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The Estimation of Genetic and Phenotypic Parameters of Growth Curve Traits in Sirohi Goat Using Brody Function

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ABSTRACT

The objectives of this study were to investigate growth patterns of Sirohi goat applying the Brody function and estimated the parameters of growth curve including genetic evaluation of growth curve traits. The data used in this study, collected in All India Co-ordinated Research Project (AICRP) on goat improvement, Livestock Research Station, Vallabhnagar, Udaipur, India from year 2009 to 2017 and were included 340 male and 715 female kids body weight measured at birth to 12th month of age in every three months interval. Least-squares means for growth curve parameters of A (Asymptotic weight), B (folding point of growth) and K (maturity rate) were 26.18±3.11 (kg), 0.88±0.00 (kg) and 0.16±0.00 (days), respectively. Fixed effects (cluster, year and season of birth, sex, and type of birth) were significantly influenced the parameters of growth curve. The heritability estimates ranged from 0.02±0.01 (“K”) to 0.40±0.05 (“A”). The genetic correlation between A-K and B-K was negative, which might be due to the compensatory growth effect.

Keywords: Brody Function, Growth curve, Heritability, Sirohi goat

The most important characteristic of live material is growth, described as an increase in both the weight and size in a certain period of time (Thornley and Johnson, 1990). The growth rate and body size, along with changes in body composition of animals are of great economic importance for efficient production of meat animals. Body weights and growth during the early period are often considered as an early indicator of the late growth and economic benefit (Portolano *et al*., 2002; Hanford *et al*., 2006; Benerjee and Jana, 2010) and their rapid growth can minimize the cost of rearing and thus provide more profit to the farmer.

The slow growth rate is mainly endorsed to poor nutrition, management and environmental factors. Growth rate in terms of body weight at market age is one of the main determinants of profit from goat farming for pastoral and poor villagers. Marketable weight is therefore influenced by growth rate and animal’s body size, which are dependent on live weight or dimension for a period of time. Better understanding of animal growth using mathematical modeling of growth data allows better explanation and interpretation of growth events which in turn contribute to improving overall productivity.

The non-linear regression models are more effective than linear regression models because growth has a sigmoid form (Tariq *et al.*, 2013). Growth can be illustrated graphically by means of a sigmoid or S-shaped curve, which represents the continuous changes in body confirmation and composition. These changes include gradual increases in bone, muscle and fat in that order (Webb and Casey, 2010). In terms of quantitative growth characteristics, this is reflected in the growth curve curvature, until it reaches the highest growth rate point. After this inflection point, the growth rate gradually decreases. This tendency continues until growth is stabilized and it reaches its maximum value that coincides with the horizontal asymptote (Lupi *et al*., 2016).

Growth curve models are of great importance for animal production, determining nutritional requirement and assessing the genetic potential of animal for growth. The growth curve parameters adjustment provides to help for a better herd management and kid's fattening according to each genotype potential. The parameters obtained from growth curve function are highly heritable and have been used in selection studies (Lupi *et al*., 2016).

Sirohi is the predominant goat breed of Rajasthan, known for its agile look, with white spots on brown colored body and famous for chevon and milk production. They are mainly reared for chevon purpose, but income from sale of milk is also significant as on average Sirohi goat yields 933 g milk per day in first 90 days of lactation (Shinde *et al.,* 2008).

Study on parameters of growth curve of this breed is very scanty. Therefore, the objective of the present research was to estimate parameters of Brody growth curve model and growth curve related traits were evaluated by non-genetically and genetically; using heritability estimates, genetic and phenotypic correlations among them.

MATERIALS AND METHODS

Data

Data were collected from All India Co-ordinated Research Project (AICRP) on goat improvement, Livestock Research Station, Vallabhnagar, Udaipur, India. The data used in this study, were collected from year 2009 to 2017 and included 340 male and 715 female kids' body weight recorded at birth, 3rd, 6th, 9th and 12th months of age.

Feeding and Management

The Sirohi goats are maintained under field grazing (Extensive system) in project area. The goats remained on pasture for six to eight hours every day. Available trees, shrubs and grasses varied with different seasons as mansoon (Kair, Dhaman, Dudh, Patharchatta, Motha, Akra and Thur), winter (Neem, Motha, Akra, Keekar and Beri) and summer (Post harvest left over residue of Gram pea (Chickpea), Babul, Kair and Khejri) for Sirohi goat in southern Rajasthan.

Statistical Analysis

Body weights were standardized for 30, 60, 120,150, 210, 240, 300 and 330 days using the following methodology (Warwick and Legates, 1979):

$$P_i = Pnear_i + ADG\,(i - age\ Pnear_i)$$

Where, P_i is the standardized weight at standard age (i), $Pnear_i$ is the weight nearest to standard age (i), ADG is average daily gain considered among the weights after standard age (i) and before standard age (i), (i) is age to which weight is standardized, and age $Pnear_i$, age to weight nearest to standard age (i) considering.

Average daily gain in the body weight of individual animal was calculated by using the following formula (Brody, 1964).

$$\text{Average daily gain} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where: W_2= Final body weight (kg); W_1= Initial body weight (kg); t_2= Age of the animal at the end of the period (days); t_1= Age of the animal at the beginning of period (days)

Brody model (Brody, 1945) was used to estimate parameters of the growth curve for each animal. The mathematical function is:

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

Where, W_t= the expected body weight (Kg) at 't' time; A = is the asymptotic weight; B = the folding point of growth; K = the rate of growth; $\mathcal{E}_t$= random error; e = the base of natural logarithm; t = time (birth to 12th month of age)

The function was fitted to weight (kg) - age (t) data of each animal using the SPSS software version 22 with the Gauss Newton iterative methods.

Environmental factors

The data on parameters of growth curve were analyzed through Mixed Model Least-Squares and Maximum Likelihood method designed by Harvey (1990).

To evaluate the environmental factors affecting on growth curve parameters, cluster, season of birth, year of birth, parity, sex and type of birth on parameters the following statistical model were used:

$$Y_{ijklmnop} = \mu + A_i + B_j + C_k + D_l + E_m + F_n + G_o + b(DW_{ijklmno} - DW) + e_{ijklmnop}$$

Where,

$Y_{ijklmnop}$ = Performance record of the pth progeny of ith sire belonging to jth cluster, kth season of birth, lth year of birth, mth parity, nth type of birth and oth sex.

μ = Population mean

A_i = Random effect of ith sire

B_j = Fixed effect of jth cluster (j = 1,2,3,4)

C_k = Fixed effect of kth season of birth (k = 1, 2, 3)

D_l = Fixed effect of lth year of birth (l = 1, 2, 3, 4,5,6,7,8,9)

E_m = Fixed effect of mth parity (m= 1,2,3,4, ≥ 5)

F_n = Fixed effect of nth type of birth (n = 1, 2)

G_o = Fixed effect of oth sex (o = 1, 2)

$e_{ijklmnop}$ = Residual random error associated with and assumed to be identically and independently distributed with mean zero and constant variance

$b(DW_{ijklmno} - DW)$ = The regression of the trait on dam's weight at kidding

Duncan's Multiple Range Test as modified by Kramer (1957) was used for testing differences among least squares means (using the inverse coefficient matrix). The differences were considered significant at P≤0.05.

Estimation of Genetic parameter

The genetic parameter and their standard error was estimated using the Mixed Model Least-Squares and Maximum Likelihood method designed by Harvey (1990), after adjustment of the data for environmental factors.

Heritability estimation

$$Y_{ijk} = \mu + F_i + A_j + e_{ijk}$$

Where:

Y_{ijk} = is measurement of particular trait; μ = Population mean; F_t = Fixed effect observed to be significant from the initial analysis; A_j = Random addition genetic effect j^{th} sire; e_{ijk} = Residual random error with mean zero and variance σ^2_e.

$$h^2 = \frac{4\sigma_s^2}{\sigma_s^2 + \sigma_w^2}$$

Where; σ^2_s = Sire component variance; σ^2_w = within sire component variance.

Estimation of genetic correlation

The genetic correlation was estimated as the ratio of the genetic covariance between the two traits to geometric mean of the genetic variance of the two traits by using formula:

$$R_{gxy} = \frac{Cov_{sxy}}{\sqrt{\left(\sigma_{sx}^2\right)\left(\sigma_{sy}^2\right)}}$$

Where:

R_{gxy} = the genetic correlation coefficient between x and y character of an individual; Cov_{sxy} = Sire component of co-variance between x and y character; σ^2_{sx} = Sire component of variance for x character; σ^2_{sy} = Sire component of variance for y character

Estimation of phenotypic correlation

The phenotypic correlation was estimated by using formula:

$$r_{pxy} = \frac{\sigma_{Sxy} + \sigma_{Wxy}}{\sqrt{\left(\sigma_{Sx}^2 + \sigma_{Wx}^2\right) \times \left(\sigma_{Sy}^2 + \sigma_{Wy}^2\right)}}$$

Where: σ_{Sxy} = Sire component of co-variance between x and y character; σ_{Wxy} = Error component of co-variance between x and y character; σ^2_{Sx} = Sire component of variance for x character; σ^2_{Wx} = Error component of variance for x character; σ^2_{Sy} = Sire component of variance for y character; σ^2_{Wy} = Error component of variance for y character

RESULTS AND DISCUSSION

Least-squares means with standard error of growth curve parameters (A, B and K) are presented in Table 1. The overall least-squares means for A, B and K were estimated

Table 1: Least-Squares means (±SE) of growth curve parameters in Sirohi goat

Effects	N	A	B	K
Overall	1055	26.18±3.11	0.88±0.00	0.16±0.00
Sire		**	**	*
Cluster		**	**	NS
Vallabhnagar	139	$26.13±3.15^{b}$	$0.87±0.00^{a}$	0.16±0.01
Railmagra	700	$25.20±3.11^{b}$	$0.87±0.00^{c}$	0.16±0.00
Devgarh	185	$30.48±3.13^{c}$	$0.89±0.00^{d}$	0.15±0.01
Nathdawara	31	$22.91±3.27^{a}$	$0.87±0.01^{b}$	0.16±0.01
Season		NS	NS	*
Rainy	371	25.83±3.11	0.88±0.00	$0.16±0.00^{ab}$
Winter	507	25.97±3.11	0.88±0.00	$0.17±0.00^{b}$
Summer	177	26.74±3.12	0.88±0.00	$0.15±0.00^{a}$
Year		**	**	**
2009	62	$15.71±3.30^{a}$	$0.86±0.01^{a}$	$0.22±0.01^{d}$
2010	46	$18.49±3.31^{b}$	$0.87±0.01^{b}$	$0.18±0.01^{c}$
2011	105	$20.35±3.28^{c}$	$0.87±0.01^{b}$	$0.16±0.01^{b}$
2012	402	$23.71±3.29^{d}$	$0.88±0.01^{c}$	$0.16±0.01^{b}$
2013	48	$31.77±3.21^{f}$	$0.90±0.00^{e}$	$0.16±0.01^{b}$
2014	106	$32.35±3.29^{f}$	$0.89±0.01^{d}$	$0.14±0.01^{a}$
2015	160	$33.04±3.29^{f}$	$0.88±0.01^{c}$	$0.13±0.01^{a}$
2016	98	$32.01±3.31^{f}$	$0.88±0.01^{c}$	$0.13±0.01^{a}$
2017	28	$28.20±3.40^{e}$	$0.86±0.01^{a}$	$0.14±0.02^{a}$
Kidding Order		NS	NS	NS
First	259	26.41±3.12	0.88±0.00	0.16±0.00
Second	176	25.89±3.12	0.88±0.00	0.16±0.00
Third	172	26.38±3.12	0.88±0.00	0.17±0.00
Four	166	26.33±3.13	0.88±0.00	0.16±0.01
Five and above	282	25.90±3.12	0.87±0.00	0.16±0.00
Type of Birth		*	**	NS
Single	713	$25.83±3.11^{a}$	$0.86±0.00^{a}$	0.16±0.00
Multiple	342	$26.53±3.11^{b}$	$0.89±0.00^{b}$	0.16±0.00
Sex		**	NS	NS
Male	340	$26.81±3.11^{b}$	0.87±0.00	0.16±0.00
Female	715	$25.55±3.11^{a}$	0.88±0.00	0.16±0.00
Regression of dam's weight at kidding		$0.09±0.07^{NS}$	$-0.00±0.00^{NS}$	$-0.00±0.00^{NS}$

Note: N= Number of observation, A=Asymptotic mature body weight, B=Folding point of growth curve, K=Growth rate, *= Significant (P≤0.05), **= Highly significant (P≤0.01) and NS= non-significant

as 26.18±3.11, 0.88±0.00 and 0.16±0.00, respectively. Waiz *et al*. (2019) compared Brody, Gompertz, Logistic, Richrds and Weibull functions in Sirohi goat. They reported Brody function parameters in Sirohi male kids (32.27±5.03, 0.90±0.03 and 0.38±0.13) and female Sirohi kids (26.89±2.56, 0.90±0.03 and 0.47±0.11) for A, B and K respectively. Similar to the current study, Waheed *et al*. (2011) reported the A, B and K parameters of Brody growth curve function in Beetal goat as (29.13±1.15, 0.91±0.01 and 0.10±0.01), respectively. The least-squares analysis of variance observed that the random effect of sire had highly significant (P≤0.01) effect on parameters (A) and (B) however, significant (P≤0.05) effect on parameter (K). The results were in accordance with the finding of Bathaei and Leroy (1998) in Mehraban Iranian fat-tailed sheep. This indicated that sire plays significant role in the asymptotic mature weight, proportion of asymptotic mature weight to be attained after birth and growth rate due to difference in breeding value of sire. Superior sire could be used for improvement of body weights in farmer's flock and inferior sire could be culled. In the present study, Cluster had highly significant (P≤0.01) effect on parameters (A) and (B). The present findings are corroborated with the reports of Waheed *et al.* (2011) in Beetal goat. The significant (P≤0.01) effect of cluster on asymptotic mature weight (A) and folding point of growth curve (B) is attributed to management and environmental conditions viz. grazing, feed availability, socio-economic status of farmer, flock size, housing and supplementation level in different clusters. Season of birth was found to have non-significant effect on parameters (A) and (B) whereas, significant (P≤0.05) effect was observed on parameter (K). The results were in close agreement with the finding of Cayo *et al.* (2015) in Peruvian young llamas (*Lama glama*). Result showed that higher maturity rate was in winter born kids as compared with rainy and summer born kids. This may be due to scarcity of grazing area in summer as well as excessive parasitical infestation load in rainy season. Birth year of kids had significant effect on all the parameters of growth curve (P≤0.01). The parameters of growth curve ranged for "A" as (15.71 – 33.04), "B" as (0.86 – 0.90) and "K" as (0.13 – 0.22). The difference between maximum and minimum value for the parameters of growth curve of Sirohi goat were statistically significant (P≤0.01) whereas, climatic variation and managerial practices through the years may influence on the growth of the animals. Similar findings were reported by Ghiasi *et al*. (2018) in Raeni Cashmere goat. However, influence of sex on asymptotic mature weight "A" was significant ((P≤0.01). Asymptotic mature weight of the male kids was 1.05 times of the female kids. Influence of sex on mature weight was also reported by Saghi *et al*. (2012) and Abegaz *et al*. (2011). This may be due to anabolic effect of sex hormone (androgen) influencing growth that allows higher asymptotic mature weight. The present finding observed that no significant difference on proportion of asymptotic mature weight to be achieved after birth (B) and growth rate (K) of male and female sex of Sirohi goat. The effect of type of birth was significant (P≤0.01) on "B" parameters of growth curve. Results showed that the proportion of body weight gain from birth weight to mature weight is significantly (P≤0.01) higher in multiple birth as compared single born kids. However, multiple born kids were significantly (P≤0.05) heavier (+3%) than single kids at asymptotic mature weight (A). This could be due to maternal influence on kids growth on early ages, which is mainly related to the dam's milk production. Similar results were observed by Abegaz *et al*. (2011). Parity and regression of dam's weight at kidding on parameters of growth curve had no significant effect on all the parameters of growth curve.

Phenotypic and Genetic parameters

The knowledge of genetic and phenotypic parameters of economic growth curve parameters were essential to device suitable breeding plans for bringing about genetic improvement and to predict the expected genetic gain in body weight. The heritability estimates, genetic and phenotypic correlation of different parameters of growth curve were presented in Table 2.

Table 2: Heritability estimates (on diagonal), genetic correlations (above diagonal) and phenotypic correlations (below diagonal) of growth curve parameters of Sirohi goat

Parameters	A	B	K
A	0.40±0.05	1.00±0.04	-0.96±0.31
B	0.45	0.13±0.03	-0.67±0.33
K	-0.43	-0.14	0.02±0.01

Note: A= Asymptotic mature body weight, B= Folding point of growth curve and K= Growth rate

The heritability estimates of parameters (A), (B) and (C) in the present study was estimated as 0.40±0.05, 0.13±0.03 and 0.02±0.01, respectively. The heritability estimates for A was moderate and for B and K were low. The heritability of A is comparable to estimates of 0.39 for Guilan sheep (Hossein-Zadeh *et al*., 2015). However, it is higher than the estimates of 0.14 for Raeini Cashmere goat (Ghiasi *et al*., 2018). Heritability estimates of B and K were similar with reports of Ghiasi *et al*. (2018) in Raeini goat.

The genetic correlations among parameter (A)-(B), (A)-(K) and (B)-(K) were estimated as 1.00±0.04, -0.96±0.31 and -0.67±0.33, respectively. The highly positive genetic correlations between asymptotic mature weight and proportion of birth weight to mature weight indicate that selection of higher proportion of birth weight could leads to higher mature weight. The genetic correlation between asymptotic mature weight and maturity rate was highly negative indicate that selection of faster and higher maturity rate could leads to lighter mature weight. The negative correlation between parameter (B) and (K) indicate that higher maturity rate could result lower birth weight.

The phenotypic correlations among parameters (A)-(B), (A)-(K) and (B)-(K) were estimated as 0.45±0.00, -0.43 ±0.00 and -0.14±0.00 respectively. The positive phenotypic correlation between growth curve parameters (A) and (B) indicates that selection used to increase asymptotic mature body weight could leads to increase birth weight to mature weight proportion. The negative phenotypic correlation between parameters (A) and (K) indicates that selection was used for increase asymptotic body weight could leads to decrease maturity and growth rate. Negative phenotypic correlation between growth curve parameters (B) and (K) indicates that selection used to increase birth weight and mature weight proportion could leads to decrease maturity rate. Similar estimates for phenotypic and genetic correlation between parameters of growth curve have been reported by Ghiasi *et al*. (2018), Saghi *et al*. (2012) and Abegaz *et al*. (2010).

CONCLUSION

The result of this study indicated that clusters, season and year of birth, type of kidding and sex were the major factors affecting parameters of growth curve model of Sirohi goat. Superior sire could be used for improvement of body weights in farmer's flock and inferior sire should be culled. The moderate heritability estimates and high genetic correlation among parameters of growth curve indicated that non-additive genetic variance had moderate influence in growth pattern of Sirohi goat. The antagonistic relationship between asymptotic mature body weight and growth rate indicated that early maturing animal had lower mature weight.

CONFLICT OF INTEREST

The authors declare that there are no conflict of interest among authors and between authors and others people and organization.

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