Agricultural Journal 9 (1): 5-14, 2014
ISSN: 1816-9155

Characterization of Goat Population and Breeding Practices of Goat Owners in Gumara-Maksegnit Watershed-North Gondar, Ethiopia

[1]Alayu Kidane, [1]Surafel Melaku and [2]Aynalem Haile
[1]Amhara Region Agricultural Research Institute, Gondar Agricultural Research Center, P.O. Box 1337, Gondar, Ethiopia
[2]International Center for Agricultural Research in the Dry Areas, P.O. Box 5466, Aleppo, Syria

Abstract: The intention of this study was characterizing the goat population of Gumara-Maksegnit watershed area by defining the breeding practices of the goat owners in the area, as well as based on physical appearance traits and body measurements. The study area lies in North Gondar Administrative Zone of Ethiopia. Questionnaire was collected from 71 respondent farmers who raise goats. Beside, quantitative linear measurement traits and body weights were taken from 435 female, 142 male, 27 castrate and a total of 604 goats at age of about 10 months and above. The average goat flock size per household was found to be 8.13. The primary reason of goat owners for keeping goats was found to be generating income. The major selection criteria for breeding does were kid growth, height and mothering ability whereas for breeding bucks, height, coat color and fast growth. Most of the respondents (93 and 98.6%) practice selection of best male and female goats from their flock for breeding. The average (mean±SD) age at sexual maturity in male and female goats obtained were 9.74±2.53 and 7.61±2.62 months, respectively. The average age at first kidding is 13.86±3.31 months. The overall mean kidding interval of goats was 6.35±1.11 months. The overall average litter size of the present study was 1.85±0.36 kids per doe per kidding. The major goat production problems identified were disease, predator and feed shortage in their priority. White coat color (24.2%) is the dominant in a plain pattern followed by red with white color (19.5%) in a patchy or spotted pattern. Least mean square means of body measurements of goats were 33.4±0.5 kg body weight, 74.4±0.5 cm wither height, 62.6±0.4 cm body length, 74.2±0.5 cm heart girth, 22.0±0.4 cm scrotal circumference and 2.9±0.1 body condition score. Male goats were found to have higher body size than females. The growth of the goats can be better explained by quadratic curve (R^2 = 72.6%) than linear curve (R^2 = 67.3%). The goats attain their maturity at age of eruption of 3 pair of permanent incisors. Heart girth was the most highly correlated trait with live weight followed by body length and thus the prediction equations for does of pooled age group: BW = 0.92 HG-42.8 and BW = 0.67HG+0.29+BL-44.3 while for bucks of pooled age group: BW = 0.97 HG-45.5. Development of health care interventions and practicing cut and carry feeding strategies using available feeds and development of adaptive forage species and conservation methods can be helpful to alleviate goat production constraints. The presence of high variation in live weight and other body measurements of the goats can indicate the possibility of selection as promising intervention option for future improvement. At farmers' management condition, heart girth of male goats and combination of heart girth with body length of female goats can be used to estimate body weight based on the prediction equations.

Key words: Body weight, growth curve, linear measurements, qualitative traits, goats

INTRODUCTION

Goats, due to their naturally endowed physiological adaptation and general lower husbandry requirements, form an integral part of livestock production in the tropics and subtropics (Morand-Fehr *et al*., 2004; Mengistu, 2007). DNA level genetic differences and variations in physical characteristics showed that there are 4 families and 12 breeds of goats identified in Ethiopia (Alemu, 2004). Genetic characterization of Ethiopian goats by Alemu (2004) was inconsistent with classification of Farm Africa. Following the analysis of 15 microsatellite loci, the results indicate eight separate genetic entities: The Arsi-Bale, Gumez, Keffa, Woyto-Guji, Abergalle, Afar, Highland Goats (previously separated as Central and North-West Highland) and the goats from the previously

Corresponding Author: Alayu Kidane, Amhara Region Agricultural Research Institute, Gondar Agricultural Research Center, P.O. Box 1337, Gondar, Ethiopia

known Hararghe, Southeastern Bale and Southern Sidamo provinces (Hararghe Highland, Short-eared Somali and Long-eared Somali goats).

According to Ethiopian sheep and goat productivity improvement program, there are key identifying physical characteristics that distinguish a breed. A combination of characteristics is required to differentiate one breed from another. The key characteristics that should be observed or measured to identify the breeds of goat population in Ethiopia are coat color, body size, ear and horn and facial profile (Ayalew *et al*., 2004).

The fact that Ethiopia has many different goat breeds, a diverse agro ecology ranging from cool highlands to hot lowlands and diverse goat production systems indicates that undertaking characterization studies of the goat populations in various agro-ecologies is very vital, as it would provide a benchmark for genetic improvement and biodiversity conservation. Moreover, this study is supposed to be an input for a sire selection and exchange scheme planned to be established in Gumara-Maksegnit watershed.

Therefore, this study was conducted with the objective of characterizing the goat population of Gumara-Maksegnit watershed area based on physical appearance traits and body measurements.

MATERIALS AND METHODS

Area description: Gumara-Maksegnit watershed lies in the Lake Tana basin of Northwest Amhara region in Ethiopia. This catchment drains into the Gumara River which ultimately reaches to Lake Tana. The Gumara-Maksegnit watershed is found in Gondar Zuria woreda of north Gondar Administrative zone. It is located between 347500 E and 1383500 N at the upper part of the watershed and 344000 E and 1371000 N at the outlet. The watershed is located at about 45 km Southwest of Gondar town. Altitude within the watershed ranges from 1933-2852 m above sea level. The topography of the area ranges from gentle slope to sharp steep slope. The total area of the Gumara-Maksegnit watershed is about 60 km^2. The watershed is inhabited by 1148 households and 4246 individuals with an average family size of four persons. Settlement in the watershed is scattered and the landholding is characterized as small and fragmented. About 55% of the total land is cultivable, 23% of the area is covered by forest and grazing land, 7% is waste land and 15% of the land is used for settlement. Livelihood of households in the watershed is dependent on forests, livestock and crop production.

Data collection: Quantitative linear measurement traits including body length, heart girth, wither height, pelvic width and ear length were measured using standard plastic tapes (cm) and body weights were taken using 100 kg portable balance. Total of 604 goats (435 female, 142 male and 27 castrate) aged about 10 months and above were used for this study.

Physical measurements were taken only from a representative set of adult animals (as judged by dentition) as recommended by FAO (2012).

Scrotal circumference of the male population was also measured. For growth curve construction, dentition and body weight data were collected from a total of 763 goats including kids at very early ages.

Additionally, data on nine qualitative traits were collected for description of the population. These included coat color type and pattern, presence or absence of ruff and wattle, horn shape and orientation, head profile, ear form and body condition score. Body condition score was assessed subjectively using a 5 point scale (1 = Very thin, 2 = Thin, 3 = Average, 4 = Fat and 5 = Very fat/obese). The score of an animal was done by feeling the back bone and the ribs with the thumb and finger tips.

Moreover, survey was conducted using a semi-structured questionnaire to study the production system and breeding practices of goat owners. A total of 71 households were randomly sampled for the survey from two villages, Dinzaz and Denkele which were selected with the help of development agents based on their suitability for goat production, market and road access.

The questionnaire was designed to obtain information on general household characteristics, purpose of keeping goat, flock size and structure, ownership and sources of goats, herding and breeding practices and selection criteria of breeding bucks and does. The questionnaire was tested before the survey started to ensure that all questions were clear for the interviewees.

Data analysis: Prior to analysis the data was checked using scatter plot method of SPSS and the largest and smallest out layer values were filtered out from the data. Data were analyzed using Statistical Analysis System (SAS) version 9 and SPSS version 16. SPSS was employed for descriptive statistical analysis including frequency and percentage analysis, as well as to perform multiple linear regression analysis to determine the prediction equations of body weight using body measurements. Quantitative measurements were analyzed using GLM of SAS. The fixed effects of sex and dentition were considered in the model. Zero Pair of Permanent Incisors (0PPI) refers to goats with fully grown milk teeth that started to spread apart, wear down or are fully spread apart, 1 Pair of Permanent Incisors (1PPI) means goats with erupted and growing one pair of permanent incisors, 2PPI include goats with erupted and growing 2 pairs of permanent incisors, 3PPI is for goats with erupted and growing 3 pairs of permanent incisors, 4PPI encompasses goats with erupted and growing four pairs of permanent incisors and 5 represents goats whose 4 pairs of permanent incisors have started to wear down, spread apart and completely lost (broken mouth and smooth mouth). 0PPI is estimated to be <1 year, 1PPI, 1-1.5 year, 2PPI, 1.5-2 years, 3PPI, 2.5-3 years, 4PPI is grown after >3 years of age (ESGPIP, 2009).

Pearson's correlation coefficients between body weight and other linear measurements were computed for the population within each sex and dentition groups to see the relationship.

The stepwise regression procedures of SPSS were used to determine the relative importance of live-animal body measurements in a model designed to predict body weight. Live weight was regressed on the body measurements separately for each dentition class and for the pooled data by sex categories. The choice of the best fitted regression model was assessed using coefficient of determination (R^2).

The Statistical Model employed for linear body measurements:

$$Y_{ij} = \mu + S_i + D_j + (S*D)_{ij} + e_{ij}$$

Where:

- Y_{ij} = The observations on body weight, wither height, body length, heart girth, pelvic width, ear length and scrotal circumference
- μ = Overall mean
- S_i = Fixed effect of sex (k = Male, female)
- D_j = Fixed effect dentition (j = 0-5PPI)
- $(S*D)_{ij}$ = Interaction effect of sex and dentition
- e_{ij} = Error effects

The multiple linear regression model for females:

$$Y_j = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + e_{ij}$$

Where:

- Y_j = The dependent variable body weight
- β_0 = The y intercept for the independent variables X_{1-5} which are body length, height at wither, chest girth, pelvic width, ear length, respectively
- β_1-β_5 = The regression coefficients of the variables X_{1-5}, respectively
- e_j = The residual error

The multiple linear regression model for males:

$$Y_j = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e_{ij}$$

Where:

- Y_j = The dependent variable body weight
- β_0 = The intercept
- X_{1-6} = The independent variables for body length, height at wither, chest girth, pelvic width, ear length and scrotal circumference, respectively
- β_{1-6} = The regression coefficients of the variables X_{1-6}, respectively
- e_j = The residual error

Indices were calculated to provide ranking of selection criteria and the reasons of keeping goat and calculated as Index = Sum of (3 for rank 1+2 for rank 2+1 for rank 3) given for an individual reason divided by the sum of (3 for rank 1+2 for rank 2+1 for rank 3) for overall reasons.

RESULTS AND DISCUSSION

Flock composition: The total number of observation was 764 goats including kids obtained from 74 participant farmers in the watershed. Therefore, the average goat flock size per household was found to be 8.13. From Table 1, it is observed that the number of male goats decline as age advances implying that higher number of females are kept in the flock for longer age than male goats. This may be because male goats are taken to market at early age keeping only few breeding bucks as sire for their own flock. Small number of castrates at early age and rise at dentition 2 indicates the time when the farmers practice castration. Flock composition in terms of sex and age classes has been taken as an indicator of the management system, to some degree the management objectives, flock productivity and constraints on the system (Ibrahim, 1998).

Goat holding: Flock structure shows that mean and standard deviation of goat flock was 3.44±2.13 with range

Table 1: Flock composition by sex and dentition groups

	Dentition							
Sex	0	1	2	3	4	5	Total	[1]AFSH
Female								
N	110.0	69.0	42.0	47.0	158.0	9.0	435.0	8.13
%	18.2	11.4	7.0	7.8	26.2	1.5	72.0	
Male								
N	85.0	12.0	11.0	7.0	27.0	NA	142.0	
%	15.0	2.1	2.0	0.8	3.6		23.5	
Castrate								
N	1.0	2.0	11.0	3.0	10.0	NA	27.0	
%	0.2	0.3	1.8	0.5	1.7		4.5	
Total								
N	196.0	83.0	64.0	57.0	195.0	9.0	604.0	
%	33.4	13.8	10.8	8.6	31.5	1.5	100.0	

N = No. of observations; NA = Not Available; [1]AFSH = Average Flock Size per Household including kids of 1-13 for kids, 2.05±1.52 with range of 1-7 for kid bucks, 2.52±1.11 with range of 1-5 for kid does, 1.96±1.62 with range of 1-9 for breeding bucks, 4.51±2.9 with range of 1-20 for breeding does and 1.87±1.58 with range of 1-7 for castrated males. The total number of goats per household, on average was found to be 11.31±7.74 with range of 2-52. Of the total flock, does account for 27.58%, bucks 11.99%, castrates 11.44%, kid bucks 12.54%, kid does 15.41% and kid goats account for 21.04%. This indicates that the breeding does made a major share of the goat population in the watershed followed by kids and kid does.

Purposes of keeping goats: Ranking of the goat production objectives by smallholder farmers is presented in Table 2. The primary reason of goat owners for keeping goats was found to be generating income followed by saving, meat consumption, manure and skin in their order of importance with indices of 0.461, 0.279, 0.197, 0.056 and 0.007, respectively.

Selection criteria: Most of the respondents (93 and 98.6%) practice selection of best male and female goats as parent of the next generation from their flocks. The selection criteria for breeding does in their order of importance were kid growth, height, mothering ability, twinning rate, coat color and short kidding interval with index of 0.333, 0.217, 0.197, 0.110, 0.100 and 0.043, respectively (Table 3). Therefore, priority is given to traits of does that would ensure survival of the kids and breeders should consider kid growth does height, mothering ability and twinning ability as the first four reasons for does selection. For breeding bucks, height, coat color, fast growth, libido and horn type and orientation were the selection criteria as prioritized by farmers with indices of 0.404, 0.255, 0.255, 0.071 and 0.015, respectively.

Culling and castration: Most farmers (94.3 and 91.4%) practice culling of does and bucks, respectively. The main reasons for culling does were poor mothering ability (24.2%), as well as poor body condition and poor mothering ability together (22.7%). The main reasons for culling bucks were undesirable color and poor body condition together (29.7%) followed by poor body condition (25%). The primary use of culled goats was to generate income or to slaughter for home consumption (64.2%) and to generate income (35.8%). Most farmers practice culling of does (78.5%) and bucks (90.5%) at the age of <3 years.

About 77.5% of the respondents practice castration of their bucks using traditional (59.3%), modern (37.0%) and both (3.7%) methods. The traditional method of castration is done using wood and round stone to crush the spermatic cord. The average age of castration was 2.29±0.69 years (range 1-3 years). Most of the farmers (45.5%) castrate goats at the age of between 2 and 3 years, 41.8% of respondents at age of above 3 years and 12.7% castrate at the age of between 1 and 2 years.

The farmers who castrate their goats during October and June (twice per year) and October to December (with in period of 3 months) are 46.3 and 20.4%, respectively. High proportion (79.6%) of the farmers provide castrate goats with supplement like oil seed cake, grains, leaf of fodder trees and local beer by-product (atela) for about 3 months to >2 years with irregular pattern and amount. The purpose of castration varies among the farmers. Most of the farmers (70.9%) castrate bucks when they want to fatten and sell them while 14.5% castrate to control breeding as well as to fatten. The third priority reason of castration was fattening and controlling buck's behavior together (9.1%) followed by to control buck's behavior only (3.6%) and to maintain controlled breeding (1.8%).

Buck holding, mating and kidding pattern: The average number of intact bucks per household was 1.96±1.62 with a range of 1-9 and the average duration of stay for a buck in a flock while serving was 1.18±0.39 year with a

Table 2: Ranking breeding objectives of goat keeping farmers

Production objectives	Rank			
	1st	2nd	3rd	Index
Cash income	56	13	2	0.461
Meat	1	21	39	0.197
Manure	1	6	9	0.056
Skin	0	0	3	0.007
Saving	13	31	18	0.279

Table 3: Ranking farmers' selection criteria for breeding does and bucks

Selection criteria	Rank			
	1st	2nd	3rd	Index
Breeding does				
Height	10	19	23	0.217
Coat color	5	9	9	0.100
Kid growth	35	11	13	0.333
Mothering ability	13	16	12	0.197
Short kidding interval	2	4	4	0.043
Twinning capacity	5	11	9	0.110
Breeding bucks				
Height	39	18	7	0.404
Coat color	7	31	18	0.255
Horn type and orientation	0	2	2	0.015
Fast growth	17	10	30	0.255
Libido	3	5	9	0.071

Index = Sum of (3×No. of household ranked 1st+2×No. of household ranked 2nd+1×No. of household ranked 3rd) given for each criterion divided by: 3×total No. of household ranked 1st+2×total No. of household ranked 2nd+1×total No. of household ranked 3rd range of 1-2 years. Only 43.7% of the respondents had their own buck whereas 56.3% the respondents use their neighbors' bucks (87.5%) from communal grazing areas (5%) and from neighbors and communal grazing areas (7.5%) to mate their does in estrous in the field. Only 22.6% of the respondent farmers practice special care for their buck including additional feeding (85.7%) and health care (14.3%).

From the total respondents who have their own bucks, 74.2% respond that their sire serve their own and neighbors' flocks. The second common type of buck service is uncontrolled (19.4%). The source for replacement breeding buck were from own kid bucks (73%) from other farmer kid bucks (17.5%) from own kid bucks and market together (6.3%) and from market (3.2%), respectively.

There was no definite mating season, hence kids were born all the year round. However, months of the year with frequent births were from October to December and June to July (57.9%) from September to November and April to June (32.1%) and November and June (10%), respectively. Farmers mentioned feed availability (97.1%) as major reason for seasonal pattern of kidding.

Reproductive performances: Reproductive performance of the breeding goat is the single most important factor influencing flock productivity. Estimates of reproductive performances of this study could only be indicative, since information provided by farmers would necessarily carry some element of uncertainty.

Age at sexual maturity and first kidding: The average (mean±SD) age at sexual maturity in male and female goats was 9.74±2.53 (range 4-12 months) and 7.61±2.62 (range 4-18 months) months, respectively. The average age at first kidding was 13.86±3.31 months (range 10-24 months).

Kidding interval, litter size and reproductive life span of does: The overall mean kidding interval of goats was 6.35±1.11 months. This result was lower than reported kidding interval for Abergelle and Central Highland goats which were 11.31±2.21 and 10.3 ±1.42 months, respectively and 8.4±1.37 months for Metema goats (Alemu, 2004). The overall average litter size was 1.85±0.36 kids per doe per kidding. This result was higher than reported litter size for Abergelle and Central Highland goats which were 1.04±0.03 and 1.16±0.04 kids per doe per kidding, respectively.

The overall mean reproductive life time of does in the flock was 9.86±2.73 with a range of 6-20 years and the average number of kids per doe per life time was 19.99±7.16 with a range of 8-45. These results are good indicator of the high reproductive potential of the goats in the area.

Constraints to goat production: Production constraints, which were defined by goat owners in the watershed are presented in Table 4. Disease was the leading goat production constraint (index of 0.31) identified in the study area followed by wild animal attack (index of 0.22) and feed shortage (index of 0.10). Water shortage, drought, input access, poor performance of the breed, labor shortage, extension service, theft and market access were also the constraints for goat production. Low genetic potential of the goat population was ranked lowly in the study area. This might be due to lack of awareness of goat owners about genotype. Furthermore in the study area, the interest of goat owners for better height, fast growth and mothering ability were indirect indicators of their interest on improvement of their goat genotype.

Qualitative physical traits: Coat color pattern and type and physical characteristics of the goat population in Gumara-Maksegnit watershed area is presented in Table 5. The result shows that the proportions of plain, patchy and spotted patterns are almost similar. As far as color type is concerned, white (24.2%) is the dominant in a plain pattern followed by red with white color (19.5%). Their hair type is dominantly (88.6%) fur short and smooth type. Hairy thighs were observed on 3.9% of females and 2.2% of males. Head profile of 89.4% of the goats was found to be straight. Wattle and ruff were present only on 10.6 and 22.3% of the goats, respectively. About 54% of the goats' ears are carried horizontally and 46% semi-pendulous. Horn shape for 86.4% goats is straight with 91.8% backward orientation. Polled goats were 1.8% female and 1.3% male of the total population (Fig. 1).

Table 4: Ranking production constraints of goat keeping farmers

Production constraints	Rank 1st	2nd	3rd	4th	5th	Index
Disease	49	12	5	3	0	0.31
Feed shortage	2	6	13	12	10	0.10
Water shortage	3	5	10	5	3	0.08
Labor shortage	0	5	4	6	2	0.04
Market access	0	1	1	1	0	0.01
Predator/wild animal attack	11	30	9	7	4	0.22
Poor performance of the breed	1	2	6	6	5	0.05
Input access	0	5	6	7	4	0.06
Extension service	0	0	4	2	10	0.03
Drought	1	2	9	9	13	0.07
Thief	2	1	0	4	6	0.03

Index = Sum of (5×No. of household ranked 1st+4×No. of household ranked 2nd+3×No. of household ranked 3rd+2×No. of household ranked 4th+1×No. of household ranked 5th) given for each purpose divided by (5×total No. of household ranked 1st+4×total No. of household ranked 2nd+3×total No. of household ranked 3rd+2×total No. of household ranked 4th+1×total No. of household ranked 5th)

Table 5: Physical body characteristics of goats in Gumara-Maksegnit watershed area

		Female		Male		Total	
Traits	Attributes	N	%	N	%	N	%
Coat color pattern	Plain	135	22.4	71	11.8	206	34.2
	Patchy	134	22.2	54	8.9	188	31.1
	Spotted	166	27.5	43	7.1	209	34.7
Coat color type	White	88	15.4	50	8.8	138	24.2
	Black	5	0.5	11	1.3	16	1.8
	Grey	12	2.1	3	0.6	15	2.6
	Roan	27	3.4	20	3.1	37	6.5
	Red and white	90	15.8	21	3.7	111	19.5
	White, red and black	58	10.2	14	2.4	72	12.6
	Red and black	19	2.1	10	1.8	22	3.9
	Roan, white and red	18	3.2	5	0.9	23	4.0
	White and black	11	1.9	3	0.6	14	2.5
	Fawn and white	70	12.3	35	6.2	105	18.4
	Roan, black and white	19	2.0	14	2.0	23	4.0
Hair type	Fur short and smooth	393	66.6	130	22.0	523	88.6
	Fur long and coarse	13	2.2	18	3.0	31	5.3
	Fur with hairy thighs	23	3.9	13	2.2	36	6.1
Head profile	Straight	398	66.2	139	23.2	537	89.4
	Slightly concave	31	5.2	23	3.8	54	9.0
	Markedly concave	6	1.0	4	0.6	10	1.6
Wattle	Absent	391	65.1	146	24.3	537	89.4
	Present	44	7.3	20	3.3	64	10.6
Ruff	Absent	403	67.2	63	10.5	466	77.7
	Present	31	5.2	103	17.2	134	22.3
Ear form	Carried horizontally	230	38.3	94	15.6	324	53.9
	Semi-pendulous	205	34.1	72	12.0	277	46.1
Horn shape	Polled	11	1.8	8	1.3	19	3.2
	Scurs	18	3.0	13	2.2	31	5.2
	Straight	385	64.1	134	22.3	519	86.4
	Curved	21	3.4	11	1.8	32	5.2
Horn orientation	Obliquely upward	5	0.8	3	0.5	8	1.3
	Backward	404	67.3	147	24.5	551	91.8
	Polled	4	0.7	3	0.5	7	1.2
	Scurs	21	3.5	13	2.2	34	5.7

N = No. of observations

Fig. 1: Phenotypic appearances of goats in Gumara-Maksegnit watershed and group discussion with farmers in the area

Linear body measurements: Least square means of body measurements of goat population in Gumara-Maksegnit watershed as displayed in Table 6 were 33.4±0.5 kg body weight, 74.4±0.5 cm wither height, 62.6±0.4 cm body length, 74.2±0.5 cm heart girth, 12.3±0.1 cm pelvic width, 13.9±0.1 cm ear length, 22.0±0.4 cm scrotal circumference and 2.9±0.1 body condition score.

Strongly significant differences ($p<0.001$) were observed in all body measurements and body condition scoring between male and female goats except for ear length. Males have higher body size than females. Castrates also have larger ($p<0.01$) body measurements than intact male goats and female goats except ear length. Additionally, castrates were significantly larger ($p<0.01$) in body weight than mature intact male goats which in turn were larger than mature females.

Except for ear length, all body measurements including body weight showed highly significant variation at 0-3 Pairs of Permanent Incisors (PPI). There was a sharp decline in difference between values for body weight, wither height, body length, chest girth and pelvic width post dentition group 3. Under normal conditions, this is expected since animals grow fast when younger but grow slowly when they reach maturity (Mekasha, 2007). Hence, the goat populations in the area attain maturity at 3PPI. Moreover, body length, wither height, heart girth and pelvic width showed significant variability in an increasing trend as the animal age advances. This implies that growth pattern of the animals might be explained well by body measurements. These results are in line with Girum who found similar results on short eared Somali Goat population around Dire Dawa, Ethiopia. Scrotal circumferences at dentition 0PPI were identical with dentition 1PPI and 3PPI but significantly smaller than those at dentition 2PPI ($p<0.001$). This can be a good indicator of the age at which the animals attain their maximum sexual maturity and start to decline after age of 2 years and above as differences in physiological stage due to age influence body size and testicular growth in domestic animals (Karagiannidis *et al*., 2000).

Body condition of females was similar with males but better ($p<0.001$) body condition was observed on castrates than both females and males. There was no significant difference in body condition of goats

Table 6: Linear body measurements of goat population in Gumara-Maksegnit watershed by sex and dentition

		Least Squares Means±Standard Error							
Variables	N	BW	WH	BL	HG	PW	El	SC	BC
Overall	604	33.4±0.5	74.4±0.5	62.6±0.4	74.2±0.5	12.3±0.1	13.9±0.1	22.0±0.4	2.9±0.1
CV		17.9	6.41	7.45	6.39	10.8	8.41	13.6	22.8
R^2		0.75	0.66	0.68	0.76	0.66	0.26	0.30	0.12
Sex		***	***	***	***	***	NS	-	***
Female	435	27.4^{c}	69.3^{c}	58.9^{c}	69.8^{c}	11.8^{c}	14.1	-	2.5^{b}
Male	142	33.3^{b}	74.7^{b}	61.4^{b}	74.3^{b}	12.1^{b}	13.8	-	3.1^{b}
Castrate	27	40.8^{a}	81.2^{a}	68.3^{a}	79.3^{a}	13.1^{a}	13.9	-	3.4^{a}
Dent		***	***	***	***	***	NS	***	**
0	214	20.8^{d}	66.6^{c}	53.7^{d}	62.7^{d}	10.4^{d}	13.3	19.2^{b}	2.7^{b}
1	90	27.2^{c}	72.4^{b}	60.3^{c}	69.6^{c}	11.1^{c}	13.6	22.1^{ab}	2.8^{b}
2	67	35.0^{b}	76.7^{a}	63.8^{b}	75.9^{b}	12.4^{b}	13.9	24.1^{a}	2.8^{b}
3	52	41.1^{ab}	78.9^{a}	67.0^{b}	80.1^{ab}	13.8^{a}	14.5	22.6^{ab}	3.3^{a}
4	172	42.7^{a}	79.2^{a}	67.5^{ab}	82.1^{a}	13.5^{ab}	14.4	-	3.3^{a}
5	9	34.2^{ab}	73.7^{a}	65.1^{a}	75.9^{ab}	13.4^{ab}	13.8	-	2.3^{c}
Sex*Dent.		***	***	*	***	NS	NS	-	**
Female*0	110	17.0^{h}	60.9^{f}	50.1^{h}	59.2^{i}	9.2	13.1	-	2.7^{c}
Female*1	69	22.9^{f}	67.1^{e}	55.6^{g}	66.4^{h}	11.1	14.1	-	2.5^{e}
Female*2	42	26.9^{e}	70.0^{d}	58.8^{f}	69.7^{g}	11.9	14.2	-	2.4^{e}
Female*3	47	29.8^{d}	71.4^{cd}	60.7^{e}	72.4^{f}	12.5	14.5	-	2.5^{de}
Female*4	157	33.4^{c}	72.7^{cd}	63.0^{cd}	75.3^{e}	12.9	14.6	-	2.6^{de}
Female*5	9	34.2^{c}	73.8^{cd}	65.1^{cd}	75.9^{de}	13.4	13.8	-	2.3^{e}
Male*0	103	18.4^{g}	63.0^{e}	51.0^{h}	59.9^{i}	9.1	12.9	-	2.6^{de}
Male*1	19	28.2^{de}	73.5^{d}	59.8^{ef}	70.8^{fg}	11.1	13.6	-	2.9^{bcd}
Male*2	14	35.6^{c}	78.1^{c}	64.1^{d}	76.8^{de}	12.4	13.8	-	2.8^{cde}
Male*3	2	42.1^{b}	81.0^{ab}	67.0^{bcd}	81.5^{bcd}	14.5	14.0	-	3.5^{abc}
Male*4	4	42.2^{b}	78.0^{bcd}	65.2^{cd}	82.7^{bc}	13.2	14.7	-	3.7^{ab}
Castrate*0	1	27.0^{defg}	76.0^{bcd}	60.0^{cdefg}	69.0^{efgh}	13.0	14.0	-	3.0^{abcde}
Castrate*1	2	30.5^{cde}	76.7^{bcd}	65.5^{cde}	71.5^{defgh}	11.0	13.2	-	3.0^{abcde}
Castrate*2	11	42.5^{b}	82.1^{b}	68.3^{bc}	81.2^{b}	13.0	13.6	-	3.2^{ab}
Castrate*3	3	51.5^{a}	84.3^{ab}	73.3^{ab}	86.7^{ab}	14.3	15.0	-	4.0^{a}
Castrate*4	10	52.4^{a}	87.1^{a}	74.4^{a}	88.3^{a}	14.4	13.8	-	3.6^{a}

[1]Dentition: 0 = Sheep with milk teeth (>9 months); 1 = Sheep with 1 Pair of Permanent Incisor (PPI); 2 = Sheep with 2PPI; 3 = Sheep with 3 PPI; 4 = Sheep with 4 PPI; 5 = Goats with broken and smooth mouth; NS: Not Significant ($p>0.05$); *, **, ***$p<0.05$, 0.01 and 0.00, respectively; BW = Body Weight; WH = Wither Height; BL = Body Length; HG = Heart Girth; PW = Pelvic Width; EL = Ear Length; SC = Scrotal Circumference; BC = Body Condition scoring

at 0-2PPI which were smaller than the goats at later ages (3 and 4 PPI). Meanwhile, the oldest goats at 5PPI showed thin body condition. Nevertheless, at youngest age group body condition was the same for male and female goats. Mature castrate and intact goats were also identical but significantly ($p<0.01$) better than those of mature females. This might be explained by the effect of nourishing kids that breeding does loss condition as they provide milk for their offspring.

Growth curve of the goat population: About 5 dentition categories were used for growth curve of the goat population in the watershed (0-5PPI). The curve obtained from growth data of the goat population in the scatter plot of Fig. 2 is close to sigmoid shape (Yakupoglu, 1999). As illustrated in Fig. 2, the growth of the goats can be better

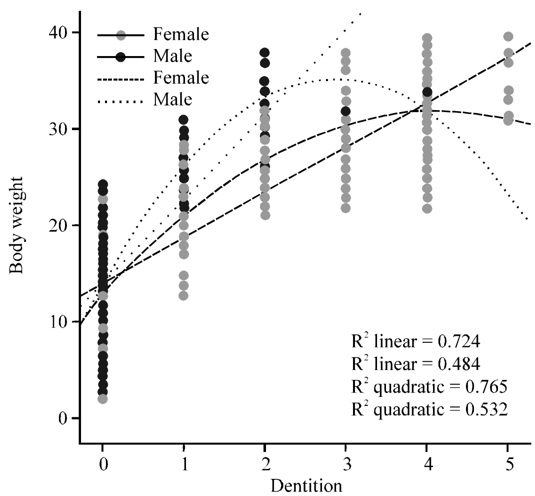

Fig. 2: Growth curve of goat population in Gumara, Markesegnit watershed area

explained by quadratic curve (R^2 = 72.6%) than linear curve (R^2 = 67.3%). Besides, it can be clearly observed that the goats kept growing at an increasing rate up to dentition 2 and at a declining rate up to dentition 3. Afterwards, no rise in body weight was noticed on the curve. Therefore, it is possible to conclude that the goats attain their maturity at age of dentition 3.

Correlation between body weight and measurements: Correlation between body weight and other linear body measurement of male and female goats at different age categories were explained by correlation coefficients (r) (Table 7). The most significantly correlated body measurement with body weight was heart girth in both male and female goats at all stages of growth. Other body measurements which had strongly positive and highly significant correlations with body weight were wither height, body length and pelvic width at most age categories. This high association between heart girth and body weight indicates that this variable could provide a good estimate in predicting live weight of the population. Studies by Badi *et al.* (2002) on Barka and Afar goat types, Girum on Somali goat types and Slippers *et al.* (2000) on Nguni goats also came up with similar results. Scrotal circumference showed the highest association with body weight at ages of 3-4PPI of bucks (0.92) but non-significant correlation at 1 and 2PPI implying that at mature age (3PPI and above), goats with larger scrotal circumference may have larger body size. Strong correlation ($p<0.01$) between body weight and body condition score was only observed for male dentition 2PPI and pool data. Otherwise, non significant and negative associations between body weight and body condition scoring were observed. This may be related to facts reported by Mekasha (2007) and Nsoso *et al.* (2003) that

Table 7: Correlation coefficients of body weight and other body measurements within age groups and sex

		Age groups									
		Female					Male				
Traits		0PPI	1PPI	2PPI	3-5PPI	0-5PPI	0PPI	1PPI	2PPI	3-4PPI	0-4PPI
WH	r	0.70**	0.57**	0.43**	0.40**	0.78**	0.79**	0.83**	0.73**	0.76**	0.92**
	N	110	69	42	213	434	103	21	25	19	168
BL	r	0.65**	0.67**	0.67**	0.63**	0.86**	0.83**	0.64**	0.85**	0.85**	0.94**
	N	110	69	42	213	434	104	21	25	19	169
HG	r	0.82**	0.84**	0.80**	0.76**	0.92**	0.93**	0.83**	0.89**	0.93**	0.97**
	N	110	69	42	213	434	104	21	25	19	169
PW	r	0.69**	0.47**	0.22^{NS}	0.44**	0.79**	0.71**	0.71**	0.77**	0.42^{NS}	0.91**
	N	110	69	42	213	434	104	21	25	19	169
EL	r	0.37**	0.42**	0.30	0.20**	0.49**	0.36**	0.20^{NS}	0.08^{NS}	0.16^{NS}	0.43**
	N	110	69	42	213	433	104	21	25	19	169
SC	r	NA	NA	NA	NA	NA	0.61**	0.35^{NS}	0.31^{NS}	0.91**	0.72**
	N	NA	NA	NA	NA	NA	86	18	13	3	120
BC	r	-0.09^{NS}	0.28**	0.38*	0.34**	0.12*	0.20*	0.36^{NS}	0.51**	0.13^{NS}	0.52**
	N	110	69	42	213	434	104	21	25	19	169

NS = Non Significant; $^{*, **}$p<0.05 and 0.01, respectively; WH = Wither Height; BL = Body Length; HG = Heart Girth; PW = Pelvic Width; EL = Ear length; SC = Scrotal Circumference; BC = Body Condition Score; PPI = Pair of Permanent Incisors; NA = Non-Applicable body condition score is an important variable measuring body reserves, i.e., lipids than body weight and thus, the nutritional status of an animal.

Prediction of body weight from linear measurements: Through stepwise elimination procedure, out of 6 body measurements, those that best fitted the models in the pooled data were heart girth, body length, wither height and pelvic width. However in the females pooled regression model, only three regressors (heart girth, body length and wither height) and in male goats three regressors (heart girth, body length and pelvic width) were found to have significant association with body weight at $p<0.05$. Meanwhile, heart girth and body length were the variables found to best fit to predict live weight of goats when all age categories and both sex of the goat population were pooled (Table 8).

The adjusted coefficient of determination (adjusted R^2) represents the proportion of the total variability explained by the model. The adjusted R^2 values computed for the body measurements were generally higher for the male's pooled data (95.0%) than the pooled data for females (86.0%). This may imply that body weight could be predicted with better accuracy for males than for their female counterparts. Similar inference was made by Girum for higher R^2 values of males than females of short eared Somali goats.

Heart girth was found to be the best estimator of live weight for both female (adjusted R^2 = 84.0%) and males (adjusted R^2 = 95.0%) goats and consistently selected and entered into the model in step one procedure of stepwise regression due to its larger contribution to the model than other variables. Nevertheless, parameter estimates in multiple linear regression models showed that subsequent inclusions of parameters on the heart girth improved the adjusted R^2 value from 84-86% for does. This suggests that for female goats, body weight could be more accurately predicted by combinations of heart girth and body length than heart girth alone. Gul also came up with similar results on Damascus goats. However, measurement of additional traits also has cost implications and it may be unpractical to consider many traits under farmers' conditions though no economic feasibility study was conducted.

Thus, researchers suggest prediction equations for does of pooled age group: BW = 0.92 HG-42.8 and BW = 0.67 HG+0.29 BL-44.3 and for bucks of pooled age group: BW = 0.97 HG-45.5 under farmers' management conditions.

Table 8: Regression models for predicting body weight of goats in Gumara-Maksegnit watershed at different age groups

Dentition[1]	Model[2]	b_0	b_1	b_2	b_3	Adjusted R^2	R^2 change	SE
Female								
0	$a \pm b_1 HG$	-22.0	0.817			0.66	0.00	2.26
	$a \pm b_1 HG \pm b_2 BL$	-25.7	0.676	0.226		0.69	0.03	2.16
1	$a \pm b_1 HG$	-44.0	0.838			0.70	0.00	2.63
	$a \pm b_1 HG \pm b_2 BL$	-46.2	0.683	0.254		0.73	0.03	2.47
2	$a \pm b_1 HG$	-30.2	0.804			0.64	0.00	2.05
	$a \pm b_1 HG \pm b_2 BL$	-40.7	0.635	0.402		0.77	0.13	1.64
3	$a \pm b_1 HG$	-55.2	0.834			0.69	0.00	2.41
	$a \pm b_1 HG \pm b_2 BL$	-61.6	0.700	0.282		0.74	0.05	2.18
4	$a \pm b_1 HG$	-48.4	0.732			0.53	0.00	4.28
	$a \pm b_1 HG \pm b_2 BL$	-60.2	0.563	0.320		0.60	0.07	3.94
5	$a \pm b_1 HG$	-52.6	0.864			0.71	0.00	1.72
Female pooled	$a \pm b_1 HG$	-42.8	0.917		0.84		0.00	3.33
	$a \pm b_1 HG \pm b_2 BL$	-44.3	0.672	0.288		0.86	0.02	3.08
	$a \pm b_1 HG \pm b_2 BL \pm WH$	-42.5	0.702	0.328	-0.077	0.86	0.00	3.07
Male								
0	$a \pm b_1 HG$	-25.2	0.933			0.87	0.00	1.56
	$a \pm b_1 HG \pm b_2 BL$	-26.3	0.740	0.239		0.89	0.02	1.44
1	$a \pm b_1 HG$	-36.9	0.830			0.67	0.00	2.22
	$a \pm b_1 HG \pm b_2 BL$	-46.5	0.679	0.332		0.75	0.08	1.93
	$a \pm b_1 HG \pm b_2 BL \pm PW$	-41.1	0.524	0.285	0.309	0.81	0.06	1.69
2	$a \pm b_1 HG$	-65.2	0.895			0.79	0.00	2.86
	$a \pm b_1 HG \pm b_2 BL$	-67.8	0.583	0.410		0.86	0.07	2.35
	$a \pm b_1 HG \pm b_2 BL \pm PW$	-69.2	0.513	0.302	0.237	0.88	0.02	2.12
3	$a \pm b_1 HG$	-93.4	0.996			0.99	0.00	0.99
4	$a \pm b_1 HG$	-73.4	0.900			0.79	0.00	3.19
Male pooled	$a \pm b_1 HG$	-45.5	0.973			0.95	0.00	2.80
	$a \pm b_1 HG \pm b_2 BL$	-46.8	0.759	0.227		0.95	0.00	2.65
	$a \pm b_1 HG \pm b_2 BL \pm PW$	-45.8	0.681	0.218	0.094	0.95	0.00	2.65
Overall	$a \pm b_1 HG$	-43.2	0.939			0.88	0.00	3.28
	$a \pm b_1 HG \pm b_2 BL$	-45.3	0.692	0.278		0.90	0.02	3.05

[1]Dentition: 0 = Goats with milk teeth; 1 = Goats with one Pair of Permanent Incisor (PPI); 2 = Two PPI; 3 = Three PPI; 4 = Four PPI and 5 = Goats with broken and smooth mouth; [2]Dependent variable: BW (Body Weight); HG = Heart Girth; BL = Body Length; WH = Height at wither; PW = Pelvic Width

CONCLUSION

Phenotypically, the goat population in Gumara-Maksegnit watershed area can be characterized by white coat color in a plain pattern followed by red with white color in patchy and spotted pattern. Determination of economic value of these qualitative traits may help while selecting breed improvement alternatives.

As there was no significant change in body weight after eruption of 3 pair of permanent incisors, this age can be considered as the age at which the goat population in the area attains maturity.

Highly significant variation in live weight and body measurement traits of the goat at different stages of growth was noticed. This variation implies the possibility of selection as promising intervention option for future improvement.

At farmers' management condition, heart girth of male goats and combination of heart girth with body length of female goats can be used to estimate body weight based on the prediction equations at conditions where measuring live weight is impractical for cases like determining dose of drugs on live weight bases for huge number of flocks. It's also possible to prepare a reference chart where list of measurements and proportional body weights can be easily been obtained.

The major goat production problems identified were disease, predator and feed shortage in their priority. Thus, development of health care interventions and practicing cut and carry feeding strategies using available feeds and development of adaptive forage species and conservation methods can be helpful.

ACKNOWLEDGEMENTS

Researchers would like to thank International Center Agricultural Research in the Dry Areas (ICARDA) for financing this research. We sincerely acknowledge researchers in Gondar Agricultural Research Center for their support during data collection as well as farmers and development agents in study areas for their collaboration and participation.

REFERENCES

Alemu, T., 2004. Genetic characterization of indigenous goat populations of Ethiopia using microsatellite DNA markers. Ph.D. Thesis, National Dairy Institute, Haryana, India.

Ayalew, W., A. van Dorland and J. Rowlands, 2004. Design, execution and analysis of the livestock breed survey in Oromia Regional state, Ethiopia. OADB (Oromiay Agricultural Bureua), Addis Ababa, Ethiopia, ILRI, Nairobi Kenya.

Badi, A.M.I., N. Fissehaye and P.J.S. Rattan, 2002. Estimation of live body weight in Eritrean goat from heart girth and height at withers. Indian J. Anim. Sci., 72: 893-895.

ESGPIP, 2009. Estimation of weight and age of sheep and goats. Technical Bulletin No. 23. http://www.esgpip.org/PDF/Technical%20bulletin%20No.23.pdf.

FAO, 2012. Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines No. 11, Rome, Italy.

Ibrahim, H., 1998. Small Ruminant Production Technique. International Livestock Research Institute, Nairobi, Kenya, Pages: 207.

Karagiannidis, A., S. Varsakeli and G. Karatzas, 2000. Characteristics and seasonal variations in the semen of Alpine, Saanen and Damascus goat bucks born and raised in Greece. Theriogenology, 53: 1285-1293.

Mekasha, Y., 2007. Reproductive traits in Ethiopian male goats, with special reference to breed and nutrition. Ph.D. Thesis, Department of Clinical Sciences, Faculty of Veterinary Medicine and Animal Sciences, Swedish University of Agricultural Science, Uppsala, Sweden.

Mengistu, U., 2007. Performance of the Ethiopian Somali goats during different watering regimes. Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Morand-Fehr, P., J.P. Boutonnet, C. Devendra, J.P. Dubeuf and G.F.W. Haenlein *et al*., 2004. Strategy for goat farming in the 21st century. Small Rumin. Res., 51: 175-183.

Nsoso, S.J., B.P. Aganga, B.P. Moganetsi and S.O. Tshwenyane, 2003. Body weight, body condition score and heart girth in indigenous Tswana goats during the dry and wet seasons in southeast Botswana. Livestock Res. Rural Dev., 15: 1-7.

Slippers, S.C., B.A. Letty and J.F. De Villiers, 2000. Predicting the body weight of Nguni goats. S. Afr. J. Anim. Sci., 30: 127-128.

Yakupoglu, C., 1999. Etlik piliclerde buyume egrilerinin karsilastirilmasi. M.Sc. Thesis, Ege University Natural Science Institute, Izmir, Turkey.