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±2.71d, 383.01±2.61d, 1.13±0.03, 1.90±0.05, 42.41±0.84d and 186.44±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, Borochala, 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, Borochala, 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
phenotypic performance and response to selection of Black Bengal Goat

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 ≥250ml 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-balanceness 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,

\[ Y_{ijkl} = \text{Record of } l\text{th kid born in } i\text{th generation under } j\text{th breeding strategy in } k\text{th village flock.} \]
\[ \mu = \text{Overall population mean for reproductive traits;} \]
\[ G_i = \text{Effect of } i\text{th generation (where } i = 1\text{st generation, 2nd generation and 3rd generation),} \]
\[ B_j = \text{Effect of } j\text{th breeding strategy (where } j = \text{BS1, BS2 and BS3),} \]
\[ F_k = \text{Effect of } k\text{th flock (where } k = \text{Gangatia, Borochala and Pachpai),} \]
\[ e_{ijkl} = \text{Random residual error associated with } Y_{ijkl} \text{ observation} \]

**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, \( Y = \text{Vector of observations, } X, Z, \text{ and } W = \text{Known incidence matrices associated with levels of } b, a \text{ and } c \text{ with } Y, b = \text{Unknown vector of fixed effects (i.e. generation, flock etc.), } a = \text{Unknown vector of breeding value, } c = \text{Unknown vector of permanent environmental effects and } e = \text{Vector of residual effect.} \)

**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,

\( R = \text{response to selection in the next generation for the trait,} \)
\( i = \text{selection intensity, } h^2 = \text{heritability of the trait,} \)
\( sdp = \text{phenotypic standard deviation of the trait.} \)
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 | ASM (d) | AFK (d) | SPC (no) | LS (no) | PPHP (d) | KI (d) |
|--------|---------|---------|----------|---------|----------|--------|
| Generation | *** | *** | NS | *** | *** | *** |
| G₀ | 60.54±2.91 (173) | 124.5±2.28 (233) | 115±0.031 (127) | 160±0.051 (169) | 47.99±1.09 (122) | 96.23±1.19 (129) |
| G₁ | 37.67±2.66 (202) | 142.33±2.38 (161) | 114±0.03 (161) | 46.50±0.93 (161) | 89.06±1.05 (161) |
| G₂ | 20.88±4.02 (75) | 75.60±4.90 (048) | 111±0.06 (055) | 39.24±1.55 (055) | 83.66±1.76 (055) |
| G₃ | 13.27±6.11 (038) | 51.64±8.27 (016) | 113±0.09 (021) | 35.92±2.47 (021) | 76.81±2.78 (021) |
| BS | *** | *** | NS | *** | *** | ** |
| BS₁ | 204.91±2.88 (217) | 347.94±6.15 (207) | 117±0.04 (133) | 38.14±1.68 (144) | 81.50±2.21 (154) |
| BS₂ | 223.63±4.34 (196) | 379.47±6.42 (133) | 113±0.03 (122) | 40.88±1.80 (147) | 90.22±2.28 (144) |
| BS₃ | 270.73±5.95 (81) | 421.61±5.55 (096) | 119±0.04 (109) | 42.81±1.81 (068) | 80.09±2.33 (069) |
| Flock | * | NS | * | * | *** | *** |
| Gangatia | 38.77±4.24 (228) | 83.05±7.09 (180) | 119±0.04 (125) | 41.88±1.96 (112) | 87.04±2.64 (125) |
| Borochala | 37.17±5.47 (159) | 79.36±4.39 (133) | 117±0.05 (109) | 53.17±1.31 (125) | 70.53±1.57 (112) |
| Pachpai | 23.32±2.71 (149) | 61±6.40 (186) | 103±0.04 (130) | 32.19±2.01 (122) | 64.74±2.38 (130) |

Overall mean 333.09±2.71 (531) 83.01±2.61 (499) 113±0.03 (364) 90.0±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.

![% values of age at sexual maturity for different breeding strategies](image)

**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 Hussain 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)](image)

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 BS$_1$, followed by BS$_2$ and BS$_3$. This is obviously due to genetic potentially of superior parents transmitted to their offspring. Conversely, Choudhury et al., (2012) in the same flock 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 flock 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 $\sigma^2$ | $\sigma^2_e$ | $\sigma^2_p$ | $h^2 \pm SE$ |
|--------------------|-------------------------------|-------------|-------------|--------------|
| 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; $\sigma^2_a$, additive genetic variance; $\sigma^2_e$, permanent environmental variance; $\sigma^2_p$, 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 inconsistence 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     | -      | -      | 0.012±0.054 | -0.159**±0.054 | -0.260**±0.054 |
|          |        |        |        |        |        |
| ASM      | 0.091±0.042 | -      | -0.165**±0.054 | 0.356**±0.051 | 0.372**±0.051 |
| 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   | BS1 Response (R) to selection measured per generation | BS2 | BS3 | 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; Rp, predicted response; Ra, actual response; G1, generation 1; G2, generation 2; G3, generation 3)

![Graph showing response to selection for age at sexual maturity.](image)

|     | G1 | G2 | G3 | Pooled |
|-----|----|----|----|--------|
| BS1 | -1.75 | -11.62 | -2.28 | -5.22 |
| BS2 | -2.15 | -9.63 | -7.93 | -6.57 |
| BS3 | -1.18 | -13.74 | 0 | 38.89 |
| Overall | -7.73 | -19.57 | -7.41 | -8.07 |

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

![Graph showing response to selection for litter size.](image)

|     | G1 | G2 | G3 | Pooled |
|-----|----|----|----|--------|
| BS1 | 0.18 | 0.13 | 0.09 | 0.13 |
| BS2 | 0.08 | 0.06 | 0.06 | 0.14 |
| BS3 | 0.15 | 0.16 | 0.03 | 0.13 |
| Overall | 0.14 | 0.09 | 0.06 | 0.12 |
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Fig. 9. Response to selection for post-partum heat period (BS1, breeding strategy 1; BS2, breeding strategy 2; BS3, breeding strategy 3; Rp, predicted response; Ra, 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; Rp, predicted response; Ra, 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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