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GENETIC PARAMETERS FOR EWE PRODUCTIVITY TRAITS IN THE COLUMBIA, SUFFOLK AND TARGHEE BREEDS[1]

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ABSTRACT

Estimates of repeatability and heritability were obtained for the following productivity traits of ewes: litter weight at birth (LWB) and weaning (LWW), litter size at birth (LSB), litter size alive at birth (NBA), litter size at weaning (LSW), neonatal survival rate (SRB) and preweaning survival rate (SRW). Phenotypic and genetic correlations were estimated for litter traits. The data set contained 6,394 ewe breeding records from three state stations over 10 yr on 1,731 ewes that were the progeny of 488 sires among three breeds (Columbia, Suffolk and Targhee). Pooled intra-station estimates of repeatability ranged from .11 to .22 for LWB and LWW among the three breeds. For litter size at birth, number born alive and litter size at weaning these estimates varied from .09 to .17 and for the survival traits (SRB and SRW) the variation was from .11 to .20. Intra-station estimates of heritability for the three breeds varied from .12 to .28 for LWB and LWW, and for LSB, NBA and LSW estimates varied from .05 to .35. Heritability estimates for survival traits (SRB and SRW) were low, ranging from .00 to .14. Phenotypic correlations among LWB, LWW, NBA and LSW ranged from .35 to .92 among the breed-station subclasses, with higher correlations occurring where a part-whole relationship existed. The study suggests that selection of ewes with high litter size at birth or at weaning and(or) litter weight at birth or at weaning will genetically improve total litter weight at weaning per ewe lambing.
(Key Words: Sheep, Ewe Productivity, Genetic Parameters.)

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Introduction

Ewe productivity continues to be a major concern of the sheep industry. Improving female reproductive performance is an important objective for increasing the profitability of sheep (Parker and Pope, 1983). The number of lambs born and number of lambs weaned per ewe lambing also affect selection intensity, the number of surplus animals available for disposal and flock structure (Young et al., 1963).

Estimates of heritability for reproductive traits generally have been low (Turner, 1969). However, few estimates are available for lamb survival (Shelton and Menzies, 1970) and litter weight (Martin et al., 1981). Also, few estimates of genetic correlations between various reproductive traits have been reported in the literature (More O'Farrell, 1976; Martin et al., 1981).

Selection for high litter size and(or) litter weight at birth or at weaning is of particular importance in Columbia, Suffolk and Targhee breeds because of their comparatively low reproductive rates. Development of an efficient selection program depends on reliable esti-

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TABLE 1. NUMBERS OF EWES AND LEAST SQUARES MEANS ± SE BY BREED-STATION-LINE SUBCLASSES

Breed[b]	No. of Ewes	Traits[a]						
		LWB, kg	LWW, kg	LSB, no.	NBA, no.	LSW, no.	SRB, %	SRW, %
OHTO	661	6.91 ±.14	34.6 ±1.2	1.47 ±.04	1.40 ±.04	1.21 ±.05	.95 ±.01	.86 ±.02
ILTO	553	8.11 ±.18	38.8 ±1.4	1.61 ±.05	1.52 ±.05	1.32 ±.06	.94 ±.02	.86 ±.03
OHTI	594	6.60 ±.21	28.1 ±1.6	1.35 ±.05	1.30 ±.05	1.00 ±.06	.96 ±.02	.77 ±.03
ILTI	650	7.55 ±.15	34.5 ±1.1	1.57 ±.03	1.48 ±.04	1.26 ±.04	.94 ±.01	.86 ±.02
OHCO	589	6.44 ±.15	30.2 ±1.6	1.49 ±.04	1.42 ±.04	1.12 ±.06	.95 ±.01	.79 ±.03
NDCO	459	6.38 ±.18	28.9 ±1.8	1.33 ±.05	1.26 ±.05	1.01 ±.06	.94 ±.02	.81 ±.04
OHCN	429	5.77 ±.21	24.1 ±1.4	1.30 ±.05	1.18 ±.05	.97 ±.06	.91 ±.02	.78 ±.04
NDCN	377	6.34 ±.18	26.7 ±1.2	1.37 ±.05	1.28 ±.04	1.04 ±.05	.93 ±.02	.78 ±.03
ILSI	607	6.96 ±.19	36.7 ±1.7	1.47 ±.04	1.37 ±.04	1.16 ±.05	.94 ±.02	.84 ±.02
NDSI	498	7.02 ±.24	31.8 ±2.1	1.65 ±.05	1.55 ±.06	1.14 ±.06	.94 ±.02	.74 ±.03
ILSN	449	6.73 ±.22	38.7 ±1.7	1.37 ±.05	1.30 ±.05	1.18 ±.06	.95 ±.02	.91 ±.03
NDSN	528	7.39 ±.18	34.7 ±1.3	1.48 ±.04	1.40 ±.04	1.10 ±.05	.95 ±.02	.78 ±.03

[a]LWB: birth litter weight, LWW: weaning litter weight, LSB: birth litter size, NBA: number born alive, LSW: litter size at weaning, SRB: neonatal survival rate, SRW: preweaning survival rate.

[b]OHTO: Ohio Targhee at Ohio, ILTO: Illinois Targhee at Ohio, OHTI: Ohio Targhee at Illinois, ILTI: Illinois Targhee at Illinois, OHCO: Ohio Columbia at Ohio, NDCO: North Dakota Columbia at Ohio, OHCN: Ohio Columbia at North Dakota, NDCN: North Dakota Columbia at North Dakota, ILSI: Illinois Suffolk at Illinois, NDSI: North Dakota Suffolk at Illinois, ILSN: Illinois Suffolk at North Dakota, NDSN: North Dakota Suffolk at North Dakota.

mates of heritability as well as phenotypic and genetic correlations among the various component traits. In the present study, repeatability, heritability, phenotypic and genetic correlations of several reproductive traits were estimated.

Materials and Methods

Sheep. Data were made available by the Department of Animal Science, Ohio Agricultural Research and Development Center, Wooster. The data were collected routinely for a period of 10 yr from 1963 to 1972 on three straightbred breeds, Columbia, Targhee and Suffolk. Each breed was maintained at two state stations, Columbia at Ohio and North Dakota, Targhee at Ohio and Illinois, and Suffolk at North Dakota and Illinois. Each station maintained two lines of each breed; one originated at that station and the other line initially was established by transfer of animals from one of the other two stations. Data included 6,394 ewe breeding records from 1,731 ewes by 488 sires (Table 1). Random breeding for each breed-station-line was initiated in 1961. Approximately eight ewes were assigned within subgroup to one of six unrelated rams. Ewes were retained in the breeding flock a minimum of 2 yr and thereafter were removed only for consecutive failure to conceive or at random when a replacement was available. Breeding rams were mated for a single breeding season and replaced the following year by a son. Two replacement ram lambs from each sire were chosen randomly at an average age of 60 d. The second ram was available as a backup for breeding. All female progeny were eligible as replacements except for animals with sound-

TABLE 2. REPEATABILITY ESTIMATES (r) AND SE FOR LWB, LWW, LSB, NBA, LSW, SRB AND SRW BY BREED-STATION AND BREEDS

Breed[b]	Traits[a]						
	LWB	LWW	LSB	NBA	LSW	SRB	SRW
OHT	.14	.21	.13	.11	.21	.16	.30
	.06	.06	.06	.06	.06	.06	.07
ILT	.20	.10	.12	.14	.09	.19	.10
	.06	.06	.06	.06	.06	.06	.05
Pooled r	.17	.14	.12	.13	.13	.18	.17
Pooled SE	.04	.04	.04	.04	.04	.04	.04
OHC	.21	.28	.23	.17	.22	.11	.28
	.06	.06	.06	.06	.06	.05	.06
NDC	.22	.11	.12	.07	.05	.10	.11
	.07	.06	.06	.06	.06	.06	.07
Pooled r	.21	.22	.17	.13	.15	.11	.21
Pooled SE	.05	.04	.04	.04	.04	.04	.05
ILS	.18	.07	.07	.09	.07	.16	.13
	.06	.06	.06	.06	.06	.06	.06
NDS	.19	.16	.13	.13	.15	.29	.22
	.06	.06	.06	.06	.06	.06	.06
Pooled r	.18	.11	.09	.10	.10	.20	.17
Pooled SE	.04	.04	.04	.04	.04	.04	.04

[a]LWB: birth litter weight, LWW: weaning litter weight, LSB: birth litter size, NBA: number born alive, LSW: litter size at weaning, SRB: neonatal survival rate, SRW: preweaning survival rate.

[b]OHT: Targhee at Ohio, ILT: Targhee at Illinois, OHC: Columbia at Ohio, NDC: Columbia at North Dakota, ILS: Suffolk at Illinois, NDS: Suffolk et North Dakota.

ness defects associated with breeding or rearing and individuals with black wool. Mating relationships of half-sib and closer were avoided.

Details of the origin of flocks, flock management, number of ewes in various breed-station-lines, and adjustment of data for sex and age of dam within type of birth are given by Abdulkhaliq (1985) and the North Central Regional Research Publication (1970).

Management. The breeding season throughout the course of the study began on September 1 and continued to October 22, a total of 51 d. All ewes were on pasture during the grazing season and were supplemented with concentrates in the diet during pregnancy, the 10-d postnatal period and the nursing period. Ewes were housed during the lambing season. Ewe and lamb management practices were similar for all breed-station-groups. Lambs were creep fed and weaned at 90 d of age and not subjected to any form of selection unless they were physically unsound or had black wool.

Data Recording. Data were recorded on lambs from 1963 to 1972. The following reproductive traits were calculated for each ewe for each year of lambing: litter weight at birth (**LWB**) and weaning (**LWW**), litter size at birth (**LSB**), litter size alive at birth (**NBA**), litter size at weaning (**LSW**), neonatal survival rate (i.e., NBA/LSB) (**SRB**) and preweaning survival rate, (i.e., LSW/NBA) (**SRW**).

Statistical Procedures. The data were analyzed by mixed models with least squares procedures for unequal subclass numbers as described by Harvey (1985). Sex effects for lambs born as singles were estimated from the original lamb data, separately for each breed-station by fitting constants for lines, years, ages of dam and sex effects. All two-way interactions among these effects were insignificant. In the analysis of data on lambs born as multiples, it was necessary to include ewe effects in the above model. Therefore, maximum likelihood procedures were used to estimate sex effects in lambs born as multiples. Repeatabilities of individual lamb birth weight and weaning weight used in these analyses were estimated for each breed-station from the lamb data (Table 2). Multiplicative correction factors obtained from the estimated sex effects were used to adjust individual lamb birth and weaning weight for sex effects.

Litter weight at birth and at weaning were adjusted to a 3-yr-old ewe equivalent within type of birth of lambs, in order to complete least squares analyses for estimating genetic parameters because year, age of dam and ewe effects are confounded. The age of dam multiplicative factors were calculated from the estimated age of dam × type of birth subclass effects, which were obtained by fitting constants for lines, years, age of dam × type of birth subclasses and line × year interactions. The age of dam × type of birth interaction previously had been found to be significant.

Analyses of variance were calculated on adjusted data to obtain half-sib estimates of heritability for each trait and estimates of repeatability for each breed-station subclass and for each breed across stations. The following model was used to describe adjusted data for each breed-station: $Y_{ijklm} = \mu + g_i + s_{ij} + d_{ijk} + t_l + (gt)_{il} + e_{ijklm}$, where Y_{ijklm} = the m^{th} record on the k^{th} ewe born to the j^{th} sire in the i^{th} line in the l^{th} year, μ = overall population mean, g_i = effect of the i^{th} line for this breed, s_{ij} = effect of the j^{th} sire in the i^{th} line, d_{ijk} = effect of the k^{th} ewe born to the j^{th} sire in the i^{th} line, t_l = effect of the l^{th} year, $(gt)_{il}$ = effect of the interaction between the i^{th} sire in the l^{th} year and e_{ijklm} = random error. Heritability (h^2) and repeatability (r) were estimated as: $h^2 = 4\,\hat{\sigma}^2_{s:g} / \hat{\sigma}^2_p$ and $r = (\hat{\sigma}^2_{s:g} + \hat{\sigma}^2_{d:sg}) / \hat{\sigma}^2_p$, where $\hat{\sigma}^2_p = \hat{\sigma}^2_{s:g} + \hat{\sigma}^2_{d:sg} + \hat{\sigma}^2_e$ and $\hat{\sigma}^2_{s:g}$, $\hat{\sigma}^2_{d:sg}$ and $\hat{\sigma}^2_e$ are estimates of variance components for sires, ewes and random error, respectively. Approximate standard errors for h^2 and r were computed by the formula given by Swiger et al. (1964). Phenotypic and genetic correlations also were estimated among traits from the corresponding estimates of covariance components and variance component estimates in the usual manner.

Results and Discussion

Least square means by breed-station-line subclasses are given in Table 1 for the seven productivity traits along with numbers of ewes and standard errors.

Repeatability. Repeatabilities estimated for ewe reproductive performance traits by breed-station and their standard errors are presented in Table 2. Pooled estimates for each breed were obtained by pooling data from the same breed across station for each trait. The average number of records per ewe was 1.7 for litter weight at birth and weaning, birth litter size, number born alive and weaning litter size and 2.4 for neonatal survival and preweaning survival rate.

The repeatabilities, pooled, of birth litter size (LSB) were .12, .17 and .09 for the Targhee, Columbia and Suffolk breeds, respectively. These estimates are in general agreement with estimates obtained by Yalcin and Bichard (1964), Mechling and Carter (1969), Shelton and Menzies (1970), Mann et al. (1978), Notter (1981). Dzakumma et al. (1982), Clark and Hohenboken (1983) and Fogarty et al. (1985). However, the repeatability estimates of .12 and .17 for the Targhee and Columbia are larger than the .07 estimate obtained by Kennedy (1967) and .08 estimate obtained by Hanrahan (1977).

Repeatability estimates of litter size at weaning (LSW) ranged from .05 to .22. The pooled estimates were .13, .15 and .10 for the Targhee, Columbia and Suffolk breeds, respectively. These estimates are slightly higher than the estimate of .08 obtained by Yalcin and Bichard (1964), Kennedy (1967), and Clark and Hohenboken (1983) and the average of literature estimates (.07) given by Turner (1969). Repeatability estimates of livability (number of lambs born alive per ewe lambing, NBA) for Targhee, Columbia and Suffolk were .13, .13 and .10, respectively. These estimates are about the same as those found by Lal (1968) for Columbia (.13) and are much higher than the −.16 that he found for Targhee.

Repeatability estimates for birth litter weight (LWB) were .17, .21 and .18 for Targhee, Columbia and Suffolk breeds, respectively. No estimates were found in the literature for this trait.

Pooled estimates for repeatability for weaning litter weight (LWW) were .14, .22 and .11 for Targhee, Columbia and Suffolk, respectively. Gjedrem (1967) obtained an estimate of .21 for litter weight at weaning. Other estimates of repeatability for this trait are .16 by Eikje (1975), .09 by Clark and Hohenboken (1983) and .10 by Fogarty et al. (1985).

The higher estimates of repeatability for Columbia for weaning litter weight may be due to the smaller average litter size in Columbia (1.37) than in the Targhee and Suffolk breeds (1.50). Smaller litter size could have resulted in a better average environment

TABLE 3. HERITABILITY ESTIMATES AND PHENOTYPIC AND GENETIC CORRELATIONS BETWEEN SOME PRODUCTIVE TRAITS IN COLUMBIA, SUFFOLK AND TARGHEE SHEEP BREEDS[a]

Station[c]		Traits[b] LWB	LWW	LSB	NBA	LSW
		Columbia				
OH	LWB	.19[d]	.46	.81	.80	.51
ND		.21	.45	.85	.72	.53
OH	LWW	.39	.32	.37	.49	.91
ND		1.18	.20	.35	.57	.91
OH	LSB	1.02	.55	.24	.84	.51
ND		1.04	.62	.47	.77	.48
OH	NBA	1.64	.91	2.02	.04	.63
ND		1.34	.75	1.17	.19	.69
OH	LSW	.41	.95	.65	1.12	.30
ND		1.60	1.08	.97	.91	.18
		Suffolk				
IL	LWB	.26	.52	.77	.70	.53
ND		.31	.55	.82	.75	.57
IL	LWW	1.15	.26	.40	.62	.92
ND		.86	.03	.41	.55	.93
IL	LSB	.57	.97	.07	.79	.52
ND		1.09	.43	.28	.85	.52
IL	NBA	3.24	5.08	2.11	.00	.70
ND		1.47	−.58	1.57	.10	.65
IL	LSW	1.46	1.04	1.58	1.65	.08
ND		.61	1.42	.39	.22	.16
		Targhee				
IL	LWB	.16	.54	.79	.72	.55
OH		.08	.47	.86	.80	.58
IL	LWW	1.16	.11	.49	.65	.92
OH		1.00	.16	.40	.55	.91
IL	LSB	.70	1.39	.14	.81	.59
OH		1.13	1.29	.34	.85	.58
IL	NBA	.32	1.87	1.04	.08	.75
OH		1.16	1.31	1.08	.30	.70
IL	LSW	.95	.91	1.06	1.08	.11
OH		.99	1.07	1.10	1.12	.30

[a]Phenotypic correlations above the diagonal, genetic correlations below the diagonal and heritability estimates on the diagonal.

[b]LWB: birth litter weight, LWW: weaning litter weight, LSB: litter size at birth, NBA: number born alive, LSW: litter size at weaning.

[c]OH: Ohio, ND: North Dakota, IL: Illinois.

[d]Standard errors of heritability estimates vary from .15 to .23.

for Columbia preweaning lamb growth, and hence for greater expression of their genetic potential.

Repeatabilities of neonatal survival rate (SRB) were .20 for the Suffolk, .18 for the Targhee and .11 for the Columbia. These estimates are higher than the estimate of .03 found by Fogarty et al. (1985).

Repeatability estimates for preweaning survival rate (SRW) were .17, .21 and .17 for the Targhee, Columbia and Suffolk breeds, respectively. These repeatability estimates are higher than those reported by Fogarty et al. (1985), .05 and .02, and higher than the value of .08 obtained by Shelton and Menzies (1970) for this trait. Piper et al. (1982), however, obtained estimates of .16 and .15 for repeatability of preweaning survival in two flocks of Merinos.

Heritability Estimates. Estimates of heritability for ewe reproductive performance based on sire-of-ewe variance component, by breed-station and breed (pooled), are presented in Table 3. A number of the heritability estimates are larger than corresponding repeatability estimates given in Table 2. Sampling errors could explain these differences, but these results may suggest that negative correlations exist within ewes, especially for litter size traits.

Heritability estimates for birth litter size (LSB) were found to be .23, .35 and .18 for the Targhee, Columbia and Suffolk breeds, respectively. These estimates are similar to the estimate of .29 reported by Karam and Regab (1958) but higher than the estimates of –.01 and .14 found by Lal (1968) for the Targhee and Columbia, respectively. Other estimates for purebreds include .03 (Ch'ang and Rae, 1961), .08 (Forest and Bichard, 1974; Eikje, 1975), .10 (Mann et al., 1978), .19 (Jonmundsson, 1977), .20 (Kennedy, 1967) and .26 (Shelton and Menzies, 1968). The results of this study are in general agreement with those published in the literature and indicate that additive genetic effects on litter size in Columbia, Targhee and Suffolk breeds are important and that genetic progress can be made by selecting for litter size at birth.

Heritability estimates for number born alive (NBA), for each breed across station, were found to be .17 for Targhee, .11 for Columbia and .05 for Suffolk. These estimates are larger than estimates previously reported. Lal (1968) obtained estimates of .06 and –.04 for the Columbia and Targhee breeds, and Martin et al. (1981) obtained an estimate of .01.

Heritability estimates for number of lambs weaned per ewe lambing (LSW) were .19, .26 and .12 for the Targhee, Columbia and Suffolk breeds, respectively. These estimates are higher than the estimates of .06 (Kennedy, 1967), .03 (Eikje, 1975) and .02 (Martin et al., 1981), similar to the estimates of .15 and .18 obtained by Young et al. (1963) and less than the .43 estimate given by Basuthakur et al. (1973).

The pooled estimates of heritability of birth litter weight (LWB) were .12, .20 and .28 for the Targhee, Columbia and Suffolk breeds, respectively. These estimates are similar to the estimates of .24 and .21 reported by Martin et al. (1981).

Estimates of heritability for weaning litter weight (LWW) were .13, .28 and .25 for the Targhee, Columbia and Suffolk breeds, respectively. Heritabilities published in the literature ranged between –.05 (Clark and Hohenboken, 1983) and .50 (Basuthakur et al., 1973). Other estimates from purebred populations include .12 (Eikje, 1975), .17 (Gjedrem, 1967), .21 (Shelton and Menzies, 1968; Parker, 1969), .24 (Jonmundsson, 1976) and .25 (More O'Ferrall, 1976).

Heritability estimates also were obtained for neonatal survival rate, SRB (NBA/LSB), and preweaning survival rate, SRW (LSW/NBA), but because the estimate of the sire component of variance was negative in 7 of the 12 trait-breed-station subclasses, columns for SRB and SRW are omitted from Table 3. The pooled heritability estimate for SRW in the Columbia was .14 and was .07 in the Suffolk. The pooled sire component of variance was negative for this trait in the Targhee data. Lal (1968) reported estimates of heritability for preweaning survival rate in the Columbia and Targhee breeds of .27 and .14, and Fogarty et al. (1985) obtained an estimate of .07 for the heritability of this trait. There is close agreement between the results obtained in this study and those reported in the literature.

The pooled estimates of heritability for neonatal survival rate (SRB) were zero except for the Targhee at Illinois (.07).

Because of the economic importance of preweaning survival rate, further studies are needed to determine whether indirect selection for a trait such as lamb birth coat grade would reduce preweaning mortality. Guirgis et al. (1979) reported that high birth coat grades improve early survival of lambs; lambs with low birth coat grades suffer, particularly under harsh conditions at lambing time, because of greater loss of body heat and energy reserves. Selection for birth coat type (high halo-hair grade) has been shown to improve neonatal survival (Purser and Karam, 1967).

Correlations. Estimates of phenotypic and genetic correlations among litter traits (litter size at birth and at weaning, litter weight at birth and at weaning and number of lambs born alive) in the Columbia, Targhee and Suffolk breeds are presented in Table 3. The phenotypic correlations, in the three breeds, ranged from .37 (between litter size at birth and weaning litter weight) to .93 (between litter size and litter weight at weaning). The estimates obtained in this study are in close agreement with those published in the literature by Basuthakur et al. (1973) and Martin et al., 1981).

Estimates of genetic correlations among ewe productivity traits from these data were highly variable (Table 3) and in many cases had standard errors larger than the estimates themselves. Thus, these estimates are not considered of any practical value. Further investigation using larger samples is required to estimate genetic correlations.

Conclusions

Ewe productivity is a composite trait with multiplicative contributions from fertility, litter size, neonatal survival, preweaning survival and litter weight. Similarly, litter weight at weaning per ewe lambing is a composite trait representing total lamb production per ewe. Litter weight at weaning can be considered as a biological phenotypic index that is completely determined by litter size, neonatal survival, preweaning survival and lamb weaning weight. The results obtained from this study highlight the importance of including litter size and(or) litter weight at weaning in a selection program to increase ewe productivity.

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