

PHENOTYPIC PERFORMANCE AND RESPONSE TO SELECTION FOR REPRODUCTIVE TRAITS OF BLACK BENGAL GOAT (BBG) IN A COMMUNITY BREEDING PROGRAM

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Abstract

Black Bengal Goat (BBG) is only one goat breed in Bangladesh popularly known for its fecundity and carcass quality. The study aimed to investigate the genetic improvement of this goat breed *in-situ* through a community-based breeding program under a low input production system in three villages namely *Gangatia*, *Borochala*, and *Pachpai* in Bhaluka upazila of Mymensingh district. Data on a total of 657 individuals included with three progressive generations taken during 2009 - 2015 were analyzed for performance evaluation and genetic improvement as a result of two breeding strategies (BS) viz. mating within superior bucks and does, and within superior bucks and existing does and also compared with a control group mated among existing bucks and does. Statistical analysis was performed by SPSS 17.0 and genetic parameters by VCE 4.2.5. The average age at sexual maturity (ASM), age at first kidding (AFK), services per conception (SPC), litter size (LS), postpartum heat period (PPHP), and kidding interval (KI) were $233.09 \pm 2.71d$, $383.01 \pm 2.61d$, 1.13 ± 0.03 , 1.90 ± 0.05 , $42.41 \pm 0.84d$ and $186.44 \pm 0.95d$, respectively. Generation and BS had significant effect on all traits, except SPC, except AFK, all other traits differed significantly among the flocks. The heritability estimates of all reproductive traits were medium ranging from 0.32 to 0.57. Genetic and phenotypic correlations among reproductive traits were low to medium (-0.03 to 0.37). The overall responses of up to three generations for ASM, LS, PPHP, and KI were -15.59d, 0.12 no, -6.14d and -7.66d per generation, respectively. It is concluded that community based breeding program with selected superior bucks and does is very rationale under a low input production system, as it improves reproductive performance in progressive generations. However, estimates of heritability and genetic correlations indicate the scope of improvement for reproductive traits with selection and breeding among does and bucks with proven genetic worth.

Keywords: Black Bengal Goat, Community breeding, Genetic parameters, Reproductive traits

Introduction

Black Bengal Goat (BBG) is the most suitable small ruminant species in Bangladesh that is easily manageable and profitable with its best environment almost all over the country. As a reservoir of genetic resources, BBG occupies a very illustrious position among the dwarf meat-type goat in the world. They have several desirable

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characteristics. They attain sexual maturity quite earlier and breed around the year, kid twice a year or more commonly thrice in two years, can produce and reproduce in the very low plane of nutrition, are well adapted to the stressful adverse environmental condition, higher resistance against common diseases and parasites. Besides, it also produces high-quality flavoured, tender and delicious chevon and superior skin, which have a tremendous demand at home and abroad (Devendra and Burns, 1983; Husain, 1993). But, due to their poor genetic potentiality in terms of milk production, the kid mortality is higher. However, another limitation is not directly due to genetics, but rather the system of breeding, often the poorest males are used for breeding, leading to negative selection response (Amin, 2014).

Community breeding program may lead to improve the genetic potentiality of indigenous goat in Bangladesh like other countries. Community breeding means breeding program with participating farmers. The basic steps in community based breeding program are selection of the target community and breeds, description of the production system, definition of breeding goals in participatory manner, assessment of alternative schemes and implementation of feasible schemes (Haile *et al.*, 2011). As about 98% of BBG are being reared in the traditional village system of the country (Husain, 1998), therefore, farmer's participatory breeding program like community breeding program may play a vital role in the improvement of BBG. In this consideration, the study was aimed to determine the performance and response to selection for some economically important reproductive traits of BBG in three community goat breeding flocks at Bhaluka upazila under Mymensingh district of Bangladesh.

Materials and Methods

Location of the study

The study was conducted at rural community level goat flocks of three villages; Gangatia, Boro-chala, and Pachpaiat Bhaluka under upazila 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 is more or less same having temperature ranges from 12°C (Winter) to 33°C (Summer), and the annual rainfall averages 2147mm during the research period. High lands was available which were reddish in color, some forests present in Pachpai village. Grazing lands were available in Gangatia, Boro-chala, and Pachpai villages for the goat.

Selection of sire and dam

Superior bucks and does were selected to establish community foundation flocks of BBG in three villages. The superior bucks were selected from Bangladesh Livestock Research Institute (BLRI), Department of livestock Services (DLS), and simultaneously from the flocks of the community farmers based on physical appearance and reproductive performance. Parent's history was also collected from the goat owner during the selection

process of bucks and does from farmer's community. Superior bucks were selected on the basis of body weight at 6-month of age ≥ 8 kg, good body conformation, early age at puberty <180 days, dams yielded ≥ 250 ml milk/day and kidded ≥ 2 kids in previous birth(s). Superior does were selected on the basis of kidding interval (earlier, preferably <180 days), litter size (preferably multiple, ≥ 2 kids per kidding), age at first kidding (earlier, preferably <360 days), 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 physical 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, leftovers of family meals, table salt and cut and carry green grass ad lib during the day time. Goats were allowed to feed concentrate feed such as rice gruel, rice bran, broken rice, wheat bran etc. during pregnancy and lactation period @ 200 g/day. The breeding bucks were also fed whole gram @ 50 g/day in the morning. 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. Three breeding strategy (BS) were followed; mating among selected superior bucks and does (those supplied to the farmers by the project aid) denoted as BS1, mating of existing does (owned by the community farmers) with selected superior bucks denoted as BS2 and mating among existing does and bucks (test group) denoted as BS3. Only superior males were selected as sire to produce progeny in progressive generations. The selection criteria were based on the reproductive potential of their dam.

Recording and data collection

All animals were neck tagged and data-sheet for each individual was 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) consisting 285 base populations (25 males and 260 females) and 372 progeny (76 males and 296 females) from three flocks in three progressive generations were included in this study.

Statistical model and data analysis

The study covered various economic traits of BBG in progressive generations. The animals were of different populations and ages as well as both parents and progeny groups. Therefore, data were sufficient un-balancedness 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 using SPSS 17.0 (1998) program. 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 of the following model:

$$Y_{ijkl} = \mu + G_i + B_j + F_k + e_{ijkl}$$

where,

Y_{ijkl} = Record of l th kid born in i th generation under j th breeding strategy in k th village flock.

μ = Overall population mean for reproductive traits;

G_i = Effect of i th generation (where i = 1st generation, 2nd generation and 3rd generation),

B_j = Effect of j th breeding strategy (where j = BS1, BS2 and BS3),

F_k = Effect of k th flock (where k = Gangatia, Boro-chala and Pachpai),

e_{ijkl} = Random residual error associated with Y_{ijkl} observation

Estimation of genetic parameters

The genetic parameters including (co)variance components, heritability and genetic correlations were estimated by using VCE 4.2.5 (Groeneveld, 1998) package with residual maximum likelihood (REML) approach. For REML analysis, animal model was used considering 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 (i.e. generation, flock etc.), a = Unknown vector of breeding value, c = Unknown vector of permanent environmental effects and 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):

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

Where,

R = response to selection in the next generation for the trait,

i = selection intensity, h^2 = heritability of the trait,

sdp = phenotypic standard deviation of the trait.

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

Results and Discussion

Reproductive performance

The least squares means for reproductive traits of economic importance in BBG as affected by sex (S), generation (G), BS and flock (F) are described in the Table 1.

Age at sexual maturity (ASM)

The ASM as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. The overall mean ASM of BBG is 233.09±2.71 days, irrespective of generation, BS and flock which closely agrees with 234.16 days as reported by Halim *et al.*, (2011). Ray *et al.*, (2016) reported ASM to be 249.15±1.01 days for indigenous goat in northern Odisha, India. Earlier, Amin *et al.*, (2001) in a selective breeding program of BBG obtained ASM in first and second generation were 249.63±15.57 and 241.68±11.45 days, respectively. Their reports are in the line of our study. Sexual maturity depends on sex, hormonal activity, and development of reproductive organs, photoperiod and nutritional status of the goat.

Table 1. Reproductive performance of BBG as affected by various non-genetic factors

Factor	Reproductive parameters (Mean±SE)					
	ASM (d)	AFK (d)	SPC (no)	LS (no)	PPHP (d)	KI (d)
Generation	***	***	NS	***	***	***
G ₀	60.54 ^d ±2.91 (177)	12.45 ^c ±2.28 (233)	1.15±0.03 (127)	1.60 ^c ±0.05 (169)	47.99 ^c ±1.09 (122)	96.23 ^d ±1.19 (129)
G ₁	37.67 ^c ±2.66 (241)	9.23 ^b ±2.38 (202)	1.14±0.03 (161)	1.84 ^{bc} ±0.05 (162)	46.50 ^c ±0.93 (161)	89.06 ^c ±1.05 (162)
G ₂	220.88 ^b ±4.02 (75)	75.60 ^a ±4.90 (048)	1.11±0.06 (055)	2.02 ^b ±0.09 (055)	39.24 ^b ±1.55 (055)	83.66 ^b ±1.76 (055)
G ₃	13.27 ^a ±6.11 (038)	51.64 ^a ±8.27 (016)	1.13±0.09 (021)	2.15 ^a ±0.14 (021)	35.92 ^a ±2.47 (021)	76.81 ^a ±2.78 (021)
BS	***	***	NS	***	***	**
BS ₁	04.91 ^a ±2.88 (217)	47.94 ^a ±6.15 (207)	1.07±0.05 (133)	2.12 ^a ±0.11 (164)	38.14 ^a ±1.68 (144)	81.50 ^a ±2.21 (154)
BS ₂	23.63 ^b ±3.44 (233)	79.47 ^b ±6.42 (196)	1.13±0.03 (122)	1.98 ^b ±0.09 (138)	40.88 ^b ±1.80 (147)	90.22 ^b ±2.28 (144)
BS ₃	270.73 ^c ±5.95 (81)	21.61 ^c ±5.55 (096)	1.20±0.06 (109)	1.61 ^c ±0.09 (105)	48.21 ^c ±1.81 (068)	108.09 ^c ±2.33 (069)
Flock	*	NS	*	*	***	***
Gangatia	38.77 ^b ±4.24 (223)	83.05±7.09 (180)	1.19±0.04 (125)	1.86 ^b ±0.09 (124)	41.88 ^b ±1.96 (112)	87.04 ^b ±2.64 (125)
Borochala	37.17 ^b ±5.47 (159)	79.36±4.39 (133)	1.17±0.05 (109)	1.75 ^c ±0.08 (130)	53.17 ^c ±1.31 (125)	107.53 ^c ±1.57 (112)
Pachpai	23.32 ^a ±2.71 (149)	86.61±6.40 (186)	1.03±0.04 (130)	2.10 ^a ±0.11 (153)	32.19 ^a ±2.01 (122)	64.74 ^a ±2.38 (130)
Overall mean	233.09±2.71 (531)	83.01±2.61 (499)	1.13±0.03 (364)	1.90±0.05 (407)	42.41±0.84 (359)	86.44±0.95 (367)

ASM, AFK, SPC, LS, PPHP, KI and BS denote age at sexual maturity, age at first kidding, number of services per conception, litter size, postpartum heat period, kidding interval and breeding strategy, respectively; G₀, foundation flock; G₁, generation 1; G₂, generation 2; G₃, 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 differ significantly (p<0.05).

About 76% of the goats produced from the breeding strategy 1 attained sexual maturity within 8-month of age (Fig. 1). On the otherhand, only about 25% of the goats produced from the third breeding strategy attained sexual maturity within this age. The age at sexual maturity was intermediate between breeding strategy 1 and breeding strategy 3 for goats of the second breeding strategy.

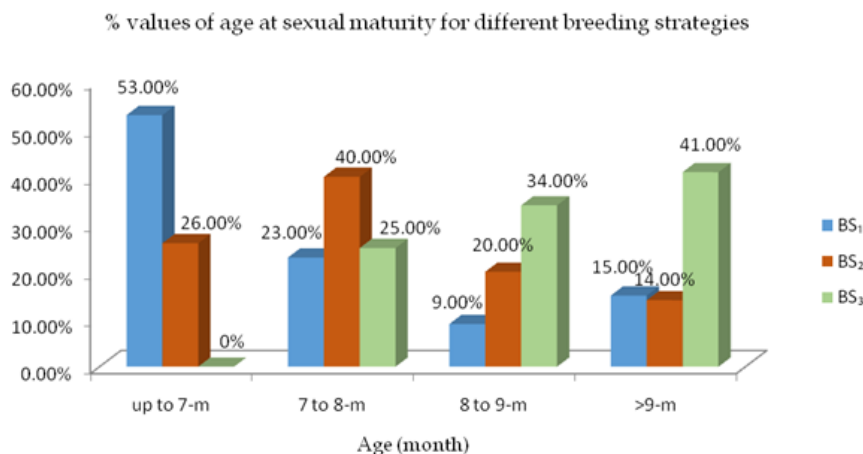


Fig. 1. Distribution of age at sexual maturity for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

Age at first kidding (AFK)

The distribution of age at first kidding for different breeding strategies is illustrated in Fig. 2 which showed that about 49% of the goats produced from the breeding strategy 1 dropped first kid within 12-month of age. On the other hand, none of the goats produced from the breeding strategy 2 dropped first kid within this age. The age at first kidding was intermediate between breeding strategy 1 and breeding strategy 3 for goats of breeding strategy 2.

The AFK as affected by generation, breeding strategy and flock is given in Table 1, which shows that except flock, other fixed factors had significant effect on it. The average AFK was obtained in this study (383.01 ± 2.61 days) closely agree with the study of Faruque *et al.*, (2010) and Husain (1993) for the same genotype (370.26 ± 25.48 and 391.94 ± 10.72 days, respectively). Chowdhury *et al.*, (2002) observed that doe under semi-intensive rearing system gave birth to their first kid at an average age of 13.5-months (equivalent to 405 days) and Hossain *et al.*, (2004) reported was 401.5 days. Ray *et al.*, (2016) reported 410.721 ± 17 days for giving first kid for indigenous goat in northern Odisha, India. Their estimates were somewhat higher than our study. Earlier, lower AFK of 283.83 ± 31.16 and 360.5 days, respectively were reported by Faruque *et al.*, (2010) in an intensive system and Hassan *et al.*, (2007) for the same breed. However, very higher estimates of AFK were reported by Hassan *et al.*, (2010) (448-450 days) and Haque *et al.*, (2013) (465.6 ± 12.45 days) for the same genotype. Variations within same genotype could be due to variable environment, management and feeding provided by the farmers.

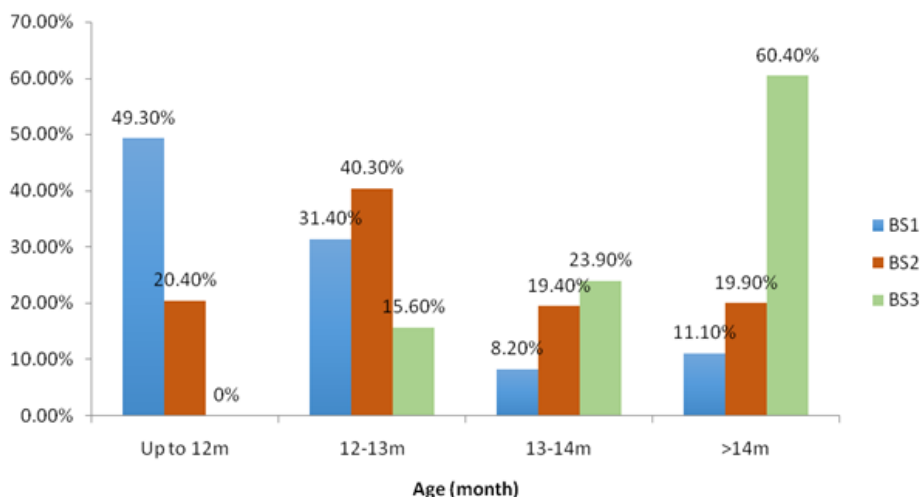


Fig. 2. Distribution of age at first kidding for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

Service per conception (SPC)

The distribution of service per conception for different breeding strategies is illustrated in Fig. 3 which showed that about 88% does conceived from single service for the breeding strategy 1; 86.8% for the breeding strategy 2 and 85.5% for the breeding strategy 3.

The SPC as affected by generation, breeding strategy and flock is given in Table 1, which shows that except flock, other fixed factors had no significant effect on it. The mean SPC in the present study was 1.13 ± 0.02 , irrespective of generation, BS and flock. However, the present estimate was very close to 1.10 ± 0.05 (Choudhury *et al.*, 2012), 1.10 ± 0.02 (Majumder, 2011) and 1.16 ± 0.19 (Faruque *et al.* 2010) and lower than 1.27 (Hossain *et al.* 2004), 1.45 (Chowdhury *et al.*, 2002) and 1.76 (Islam, 2014). It is evidenced that almost 100% goat keepers mated their does naturally in the rural community; as a result required number of services is vicinity to one.

Litter size (LS)

The distribution of litter size for different breeding strategy is illustrated in Fig. 4 which shows that the highest about 66% does produced from the breeding strategy 3 gave single kid per kidding, about 56% does produced from the breeding strategy 2 gave twin kids per kidding and about 30% does produced from the breeding strategy 1 gave triple kids per kidding. Interestingly, about 2.5% and 0.7% does produced from the breeding strategy 1 and breeding strategy 2 gave quadruple kids per kidding.

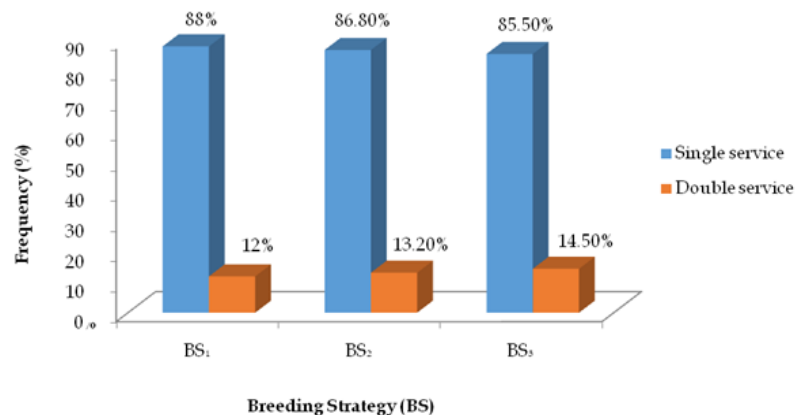


Fig. 3. Distribution of service per conception for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

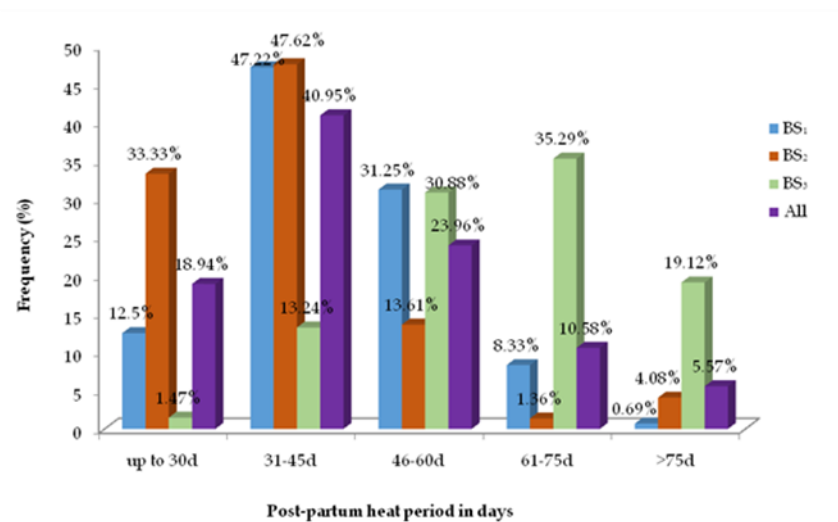


Fig. 4. Distribution of litter size for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

The LS as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. Irrespective of generation, BS and flock, the mean LS obtained in this study is 1.90 ± 0.05 (Table 1), which is in general consistent with Majumder (2011) and Husain (1993) who reported it to be 2.03 ± 0.09 and 1.93 ± 0.05 , respectively for the same genotype. Comparatively lower estimates (1.50 to 1.61) were reported by Haque (2014); Choudhury *et al.*, (2012); Mia (2011) and Faruque *et al.*, (2010), respectively. In another study, Amin *et al.* (2001) studied LS of BBG in a selective breeding program under farmer's house and obtained

2.15±0.14 kids per kidding in second generation which is higher than our study. Variations among different reports for the same breed could be due to variations of kidding parities among authors from which data were taken, because multiparous does give birth more kids than maiden does

Post-partum heat period (PPHP)

The distribution of post-partum heat period for different breeding strategies is illustrated in Fig. 5 which shows that about 19% goats came into post kidding estrous within 1 month, 41% within 1 to 1.5- months, 24% within 1.5 to 2-months, 11% within 2 to 2.5-months and 6% above 2.5-months. However, more than 90% of the goats produced from the breeding strategy 1 and breeding strategy 2 had post-partum heat period within 2-months. On the other hand, about 46% of the goats produced from the breeding strategy 3 had kidding interval within this age.

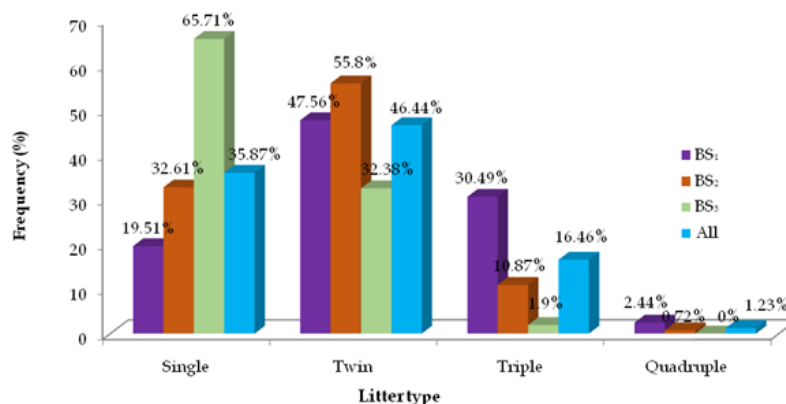


Fig. 5. Distribution of post-partum heat period for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

The PPHP as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. The PPHP was obtained in this study averaged 42.41±0.84 days, irrespective of generation, BS and flock (Table 1). Majumder, (2011) and Hossain *et al.*, (2004) reported PPHP in BBG to be 46.3 and 43.07 days, respectively which clearly matches with the findings of the present study. On the other hand, Faruque *et al.*, (2010) reported PPHP for the same genotype to be 28.53 days, which was lower than this study. However, higher PPHP (60 and 123.84 days) were obtained by Devendra and Burns, (1983) and Haque *et al.*, (2013) for the same breed. Apparently, generation, parity, better management and nutrition were reported to be the most contributing factors responsible for lowering the PPHP (Hossain *et al.*, 2004). BBG are renowned for their fecundity as they give birth kids twice in a year. This is possible if does come into estrous 35-days post kidding.

Kidding interval (KI)

The distribution of kidding interval for different breeding strategies is illustrated in Fig. 6 which shows that about 34% goats had kidding interval within 6-months, 54% within 6 to 7-months, 9% within 7 to 8-months and 3% above 8-months. However, about 91% of the goats produced from the breeding strategy 1 had kidding interval within 7-months. On the other hand, only about 9% of the goats produced from the breeding strategy 3 had kidding interval within this age. The kidding interval was intermediate between breeding strategy 1 and breeding strategy 3 for goats of the breeding strategy 2.

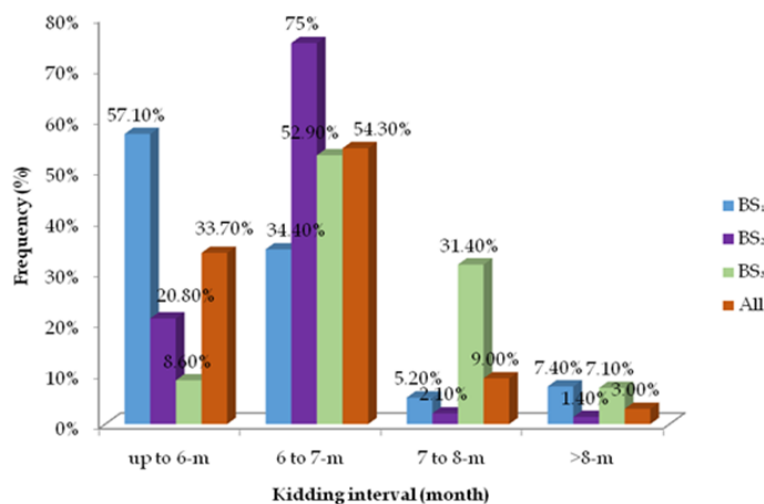


Fig. 6. Distribution of kidding interval for different breeding strategies (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3)

The KI as affected by generation, breeding strategy and flock is given in Table 1, which shows that all fixed factors had significant effect on it. The mean KI without considering generation, BS and flock is 186.44 ± 0.95 days (Table 1), which closely agrees with Choudhury *et al.*, (2012) who studied BBG in the same villages and reported it as 188.55 ± 8.82 days. The finding of the present study also corroborates with earlier reports of 181.23 ± 4.55 and 190.2 ± 0.20 days, respectively as obtained by Faruque *et al.*, (2010) and Hasan *et al.*, (2014) for the same breed. On the other hand, Haque *et al.*, (2013) reported 302.5 ± 4.55 days KI for the same genotype, which looks much higher than our study. The variations of KI with wider ranges among investigators within same genotype could be due to difference of management practices, feeding, reproductive care, seasonality or insufficient breeding bucks.

Effect of non-genetic factors on reproductive traits

Generation had highly significant ($p < 0.001$) effect on all reproductive traits studied here, except that of SPC, those improved steadily in later generations. This could be due

to selection of superior parents in successive generations under two breeding policies mentioned earlier. Similar finding was also obtained by Amin *et al.*, (2001) and Haque *et al.*, (2013). Faruque *et al.*, (2010) reported KI to have no significant difference among generations, which contradicts with our result. It was reported by many researchers (Islam, 2014; Khandoker *et al.*, 2011) that almost 100% goat keepers mated their does naturally in the rural community, as a result SPC was very close to single, as had been found in this study. Consequently, SPC was not influenced significantly ($p>0.05$) for the effect of generation and BS. Actually, genetic influence on SPC was very negligible, rather than environment. This is in consistence with Choudhury *et al.* (2012), Chowdhury *et al.*, (2002) and Amin *et al.*, (2001). Among three BS practiced in the community breeding program, best reproductive performances were obtained from the population produced from BS₁, followed by BS₂ and BS₃. This is obviously due to genetic potentially of superior parents transmitted to their offspring. Conversely, Choudhury *et al.*, (2012) in the same flocks did not find any significant differences of LS and KI between natural control and natural uncontrolled breeding practices followed in those populations. The variation between works in the same flocks could be due to sample size, as the author evaluated only from 31 kidding records. While in the present study, 367 kidding records in 3 progressive generations were considered. Significant variations were also noticed for all reproductive traits estimated among three flocks, except that of AFK. The variations among flocks could be due to genetic (selection differential of the parents) or other environmental factors like parity, age, management, feeding etc. Haque *et al.*, (2013); Faruque *et al.*, (2010) and Hasan *et al.*, (2014) obtained significant variations for the same traits among different flocks of BBG in their investigations, which clearly ensue of our findings. However, Choudhury *et al.*, (2012) disagrees for LS and KI in the same village flocks, but what the author found may not be reliable enough, as the author worked with very small population.

Heritability of reproductive traits

The heritability estimates for different reproductive traits in BBG are presented in Table 2 which shows medium magnitudes for all parameters studied ranging from 0.32 to 0.48. Haque *et al.*, (2013) in their study reported heritability to be 0.21 ± 0.11 , 0.14 ± 0.12 , 0.24 ± 0.14 and 0.17 ± 0.11 , respectively for AFK, LS, PPHP and KI in the same breed, which seem to be medium estimates of heritability. The corresponding values of this study was though, somewhat high, but agree with magnitude of heritability. Many estimates appeared to be low estimates of reproductive traits (Mia *et al.*, 2013; Faruque *et al.*, 2010). High variability exists in the literatures with respect to the estimates of heritability of reproductive traits in BBG could be due to estimation errors associated with the sample size, structure of the data, management conditions, and estimation methodology used (Moioli *et al.*, 2007). The heritability estimates for reproductive traits as obtained in this study confirms that selection based on the said parameters could be effective for modifying these traits in BBG.

Table 2. Variance components and heritability estimates for reproductive traits in BBG

Reproductive trait	Variance component			$h^2 \pm SE$
	σ_a^2	σ_e^2	σ_p^2	
ASM	448.079	53.027	949.185	0.47±0.03
AFK	537.795	623.108	1698.698	0.32±0.02
SPC	0.055	0.033	0.143	0.38±0.07
LS	0.207	0.020	0.434	0.48±0.03
PPHP	97.362	36.611	231.335	0.42±0.06
KI	85.441	50.406	221.288	0.39±0.07

ASM, AFK, SPC, LS, PPHP and KI denote age at sexual maturity, age at first kidding, number of services per conception, litter size, postpartum heat period and kidding interval, respectively; σ_a^2 , additive genetic variance; σ_e^2 , permanent environmental variance; σ_p^2 , total phenotypic variance; h^2 , heritability for the trait; SE, standard error.

Genetic and phenotypic correlations among reproductive traits

The genetic (r_g) and phenotypic correlations (r_p) among reproductive traits were estimated and illustrated in Table 3 which shows both synergistic and antagonistic relationship, though the strengths are merely poor among the pairs of traits. BWSM has antagonistic r_g with other traits, except that of ASM and LS. ASM has negative r_g with LS and KI, but positive with PPHP, although the magnitudes are vicinity to zero. LS have negative r_g and r_p with PPHP, but positive r_g and r_p with KI. PPHP has positive r_g and r_p with KI. The literatures related to r_g and r_p on reproductive traits in BBG are not available for justification of these findings. In other works, Belay *et al.*, (2011) found medium to high r_g among reproductive traits of Arsi-Bale goats, and Ray *et al.*, (2016) reported r_g of 0.78 ± 0.14 , 0.08 ± 0.11 and 0.17 ± 0.16 between pairs of ASM and BWSM, ASM and KI and BWSM and KI, respectively, with their corresponding r_p of 0.74 ± 0.22 , 0.24 ± 0.09 and 0.27 ± 0.12 for indigenous goat in Odisha, India. Their estimated correlations appear to be inconsistency with our study and this could be due to difference of genotype, environmental and maternal effects, sample size or methods of estimation. However, estimation of r_g among reproductive traits are very tricky, as the products of the respective genetic variance components are usually either zero or negative in most cases. However, it is necessary to carry out further research on the adverse or undesirable genetic relationships observed in this study between BWSM with ASM and LS and between ASM and KI, to obtain correct foundations to know whether these traits may be used in indirect selection.

Based on these findings, it can be said that the strengths of r_g and r_p among reproductive traits indicate that genes controlling for different reproductive traits are probably different, and due to very apart antagonistic relationships, selection for one trait will not result any significant adverse effect for other traits. However, r_g and r_p also suggest for tandem selection or independent culling method for genetic improvement of more than single trait. Further, reproductive traits could be improved adopting good management practices.

Table 3. Genetic correlations (below diagonal) and phenotypic correlations (above diagonal) among reproductive traits in BBG

Traits	BWSM	ASM	LS	PPHP	KI
BWSM	-	- 0.155**±0.054	0.012±0.054	-0.159**±0.054	-0.260**±0.05
ASM	0.091±0.042	-	-0.165**±0.054	0.356**±0.051	0.372**±0.05
LS	-0.026±0.047	-0.084±0.041	-	-0.172**±0.054	0.010±0.054
PPHP	-0.088±0.067	0.068±0.058	-0.101±0.064	-	0.286**±0.052
KI	-0.113±0.008	-0.043±0.066	0.133±0.072	0.047±0.105	-

BWSM, ASM, LS, PPHP and KI denote body weight at sexual maturity, age at sexual maturity, litter size, postpartum heat period and kidding interval, respectively; **significant at 1% ($p < 0.01$)

Table 4. Response to selection for reproductive traits in BBG

Traits	Response (R) to selection measured 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}
ASM	-5.22d	-20.66d	-6.57d	-13.10d	-	-4.80d	-8.07d	-15.59d
LS	0.13	0.21	0.10	0.14	-	0.13	0.12	0.12
PPHP	-1.76d	-8.26d	-2.72d	-5.22d	-	-0.62d	-0.75d	-6.14d
KI	-2.57d	-8.78d	-1.96d	-7.09d	-	-0.43d	-3.13d	-7.66d

ASM, LS, PPHP and KI denote age at sexual maturity, litter size, postpartum heat period and kidding interval, respectively.

Response for reproductive traits

The response or genetic gain per generation due to selection for some economic important reproductive traits in BBG are presented in Table 4 and Fig. 7 to Fig. 10 which reveal that actual genetic trends were obtained higher than genetic trends predicted for all traits in first two BS. In all population, overall genetic trends per generation for ASM, PPHP and KI were predicted to decrease by 8.07, 0.75 and 3.13 days, respectively, but actual genetic trends were 15.59, 6.14 and 7.66 days, respectively. Besides, response predicted for LS was to increase by 0.12 kids per kidding, while actual response was obtained unchanged. The results also reveal that actual genetic improvement for the said traits in BS₁ population was higher than actual response for the same traits as found in BS₂ and BS₃ populations. This could be due to genetic effect of superior parents transmitted to the progeny of that population. The literatures in regards to genetic improvement of reproductive traits of BBG in Bangladesh are not available to compare with this study. However, this parameter may vary from breed to breed, environment to environment or different breeding policy with different issues.



Fig. 7. Response to selection for age at sexual maturity (BS₁, breeding strategy 1; BS₂, breeding strategy 2; BS₃, breeding strategy 3; R_p, predicted response; R_a, actual response; G₁, generation 1; G₂, generation 2; G₃, generation 3)

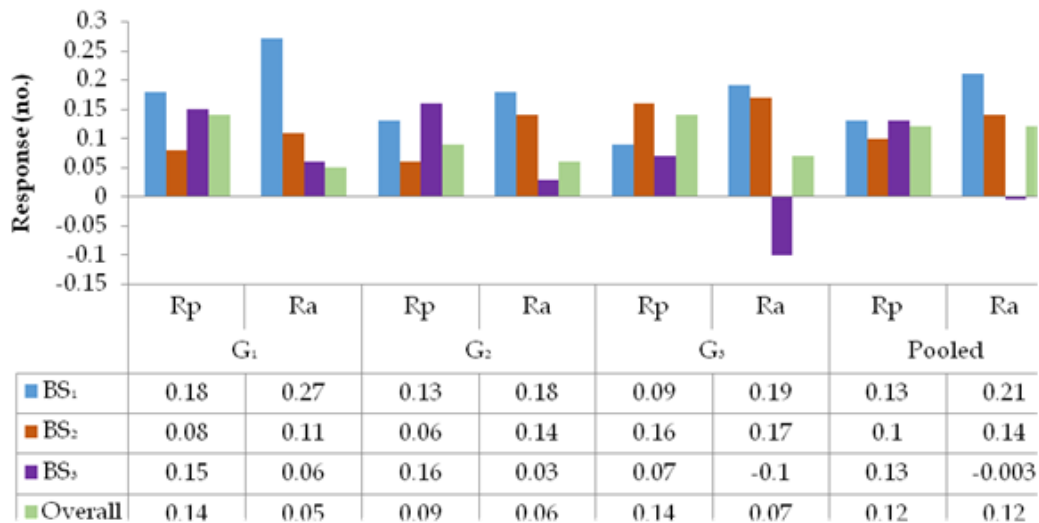


Fig. 8. Response to selection for litter size (BS₁, breeding strategy 1; BS₂, breeding strategy 2; BS₃, breeding strategy 3; R_p, predicted response; R_a, actual response; G₁, generation 1; G₂, generation 2; G₃, generation 3)

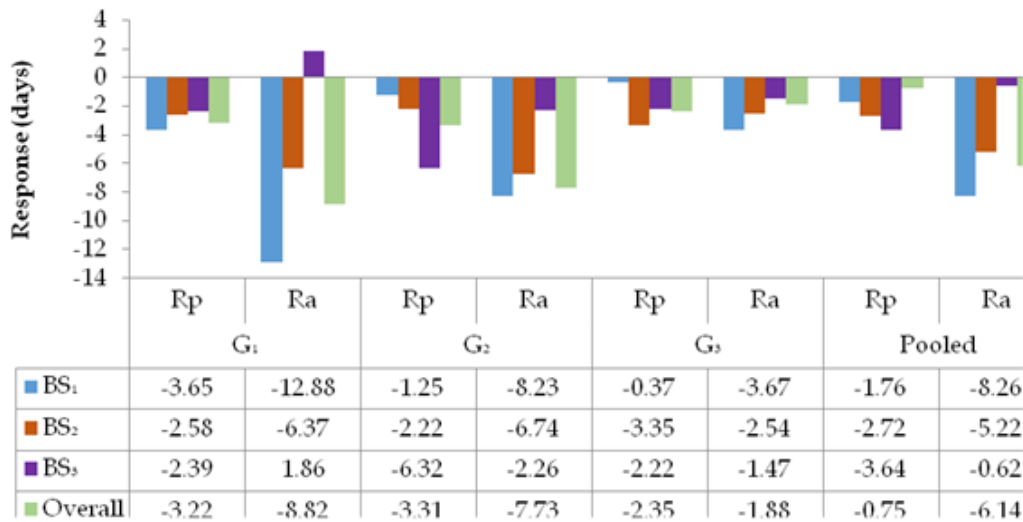


Fig. 9. Response to selection for post-partum heat period (BS₁, breeding strategy 1; BS₂, breeding strategy 2; BS₃, breeding strategy 3; R_p, predicted response; R_a, actual response; G₁, generation 1; G₂, generation 2; G₃, generation 3)

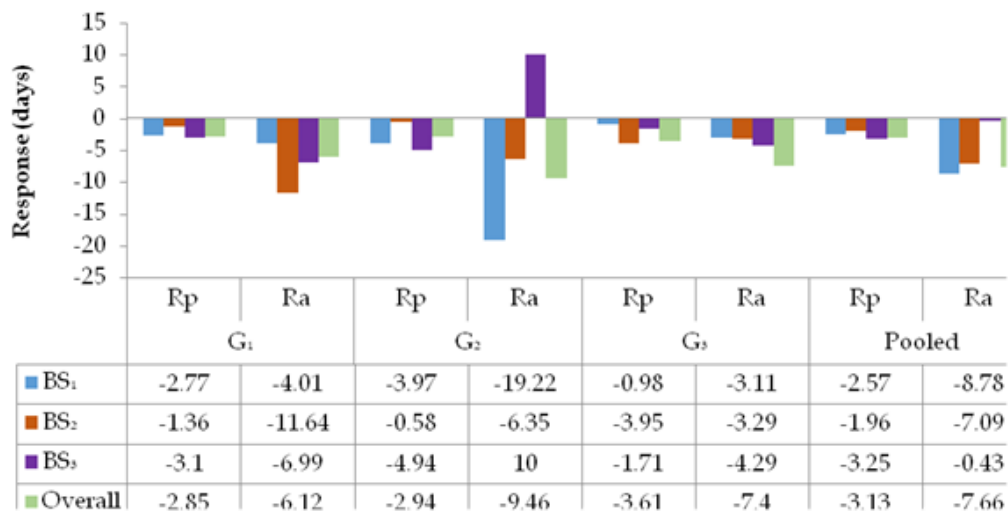


Fig. 10. Response to selection for kidding interval (BS₁, breeding strategy 1; BS₂, breeding strategy 2; BS₃, breeding strategy 3; R_p, predicted response; R_a, actual response; G₁, generation 1; G₂, generation 2; G₃, generation 3)

Conclusion

It may be concluded that community-based goat breeding approach under low input production system at rural areas by exchanging superior bucks and does, even exchange only of superior bucks with proper selection and culling for screening progeny with good genetic merit may accelerate reproductive performance of BBG in Bangladesh.

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References

- Amin, M.R. 2014. BLACK BENGAL – a promising goat genetic resource of Bangladesh, Joint FAO and IEA Program, International Atomic Energy Agency (2013-2014), P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna, Austria.
- Amin, M.R., S.S. Husain, and A.B.M.M. Islam. 2001. Reproductive peculiarities and litter weight in different genetic groups of Black Bengal does. *Asian-Aus. J. Animal Sci.* 14 (3):297-301.
- Belay, T.K., A. Haile, H. Dadi and T. Alemu. 2011. Genetic and phenotypic parameter estimates for reproduction traits in indigenous Arsi-Bale goats. *Trop. Animal Health Produc.* 44(5):1007-15.
- Choudhury, M.P., S.C. Sarker, F. Islam, A. Ali, A.K.F.H. Bhuiyan, M.N.M. Ibrahim and A.M. Okeyo. 2012. Morphometry and performance of Black Bengal Goats at the rural community level in Bangladesh. *Ban. J. Animal Sci.* 41(2): 83-89.
- Chowdhury, S.A., M.S.A. Bhuiyan and S. Faruque. 2002. Rearing Black Bengal Goat under semi-intensive management, physiological and reproductive performances. *Asian-Aus. J. Animal Sci.* 15(4):477-484.
- Devendra, C. and M. Burns. 1983a. Goat Production in the Tropics. Common Wealth Agricultural Bureaux, Farnham House, UK. pp. 49-54.
- Falconer, D.S. 1989. Introduction to Quantitative Genetics. 3rd ed. Longman Group Ltd. England.
- Faruque, S., S.A. Chowduury, N.U. Siddiquee and M.A. Afroz. 2010. Performance and genetic parameters of economically important traits of Black Bengal Goat. *J. Bang. Agril Uni.*, 8(1):67-78.
- Groeneveld, E. 1998. Pest user's manual, Institute of Animal Science, Höltystraße 10, D-31535 Neustadt, Germany.
- Haile. A., M. Wurzinger, J. Mueller, T. Mirkena, D. Duguma, M. Mwai, J. Sölkner and R. Rischkowsky. 2011. Guidelines for setting up community-based sheep breeding programs in Ethiopia. ICARDA - tools and guidelines No.1. Aleppo, Syria, ICARDA.
- Halim, M.A., M.A. Kashem, A. Mannan, S.S.U. Ahmed and M.A. Hossain. 2011. Reproductive and productive performances of Black Bengal Goats reared by the NGO beneficiaries under semi-intensive system in Bangladesh. *Int. J. Natural Sci.* 1(2):39-43.

- Haque, M.N. 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.
- Haque, M.N., S.S. Husain, M.A.M.Y. Khandoker, M.M. Mia and A.S. Apu. 2013. Selection of Black Bengal buck based on some reproductive performance of their progeny at semi-intensive rearing system. *J. Agric. Sci.* 5(8):142-152.
- Hasan, M.J., J.U. Ahmed and M.M. Alam, 2014. Reproductive performances of Black Bengal Goat under semi-intensive and extensive conditions at rural areas in Bangladesh. *J. Adv. Vet. Animal Res.* 1(4):196-200.
- Hassan, M.M., S.M.N. Mahmud, S.K.M.A. Islam and O.F. Miazi, 2007. A comparative study on reproductive performance and productivity of the Black Bengal and cross goat at Atrai, Bangladesh. *J. Zool. Sci.* 26:55-57.
- Hassan, M.R., M.A.I. Talukder and S. Sultana. 2010. The production characteristics of the Jamunapari goat and its adaptability to farm conditions in Bangladesh. *The Bang. Vet.* 27(1):26- 35.
- Hossain, S.M.J., N. Sultana, M.R.A. Alam and M. R. Hasnath. 2004. Reproductive and productive performance of Black Bengal Goat under semi-intensive management. *J. Biol. Sci.* 4(4):537-541.
- Husain, S.S. 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, S.S. 1998. Preservation of buck semen and their use in artificial insemination for rapid genetic improvement of rural goats population. Project Paper of Bangladesh Agricultural Research Systems, Mymensingh.
- Islam, A.F.M.F. 2014. Study on breeding and performance profile of Black Bengal Goats in Mymensingh district. MS thesis, Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh. pp. 1-45.
- Khandoker, M.A.M.Y., A.S. Apu, S.S. Husain and D.R. Notter. 2011. A baseline survey on the availability of Black Bengal breeding bucks in different districts of Bangladesh. *J. Bang. Agril. Uni.* 9(1):91-96.
- Majumder, M.K.H. 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.
- Mia, M.M. 2011. Genetic evaluation of performance of Black Bengal Goat. Ph.D. Thesis, Department of Animal Breeding and Genetics, Bangladesh Agricultural University, Mymensingh.
- Mia, M.M., M.A.M.Y. Khandoker, S.S. Husain, M.O. Faruque and D.R. Notter. 2013. Estimation of genetic and phenotypic parameters of some reproductive traits of Black Bengal does. *Iran J. Appl. Animal Sci.* 3(4):829-837.
- Moioli, B., M. D'Andrea and F. Pilla. 2007. Candidate genes affecting sheep and goat milk quality. *Small Rumi. Res.* 68:179-192.
- Ray, S., S.K. Dash, S.K. Dhal, G.D. Nayak and A.K. Parida. 2016. Genetic studies on reproductive performance of indigenous goats in Northern Odisha. *Explan. Animal and Medical Res.* 6(2):192-198.
- SPSS. 1998. Statistical Package for the Social Sciences. SPSS Inc. an IBM Company Headquarters. Chicago, Illinois, USA.

