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Full Length Research Paper

Morphological characteristics of indigenous Djallonké sheep in rural areas in the south of Mali

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This study aimed at evaluating some morphological traits in Djallonké sheep reared in four localities (Dioïla, Kolondiéba, Yanfolila and Kita) in the south of Mali. Two hundred and sixty sheep (40 males and 220 females) randomly selected from these localities were used for measuring the following traits: Coat color, presence of horns/wattles, height at withers (HW), and live body weight (LBW). Animals belonged to five age groups ranging from < 1 year to ≥ 4 years, with females being predominant in each group. Nearly all males had horns (94%), whereas these were present only in a small subset of females (6%). For all animals, wattles were less frequent (10%) and the dominant coat color was plain white (45%) and white with particularities (38%). HW and LBW values were not significantly different between rams from Dioïla and Kolondiéba but were higher than those of their counterparts from Kita and Yanfolila. Ewes from Kita, Kolondiéba, and Yanfolila displayed comparable values for both HW and LBW but these were lower than those of their counterparts from Dioïla. These findings might serve as a basis for designing and implementing a genetic project aimed at ensuring the sustainable conservation and valorization of Djallonké sheep in Mali.

Key words: Djallonké sheep, morphological traits, Mali

INTRODUCTION

Among the important livestock species reared in rural areas in the south of Mali is sheep, with the West African Dwarf (Djallonké) sheep breed being widely appreciated owing to its adaptation to local husbandry and environmental conditions.

Djallonké sheep is mainly characterized by a precocious reproductive development combined with a good rate of prolificacy, and a high degree of resistance to animal trypanosomiasis (Traoré et al., 2008; Birteeb et al., 2013) a disease that is commonly prevalent in the tropics. However, despite this potential, Djallonké is a breed with small adult size, making it less attractive for sheep meat sellers/producers than Sahelian sheep, which is larger and can cohabit in the same zones yet with increased susceptibility to local diseases.

In recent decades, this situation – in rural zones in the South of Mali – has resulted in the increased practice of uncontrolled crossbreeding between Djallonké and

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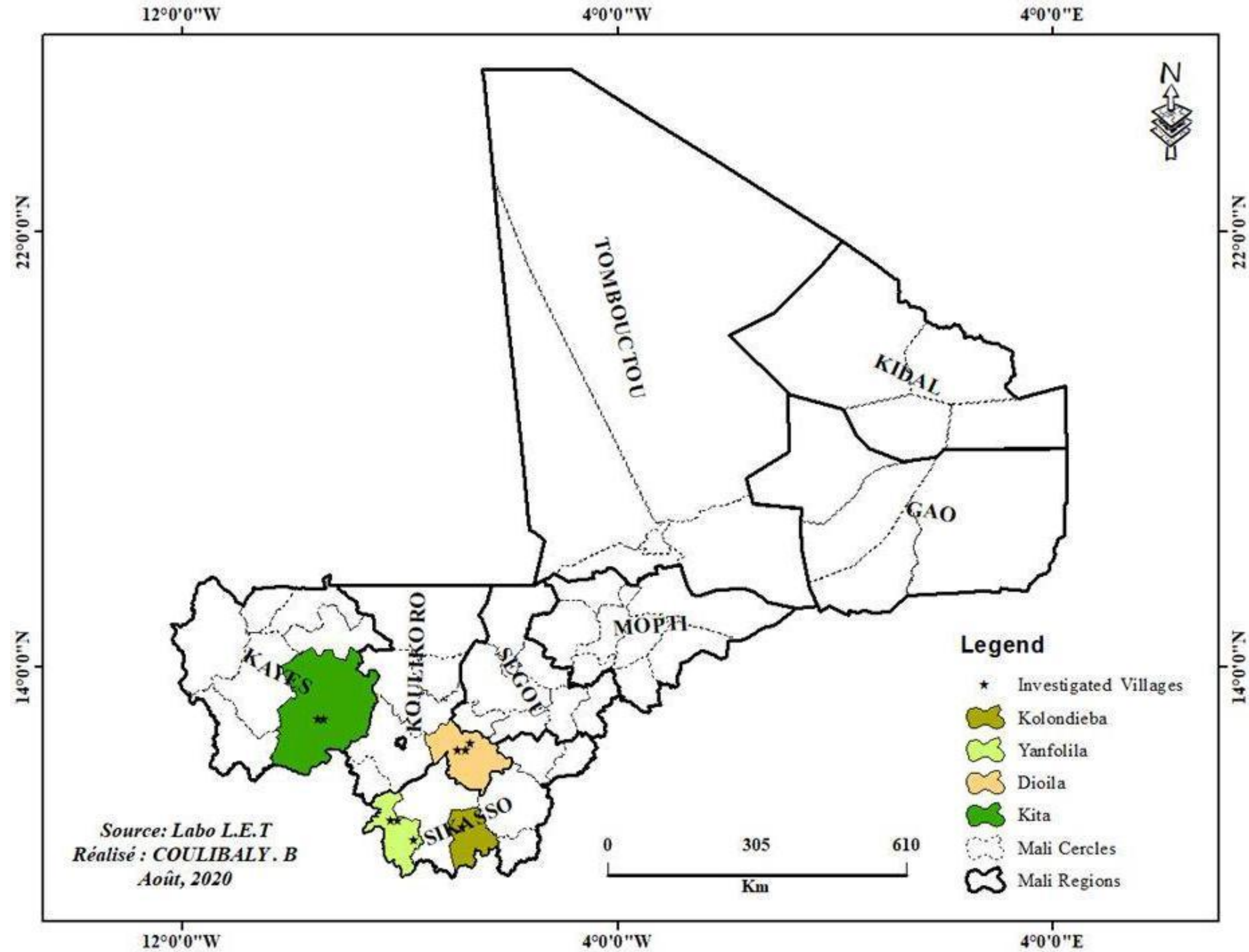

Figure 1. Map showing the location of the study zones.
Source: Coulibaly Laboratory LET (2020).

Sahelian sheep for maximizing profit through the production of offsprings with important zootechnical and economic traits of both parents. Since this can ultimately alter the genetic integrity of indigenous Djallonké sheep, immediate actions are needed to protect and preserve this animal genetic resource.

National breeding programs that use selection and/or artificial insemination are being developed to improve the growth performance of local Djallonké sheep while ensuring sustainable conservation of its biodiversity. The successful implementation of such programs requires a prior extensive knowledge of Djallonké sheep biology, notably its morphological and genetic characteristics. However, the last studies describing the morphological traits of this breed in Mali date back to the colonial period and were performed by Georges Doutressoule in 1947.

The present study aimed at assessing some morphological characteristics of Djallonké sheep reared in rural zones in the south of Mali to provide updated data needed for their sustainable use, improvement, and conservation.

MATERIALS AND METHODS

Study area

The study was conducted in ten villages across four selected localities in the south of Mali including Dïoila and Kita (in Koulikoro and Kayes regions, respectively), and Kolondiéba and Yanfolila (in the region of Sikasso) (Figure 1). All these localities lie within humid (Sudano-guinean) and sub-humid (Sudane) zones located between 10° to 13° north latitudes and between 6° to 9° west longitudes with an altitude of 291 to 381 m.

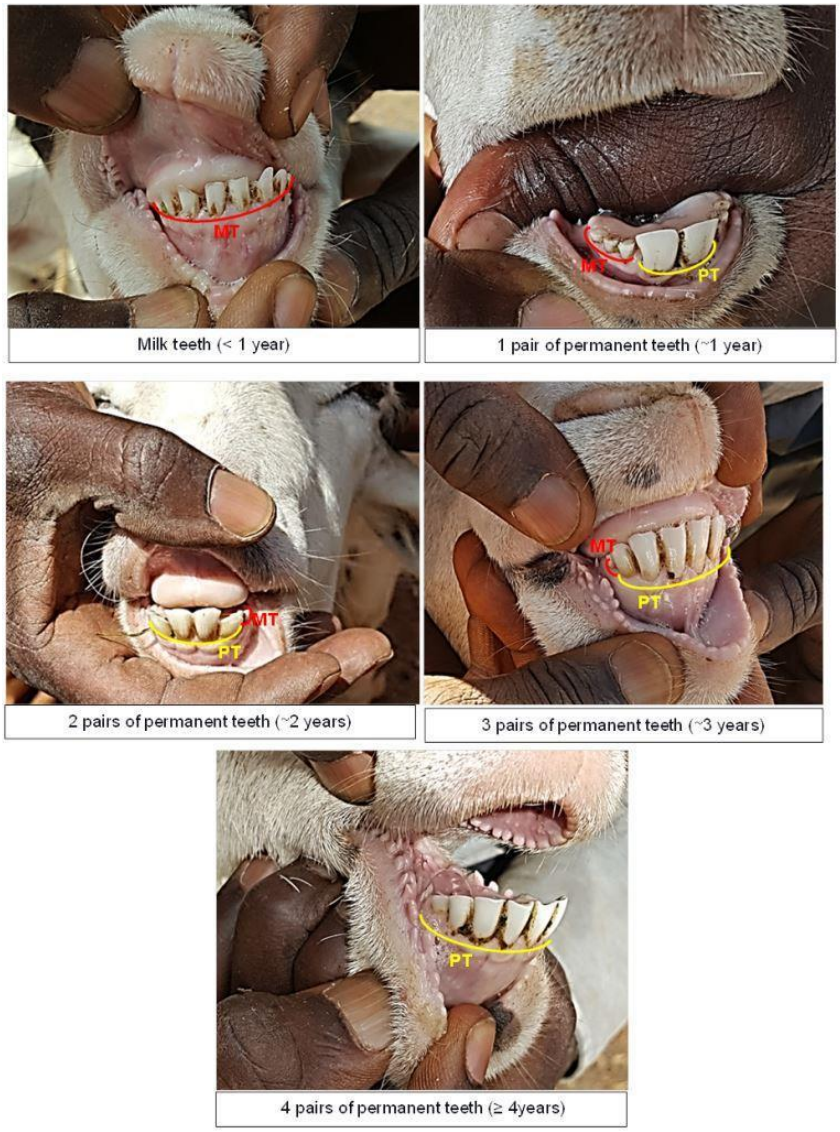

Figure 2. Tooth morphology-based method to estimate the sheep age. MT and PT stand for milk teeth and permanent teeth, respectively.

These zones are climatically defined by a long rainy season (from May to October), with the mean annual rainfall varying from 600-1000 mm (Sudanese zone) or exceeding 1000 mm (Sudano-Guinean zone) (DNM-PNUD, 2007). For both zones, the average annual temperature is usually above 28°C. Moreover, the vegetation cover mainly consists of wooded and shrubby savannas with an important herbaceous stratum. Local food and cereal crops include cotton, peanuts, maize, millet, sorghum, fonio, and beans.

Animals

A total of 260 (40 rams and 220 ewes) Djallonké sheep were randomly selected in 19 farms from the above villages, which were chosen based on their sheep population and accessibility. Also, care was taken to ensure that villages are isolated enough from each other to minimize the degree of relatedness between herds. The animals were managed extensively. During the rainy season, they were fed (almost exclusively) on natural pastures. However, supplements such as maize and millet were provided after the grazing of natural pastures in the dry season. Only healthy animals were included in this study.

Population structure

Visual examination of dentition was used to estimate the age structure of Djallonké sheep populations across investigated localities (Figure 1) as in Landais and Bassewitz (1982), Tesfay et al. (2017) and Patrick et al. (2018). The age ranges were grouped as MT (milk teeth, < 1 year), 1 PPT (one pair of permanent teeth, ~1 year), 2 PPT (~2 years), 3 PPT (~3 years), and 4 PPT (≥ 4years) (Figure 2). The proportion of each age group was estimated to be as follows: MT (20.38%), 1 PPT (17.31%), 2 PPT (23.08%), 3 PPT\ (22.69%), and 4 PPT (16.54%) (Table 1). The distribution profile of these age groups was comparable between each pair of localities, except for Kita and Kolondiéba. Moreover, the sex ratio in each age group as well as in individual localities was skewed towards

Table 1. Age structure of Djallonké sheep populations in investigated localities.

Locality	Dïoila (n=47)		Kita (n=56)		Kolondiéba (n=37)		Yanfolila (n=120)		All (n=260)	
Age	n	%	n	%	n	%	n	%	n	%
MT	10	21.28	5	8.93	10	27.03	28	23.33	53	20.38
1PPT	7	14.89	11	19.64	7	18.92	20	16.67	45	17.31
2PPT	11	23.40	15	26.79	8	21.62	26	21.67	60	23.08
3PPT	13	27.66	14	25.00	9	24.32	23	19.17	59	22.69
4PPT	6	12.77	11	19.64	3	8.11	23	19.17	43	16.54

Comparison between regions or localities		X^2	P value
Locality	Dïoila vs Kita	7.129	0.1292
	Dïoila vs Kolondiéba	2.741	0.6021
	Dïoila vs Yanfolila	3.087	0.5434
	Kita vs Kolondiéba	14.04	0.0072
	Kita vs Yanfolila	7.697	0.1033
	Kolondiéba vs Yanfolila	5.494	0.2403

MT, Milk teeth. PPT, pair of permanent teeth. n, number of animals. %, percentage of animals.

Table 2. Distribution of age groups by sex in Djallonké sheep flocks in investigated localities.

Locality		Dïoila (n=47)		Kita (n=56)		Kolondiéba (n=37)		Yanfolila (n=120)	
Age	Sex	n	%	n	%	n	%	n	%
MT	♂	3	30	2	40	2	20	12	42.86
	♀	7	70	3	60	8	80	16	57.14
1PPT	♂	1	14.29	1	9.09	0	0	1	5
	♀	6	85.71	10	90.91	7	100	19	95
2PPT	♂	1	9.09	3	20	3	37.50	3	11.54
	♀	10	90.91	12	80	5	62.50	23	88.46
3PPT	♂	2	15.38	1	7.14	0	0	2	8.70
	♀	11	84.62	13	92.86	9	100	21	91.30
4PPT	♂	0	0	0	0	1	33.33	2	8.70
	♀	6	100	11	100	2	66.67	21	91.30

MT, Milk teeth. PPT, pair of permanent teeth. n, number of animals. %, percentage of animals. ♂, male. ♀, female.

females (57.17 to 100% females) (Tables 2 and 3). In general, **a**nimals sampled consisted of 15.38% males and 84.62% females) (Table 2).

Morphological characterization

Phenotypic measurements were performed following the FAO guidelines (FAO, 2013). The quantitative traits including height at withers and live body weight were measured using a measuring tape and spring scale, respectively as in Cilek and Gotoh (2014, 2015). Qualitative variables such as coat color and presence of horns and wattles were determined by visual observation and expressed in percentage as a function of sex and locality (Djoufack et al., 2020; N'Goran et al., 2018). Given that advanced pregnancy and breastfeeding may influence the body conformation, we decided to exclude lactating lambs and ewes in an advanced stat of pregnancy (more than four months) from weighing and body measurements.

Statistical analysis

Data are presented as the mean ± standard deviation with the number (n) of animals included in Figure 5(A and B). Where relevant, *P* values were determined using One-way analysis of variance (ANOVA, with Tukey's Multiple comparison of means post hoc test) (Table 2), except for Pearson's coefficients of correlation (r) between WH and LBW where two-tailed *Student's t*-test was used (Figure 6). The distribution of age groups (between localities) and sexes (for all animals) were determined using *Chi-square* test (Tables 1 and 3). Differences were considered significant for *P*-values <0.05 (N'Goran et al., 2019).

RESULTS

Qualitative traits

To begin the morphological characterization of Djallonké

Table 3. Proportion of males and females within Djallonké sheep flocks in investigated localities.

Locality	Dïoila (n=47)		Kita (n=56)		Kolondiéba (n=37)		Yanfolila (n=120)		All n=260			
Sex	n	%	n	%	n	%	n	%	n	%	χ^2	P value
♂	7	14.89	7	12.50	6	16.22	20	16.67	40	15.38	124.62	6.17802E-20
♀	40	85.11	49	87.50	31	83.78	100	83.33	220	84.62		

n, Number of animals. %, percentage of animals. ♂, male. ♀, female.

sheep populations reared in Dioïla, Kolondiéba, Yanfolila and Kita, we first assessed the distribution and frequencies of horns, wattles, and coat color. In general, we found that the vast majority of males (86 to 100% depending on localities) had horns. In marked contrast, these were present only in a small proportion of females (3 to 15%) (Figure 3A), demonstrating a sex-based difference in the presence of horns in sampled animals. For all animals, the frequency of wattles was found to be relatively low. Nonetheless, we noted some obvious differences between populations as a function of sex and locality (Figure 3B), with males from Dioïla (43%) and Kita (29%) as well as females from Kita (18%) and Kolondiéba (10%) possessing wattles at relatively higher frequencies (Figure 3B). Therefore, both the sex and environment might affect the presence of wattles in Djallonké sheep across investigated localities.

Visual examination of coat color of sampled animals revealed four pigmentation patterns consisting of white with particularities, plain white, piebald, and black (Figure 4A). Of note, white with particularities corresponds to white combined with black and/or brown, whereas piebald corresponds to black and white. Males (regardless of locality) were characterized, in order of abundance, by white with particularities (35 to 50%), white (28 to 43%), and piebald (14 to 30%) (Figure 4B). In marked contrast, the predominant color in females was white (34 to 69%), followed by white with particularities (21 to 45%), piebald (5 to 21%), and black (2%) (Figure 4B). At the locality level, a small difference was observed, with the black color being detected only in females from Kita. Taken together, these observations suggest that the sex is likely to influence the coat color patterns in sampled Djallonké sheep.

Quantitative traits

To complete our morphological characterization, the height at withers (HW) and live body weight (LBW) was next measured using tape and spring scale, respectively. It is worth mentioning that for this and the remaining analyses, only adult rams and ewes having 2 to 3 pairs of permanent teeth (aged about 2-3 years) were evaluated separately because of the small numbers of animals of both sexes within each age group in certain localities (Table 2). Without being significantly different from each other, rams from Dioïla and Kolondiéba had significantly higher values (P < 0.05) for both HW and LBW compared to age- and sex-matched counterparts from Kita and Yanfolila (Figure 5A, B). The HW and LBW measures were similar in ewes from Kita, Kolondiéba, and Yanfolila but were lower than those of their age - and sex-matched counterparts from Dioïla (Figure 5A, B). However, this difference between animals from Dioïla and Kolondiéba did not reach statistical significance with respect to HW (Figure 5A). Although we do not exclude the fact that the sample size for rams is small, we believed that these results indicate that adult Djallonké sheep from Dioïla and Kolondiéba are larger and weigh heavier than those from Kita and Yanfolila. In general, males are heavier and taller than females but the difference is not significant (Supplemental Figure 1).

Correlation between the height at withers and live body weight

In many scientific studies, a high correlation has been reported between several morphological traits – including the chest circumference, body length and height at withers – and body weight (Oke and Ogbonnaya, 2011; Okpeku et al., 2013; Cilek and Petkova, 2016; Kumar et al., 2018). Unlike these studies, the quantitative traits investigated in the present study are limited to WH and LBW. Given that almost all the above adult animals were evaluated for both WH and LBW, we elected to assess the relationship between these two traits in rams and ewes separately. In both cases, strong correlations were detected (Figure 6). However, the Pearson's correlation coefficient for rams (r = 0.87) was found to be higher than that for ewes (r = 0.60), a difference that is most likely due to the small number of rams. The correlation value found in this study was found to be higher than the other researchers (Cilek and Petkova, 2016; Bebek and Keskin, 2020). These results indicate that the height at withers is a good predictor of live body weight in Djallonké sheep. It is concluded that live weight can be predicted with withers height.

DISCUSSION

Via a comprehensive analysis of several morpho-biometric traits of Djallonké sheep reared in four rural

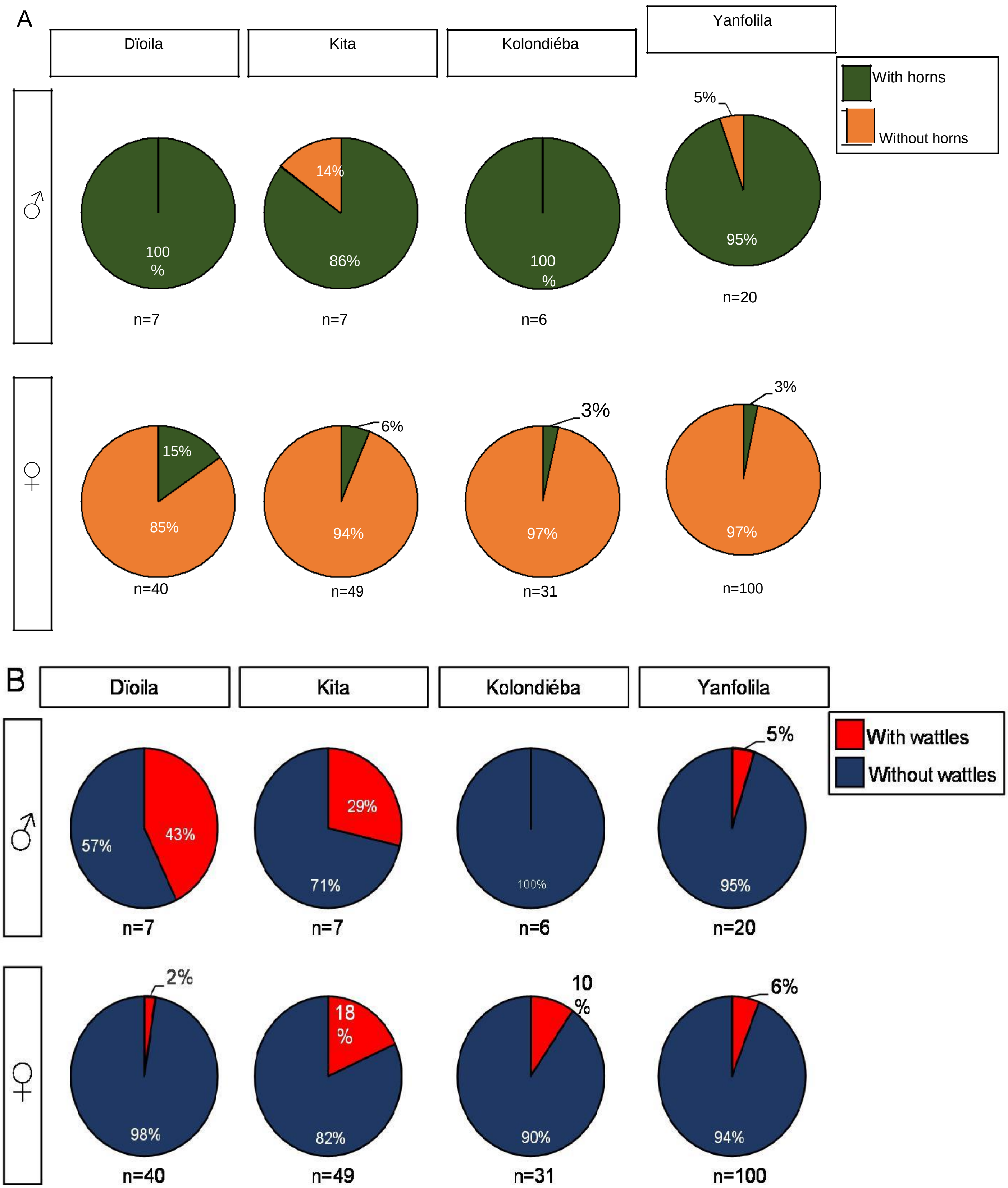

Figure 3. Presence or absence of horns and wattles in Djallonké sheep of both sexes within the study zones. (A, B) The pie charts display the percentage of investigated sheep with or without horns (A) and wattles (B). The presence or not of each trait is color-coded and indicated on the top right side of each panel. n= Number of observations.

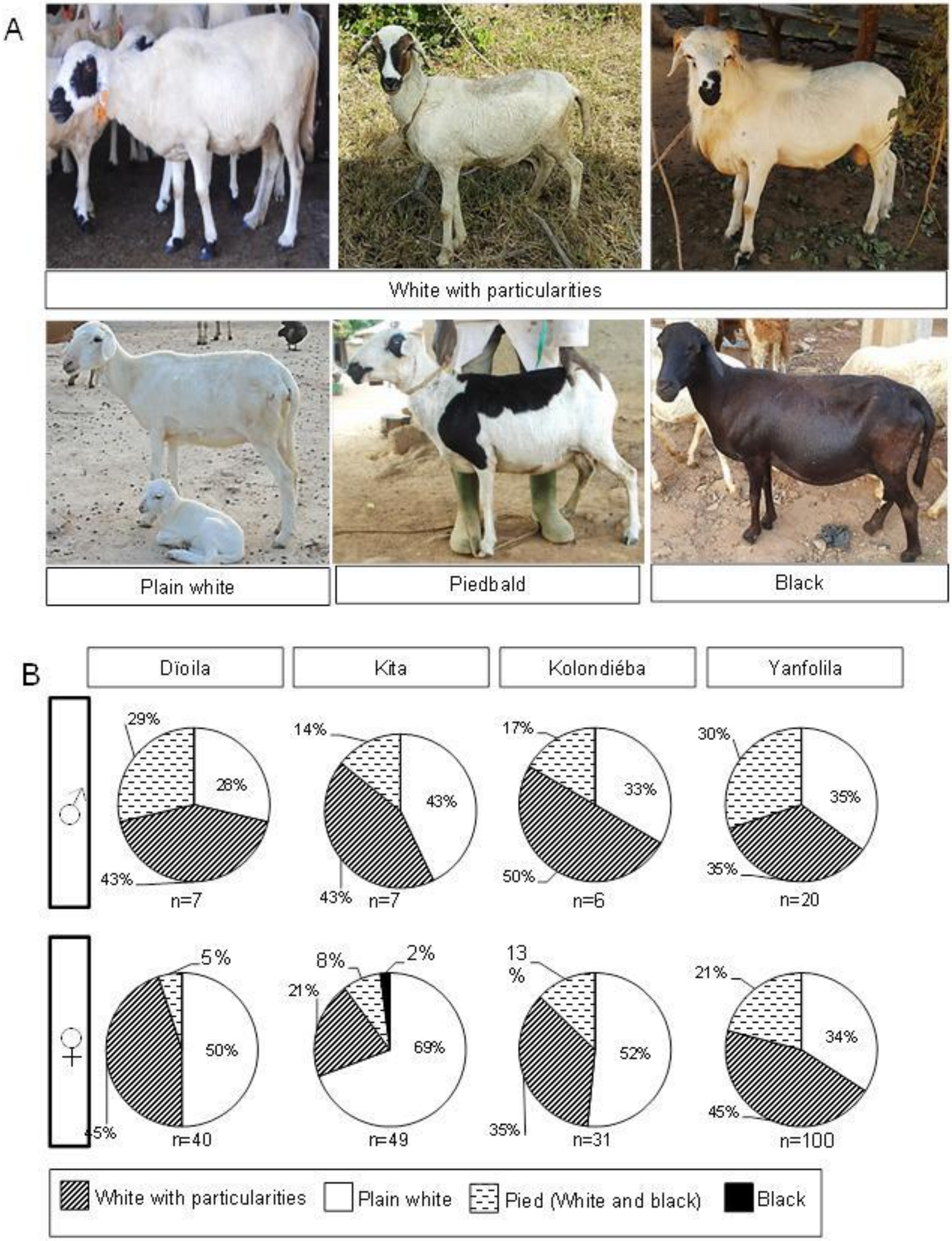

Figure 4. Coat colors in Djallonké sheep of both sexes within the study zones. (A) Representative images showing the diversity of coat colors in sheep studied. (B) The pie charts display the percentage of different color hues. Hues are color-coded and indicated in the lower part of the bottom panel.

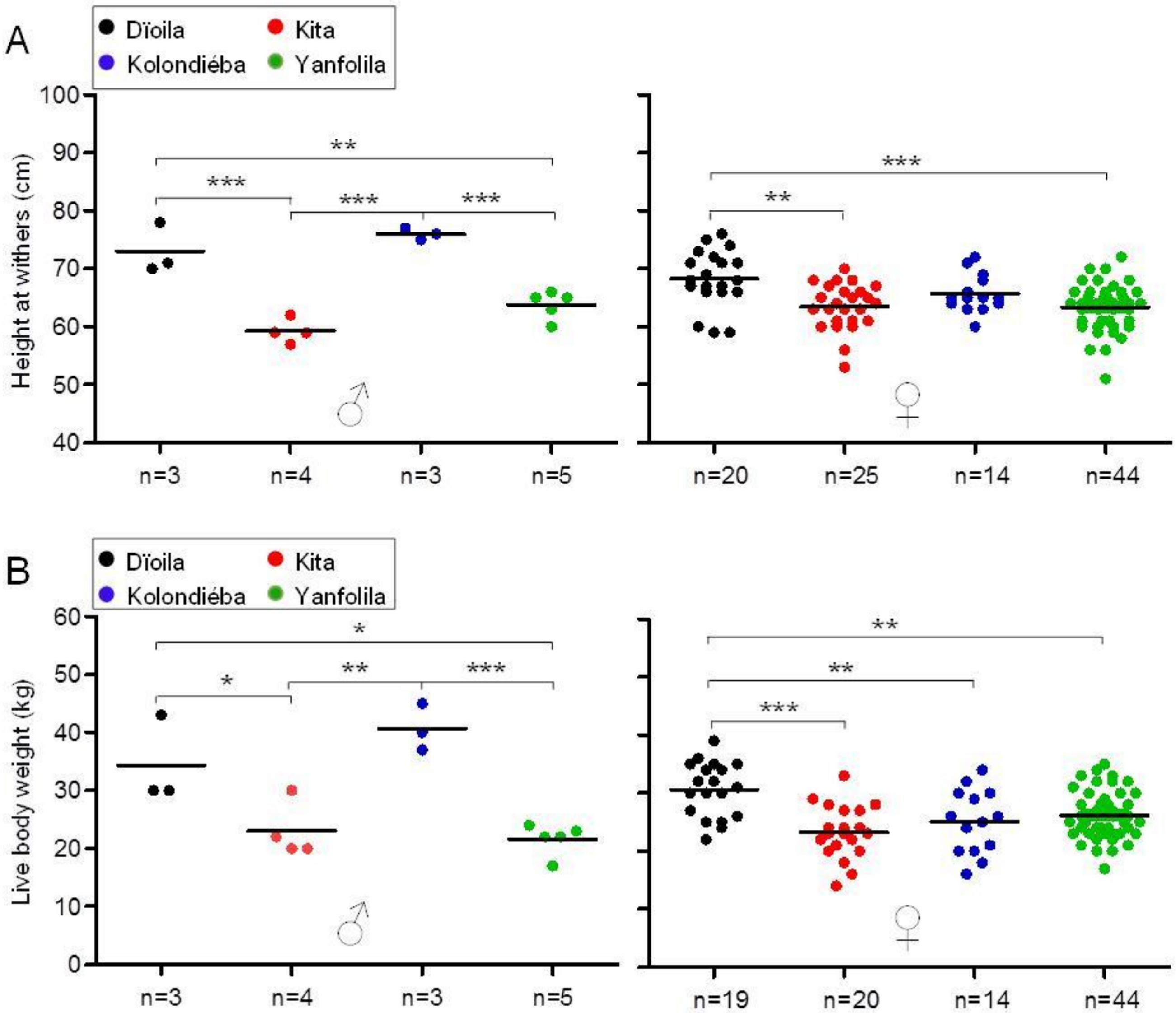

Figure 5. Estimation of height at withers (A) and live body weight (B) in adult Djallonké sheep of both sexes aged between 2 and 3 years within the study zones. (*P < 0.05, ** P < 0.01, ***P < 0.001; one-way ANOVA).

localities (Dïoila, Kita, Yanfolila, and Kolondiéba) in the south of Mali, we show that females largely outnumber males regardless of locality and age groups. Moreover, we observed that the most frequent color pattern in males was white with particularities followed by plain white and piebald, whereas females presented with plain white, followed by white with particularities, piebald, and black. Other data indicate that rams and ewes from Dioïla and Kolondiéba are larger and weigh heavier than those from Kita and Yanfolila. Males are heavier and taller than females and could be due to sexual dimorphism. We believed that these findings could have scientific relevance for the development of conservation and breeding programs of Djallonké sheep in Mali.

In this work, an interesting feature of Djallonké sheep populations across investigated localities was the numerical superiority of females within flocks regardless of age and locality (Tables 2 and 3). A similar observation was made by Wilson (1991) who reported that flocks in sub-Saharan Africa are mostly composed of females (75 to 95%). Two possible explanations for this female predominance in the present study could be the fact that males are most often sold, or the limited practice of sheep fattening activity – which mainly involves males – in investigated localities. In support of second possibility, male sheep outnumbered females in an area of Burkina Faso where sheep fattening is commonly practiced (Traoré et al., 2006).

This work revealed that nearly all males had horns while females usually were polled. Interestingly, such

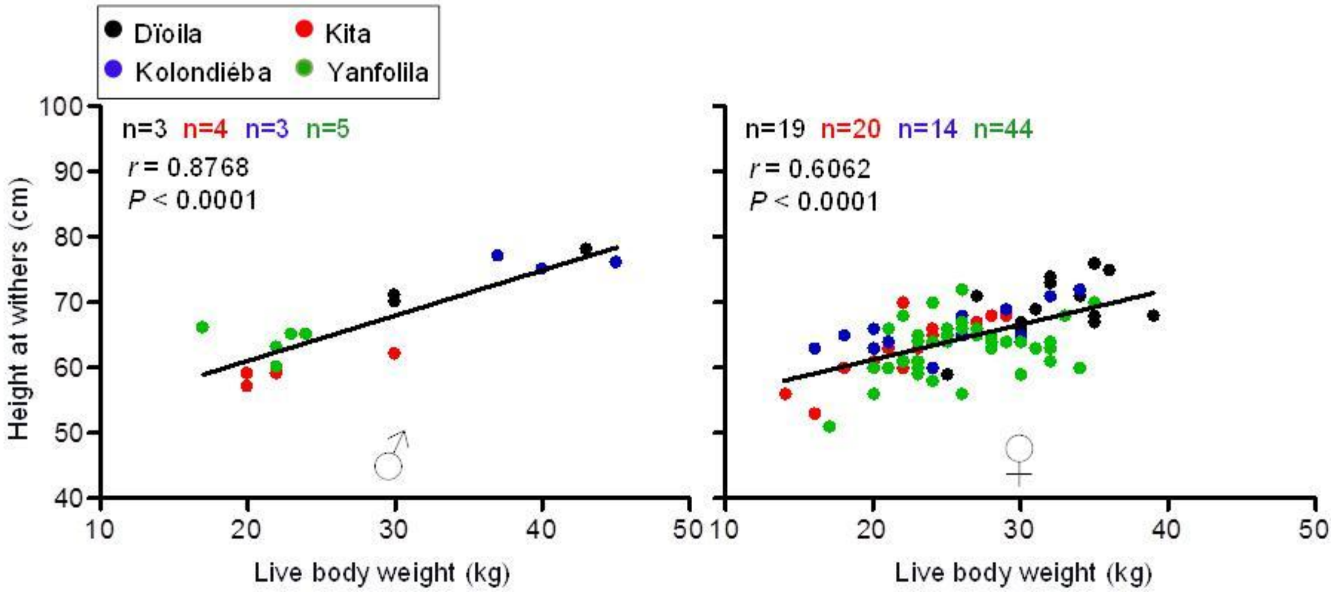

Figure 6. Correlation between height at withers and live body weight in adult Djallonké sheep of both sexes aged between 2 and 3 years within the study zones.

strong male-biased in the presence of horns has also been recently reported in neighboring countries: Burkina-Faso, Cameroon, and Liberia (Traore et al., 2006; Karnuah et al., 2018; Djoufack et al., 2020). Moreover, despite some sex- and locality-dependent differences, wattles were globally less frequent in sampled animals. In this regard, the similarity with studies reporting decreased frequency or total absence of wattles in small ruminants in several West African countries (Gueye, 1997; Salako, 2013; Kolo et al., 2015; Fajemilehin and Adegun, 2020) is especially interesting. Indeed, this is believed to result from the use of goat and sheep without wattles for idolatry sacrifices, a widespread animistic practice in rural zones of these countries.

In this work, we observed four coat pigmentation patterns in Djallonké sheep across investigated localities. Although the frequency of each pattern varied in sex- and locality-dependent manners, for all animals, the predominant pattern was plain white (45%) followed by white with particularities (38%), piebald (16%), and black (1%) (data not shown).

These results are not in agreement with prior studies identifying (in order of abundance) piebald, red or black and plain white as the most frequent color patterns in Djallonké sheep populations reared in Burkina-Faso, Togo, Senegal and Cote d'Ivoire (Gueye, 1997; Traoré et al., 2006; Dayo et al., 2015; N'Goran et al., 2019). They also differ from additional previous studies identifying piebald and brown–white as the predominant color patterns in Djallonké sheep populations in Burkina Faso and Ghana, respectively (Traoré et al., 2008; Birteeb and Donkor, 2016). Collectively, these observations demonstrate a cross-country variation of the predominant coat color in Djallonké sheep populations that is likely to result from the preferences or tastes of Djallonké sheep keepers and consumers.

In the present study, the HW and LBW values obtained in males and females adult (about 2-3 years of age) Djallonké sheep varied as a function of locality, with rams and ewes from Dioïla and Kolondiéba being larger and heavier than those from Kita, and Yanfolila. These inter-locality differences point to the presence of a great genetic diversity of Djallonké sheep across investigated localities.

They also demonstrate that environmental conditions can influence HW and/or LBW measures. Accordingly, while our HW values (for adults) are in agreement with those reported by Wilson (1991), Yunusa et al. (2013), Birteeb et al. (2014), Natoumé et al. (2018) for age-matched Djallonké sheep populations in Mali, Nigeria, and Ghana, this is not the case in other studies carried out in Burkina-Faso and Nigeria (Traoré et al., 2008; Okpeku et al., 2013). Unlike HW values, our LBW measures for adult animals largely agree with those previously reported in age-matched Djallonké sheep populations in Mali, Senegal, and Nigeria (Wilson, 1991; Gueye, 1997; Okpeku et al., 2013; Birteeb et al., 2014; Natoumé et al., 2018). Similarly, in animals with MT and 1PPT, our HW measures (males: 55.78±3.70 cm, females: 61.80±6.10 cm) and LBW values (males: 16.67±2.19 kg, females: 20.89±5.27 kg) (data not shown) agree with those obtained in Djallonké sheep populations from several other West African countries (Kadanga, 1996; Gueye, 1997; Agaviezor et al., 2012; Asamoah-Boaheng and Sam, 2016; N'Goran et al., 2019; Ayantunde et al., 2020).

Our correlation analyses have shown a strong positive correlation between HW and LBW in both rams and ewes. A similar high correlation was observed not only in Djallonké sheep populations from Nigeria, Cameroon, and Ghana (Oke and Ogbonnaya, 2011; Okpeku et al., 2013; Birteeb et al., 2014) but also in other sheep breeds (e.g. Malya and South Karaman sheep) reared in countries outside the African continent (Cilek and Petkova, 2016; Kumar et al., 2018; Bebek and Keskin, 2020). Therefore, our findings not only support these studies but also strengthen the notion that the body weight can be predicted using the height at withers. Further, the difference between our values of correlation coefficients and those of the work mentioned above could be attributable to either the effect of sexual dimorphism or the differences in the number of sampled animals. In strong support of this possibility, our sex-stratified correlation analyses revealed a higher relationship between HW and LBW in females when compared to males.

Conclusion

Djallonké Sheep is a widespread and well adapted indigenous breed that plays a key role in the socio-economic life of people living in rural areas in the South of Mali. However, there is a lack of recent information on their morphological traits needed for their sustainable use, improvement, and conservation. The results of the present study show that Djallonké sheep is a breed with small adult size. They further showed sex- and locality-dependent morphological variability among investigated Djallonké sheep populations in the South of Mali, with animals from Dioïla and Kolondiéba being larger and weighing heavier than those from Kita and Yanfolila. Completing these phenotypic data with molecular genetic analyses could aid in developing coherent and clear long-term conservation and valorization strategies for this breed at the regional and national levels.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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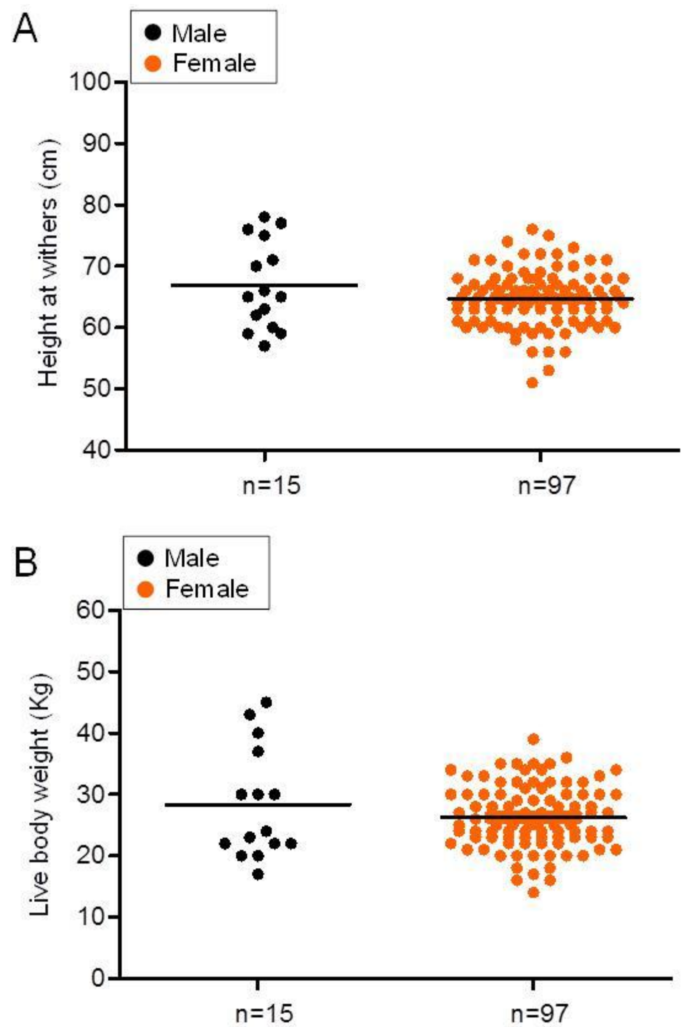

Supplemental Figure 1. Average height at withers (A) and live body weight (B) as function of sex in all adult (about 2-3 years of age) Djallonké sheep regardless of study locality.