Fleece and fiber characteristics of Rambouillet, Targhee, and their reciprocal-crosses at first shearing[1,2]

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INTRODUCTION

The eight states in the Intermountain West contain 33% of U.S. breeding ewes (USDA NASS, 2020), the majority of which are described as finewool or medium wool breed type (73%; USDA APHIS, 2014). Although average wool revenues (7% to 13% of total revenue) are lower than those from lamb in these states (76% to 83%; LMIC, 2016), wool is an important income source for extensively managed operations. Additive breed effects, heterosis, and strategic use of complementary crossbreeding can enhance flock performance. The largest relative improvements due to heterosis are typically seen in lowly heritable traits such as ewe reproductive performance and lamb survival. Because fleece and fiber traits are more highly heritable, heterosis is not expected to be large but depends on the specific breeds/lines contributing to the cross. Additionally, development of skin follicles occurs during gestation and ceases at parturition, so that lifetime wool production can be influenced by in utero maternal effects. Finally, fiber characteristics are heterogenous across the body and this is more sparsely quantified in the literature. The objectives of this study were to investigate heterosis and maternal effects on fleece characteristics at multiple locations across the body in finewool sheep.

MATERIALS AND METHODS

Animals

All sheep were managed at the U.S. Sheep Experiment Station (Dubois, ID). In each of three October mating seasons (2015 through 2017), Rambouillet (R) and Targhee (T) ewes were exposed to rams to generate purebred (R × R and T × T) and reciprocal-cross (R × T and T × R) progeny. A total of 28 R and 31 T rams sired progeny in the present experiment. Seven R and nine T rams sired lambs in 2 yr of the experiment; all others were used for a single mating season. Ewes were bred to lamb at 2 to 7 yr of age, mated in single-sire pens for 21 d, and managed as a single contemporary group thereafter.

Following breeding, ewes were turned out to winter range through early January, then maintained in a feedlot until the end of lambing (March to May). Ewes were fed daily to meet or exceed nutritional requirements for pregnancy and lactation. From May through August, sheep grazed

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sagebrush steppe and sub-alpine forest. Lambs were weaned at 90 to 120 d and maintained on improved pasture through early September. Retained ewe lambs were placed in a feedlot and fed a daily ration formulated to allow an average body weight (BW) gain of 180 g/d. Beginning in mid-October, ewe lambs were exposed to terminal sires for 35 d. Ewe lambs were maintained in a feedlot environment through lambing and fed a ration to meet or exceed nutrition requirements for pregnancy.

Fleece and Fiber Traits

Prior to shearing, 12 × 12 cm wool samples were taken from the midside and britch of each ewe. Shearing took place in mid-February each year and greasy fleece weight (GFW) was recorded. Whole fleeces were then individually cored in a custom-built apparatus (Gerbers of Montana, Inc., Great Falls, MT) consisting of 16 coring tubes (2.2 cm in diameter) that were plunged into and retracted from compacted fleeces by hydraulic cylinders. Midside, britch, and whole-fleece core samples were sent to the Montana Wool Laboratory at Montana State University (Bozeman) to obtain objective measurements of fiber traits.

Cores were split into duplicate 25-g subsamples for each ewe to determine average laboratory scoured yield (LSY; ASTM, 1990) from which clean fleece weight (CFW) was also estimated. Washed midside and britch wool samples and a single washed core subsample were analyzed on an Optical-based Fibre Diameter Analyser 2000 (OFDA; BSC Electronics Pty. Ltd., Attadale, Western Australia) to quantify average fiber diameter (A-FD) and coefficient of variation (CV) of fiber diameter (CV-FD; IWTO, 2013).

Statistical Analyses

A total of 205 R × R, 196 T × T, 34 R × T, and 50 T × R ewe lambs had fleece traits recorded. Greasy fleece weight (n = 484), CFW (n = 476), and LSY (n = 476) as well as A-FD and CV-FD of midside (n = 449), britch (n = 457), and core samples (n = 395) were separately analyzed in the MIXED procedure of SAS (v 9.4; SAS Institute Inc., Cary, NC). The model included fixed effects of sire breed, dam breed, birth type (1 or 2+), age of dam (2 to 4+ yr), and birth year and the random effect of sire (nested within sire breed and birth year). All two-way interaction effects were tested and then removed if they were not significant ($P > 0.05$). Contrasts were generated using the LSMESTIMATE argument to estimate individual heterosis (H_I) and reciprocal-cross differences (i.e., additive maternal breed effects) from least-squares means of the sire breed × dam breed interaction effect.

RESULTS

Fleece Weights and Yield

Ewe birth year influenced all fleece traits ($P < 0.01$), but main or interactive effects involving it are not discussed. The birth type × age of dam interaction was significant for GFW and CFW ($P < 0.01$). Greasy fleece weight was greater for single-born than multiple-born ewes within those gestated by 2-yr-old dams (3.48 ± 0.08 and 3.03 ± 0.07 kg, respectively) and 3-yr-old dams (3.66 ± 0.11 and 3.24 ± 0.05 kg; $P < 0.01$). Similarly, CFW was greater for single-born than multiple-born ewes within 2-yr-old dams (2.11 ± 0.05 and 1.87 ± 0.04 kg, respectively) and 3-yr-old dams (2.25 ± 0.07 and 1.99 ± 0.03 kg; $P < 0.01$). Neither GFW nor CFW was affected by birth type within ewes born to 4-yr-old dams ($P \geq 0.66$). The sire breed × birth type interaction was significant for LSY ($P < 0.01$). Within single-born ewes, LSY was greater for those sired by R than T (62.0 ± 0.60 vs. 59.1 ± 0.58%; $P < 0.01$). However, there was no difference in LSY between sire breeds within multiple-born ewes ($P = 0.17$).

Least-squares means (± SE) for main effects on fleece traits are displayed in Table 1. Overall, single-born ewes had greater GFW and CFW than multiple-born ewes ($P < 0.01$). Greasy fleece weight was greater for ewes born to 3-yr-old dams than 2-yr-old dams ($P = 0.03$), but not different between any other dam ages ($P \geq 0.06$), whereas CFW was greatest for those born to 3-yr-old dams ($P \leq 0.02$). Neither sire nor dam breed influenced GFW and CFW ($P \geq 0.14$). Rambouillet-sired ewes had greater LSY than T-sired ewes ($P < 0.01$); no other main effect influenced this trait ($P \geq 0.09$).

Fiber Metrology

The sire breed × dam breed interaction influenced A-FD at all fleece locations (Table 2) and CV-FD of whole-fleece core samples ($P \leq 0.05$). Average A-FD of reciprocal-cross ewes was greater than purebred ewes within all samples ($P \leq 0.05$), indicating positive (i.e., unfavorable) H_I. However, reciprocal crosses also differed from one another for midside and britch A-FD ($P \leq 0.01$), which

Table 1. Least-squares means (± SE) for main effects of sire breed, dam breed, birth type, and age of dam on greasy fleece weight (GFW, kg), laboratory scoured yield (LSY, %), and clean fleece weight (CFW, kg)

Effect	Level	GFW	LSY	CFW
Sire breed[1]	R	3.35 ± 0.05	61.9 ± 0.41[a]	2.06 ± 0.03
	T	3.31 ± 0.05	60.0 ± 0.38[b]	2.00 ± 0.03
Dam breed[1]	R	3.34 ± 0.05	60.6 ± 0.33	2.02 ± 0.03
	T	3.32 ± 0.05	61.3 ± 0.35	2.04 ± 0.03
Birth type, *n*	1	3.48 ± 0.06[a]	60.6 ± 0.40	2.11 ± 0.04[a]
	2+	3.18 ± 0.03[b]	61.3 ± 0.26	1.95 ± 0.02[b]
Dam age, yr	2	3.26 ± 0.05[b]	61.2 ± 0.38	1.99 ± 0.03[b]
	3	3.45 ± 0.06[a]	60.9 ± 0.38	2.12 ± 0.04[a]
	4+	3.28 ± 0.05[a,b]	60.8 ± 0.32	1.99 ± 0.03[b]

[1]R = Rambouillet, T = Targhee.

[a,b]Means within a column and effect with no common superscript are different ($P \le 0.03$).

Table 2. Least-squares means (± SE) for the interactive effect of sire breed × dam breed and estimates of individual heterosis (H_I) for average fiber diameter (µm) measured on midside, britch, and whole-fleece core wool samples

	Location		
Sire breed × dam breed[1]	Midside	Britch	Core
R × R	21.7 ± 0.17	24.1 ± 0.21	21.7 ± 0.15
T × T	21.6 ± 0.16	22.6 ± 0.21	21.6 ± 0.14
R × T	22.8 ± 0.27[a]	25.2 ± 0.34[a]	22.4 ± 0.25
T × R	21.2 ± 0.24[b]	23.5 ± 0.29[b]	21.8 ± 0.20
H_I[2]	0.34 ± 0.17*	0.97 ± 0.21*	0.42 ± 0.16*

[1]R = Rambouillet; T = Targhee.

[2]$H_I = \left[\frac{1}{2}(R\ x\ T + T\ x\ R - R\ x\ R - T\ x\ T)\right]$

*Estimate of H_I was significantly different from zero ($P \le 0.05$).

[a,b]Means of reciprocal-cross ewes within a column with no common superscript are different ($P \le 0.01$).

indicated a more favorable additive maternal effect for R. Additionally, H_I was estimated to be unfavorable for CV-FD within core samples (0.67 ± 0.23%; $P < 0.01$) but performance between reciprocal-cross ewes did not differ ($P = 0.25$).

Least-squares means (± SE) for main effects on fiber traits are displayed in Table 3. Targhee-sired ewes had finer midside and britch A-FD than R-sired ewes ($P < 0.01$), but ewes born to T dams had coarser midside A-FD than ewes born to R dams ($P < 0.01$). Dam breed did not affect britch A-FD ($P = 0.80$) and neither parental breed influenced core A-FD ($P \ge 0.10$). Ewes born to R dams or sired by R rams had greater britch CV-FD ($P \le 0.03$) but neither parental breed influenced midside or core CV-FD ($P \ge 0.20$). Single-born ewes had lower midside CV-FD than multiple-born ewes ($P < 0.01$). No other main effects were significant in the analyses of fiber metrology ($P \ge 0.17$).

DISCUSSION

Sheep skin contains primary follicles, from which wool, hair, and kemp fibers grow, and secondary follicles that only grow wool fibers. Development of primary follicles begins on the poll and face at approximately 40 d of gestation and progresses posteriorly until approximately 90 d. Secondary follicles develop in a similar fashion, increasing in number at a linear rate from 70 to 90 d until birth (Hocking Edwards, 1999), while fetal size and skin surface area increase at an exponential rate. Therefore, secondary follicle density is lower at posterior regions and is the main reason for observed variation in fiber characteristics across the body. In the present study, A-FD was coarser and CV-FD was greater in britch than midside wool samples, which agrees with studies reviewed by Scobie et al. (2015).

Variation in fiber metrology across the body necessitates sampling techniques that account for whole-fleece heterogeneity. Equipment used in the present study captured such variability, yet its throughput and cost likely make it impractical for use in the field. Past work examining variation in fiber metrology across Merino (Young and Chapman, 1958) and Romney (Sumner and

Table 3. Least-squares means and greatest SE for the main effects of sire breed, dam breed, and birth type on average (A-FD, μm) and CV of fiber diameter (CV-FD, %) for midside, britch, and whole-fleece core wool samples

		Location					
		Midside		Britch		Core	
Effect	Level	A-FD	CV-FD	A-FD	CV-FD	A-FD	CV-FD
Sire breed[1]	R	22.2[a]	17.8	24.6[a]	21.3[a]	22.1	19.7
	T	21.4[b]	17.8	23.1[b]	20.4[b]	21.7	19.9
Greatest SE		0.18	0.23	0.23	0.27	0.16	0.22
Dam breed[1]	R	21.4[b]	17.8	23.8	21.6[a]	21.8	19.9
	T	22.2[a]	17.8	23.9	20.1[b]	22.0	19.6
Greatest SE		0.16	0.20	0.20	0.24	0.15	0.20
Birth type, *n*	1	21.7	17.5[b]	23.9	20.7	21.9	19.6
	2+	21.9	18.1[a]	23.8	21.0	21.9	19.9
Greatest SE		0.18	0.23	0.22	0.28	0.17	0.23

[1]R = Rambouillet; T = Targhee.

[a,b]Means within a column and effect with no common superscript are different ($P \le 0.03$).

Revfeim, 1973) fleeces indicated that A-FD at the upper shoulder or midside were the best indicators of whole-fleece A-FD. Though correlations of fiber traits taken across the fleece were not estimated in the present study, A-FD means were more similar for midside and core samples than britch samples.

Environmental factors that affect the uterine environment of pregnant ewes (e.g., maternal nutrition, etc.) can affect fiber follicle development of progeny. Similarly, reduced fleece weight of twin-born sheep vs. single-born sheep has been documented (Basuthakur et al., 1973; González et al., 1986) and is likely due to greater in utero competition for macronutrients or differences in placental function (Bell and Ehrhardt, 2002). Interestingly, midside CV-FD was also lower in single-born ewes than multiple-born ewes but has not been extensively reported in the literature.

Main effects of sire and dam breed did not affect fleece weights, but had an interactive effect on A-FD. Studies involving maternal crossbreeding systems in Western white-faced sheep have generally investigated the impact of incorporating prolific breeds on reproductive performance. There are fewer evaluations of crosses among finewool breeds and fewer estimates of H_I for fleece parameters. Estimates of H_I for GFW were variable across breed combinations involving meat-type sheep (−1.6% to 17%; Sidwell et al., 1971; Fahmy and Bernard, 1973). Of the dual-purpose breeds evaluated in Sidwell et al. (1971), there was little advantage for fleece and fiber traits (−2.4% to 4%) in Columbia-Southdale × T ewes compared with parental averages.

McGuirk et al. (1978) evaluated Merino, Border Leicester, and reciprocal-cross hoggets and found H_I was positive for GFW, LSY, and CFW (3% to 12%) but insignificant for A-FD. However, there was no evidence of a reciprocal effect (i.e., additive maternal effect) on any wool trait measured. Conversely, Nawaz et al. (1992) found no H_I for GFW in Polypay (P), Coopworth (C), and their reciprocal crosses but GFW was 25% greater for C × P than P × C ewes. Results from this study found no H_I for fleece weights and LSY and unfavorable H_I for A-FD. A consistent additive maternal effect was detected for midside and britch A-FD and indicated more favorable performance for ewes gestated by R dams than T dams.

Fleece and fiber characteristics change as ewes approach mature BW and partition nutrients for gestating and nursing lambs. However, the present study only evaluated wool production at first shearing and it is possible that performance may continue to diverge among breed types as they mature. Future analyses will focus on lamb and wool production of these ewes through 4 yr and serve as a resource for the utility of finewool crossbreeding systems in the Western United States.

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