Comparison of U.S. Fine-Wool Breeds and Australian Merino F1 Crosses: I. Wool Characteristics and Body Weight[1]

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Summary

This study investigated the effects of infusing genes from two dissimilar Australian Merino types [fine-wool (FWM) and strong-wool (SWM)] into different U.S. fine-wool flocks on wool characteristics of resulting first cross (F1) ewes. The F1 ewes were the offspring from U.S. fine-wool ewes in different flocks located in four states (CA, ID, MT, TX) mated naturally or artificially to one of three ram types: FWM, SWM or Texas Rambouillet (RAMB). Identical six rams per sire breed were used to produce the F1 ewes (FWM, SWM and RAMB, respectively) for evaluation of body weight (BW) and wool characteristics at one and two years of age. Body weights were heaviest for ewes sired by RAMB compared with SWM and FWM ewes ($P < 0.05$). Fleece weight, staple length and yield (Y) were significantly increased ($P < 0.05$) by crossbreeding Australian Merino types on U.S. fine-wool ewes. Fleece weights at one and two years of age were greatest for SWM cross ewes ($P < 0.05$). Fiber diameters were 0.5 µm finer in FWM ewes compared to RAMB ewes. Variability of fiber diameters was lower for RAMB ewes than FWM and SWM ewes ($P < 0.05$). Subjective scores for wool face covering and belly wool covering were not very different among the three groups of ewes. However, subjective scores for quantity of skin folds were higher for FWM and SWM ewes compared with RAMB ewes ($P < 0.05$). In conclusion, wool production in U.S. fine-wool breeds can be improved by crossbreeding to selected Australian Merino rams. However, a decision to use this approach should also consider other production parameters.

Key words: crossbreeding, merino, sheep, wool, fiber.

Introduction

The Australian Merino has been subjected to selection pressure for improving wool characteristics (particularly clean fleece weight, staple length, fiber diameter) since the early 1800s. Consequently, the fleece weight in some Australian Merino strains was increased from 3.6 to more than 10 kg (Austin, 1944). Some of the early genetic improvements in staple length and fleece weight of Australian Merinos were attributed to the importation of U.S. Rambouillet and Vermont Merinos starting as early as 1866. In fact, the Australian Peppin Merino strain came to fame shortly after breeding Australian ewes to such well-known U.S. rams as *Emperor* and *Grimes* that sheared fleeces of more than 11.5 kg in 1866 (Austin, 1944). Over time, U.S. and Australian fine-wool sheep diverged in appearance and fleece traits due to selection for different parameters. U.S. breeders have tended to favor a dual-purpose animal while Australian breeders continued to focus mainly on wool traits.

A relaxation in the ban against exporting Australian Merino sheep

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during the 1980s resulted in the availability of Australian Merino genetics to U.S. producers. Previous research (in the 1930s) for improving U.S. wool production by importing and breeding Australian Merinos showed favorable responses in fiber diameter, follicle density and clean fleece weights (Bell et al., 1936). The present study was undertaken to evaluate potential advantages of crossbreeding modern Australian Merinos with U.S. fine-wool sheep.

Materials and Methods

This study was conducted as a multi-institution research project involving four locations: U.S. Sheep Experiment Station (Dubois, ID); Montana State University (Bozeman, MT); Texas Agricultural Experiment Station, Texas A&M University System (San Angelo, TX); and Hopland Research and Extension Center, University of California (Hopland, CA). The research project was designed to characterize wool production, lamb production (Snowder et al., 1998a) and carcass traits (Snowder et al., 1998b) of the offspring from two strains of Australian Merino sheep crossed with U.S. fine-wool sheep. The overall study was conducted between 1988 and 1993. Wool performance was measured on animals born in 1989 and sheared in 1990 and 1991.

Two specific types of Australian Merinos were utilized. The fine-wool Merino is recognized for finer fiber diameters and dense fleeces. The strong-wool Merino is characterized by relatively heavy and high-yielding fleeces and long staple length. Six rams from each strain were selected from many with available frozen semen. The Australian rams were classified into one of the two types based on their own fleece data and the strains of origin. Rams were primarily selected for fleece characteristics representative of their strain (i.e., fiber fineness or clean fleece weight) based upon reported data. Rams with excessive body folds and/or small body size were not desirable and were selected against in the strong-wool Merino types but low numbers of available fine-wool Merino rams did not make this independent culling practical. The six fine-wool Merino rams used in this study ranged in average fiber diameter (AFD) from 17.3 to 23.6 µm and each grew approximately 13 kg of clean wool per year. AFD among the selected strong-wool Merino rams ranged from 24.1 to 28.1µm with annual clean wool production averaging more than 14 kg. In both cases, the data provided in sales catalogues were used to make the selection decision. Frozen semen from each ram was purchased from a international commercial dealer.

Six Rambouillet rams were selected from Rambouillet flocks in Texas. All rams selected had performed well on a central ram performance test (Shelton, 1979) or were derived from flocks that had successfully participated in the test program for a number of years. The crossbred offspring from fine-wool Merino and strong-wool Merino rams were compared with offspring from the selected Rambouillet sires.

Reported data were used to compare sire types for fleece characteristics. Yearling fleece weights and yields of the selected Australian Merino rams were generally superior to those of the selected Rambouillet rams (Table 1). Average clean fleece weight of the fine-wool Merino and strong-wool Merino rams exceeded that of the Rambouillet rams by 84 and 143%, respectively. Percentage yield in the strong-wool Merino rams averaged 78.4%, 50% higher than the Rambouillet rams. AFD of the Rambouillet sires was greater than fine-wool Merino and less than strong-wool Merino sires. However, it should be pointed out that these sire data were not collected under comparable conditions.

Generation of Lambs

Fl ewes were produced by mating the two strains of Australian Merino rams to ewes from two typical U.S. western range breeds, Rambouillet (at three locations) and Targhee (at one location). Crossbred offspring of the Merino rams were identified according to the sire Merino strain [i.e., fine-wool Merino (FWM) or strong-wool Merino (SWM)]. Control ewe populations (RAMB) were established at each location by breeding ewes (Targhee or Rambouillet) to the selected Rambouillet rams.

Six rams of each Australian Merino strain and six Texas Rambouillet rams were bred by artificial insemination or natural matings to Targhee ewes at Hopland (CA) and Rambouillet ewes at Dubois (ID), Bozeman (MT) and San Angelo (TX). Ewe populations at each location were randomly assigned to three groups of approximately equal numbers before breeding. Each ewe was artificially inseminated or naturally bred to a single sire. Age of ewes at breeding ranged from two to six years. The California ewes were bred during June while ewes at other locations were bred in autumn.

Management of Ewes

The management system of each location varied according to routine production procedures. In Idaho, ewes were managed under herded conditions on public lands typical of

Table 1. Mean fleece characteristics of highly selected Australian Merino and Rambouillet rams based on individual reported data.[a]

Sire breed[b]	Grease fleece weight, kg	Clean yield, %	Clean fleece weight, kg	AFD, µm
FWM	14.4	74.3	10.7	20.7
SWM	18.0	78.4	14.4	25.0
RAMB	11.1	52.4	5.8	21.4

[a] These data were not collected under comparable conditions. The data on Australian rams came from advertising material, while the data on Rambouillet rams came from central performance test records.
[b] FWM = Australian Merino fine-wool strain; SWM = Australian Merino strong-wool strain; RAMB = purebred Rambouillet.

western range sheep production. Spring grazing occurred on sagebrush mixed-grass ranges while summer grazing was on high-elevation mountain meadows and forest. In autumn, sheep grazed sagebrush pastures until breeding when they were confined in large open pens with rams and fed approximately 2.3 kg/(head•day) of chopped alfalfa hay and 0.5 kg/(head•day) whole barley grain. After breeding, the ewes were transported to western slope desert mountain ranges for winter grazing. Before lambing, ewes were returned to large open pens and fed a chopped alfalfa hay and whole barley grain diet similar to that at breeding. Ewes remained in the feedlot until shearing which occurred approximately 30 days before lambing. After shearing, pregnant ewes were placed in small feedlots and shed-lambed. At approximately 40 days post-lambing, ewes and lambs were turned out onto spring sagebrush pastures.

Ewes in California were generally managed under pasture-grazing conditions year round. At approximately 10 days before lambing, ewes were moved into the lambing shed and fed 1.8 kg/(head•day) of alfalfa hay. Ewes and lambs were shed-confined after lambing for three to five days and fed approximately 2.7 kg/(head•day) of alfalfa pellets. Post-lambing, ewes and lambs were maintained on subterranean clover and annual grass pastures.

Management of ewes in Montana was similar to that of California. Ewes grazed upland range grasses and forbs year round under fenced pasture conditions at altitudes ranging from 1,402 to 1,889 m. Prior to lambing, ewes were brought into feedlots with ad libitum access to alfalfa hay and supplemented with 0.6 kg/(head•day) of whole barley grain. At approximately 40 days post-lambing, ewes and lambs were returned to upland range grass pastures.

In Texas, ewes were managed on fenced pasture at Brady, TX. Late-autumn grazing was supplemented with access to a salt-limited protein and energy supplement until lambing. At lambing, ewes and lambs were confined in small pens for one or two days before being returned to pasture.

Ewe Body Weight

F1 ewes were weighed before breeding. Because of age differences at weighing, both within and across locations, BW were adjusted to weight on days 365 and 730 for statistical comparisons among sire breeds across locations.

Wool Characteristics

At approximately one year of age, lambs were visually evaluated for face covering, degree of skin folds and belly wool covering. Subjective scores for these variables ranged from 1 to 4 with lower values representing less expression of the trait. Face covering was scored according to Terrill (1949) as follows: "1" = open, wool not extending beyond the poll; "2" = wool covering to the eyes; "3" = wool covering slightly below the eyes but opened face; and "4" = wool covering below the eyes but the eye channel not completely blocked and subject to wool blindness. In Texas, the face cover scores were assigned according to the scale used in the Texas Ram Test (Shelton, 1979). In this case, the "1" score represents sheep with no wool below the eyes. This difference in scoring method resulted in obviously different values (as reported in Table 5), but did not influence the conclusions to be drawn from the breed comparisons.

Wool covering the belly typically contains a different (bolder) type of staple crimp compared to wool at other body locations. It also tends to be finer, shorter and less dense than the rest of the fleece. Belly wool scores relate to the area of belly wool with a score of "1" indicating a small confined area on the ventral side and a "4" representing belly wool extending from ventral to mid-side. Belly wool data were not collected on sheep from Montana. The sheep were not rescored the following year as two-year-olds.

Prior to shearing, a sample of wool of approximately 150 g was shorn from the mid-side of each animal. These wool samples were analyzed for yield (Y), AFD and variation in fiber diameter (CV). The proportion of wool weight represented by clean fibers (Y) was determined at the Montana State University Wool Lab in Bozeman, MT, using a standard method (ASTM, 1993). Subsequently, subsamples from the clean wool samples were sent to the Wool and Mohair Research Lab in San Angelo, TX, for measurement of AFD and CV. The AFD were determined using the Peyer Texlab FDA 200 System (Lynch and Michie, 1976). Clean fleece weight was calculated as the product of an individual ewe's grease fleece weight and estimated clean wool yield. Relaxed staple length was measured by ruler on the live animal at three locations: point of the shoulder, mid-side and hip. The three values were averaged for each animal to derive a mean staple length. Recorded grease fleece weight was the sum of the sheared fleece weight and the weight of fleece sample. Because not all sheep were shorn at the same age, especially as yearlings, fleece weight and staple lengths were adjusted to a 365-day basis (average age at shearing varied from 336 to 404 days among locations).

Statistical Analyses

The statistical analyses were performed using Harvey's Mixed Model Least-Squares and Maximum Likelihood computer program (1990). The experimental design of this project was a nested split-plot. Therefore, Harvey's statistical model 7 was used because it allows analyses of experimental designs with nested effects that interact with a set of cross-classified fixed effects. BW and fleece characteristics were analyzed with fixed effects for sire breeds (FWM, SWM, RAMB) and location (ID, CA, TX, MT). The sire-of-the-ewe effect (n = 18) was considered random, nested within sire breeds and was used as the error term for sire breed effect. The interaction of location by sire within sire breed was used as the error term for the effect of location and the location-by-sire breed interaction. Preliminary analyses suggested that all other first level interactions were not important ($P > 0.10$).

Because most ewes were pregnant at the second shearing (79 to 100%

within a sire breed and location) it was necessary to determine if only pregnant ewes should be included in the statistical analyses. The low number of unbred ewes did not permit statistical testing of differences between bred and unbred ewes within sire breeds. Therefore, preliminary statistical analyses of wool characteristics from ewes that subsequently lambed were conducted to decide whether pregnancy changed the rank or significant differences due to sources of variation using all ewes (bred and unbred). Because most ewes were pregnant there was a large imbalance in the data set with some empty statistical cells. Therefore, it was not practical to use pregnancy status as an effect in the overall model. Least-squares means (LSM) from statistical models using only pregnant ewes and the models including all ewes were compared within sire breeds by Student's t-test. No differences ($P > 0.10$) were found between LSM derived from only pregnant ewes and from all ewes. Therefore, the reported statistical analyses included data from all ewes. Pregnancy has been shown to decrease wool production in the last trimester of pregnancy (Black and Reis, 1979) but its effect in this study could not be adequately determined.

Statistical comparisons of sire breeds were accomplished by contrasting LSM of independent variables using a priori pairwise Student's t-tests. When the interaction of sire breed-by-location was not significant, only the overall means for sire breeds were contrasted.

Because the rams were highly selected within each sire breed, it was of interest to determine differences among sires within their sire breed for wool characteristics. The identity of important differences among rams within a sire breed infers that selection within a sire breed may be as or more important than random selection within a sire breed. This was accomplished by separate statistical analyses for each sire breed. The statistical model for yearling wool characteristics included sire and location as fixed effects. Preliminary analyses suggested the sire-by-location interaction was not significant for wool characteristics. Sire LSM were contrasted within sire breed.

The effect of heterosis on wool production of the crossbred ewes could not be determined because purebred Merino and reciprocal cross populations were not produced. Jones and Napier (1984) found that levels of heterosis between Merino strains for fleece traits were small (0% for fiber diameter, 4% for clean fleece weight). Changes in wool traits resulting from infusion of Merino genes are more likely due to additive genetic effects.

Results and Discussion

The number of ewes varied across years as affected by natural attrition and predation. There were 650 yearling ewes and 563 ewes at two years of age (Table 2). The smaller sample size of the initial RAMB population (n = 175) compared with that of FWM (n = 231) and SWM (n = 245) was attributed to the relatively poor quality of the frozen RAMB semen.

No interactions of fixed effects were significant for BW or wool characteristics; all sire breeds responded similarly across locations ($P > 0.10$). Large differences among locations ($P < 0.01$) were observed for most response variables but are not discussed in detail. Differences among locations were due to many factors that could not be separated for proper explanation. Causes of variation among locations include genetic differences among sheep flocks and differences in management.

Sire breed influenced ewe body weights at both ages ($P < 0.05$; Table 3) with RAMB ewes being the heaviest ($P < 0.01$) and FWM ewes the lightest ($P < 0.05$). Overall, RAMB ewes were approximately 12% heavier than FWM ewes at each age. The average weight of SWM ewes was intermediate to FWM and RAMB ewes ($P < 0.05$). It was determined that the lighter weights of the FWM were not the result of slower growth rates but reflect a smaller mature size. This was inferred from a comparison of lamb carcass characteristics on wethers, half-sibs to the ewes in this study, that showed FWM carcasses were fatter and more physiologically mature than SWM or RAMB carcasses at comparable live weights and ages (Snowder et al., 1998b). In an earlier study, U.S. Merino ewes were 26% heavier than an imported strain of fine-wool Tasmanian Merinos at 2 years of age (Bell et al., 1936).

Wool traits differed among the progeny of the different ram strains (Table 3). Grease fleece weights of FWM and SWM ewes were heavier than those of RAMB ewes ($P < 0.05$). The heaviest fleeces were from SWM ewes and exceeded RAMB fleeces by 15 and 22% and FWM fleeces by 7 and 9% at one and two years of age, respectively. Fleeces from FWM ewes were 8 and 12% heavier compared to RAMB fleeces at one and two years of age, respectively.

Table 2. Number of F1 daughters of Australian Merino and Rambouillet rams by age and location.[a]

	1 year				2 years			
State	FWM	SWM	RAMB	Total	FWM	SWM	RAMB	Total
ID	53	61	39	153	52	61	37	150
TX	55	67	49	171	47	64	43	154
MT	53	45	25	123	44	35	23	102
CA	70	71	62	203	51	62	44	157
Total	231	244	175	650	194	222	147	563

[a] FWM = one-half Australian Merino fine-wool strain; SWM = one-half Australian Merino strong-wool strain; RAMB = purebred Rambouillet (ID, MT, TX) or one-half Rambouillet and one-half Targhee (CA).

The heavier fleeces from SWM crossbred ewes were associated with longer staple lengths (Table 3). It was also visually apparent that ewes from both Merino strains grew fleeces that were more dense than the RAMB ewes. This observation was not quantified. The longest staple lengths were observed in SWM ewes ($P < 0.05$). For yearling ewes, staple length of FWM and RAMB did not differ significantly ($P > 0.10$). However, the average staple length of two-year-old FWM ewes was slightly longer than for RAMB ($P < 0.05$). Staple lengths produced by all sire breeds were considered adequate for marketing as "staple" wool. Bell et al. (1936) also reported longer staple lengths for Australian Merinos compared with U.S. Merinos.

For Y of clean wool fibers, SWM was greater than FWM which was greater than RAMB ($P < 0.05$). Fleeces from FWM and SWM yearling crossbred ewes were higher yielding compared to RAMB fleeces (9 and 15%, respectively). Differences among sire breeds for Y did not change with age (one year old vs. two years old). However, fleeces from two-year-old ewes yielded higher than from yearlings ($P < 0.05$). The efficiencies of cleaning (scouring) and effluent treatment are both increased as clean Y increases. Thus, even though most wool is currently purchased on an clean weight basis, higher yielding wools are increasingly favored by the processing industry. It is also apparent that Y of fleeces from Idaho yearling ewes were considerably lower than those at other locations; this was caused by heavy dirt contamination that occurred between weaning and subsequent shearing when the ewe lambs were in a feedlot adjacent to plowed sandy potato fields subject to frequent strong winds.

Table 3. Least-squares means (LSM) for body weight (BW), fleece weights, yield (Y) and staple length of F1 Australian Merino and Rambouillet-type ewes.[a]

	Yearling ewes			2-year-old ewes		
Trait by location	FWM	SWM	RAMB	FWM	SWM	RAMB
BW, kg						
ID	37.1	38.2	41.5	48.1	50.5	54.8
TX	37.3	37.8	40.2	45.1	46.0	49.3
MT	50.6	54.4	57.6	54.4	54.6	59.9
CA	39.8	41.8	44.7	51.6	54.3	59.0
Overall ± SE	41.2 ± 0.74[b]	43.0 ± 0.74[c]	46.0 ± 0.75[d]	49.8 ± 0.90[b]	51.3 ± 1.00[c]	55.7 ± 1.00[d]
Grease fleece weight, kg						
ID	4.1	4.3	3.7	4.7	5.1	4.4
TX	3.5	4.1	3.6	4.8	4.9	4.1
MT	4.7	5.4	4.5	5	5.5	4.4
CA	4.0	4.2	3.7	4.1	4.3	3.5
Overall ± SE	4.2 ± 0.07[c]	4.5 ± 0.07[d]	3.9 ± 0.08[b]	4.6 ± 0.08[c]	5.0 ± 0.08[d]	4.1 ± 0.08[b]
Y, %						
ID	38.9	45.3	36.1	55.8	58.7	51.6
TX	59.6	58.8	54.1	66.1	68.9	62.1
MT	57.0	59.7	52.1	66.3	69.6	63.9
CA	64.0	67.4	58.8	69	71.9	63.4
Overall ± SE	54.9 ± 0.52[c]	57.8 ± 0.52[d]	50.3 ± 0.58[b]	64.3 ± 0.19[c]	67.3 ± 0.19[d]	60.2 ± 0.20[b]
Clean fleece weight, kg						
ID	1.6	2.0	1.3	2.6	3.0	2.3
TX	2.3	2.4	1.9	3.2	3.4	2.5
MT	2.6	3.0	2.3	3.3	3.8	2.8
CA	2.6	2.8	2.1	2.9	3.1	2.2
Overall ± SE	2.3 ± 0.10[c]	2.6 ± 0.10[d]	1.9 ± 0.10[b]	3.0 ± 0.08[c]	3.3 ± 0.08[d]	2.5 ± 0.08[b]
Staple length, cm						
ID	8.0	8.8	8.1	8.7	9.3	8.6
TX	8.9	9.1	8.7	11.1	11.7	11.0
MT	8.8	9.2	8.8	10.8	11.5	10.8
CA	9.4	10.2	9.2	9.2	9.8	8.5
Overall ± SE	8.8 ± 0.15[c]	9.3 ± 0.15[d]	8.7 ± 0.15[c]	10.0 ± 0.16[c]	10.6 ± 0.16[d]	9.8 ± 0.16[b]

[a] FWM = one-half Australian Merino fine-wool strain; SWM = one-half Australian Merino strong-wool strain; RAMB = purebred Rambouillet (ID, MT, TX) or one-half Rambouillet and one-half Targhee(CA).

[b,c,d] Values with different superscripts in the same row and age group column are different ($P < 0.05$).

Estimated clean fleece weight varied significantly among sire breeds (P < 0.01). Clean fleece weights of RAMB ewes were lighter by more than 20 and 30% compared with the clean fleece weights of FWM and SWM ewes, respectively, at both ages. The SWM ewes had clean fleece weights that were 10 to 13% heavier than FWM clean fleece weights. As previously mentioned, the heavier and higher yielding fleeces of the Australian Merino crossbred ewes were associated with longer staple lengths and greater density of wool follicles. Australian fine-wool and strong-wool Merinos have been reported to have 71.7 and 57.1 fibers/mm^2 (Botkin et al., 1988) compared to 32 to 40 fibers/mm^2 for Rambouillet sheep (Rogers, 1994).

The use of FWM rams resulted in an improvement (a decrease) in fiber diameter of 0.5 µm compared to U.S. fine-wool breeds (Table 4). An improvement in fiber diameter of only 0.5 µm suggests that the difference between the Australian fine-wool Merino and the Texas Rambouillet is now smaller than previously reported (Bell et al., 1936). A plausible explanation for the genetic improvement in fiber diameter of the Texas Rambouillet is that a central ram performance test has been conducted at Sonora, TX, for more than 45 years allowing breeders and producers to identify and select rams superior for *(inter alia)* wool traits (Shelton, 1979). AFD was not reduced by breeding SWM rams to U.S. fine-wool breeds. Measures of AFD for SWM and RAMB yearling ewes were not different (P > 0.05). For fleeces from two-year-olds, SWM AFD were slightly coarser (0.4 µm) than for RAMB ewes (P < 0.05).

The CV of fiber diameter for RAMB ewes were superior (lower) to FWM and SWM ewes (P < 0.05) at both ages. It has been noted previously that U.S. wools are more uniform than Australian wools in terms of fiber diameter (Lupton, 1995). A slight decrease in uniformity of fiber diameter was observed with increasing age in the FWM and RAMB ewes but not in the SWM ewes.

Subjective scores for wool face covering were similar among sire breeds but varied widely among locations (Table 5). The latter may be due to differences among ewe flocks or, more likely, differences in scoring methods. In general, none of the groups had much wool on the face. The important observation remains that infusion of SWM or FWM germplasm into U.S. fine-wool populations did not affect face cover score in any of the flocks studied.

Skin folds varied among sire breeds. The FWM ewes had more skin folds than SWM ewes (P < 0.05), and RAMB ewes had the lowest skin fold score (P < 0.05). A greater number of skin folds in Australian sheep compared with U.S. breeds has been previously observed (Bell et al., 1936; Austin, 1944). This extra skin is also associated with higher wool production in Australian Merino sheep. Skin folds have been shown to have a positive phenotypic and genetic relationship with greasy wool weight; its association with clean wool weight is positive phenotypically but slightly negligible genetically (Turner and Young, 1969). Wool produced on a skin fold (wrinkle) can have a higher fiber diameter and greater variability in fiber diameter than wool produced on a tight skin area (Sutton et al., 1995).

Subjective scores for belly wool covering did not differ among SWM and FWM ewes (P > 0.05). Belly wool score was higher (less desirable) for RAMB ewes compared with SWM and FWM ewes (1.6 vs. 1.4; P < 0.05). Visual inspection of the FWM and SWM cross ewes (TX) clearly revealed that Merino crossbreeding dramatically increased the quantity

Table 4. Least-squares means (LSM) of average fiber diameter (AFD) and coefficient of variation (CV) of fiber diameter for F1 Australian Merino and Rambouillet-type ewes by age and location.[a]

	Yearling ewes			2-year-old ewes		
Trait by location	FWM	SWM	RAMB	FWM	SWM	RAMB
AFD, µm						
ID	18.7	19	19.2	18.6	19.6	19.3
TX	19.2	19.7	19.7	18.6	19.2	19.3
MT	19.4	20.2	20.2	19.8	20.8	20.5
CA	21.7	22.8	22.3	23.2	24.2	22.9
Overall ± SE	19.8 ± 0.2[b]	20.5±.2[c]	20.3 ± 0.2[c]	20.0 ± 0.2[d]	20.9 ± 0.2[c]	20.5 ± 0.2[b]
CV						
ID	20.4	19.8	18.7	21	20.3	20
TX	18.5	18.7	18.2	19.6	19	18.1
MT	20	19.9	17.8	20.3	19.3	18.7
CA	19.8	20.2	19.3	20.3	19.7	20.3
Overall ± SE	19.7 ± 0.5[c]	19.6 ± 0.5[c]	18.5 ± 0.5[b]	20.3 ± 0.4[c]	19.6 ± 0.4[b]	19.1 ± 0.4[d]

[a] FWM = one-half Australian Merino fine-wool strain; SWM = one-half Australian Merino strong-wool strain; RAMB = purebred Rambouillet (ID, MT, TX) or one-half Rambouillet and one-half Targhee (CA).
[b,c,d] Values with different superscripts in the same row and age group column are different (P < 0.05).

and changed the appearance of the crimp in the belly wool. In fact, belly wool produced by the Merino cross ewes was hardly distinguishable from fleece wool in many instances. Unfortunately, this observation was not quantified.

Because sires of dams were highly selected on reported data within their sire breeds, it was meaningful to evaluate progeny phenotypic differences in wool traits among sires within their sire breed. Differences among sires within their sire breed for a wool trait suggest the trait may be improved by selection within the sire breed. The effect of sire within sire breed was significant ($P < 0.05$) for all sire breeds in most wool traits (Table 6), CV of fiber diameter in FWM and SWM fleece weights and staple lengths being the exceptions ($P > 0.10$). Sire differences were observed in all sire breeds for AFD and CV of fiber diameter; superior sires were identified in each sire breed (FWM 2, SWM 6, RAMB 4). CV can also be improved within each sire breed by selection because there were significant differences among sires with sires FWM 3, SWM 1 and RAMB 1 having the lowest CV of fiber diameter. Although overall fleece weights were greater for SWM ewes, there was no difference among sires ($P > 0.10$). However, there was potential to increase fleece weight by selecting within FWM and RAMB sire breeds for superior sires such as FWM 1 and RAMB 4. Staple length can also be improved by selection within sire breed; sires FWM 6, SWM 5 and RAMB 6 had longer staple lengths compared to other sires within their sire breeds ($P < 0.05$).

The comparison of sires evaluated in this study within their sire breed may not be indicative of the true range in variation of fleece characteristics that exist among all potential sires. However, significant variation among sires within sire breed suggests that further genetic improvement in wool characteristics can be made within sire breeds. The large variability in the progeny averages for wool traits among these highly-selected rams indicates that the rams were not as uniform as their reported individual performance suggests and also that progeny test data is a more reliable source of accurate data.

Table 5. Least-squares means (LSM) of subjective scores for face covering, skin folds and belly wool covering of F1 Australian Merino and Rambouillet-type yearling ewes.[a,b]

Trait by location	FWM	SWM	RAMB
Face covering			
ID	2.7	2.6	2.4
TX	1.0	1.0	1.0
MT	2.9	2.9	3.1
CA	2.2	2.0	2.0
Overall ± SE	2.2 ± 0.05	2.1 ± 0.05	2.1 ± 0.05
Skin folds			
ID	2.1	2.0	1.4
TX	2.1	1.8	1.4
MT	2.6	2.6	2.1
CA	2.2	1.9	1.2
Overall ± SE	2.3 ± 0.06[c]	2.1 ± 0.06[d]	1.5 ± 0.07[e]
Belly wool covering			
ID	1.3	1.3	1.5
TX	1.7	1.8	2.0
CA	1.0	1.1	1.3
Overall ± SE	1.4 ± 0.04[d]	1.4 ± 0.03[d]	1.6 ± 0.04[c]

[a] Scores were on a scale of 1 to 4, with "1" representing less expression of the trait.
[b] FWM = one-half Australian Merino fine-wool strain; SWM = one-half Australian Merino strong-wool strain; RAMB = purebred Rambouillet (ID, MT, TX) or one-half Rambouillet and one-half Targhee (CA).
[c,d,e] Values with different superscripts in the same row differ ($P < 0.05$).

Conclusions

From the selected rams used in this study it was concluded that FWM and SWM rams increased fiber production in crossbred populations. In the case of the SWM, this was accompanied by a small increase in AFD while FWM rams generally produced a decrease in AFD compared to RAMB sires. Comparison of sire breed means for wool characteristics suggests that U.S. wool fleece weight and fiber diameter can be improved by crossbreeding Australian Merinos to U.S. fine-wool breeds. However, fleece uniformity (inversely proportional to CV of fiber diameter) may be slightly decreased and mature body size will tend to be lower in animals with Australian Merino breeding.

In the U.S. wool marketing system, the observed differences in AFD, CV, Y and staple length would probably not affect unit prices paid for the wool produced by the three sire breeds. However, estimated gross returns from wool in 1989 would have been approximately $26.45, $29.10 and $22.05/ewe for FWM, SWM and RAMB two-year-olds, respectively. The lower wool prices in 1996 would have resulted in corresponding returns of $14.22, $15.64 and $11.85, respectively.

Producers seeking Australian Merino rams or their semen for breeding are advised to consider all available information including any estimated breeding values (EBV) for important wool characteristics to take advantage of the Australian Merino's wool characteristics and to minimize the negative effects on mature size and variation in fleece fiber diameter.

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Table 6. Least-squares means (LSM) of yearling ewe wool traits within sire breed.

Sire breed	Sire	Number of progeny	Grease fleece weight, kg	Staple length, cm	AFD, µm	CV of fiber diameter, %
FWM[a]	1	38	4.49[b]	8.86[c]	20.3[b]	21.7[b]
	2	29	4.06[c]	8.60[d]	19.0[e]	18.8[d]
	3	43	3.61[d]	7.96[e]	19.5[d]	18.1[d]
	4	47	3.54[d]	8.31[d]	19.9[c]	19.8[c]
	5	40	4.31[b,c]	9.04[c]	19.9[c]	19.4[c]
	6	34	4.27[b,c]	9.51[b]	19.9[c]	19.8[c]
SWM[a]	1	35	4.49	9.42[b]	21.1[b]	17.7[d]
	2	42	4.7	9.44[b]	20.3[c]	19.3[c]
	3	49	4.5	9.41[b]	20.4[c]	20.0[b]
	4	34	4.56	9.11[c]	20.8[c]	19.9[c]
	5	44	4.31	9.45[b]	20.5[c]	18.4[c]
	6	40	4.42	9.00[c]	19.3[d]	22.0[b]
RAMB[a]	1	27	4.47[b]	8.92[c,d]	20.1[c]	16.6[d]
	2	34	3.60[c]	8.19[d]	20.0[c]	18.9[b]
	3	31	3.80[d,e]	8.75[c]	20.1[c]	17.8[c]
	4	21	4.21[b,c]	9.09[b,c]	19.7[d]	19.6[b]
	5	28	3.89[c,d]	8.93[c]	21.0[b]	19.5[b]
	6	23	4.06[c,d]	9.14[b]	20.9[b]	18.5[c]

[a] FWM = one-half Australian Merino fine-wool strain; SWM = one-half Australian Merino strong-wool strain; RAMB = purebred Rambouillet (ID, MT, TX) or one-half Rambouillet and one-half Targhee (CA).

[b,c,d,e] Values with different superscripts within sire breed in the same column differ ($P < 0.05$).