The determination of growth in Akkeci (White goat) female kids by various growth models

A. Kor[1], E. Baspinar[2], S. Karaca[1], S. Keskin[1]

[1]Department of Animal Science, Agricultural Faculty, Yuzuncu Yil University, Van, Turkey
[2]Department of Animal Science, Agricultural Faculty, Ankara University, Ankara, Turkey

ABSTRACT: This study aimed to determine the growth of 26 Akkeci (White goat = Saanen × Kilis (Bı) crossbreed) female kids by measuring their body weight, withers height, body length, heart girth depth, heart girth width, heart girth circumference, leg circumference and volume index in two-week intervals from birth to 500 days of age and by using different growth models (Monomolecular, Gompertz, Weibull and Richards). An approximate volume index was calculated by multiplying the values of heart girth depth, body length and heart girth width. The best one among these models was determined in respect of RMS (square root of Residual Means Squares which is calculated from the Square Root of Error Mean Square in ANOVA), R^2%, Adjusted R^2%, Mallow's C_p statistic, and asymptotic correlation coefficients criteria. As a result, it was determined that Weibull growth model (which is not concerned with Weibull statistical distribution but is related to parameters of Weibull distribution) was suitable for the above-mentioned material and studied traits.

Keywords: growth curves; body measurements; volume index

Growth is one of the important traits in farm animals. Body growth is related to an increase in cell number and volume. Growth in any trait is a result of the genetic potential of the individual and genetic × environment interaction. Growth curve explains the time (or age) related changes in yield occurring due to such interaction. Age related changes can be observed in the weight or size of any organ, in the composition of tissues, in cell size and number as well as in live weight (Eisen, 1976).

Researchers defining growth by different growth models on various breeds reported that the interpretation of growth varied according to breed and model (Mukundan et al., 1982; Jenkins and Leymaster, 1993; Kocabas et al., 1997; Akbas et al., 1999). In the world, researches used growth curves in sheep and goats to estimate adult body weight and increase in live weight (Bhadula and Bhat, 1980; Mukundan et al., 1982; Moore, 1986; Salah et al., 1988; Nasholm, 1990; Nasholm and Danell, 1990; Jenkins and Leymaster, 1993).

It was stated in many studies that the Saanen × Kilis (Bı) crossbreed called Akkeci could be successfully used for the improvement of Turkish goats (Eker et al., 1976; Elicin et al., 1976; Cakmak, 1992; Kor, 1997; Kor and Ertugrul, 2000). Therefore, the objective of this study was to determine the growth parameters of this genotype which has been raised for milk in Turkey since the 1960s.

One of the aims of this study was to estimate the growth functions for their practical use, for the regulation of growth intensity, and for attaining adequate growth and development of Akkeci female kids by feeding regimes; the other one was to solve some herd management problems.

MATERIAL AND METHODS

Twenty-six Akkeci female kids born in 2002 constituted the animal material. Kids were raised without the application of growth methods on the farm of Agricultural Faculty of Ankara University. Kids were freely nursed by their mothers and were grazed until 2.5 months of age. Moreover, supplemental feeding consisting of 2 500 ME Kcal/kg and 17.23% crude protein was supplied to the kids since 2 weeks of age.

Body weight, withers height, body length, heart girth depth, heart girth width, heart girth circumference, leg circumference of kids were measured in two-week intervals from birth to 500 days of age. Moreover, a new trait called volume index was calculated by multiplying the values for heart girth depth, body length and heart girth width and their growth curves were also determined by some growth models. Arithmetic means of analyzed traits for all measurement periods (Y_t) were used for the estimation of average growth function.

Growth curves of the above-mentioned traits were determined by the following models;

1. Monomolecular model

$$Y_t = \alpha\left(1 - e^{-\beta(\tau-\kappa)}\right)$$

where:

Y_t = the expected size of an organism at time τ
α = the limiting size of the organism
β = the growth rate constant
κ = the zero time
e = the base of natural logarithm

The monomolecular model does not have an inflection point and the growth rate decreases linearly as the size increases $dY_t/d\tau = \kappa\,(\alpha - Y_t)$

2. Gompertz model

$$Y_t = \alpha\left(e^{-e^{-\beta\tau-\kappa}}\right)$$

where:

α = the final size achieved
β = the scaling factor
κ = the x-ordinate of the inflection point

The corresponding y-ordinate of the inflection point occurs at α/e at the maximum growth rate $\alpha\beta/e$. The following constraints apply to the selection of parameter values for Gompertz model α, β, κ > 0

3. Weibull model

$$Y_t = \alpha - (\alpha - \beta)\left(e^{-\kappa\tau}\right)^{\lambda}$$

where:

α = the value of the upper curve asymptote
β = the value of the lower curve asymptote
κ = the scaling parameter
λ = the parameter that controls the x-ordinate for the inflection point of the curve at $\frac{1}{\kappa}\left(\frac{\lambda-1}{\lambda}\right)^{1/\lambda}$

The following constraints apply to the curve fit parameters: α, β, κ, λ > 0 and α > β.

4. Richards model

$$Y_t = \alpha\left(1 + (\beta - 1)e^{-\kappa(\tau-\lambda)}\right)^{\frac{1}{1-\beta}},\ \beta \neq 1$$

where:

α = the upper asymptote
λ = the location of the inflection point on the x axis
κ = the scaling factor
β = the parameter that indirectly locates the inflection point

The y-ordinate of the inflection point is determined from $\alpha/\beta^{1/(\beta-1)}$, $\beta > 0$

Richards also derived the average normalized growth rate for the curve as $\kappa/2(\beta + 1)$

The following constraints apply to the fit coefficient values: α, β, κ, λ > 0, α > β and β ≠ 1

The parameters of these models are estimated using the Levenberg-Marquardt nonlinear least-squares algorithm (Anonymous, 2001).

To compare the effectiveness of the models, RMS, R^2, Adjusted R^2, Mallow's C_p statistic and asymptotic correlation coefficients statistics were used. For the effectiveness of the best model RMS should be lowest, R^2 and Adjusted R^2 should be highest, expected value of Mallow's C_p statistic should be equal to the number of parameters in the model and asymptotic correlation coefficients should be high (absolute value higher than 0.95); then there will be no suspicions about the precision of the parameters in each model (Gage and Tyler, 1985; Cellario and Fenaux, 1990; Neter et al., 1990; Draper and Smith, 1998; Lamare and Mladenov, 2000).

Parameter estimation related to the above-mentioned models was done by NCSS statistical package (Anonymous, 2001).

RESULTS AND DISCUSSION

Table 1 presents the parameters of different growth models and selection criteria (e.g. RMS, R^2, Adjusted R^2, and Mallow's C_p statistic) for the best growth model of body weight and various body measurements.

Table 2 presents asymptotic correlation coefficients between some parameters (e.g. α, β, κ, λ) estimated from the models.

When the criteria (RMS, R^2, R^2_{Adj}, Mallow's C_p, asymptotic correlation coefficients) in Table 1 and

Table 1. Various growth models and estimation equations of parameters in Akkeci female kids

Model	Traits	α	β	κ	λ	RMS	R^2%	R^2_{Adj}%	C_p
Monomolecular	BW	57.0	–0.030	–34.94	–	1.29	98.80	98.72	2.99999
	WH	66.6	–0.060	–117.52	–	1.00	98.61	98.51	2.99999
	BL	68.6	–0.001	–103.16	–	1.38	97.72	97.56	3.00000
	HD	27.3	–0.001	–77.81	–	0.43	99.00	98.93	3.00000
	HW	17.0	–0.010	–46.06	–	0.25	99.08	99.02	3.00000
	HC	82.8	–0.006	–105.76	–	1.14	99.06	99.00	3.00001
	LC	74.7	–0.007	–105.74	–	1.00	98.97	98.90	3.00001
	VO	154 471.5	–0.003	–28.60	–	3 189.50	99.08	99.02	3.00000
Gompertz	BW	48.4	–0.006	103.27	–	1.73	97.85	97.70	3.00000
	WH	66.0	–0.008	–65.38	–	1.14	98.21	98.09	2.99999
	BL	67.9	–0.008	–54.00	–	1.53	97.19	97.00	3.00000
	HD	26.9	–0.009	–23.56	–	0.51	98.55	98.45	3.00000
	HW	16.9	–0.010	–10.30	–	0.28	98.87	98.79	2.99999
	HC	81.8	–0.007	–47.23	–	1.34	98.69	98.60	3.00000
	LC	74.0	–0.008	–56.40	–	1.16	98.63	98.54	3.00000
	VO	132 350.4	–0.006	–100.93	–	4 503.90	98.16	98.03	3.00000
Weibull	BW	199.3	–1.280	0.00	0.57	0.99	99.32	99.25	4.00000
	WH	101.7	10.110	0.02	0.31	0.55	99.59	99.55	4.00001
	BL	150.3	19.360	0.00	0.18	0.85	99.17	99.08	4.00000
	HD	30.9	6.190	0.01	0.56	0.30	99.54	99.49	4.00000
	HW	17.2	5.640	0.01	0.88	0.25	99.13	99.04	4.00000
	HC	107.2	19.630	0.00	0.44	0.65	99.73	99.70	4.00000
	LC	84.8	24.280	0.01	0.52	0.66	99.57	99.52	3.99999
	VO	545 665.2	6 852.350	0.00	0.56	2 399.81	99.50	99.45	4.00000
Richards	BW	91.4	–0.690	0.00	–736.40	1.02	99.28	99.20	4.00001
	WH	72.6	–3.350	0.00	–692.10	0.60	99.52	99.47	3.99998
	BL	74.5	–3.320	0.00	–638.10	0.93	99.01	98.90	4.00001
	HD	29.4	–2.190	0.00	–402.10	0.30	99.59	99.55	3.99999
	HW	17.1	–0.680	0.01	–79.30	0.25	99.13	99.04	4.00001
	HC	91.3	–2.730	0.00	–627.70	0.65	99.70	99.67	4.00000
	LC	80.1	–2.970	0.00	–532.60	0.66	99.57	99.52	4.00000
	VO	224 882.4	–0.630	0.00	–501.80	2 511.83	99.45	99.39	4.00000

BW: body weight, WH: withers height, BL: body length, HD: heart girth depth, HW: heart girth width, HC: heart girth circumference, LC: leg circumference, VO: volume = BL × HD × HW

Table 2 for determination of the best growth model were evaluated together, in Monomolecular model RMS ranged from 0.25 to 1.38, R^2% ranged from 97.72% to 99.08%, R^2_{Adj}% ranged from 97.56% to 99.02%, Mallow's C_p ranged from 2.99999 to 3.00001 (4 out of 8 parameters were found to be exactly 3) and absolute asymptotic correlation coefficients ranged from 52.55% to 98.24%; in Gompertz model,

Table 2. Asymptotic correlation coefficients (%) between parameters of various growth models for traits in Akkeci female kids

Model	Traits	$r_{\alpha\beta}$	$r_{\alpha\kappa}$	$r_{\alpha\lambda}$	$r_{\beta\kappa}$	$r_{\beta\lambda}$	$r_{\kappa}\lambda$
Monomolecular	BW	−98.24	−77.14	85.73			
	WH	−88.71	−75.13	95.32			
	BL	−86.99	−72.17	94.76			
	HD	−86.85	−69.40	93.00			
	HW	−73.25	−52.55	91.10			
	HC	−89.84	−75.37	94.60			
	LC	−87.49	−72.92	94.85			
	VO	−95.22	−67.37	82.24			
Gompertz	BW	−92.96	84.93	−69.45			
	WH	−84.19	−56.10	87.76			
	BL	−81.90	−51.64	86.46			
	HD	−80.17	−38.33	77.84			
	HW	−65.21	−26.67	78.69			
	HC	−84.86	−50.10	83.00			
	LC	−82.57	−52.37	86.46			
	VO	−85.52	55.04	−25.58			
Weibull	BW	−91.88	−99.98	−98.44	92.57	97.07	98.77
	WH	−96.60	−99.76	−98.96	94.59	99.26	97.76
	BL	−98.84	−99.96	−99.64	98.40	99.77	99.38
	HD	−87.22	−79.64	−95.66	40.22	96.99	59.42
	HW	−60.49	27.03	−77.77	−90.09	92.11	−76.09
	HC	−92.82	−98.87	−97.81	86.25	98.30	93.75
	LC	−88.83	−85.67	−96.26	52.64	97.42	69.11
	VO	−89.51	−99.94	−97.45	88.26	96.71	96.94
Richards	BW	80.84	−19.25	65.28	40.18	97.10	60.81
	WH	−19.68	−50.64	−36.82	93.67	98.12	98.66
	BL	9.26	−30.11	−10.38	90.76	97.65	97.65
	HD	−96.89	−98.99	−98.37	99.32	99.72	99.91
	HW	−68.07	−83.59	−75.73	94.14	98.42	98.38
	HC	−61.61	−80.28	−73.00	95.95	98.63	99.27
	LC	−89.30	−95.46	−93.46	98.43	99.38	99.78
	VO	−95.92	−99.23	−98.06	98.58	99.57	99.71

BW: body weight, WH: withers height, BL: body length, HD: heart girth depth, HW: heart girth width, HC: heart girth circumference, LC: leg circumference, VO: volume = BL × HD × HW

RMS was in the range from 0.28 to 1.73, R^2% from 97.19% to 98.87%, R^2_{Adj}% from 97.00% to 98.79%, Mallow's C_p from 2.99999 to 3.00000 (5 out of 8 parameters were found to be exactly 3) and absolute asymptotic correlation coefficients ranged from 25.58% to 87.76%; in Richards model, RMS

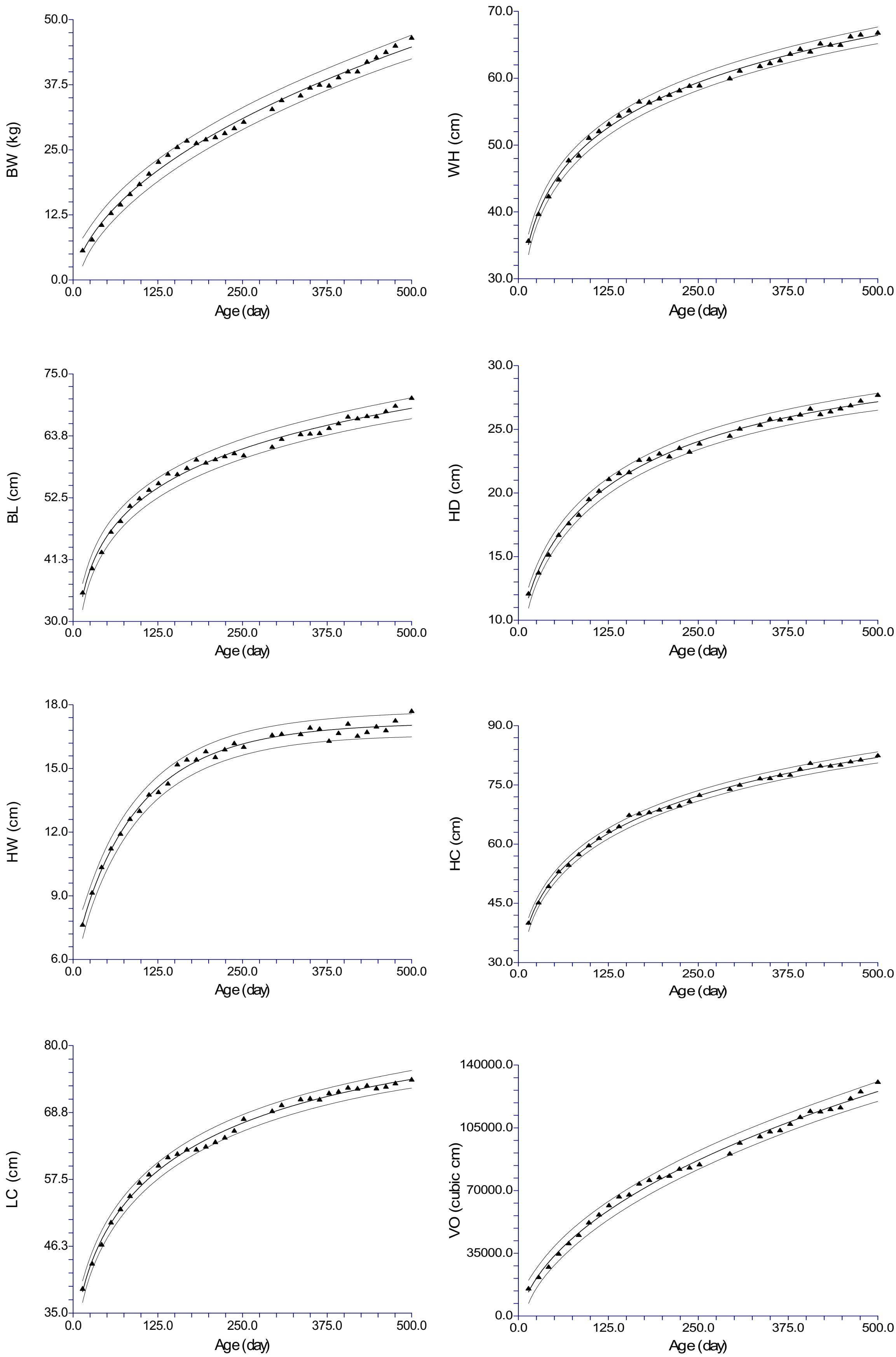

Figure 1. Growth curves of traits for Weibull growth models and prediction limits

ranged from 0.25 to 1.02, R^2% ranged from 99.01% to 99.70%, R^2_{Adj}% ranged from 98.90% to 99.67%, Mallow's C_p ranged from 3.99998 to 4.00001 (3 out of 8 parameters were found to be exactly 4) and absolute asymptotic correlation coefficients ranged from 9.26% to 99.91%; however, in Weibull model, RMS was in the range from 0.25 to 0.99, R^2% from 99.13% to 99.73%, R^2_{Adj}% from 99.04% to 99.70%, Mallow's C_p ranged from 3.99999 to 4.00001 (6 out of 8 parameters were found to be exactly 4) and absolute asymptotic correlation coefficients ranged from 27.03% to 99.98%. As seen from these findings, Weibull growth model was the best one for providing the most suitable values for all investigated traits. Therefore, it could be concluded that Weibull growth model was the most appropriate model for the herd of Akkeci female kids whose body weights and various body traits were measured. Weibull growth curves and their prediction limits of the evaluated traits based on this model are represented in Figure 1.

When Figure 1 was examined, the observed values for all traits were placed in prediction limits; therefore, there was no outlier. By using these Weibull growth curves obtained in this study for the herd of Akkeci female kids, any deviation from the curve or fit to the curve could be referred as whether or not there might be any problem related to the herd management. Moreover, obtaining the fit to this curve might give some clues for the management of suitable feeding schedule.

In this study, approximate volume indices of the animals were determined by multiplying the values of heart girth depth, body length and heart girth width. Weibull model having the lowest RMS (2 399.81) was the best model explaining this trait.

On the other hand, one or more traits determining the growth of any organism can be measured in one or more growth periods. The more measured traits, the better estimation of the growth (Draper and Smith, 1998). Measurements in animals in a determined period could be used in any accepted growth model. The best practical utilization of growth model is to save time. For instance, inferior breeding animals could be discarded by checking their early growth parameters, therefore selection in breeding material could be more cost efficient.

In this study, four different growth models (Monomolecular, Gompertz, Weibull and Richards) were studied to determine the growth changes in the herd of Akkeci female kids, and Weibull growth model was found to be the best model for the studied growth traits.

REFERENCES

Akbas Y., Taskin T., Demiroren E. (1999): Comparison of several models to fit the growth curves of Kivircik and Daglic male lambs. Turk. J. Vet. Anim. Sci., *23*, 537–554.

Anonymous (2001): NCSS and PASS. Number Cruncher Statistical Systems. Kaysville, Utah. www-NCSS.com

Bhadula S.K., Bhat P.N. (1980): Note on growth curve in sheep. Indian J. Anim. Sci., *50*, 1001–1003.

Cakmak N. (1992): Researches on the effects of some environmental factors on the milk yield in Akkeci (White goat). [Agric. Thesis.] Ankara University, Graduate School of Natural and Applied Sciences. MSc. Ankara, Turkey. 79 pp.

Cellario C., Fenaux L. (1990): *Paracentrotus lividus* (Lamarck) in culture (larval and benthic phases): parameters of growth observed during two years following metamorphosis. Aquaculture. *84,* 173–188.

Draper N.R., Smith H. (1998): Applied Regression Analysis. John Wiley and Sons. Inc., Chichester. 706 pp.

Eisen E.J. (1976): Result of growth curve analysis in mice and rats. J. Animal Sci., *42*, 1008–1023.

Eker M., Tuncel E., Askin Y., Yener S.M. (1976): Studies on live weight and body development of Saanen × Kilis goats. Ann. Ankara Univ. Agric. Fac., *26*, 164–175.

Elicin A., Tepe F., Tuncel E. (1976): Adaptation studies of Saanen × Kilis dairy goats to the condition of Antalya Agricultural Research Institute. II. Live weight, body measurements and growth rate. Ann. Ankara Univ. Agric. Fac., *26*, 107–120.

Gage J.D., Tyler P.A. (1985): Growth and recruitment of the deep-sea urchin *Echinus affinis.* (N.Y.), Mar. Biol., *90*, 41–53.

Jenkins T.G., Leymaster K.A. (1993): Estimating of maturating rates and masses at maturity for body components of sheep. J. Anim. Sci., *71*, 2952–2957.

Kocabas Z., Kesici T., Elicin A. (1997): Growth curves of Akkaraman, Awassi × Akkaraman and Malya × Akkaraman lambs. Turk. J. Vet. Anim. Sci., *21*, 267–275.

Kor A. (1997): The effects of castration at different ages of male kids of various genotypes on the fattening performance, carcass characteristics and meat quality (in Turkish). [Ph.D. Agric. Thesis.] Ankara University, Graduate School of Natural and Applied Sciences, Ankara, Turkey. 118 pp.

Kor A., Ertugrul M. (2000): Some slaughtering-carcass characteristics and meat composition of Akkeci male goats. Ankara University. J. Agric. Sci., *6*, 86–91.

Lamare M.D., Mladenov P.V. (2000): Modelling somatic growth in the sea urchin *Evechinus chloroticus* (Echinoidea: Echinometridae). J. Exp. Mar. Biol. Ecol., *243,* 17–43.

Moore A.J. (1986): A mathematical equation for animal growth from embryo to adult. Anim. Prod., *40*, 441–453.

Mukundan G., Khan B.U., Bhat P.B. (1982): Mote on growth curve in Malabari goats and Saanen half-breeds. Indian J. Anim. Sci., *52*, 1112–1113.

Nasholm A. (1990): Mature weight of ewe as a trait in sheep breeding. In: Proc. 4th World Congress on Genetics Applied to Livestock Production, Genetics and Breeding Fibre, Fur and Meat Quality. Edinburgh. *154*, 88–91.

Nasholm A., Danell O. (1990): Growth and mature weight of Swedish Fine wool Landrace ewes. I. Growth curves and estimation of individual mature weight. Acta Agric. Scan., *40,* 71–81.

Neter J., Wasserman W., Kutner M.H. (1990): Applied Linear Statistical Models. 3rd ed., R.D. Irwin, Inc., Boston. 1181 pp.

Salah M.S., Basmaeil S.M., Mogawer H.H. (1988): Growth curve in Aardi goats. Ardo Gulf J. Sci. Res., B. Agric. Bio. Sci., *6*, 369–379.

Received: 2004–12–27
Accepted after corrections: 2005–09–20

Corresponding Author

Assist. Prof. Dr. Askin Kor, Department of Animal Science, Agricultural Faculty, Yuzuncu Yil University, 65080 Kampus, Van, Turkey
Tel. +90 432 225 1097, fax +90 432 225 1123, e-mail: akor@yyu.edu.tr