BREED AND HETEROSIS EFFECTS ON WOOL AND LAMB PRODUCTION OF ROTATIONALLY CROSSED EWES[1]

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ABSTRACT

One thousand twenty-three lambing records of 351 ewes bred in a rotational crossbreeding system involving Columbia or Targhee (Whiteface), Hampshire and Finnish Landrace were examined. A regression approach was used to determine the effects of breed composition and heterosis of the ewe and the litter, as appropriate, on wool grade, greasy fleece weight, ewe weight at lambing, lambing date, number of lambs born and weaned and litter weight at birth and weaning. A ewe production index equal to the weight of lamb weaned by a ewe plus three times her greasy fleece weight was computed for various purebred and crossbred matings. Whiteface inheritance caused heavier than average ewes, fleeces and litters at weaning. Finnish Landrace inheritance increased prolificacy but not number of lambs weaned per litter, partly because lambs in excess of two per litter were not raised by any ewe. Hampshire inheritance in the ewe was detrimental to litter production traits, and Hampshire inheritance in the litter decreased the number of lambs born and weaned but increased litter weaning weight. Ewe heterosis was approximately four times larger than lamb heterosis for 120-d litter weaning weight. Fleece weight and ewe weight at lambing were highly repeatable, but repeatabilities of lamb production traits were low. Average estimated production indices from three-breed terminal crosses were highest, followed by backcrosses of crossbred ewes to a parental breed or three-breed rotational crosses at equilibrium, which were approximately equal to each other. All crossbreeding systems had higher estimated production indices than straightbred matings, but two-breed terminal crosses often did not exceed the highest straightbred group.

(Key Words: Sheep, Breeds, Heterosis, Crossbreds, Lamb Production.)

Introduction

From 1973 to 1981, a sheep crossbreeding experiment was conducted at the Eastern Oregon Agricultural Experiment Center, Union, Oregon. Columbia and Targhee ewes were mated to Hampshire and Finnish Landrace rams in the early years of the experiment. Thereafter, replacement females were mated in a three-breed rotational cross (Columbia or Targhee, Hampshire and Finnish Landrace).

The first objective of this study was to compare the effects of Columbia or Targhee, Hampshire and Finnish Landrace inheritance in the ewe and in the litter and to quantify ewe and litter heterosis (as appropriate) on several production traits (wool grade, greasy fleece weight, ewe weight, date of lambing, number of lambs born, number of lambs weaned, birth weight of the litter and 120-d adjusted weaning weight of the litter). The second objective was to examine, through correlations, the relationships among some of the traits. The third objective was to calculate repeatabilities of the traits (with the exception of wool grade). The fourth objective was to compare predicted performance from several possible straightbred and crossbred matings among the three breeds.

Materials and Methods

Population. This experiment was conducted at the Eastern Oregon Agricultural Research Center, Union, Oregon (location 45° 13′N latitude, 117° 52′W longitude, elevation 853 m, annual rainfall 330 mm, average growing season 120 d). The initial population was composed of straightbred Columbia and Targhee ewes born in the spring of 1973. For the remainder of the experiment and analysis, Columbia and Targhee ewes were considered together as "whiteface" ewes (W), due to their common ancestry of Rambouillet and Lincoln breeding. These ewes

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were bred to Hampshire (H), Finnish Landrace (F) and W rams, in a three-way rotational crossbreeding system, from 1973 until 1980. Whiteface and Hampshire rams were chosen to be representative of the sort that would readily be available for purchase by commercial sheep growers in the area, whereas selection of Finnish Landrace rams was restricted to those available from other research institutions and one private breeder in the region. Eight breed types composed of varying levels of W, H and F breeding were created.

Ewes were managed as a typical western intermountain area farm flock. Throughout most of the year, ewes and lambs were run on fescue-Ladino clover or orchardgrass-alfalfa pastures or hay stubble. Supplemental feeding of hay or hay and grain was necessary during late gestation and early lactation. Replacement ewe lambs were selected on age-adjusted weaning weight, type of birth and conformation traits.

Ewes were bred at approximately 7 mo of age to Montadale rams, which were used in the interest of limiting dystocia. No replacements were kept from these first matings, and ewes that failed to lamb in their first year were culled. Because Montadale ram use was restricted to ewe lamb matings, Montadale breed effects were not estimated in subsequent analyses.

Estimates of wool grade (Bradford spinning count) were made on all ewes during their first production year; measurements of greasy fleece weight, ewe weight immediately following lambing, date of lambing, number of lambs born, number of lambs weaned, birth weight of the litter and 120-d adjusted weaning weight of the litter were made for all production years. Ewes giving birth to more than two lambs were allowed to raise no more than two of them and were credited only for the lambs which they themselves raised. The remaining lambs were fostered onto other ewes or raised artificially; but in these analyses, ewes were not given credit for rearing foster lambs.

The experiment terminated in 1981. Ewes born in 1973 had eight potential years of production. Each later birth year group of ewes (1974 to 1979) had one less year of potential production. None of the 1980 birth year ewes was kept as replacements.

Statistical Procedures. Weaning weights were adjusted for sex and to a common 120-d weaning age using the methods of Scott (1982).

To evaluate maternal and(or) direct effects of the breeds in the experiment and of heterosis on the ewe production traits, a regression approach (Dickerson, 1969) was used. The percentage of inheritance from each breed in each ewe and in each litter was first determined. To remove dependencies among variables in subsequent analyses, the percentage of W inheritance in each ewe was subtracted from each ewe's percentage of W, H and F inheritance. Likewise, percentage of W inheritance of each litter was subtracted from W, H and F inheritance of the same litter.

The percentage of maximum potential heterozygosity retained (i.e., the extent to which heterosis could be expressed) was calculated for ewes (h_E) and litters (h_L) as follows:

$$h_E \text{ or } h_L = [1.00 - (W_s \times W_d) - (H_s \times H_d) - (F_s \times F_d)] \times 100, \quad [1]$$

where s refers to the sire and d the dam of the ewe for h_E and of the litter for h_L, respectively, and where subscripted W, H and F are proportions of inheritance from each breed in the sire or dam.

The data were subjected to least-squares analysis of variance procedures to compute least-squares means, regression coefficients, residual correlations and significance levels for effects in the models (Harvey, 1977). Using coded values for ewe and litter inheritance and values from equation [1] for proportion of ewe and litter heterosis, an equation of the following form was written for each record:

$$Y = M + B + b_1 H_E + b_2 F_E + b_3 H_L + b_4 F_L + b_5 h_E + b_6 h_L, \quad [2]$$

where Y is an observed litter trait (date of lambing, number of lambs born, number of lambs weaned, birth weight of the litter, weaning weight of the litter), M is the least-squares mean, B is a fixed effect for ewe birth year × production year subclass, H_E and F_E are the coded proportions of H and F inheritance in the ewe, H_L and F_L are coded proportions of H and F inheritance in the litter, h_E and h_L are as defined previously, b_1 and b_2 are effects on the trait of H and F inheritance in the ewe, b_3 and b_4 are effects on the trait of H and F inheritance in the lamb, b_5 is ewe heterosis and b_6 is litter heterosis. This, in essence, became the linear model for the least-squares analysis of variance.

Because of the manner in which restrictions were imposed on the equations, the effect of W inheritance in the ewe could be estimated as negative ($b_1 + b_2$), and the W litter inheritance effect could be estimated as negative ($b_3 + b_4$). Deviations in heterosis of specific breed cross combinations from average heterosis values (b_5 and b_6) will contribute to, and be partially confounded with, the breed effects.

For analysis of variance of greasy fleece weight and ewe weight, we assumed that litter effects would not be important, and b_3H_L, b_4F_L and b_6h_L were deleted from the model. Wool grade was scored only once per ewe, not annually, so in the analysis of wool grade, birth year replaced birth year × production year subclass as a fixed effect.

The model for computing repeatabilities included the main fixed effects of birth year, ewe age and breed type nested within birth year, plus the random effect of ewe identification nested within breed type within birth year.

One thousand twenty-three lambing records of 351 ewes were used in the analyses. In order to compare the predicted performances of breed combinations, some of which did not exist in the study, production indices were calculated, using constants and regression coefficients, for all possible purebred matings, two- and three-way crosses and backcrosses and crosses that could take place when a three-way rotational cross reached equilibrium. The index was calculated as the sum of the weight of lamb weaned by a ewe plus three times her greasy fleece weight (Oltenacu and Boylan, 1981), based on the assumption that the dollar value of 1 kg of wool is equal to that of 3 kg of weaned lamb.

Results and Discussion

Breed and Heterosis Effects on Ewe Production Traits. Breed and heterosis effects on ewe body weight and wool traits are presented in table 1. Breed effects are deviations from the overall least-squares mean, and the regression coefficients for heterosis represent the average difference, for each trait, between crossbred (first cross or three-breed cross) and straightbred ewes.

The effect of W inheritance was to increase both ewe weight and wool production, but to cause wool of a coarser grade. The effect of F inheritance was to lower ewe weight and wool production, with the effect of H inheritance being intermediate between W and F for those two traits. That W effects on ewe weight were substantially larger than H effects on the trait was unexpected. We have no explanation for that result other than that it may have been caused by the particular samples of rams used in each breed. For wool grade, the finest fleeces were associated with H inheritance, but the range in grade from W to H (4.7 spinning count units) was not large.

The negative heterosis effect on wool grade (−9%) is in agreement with Sidwell et al. (1971), who reported increased fiber diameter in five of seven two-breed crosses and in one of two three-breed crosses. Heterosis percentages were 13 both for wool production and ewe body weight. Nitter (1978), combining results from several studies, reported average heterosis percentages of 13.4 for fleece weight and 5.0 for ewe body weight.

Ewe and Litter Breed and Heterosis Effects on Litter Production Traits. Genetic effects on traits that conceivably could be influenced by genotype of the litter presented in table 2.

TABLE 1. BREED AND HETEROSIS EFFECTS ON EWE PRODUCTION TRAITS

Effect	Wool grade	Greasy fleece weight, kg	Ewe weight, kg
Mean	53.3 ± .2	4.26 ± .03	42.6 ± .3
Whiteface	−2.5 ± .9	1.96 ± .13	19.6 ± 1.4
Hampshire	2.2 ± 1.2	−.57 ± .17	−5.7 ± 1.7
Finnish Landrace	.3 ± 1.1	−1.39 ± .17	−14.0 ± 1.7
Heterosis	−4.9 ± 1.7**	.57 ± .25*	5.7 ± 2.5*

*P<.05.

**P<.01.

TABLE 2. BREED AND HETEROSIS EFFECTS OF EWES AND LITTERS ON LITTER PRODUCTION TRAITS

Effect	Date of lambing	No. lambs born	No. lambs weaned	Litter birth wt, kg	Litter weaning wt, kg
Mean	34.1 ± .4	1.83 ± .02	1.51 ± .03	8.0 ± .1	49.8 ± .7
Whiteface ewe	–8.6 ± 2.7	–.01 ± .16	.32 ± .21	.7 ± .6	6.2 ± 5.1
Hampshire ewe	3.9 ± 3.1	–.47 ± .18	–.37 ± .24	–.1 ± .7	–5.0 ± 5.9
Finnsheep ewe	4.8 ± 3.1	.48 ± .17	.04 ± .24	–.6 ± .7	–1.2 ± 5.8
Whiteface litter	8.4 ± 2.1	–.11 ± .12	.33 ± .17	.2 ± .5	1.6 ± 4.1
Hampshire litter	–6.9 ± 2.7	–.05 ± .15	–.23 ± .21	.8 ± .6	2.7 ± 5.0
Finnsheep litter	–1.5 ± 2.6	–.06 ± .15	–.10 ± .20	–1.1 ± .6	–4.4 ± 4.8
Ewe heterosis	–8.6 ± 6.4	.28 ± .37	.65 ± .49	.9 ± 1.4	16.6 ± 12.0
Litter heterosis	9.2 ± 3.4	.30 ± .20	.26 ± .26	.6 ± .8	3.9 ± 6.4

Inheritance from Columbia and Targhee ewes (W) had the most beneficial overall effects on litter traits, i.e., an earlier date of lambing and an increase in number of lambs and litter weight weaned. Finnsheep inheritance did cause increased prolificacy, as has been reported in numerous other experiments, but this had little effect on number of lambs weaned or litter weaning weight. In the experiment, lambs in excess of two born to a ewe were reared artificially or fostered onto another ewe, and the ewe from which the extra lamb or lambs were taken received no credit for them. This would tend to mask potential breed effects on total lamb production caused by differences in prolificacy. Poorest maternal performance was associated with H inheritance.

Litter effects on total weight of lamb weaned were positive for W inheritance, because of an increased proportion of lambs weaned of lambs born. They were positive for H inheritance, because of increased individual lamb weights. The effect of F inheritance in the litter was to decrease the number of lambs born and weaned, compared with the overall experimental average, and lamb weaning weights as well. The F litter effect was 7% below average for lambs weaned per litter and 9% below average for litter weaning weight.

Maternal heterosis was large and beneficial, causing earlier lambing plus increases in lambs born, lambs weaned, litter birth weight and litter weaning weight of 15, 43, 11 and 33%, respectively. From Nitter's (1978) review, average heterosis percentages were 3.2 for prolificacy and 18 for total weight of lamb weaned per ewe exposed to mating.

The effect of a crossbred litter was to delay date of lambing, but to cause increases of 16% in number of lambs born, 17% in number of lambs weaned, 8% in birth weight of the litter and 8% in weaning weight of the litter. Average litter heterosis percentages from Nitter's (1978) review are 2.8% for prolificacy and 17.8% for total weight of lambs weaned per ewe exposed. From Nitter (1978), ewe and litter heterosis each contributed equally (approximately 18%) to increased litter weight per ewe exposed; but in this experiment, the benefit from crossbred ewes were some four times larger than the benefit from crossbred litters.

Relationships Among Litter Production Traits. The residual correlations among litter traits from the analysis of variance are presented in table 3. Date of lambing was not correlated with any of the other litter traits. The correlations between number of lambs born and number and weight of lambs weaned likely were low (.35) because of the practice of allowing a ewe to raise, at most, only two lambs. The relatively low correlation between number and weight of lambs weaned (.53) suggests large variability in individual lamb weaning weights, but that statistic is not presented here.

Repeatabilities of Ewe Production Traits. Repeatabilities and standard errors were calculated from variance components from the analyses of variance (Becker, 1984), and are presented in table 4.

The repeatability of greasy fleece weight is in good agreement with the estimate of .62 reported by Lewer et al. (1983) for Perendale ewes. Clarke and Hohenboken (1983) reported a repeatability of body weight at mating of .61, which is consistent with our estimate of .62 for weight at lambing. The repeatability of lambing date of .16 is less than the estimate reported by Hanrahan (1983) of repeatability of date of first estrus of .22 for Suffolk and Texel ewes

TABLE 3. RESIDUAL CORRELATIONS AMONG LITTER PRODUCTION TRAITS[a]

Ewe production traits	(2)	(3)	(4)	(5)
(1) Date of lambing	−.03	−.03	.03	−.02
(2) No. lambs born		.35	.67	.35
(3) No. lambs weaned			.37	.53
(4) Litter birth weight				.51
(5) Litter weaning weight				

[a]All correlations except those involving date of lambing are significant (P<.01).

TABLE 4. REPEATABILITIES OF EWE PRODUCTION TRAITS

Ewe production traits	Repeatability	SE
Greasy fleece wt	.60	.03
Ewe weight at lambing	.62	.03
Lambing date	.16	.04
No. lambs born	−.01	.03
No. lambs weaned	.08	.04
Litter birth wt	.06	.04
Litter weaning wt	.04	.04

and .37 for Galway and Cheviot ewes. Clarke and Hohenboken (1983) found a higher positive repeatability than in this study for number of lambs born per ewe lambing (.19 vs −.01), but their estimates of .08, .07, and .09 for number of lambs weaned, birth weight of the litter and weaning weight of the litter, respectively, are in good agreement with present results.

Production Indices. Production indices, using breed and heterosis effects from tables 1 and 2 as appropriate, were computed for straightbred, two-breed cross, three-breed cross, backcross and rotational cross matings. Results are presented in tables 5 and 6.

The average two-breed cross exceeded the straightbred average for production index, but only two of the crosses exceeded straightbred whiteface matings, the most productive straightbred group. All three-breed cross matings, with the benefit of maternal heterosis, exceeded W × W matings; and, in most cases, they exceeded two-breed cross matings as well. Backcross matings retained maternal heterosis but lost one-half of litter heterosis effects, accounting for their lower average compared with the three-breed cross matings. The average production index of all mating combinations that could occur in a three-breed rotational cross at equilibrium (table 6) was similar to the average of all backcross matings.

Three-breed cross matings were most productive overall, and the highest individual value (88.8) was for the H × WF mating. Production of WF ewes within a farm, however, would require that a substantial proportion of straightbred ewes be maintained, which would lower average system productivity. For farms producing their own female replacements, the three-breed rotational system would likely be the most productive. If, however, healthy crossbred ewe lambs from breeds with good maternal potential were available for purchase on a regular basis and at a reasonable cost, a three-way terminal cross could be practiced more easily. Only one type of mating would be necessary; and specialized sire and dam breeds, such as the Hampshire and Finnish Landrace, respectively, could be utilized more effectively.

Within mating systems, combinations in which W contributed predominantly to ewe inheritance were most productive, due to positive W effects, both on litter weight and wool production. The Finnish Landrace did little to enhance productivity, whether used as male or female parent, because of negative

TABLE 5. PREDICTED LITTER WEIGHTS, FLEECE WEIGHTS AND PRODUCTION INDICES OF STRAIGHTBRED AND CROSSBRED EWES MATED TO STRAIGHTBRED RAMS

Ram	Ewe	Predicted 120-d litter wt, kg	Predicted fleece wt, kg	Production index[a]
Straightbreeding				
W	W	57.6	6.2	76.3
H	H	47.6	3.7	58.6
F	F	44.2	2.9	52.9
Avg		49.8	4.3	62.6
Firstcrossing				
W	H	50.9	3.7	62.0
W	F	51.1	2.9	59.8
H	W	62.1	6.2	80.7
H	F	51.7	2.9	60.2
F	W	58.3	6.2	77.2
F	H	47.9	3.7	59.0
Avg		53.7	4.3	66.5
Three-breed crossing				
W	HF	67.7	3.8	79.2
H	WF	73.5	5.1	88.8
F	WH	69.9	5.5	86.4
Avg		70.4	4.8	84.8
Backcrossing				
W	WH	70.9	5.5	87.5
W	WF	65.6	5.1	80.9
H	WH	71.4	5.5	88.0
H	HF	66.8	3.8	78.3
F	WF	68.0	5.1	83.3
F	HF	62.7	3.8	74.2
Avg		67.6	4.8	82.0

[a]Production index is 120-d litter weight plus three times greasy fleece weight.

TABLE 6. PREDICTED LITTER WEIGHTS, FLEECE WEIGHTS AND PRODUCTION INDICES FROM THE SIX POSSIBLE MATINGS IN A THREE-BREED ROTATIONAL CROSS AT EQUILIBRIUM

Ram breed	Ewe genotype 4/7	2/7	1/7	Predicted litter wt, kg	Predicted wool wt, kg	Production index[a]
F	W	H	F	67.7	5.5	84.2
H	F	W	H	68.3	4.4	81.6
W	H	F	W	66.1	4.3	79.0
H	W	F	H	71.2	5.4	87.4
F	H	W	F	64.6	4.8	78.9
W	F	H	W	66.2	4.1	78.4
Avg				67.4	4.8	81.6

[a]Production index is 120-d litter weight plus three times greasy fleece weight.

effects on wool and lamb growth, and because the management system did not allow their higher prolificacy to be expressed as larger litter size weaned. As expected, the Hampshire was more beneficial in a paternal than in a maternal role.

Literature Cited

Becker, W. A. 1984. Manual of Quantitative Genetics. Academic Enterprises, Pullman, WA.

Clarke, S. E. and W. D. Hohenboken. 1983. Estimation of repeatability, heritability and breed differences for lamb production. J. Anim. Sci. 56:309.

Dickerson, G. E. 1969. Experimental approaches in utilising breed resources. Anim. Breed. Abstr. 37:191.

Hanrahan, J. P. 1983. Repeatability of date of first estrus. In: Animal Production Report from Dunsinea, Moorepark and Western Research Centres. Research Report 1982. Dublin, Irish Republic.

Harvey, W. R. 1977. User's Guide for LSML76, mixed-model least-squares and maximum likelihood computer program. Ohio State Univ., Columbus.

Lewer, R. P., A. L. Rae and G. A. Wickham. 1983. Analysis of records of a Perendale flock. 5. Repeatabilities and genetic correlations between ages. New Zealand J. Agr. Res. 26:315 (Abstr.).

Nitter, G. 1978. Breed utilisation for meat production in sheep. Anim. Breed. Abstr. 46:131.

Oltenacu, E.A.B. and W. J. Boylan. 1981. Productivity of purebred and crossbred Finnsheep. II. Lamb weights and production indices of ewes. J. Anim. Sci. 52:998.

Scott, G. E. 1982. The Sheepman's Production Handbook. Sheep Industry Development Program, Inc., Denver, CO.

Sidwell, G. M., R. L. Wilson and M. E. Hourihan. 1971. Production in some pure breeds of sheep and their crosses: IV. Effect of crossbreeding on wool production. J. Anim. Sci. 32:1099.