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Growth and mature weight of Mehraban Iranian fat-tailed sheep

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Abstract

The growth curves of 1239 Mehraban Iranian fat-tailed sheep were fitted using Brody's model. A is the asymptotic weight in the equation $W_t = A \times (1 - Be^{-kt})$, where W is the weight at time t and B and k are constants. Least-squares analyses were run on the estimates of mature weight, rate of maturing and weight from birth to 48 months. Year, sex and type of birth significantly affected all growth curve parameters. Lambing year, age of dam at lambing, sex and type of birth significantly affected the pre-weaning growth period (90 days) while the major source of variation in post-weaning growth were sex and type of birth. None of the first-order interactions included in the analysis were significant. Males were heavier at mature weight (81.04 ± 2.39 kg vs 62.95 ± 1.88) than females but they matured more slowly. Twins were lighter at mature weight (60.82 ± 2.07 kg vs 81.04 ± 2.18) than singles. It was concluded that to improve the growth rate, attempts must be made to improve the management with special attention to nutrition conditions.

Keywords: Mehraban fat-tailed sheep; Growth curves; Mature weight; Iran

Keywords: Race Mehraban à queue grasse; Courbe de croissance; Poids à maturité; Iran

1. Introduction

Animal growth and development are often discussed as the integration of all facets of animal biology including nutrition, genetics or animal breeding, physiology and meat science (Trenkel and Marple, 1983). Animal growth has long been characterised by observing the change in body weight per unit of time or by plotting body weight against age. The former results can easily be used to compare the effects of treatment and to describe the rate of growth and the latter results to describe the patterns of growth of animals. The long series of weights recorded during the life span of a sheep is difficult to interpret. The use of mathematical growth models provides a good way of condensing the information contained in such a data series into a few parameters with biological meaning (Fitzhugh, 1976). The Brody (1945) growth model Brown (1970) is favourably compared with other models for describing growth.

There is increasing interest in the production of meat from small ruminants in Iran. In order to increase production, efforts must be directed at improvement in feeding, breeding and management of these animals. Growth is therefore a potential economic trait to be included in the sheep breeding programme in Iran. Previous work on growth of Mehraban sheep has been primarily focused on the

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early stages, including pre-weaning (Bathaei and Leroy, 1994) and postweaning growth (Bathaei, 1995). Growth of Mehraban sheep throughout their lifespan under semi-extensive conditions should be determined to characterize the breed for design of future breeding programs.

The objective of this study was to estimate growth curve parameters of Mehraban Iranian fat-tailed sheep, using Brody's model, and to determine their phenotypic relationship to each other. The effects of year, age of dam, sex, type of birth and their first-order interactions on the growth curve parameters were also examined.

2. Materials and methods

2.1. Data Collection

The data consisted of performance records of 1239 Mehraban fat-tailed sheep, spread over the 7-year period, 1984–1990, from a Mehraban's flock kept in a private farm, in Hamadan western Iran (33°55′ and 35°48′). In this region, the predominant breed is Mehraban, with 2.2 million head, which represents 6% of the local breed population in Iran. The region average annual rainfall is between 300 and 500 mm, mean temperature 19 C°, average elevation 1747 m. Each year the identity and pedigree of the animals, different treatments, diseases, lambing results, individual weights at birth, between birth and weaning (at 90 days) with an interval of 10 days, weaning and monthly during the post-weaning period up to 48 months were recorded. The pre-weaning period considered from birth to weaning at 90 days of age and post weaning period from 90 days of age to 48 months.

2.2. Management and feeding

Animals were maintained under farm conditions (semi-extensive) and generally grazed on range which was medium in vegetation of such genera as *Artemisia*, *Astragalus*, *Bromus* and *Stipa*. Pasture production is markedly seasonal and depends on winter and spring precipitation, and this affects the nutritional status of the sheep. The range became poor during the late autumn and winter months, and therefore, the sheep received supplemental feed for 6 months of the year. During this period, sheep had ad libitum access to alfalfa hay, and received up to 0.5 kg day^{-1} concentrates (approximately 16% protein and 72% TDN) composed of 58% barley, 25% dried sugar beet pulp, 15% wheat bran, 1% bone meal and 1% common salt. Feeding experiments in dry lot were performed during the last part of pregnancy and after lambing. Each year the mating period lasted from October to December. Lambing takes place from March to May, and early in April the sheep were sent to pasture. The lambs were weaned at 90 days of age.

2.3. Growth model

The Brody (1945) model was fitted to the weight–age data from birth to maturity of each animal for describing its growth curve.

$$W_t = A \times (1 - Be^{-kt}) \quad (1)$$

where W_t = observed weight at age t expressed in months, and A = the asymptotic limit of the weight when age (t) approaches infinity. This does not imply that A is the heaviest weight attained by the individual, but it indicates the average weight of the mature sheep, independent of short-term fluctuation in weight due to temporary environmental effects of climate and feed availability, or pregnancy/lactation status. B indicates the proportion of the asymptotic mature weight to be gained after birth, established by the initial values of W and t. This parameter ajusts for the situation in which W (initial weight) on t (time of origin) $\neq 0$. As can be observed in the equation, when $W = t = 0$, then $B = 1$. k is a function of the ratio of maximum growth rate to mature size, normally referred to as maturing rate. It is related to postnatal rate of maturing and serves both as a measure of growth rate and rate of change in growth rate. Large k values indicate early maturing animals, and vice versa; e is Napier's base for natural logarithms; t is age expressed in months.

Individual estimates of growth parameters were obtained using the modified Gauss–Newton iterative procedure available in the SAS program (Statistical Analysis Systems Institute Inc., 1985). Convergence was assumed when the difference in residual sums of squares between the $i^{th}-1$ and the i^{th} iteration relative to the iteration $+10^{-6}$ was $<10^{-8}$.

$$\frac{(SSE_{i-1} - SSE_i)}{(SSE_i + 10^{-6})} \leq 10^{-8}$$

where SSE_i is residual sum of squares for the i^{th}.

Brody's model was selected because of simplicity of interpretation and ease of estimation. This model was shown by Brown (1970), in a comparison of five stochastic models, to be adequate for comparing individual differences in rate of maturing and mature weight.

2.4. Statistical analysis

Non-genetic effects for each of the growth curve parameters, A, B and k, and for weights at different ages were analysed using the least-squares procedure described by Harvey's LSML 85 program (Harvey, 1985). The fixed model included lambing year, age of dam at lambing, sex, type of birth as main effects. Means were compared by a t-test using the error variance of the analyse of variance of the linear model. All two-way interactions were included in the model. Final analyses excluded interactions that were neither significant nor important.

$$\begin{aligned} Y_{ijklm} = \mu + a_i + b_j + s_k + t_l + (as)_{ik} + (bs)_{jk} \\ + (bt)_{jl} + (at)_{il} + (ab)_{ij} \\ + (st)_{kl} + e_{ijklm} \end{aligned} \quad (2)$$

where Y_{ijklm} is the growth curve parameters or weight of m^{th} individual of the i^{th} year, j^{th} of age class of dam, of k^{th} sex and of l^{th} type of birth. μ is overall

Table 1
Least-squares means and standard errors for growth curve parameters A, B and k by age of dam, lambing year, type of birth and sex in Mehraban sheep

Classification	Parameter estimate						
	A			*B*		*k*	
	n	Mean	S.E.	Mean	S.E.	Mean	S.E.
Overall mean	1239	72.15	2.78	0.96	0.02	0.1194	0.0144
Age of dam							
1	211	69.85 [a]	2.36	0.95 [a]	0.02	0.0992 [a]	0.0045
2	257	71.36 [a]	1.78	0.96 [b]	0.02	0.1053 [a]	0.0078
3	237	72.15 [a]	3.35	0.97 [c]	0.01	0.1205 [a]	0.0037
4	252	69.25 [a]	1.89	0.94 [a]	0.02	0.0985 [a]	0.0076
5	193	73.38 [a]	2.06	0.96 [c]	0.02	0.1285 [a]	0.0047
6	89	69.96 [a]	1.64	0.96 [b]	0.02	0.1004 [a]	0.0059
Lambing year							
1984	252	69.81 [a]	2.36	0.95 [a]	0.02	0.0997 [a]	0.011
1985	195	73.69 [b]	1.75	0.96 [b]	0.02	0.1276 [b]	0.0045
1986	189	74.06 [b]	1.88	0.97 [c]	0.01	0.1304 [b]	0.0063
1987	135	68.36 [a]	2.25	0.95 [a]	0.01	0.0978 [a]	0.0029
1988	190	71.89 [b]	1.05	0.95 [a]	0.01	0.1347 [b]	0.0087
1989	137	72.26 [b]	1.34	0.95 [a]	0.01	0.1347 [b]	0.0087
1990	141	68.39 [a]	1.49	0.97 [c]	0.01	0.0892 [a]	0.0022
Type of birth							
Single	1079	71.03 [a]	2.39	0.94 [a]	0.03	0.1197 [a]	0.025
Twin	160	62.95 [b]	1.88	0.96 [b]	0.02	0.1041 [b]	0.055
Sex							
Male	647	81.04 [a]	2.18	0.97 [a]	0.01	0.1034 [a]	0.072
Female	592	60.82 [b]	2.07	0.95 [b]	0.03	0.1305 [b]	0.012

[a,b,c] In the same column, all mean within a particular sub-class differ ($P < 0.05$) except those followed by the same superscript.

mean, a_i is i^{th} lambing year ($i = 1, \ldots, 7$) from 1984 to 1990, b_j is j^{th} age of dam ($j = 1, \ldots, 6$) 1,..., 6 years old, s_k is k^{th} sex (1 = male; 2 = female), t_l is l^{th} type of birth (1 = single; 2 = twin) (there were no triplets born during 1984–90), $(as)_{ik}$ is the interaction effect between i^{th} lambing year and k^{th} sex; $(bs)_{jk}$ is the interaction effect between j^{th} age of dam and k^{th} sex, $(bt)_{jl}$ is the interaction effect between j^{th} age of dam and l^{th} type of birth, $(at)_{il}$ is the interaction effect between i^{th} lambing year and l^{th} type of birth, $(ab)_{ij}$ is the interaction effects between i^{th} lambing year and j^{th} age of dam, $(st)_{kl}$ is the interaction effect between k^{th} sex and l^{th} type of birth, e_{ijklm} is a random element assumed normally and independently distributed.

3. Results

The analysis of variance showed that sex, type of birth and lambing year were sources ($P < 0.01$ and $P < 0.05$) of variation in the A, B and k values. Age of dam had only an effect ($P < 0.05$) on B value and did not contribute to differences in A and k values. The first-order interactions that were tested were not significant.

Least-squares means and standard errors of growth curve parameters A, B and k for the lambing year, age of dam, sex and type of birth and test of significance for differences between means are presented in Table 1. Year affected A and k more than B values. The A and k values differ slightly between different classes of dam's age but the differences were not significant, since the seven curves are almost parallel and, consequently, the rate of maturing is nearly similar. But there is a great difference between both sex and type of birth. The males were about 20 kg heavier at maturity than females, but they matured more slowly, $k = 0.1034$, when compared with their counterparts, $k = 0.1305$ (Table 1). The females matured faster during early life than males and reached 98% of their maturity at about 28 months of age, whereas males continued maturing until about 37 months of age (Fig. 1). The same observation was obtained for type of birth, the singles matured more quickly, $k = 0.1197$, than twins, and when compared with their counterparts, $k = 0.1041$ (Table 1). The singles grew faster during

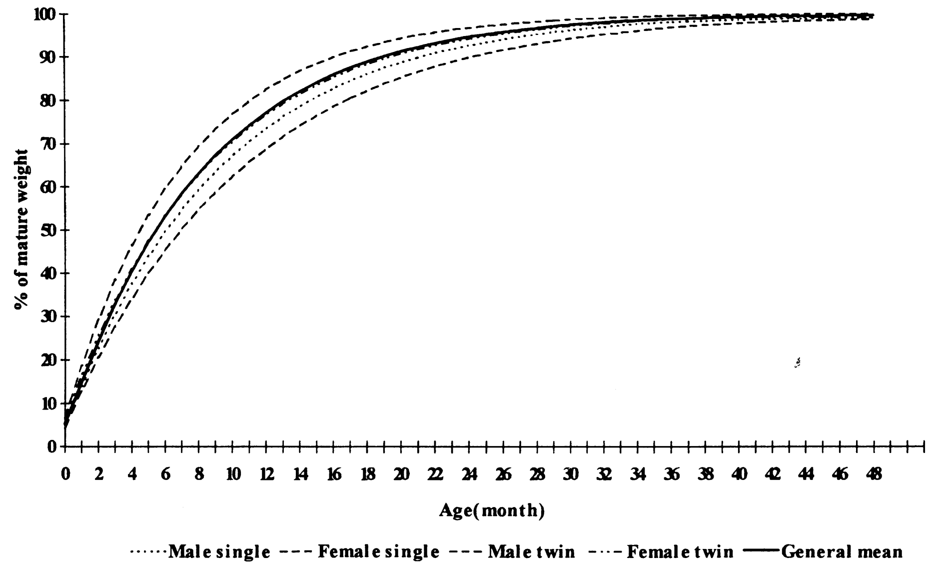

Fig. 1. Average percentage of mature weight by fitting Brody function to the averages of predicted weights within sex and type of birth group in Mehraban sheep.

Table 2
Phenotypic correlations [a] between growth parameters A, B, k and weights at different ages of Mehraban sheep

Growth parameters	Weight											
	W_3 [b]	W_6	W_9	W_{12}	W_{15}	W_{18}	W_{21}	W_{24}	W_{27}	W_{30}	W_{33}	W_{35}
A	0.30 **	0.15 *	0.20 *	0.21 *	0.24 *	0.37 **	0.45 **	0.56 **	0.68 **	0.79 **	0.87 **	0.93 **
B	−0.64 **	−0.49 **	−0.34 *	−0.25 *	−0.18 *	−0.15 *	−0.12 *	−0.14 *	−0.11 *	−0.08 *	−0.05	−0.02
k	−0.14 *	−0.35 *	−0.41 *	−0.45 *	−0.45 *	−0.42 *	−0.36 *	−0.31 *	−0.19 *	−0.08	−0.05	−0.10

[a] All standard errors were less than 0.10; [b] Subscripts of W represents age of the animal in months when weight was measured.
* $P < 0.05$, ** $P < 0.01$.

early life than twins and reached 98% of their mature weight sooner than twins, at about 32 months of age (Fig. 1), while twins continued to grow until about 43 months of age (Table 1).

The analysis of variance for body weight at various ages showed all fitted effects were significant ($P < 0.01$) for weight before 3 months of age (pre-weaning period). Age of dam had a significant effect on the pre-weaning growth period and this effect declined quickly after weaning (90 days). The same effect was observed for lambing year which became non-significant after 27 months of age. Only sex and type of birth had an effect on growth ($P < 0.05$) after weaning until 33 months of age.

The differences between successive weights, with an interval of 3 months, became non significant at 31 and 39 months of age in single females and males, respectively. Whereas for twins females and males it became non-significant at 34 and 46 months of age, respectively.

The correlations between A and immature body weights were all positive and indicate that emphasis on weight at any age would cause a correlated increase in mature weight (Table 2). Phenotypic correlations between B and immature body weights were all negative and decreased with age. Negative correlations between immature weights and k until 27 months of age were observed.

The phenotypic correlations among growth parameters are given in Table 3. In both sexes, negative correlations between A and k, and between A and B were observed. The former was significant ($P < 0.05$ and $P < 0.01$) while the latter was not. Correlations between B and k were high and positive ($P < 0.01$ in both sexes).

Table 3
Phenotypic correlations [a] among growth parameters of the growth curve in Mehraban sheep

Growth parameters	A	B
Male		
B	−0.22	
k	−0.50 *	0.72 **
Female		
B	−0.20	
k	−0.61 **	0.67 **

[a] All standard errors were less than 0.10.
* $P < 0.05$, ** $P < 0.01$.

4. Discussion

The weight of an animal, especially ewe, fluctuates during the year according to a lot of factors (e.g. quality and amount of feed and pasture, stage of pregnancy and nursing). In the traditional Mehraban's breeding system, the sheep generally reach their mature weight about 4–5 years old (Bathaei, 1993). In this study, the animals were fed on a diet of a better quality and quantity than that of the traditional system, in which the animals do not receive any supplementary feeding, so the animals take a shorter time to reach 98% of their mature weight (at about 36 months of age). These results are in agreement with other investigations. According to Thompson (1986) and Searle et al. (1989) level and quality of nutrition affect the animal's growth. Animals fed ad libitum would be expected to reach their mature weight at about 2 years of age, while on a lower level of nutrition it takes longer to reach the same mature weight.

The effect of lambing year on mature weight (A) could be due to environmental factors. The year in which an animal is born fixes the set of environmental circumstances to which it will be exposed. Animals born in different years will not share identical circumstances, because magnitudes of environmental effects are related to the age and degree of development of the animal and the fixed set of environmental conditions encountered at specific times. In this study an important part of growth rate of sheep raised under farm conditions was related to the amount and quality of forage available for consumption in the pasture during 6 months of the year. So, one possible explanation for different mature weights (A) in different years might be less forage available in pasture. This would require the sheep to spend more energy to obtain a supply of food, thus leaving less surplus of energy for fat deposition. Influence of sex and type of birth on mature weight (A) were also reported by Wiener (1967), Epstein (1985) and Taylor (1985). The significance of lambing year and age of dam on B is a further indication of the relationship of B to early weight changes.

The analysis of variance for body weight at various ages showed all fitted effects to be highly significant in the pre-weaning period. Several studies have shown that sex, type of birth, age of dam and year influence weaning weight (Shiekh et al., 1986; El-Karim and Owen, 1988; Bathaei and Leroy, 1994). Age of dam declined in importance as the animal weaned. Pre-weaning weight was greatly influenced by the level of milk production of the Mehraban ewes and age had a considerable influence on milk production (Bathaei, 1993; Bathaei and Leroy, 1994). It appears reasonable that weight becomes more uniform after the maternal influence and weaning stress have passed. Later, differences in gestation status and changes in weight due to variation in milk production again generate more variability in body weight (Bathaei, 1995). Eikje (1971) reported that lactation stress seemed to affect the weight of the ewe. For a young ewe her own growth and maturation were additional factors.

A non-significant effect of the age of dam on post-weaning weight of lambs, as observed here, was reported by Fahmy et al. (1972), Makarechian et al. (1977) and Shiekh et al. (1986). Lambing year declined in importance for weight in matured animals. Sex and type of birth were the main source of variation in weight at different ages up to 30 months and mature weight. These results are in agreement with other investigators (Taylor, 1967; Trenkel and Marple, 1983; Wilson, 1987).

Biologically, the more important relationship is that between A and k. The negative phenotypic correlation between these two parameters indicates that animals maturing early are less likely to attain as large mature weights as those that mature more slowly in early life. In the present study, A and k are more highly correlated in females, -0.61, than in males, -0.50. The phenotypic association between B and k is large and positive, 0.76 and 0.67 for male and female, respectively. A possible biological interpretation of this correlation is as follows: light lambs at weaning (high values of B) are more likely to have faster relative growth rates (weight gain/weight) at young ages and subsequently higher maturing rates (high values of k) than heavy lambs at weaning. The negative correlation between mature weight and the B parameter was relatively similar for both sexes, indicating that light pre-weaning and weaning weights tend to result in light weight at maturity.

5. Conclusion

Lamb growth is of great economic importance to the Iranian producer. Knowledge of environmental factors which influence the growth curve should be used to help breeding programs. Retardation of growth in traditional breeding system is due to insufficient availability of food related to seasonal variations, mismanagement and overgrazing of ranges, especially when about 65% of the total feed requirement of Iran's livestock population is provided by natural forage where sheep suffer from low forage production on the ranges which are generally overgrazed.

Results of this study indicate that improved growth rate could be realised through the addition of supplementary feed to animals when they are managed under less than optimum nutritional and management conditions. In this case, the animals reach their mature weight in a shorter period and at a younger age, and consequently increase throughput, reducing overheads and labour costs and risk of loss from accident and disease.

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