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SHORT COMMUNICATION

Genetic analysis of body weights and average daily weight gains of Black Bengal goats

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Abstract: The impact of environmental factors on growth traits was evaluated by least-squares analysis of variance followed by estimation of variance components along with heritability of different growth traits and average daily weight gain using simple animal model. Average body weights of Black Bengal kids at birth, 3, 6, 9 and 12 months of age were 1.05±0.01, 3.13±0.05, 6.16±0.13, 9.12±0.46 and 11.28±0.40 kg., respectively. Average daily weight gains at 0-3 months (ADG0-3M), 3-6 months (ADG3-6M), 6-9 months (ADG6-9M) and 9-12 months (ADG9-12M) of age were 23.68±0.59, 31.80±1.21, 23.72±2.83 and 26.68±2.73 g respectively. The study revealed that birth-year of kids significantly (P<0.05) influenced the body weight traits and average daily weight gains (ADG) at different age stages and age intervals of growth, except for 9 months of age. Season of birth showed significant (P<0.05) effect on body weights and ADGs except for 12 months body weight and ADG9-12M. Significant variations for birth weight, 3-and 6-month weights as well as ADG0-3M of kids were observed in different parities of does. Male kids exhibited significantly higher body weights than their female counterparts at all ages except at birth and ADG9-12M. Birth status of kids showed significant effect on 6 months, ADG0-3M and ADG6-9M of animals. Direct heritability estimates of different growth traits ranged from 0.12 to 0.44 whereas ADG at different phases of growth varied from 0.22 to 0.32; indicating some scope for genetic improvement of these traits under study may be possible through selection.

Keywords: Environmental factors, Growth traits, Average daily gain, Heritability, Black Bengal goat

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Growth traits are important for profitability of goat production system mostly reared for meat purposes (Zhanget al. 2009), because rapid growth during the early part of life reduces maintenance costs and can be considered as an early indicator of post-weaning animal growth. Besides this, growth rate in terms of body weight at market weight is one of the main determinants of profit from goat farming for pastoral communities and poor villagers (Gautam et al. 2019). Thus, body weights and average daily gains are important selection traits for improving production performance by selective breeding (Rout et al. 2018). Various studies (Mandal et al. 2018, Gautam et al. 2019) showed that a number of environmental factors can affect the growth traits, which may directly obscure the recognition of the genetic potential of animals. Adjustment of data for different environmental/non-genetic factors is of utmost importance for obtaining the reliable estimates for the traits of interest and for precise estimation of genetic parameters of the traits to increase the accuracy of selection of breeding animals in any breeding program. Therefore, the present study was carried out to determine the important environmental factors affecting the growth performance and their genetic control in Black Bengal goats.

Data on body weights from 416 Black Bengal goats, descended from 21 sires and 61 dams born during the period of 7 years (2016 to 2022), maintained at ICAR-National Dairy Research Institute, Eastern Regional Station, Kalyani, Nadia, West Bengal, were collected and used for the present study. Growth traits included for this study were birth weight and weights at 3, 6, 9 and 12 months of age. Pre-weaning average daily weight gains (ADG) at 0-3 months (ADG0-3M) and post-weaning ADG at 3-6 months (ADG3-6M), 6-9 months (ADG6-9M) and 9-12 months (ADG9-12M) were also considered for the present study.

The data were classified according to year of birth / kidding, season of birth, parity of dam, sex of kid and type of birth. Mixed model least-squares analysis was implemented for fitting constants (Harvey 1990) including all main effects as follows:

$$Y_{ijklmn} = \mu + Y_i + Sj + A_k + E_l + T_m + e_{ijklmn}$$

Where, Y_{ijklmn} is the record for the n^{th} kid, Y_i is the effect of the i^{th} year of birth, S_j is the effect of the j^{th} season of birth, A_k is the effect of the k^{th} parity of dam, E_l is the effect of the l^{th} sex of kid, T_m is the effect of the m^{th} birth status / type of kid born, e_{ijklmn} is the residual error element. The comparison of different sub-groups means was made by Duncan's multiple range test (DMRT) as described by Kramer (1957).

Variance components as well as heritability of different growth traits were estimated by simple animal model. Only significant fixed effects obtained from least-squares analysis for each growth trait were included in the final model used for genetic parameter estimation of growth traits by animal model. The components of variance were estimated by Restricted Maximum Likelihood (REML), through Average Information-REML algorithm on WOMBAT program using single-trait animal model (Meyer 2007).The following simple animal model was used:

$$Y=X\beta + Z_l a + e$$

Where, Y is the vector of observations for the dependent variable (growth traits); X is the incidence matrix of fixed effects for the dependent variable and β is the corresponding vector of fixed effects; Z_l is the incidence matrix of the direct additive genetic effects; a is the vector of direct additive genetic effects associated with the Z_l incidence matrix and e is the vector of residual random effects associated with the observations.

The average body weights of Black Bengal kids at birth, 3, 6, 9 and 12 months of age were 1.05±0.01, 3.13±0.05, 6.16±0.13, 9.12±0.46 and 11.28±0.40 kg., respectively (Table 1). The average values for ADG0-3M, ADG3-6M, ADG6-9M and ADG9-12M were recorded as 23.68±0.59, 31.80±1.21, 23.72±2.83 and 26.68±2.73 g, respectively (Table 2). The average body weights at various ages in the present study were well comparable with the findings of

Table 1: Least-squares means along with standard errors of different growth traits of Black Bengal Goats

Effects	Growth traits (Kg)				
	Birth wt.	3-month wt.	6-month wt.	9-month wt.	12-monthwt.
Overall mean	1.05±0.01 (326)	3.13±0.05 (281)	6.16±0.13 (234)	9.12±0.46 (148)	11.28±0.40 (117)
Year of Birth	**	**	**	NS	**
2016-17	1.26±0.03^{a} (36)	3.53±0.12^{a} (33)	7.02±0.27^{a} (35)	9.83±0.49 (34)	13.37±0.67^{a} (27)
2017-18	1.00±0.03^{bcd} (35)	3.31±0.11^{ab} (32)	6.56±0.28^{ab} (27)	8.79±0.49 (26)	10.26±0.72^{b} (19)
2018-19	1.03±0.03^{bc} (27)	3.14±0.13^{bc} (24)	6.20±0.30^{bc} (22)	8.93±0.79 (8)	11.40±0.91^{b} (10)
2019-20	0.94±0.02^{d} (83)	2.98±0.09^{c} (58)	6.21±0.20^{b} (62)	9.05±0.40 (51)	11.41±0.48^{b} (49)
2020-21	1.00±0.02^{cd} (78)	2.95±0.08^{c} (69)	5.83±0.21^{c} (47)	8.33±0.50 (23)	9.96±0.87^{b} (12)
2021-22	1.06±0.02^{b} (67)	2.89±0.09^{c} (65)	5.16±0.27^{d} (41)	9.71±0.31 (6)	
Season of Birth	**	**	**	**	NS
Summer	1.09±0.02^{a} (122)	3.56±0.08^{a} (91)	6.54±0.17^{a} (110)	8.68±0.48^{ab} (82)	10.68±0.56 (55)
Rainy	1.03±0.02^{b} (124)	3.01±0.07^{b} (118)	5.56±0.19^{b} (81)	8.48±0.59^{b} (35)	11.39±0.62 (30)
Winter	1.02±0.02^{c} (80)	2.83±0.08^{c} (72)	6.39±0.23^{a} (43)	10.15±0.59^{a} (31)	11.78±0.53 (32)
Parity of dam	**	**	*	NS	NS
1	1.01±0.02^{c} (93)	2.94±0.08^{c} (81)	5.57±0.20^{b} (65)	9.01±0.65 (34)	11.11±0.68 (27)
2	1.02±0.02^{c} (73)	2.83±0.09^{c} (66)	5.63±0.22^{b} (53)	9.06±0.62 (35)	11.73±0.60 (29)
3	0.99±0.02^{c} (50)	2.96±0.10^{c} (42)	6.07±0.22^{a} (41)	9.06±0.59 (28)	11.58±0.58 (24)
4	1.05±0.03^{bc} (26)	3.11±0.14^{bc} (23)	6.70±0.33^{a} (19)	9.89±0.77 (14)	12.77±0.93 (11)
5	1.05±0.03^{bc} (30)	3.09±0.12^{c} (27)	5.94±0.29^{a} (22)	8.90±0.74 (11)	11.51±0.78 (12)

6	1.15±0.03[a] (25)	3.46±0.14[ab] (20)	6.50±0.34[a] (18)	8.98±0.82 (13)	10.43±1.13 (6)
7	1.13±0.04[ab] (11)	3.77±0.23[a] (7)	6.96±0.56[a] (6)	9.20±1.11 (5)	10.35±1.66 (3)
8	0.98±0.04[c] (18)	2.91±0.17[c] (15)	5.94±0.45[a] (10)	8.75±1.03 (8)	10.77±1.30 (5)
Sex of kid	NS	*	**	**	**
Male	1.06±0.01 (182)	3.23±0.06[a] (155)	6.62±0.15[a] (121)	9.94±0.46[a] (80)	12.29±0.46[a] (53)
Female	1.03±0.01 (144)	3.04±0.07[b] (126)	5.70±0.17[b] (113)	8.28±0.52[b] (68)	10.28±0.50[b] (64)
Type of birth	NS	NS	*	NS	NS
Single	1.05±0.02 (115)	3.21±0.08 (94)	6.36±0.20[a] (79)	9.20±0.58 (54)	11.08±0.59 (41)
Twin	1.04±0.02 (164)	3.02±0.06 (145)	5.89±0.15[b] (120)	8.99±0.49 (68)	10.91±0.44 (61)
Triplet	1.04±0.03 (47)	3.17±0.11 (42)	6.27±0.26[b] (35)	9.13±0.70 (26)	11.86±0.84 (15)

Means with different superscripts between the rows in a column differed significantly
NS, Not significant; *, Significant (P<0.05); **, Highly Significant (P<0.01)

Kumar et al. 2021 and Alam et al. 2021 for this breed. However, higher body weights of Black Bengal kids at different stages of growth were reported by Solaiman et al. (2020) at 6-12 months age and Chakrabarti et al. (2022) at birth and 3 months of age.

Different environmental factors significantly (P<0.05) affected most of the growth traits of the kids in this study. Birth year had significant (P<0.01) effect on all the growth traits except for 9-months body weight. Significant effects of year of birth on body weights were also reported by Mandal et al. (2018) and Jasmine et al. (2022) for various breeds of goat. Variations in body weight of kids in this study across birth years may be due to variations in managemental condition and varied climatic conditions including humidity, rainfall, and temperature etc. in the flock over the years. Significant variations for all growth traits except weight at 12 months and ADG9-12M were observed among kids born in different seasons. Kids born in summer season had higher weight at birth and subsequent body weights until 6 months of age than kids born during rainy and winter seasons. The lower body weights at birth of the kids, born in rainy / winter season in this study may be an unfavorable effect of the temperature, since gestation period of the does would occur during hot period of the year. Parity of doe showed significant (P<0.05) effect on only ADG0-3 months and all growth traits except 9 and 12 month of age (Table 1 and 2). Kids born from does of later parities had significantly (P<0.05) higher body weights than kids born from does of earlier parities. Similar significant effect of parity of doe on different body weights of kids was observed by Singh et al. (2013) in Jamunapari and Bhusan & Dass (2015) in Jakhrana goats. Similarly, Amy (2020) and Jasmine et al. (2022) also observed the significant effect of parity on all body weight traits except weight at 9 and 12 months of age in Black Bengal goats.

Sex of kid had significant effect on all growth traits except weight at birth and ADG9-12 months of Black Bengal goats . Single born kids exhibited significantly (P<0.01) higher body weight only at 6 month of age and ADG 6-9M than kids born as twins or triplets. However, significantly heavier male kids than female at all the ages were reported by Haque et al. 2013 in Black Bengal Goats.

Variance components and heritability estimates of different body weights and average daily weight gains at different ages of Black Bengal goats are presented in Table 3. Estimates of direct heritability for birth weight, 3, 6, 9, and 12-months body weights were low to moderate in magnitude, which ranged from 0.12 - 0.44. The heritability of body weights exhibited a decreasing trend from birth to 6 months of age whereas a increasing trend was observed from 9 to 12 months. Several researchers (Rout et al. 2018 and Gautam et al. 2019) reported the heritabilities for body weights of kids at different ages in various goat breeds, which were in agreement with our findings. The decreasing heritability of kids' body weights at the later stages of developmental process except 12 months in this study indicates that environmental factors, in relation to additive genetic factors, had more influence on weights attained later in the developmental stages. This attributes to the maternal influence associated with kid performance at early stage of growth. Estimates of heritability of all body weight traits at different ages in this study were low to moderate in magnitude, indicating genetic progress is possible for these traits under prevalent management system. Direct heritability estimates for average daily weight gains at 0-3 months (ADG0-3M), 3-6 months (ADG3-6M), 6-9 months (ADG6-9M) and 9-12 months (ADG9-12M) of age were moderate to high in nature, which ranged from 0.22 – 0.32 (Table 3). The heritability estimate of AGD at 0-3 M was slightly increased in the subsequent

Table 2: Least-squares means along with standard errors of average daily gains (ADG's)

Effects	Average daily weight gains (g)			
	ADG0-3M	ADG3-6M	ADG6-9M	ADG9-12M
Overall mean	23.68±0.59 (282)	31.80±1.21 (212)	23.72±2.83 (140)	26.68±2.73 (105)
Year of Birth	**	**	**	*
2016-17	27.26±1.29^{a} (35)	35.01±2.43^{a} (34)	35.94±3.10^{a} (31)	35.86±3.85^{a} (27)
2017-18	25.68±1.28^{a} (32)	35.86±2.54^{a} (26)	27.43±3.03^{b} (26)	21.54±4.08^{b} (18)
2018-19	24.19±1.38^{ab} (25)	32.42±2.63^{a} (22)	24.27±4.82^{b} (8)	29.12±7.72^{ab} (4)
2019-20	22.77±0.93^{b} (58)	33.76±1.88^{a} (48)	27.72±2.35^{b} (50)	26.42±2.68^{b} (48)
2020-21	21.11±0.86^{b} (68)	31.95±1.95^{a} (41)	19.36±3.28^{c} (25)	20.44±5.77^{b} (8)
2021-22	21.08±1.03^{b} (64)	21.82±2.39^{b} (41)		
Season of Birth	**	**	*	NS
Summer	27.04±0.83^{a} (91)	32.07±1.54^{a} (91)	20.61±3.01^{b} (77)	25.01±3.43 (54)
Rainy	22.51±0.81^{b} (119)	27.00±1.72^{b} (78)	20.83±3.66^{b} (33)	29.63±3.93 (24)
Winter	21.50±0.90^{b} (72)	36.33±2.04^{a} (43)	29.70±3.66^{a} (30)	25.39±3.59 (27)
Parity of dam	**	NS	NS	NS
1	22.36±0.89^{c} (82)	29.10±1.80 (61)	28.64±4.02 (32)	30.65±4.27 (26)
2	20.56±0.95^{c} (66)	30.71±1.95 (49)	26.42±3.82 (32)	31.86±3.73 (26)
3	21.27±1.05^{c} (41)	33.16±2.01 (35)	22.96±3.63 (28)	31.93±3.41 (23)
4	23.91±1.49^{bc} (23)	37.77±3.14 (16)	27.99±4.77 (13)	34.29±5.53 (10)
5	22.67±1.33^{c} (27)	30.86±2.73 (19)	25.94±4.51 (11)	23.47±5.02 (10)
6	27.53±1.53^{ab} (21)	30.07±3.04 (18)	17.70±5.01 (13)	19.07±8.01 (4)
7	29.91±2.55^{a} (7)	33.11±5.29 (5)	18.70±7.37 (4)	20.24±10.74 (2)
8	21.28±1.80^{c} (15)	29.64±4.07 (9)	21.36±6.57 (7)	21.90±8.60 (4)
Sex of kid	*	**	**	NS
Male	24.59±0.68^{a} (157)	35.23±1.40^{a} (110)	28.01±2.86^{a} (74)	28.99±2.89 (47)
Female	22.78±0.74^{b} (125)	28.38±1.50^{b} (102)	19.42±3.23^{b} (66)	24.36±3.30 (58)
Type of birth	*	NS	*	NS
Single	23.96±0.89^{ab} (95)	33.23±1.81 (70)	19.30±3.62^{b} (50)	22.66±3.73 (39)
Twin	22.17±0.69^{b} (144)	30.27±1.41 (108)	27.12±2.99^{a} (65)	22.56±3.02 (52)
Triplet	24.92±1.19^{a} (43)	31.91±2.38 (34)	24.72±4.30^{ab} (25)	34.81±5.43 (14)

Means with different superscripts between the rows in a column differed significantly

NS, Not significant; *, Significant (P<0.05); **, Highly Significant (P<0.01)

Table 3: Estimates of variance components and heritability along with standard errors of different body growth traits of Black Bengal Goats

Traits	σ_a^2	σ_e^2	σ_p^2	h^2
Birth weight	0.006	0.02	0.02	0.29±0.14
3-month weight	0.06	0.31	0.37	0.17±0.14
6-month weight	0.21	1.55	1.76	0.12±0.15
9-month weight	0.67	3.89	4.56	0.15±0.16
12-month weight	3.04	3.77	6.81	0.44±0.27
ADG0-3M	9.69	34.46	44.15	0.22±0.14
ADG3-6M	44.65	93.65	138.30	0.32±0.20
ADG6-9M	62.45	132.49	194.94	0.32±0.22
ADG9-12M	59.72	140.19	199.91	0.30±0.27

σ_a^2, additive genetic variance, σ_e^2, residual variance, σ_p^2, phenotypic variance; h^2, heritability

time and remained at constant upto 9-12 months. Similar to the findings of the present study, Rout et al. (2018) and Gautam et al. (2019) obtained moderate heritability estimates of average daily weight gains of kids at different ages/phases of growth in various goat breeds. The moderate to high estimates of heritability for all ADG under study suggested that there is ample scope of genetic improvement of these traits through genetic selection.

Conclusion

Body weights and average daily gains are essential traits for improving production performance by selective breeding in goat. The study revealed that environmental factors significantly impacted the growth traits of Black Bengal. The growth performance of the Black Bengal goats at the farm level showed that, despite its climate vulnerability, this breed can perform admirably at organized flocks.

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