Sexual activity and climatic adaptation assessment of West African Dwarf goats introduced into Algeria

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Abstract

This study aimed to highlight the effects of variations in age, seasons and climatic conditions on the reproductive activity of West African Dwarf Goats imported from tropical zones in Algeria, and to verify the degree of their adaptation to Mediterranean climatic conditions. For this purpose, testicular biometry and hormonal analysis (testosterone and LH levels) using the radioimmunological method were carried out monthly. In total, seven goats aged between 18 to 48+ months were surveyed during the period from September 2021 to March 2022. The results showed a considerable effect of age on testicular measurements. Bucks less than 18 months recorded the lowest average testicular length, width, thickness and volume, scrotal width and circumference, as levels of testosterone concentrations. All variables were strong correlated. Seasonal variations in the average testicular measurements and hormonal concentrations were observed, without affecting testicular activity. Apart from the negative action of ambient temperature, no effects of relative humidity or atmospheric pressure were revealed. West African Dwarf Goats showed a good capacity to adapt to Mediterranean climatic conditions through their continuous testicular activity during the year.

Key words: *Sexual activity; Testicular biometry; Hormones; Reproduction; West African Dwarf Goats*

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Introduction

In agriculture, goats are of capital importance in rural development. This zoogenetic resource constitutes an essential element of food security and contributes to the livelihoods of more than a billion people around the world (Chekikene et al., 2021; Yahia et al., 2024). In fact, this population provides milk and meat for consumption and secures a small income, particularly during rainy years. Among breeders, it also provides manure to replace chemical fertilisers, both in market gardening and forage crops (Saidani et al., 2019).

In goat production, reproductive efficiency must be taken into consideration (Khelifi et al., 2020) due to the seasonality mode in this species (Pellicer-Rubio et al., 2019). The reproductive activity of most small ruminants is activated mainly by annual photoperiodism, exhibiting seasonal variations that extend proportionally with latitude. A period of low sexual activity could be manifested and is characterised by a decrease in the intensity of sexual behaviour (libido), testicular size, hormonal secretion, and semen production both in quantity and quality (Ahmad and Noakes, 1995; Taherti et al., 2023).

Testicular biometry constitutes an important element for the evaluation of the normality of the testicles and sperm production potential (Paula et al., 2001). Measurements relating to scrotal circumference (SC), testicular length (TL), testicular weight (TW), testicular volume (TV) and testicular parenchyma volume (TPV) are essential in the androgenic evaluation of reproducer males (Brito et al., 2004; Sahi et al., 2019).

In seasoned goat breeds, significant changes in plasma concentrations of melatonin, (gonadotropin releasing hormone (GnRH), follicular stimulating hormone (FSH), luteinizing hormone (LH), oestrogen, testosterone, and progesterone were observed during different seasons and following photoperiod variations (Pehlivan et al., 2017). For this reason, the evaluation of testosterone levels is important to determine the development of the reproductive system in goats. These concentrations are related to age, season (Delgadillo et al., 2016) and the frequency of LH pulses (Delgadillo et al., 1992).

In hot regions, the sustainability of livestock systems depends on the capacity of animals to adapt to multiple climatic and biological constraints. Understanding physiological and genetic adaptation mechanisms is a major challenge for the science and breeding sectors. Tropical animal populations are the best models for studying adaptation processes, and the knowledge gained is used in warm regions, but can also be remobilised in temperate regions, especially given the current state of climate change (Mandonnet et al., 2011).

In this context, the aim of this study was to highlight the effect of variations in age and season on the reproductive activity of West African Dwarf (WAD) goats raised in Algeria, mainly on variations in testicular measurements and plasma concentrations of testosterone and LH. Another aim was to assess the level of their adaptation to the Mediterranean climate.

Material and methods

Study area description

The study was carried out at the Brabtia wildlife park in the El-Kala region (wilaya of El-Tarf, Algeria). This region is known for its subhumid climate and extreme seasonal variations in perceived

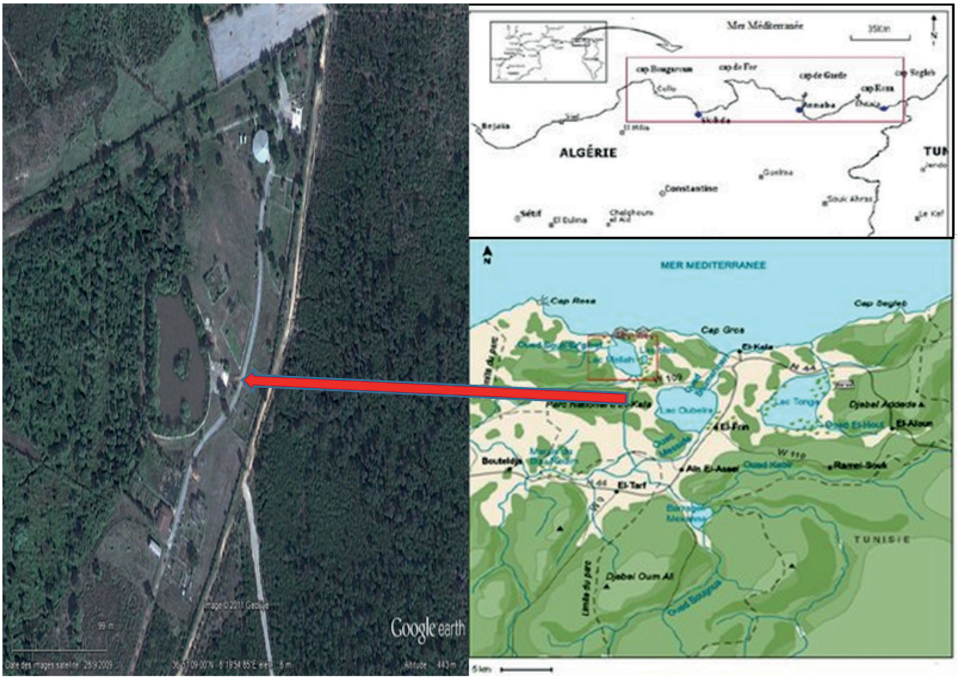

Figure 1. Location of the study area

humidity. The busiest season of the year is from June to October. The annual temperature is under a maritime influence, with an average around 18.7°C. The average winter temperature is 12°C while the summer temperature is 25°C. This area receives 803.45 mm of rain per year. Frost occurs year round, with a fairly long period from December to March. In addition, sirocco winds are frequent (14.2 days per year), most often during July. The figure below was made using Google map to indicate the location.

Animals

The study was carried out on a population of seven WAD goats, aged between 18 to 48+ months over a period of seven months (from September 2021 until March 2022). Four age categories (<18 months, between 18–24 months, between 24–36 months and >48 months) were taken into account depending on the availability of animals at the park during the study period. The age of goats was estimated according to the type of teeth by referring to the number (Vatta et al., 2006) and the shape of the teeth (incisors) (Desta, 2009). The animals received a diet consisting of 500 g dry fodder, 250 g carrots, 300 g livestock feed and water *ad libitum*. Furthermore, vitamins were added to drinking water, and minerals were presented in the form of licking stones.

Testicular biometrics

Before proceeding with testicular biometry, a clinical examination was carried out on all animals. Testicular palpation made it possible to identify testicular lesions on each goat.

Monthly testicular measurements were taken. This operation consisted of determining the testicular length, width and thickness (TL, TW, TT, respectively), the scrotal width and circumference (SW and SC, respectively) and finally, the testicular volume (TV).

The measurement of scrotal circumference (SC) was carried out using a flexible metric tape at the point of maximum perimeter and formed a right angle with the axis of the testicles when the goat was calm and the tension was standard and identical throughout the experiment. The other measurements were made using calibres.

The testicular volume (TV) was calculated by applying the formula: $2 [(r^2) \times \pi \times h]$, in which r = width/2, π= 3.14, and h the length of the testicle (Machado Junior et al., 2011). This formula is more reliable compared to the results obtained by the liquid displacement technique (Machado Junior et al., 2011).

Hormonal analysis

Hormonal assays were carried out on serum obtained after centrifugation at 3000/min for 10 minutes of blood collected by monthly jugular puncture, early in the morning and from fasting animals. The blood was placed in Eppendorf tubes (1.5 mL) and stored by freezing at (-20°C) until the time of analysis (Daramola et al., 2007).

Testosterone and LH levels were assessed by radio-immunoassay (RIA) using specific commercially available kits according to the manufacturer's instructions.

For testosterone concentrations, Immunotech Testosterone, direct IM 1119 kit was used with an analytical sensitivity of 0.025 ng/ml and intra-assay precision with coefficients of variation less than or equal to 15%. The measurement range of analytical sensitivity at the highest calibrator is 0.025–20 ng/mL.

For LH levels, LH IRMA kit was used. The analytical sensitivity is 0.2 IU/L, compared to 0.4 IU/L for the functional sensitivity. The precision of the test gives intra-assay coefficients of variation less than or equal to 6.7%, and inter-assay coefficients of variation less than or equal to 3.7%. Accuracy evaluated by the dilution test on high concentration samples diluted in zero calibrators gave percent recovery, ranging between 83 and 113%.

Ethical statement

All the animal studies were conducted with the utmost regard for animal welfare, and all animal rights issues were appropriately observed. No animal suffered during the course of the work. All the experiments were carried out according to the guidelines of the Institutional Animal Care Committee of the Algerian Higher Education and Scientific Research (Agreement Number 45/DGLPAG/DVA.SDA.14).

Statistical analysis

Descriptive statistics (means ± SD) were used to describe biometric characteristics. The averages of all parameters studied as a function of age and season were considered independent.

In order to verify variations in testicular measurements and plasma concentrations of testosterone and LH according to age, season, and climatic parameters (temperature, relative humidity and atmospheric pressure) and study the effect of these different factors on the variations of the variables studied, a one-way analysis of variance (ANOVA I) was carried out. Correlations between the different testicular, hormonal and climatic parameters have been established. A test for equality of variance (with a 95% confidence interval for standard deviations) was applied to compare the different variables. For the applied tests, a probability less than

0.05 was considered significant. These tests were carried out with SPSS software (PASW Statistic 25).

Results and discussion

In tropical regions, goats are often assumed to be capable of breeding year round (Delgadillo et al., 1997), although they may exhibit significant periods of sexual inactivity caused by insufficient nutrition (Taherti et al., 2023).

Variations in testicular measurements and hormonal concentrations according to age

Age at puberty is highly variable and depends on the genetic factors and the breeding system. In tropical zones, the age of sexual maturity is a subject of debate. In African goat breeds, sexual maturity is reached at a very young age of between 3 and 6 months (Webster and Wilson, 1989; Steele, 1996) while in unfavourable breeding conditions, it is reached between 8 and 14 months. In animals of European breeds raised in the tropics, puberty is only observed between 12 and 20 months of age (Delgadillo et al., 1996).

In the WAD goats studied, data showed that the age plays a very important role in variations in testicular biometry ($P<0.05$). Previously, Daramola (2007) found same result in young dwarf goats from Nigeria aged between 2 and 3 months and weighing 4.82±0.87 kg. It was observed after bringing the animals to maturity following treatment with melatonin at increasing doses. Indeed, these goats presented accelerated reproductive activity and sexual maturity. They expressed a testicular length and a scrotal circumference (TL = 6.6 cm and SC = 15.1 cm) similar to those obtained in the adult animals used in our study (Table 1). Melatonin is known for its effects on testicular activity, sperm production, puberty and sexual behaviour (Daramola et al., 2006; Pellicer-Rubio et al., 2019).

On the other hand, our results are lower than those obtained by Abd-Allah et al. (2007) in goats native to Egypt and by Souza et al. (2011) in Anglo-Nubian goats (r=0.68 with $P<0.01$). Age also influences body conditions, scrotal circumference, scrotal length and width (Osinowo et al., 1988; Zamiri and Heidari, 2006).

Table 1. Testicular biometrics and hormonal rates according to age

Variables	Age				
	< 18 month	[18 - 24] months	[24 - 36] months	> 48 months	*P*
TL (cm)	2.81±0.38	7.55±1.04	7.66±0.15	7.97±0	0.01
TW (cm)	1.71±0.28	3.44±0.28	3.46±0.08	3.82±0	0.01
TT (cm)	1.5±0.28	3.37±0.47	3.43±0.028	3.56±0	0.02
SW (cm)	3.59±0.54	7.06±0.57	7.05±0.13	7.81±0	0.01
SC (cm)	9.89±0.97	19.68±1.46	20±0.20	22.07±0	0.01
TV (cm^3)	107.69±47.21	287.77±84.68	289.64±18.35	364.72±0	0.09
[Testosterone] (ng/ml)	0.8±0.26	1.74±0.40	1.62±0.43	2.45±0	0.11
[LH] (IU/L)	0.38±0.028	0.45±00	0.36±0.00	0.4±0.0	0.04

In the studies of Raji et al. (2008) on white Borno goats (11º N) and Keith et al. (2009) on Boer goats (32°N), a high positive correlation (r= 0.82 and r= 0.78 respectively) was found between scrotal circumference and body weight, which revealed that in addition to breed and latitude, testicular development is also related to body weight and age of goats.

For the WAD goats studied, the minimum concentrations of testosterone were noted in animals whose age was less than 18 months while those aged over 4 years expressed the highest values. Abd-Allah et al. (2007), in a study carried out on goats native to Egypt, obtained lower testosterone concentrations in one-year-old goats ([Testosterone] = 1.17 ± 0.12 ng/mL) in comparison with those aged between 2 years ([Testosterone] = 2.30 ± 0.19 ng/mL) and 3 years ([Testosterone] = 2.80 ± 0.22 ng/mL). The maximum levels were recorded in animals over 3 years old.

In young Anglo-Nubian goats evolving in a semi-intensive environment, the plasma concentrations of testosterone in goats were related to age (*P*<0.05). Indeed, at 20 months of age, these animals presented a testosterone rate equal to 2.70 ± 1.40 ng/mL while at 28 months, it was 8.50 ± 4.66 ng/mL. This value decreased at the age of 38 months to 2.21 ± 2.28 ng/ml (Souza et al., 2011).

Testosterone concentrations expressed in the animals studied were strongly correlated with certain testicular parameters, in particular with the testicular width (r=0.77 with *P*<0.05), scrotal width (r=0.82 with *P*<0.05), scrotal circumference (r=0.78 with *P*<0.05) and testicular volume (r=0.69). Whereas, LH concentrations were positively correlated with all testicular measurements (0.23 < r<0.31).

Variations in testicular measurements and hormonal concentrations according to the season

In small ruminants, the onset of sexual activity mainly depends on the breed, operating system and season of birth (Ahmad and Noakes, 1995; Almeida et al., 2007).

The WAD goats studied demonstrated continued testicular activity during the study period (*P*>0.05). The breed in question (imported into the Mediterranean area) lives preferentially below the parallel 6°N, which indicated that the change in latitude from tropical to Mediterranean area had no effect on testicular growth. This was the case for local goats in western Algeria that have annual breeding activity, a constant diet and a permanent presence of females (Canedo et al., 1996; Hammoudi et al., 2010) unlike European goat breeds imported into tropical or subtropical zones (Le Gal and Planchenault, 1993; Delgadillo, 1996; Alexandre et al., 2012). However, Zarazaga et al. (2009) demonstrated that during overfeeding, no variation in the seasonality of Payoya goats was observed and no differences on reproductive activity were observed due to supplementation of the food ration and that only season showed a difference, despite the weight gain.

The present study revealed that the average values of TL, TT, SC and TV varied by season (Table 2). They showed a decrease between autumn and winter and an increase in spring. Minimum values of TW and SW were recorded during autumn. A slight increase was then recorded in winter, reaching a maximum in spring. The most important results concerning TW, TT, SW, SC and TV were observed in spring (Table 2), and these variables were highly correlated (0.94 < r <1.00; *P*<0.01).

Table 2. Effect of season on variations in testicular biometrics and hormonal concentrations

Variables	Season			
	Autumn	Winter	Spring	*P*
TL (cm)	6.74 ± 2.66	5.80 ± 2.26	6.32 ±0	0.78
TW (cm)	2.98±0.91	2.99±0.92	3.11±0	0.96
TT (cm)	2.86±0.98	2.80±0.90	3.16±0	0.80
SW (cm)	6.11±1.85	6.17±1.81	6.36±0	0.97
SC (cm)	17.13±5.59	17.03±5.08	18.71±0	0.79
TV (cm^3)	261.68±118.39	226.99±101.27	268.90±0	0.77
[Testosterone] (ng/ml)	3.70±1.72	0.48±0.32	0.37±0	0.00
[LH] (IU/L)	0.42±0.11	0.37±0.07	0.42±0	0.00

As in the WAD goats studied, Kashmir goats of Iran have significant sexual activity between September and October with a maximum in November (Farshad et al., 2008; Talebi et al., 2009). Contrary to our results, many studies mentioned a great influence of the time of year on variations in testicular and scrotal biometrics ($P<0.05$) of animals living in temperate or subtropical regions, resulting in a large variation between dry and rainy seasons (Ferreira et al., 1988; Bailey et al., 1998; Moreira et al., 2001; Almeida et al., 2010; Machado Junior et al., 2011). This result was found also in British and French goats that demonstrated better testicular parameters in summer and autumn than in winter and spring ($P<0.01$) (Ahmad and Noakes, 1995; Lurette et al., 2016).

For goats, seasonal variations in fertility were due to changes in day length throughout the year. This factor determines the annual rhythm of hormonal secretions by the hypothalamic-pituitary-gonadal axis, particularly the frequency of LH pulses that stimulate the release of testosterone by the testes (Hammoudi et al., 2010). Pulsatile LH activity is stimulated by short days and inhibited by long days (Chemineau and Delgadillo, 1994). These authors suggested that each LH pulse is followed by a testosterone pulse whose amplitude varies depending on the physiological situation of the male, as confirmed in the present study. This is related to daily changes in day length and concentrations of melatonin produced (Pellicer-Rubio et al., 2019).

During the study period, we observed a variation in testosterone concentrations ($P<0.001$). The maximum average recorded in autumn decreased in winter while the minimum appeared at the beginning of spring (Table 2). These results coincide perfectly with the observations of Ahmed and Noakes (1995), who described maximum values of testosterone concentration in autumn (September) in British goats.

The WAD studied recorded maximum testosterone concentration values in November (4.21±3.50 ng/mL) followed by a significant drop during December (0.32±0.20 ng/mL). These levels increased again during February (0.75±0.46 ng/mL), then decreased during March (0.37±0.35 ng/mL). Delgadillo et al. (1999) mentioned minimum values of testosterone concentration (0.1 ng/mL) during January and February in Alpine goats, while peaks were observed during July and August. For their part, Todini et al. (2007) demonstrated that goats in Mediterranean areas were also affected by seasonal variations in testosterone concentrations with high levels during summer and autumn. This observation was confirmed by Hammoudi et al. (2010) for the Arbia breed from Algeria and Sogorescu et al. (2011) for Carpathian goats from Romania.

Blood LH concentrations varied from one season to another (*P*<0.001), as did testosterone levels (Table 2). The basal concentrations of LH recorded during December ([LH] = 0.25±0.13 IU/L) were lower than those described in Alpine goats ([LH] = 0.3 ng/mL) (Chemineau and Delgadillo 1994). The maximum LH concentrations were obtained during January ([LH] = 0.45±0.18 IU/L). Alpine goats presented high levels of LH in August and September, with a progressive decrease until January, then the annual cycle begins again (Saumande and Rouger, 1972; Delgadillo et al., 1992). Conversely, Australian Cashmere goats in the Southern hemisphere showed the same variations but with a lag of six months (Walkden-Brown, 1991). Our animals presented a decrease in LH concentrations between October ([LH] = 0.45±0.16 IU/L) and December ([LH] = 0.25±0.13 IU/L). These rates increased in January ([LH] = 0.47±0.18 IU/L) then decreased in February. After this period, the annual LH secretion cycle begins to increase again in March.

Variations in testicular measurements and hormonal concentrations according to climate parameters

Our study demonstrated a negative effect of ambient temperature on the variations of all variables studied (Table 3).

Moreira et al. (2001) obtained a negative correlation between high environmental temperatures, scrotal circumference and testicular length. However, Ferreira et al. (1988) noted a positive correlation between high temperatures and scrotal circumference. While atmospheric pressure positively affected scrotal width and testicular volume, relative humidity was negatively correlated with LH concentration. The difference of the results can be explained by the variety of the species, diet, number of animals used, and

Table 3. Correlation between climatic variables and the different parameters studied

Variables	T (°C)	P (mmhg)	U (%)
TL (cm)	-0.89 **	0.75	0.57
TW (cm)	-0.85 *	0.73	0.51
TT (cm)	-0.88 **	0.75	0.54
SW (cm)	-0.89 **	0.77 *	0.59
SC (cm)	-0.85 *	0.74	0.51
TV (cm^3)	-0.82 *	0.78 *	0.46
[Testosterone] (ng /ml)	-0.55	0.69	0.19
[LH] (IU/L)	0.14	0.23	-0.16

T: temperature; P: atmospheric pressure; mmhg: millimetre of mercury; U: relative humidity; *: *P*<0.05; ***P*<0.01.

Table 4. Correlation results between all the parameters studied

r	TL	TW (cm)	TT (cm)	SW (cm)	SC (cm)	TV (cm^3)	[TESTO] (ng/ml)	[LH] (IU/L)	Tn (°C)	Tx (°C)	T (°C)	P (mmhg)	U (%)
TL (cm)	1	0.992**	0.998**	0.983**	0.992**	0.957**	0.737	0.284	-0.884**	-0.876**	-0.889**	0.746	0.569
TW (cm)		1	0.993**	0.979**	1.000**	0.970**	0.771*	0.306	-0.852*	-0.836*	-0.854*	0.730	0.511
TT (cm)			1	0.973**	0.993**	0.966**	0.719	0.288	-0.873*	-0.867*	-0.879**	0.748	0.539
SW (cm)				1	0.980**	0.936**	0.820*	0.232	-0.895**	-0.866*	-0.886**	0.773*	0.586
SC (cm)					1	0.970**	0.776*	0.313	-0.849*	-0.832*	-0.851*	0.735	0.506
TV (cm^3)						1	0.687	0.292	-0.813*	-0.791*	-0.815*	0.779*	0.460
[TESTO] (ng/ml)							1	0.232	-0.600	-0.511	-0.553	0.691	0.193
[LH] (IU/L)								1	0.168	0.136	0.138	0.234	-0.159
TN (°C)									1	0.989**	0.996**	-0.621	-0.770*
TX (°C)										1	0.998**	-0.554	-0.811*
T (°C)											1	-0.583	-0.793*
P (mmhg)												1	0.187
U (%)													1

climate factors (Taherti et al., 2024). Table 4 outlines the correlations among all parameters and factors as described above.

Conclusions

To our knowledge, the present study is the first to be carried out on variations in testicular measurements and hormonal concentrations in West African Dwarf goats imported from African tropical zones to Mediterranean areas. The results allow us to conclude that during the study period only variations in age and ambient temperature can interfere with testicular activity. In addition, the WAD breed has demonstrated its adaptation to the Mediterranean climate prevailing in Algeria. Since, these findings are important and useful with high economic impact, further investigations using a larger number of animals are recommended in the future.

Acknowledgements

The authors warmly thank all the staff of the Brabtia animal park for their help and collaboration during the realisation of the experimental part.

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Procjena spolne aktivnosti i klimatske prilagodbe zapadnoafričkih patuljastih koza uvezenih u Alžir

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Cilj je ove studije bio naglasiti učinke razlika u dobi, godišnjim dobima i klimatskim uvjetima na reproduktivnu aktivnost zapadnoafričkih patuljastih koza (ZAP) uvezenih iz tropskih zona u Alžir i provjeriti stupanj njihove prilagodbe uvjetima mediteranske klime. U tu je svrhu mjesečno provođena biometrija testisa i hormonalna analiza (razine testosterona i LH) uporabom radioimunološke metode (RIA). Ukupno sedam koza u dobi između 18 i više od 48 mjeseci je tijekom razdoblja od rujna 2021. do ožujka 2022. godine testirano. Dobiveni rezultati pokazali su značajan učinak dobi na dimenzije testisa ($P<0,05$). Jarci u dobi ispod 18 mjeseci pokazali su najnižu prosječnu duljinu, širinu, debljinu i volumen testisa (TL= 2,81±0,38 cm; TW= 1,71±0,28 cm; TT= 1,5±0,28 cm i TV= 107,69±47,21 cm^3), širinu i opseg skrotuma (SW= 3,59±0,54 cm, odnosno SC= 9,89±0,97 cm), kao i najniže vrijednosti koncentracija testosterona ([testosteron]= 0,8±0,26 ng/mL) i LH ([LH]= 0,38±0,028 IU/L). Sve su te varijable pokazale vrlo snažnu međusobnu korelaciju ($0,936< r<1,00$). Razlike prosječnih dimenzija testisa i koncentracija hormona su zamijećene tijekom godišnjih doba razmatranih u studiji, bez utjecaja na aktivnost testisa ($P>0,05$). Osim negativnog djelovanja temperature ambijenta ($P<0,05$), nije zamijećen nikakav učinak relativne vlažnosti zraka i atmosferskog tlaka na proučavane parametre. ZAP su pokazale vrlo dobar kapacitet prilagodbe uvjetima mediteranske klime kroz kontinuiranu aktivnost testisa tijekom različitih razdoblja u godini.

Ključne riječi: *spolna aktivnost, biometrija testisa, hormoni, reprodukcija, ZAP*