. Lambing at 1 yr of age does not seem to adversely affect the ewes or their lambs (Fogarty et al., 2007). However, compared to ewes that lamb at 1 yr of age, ewes that lamb for the first time at 2 yr of age require an additional 12 mo of inputs without commensurate output, and overall production efficiency (i.e., ratio of useful output to total input) is expected to be less. Thus, a study was initiated at the USDA, ARS, U.S. Sheep Experiment Station (USSES) to determine the additive genetic control of the probability of lambing at 1 yr of age in Targhee ewes and estimate genetic and phenotypic relationships between the probability of lambing and lamb-weaning weight.

Materials and Methods

The USSES Institutional Animal Care and Use Committee reviewed and approved the husbandry practices and experimental procedures used in this study.

Animals

Lambing performance at 1 yr of age was analyzed using records of 5,967 Targhee ewe lambs born from 1989 to 2012 at USSES. Ewes lambed from mid-March through early May. Ewes and lambs were herded on sagebrush steppe range beginning in late April or early May and subalpine range beginning in early July. Selection and management of ewe lambs, after weaning and during breeding, varied across years, as experimental priorities shifted over time (Table 1). Before 2010, ewe lambs were weaned in late August, placed in feedlot pens for breeding, and managed in a feedlot until lambing. Beginning in 2010, ewe lambs were weaned in early September and managed in a feedlot until lambing. Before 2010, ewe lambs were penned with service sires for breeding for 55 d. Beginning in 2010, the breeding period was reduced to 34 d. The average age at weaning was 113 d, and the average age at the start of breeding was approximately 200 d. Ewe lambs were occasionally mated in multi-sire pens (Table 1), producing either purebred or crossbred lambs. Lambs resulting from these matings were not retained in the USSES purebred Targhee flock. In 1998 and 2002, mixtures of single-sire and multi-sire pens were used. From 2007 to 2011, ewe lambs were hand-mated to rams in an experiment to study the attainment of puberty in ewe lambs. Protocols for this puberty study dictated that ewe lambs were randomly assigned to service sires at each mating opportunity, so ewe lambs could have been mated to more than one ram during the breeding season, precluding identification of a specific service sire for the entire breeding season. Because of this constraint, the service sire of the ewe lambs was set equal to the breeding-pen number. As a result, differences in probability of lambing associated with service-sire effects in these years represented a general effect of the breeding pen.

Measurements

The data record for each lamb born included the birth date, sire, dam, type of birth and rearing, dam age, and weaning weight. Records for ewe lambs that were exposed to rams also included the breeding pen and subsequent lambing data. The type of birth and rearing variable grouped lambs according to number born and number reared and had seven classes (1-1, 1-2, 2-1, 2-2, 3-1, 3-2, and 3-3). A small number of lambs (0.004 percent of the data) born in litters of size four were removed from the data. The record of lambing success for a yearling ewe was a binomial trait (i.e., 1 or 0). Yearling ewes that delivered live or stillborn, but apparently full-term, lambs within approximately 10 d of their expected lambing date received a lambing success code of 1; yearling ewes that did not meet this criterion received a code of 0. We did not differentiate between ewe lambs that did not conceive and those that conceived, but did not deliver a full-term lamb. Ewe lambs in the fertility data set had 324 sires and 1,753 dams.

Weaning weights of ram (n = 4,503), wether (n = 1,338), and ewe lambs (n = 5,935) born in 1989 through 2012 and therefore contemporary with the ewe lambs in the yearling ewe fertility data set and their progeny were also extracted from USSES data sets. Based mainly on the productivity of their dams and associated low likelihood that they would be retained as breeding rams, an average of 23 percent of male lambs were selected before lambing to be castrated. However, the proportion of males that were castrated varied widely across years, from less than 1 percent to 51 percent. The final additive genetic relationship matrix for all lambs with weaning weights or yearling-ewe-lambing records contained 14,041 animals.

Statistical Methods

The ASREML software package (VSN International; Hemel Hempstead, U.K.) was used to estimate genetic parameters, and chi-squared tests ($P < 0.05$) of log-likelihood values were used to arrive at the final model. A univariate analysis of probability of lambing at 1 yr of age (Kirschten et al., 2013) using this dataset was previously completed using a binomial model. However, the bivariate model used to jointly analyze effects of probability of lambing and lamb-weaning weight in the current study did not

Table 1. Distribution of yearling lambing data among years.

Year born	No. of ewe lambs		Weaning weight mean and SD (kg) for ewe lambs:		Probability of lambing[a]	Single-sire mated?
	Weaned	Exposed to rams	Weaned	Exposed to rams		
1989	259	166	33.7 ± 5.9	36.7 ± 4.3	0.74	No
1990	311	170	32.2 ± 5.7	35.9 ± 3.7	0.61	No
1991	302	164	32.9 ± 5.4	35.6 ± 4.4	0.43	Yes
1992	442	197	29.8 ± 5.5	33.2 ± 4.3	0.31	No
1993	232	108	28.1 ± 6.1	28.1 ± 5.7	0.42	Yes
1994	193	90	30.1 ± 5.9	32.8 ± 4.2	0.38	Yes
1995	199	83	32.5 ± 5.4	33.8 ± 4.6	0.63	No
1996	273	124	32.2 ± 5.0	35.0 ± 3.7	0.79	No
1997	250	122	29.8 ± 5.1	32.2 ± 3.7	0.53	Yes
1998	240	144	32.8 ± 5.2	33.8 ± 5.1	0.71	Mix[b]
1999	275	142	32.8 ± 5.5	34.5 ± 4.5	0.46	Yes
2000	251	135	31.4 ± 6.6	33.9 ± 5.8	0.41	Yes
2001	202	129	34.3 ± 5.3	35.8 ± 5.2	0.40	Yes
2002	288	118	34.2 ± 5.7	38.9 ± 3.7	0.26	Mix[b]
2003	140	67	36.9 ± 4.9	39.7 ± 3.4	0.36	Yes
2004	183	118	36.1 ± 5.2	38.7 ± 4.0	0.69	Yes
2005	217	159	38.3 ± 5.7	40.2 ± 4.7	0.46	Yes
2006	201	163	34.2 ± 4.9	35.3 ± 4.3	0.56	Yes
2007	206	174	30.5 ± 5.7	30.7 ± 4.4	0.53	No
2008	204	177	35.6 ± 6.3	35.7 ± 5.8	0.34	No
2009	188	183	38.2 ± 5.9	38.3 ± 5.9	0.54	Yes
2010	239	135	35.4 ± 6.1	37.1 ± 5.8	0.34	No
2011	185	33	31.3 ± 6.3	37.5 ± 5.0	0.49	No
2012	238	185	31.4 ± 6.1	33.3 ± 5.3	0.49	Yes

[a] Number lambed / number mated
[b] Mixtures of single-sire and multi-sire pens.

converge when the probability of lambing was modeled as a binomial trait. A continuous normal distribution was therefore assumed for both traits to allow estimation of genetic parameters in the bivariate model. The final model for both traits in the current study included fixed effects of birth year, dam age, and type of birth and rearing and a random-animal, additive-genetic effect. The final model for weaning weight also included maternal-additive and permanent-environment effects (both fitted as random) and a continuous-linear effect of weaning age. The final model for probability of lambing at 1 yr of age also included a random effect of breeding pen and a continuous-linear effect of birth date of the ewe lamb.

Results and Discussion

Preliminary analyses of 120-d weaning weights revealed significant heterogeneity of variance among sexes (Table 2). Ram lambs were heavier than both ewe and wether lambs, and, based on F ratios of residual variances, also more variable ($P < 0.001$ and $P = 0.02$, respectively). However, CV differed among sexes by at most 1.1 percent. Lamb weaning weights were therefore standardized to a ewe-lamb basis before estimation of genetic parameters by multiplying weaning weights of ram and wether lambs by 0.923 and 0.977, respectively. By contrast, yearly means for weaning weights of unselected ewe lambs (Table 1) exhibited only a small negative correlation (r) with SD (r = -0.15; $P > 0.40$), and therefore uniformity of variation in weaning weight among years was assumed. A more substantial negative correlation was observed between annual means and CV (r = -0.75; $P < 0.001$). Favorable environmental conditions that increased the mean-weaning weight were thus not associated with greater absolute variation among animals and reduced variation relative to the mean.

The heritability estimate for weaning weight was 0.14 ± 0.02, the maternal heritability was 0.11 ± 0.02, and the permanent environmental effects of the dam accounted for 0.07 ± 0.01 of phenotypic variance for the Targhee lambs evaluated in this study (Table 3). In an extensive review of published parameters (Safari et al., 2005), the weighted average heritability of weaning weight was 0.23 ± 0.02 for 15 studies of wool breeds and 0.18 ± 0.02 for 40 studies of dual-purpose breeds. When studies reviewed by Safari et al. (2005) were limited to only those that fitted both direct- and maternal-additive-genetic effects, the average proportions of phenotypic variance accounted for by addi-

Table 2. Means, SD, and CV for weaning weight by sex of lamb.

Lamb sex	Mean, kg	SD, kg[a]	CV, %[a]
Ewe	32.8	5.7	17.2
Ram	35.6	6.5	18.3
Wether	33.8	5.8	17.1

[a] Pooled residual SD and CV for each sex after adjusting for mean effects of year

tive-direct, additive-maternal, and ewe-permanent environmental effects on weaning weight were 0.21, 0.16, and 0.06, respectively, in wool breeds and 0.16, 0.10, and 0.07, respectively, in dual-purpose breeds. The average-genetic correlation between direct and maternal effects on lamb-weaning weight in studies reviewed by Safari et al. (2005) was 0.34, but this association was not significant for the Targhee lambs in the current study. A previous analysis of 32,715 USSES Targhee weaning-weight records for lambs born between 1950 and 1998 yielded estimates of direct and maternal heritabilities of 0.22 ± 0.02 and 0.11± 0.01, respectively, and the proportion of phenotypic variance account for by ewe-permanent-environmental effects was 0.06 ± 0.01 (Hanford et al., 2003). An analysis of 9,736 weaning-weight records for Targhee sheep raised under similar extensive rangeland conditions in Montana yielded estimates of direct and maternal heritabilities and of the proportion of variation accounted for by ewe-permanent environmental effects of 0.12, 0.08, and 0.04, respectively (Borg et al., 2009). An analysis of weaning weights of Targhee lambs from 20 industry flocks participating in the U.S. National Sheep Improvement Program produced estimates of 0.10 and 0.05 for direct and maternal heritabilities, respectively, and the proportion of phenotypic variance accounted for by ewe-permanent-environmental effects was 0.08 (Notter and Hough (1997).

Table 3. (Co)variance components, heritabilities, and genetic and phenotypic correlations between weaning weight and probability of lambing at 1 yr of age in Targhee sheep.

Item	Weaning weight, kg	Probability of lambing
Additive variances	3.29	0.03
Additive maternal variance	2.66	
Dam permanent environmental variance	1.70	
Residual variances	15.90	0.19
Phenotypic variances	23.55	0.22
Heritabilities	0.14 ± 0.02	0.15 ± 0.04
Additive covariance and correlation[a]	-0.07	-0.23 ± 0.18
Phenotypic covariance and correlation[a]	0.40	0.18 ± 0.02

[a] Columns 2 and 3, respectively.

The heritability estimate for probability of lambing at 1 yr of age was 0.15 ± 0.04 (Table 3). Maternal-additive and permanent-environmental effects on probability of lambing were tested in preliminary analyses but were not significant and not included in the final model. Heritability estimates from the literature for measures of reproductive success in ewe lambs bred to lamb for the first time at approximately 1 yr of age are limited and vary widely. In a study of 4,219 ewes of various breeds and crosses, Fogarty et al. (1985) obtained a heritability estimate of 0.04 ± 0.05 for the probability of lambing at 1 yr of age, and the estimate of the heritability of age at first lambing in Dorset sheep was 0.07 ± 0.05 (Lewis et al., 1998). Heritability estimates of 0.12 and 0.14 were reported for age at first lambing in two flocks of Raza Aragonesa ewes (Gabina, 1989). Larger heritabilities for age at first lambing were reported by Iniguez et al. (1986) for Morlam composite ewes (0.31) and Vanimisetti and Notter (2012) for Polypay ewes (0.39). However, sheep in all of these studies were in accelerated-lambing systems, and the applicability of these estimates to sheep managed in extensive rangeland-production systems is not known.

The estimate of the phenotypic correlation between weaning weight and probability of lambing was 0.18 ± 0.02, and the estimated genetic correlation was -0.23 ± 0.18 (Table 3). These results suggest that larger ewe lambs have a somewhat greater probability of lambing at 1 yr of age, but only 3 percent of the phenotypic variation in yearling lambing rate was explained by differences in weaning weight. The genetic association between weaning weight and probability of lambing was small and negative and did not differ significantly from zero. This result suggests that a genetic antagonism between the two traits, if present at all in these data, could be easily managed by placing modest positive selection pressure on both traits.

Conclusion and Implications

Results from this study indicate that genetic variation exists among ewe lambs in weaning weight and in their ability to lamb at 1 yr of age. Ewe lambs with larger weaning weights were predicted to be more likely to lamb at 1 yr of age. This positive association was primarily environmental, indicating that management practices that increase weaning weight would be expected to increase the probability of lambing. By contrast, a small negative-genetic relationship was observed between the two traits, but the relatively low magnitude of the correlation indicates that multiple-trait selection using estimated breeding values would permit concurrent improvement in both weaning weight and the probability of lambing at 1 yr of age.

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Use of Annual Forage Crops as a Late-Season Forage for Pregnant Ewes, Insect Habitat and to Improve Soil Health

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Summary

Incorporating annual forages into an integrated livestock-crop management system may help prolong the grazing season for most livestock-management systems in the Upper Great Plains. The objectives of this study were to determine (1) the differences in sheep performance ADG (average daily gain) among two mixtures of annual forages and mixed-grass pasture grazed during the dormant season, (2) if differences exist in insect biomass among annual forage mixtures and mixed grass, and (3) to document changes in soil chemical and nutrient status under grazed annual-forage production and grazed mixed-grass pastures. One hundred and eight pregnant Rambouillet ewes were stratified by weight and randomly allotted to one of nine paddocks with two treatments and a control (n = 3) for three consecutive years. Treatments include two spring annual forage plantings (**AF1** and **AF2**), and an introduced mixed-grass and forb mixture that served as the control (**CON**). Grazing occurred continuously for 21d to 22-d during October. Ewe weight gain was increased ($P \leq 0.02$) in the annual forage treatments compared to CON, but was similar between annual forage treatments ($P \geq 0.05$). Similarly, crude protein was greater ($P < 0.01$) in **annual forage treatments** relative to the **CON**; 11.84, 12.04, and 5.90, respectively. The higher crude protein in annual forage treatments was likely responsible for the observed response in weight gain. Insect biomass was greatest for AF2, intermediate for AF1 and lowest for CON ($P \leq 0.05$). Soils analysis generally revealed no treatment differences during the three-year study period ($P \geq 0.05$). Our research indicates that annual forages can provide feed with adequate nutritional value to pregnant ewes and may be an option to lengthen the grazing season and delay the onset of supplemental feeding. Insect biomass differed among treatments ($P = 0.02$), which could have ecological impacts to the surrounding environment due to the important role that insects play in transferring energy within trophic levels. Additional research is needed to further quantify changes occurring in soil nutrients as a result of long-term propagation and grazing of annual forages within an integrated, crop-livestock system in the Northern Great Plains.

Key Words: Annual Forage, Cover Crop, Insects, Grazing, Sheep, Soil

Introduction

A growing group of livestock producers have recognized the benefits of integrating crop production into livestock enterprises. Crop production can generate revenue from grain sales and supply forage for livestock. In addition, integrated systems can provide greater environmental benefits over conventional farming systems (Tracy and Zhang, 2008).

The integration of forages into crop rotations has recently received greater attention as a means to diversify cropping systems, reduce weed populations, reduce agronomic inputs, and provide both wildlife habitat and forage for livestock (Entz et al., 2002; McCartney et al., 2008; Lenssen et al., 2010). The use of forages to increase the length of the grazing season has become particularly intriguing to producers, who continuously seek ways to reduce costs and increase efficiencies (McCartney et al., 2008). Oats, barley, and corn have been important forage crops sown in the Northern Great Plains (NGP). These crops are typically harvested for grain with livestock grazing the residual. However, economic and environmental concerns have led producers and scientists to evaluate other species (McCartney et al., 2008). Neville et al. (2008) reported that annual forage mixtures, including turnips, radishes and other forage species, provided high-quality feed for cattle and helped extend the grazing season. Similarly, Sheaffer et al. (1992) reported high daily gains for sheep grazing soy beans and cowpea planted as a cover crop following barley harvest.

In addition to providing a food source for livestock, forage crops sown for late-season grazing may provide environmental benefits (SAN, 2007; Maughan et al. 2009). Legumes can incorporate additional N into the system, while cool-season-grass species may help prevent nutrient leaching (SAN, 2007; Unkovich and Pate, 2000). Schoofs and Entz (2000) reported that forage crops reduced populations of wild oats as effectively as a sprayed control.

Livestock grazing of annual-forage crops may influence the environmental benefits received from annual forages, particularly as it pertains to the soil (Haynes and Williams, 1993; Maughan et al., 2009). Soil compaction as a result of livestock grazing may reduce crop yields (Krenzer et al., 1989) and can be magnified if soggy conditions prevail (Maughan et al., 2009). However, not all findings have been negative; Tracy and Zhang (2008) reported no negative effect on corn yield due to the presence of cattle prior to planting.

In addition to providing forage for livestock and potential benefits to the soil, annual forage crops may attract insects. Insects are important to the ecosystem and play a critical role in the transfer of energy from plants to animals (Wilson, 1987; Losey and Vaughan, 2006). Some insects, such as pollinators, fulfill vital roles for society, while others are agricultural pests (Meffe, 1998; Altieri and Nicholls, 2004; Klein et al., 2007). Klein et al., (2007) determined that pollination is important for roughly 35 percent of global crop production.

Sheep producers in the NGP are in search of high-quality feed that can be used to extend the grazing season. In areas of the NGP, limited pasture-land, economics and other issues have led sheep producers to integrate crop production into their operations. Some producers have diversified the crops used in recent years by incorporating mixtures of annual forages into rotations. Annual forage crops can be used as hay or grazed. While some data exist concerning annual forages and cattle in the NGP, little information is available regarding sheep performance, while grazing annual forages planted as a main crop (Neville, 2008). The purpose of this study was to evaluate the potential to incorporate annual forage crops into a 12-month integrated, sheep-cropping system to extend the grazing season. The objectives of this study were to determine (1) differences in sheep performance AGD (average daily gain) among two mixtures of annual-forage crops and mixed-grass pasture grazed during the dormant season, (2) if differences exist in insect biomass among annual-forage mixtures and mixed grass, and (3) to document changes in soil-chemical and nutrient status under grazed, annual-forage production and grazed, mixed-grass pastures. Dormant season was defined for this study as the period of plant dormancy or death brought on by cooler temperatures (Warren et al., 1986).

Materials and Methods

All procedures were approved by the North Dakota State University (NDSU) Institutional Animal Care and Use Committee (Protocol # A10057). The study was conducted at the Hettinger Research Extension Center near Hettinger, North Dakota, in Adams County. The 12-month integrated system used at the station requires sheep to graze native and non-native pasture from mid-April to mid-August or September. Sheep are then moved to graze oat or barley stubble. From September to November/December sheep graze native and non-native pasture and are supplemented with other feeds. Sheep typically lamb in January as part of this system. Oats and barley are the primary small-grain crops sown for both forage and cash. The research was done on nine, 0.81-ha paddocks. Six paddocks are contiguous and ±410 m from the three remaining contiguous paddocks. The research site is in an area mapped as Stady loam (0 percent to 2 percent slope) and Manning Fine Sandy loam (0 percent to 6 percent slope). Both are derived from sedimentary rock (Soil Survey Staff, 2014). Previous land use was small grains or idled pasture. The study area averages 40 cm of precipitation annually, with average summer temperature (June through August) of 19°C (NDAWN, 2012).

Grazing Treatments

The study was done using a completely randomized design with three replicates each of two annual forage crops and one of mixed grass and forb control. Treatments were assigned randomly to paddocks during year 1 and remained in the same paddock throughout the trial. Annual forage crop 1 (**AF1**) was a mixture of oats (18 kg/ha), forage soybean (10 kg/ha), proso millet (2.2 kg/ha), sorghum (2.2 kg/ha), purple-top turnip (1.8 kg/ha), yellow sweet clover (1.1 kg/ha), and forage radish (0.67 kg/ha). Annual forage crop 2 (**AF2**) was a mixture of purple-top turnip (4.0 kg/ha), proso millet (3.4 kg/ha) and forage radish (1.8 kg/ha). The control (**CON**) was pasture dominated by crested wheatgrass (55 percent canopy cover; *Agropyron cristatum*) and alfalfa (25 percent canopy cover; *Medicago sativa*). **AF1** is more diverse, and the species were chosen based on their ability to grow in the NGP, forage potential, phenology, environmental benefits and functional group (SAN, 2007). **AF2** consisted of species selected based on their ability to produce forage for livestock and to add functional group diversity (Smart et al., 2004; SAN, 2007). **CON** consisted of mixed grasses and forbs that had been established for > 20 years. The **CON** replicates had been left idle and not used for > 5 years.

A tank-mixed application of glyphosate (2.34 l/ha) was applied as a pre-planting herbicide on all annual-forage-crop paddocks to control weeds. Annual-forage crops and fertilizer were planted/applied using a 2.4 m Truax™ Flex II no-till drill (Truax Company, Inc, New Hope, Minn.). Planting occurred in mid-June, with fertilizer (11-52-0) applied to annual forage crops at 56 kg/ha during the time of planting. A minimal amount of starter fertilizer was used to reduce costs. No additional fertilizer was applied to the annual forage crops and the **CON** was not fertilized during the experiment.

Forage data were collected annually at the onset of sheep grazing in late-September. Forage production was determined in late-September on a dry matter basis. A 0.25 m^2 frame was used to sample vegetation. All vegetation was clipped to ground level and sorted by species. Nine frames per paddock were clipped. Vegetation was dried using a forced-air oven (55º C) for 48 h and weighed. Dry weights were used to calculate the average total $kg \cdot ha^{-1} \cdot species^{-1}$ for each treatment. Dried samples were sent to Midwest Laboratories Inc. for nutrient analysis of DM (method 930.15: AOAC Int., 2009), N (method 990.03; AOAC Int., 2009), NDF (Van Soest et al. 1991) as modified by Ankom Technology (Fairport, N.Y.) using an Ankom 200 Fiber Analyzer without sodium sulfide, with amylase and without ash corrections as sequentials, ADF (Goering and Van Soest, 1970), and minerals (inductively coupled atomic plasma and wet digest procedure) including sulfur, potassium, calcium, and others.

Livestock

One hundred and eight, 1- to 5-year-old (average 2 years old) Rambouillet ewes bred to lamb approximately on January 15 were used to evaluate livestock performance. Two-day weights were taken at the beginning and end of the grazing period to determine average daily gain (ADG). Ewes were stratified by weight (63 kg ± 0.93 kg initial BW) and sorted to have similar average weights among treatments and randomly assigned to one of nine paddocks (12 ewes per paddock; n = 3). Each of nine paddocks was grazed simultaneously and continuously for 21 to 22 days in October during 2010, 2011, and 2012. Grazing occurred for no greater than 22 days to ensure sustained forage availability for sheep and to maintain residual cover. Forage availability was monitored visually.

Insects

Insects were sampled with 40 cm canvas hoop nets along three, 25-m transects randomly located in each paddock. Insects were collected between 1000 h and 1600 h during dry conditions as suggested by Whipple et al. (2010). Insects were sampled annually in late-July or early-August. Insects were sampled during this time period to coincide with the brooding period of ring-necked pheasants (Mazza, 2013), which actively consume insects during this life stage (Hill, 1985). Furthermore, by late-July AF1 and AF2 were well established. Researchers swept insects while walking along each side of the 25 m tape. Captured insects were transferred to a plastic storage bag, frozen, and later dried and weighed. Insects were dried at 55°C for 48 hours. In 2012, insects were sorted into groups by taxonomic order.

Soils

Soil was sampled annually (mid-May) to a depth of 15.24 cm with a hand-held soil probe. Three samples were taken per paddock and hand mixed together to form one representative sample. Soil samples were sent to the North Dakota State University Soil Testing Laboratory for analysis of nitrogen, phosphorus, potassium, and organic matter.

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc, Cary, N.C.). Paddock served as the experimental unit (n = 3). The covariance structure was Autoregressive. The fixed effect included in the model was treatment. Treatment, year, and treatment x year interactions were evaluated. When a significant F-test was observed ($P < 0.05$) for treatment, preplanned orthogonal contrasts were performed to assess differences only if a treatment x year interaction did not exist. Preplanned orthogonal contrasts include 1) AF1 versus AF2 and 2) AF1 + AF2 versus CON. When a significant F-test was observed ($P < 0.05$) for year or treatment x year interaction, LS Means with a Tukey's adjustment were used to partition effects. Significance was determined at $P < 0.05$. When treatment x year interactions were observed ($P < 0.05$), interactions are presented in bold in Table 2. However, the associated treatment and year effects are presented to allow the reader to determine their relative importance, but only the highest order of significance is discussed. Significant year interactions ($P < 0.05$) are discussed only within the text because they are assumed to be associated with environmental factors and averages were not reported within the tables. All interactions that were not significant ($P < 0.05$) were removed from the model.

Results and Discussion

Climate

Precipitation was 10 mm above normal in 2010 and >30 mm below normal in 2011 and 2012 (Table 1). Air temperature, like precipitation, was variable. Sixty-eight percent of normal precipitation fell in June and 162 percent of normal precipitation fell in July in 2012. In addition, July temperatures were warmer than average, which may have given warm-season species a competitive advantage over cool-season species, such as turnips that are not drought tolerant. Turnips are however somewhat frost tolerant and fall regrowth may have been unaffected by the first killing frost of the year, which occurred on September 18, 2010; September 4, 2011; and September 13, 2012.

Livestock and Forage Production

Average daily gain of pregnant Rambouillet ewes was affected

Table 1. Monthly and annual precipitation and average temperature from 2010-2012 at the experimental site in Hettinger, ND.[1]

	Precipitation (mm)				Temperature (°C)			
Month	**2010**	**2011**	**2012**	**30-yr avg.**	**2010**	**2011**	**2012**	**30-yr avg.**
April	30	55	72	38	7	4	8	6
May	85	106	58	62	10	10	12	12
June	77	82	55	81	16	16	19	17
July	92	34	94	58	20	22	24	21
August	56	53	49	49	20	20	20	21
September	75	10	1	37	13	14	15	14
October	6	18	18	35	9	9	6	7
Total	443	398	375	434				

[1] Data are from National Oceanic and Atmospheric Administration (www.nws.noaa.gov) and North Dakota Agricultural Weather Network (www.ndawn.ndsu.nodak.edu).

($P = 0.02$) by treatment and year ($P < 0.01$), with no treatment-by-year interactions ($P = 0.91$). Average daily gain did not differ between AF1 and AF2 ($P = 0.75$), but was greater for annual forage treatments than CON ($P < .001$; 0.12 kg/d ±0.09 kg/d, 0.14 kg/d ± 0.10 kg/d, and -0.01 kg/d ± 0.12 kg/d, respectively) across all years. Year effects within the ADG dataset were largely the result of the reduced ADG in 2011. While many factors may have affected ADG, it was likely the result of internal parasites (data not reported). Forage quantity did not appear to be the reason for the difference in performance between AF1 (2478 ± 139 kg/ha), AF2 (2371 ± 123 kg/ha), and CON 2180 kg/ha ± 58 kg/ha), as no effects were observed for treatment, year, or treatment x year interactions ($P > 0.76$). The lowest observed biomass at the beginning of each grazing season in all three years was 2066 kg/ha, which provided 1782 kg/paddock. Based on the NRC for Small Ruminants (2007), DM intake requirements for each ewe were 1.31 kg/d. Therefore, the intake requirements for 12 ewes and a maximum of 22 days of grazing was 346 kg, indicating that forage production appeared adequate for all treatments in all years.

Forage Nutrient Analysis

Treatment x year interactions for CP and TDN (Table 2) were observed ($P < 0.02$). While variable across years, AF1 and AF2 tended to have greater CP concentrations relative to CON (11.84 percent and 12.04 percent, vs. 5.9 percent, respectively). This effect largely explains differences in weight gains across treatments, as energy (expressed as TDN) was not affected by treatment ($P = 0.21$). Additionally, the CP requirement for 60 kg ewes in early gestation is approximately 8 percent (NRC, 2007), which was exceeded by AF1 and AF2 treatments, but deficient in the CON. Furthermore, ADF was greater ($P < 0.01$) for CON (44.97 percent ± 1.26 percent) compared to AF1 and AF2 (30.94 percent ± 3.41 percent and 27.99 percent ± 2.60 percent, respectively), further explaining differences in performance. There was no year effect or treatment by year interaction for ADF. The combined CP deficiency and simultaneous increase in ADF concentration for the CON treatment explain the differences in performance. However, the calculated TDN results appear to conflict with the ADF concentrations observed. We have no explanation for these differences. Finally, there was no difference in crude fat among AF1 (2.22 percent ± 0.18 percent), AF2 (1.70 percent ± 0.08 percent) and CON (1.97 percent ± 0.25 percent).

Forage Mineral Analysis

Treatment x year interactions for Ca and Cu were observed ($P < 0.02$). Similar to nutrient concentrations, variability existed between years, especially for the annual forage treatments (Table 2). CON had consistently lower Ca and Cu concentrations than AF1 orAF2. This trend of increased concentrations of minerals in annual forage treatments also was present for S, P, K, Mg, and Zn, which exhibited a treatment effect ($P < 0.03$). However, two minerals, Fe and Mn, exhibited a treatment effect ($P < 0.03$) in which AF1 was different from AF2 ($P \leq 0.003$) but when combined were similar to the CON ($P \leq 0.20$). While it is impossible to provide all possible comparisons to grain-type annual forages, we compared the mineral concentrations of the average of AF1 and AF2 to oats, a common, annual forage in this region (NRC, 2000). Concentrations of the minerals S, P, Na, Cu, and Zn all fell within the general range of oats. However, K, Mg, Ca, Fe, and Mn were generally greater than expected in oats (4.4, 2.5, 18, 2.3, and 1.5 times greater, respectively). When designing mineral supplementation programs for ewes consuming mixtures of annual forages, these minerals should be considered minerals of interest, as mineral programs may need to be adjusted to avoid potential negative interactions. Year interactions were present for P, K, and Fe in forage analyses (Table 2). Phosphorus concentration was similar during the first two years of the study ($P = 0.15$ percent; 0.27 percent and 0.24 percent, respectively), but significantly decreased in 2012 to 0.19 percent across treatments ($P \leq 0.04$). Similarities were seen between 2011 and 2012 for percent K ($P \leq 0.06$) with average K of 1.43 and 1.14 percent, respectively. Percent K was different in 2010 ($P < 0.001$), with an average of 1.98 percent K. Concentrations of Na did not differ among treatments for AF1 (0.02 percent ± 0.01 per-

Table 2.Sheep production, vegetative biomass production, and feed nutritional analysis from a sheep cover crop grazing trial in southwest North Dakota (October 2010, 2011, and 2012)[1]

	Annual Forage 1[2]				Annual Forage 2[3]				Mixed-Grass Prairie[4]					P-value		
Items	2010	2011	2012	Avg	2010	2011	2012	Avg	2010	2011	2012	Avg	SEM^{Trt}	Trt	Yr	Trt*Yr
Nutrient Analysis																
CP, %	**14.72**^{de}	**10.33**^{bc}	**10.49**^{bcd}	11.84	**15.17**^{e}	**7.97**^{ab}	**13.00**^{cde}	12.04	**6.22**^{ab}	**5.59**^{a}	**5.89a**	5.90	**0.84**	<0.01	0.13	**0.02**
TDN, %	**63.07**^{ab}	**65.07**^{cd}	**66.33**^{de}	64.82	**62.23**^{a}	**66.83**^{e}	**64.03**^{abc}	64.37	**64.07**^{bc}	**65.90**^{cde}	**65.07**^{cde}	65.01	**0.37**	0.21	0.02	**<0.01**
Mineral Analysis																
S, %	0.343	0.313	0.143	**0.27**	0.483	0.247	0.447	**0.39**	0.113	0.103	0.090	**0.10**	0.064	**0.02**	0.58	0.50
P, %	0.310	0.247	0.217	**0.26**	0.357	0.340	0.260	**0.32**	0.150	0.130	0.080	**0.12**	0.016	**<0.01**	0.01	0.86
K, %	2.71	1.98	1.55	**2.08**	2.70	1.77	1.65	**2.04**	0.52	0.54	0.22	**0.43**	0.11	**<0.01**	<0.01	0.15
Mg, %	0.420	0.350	0.333	**0.37**	0.523	0.313	0.393	**0.41**	0.117	0.157	0.093	**0.12**	0.040	**<0.01**	0.51	0.20
Ca, %	**2.26**^{b}	**0.76**^{a}	**0.54**^{a}	1.19	**2.87**^{b}	**0.58**^{a}	**0.97**^{a}	1.48	**0.47**^{a}	**0.61**^{a}	**0.39**^{a}	0.49	**0.15**	<0.01	<0.01	**<0.01**
Fe, ppm	101.3	85.67	196.7	**127.9**	195.0	140.3	375.3	**236.9**	135.7	107.0	249.3	**164.0**	22.33	**0.01**	0.01	0.54
Mn, ppm	47.7	51.7	50.0	**49.78**	104.3	52.0	90.7	**82.33**	87.3	63.0	91.7	**80.0**	9.84	**0.03**	0.38	0.31
Cu, ppm	**3.00**^{abc}	**3.67**^{bcd}	**6.00**^{f}	4.22	**4.33**^{cde}	**4.67**^{def}	**5.67**^{ef}	4.89	**2.67**^{ab}	**3.00**^{abc}	**2.00**^{a}	2.56	**0.28**	<0.01	0.03	**0.02**
Zn, ppm	28.0	24.0	27.3	**26.44**	37.33	43.00	34.33	**38.22**	23.33	20.00	26.67	**23.33**	3.10	**0.03**	0.99	0.77

Contrasts[5]	AF1 vs AF2	AFs vs CON
S, %	0.17	0.01
P, %	0.02	<0.001
K, %	0.83	<0.001
Mg, %	0.32	<0.001
Fe, ppm	0.003	0.49
Mn, ppm	0.009	0.20
Zn, ppm	0.04	0.04

[1] Bolded items indicate main and interaction effects with highest order of significance.
[2] Annual forage mix with greater diversity (**AF1**).
[3] Annual forage mix with less diversity (**AF2**).
[4] Mixed-grass prairie consisting mostly of crested wheatgrass, and alfalfa (**CON**).
[5] P-values for preplanned contrasts for items with a significant Trt effect in a Repeated Measures ANOVA ($P \leq 0.05$)
[a,b,c,d,e] Means within a row, with a significant Trt x Yr interaction, without a common superscript differ ($P \leq 0.05$).

cent), AF2 (0.06 percent ± 0.02 percent), and CON (0.05 percent ± 0.0 percent) nor were there any year or treatment by year interactions ($P > 0.05$).

Insect Abundance

Insect abundance was quantified as biomass (g) per transect. Year or treatment by year interactions did not occur in insect abundance ($P > 0.05$); however, insect abundance differed among treatments ($P < 0.02$). AF1 and AF2 were similar ($P = 0.32$), but differed from CON ($P = 0.01$) at 4.49 ± 1.33, 5.91 ± 3.46, and 1.38 ± 0.53 g/transect; respectively. In 2012, when insects were sorted by order, Orthoptera (grasshopper) comprised approximately 93 percent of the total biomass of dried insects. While unclear which insect orders made the majority of biomass in 2010 and 2011, grasshoppers were observed frequently during all years. Many of the plant species within the CON had reached maturity by the time insects were sampled (personal observation) and grasshoppers may have been attracted to the newer lush growth associated with forage treatments (Rogers and Uresk, 1974; Pfadt, 1994). Grasshoppers may compete with livestock for forage (Hewitt and Onsager, 1983), but that was not evaluated. In addition to grasshoppers, other insects of different orders may have been attracted to flowers associated with annual forage treatments, leading to increased insect biomass (Carreck and Williams, 2002). Along with grasshoppers, 6 percent of the total insect biomass for 2012 was attributed to the order Hemiptera and the remaining 1 percent consisted primarily of Coleoptera (beetles). Limited inferences should be made from a single, point-in-time sampling of insects such as this, however, these data may illuminate the point that integrating annual crops into a rotation will impact the environment in a multitude of ways.

Soils Analysis

Soil phosphorus differed among years ($P \leq 0.01$: Table 3). Years 2010 and 2011 were similar ($P \geq 0.09$), while phosphorus was greater in 2012 ($P \leq 0.04$ and $P < 0.01$, respectively; Table 3). Average P was 11 ppm, 7 ppm, and 17 ppm for 2010, 2011, and 2012, respectively. Mechanisms driving increased soil phosphorus during 2012 are unknown. Above average temperatures and precipitation in April of 2012 may have led to increased soil temperatures enhancing release of P from recalcitrant P pools in the soils (Peverill et al., 1999). Additionally, increased soil P may be attributed to

Table 3.Soil characteristics and analysis from a sheep cover crop grazing trial in southwest North Dakota (October 2010, 2011, 2012)

	Annual Forage 1[1]				Annual Forage 2[2]				Mixed-Grass Prairie[3]					P-value		
Items	2010	2011	2012	Avg	2010	2011	2012	Avg	2010	2011	2012	Avg	SEM^{Trt}	Trt	Yr	Trt*Yr
Soils Analysis																
N, kg/ha	13.81	17.92	10.08	13.93	18.29	19.41	22.40	20.03	13.07	21.65	6.72	13.81	3.37	0.23	0.53	0.50
P, ppm	8.67	6.67	18.67	11.33	11.33	9.33	19.00	13.22	14.33	6.33	12.00	10.89	1.51	0.57	0.01	0.24
K, ppm	303.33	323.33	386.67	337.78	283.33	302.00	411.67	332.33	336.67	358.33	401.67	365.56	16.55	0.15	0.07	0.37
OM, %	2.97	3.17	3.57	3.23	2.90	3.00	2.97	2.96	2.57	2.90	3.57	3.01	0.22	0.29	0.53	0.22

[1] Annual forage mix with greater diversity (**AF1**).
[2] Annual forage mix with less diversity (**AF2**).
[3] Mixed-grass prairie consisting mostly of crested wheatgrass, and alfalfa (**CON**).

P recycling through increased abundance of residue and litter (Bowman and Halvorson, 1997), although soil OM was not affected by treatment, year, or the treatment x year interaction ($P \geq 0.09$). We hypothesize that OM would increase over time in annual forage paddocks if forage crops were continued.

A minimal amount of fertilizer was used during this trial to reduce costs, which have been an expressed concern of producers. As such, N was below recommended values for all species included in annual forage treatments, had they been planted as a sole crop (Franzen, 2010). Applying additional N would likely increase productivity of forage crops and in return provide greater forage for livestock. Additional research is required over longer time-intervals to assess costs and benefits to the soil associated with incorporating annual forage crops into a rotation, as changes in soil characteristics may not occur quickly (Werner, 1997; Clark et al., 1998).

Conclusion and Implications

Annual forages resulted in ADG in pregnant ewes that were significantly greater than ADG for ewes that grazed mixed-grass prairie in the early fall. These results indicate that annual forages have the potential to provide dormant season forage and in return, prolong the grazing season. Further research should be conducted to determine if an optimal forage mixture and or timing of grazing exists to maximize forage and livestock production. The use of annual forages in an integrated system may impact the local insect community although future research should focus on which insect orders are selecting annual forages and further, strive to evaluate how the insect community is changing over time and which factors may be responsible. Finally, if benefits to the soil can occur from incorporating annual forages into an integrated system, more time may be required for these benefits to be recognized.

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Performance and Behavior by Spring-Born Katahdin Lambs Weaned Using Traditional or Fenceline-Weaning Methods in the Morning or Evening

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Summary

Many stressors, including social, environmental, physical, and nutritional, are involved with traditional weaning, which may negatively impact animal performance and behavior. Alternative weaning strategies may be a possible solution to minimize these negative effects. Therefore, the objective of this study was to determine the effects of weaning method and time of day on lamb performance and behavior. Over two consecutive years, 190 spring-born Katahdin ram and ewe lambs (n = 93, 26 kg ± 0.47 kg initial BW, 96 d of age, average in year 1; n = 97, 18 kg ± 0.99 kg initial BW, 89 d of age, average in year 2) were separated from their dams, stratified within litter size at weaning and by BW, sex, and age of their dam and allocated randomly in a 2 × 2 factorial design to one of four treatments representing: 1) Fenceline AM; 2) Fenceline PM; 3) Traditional AM; and 4) Traditional PM for a 14-d weaning period. Lamb weights were collected at the beginning (d 0) and 14-d post-weaning. Behavioral measurements were taken for 10 min per pen at 12 h, 24 h, 48 h, and 72 h post-weaning. Weaning and final weight, ADG, and total gain did not differ ($P \geq 0.88$) across treatments. Percentage of lambs vocalizing were greater ($P = 0.01$) from fenceline weaned lambs compared with traditionally weaned lambs. Percentages of animals walking rapidly, running, standing, and lying down did not differ ($P \geq 0.13$) across treatments. A time effect was detected ($P < 0.01$) for percentage of lambs vocalizing. A treatment × time interaction ($P = 0.04$) was observed for percentage of lambs lying down. Therefore, utilizing alternative weaning strategies may not improve performance by spring-born Katahdin lambs and may have negative effects on lamb behavior.

Key Words: Behavior, Katahdin, Performance, Weaning

Introduction

Weaning is a common livestock management practice; however, negative effects on animal performance in sheep (Knights et al., 2012) and cattle (Lefcourt and Elsasser, 1995; Meyers et al., 1999; Price et al., 2003; Boyles et al., 2007) and negative effects on behavior in sheep (Orgeur et al., 1998; Orihuela et al., 2004; Schichowski et al., 2008) and cattle (Stookey et al., 1997; Price et al., 2003; Boland et al., 2008; Ness et al., 2012) have been reported during the weaning process. Typically, livestock are weaned by abruptly separating offspring away from their dams without visual or audible contact (Enríquez et al., 2011). It has been reported that when lambs are abruptly separated from their dams, they vocalize more (Orgeur et al., 1998; Schichowski et al., 2008) and have higher agitation scores (Schichowski et al., 2008) compared with lambs that are gradually weaned. In recent years, fenceline weaning has increased in popularity. Fenceline weaning is a management practice where offspring are separated from their dams by some form of barrier that allows the animals to have nose-to-nose contact with their dams. When compared with traditional weaning in cattle, fenceline weaning may positively affect animal gain (Price et al., 2003; Boyles et al., 2007; Ness et al., 2012) and behavior (Stookey et al., 1997; Price et al., 2003; Boland et al., 2008; Ness et al., 2012). Another alternative weaning strategy is shifting the time weaning is initiated, such as weaning in the evening compared with weaning in the morning. Evening weaning may increase pig performance and feed intake (Ogunbameru et al., 1992) and improve cattle performance and behavior (Ness et al., 2012) over the weaning period. Using fall-born calves, Ness et al. (2012) evaluated the effects of alternative weaning strategies and time of day. It was observed that calf ADG and total gain was improved and percentage of calves vocalizing was lower with fenceline and evening weaning strategies compared with traditional weaning in the morning after a 14 d weaning period. However, little information is available on the effects of these weaning-management practices and time of day sheep are weaned, particularly in Katahdin hair sheep. Therefore, the objective of this study was to determine the effects of weaning method and time of day weaning is initiated on spring-born Katahdin lamb performance and behavior.

Materials and Methods

Animal Management

This study was conducted at the Lincoln University Carver Farm located in Jefferson City, Mo. All animals were treated according to the recommendations of The Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Consortium, 1988). Over two consecutive years, Katahdin ewes (n = 132) and their spring-born lamb progeny (n = 190; n = 93, 26 kg ± 0.47 kg initial BW, 96 d of age, average in year 1; n = 97, 18 kg ± 0.99 kg initial BW, 89 d of age, average in year 2) were used in a 2 × 2 factorial design to determine the effects of weaning strategy and time-of-day weaning was initiated. Each year, lambs were born during a 45-d lambing period, reared on pasture in a similar environment, and had access to a grain-based, supplemental-creep feed (Table 1). Each year, prior to weaning, ram and ewe lambs were stratified within litter size at weaning and by BW, sex, and age of their dam and were allocated randomly to one of eight groups. At initiation of the weaning period each year, lambs were separated from their dams, vaccinated for *Clostridium Perfringens types* C and *D* and *Tetanus Toxoid* (Bar-vac© CD/T; Boehringer Ingelheim, Inc., St. Joseph, Mo.), dewormed (Cydectin©; Boehringer Ingelheim, Inc., St. Joseph, Mo.), and groups were assigned randomly in replicate to one of four weaning treatments representing: 1) Fenceline AM (n = 46); 2) Fenceline PM (n = 46); 3) Traditional AM (n = 50); and 4) Traditional PM (n = 48) for a 14-d weaning period. Inherent differences between fenceline and traditional treatments related to nutrition, space, etc. were intentional to emulate typical production settings. Morning weaning occurred at 0730 h and PM weaning was at 1730 h. Fenceline weaned lambs were placed, adjacent to their dams, in 0.1-ha paddocks consisting predominantly of endophyte-infected tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh; 61 percent NDF and 32 percent ADF]. Traditionally weaned lambs were housed in a 37.2 m^2 drylot away from their dams and had access to endophyte-infected tall fescue hay (69 percent NDF and 38 percent ADF). All lambs had *ad libitum* access to water and sheep trace mineral (ADM Alliance Nutrition, Inc., Quincy, Ill.) and in order to minimize nutritional variations between treatments, were offered the same grain-based supplement (Table 1) that was available prior to weaning, at equivalent to 2 percent of BW at 0930 for the duration of the 14-d weaning period.

Lambs were weighed at the end of the weaning period and were revaccinated. Behavioral measurements were observed for each group of lambs over a 10-min period at 12 h, 24 h, 48 h, and 72 h post-weaning according to Ness et al. (2012). Behavior measurements taken in the AM were taken prior to feeding. Each group was observed by one of two of the same trained observers each year to determine if each individual lamb vocalized, walked rapidly, ran at a quick speed throughout its pen, was standing, or lying down. Each lamb could exhibit any of the aforementioned behavior measurements over each of the 10-min observation periods; however, lambs were recorded only once per behavior variable at each collection period. Pen average for each behavioral measurement was calculated by dividing the number of lambs that

Table 1. Percentage of feedstuff in the supplemental diet (DM).

Feedstuff	Percentage
Cracked corn	42.0
Dry distillers grain with solubles	53.8
Soybean meal	3.0
Ammonium chloride	0.2
Calcium carbonate	1.0

.exhibited the behavior by the total number of lambs in the pen and multiplying by 100; this was done to determine the percentage of lambs that exhibited each behavioral measurement at each observation time.

Statistical Analyses

The experimental design of the study was a 2 × 2 factorial design, and performance measurements were analyzed using the PROC MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.) with pen of animals considered as the experimental unit, pen (treatment) as the error term, and year the random effect. Sire (pen) was added in the random statement to remove sire variation. Three pre-planned, orthogonal-contrast statements were used: 1) the mean of fenceline weaning compared with the mean of traditional weaning; 2) the mean of AM weaning compared with the mean of PM weaning; 3) and their interactions. Treatment means were reported as least squares means.

Behavioral measurements were analyzed using the PROC MIXED procedures for repeated measures of analysis of variance with group of animals considered the experimental unit and observation time considered the repeated measurement. Year was considered the random effect and pen(treatment) as the error term. The same orthogonal contrast statements for performance measurements were used to evaluate behavior. If a treatment × time interaction was observed then means were separated using an F-protected *t*-test, and all treatment means were reported as least squares means. If no treatment × time interactions were observed, then only main effects were tested.

Results and Discussion

Lamb mortality was not observed over the 14-d weaning period for any treatment. Weaning weight, final weight, ADG, and total gain for the duration of the 14-d weaning period did not differ ($P \geq 0.88$) across treatments (Table 2). Similar results were observed in crossbred-tropical hair lambs (72 d of age) that were weaned using restricted suckling mechanisms (Orihuela et al., 2004). In cattle, Ness et al. (2012) reported comparable findings for weaning weight and 14-d weight; however, PM and fenceline weaned calves had greater ADG and total gain over the weaning period compared with AM and traditional weaning. Similarly, comparing fenceline with traditional weaning in cattle, others (Price et al., 2003; Boyles et al., 2007) have reported an increase in animal performance. Also, PM weaning has been reported (Ogunbameru et al., 1992) to positively impact pig performance with PM weaned pigs having increased ADG compared with AM weaned pigs; however, similar results in sheep were not detected in the current study. In a study with weaned Targhee and crossbred-wool lambs, McClure et al. (1994) evaluated the effects of dietary treatment on post-weaning performance. Lambs assigned to the drylot treatment had access to a 13.9 percent CP (as-fed) all-concentrate diet and lambs on pasture treatments had access to either ryegrass (*Lolium perenne*), orchardgrass (*Dactylis glomerata L*), or alfalfa (*Medicago sativa*) pastures ranging from 22 percent to 29 percent CP as-fed. Authors reported that lambs offered the all concentrate diet had higher end BW, ADG, and total gain compared with lambs grazing pasture treatments. In our study, performance in newly weaned lambs was similar between pasture (with grain-based supplement) and drylot (with hay and grain-based supplement) weaning strategies.

Fenceline-weaned lambs vocalized more ($P < 0.01$) compared with traditional weaned lambs; however, percentage of lambs vocalizing did not differ ($P = 0.56$) from AM compared with PM (Table 3). Oriheula et al. (2004) reported fenceline-weaned lambs vocalized more compared with alternative restricted suckling weaning strategies; similar behavior was observed in our study. In their study, fenceline weaned lambs continue to vocalize until d 3, whereas, other treatments stopped vocalizing by d 2. In contrast, Ness et al. (2012) reported that the percentage of calves vocalizing was greater from traditionally weaned calves compared with fenceline-weaned calves and calves weaned in the AM vocalized more compared with PM-weaned calves. Weaning treatment had no effect ($P \geq 0.13$) on the percentage of lambs walking rapidly, running, standing, or lying down during the 10-min observational period, which disagrees with previous work completed on cattle (Price et al., 2003). In that

Table 2. Performance by spring-born Katahdin lambs weaned in the morning or evening using either fenceline or traditional weaning strategies.

	Treatment[a]					
Item	FAM	FPM	TAM	TPM	SEM[b]	Contrast[c]
Weaning BW, kg	22.0	22.0	22.0	22.2	3.69	NS
Final BW, kg	24.9	24.9	25.0	24.7	4.89	NS
ADG, kg	0.19	0.21	0.21	0.19	0.088	NS
Total wt. gain, kg	2.7	2.8	2.9	2.6	1.23	NS

[a] FAM = Fenceline AM; FPM = Fenceline PM; TAM = Traditional AM; TPM = Traditional PM.
[b] SEM = Pooled standard error of the mean.
[c] Contrast: NS = No significant difference ($P > 0.05$). The three pre-planned orthogonal contrast statements were: 1) the mean of fenceline weaning compared with the mean of traditional weaning; 2) the mean of AM weaning compared with the mean of PM weaning; 3) and their interactions.

Table 3. Behavioral measurements by spring-born Katahdin lambs weaned in the morning or evening using either fenceline or traditional weaning strategies.

	Treatment[a]					
Item	**FAM**	**FPM**	**TAM**	**TPM**	**SEM**[b]	**Contrast**[c]
Vocalization, %	33	28	19	13	5.6	W
Walking rapidly, %	2	6	1	1	2.3	NS
Running, %	7	0	0	0	5.4	NS
Lying down, %	38	21	44	35	8.5	NS
Standing, %	80	92	87	83	5.1	NS

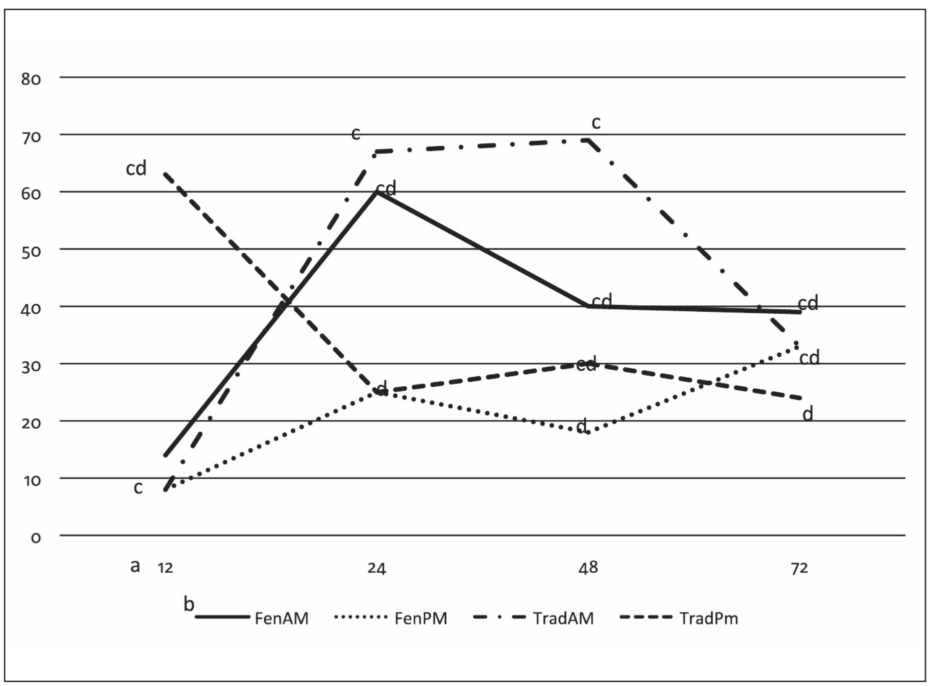
[a] FAM = Fenceline AM; FPM = Fenceline PM; TAM = Traditional AM; TPM = Traditional PM.
[b] SEM = Pooled standard error of the mean.
[c] Contrast: W = Mean of fenceline weaned lambs compared with the mean of traditional weaned lambs ($P < 0.01$); NS = No significant difference ($P > 0.05$). The three pre-planned orthogonal contrast statements were: 1) the mean of fenceline weaning compared with the mean of traditional weaning; 2) the mean of AM weaning compared with the mean of PM weaning; 3) and their interactions.

study, fenceline weaned calves walked 73 percent less and laid down 19 percent more compared with traditionally weaned calves on pasture or in a drylot (Price et al., 2003). However, Boland et al. (2008) and Ness et al. (2012) reported no differences in standing and lying down between fenceline and traditionally weaned calves. A time effect was detected ($P < 0.01$) with lambs vocalizing more at 12 h (41 percent) and 24 h (30 percent) h compared with 48 h (14 percent) and 72 h (7 percent) h (data not shown). Galeana et al. (2007), while not measuring lamb vocalization, did observe that the number of ewes in proximity to a barrier fence in fenceline-weaned animals decreased significantly after 72 h in comparison with 24 h. Our findings agree with work in cattle by Stookey et al. (1997), who reported that calves vocalized more on d 1 and d 2 of the study compared with d 4 to d 6 and d 8 to d 10. A treatment × time interaction ($P = 0.04$) was detected for percentage of lambs lying down, with traditional AM lambs lying down more at 24 h and 48 h post-weaning compared with lambs from fenceline AM at 12 h, fenceline PM at 12 h, 24 h, and 48 h, traditional AM at 12 h, and traditional PM at 24 h and 72 h (Figure 1). Therefore, lamb behavior during the weaning period may not be improved by alternative weaning strategies and time of day, contrary to what has been reported in other livestock species. This is possibly due to the gregarious nature of sheep.

Conclusion and Implications

Based on these findings, lamb performance may not be improved when utilizing alternative weaning strategies, such as fenceline or evening weaning; however, alternative weaning strategies may haffect lamb behavior. Considering the advantageous findings in earlier research with cattle that were fenceline weaned in the evening, it appears that sheep respond differently to weaning practices.

Figure 1. Percentage of spring-born Katahdin lambs lying down after weaned in the morning or evening using either fenceline or traditional weaning strategies at 12 h, 24 h, 48 h, and 72 h post-weaning.



[a] FAM = Fenceline AM; FPM = Fenceline PM; TAM = Traditional AM; TPM = Traditional PM.
[b] Behavioral measurements taken at 12 h, 24 h, 48 h, and 72 h post weaning.
[c-d] Means without common superscript differ ($P \leq 0.05$).

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Movements of Domestic Sheep in the Presence of Livestock Guardian Dogs[1]

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Summary

Livestock guardian dogs (LGD) are one of the most effective methods available to reduce depredation on livestock. The purpose of this study was to determine if the presence of LGD changes grazing behavior of domestic sheep in an environment where predators are common. Western white-face ewes (n = 560) with attending lambs were used. Ewes were 32 d and 45 d postpartum and familiar with LGD. Ewes were divided into four groups (n = 140). Within each group, 12 to 18 ewes were randomly selected to be fitted with GPS tracking collars, which were programmed to collect and record the ewe's location and velocity at 1-s intervals. In random order, each group was assigned to graze with two LGD present for a 2-d trial period and then graze without LGD present for a 2-d trial period or vice versa. A LGD Presence × Day of Trial interaction was detected ($P < 0.05$). On Day 2 of the trial, ewes grazing with LGD present traveled farther than ewes grazing without LGD present (8,210 ± 571 m vs. 6,797 ± 538 m, respectively; $P = 0.04$). No other differences were detected. This study demonstrated that ewes grazing with accompanying LGD will travel greater daily distances compared with ewes grazing without LGD accompaniment. As a result of traveling greater distances, ewes may also be exposed to more and varied foraging opportunities.

Key Words: Behavior, GIS, GPS, Guardian Dog, Predator, Sheep

Introduction

Increasing predator populations on rangelands in the United States have resulted in a concomitant increase in livestock depredation (USDA, 2000, 2001, 2010, and 2011). The National Agricultural Statistics Service reported livestock depredation resulted in losses of $16.5 million in 1999 for the sheep and goat industries and $51.6 million in 2000 for the cattle industry. Over the last 10 years, annual costs related to depredation almost doubled, with economic losses estimated at $20.5 million in 2009 for sheep and $98.5 million in 2010 for cattle. While direct death and injury losses of livestock to depredation is of primary importance for producers, stress induced in livestock exposed to depredation threat is also a substantial concern. Stress may adversely impact livestock health and productivity, including stress-reduced livestock weaning weight, decrease in overall animal health, and increased proportions of unusable meat (Grandin, 1989 and 1997). Chronic exposure of livestock to depredation threat, consequently, may adversely impact ranch profitability. Livestock producers throughout the United States have invested in livestock protection strategies to mitigate economic losses due to predation (Berger 2006; Rashford et al., 2010).

For sheep (*Ovis aries*) producers, livestock guardian dogs (LGD) are often the most effective and affordable method for substantially reducing predation (Black, 1981; Coppinger et al., 1983; Andelt, 1992, 1999; USDA, 1994; Rigg, 2001; Hansen et al., 2002; Marker et al., 2005). Not addressed in studies investigating the utility of LGD as predator deterrents for sheep flocks, was an analysis of sheep behavior (e.g., movement) in the presence of LGD. Such analysis can be informative from both an animal behavior and livestock production perspective. The objective of this study was to evaluate whether the presence of LGD affected daily distance traveled or percent time spent traveling by domestic sheep that were grazing sagebrush steppe rangelands.

Materials and Methods

Study Area

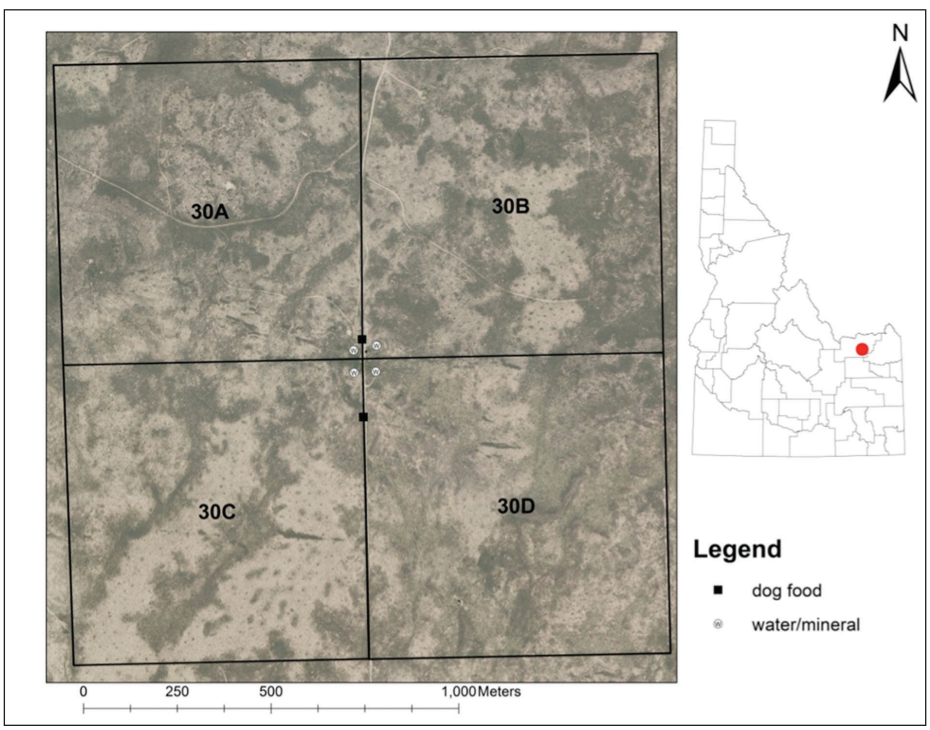
The study was conducted at the Range Sheep Production Efficiency Research Unit (RSPER) Headquarters near Dubois, Idaho. At the time of the study, the RSPER maintained approximately 3,000 adult sheep (Rambouillet, Targhee, Columbia, Polypay, Suffolk, and crossbreeds) with additional attending young (Dr. J. B. Taylor, personal communication). Throughout the year sheep are grazed, with attending LGD, on various sagebrush steppe and forested rangelands, and are exposed to predation threats by black bears (*Ursus americanus*), mountain lions (*Puma concolor*), grey wolves (*Canis lupus*), and coyotes (*Canis latrans*) that frequent the grazing areas (Kozlowski, 2009).

The study area (259 ha) was located at approximately 1,670 m elevation on the RSPER headquarters property near Dubois, Idaho (lat. 44°13’24”, long. 112°11’03”). This area was surrounded and cross-fenced with 2-m high predator-proof fencing, forming four 65-ha pastures in a 2 × 2-grid, resulting in 4 pastures free of predators (Figure 1). Sheep watering and mineral-supplement locations for each pasture were near the center of the 2 × 2 grid. Topography is gently rolling with slopes ranging from 0 percent to 20 percent and averaging about 4 percent. The plant community in each pasture is dominated by three-tip sagebrush (*Artemisia tripartita*) and bluebunch wheatgrass (*Psuedoroegenaria spicata*). Annual forage production was similar among the four pastures and estimated at 144 animal unit months (AUM) for each pasture. Except for the year of the study, the pastures were managed similar to adjacent pastures and in accordance with RSPER grazing management plan.

Animals, Treatment Assignment, and Data Collection

The use of GPS technology and radio telemetry (Shivik et al., 1996) to map and analyze animal activities is common (Morehouse, 2011), and results from Johnson and Ganskopp (2008) demonstrated a positive relationship between the frequency of positional data collection and the accuracy of animal activity measurements. Subtle changes in activity may need more frequency in

Figure 1. Map of four pastures (65 ha each), located at the Range Sheep Production Efficiency Research Unit near Dubois, ID. Pastures were enclosed with predator-proof fencing and used for sheep behavioral trials investigating the effects of livestock guardian dog (LGD) presence on the daily distance traveled by sheep grazing sagebrush steppe rangelands. Water/mineral supplement and dog food locations are marked.



sampling intervals; therefore, we used 1-s sampling intervals.

The study flock consisted of 560 mature ewes with suckling lambs (Targhee, Columbia, Polypay, or crossbreeds of these breeds), which is about 19 percent of the RSPER adult population. All procedures relating to sheep care, handling, and well being was reviewed and approved by the RSPER Institutional Animal Care and Use Committee. Ewes were between 32 d and 45 d postpartum when placed in the study pastures. Ewes were experienced with LGD, and prior to the study, ewes had been continuously managed with them throughout most of the year. Ewes and attending lambs were randomly assigned to 4 groups (Groups 1, 2, 3, and 4) of 140 ewes each. Groups were studied in specific trial periods called Trials 1, 2, 3, and 4, which are described in more detail below and presented in Table 1. Groups 1 and 2 were used during Trials 1 and 2 and Groups 3 and 4 were used during Trials 3 and 4. During each trial, groups were placed in diagonally adjacent pastures, 1 group with 2 LGD (an Akbash and an Akbash/Great Pyrenees cross) and 1 group without LGD. At the end of each trial, groups were moved to opposing pastures, and the LGD were placed with the previously unaccompanied group of sheep. Following Trial 2, ewes and lambs were removed from the pastures and the experiment was replicated with the remaining 2 groups of sheep, Groups 3 and 4, utilizing the same LGD. Throughout the course of this study, ewes were provided *ad libitum* access to water and mineral supplements. LGD were also provided *ad libitum* access to water (shared with the sheep) and dog food.

A random selection of ewes from each group were fitted with GPS tracking collars, (n = 12, 18, 12, and 18, respectively for Groups 1, 2, 3, and 4). The somewhat disproportional sampling design was due to logistical difficulties experienced as ewes were collared and placed in pastures. The average age of collared ewes was 2.6 yr (SE = 0.10). Two GPS collar types were distributed between each set of Groups and later determined to be distinguishable by their level of positional accuracy. Horizontal positional accuracy for collar type #1 was ± 4.45 m at 95 percent CI. Horizontal positional accuracy for collar type #2 was ± 3.56 m at 95 percent CI. All GPS collars were programmed to collect and record the collared ewe's location and velocity at 1-s intervals during the trials. The date and time of each location record, along with additional quality parameters such as the number of GPS satellites used to calculate the location, were also recorded.

Table 1. Livestock guardian dog (LGD) treatment and pasture assignments for sheep groups in trials conducted at the Range Sheep Production Efficiency Research Unit near Dubois, ID.

Test Period	Trial	Start Date	End Date	Sheep Group	Pasture[1]	LGDs
1	1	4/29/2010	4/30/2010	1	30D	Present
1	1	4/29/2010	4/30/2010	2	30A	Absent
1	2	5/2/2010	5/3/2010	1	30C	Absent
1	2	5/2/2010	5/3/2010	2	30B	Present
2	3	5/6/2010	5/7/2010	3	30A	Present
2	3	5/6/2010	5/7/2010	4	30D	Absent
2	4	5/9/2010	5/10/2010	3	30B	Absent
2	4	5/9/2010	5/10/2010	4	30C	Present

[1] Refer to Figure 1 for map of pasture layout.

Each trial was 2 d (48 h) in duration (Table 1) and was immediately preceded by a 12-h pretrial period during which ewes and attending young were moved into the trial pastures and allowed to explore and acclimate to the pasture environment. Trial 1, involving Groups 1 and 2 began on 29 April, 2010. Group 1 was accompanied by 2 LGD and placed in the southeast pasture (30D; Figure 1), Group 2 was not accompanied by LGD and placed in the diagonally-opposed pasture (30A) to minimize or eliminate interaction between groups. Trial 2 began on 2 May, 2010 involving Groups 1 and 2. Before the trial and pretrial acclimation period, Group 1 was moved to the southwest pasture (30C) and Group 2 was moved to the diagonally-opposed pasture (30B). The LGD were moved from pasture 30D and placed in pasture 30B with sheep Group 2. At the end of Trial 2, the GPS collars from sheep Groups 1 and 2 were removed, GPS data were downloaded to a computer, collar batteries were replaced, and the collars were then placed on ewes in Groups 3 and 4. Trial 3 began on 6 May, 2010, with Group 3 in the southeast pasture (30D) (LGD absent), and Group 4 placed in the diagonally-opposed pasture (30A) (LGD present). Trial 4 began on 9 May, 2010 with Group 3 in the southwest pasture (30C) and Group 4 in the diagonally-opposed pasture (30B). The LGD were placed with Group 3 in pasture 30C; Group 4 did not have LGD present for this final trial. Consequently, the experiment was repeated during 2 test periods in which Period 1 included Trials 1 and 2 and involved sheep Groups 1 and 2, while Period 2 included Trials 3 and 4 and involved sheep Groups 3 and 4. The LGD treatment assignments were reversed between Period 1 and Period 2 to allow separation of LGD and Period effects.

Data Processing and Analyses

Data were downloaded from the GPS collars and imported into a spreadsheet for error checking. Errors caused by GPS low-battery conditions, power interrupts, signal loss, and multi-path interference effects were detected and removed using the following procedure. First, an initial screening was conducted to identify and remove corrupted data, which were readily recognized as strings of random characters instead of numeric positional data. Second, geospatial consistency testing was applied by importing the screened data as point features into a GIS and projected into Idaho Transverse Mercator (IDTM) NAD83 coordinate system. These point vectors were overlaid on a GIS layer representing the boundaries of the study site pastures. Points falling outside the perimeter of the study pasture and at a distance greater than the GPS horizontal accuracy for that particular collar type were tagged as erroneous and removed from the data set. On average only 0.27 percent of the points from each 2-d (48-h) trial were removed due to this error. The data from within the study pastures were classified into stationary (< 0.09 m/s) or non-stationary (moving). Speed measurements used were determined from outputs calculated by the GPS units, using Doppler shift and positional change calculations (Townshend et al., 2008). The third error-removal process used GIS to convert the time-stamped positions or point features from each sheep into a line feature representing the movement path of the sheep. Because all GPS data contain some amount of positional error, the GPS positions collected from a completely stationary collared animal will tend to wander about rather than all the positions falling on the single, true stationary location of the animal. To minimize the number of these erroneous positions, each line was simplified by removing line vertices that were within 1 m of the preceding vertex. This distance threshold value was selected because it was well within the known accuracy of the GPS chipsets and thereby removed erroneous positions, while preserving actual movement observations. The intended result of this line simplification procedure was to remove most of the positions or vertices of stationary animals except for the initial position, when the animal first became stationary. Removal of these stationary positions, which were extraneous, would thus prevent the GPS error associated with these positions from inflating the recorded movement budget and daily travel distance for the animal. The length of each simplified line was recorded as the daily travel distance, in meters, for each collared sheep.

Preparation of data for percentage time spent in each speed class (stationary or non-stationary) required a final error-removal step, whereby data describing unrealistic speeds (> 9 m/s) were identified and removed. The maximum number of points removed at this step was < 200 (0.23%) per daily collection period (n = 86,400).

Statistical Analyses

The treatment effect of LGD presence on daily distance traveled and the percentage time spent moving by domestic sheep was analyzed using a mixed linear model procedure (Baayen et al., 2008; Littell et al., 1998; Singer, 1998) within SAS PROC MIXED (SAS Software v. 9.2; SAS Inst. Inc. Cary, N.C.; SAS, 2011). Both the daily distance-traveled model and the percentage-time-spent-moving models included LGD presence, Day of Trial, Collar Type, and all their interactions as fixed effects and Period as a random effect. Individual sheep were considered the sample units or subjects in both models. The interaction of Trial and Day of Trial was used as the repeated measure term in both models. In both models, Shapiro-Wilk tests indicated the model residuals met normality assumptions. Mean separations were accomplished using a Tukey-Kramer adjustment to account for unequal sample sizes. All differences reported in this article were significant at $P < 0.05$.

Results and Discussion

Distance Traveled

All data used in the analysis met the Shapiro-Wilk's test of normality ($P > 0.05$). Collar Type was included in the model to account for variation of the 2 types of collars used. Collar Type was found to be significant ($P < 0.05$), while Collar Type × Day of Trial, Collar Type × LGD, and Collar Type × Day of Trial × LGD were not significant ($P = 0.84$, 0.89, and 0.99, respectively). The effect of Collar Type was more of a function of technology accuracy/sensitivity rather than an effect on ewe-grazing behavior in the presence or absence of LGD.

Least squares means for distance traveled are presented in Table 2. The effect of LGD and LGD × Day of Trial was significant ($P = 0.04$), but effect of Day of Trial was not significant ($P = 0.97$). Ewes that were grazing with LGD present traveled a greater distance than ewes grazing without LGD present ($P = 0.04$). When considering the interaction, the results further indicated that this difference was mainly a function of Day 2 of the trial. Lack of Day of Trial effect indicated that simply being in the pasture from Day 1 to Day 2 did not determine distance traveled. These results addressed our original question, "Does the presence of LDG affect daily distance traveled by grazing domestic sheep?"

Percentage of Time Traveling

Livestock guardian dog presence ($P = 0.32$), Day of Trial ($P = 0.49$), Collar Type ($P = 0.07$), and corresponding interactions (LDG × Day of Trial, $P = 0.78$; LDG × Collar Type, $P = 0.93$; Day of Trial × Collar Type, $P = 0.78$; and LDG × Day of Trial × Collar Type, $P = 0.39$) did not significantly affect per-

Table 2 Least squares means[1] (SE) of distance traveled (m) by ewes[2] that were grazing rangeland in the absence or presence of livestock guardian dogs[3] (LGD).

	Day of Trial		
LGD	1	2	*Day 1 vs.2 (P-value)*
Absent	7,515 m (495)	6,797 m (538)[y]	0.49
Present	7,517 m (465)	8,210 m (517)[x]	0.44
Absent vs. Present (*P*-value)	1.00	0.04	

[a, b] Unlike superscripts within respective row indicate that means were different ($\alpha = 0.05$).
[x, y] Unlike superscripts within respective column indicate that means were different ($\alpha = 0.05$).
[1] The effect of the LGD × Day of Trial interaction was significant ($P < 0.05$).
[2] Ewes were accompanied by suckling young. Breeds with groups were Targhee, Columbia, Polypay, or western whiteface crossbreeds.
[3] Livestock guard dog breeds were Akbash and an Akbash/Great Pyrenees cross.

centage of daily time that ewes spent traveling vs. remaining stationary. Ewes accompanied by LGDs spent a mean of 27.6 percent of the daily time traveling, which was similar to the mean (25.9 percent) for ewes grazing without LGDs present. Since LGDs are not herding dogs this result was anticipated. A related study (Jensen et al. 2013) suggests the presence of LGDs affects overall flock fidelity, where LGD presence may decrease individual vigilance activity and allow broader pasture utilization. Jensen's study demonstrated flock association decreased with the presence of LGDs suggesting a more dispersed pattern of movement.

These results suggested that the presence of LGD influenced the daily distance traveled by ewes grazing sagebrush steppe rangelands. Ewes traveled farther when accompanied by LGDs than without LGD accompaniment. There are many factors that could help explain this observation: 1. sheep without LGD may remain near areas previously proven safe from predation; 2. sheep without LGD may be trying to remain in close proximity to other sheep (Sibbald et al. 2008) as a safety mechanism (e.g., herd effect); and/or 3. sheep with LGD may be more mobile, as they spend less time being attentive to danger and spend more time grazing and moving.

Exploring ewe-movement speed showed no difference in the percent time ewes spent stationary or traveling relative to the presence of LGD. This is important to note, because while sheep with LGD traveled farther, they did not spend significantly more time travelling. This in turn suggested sheep with LGDs tended to move at higher velocities than sheep without LGDs. However, the data developed for this study cannot support such granularity. Nevertheless, our findings support the hypothesis that sheep with LGD spend less time being vigilant for predators and more time moving, although a more in-depth study needs to be done to determine animal activity budgets. Consequently, the presence of LGD may offer more than just protection for domestic livestock. Their presence may result in less restricted movement and decreased stress. While this study cannot show any direct positive impact on the general health of domestic sheep it does show that sheep behavior (distance traveled) has been altered by the presence of LGD.

Conclusion

Animals grazing in areas with high-predator populations may continually be placed under acute or chronic stress by either direct predation attempts (e.g., pursuit events) or fear memories of predation (Grandin, 1998). This stressful state may have a negative impact on the overall health of livestock, including reductions in weight gain, increased disease susceptibility, and lowered reproductive success. The end result is an economic loss to the rancher and the livestock industry.

This study demonstrated that ewes grazing with accompanying LGD will travel greater daily distances compared with ewes grazing without LGD accompaniment. As a result of traveling greater distances, ewes may also be exposed to more and varied foraging opportunities. The observed changes in movement behavior may result in more effective use of pasture resources. The more effective use of pasture may result in the increase in the net rate of nutrient intake, which could also lead to increase health of the animals. While it is unknown if the animal utilized the varied foraging opportunities presented, this study offers insight into domestic animal interactions that may also help direct future studies.

Research by Grandin (1989, 1997, and 1998) and Coppinger (1983) has changed the way livestock are managed. This study offers another step toward improving the health of domestic livestock, as well as increased awareness of the benefits of LGD. If the presence of LGD is shown to increase weight gains, improve animal health, and increase lamb weaning weights, then the use of LGD will carry increased economic importance to the livestock industry. While currently only speculation, these questions should be investigated in future studies..

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Gastro-intestinal Parasite (GIP) Infestation and its Associated Effects on Growth Performance of Bucks on a Pasture-based Test in Maryland[a]

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Summary

Gastro-intestinal parasite (GIP) infestation is a major problem in sheep and goats and results in substantial economic losses. We investigated the prevalence of GIP infestation and its effects on the growth traits of bucks (n=416) on performance test in Maryland over a 12-week-test period. Out of the total bucks tested, 53 percent did not receive any deworming treatment (RG: resistance group) whereas 47 percent of bucks received one or more anthelmintic treatments (SG: susceptible group). The RG bucks had higher ADG (54.33 g vs 42.92 g; $P < 0.01$), higher body condition scores (BCS: 2.42 vs 2.26; $P < 0.001$) and were less anemic (lower FAMACHA© score (FAM); $P < 0.001$), but had no difference in Fecal Egg Counts (FEC) than SG bucks. Correlations between start-of-test body weight (BW) with FAM (-0.22, $P < 0.0001$), and between end-of-test BW with FAM (-0.24; $P < 0.0001$) were negative. Regression ADG on FAM was negative (-5.99; $P < 0.001$) indicating that an increase of a unit of FAM score could reduce ADG of bucks by 5.99 g. The probability estimates from logistic regression analyses showed that a unit increase in FAM at the start of test, the *z*-score (probability of ranking bucks above average category) decreases by -0.23 and for each unit (kg) increase in start-of-test BW, corresponding probability decreases by 0.04. An understanding of the level of GIP infestation, its effects on performance of bucks and their relationships could benefit the goat industry. Only bucks that ranked high for growth performance and that are resistant to GIP should be considered for breeding.

Key Words: Gastro-intestinal Parasites, Goats, Performance Testing

Introduction

Infestation of gastro-intestinal parasites (GIP) is one of the major problems faced by sheep and goat producers across the world (Baker 1998, Krawczyk and Slota, 2009; Mandonnet et al., 2014). Symptoms of GIP infections in goats may include weight loss, anemia, poor-body condition, rough-hair coat, diarrhea, and could even result in death. In the United States, particularly in the southeastern region, higher incidence of GIP infestation has been reported in sheep and goats (Kaplan et al., 2004; Vanimisetti et al., 2004; Burke et al., 2007). Goat producers suffer substantial economic loss due to high mortality of kid goats, poor animal performance and the high cost of anthelmintic drugs that are used for treating GIP infected animals, particularly, the blood-sucking, barber-pole worm (*Haemonchus contortus*). Chemical control of parasites has been successful to some extent but continued use of anthelmintic drugs has led to the parasites resistance to many drugs (Zajac and Gipson, 2000; Mortensen et al., 2003; Fleming et al., 2006). However, some animals might tend to exhibit more resistance or resilience to GIP infection than others due to their genetic makeup. There is evidence that selection for resistance to intestinal parasites is feasible in sheep (Bishop, 1997; Bishop and Stear, 2003, Vanimisetti et al., 2004, Doeschl-Wilson, et. al., 2008). Beside the fecal egg count (FEC), another technique for estimating GIP parasitic infestation is called FAMACHA©. The FAMACHA technique was developed in South Africa (Van Wyk and Bath, 2002) to provide sheep and goat producers with a tool for improving their management of *Haemonchus contortus* infestation. Animals that are heavily infected with GIP become anemic and can be characterized by pale mucous membranes, particularly visible in the lower eyelid. Thus, the FAMACHA© system is designed to assess animals with clinical anemia by scoring the eye color of individual animals on a linear scale from 1 to 5, due to *Haemonchus contortus* infestation (Kaplan et al., 2004). This technique is widely used in research stations, buck-performance-testing centers and in farmers' flocks to screen animals for worm infestation and rank bucks for resistance to parasites (Burke, et al., 2007; Nadarajah et al., 2013). Other indirect measures to quantify GIP infestation may include packed-cell volume (PCV) in blood samples, body condition (from thinness to fatness) and hair coat (smooth/shiny to rough coat) of individual animals.

The objective of this study was to investigate buck's resistance/resilience to GIP infestation and its effects on performance traits of bucks that completed an annual buck-testing program carried out across six years (2009 to 2014) at the Western Maryland Research and Extension Center (WMREC). The aim of this project was to focus especially between animal variations for growth and GIP infestation through analyses of individual-animal records collected through the aforesaid performance-testing program.

Materials and Methods

Since 2006, the performance testing of young meat-goat bucks at WMREC has been carried out as an annual research and extension-program component during summer months (from early-June until mid-September) under a common environment. Each year, several meat-goat producers, who were interested in the buck-performance-testing program from the eastern United States, would enter an average of 60 to 70 young bucks of any breed or cross-breed types into the performance-testing program. The purpose of the buck-performance test is to evaluate the post-weaning growth performance of young male goats on a pasture-based diet that is typical of Mid-Atlantic goat-production systems. However, starting in year 2009, a much more organized and expanded data-collection process was put in place. Also, for the first time, effective from test year 2014, the test was modified so that bucks on test received a supplemental feed of pelleted soybean hulls during the second half of the test. At the end-of test, based on individual performance of bucks for average daily gain (ADG) and FAMACHA© scores (FAM), bucks were ranked, and top performers were recognized.

For the current study, we used the data from the WMREC buck-performance tests carried out during the past six years (2009 to 2014). Bucks entered into the test program each year were assumed to be a representative sample of that region. Because the bucks in test groups consisted of several breeds, such as Kiko, Boer, Spanish, and their crosses or unknown crosses, all bucks were referred to as " meat-goat bucks," with no reference to breed. Unfortunately, the lack of pedigree information on individual bucks in the data sets was the limiting factor for estimating any genetic (co)variances from the data.

Individual-animal-performance records of 416 bucks on test were used for this investigation, which included body weights (BW) at start-of test and end-of test, ADG, FAM score, fecal-egg counts (FEC, number of eggs/g feces), body condition score (BCS) and hair-coat scores (HCS) at start of test and thereafter every 2 weeks until the end of the 12-week-test period, over the six years of tests data. The BCS and HCS scores were assigned by an experienced test manager (same person) in all years. All bucks entered on test, regardless of the infestation levels, received an initial anthelmintic treatment for GIP infestation (de-wormers from 2 to 3 anthelmintic classes, namely, benzimidazoles, macrocyclic lactones, and nicotinic agonists) at the start of test. Thereafter, in subsequent scorings, goats with FAM scores of 1 or 2 did not receive any deworming treatments and were assumed to be resistance to GIP. All other bucks that had FAM scores equal to 3 (except a few based on a five-point checks: eye, jaw, back, tail and nose by test manager) and those greater than 3 anytime during the test period received deworming dose based on BW with either levamisole or moxidectin. At each sampling of feces, individual-animal-fecal samples were used to determine FEC (number of eggs/g feces) using the Modified McMaster technique (Sloss, et al., 1994), while pooled-bulk samples were cultured for larval-species identification (Peña, et al., 2002). Bucks were managed as a single group on pasture and were rotationally grazed among six, two-acre paddocks composed of orchard grass, MaxQ tall fescue, chicory, dwarf pearl millet, forage sorghum, cowpeas, chicory, and natural forbs/weeds along with free-choice minerals. Animals did not receive any supplemental feed, except during high-drought conditions that necessitated the feeding of hay and/or protein tubs. The test bucks always had access to a central laneway containing port-a-hut shelters, mineral feeders, water, a treatment pen, and a handling system. In 2014, a hoop-structure roof was installed over the handling system that provided additional shelter for animals and improved comfort during handling.

Fecal-egg counts were not distributed normally and therefore the FEC records were subjected to log transformations (LFEC) and were tested for normality of data with the univariate procedure in SAS (SAS Inst., Inc., Cary, N.C.) and LFEC, which is computed as ln(FEC+10) was used in the linear model and regression analyses. Means and regression coefficients for LFEC were back transformed in reporting. The standard error (SE) was estimated by assuming the SE on the logarithmic scale was approximately equal to the CV (coefficient of variation) on the actual scale. Between–animal variations were examined from phenotypic means and variations (SD and CV) for traits of interest that were computed using test data pooled over six years. Correlations between measurements of parasitic infestation (FEC and FAM) on individual animals at initial start-of test and end-of test were examined closely to determine how well the subjective FAMACHA scores and a more objective measure of FEC were at predicting the parasitic infestation in goats.

Based on the incidence of GIP-infestation load and subsequent anthelmintic treatments of bucks while on test, following the initial anthelmintic treatment, bucks were assigned to two groups: bucks who did not receive any worming treatment during test period (resistance group - RG) and bucks who received one or more anthelmintic treatments (susceptible group - SG). Across test years, prevalence of GIP in year 2013 was extremely high (more than 90 percent of the bucks received one or more additional anthelmintic treatments) compared to the other test years. In, data pooled over all test years, 53 percent of the bucks (n = 221) did not receive deworming treatment (resistance group – RG) where as 47 percent of the bucks (n = 171) received one or more anthelmintic treatments (susceptible group- SG). Data were analyzed using GLM in SAS to examine differences between RG and SG bucks for performance by fitting a model that included test year, anthelmintic-treatment group, and their interactions with age of buck, as a covariate and residual error. Furthermore, the linear model was extended to compute regression parameters from a multivariate-regression model to study the effects of GIP-indicator traits (FEC, LFEC, FAM, BCS and HCS) on growth performance of bucks (BW at start-of test and end-of test), as well as the ADG of bucks at the end-of test.

Additionally, we examined a statistical model to predict the probability of ranking of bucks at above- or below-average category at the end-of-test. We used the independent-variable measurements of BW, FEC, FAM, BCS, and HCS at start-of test, and our model allowed the assessment of the these variables' influence of ADG, FAM, and FEC variables for animal performance and associated quantitative-risk probabilities. Such information could be used in selecting bucks for future breeding. For this purpose, we used a logistic-probability model (PROC LOGISTIC/PROBIT) in SAS that is designed to use the maximum-likelihood-estimation procedure to obtain the estimates of the model parameters. We specified the initial-performance-test year 2009 as the reference year in the analyses. The logistic/probit regression model is traditionally used to analyze dichotomous or binary outcome variables, where the inverse standard-normal distribution of the probability is modeled as linear combinations of the predictors to obtain estimates of attributes that have an influence or risks on the outcome (Hosmer and Lemeshow, 2000). Here we assumed an individual buck i, belonging to a participating producer, enters into a performance test, with the start-of-test entry date (at time = 0), and has vector of attributes x_i, BW and other independent measurements, including FEC, FAM, BCS, and HCS at the start-of test that could influence an individual animal's performance and eventually the rankings of the buck at the end-of test. The random variable y_i indicates the outcome of an individual buck i (y_i is observed), based on critical cut-off points traditionally used to evaluate bucks for performance for ADG, FAM or FEC at the end-of test, to identify and rank the top 10, 20 or 30 percentile ranks (y_i = 1) or failed-to-rank above average (y_i = 0) at the end-of-test, thereby not making the final selection of bucks for genetic merit. Within each test year, a buck that scored three or more for FAM score and less-than-group mean for ADG was given 0 as a binary outcome. Therefore, the estimate of coefficients from logistic/probit models indicate the change in the probit index, also called z-score (a probability of predictive value) for a one-unit increase in the predictor variable with regards to ranking of bucks on test.

Results and Discussion

The average performance of bucks pooled over six test years is shown in Table 1a. The start-of-test and end-of-test BW for bucks was 19.8 kg ± 4.1 kg and 25.2 kg ± 4.5 kg, respectively. The averages for FEC at the start-of test and end-of test were 934 ± 1950 and 2029 ± 2362, respectively where the SD was larger than the means, indicating a large variability in FEC (CV 111 percent). Means for ADG (48.1 g ± 31.4 g) with the CV of 65 percent among all bucks on test across years was expected and indicate the potential opportunities for

Table 1a. Mean performance of bucks for BW (SD) at start-of-test and end-of-test pooled over six test years from 2009-2014 (n=416).

Item	Start-of Test	End-of - Test	End-of-test: CV
Weight in kg (BW)	19.8 (4.1)	25.2 (4.5)	18%
Fecal Eggs Count/g of feces (FEC)	934 (1950)	2049 (2362)	111%
FAMACHA© score (FAM)	1.9 (0.8)	2.1 (0.9)	43%
Body Condition score (BCS)	2.4 (0.4)	2.3 (0.4)	17%
Hair Coat score (HCS)	2.1 (0.3)	2.0 (0.2)	10%
Average Daily Gain (ADG) in g	-	48.1 (31.4)	65%

selecting young bucks with higher rate of gain for genetic improvement in meat-goat herds.

Across test years, 53 percent of bucks did not receive any deworming treatment (RG group), whereas 47 percent of the bucks received one or more addtional anthelmintic treatments (SG group). In certain test years, for example 2013, the parasitic infestation was very high, and a majority of animals received deworming treatments. The results from across-test-years data from the general linear-model analyses in Table 1b, showed the test-year LS means for starting BW ranged from 17.6 kg to 21.9 kg and ending BW ranged from 23.1 kg to 27.4 kg. The mean age of bucks at the start and end of test were 111 days and 209 days, respectively. At the end-of test (Table 2), RG bucks had higher ADG 54.33 g vs 42.92 g ($P < 0.01$), better FAM (1.75 vs 2.80; $P < 0.001$), lower log FEC (6.93 eggs/g vs 7.09 eggs/g; NS) and higher BCS (2.42 vs 2.26; $P < 0.001$) than SG bucks. The HCS of RG and SG bucks differed slightly (2.1 vs 2.0; $P < 0.01$).

Virginia sheep-breeding research (Vanimisetti et al., 2004) reported that lambs with higher-genetic merit for body weight were more resistant to GIP infection, and alternatively selecting animals for resistance to GIP would improve growth of lambs. In lambs, the heritability estimate for log FEC (LFEC) was 10 percent but in ewes it was 31 percent, and the repeatability estimates for LFEC were moderate for both lambs and ewes.

Phenotypic correlations among performance traits presented in Table 3a indicate the association between start-of-test BW with FAM was negative (-0.22, $P < 0.0001$) and with FEC was also negative (-0.08) but not significant. Positive correlation coefficients were observed between start-of-test BW with BCS (0.55; $P < 0.001$) and HCS (0.28; $P < 0.001$). Correlations between end-of-test BW with FAM (-0.24; $P < 0.0001$) and with FEC (-0.07) showed GIP infestation affected growth and weight gain of bucks. The relationships between end-of test BW with BCS (0.57; $P < 0.0001$) and with HCS (0.19; $P < 0.0001$) were positive and significant. Estimates of correlations between ADG with FEC (-0.18) and with FAM (-0.24) had a negative effect ($P < 0.0001$), whereas BCS and HCS showed positive ($P < 0.0001$) relationships with ADG (Table 3a). Both FEC and FAM were measures to predict GIP-infestation load at start-of test and end-of test, and correlations between them were moderate (0.16 and 0.32) but significant ($P < 0.001$). In an Arkansas study, (Burke et al., 2007) evaluated the effects of gastro-intestinal-parasite-infestation load involving both sheep and goats, reporting a significantly high correlation (r= 0.27, $P < 0.001$) between FAM and FEC. The authors concluded that the FAMACHA techniques could be a valuable tool to identify anemic sheep and goats, and producers could use this technique for monitoring the health management of their flock or herd. In our study, we noticed the FAM had a significant-negative correlation with BCS (-0.23) and with HCS (-0.14) at the start-of test, as well as at the end-of test (-0.22 and -0.11), respectively ($P < 0.001$). Association between FEC and FAMACHA© measures from 627 samples obtained from 20 small-holder-goat farms in Mexico, (Torres-Acosta et al., 2014) reported that although FEC was used to identify goats needing anthelmintic treatment, FAMACHA© was a valuable tool to identify anemic animals but no association was found with animal's FEC. Furthermore, these authors concluded that using FAMACHA© combined with BCS can be more effective as a screening procedure to identify adult animals at risk of high GIP infection.

Estimates of regression parameters in Table 3b, showed that BCS, HCS and age of bucks effected the BW at start-of-test ($P < 0.05$) and FAM, log FEC, BCS and age of bucks influenced the end-of-test BW ($P < 0.05$). Regression ADG on FAM was negative (-5.99; $P < 0.001$) and was positive on BCS (34.99; $P < 0.0001$), indicating that a unit of increase in each of the above respective traits could influence ADG of bucks.

Table 1b. LS means and SE of test years (2009-2014) for Start-of-test and End-of-test weights of bucks entered into performance test.

Test Year	# of bucks entered	Start-of Test BW (kg)	End-of – Test BW (kg)
2009	60	19.5 ± 0.43[a]	25.6 ± 0.51[a]
2010	72	18.3 ± 0.42[b]	26.2 ± 0.51[ac]
2011	80	21.1 ± 0.39[cd]	23.1 ± 0.42[b]
2012	47	17.6 ± 0.50[b]	27.4 ± 0.54[c]
2013	80	20.2 ± 0.36[a]	24.9 ± 0.46[a]
2014	77	21.9 ± 0.41[d]	25.6 ± 0.48[a]

[abcd] Values within each column with different superscripts differ significantly ($P<0.05$)

Table 2. LS means and SE for performance traits of bucks for GIP resistance (RG) and susceptible (SG) groups at the end-of-test.

Items	Resistance Group (RG: n=221)	Susceptible Group (SG: n=171)	P - value
Average Daily Gain (ADG) in g	54.33 ± 2.54	42.92 ± 2.43	<0.0013
Fecal Eggs Count/g of feces (FEC) in Log value	6.93 ± 0.10	7.09 ± 0.10	NS
FAMACHA© score (FAM)	1.75 ± 0.06	2.80 ± 0.05	<0.0001
Body Condition score (BCS)	2.42 ± 0.03	2.26 ± 0.03	<0.0001
Hair Coat score (HCS)	2.09 ± 0.01	2.03 ± 0.01	<0.01
Fecal Egg Count/g of feces (FEC) back-transformed to actual value	1028.33	1202.60	-

NS= Non-significant

Table 3a. Correlation Coefficients among traits and level of significance (*P*-values) at start and end of test.

Test Period	Traits	FEC	FAM	BCS	HCS
Start of Test	BW	-0.08 (NS)	-0.22 (<0.0001)	0.55 (<0.001)	0.28(<0.0001)
	FEC		0.16 (0.001)	-0.01 (NS)	0.05 (NS)
	FAM			-0.23 (<0.0001)	-0.14 (0.005)
	BCS				0.41 (<0.0001)
End of Test	BW	-0.07 (NS)	-0.24 (<0.0001)	0.57 (<0.0001)	0.19 (<0.0001)
	FEC		0.23 (<0.0001)	-0.10 (0.04)	-0.09 (0.04)
	FAM			-0.22 (<0.0001)	-0.11 (0.04)
	BCS				0.22 (<0.0001)
	ADG	-0.18 <0.0001	-0.24 (<0.0001)	0.56 (<0.0001)	0.20 (<0.0001)

NS= Non-significant

The logistic/probit model used to predict the outcome of the probability of ranking of bucks in the top 50 percentiles was a function of the predictor variables BW, FAM, FEC, BCS, and HCS at the start-of test that accounted for across-test-year variations, as a fixed effect in the analyses. The logistic/probit model that we fitted to obtain the maximum likelihood (ML) probability estimates satisfactorily converged at the set-in criteria of 10^{-8}. The likelihood ratio Chi-square of 91.25 with a *P*-value of < 0.0001 indicated that the logistic/probit regression model as a whole fits well to data applied to this model. Furthermore, the Chi-square values for the respective statistical test for the Score (65.15) and Wald (18.82) are asymptotically equivalent tests of the same hypothesis tested by the likelihood-ratio test, indicating that the model was statistically significant ($P < 0.0001$ and $P < 0.05$) for the respective Chi-square values. The Wald Chi-square test statistics specific to individual attributes and associated *P*-values for BW at start-of test (BW: 3.56, $P = 0.059$) and for FAM (FAM: 6.01, $P < 0.05$) significantly affected the end-of-test ranking of bucks based on combination of ADG and FAM, respectively. Other start-of-test measurements (FEC, BCS and HCS) fitted in the model did not significantly affect the outcome ranking of the bucks. The logistic-regression coefficients (Maximum Likelihood [ML] estimates) and their SE, for start-of-test FAM (-0.23, SE= 0.10) and for BW (-0.04, SE=0.02), respectively, were significant ($P < 0.05$). The ML estimates among test years did not influence the ranking of bucks, however, in test year 2013 more bucks ranked below (-5.45) than the average 50 percentile of the ranking of bucks in 2009 (reference test year). Test year 2013 had the highest prevalence of GIP than any other test year during the study and resulted in the death of 11 bucks participating in the study. We conclude from the results of logistic/probit regression analyses that for every one unit increase in FAM at the start-of test the *z*-score (probability of ranking bucks in above-average category) decreases by -0.23, and for every one unit (kg) of increase in start-of-test BW, the *z*-score (probability of ranking bucks in above-average category) decreases by -0.04. The coefficients for the fixed effect of test year have a slightly different interpretation, where a buck that participated in test year 2013, relative to the test year 2009 (set as reference year), will have a much lower chance of ranking above average among all bucks as reflected by the negative *z*-score (-5.45) estimate.

Conclusion

The investigation of the prevalence of GIP infestation in goats and understanding its relationships with goat-production traits may benefit the goat industry and help to develop genetic-evaluation programs based on the GIP prevalence. From a selection point of view, focus should be aimed at identification of those individual bucks that could withstand and exhibit resistance or resilience to GIP, allowing them to maintain optimum levels of production. The present study showed that between-animal variation for GIP infestation and growth performance exists among bucks that completed the test program. Goat producers should take advantage of evaluating potential sires through participation in national- or regional-buck-performance-test programs to select top sires of genetic

Table 3b. Regression coefficients and level of significance (*P*-values) for performance traits and GIP infestation measures adjusted to age.

Traits	FAM	log_FEC	BCS	HCS	AGE
Start-of-test BW in kg	-0.251 (NS)	-0.004 (NS)	6.829 (<0.0001)	1.40 (0.0354)	0.016 (< 0.0001)
End-of-test BW in kg	-0.791 (0.001)	0.466 (0.003)	6.015 (< 0.0001)	0.978 (NS)	0.015 (<0.0002)
ADG in g	-5.987 (0.0004)	-1.487 (NS)	34.991 (< 0.0001)	11.988 (NS)	-0.016 (NS)

NS=Non-significant

merit as breeding animals. Only bucks that rank high for growth performance and that are resistance to GIP should be considered for breeding rather than selection of bucks that need frequent deworming treatment, regardless of their growth performance.

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Effects of Photoperiodic Manipulation on Growth Rate and Ability to Breed Fall-born Ewe Lambs in Spring[1]

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Summary

Effects of photoperiod in winter on puberty and growth were examined in fall-born ewe lambs, 44 Dorset (D) in year 1 and 23 D, 14 Suffolk x D (SD) and 12 Texel x D (TD) in year 2. Lambs were randomized within age, weight, breed and type of birth and rearing, to be exposed to either natural photoperiod (controls) or both natural and supplemental light (evening, ~100 lux at lamb eye-level) to produce a photoperiod of 16 h light:8 h dark for 14 weeks. At completion of supplemental lighting, each treated lamb received an ear implant of melatonin (20 mg s.c.). Lambs were weighed at weaning, light completion and insertion of controlled-internal, drug-releasing devices containing progesterone (CIDR) to synchronize estrus. Serum progesterone was measured at light completion, and one week before and at CIDR insertion. CIDRs were removed and fertile rams introduced for 27 days or 33 days. Pregnancy was determined by transrectal ultrasonography. At light completion, treated ewe lambs had gained 4.7 kg ± 1.6 kg more than controls in year 1 ($P < 0.05$), but 3.2 kg ± 2.2 kg less in year 2 ($P > 0.05$). There was a tendency for more treated than control lambs to have progesterone above 0.3 ng/mL one week before or at CIDR insertion ($P < 0.10$). Estrous response (year 1) and pregnancy rate (56 percent year 1 and 31 percent year 2) did not differ with treatment. At ages tested, photoperiodic manipulation did not hasten puberty or response to progesterone and ram introduction in fall-born ewe lambs.

Key Words: Ewe Lambs, Photoperiod, Pregnancy, Puberty, Season

Introduction

Ewe lambs born in autumn typically reach puberty in the next breeding season (Foster, 1981), while winter- or spring-born ewe lambs reach puberty as early as 6 months to 8 months of age. To maximize lifetime productivity in out-of-season breeding programs, fall-born ewe lambs need to conceive in spring. Foster (1981) reported that placing fall-born Suffolk ewe lambs into a photoperiodic environment simulating that which occurs naturally for spring-born lambs hastened puberty. Blocks of long days at 12 to 22 weeks of age led to normal luteal cycles in fall-born ewe lambs beginning at an age equivalent to spring-born lambs (34 weeks; Yellon and Foster, 1985). Decreasing day length is necessary to initiate puberty in spring-born ewe lambs (Ebling and Foster, 1988). Thus, light sequence is the basis for great differences in age at puberty in ewe lambs in relation to season of birth. Slyter et al. (1997) found that April-born, crossbred-ewe lambs exposed to 16 h to 18 h light during December through February gained more weight during the trial, and a greater proportion became pregnant to April-May breeding the following year (84 percent vs. 57 percent of controls).

Melatonin, which is secreted from the pineal gland during darkness, has been shown to be a key component of regulation of the breeding season and timing of puberty in sheep (reviewed by Foster and Hileman, 2015). Supplemental treatments with melatonin have been used to hasten the breeding season (Nett and Niswender, 1982 and others) and were more effective in fall-born ewe lambs when used following 12 weeks of extended light (Stellflug et al., 1989).

Treatment with progesterone for as few as 5 d and ram introduction at progesterone withdrawal induces fertile estrous cycles in anestrous adult ewes (Knights et al., 2001 a, b), but has not been effective during spring in fall-born ewe lambs. However, Knights et al. (2002) observed an estrous response in 82 percent of fall-born ewe lambs in July after treatment with progesterone for 5 d followed by ram introduction at withdrawal and 25 µg estradiol benzoate 24 h later.

The objectives of the present experiment were to determine if an artificial photoperiod of 16 h light and 8 h dark, in the winter after fall birth, followed by implantation with melatonin will: 1) hasten puberty or the response to progesterone and ram introduction in fall-born purebred Dorset, Suffolk x Dorset and Texel x Dorset ewe lambs, 2) increase weight gain in prepubertal fall-born ewe lambs, and 3) lead to an increased proportion that will become pregnant for fall lambing.

Materials and Methods

Animals and Treatments

The effects of an artificial long photoperiod on hastening puberty in fall-born ewe lambs were examined at a cooperating producer's farm in Aurora, West Virginia (latitude 39.58N, longitude 79.34W, elevation 894 m) beginning in December, 2011 and repeated beginning in December, 2012. The flock had been used for fall lambing studies with progesterone and ram introduction in adult ewes since approximately 2000.

Forty-four prepubertal Dorset ewe lambs born in October and November (year 1; n = 22 control and 22 treated) or 52 prepubertal Dorset, Suffolk x Dorset and Texel x Dorset ewe lambs born in late September through early December (year 2; n = 26 control and 26 treated) were randomized within breed type, age, and type of birth and rearing to one of two groups, control or treated. These ewes were sired by 2 Dorset rams in year 1 and 5 rams (2 Dorset, 1 Suffolk and 2 Texel) in year 2. In year 1, one control and two treated ewe lambs died from apparent enterotoxaemia, and one ewe lamb was found to possess a small vagina, so that proper insertion of a CIDR was not possible. At slaughter, she had a malformed reproductive tract and was therefore removed from the experiment. In year 2, one ewe lamb drowned and two died from probable enterotoxaemia. Forty lambs in year 1 and 49 in year 2 (23 Dorset, 14 Suffolk x Dorset and 12 Texel x Dorset) completed the study.

Control ewe lambs were housed in a 3.7 meter x 18.5 meter section of a barn with exposure to natural photoperiod for a 14-week period. Treated ewe lambs were housed in an 5.5 meter x 18.5 meter section of the same barn, but exposed to an artificial photoperiod consisting of 16 h light:8 h dark for a period of 14 weeks. Treatments were implemented from December 16, 2011 until March 24, 2012, or from December 17, 2012 until March 25, 2013. Mean ages at onset of treatment were 51.6 d ± 1.5 d (7 weeks) and 42.6 d ± 3.5 d (6 weeks) in year 1 and year 2, respectively, and did not differ with treatment. In year 2, breeds differed in average age at beginning of treatment (Dorset 59.2 d ± 5.2 d, Suffolk x Dorset 31.5 d ± 2.7 d, and Texel x Dorset 24.0 d ± 2.8 d). At completion of artificial light treatment, each treated ewe lamb received a silastic implant containing 20 mg of melatonin (Melovine®), subcutaneously in the ear.

The barn was divided by black plastic sheeting (4 mil, Blue Hawk, Poly-America, Grand Prairie, Texas) to prevent control lambs from being exposed to the supplemental light provided to the treated lambs. Light intensity during the supplemental lighting period for the treated group was measured at random intervals throughout the experiment and averaged ~100 lux at ewe lamb eye level, as measured by a Digital Light Meter (LX1010B, Mastech Holdings, Inc., Pittsburgh, Penn.). The farm owner made a change in the barn between years, adding a row of windows on the east side of the barn, which contained the control group. Thus the control group received morning sunlight more intensely during the second than the first year. After the change, light intensity at midday averaged 643 lux in the control section and 600 lux in the treated section of the barn, compared to 600 lux in the middle of each section in year 1.

In the first 5 weeks of the treatment periods, ewe lambs were housed with their dams and wether siblings. Wether lambs were marketed at various times shortly before ewe lambs were weaned. All lambs had *ad libitum* access to a supplemental creep ration (Table 1), and to the second cutting grass hay that was provided to their dams, beginning prior to initiation of the study and continued throughout the light treatment phase. All ewe lambs were weaned from the ewes on January 28, 2012 (year 1; mean age 95 d ± 1.5 d) or on February 16, 2013 (year 2; mean age 104 d ± 3.5 d). After completion of light supplementation, ewe lambs were comingled and received the creep ration daily at a maintenance

Table 1. Creep ration provided to lambs during experiments.

Ingredients Composition	Percent of ration
Corn	64.92
Soy Hulls	16.00
Soybean Meal	14.82
Southern States Sheep Mineral	2.5
Limestone	1.24
Salt	0.45
Sodium Bicarbonate	0.045
TDN	85.1
Cr. Prot.	16.5
Ca++	0.55
P	0.36

level of 0.45 kg, along with free access to native grass pastures.

Growth was monitored, as both weight and age are integral components of puberty (Dyrmundsson, 1981). All ewe lambs were weighed at four time points, including onset of light treatment, weaning, light completion and CIDR insertion (EAZI-BREED CIDR®, Pfizer Animal Health, now Zoetis Animal Health, Kalamazoo, Mich.). Weights were collected on a single day at each point, without alteration of the *ad libitum* access to feed and water.

Jugular venous blood samples were collected at three time points: 1) light completion; 2) 1 week prior to CIDR insertion; and 3) CIDR insertion. Each sample was centrifuged at 4 °C for 20 min at 1,000 x g and the serum was drawn off, placed in a glass vial and frozen at -15 °C. Progesterone was assayed by the RIA method described by Sheffel et al. (1982). The limit of detection was 0.1 ng per mL.

Each ewe lamb was treated to synchronize estrus with a CIDR-G, inserted on May 18 of each year. On May 23, CIDR inserts were removed and intact fertile rams were introduced. Rams had passed a breeding soundness exam prior to introduction. Prior to synchronization, on May 7, 2012 or April 18 or 24, 2013, ewe lambs were shorn and treated for internal parasites. All ewe lambs and four rams were pastured together, thus ewe-to-ram ratio was 10:1 in year 1 and 12.5:1 in year 2. Rams were equipped with marking harnesses bearing crayons to monitor mating (estrous) activity. Rump marks on ewe lambs were recorded for 7 d post ram introduction, only in year 1. Rams were removed on June 19, 2012 or June 25, 2013, thus allowing a breeding period of two opportunities for behavioral estrus (Knights et al., 2001a). Pregnancy was determined by transrectal ultrasonography (Aloka 500 console, 7.5 MHz linear probe; Hitachi Aloka Medical America, Inc., 10 Fairfield Boulevard Wallingford, CT 06492) 25 d after removal of the rams.

Statistical analyses

Lamb weights at each weigh period, within year, were compared between treatments by Students t-test. Concentrations of progesterone at CIDR insertion were classified as above or below the threshold of 0.3 ng/mL reported by Keisler et al. (1983) as an indicator of first ovulation during puberty, and compared by Chi-square with Fisher's exact test (PROC FREQ, SAS Version 9.3). Likewise, proportional data for estrous activity and for pregnancy were examined by Chi-square. Upon inspection of the data, ages and weights varied with breed in year 2. Therefore effects of age and weight groups (less than the mean vs equal to or greater than the mean) on pregnancy rate were examined by Chi square, both within breed and overall. Differences were considered significant at $P < 0.05$.

Results

Growth

Average weights for each treatment at each stage are reported in Table 2. At onset of light treatment, weights averaged 17.8 kg ± 1.1 kg at an average age of 53 d ± 1.5 d in year 1 and 15.3 kg ± 1.7 kg at 43 d ± 3.5 d of age in year 2. Weights differed with treatment only at light termination in year 1, when treated ewes weighed an average of 52.9 kg ± 1.6 kg compared to 48.1 kg ± 1.6 kg for control ewes ($P < 0.05$).

Reproductive performance

Proportions of ewe lambs with progesterone greater than 0.3 ng/mL 1 week before, or at, CIDR insertion did not differ between treated (11/21) and control (14/18) animals ($P = 0.18$) in year 1. However in year 2, more treated ewe lambs (20 /26) had progesterone greater than 0.3 ng/mL 1 week before, or at, CIDR insertion than control lambs (11/24; $P < 0.03$). Data for estrous activ-

Table 2. Weights of ewe lambs (kg) during and after extended light or control treatments.

	Year 1		Year 2	
Stage at weighing	Treated	Control	Treated	Control
Onset of treatment	17.8 ± 1.0	17.7 ± 1.1	15.6 ± 1.8	15.0 ± 1.6
Weaning	35.4 ± 1.2	33.6 ± 1.9	32.4 ± 2.0	34.6 ± 2.1
End of extended light	52.9 ± 1.6[a]	48.1 ± 1.6	46.0 ± 2.1	48.6 ± 2.2
At CIDR insertion	50.5 ± 3.0	47.9 ± 3.2	53.9 ± 9.2	51.6 ± 8.3

[a] Differed from control ewes within year 1 ($P < 0.05$).

Table 3. Estrous response [n (%)] in year 1[a]

Treatment	N	Heavy	Mild	Light	None
Control	21	12 (57)	1 (5)	4 (19)	4 (19)
Treated	18	14 (78)	1 (5)	3 (17)	0 (0)
Overall	39	26 (67)	2 (5)	7 (18)	4 (10)

[a] $P = 0.23$ for differences between control and treated groups.

ity in year 1 were classified based upon the degree of marking on the rumps of the ewes. Treated and control ewes displayed similar responses ($P = 0.23$; Table 3).

Perhaps surprisingly, 11/21 (52 percent) control ewe lambs were pregnant to first service compared to 6/18 (33 percent) in the treated group ($P = 0.33$) in year 1. After a second service period, overall pregnancy rates were 14/21 (67 percent) control and 8/18 (44 percent) treated females ($P = 0.21$). Lambing data for year 1 showed that two treated ewes and no controls lost pregnancy due to fetal death. In year 2, only 4/23 (17 percent) controls and 5/26 (19 percent) in the treated group were pregnant to first service. After a second service period, overall pregnancy rates were 7/23 (30 percent) control and 8/26 (31 percent) treated ewes ($P > 0.05$). Overall pregnancy rates were lower in year 2 than in year 1, but varied with breed ($P < 0.001$), with 13 of 23 Dorsets, 2 of 14 Suffolk crosses (both treated) and none of 12 Texel crosses becoming pregnant. Thus the results for Dorsets (57 percent) were similar overall to year 1 (56 percent), and did not differ with treatment.

Upon inspection of ages of the lambs when they went on treatment, Dorset ewes averaged 51.6 d ± 3.1 d in year 1 and 59.2 d ± 5.2 d in year 2, while the Suffolk x Dorset ewes averaged 31.5 d ± 2.7 d and the Texel x Dorset ewes averaged only 24.0 d ± 2.8 d in year 2. Thus the ages at ram introduction also varied with breed in year 2. When Dorset ewes were divided into those 220 d to 250 d of age (31 weeks to 36 weeks) and those only 170 d to 197 d (24 weeks to 28 weeks) at ram introduction, pregnancy rates for the older group were 7/16 at first service period and 5/9 at second service period for a total pregnancy rate of 75 percent, whereas none of the seven younger Dorsets conceived. The Suffolk x Dorset ewes averaged 190 d of age at ram introduction and the two treated ewes that became pregnant were 181 (first service) and 170 (second service) d of age at ram introduction. The Texel crosses averaged only 182 d (26 weeks) of age at ram introduction.

Weights at CIDR insertion varied with breed in year 2, as would be expected, given the age differences noted above. Dorset lambs averaged 58.5 kg ± 3.0 kg, while Suffolk x Dorset crosses weighed 50.8 kg ± 2.3 kg and Texel x Dorset crosses averaged 45.0 kg ± 2.2 kg. Therefore all ewe lambs, regardless of treatment were divided by weight at CIDR insertion into those equal-to or greater-than the overall mean (49 kg in year 1 and 52 kg in year 2) and those less than the mean. In year 1, 62 percent of the heavy group and 47 percent of the light group of Dorset ewe lambs became pregnant ($P = 0.35$). In year 2, including all three breed groups, 57 percent of the heavier group and only 7 percent of the lighter group ($P < 0.001$) became pregnant after two service opportunities. Within the Dorsets, 61 percent of 18 ewes heavier than 52 kg conceived, compared to 20 percent of 5 lighter weight ewes ($P = 0.13$).

Discussion

Results showed that some fall-born Dorset ewe lambs will breed out-of-season without the aid of artificial photoperiods. However, treatment with 16 h light:8 h dark for 14 weeks, followed by melatonin implants during the period that the lambs were on pasture after the light treatment (March 24 or 25 to end of the study) did not enhance the response of these fall-born ewe lambs to treatment with progesterone for 5 d and introduction of rams on May 23. Breeds that experience a longer breeding season, such as Dorset and Finnsheep, reach puberty at an earlier age than Suffolk or Hampshire breeds (Dickerson and Laster, 1975). As reviewed by Notter (2002, 2012), the Dorset breed is less seasonal than many others and both rams and ewes performed better than other breeds in use of the "ram effect" in May. For a complete discussion of factors that influence the ram effect, see Delgadillo et al. (2009), Hawken and Martin (2012) or Jorre de St. Jorre et al. (2014).

Initial analyses showed a breed-type difference in pregnancy rate in response to progesterone and ram introduction in these fall-born ewe lambs in year 2. Despite the use of an estrous synchronization technique that induced estrus and ovulation in a portion of Dorset-ewe lambs (56 percent to 57 percent became pregnant), only two of the ewes sired by Suffolk rams and none sired by Texel rams from Dorset ewes became pregnant. In several studies, treatments with progesterone and ram introduction, including those that used melatonin feeding to simulate short days (T. Holler and E. K. Inskeep, unpublished) have not been adequate to induce puberty during spring months in blackfaced or crossbred fall-born ewe lambs, although Knights et al. (2002) induced an estrous response in 82 percent of fall-born ewe lambs in July. The Suffolk and Texel breeds are known for shorter breeding seasons that may impact their likelihood of expressing ability to breed out-of-season.

Further analyses of the data revealed that breed was confounded with both age and weight at the time of CIDR insertion. The Dorset ewe lambs that exceeded 220 d of age at CIDR insertion had a 75 percent pregnancy rate in year 2. That age is comparable to the 227-d mean at first estrus observed by Keisler et al. (1983) in spring-born-crossbred, white-faced lambs. In all except two Dorset in year 1 and one Dorset and two Texel x Dorset in year 2, weights at CIDR insertion exceeded the 39 kg at first estrus observed by Keisler et al. (1983). However, lambs that weighed less than the overall mean of 52 kg at CIDR insertion had a lower pregnancy rate in year 2; the effect of weight was not significant in Dorset ewe lambs in either year.

Results in this study did not indicate a value of extended light treatment for 14 weeks, followed by melatonin implants, to improve the response of fall-born ewe lambs to progesterone and ram introduction in May. The equal pregnancy rates in control and treated Dorset ewe lambs contrasts with the conclusion by Foster (1981), based on data in fall-born Suffolk ewe lambs, that ewes must be exposed to a set minimum period of long days before they are able to respond to short days by early pubertal development. Lack of effect of treatments in any breed-type may be a function of the ages of these ewe lambs at treatment. Except for seven Dorset ewes in year 2, lambs in both years were younger than 12-weeks of age when the 16-h light period was initiated.

Yellon and Foster (1985) determined that blocks of long days followed by short days, at 3 weeks to 13 weeks of age, resulted in only a few cyclic animals, but when the block of long days occurred at 12 weeks to 22 weeks of age, normal luteal cycles began at a "normal" age, equivalent to spring-born lambs (34 weeks). Exposure to 16 h to 18 h light during December to February increased the proportion of April-born crossbred ewe lambs raised under range conditions that became pregnant after exposure the following year to teaser rams beginning on April 1 and intact rams on April 15 (for 35 d; Slyter et al., 1997). In the latter study, lambs sired by Hampshire rams from Finn-Dorset-Targhee ewes did not respond as well as Finn-Dorset-Targhee lambs, which fits with the shorter breeding season in the Hampshire breed (Hafez, 1952). Thus one can conclude that both breed-type and age are key variables in determining whether fall-born ewe lambs will respond to extended light in winter or breed in response to progesterone and ram introduction in a given spring month.

There was limited evidence that extended light increased weight gain during the light treatment, based upon greater weights in the treated group of fall-born Dorset ewe lambs at the end of light treatment in year 1. The decrease in weight from light termination to CIDR insertion in year 1 was likely due to the change from confinement to pasture along with a reduction in feed from *ad libitum* to a maintenance ration. Weight was not increased during light treatment compared to controls in year 2, which might be due to the increased morning light seen by the control group in the second year.

Note on alternative marketing

To evaluate alternative marketing of fall-born ewe lambs, those from year 1 were sold at the West Virginia Ram Lamb Performance Test Sale in July, 2012. Prices averaged $341 for ewe lambs pregnant to first service, $350 for those pregnant to second service, and $315 for non-pregnant ewe lambs, ready to be bred in August or September. These sale prices minus added expenses, including feed and transportation, resulted in an estimated net gain of $56.65 per ewe over prices that would have been received from sale for slaughter at earlier ages (prices received for their wether siblings at weaning time).

Conclusion

A majority of fall-born Dorset ewe lambs aged 31 weeks to 36 weeks became pregnant in their first spring season in response to progesterone followed by ram introduction, without the aid of an artificial photoperiod. An extended light treatment during winter, followed by melatonin implants to simulate shorter day length, did not advance puberty or enhance response to progesterone and ram introduction. That failure may have been due to age of the lambs at initiation of treatment, but also may be influenced by the breed composition, compared to reports on Suffolk ewe lambs in the literature. Younger Dorset-, Suffolk-, and Texel-sired, fall-born ewe lambs from Dorset ewes did not have the ability to breed in May seen in older purebred Dorset ewe lambs.

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Effects of Fenceline or Traditional Weaning Methods in Drylot on Performance and Behavior by Katahdin Crossbred Lambs

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Summary

Traditional weaning, characterized by abrupt and complete separation of offspring from their dam, is a common management practice utilized by sheep producers; however, animal performance and behavior may be negatively impacted. Fenceline weaning, an alternative method that has been extensively examined and generally accepted to be effective in cattle, may mitigate the negative effects associated with weaning in sheep. Therefore, our objective was to evaluate the effects of traditional compared with fenceline-weaning methods in drylot, on performance and behavior of Katahdin crossbred lambs. Over two consecutive years, 168 Katahdin crossbred ram and ewe lambs (17 kg ± 0.32 kg initial BW; 74 d ± 4.4 d of age) were stratified within litter size by BW, DOB, and sex and were allocated randomly to one of two weaning treatments: 1) traditional (TRAD) or 2) fenceline (FEN). Lamb BW and BCS were taken on d 0, d 14, and d 43 (year 1) or d 45 (year 2) of the study. Behavioral measurements were taken for 10 min at 12 h, 24 h, 48 h, and 72 h post-weaning. Lamb performance and behavior did not differ ($P \geq 0.28$) between treatments. A time effect was detected ($P < 0.01$) for percentage of lambs vocalizing, running, standing, and lying down. A treatment × time interaction ($P < 0.01$) was detected for percentage of lambs vocalizing with FEN vocalizing more at 12 h compared with all other treatment and time combinations. Therefore, fenceline weaning in drylot may not improve lamb performance and behavior in Katahdin-crossbred lambs.

Key Words: Behavior, Fenceline, Lambs, Weaning

Introduction

Traditional weaning typically involves abrupt separation of ewes and offspring without visual or audible contact and affects lambs twofold by discontinuing social companionship from their dam and eliminating a major source of nutrients (Orihuela et al., 2004; Enríquez et al., 2011). Consequentially, traditional weaning in sheep has been reported to decrease animal performance (Knights et al., 2012) and negatively affect behavior (Orgeur et al., 1998; Orihuela et al., 2004; Schichowski et al., 2008). One alternative is fenceline weaning, which has been extensively examined in cattle and has been reported to improve performance (Price et al., 2003; Boyles et al., 2007; Ness et al., 2012) and behavior (Stookey et al., 1997; Price et al., 2003; Boland et al., 2008; Ness et al., 2012). Under this strategy, offspring and dams are separated with some form of a barrier that prevents the offspring from nursing their dams, but allows for social contact; however, fenceline weaning has not been well-evaluated in sheep. In an earlier study (Backes et al., 2015), our research group evaluated the effects of weaning strategy and time weaning was initiated in spring-born Katahdin lambs and found no improvement in animal performance or behavior in fenceline weaning compared to traditional weaning. However, that study was designed similar to cattle experiments, whereby traditional weaned lambs were maintained in drylot completely separate from their dams while fenceline weaned lambs grazed pasture adjacent to their dams. Therefore, the objective of this study was to evaluate performance and behavior by Katahdin-crossbred lambs using fenceline or traditional weaning in drylot.

Materials And Methods

Animal Management

This study was conducted at the Lincoln University Carver Farm located in Jefferson City, Mo. Animals were raised in accordance with the *Guide for the Care and Use of Animals in Agricultural Research and Teaching* (FASS, 2010), and their care was approved by the Lincoln University Animal Care and Use Committee. Over two consecutive years, 119 Katahdin and Katahdin-Dorper ewes and their Dorper- or Texel-sired, spring-born ram and ewe lambs (n = 168; year 1 = 72; year 2 = 96; 17.0 kg ± 0.32 kg initial BW; 74 d ± 4.4 d of age) were used to determine the effects of weaning strategy on lamb performance and behavior. Four Dorper sires were used in year 1 and four Texel sires were used in year 2. Each year, ewes were lambed on pasture and remained on pasture with their lambs until weaning. In year 1, lambs were born from April 24 to May 10, 2012 and in year 2 lambs were born from April 24 to May 20, 2013. All lambs had access to a dry distillers grain with solubles/corn-based supplemental creep feed (CP = 24.8 percent; NDF = 35 percent; ADF = 7.4 percent; Table 1). Prior to weaning, lambs were stratified within litter size by BW, DOB, and sex into one of six groups per year. At weaning, groups were assigned randomly in replicate to one of two weaning treatments consisting of: 1. traditional (TRAD; n = 6 replications) or 2. fenceline (FEN; n = 6 replications) for a 14-d weaning period. At weaning, lambs were vaccinated for *Clostridium Perfringens types C and D* and *Tetnus Toxoid* (Bar-vac© CD/T; Boehringer Ingelheim, Inc., St. Joseph, Mo.) and dewormed (Cydectin©; Boehringer Ingelheim, Inc., St. Joseph, Mo.). Weaning was initiated at approximately 0730. Traditionally weaned lambs were placed in a 37.2 m^2 drylot completely separated from their dams without audible or visual contact. In a completely separate area, fenceline weaned lambs were also placed in a 37.2 m^2 drylot, but adjacent to their dams. During the weaning period, all lambs had *ad libitum* access to endophyte-infected tall fescue hay ([*Lolium arundinaceum* (Schreb.) Darbysh]; CP = 8.3 percent; NDF = 67.2 percent; ADF = 36.2 percent; IVDMD = 62 percent) placed in a feeder (Sydell, Inc, Burbank, S.D.) that was in close proximity to the boundary fence, water, sheep trace mineral (ADM Alliance Nutrition, Inc., Quincy, Il.), and were offered the same grain-based supplement that was offered prior to weaning at 1 percent BW at approximately 0930 daily. Supplement was placed in a 2.4 m grain feeder (Sydell, Inc., Burbank, S.D.) that was located centrally in the pen. At the end of the 14-d weaning period, lambs were revaccinated, were comingled into one group, and grazed tall-fescue-based pastures without supplementation for a total of 43 d (year 1) or 45 d (year 2) after weaning. Lamb BW and BCS (year 1 only; 1 to 5 scale; 1 = emaciated; 5 = obese; Russel et al., 1969) were determined at weaning (d 0), at the end of the weaning period (d 14) and end of the study. Lamb behavior was evaluated according to Ness et al. (2012). Briefly, each replication was evaluated at 12, 24, 48, and 72 h post-weaning to determine the percentage of lambs that were vocalizing, walking rapidly, running, standing, and lying down during a 10 min observation period. Behavior measurements were taken in the AM prior to feeding and were taken by one of two of the same trained observers each year. Any of the aforementioned behavior measurements could be expressed during the 10 min observation period; however, each animal was recorded once per exhibited behavior measurements. To determine the percentage of animals exhibiting each behavior measurement during each observation time, pen averages were calculated by dividing the number of individuals that exhibited the respected behavior measurement by the total number of individuals in the pen and then multiplying that number by 100.

Statistical Analyses

Lamb performance was analyzed using the PROC MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Group of animals was considered the

Table 1. Percentage of feedstuff in the supplemental diet (DM).

Feedstuff	Percentage
Cracked corn	42.0
Dry distillers grain with solubles	53.8
Soybean meal	3.0
Ammonium chloride	0.2
Calcium carbonate	1.0

Table 2. Effects of fenceline or traditional weaning method in drylot on performance by Katahdin crossbred lambs.

Item	Treatments[a] TRAD	FEN	SEM[b]	P-value
Body weight, kg				
At weaning	16.9	16.7	0.60	0.88
End of weaning	19.5	19.2	1.20	0.70
End of study	22.8	22.5	3.10	0.79
Wean ADG, kg/d[c]	0.18	0.18	0.066	0.91
Wean gain, kg[d]	2.6	2.5	0.92	0.91
ADG, kg/d	0.14	0.13	0.067	0.84
Total gain, kg	5.8	5.7	2.96	0.82
BCS[e]				
At weaning	2.9	3.0	0.12	0.37
End of weaning	2.9	2.9	0.08	0.76
End of study	2.9	3.0	0.16	0.65
Wean BCSch[f]	0.06	-0.09	0.090	0.28
BCSch[g]	0.11	0.01	0.100	0.52

[a] TRAD = Traditional weaning; FEN = Fenceline weaning.
[b] SEM = Pooled standard error of the mean.
[c] Wean ADG = ADG gain over the 14-d weaning period.
[d] Wean gain = Gain over the 14-d weaning period.
[e] BCS = Body condition score; 1 to 5 scale; 1 = emaciated; 5 = obese (Russel et al., 1969); year 1 data only.
[f] Wean BCSch = Body condition change over the 14-d weaning period.
[g] BCSch = Body condition score change over the duration of the study.

experimental unit, year was considered the random effect, and pen(treatment) as the error term. To remove sire variation, sire(pen) was included in the random statement. Significance level was set at $P \leq 0.05$. All treatment means are reported as least squares means.

Lamb behavior measurements were analyzed using the PROC MIXED procedure of SAS for repeated measures of ANOVA. Group of animals was considered the experimental unit and time was considered a repeated measurement. Pen(treatment) was considered as the error term and year the random effect. If a treatment × time interaction was observed, then means were separated using an F-protected *t*-test; however, if an interaction was not detected ($P > 0.05$), then the interaction was removed from the model and only main effects were reported. Significance level was set at $P \leq 0.05$. All treatment means are reported as least squares means.

Results And Discussion

Over the study period, lamb mortality was not observed for any treatment. Lamb body weight at weaning (d 0), end of weaning (d 14), and end of study (d 43 or d 45) did not differ ($P \geq 0.70$) between treatments (Table 2). Average daily gain and total gain over the weaning period and ADG and total gain over the duration of study did not differ ($P \geq 0.82$) between TRAD and FEN weaned lambs. Body condition scores at weaning (d 0), at the end of weaning (d 14), and at end of study and change in BCS from d 0 to d 14 and from d 0 to the end of study did not differ ($P \geq 0.28$) between treatments. Similar results were reported in spring-born Katahdin lambs that were traditionally or fenceline weaned in the AM or PM (Backes et al., 2015) and in crossbred tropical hair lambs that were weaned using restricted-suckling mechanisms (Orihuela et al., 2004). However, in cattle, Price et al. (2003) and Boyles et al. (2007) reported higher gain over the weaning period in fenceline compared with traditional weaning. The advantageous benefits associated with fenceline weaning in cattle may not be evident in spring-born, weaned crossbred-Katahdin lambs, thus possibly indicating species-specific differences associated with the weaning process.

Percentage of lambs vocalizing, walking rapidly, running, standing, or

Table 3. Effects of fenceline or traditional weaning method in drylot on behavior by Katahdin crossbred lambs.

Item	Treatments[a] TRAD	FEN	SEM[b]	P-value
Vocalization, %	23	29	4.3	0.33
Walking rapidly, %	0	0	0.3	0.84
Running, %	2	0	0.8	0.22
Standing, %	88	88	3.6	0.94
Lying down, %	49	43	4.8	0.34

[a] TRAD = Traditional weaning; FEN = Fenceline weaning.
[b] SEM = Pooled standard error of the mean.

Table 4. Time effect for behavior by Katahdin crossbred lambs weaned with fenceline or traditional methods in drylot.

	Observation time[a]				
Item	12	24	48	72	SEM[b]
Vocalization, %	39[c]	27[c]	27[c]	12[d]	4.1
Running, %	6[c]	0[d]	0[d]	0[d]	1.2
Standing, %	98[c]	72[d]	94[c]	88[c]	7.7
Lying down, %	15[e]	63[c]	41[d]	63[c]	6.3

[a] Behavior measurements were observed for 10 min and were recorded at 12, 24, 48, and 72 h post-weaning for each pen.
[b] SEM = Pooled standard error of the mean.
[c-e] Means within a row without common superscript differ ($P < 0.05$).

lying down did not differ ($P \geq 0.22$) between treatments (Table 3). In contrast to our findings, it has been reported that fenceline weaned lambs vocalized more compared with lambs weaned via restricted suckling (Oriheula et al., 2014) or lambs weaned traditionally (Backes et al., 2015). Ness et al. (2012) reported that in cattle, the percentage of calves vocalizing was greater from traditionally weaned compared with fenceline weaned calves. However, Boland et al. (2008) and Ness et al. (2012) reported no differences in standing and lying down between fenceline and traditionally weaned calves. A time effect was detected ($P < 0.01$) for percentage of lambs vocalizing, running, standing, and lying down (Table 4). Lambs vocalized more at 12 h, 24 h, and 48 h compared with 72 h post-weaning. Percentage of lambs running was greatest, and lying down was lowest at 12 h compared with 24 h, 48 h, and 72 h. Lambs were standing more at 12 h, 48 h, and 72 h compared with 24 h. A treatment × time interaction ($P < 0.01$) was detected for percentage of lambs vocalizing with FEN lambs vocalizing more at 12 h compared with all other treatment and time combinations (Table 5). Therefore, it seems that after 48 h post-weaning, lamb behavior associated with weaning is minimal.

Conclusion

Based on these results in Katahdin-crossbred lambs, implementing fenceline weaning relative to traditional weaning in a drylot situation may not be warranted. It seems that breaking of the ewe-lamb bond and subsequent development of a new social hierarchy either with or without fenceline comfort from the dam was not sufficiently meaningful to affect lamb performance or behavior. Consequently, benefits associated with fenceline weaning in cattle were not found with sheep in the present study, suggesting species-specific differences associated with the weaning process.

Table 5. Percentage of Katahdin crossbred lambs vocalizing after being weaned using fenceline or traditional methods in drylot at 12, 24, 48, and 72 h post-weaning.

	Treatment[a]	
Observation time[b]	TRAD	FEN
12	25[de]	52[c]
24	23[de]	30[d]
48	30[d]	24[de]
72	14[e]	10[e]

[a] TRAD = Traditional weaning; FEN = Fenceline weaning.
[b] Behavior measurements were observed for 10 min and were recorded at 12, 24, 48, and 72 h post-weaning for each pen.
[c-e] Means without common superscript differ ($P < 0.05$).

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