Evaluation of Dorset, Finnsheep, Romanov, Texel, and Montadale breeds of sheep: II. Reproduction of F_1 ewes in fall mating seasons[1,2]

E. Casas,[3] B. A. Freking, and K. A. Leymaster

ARS, USDA, U.S. Meat Animal Research Center, Clay Center, NE 68933-0166

ABSTRACT: Objectives were to estimate effects of sire breed (Dorset, Finnsheep, Romanov, Texel, and Montadale), dam breed (Composite III and northwestern whiteface), mating season (August, October, and December), ewe age (1, 2, and 3 yr), and their interactions on reproductive traits of F_1 ewes. A total of 1,799 F_1 ewes produced 3,849 litters from 4,804 exposures to Suffolk rams during 35-d mating seasons over 3 yr. Ewes were weighed at breeding. Conception rate and ewe longevity (present or absent at 42 mo of age) were determined. Number born and litter birth weight were recorded, and number and weight at weaning and 20 wk of age were analyzed separately for dam- and nursery-reared litter mates. Total productivity through 3 yr of age for each ewe entering the breeding flock was calculated as the sum of 20-wk weights for dam- or nursery-reared lambs. Interactions of sire breed × mating season, sire breed × ewe age, and mating season × ewe age were generally significant, whereas interactions of sire breed, mating season, and ewe age × dam breed were seldom detected. Interactions of sire breed × mating season were often due to changes in rank as well as magnitude, indicating the importance of matching sire breed to a specific mating season. The number born to Dorset-, Texel-, and Montadale-sired ewes was not affected by dam breed; however, Finnsheep-sired ewes out of northwestern whiteface dams were more prolific than Finnsheep-sired ewes out of Composite III dams, and the opposite situation existed for Romanov-sired ewes. Least squares means of sire breeds ($P < 0.001$) for total productivity of dam-reared lambs were 98.5, 103.5, 106.9, 124.6, and 154.9 kg/ewe entering the breeding flock for Texel, Dorset, Montadale, Finnsheep, and Romanov, respectively. Superior reproduction of Romanov-sired ewes was due to greater conception rate and prolificacy for each mating season and ewe age, as well as greater ewe longevity. Total productivity of F_1 ewes by Composite III dams (125.6 kg) was greater ($P < 0.001$) than for ewes born to northwestern whiteface dams (109.7 kg), and the effect of mating season increased ($P < 0.001$) from August to October to December. Litter weight at 20 wk of age of 2- and 3-yr-old ewes was similar but greater ($P < 0.001$) than for 1-yr-old ewes. Experimental results provide comprehensive information about the appropriate use of these breeds in crossbreeding systems to meet specific production-marketing objectives.

Key Words: Ewe Productivity, Reproductive Traits, Sire Breeds

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Introduction

Genetic differences among breeds in reproduction, growth, and fitness traits offer important opportunities for improving the efficiency and quality of market lamb production through crossbreeding systems. Differences among breeds in performance for economically important traits are genetically based and can be exploited through strategic use in crossbreeding systems, including creation of new composite populations. Evaluations of the available germplasm resources to understand its potential role in crossbreeding systems are important for the U.S. sheep industry.

An experiment was designed to comprehensively evaluate five breeds of sheep. The Dorset is a widely used general-purpose breed that has desirable characteristics in crossbreeding programs (Mohd-Yusuff et al., 1992). The Finnsheep has become the standard for comparison for reproductive performance (Young et al., 1996) and has been previously used to produce crossbred ewes for intensive lamb production. It has been reported that Romanov crossbred ewe lambs were similar to Finnsheep crossbred ewe lambs in re-

[1]L. Young (deceased) provided leadership for conceiving, designing, and conducting this experiment.

[2]Mention of a trade name, proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

[3]Correspondence: P.O. Box 166 (phone: 402-762-4168; fax: 402-762-4173; e-mail: casas@email.marc.usda.gov).

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productive performance (Vesely and Swierstra, 1986). The Texel has been recognized for its superior carcass leanness (Leymaster and Jenkins, 1993). The Montadale breed was developed in the United States by crossing Cheviot rams and Columbia ewes, but had not been evaluated prior to this experiment.

Freking et al. (2000) reported results from the first phase of this experiment, evaluation of these five breeds when used as rams for mating. This report includes an evaluation of reproduction of F_1 ewes produced from these breeds. Thus, objectives were to assess effects of sire breed (Dorset, Finnsheep, Romanov, Texel, and Montadale), dam breed (Composite III and northwestern whiteface), season of mating (August, October, and December), age of ewe (1, 2, or 3 yr old), and their interactions on reproductive traits of F_1 ewes in fall mating seasons.

Materials and Methods

General Experimental Design

Freking et al. (2000) described the design of the first phase of the experiment. Briefly, Dorset, Finnsheep, Romanov, Texel, and Montadale rams were mated to Composite III and northwestern whiteface ewes for 3 yr during three separate 35-d-long fall mating seasons beginning approximately August 5, October 15, and December 15 each year. A total of 102 rams (20 Dorset, 21 Finnsheep, 19 Romanov, 23 Texel, and 19 Montadale) produced daughters that contributed data for this experiment. The Composite III flock was developed at the U.S. Meat Animal Research Center from a ½ Columbia, ¼ Hampshire, and ¼ Suffolk crossbred foundation (Leymaster, 1991). The northwestern whiteface ewes of Rambouillet background were purchased from producers in Montana.

The experiment was designed to produce 20 F_1 ewe lambs from each sire breed × ewe breed combination in each season, each year, for the evaluation of reproductive traits, a total of 1,800 ewes. All sound and healthy ewe lambs up to 20 per sire breed × dam breed combination were retained for breeding each season each year. Replacement ewe lambs went into the same 12-mo production systems from which they were produced. All F_1 ewes were group-mated to fertile Suffolk rams (20 to 25 ewes per ram), so as to lamb at 1, 2, and 3 yr of age. Ewes born in 1991 lambed in 1992, 1993, and 1994; ewes born in 1992 lambed in 1993, 1994, and 1995; and ewes born in 1993 lambed in 1994, 1995, and 1996.

Description of Traits and Flock Management

Traits evaluated were divided into those measured from the start of the breeding season to weaning of the lambs, those measured at 20 wk of age of the lambs, and those measured after ewes were 3 yr of age. Traits measured from the start of the breeding season to weaning were weight of the ewe at the beginning of the breeding season, conception rate, number born, litter birth weight, number of dam-reared weaned lambs, number of nursery-reared weaned lambs, dam-reared litter weaning weight, and nursery-reared litter weaning weight. Traits measured at 20 wk of age were the number of dam-reared lambs at 20 wk of age, number of nursery-reared lambs at 20 wk of age, dam-reared litter weight at 20 wk of age per ewe lambing, nursery-reared litter weight at 20 wk of age per ewe lambing, dam-reared litter weight at 20 wk of age per ewe exposed, and nursery-reared litter weight at 20 wk of age per ewe exposed. Total productivity through 3 yr of age for each ewe entering the breeding flock was calculated as the sum of 20-wk weights for dam- or nursery-reared lambs. Traits measured at weaning and 20 wk of age were defined separately for dam-reared and nursery-reared lambs to evaluate reproduction of crossbred ewes in different production systems.

Crossbred ewes were managed together as a single group within each season. Ewes were exposed in three consecutive years. Ewes were weighed before each breeding season and were exposed to multiple Suffolk rams during 35-d periods beginning August 5, October 15, and December 15. Ewes joined in August only were exposed to vasectomized rams for approximately 17 d before exposure to fertile Suffolk rams. Ewes were on brome pasture during gestation and were given supplemental feed only as needed to meet their nutritional requirements. Ewes were treated for parasites, vaccinated against type C and D enterotoxemia, and given vitamins A, D, and E. Conception rate was determined on ewes present at the beginning of each lambing season. Approximately 1 wk before parturition, ewes were moved to a building with an elevated woven-wire floor, where they lambed. The number born and the weight of the litter at birth were recorded within the first 24 h after lambing. Throughout the study, lambs were placed in nursery facilities for artificial rearing only when the nutritional status of the lamb was observed to be failing. Typically, lambs within the litter that were least successful in obtaining milk from the ewe were removed. All males were castrated at approximately 14 d of age. All lambs were offered a total-mixed creep diet (2.90 Mcal of ME/kg DM with 17.5% CP) by approximately 14 d of age. At weaning (56 d for lambs reared by the ewe and 32 d for lambs reared in the nursery), the number of lambs reared by the ewe and in the nursery was recorded. Weaning weight was recorded for each lamb and adjusted for variation in age to 56- and 32-d for dam- and nursery-reared lambs, respectively. Litter weight of lambs reared naturally by the ewe and in the nursery was calculated.

After weaning, lambs reared in the nursery were brought to the pen with their contemporaries. All lambs were kept in finishing pens and switched to a total-mixed diet (2.96 Mcal of ME/kg of DM with 14.5%

CP) at approximately 10 wk of age. The number of lambs at 20 wk of age reared by the ewe and in nursery was tabulated for each ewe. Lamb weights were adjusted to 20 wk of age and dam- and nursery-reared litter weights of lambs were calculated both per ewe lambing and per ewe exposed.

Total productivity of ewes for dam- or nursery-reared lambs was calculated as previously described. Total productivity was used as a natural index of overall reproductive performance, determined by phenotypic variation in component traits of conception rate, prolificacy, maternal ability, growth, and longevity. Longevity of each ewe was measured as a binary trait based on presence or absence of the ewe in the breeding flock at 42 mo of age. Ewes were culled only for reasons that adversely affected their ability to produce or raise lambs. Primary culling reasons were mastitis, pneumonia, poor health, unilateral mammary failure, and vaginal prolapse.

Each record was considered a trait of the ewe. A total of 4,804 records were analyzed for weight of the ewe at the beginning of the breeding season, conception rate, dam-reared litter weight at 20 wk of age per ewe exposed, and nursery-reared litter weight at 20 wk of age per ewe exposed. A total of 3,849 records were analyzed for traits based on number of ewes lambing, such as number born, litter birth weight, number of dam-reared weaned lambs, number of nursery-reared weaned lambs, dam-reared litter weaning weight, nursery-reared litter weaning weight, number of dam-reared lambs at 20 wk of age, number of nursery-reared lambs at 20 wk of age, dam-reared litter weight at 20 wk of age per ewe lambing, and nursery-reared litter weight at 20 wk of age per ewe lambing. Records on 1,799 ewes entering the breeding flock were analyzed for total productivity and longevity.

Statistical Analysis

Data were analyzed with the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). The model included fixed effects of birth year of the ewe (1991, 1992, and 1993), sire breed (Dorset, Finnsheep, Romanov, Texel, and Montadale), dam breed (Composite III and northwestern whiteface), mating season (August, October, and December), ewe age (1, 2, and 3 yr), and all possible two-way interactions among these fixed effects. The random effect of sires within birth year and sire breed was included. Age was treated as a repeated effect of ewe within birth year, sire breed, dam breed, and mating season. Effects of birth year, sire breed, and birth year × sire breed were tested with the sire within birth year and sire breed mean square and were considered approximations due to unbalanced data. Mating season, dam breed, and all two-way interactions that included at least one of these effects were tested with the effect of ewe within year of birth, sire breed, dam breed, and mating season. Effects of ewe age and its interactions were tested against the residual mean square. A compound symmetry structure was assumed for the residual (co)variance matrix. The fixed effect of ewe age and its use as a repeated measurement was removed from the model when analyzing total productivity and longevity. Pairwise differences between least squares means were tested for significant main effects of sire breed, mating season, and ewe age. Probability values are nominal and are not corrected for multiple testing.

Results and Discussion

Levels of significance and least squares means are reported for effects of sire breed, dam breed, mating season, ewe age, and two-way interactions between sire breed, mating season, and ewe age (Tables 1 to 8). Interactions of sire breed, mating season, and ewe age × dam breed were seldom detected and therefore, results are discussed but not tabulated. Effects of year and its interactions were not discussed. Year effects cannot be predicted to recur in the future, and it is more appropriate for producers to make decisions about sire breeds, dam breeds, and mating seasons based on information averaged over several years. Results for total productivity and longevity traits will be discussed separately.

Mating Season × Sire Breed Interaction

The importance of this interaction illustrates how sire breeds can be better used in specific mating seasons to achieve optimal levels of performance. Levels of significance of this interaction for all traits are shown in Tables 1 and 2. This interaction was important ($P < 0.05$) for all traits except weight of the ewe at breeding and dam-reared litter weight at 20 wk of age per ewe exposed. Changes in rank of the sire breeds between August and December mating seasons often occurred. For Romanov, Texel, and Montadale breeds, the greatest number born and heaviest litter weights at birth, weaning and 20 wk of age were produced from the October breeding season, with the single exception of number born to Montadale-sired ewes. Dorset-sired ewes that lambed were most productive at weaning and 20 wk of age from August matings, whereas Finnsheep-sired ewes were most productive from December matings. Among sire breeds, conception rate of Romanov-sired ewes was least affected by mating season. Ewes produced by Romanov sires had the greatest conception rate and prolificacy at each mating season, with Finnsheep-sired ewes ranked second at each season. Generally, highly prolific breeds are most prolific when bred during fall. Glimp (1971) and Shelton and Morrow (1965), indicated that the October breeding season is when the peak ovulation rate occurs. Maijala (1996) indicated that the optimal breeding season for Finnsheep is between September and November. The breeding season for the Romanov is longer and has been established to be between Au-

Table 1. Levels of significance, least squares means, and average standard errors for the interaction of mating season × sire breed for traits measured to weaning

Item	Weight at breeding, kg[a]	Conception rate, %[a]	Birth traits[b]		Weaning traits[b]			
					Number		Litter weight, kg	
			Number	Litter weight, kg	Dam reared	Nursery reared	Dam reared	Nursery reared
Significance	0.276	<0.001	<0.001	0.012	0.009	<0.001	0.003	<0.001
Least squares means								
August × Dorset	71.4	65.7	1.46	7.78	1.17	0.08	24.3	0.9
August × Finnsheep	67.6	70.4	1.96	7.80	1.34	0.28	25.0	2.2
August × Texel	67.5	68.7	1.38	7.20	1.01	0.11	20.9	1.1
August × Romanov	65.5	82.1	2.07	8.43	1.49	0.26	28.1	2.2
August × Montadale	71.7	65.5	1.54	7.69	1.11	0.19	22.8	1.9
October × Dorset	67.9	85.9	1.52	8.19	1.17	0.16	24.0	1.6
October × Finnsheep	64.0	89.2	2.19	8.70	1.36	0.46	23.6	4.1
October × Texel	63.4	83.6	1.52	7.97	1.18	0.11	22.6	1.1
October × Romanov	61.8	92.7	2.35	9.38	1.65	0.45	28.9	3.8
October × Montadale	67.1	72.0	1.52	8.30	1.21	0.13	25.0	1.4
December × Dorset	64.4	82.6	1.38	7.42	1.11	0.11	22.0	1.1
December × Finnsheep	60.7	89.9	2.01	8.39	1.47	0.34	26.8	3.1
December × Texel	59.9	87.5	1.32	7.09	1.07	0.09	21.3	0.9
December × Romanov	60.6	92.5	2.18	8.72	1.58	0.35	28.3	3.1
December × Montadale	64.5	87.4	1.27	7.11	1.04	0.07	21.2	0.6
SEM	0.7	2.1	0.04	0.19	0.04	0.03	0.8	0.3

[a]Per ewe exposed.
[b]Per ewe lambing.

gust and March (Fahmy, 1996). These conclusions are consistent with results of the present study.

From the first phase of this experiment, Freking et al. (2000) reported that the ram breed × mating season interaction was important for number born and litter birth weight. They did not evaluate number of animals and weight of litter at 20 wk of age.

The interaction between sire breeds and mating seasons is accentuated in the present experiment when comparing number and litter weight of nursery-reared

Table 2. Levels of significance, least squares means, and average standard errors for the interaction of mating season × sire breed for traits measured at 20 wk of age

Item	Number[a]		Litter weight, kg				Total productivity, kg		
	Dam reared	Nursery reared	Dam reared[a]	Nursery reared[a]	Dam reared[b]	Nursery reared[b]	Dam reared[c]	Nursery reared[c]	Longevity, %[c]
Significance	0.004	0.001	0.007	0.032	0.143	0.021	0.015	0.113	0.79
Least squares means									
August × Dorset	1.11	0.06	52.4	2.6	37.1	1.6	97.8	4.2	67.8
August × Finnsheep	1.28	0.24	57.6	8.2	42.4	6.2	112.5	15.8	71.7
August × Texel	0.97	0.08	45.1	2.8	33.7	1.8	87.9	4.2	66.6
August × Romanov	1.40	0.23	62.8	8.4	53.3	7.5	151.5	20.9	82.5
August × Montadale	1.07	0.16	50.9	5.7	35.9	3.8	98.6	10.4	75.0
October × Dorset	1.12	0.12	51.1	3.9	45.5	3.6	113.4	8.8	61.6
October × Finnsheep	1.27	0.37	52.4	11.2	47.1	10.0	113.2	23.8	61.6
October × Texel	1.11	0.07	47.2	2.3	40.3	2.0	103.4	4.9	64.1
October × Romanov	1.58	0.38	65.3	11.9	60.6	11.1	156.8	28.0	67.9
October × Montadale	1.19	0.10	54.3	3.9	41.3	3.2	112.0	8.6	71.8
December × Dorset	1.06	0.09	47.6	3.2	39.6	2.7	99.3	6.6	68.5
December × Finnsheep	1.41	0.25	59.6	8.5	53.8	7.7	148.0	20.5	78.4
December × Texel	1.02	0.08	44.7	2.8	39.7	2.5	104.1	6.7	75.4
December × Romanov	1.51	0.28	63.1	9.7	58.4	9.2	156.3	24.1	80.2
December × Montadale	1.01	0.05	45.3	1.6	40.6	1.6	110.1	4.2	82.1
SEM	0.04	0.03	2.0	1.0	1.9	0.8	6.2	2.2	4.2

[a]Per ewe lambing.
[b]Per ewe exposed.
[c]Per ewe entering breeding flock.

Table 3. Levels of significance, least squares means, and average standard errors for the interaction of mating season × age of ewe (yr) for traits measured to weaning

			Birth traits[b]		Weaning traits[b]			
					Number		Litter weight, kg	
Item	Weight at breeding, kg[a]	Conception rate, %[a]	Number	Litter weight, kg	Dam reared	Nursery reared	Dam reared	Nursery reared
Significance	<0.001	<0.001	<0.001	0.288	0.01	<0.001	0.002	<0.001
Least squares means								
August × 1 yr	55.1	40.1	1.45	6.39	1.01	0.19	19.2	1.6
August × 2 yr	70.6	83.6	1.72	7.84	1.31	0.14	26.1	1.2
August × 3 yr	80.4	87.7	1.87	9.10	1.35	0.23	27.2	2.2
October × 1 yr	50.1	66.6	1.47	6.91	1.05	0.16	19.5	1.4
October × 2 yr	66.7	93.1	1.90	8.81	1.45	0.22	27.3	1.8
October × 3 yr	77.8	94.3	2.09	9.81	1.44	0.41	27.6	3.9
December × 1 yr	52.0	74.7	1.38	6.25	1.07	0.13	20.9	1.1
December × 2 yr	60.7	95.3	1.59	7.87	1.29	0.16	25.8	1.5
December × 3 yr	73.4	93.9	1.92	9.11	1.40	0.28	25.1	2.7
SEM	0.3	1.5	0.03	0.12	0.03	0.02	0.6	0.2

[a]Per ewe exposed.
[b]Per ewe lambing.

lambs. Finnsheep and Romanov have the greatest numbers of lambs born, at weaning, and at 20 wk of age. This increased level of prolificacy is best utilized when nursery facilities are a management option.

Mating Season × Ewe Age Interaction

This interaction was detected ($P < 0.05$) for all traits except litter weight at birth, number of dam-reared lambs at 20 wk of age, litter weight of nursery-reared lambs at 20 wk of age per ewe lambing, and litter weight of nursery-reared lambs at 20 wk of age per ewe exposed (Tables 3 and 4). Interactions of mating season and ewe age for number born and ewe weight were due to different magnitudes of effects of ewe age across mating season. Significant interactions for remaining traits were associated with changes in both rank and magnitude of effects. For traits based on dam-reared lambs, effects of 2- and 3-yr-old ewes were similar in magnitude, but rank often switched across mating seasons. For traits based on nursery-reared lambs, ranks of 1- and 2-yr-old ewes varied among mating seasons.

Sire Breed × Ewe Age Interaction

This interaction was important ($P < 0.05$) for all traits except litter birth weight, number of dam-reared lambs at weaning, litter weight of dam-reared lambs at weaning, and number of dam-reared lambs at 20 wk of age (Tables 5 and 6). Highly prolific breeds tend to mature at an earlier age, as is the case for Romanov and Finnsheep (Fahmy, 1996; Maijala, 1996). Ewes sired by Romanov had a greater conception rate at

Table 4. Levels of significance, least squares means, and average standard errors for the interaction of mating season × age of ewe (yr) for traits measured at 20 wk of age

	Number[a]		Litter weight, kg			
Item	Dam reared	Nursery reared	Dam reared[a]	Nursery reared[a]	Dam reared[b]	Nursery reared[b]
Significance	0.174	0.035	0.005	0.179	<0.001	0.209
Least squares means						
August × 1 yr	0.94	0.15	41.6	4.5	17.7	1.8
August × 2 yr	1.26	0.13	59.2	4.7	50.1	4.0
August × 3 yr	1.30	0.19	60.5	7.4	53.6	6.7
October × 1 yr	1.01	0.13	43.7	4.3	29.9	3.2
October × 2 yr	1.37	0.18	59.3	5.4	55.3	5.0
October × 3 yr	1.39	0.31	59.1	10.2	55.6	9.7
December × 1 yr	1.03	0.10	45.7	3.1	34.5	2.5
December × 2 yr	1.26	0.14	55.8	5.1	53.3	4.8
December × 3 yr	1.32	0.22	54.7	7.4	51.4	6.9
SEM	0.03	0.02	1.4	0.7	1.4	0.5

[a]Per ewe lambing.
[b]Per ewe exposed.

Table 5. Levels of significance, least squares means, and average standard errors for the interaction of sire breed × age of ewe (yr) for traits measured to weaning

Item	Weight at breeding, kg[a]	Conception rate, %[a]	Birth traits[b]		Weaning traits[b]			
					Number		Litter weight, kg	
			Number	Litter weight, kg	Dam reared	Nursery reared	Dam reared	Nursery reared
Significance	<0.001	<0.001	0.016	0.154	0.261	<0.001	0.113	<0.001
Least squares means								
Dorset × 1 yr	54.5	54.0	1.27	6.36	0.95	0.09	19.2	0.9
Dorset × 2 yr	69.2	90.4	1.44	7.83	1.18	0.08	24.6	0.7
Dorset × 3 yr	80.1	89.8	1.70	9.21	1.30	0.18	26.5	1.9
Finnsheep × 1 yr	51.7	63.6	1.71	6.68	1.20	0.26	21.7	2.1
Finnsheep × 2 yr	65.1	92.7	2.10	8.53	1.49	0.29	27.0	2.4
Finnsheep × 3 yr	75.5	93.2	2.34	9.68	1.48	0.53	26.6	4.9
Texel × 1 yr	51.2	57.9	1.18	6.16	0.85	0.09	17.4	0.9
Texel × 2 yr	64.3	90.0	1.41	7.57	1.21	0.06	24.2	0.6
Texel × 3 yr	75.5	91.9	1.63	8.53	1.21	0.16	23.2	1.7
Romanov × 1 yr	50.7	80.3	1.86	7.17	1.33	0.24	23.1	1.9
Romanov × 2 yr	62.9	92.9	2.25	9.03	1.69	0.32	31.1	2.6
Romanov × 3 yr	74.3	94.1	2.49	10.33	1.71	0.50	31.1	4.5
Montadale × 1 yr	53.9	46.5	1.20	6.22	0.87	0.11	17.9	1.1
Montadale × 2 yr	68.5	87.3	1.48	7.92	1.21	0.12	25.2	1.3
Montadale × 3 yr	80.8	91.1	1.65	8.96	1.29	0.15	25.9	1.6
SEM	0.6	1.9	0.04	0.17	0.04	0.03	0.7	0.3

[a]Per ewe exposed.
[b]Per ewe lambing.

1 yr of age, followed by Finnsheep-sired ewes, when compared with other breeds. Ewes produced by Montadale sires had the lowest conception rate at 1 yr of age. Ewes from the five sire breeds had conception rates of approximately 90% at 2 and 3 yr of age. These results indicate that Romanov-sired ewes mature at an earlier age. Gallivan et al. (1993) and Fahmy (1996) stated this finding previously. Romanov-sired ewes can be expected to exceed performance of other breeds under management systems that expect first lambing at 1 yr of age and nursery facilities are used.

Sire breed and ewe age interacted to affect number of lambs and litter weights. At 1 yr of age, Romanov-sired ewes had the greatest number of lambs and the

Table 6. Levels of significance, least squares means, and average standard errors for the interaction of sire breed × age of ewe (yr) traits measured at 20 wk of age

Item	Number[a]		Litter weight, kg			
	Dam reared	Nursery reared	Dam reared[a]	Nursery reared[a]	Dam reared[b]	Nursery reared[b]
Significance	0.062	<0.001	0.017	<0.001	0.002	<0.001
Least squares means						
Dorset × 1 yr	0.88	0.07	40.5	2.4	22.3	1.2
Dorset × 2 yr	1.14	0.07	53.1	2.2	48.2	2.1
Dorset × 3 yr	1.28	0.13	57.6	5.1	51.7	4.6
Finnsheep × 1 yr	1.16	0.21	49.8	6.5	32.2	4.1
Finnsheep × 2 yr	1.41	0.23	61.3	7.6	56.9	7.1
Finnsheep × 3 yr	1.38	0.42	58.4	13.8	54.3	12.8
Texel × 1 yr	0.81	0.07	36.3	2.4	21.6	1.4
Texel × 2 yr	1.15	0.04	52.0	1.6	47.1	1.4
Texel × 3 yr	1.13	0.11	48.8	3.9	44.9	3.6
Romanov × 1 yr	1.26	0.19	52.7	6.1	42.3	5.1
Romanov × 2 yr	1.62	0.31	70.4	10.1	65.6	9.5
Romanov × 3 yr	1.62	0.41	68.1	13.8	64.3	13.2
Montadale × 1 yr	0.85	0.08	39.2	2.4	18.6	0.8
Montadale × 2 yr	1.16	0.11	53.7	3.7	46.8	3.2
Montadale × 3 yr	1.27	0.13	57.6	5.1	52.4	4.6
SEM	0.04	0.03	1.8	0.9	1.8	0.7

[a]Per ewe lambing.
[b]Per ewe exposed.

Table 7. Levels of significance, least squares means, and average standard errors for the main effects of sire breed, dam breed, season of mating, and age of ewe (yr) for traits measured to weaning

			Birth traits[f]		Weaning traits[f]			
					Number		Litter weight, kg	
Item	Weight at breeding, kg[e]	Conception rate, %[e]	Number	Litter weight, kg	Dam reared	Nursery reared	Dam reared	Nursery reared
Sire breed								
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Least squares means								
Dorset	67.9[a]	78.1[a,b]	1.45[a]	7.80[a]	1.15[a]	0.12[a]	23.4[b]	1.2[a]
Finnsheep	64.1[b]	83.2[c]	2.05[b]	8.30[b]	1.39[b]	0.36[b]	25.1[c]	3.1[b]
Texel	63.6[b,c]	79.9[b,c]	1.41[a]	7.42[a]	1.09[a]	0.11[a]	21.6[a]	1.1[a]
Romanov	62.6[c]	89.1[d]	2.20[c]	8.84[c]	1.57[c]	0.35[b]	28.4[d]	3.0[b]
Montadale	67.7[a]	75.0[a]	1.44[a]	7.70[a]	1.12[a]	0.13[a]	23.0[a,b]	1.3[a]
SEM	0.5	1.2	0.03	0.14	0.03	0.02	0.5	0.2
Dam breed								
Significance	<0.001	0.03	0.99	0.953	0.013	0.086	0.001	0.094
Least squares means								
Composite III	66.1	82.2	1.71	8.02	1.29	0.20	25.0	1.8
Northwestern whiteface	64.3	79.9	1.71	8.01	1.24	0.23	23.6	2.1
SEM	0.3	0.8	0.02	0.07	0.02	0.01	0.30	0.01
Mating season								
Significance	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.22	<0.001
Least squares means								
August	68.7[a]	70.5[a]	1.68[a]	7.78[a]	1.22[a]	0.18[a]	24.2	1.7[a]
October	64.8[b]	84.7[b]	1.82[b]	8.51[b]	1.31[b]	0.26[b]	24.8	2.4[b]
December	62.0[c]	88.0[c]	1.63[a]	7.75[a]	1.25[a]	0.19[a]	23.9	1.8[a]
SEM	0.3	0.9	0.02	0.08	0.02	0.01	0.4	0.1
Age of ewe, yr								
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Least squares means								
1	52.4[a]	60.5[a]	1.44[a]	6.52[a]	1.04[a]	0.16[a]	19.9[a]	1.4[a]
2	66.0[b]	90.7[b]	1.74[b]	8.18[b]	1.35[b]	0.17[a]	26.4[b]	1.5[a]
3	77.2[c]	90.2[b]	1.96[c]	9.34[c]	1.40[c]	0.31[b]	26.6[b]	2.9[b]
SEM	0.2	0.9	0.02	0.08	0.02	0.01	0.3	0.1

[a,b,c,d]Within a trait and source of variation, means without a common superscript differ ($P < 0.05$).
[e]Per ewe exposed.
[f]Per ewe lambing.

heaviest litter weights at weaning and at 20 wk of age, followed by Finnsheep-sired ewes. At 2 yr of age, the number of lambs and litter weights increased regardless of sire breed. At 3 yr of age, the number of lambs and litter weights of dam-reared lambs at weaning and at 20 wk of age were similar to production at 2 yr of age. However, the number and litter weights of nursery-reared lambs at weaning and at 20 wk of age increased from 2 to 3 yr of age. This is particularly true for ewes sired by Romanov and Finnsheep. Production of nursery-reared lambs increased at 3 yr of age because of management decisions to move lambs to the nursery in cases where ewes had produced more lambs than they could naturally rear.

Other Interactions

The dam breed × ewe age for conception rate interaction ($P < 0.001$) demonstrates that ewes from Composite III dams mature at an earlier age than do ewes from northwestern whiteface dams. At 1 yr of age, ewes from Composite III dams had a greater conception rate (64%) than did ewes from northwestern whiteface dams (57%). At 2 and 3 yr of age, conception rates were similar for ewes from both dam breeds (90%).

Interaction of sire breed and dam breed was only significant for the number born per ewe lambing ($P = 0.005$). Finnsheep-sired ewes out of northwestern whiteface dams were more prolific (2.11 lambs) than Finnsheep-sired ewes out of Composite III dams (1.99 lambs). However, Romanov-sired ewes out of northwestern whiteface dams were less prolific (2.14 lambs) than Romanov-sired ewes out of Composite III dams (2.27 lambs). Prolificacy of Dorset-, Texel-, and Montadale-sired ewes was not affected by dam breed. Freking et al. (2000) detected an interaction of ram breed × ewe breed for conception rate during the first phase of this experiment. Specifically, Composite III and northwestern whiteface ewes differed in conception rate (86 and 73%, respectively) when present in the same single-sire mating pens as Romanov rams. They proposed several explanations for this phenomenon, such as sire preference to mate Composite III ewes or

Table 8. Levels of significance, least squares means, and average standard errors for the main effects of sire breed, dam breed, season of mating, and age of ewe (yr) for traits measured at 20 wk of age

	Number[e]		Litter weight, kg				Total productivity, kg		
Item	Dam reared	Nursery reared	Dam reared[e]	Nursery reared[e]	Dam reared[f]	Nursery reared[f]	Dam reared[g]	Nursery reared[g]	Longevity, %[g]
Sire breed									
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Least squares means									
Dorset	1.10[a]	0.09[a]	50.4[a]	3.2[a]	40.7[a]	2.6[a]	103.5[a]	6.5[a]	65.9[a]
Finnsheep	1.32[b]	0.29[b]	56.5[b]	9.3[b]	47.8[b]	8.0[b]	124.6[b]	20.1[b]	70.5[a,b]
Texel	1.03[a]	0.08[a]	45.7[c]	2.6[a]	37.9[a]	2.1[a]	98.5[a]	5.3[a]	68.7[a]
Romanov	1.50[c]	0.30[b]	63.7[d]	10.1[b]	57.4[c]	9.3[b]	154.9[c]	24.3[c]	76.8[b]
Montadale	1.09[a]	0.11[a]	50.2[a]	3.8[a]	39.3[a]	2.9[a]	106.9[a]	7.7[a]	76.3[b]
SEM	0.02	0.02	1.3	0.6	1.3	0.5	3.7	1.4	2.5
Dam breed									
Significance	0.009	0.058	0.001	0.068	<0.001	0.201	<0.001	0.622	<0.001
Least squares means									
Composite III	1.24	0.16	54.9	5.3	46.4	4.7	125.6	12.5	75.2
Northwestern whiteface	1.18	0.18	51.7	6.2	42.8	5.2	109.7	13.1	68.1
SEM	0.02	0.01	0.7	0.4	0.7	0.3	2.3	0.8	1.5
Mating season									
Significance	0.008	0.002	0.202	0.04	<0.001	0.001	0.002	0.023	<0.001
Least squares means									
August	1.17[a]	0.16[a]	53.8	5.5[a,b]	40.5[a]	4.2[a]	109.6[a]	11.1[a]	72.7[a]
October	1.26[b]	0.21[b]	54.1	6.6[a]	47.0[b]	6.0[b]	119.8[b]	14.8[b]	65.4[b]
December	1.21[a,b]	0.15[a]	52.1	5.2[b]	46.4[b]	4.8[a]	123.5[b]	12.4[a]	76.9[a]
SEM	0.02	0.01	0.9	0.5	0.9	0.3	2.8	1.0	1.9
Age of ewe, yr									
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—	—	—
Least squares means									
1	0.99[a]	0.13[a]	43.7[a]	4.0[a]	27.4[a]	2.5[a]	—	—	—
2	1.30[b]	0.15[a]	58.1[b]	5.1[a]	52.9[b]	4.6[b]	—	—	—
3	1.34[b]	0.24[b]	58.1[b]	8.4[b]	53.5[b]	7.8[c]	—	—	—
SEM	0.02	0.01	0.8	0.4	0.8	0.3	—	—	—

[a,b,c,d]Within a trait and source of variation, means without a common superscript differ ($P < 0.05$).
[e]Per ewe lambing.
[f]Per ewe exposed.
[g]Per ewe entering breeding flock.

aggressiveness of Composite III ewes to mate with Romanov sires. Perhaps there is a common basis for the unexpected results in both experiments.

Main Effects

Main effects of sire breed, dam breed, mating season, and ewe age are summarized in Tables 7 and 8. Sire breed was an important ($P < 0.05$) source of variation for all traits after accounting for other effects. Ewes sired by Romanov rams were lightest at breeding and had the greatest conception rate, the greatest number of lambs at birth, at weaning, and at 20 wk of age when raised by the dam, and the heaviest litter weights at birth, weaning, and at 20 wk of age when raised by the dam. Finnsheep-sired ewes ranked next to Romanov-sired ewes for these traits. Ewes by Montadale and Dorset sires were heaviest at breeding ($P < 0.05$), had the lowest conception rate ($P < 0.05$), and numbers of lambs at birth, weaning, and 20 wk of age were comparable with that of ewes from Texel sires. Ewes by Montadale, Texel, and Dorset sires were similar for litter weights of dam-reared lambs. Gallivan et al. (1993) reported that ewes from Romanov sires had a greater ovulation rate, produced and reared more lambs, and produced heavier lambs than did ewes from Finnsheep sires.

Dam breed was an important source of variation ($P < 0.05$) for weight of the ewe at breeding, conception rate, number of lambs reared by the ewe at weaning, litter weight of dam-reared lambs at weaning, number of lambs reared by the ewe at 20 wk of age, litter weight of dam-reared lambs at 20 wk of age per ewe lambing, and litter weight of dam-reared lambs at 20 wk of age per ewe exposed (Tables 7 and 8). Ewes from Composite III dams were heavier at breeding ($P < 0.001$) and produced a slightly greater number of lambs at weaning ($P < 0.05$) and at 20 wk of age ($P < 0.01$) than did ewes produced by northwestern whiteface dams. They also produced the heaviest litters at 20 wk of age. Freking et al (2000) compared reproductive performance of Composite III and northwestern whiteface ewes. These authors reported that Composite III ewes had a greater conception rate, a greater number of lambs born (not observed in present study) and at weaning, and heavier litters at birth (not ob-

served in the present study) and at weaning. In data reported by Freking et al. (2000), ewe age and ewe breed were partially confounded such that northwestern whiteface ewes, on average, were younger than Composite III ewes. Effects of age of ewe were not fitted in the statistical model and therefore contributed to effects of ewe breed reported by Freking et al. (2000). In the present study, crossbred ewes by Composite III and northwestern whiteface dams were produced as contemporaries to each other.

Averaged over levels of other effects, mating season was significant ($P < 0.01$) for all traits but litter weight of dam-reared lambs at weaning and at 20 wk of age per ewe lambing (Tables 7 and 8). Ewes entering the breeding season during August were heavier than ewes that entered the breeding season in October, and these ewes were heavier than those entering the breeding season in December ($P < 0.001$). Conception rate was greater during December, followed by October and August ($P < 0.001$). Glimp (1971), studying several sheep breeds, showed that the breeding season during which the conception rate was maximized was between October and December. Although the conception rate in this study was highest for the December mating season, the most lambs were born from the October mating season. Ewes bred during the October season produced more lambs at weaning ($P < 0.05$) and at 20 wk of age ($P < 0.05$), and litters were heaviest at weaning and at 20 wk of age for this season ($P < 0.05$). Freking et al. (2000) reported similar results.

Age of the ewe at lambing was highly significant for all traits after adjusting for levels of other effects (Tables 7 and 8). One-yr-old ewes were lighter at the beginning of the breeding season when compared with mature ewes ($P < 0.05$). They also had lower conception rates and the least number of lambs at birth, weaning, and 20 wk of age when compared with older ewes ($P < 0.05$). The litter weight of 1-yr-old ewes was also lighter than the litter weights of older ewes at weaning and 20 wk of age ($P < 0.05$). Two- and three-yr-old ewes generally had similar levels of performance for litter weights of dam-reared lambs at weaning and at 20 wk of age. However, when comparing the number of lambs and kilograms produced at weaning and at 20 wk of age of nursery-reared lambs, there was an increase between 2 and 3 yr of age, especially from ewes sired by Romanov and Finnsheep ($P < 0.05$). Mature ewes from these last two breeds produced more lambs than they could rear. Prolificacy of Romanov and Finnsheep must be considered to determine optimal breed composition of crossbred ewes.

Total Productivity and Longevity

The mating season × sire breed interaction was important ($P < 0.05$) for total productivity per ewe entering the breeding flock based on dam-reared lambs (Table 2). Romanov-sired ewes consistently had the greatest production, regardless of season. Finnsheep-sired ewes had greater production than Texel-, Dorset- and Montadale-sired ewes for August and December matings, but were similar for October mating. Averaged over all effects, total productivity of Romanov-sired ewes for dam-reared lambs was 24% greater than ewes by Finnsheep sires (Table 8). Total productivity of Finnsheep-sired ewes was intermediate between Romanov-sired ewes and ewes sired by other breeds. Sire breed also influences the total productivity per ewe entering the breeding flock based on nursery-reared lambs (Table 8). A pattern similar to one previously described was observed (i.e., Romanov-sired ewes have the greatest total productivity [$P < 0.05$], followed by Finnsheep-sired ewes [$P < 0.05$]). Total productivity of nursery-reared lambs was lowest for the other sire breeds since there were fewer lambs in the nursery.

Dam breed affected total productivity per ewe entering the breeding flock ($P < 0.001$) based on dam-reared lambs (Table 8). Ewes from Composite III dams were 14% more productive than ewes from northwestern whiteface dams.

Averaged over all effects, mating season significantly affected total productivity (Table 8). For dam-reared lambs, October and December were the most productive seasons ($P < 0.01$). This season effect has been established previously in several studies (Shelton and Morrow, 1965; Fahmy, 1996; Maijala, 1996; Young et al., 1996). This pattern was different for nursery-reared lambs. For this trait, the most productive season was October ($P < 0.01$). Differences were largely due to season effects on number of nursery-reared lambs.

Main effects of sire breed, dam breed, and mating season influenced ($P < 0.01$) longevity. Ewes with the greatest longevity were those sired by the most productive sire breed (Romanov) and also by one of the least productive (Montadale). Of the two prolific breeds, the greater longevity of Romanov-sired ewes (76.8%) provided further advantage relative to ewes by Finnsheep sires (70.5%). Greater longevity of ewes by Composite III dams (75.2%) contributed to greater total productivity relative to ewes by northwestern whiteface dams (68.1%).

Implications

Differences among breeds of sheep in levels of performance for economically important traits are genetically based and can be exploited through the use of crossbreeding systems. The comparison of F_1 ewes from five different sire breeds provides information to help producers identify breeds that meet specific production requirements. Superior performance of Romanov-sired ewes was due to greater conception rate and prolificacy at each mating season and ewe age, as well as greater longevity relative to ewes by Finnsheep, Texel, Dorset, and Montadale sires. Broader use of crossbred ewes incorporating Romanov germ-

plasm would greatly increase the efficiency of commercial sheep production.

Literature Cited

Fahmy, M. H. 1996. The Romanov. Pages 47–72 in Prolific Sheep. M. H. Fahmy, ed. CAB International, Wallingford, U.K.

Freking, B. A., K. A. Leymaster, and L. D. Young. 2000. Evaluation of Dorset, Finnsheep, Romanov, Texel, and Montadale breeds of sheep: I. Effects of ram breed on productivity of ewes of two crossbred populations. J. Anim. Sci. 78:1422–1429.

Gallivan, C., R. A. Kemp, Y. M. Berger, and L. D. Young. 1993. Comparison of Finnsheep Landrace, and Romanov as prolific breeds in a terminal-sire crossbreeding system. J. Anim. Sci. 71:2910–2918.

Glimp, H. A. 1971. Effect of breed and mating season on reproductive performance of sheep. J. Anim. Sci. 32:1176–1182.

Leymaster, K. A. 1991. Straightbred comparison of a composite population and the Suffolk breed for performance traits in sheep. J. Anim. Sci. 69:993–999.

Leymaster, K. A., and T. G. Jenkins. 1993. Comparison of Texel- and Suffolk-sired crossbred lambs for survival, growth, and compositional traits. J. Anim. Sci. 71:859–869.

Maijala, K. 1996. The Finnsheep. Pages 10–46 in Prolific Sheep. M. H. Fahmy, ed. CAB International, Wallingford, U.K.

Mohd-Yusuff, M. K., G. E. Dickerson, and L. D. Young. 1992. Reproductive rate and genetic variation in composition and parental populations: Experimental results in sheep. J. Anim. Sci. 70:673–688.

Shelton, M., and J. T. Morrow. 1965. Effect of season on reproduction of Rambouillet ewes. J. Anim. Sci. 24:795–799.

Vesely, J. A., and E. E. Swierstra. 1986. Reproductive parameters of crossbred ewe lambs sired by Romanov, Finnsheep, Landrace, Dorset, and Western range rams. J. Anim. Sci. 62:1555–1562.

Young, L. D., M. H. Fahmy, and G. Torres-Hernandez. 1996. The use of prolific sheep in North America. Pages 289–349 in Prolific Sheep. M. Fahmy, ed. CAB International, Wallingford, U.K.