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TITLE: CROSSBRED LAMB PRODUCTION FROM COLUMBIA AND SUFFOLK EWES

I. EWE PRODUCTION AND LAMB TRAITS

II. SIMULATION OF THE SHEEP FLOCK: NET INCOME PER EWE

Abstract approved: Redacted for privacy

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I. EWE PRODUCTION AND LAMB TRAITS

Four hundred and thirty seven Suffolk and Columbia-type range ewes maintained on western Oregon hill pastures from August, 1972 to July, 1974 were mated to North Country Cheviot, Dorset, Finnsheep, and Romney rams and evaluated for lamb and wood production. Fertility (ewes lambing as a percent of ewes exposed to rams) averaged 93% with little difference between Columbia and Suffolk dams or among mates of the four breeds of sire. Suffolk dams bore .08 more lambs per ewe bred than did Columbia dams, and there was little difference in date of lambing between the two breeds. Lambs born to Suffolk dams weighed .3 kg more at birth, 2.2 kg more at 7 weeks of age, and 3.2 kg more at weaning ($P<.01$). Lambs sired by Finn rams weighed .5 kg less at birth than lambs sired by the remaining three breeds of sire ($P<.01$). Lamb survival to weaning averaged 83%. Suffolk dams weaned .06 more lambs per year than did Columbia dams. Suffolk ewes had lambs whose total 7 week weight was 4.7 kg greater and whose

total weaning weight was 8.2 kg greater per ewe bred per year than lambs born to Columbia ewes (P<.01). There were no significant differences among breeds of sire for total 7 week weaning weight or for number of lambs weaned. Differences did exist, however, among individual sires within breeds. Columbia ewes produced 1.3 kg more grease wool per year than did Suffolk ewes (P<.01).

II. SIMULATION OF THE SHEEP FLOCK; NET INCOME PER EWE

Net return per ewe and per hectare was estimated for Suffolk and for Columbia-type range ewes maintained on western Oregon hill pasture and mated to North Country Cheviot, Dorset, Finnsheep and Romney rams. Differences in feed requirements for the two breeds were taken into account as well as price differentials for blackface and whiteface feeder lambs, Columbia and Suffolk grades of wool, and lamb wool and shorn wool incentive payments. A deterministic, discrete-step simulation model of the two ewe breeds grazing hill pastures for the 1973 and 1974 production years was run. Input included least squares means for ewe weight plus lamb production statistics from a preceeding paper. Results were compared to an independent grazing study conducted at the same time under similar pasture conditions. At the start of mating, Suffolk ewes averaged 71.2 kg vs 57.4 for Columbia ewes (P<.01). For 1973, Columbia ewes and their lambs consumed 378 kg dry matter (DM) of pasture and 208.7 kg DM of supplemental feed for a total feed cost of \$21.94, while Suffolk ewes and their lambs consumed 433.5 kg DM of pasture and 240 kg DM of supplemental feed for a total cost of \$25.21. For 1974 Columbias consumed 439 kg DM of pasture and 201 kg DM of supplemental feed for a total cost of $22.17, while results for Suffolks were 487.7 kg DM pasture, 228 kg DM supplemental feed, and a total cost of $25.34. Lamb income was $27.14 for Columbias and $34.87 for Suffolks for 1973 and $17.94 and $25.27 for the two breeds, respectively, for 1974. Wool income was $6.75 for Columbias and $3.52 for Suffolks in 1973 and was $6.34 and $3.19 for Columbias and Suffolks, respectively, in 1974. Return per ewe above feed costs was $11.95 for Columbias and $13.18 for Suffolks for 1973 and $2.11 for Columbias and $3.12 for Suffolks during 1974. Taking into account variable costs for labor, depreciation and interest, net return per ewe was $8.09 for Columbias and $9.63 for Suffolks during 1973, and $-1.03 and $.46 for the two breeds, respectively, during 1974. Net return per hectare was $94.65 for Columbias and $96.20 for Suffolks during 1973 and $-12.05 for Columbias and $4.60 for Suffolks during 1974.

CROSSBRED LAMB PRODUCTION FROM COLUMBIA AND SUFFOLK EWES

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CROSSBED LAMB PRODUCTION FROM COLUMBIA AND SUFFOLK EWES
I. EWE PRODUCTION AND LAMB TRAITS[1,2]

J. M. Levine[3] and William Hohenboken[3]

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[1]Technical Paper No. 4681, Oregon Agricultural Experiment Station.

[2]Contribution to North-Central Regional Project NC-111, Increased Efficiency of Lamb Production.

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SUMMARY

Four hundred and thirty seven Suffolk and Columbia-type range ewes maintained on western Oregon hill pastures from August, 1972 to July, 1974 were mated to North Country Cheviot, Dorset, Finnsheep, and Romney rams and evaluated for lamb and wool production. Fertility (ewes lambing as a percent of ewes exposed to rams) averaged 93% with little difference between Columbia and Suffolk dams or among mates of the four breeds of sire. Suffolk dams bore .08 more lambs per ewe bred than did Columbia dams, and there was little difference in date of lambing between the two breeds. Lambs born to Suffolk dams weighed .3 kg more at birth, 2.2 kg more at 7 weeks of age, and 3.2 kg more at weaning (P<.01). Lambs sired by Finn rams weighed .5 kg less at birth than lambs sired by the remaining three breeds of sire (P<.01). Lamb survival to weaning averaged 83%. Suffolk dams weaned .06 more lambs per year than did Columbia dams. Suffolk ewes had lambs whose total 7 week weight was 4.7 kg greater and whose total

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(Key words: Crossbred Lamb, Columbia, Suffolk, Wool).

weaning weight was 8.2 kg greater per ewe bred per year than lambs born to Columbia ewes ($P<.01$). There were no significant differences among breeds of sire for total 7 week and total weaning weight or for number of lambs weaned. Differences did exist, however, among individual sires within breeds. Columbia ewes produced 1.3 kg more grease wool per year than did Suffolk ewes ($P<.01$).

INTRODUCTION

Crossbreeding has long been advocated as a method to increase productivity of sheep (Rae, 1952). It is important that crossbreeding systems employ breeds and crosses which are regionally adapted. This experiment is part of continuing research to develop breed and mating system recommendations for the mild, high rainfall environment of the coastal Pacific Northwest. Earlier experiments (Hohenboken, 1976; Hohenboken et al., 1976a,b; Hohenboken and Cochran, 1976) established the overall advantage of systematic crossbreeding over straightbred lamb production under western Oregon conditions. In this study, Suffolk and Columbia-type ewes, mated to North Country Cheviot, Dorset, Finnsheep and Romney rams, are evaluated for lamb and wool production.

MATERIALS AND METHODS

Approximately 200 each of Suffolk and Columbia-type range ewes were maintained on western Oregon hill pastures from August, 1972 through July, 1974. The Columbia ewes were purchased from one range sheep operation, and the Suffolk ewes either were raised in the OSU flock, or purchased from a single California purebred breeder. Except for the mating season, all ewes were run together and subjected to the same management. From September 10 to October 20 of each year, groups of approximately 12 Suffolk and 12 Columbia ewes, selected at random within breed, were placed in single sire pastures with a semen tested ram of North Country Cheviot, Dorset, Finnsheep, or Romney breeding. Four rams of each breed were used each year for a total of 32 sires during the two-year course of the experiment. The rams were representative of the type readily available to commercial sheepmen. All ewes were shed lambed from February through mid-March each year and then returned to hill pastures. Lambs were weaned in June, as pasture quality began to deteriorate, at an average age of 15 and 16 weeks for 1973 and 1974, respectively. The lambs were not creep fed. The environment and management practices are described in more detail by Hohenboken et al. (1976a) and Cedillo et al. (1977).

Statistical analyses were performed by least squares analysis of variance (Harvey, 1960). Four mathematical models were used in the analyses. Model I was used to analyze actual birth, April (when lambs were approximately 7 weeks of age) and weaning weight per lamb. Breed of dam, breed of sire, breed of dam x breed of sire interaction, year, sex, type of birth and rearing, and age of dam were fixed independent variables. For April and weaning weight, birth and rearing classes were single/single, twin/single and twin/twin with all other combinations included in the twin/single category. For birth weight, categories were single, twin or triplet. The random effect of sires nested within breeds and years and date of lambing as a continuous independent variable were also included. Birth, April and weaning weight per lamb were then adjusted to a common male equivalent and to a mature ewe basis using constant estimates from the least squares analyses. Total April and weaning weight per ewe bred per year were then calculated, and these were subjected to further analyses.

Model II was used to analyze number of ewes lambing per ewe exposed to a ram (fertility), number of lambs born per ewe bred, lambing date, number of lambs weaned, and total April and weaning weight of lamb per ewe exposed per year. Breed of dam, breed of sire, breed of dam x breed of sire interaction, and year were fixed independent variables, while sires nested within breeds and years was a random variable.

A third model was used to analyze lamb survival to weaning. This model included the same fixed and random effects as Model II in addition to sex, type of birth, and age of ewe as fixed independent variables. Model IV, consisting of breed of ewe, year and age of ewe as fixed independent variables, was used to analyze grease wool production.

There were 874 ewes bred, 813 lambings, 1159 lambs born, and 965 lambs weaned. Fertility averaged 93%, lambs born per ewe lamging averaged 1.43, and lamb survival to weaning averaged 83%.

RESULTS AND DISCUSSION

Least squares means for ewe reproduction and production traits and for individual lamb weights are presented in tables 1 and 2, respectively. Analysis of variance tables are not included, but they may be obtained from the authors.

Ewe Reproduction. There was little difference in fertility between Suffolk and Columbia ewes, the latter having a slight advantage (94 *vs* 92%). There was little difference among breeds of sire for this trait. Although the pooled effect of sires nested within breeds and years was not significant, there were highly significant fertility differences among mates of individual Dorset and Finn rams in 1974. In the second breeding season of the experiment, one of the four Romney rams successfully bred all the Suffolk ewes but only 20% of the Columbia ewes. This, and other unpublished observations at OSU, suggests that individual rams may express a breed preference in seeking out ewes in estrus. Bourke (1967) has reported that Merino rams preferentially mated Merino ewes, and in the converse situation Lees and Weatherhead (1970) found that Clun Forest ewes exhibited a strong preference to mate with rams of their own breed. Differences among environmental effects (year and age of dam) for fertility were small and not significant.

Suffolk dams bore .08 more lambs per ewe bred than did Columbia dams. This is in general agreement with findings in the literature (Sidwell and Miller, 1971a; Dickerson and Glimp, 1975; Bradley *et al*., 1972). There was little difference among breeds of sire for this trait. Overall, ewes bred to Romney rams were slightly more prolific. There were significant differences among mates of individual Dorset, Finn and Romney sires in 1974 for this trait. The year effect was significant.

Lambing date, an indicator of fertility in the ewe and of sexual potency in the ram, was almost identical for the various breed of dam and breed of sire combinations. There were highly significant differences between years, with lambs born three days earlier in 1973 than in 1974. The age of dam effect was not significant.

Lamb Traits. There were highly significant breed of dam and breed of sire effects for birthweight. Lambs born to Suffolk dams weighed .3 kg more than lambs born to Columbia dams, in agreement with findings by Sidwell and Miller (1971b), Rastogi et al. (1975) and Vesley et al. (1977). Lambs sired by Finn rams weighed .5 kg less than lambs sired by the remaining three breeds of sire, which is consistent with results obtained by Dickerson et al. (1975). There were significant differences among progeny of individual Cheviot and Dorset sires for 1973, of individual Romney sires for 1974, and highly significant differences among individual Cheviot, Dorset, and Finn sires for 1974. The breed of sire x breed of dam interaction was not significant.

All environmental effects on birth weight were significant except lambing date. Lambs born in 1974 were .3 kg heavier than lambs born the previous year; male lambs outweighed female lambs by .3 kg; lambs born as singles were significantly heavier than lambs born as twins or triplets; and two year-old ewes bore lambs .2 kg lighter than three year-old ewes and .3 kg lighter than mature ewes.

There were highly significant differences between dam breeds for April weight per lamb. Lambs with Suffolk dams weighed 2.2 kg more than lambs with Columbia dams. Breed of sire and breed of sire x breed of dam interaction effects were small and not significant. There were highly significant differences among progeny of individual Finn sires for 1974. Years, type of birth and rearing classes, and lambing date each caused significant variation. Lambs born in 1973 weighed 2.5 kg more in April than lambs born in 1974. The regression of April weight on age of lamb was .15 kg per day. Lambs born and raised as singles outweighed lambs born and raised as twins and lambs born as twins but raised as singles by 4.9 and 3.2 kg, respectively.

There also were highly significant differences between breeds of dam for lamb weaning weight. Lambs born to Suffolk dams weighed 3.2 kg more than lambs born to Columbia dams. The breed of sire effect was small with a 1 kg difference between the highest (lambs sired by Cheviot or Dorset rams) and lowest (lambs sired by Romney rams) weaning weight averages. The year effect was significant. Male lambs weighed 1.9 kg more than female lambs at weaning ($P<.01$); lambs born and raised as singles weighed 6.2 kg more at weaning than lambs born and raised as twins and 5.3 kg more than lambs born twin but raised single ($P<.01$). The regression of weaning weight on weaning age was .103 kg per day ($P<.01$). The age of dam effect was not significant. These environmental effects are consistent with reports in the literature (Rastogi et al., 1975; Hohenboken et al., 1976b; Olson et al. 1976; Vesley et al., 1977). The advantage of progeny from Suffolk ewes over progeny from Columbia ewes is graphically presented in figure 1.

Lamb survival to weaning averaged 83%. None of the genetic effects was significant for this trait except for among progeny of individual Cheviot sires for 1974 ($P<.05$). This study failed to substantiate an advantage in survival percent of Finnsheep crossbed lambs reported by Dickerson and Glimp (1975) and Dickerson and Laster (1975) and small differences in favor of Finn x Dorset lambs reported by Wiener et al. (1973). There were highly significant differences between years, with 95% surviving in 1973 and 72% surviving in 1974. The major reason for the lower survival rate during 1974 was several serious predator attacks which killed a total of 58 lambs. Also, a number of lambs were raised as orphans in 1974, and for the purposes of this analysis, orphans were considered deaths.

Wether lambs had higher survival than female lambs ($P<.01$) which was contrary to the findings of Hight & Jury (1969) and Dickerson et al. (1975). Lambs born as singles had a highly significant survival advantage over lambs born as twins, which was in general agreement with the above two studies. The age of dam effect was not significant.

Ewe Production Traits. Total April and weaning weight of lamb per ewe exposed per year, adjusted to a male equivalent and to a mature ewe basis, were analyzed as well as number of lambs weaned per ewe and grease wool production.

Total April weight of lambs from Suffolk dams was 4.7 kg greater than for lambs from Columbia dams ($P<.01$). After subtracting the difference in birthweight, April lamb weight was still 3.9 kg greater for Suffolk dams. This indicates that Suffolk dams provided better maternal environment than did Columbia dams, since lambs are highly dependent on their dams during their first 8 weeks of life (Gardner and Hogue, 1966). The breed of sire effect was not significant for this trait nor was the breed of sire x breed of dam interaction. There were highly significant differences among mates of individual Finn sires in 1974. The year effect was also highly significant, which was due to the lower survival of lambs during 1974.

There were no significant genetic differences for number of lambs weaned except for among mates of individual Romney sires for 1974. Suffolk dams weaned .06 more lambs than Columbia dams, and more lambs sired by Romney rams reached weaning age than from the remaining three breeds of sire. The year effect for this trait was highly significant, again due to the highly significant difference in lamb survival for the 2 years of the experiment.

There were highly significant differences between dam breeds for kilograms of lamb weaned per ewe bred per year. Total weight of lambs born to Suffolk dams was 8.2 kg more than lambs born to Columbia dams. The superiority of the Suffolk breed for kilograms of lamb weaned is well documented in the literature (Sidwell and Miller, 1971b; Rastogi et al., 1975; Holtman and Bernard, 1969; Hohenboken, 1976; Hohenboken et al., 1976b; Singh et al., 1967). Subtracting the difference between breeds of 4.7 kg for April lamb weights still leaves a difference of 3.5 kg in favor of the lambs born to Suffolk dams. The superiority of Suffolk dams for total lamb weight is presented graphically in figure 1.

Breed of sire and the breed of sire x breed of dam interaction effects were not significant. Lambs sired by Romney rams weighed the most at weaning, followed by lambs sired by Dorset, Finn, and Cheviot rams, in that order. The year effect was highly significant, once again due to the highly significant difference in lamb survival between 1973 and 1974.

Columbia ewes produced more grease wool than Suffolk ewes ($P<.01$), which is consistent with reports in the literature (Sidwell and Miller, 1971c; Sidwell et al., 1971d; Bradley et al., 1972; Cedillo et al., 1977). There were small and nonsignificant differences for year and age of dam effects.

Discussion. Suffolk dams were slightly more prolific than Columbia dams and produced heavier lambs at weaning. A possible source of the superior performance of Suffolk dams is better adaptation to the high rainfall conditions of western Oregon. Columbias were bred for a more arid, inter-Mountain climate. Columbia ewes were included in this study because their large numbers in the range States make them a potential source of crossbred replacement ewes from contract matings.

There was little difference among sire breeds for any of the traits analyzed. Thus, a suitably tested ram of any of the four sire breeds could successfully sire crossbred lambs.

There was considerable variation among individual sires for the traits analyzed. The thirty-two individual sires used in this study were chosen as representative of their respective breeds and were semen tested. The variation in their production of crossbred lambs suggests the need for more rigorous testing and intensive selection of individual sires if a breeding program is to be successful.

As lifetime production information of crossbed ewe lambs born during this study and retained for breeding becomes known, the Cheviot, Dorset, Finn, Romney, Suffolk and Columbia breeds will be evaluated for genetic merit as parents of replacement ewes. Cedillo et al. (1977) have studied reproduction and lamb and wool production of ewe lambs from all eight crossbed groups under western Oregon conditions, and Hohenboken (1977) reported postweaning growth and carcass merit of the wether lambs born during this study.

TABLE 1. LEAST SQUARES MEANS FOR EWE REPRODUCTION AND PRODUCTION

Effect	Fertility	Number of lambs born[a]	Lambing date[b]	Total April weight of lamb[a] (kg)	Number of lambs weaned[a]	Total weaning weight[a] (kg)	Wool production (kg)
Breed of dam:							
Columbia	.94	1.35	47.0	19.7**	1.14	29.4**	3.3**
Suffolk	.92	1.43	47.8	24.4	1.20	37.6	2.0
Breed of sire:							
N.C. Cheviot	.90	1.38	46.7	20.7	1.13	31.6	-
Dorset	.94	1.35	48.8	21.8	1.16	34.4	-
Finn	.96	1.38	46.4	22.0	1.13	33.0	-
Romney	.92	1.48	47.5	23.7	1.28	35.0	-
Breed of sire x breed of dam:							
N.C. Cheviot x Columbia	.93	1.16	46.3	18.7	1.19	29.4	-
Dorset x Columbia	.95	1.28	48.9	18.7	1.09	28.9	-
Finn x Columbia	.96	1.40	44.9	21.5	1.14	30.6	-
Romney x Columbia	.91	1.40	47.5	20.0	1.15	28.7	-
N.C. Cheviot x Suffolk	.87	1.28	47.0	22.8	1.07	33.8	-
Dorset x Suffolk	.93	1.41	48.6	24.0	1.20	39.9	-
Finn x Suffolk	.96	1.35	47.8	22.6	1.12	35.4	-
Romney x Suffolk	.92	1.55	47.4	27.5	1.38	42.4	-
Year:							
1973	.94	1.46*	45.9**	24.7**	1.30**	36.5**	2.7
1974	.92	1.33	48.8	19.4	1.04	30.5	2.6
Mean	.93	1.40	47.4	22.0	1.17	33.5	2.7

[a]Per ewe exposed per year.

[b]Measured as number of days born after December 31 of previous year.

*P<.05.

**P<.01.

TABLE 2. LEAST SQUARES MEANS FOR LAMB TRAITS

Effect	Birth weight (kg)	April weight (kg)	Weaning weight (kg)	Percent survival
Breed of dam:				
Columbia	4.1**	17.3**	27.4**	.83
Suffolk	4.4	19.5	30.6	.84
Breed of sire:				
N.C. Cheviot	4.4**	18.2	29.3	.83
Dorset	4.4	18.5	29.3	.84
Finn	3.9	18.9	28.9	.82
Romney	4.4	17.9	28.3	.84
Breed of sire x breed of dam:				
N.C. Cheviot x Columbia	4.2	16.8	27.7	.84
Dorset x Columbia	4.3	17.1	27.1	.86
Finn x Columbia	3.8	18.7	27.6	.81
Romney x Columbia	4.4	16.5	27.0	.83
N.C. Cheviot x Suffolk	4.6	19.6	30.8	.83
Dorset x Suffolk	4.5	19.9	31.5	.83
Finn x Suffolk	4.0	19.1	30.2	.85
Romney x Suffolk	4.4	19.3	29.6	.87
Year:				
1973	4.1**	19.6**	29.4*	.95**
1974	4.4	17.1	28.6	.72
Sex:				
Male	4.4**	18.8	30.0**	.86**
Female	4.1	17.9	28.1	.81
Type of birth/rearing[a]:				
Single/single	5.0**	21.1**	32.9**	.93**
Twin/single[b]	-	17.8	27.3	-
Twin/twin	3.6	16.2	26.7	.74
Age of dam:				
Two	4.1**	18.0	28.3	.82
Three	4.3	18.7	29.8	.87
Four+	4.4	18.4	28.6	.81
Regression of trait on lambing date:	.005	.15**	.103**	-
Mean	4.2	18.4	29.0	.83

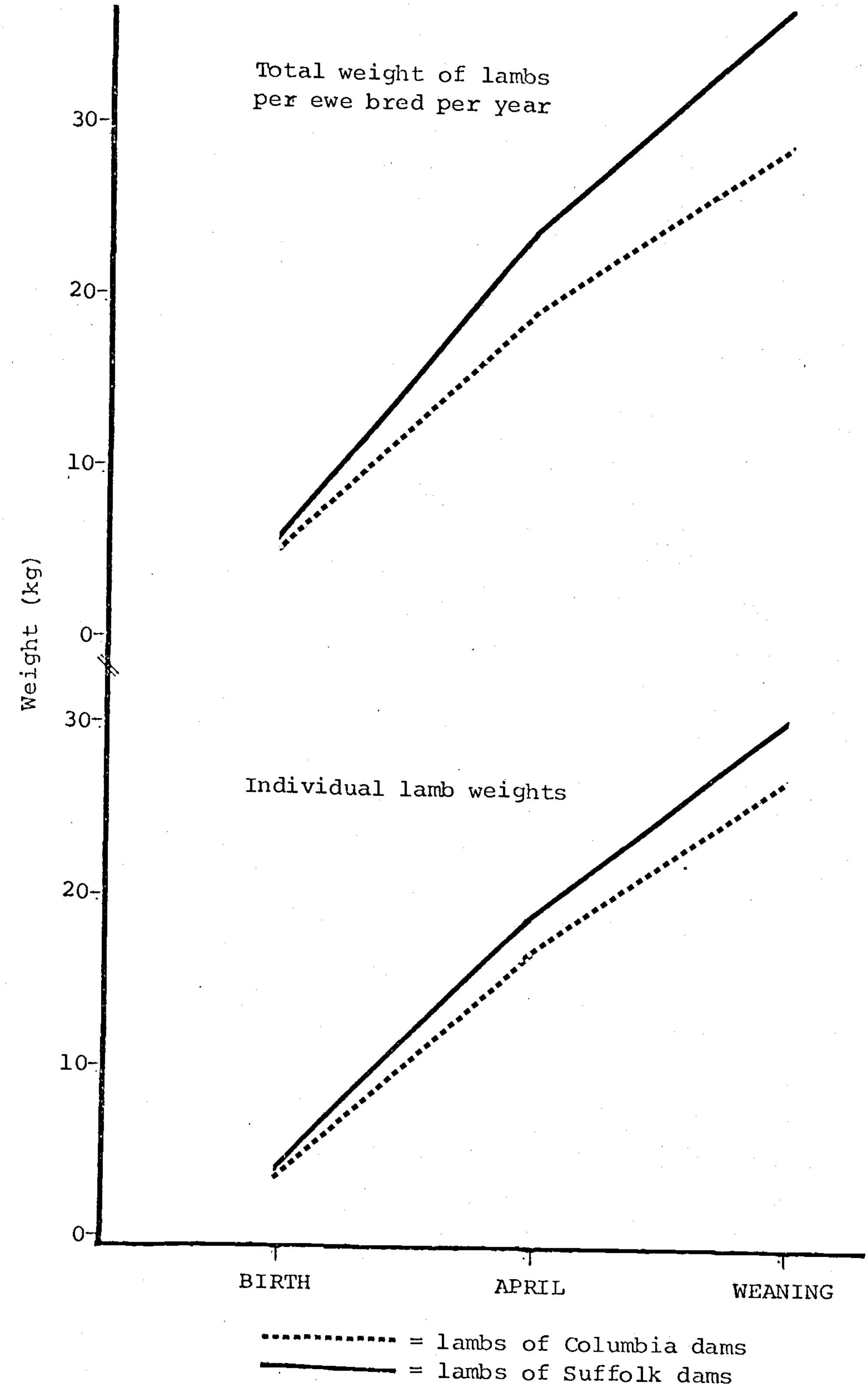
[a]For survival analysis, type of birth only.

[b]This category also included a small number of triplet lambs raised as twins or singles.

*P<.05 level of significance for the main effect.

**P<.01 level of significance for the main effect.

Figure 1. Lamb birth, April and weaning weights per lamb and total lamb per ewe bred per year (adjusted for age of dam and sex).



CROSSBED LAMB PRODUCTION FROM COLUMBIA AND SUFFOLK EWES
II. SIMULATION OF THE SHEEP FLOCK; NET RETURN PER EWE[1,2,3]

J. M. Levine[4], William Hohenboken[4] and A. Gene Nelson[5]

[1]Technical Paper No. 4682, Oregon Agricultural Experiment Station.

[2]Contribution to North-Central Regional Project NC-111, Increased Efficiency of Lamb Production.

[3]Assistance of Martin Dally, Oregon State University Animal Science graduate student, in price determinations is gratefully acknowledged.

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SUMMARY

Net return per ewe and per hectare was estimated for Suffolk and for Columbia-type range ewes maintained on western Oregon hill pastures and mated to North Country Cheviot, Dorset, Finnsheep and Romney rams. Differences in feed requirements for the two breeds were taken into account as well as price differentials for blackface and whiteface feeder lambs, Columbia and Suffolk grades of wool, and lamb wool and shorn wool incentive payments. A deterministic, discrete-step simulation model of the two ewe breeds grazing hill pastures for the 1973 and 1974 production years were run. Input included least squares means for ewe weight plus lamb production statistics from a preceeding paper. Results were compared to an independent grazing study conducted at the same time under similar

pasture conditions. At the start of mating, Suffolk ewes averaged 71.2 kg vs 57.4 for Columbia ewes ($P<.01$). For 1973, Columbia ewes and their lambs consumed 378 kg dry matter (DM) of pasture and 208.7 kg DM of supplemental feed for a total feed cost of $21.94, while Suffolk ewes and their lambs consumed 433.5 kg DM of pasture and 240 kg DM of supplemental feed for a total cost of $25.21. For 1974 Columbias consumed 439 kg DM of pasture and 201 kg DM of supplemental feed for a total cost of $22.17, while results for Suffolks were 487.7 kg DM pasture, 228 kg DM supplemental feed and a total cost of $25.34. Lamb income was $27.14 for Columbias and $34.87 for Suffolks for 1973 and $17.94 and $25.27 for the two breeds, respectively, for 1974. Wool income was $6.75 for Columbias and $3.52 for Suffolk in 1973 and was $6.34 and $3.19 for Columbias and Suffolks, respectively, in 1974. Return per ewe above feed costs was $11.95 for Columbias and $13.18 for Suffolks for 1973 and $2.11 for Columbias and $3.12 for Suffolks during 1974. Taking into account variable costs for labor, depreciation and interest, net return per ewe was $8.09 for Columbias and $9.62 for Suffolks during 1973, and $-1.03 and $.46 for the two breeds, respectively, during 1974. Net return per hectare was $94.65 for Columbias and $96.20 for Suffolks during 1973 and $-12.05 for Columbias and $4.60 for Suffolks during 1974.

(Key words: Simulation, Net return, Columbia, Suffolk)

INTRODUCTION

To increase productivity of sheep by crossbreeding it is important to consider the net return to the producer. Increased lamb and wool production require increases in feed and other costs. The choice of a breeding system for a specific environment should maximize the difference between increased productivity and increased costs. The objective of this study was to estimate the net return per ewe and per hectare of Suffolk and Columbia-type ewes mated to North Country Cheviot, Dorset, Finnsheep and Romney rams and raised under western Oregon hill pasture conditions, taking into account the difference in feed requirements for the two breeds of ewe, different market prices for blackface and white-face feeder lambs and for Suffolk and Columbia wool as well as wool incentive payments.

MATERIALS AND METHODS

Population and Management. Approximately 200 each of Suffolk and Columbia-type range ewes were maintained on western Oregon hill pastures during the 1973 and 1974 production years. A total of 1159 lambs, sired by North Country Cheviot, Dorset, Finnsheep and Romney rams, were born; and nine hundred and sixty-five lambs survived to weaning age. All ewes were shed lambed from February through mid-March each year and then returned to hill pastures. Lambs were not creep fed and were weaned in June. Ewes were maintained without supplemental feed on dormant pasture throughout the summer and during the early fall when some pasture growth occurred. From November to mid-March all ewes were fed first grass hay (1 02 250) and molasses (4 04 696) and then alfalfa hay (1 00 059) ad libitum plus a grain mix. Management practices, experimental design, and procedures are described in greater detail by Levine and Hohenboken (1978). Least squares means for ewe reproduction and lamb production and the individual lamb traits are available from the same peper.

Statistical analysis. A least squares analysis of variance was performed with ewe weight in the autumn as the dependent variable (Harvey, 1960). Independent variables were breed of ewe, year and age of ewe.

The simulation model for sheep grazing. Determination of net return per ewe bred (exposed to a ram) proceeded as follows. Using least square means for Columbia and Suffolk ewe weights and lamb production pooled over breeds of sire, a discrete step, deterministic simulation of Columbia and Suffolk ewes grazing western Oregon hill pastures was run for the years 1973 and 1974 using a model adapted from the literature (Smith and Williams, 1973) to obtain estimates of feed intake per ewe. The model monitored five main state variables on a daily basis: the weight of herbage on offer (the total dry matter (DM) weight of the pasture on a given day), plant density, pasture height, liveweight of sheep per hectare, and soil moisture in the top 30 cm of the soil. The growth of the pasture was estimated as a function of soil radiation, leaf area exposed, and amount of pasture removed by grazing sheep. Changes in soil moisture were calculated from open pan evaporation and rainfall data, which, along with solar radiation, were available on a daily basis for 1973 and 1974 from NOAA, National Weather Service, Microclimate Station for Agriculture, Oregon State University Hyslop Agronomy Farm (unpublished data), and were read into a Control Data Corporation Cyber 73 Series computer to run the simulation. Defoliation by grazing sheep was calculated as a function of stocking rate, pasture weight, and height of pasture. The liveweight change of ewes and lambs was determined by the amount of pasture intake, the digestibility of the pasture and the partitioning of metabolizable energy (ME) of ingested pasture among maintenance, lactation and growth requirements. Full details of the model are reported elsewhere (Smith and Williams, 1973).

The Smith and Williams model simulated the growth of feeder lambs for 105 days during the spring grazing season. This model was expanded to simulate the sheep flock for the entire production year. Complete details of the adapted model are available from the authors. Additional equations were developed to simulate the pasture intake of the lactating ewe. Energy requirements of the ewes were calculated using formulas modified from Smith and Williams (1973) and Young and Corbett (1968). Maintenance ME requirements were calculated from the Young and Corbett formula:

$$(1)\ \text{ME (Mcal/day)} = .132 \times (\text{liveweight})^{.75}$$

Ewes nursing single lambs were credited with ME intake 1.50 times maintenance, and ewes nursing twin lambs, 1.85 times maintenance requirements. ME intake for weight gain during the ewe's dry period was calculated by the formula, (modified from Young and Corbett, 1968):

$$(2)\ ME = .132 \times \text{liveweight}^{.75} (1 + .0055\ g)$$

where g is gain in grams. The estimated supplemental feed for November through mid-March was calculated by computer by dividing the ME needs of the ewe on a particular day by the ME content/kg of the uniform supplemental feed, which was calculated using NRC feed tables (1969). To run the model year around, pasture digestibility was adjusted seasonally in accordance with findings of Bedell (1970).

In order to run the adapted Smith and Williams model under western Oregon conditions, values had to be fitted for SPM (soil productivity multiplier), a dimensionless scaling factor allowing for adjustment in soil fertility and condition from site to site and year to year, and for EMAX (maximum amount of pasture intake of the lactating ewe). Values for SPM and EMAX were chosen within the bounds of biological meaning and to produce stability in the simulation runs. Stability in the model was defined as producing weight changes in the ewes and growth patterns in the lambs that were realistic and that conformed to the data. The average metabolic weight ($W^{.75}$) of ewes and weaned lambs was computed per breed of ewe. The ratio of these two totals was used to estimate the relative difference in energy requirements for Columbia and Suffolk dams grazing pasture with their lambs. This relative difference was then used to distinguish quantitatively between stocking rates for the two breeds of ewe. Under the conditions for western Oregon hill pastures during 1973 and 1974, stocking rate per hectare of 10 Suffolk ewes with their lambs was equivalent to a stocking rate of 11.7 Columbia ewes with their lambs. Separate simulations were then run for 1973 and 1974 for each breed of ewe using these stocking rates to obtain estimates of their actual pasture and supplemental feed intake. Pasture intake estimates of the lambs were obtained by computing the difference between estimates of energy supplied by the dam's milk and energy required by the lambs to grow at their observed levels. Results are presented in table 4.

Estimates of pasture intake from the simulation were then compared with results from an independent grazing study conducted during the same two years and under similar pasture conditions (Thetfold, 1976). In the grazing trial commercial black-face-type ewes and their lambs were stocked at three different intensities (7.4, 9.9 and 12.4 ewes/ha), and pasture growth and ewe and lamb intake were estimated by the before-and-after cage plot technique (Carter, 1962). The most relevant comparison between the simulation and the grazing trial is between the Suffolk simulation and the grazing experiment with a stocking rate of 9.9 ewes/ha. Table 5 presents the results of that comparison.

Calculation of net return. Once estimates of feed intake per breed of ewe were obtained from the simulation and tested against values obtained from the grazing study, costs were assigned to them. Cost of pasture intake was calculated on the basis of the net worth of the pasture if it had been used to produce hay. This net worth was determined by computing an average price of a metric ton of grass/clover hay, dry matter basis, from 1972 through 1976 using local market prices (Oregon Farmer-Stockman, 1972-76), and then subtracting an estimate of baling costs. For the purposes of computing the cost of supplemental feed fed to the ewes from November to mid-March each year, it was assumed that the feed consisted of a uniform ration of 50% grass hay (1 02 250), 25% alfalfa (1 00 059), 5% molasses (4 04 696) and a 20% grain mix of equal amounts of barley, wheat and ryegrass screenings (4 02 156). Costs were assigned to this feed using average prices paid by the Oregon State University (OSU) sheep operation from 1972 through 1976. A total cost of pasture plus supplemental feed per Suffolk and Columbia ewe bred plus their lambs was then computed. Results are presented in table 4.

Gross income was then computed for the two breeds of dam, taking into account the price differential for blackface and whiteface feeder lambs, Suffolk and Columbia wool grades, and the Wool Incentive Program payments for shorn and unshorn wool. All lambs weaned during the experiment were feeder lambs. For the purposes of calculating lamb income per ewe bred, all lambs were assumed to be sold for market with no replacements retained. Table 4 and table 5 present results for lamb income and wool income, respectively. Net return above feed costs per ewe bred was then calculated for each breed of ewe. These results are presented in table 8 and illustrated graphically in figure 2.

Net return above variable costs per hectare was also computed for each breed of ewe. Costs for supplemental feed were subtracted from gross income as were costs for variable labor, ewe depreciation and interest in order to determine net return per ewe above variable costs (Enterprise Cost Studies, Extension Farm Management Staff, Oregon State University, unpublished data). This net return was then multiplied by the stocking rate per hectare for each breed of ewe to calculate net return above variable costs per hectare. Results are presented in table 9 and illustrated graphically in figure 2.

RESULTS AND DISCUSSION

Ewe weight. Least squares means for ewe weight are presented in table 2. There were highly significant differences for all variables in the model. Suffolk ewes weighed 13.8 kg more than Columbia ewes. This finding is consistent with reports in the literature (Sidwell and Miller, 1971; Bradley *et al*., 1972, Rastogi *et al*., 1975). Ewes weighed 4.8 kg more in 1973 than in 1974, and ewes four years of age and older weighed 4.2 kg more than both two and three-year old ewes. The least squares means for ewe weight were used in the simulation to distinguish between the two breeds of ewe.

Performance of the model. Results of the simulation for 1973 and 1974 estimating pasture and supplemental feed intake for Columbia and Suffolk ewes and their lambs, as well as a comparison of these results to a separate grazing study undertaken at the same time under similar conditions, are presented in tables 4 and 5.

There was general agreement between the simulation and the grazing experiment (Thetford, 1976) for amount of dry matter production of pasture. In the simulation, DM pasture production was 4244 and 5104 kg/ha for 1973 and 1974, respectively, while the grazing trial estimated DM pasture production at 4890 and 5975 kg/ha for the two years, respectively. For both years the simulation produced estimates 15% lower than the grazing trial. Possible explanations for this difference include differences in the soil fertility, water table, level of previous fertilization, and temperature between the site of the grazing trial and the hill pastures where data for the simulation were obtained, experimental error in the cage plot technique, or a downward bias in the simulation.

An additional test of the simulation is its sensitivity to yearly weather changes. The spring grazing season for 1973 was abnormally dry while the 1974 season had more normal rainfall (Bates and Calhoun, 1977). Dry matter pasture production estimates produced by the simulation were consistent with the weather for the two years.

There was also general agreement between the simulation and the grazing trial for daily DM intake with the exception of late spring 1973 and early spring 1974 when the grazing trial intake exceeded the simulation intake. During the early spring of 1973, simulation and grazing trial estimates of dry matter were almost identical, but during late spring, grazing estimates were 2.4 kg/day higher than for the simulation. By summer, simulation estimates were slightly higher than grazing trial estimates, and this difference widened by fall. The same trend occurred for 1974 with early spring grazing trial intake 2.3 kg/day higher than simulation intake, while by summer the simulation intake exceeded the grazing trial intake by .3 kg/day. A possible explanation of this is that in the grazing trial more of the pasture growth occurred during the spring season and less during the summer and fall than with the simulation, so the simulation undervalued intake in the spring and biased intake upward during the summer and fall. If this were so, this source of error partially cancelled itself out.

Another reason for the lower simulation intake values for early spring 1973 and late spring 1974 was that the model assigned a ceiling of 2.93 kg/day to EMAX, the maximum possible intake of pasture by a lactating ewe. Smith and Williams (1973) assign a value of 1.14 kg for EMAX for feeder lambs. The simulation model therefore imposed a ceiling of 5.21 kg/day of ingested pasture for ewes grazing with twin lambs. This is still .5 kg/day less than values obtained from the grazing trial for late spring 1973, and all of the ewes did not raise twins. The before-and-after cage plot technique used in the grazing trial to estimate ewe and lamb intake also included losses due to trampling and uprooting of pasture. This probably caused an upward bias of intake during maximum spring growth conditions where these losses would be maximal.

There was very close agreement between the simulation and the grazing trial for total dry matter consumption of pasture for 1973 (433.5 vs 447.6 kg, respectively) and reasonable agreement for the 1974 season (487.7 vs 529.5 kg). The value of this state variable is of primary concern in assigning pasture costs to the grazing ewes.

No estimates were available from the grazing trial for supplemental feed fed during the late fall and winter months. Ewes were assigned supplemental feed by the simulation, based on their known weight change and physiological status (formula 1 and 2). Results were consistent with estimates of that portion of total OSU sheep operation feed purchases for 1973 and 1974 allocated to this experiment.

The Young and Corbett (1968) maintenance energy requirement used by Smith and Williams (1973) is 35% greater than the most recent NRC requirement (1975) and 18% higher than an earlier NRC recommendation (1968). The higher maintenance requirement was used because results by Young and Corbett (1968) have indicated greater maintenance requirements for sheep maintained on pasture than in drylot. The higher maintenance and lactation requirements were also used in the OSU simulation runs as a correction factor to account for energy and growth losses due to the higher worm infestations of sheep maintained most of the year on pasture than those raised in drylot. The detailed modelling of the seasonal effects of parasite infestation was beyond the scope of this study.

Net return. Lamb income from Suffolk dams was $7.73 greater in 1973 and $7.33 greater in 1974 than lamb income from Columbia dams (table 6). This advantage was due both to the greater quantity of lamb weaned by Suffolk dams (Levine and Hohenboken, 1978) and to the higher price paid per kilogram for blackface than for whiteface feeder lambs by Northwest feeders and grazers. Lamb prices were calculated on the basis of Portland, Oregon sale prices for U.S. Choice (whiteface) and U.S. Fancy (blackface) lambs from mid-May to mid-June each year from 1972 through 1976 (Oregon Cooperative Extension Service, 1972-76). Lamb wool incentive payments, paid for unshorn wool on lambs, were computed according to U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service (1977) information. Since lamb wool incentive payments are based upon the number of kilograms of lamb marketed regardless of wool quality, payments for lambs born to Suffolk dams were slightly higher for both years.

Wool income for Columbia ewes was considerably higher than wool income from Suffolk ewes for both years (table 5). This was a reflection of the higher production from Columbia dams, the higher value of Columbia wool, and the higher incentive payments paid for shorn Columbia wool under the Wool Incentive Payment Program. These three sources of wool income resulted in almost double the income from wool for Columbia dams for both years. Average wool prices for 1972 through 1976 were obtained from the Douglas County, Oregon, Pool

(Oregon Cooperative Extension Service, 1972-76); price differentials for Columbia and Suffolk wool were obtained from the California WoolMarketing Association (unpublished information, 1977); and the wool incentive payments for shorn wool were calculated according to U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service Information (1977).

Total gross income for Suffolk ewes for 1973 was \$38.39 vs \$33.89 for Columbia ewes. For 1974, gross income was \$28.46 and \$24.28 for Suffolk and Columbia ewes, respectively. The lower income for 1974 was due to the lower lamb survival rate for that year, as discussed in a preceeding paper (Levine and Hohenboken, 1978). Suffolk ewes enjoyed an average advantage of \$4.34/year in gross income. This advantage in favor of Suffolk ewes was altered considerably when differences in feed costs were taken into account (table 8). Total feed costs for Suffolk ewes and their lambs were \$3.27 greater than for Columbia ewes and their lambs in 1973 and \$3.17 greater in 1974. This reduced the net advanrage in return above feed costs per ewe bred for Suffolk dams to \$1.23 in 1973 and \$1.01 in 1974, or an average of \$1.12. The highly significant difference in lamb production in favor of Suffolk dams (Levine and Hohenboken, 1978) is altered when the economic realities of breeding systems are considered. Lower feed costs, higher wool income, and higher wool incentive payments for Columbia ewes must be taken into consideration when recommendations for a specific crossbreeding system are made (Figure 2).

Net return per ewe above variable costs in 1973 was $8.09 for Columbias and $9.62 for Suffolks (table 9). Higher stocking rates for Columbia ewes and their lambs resulted in small differences in net return per hectare for 1973, with $94.65 and $96.20 for the two breeds, respectively. For 1974, Suffolk ewes enjoyed a similar advantage of approximately $1.50 per ewe over Columbia ewes, but lower gross income for both breeds due to a low survival rate for lambs resulted in a $.46 per ewe profit for Suffolks and $1.03 per ewe loss for Columbias. Net return per hectare for 1974 was $-12.05 for Columbias and $4.60 for Suffolks.

Calculating net return above variable costs per hectare avoids having to assign any monetary value to standing forage. Costs are fixed from year to year on pasture land, but yield varies in both quantity and quality due to weather, previous grazing use, and other practices. Thus, assigning a constant value to the standing forage becomes somewhat arbitrary and subject to error. Calculation on a net return above valuable costs per hectare basis considers the components of income and expense that a producer would actually accrue and measures his rate of return on his most basic resource, his land. Calculation on this basis suggests that in years of low productivity in the sheep flock, such as in 1974, a smaller number of larger, more prolific Suffolk ewes with more rapidly gaining lambs will be more profitable than a greater number of smaller, less prolific, higher wool producing Columbias with less rapidly growing lambs.

<u>Discussion</u>. The use of simulation techniques to study grazing animals offers an opportunity to synthesize an entire biological

system out of the specialized subunits of genetics, range management, agronomy, computer science, statistics, and nutrition. Specialized knowledge in any of these fields may then be tested on its ability to add knowledge to the entire system (Wright and Dent, 1969). In land-grant universities where responsibilities are often divided between teaching and research, the building and use of a simulation model creates a versatile and efficient tool for both activities (Mill and Longwirth, 1975). In the present instance, the model developed by Smith and Williams (1973) was chosen because of its versatility and the philosophy implicit in its construction. Equations were developed which had biological meaning and validity, and any changes in those equations had to be justified by known biological changes in the real system that was being simulated. The model thus attempted to provide a quantitative biological explanation for the entire grazing ecosystem. It has the potential to yield a wealth of information in addition to its use in this study to obtain estimates of feed intake for Columbia-type and Suffolk ewes.

Another aspect of simulation modeling is that it uncovers gaps in the knowledge of the system. In modeling ewes grazing western Oregon hill pastures, very little information was available about grazing behavior, nor were accurate data available for pasture intake at different ages and physiological stages and by different breeds. Arnold and Dudzinski (1967) found breed differences among ewes for amount of grazing time and appetite, as well as intake differences associated with age and physiological status. They stressed the need for more detailed knowledge of grazing behavior. Very little is known about the grazing behavior of young lambs. No equations could be found in the literature to model preweaning lamb pasture performance. Langlands (1973) found breed differences in the relative amount of milk and pasture intake in young lambs. Accurate data are needed in this area, especially since it may provide information on survivability of young lambs, the most critical factor in the success or failure of a sheep enterprise. In this experiment the use of a simulation model and economic analyses added another dimension of information to the traditional statistical analysis of lamb and wool production data, providing a more precise and accurate framework in which management decisions on breed selection for hill pasture sheep operations can be made.

TABLE 3. Least squares means for ewe weight

Effect	Least squares means
Breed of ewe	
Columbia	57.4**
Suffolk	71.2
Year	
1973	66.7**
1974	61.9
Age of ewe	
Two	62.9**
Three	62.9
Four +	67.1
Mean	64.3

**P<.01 level of significance for the main effect.

TABLE 4. Simulation results for pasture and supplemental feed dry matter (DM) intake and feed costs per ewe bred.

Year	Breed of ewe	DM pasture intake of ewe (kg)	DM pasture intake of lambs[a] (kg)	Cost of pasture[b]	DM supplemental feed (kg)	Cost of supplemental feed[c] ($)	Total nutrient cost ($)
1973	Columbia	319.0	59.0	$ 8.69	208.7	13.25	21.94
	Suffolk	377.8	55.7	$ 9.97	240.0	15.24	25.21
1974	Columbia	351.0	58.0	$ 9.41	201.0	12.76	22.17
	Suffolk	422.7	55.0	$10.87	228.0	14.47	25.34

[a] Total of all lambs weaned/ewe exposed to mating.

[b] Calculated at rate of $23/metric ton, 1972-76 average.

[c] Calculated at rate of $63.50/metric ton, 1972-76 average.

TABLE 5. Comparison of dry matter (DM) intake estimated by simulation and by grazing experiment

	Simulation[a]	Grazing trial
1973		
DM production (kg/ha)	4244.00	4890.00
Daily DM intake[b]		
Early spring	2.48	2.56
Late spring	3.40	5.77
Summer	1.82	1.65
Fall	1.00	0.34
Total DM intake[b]	433.50	447.60
1974		
DM production (kg/ha)	5104.00	5975.00
Daily DM intake[b]		
Early spring	2.60	4.90
Late spring	1.90	2.00
Summer	1.20	0.90
Total DM intake[b]	487.70	529.50

[a]Suffolk ewe simulation results vs commercial blackface-type grazing trial ewes.

[b]Intake for ewes plus lambs, per ewe exposed to mating.

[c]Grazing trial data available only through summer for 1974.

TABLE 6. Lamb income per ewe bred

Year	Breed of ewe	Kg lamb weaned	Price/ kg[a] ($)	Value of lamb ($)	Lamb wool incentive payment[b] ($)	Total income ($)
1973	Columbia	35.4	.754	26.69	.45	27.14
	Suffolk	43.6	.787	34.31	.56	34.87
1974	Columbia	23.4	.754	17.64	.30	17.94
	Suffolk	31.6	.787	24.87	.40	25.27

[a] 1972-76 average U.S. choice grade for whiteface, U.S. fancy grade for blackface feeder lambs.

[b] $.58/each 45.43 kg of lamb sold.

TABLE 7. Wool income per ewe bred

Year	Breed of ewe	Kg of wool[a]	Price/ kg[b] ($)	Value of wool ($)	Wool incentive payment[c] ($)	Total wool in income ($)
1973	Columbia	3.4	1.42	4.83	1.92	6.75
	Suffolk	2.1	1.20	2.52	1.00	3.52
1974	Columbia	3.2	1.42	4.54	1.80	6.34
	Suffolk	1.9	1.20	2.28	0.91	3.19

[a]Grease fleece basis.

[b]1972-76 average.

[c]Payment at rate of $.56/kg for Columbia wool and $.48/kg for Suffolk wool.

TABLE 8. Net return above feed costs per ewe bred

Year	Breed of ewe	Pasture costs	Dry feed costs	Wool income	Lamb income	Net income
1973	Columbia	$ 8.69	$13.25	$6.75	$27.14	$11.95
	Suffolk	$ 9.97	$15.24	$3.52	$34.87	$13.18
1974	Columbia	$ 9.41	$12.76	$6.34	$17.94	$ 2.11
	Suffolk	$10.87	$14.47	$3.19	$25.27	$ 3.12

TABLE 9. Net return above variable costs per hectare

	1973		1974	
	Columbia	Suffolk	Columbia	Suffolk
Gross income	$33.89	$38.39	$24.28	$28.46
Supplemental feed	$13.25	$15.24	$12.76	$14.47
Variable labor[a]	$ 7.50	$ 7.50	$ 7.50	$ 7.50
Depreciation (ewe)[a]	$ 3.43	$ 4.30	$ 3.43	$ 4.30
Interest on ewe investment[a]	$ 1.62	$ 1.73	$ 1.62	$ 1.73
Net return/ewe	$ 8.09	$ 9.62	$-1.03	$ .46
Stocking rate/ha	11.7	10	11.7	10
Net return/ha	$94.65	$96.20	$-12.05	$ 4.60

[a]Enterprise Cost Studies, Extension Farm Management Staff, OSU (unpublished).

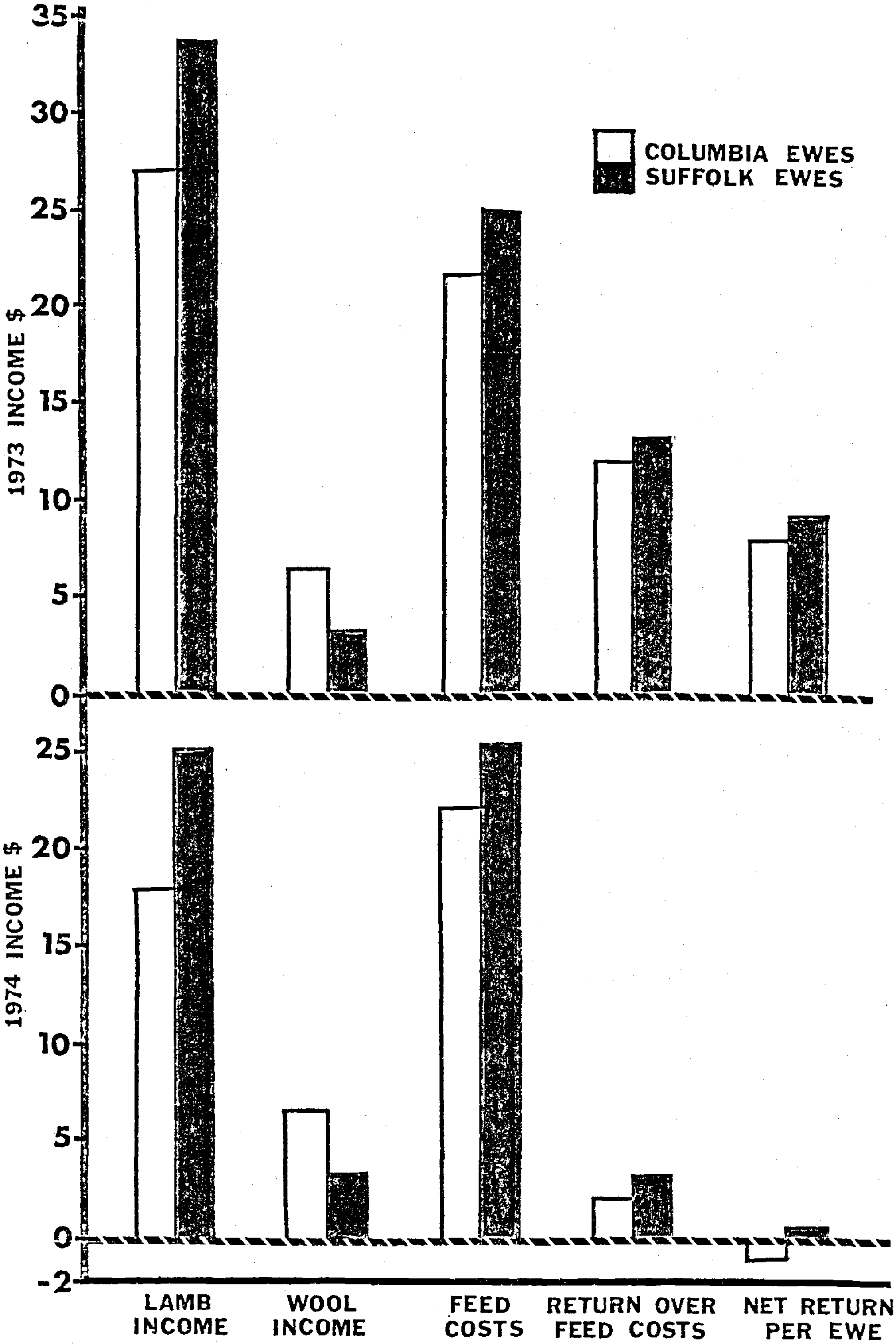

FIGURE 2. Summary of 1973 and 1974 income components, costs and returns per Suffolk and Columbia ewe exposed to mating.

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A P P E N D I C E S

APPENDIX 1. MEAN SQUARES FOR TABLE 1 -- EWE REPRODUCTION AND PRODUCTION

Effect	Fertility	Number of lambs born	Lambing date	Total April weight of lamb (kg)	Number of lambs weaned	Total weaning weight (kg)	Wool production (kg)
Breed of dam	.04	.95	83.0	3527.0**	.91	10423.0**	123.30**
Breed of sire	.09	.39	153.7	178.7	.60	308.9	-
Breed of sire x breed of dam	.05	.52	90.6	383.5	1.20	890.0	-
Sires/within breeds/year[a]	.43	.99	232.7	373.8	.76	835.7	-
Year	.06	2.85*	1370.0**	5486.5**	13.16**	6795.0**	1.40
Age of dam	.73	.03	90.5	291.8	.09	181.3	.94
Residual	.30	.58	86.6	237.0	.52	433.8	.53

[a]Pooled MS for individual sires.

APPENDIX 2. MEAN SQUARES FOR TABLE 2 -- LAMB TRAITS

Effect	Birth weight (kg)	April weight (kg)	Weaning weight (kg)	Percent survival
Breed of dam	18.10**	814.0**	1676.0**	.014
Breed of sire	13.20**	38.7	46.9	.025
Breed of sire x breed of dam	1.40	76.1	37.5	.098
Sires/bred/year	2.39	87.5	46.2	.230
Year	27.60**	1321.0**	101.9*	14.10**
Sex	18.60**	192.7	788.0**	.90**
Type of birth/rearing[a]	92.80**	1915.0**	3059.0**	8.50**
Age of dam	2.90**	13.5	55.5	.23
Regression of trait on lambing date	1.90	1275.0**	593.0**	-
Residual	.61	58.3	19.3	.15

[a]For survival analysis, type of birth only.

APPENDIX 3. MEAN SQUARES FOR EWE WEIGHT ANOVA

Effect	df	Mean Squares
Breed of ewe	1	29421**
Year	1	4428**
Age of ewe	2	817**
Residual	786	72

APPENDIX 4. LAMB WOOL INCENTIVE PAYMENTS[a]

Support price - National average = Price paid/kg wool

$1.58/kg[b] - $1.26/kg[c] = $ .32/kg[c]

Each 45.43 kg of lamb sold = Credit for 2.27 kg of lamb wool.

Incentive payment = 80% x $.32/kg x 2.27 kg/each 45.43 kg of lamb sold.

Incentive payment = $.58/ea 45.43 kg of lamb sold.

[a]Unshorn wool sold on lamb.

[b]Fixed by U.S. Congress.

[c]Five year averages, 1972-76.

APPENDIX 5. Wool incentive payments - Shorn wool[a]

Support Price - National average = Difference

$$\frac{\text{Difference}}{\text{National Avg.}} = \text{Shorn wool payment rate.}$$

$$\text{Individual ranch's sale price of wool} \times \text{Shorn wool payment rate} = \text{Incentive payment/kg of wool}$$

$$\text{Incentive payment/kg of wool} = .397^{b} \times \text{Individual ranch's sale price of wool}$$

[a]Grease fleece basis.

[b]1972-1976 average payment rate.

APPENDIX 6. THE SMITH-WILLIAMS SHEEP SIMULATION MODEL ADAPTED TO WESTERN OREGON CONDITIONS

A. CONDITIONS FOR 1973 YEAR RUN

Set SPM = 2.31

Call 1973 weather

Set	Suffolks	Columbia
XLWE1	73.60	60.0
XM1	1.65	1.6
SR	10.0	11.7

B. CONDITIONS FOR 1974 YEAR RUN

Set SPM = 1.65

Call 1974 weather

Set	Suffolks	Columbia
XLWE1	69.0	55.20
XM1	1.6	1.55
SR	10.0	11.70

C. XLWE1 output gives ewe parameters.

XLWL1 output gives lamb parameters.

```
      PROGRAM SHEEP (INPUT,OUTPUT,TAPE1=INPUT,TAPE2=OUTPUT,TAPE3)
C
C
C
C     RUN NUMBER ONE. SHEEP FLOCK SIMULATION
C
C     DETERMINISTIC MODE WITH WEATHER DATA FROM 1973.
C
C
      RAIN=EVAP=SUN=H1=HW1=HA=XI=EI=XLWEO=SUPPLEO=XLWE1=SUPPLE1=XLWL1
     1=XLWE2=SUPPLE2=SUPPL1=XLWL2=SUPPL2=0.0
C
C
C
C     WRITE HEADINGS FOR STATE VARIABLES
C
C
C
      WRITE(2,7)
 7    FORMAT(1H1,T8,≠DAY≠,T18,≠RAIN≠,T29,≠SUN≠,T38,≠PAST. HT.≠,T51,
     1≠PAST. HT.≠,T65,≠GROWTH RATE≠,T84,≠PAST. INTAKE≠,T103,≠E. INTAKE
     1(PASTURE)≠)
      WRITE(2,9)
 9    FORMAT(1H ,T20,≠(CM)≠,T26,≠(CAL/CM2)≠,T40,≠(CM)≠,T51,≠(KG/HA)≠,
     1T65≠(KG/HA/DA)≠,T84,≠(KG/EWE/DA)≠,T103,≠(MCAL/EWE/DA)≠)
      WRITE(3,27)
 27   FORMAT(1H1,T8,≠DAY≠,T15,≠DRY EWE≠,T28,≠SUPFEED≠,T39,≠SING.EWE≠
     1,T51,≠SUPFEED≠,T60,≠EWE W.≠,T74,≠SUPFEED≠,T86,≠SINGLE≠,T97,
     1≠SUPFEED≠,T109,≠THIN≠,T119,≠SUPFEED≠)
      WRITE(3,29)
 29   FORMAT(1H ,T15,≠WT.(KG)≠,T28,≠(KG)≠,T39,≠WT(KG)≠,T51,≠(KG)≠,
     1T60,≠TWINS(KG)≠,T74,≠(KG)≠,T86,≠LAMB(KG)≠,T97,≠(KG)≠T109,
     1≠LAMB(KG)≠,T122,≠(KG)≠)
C
C
C
C     BEGIN RUN FOR THE YEAR.
C     READ FROM DATA FILE FOR DAY OF YEAR,AMOUNT OF RAIN,AMOUNT OF
C     OPEN PAN EVAPORATION (EVAP), AMOUNT OF SUNSHINE(CAL/CM2)
C
C
 20   READ(1,8)N,J,K,M
 8    FORMAT(4(I3,2X))
      IF (K.EQ.0) EVAP = .169
      IF (K.EQ.0) GO TO 16
      EVAP = .00254*K
 16   SUN = M
      RAIN = .0254*J
C
C
C     PASTURE IS ASSUMED TO EMERGE ON DAY 73  OR MARCH 14.
C     FROM JAN 1 TO MARCH 14 EWES ARE KEPT IN DRY LOT AND
C     FED IN SUBROUTINE WINTER. THEY ALSO LAMB DURING THIS TIME.
C
C
C
C     EWES ARE REMOVED FROM THE PASTURE AFTER DAY 319 OR NOV 15 AND
```

```
      C     SENT BACK TO DRYLOT TO BE FED.
      C
      C
            IF (N.GE.319) GO TO 13
            IF (N.GE.74) GO TO 12
            IF (N.GT.1.0) GO TO 50
      C
      C
      C     INITIALIZE LAMB AND EWE WEIGHTS ON JAN. 1
      C
      C
      C     XLWL1 = LIVEWEIGHT OF LAMB BORN AS SINGLE
      C     XLWL2 = LIVEWEIGHT OF LAMB BORN AS TWIN
      C     XLWEO = LIVEWEIGHT OF EWE WHICH HAS FAILED TO BREED THE PREVIOUS
      C     AUTUMN
      C     XLWE1 = LIVEWEIGHT OF EWE THAT WILL BEAR A SINGLE LAMB THIS YR.
      C     XLWE2 = LIVEWEIGHT OF EWE ABOUT TO BEAR TWINS
      C
      C
            XLWL1=XLWL2= 0.0
            XLWEO= 60.0
            XLWE1 = 65.0
            XLWE2 = 70.0
      C
      C
      C     BEGIN SUBROUTINE FOR FEEDING BEFORE PASTURE EMERGENCE
      C
      50    CALL WINTER(N,XLWEO,SUPPLEO,XLWE1,SUPPLE1,XLWE2,SUPPLE2,XLWL1,
           1XLWL2)
      C
      C
      C     INITIALIZE CONDITIONS OF PASTURE SYSTEM ON DAY ONE OF EMERGENCE.
      C     EWES WITH LAMBS WILL BE MOVED ONTO PASTURE ON DAY ONE
      C     IN THIS RUN
      C
            IF (N.EQ.73) GO TO 11
            GO TO 15
      C     HW1 = TOTAL WEIGHT OF PASTURE ON DAY ONE OF EMERGENCE(KG/HECTARE)
      11    HW1 = 100.0
      C     SPM = SOIL PRODUCTIVITY MULTIPLIER, A DIMENSIONLESS COFFECTION
      C     FACTOR THAT ALLOWS THIS MODEL TO BE USED UNDER DIFFERENT
      C     CONCITIONS OF SOIL FERTILITY AND TEMPERATURE.
            SPM = 2.31
      C     EMAX = MAX. AMOUNT OF PASTURE (KG) THAT LACTATING EWE WILL GRAZE
      C     IN ONE DAY
            EMAX = 2.93
      C     SM1 = CM OF SOIL MOISTURE IN TOP 30CM. 5.0 = FIELD CAPACITY
            SM1 = 5.0
      C     OFF = KGS OF PASTURE/HECATRE REMOVED BY GRAZING
            OFF = 10.0
      C     PW=(REDUCTION IN GROWTH RATE(KG/HA/DA) DUE TO PLANTS BEING
      C     UPROOTED BY GRAZING SHEEP.
            PW = 0.0
      C     DT = ONE DAY
            DT = 1.0
      C     PD1 = PLANT EMERGENCE DENSITY(PLANTS/DM2)
            PD1 = 20.0
```

```
C     SR = STOCKING RATE PER EWE RAISING SINGLES PER HECTARE
      SR = 10.0
C     H1 = HEIGHT OF PASTURE (CM)
      H1 = 1.0
      XLWEO = 0.0
      SUPPLEO = 0.0
C     SUPPLEO = SUPPLE1= SUPPLE2= SUPPL1=SUPPL2 = SUPPLEMENTAL FEED
C     FED TO DRY EWES,SINGLE EWES,EWES W.TWINS,SINGLE AND TWIN LAMBS,
      SUPPLE1 =SUPPLE2= 0.0
      SUPPL1 = SUPPL2 = 0.0
C
C
C     START GRAZING SYSTEM AND SIMULATE OVER GRAZING SEASON
C
C
   12 CALL SPRING(N,RAIN,EVAP,SUN,H1,HW1,WA,XI,EI,XLWE1,XLWE2,XLWL1,
     1SUPPL1,XLWL2,SUPPL2,SPM,SM1,DEF,PM,DT,PO1,SR,H2,HW2,PO2,SM2,EMAX)
      GO TO 15
C
C
C     SUPPLE1 = FEED REQMT OF EWE THAT RAISED SINGLE LAMB DURING
C       PREVIOUS YEAR,FED TO GAIN 100 GRAMS/DAY
C     SPRING SEASON,FED TO GAIN 250 GRAMS/DAY
C     SUPPLE2 = FEED REQMT  FOR EWE THAT RAISED TWINS THE PREVIOUS
C
C
   13 SUPPLE1 = (.159*XLWE1**.75)/2.0
      SUPPLE2 = (.182*(XLWE2**.75))/2.0
      XLWE1N = XLWE1 + .100
      XLWE2N = XLWE2 +.250
      XLWE1 = XLWE1N
      XLWE2 =XLWE2N
      XLWL1= XLWL2= 0.0
      H1= HW1= WA=XLWEO=SUPPLEO=XI=EI=SUPPL1=SUPPL2=0.0
C
C
C
C     PRINT VALUES OF STATE VARIABLES FOR EACH DAY OF CYCLE. RESET
C     STATE VARIABLES DESCRIBED IN TIME-LAG EQUATIONS TO CURRENT VALUES,
C
C
C
   15 WRITE(2,100)N,RAIN,SUN,H1,HW1,WA,XI,EI
      WRITE(3,101)N,XLWEO,SUPPLEO,XLWE1,SUPPLE1,XLWE2,SUPPLE2,XLWL1,
     1SUPPL1,XLWL2,SUPPL2
  100 FORMAT(1H ,2X,I6,6X,F5.2,6X,F5.0,6X,F6.2,6X,F9.3,6X,F8.3,13X,
     1F8.3,10X,F8.3)
  101 FORMAT(1H ,2X,I6,5(5X,F7.3,5X,F6.3))
      SUPPLEO = SUPPLE1 = SUPPLE2 = SUPPL1= SUPPL2 =0.0
      HW1=HW2
      H1=H2
      PO1 =PO2
      SM1 = SM2
      IF (N.LT.365) GO TO 20
      STOP
      END
```

```
        SYMBOLIC REFERENCE MAP (R=1)

 ENTRY POINTS
  6153  SHEEP

 VARIABLES        SN  TYPE            RELOCATION
  6632  DEF           REAL                              6634  DT          REAL
  6610  EI            REAL                              6630  EMAX        REAL
  6602  EVAP          REAL                              6605  HW1         REAL
  6640  HW2           REAL                              6604  H1          REAL
  6637  H2            REAL                              6624  J           INTEGER
  6625  K             INTEGER                           6626  M           INTEGER
  6623  N             INTEGER                           6635  PO1         REAL
  6641  PO2           REAL                              6633  PW          REAL
  6601  RAIN          REAL                              6631  SM1         REAL
  6642  SM2           REAL                              6627  SPM         REAL
  6636  SR            REAL                              6603  SUN         REAL
  6612  SUPPLEO       REAL                              6614  SUPPLE1     REAL
  6617  SUPPLE2       REAL                              6620  SUPPL1      REAL
  6622  SUPPL2        REAL                              6606  WA          REAL
  6607  XI            REAL                              6611  XLWEO       REAL
  6613  XLWE1         REAL                              6643  XLWE1N      REAL
  6616  XLWE2         REAL                              6644  XLWE2N      REAL
  6615  XLWL1         REAL                              6621  XLWL2       REAL

 FILE NAMES          MODE
     0  INPUT                     2041  OUTPUT                  0  TAPE1      FMT         2041  TAPE2      FMT
  4102  TAPE3         FMT

 EXTERNALS             TYPE    ARGS
        SPRING                  27                          HINTER               9

 STATEMENT LABELS
  6367  7         FMT                 6506   8        FMT                6411   9        FMT
  6231  11                            6250  12                           6253  13
  6276  15                            6205  16                           6175  20
  6431  27        FMT                 6456  29        FMT                6224  50
  6541  100       FMT                 6550  101       FMT

 STATISTICS
   PROGRAM LENGTH                 5018      321
   BUFFER LENGTH                 61440     3172
```

```
      SUBROUTINE WINTER(N,XLWEO,SUPPLEO,XLWE1,SUPPLE1,XLWE2,SUPPLE2,
     1XLWL1,XLWL2)
C
C
C
C     THIS SUBROUTINE DESCRIBES GROWTH PATTERNS OF EWES FROM JAN 1
C     UNTIL PASTURE
C     EMERGENCE ON MAR 14. DAILY WEIGHT CHANGES ARE LISTED, AND
C     AMOUNT OF DRY FEED (ALFALFA PELLETS) NECESSARY TO MAINTAIN
C     EWES AT THEIR OBSERVED LEVELS OF GROWTH  ARE CALCULATED
C     AND FED TO THE EWES. LAMBS ARE BORN ON JAN 30 AND NEW EQUATIONS
C     FOR EWE'S FEED REQUIREMENTS ARE ESTABLISHED.
C     THIS SUBROUTINE DOES NOT ATTEMPT TO EXPLAIN BIOLOGICAL CAUSES
C     OF GROWTH PATTERNS AT THIS STAGE OF YEAR CYCLE, BUT ESTIMATES
C     FEED REQUIREMENTS FOR IT.
C
C
C
C
C     MCAL OF METABOLIZABLE ENERGY (ME) TO MAINTAIN EWE BODY WEIGHT+GAIN
C     250 GRAMS PER DAY DURING LATE GESTATION = .182* LW**.75
C
C     1 KG OF ALFALF PELLETS HAVE 2.00 MCAL OF ME
C
C
      XLWEON =XLWEO + .25
      IF (N.LE.30) XLWE1N = XLWE1 + .25
      IF (N.LE.30) XLWE2N = XLWE2 + .25
      SUPPLEO = (.182 * (XLWEO**.75))/2.0
      IF (N.LE.30) SUPPLE1 = (.182*(XLWE1**.75))/2.0
      IF (N.LE.30) SUPPLE2 = (.182*(XLWE2**.75))/2.0
      IF (N.LE.30) GO TO 11
      IF (N.EQ.31) XLWE1N = XLWE1 - 10.0
      IF (N.EQ.31) XLWE2N = XLWE2 - 15.0
      IF (N.EQ.31) GO TO 10
      IF (N.GE.32) XLWE1N = XLWE1 -.040
      IF (N.GE.32) XLWE2N = XLWE2 -.060
      IF (N.GE.32) XLWL1N = XLWL1 + .25
      IF (N.GE.32) XLWL2N = XLWL2 + .225
   10 SUPPLE1 = 1.25*(.132*(XLWE1**.75))
      SUPPLE2 = 1.425*(.132*(XLWE2**.75))
   11 IF (XLWL1.EQ.0.0) XLWL1N = 0.0
      IF(XLWL2.EQ.0.0) XLWL2N = 0.0
      XLWEO = XLWEON
      XLWE1 = XLWE1N
      XLWE2 = XLWE2N
      XLWL1 = XLWL1N
      XLWL2 = XLWL2N
C
C
C     LIVEWEIGHT OF LAMB BORN AS SINGLE = 4.3 KG,LAMB BORN AS TWIN =3.4
C     KG AT BIRTH.
C
      IF (N.EQ.31) XLWL1 = 4.3
      IF (N.EQ.31) XLWL2 = 3.4
      IF (N.EQ.73) XLWEO = 0.0
```

```
      RETURN
      END
```

SYMBOLIC REFERENCE MAP (R=1)

```
ENTRY POINTS
    3  WINTER

VARIABLES      SN  TYPE            RELOCATION
    0  N           INTEGER            F.P.          0  SUPPLEO    REAL                F.P.
    0  SUPPLE1     REAL               F.P.          0  SUPPLE2    REAL                F.P.
    0  XLWEO       REAL               F.P.        166  XLWEON     REAL
    0  XLWE1       REAL               F.P.        167  XLWE1N     REAL
    0  XLWE2       REAL               F.P.        170  XLWE2N     REAL
    0  XLWL1       REAL               F.P.        171  XLWL1N     REAL
    0  XLWL2       REAL               F.P.        172  XLWL2N     REAL

STATEMENT LABELS
  104  10                         116  11

STATISTICS
  PROGRAM LENGTH            173B      123
```

```
      SUBROUTINE SPRING(N,RAIN,EVAP,SUN,H1,HW1,WA,XI,FI,XLWE1,XLWE2,
     1XLWL1,SUPPL1,XLWL2,SUPPL2,SPM,SM1,DEF,FW,DT,FD1,SF,H2,HW2,FD2,
     1SM2,EMAX)
C
C
C
C     THIS SUBROUTINE SIMULATES THE GROWTH OF OSU HILL PASTURE DURING
C     THE GRAZING SEASON FROM APPROX MARCH 15 TO NOV. 15 AND THE
C     GROWTH PATTERNS AND ENERGY INTAKE OF EWES AND THEIR LAMBS.
C
C
C
C
C
C     THIS SUBROUTINE ATTEMPTS TO PROVIDE A QUANTATATIVE BIOLOGICAL
C     EXPLANATION FOR THE GROWTH OF THE PASTURE AND OF THE EWES AND
C     LAMBS.
C
C
C     HERBAGE HEIGHT AND SOIL MOISTURE EQUATIONS
C
C
C
C     XL = LEAF AREA INDEX (M2/M2)
C
      XL = .00147*HW1
C
C     XK = COEFFICIENT USED TO DETERMINE WMAX
C
      XK = .54 - (.00037*SUN)
C
C     WMAX = MAXIMUM HERBAGE GROWTH RATE WITH ONLY SUN LIMITING (KG/HA/
C     DAY)
C
      WMAX = 250.0*(1.0-EXP(-.0027*SUN))
C
C     WP = POTENTIAL HERBAGE GROWTH RATE WITH LEAF AREA INDEX AND
C     SUN LIMITING (KG/HA/DAY)
C
      WP = WMAX*(1.0-EXP(-1.*XK*XL))
C
C     SMM = SOIL MOISTURE MULTIPLIER,, USED TO ESTIMATE THE RELATIVE
C     AMOUNT OF MOISTURE AVAILABLE FOR PLANT GROWTH
C
      SMM = 1.0 -EXP(-1.33*(SM1-2.1))
      IF (SM1.LT.0.0) SMM = 0.0
C
C     VALUE OF SPM(SOIL PRODUCTIVITY MULTIPLIER) IS LOWERED IN THE
C     FALL AS A CORRECTION FACTOR FOR DECREASED SOIL TEMPERATURE AND
C     NATURAL DORMANCY OF PASTURE SPECIES.
C
      IF (N.GT.230) SPM = .29
C     WA = ACTUAL GROWTH RATE OF PASTURE (KG/HA/DAY), WITH LEAF AREA
C     INDEX, SUN, AND SOIL MOISTURE, AND SOIL PRODUCTIVITY AS LIMITING
C     FACTORS
C
      WA = WP*SPM*SMM
```

```
C     HW2 = WEIGHT OF PASTURE AT TIME T+1(KG/HA),THAT IS, THE TOTAL
C     D.M.(DRY MATTER WT) OF THE PASTURE ON THAT DAY. IT EQUALS THE TOTAL
C     WEIGHT OF THE PREVIOUS DAY  + GROWTH -GRAZING - UPROOTING
C
      HW2 = HW1 +(HA-DEF-PW)*DT
C
C     ETEO =
C     RATIO  OF POTENTIAL EVAPOTRANSPIRATION TO OPEN PAN EVAPORATION
C
      ETEO = AMIN1(1.0,0.5+(.544*XL))
C
C     EAET  = RATIO OF POTENTIAL EVAPOTRANSPIRATION TO ACTUAL EVAPO-
C     TRANSPIRATION
C
      EAET = AMIN1(1.0,-0.8 + .5*(SM1+RAIN))
C
C     EA = ACTUAL EVAPOTRANSPIRATION (CM/DAY)
C
      EA = EVAP*ETEO*EAET
C
C     SM2 = SOIL MOISTURE AT TIME T+1
      SM2 = AMIN1(5.0,SM1 + (RAIN-EA)*DT)
C
C
C     HERBAGE REMOVED BY GRAZING
C
C
C
C     PDM = PLANT DENSITY MULTIPLIER
      PDM = .063*PD1
C
C
C     DPD = RATE OF CHANGE OF PLANT DENSITY. THIS MODEL ASSUMES THAT
C     PW(LOSSES DUE TO UPROOTING) WILL OCCUR ONLY DURING PERIOD
C     OF EARLY EMERGENCE
C
      IF (N.LE.84) DPD = -(0.16-0.014*(N-73))*SR*PDM
      IF (N.GT.84) DPD = 0.0
C
C     PW = LOSS OF HW DUE TO PLANTS BEING UPROOTED(KG/HA/DA)
C
      PW = -(HW1/PD1)*DPD
C
C     DEF = DEFOLIATION BY GRAZING SHEEP (KG/HA/DAY)
C
      DEF = SR*EMAX*(1.0-EXP(-0.0009*H1*HW1))
C
C     PD2 = PLANT DENSITY AT TIME T+ 1 (PLANTS/DM2)
C
      PD2 = PD1 + DPD*DT
C
C
C
C     EQUATIONS FOR PASTURE HEIGHT
C
C
      IF (HA.EQ.0.0) GO TO 99
```

```
C
C     DH = RATE OF CHANGE OF HEIGHT OF PASTURE(CM/DA)
C
      DH = 0.056- 0.16*(DEF/HA)
      IF (HA.GT.0.0) GO TO 100
 99   DH = 0.0
C
C     H2 = HEIGHT OF PASTURE (CM) AT TIME T+1
C
 100  H2 = AMAX1(0.53,H1+DH*DT)
C
C
C
C     LIVEWEIGHT OF SHEEP
C
C
C
C     XI = INTAKE OF PASTURE BY GRAZING SHEEP,PER EWE(KG/HA/DA)
C
      XI = (DEF+ (.75*PH))/SR
C
C     XLEV = REDUCTION IN DIGESTIBILITY OF PASTURE DUE TO LEVEL OF
C     INTAKE
C
      XLEV = .02*XI
C
C     PSIO = PROPORTION OF SILICA IN FECES
C
      PSIO = EXP((.0005-.00096*H1*HH1))
C
C     D = ORGANIC MATTER DIGESTIBILITY OF PASTURE,ADJUSTED FOR SEASON
C
      IF(N.LE.181) D = .802-(.17*PSIO)-XLEV
      IF (N.GT.181) D = .65 - .17*PSIO - XLEV
C
C     METABOLIZABLE ENERGY OF FEED ( MCAL/KG)
C
      XME = 3.6*D
C
C     EI = ENERGY INTAKE OF GRAZING SHEEP (MCAL/HA/DA)
C
      EI = XI*XME
C
C     XMDRY1=MAINTENANCE REQMT OF EWE THAT BORE ONE LAMB (MCAL/HA/DA)
C
      XMDRY1 = .132*(XLWE1**.75)
C
C     XMDRY2 = MAINTENANCE REQMT OF EWE WITH TWINS(MCAL/HA/DA)
      XMDRY2 = .132*(XLWE2**.75)
C
C     XM1,XM2 =LACTATION REQMTS OF EWES NURSING ONE AND TWO LAMBS,
C     RESPECTIVELY (MCAL/HA/DA)
C
      XM1 = 1.5*XMDRY1
      XM2 = 1.85*XMDRY2
C
C     XKF = COEF OF EFFICIENCY OF UTILIZATION OF ENERGY FOR GAIN
```

```
C      OR FOR LACTATION C, A MEASURE OF FEL NET ENERGY OF LACTATION AVAIL
       XKF = 0.16 + (.63*D)
C
C
C      C = C1 =C2 = CALORIFIC VALUE OF ANIMAL TISSUE ANABOLIZED(MCAL/KG)
       C1 = .13*XLWE1
       C2 = .13*XLWE2
C
C
C      DLWL1,DLWL2,DLWE1.DLWE2, ARE DAILY CHANGE IN WEIGHT OF SINGLE
C      LAMB,TWIN LAMB,EWE W.SINGLE,AND EWE WTWINS,RESP(KG/DA)
C
C
C      DURING LACTATION, WEIGHT GAIN OF LAMB IS ESTIMATED TO COME FROM
C      DIFFERENCE BETWEEN E INTAKE BY EWE AND HER DRY LEVEL MAINTENANCE
C      REQMT
C
C
       DLWL1 = (EI-XMDRY1)*(XKF/C1)
       DLWL2 = .9*(EI-XMDRY2)*(XKF/C2)
C      AFTER LAMBS HAVE BEEN WEANED, THE ENERGY EWES
C      WERE USING FOR LACTATION NOW GOES INTO THEIR OWN WEIGHT GAIN.
C      AFTER AN ADJUSTMENT PERIOD THEIR FEED INTAKE WILL LEVEL OFF
C      AND THEN DECREASE TO DRY EWE LEVEL AND WEIGHT CHANGES WILL
C       EVEN OUT
C
C
       IF (N.GT.200) DLWE1 = .5*(DLWL1+DLWL2)
       IF (N.GT.200) DLWE2 = .5*(DLWL1+DLWL2)
       IF (N.GT.200) GO TO 10
       IF (XLWL1.EQ.0.0) DLWE1 = DLWL1
       IF (XLWL1.EQ.0.0) GO TO 10
       IF (XLWL2.EQ.0.0) DLWE2 =DLWL2
       IF (XLWL2.EQ.0.0) GO TO 11
C
C      [illegible]
C      [illegible]
C
C
       IF(DLWL1.LT..2) CALL FEED1(N,DLWL1,XLWL1,SUPPL1)
       IF (DLWL2.LT..2) CALL FEED2(N,DLWL2,XLWL2,SUPPL2)
C
C      DURING LACTATION WEIGHT LOSS OF EWES IS ESTIMATED FROM DIFFERENCE
C      BETWEEN E INTAKE AND LACTATION REQUIREMENTS
C
       DLWE1 =(EI-XM1)/5.5
       DLWE2 = (EI-XM2)/5.5
 10    XLWE1N = XLWE1 + (DLWE1*DT)
 11    XLWE2N = XLWE2 + (DLWE2*DT)
       XLWE1 = XLWE1N
       XLWE2 = XLWE2N
       XLWL1N = XLWL1 + (DLWL1*DT)
       XLWL2N = XLWL2 + DLWL2*DT
       IF (XLWL1.EQ.0.0) XLWL1N = 0.0
       IF (XLWL2.EQ.0.0) XLWL2N = 0.0
       XLWL1 = XLWL1N
       XLWL2 = XLWL2N
```

```
              C
230           C
              C       LAMBS ARE WEANED IN MID JUNE. IF THEY ARE LESS THN 45 KG THEY WILL
              C       GO INTO ADDITIONAL FEEDING PERIOD(NOT MODELLED HERE).
              C       IF THEY ARE MORE THAN 45 KG THEY WILL GO DIRECTLY TO MARKET
              C
235           C
                      IF (N.GT.180) XLWL1 =XLWL2 = 0.0
                      RETURN
                      END
```

```
SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
    3  SPRING

VARIABLES      SN  TYPE         RELOCATION
  422  C1          REAL
  413  D           REAL
  410  DH          REAL
  427  DLWE2       REAL
  425  DLWL2       REAL
    0  DT          REAL         F.P.
  404  EACT        REAL
    0  EMAX        REAL         F.P.
    0  EVAP        REAL         F.P.
    0  HW2         REAL         F.P.
    0  H2          REAL         F.P.
  406  PDM         REAL
    0  PD2         REAL         F.P.
    0  PH          REAL         F.P.
  402  SMM         REAL
    0  SM2         REAL         F.P.
    0  SR          REAL         F.P.
    0  SUPPL1      REAL         F.P.
    0  WA          REAL         F.P.
  401  WP          REAL
  377  XK          REAL
  376  XL          REAL
    0  XLWE1       REAL         F.P.
    0  XLWE2       REAL         F.P.
    0  XLWL1       REAL         F.P.
    0  XLWL2       REAL         F.P.
  415  XMDRY1      REAL
  414  XM2         REAL
  420  XM2         REAL

  423  C2          REAL
    0  DEF         REAL         F.P.
  426  DLWE1       REAL
  424  DLWL1       REAL
  407  DPD         REAL
  405  EA          REAL
    0  EI          REAL         F.P.
  403  ETEO        REAL
    0  HW1         REAL         F.P.
    0  H1          REAL         F.P.
    0  N           INTEGER      F.P.
    0  PD1         REAL         F.P.
  412  PSIO        REAL
    0  RAIN        REAL         F.P.
    0  SH1         REAL         F.P.
    0  SPM         REAL         F.P.
    0  SUN         REAL         F.P.
    0  SUPPL2      REAL         F.P.
  400  WMAX        REAL
    0  XI          REAL         F.P.
  421  XKF         REAL
  411  XLEV        REAL
  430  XLWE1N      REAL
  431  XLWE2N      REAL
  432  XLWL1N      REAL
  433  XLWL2N      REAL
  416  XMDRY2      REAL
  417  XM1         REAL

EXTERNALS        TYPE    ARGS
      EXP        REAL      1 LIBRARY
      FEED2                4
      FEED1                4
```

60

```
      SUBROUTINE FEED1(N,DLWL1,XLWL1,SUPPL1)
      IF (DLWL1.LE.0.0) XMCAL = .28*(XLWL1**.75)
      IF (DLWL1.GT.0.0) XMCAL = (1.0-(DLWL1/.250))*.28*(XLWL1**.75)
      SUPPL1 = XMCAL/3.39
      DLWL1= .25
      RETURN
      END
```

```
         SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
     3   FEED1

VARIABLES      SN   TYPE            RELOCATION
     0   DLWL1      REAL                F.P.          0   N          INTEGER   *UNUSED   F.P.
     0   SUPPL1     REAL                F.P.          0   XLWL1      REAL                F.P.
    36   XMCAL      REAL

STATISTICS
  PROGRAM LENGTH                  37B        31
```

```
      1                 SUBROUTINE FEED2(N,DLWL2,XLWL2,SUPPL2)
                        IF (DLWL2.LE.0.0) XMCAL = .25*(XLWL2**.75)
                        IF (DLWL2.GT.0.0) XMCAL = (1.0-(DLWL2/.25))*.28*(XLWL2**.75)
                        SUPPL2 = XMCAL/3.39
      5                 DLWL2 = .250
                        RETURN
                        END
```

```
       SYMBOLIC REFERENCE MAP (R=1)

ENTRY POINTS
     3 FEED2

VARIABLES      SN  TYPE            RELOCATION
     0 DLWL2       REAL                F.P.          0  N          INTEGER   *UNUSED    F.P.
     0 SUPPL2      REAL                F.P.          0  XLWL2      REAL                 F.P.
    36 XMCAL       REAL

STATISTICS
  PROGRAM LENGTH                 37B        31
```

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