



# Effect of seasonal variations during dry and wet seasons on reproductive performance and biological and economic criteria of hair sheep under Halaieb rangeland conditions

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**Abstract.** This study was conducted to evaluate the impact of seasonal variations (wet and dry season) on the reproductive and productive performance and to do an economic evaluation of hair sheep under Halaieb rangeland conditions and determine which season is the best in grazing areas. A total of 64 multiparous Abou-Delik ewes were bred in two different seasons. During the first season (dry season), a total of 35 ewes, 2–4 years of age and  $32.02 \pm 0.52$  kg weight, were bred during May and June, while lambing and lactation took place in the months of November, December and January. On the other hand, during the wet season, 29 ewes, 2–4 years age and  $31.06 \pm 0.57$  kg weight, were bred during November and December, whereas lambing and lactation took place in the months of May, June and July. Sheep grazed 8 h daily in the same pastures during the study and then moved back to the barns to receive a sorghum vulgare supplement with a dosage of 250 g per head per day. The results revealed that there were no significant effects of breeding season on conception, lambing and abortion rates. However, the wet season had higher ( $P < 0.05$ ) prolificacy, mortality rates, lambs' weight and lambs born to ewes serviced. Contrariwise, dry-season lambs had a higher ( $P < 0.05$ ) weaning weight. Also, milk yield ( $\text{mL d}^{-1}$ ) and number of lambs weaned per lambs born (LW/LB) increased ( $P < 0.05$ ) in the dry season compared to the wet season. No significant differences between the two seasons regarding the biological criteria studied were observed. On the other hand, the flock bred in the dry season generated a higher gross margin than that bred in the wet season. In this context, variable costs of the wet breeding season flock were recorded to be close to the value of the dry breeding season.

Hence, it is concluded that the reproductive and productive performance of hair sheep raised in grazing areas in the Halaieb triangle is affected when lambs are born during the dry season because of the higher lamb mortality rate during this period which eliminates any comparative advantage for the good reproductive performance of ewes during the period of feed availability in the wet season. The high lamb mortality rates and low weaning weights in the wet breeding season lessen the economical merits of higher reproductive performance during the seasonal availability of feed in the wet season.

## 1 Introduction

The Halaieb, Shalateen and Abou-Ramad triangle region has a vital and strategic importance to Egypt. This region is a mountainous desert with several valleys dissecting mountains. Rainfall sometimes starts from October up to February. The source of income of most inhabitants depends mainly on range animals. The range vegetation is considered the basic source of ruminants feed in triangle region. The main nutritional problems of animals on rangelands are erratic, and short duration of rains precipitation leads to long drought periods, shortage of forage production and seasonal starvation of animals.

Small ruminant production is the main activity of the local Bedouins in the Halaieb, Shalateen and Abou Ramad triangle region as it is considered one of the main sources of their income. They depend on natural vegetation as a fundamental feed resource. Unfortunately, there is a lack of sufficient feed to meet the nutritional requirements for animals in these regions, particularly during the dry season (summer). Environmental factors lead to severe seasonal fluctuations that cause a periodical restriction in feed quality and quantity. Hair sheep, raised in grazing areas, are highly efficient in converting non-dense pastures to meat and milk without consuming large quantities of feed concentrates (that are in short supply in Egypt) compared to large ruminants. They are capable of traveling long distances during grazing and withstanding harsh environmental conditions.

The range vegetation in the Halaieb region is considered the basic renewable source of ruminant feed despite the short duration of rains precipitation, long drought periods, shortage of forage production, and improper economic interrelationship between animal productivity and potential utilization of range plants (El Shaer et al., 1997). Inappropriate climatic conditions reduce the productive and reproductive performance of sheep, causing alterations in the estrus behavior, embryo death and birth of weak lambs and several disorders (Ozawa et al., 2005). It is known that other environmental factors such as heat stress and the quality and availability of feed can directly interfere with animal reproduction (Simplicio, 2008). Thus, climatic factors are closely related to animal productive and reproductive performance, which may vary according to the region in which the animals are raised (Oliveira et al., 2013). High summer temperatures, low winter temperatures, and a variation in rainfall rates require studies to understand and limit the obstacles imposed by environmental factors, in addition to searching for adequate management in order to allow for the rationalization of sheep farming in this region.

Thus, the present study aimed to evaluate the impact of seasonal variations (wet and dry season) on reproductive and productive performance of hair sheep under natural grazing conditions of the Halaieb, Shalateen and Abou-Ramad triangle, determining breeding seasons in periods of dry and wet

weather in order to understand the most suitable time of the year to apply reproductive techniques in sheep.

## 2 Materials and methods

### 2.1 Location and climate

The study was conducted at Ras Hederba Valley, Halaieb and Shalateen Experimental Research Station, Desert Research Center, Ministry of Agriculture, Egypt. The station is located in the Halaieb, Shalateen and Abou-Ramad triangle region, Red Sea Governorate, about 1300 km southeast of Cairo with latitude 22°00'720" N and longitude 36°48'955" E. The Halaieb triangle is located on the southern border of Egypt and the northern border of Sudan. It covers an area of 7945 square miles (20 580 km<sup>2</sup>) and has a coastline on the Red Sea. The climate of the Halaieb triangle is normally very hot and receives little precipitation outside of a rainy season. Near the Red Sea, the climate is milder, and there is more precipitation. The climate during the dry and wet seasons is mentioned in Table 1. Historical climate data for the study area were obtained from the Central Laboratory for Agricultural Climate (CLAC ARC) of Egypt.

### 2.2 Animals, management and experimental design

It is not possible to rely on grazing pasture only, especially in the dry season, because the pastures do not meet the needs of sheep during the different physiological stages. Sheep grazed for a duration of 8 h daily, in the morning (from 06:00 to 12:00) and the afternoon (from 15:00 to 17:00), and then were moved back to the barns to receive a sorghum vulgare supplement with a dosage of 250 g per head per day, with ad libitum access to water. The chemical compositions of rangeland plants in the study area are shown in Table 2. According to Badawy (2005) and Raef (2012), desert grass *Panicum turgidum* is the main dominant pasture grass that is abundant (95.9 % and 97.7 %) and dense (0.455 and 0.296 plant m<sup>-2</sup>) in wet and dry seasons, respectively. The dry biomass yield of *Panicum turgidum* was 1.46 t per feddan (4200 m<sup>2</sup>) in the wet season and 1.25 t per feddan in the dry season, respectively. Within both seasons, ewes were kept in the same pastures during the study.

A total of 64 multiparous Abou-Delik ewes were introduced for breeding in two different breeding seasons. The first season was in the dry season (mating occurred during 1 May to 3 June; lambing and lactation in November, December and January;  $N = 35$  ewes; 2–4 years age; and  $32.02 \pm 0.52$  kg weight), and the second season was in the wet season (mating occurred during 1 November to 4 December; lambing and lactation in May, June and July;  $N = 29$  ewes; 2–4 years age; and  $31.06 \pm 0.57$  kg weight; see Fig. 1). In this study, Abou-Delik rams used for mating in both seasons were the same ones. Lambs were weaned at 4 months of age, and lambs were weighed at this time.

**Table 1.** Mean meteorological data during dry and wet seasons, provided by the Central Laboratory for Agricultural Climate, Cairo, Egypt. THI denotes the temperature humidity index, and AT refers to ambient temperature.

Season	Month	Temperature (°C)			Relative humidity (RH, %)	Precipitation (mm)	Wind speed (m s <sup>-1</sup> )	THI*
		Max	Min	Average				
Dry	March	26.55	20.56	23.29	62.89	0.01	5.15	70.61
	April	28.57	23.00	25.52	61.06	0.15	5.04	73.61
	May	31.80	26.25	28.79	55.86	0.05	4.96	77.39
	June	33.35	27.58	30.36	52.81	0.03	6.30	79.08
	July	35.29	29.83	32.25	52.08	0.02	4.74	81.51
	Augustus	36.05	30.80	33.11	54.16	0.04	4.24	83.02
	September	35.39	30.32	32.63	61.58	0.15	5.17	83.68
Wet	October	33.16	27.93	30.25	66.16	0.63	3.96	81.08
	November	28.81	25.13	26.70	66.06	0.41	4.98	75.91
	December	26.99	22.83	24.63	65.11	0.13	4.63	72.78
	January	23.10	18.86	20.76	61.55	0.01	6.35	66.97
	February	24.04	19.16	21.35	65.01	0.04	5.71	68.03

\* THI =  $0.8 \times AT$  (°C) + [(%RH) 100 × (AT - 14.4)] + 46.4.

**Table 2.** Chemical composition of rangeland plants at Halaieb study area during the wet season (% dry matter basis).

Item	Wet season					
	Dry matter	Ash	Organic matter	Ether extract	Crude fiber	Crude protein
<i>Panicum turgidum</i>	92.84 <sup>a</sup>	7.26 <sup>d</sup>	92.74 <sup>a</sup>	3.54 <sup>b</sup>	33.58	7.72 <sup>d</sup>
<i>Acacia raddiana</i>	92.95 <sup>a</sup>	7.45 <sup>d</sup>	92.55 <sup>a</sup>	3.87 <sup>a</sup>	31.11	11.57 <sup>b</sup>
<i>Lycium shawii</i>	92.68 <sup>a</sup>	10.86 <sup>c</sup>	89.14 <sup>b</sup>	3.17 <sup>c</sup>	32.82	12.96 <sup>a,b</sup>
<i>Maerua crassifolia</i>	91.83 <sup>b</sup>	11.94 <sup>a</sup>	88.06 <sup>d</sup>	2.84 <sup>e</sup>	34.46	13.34 <sup>a</sup>
<i>Alhagi maurorum</i>	92.04 <sup>b</sup>	11.18 <sup>b</sup>	88.82 <sup>c</sup>	3.10 <sup>d,c</sup>	39.24	9.53 <sup>c</sup>
<i>Aerva javanica</i>	92.99 <sup>a</sup>	11.86 <sup>a</sup>	88.14 <sup>d</sup>	2.87 <sup>d,e</sup>	32.72	9.65 <sup>c</sup>

a,b,c,d and e: Means in the same column with different superscripts are significantly different ( $P < 0.05$ ).

Reproductive performance was assessed by the following: (1) conception rate is the number of pregnant ewes × 100 divided by the total number of ewes in the breeding season. (2) Lambing rate is the number of lambs lambd × 100 divided by the number of pregnant ewes. (3) Prolificacy rate is the number of lambs born × 100 divided by the total number of lambd ewes. (4) Lamb mortality rate is the number of dead lambs × 100 divided by the total number of lambs alive at 120 d postpartum.

Biological criteria considered were number of lambs born per ewe joined (LB/EJ), number of lambs weaned per ewe joined (LW/EJ), number of lambs weaned per ewe lambd (LW/EL), number of lambs weaned per lambs born (LW/LB) and kilogram weaned per ewe joined (KGW/EJ).

In order to compare the two simulated experimental flocks, and to estimate the economic consequences of breeding season in two different seasons, the following general assumptions were used:

- The number of joined ewes in the dry season was 35 ewes, while there were 29 ewes in the wet season.

- Ewes in both seasons were raised under a free grazing system.
- The management used was equal in the two flocks for both seasons.
- The weaning age was 4 months.
- Annual veterinary care under both flocks was LE 50 per ewe.
- The price of kilogram of feed at the time of the experiment was LE 5.

### 2.3 Milk yield

Milk production (total 20 ewes) was recorded every 2 weeks for individual ewes from the second week after parturition until the eighth week of the lactation period using a manual milking technique after the ewes were separated from their offspring temporary for 1 d in individual pens.

## 2.4 Chemical composition of rangeland plant species

The chemical compositions of rangeland plants in the study area in the wet season are shown in Table 2 according to Mohamed et al. (2019). Chemical composition of rangeland plant species in the dry season was determined as described by AOAC (2007) and is shown in Table 3.

## 2.5 Statistical analysis

Data of birth and weaning weights, mortality rate and milk yield were analyzed by the general linear model (GLM) procedure (SAS, 2006). Duncan's multiple range tests were used to separate means. Data expressed as percentages (including conception rate, lambing rate, prolificacy rate and biological performance) were analyzed using the chi-squared test.

## 3 Results

Mean values of chemical composition of rangeland plant species in the Halaieb area are presented in Tables 2 and 3. It can be noticed that *Maerua crassifolia* had the highest value of crude protein of 13.34% and 11.52% in wet and dry seasons, respectively, followed by *Lycium shawii* and *Acacia raddiana* in the wet season (12.96% and 11.57%, respectively) and in the dry season (11.02% and 10.95%, respectively), whereas *Panicum turgidum* (most covered with pasture) had the highest value of organic matter (92.74%) in the wet season, and *Acacia raddiana* had the highest value of organic matter (90.55%) in the dry season. Concerning reproductive performance, the obtained results revealed that there were no significant ( $P > 0.05$ ) effects of breeding season on the reproductive rates of dry and wet seasons, with values being 91.43% vs. 86.21% for conception rate, 84.38% vs. 96% for lambing rate and 15.63% vs. 4.00% for abortion rate. However, the data of prolificacy rate showed that animals bred in the wet season significantly exceeded their counterparts of the dry season by 12%; see Table 4.

As regards the productive performance, the present findings demonstrated that ewes bred in the wet season had higher ( $P < 0.05$ ) lambs' weight at birth (2.81 kg) than in the dry season (2.29 kg). However, weaning weight (at 4 months old) was higher (15.24 kg) in lambs born to ewes serviced in the dry season ( $P < 0.05$ ) compared to lambs born to ewes serviced in the wet season (13.69 kg). Moreover, the mortality rates were higher ( $P < 0.05$ ) for lambs born to ewes serviced in the wet season (33.33%) compared to the group of ewes serviced in the dry season (7.41%); see Table 5.

When the lactation period coincided with the start of the wet season, the ewes produced approximately 440 mL d<sup>-1</sup> during the first 2 weeks, and this then increased to 655 mL d<sup>-1</sup> of milk through the lactation period, whereas when the ewes' lactation period coincided with the dry season, they produced approximately 240 and 530 mL d<sup>-1</sup> of milk, respectively, during this same time period. Ewes ser-

viced in summer season and lambed in the wet season had higher ( $P < 0.05$ ) total milk yield (550 mL d<sup>-1</sup>) as compared to ewes lambed at dry season (serviced in the wet season) (380 mL d<sup>-1</sup>). Moreover, milk yield of ewes serviced during the dry season exceeded their counterparts of wet season along the lactation period; see Fig. 2.

Regarding the biological performance of Abou-Delik sheep, the present findings revealed that ewes serviced in the wet season had a higher (93.10%) value of lambs born per ewe joined (LB/EJ) than those serviced in the dry season (77.14%). Nevertheless, ewes serviced in the dry season exceeded their counterparts of the wet season for the percentage of lambs weaned per ewe joined (LW/EJ) (71.43% vs. 62.07%) and lambs weaned per ewe lambed (LW/EL) (92.59% vs. 75.0%) in addition to the kilograms weaned per ewe joined (KGW/EJ) (10.53 kg vs. 8.41 kg) in a non-significant manner. The seasonal variation was more pronounced that LW/LB of the dry breeding season exceeded ( $P < 0.05$ ) that of ewes breeding in the wet season (92.59% vs. 66.67%); see Table 6.

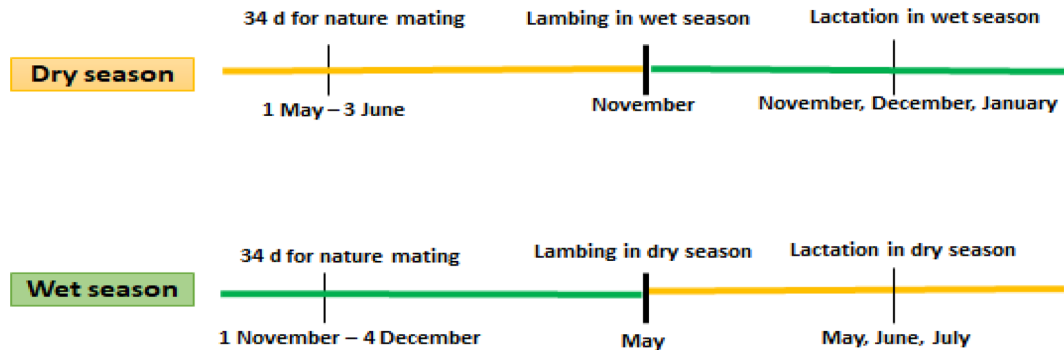
Regarding the economical analysis of the two simulated flocks, it showed that the flock of the dry breeding season generated a higher gross margin than that of the wet breeding season (LE 8467 vs. LE -141). In this context, variable costs of the wet breeding season flock were recorded to be close to the value of the dry breeding season (LE 17 396 vs. LE 18 203); see Table 7.

## 3.1 Discussion

The present findings of the chemical composition of rangeland plants (*Panicum turgidum*, *Acacia raddiana*, *Lycium shawii*, *Maerua crassifolia*, *Alhagi maurorum*, *Aerva javanica*) during wet and dry seasons revealed that wet-season rangeland plants exceeded their counterparts of the dry season in organic matter and crude protein (Tables 2 and 3). Our results demonstrated that ewes serviced during the wet season in the Halaieb region achieved higher lambing rates and prolificacy and a low abortion rate (Table 4), which could be due to the greater quality of the pastures available at that time, whereas the values of crude protein increased for all rangeland plants analyzed in the wet season compared with the dry season. It is important to point out that the prolificacy of Abou-Delik ewes in the wet season was significantly greater than that observed in the dry season. Although prolificacy is a genetic trait, the degree to which it can be expressed is influenced by environmental factors, in particular those related to nutrition and its availability (Abecia et al., 2006). However, in this study, the lower weaning rates of lambs reduced this comparative advantage during the wet season. Drought in the dry severely affects sheep production systems due to low pasture growth and quality, thus limiting the feed available for grazing ewes during the pre-mating and mating periods (Table 3). Feeding ewes at a level below maintenance results in loss of live weight (LW) and body condition score

**Table 3.** Chemical composition of rangeland plants in the Halaieb study area during the dry season (% , dry matter basis).

Item	Dry season					
	Dry matter	Ash	Organic matter	Ether extract	Crude fiber	Crude protein
<i>Panicum turgidum</i>	93.54	10.28	89.72	3.86	36.51	5.21
<i>Acacia raddiana</i>	93.02	9.45	90.55	4.05	33.25	10.95
<i>Lycium shawii</i>	92.98	12.86	87.14	3.89	35.84	11.02
<i>Maerua crassifolia</i>	92.05	12.88	87.12	3.45	36.98	11.52
<i>Alhagi maurorum</i>	92.89	13.02	86.98	3.79	42.02	7.95
<i>Aerva javanica</i>	93.85	13.88	86.12	3.58	35.02	8.01



**Figure 1.** Schematic representation of experimental design: two groups according to the time of the year of their breeding season and periods of lambing and lactation.

**Table 4.** Effect of dry and wet seasons on reproductive performance of Abou-Delik ewes.

	Mating season		Prob.
	Dry, N = 35	Wet, N = 29	
Conception rate	91.43 (32)	86.21 (25)	0.5
Lambing rate	84.38 (27)	96 (24)	0.1
Abortion rate	15.63 (5)	4 (1)	0.1
Prolificacy	1.0 <sup>b</sup> (0)	1.12 <sup>a</sup> (3)	0.05

<sup>a</sup> and <sup>b</sup>: Means in the same row with different superscripts are significantly different ( $P < 0.05$ , chi-squared test) between the two seasons.

(BCS) and, during mating, severely reduces lambing percentage (McWilliam et al., 2005).

The present results of prolificacy agreed with those reported by Farrag (2019), where prolificacy in Abou-Delik sheep increased as a consequence of increasing feed provided to ewes. Grazing sheep in the Halaieb triangle, like other Egyptian sheep, are characterized by pretty good fertility rates, an extended breeding season, but low prolificacy (Gabr et al., 2016), thus not significantly influenced by seasonality (i.e., ewes cycle all year round), which occurs due to slight variations in day length throughout the year. Farrag (2019) referred to the Abou-Delik sheep breed as a good breed originally under grazing conditions in arid zones, and it has productive and reproductive characteristics that can be

improved. Despite the differences that occurred in the climate between the studied seasons, they were not determinant to the reproductive parameters evaluated in this study, confirming the possibility of adopting reproductive strategies in both periods, taking into consideration the preference of one season over another according to many aspects, including the availability of feed and the surrounding climatic conditions. The lower quality of pasture during the dry season could lead to a decrease in reproductive efficiency rates. However, synchronization of lambing with the start of the wet season reduces the impact of this decline.

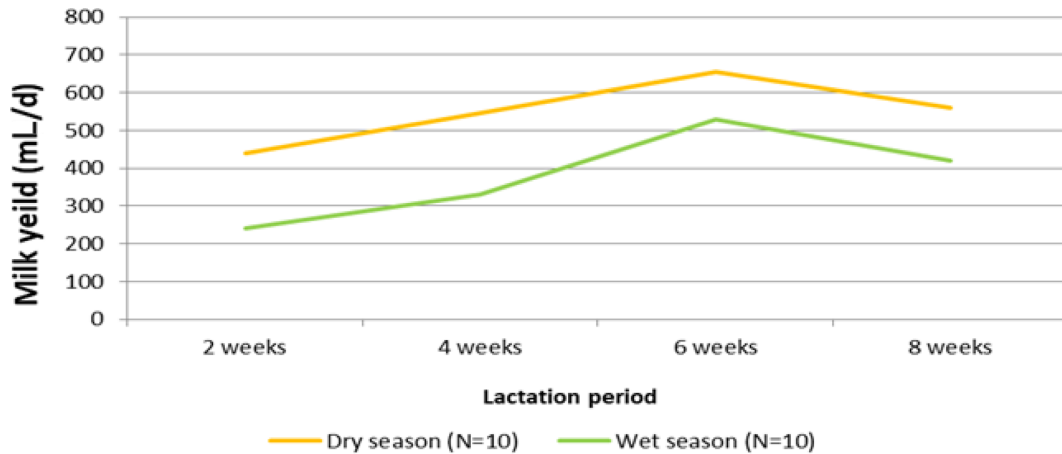
On the other hand, the higher availability in quantity and quality of pastures during the wet season (Martins et al., 2003) improved the body weight and birth weight of lambs. Less weight was seen for lambs born to ewes serviced in the dry season ( $P < 0.05$ ). This may be due to the poor body condition of ewes as a result of their exposure to the dry season and lack of feed during the periods of mating and pregnancy (Table 4). In contrast, Moura et al. (2014) reported that no significant differences were noticed between dry and wet periods regarding lamb birth weight. The average birth weights of Abou-Delik ewes recorded in this study were within the range reported by Farrag (2019). The increase in lambs' weight at weaning born to ewes serviced in the dry season, despite the low birth weight, means that the lambs would benefit from both increasing milk production and vegetation during periods of rainfall and pasture growth. This situation



**Table 5.** Effect of dry and wet seasons on birth and weaning weight and mortality rate of Abou-Delik lambs (LSM  $\pm$  SE).

Mating season	<i>N</i>	Birth weight	<i>N</i>	Mortality rate	<i>N</i>	Weaning weight
Dry	27	2.29 $\pm$ 0.04 <sup>b</sup>	2	7.41 <sup>b</sup>	25	15.24 $\pm$ 0.16 <sup>a</sup>
Wet	27	2.81 $\pm$ 0.04 <sup>a</sup>	9	33.33 <sup>a</sup>	18	13.69 $\pm$ 0.20 <sup>b</sup>

<sup>a</sup> and <sup>b</sup>: Means in the same row with different superscripts are significantly different ( $P < 0.05$ ). LSM is the least-squares mean, and SE is the standard error.

**Figure 2.** Effect of dry and wet seasons on milk yield of Abou-Delik ewes.

was reversed, as the weaning weights of lambs increased, which may be due to the coincidence of lambing and lactation during the period of rain and growth of pasture. Lambs born at the beginning wet season (October and November) had a lower birth weight compared with those born at the beginning dry season (May and June). This may be because the dams experienced a lack of feed during conception period in the dry season, which affected fetal development and resulted in a lighter weight. Generally, the dry season significantly affected the quality and quantity of vegetation and the availability of water for irrigation (Sejian et al., 2016), but with the onset of the rainy season, the vegetation is more varied and nutritious compared with the dry season, which gives a greater chance for lambs to grow until the weaning stage, which is what happened in this study (Table 3). The present results verified significant effects of season on the weaning weight ( $P < 0.05$ ). The heaviest weaning weight was attained by lambs lambled in the wet season (15.24 kg), compared to those lambled in the dry season (13.69 kg) (Table 5).

Mortality rates of lambs differed ( $P < 0.05$ ) between wet and dry seasons, with a high mortality rate of lambs born to ewes serviced in the wet season (Table 5). Despite the higher lambs' birth weight of ewes serviced in the wet season, the effect of reduced milk production on the survival rate of newborns was clear. The high rate of pre-weaning mortality is not related to low birth weight during the wet season as much as with low milk production and climatic conditions in the dry season. Basman et al. (2015) found that mortality rate

depends on the litter size, milk production and heat stress experienced by ewes and their lambs. This was confirmed in this study by higher mortality rates during the coincidence of the births with dry season. Contrary to our results, Wildeus and Collins (1993) reported that mortality rate of lambs was higher during the rainy season in hair sheep; this may be due to the different climatic conditions in both studies. As for the wet season, a sharp rise in mortality rate of lambs and decrease of weaning weights for weaned lambs were observed. This might be due to the lambs born in the dry season encountering high temperatures and dry pasture. In this study, the higher mortality rates in lambs born during the dry season comply with Moura et al. (2014), who reported greater mortality in lambs born during the dry season, suggesting a correlation between the low milk production and dry and low-quality pasture observed during this period. These results suggested that the influence of nutrition and climate on sheep production and reproduction, as well as weaning weight of lambs, will be reflected positively or negatively in the availability of feed for lambs, which calls for the provision of an alternative feed during the severe dry season. In this study, we can point out that weaning weights of lambs born in the wet season increased as a result of availability of green grasses and forage, and young succulent plants that contain an edible portion that provides high energy in the rainy season compared to older browsing plants with undigested fiber which are found in the dry season.

**Table 6.** Effect of dry and wet seasons on biological performance of Abou-Delik sheep.

Indicator	Mating season		Prob.
	Dry, <i>N</i> = 35	Wet, <i>N</i> = 29	
LB/EJ, percentage of lambs born per ewe joined	77.14	93.10	0.08
LW/EJ, percentage of lambs weaned per ewe joined	71.43	62.07	1.42
LW/EL, percentage of lambs weaned per ewe lambed	92.59	75.0	0.08
LW/LB, percentage of lambs weaned per lambs born	92.59 <sup>a</sup>	66.67 <sup>b</sup>	0.01
KGW/EJ, kilograms weaned per ewe joined	10.53	8.41	0.34

**Table 7.** Breakdown of revenues and variable costs of the two simulated flocks.

Item	Mating season	
	Dry, <i>N</i> = 35	Wet, <i>N</i> = 29
Revenues: weaned lambs	381 kg × LE 70 = 26 670	246.5 × LE 70 = 17 255
Variable costs:		
Feeding	2362 kg × LE 1.25 = 2953	1957 kg × LE 1.25 = 2446
Labor	13 500	13 500
Veterinary care	1750	1450
Total variable costs	18 203	17 396
Total gross margin	8467	−141
Economic efficiency per ewe	241.9	−4.86

The data presented in Fig. 2 showed that the milk yield ( $\text{mL d}^{-1}$ ) was significantly ( $P < 0.05$ ) increased when the ewes' lactation period coincides with the dry season compared to when the ewes' lactation period coincides with the start of the wet season. In the same context, milk yield increased as the lactation period progressed to the sixth week (milk curve peak) and then began to decline in the eighth week for both seasons. This might have contributed to the lower weaning weights of the lambs. These results are in agreement with those of Godfrey and Dodson (2003), in which hair sheep had lower weaning weights when they were raised during the dry season. In the current study, the effect of season on weaning weights of lambs was evidenced by the increasing weaning weight of lambs during rainfall period. This may be related to the milk production pattern of the ewes, which also increased during the same period. During the wet season, the growth of vegetation reaches its highest quality and quantity. This will influence the formation of prolactin hormone and increased milk production. A high milk production will determine the weaning weight later. The seasonal effect is in agreement with results of Concalves and Wechsler (2001), who found that ewes lambed in the wet season had higher lactation milk yields and longer lactation length compared with ewes lambed in the dry season. This variation is due to the availability of green pastures during the wet season compared to low-quality forage in the dry season. The reduction in milk production during exposure to heat or

during the summer cannot be attributed solely to a fall in feed intake or forage quality. The effect of heat on physiological mechanisms related to lactation is also of importance, mainly the low level of thyroxin during the summer.

In the present study, reduction of LB/EJ in the dry breeding season may be due to the increase in prenatal mortality as a result of heat stress during pregnancy in the hot summer months (Vanroose et al., 2003). The number of lambs weaned per ewe joined (LW/EJ) combines fertility of ewes and rams, prolificacy and the survival of lambs. LW/EJ in dry breeding season was 71.43 %, while in the wet season it was 62.07 %. This may be due to availability of pasture plants in the lambing season and in the beginning of the rainy season, which might improve milking ability, in addition to increasing ambient temperature, which might inhibit pathogenic factors that cause lamb mortality. LW/EL was higher in the dry breeding season than the wet breeding season (92.59 % vs. 75.0 %). Seasonal variation was more pronounced; LW/LB of the dry breeding season exceeded ( $P < 0.05$ ) that of ewes breeding in the wet season (92.59 % vs. 66.67 %). These measures showed a clear decrease in the weaning rates of lambs during the wet season, which corresponded to the occurrence of lambing at the beginning of the period of dryness and high temperature. Analysis indicated that KGW/EJ tended to be higher in the dry than the wet breeding season (10.53 kg vs. 8.41 kg). Kilogram of weaned lamb per kilogram joined ewes was greater for ewes serviced during the

dry season than that lambed during the wet season, related to the record of greater weight at weaning and reduced mortality rate of their lambs. This parameter indicates the mothering ability of ewes and the growth rate of lambs in the flock. In addition, the economical performance of sheep farms is finally evaluated on the basis of the total value of lamb crop produced.

In this study, when comparing the achieved total gross margin of the two simulated flocks, it was shown that the flock of the dry breeding season generated higher gross margin than that of the wet breeding season (LE 8467 vs. LE –141). In this context, variable costs of the wet breeding season flock were recorded to be close to the value of the dry breeding season (LE 17 396 vs. LE 18 203). The significant increase in mortality rate of lambs in the wet season (which corresponds to the beginning of the dry season and high temperature) led to less quantity of meat produced and a decrease in the economic return of this season despite the good biological performance of this season. Through our current study, we can say that applying the dry breeding season improved the gross margin per ewe by LE 241.9, with the same amount of feed provided during the dry and wet seasons.

#### 4 Conclusion

Good reproductive rates presented by the sheep show satisfactory reproductive activity during the two seasons, characterizing good adaptation to the region. The dry season seems to be a season that requires the provision of an alternative feed in this critical period, which is characterized by the scarcity of rain and thus the dryness of the pastures.

We can say that the reproductive and productive performance of hair sheep raised in grazing areas in the Halaieb triangle is affected when lambs are born during the dry season because of higher lamb mortality rate during this period, which eliminates any comparative advantages for the good reproductive performance of ewes during the period of feed availability in the wet season. The high lamb mortality rates and low weaning weights in the wet season economically reduce the good reproductive performance during the seasonal availability of feed in the wet season.

**Data availability.** The data are available from the corresponding author upon request.

**Ethical statement.** The experiment was carried out according to all ethics and animal rights (DRC) considering all regulations in conformity with the European Union Directive for the protection of experimental animals (2010/63/EU).

**Author contributions.** BF conducted all the manuscript steps.

**Competing interests.** The author has declared that there are no competing interests.

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