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Phenotypic performance and response to selection for body weight gains of Black Bengal goat in a community breeding program

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Black Bengal goat is a potential animal genetic resource of Bangladesh. The aim of this study was to investigate the genetic improvement of growth rate (GR) *in-situ* through a community based breeding program under a low input production system. Data on a total of 451 individuals from 2009 to 2015 in three generations were taken. In the community, two breeding strategies (BS); mating among superior bucks and does (BS1) and mating existing does with superior bucks (BS2) were followed. Mating among existing bucks and does (BS3) were considered as test group. The average GR from 0 to 3m, 3 to 6m, 6 to 9m, 9 to 12m and 0 to 12m were 43.05±0.78, 21.27±0.48, 21.42±0.37, 19.42±0.46 and 36.17±0.28 g/d, respectively. GR at different ages differed significantly (p<0.001) for sex, except at 0 to 3m. Generation and BS influenced GR at all ages significantly. Better growth rates were obtained in BS1 progeny and in later generations. The heritability (h^2) estimates for GR at different ages ranged from 0.32 to 0.57. The genetic and phenotypic correlations for GR at different ages ranged from 0.02 to 0.87. The average responses for GR varied from 2.31 to 4.52 g/d per generation. It may be concluded that community based breeding program with superior bucks and does is very rationale under low input production system, as it improved growth performance in progressive generations. However, h^2 and r_G indicated scope of genetic improvement for GR if rigorous culling of inferior does and bucks can be adopted.

Key words: Black Bengal goat, growth rate, genetic evaluation, response to selection.

INTRODUCTION

There are about 300 breeds and types of goats in the world. Bangladesh comprises three genotypes of goat which are: pure Black Bengal goat (BBG), few exotic breeds and crossbred between BBG and exotic breeds. Some other pure exotic breeds such as Serohi, Beetal, Jamnapari and the crossbreds between BBG and exotic

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breeds are also available. About 90% of the total goat population of the country are of BBG breed with some inconsistency in coat color, the rest 10% are of exotic breeds and crosses between BBG and exotic breeds (Husain, 1993; Amin et al*.,* 2001).

The BBG is an important indigenous small farm animal genetic resource in Bangladesh for their attractive flavored meat, quality skin and multiple litter size. However, in most cases multiple kids cannot survive due to poor milk secretion from the udder of the does. On the other hand, their slow growth rates cannot produce substantial amount of meat within very short periods when they get to marketing ages of about 8-12 months. To accomplish the demand of meat, it is essential to improve the genetic potentiality for fast growth rates with higher carcass weight. Importantly, Husain et al. (1996) observed the existence of large variations within BBG population in terms of body weight and growth rate, which may be exploited for their immediate improvement through selective breeding. As BBG are solely being reared by the people for meat production, growth rate could be considered for selection and breeding in genetic improvement program to obtain higher carcass weight. Keeping this in view, this study was conducted to find out response to selection for growth traits of BBG in a community breeding program at three village flocks in Bhaluka upazila of Mymensingh district.

MATERIALS AND METHODS

Location of the study

The study was conducted at a rural community level goat flocks of three different villages; *Gangatia*, *Borochala* and *Pachpai* at Bhaluka upazila (sub-district) in Mymensingh district of Bangladesh. Bhaluka is geographically located in between 24°16´ and 24°29´ N latitude and in between 90°14´ and 90°29´ E longitudes. The study area is located at 70 km north from the capital city, Dhaka.

Ecology and climate

The ecology of the three villages of Bhaluka have same temperature, ranging from 12 (winter) to 33°C (summer), and the annual rainfall averages 2147mm during the study period. High lands available which were reddish in color, some forests were present in *Pachpai* village. Grazing lands were available in *Gangatia*, *Borochala* and *Pachpai* village for the goat. In the study areas, dogs, wild cats, foxes and snakes were the main predators during grazing of goats.

Selection of sire and dam

Superior bucks and does were selected to establish community foundation flocks in the three villages. The superior bucks were selected from Bangladesh Livestock Research Institute (BLRI), Department of livestock Services (DLS) and simultaneously from the based on physical appearance and daily body weight gains.

Performance records from the goat owners by investigating the contemporary history of the animals were taken. Superior bucks were selected on the basis of body weight at 6 months of age ≥ 8 kg, good body conformation and dams yielded at least 250ml milk/day and kidded ≥ 2 kids in previous birth(s). Superior does were selected on the basis of adult body weight (preferably >15.0 kg), litter size (preferably multiple, ≥2 kids per kidding) and daughter of a prolific dam who yielded at least 250 ml milk/day and kidded ≥2 kids in previous birth(s) and free from any kind of defects and diseases.

Husbandry practices

Traditional housing with semi-intensive management systems was practiced by the BBG keeper farmers. The bucks and does were allowed to graze separately tethered by rope in naturally available pasture land and adjoining fields of the farmer’s house. Goats were also provided with tree leaves*,* kitchen waste, leftover of family meals, table salt and cut and carry green grass *ad lib* during the day time. Goats were allowed to feed on concentrate feed such as rice gruel, rice bran, broken rice, wheat bran etc. during pregnancy and lactation at 200 g/day/animal. The breeding bucks were also fed whole gram at 50 g/day/animal in the morning. Fresh drinking water was also supplied for the goat *ad lib.* All goats under the project areas were vaccinated and de-wormed routinely against prevalent diseases and parasites.

Breeding and selection

For mating does with superior bucks, three “Buck Parks” in each village, were established by the foreign aided project. Superior bucks were kept in the buck park most of the time except feeding and exercise for half an hour twice in a day. Two breeding strategy/intervention (BS) were followed: mating among selected superior bucks and does (those supplied to the farmers by the project aid) denoted as BS_1 and mating of existing does (owned by the community farmers) with selected superior bucks denoted as BS_2. Besides, a test group denoted as BS_3 was also observed to compare with other two BS. In the test group, mating was followed among existing does and bucks (owned by the farmers). Only superior males were selected as sire to produce progeny in progressive generations. The selection criteria were based on individual growth and body conformation of their dam.

Recording data

All animals were neck tagged and data sheet for each individual were maintained for recording data. The data was collected over 3 progressive generations from three flocks. There were a total of 657 individuals (101 males and 556 females) comprising 285 base populations (25 males and 260 females) and 372 progeny (76 males and 296 females) from three flocks in three progressive generations included in this study.

Statistical model and data analysis

The study covered various stages of growth rates of BBG in progressive generations. The animals were of different populations and ages as well as both parents and progeny groups. Therefore, data were sufficiently unbalanced and hierarchy in nature. So, statistical design of the study was essentially non-orthogonal factorial in nature. Descriptive statistics, analysis of variance and phenotypic correlations (Pearson’s model) were performed by SPSS 17.0 (1998) package. The significance of independent variables (fixed or non-genetic factors) was tested by least-squares analyses of variance using the general linear model (GLM) procedure as follows:

$$Y_{ijklm} = \mu + S_i + G_j + B_k + F_l + e_{ijklm}$$

where, Y_{ijklm} = Record of m^{th} kid belonging to i^{th} sex, born in j^{th} generation under k^{th} breeding strategy in l^{th} village flock. μ = Overall population mean for GR at different ages; S_i = Effect of i^{th} sex (where i = male and female); G_j = Effect of j^{th} generation (where j = 1^{st} generation, 2^{nd} generation and 3^{rd} generation); B_k = Effect of k^{th} breeding strategy (where k = BS_1, BS_2 and BS_3); F_l = Effect of l^{th} flock (where l = *Gangatia, Borochala and Pachpai* village flocks); e_{ijklm}= Random residual error associated with Y_{ijkl} observation

Estimation of genetic parameter

The genetic parameters including (co)variance components, heritability and genetic correlations were estimated using VCE 4.2.5 (Groeneveld, 1998) package with residual maximum likelihood (REML) approach. For REML analysis, animal model was used to consider sex, generation, breeding strategy and flock as fixed effects. The general form of the animal model was as follows:

$$Y = Xb + Za + Wc + e$$

Where, Y = Vector of observations; X, Z, and W = Known incidence matrices associated with levels of b, a and c with Y. b = Unknown vector of fixed effects (that is sex, generation, etc.); a = Unknown vector of breeding value; c = Unknown vector of permanent environmental effects; e = Vector of residual effect

Estimation of selection response

The predicted or expected responses to selection in the progressive generations for the economic important traits were estimated using the following formula given by Falconer (1989):

$$R= i \times sd_p \times h^2$$

where, R = response to selection in the next generation for the trait; i = selection intensity; h^2 = heritability of the trait; sd_p = phenotypic standard deviation of the trait.

The observed or actual response to selection was the difference of phenotypic mean between progeny of the selected parents and group of the selected parents.

RESULTS AND DISCUSSION

Growth rates at different ages

The growth rates (GR) of BBG as estimated in this study for various ages are demonstrated in Table 1. GR at the age from birth to 3 months (GR_{0-3}), 3 to 6 months (GR_{3-6}), 6 to 9 months (GR_{6-9}), 9 to 12 months (GR_{9-12}) and birth to 12 months (GR_{0-12}) are 43.05±0.78, 21.27±0.48, 21.42±0.37, 19.42±0.46 and 36.17±0.28 g/d, respectively. Husain et al. (1997) had shown that body weight gain per day in BBG averaged 43.3, 39.5, 26.5 and 23.0g/d at GR_{0-3}, GR_{3-6}, GR_{6-9} and GR_{9-12}, respectively. Amin (2000) also found similar rate of gains in his investigation. Haque (2014) reported GR of BBG at GR_{0-3}, GR_{3-6}, GR_{6-9} and GR_{9-12} to be 39.93, 32.64, 31.29 and 27.35 g/d, respectively. Their results seem to be agreed well by this study for the early stage of growth, but in later stages, they found slightly higher growth than this study. In another study, Majumder (2011) reported comparatively higher GR as 56.68 g/d in his study. However, the present GR in not in line with the report of a neighboring country given by Gupta et al. (2016), for Mehsana goat in Gujarat, India. They reported pre-weaning GR of 84.75±1.82 g/d in their study. They also reported post-weaning GR of 35.58±0.92 g/d which slightly agrees with this study. The variations of GR at different ages between same or other genotypes could be due to the type of breed, feeding, management and environment. Some authors studied growth parameters in nucleus flock, where good feeding and management might have been provided. As a result, obtaining higher GR as compared to this study is very usual in that circumstance.

Table 1 shows that sex had high significant ($p<0.001$) effect on GR (males grew higher than females), except that of GR_{0-3}. Gupta et al. (2016) reported sex to have significant effect on post-weaning growth, while not for pre-weaning growth which is coincided by this study as weaning usually happen within birth to 3 months in goat. Husain (1993) observed that pre-weaning growth rate of kids was affected by sex of the kids. Generation had highly significant ($p<0.01$; $p<0.001$) effect on GR at all ages. As expected, growth appears to increase as generation progressed, which is also in agreement with Haque (2014), Akhter et al. (2006) and Amin et al. (2001). This could be due to selection of best parents in the progressive generations. BS had highly significant ($p<0.01$; $p<0.001$) effect on GR at all ages. Highest GR was obtained in the population produced from BS_1, followed by BS_2 and BS_3 (Figures 1 and 2). This superiority is due to gene, as superior bucks and does were mated each other in BS_1 to produce offspring with higher genetic worth as reflected for other traits also.

GR at any age did not differ significantly ($p>0.05$) among flocks, which indicate the unique feature of growth in BBG population and also same feeding and management systems in the rural communities. This is in disagreement by Husain (1993) who observed that pre-weaning growth rate of kids was affected by region, which could be raised due to variations of environmental factor like feeding, care, health status etc.

Heritability for growth rates

The variance components and heritability estimates of GR at different ages are illustrated in Table 2. It shows that GR at all ages profound to be medium in heritability ranges from 0.42 (GR_{3-6}) to 0.49 (GR_{0-3}). There appears to be very little information on heritability estimates for GR at different ages in BBG. However, this result is very similar to Alade et al. (2010) who found heritability for pre-weaning gain of goat to be 0.39, but contradicts with their post-weaning gain of 0.03. Bosso et al. (2007) reported heritability estimates of GR from birth to 4 months and from 4 to12 months for West African dwarf goat to be 0.32 and 0.11, which is somewhat similar

Table 1. Growth rate (g/d) of BBG at different stages.

Factor	Growth rate (g/d) (Mean±SE)				
	GR_{0-3}	GR_{3-6}	GR_{6-9}	GR_{9-12}	GR_{0-12}
Sex	NS	***	***	***	***
Male	43.88±1.21 (099)	26.21±1.12 (093)	24.45±0.94 (093)	22.74±1.37 (093)	38.92±0.47 (099)
Female	42.82±0.93 (352)	21.60±0.48 (326)	20.58±0.38 (326)	18.54±0.44 (326)	35.39±0.32 (353)
Generation	***	**	***	***	***
G_0	41.94^{bc}±1.39 (130)	19.86^{c}±0.65 (117)	19.55^{b}±0.60 (117)	17.67^{c}±0.90 (117)	35.75^{bc}±0.46 (130)
G_1	40.58^{c}±1.13 (119)	20.83^{bc}±0.76 (109)	20.82^{b}±0.50 (109)	18.94^{bc}±0.64 (109)	35.57^{c}±0.40 (119)
G_2	46.24^{b}±1.71 (107)	23.80^{ab}±1.53 (102)	24.77^{a}±0.71 (102)	21.56^{b}±0.67 (102)	37.59^{ab}±0.80 (108)
G_3	54.22^{a}±2.52 (095)	25.56^{a}±1.75 (091)	26.18^{a}±1.95 (091)	25.23^{a}±1.52 (091)	38.34^{a}±1.13 (095)
BS	***	**	**	***	***
BS_1	50.85^{a}±0.97 (198)	22.83^{a}±0.82 (183)	22.99^{a}±0.60 (183)	20.73^{a}±0.61 (183)	38.75^{a}±0.40 (198)
BS_2	39.48^{b}±1.23 (138)	20.93^{a}±0.66 (129)	20.64^{b}±0.52 (129)	18.67^{ab}±0.55 (129)	35.08^{b}±0.41 (138)
BS_3	29.26^{c}±1.25 (115)	17.53^{b}±0.94 (107)	18.80^{b}±0.82 (107)	17.50^{b}±1.87 (107)	31.20^{c}±0.35 (116)
Flock	NS	NS	NS	NS	NS
Gangatia	40.82^{b}±1.43 (172)	20.71±0.84 (161)	20.16^{b}±0.46 (161)	20.60±0.33 (161)	34.41^{b}±0.52 (172)
Borochala	40.31^{b}±1.26 (148)	21.41±0.81 (139)	22.95^{a}±0.80 (139)	22.05±0.71 (139)	36.56^{a}±0.70 (148)
Pachpai	48.64^{a}±1.20 (131)	21.75±0.84 (119)	21.10^{b}±0.58 (119)	21.91±0.36 (119)	38.02^{a}±0.39 (132)
Overall mean	43.05±0.78 (451)	21.27±0.48 (419)	21.42±0.37 (419)	19.42±0.46 (419)	36.17±0.28 (451)

GR_{0-3}, GR_{3-6}, GR_{6-9}, GR_{9-12}, GR_{0-12} denote growth rates from 0-3 months, 3-6 months, 6-9 months, 9-12 months and 0-12 months; BS, breeding strategy; G_0, foundation flock; G_1, generation 1; G_2, generation 2; G_3, generation 3; Figures in the parenthesis indicate number of observations; NS, not significant (p>0.05); *, Significant at 5% level (p<0.05); **, Significant at 1% level. (p<0.01); ***, Significant at 0.1% level (p<0.001); means with uncommon superscripts within the same column differed significantly.

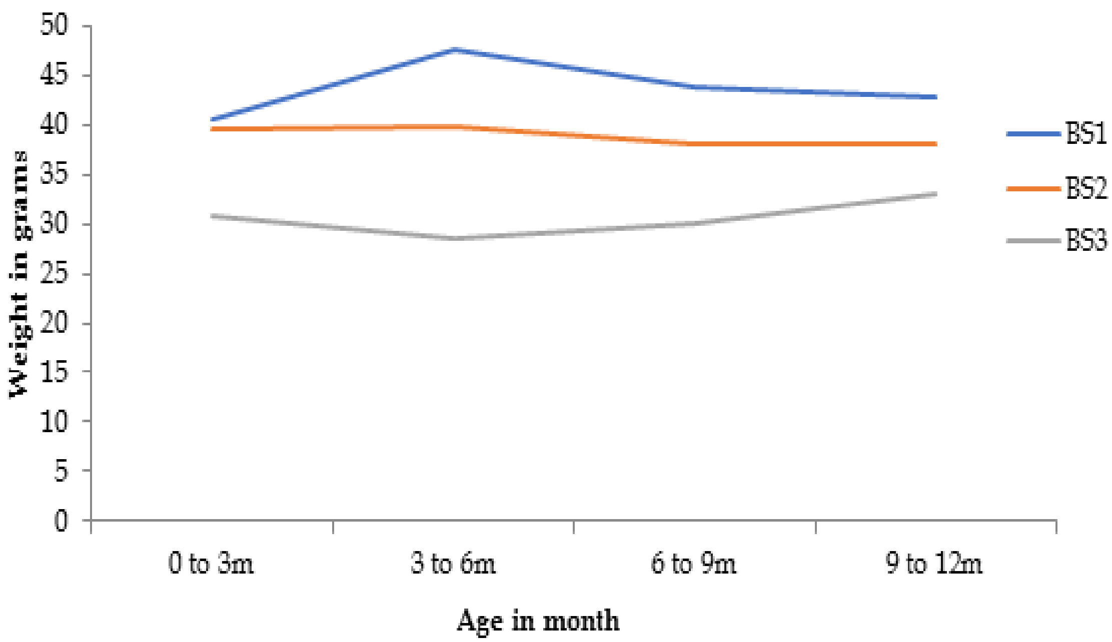


Figure 1. Growth curve of male kids for different breeding strategies.

to our study for early stage of growth. In another study, Zhou et al. (2014) reported low estimates of heritability for GR at three different stages from birth to 12 months of age for Hainan black goat in China. Lower estimates of heritability (from 0.10 to 0.12) for average daily gain up to 3 months, 6 months, 12 months and up to 18 months

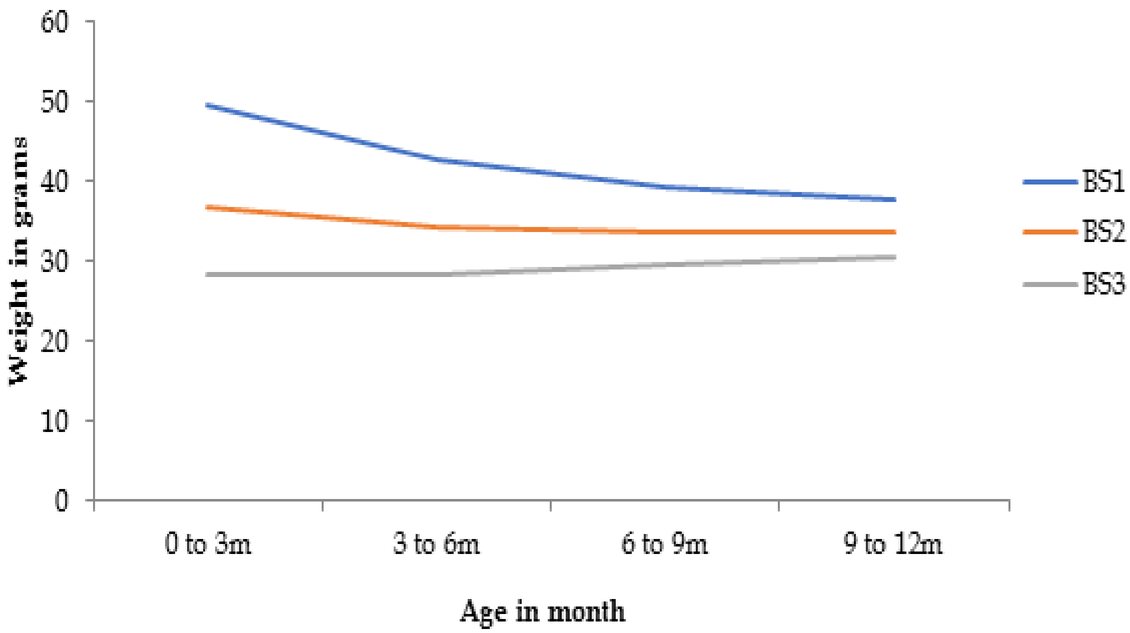


Figure 2. Growth curve of female kids for different breeding strategies.

Table 2. Variance components and heritability for growth rates at different stages.

Growth rate at various stage	Covariance component			h^2 (±SE)
	σ^2_a	σ^2_e	σ^2_p	
GR_{0-3}	111.809	3.390	227.008	0.49±0.02
GR_{3-6}	34.141	12.693	80.975	0.42±0.03
GR_{6-9}	10.184	0.750	21.118	0.48±0.02
GR_{9-12}	11.776	2.943	26.495	0.44±0.02
GR_{0-12}	11.806	1.519	23.612	0.46±0.02

GR_{0-3}, GR_{3-6}, GR_{6-9}, GR_{9-12}, GR_{0-12} denote growth rates from 0-3 months, 3-6 months, 6-9 months, 9-12 months and 0-12 months; σ^2_a, additive genetic variance; σ^2_e, environmental variance; σ^2_p, total phenotypic variance; h^2, heritability; SE, standard error.

were also reported by Petrovic et al. (2012) for Balkan goat in Serbia. In another study, Kuthu et al. (2015) reported the values of 0.17, 0.12 and 0.15 for heritability estimates of post-weaning growth at 6, 9 and 12 months for Teddy goats which were also lower than this study.

The differences for the degrees of heritability calculated by different authors for the same traits in goat could be due to difference in breed, location, environment, sample size and methods of estimation. The heritability estimates for GR further reveal that growth of BBG can be improved by phenotypic selection. However, the heritability values obtained in our study indicate that mass selection may be more useful for further genetic improvement of GR in BBG. Furthermore, due to medium heritability for GR at all ages, early selection of individual based on their growth performances for first 3 months may be more helpful for taking decision of selection or culling and to reduce feed and management cost of the farmers.

Genetic and phenotypic correlations among growth at different ages

Both genetic (r_g) and phenotypic correlations (r_p) among GR_{0-3}, GR_{3-6}, GR_{6-9}, GR_{9-12} and GR_{0-12} were estimated and are illustrated in Table 3, which shows the enormity of correlations to be very low to medium in extents (r_g: 0.03 to 0.87; r_p: 0.02 to 0.84) among the pairs of traits. The estimates of both r_g and r_p were however, positive and showed no genetic antagonisms among the pairs of GR traits. Table 3 also shows that the correlations among GR at different ages decreased, as the time between measurements increased, except between GR_{0-12} with others. The highest correlation was observed between

Table 3. Genetic (below diagonal) and phenotypic (above diagonal) correlations among growth rates at different stages.

Growth stage	GR_{0-3}	GR_{3-6}	GR_{6-9}	GR_{9-12}	GR_{0-12}
GR_{0-3}	-	0.341**±0.046	0.161**±0.047	0.022±0.047	0.837**±0.029
GR_{3-6}	0.319±0.040	-	0.199**±0.047	0.025±0.047	0.682**±0.037
GR_{6-9}	0.165±0.037	0.301±0.039	-	0.253**±0.047	0.142**±0.047
GR_{9-12}	0.030±0.040	0.126±0.039	0.236±0.037	-	0.048±0.047
GR_{0-12}	0.867±0.023	0.648±0.033	0.266±0.046	0.129±0.048	-

GR_{0-3}, GR_{3-6}, GR_{6-9}, GR_{9-12}, GR_{0-12} denote growth rates from 0-3 months, 3-6 months, 6-9 months, 9-12 months and 0-12 months; *, significant at 5% ($p<0.05$); **, significant at 1% ($p<0.01$).

Table 4. Response to selection for growth traits of BBG in different breeding strategy (BS).

Trait	Response (R) to selection measured in gram per generation							
	BS_1		BS_2		BS_3		All population	
	$R_{Predicted}$	R_{Actual}	$R_{Predicted}$	R_{Actual}	$R_{Predicted}$	R_{Actual}	$R_{Predicted}$	R_{Actual}
GR_{0-3}	2.02	7.46	2.05	2.97	-	1.67	2.69	4.52
GR_{3-6}	1.97	3.05	1.32	2.39	-	-0.64	2.60	2.31
GR_{6-9}	1.27	3.65	0.81	2.52	-	0.72	1.46	2.59
GR_{9-12}	1.14	1.59	0.71	0.98	-	0.32	1.20	3.00
GR_{0-12}	0.72	5.10	0.59	3.64	-	1.82	1.12	3.69

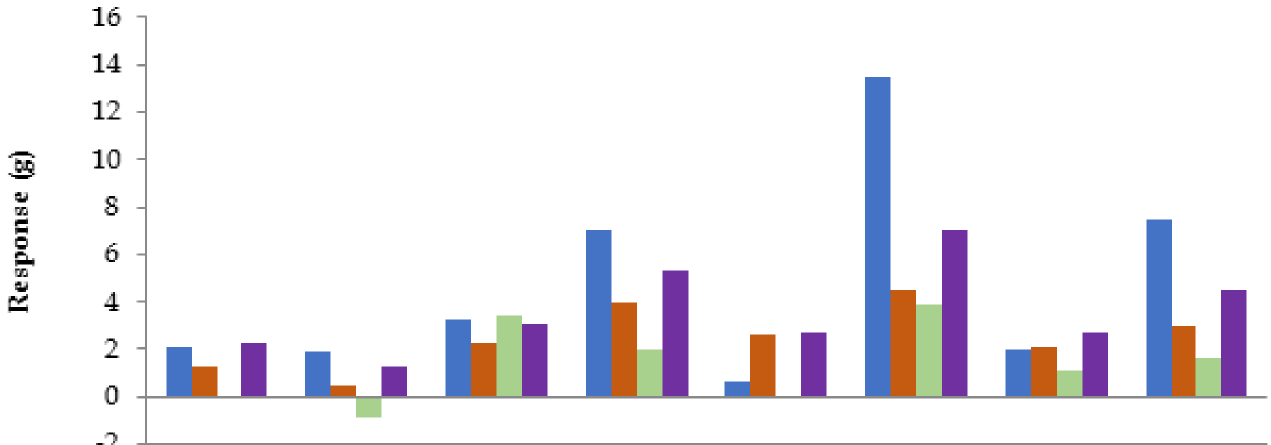
GR_{0-3}, GR_{3-6}, GR_{6-9}, GR_{9-12}, GR_{0-12} denote growth rates from 0-3 months, 3-6 months, 6-9 months, 9-12 months and 0-12 months.

GR_{0-3} and GR_{0-3} (r_g =0.87; r_P =0.84**). There appears to be very little information available regarding r_g and r_p among GR in BBG, but available for other types of goat in other countries, which may be compared with this study. Al-Shorepy et al. (2002), Neopane (2000) and Concepta et al. (2008) confirmed that r_g and r_p between growth traits were positive and medium to high. The r_g and r_p among GR as obtained in this study are analogous with the finding of Zhou et al. (2014), who also found r_g and r_p among average daily gain traits to be positive and relatively low for Hainan Black goat in Southern China. Alade et al. (2010) reported low but negative correlations between post-weaning and pre-weaning gain (r_g: -0.10, r_P: -0.04), which partially agrees with this study in terms of the extent of relation. Significantly positive and strong correlations (0.99 for both r_g and r_p) between pre-weaning and post-weaning growth were evidenced by Gupta et al. (2016), which are not in agreement with this study. In another study, Kuthu et al. (2015) reported very low to high r_p (0.01 to 0.97) and high r_g (0.63 to 0.75) among post-weaning growth at 6, 9 and 12 months for Teddy goat, which were not in line with the results of this study. The amalgamation of results for both direction and strength of correlations as estimated by different authors may be due to difference of breeds, extent of environmental and maternal effect, sample size and methods of estimation.

The r_g and r_p among GR at different ages indicate that selection for genetic improvement of one trait may have little chance of improvement for other traits, due to very poor relationships among most pairs of traits, except between GR_{0-3} and GR_{0-12} and between GR_{3-6} and GR_{0-12}. However, GR_{0-3} is the best predictor of selection criteria for genetic improvement of GR for GR_{0-12}, as higher r_g and r_p were obtained between the traits.

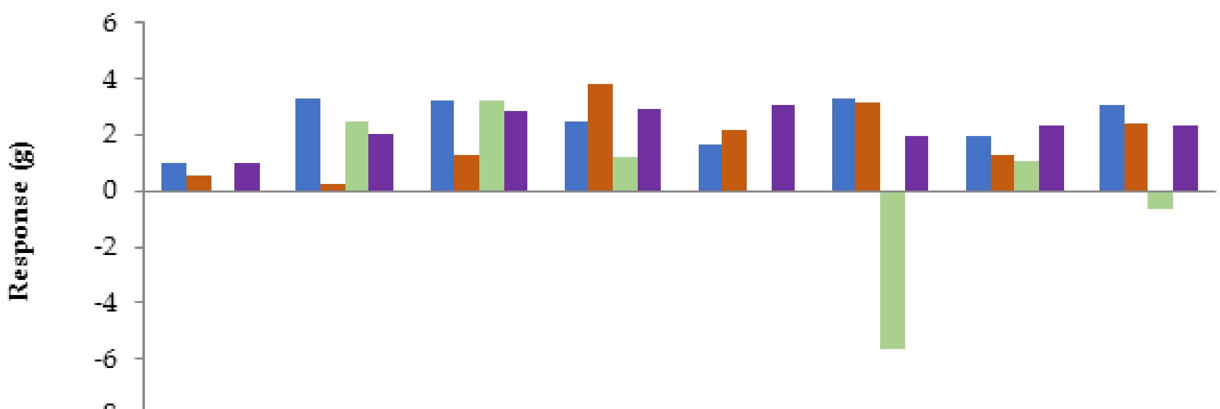
Response for growth rates

The response or genetic progress per generation due to selection for GR in BBG are presented in Table 4 and Figures 3 to 7 which demonstrate that actual responses were higher than responses predicted for all ages of GR in the first two BS. In all population, overall genetic improvement per generation for GR_{0-3}, GR_{3-6}, GR_{6-9}, GR_{9-12} and GR_{0-12} were predicted to increase by 2.69, 2.60, 1.46, 1.20 and 1.12 g, respectively, while those of actually gains were 4.52, 2.31, 2.59, 3.00 and 3.69 g, respectively. The results further revealed that actual genetic improvement for GR in BS_1 was higher than actual response for GR and does, even only superior bucks enhanced growth performance in progressive generations. However, geneticimprovement of body weight gain is also possible due to moderate estimates of heritability, but selection of animals based on growth at any stage may not result in simultaneous improvement at other stages. The result also shows that selection on body weight gain at birth to 3 months may result in



	G1 Rp	G1 Ra	G2 Rp	G2 Ra	G3 Rp	G3 Ra	Pooled Rp	Pooled Ra
BS_1	2.09	1.94	3.28	6.99	0.68	13.45	2.02	7.46
BS_2	1.25	0.43	2.26	3.97	2.63	4.5	2.05	2.97
BS_3	0	-0.85	3.38	1.96	0	3.89	1.13	1.67
Overall	2.3	1.25	3.06	5.28	2.7	7.03	2.69	4.52

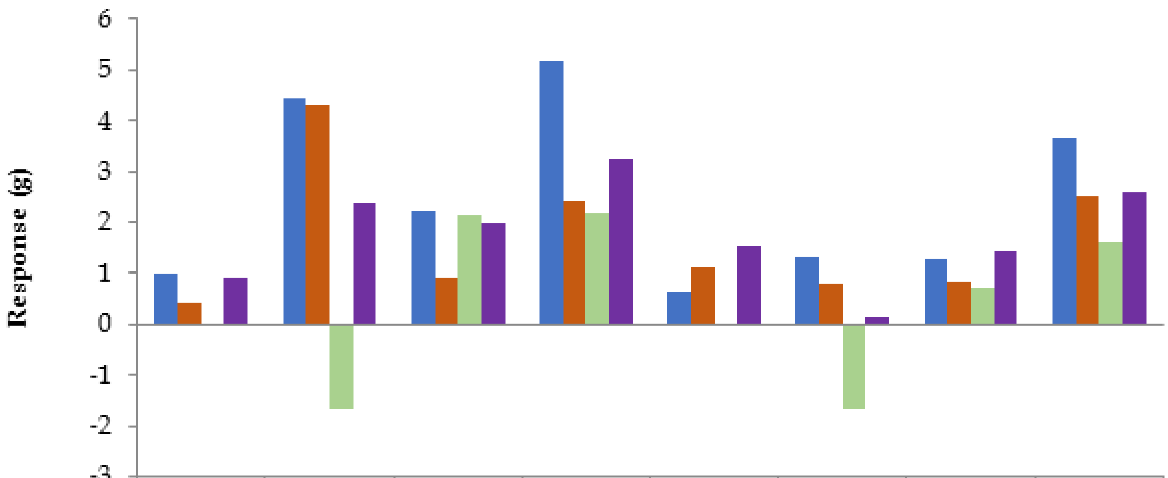
Figure 3. Response to selection for growth rate at birth to 3 months old (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3).



	G1 Rp	G1 Ra	G2 Rp	G2 Ra	G3 Rp	G3 Ra	Pooled Rp	Pooled Ra
BS_1	1.02	3.33	3.27	2.51	1.63	3.3	1.97	3.05
BS_2	0.51	0.22	1.26	3.8	2.2	3.15	1.32	2.39
BS_3	0	2.48	3.26	1.24	0	-5.64	1.09	-0.64
Overall	1.02	2.01	2.89	2.97	3.11	1.94	2.36	2.31

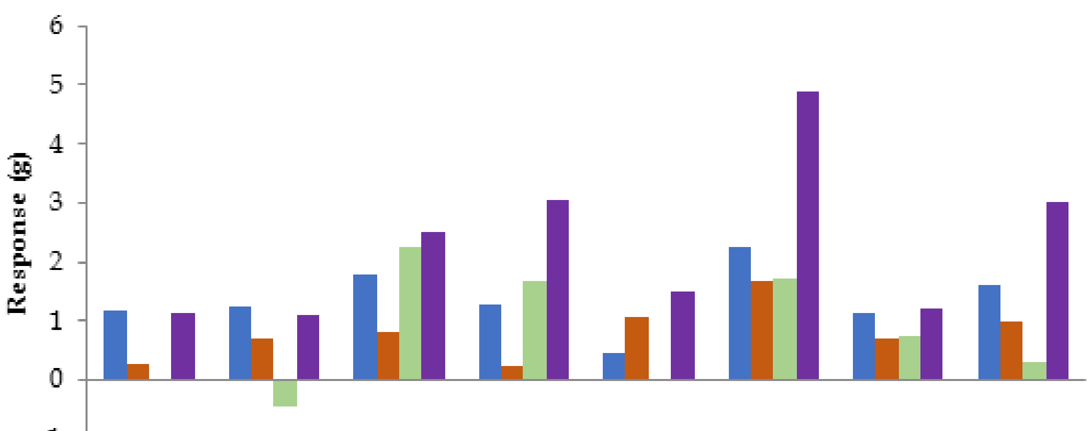
Figure 4. Response to selection for growth rate at 3 to 6 months old (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3).

improvement of overall body weight gain from birth to 12 months.



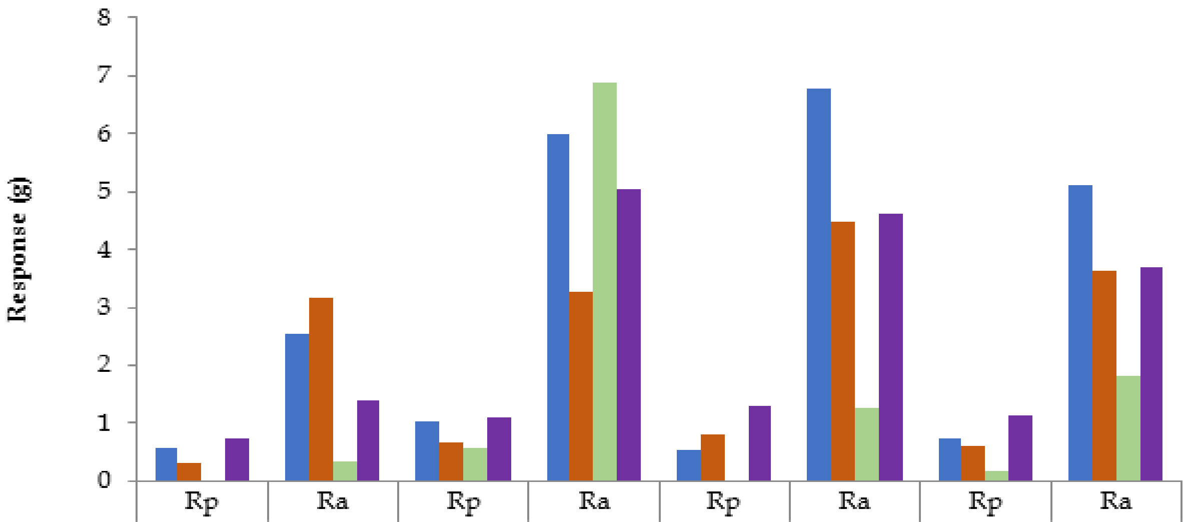
	G1 Rp	G1 Ra	G2 Rp	G2 Ra	G3 Rp	G3 Ra	Pooled Rp	Pooled Ra
BS_1	0.98	4.45	2.22	5.17	0.61	1.32	1.27	3.65
BS_2	0.4	4.32	0.91	2.44	1.11	0.79	0.81	2.52
BS_3	0	-1.67	2.15	2.17	0	-1.67	0.72	1.61
Overall	0.9	2.37	1.98	3.26	1.51	0.15	1.46	2.59

Figure 5. Response to selection for growth rate at 6 to 9 months old (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response;G_1, generation 1; G_2, generation 2; G_3, generation 3).



	G1 Rp	G1 Ra	G2 Rp	G2 Ra	G3 Rp	G3 Ra	Pooled Rp	Pooled Ra
BS_1	1.19	1.25	1.79	1.27	0.44	2.25	1.14	1.59
BS_2	0.26	0.72	0.82	0.23	1.06	1.66	0.71	0.98
BS_3	0	-0.45	2.25	1.69	0	1.71	0.75	0.32
Overall	1.14	1.1	2.5	3.03	1.5	4.89	1.2	3

Figure 6. Response to selection for growth rate at 9 to 12 months old (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3).



	Rp (G1)	Ra (G1)	Rp (G2)	Ra (G2)	Rp (G3)	Ra (G3)	Rp (Pooled)	Ra (Pooled)
BS_1	0.57	2.55	1.04	5.98	0.54	6.78	0.72	5.1
BS_2	0.31	3.16	0.66	3.26	0.79	4.49	0.59	3.64
BS_3	0	0.33	0.58	6.88	0	1.26	0.19	1.82
Overall	0.72	1.4	1.11	5.04	1.29	4.62	1.12	3.69

Figure 7. Response to selection for growth rate at birth to 12 months old (BS_1, breeding strategy 1; BS_2, breeding strategy 2; BS_3, breeding strategy 3; R_p, predicted response; R_a, actual response; G_1, generation 1; G_2, generation 2; G_3, generation 3).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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REFERENCES

Akhter S, Husain SS, Chowdhur SA, Manzur M, Dev GK (2006). Estimation of variance components and prediction of breeding value for some economically important Traits of Black Bengal goats. Bangladesh Journal of Animal Science 35(1-2):20-26.

Alade NK, Dilala MA, Abdulyekeen AO (2010). Phenotypic and genetic parameter estimates of litter size and body weights in goats. International Journal of Science and Nature 1(2):262-266.

Al-Shorepy SA, Alhadranu GA, Abdul Wahab K (2002). Genetic and Phenotypic parameters for early growth traits in Emirati goat. Small Ruminant Research 45(3):217-223.

Amin MR (2000). Genetic improvement of production traits in selective breeding and crossbreeding. A Ph.D. Thesis, Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh.

Amin MR, Husain SS, Islam ABMM (2001). Reproductive pecularities and litter weight in different genetic groups of Black Bengal does. Asian Australasian Journal of Animal Science 14(3):297-301.

Bosso NA, Cisse MF, van der Waaij, EH, Fall A, Van Arendonk JAM (2007). Genetic and phenotypic parameters of body weight in West African Dwarf goat and Djallonke sheep. Small Ruminant Research 67(2-3):271-278.

Concepta M, Guilherma SF, Helde L, Laila TD, Rodrigo DT, Luci SM (2008). Growth of Saanen, Alpine and Toggenburg goats in the Federal District, Brazil: Genetic and environmental factors. Ciencia Animal Brasileira 9(1):68-75.

Falconer DS (1989). Introduction to Quantitative Genetics. 3rd edition. Longman Group Ltd. England.

Groeneveld E (1998). PEST User's Manual, Institute of Animal Science, Höltystraÿe 10, D-31535 Neustadt, Germany.

Gupta JP, Pandey DP, Shah RR (2016). Genetic studies on growth traits of Mehsana goat of Gujarat, India. Indian Journal of Animal Research 50(2):164-167.

Haque MN (2014). Selection of Black Bengal breeding buck through progeny testing. PhD dissertation, Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh, pp. 1-142.

Husain SS (1993). A study on the productive performance and genetic potentials of Black Bengal goats. A Ph.D. Thesis, Bangladesh Agricultural University, Mymensingh pp. 3-108.

Husain SS, Horst P Islam ABMM (1996b). Study on the growth performance of Black Bengal goats in different periods. Small Ruminant Research 21(3):165-171.

Husain SS, Horst P, Islam ABMM (1997). Growth performance of Black Bengal goats in different regions of Bangladesh. Asian-Australasian Journal of Animal Science 10(5):491-494.

Kuthu ZH, Javed K, Ahmad N, Hussain A, Khan SA (2015). Genetic evaluation of post-weaning growth traits in Teddy goats. Journal of Dairy, Veterinary and Animal Research 2(2):1-7. 00032. DOI: 10.15406/jdvar. 2015.02.00032.

Majumder MKH (2011). Characterization of Black Bengal goat in north western region of Bangladesh. M.S. Thesis. Department of Animal

Breeding and Genetics, Bangladesh Agricultural University, Mymensingh.
Neopane SP (2000). Selection for improvement of the productivity of Hill Goats in Nepal. Proceedings of the 7th International conference on Goats. Organised by International Goat Association, France pp. 206-208.
Petrovic VC, Ilic Z, Muslic DR, Petrovic MP, Petrovic MM, Tomic Z, Marinkov G (2012). Analysis of environmental and genetic factors in growth characteristics of Balkan goat. Biotechnology in Animal Husbandry 28(2):275-282, DOI:10.2298/BAH1202275C.
Statistical Package for the Social Sciences (SPSS) (1998). SPSS Inc. an IBM Company Headquarters. Chicago, Illinois, USA.
Zhou HL, Gu LH, Sun YY, Xu TS, Rong G (2014). Genetic and phenotypic parameter estimates for growth traits of Hainan Black goat in Southern China. Animal Production Science 55(4): 447-453.