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Original Research

Impact of Crossbreeding Sahelian x Anglo-Nubian Goats on Growth Performance and Morphobiometric Characteristics of Kids in the Sahelian Zone

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Abstract

Goat genetic resources are one of the main agropastoral resources of West African countries. They play a key role in the fight against poverty and food insecurity. However, the productivity of these resources remains low on most farms. The aim of the study was to improve the growth performance of goats by crossbreeding Sahelian goat (SG) with Anglo-Nubian (AN) crossbred. Thus, the experiment carried out from 2010 to 2016, involved three genetic types of goats (SG, ½AN and ¾AN) raised in a semi-intensive system. In addition to grazing, the herds were supplemented with concentrates (cottonseed cake and wheat bran). Birth weight at 12 and 24 months of age and morphobiometric measurements were collected and analyzed using R 4.0.5 software. The average birth weights of ½AN (2.65±0.54 kg) and ¾AN (2.53±0.55 kg) kids were higher ($p < 0.05$) than those of SG (2.39±0.5 kg). Also, at 24 months of age, the adults of ½AN (43.3± 13.6 kg) and ¾AN (37.130±8.6 kg) crossbreds were heavier ($p < 0.001$) than those of SG (26.7±4.4 kg). Ultimately, the resulting crossbreds have very promising potential that can be used to strengthen meat production in the Sahelian zone.

KEYWORDS
Anglo-Nubian breed. Crossbreeding, Live weight, Morphobiometry, Sahelian goat.

INTRODUCTION

Livestock production plays an important role in Mali's economy. It has made Mali the largest livestock country in the West African Economic and Monetary Union and the second largest livestock country in the Economic Community of West African States after Nigeria in terms of livestock numbers (Diagne and Pelon, 2014). Sheep and goats are raised by a significant proportion of its rural and urban population. Its livestock is estimated at 20,142,677 sheep and 27,810,553 goats (DNPIA, 2020). The use of different breeds of small ruminants allows many poor households to meet their livelihood needs (food, health, schooling of children, cultural events) (Wasso *et al.*, 2018; Sacko, 2021).

The adaptive capacity of goats to arid, semi-arid and mountainous regions for feeding on available food resources differentiates them from sheep and cattle that cannot cope with these farming conditions. Goats have a relatively short reproductive cycle and a high prolificacy. They have the ability to produce milk, especially during lean periods when cows produce little milk.

The goat is also a source of several valuable products: apart from meat, which is widely consumed, there is of course the manure, but above all the milk for its marketing, the manufacture of cheese and their skins for the leather industry (Mpatswenumugabo, 2009).

In West Africa, goat farming, because of its potential and multifunctionality, can play a major role, particularly in animal-based foods. The apparent individual consumption of dairy products in Mali is 50 to 60 kg / year / hbt (Peacock, 2005; Rhissa, 2010; FAOSTAT, 2012). Despite this numerical and socio-economic importance, local sheep and goats have very low productivity compared to exotic breeds. Their daily milk production varies from 0.2 to 1 liter and their adult live weight from 20 to 35 kg against 3 to 5 liters of milk per day and 90 to 150 kg of live weight for exotic breeds, and their crossbred, 2-3 liters of milk per day; 40-80 kg live weight adult (Dao, 2016). The low milk and beef production of local breeds is partly characteristic of their genetic potential, which is low because of the absence of an effective genetic improvement program (Boly *et al.*, 2001; Sacko, 2021).

Indeed, Sahelian goats are hypermetric and long. It is tall (70 to 85 cm at the withers) and weighs between 25 and 35 kg. The goat dress is often combined with two or three colors: black, white, and red (Chamchadine, 1994). The Anglo-Nubian goat is the result of crossbreeding between English goat breeds and those from India and Africa. It is a large breed whose bucks can reach 120 kg for the male and 90 kg for the doe. Its coat has many different colors (Mauriès, 2017). In this context, crossbreeding local breeds with exotic breeds is a real and rapid opportunity to boost small ruminant production in Mali (Sanogo *et al.*, 2012).

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Crossbreeding can be a selection strategy to facilitate genetic improvement of local goat production (Hosseini *et al*., 2017). It results in a heterosis effect for milk production and weight gain when the average performance of crossbred offspring is higher than the average performance of purebred (Momani *et al*., 2012). Thus, the aim of this study was to improve the growth performance of goats by crossing the Sahelian goat with an Anglo-Nubian buck.

MATERIALS AND METHODS

Study area

The study was carried out in Mali, at the Samé Agricultural Research Station, located at 14° 29′ 00″ North, 11° 34′ 00″ West. The average annual rainfall varies from 600 to 800 mm. Two main seasons are observed: a long dry season and a rainy season, that is relatively short, from July to October. The dry season is divided into a cold dry season from November to February and a hot dry season from March to June. The average temperature is 28°C with a maximum of 44°C in the hot dry season and evapotranspiration varies between 2300 and 2500 mm per year.

Animals

The present study included 533 animals from a crossbreeding between Anglo-Nubian and Sahelian goats. They were of 2 genetic types: 154 of ½AN (F1) and 379 of ¾AN (F2) animals registered between 2010 and 2016. The Sahelian goat matrix was selected from traditional farms in the Sahelian strip of Mali. All animals ranged in age from 1 day to 24 months and were from three Anglo-Nubian goat lines.

The research was conducted under the supervision of the leader of the animal research team following the guidelines of CCAC (2009).

Methods

The herds were grazed in the morning and evening and were supplemented with 250 g to 400 g of cottonseed cake and wheat bran pellets upon their return (Nantoume *et al*., 2011). To avoid unwanted mating, females were separated from males and the herds were under the care of a shepherd and remained only in the agro-pastoral area of the station. Watering was done ad libitum and the animals were provided with licking stones to make up for the mineral deficit. The prophylaxis program was carried out according to the schedule of veterinary services in force in the Republic of Mali. The program included vaccination against plague of small ruminants, pasteurellosis and symptomatic anthrax, internal and external deworming, and treatment against animal trypanosomiasis.

Data collection and cross-referencing scheme

The initial crossbreeding involved three Anglo-Nubian goats whose first generation was inverted to avoid the risk of inbreeding in the offspring. Morphobiometry and weighing were done according to the category of the goats. Baseline weight and growth data were collected within 24 hours of parturition. The frequency of twice a month for kids from 1 day to 3 months, once a month for the category from 3 to 12 months, once every three months for the subjects from 12 to 24 months was applied. Measurements were made of scapulo-ischial length (SIL), height at withers (HaG), chest circumference (CC), back length (BL), hip width (HW). The crossbreeding scheme (Fig. 1) consisted of the absorption of Sahelian goat blood in crossbreds.

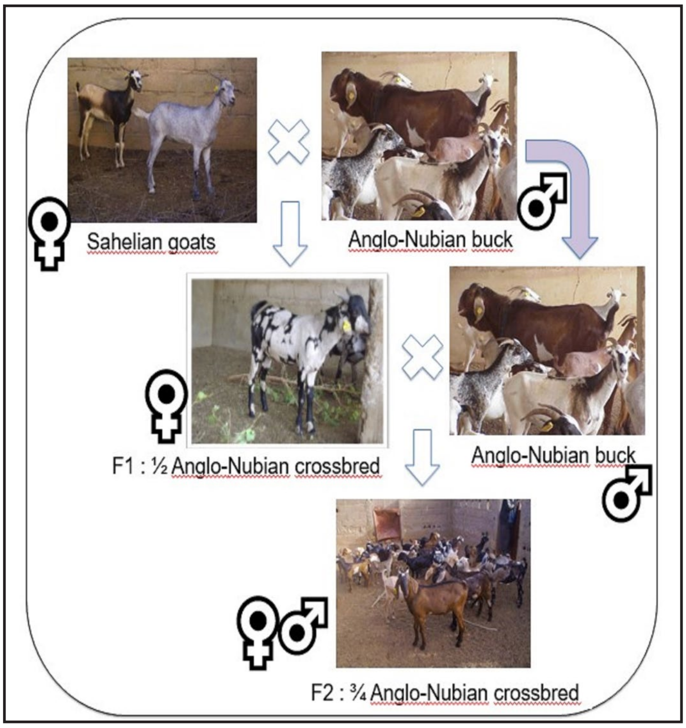

Fig.1. Schematic representation of crossbreeding Sahelian x Anglo-Nubian goats.

Data analysis

Data collected during the study were entered into Excel spreadsheet before being imported into R 4.0.5 software (R Core Team, 2021) for statistical analyses. Two-ways analysis of variance (ANOVA) (genotype x sex and genotype x age groups) was performed to assess variability in morphological traits among animals. Beforehand, tests of normality and homogeneity of variances were performed with the Ryan Joiner and Levene tests, respectively, to check if the conditions for the application of the ANOVA are validated. The Student Newman-Keuls test was used for the comparison of means in case of significant difference ($p < 0.05$) through the agricolae package (de Mendiburu, 2020).

In order to determine the morphometric variables having a linear relationship with the body weight of goats, and to establish predictive models of body weight, the relationships between body weight and the five morphometric variables considered, were established one by one, from the Pearson correlation and the coefficient of determination (R^2). A principal component analysis (PCA) followed by a hierarchical classification ascending was performed using the factoextra package (Kassambara and Mundt, 2020) to categorize the goats according to their morphometric characteristics.

RESULTS

Biometric parameters of goats according to genotype and sex

The analysis of variance showed that the differences between all genotypes (SG, ½AN and ¾AN) were statistically significant ($p < 0.001$) for the biometric variables considered (LW, SIL, CC, BL, HaW, and HW; Table 1). These biometric variables were higher ($p < 0.001$) in ½AN compared to ¾AN. The latter also have mean values of these biometric parameters that were higher ($p < 0.001$) than those of Sahelian goats. As for the sex factor, the values of

Table 1. Biometric parameters of goats according to genotype and sex

Variables	Genotype			Sex		Genotype x sex interaction						p-value		
						SG		½AN		¾AN				
	SG	½AN	¾AN	Male	Female	Male	Female	Male	Female	Male	Female	pG	pS	pGS
LW	12.3±10.8c	23.4±16.4a	20.0±14.3b	19.2±16.4a	18.0±12.7a	7.8±6.6c	14.9±11.8b	26.5±18.3a	19.5±12.5ab	20.7±15.8ab	19.5±13.1ab	***	NS	***
SIL	45.7±16.9b	53.3±15.8a	50.3±16.0a	48.7±17.3a	50.3±15.7a	38.5±13.2c	49.7±17.4c	55.1±16.8a	51.0±14.2ab	50.2±17.2b	50.5±15.2b	***	NS	***
CC	49.0±17.5c	61.6±18.5a	57.6±18.1b	55.3±19.7a	56.5±17.7a	41.5±13.1c	53.2±18.3bc	63.5±19.4a	59.0±16.9ab	57.4±19.3b	57.7±17.3b	***	NS	***
BL	31.6±12.5b	39.7±12.3a	37.5±11.5a	35.6±13.3a	36.8±11.9a	26.1±8.6c	34.6±13.3c	40.9±13.4a	38.2±10.7a	37.2±12.8b	37.4±11.2b	***	NS	***
HaW	48.7±14.7c	60.9±16.3a	57.3±15.5b	55.4±17.3a	55.7±15.1a	42.9±11.6c	51.9±15.4b	63.1±17.2a	58.2±14.6a	57.2±16.5ab	57.4±14.7ab	***	NS	***
HW	10.0±4.3c	13.1±4.4a	12.2±4.5b	11.4±1.3b	12.0±1.0a	8.1±2.9b	11.1±4.6ab	13.2±4.6a	12.9±4.0a	11.9±4.7ab	12.3±4.3a	***	**	***

SG: Sahelian goats; ½AN: F1 of Anglo-Nubian and Sahelian goats; ¾AN: F2 of ½AN and Sahelian goats; pG: probability related to genotype; pS: probability related to sex ; pGS: probability of genotype x sex interaction; LW: live weight; SIL: scapulo-ischial length; CC: chest circumference; BL: back length ; HaW: height at withers; HW: Hip width; ** : p<0.01 ; ***: p<0.001; NS : Non significant; (a,b,c): Means with different letters in the same row per category (genotype, sex and genotype x sex) differ significantly

Table 2. Biometric parameters of goats according to genotype and age classes

Variables	Genotype			Ages			Genotype x age interaction									p-value		
							[0 ;1]			]1 ;2]			]2 ;3]					
	SG	½AN	¾AN	[0 ;1]	]1 ;2]	]2 ;3]	SG	½AN	¾AN	SG	½AN	¾AN	SG	½AN	¾AN	pG	PA	pGA
LW	12.3±10.8c	23.4±16.4a	20.0±14.3b	10.8±9.0c	31.9±9.5b	39.2±10.4a	6.5±5.5a	13.2±9.9a	12.4±9.5a	23.9±5.4a	35.0±11.6a	34.3±7.6a	32±5.9a	43.9±12.4a	40.5±8.9a	***	***	NS
SIL	45.7±16.9c	53.3±15.8a	50.3±16.0b	41.4±13.4c	64.6±5.9b	69.8±6.5a	37. 4±12.2a	44.0±13.6a	42.7±13.6a	62.9±5.9a	65.5±6.5a	64.9±5.4a	72.1±4.6a	68.1±8.3a	69.6±6.1a	***	***	NS
CC	49.0±17.5c	61.6±18.5a	57.6±18.1b	46.3±14.7c	73.9±6.6b	78.6±6.2a	39.9±11.6a	50.1±14.9a	48.7±15.0a	69.1±4.9a	76.1±7.9a	75.2±5.4a	75.8±4.2a	81.1±6.8a	78.7±6.2a	***	***	NS
BL	31.6±12.5c	39.7±12.3a	37.5±11.9b	29.9±10.0c	47.9±5.1b	51.7±4.6a	25.1±7.9c	32.5±10.3c	31.7±10.0c	45.3±4.2b	48.8±6.6b	48.6±4.3b	51.8±5.4a	52.2±5.2a	51.5±3.7a	***	***	*
HaW	48.7±14.7c	60.9±16.3a	57.3±15.5b	47.6±13.1c	70.2±6.8b	75.0±5.8a	41.6±10. 8a	51.1±13.6a	49.9±13.1a	64.0±6.2a	73.6±6.5a	71.5±5.1a	70.5±3.9a	77.5±7.1a	76.1±4.4a	***	***	NS
HW	10.0±4.3c	13.1±4.4a	12.2±4.5b	9.3±3.5c	16.2 1.9b	17.2±1.7a	7.7±2.8a	10.4±3.5a	9.9±3.6a	14.8±1.5a	16.7±2.1a	16.7±1.5a	16.7±1.6a	17.2±1.9a	17.4±1.5a	***	***	NS

SG: Sahelian goats; ½AN: F1 of Anglo-Nubian and Sahelian goats ; ¾AN: F2 of ½AN and Sahelian goats; pG: probability related to genotype; pA: probability related to age classes; pGA: probability of genotype x age interaction; LW: live weight; SIL: scapulo-ischial length; CC: chest circumference; BL: back length ; HaW: height at withers; HW: Hip width ; *: p<0.05 ; ***: p<0.001; NS : Non significant; (a,b,c): Means with different letters in the same row per category (genotype, age and genotype x age) differ significantly.

SIL, BL and HW were higher ($p < 0.05$) in females. Interactions between genotype and sex showed significant differences ($p < 0.001$) for all biometric variables except for HW.

Biometric parameters of goats according to genotype and age groups

The means and standard deviations of the different biometric variables studied (LW, SIL, CC, BL, HaW, and HW) by genotype and age groups were showed in Table 2. For all variables, ½AN had significantly higher values ($p < 0.05$) than ¾AN at the age groups [0 ;1] and]1 ;2]. At]2 ;3], it was only for the variable HW that the values of the ¾AN were higher than those of the ½AN and also of the Sahelian goats. The Sahelian goats had significantly lower values ($p < 0.05$) than the other two genotypes regardless of the age groups and variable considered.

Correlation and prediction models of live weights of goats according to their biometric variables

The results of the analyses showed high and significant linear correlations between live weight of goats and the five morphometric variables studied on the one hand and between the morphometric variables taken two by two on the other hand (Table 3). The correlation values between live weight and body measurements ranged from 0.91 to 0.94 (Table 4). The coefficient of determination shows that 89% of the variables (SIL, CC, BL, HaW, and HW) were explained by goat live weights. The correlation coefficients (r) between live weight and all variables (SIL, CC, BL, HaW, and HW) were high ($r = 0.91$; $r = 0.94$; $r = 0.92$; $r = 0.92$ and $r = 0.91$ respectively) and significant ($p < 0.001$), indicating the relatively good quality of the linear relationship between goat live weight and these morphometric parameters. Thus, from the coefficient of determination obtained for the multiple regression equation (R2 = 89%), it would be possible to predict the live weight of a goat from its morphometric parameters (SIL, CC, BL, HaW, and HW).

Multivariate analyses of biometric parameters

The study of the correlations between the various variables considered made it possible to select a set of active variables for the Principal Component Analysis (PCA). The cumulative contribution to the total inertia of the first three factorial axes retained was 98.28% (Table 5).

The Hierarchical Ascending Classification (Figure 2) was used to divide the goats into three groups (Figure 3) based on their morphobiometric measurements.

Table 3. Correlation matrix between biometric parameters.

Variables	LW	SIL	CC	BL	HaW	HW
LW	1					
SIL	0.91 ***	1				
CC	0.94 ***	0.97 ***	1			
BL	0.92 ***	0.96 ***	0.97 ***	1		
HaW	0.92 ***	0.96 ***	0.97 ***	0.95 ***	1	
HW	0.91 ***	0.95 ***	0.96 ***	0.95 ***	0.95***	1

Table 4. Estimation of live weight of goats as a function of biometric variables

Relationship between live weight and biometric variables	Model	R²	r	p-value
LW - SIL	LW = -21.32 + 0.80 SIL	0.83	0.91	< 0.001
LW - CC	LW = -22.51 + 0.73 CC	0.89	0.94	< 0.001
LW - BL	LW = -19.80 + 1.06 BL	0.84	0.92	< 0.001
LW - HaW	LW = -27.59 + 0.83 HaW	0.85	0.92	< 0.001
LW - HW	LW = -15.52 + 2.90 HW	0.84	0.91	< 0.001
Multiple regression	LW = -22.79 - 0.15 SIL + 0.62 CC + 0.10 BL + 0.12 HaW + 0.33 HW	0.89	-	< 0.001

LW: live weight; SIL: scapulo-ischial length; CC: chest circumference; BL: back length ; HaW: height at withers; HW: Hip width; R²: coefficient of determination; r: correlation coefficient

Table 5. Composition of the axes of the principal component analysis graph

Axes	Eigenvalue	Percentage of variance	Cumulative percentage of variance
1	5.73	95.55	95.55
2	0.11	1.76	97.31
3	0.06	0.97	98.28
4	0.05	0.78	99.06
5	0.04	0.6	99.65
6	0.02	0.35	100

Table 6. Characteristics of goats according to principal component analysis classes and genotype

Variables	Genotype			Cluster			Cluster x Genotype interaction									p-value		
							Cluster 1			Cluster 2			Cluster 3					
	SG	½AN	¾AN	Cluster 1	Cluster 2	Cluster 3	SG	½AN	¾AN	SG	½AN	¾AN	SG	½AN	¾AN	pG	pC	pGC
LW	12.3±10.8c	23.4±16.4a	20.0±14.3b	2.6±1.8c	13.5±4.7b	33.5±9.3a	2.6±2.7d	2.6±0.7d	2.6±0.8d	11.9±4.1c	14.2±4.8c	14.2±4.8c	28.1±5.7b	36.1±11.9a	34.0±8.1a	***	***	***
SIL	45.7±16.9c	53.3±15.8a	50.3±16.0b	26.6±3.1c	49.1±5.3b	65.5±5.9a	27.1±3.3c	26.3±2.8c	26.2±2.9c	50.4±5.0b	48.7±5.4b	48.5±5.4b	67.6±5.6a	65.4±6.8a	64.9±5.5a	***	***	NS
CC	49.0±17.5c	61.6±18.5a	57.6±18.1b	30.7±3.0c	53.9±6.4b	74.7±6.4a	30.4±2.8c	30.9±2.8c	30.8±3.1c	52.5±6.9b	54.9±6.5b	54.5±6.0b	72.8±4.4a	76.1±7.9a	74.6±5.9a	***	***	NS
BL	31.6±12.5c	39.7±12.4a	37.5±11.5b	19.1±2.6c	35.6±4.5b	48.4±5.2a	18.5±2.7c	18.9±2.9c	19.7±2.3c	34.2±4.8b	36.5±4.0b	36.2±4.3b	48.1±5.4a	48.8±6.3a	48.2±4.5a	***	***	NS
HaW	48.7±14.7c	61.0±16.3a	57.3±15.5b	33.6±2.7	54.5±6.0b	71.3±6.3a	32.7±2.6c	33.6±3.2c	34.5±2.4c	53.2±6.2b	55.6±5.9b	54.9±5.8b	68.9±6.4ab	73.6±6.9a	71.6±5.3a	***	***	**
HW	10.0±4.3c	13.1±4.4a	12.2±4.5b	5.7±1.1c	11.1±1.8b	16.3±1.8a	5.6±1.4c	5.9±0.9c	5.8±0.9c	10.6±1.9b	11.8±1.7b	11.1±1.6b	15.8±1.5a	16.4±2.2a	16.4±1.6a	***	***	NS

SG: Sahelian goats; ½AN: F1 of Anglo-Nubian and Sahelian goats ; ¾AN: F2 of ½AN and Sahelian goats; pG: probability related to genotype; pC: probability related to cluster; pGC: probability of genotype x cluster interaction; LW: live weight; SIL: scapulo-ischial length; CC: chest circumference; BL: back length ; HaW: height at withers; HW: Hip width ; ** : p<0.01 ; ***: p<0.001; NS : Non significant; (a,b,c,d): Means with different leters in the same row per category (cluster; genotype and genotype x cluster) differ significantly

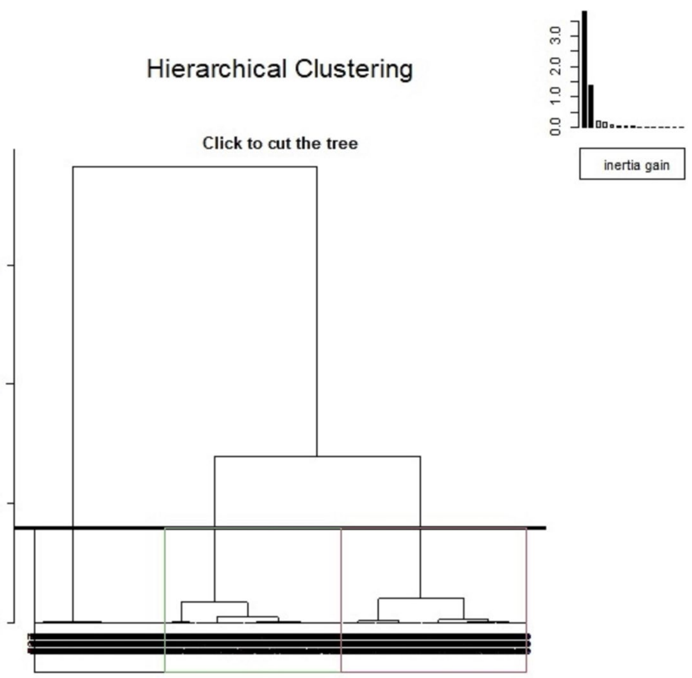

Fig. 2. Hierarchical clustering of morphobiometric parameters of goats.

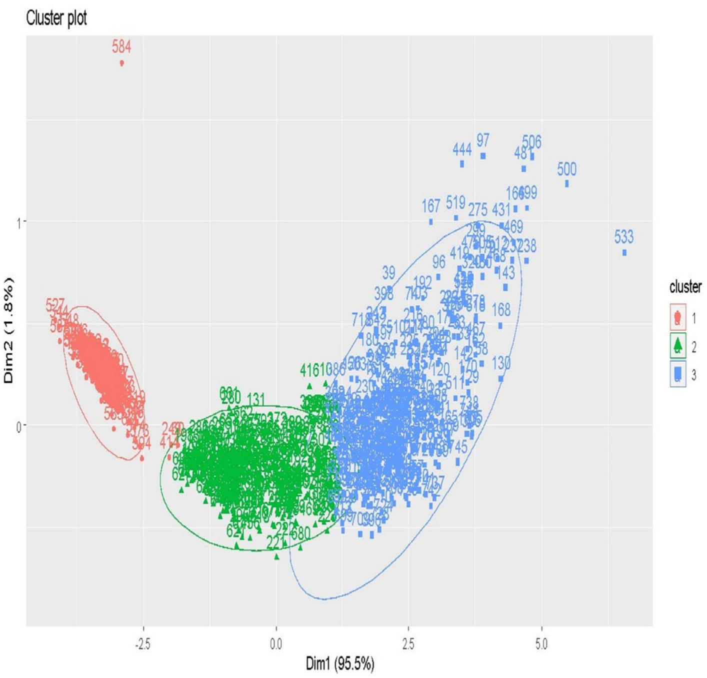

Fig. 3. Classification of animals based on morphometric variables.

The study of the distribution of the groups on the PCA graphs allowed to identify the characteristics of each group presented in Table 6. Group 1 was composed of animals with an average weight ranging from 2.59 kg for Sahelian goats to 2.62 kg for ¾AN crossbreds. In this group, the means of the variables LW, BL and HaW respectively of (2.62kg; 19.69 cm and 34.50 cm) of the ¾AN crossbreds were higher ($p < 0.05$) than those of the Sahelian goats and the ½AN crossbreds. On the other hand, for the variables CC and HW, the means values (30.96 cm and 5.89 cm respectively) of the ½AN crossbreds were higher ($p < 0.05$) than those of the Sahelian goats and the ¾AN crossbreds. Thus, only the SIL had a higher mean (27.07 cm) in Sahelian goats than in ½AN and ¾AN crossbreds ($p < 0.05$). Group 2 was composed of goats with mean weights ranging from 11.89 kg for Sahelian goats to 14.21 kg for ½AN crossbreds. For this group, the means of the variables LW, CC, BL and HaW which were respectively (14.21 kg; 54,93 cm; 36.50 cm and 55.65 cm) of the ½AN crossbreds were higher ($p < 0.05$) than those of the SG and the

¾AN crossbreds. In addition, the mean of the SIL was higher in Sahelian goats than in the other genotypes and that of HW was higher in ¾AN crossbreds than in the others. Group 3 was made of animals with the best values of all morpho-biometric variables. It includes goats with an average weight between 28.09 kg for SG and 36.06 kg for the ½AN crossbreds. In this group, as in group 2, the means of the variables LW, CC, BL and HaW of 36.06 kg; 76.07 cm; 48.84 cm and 73.59 cm respectively for the ½AN crossbreds were higher ($p < 0.05$) than those of the SG and the ¾AN crossbreds. In contrast, the mean of SIL was higher in SG than in other goats' genotypes and the mean of HW was higher in ¾AN crossbreds than in the other two genotypes. The means of the SIL remained highest in Sahelian goats than in ½AN and ¾AN crossbreds regardless of group.

DISCUSSION

The aim of this study was to improve the growth performance of goats by crossing the Sahelian goat with an Anglo-Nubian goat. The experiments were carried out on three genetic types of goats (SG, ½AN and ¾AN) raised in a semi-intensive system. A large phenotypic difference between SG, ½AN and ¾AN in morphometrics was observed. Genetic variation is vital for populations to adapt to diverse environments and to be favorable to artificial selections (Toro *et al*., 2011; Kouato *et al*., 2021). Indeed, the average birth weights of ½AN (2.65 kg) and ¾AN (2.53 kg) kids were higher than those of Sahelian goats (2.39 kg). Also, at 24 months of age, adults of ½AN (43.3 kg) and ¾AN (37.13 kg) crossbreds were heavier than those of Sahelian goats (26.7 kg). This better growth performance of the F1 offspring could be explained by hybrid vigor from Anglo-Nubian bucks. The observed difference in body size is a great asset for animal selection in genetic improvement programs in the Sahelian goat's preferred areas (Sanogo *et al*., 2012). These results would confirm the fact that direct heterosis estimates were positive for the majority of the weights studied. These results agreed with some previous findings indicating that crossbreeding native goats with exotic breeds improved the growth performance characteristics of the offspring (Gebrelul *et al*., 1994; Guzler *et al*., 2010). These results were similar to those of Momani *et al*. (2012) who show that Sahelian goats have low birth weights and measurements compared to crossbreds (Anglo-Nubian x Sahelian). Similarly, Al-Saef (2021) concluded that Saudi ½Damascus½Aradi and Saudi ¾Damascus½Aradi crosses were heavier for all body weights compared to Saudi Aradi kids. Erduran (2021) concluded that Alpine x Hair F1 (AHF1) kids had a higher birth weight than the local wool breed. In contrast, the offspring of the F2 generation from the backcross (F1 x Sahelian goat) showed lower growth performance than the F1 generation, but higher than the Sahelian goats.

Considering the results of analysis by sex, females had the highest values of morphobiometric parameters compared to males in the Sahelian goats. This finding was similar with those reported by Samuel and Salako (2008) in the Djallonke goat. Mani *et al*. (2014) in Niger drew the same conclusions, where native female goats showed higher biometric values than males regardless of region. The averages of the biometric data obtained were higher in males than females in AN crossbred. According to Vigne *et al*. (2002), sex is the most important factor influencing dimensions in goats. As with sex, the age of the animals also had a positive impact on morphometric parameters. Similar results were observed in Nigeria (Samuel and Salako, 2008), Uganda (Semakula *et al*., 2010), Niger (Mani *et al*., 2014) and Benin (Kouato *et al*., 2021).

The high positive correlations between the variables allowed us to establish a predictive model for estimating or quantifying weight performance in goats in the Sahelian region as a function of morphometric variables such as scapulo-ischial length, chest circumference, back length, height at the withers and hip width. This proposed model will allow the determination of live weight of goat resources with tape measures by measuring these morphometric variables.

The results of the principal component analysis show that regardless of age and sex, crossbreds are positively correlated with all parameters of the first principal component. This axis expresses the general conformation of goats. Thus, crossbreds had high values of biometric parameters compared to Sahelian goats. Multiple variance analysis indicated that biometric characteristics vary significantly by age, by sex and different breeds (Sahelian and crossbred). Similar findings were made by Kouato *et al*. (2021).

CONCLUSION

The study of the impact of crossing the Sahelian goat with the Anglo-Nubian goat on the growth performance and morphobiometric characteristics of kids in the Sahelian zone allows us to demonstrate that the weight gain characteristics of the offspring of the F1 (½AN crossbred) have been improved. However, the back-cross that resulted in the F2 generation (¾AN crossbred) decreased the performance obtained at F1. The sexual dimorphism recorded is in favor of females for Sahelian goats and in favor of males for ½AN and ¾AN crossbred. A genetic improvement program for goat meat production in the Sahelian zone can be implemented by opting for crosses of Sahelian goats with Anglo-Nubian bucks. It is possible to predict the body weight of goats, regardless of genotype, based on scapulo-ischial length, chest circumference, back length, height at withers and hip width with a relatively high accuracy of about 89%.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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