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Genetic and Phenotypic Parameters for Semen Characteristics and Their Relationship with Scrotal Circumference in Black Bengal Bucks

Research Article

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ABSTRACT

Black Bengal goat is the heritage and one of the potential genetic resources of Bangladesh. Genetic and phenotypic parameters for semen characteristics and their relationships with scrotal circumference in Black Bengal bucks were estimated in this experiment. Genetic parameters were estimated by residual maximum likelihood procedure, fitting an animal model ignoring maternal genetic or permanent environmental effects. The least-squares means of semen volume (mL/ejaculate), sperm concentration (10^9 cells/mL), mass motility (%), sperm livability (%) and normal spermatozoa (%) were 0.56, 2.55, 79.7, 86.8 and 90.5, respectively. Season of collection and scrotal circumference significantly affected all semen characteristics studied. Age of bucks affected all the semen characteristics, except mass motility. Body weight had a significant effect on semen volume and mass motility. Heritability estimates were moderate for sperm concentration (0.38) and low for semen volume, mass motility, sperm livability and normal spermatozoa (0.05 to 0.18). Phenotypic correlations ranged from slightly negative (-0.001) to moderately positive (0.42) and the genetic correlations ranged from moderately negative (-0.37) to strongly positive (0.99). Sperm concentration was the only semen trait of Black Bengal goat where reasonable genetic progress may be possible through selection. Selection for increased scrotal circumference should have favorable correlated response in semen characteristics.

KEY WORDS Black Bengal goat, fixed factors, genetic parameters, scrotal circumference, semen.

INTRODUCTION

Artificial insemination (AI), the manual deposition of spermatozoa in the reproductive tract of a sexually receptive female using artificial means, is considered the first reproductive biotechnology. Created with the major intention of controlling the dissemination of venereal diseases, AI still remained as the main vehicle for rapid dispersal of desirable genes and has been the method of choice for the farmers around the world to improve the genetic potentiality of their livestock (Vishwanath, 2003). The widespread use of AI together with accurate genetic evaluation can allow rapid dissemination of genetic merit of a nation. AI is the most powerful tool for livestock improvement available to the breeder (Robert and Foote, 1989). Increased milk, meat and skin production could be achieved by the development of AI (Robert and Foote, 1989).

In most livestock farming, AI is used for reproductive management and for genetic improvement, and is probably the most important technique devised to facilitate the ge-

netic improvement and conservation of animals on a large scale. Using AI, frozen semen from a single buck can impregnate many thousands of does yearly (Chemineau *et al.* 1991). Evaluation of the semen characteristics is the most effective parameters for selecting breeding buck. The quality of semen in relation to fertility is determined by the volume of ejaculate, sperm concentration, sperm motility, sperm livability and the morphological features of spermatozoa. Ejaculations containing a high percentage of morphologically abnormal spermatozoa commonly do not result in fertilization of the oocyte (Shamsuddin and Rodriguez, 1994). Morphological abnormalities of sperm can have a detrimental impact upon fertilization and embryonic development (Saacke, 2008). Sexual behavior and semen quality are the main factors that limit male reproductive efficiency during the year. These factors could vary according to the breed, geographical location, seasons (Karagiannidis *et al.* 2000), testicular size (Dufour *et al.* 1984; Ahmad and Noakes, 1995) and age (Toe *et al.* 1994). Season of the year, however, seems to be the principal cue affecting semen quality in goats. Seasonal variations in both semen quality and quantity are mainly due to changes in the day length throughout the year (Chemineau *et al.* 1992). This variation in semen quality and quantity is then one of the limiting factors in goat reproduction (Perez and Mateos, 1996). The effects of the season on spermatozoa characteristics, particularly in the tropics, have received little attention (Amir *et al.* 1986) although the fact that male fertility is known to be affected by season in temperate breeds.

Only very sparse studies have examined the association between measures of testicular or scrotal size with components of semen and spermatozoa quality or sperm output (Coulter *et al.* 1976; Knight, 1984). Heritability estimates of semen volume and spermatozoa quality traits are even more limited. However, the production of large numbers of high-quality spermatozoa of high quality by genetically superior sires is important to the improvement of overall flock fertility. Sire management practices may improve the efficiency of recovery of spermatozoa but has not been able to alter the basic spermatozoa producing capabilities of sires (Coulter *et al.* 1976). Positive genetic correlations between scrotal circumference (SC) and semen characteristics (Knights *et al.* 1984; Smith *et al.* 1989) have been reported. Coulter *et al.* (1976) found a correlation of 0.81 between SC and output of spermatozoa. Wiemer and Ruttle (1987) reported correlations between SC and volume, motility and percent abnormal cells in rams to be 0.14, 0.112 and -0.08, respectively. Brinks *et al.* (1978) reported positive correlations of SC with percent normal spermatozoa and motility and negative correlations of SC with proportion of primary and secondary abnormalities. A bull's risk of producing more than 30% abnormal spermatozoa decreases as SC increases (Coe, 1999). However, evidence of a relationship between testicular size and spermatological characteristics is inconclusive. Some researchers suggested that testicular size provide a good index of testicular sperm output in rams (Lino, 1972). Fernandez *et al.* (2004) did not record a relationship between testicular size and sperm production. These conflicting data justify the need for studies on the relationship between testicular measurements and semen characteristics in goats. Semen quality is closely related to fertility and therefore, many researchers have evaluated the semen from different breeds of goats for various characteristics. Although information is available on the semen characteristics of several goat breeds (Pandey *et al.* 1985; Singh and Purbey, 1994), very little is known about the semen characteristics and its influencing factors in Black Bengal bucks, the only breed of goat in Bangladesh. Heritability estimates for traits that affect fertility are significant because the estimates will determine if genetic selection is possible and the speed at which progress can be made through selection. Genetic correlations between traits are also important because they provide information as to how one trait will respond when selection is for another trait. Therefore, the objectives of this study were:

1. Examine the effect of season, age, body weight and scrotal circumference on semen characteristics.
2. Estimate variance components and heritability for semen characteristics.
3. Estimate genetic and phenotypic correlations among semen characteristics.
4. Examine the relationships between semen characteristics and scrotal circumference.

MATERIALS AND METHODS

Location

The study was conducted during the period from April 2007 to March 2010 in the nucleus breeding flock (NBF) at the artificial insemination centre, department of animal breeding and genetics, Bangladesh agricultural university, Mymensingh.

Animals and management

A total of 18 Black Bengal bucks were used in this study. For each individual under study, a record sheet with full details of each parameter along with pedigree information was maintained. At the onset of the experiment, the bucks were 9 to 36 months old, with a body weight (BW) of 12 to 30 kg and a scrotal circumference (SC) of 17 to 23 cm. They were housed in individual pens of one square meter in a galvanized iron sheet shed with a wooden slatted floor raised above the ground level. The house was provided with necessary arrangements for feeding and watering and for

sufficient access to fresh air. The bucks were kept under zero grazing management and stall fed twice daily on a diet consisting of Napier, German and / or maize fodder *ad libitum*. The feed was supplemented with commercial pelleted concentrate (Surma feed, BRAC feed mill, Sreepur, Gazipur) in the morning and again in the afternoon at the rate of 400 g/buck/day (crude protein: 23%, crude fat: 6.5%, crude ash: 10%, crude fiber: 4%, NFE: 45.45%, moisture: 11% and energy content: 3100 kcal ME/kg DM). The breeding bucks were also supplied with germinated *Cicer arietinum* (20 g/buck/day). They were allowed for exercise for 1 to two hours daily. Clean and safe water was made available at all times. A general management program, including dipping, deworming, disease prevention, hoof trimming and vaccination against peste des petits ruminants (PPR) was followed. Animals were clinically examined regarding the health of their external genitalia. Immediate veterinary assistance was given to bucks when necessary. Scrotal circumference (SC) was determined with a flexible measuring tape when bucks were placed in the experimental facility and at monthly intervals thereafter. Both testes were manually forced to descend into the bottom of the scrotum until ventral skin folds were eliminated. The testes were then held firmly in place by grasping the neck of the scrotum with one hand above the heads of the epididymis. The opposite hand then guided a flexible tape upward from the bottom of the scrotum. The area of the scrotum with the widest circumference was then identified, and the measurement was taken at the greatest diameter of the scrotal sac. Manual pressure on the tape was exerted to the extent of slight skin indentation. Live weights were recorded on all bucks at the time of each SC measurement, and age of buck at measurement was also recorded. Body weights (kg) were recorded in the morning before the animals were fed. The weights were taken using a platform balance to an accuracy of 10 g.

Semen collection

Collection of semen was done with artificial vagina (AV) maintaining optimum pressure and temperature of 41 to 43 $^{\circ}$C into a graduated collection tube. The bucks received homosexual stimulation by being exposed to the teaser male. Semen was collected from each buck twice a week after cleaning the prepuce with antiseptic (savlon) solution. After mounting was completed (with seeking movement of the penis), the AV was touched with the glans penis. The bucks made vigorous upward and forward thrust, which signified the occurrence of ejaculation. The tubes containing freshly collected semen were immediately transferred to the laboratory and immersed into a water bath at 37 $^{\circ}$C. The semen was not exposed to unfavorable conditions during or after collection.

Semen evaluation

The semen sample was evaluated immediately after collection, and the volume of the ejaculate was recorded directly from the graduated collection tube. Mass motility was assessed according to the wave motion (as a percentage), by viewing a drop of semen under low magnification (4×). One small drop of semen was placed on a clean prewarmed (37 $^{\circ}$C) slide and examined under the microscope without cover slip. Sperm concentration was determined using a Neubauer haemocytometer by the technique of Herman and Madden (1953). The percentages of live and dead spermatozoa were estimated by preparing a stained film as described by Chemineau *et al.* (1991). The proportion of morphologically abnormal spermatozoa was also determined by examining 200 spermatozoa in an eosin-nigrosine smear under the same magnification.

Statistical analyses

The significance of fixed effects (non-genetic factors) was tested by least-squares analyses of variance using the general linear model (GLM) procedure of the statistical analysis system (SAS, 1998) according to the following linear model:

$$Y_{ijklm} = \mu + S_i + M_j + R_k + T_l + E_{ijklm}$$

Where:
Y_{ijklm}: the dependent variable.
μ: the overall mean.
S_i: the fixed effect of i^{th} season.
M_j: the fixed effect of the j^{th} age.
R_k: the effect of k^{th} body weight.
T_l: the effect of l^{th} scrotal circumference.
E_{ijklm}: the residual error.

The year was divided into three seasons; winter (from November to February), summer (from March to June) and rainy (from July to October). Age of the bucks was grouped into classes of 9-12, >12-24 and >24-36 months. Body weight of bucks was grouped into classes of 12-18, >18-24 and >24-30 kg. The statistical package SAS (SAS, 1998) was used to carry out the phenotypic correlation analysis. Genetic parameters were estimated with residual maximum likelihood (REML) procedure fitting an animal model using VCE 4.2.5 software (Groeneveld, 1998). The models used to estimate genetic parameters included random effects and all fixed effects that were found significant in the least-squares analysis. The genetic correlations between traits were estimated using two-trait pair wise analyses. The fixed effects included in the multi-trait animal models were those in single-trait analyses. The model fitted for both unitrait and two-trait analyses were as follows:

$Y = Xb + Za + e$

Where:
Y: vector of observations.
b: vector of fixed effects.
a: vector of random animal effects (direct genetic).
X: incidence matrix for fixed effects.
Z: incidence matrix for random effects.
e: vector of random residual effects.

It was assumed that all effects in the models are independent and normally distributed.

RESULTS AND DISCUSSION

Semen characteristics

All bucks ejaculated and produced semen throughout the year. Basic statistics for semen characteristics of Black Bengal bucks are presented in Table 1. The least-squares means of semen volume (mL/ejaculate), sperm concentration (10^9 cells/mL), mass motility (%), sperm livability (%) and normal spermatozoa (%) were 0.56, 2.55, 79.7, 86.8 and 90.5, respectively. Highest coefficient of variation was observed for semen volume (37.3%), thereafter for sperm concentration (22%) and the lowest for normal spermatozoa (4.2%). The average volume of ejaculate fell within the normal range (Apu, 2007).

The average sperm concentration was comparable to that of goat breeds kept under tropical conditions (Sinha and Singh, 1982; Chemineau *et al.* 1991). The values obtained here for mass motility, sperm livability and percentage of normal spermatozoa indicate that the semen may be considered to be of good quality, as reported by Chemineau *et al.* (1991).

Analysis of fixed effects

The effect of season, age, body weight and scrotal circumference on semen parameters are set out in Table 2.

Season

Season of the year affected (P<0.01) all the semen characteristics investigated in the Black Bengal bucks. The highest ejaculate volume (mL) was obtained in winter (0.60±0.01) compared with lowest in summer (0.53±0.01) and intermediate in rainy season (0.55±0.01). The difference in ejaculate volume between summer, and the rainy season was not significant. The present results for ejaculate volume are in close conformity with those of Singh and Purbey (1994), Roca *et al.* (1992) and Karagiannidis *et al.* (2000) for buck semen. Dufour *et al.* (1984) reported that minimum semen output was recorded during the summer and maximum in the winter in rams of Canada. The present result is also in consistent with that result. However, sperm concentration, mass motility, sperm livability and normal spermatozoa followed a trend opposite to that of the ejaculate volume. Sperm concentration (10^9 cells/mL), mass motility (%), sperm livability (%) and normal spermatozoa (%) were highest in rainy season (2.79±0.05, 80.54±0.39, 88.43±0.70, 91.09±0.49) compared to summer (2.53±0.06, 79.16±0.44, 86.61±0.78, 90.32±0.57) and winter (2.43±0.08, 78.66±0.48, 80.27±1.38, 88.09±0.83). Sperm concentration and mass motility did not differ significantly between winter and summer. On the other hand, percent sperm livability and percent normal spermatozoa did not vary significantly between summer and rainy season. Except ejaculate volume highest values for all the parameters were recorded in rainy season. Season has an important effect on semen traits. Performance is usually better in winter and spring than in summer (Mathevon *et al.* 1998). Ciereszko *et al.* (2000) reported that semen quality varied with the season, including high production of spermatozoa in autumn and winter and low production in summer. On the other hand, Maina *et al.* (2006) and Alessandro *et al.* (2001) reported an insignificant seasonal variation on semen volume.

Effects of climatic factors on semen quality traits, particularly those, such as temperature, which are closely associated with seasonal weather patterns, are known to be immediate (Colas, 1983). This study is the first to report the seasonal changes in semen indices of Black Bengal bucks reared in Bangladesh. Season had a significant effect on semen characteristics. These results are in agreement with the findings of Al-Ghalban *et al.* (2004) and Roca *et al.* (1992). Though seasonal variations in semen characteristics are observed, the results of the present study indicated that Black Bengal bucks have continuous and acceptable spermatogenic activity during all seasons throughout the year. Semen of superior quality was produced in the rainy season than winter and summer, which was similar to that obtained by Van der Westhuysen (1978).

Sperm concentration was influenced significantly (P<0.01) by seasons. The present results find support from those reported by Roca *et al.* (1992), Singh and Purbey (1994) and Karagiannidis *et al.* (2000). However, Maina *et al.* (2006) reported an insignificant difference. Significant influence of season (P<0.01) was also recorded on mass motility. This result is in agreement with the findings of Al-Ghalban *et al.* (2004). There is no increase of abnormalities in summer or rainy season, which indicates no heat stress, was recorded (Chemineau *et al.* 1991).

Mass motility was high whenever spermatozoa concentration was high was not surprising: higher concentration of spermatozoa is expected to result in a higher wave motion score compared to lower concentration of spermatozoa of

Table 1 Basic statistics for semen characteristics of Black Bengal bucks

Trait	No of records	Minimum	Maximum	Least squares means	Standard deviation	CV (%)
Body weight (kg)	332	12.96	29.50	20.52	3.50	17.05
Scrotal circumference (cm)	332	17.00	23.00	19.74	1.50	7.59
Semen volume (mL)	560	0.10	1.60	0.56	0.22	37.26
Sperm concentration (10^9 cells/mL)	339	1.02	4.62	2.55	0.63	21.96
Mass motility (%)	496	65.00	90.00	79.71	4.76	5.88
Sperm livability (%)	281	61.55	96.20	86.78	6.73	7.43
Normal spermatozoa (%)	245	75.35	96.30	90.48	3.92	4.23

CV: coffiecient of variation.

Table 2 Least squares means with standard errors for semen characteristics of Black Bengal bucks as affected by various factors

Factors	Semen volume (mL)	Sperm concentration (10^9 cells/mL)	Mass motility (%)	Sperm livability (%)	Normal spermatozoa (%)
Season	**	**	**	**	**
Winter	0.60^{a}±0.01	2.43^{b}±0.08	78.66^{b}±0.48	80.27^{b}±1.38	88.09^{b}±0.83
Summer	0.53^{b}±0.01	2.53^{b}±0.06	79.16^{b}±0.44	86.61^{a}±0.78	90.32^{a}±0.57
Rainy	0.55^{b}±0.01	2.79^{a}±0.05	80.54^{a}±0.39	88.43^{a}±0.70	91.09^{a}±0.49
Age (months)	**	**	NS	*	*
9-12	0.46^{c}±0.02	2.42^{b}±0.07	79.67±0.49	88.00^{a}±0.87	91.30^{a}±0.66
> 12-24	0.55^{b}±0.01	2.52^{b}±0.04	79.82±0.34	86.52^{ab}±0.61	90.43^{a}±0.44
> 24-36	0.72^{a}±0.02	2.76^{a}±0.08	79.56±0.56	85.11^{b}±1.71	88.70^{b}±0.56
Body weight (kg)	**	NS	*	NS	NS
12-18	0.40^{c}±0.02	2.50±0.08	80.46^{a}±0.68	87.29±0.88	90.98±0.66
> 18-24	0.53^{b}±0.02	2.57±0.20	79.67^{a}±0.62	87.01±0.86	90.67±0.67
> 24-30	0.62^{a}±0.04	2.55±0.10	78.04^{b}±1.22	86.66±1.95	90.41±1.39
Scrotal circumference (cm)	**	**	**	*	*
17	0.40^{c}±0.06	2.36^{c}±0.36	80.11^{abc}±1.70	90.2^{a}±3.35	88.54^{b}±2.87
18	0.45^{c}±0.03	2.32^{c}±0.13	79.56^{abc}±0.84	86.24^{ab}±1.35	91.4^{ab}±0.94
19	0.49^{c}±0.02	2.40^{c}±0.09	78.41^{bc}±0.63	84.79^{b}±0.99	89.06^{ab}±0.72
20	0.47^{c}±0.02	2.63^{bc}±0.09	80.73^{ab}±0.67	87.78^{ab}±1.01	91.30^{ab}±0.72
21	0.58^{b}±0.03	2.46^{bc}±0.13	77.83^{c}±0.93	87.14^{ab}±1.51	92.13^{a}±0.98
22	0.60^{b}±0.03	2.8^{ab}±0.14	81.25^{a}±0.87	89.58^{ab}±2.18	90.24^{ab}±1.00
23	0.79^{a}±0.05	3.25^{a}±0.23	80.00^{abc}±1.38	88.93^{ab}±1.54	88.97^{ab}±1.82

The means within the same column with at least one common letter, do not have significant difference (P>0.05).
NS: non significant; * (P<0.05) and ** (P<0.01).

the same individual motility. Season has also been reported to have significant effect on percent sperm livability in temperate climates (Colas, 1980; Dufour *et al.* 1984). High temperatures, particularly in association with increasing day length during summer months, have been shown to be associated with poor semen quality and low fertility in rams (Dufour *et al.* 1984).

Simplicio *et al.* (1982) observed significant seasonal differences for ejaculate volume, mass motility, forward motility score, concentration of spermatozoa and testes measurements. The ejaculate of the buck is quite small in volume (0.7 to 2 mL), with a high sperm concentration (2 to 5 $\times 10^9$ cells/mL), a high percentage of motile spermatozoa (70 to 90%) and a low percentage of abnormal spermatozoa (range: 5 to 15%) (Chemineau *et al.* 1991; Roca *et al.* 1992). In our study, most of the mean values for the semen characteristics of Black Bengal bucks were almost similar to those for other goat breeds like Murciano Granadina (Roca *et al.* 1992), Saanen (Ahmed *et al.* 1997; Sinha and Singh, 1982) and Alpine, Saanen and Damascus (Karagiannidis *et al.* 2000) bucks.

Age

All the parameters except mass motility were affected by age. Volume of semen and sperm concentration increased significantly (P<0.01) with age, but the percentage of sperm livability decreased significantly (P<0.05) with age. Highest (P<0.05) percentage of normal spermatozoa was observed at the age of 9-12 months and the lowest value at the age of >24-36 months. The percentage of normal spermatozoa in the age of >12-24 months did not differ with that of 9-12 months. In our study ejaculate volume and sperm concentration increased with age, which is in agreement with the findings of Al-Ghalban *et al.* (2004) for Damascus bucks in Jordan. The results also agree with those of Alberio and Colas (1976), in that the sperm concentration increased with the age of lambs. As reported previously by Osinowo *et al.* (1988), mature rams generally have higher ejaculated volumes, sperm concentrations and total sperm per ejaculate than younger rams. The percentage of live sperm and normal sperm was also affected by age in this study. Osinowo *et al.* (1988) found no significant differences in percentage between yearlings and mature rams.

Sperm morphology changes with animal age. For example, the occurrence of abnormal sperm head shapes is reportedly higher at younger and older ages than at around the age at sexual maturity (Amann *et al*. 2000). Similarly, increased age did not affect sperm abnormalities in bucks in Ethiopia (Roca *et al*. 1992).

Body weight

Body weight had a significant effect on semen volume and mass motility. Semen volume increased significantly with rising body weight, whereas mass motility showed the reverse trend. Other semen parameters were not affected by body weight of bucks. The result is in agreement with the findings of Salhab *et al*. (2003) for Awassi sheep in Syria.

Scrotal circumference

Scrotal circumference (SC) significantly influenced ($P<0.05$) all the semen characteristics investigated in the Black Bengal bucks in the present study. The semen volume and sperm concentration increased linearly with scrotal circumference, while the other parameters did not show any linear relationship. Highest semen volume (0.79 mL) was recorded at the scrotal circumference of 23 cm, while the lowest volume (0.40 mL) was observed when the SC was 17 cm. The highest sperm concentration (3.25×10^9 cells/mL) was obtained at the scrotal circumference of 23 cm and the lowest (2.32×10^9 cells/mL) in 18 cm. Higher SC measurements indicate higher testicular mass and larger sperm production (Fernandez *et al*. 2004).

Variance components and heritability estimation

Additive genetic and residual variances, phenotypic variance and heritability estimates are listed in Table 3. For all the traits, heritability was low to moderate ranging from 0.05 to 0.38. The highest heritability was found for sperm concentration (0.38) and the lowest heritability for percentage of normal spermatozoa (0.05). The estimates for volume, mass motility and sperm livability were 0.18, 0.14 and 0.13, respectively. The heritability estimate of 0.38 implies that 38% of the variance of sperm concentration is determined by the additive effects of genes that animal received from its parents and response to genetic selection is possible. The remaining 61.9% of the variance of sperm concentration results from the non-additive genetic and environmental effects. The low estimates for other traits indicate that environment has a great influence on these traits. Rege *et al*. (2000) found the heritability of semen volume to be 0.11 in 12 month-old rams, which is slightly less than the estimate calculated from this study. Heritability estimates for overall motility (individual or mass was not identified) have been reported in the literature by Knights *et al*. (1984) as 0.13. Smith *et al*. (1989) estimated heritability for percent normal spermatozoa to be 0.07, which is slightly more than the estimate calculated from this study.

The heritability for semen characteristics in our study are in agreement with the findings of Furstoss *et al*. (2009) who reported the heritability values for semen characteristics of young buck to be 0.12 to 0.34. The levels of heritability of semen production traits were intermediate between the estimations made on young rams (David *et al*. 2007) and on young bulls (Mathevon *et al*. 1998). The main difference was for heritability of sperm concentration, which was 0.52 with young bovines and, which is clearly higher than our values.

Heritability estimates in the present study point to the opportunity for genetic improvement of sperm concentration through selective breeding. Sperm concentration had strong and favorable genetic correlations with mass motility. Thus, selection for this trait should have favorable correlated response in the mass motility.

Phenotypic and genetic correlations

Estimates of phenotypic and genetic correlations among scrotal circumference and semen characteristics are reported in Table 4. Phenotypic correlations ranged from slightly negative (-0.03) to moderately positive (0.43). However, genetic correlations ranged from moderately negative (-0.42) to strongly positive (0.99). The majority of the semen characteristics had favorable genetic correlations with each other. All of the favorable genetic correlations are promising because they indicate that positive selection in a buck for one semen characteristics could benefit the majority of the other semen characteristics in his male progeny. There were a few unfavorable genetic correlations between semen characteristics. Semen volume was negatively correlated with sperm concentration and normal spermatozoa, -0.42 and -0.34, respectively. Sperm concentration was also negatively correlated with sperm livability (-0.37). All the other genetic correlations were slightly to be strongly positive. Among semen characteristics, the strongest genetic correlation was that between normal spermatozoa with sperm livability (0.94).

Positive genetic correlations were calculated between scrotal circumference and semen volume, sperm concentration, mass motility, sperm livability and percent normal spermatozoa, 0.05, 0.95, 0.47, 0.93 and 0.99, respectively (Table 4). Correlations between scrotal circumference and seminal characteristics have been reported. Kealey (2004) calculated positive genetic correlations between scrotal circumference and volume (0.20) and spermatozoa motility (0.34). He also found negative genetic correlations between scrotal circumference and percents of spermatozoa with abnormal mid-pieces, proximal cytoplasmic droplets, secondary abnormalities and coiled tails, -0.36, -0.37, -0.43

Table 3 Estimates of additive genetic variance (σ^2a), residual variance (σ^2e), phenotypic variance (σ^2p) and heritability (h^2) for semen characteristics

Trait	σ^2a	σ^2e	σ^2p	h^2
Semen volume	0.008	0.037	0.045	0.18±0.04
Sperm concentration	0.143	0.232	0.375	0.38±0.06
Mass motility	2.930	18.398	21.328	0.14±0.04
Sperm livability	4.772	32.160	36.932	0.13±0.05
Normal spermatozoa	0.735	12.963	13.698	0.05±0.04

Table 4 Phenotypic (below diagonal) and genetic (above diagonal) correlations among scrotal circumference and semen characteristics in Black Bengal bucks

Trait	SV	SCT	MM	SL	NS	SC	BW
SV	-	-0.42±0.16	0.04±0.15	0.03±0.01	-0.34±0.06	0.05±0.06	0.46±0.14
SCT	-0.03	-	0.38±0.16	-0.37±0.14	0.00±0.01	0.95±0.06	-0.24±0.16
MM	0.00	0.30	-	0.67±0.14	0.16±0.05	0.47±0.11	-0.09±0.15
SL	-0.02	0.35	0.43	-	0.94±0.23	0.93±0.07	-0.60±0.15
NS	0.03	0.11	0.12	0.36	-	0.99±0.01	-0.76±0.22
SC	0.35	0.30	0.07	0.13	0.04	-	0.19±0.15
BW	0.37	0.07	-0.14	0.00	-0.14	0.56	-

SV: semen volume; SCT: sperm concentration; MM: mass motility; SL: sperm livability; NS: normal spermatozoa; SC: scrotal circumference and BW: body weight.

and -0.12, respectively (Kealey, 2004). From the positive relationship among scrotal circumference and semen characteristics observed in the present study, the inference can be made that bucks with large scrotums will sire progeny that could produce greater amounts of semen with good quality than if bucks with smaller scrotums were used as sires.

Overall, these relationships indicate an increased chance of a buck passing a breeding soundness evaluation if his sire had a large scrotal circumference. Relationships between scrotal circumference and semen characteristics suggest that scrotal circumference may be a helpful indicator of semen quality, especially for sperm concentration (0.95), mass motility (0.47), sperm livability (0.93) and percent normal spermatozoa (0.99). These findings are in agreement with Coe (1999), who reported a positive relationship between scrotal circumference and semen quality. Phenotypic correlation between sperm concentration and volume was slightly negative (-0.03), whereas genetic correlation was moderately negative (-0.42). It should, however, be noted that the correlations involving volume and concentration may be partly due to a 'part-whole' relationship expected due to the 'physical' relationship between the two variables in any fluid system. Karagiannidis *et al.* (2000) observed phenotypic correlation of 0.01 between semen volume and sperm concentration. A negative genetic relationship between volume and concentration was reported for many species. Our correlation value -0.42 was close to the value observed in previous studies, -0.24 to -0.53 on Lacaune and Manech tête rousse AI rams (David *et al.* 2007), -0.62 on boars (Smital *et al.* 2005), -0.50 on Saanen bucks (Furstoss *et al.* 2009) and -0.38 on Ethiopian highland sheep (Rege *et al.* 2000).

Positive and moderate phenotypic correlations were calculated between scrotal circumference and semen characteristics (Table 4). Relationships between scrotal circumference and semen characteristics suggest that scrotal circumference may be a reliable indicator of semen characteristics, especially for volume (0.35) and sperm concentration (0.30). These findings are in agreement with Coe (1999), who reported a positive relationship between scrotal circumference and semen quality. Semen volume and scrotal circumference were also positively correlated with body weight. Selection for increased scrotal circumference would have a positive effect on the majority of semen characteristics. The largest positive impact would be on sperm concentration.

CONCLUSION

Semen volume increased with age, body weight and scrotal circumference. Sperm concentration also increased with age and scrotal circumference, whereas body weight had no significant influence on sperm concentration at the same age and scrotal circumference. Mass motility did not change owing to age. The heritability of semen characteristics were low except sperm concentration, which was moderate. Sperm concentration was the only semen trait of Black Bengal goat where reasonable genetic progress may be possible through selection. Selection on sperm concentration is likely to be accompanied by favorable correlated response in mass motility. Positive genetic and phenotypic correlations between scrotal circumference and semen characteristics indicate that selection for increased scrotal circumference could have positive effects on semen characteristics. Positive genetic and phenotypic correlations among body weight, scrotal circumference and semen volume indicate that selection for body weight could be an essential tool for improving overall characteristics of semen production.

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