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CONFERENCE PAPER

# Ecophysiology of camel ovarian functioning under extremely arid conditions in Algeria

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## Abstract

The ovarian ecophysiology of mature female camels under extremely arid conditions was studied by investigating 288 non-pregnant genital tracts. The proportions of females with inactive ovaries were 31.25%, 25%, and 50% during the winter, the spring, and the summer, respectively. The mean number of active follicular structures per ovary and the proportion of females with active ovaries were significantly higher ($P<0.05$) during the winter ($0.75 \pm 0.36$, 68.75%) and spring ($0.7 \pm 0.41$, 75%) than during the summer ($0.33 \pm 0.28$, 50%). Furthermore, the proportion of active ovaries that presented active corpora lutea was also significantly higher ($P<0.05$) during the spring season (45.83%). These physiological ovarian changes significantly influenced the ovarian weight and mass. The proportion of females with active ovaries was significantly correlated with the body condition score (BCS, $P<0.05$). The results of this work indicate that the ovarian activity of Sahrawi female camels that live in extremely arid conditions in Algeria is high during the cold and rainy months (December–February) and moderately high in the spring (March–May), but drops significantly in the summer without stopping entirely. The favorable reproductive period for female camels corresponds to optimal seasonal food availability in pasture and a marked improvement in BCS.

**Keywords** Algeria · BCS · Camel · Ovarian ecophysiology · Season

## Introduction

The dromedary camel (*Camelus dromedarius*) is the largest mammal that is adapted to extreme arid environmental conditions. It also helps to combat desertification, as it grazes on a wide variety of plants, thus encouraging floristic biodiversity. These adaptations allow the dromedary to survive and reproduce in the most arid areas, despite prolonged droughts, drastic fluctuations in ambient temperatures (coldwaves and heatwaves), and food shortages (Gaughan 2001; Bouâouda et al. 2014; Tibary and El Allali 2020). It is morphofunctionally adapted to reach plant strata with high digestibilities and food efficiencies. It has ambulatory and low gregarious grazing behavior and long intestinal transit leading to improved germination of seeds after excretion.

Statistics show that the total camel population of North Africa has decreased in the last 57 years (1961–2018) from 981,692 to 928,081 heads, corresponding to a decrease from 8% to 3.25% of the global camel population (FAOSTAT 2018). The low numerical productivity of camel species is mainly due to a low fertility rate, a long gestation period, a late onset of puberty, a large time interval between

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calving, and a high mortality rate during the first year after giving birth. The fertility rate in the conditions of the Algerian Sahara is estimated to vary between 38 and 67% (Gherissi et al. 2020).

Detailed knowledge of camel seasonal physiological characteristics is required to optimize interventions at the individual and herd levels that aim to improve their reproductive traits. In this species, ovarian activity depends on interactions between food quality and climatological, geographical, and photoperiodic factors (Gherissi et al. 2014; Gherissi et al. 2018a; Ainani et al. 2018). Female dromedary camels show a strong tendency to be seasonal and almost polyestrous (Monaco et al. 2015). The breeding season of camels in North Africa varies according to food availability and the combined effect of various climatic factors that facilitate the proper functioning of the camel reproductive system. The variability of the breeding season length depends meanly on changes of these conditions. Thus, a transition period is observed at start of breeding season and before entering in the nonbreeding season leading to expression of erratic and unpredictable sexual activity (Sghiri and Driancourt 1999; Gherissi et al. 2014, 2016). During the breeding season, female camels show repeated cycles of ovarian follicle growth and regression without ovulation in the absence of mating (Monaco et al. 2015). It is mainly for this reason that the follicular cycle tends to be discussed rather than the estrus cycle in camelids. The duration of the follicular cycle in the female camel varies from 12 to 28 days depending on the geographic location of the camel, its age, the period of the breeding season (i.e., its duration and position within the year), and the nature of the ovarian structures associated with it (Zarrouk et al. 2003).

The pattern of follicular growth and regression is well documented, but it still unclear whether follicular waves persist during the nonbreeding season in camels, as they do in sheep and goats (Agrawal et al. 2015), or whether they stop during the nonbreeding season and then resume during the transition into the breeding season, as in mares (Driancourt et al. 2001). This is important information when choosing therapeutic strategies for reproduction management in camel females based on follicular growth synchronization and ovulation induction.

The study reported in the present paper was performed to establish baseline data on ovarian activity in female camels. This involved studying how the pattern of ovarian structures changed with the season in an arid environment in southeastern Algeria.

## Materials and methods

This study was conducted in the El Oued region (33–34°N, 6–8°E) of southeastern Algeria. This region has an arid climate, an average altitude of 80 m, an average annual temperature of around 25 °C (maximum 52 °C, minimum 2 °C), and an average annual precipitation of 80 mm (Fig. 1). Winter extends from December to February; spring begins in March and continues until the end of May; summer runs from June to August; and autumn lasts from September to November. This region has wet and hot seasons that vary in duration from one year to the next (Fig. 1).

A total of 288 (winter: $n = 144$, spring: $n = 72$, summer: $n = 72$) mature nonpregnant female camels (≥ 5 years) were studied between November 2012 and February 2014. Each camel was assigned a body condition score (BCS) on a scale of 5, as recommended by Faye et al. (2001); see Fig. 2. Emaciated animals were assigned a BCS of 1, while the most obese animals were assigned a BCS of 5. A survey of eight pastoral farms regarding the origins of the studied animals was carried out to highlight the seasonal botanical variability of the forage exploited by the dromedary in the study area. The annual distribution of the herd and its frequency of movement were recorded, and the evolution of the rutting behavior of the herd throughout the study period was documented.

Both ovaries of each animal were sampled after slaughter, leading to the inspection of a total of 576 ovaries. The ovarian morphometry was investigated by measuring the ovarian length (OL), ovarian width (Ol), and ovarian thickness (OT). The ovarian weight (OW) was also recorded. All follicles that were ≥ 2 mm in size were identified and categorized into small (< 5 mm), medium (5–10 mm), large (11–17 mm), cystic (≥ 18 mm), or atretic, and corpora lutea were classified as either hemorrhagic, mature, or atretic (Fig. 3). Ovaries without any structures (smooth ovaries) and those with small follicles only (black periphery ovaries) were considered to be inactive.

Ovarian functioning was studied according to Gherissi et al. (2018b) based on the following parameters: seasonal mass and weight of the ovaries, seasonal frequencies of the various ovarian structures (medium, large, atretic, and cystic follicles; hemorrhagic, mature, and regressing corpus luteum), seasonal rate of females with an active ovary (or active ovaries), and the effect of body reserves on ovarian function.

### Statistical analysis

Data were analyzed using IBM® SPSS 20 software. Continuous variables (e.g., ovarian mass, follicular diameter) were not distributed normally ($P > 0.05$ in Shapiro–Wilk normality tests). Means were compared using Kruskal–Wallis and post-hoc tests. Differences between the seasons and between BCS classes in ovarian structure frequency and ovarian status were compared using contingency tables and the chi-squared test. Results were expressed as mean ± SD values or percentages.

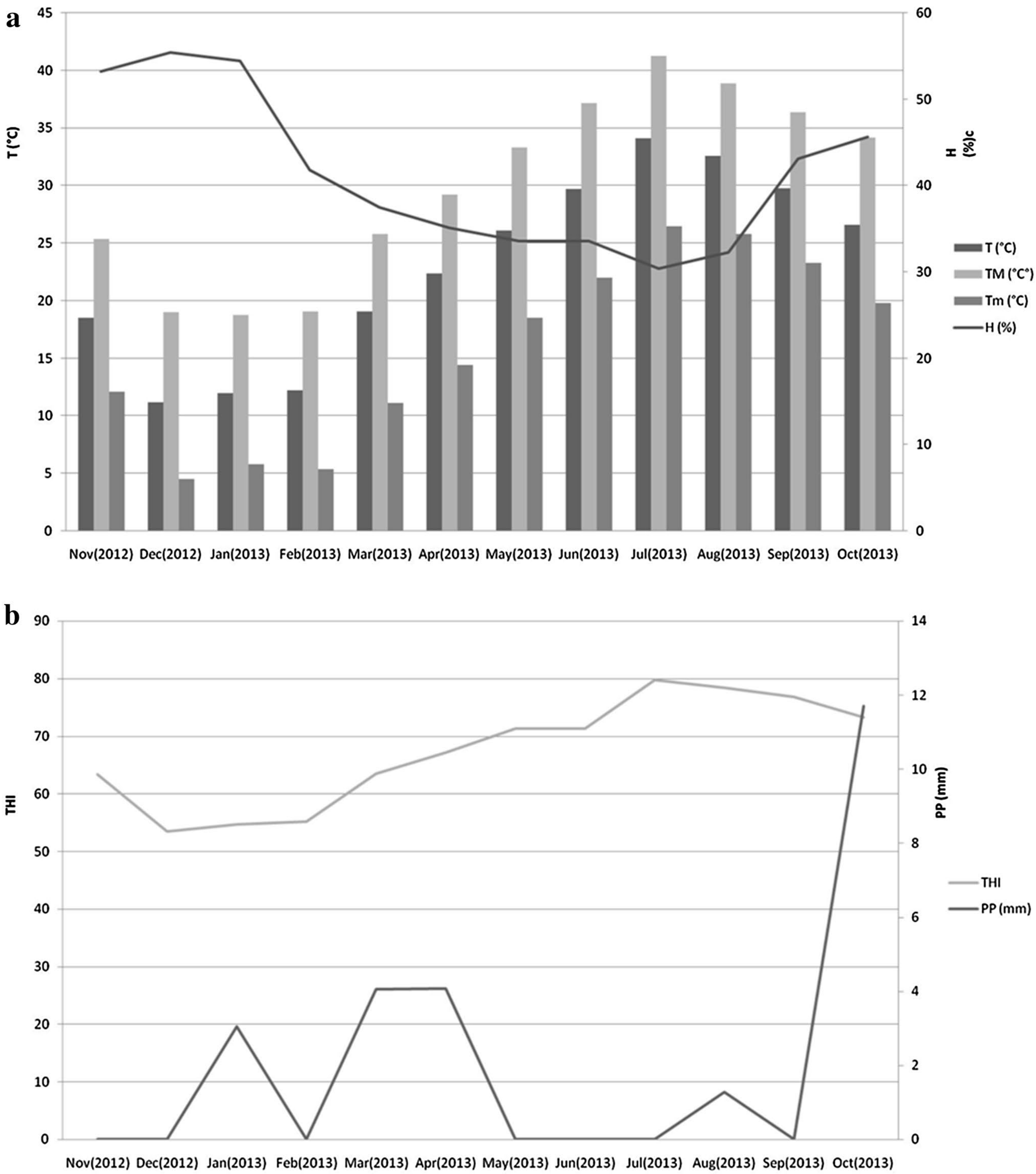


**Fig. 1** Average monthly values of climatological parameters, as measured by Guemmar Station in 2014. (**a**) *T* average temperature (°C), *TM* maximum temperature (°C), *Tm* minimum temperature (°C), *H* average relative humidity (%). (**b**) *PP* total rainfall (mm), *THI* temperature humidity index

**Fig. 2** Determination of the body condition score (BCS) for the female camels studied in this work. *Black arrows* indicate body regions that were inspected for BCS assessment

Significance levels of $P<0.05$, $P<0.01$, and $P<0.001$ were applied.

## Results

### Food availability and herd mobility

Camel rutting behavior was mainly observed during the season with open range grazing, good-to-medium grazing plant abundance, and high animal mobility (Table 1). During the wet season, 19 species of Saharan plants were grazed by camels, and concentrated food supplementation was rarely practiced (see Table 2 and the Electronic supplementary material, ESM). During the hot season, there was poor availability of natural forage on the pasture (only 8 species were observed to be grazed), and natural grazing provided only 2% of the camels' food. They become highly dependent on dry concentrated food (concentrated food supplements, bran, dates, etc.) (Fig. 4).

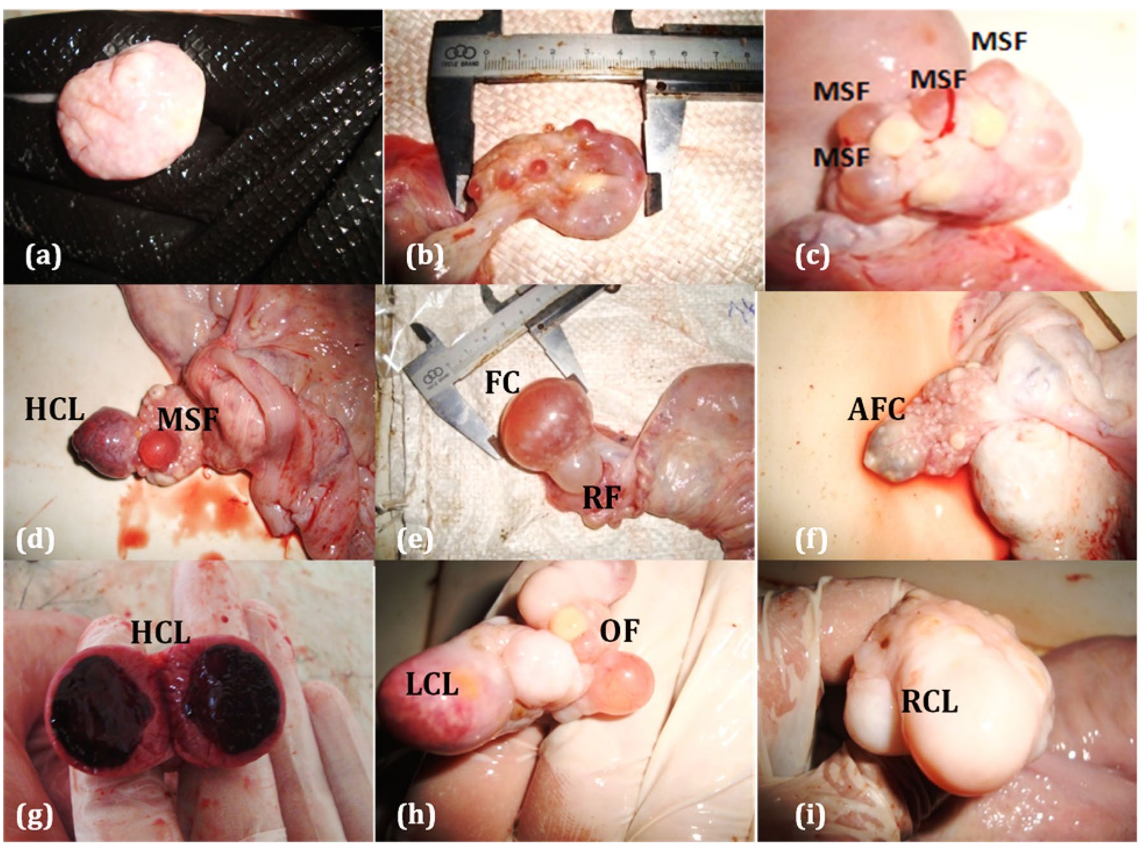


**Fig. 3** Various ovarian structures identified during examinations of female camel ovaries: **a** inactive smooth ovary, **b** inactive black periphery ovary, **c**–**i** active ovaries. *MSF* medium-size follicle, *HCL* hemorrhagic corpus luteum, *FC* follicular cyst, *RF* follicle in regression, *AFC* hemorrhagic cyst in regression, *HCL* hemorrhagic corpus luteum, *LCL* large corpus luteum, *OF* ovulatory follicle, *RCL* corpus luteum in regression

## Ovarian size, weight, and function in relation to season

Season was found to be a prominent influence on ovarian mass and weight (Table 3). Heavier ovaries were recorded during the wet season ($P<0.001$). In contrast, ovarian length, width, and thickness increased significantly ($P<0.01$) during the transition from winter to summer.

Table 4 shows that the mean number of active ovarian structures is significantly higher during winter and spring ($0.75\pm0.36$ and $0.7\pm0.41$, respectively, $P>0.05$) than during summer ($0.33\pm0.28$, $P<0.05$). To get a better understanding of ovarian activity, data for the right and left ovaries were pooled (Fig. 6a). 8.33%, 16.66%, and 20.91% of the ovaries were smooth (lacking in any observable structures) during the summer, spring, and winter seasons, respectively. 41.66%, 8.33%, and 10.41% of the ovaries had follicles < 5 mm in size (black periphery ovaries) during summer, spring, and winter, respectively ($P<0.05$). These two inactive ovarian classes together comprised 50%, 25%, and 31.32% of all ovaries during the summer, spring, and winter, respectively.

The proportion of females with active ovaries was low during the summer (50%). The proportion was significantly higher between December and May (68.75–75%; $P<0.05$; Fig. 5). During this period, the proportion of active ovaries bearing medium-size or ovulatory follicles ranged from 51.04% to 54.16% ($P<0.05$). More of the active ovaries presented corpora lutea during the winter (45.83%), and more of the ovaries presented follicular cysts during the spring (16.66%).

## Effect of BCS on ovarian activity

Figure 6 shows that a high proportion of the females with a BCS of 3–3.5 had active ovaries (71.47–88.33%, $P<0.05$), whereas the proportion of the females with a BCS of ≤ 2.5 that had active ovaries (50–77.77%) was much lower. There were no female camels with a BCS of ≥ 4 that had active ovaries during the summer. Camels in this BCS category maintained high ovarian activity during the spring and winter (70% and 100%, respectively). Regardless of body reserves, fewer of the studied animals were sexually active during the summer (0–71.47%) than during the winter and spring (Fig. 6).

**Table 1** Annual cycles of camel movement for grazing, food supplementation, and rut behavior in south east Algeria

<table>
<tr><th></th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Agu</th><th>Sep</th><th>Oct</th><th>Nov</th></tr>
<tr><td>Pasture</td><td colspan="4">Good</td><td colspan="2">Medium</td><td colspan="4">Poor</td><td colspan="2">Medium</td></tr>
<tr><td>Food supplementation</td><td></td><td colspan="6"></td><td colspan="5"></td></tr>
<tr><td>Camel Herds mobility</td><td colspan="5"></td><td colspan="5"></td><td colspan="2"></td></tr>
<tr><td>Rutting behavior</td><td colspan="4"></td><td colspan="7"></td><td></td></tr>
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**Table 2** Plant species exploited by the dromedary during the rutting and nonrutting seasons in the study area

| Plants | Rutting season | Nonrutting season |
|---|---|---|
| Azal (*Calligonum azel*) | * | * |
| Alanda (*Ephedra alata*) | * | * |
| Arta (*Calligonum comosum*) | * | * |
| Halfa (*Stipa tenacissima*) | * | |
| Smahri | * | |
| Bagel (*Anabasis articulata*) | * | |
| Retem (*Retama raetam*) | * | * |
| Tarfa (*Tamarix gallica*) | * | * |
| Djefna (*Gymocarpos decander*) | * | |
| Arfage (*Anvillea radiata*) | * | |
| Hormok | * | * |
| Methnan (*Thymelaea hirsuta*) | * | * |
| Zeita (*Limoniastrum guyonianum*) | * | |
| Souide (*Suaeda fructicosa*) | * | |
| Foul bool | * | |
| Sedra (*Zizyphus lotus*) | * | * |
| Boughriba (*Zygophyllum album*) | * | |
| Drinn (*Stipagrostis pungens*) | * | |
| Chouk (*Centaurea pungens*) | * | |

Plhotographs of the plants are provided in the ESM

## Ecophysiological pattern for camel ovaries

The approach undertaken in this study confirmed that weather conditions and seasonal feeding practices are likely to significantly influence the body condition of camels, especially during the transition from the spring season to the summer season (Fig. 7). Thus, ovarian activity (as gauged from the weight of the ovary, the frequencies of ovarian structures, the rate of active ovaries, and the proportion of the females who carried active ovaries) was observed to be high during the period of significant grazing mobility, which coincided with the rutting season, high grazing plant species availability, and enhanced body reserves for reproduction. The previously mentioned physiological

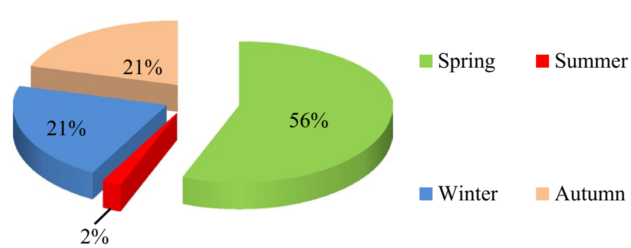


**Fig. 4** Proportion of the diet of the camel herd that derives from grazing as a function of season

**Table 3** Effect of season on ovarian size and weight

| Ovarian parameter | Winter ($n=288$) | Spring ($n=144$) | Summer ($n=144$) | Variation (%)[sig] | | |
|---|---|---|---|---|---|---|
| | | | | W/S | S/Su | W/Su |
| Length (cm) | 2.40 ± 0.48 | 3.03 ± 0.69 | 3.13 ± 0.54 | 26.25** | NS | 30.41** |
| Width (cm) | 1.60 ± 0.31 | 1.94 ± 0.59 | 1.85 ± 0.53 | 21.25** | NS | 15.62* |
| Thickness (cm) | 0.67 ± 0.25 | 0.77 ± 0.25 | 0.93 ± 0.21 | NS | NS | 38.8** |
| Weight (g) | 16.64 ± 1.7 | 12.1 ± 3.3 | 6.9 ± 1.55 | 37.52** | 17.51* | 141.15*** |

*S* spring, *Su* summer, *W* winter; *asterisks* indicate differences between seasons that were significant at the $P<0.05$ (*), $P<0.01$ (**), and $P<0.001$ (***) levels

**Table 4** Mean number of follicular structures per ovary in relation to season

| Ovarian follicular structures | Winter ($n=144$) | Spring ($n=72$) | Summer ($n=72$) | Mean | *P* value |
|---|---|---|---|---|---|
| Recruited follicles (<5 mm) | 1.35 ± 1.65 | 3.46 ± 2.46 | 2.25 ± 1.65 | 1.85 ± 1.96 | 0.088 |
| Growing follicles (5–10 mm) | 0.33 ± 0.61[a] | 0.29 ± 0.55[a] | 0.29 ± 0.55[a] | 0.31 ± 0.59 | 0.482 |
| Dominant follicles (11–17 mm) | 0.15 ± 0.38[a] | 0.17 ± 0.38[a] | 0[b] | 0.12 ± 0.36 | 0.010 |
| Follicles in regression | 0.18 ± 0.5[a] | 0.08 ± 0.28[b] | 0[c] | 0.10 ± 0.27 | 0.030 |
| Cystic follicles (18–≥40 mm) | 0.09 ± 0.26[a] | 0.17 ± 0.39[b] | 0.04 ± 0.2[c] | 0.09 ± 0.27 | 0.031 |
| Mean (AOF) | 0.75 ± 0.36[a] | 0.7 ± 0.41[a] | 0.33 ± 0.28[b] | 0.63 ± 0.44 | 0.006 |

*AOF* active ovarian follicles (size ≥5 mm). Means in the same column that have dissimilar superscripts (a, b, c) are significantly different at $P<0.05$

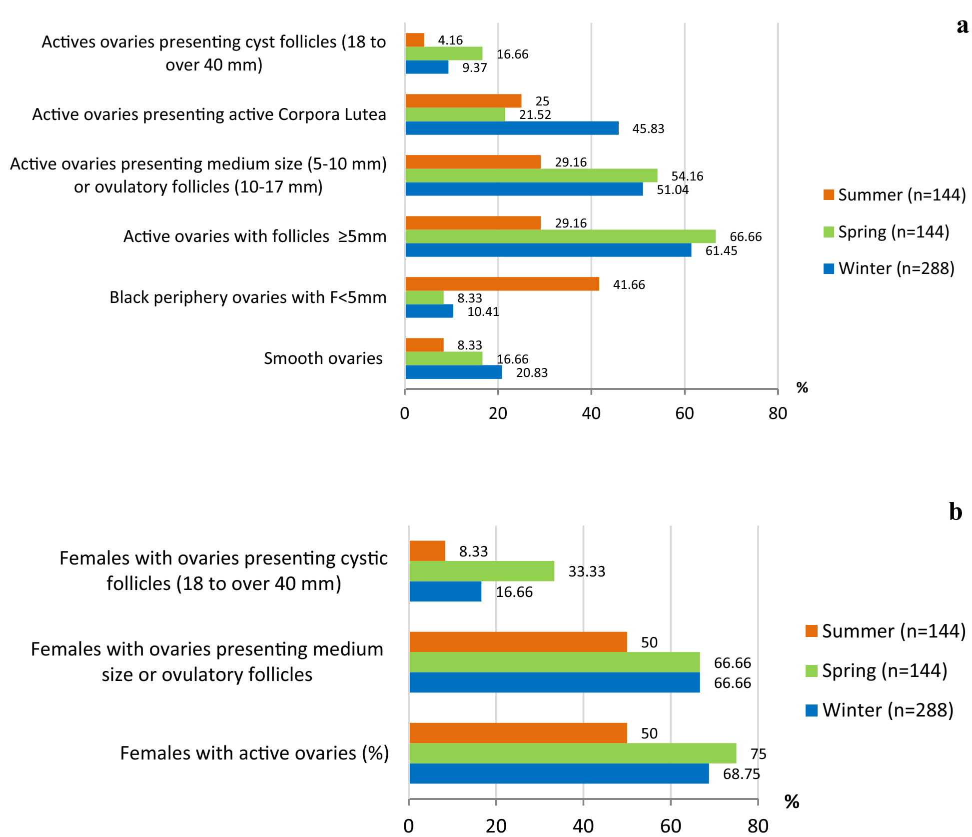


**Fig. 5** Seasonal proportions of active/inactive ovaries (**a**, $n=576$) and proportion of female camels with active ovaries (**b**, $n=288$)

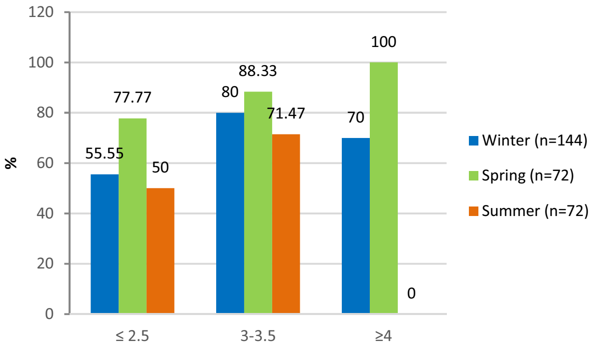


**Fig. 6** Proportion of females with active ovaries as a function of the BCS

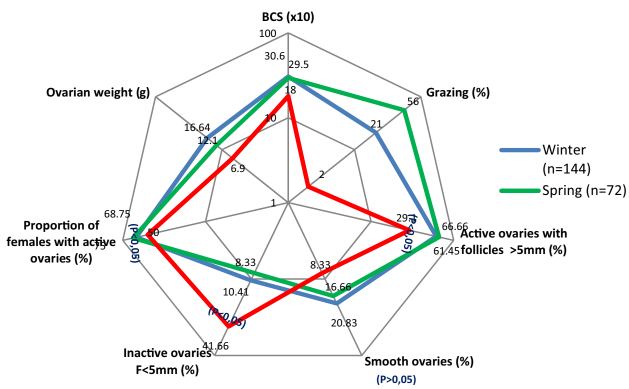


**Fig. 7** Radar curve showing the relationships between ovarian activity, grazing, and body condition in Sahrawi-type camels

parameters were positively correlated with the seasonal BCS average ($r = 0.42$–$0.73$), the duration of the photoperiod ($r = 0.47$–$0.81$), and the relative humidity ($r = 0.5$–$0.56$), and were negatively correlated with the monthly mean temperature ($r = -0.34$ to $-0.54$) (Fig. 7).

## Discussion

The present study was performed to establish baseline data on the ovarian activity of female camels reared in an extremely arid environment in southeastern Algeria. The importance of this animal to the Saharan ecosystem is strongly related to its contribution to the fight against desertification. It is known that its diet encourages high floristic biodiversity, as it feeds on a wide range of plant species that other domestic animals are reluctant or unable to eat. These plants often with poor nutritional value can be valorised by camels in products of high nutritional and dietetic values (milk and meat). The dromedary is characterized by an ability to digest poor forage, high food efficiency, and a long intestinal transit that facilitates seed germination after excretion. Anatomically, it is characterized by flexible feet that do not damage the soil and a long neck that can reach all plant layers. In its natural environment, it grazes in an ambulatory and not very gregarious way.

The large ovarian size observed during the wet season is consistent with the high number of large follicles and/or corpora lutea that occupy most ovarian stroma during this season. The seasonal variability in ovarian weight is related to the variation in the frequency of medium-sized and large follicles, which are largely composed of follicular fluid (all types of follicles), and on the variation in the frequency of luteal structures.

Camel ovarian activity was observed across all of the seasons, with the maximum activity occurring during spring and winter (December to May), which corresponded to the breeding season. Similar camel reproduction periods have been reported in most Saharan, sub-Saharan, and Middle Eastern countries (Sghiri and Driancourt 1999; Gherissi et al. 2016; Ainani et al. 2018; Tibary and Allali 2020). This seasonality of reproduction may be an adaptation strategy of the camels to harsh conditions, as the most important reproductive events—conception and calving (camel pregnancies last 12.5–13 months)—coincide with the most clement season and the period with greatest food availability. In an analysis of variations in the breeding season across 16 zoogeographical zones stretching from latitude 33°N to 40°S, Tibary and Allali (2020) found that the breeding season occurred during the months with the shortest photoperiod, the lowest temperatures, the greatest rainfall, and the lowest humidity. Climate change (irregular extreme temperature and rainfall events) impacts camel reproduction seasonality by shifting it to earlier in the year, when the days are longer. Moreover, some authors have reported that feeding female camels ad libitum leads to breeding activity year round, regardless of season-related ecological and environmental variability (Arthur et al. 1985; Tibary and Anouassi 1997).

The proportion of the female camels that had active ovaries and the incidence of inactive ovaries (smooth and black periphery ovaries) were low during the summer (50%). This lack of ovarian follicular waves may be due to insufficient FSH stimulation or inhibition of this stimulation at the ovarian level (Driancourt et al. 2001). This seasonal anestrus is deeper when low LH secretion is associated with low FSH secretion, leading to smooth or black periphery ovaries. When we investigated the importance of follicular growth issues during the nonbreeding season, we found that quite a large proportion of the females maintained ovarian cyclicity during the summer. However, recent studies have highlighted that a proteomic disorder of the follicular fluid during the nonbreeding period can disrupt oocyte maturation, leading to infertility through nonfertilization or embryonic mortality (Abdel-Khalek et al. 2010; Dutra et al. 2019). In addition, follicular growth during the nonbreeding season can be associated with alterations in ovarian steroid hormone bioavailability and thus indirectly with changes in hypothalamic–pituitary activity (Shimizu 2016). Despite this follicular growth disruption, recent reproductive technologies have shown that it is possible to control reproduction using hormonal treatments or to induce superovulation in female camels to facilitate embryo production during the hot season (Dholpuria et al. 2012; Manjunatha et al. 2020).

During the summer, none of the female camels examined presented a BCS of $\geq 4$, and females with BCS $\leq 2$ exhibited relatively low ovarian activity. However, it is difficult to study the relationship between ovarian function and physical reserves of female camels in a natural farming system. It has been suggested that female dromedaries may reduce their feed intake under conditions of heat stress, leading to decreased ovarian follicular dynamics or even the complete cessation of ovarian activity (Sghiri and Driancourt 1999; Gherissi et al. 2018b). A positive relationship between body condition and ovarian functioning is therefore expected for camels, just as observed in cattle in the Algerian semiarid region (Chacha et al. 2018). The degree (moderate or severe) and duration of the negative energy balance and its effect on follicular recruitment or terminal phase development should be considered. The energy balance depends on the energy output and the energy input. Body condition and ovarian activity improve during the season with greatest forage availability, in contrast to the summer season, when a significant drop in body condition is recorded in animals, along with a lowering of basal ovarian activity. This physiological model indicates that camels are capital breeders (Gherissi et al. 2018a). Therefore, a substantial proportion of the resources needed for reproduction and lactation are obtained through the mobilization of maternal reserves, leading to a significantly decreased body condition score. However, no mammal can exhibit a pure capital breeding strategy (Wheatley et al. 2008), so seasonal fluctuations in resource availability should also influence reproduction (Marai et al. 2009; El-Harairy and Attia 2010).

The animals studied in this work belonged to traditional extensive pastoral herds with low management. This farming system is well adapted to camel farming when foraging opportunities are unpredictable and scarce. Female camels exhibit a slow-breeding strategy in poorly productive ecosystems (Farah et al. 2004). Optimizing reproduction requires adequate maintenance of the living environment of the animals, including extra food for nonpregnant females, as well as the application of new reproductive technologies to stimulate and control ovarian activity. Thus, the reproductive performance of a camel herd can be optimized by reducing unproductive periods and increasing female camel longevity in order to allow the camels to better express their fecundity.

## Conclusion

The female dromedary camels from Algerian southeastern extreme arid environment exhibit ovarian seasonal activity characterised by high frequency of active ovarian structures and high proportion of females with active ovaries during the winter season. These features are constant during the transition period (spring season) with significant increase of frequency of ovariain cystic structures. The summer season (nonbreeding season) is characterised by decrease of follicular wave's proliferation rhythm without ceasing entirely. The relationship between climatic conditions, fourage availability and female camels body reserves confirms the pattern of seasonal ovarian functioning.

**Author contributions** DEG, FBA, and ZB designed the study. DEG, ALM, and AG performed the experiments. DEG analyzed the data and wrote the paper with input from all authors.

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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