INTRODUCTION

In spite of its economic importance in Tunisian agriculture, the sheep-farming sector has kept its traditional character of flock management which is still essentially extensive. In fact, more than 80 percent of livestock feeding resources comes from natural vegetation (Ministry of Agriculture, 1981). However, pasture productivity is intimately related to annual rainfall and to its seasonal distribution and thus is subject to all the irregularities which characterize the Tunisian Mediterranean climate.

Furthermore, the uncontrolled growth of sheep numbers, mechanization and extension of cultivated lands (cereals, fruit trees and irrigated areas) to the detriment of pastures are many factors which restrict natural fodder availability. At the same time, sheep numbers had increased from 1 400 000 reproductive females in 1975 to 3 400 000 reproductive females in 1986. Consequently, this has caused an inbalance in animal nutritional requirements and pasture production where the stocking rate is continually increasing. In 1969, Le Houerou had already estimated that the stocking rate was, according to area, 25-45 percent in excess.

The chronic state of undernutrition of the flocks may explain their low productivity. This varies on average between 0.85 lamb/ewe/year in the north (more than 400 mm of rain/year) and only 0.70 lamb/ewe/year in the centre and the south of the country (less than 400 mm of rain/year), but as soon as nutritional conditions become favourable, productivity can reach 1.20 to 1.25 lambs/ewe/year (Tchamitchian and Sarson, 1970).

To satisfy their growing needs, all countries in North Africa are importing increasing quantities of meat. Tunisia, for example, imported less than 1 000 tons of meat in 1970, 6 000 tons in 1977, 15 000 tons in 1980 and 34 000 tons in 1984.

Therefore, a significant increase in mutton production is necessary to meet the situation. This involves increasing the number of reproductive females and/or improving their productivity (individual performances). However, further overstocking of pastures will increase overgrazing and accelerate their degradation. An increase in ewe productivity could therefore contribute to solving the problem of meat production on dry land, especially in North Africa. Nevertheless, improvement in productivity must consider fodder availability in each region. Thus, in the semi-arid and arid zones, feed supplementation should allow each ewe to wean one lamb every year. In the more rainy regions, where intensification and diversification of forage crops are possible, intensive sheep production should be considered. However, these objectives can only be reached if the actual production potential is known under different management conditions. In Tunisia and Libya this refers especially to the Barbary breed since it represents 85 percent of the sheep population in these countries.

This paper will present the most important characteristics of the Barbary breed with suggestions for improving its productivity at the same time taking advantage of its remarkable hardiness. These characteristics concern principally milk production, growth, carcass quality, reproduction and their interaction with different nutritional conditions.

1. GENERAL OBSERVATIONS ON THE BARBARY SHEEP

1.1 Origin

The fat-tailed Barbary sheep is the typical sheep of Tunisia and Libya. It does not exist in Algeria, Morocco and Egypt. It accounts for about 80 percent of the total number of sheep in Tunisia (3 400 000 adult females) and 95 percent of Libyan sheep (2 000 000 head). In Tunisia, the fat-tailed sheep have been present since Carthaginian times and may have been brought from Syria by the Phoenicians (Mason, 1967). In fact, as depicted in Phoenician and Roman monuments it appears that this kind of fat-tailed sheep was introduced in Tunisia by the Phoenicians about 400 B.C. They were exploited in the country until 300 A.D. when they were replaced by a very long thin-tailed breed. The fat-tailed sheep were not reintroduced in Tunisia until 900 A.D. with the Arab invasion (Sarson, 1973). In Libya, the fat-tailed sheep came from Egypt about 1000 B.C. (Mason, 1967). It is now thought that the Barbary sheep were introduced in both Tunisia and Libya at the same time and possibly under the same conditions, but it is certain that the Barbary sheep breed originates from the Asiatic steppes.
Locally, the fat-tailed Barbary sheep are called Nejdi or Arabi sheep. The term "Barbary breed" is the European nomenclature attributed to these fat-tailed sheep originating from the Berbers, the ancient inhabitants of North Africa.

1.2 Physical characteristics

The Barbary is a robust and vigorous animal. It is characterized by its fat tail (Figure 1.1) which is a bilobed scak of fat due to an accumulation of reserve fats on each side of the coccygeal vertebra (Figure 1.2). Owing to these adipose reserves, the animals of this breed are very resistant to poor nutrition to which they are frequently submitted in Libya and the centre and south of Tunisia. The weight of the fat tail varies greatly and in some animals with a good body condition it can reach up to 15 percent of the carcass weight. The Barbary sheep is present in all regions of Tunisia from the Sahara to the north coast, but is mainly found in the central region between. Zaghouan and Gafsa. In Libya, it is found particularly in the steppes along the north coast.
The Barbary is a very hardy sheep. It is also longlegged and a good walker. The height of adult animals ranges from 60 to 80 cm in males and from 55 to 70 cm in females. Liveweight ia also varied according to regions and feeding conditions and ranges from 45 to 85 g in rams and from 28 to 65 g in ewes.
The colour of the fleece is always white but the head can be red (Figure 2) or black (Figure 3). In this latter case, animals are less sensitive to photosensitization caused by Hypericum consumption. The fleece is regular, open or semi-closed and its mean weight is 1.8 g in ewes and 2.5 g in rams. The head and legs are bare. The wool varies from coarse and

kempy to medium-fine and wavy with a quality number of 48/50' to 50/56' (Mason, 1967). This wool is used for the artisanal manufacture of carpets and rugs.

The forehead is flat or slightly concave and horns are usually absent in both males and females. The ears are long, wide and pendulous.

1.3 Flock management

In spite of its importance, the sheep sector has largely maintained an exclusively extensive character. Livestock are still considered, particularly in private farms, a means of accumulating wealth. This explains the high rate of unproductive animals sometimes found in the flocks.

Flock feeding is based essentially on natural vegetation resulting from natural pastures and fallows. In summer, feed comes only from cereal stubble and/or dry vegetation. As rainfall is irregular, these feed resources are often quantitatively and qualitatively insufficient and animals often suffer from chronic undernutrition. For this reason, farmers regularly rent pasture areas, fallows and/or cereal stubble for their flocks, especially in summer and autumn, the two most difficult seasons.

The addition of hay, straw and/or concentrates to the diet is often rare and irregular. It is done only during the very dry periods to reduce mortality rates.

Rams are always kept in the flock and the mating season is very long, from April to November. Thus, lambings occur usually between September and March with two peaks in October-November and February-March. Lambs are weaned at 4 to 5 months of age with liveweight ranging from 20 to 30 g.

The fat-tail of ewes represents a natural obstacle to mating. Thus, the intervention of the shepherd at this moment is essential to facilitate mating by lifting the tail of oestrous females to one side.

The culling of animals is not always performed at the right time. In fact, old, unproductive or low productive sheep can represent more than 35 percent of many flocks. Further prophylactic measures are not systematically undertaken. The main diseases encountered are gastrointestinal and pulmonary strongylosis, enterotoxoemia and scabies.

1.4 Performance

1.4.1 Fertility

The fertility rate of the 25 flocks surveyed over a 15-year period varied from 84 to 98 percent with a mean of 89 percent (Khaldi, 1986).

1.4.2 Prolificacy

The prolificacy rate of these flocks ranged during the same period from 102 to 139 percent with a mean value of 117 percent. Although the Barbary is not a highly prolific sheep, it has been demonstrated that prolificacy rate can reach 144 percent in spring lambing ewes, 145 percent in well-flushed ewes, 196 percent in ewes treated with 400 UI of PMSG and 172 percent

(160-181 percent) in females selected for prolificacy (Khaldi, unpublished data).

1.4.3 Birth weight and growth rate of lambs

Birth weight of Barbary sheep calculated during a period of 20 years at the Experimental Station of Ousseltia in central Tunisia varied from 3.1 to 3.6 g according to sex and litter size (Khaldi, 1980). On the other hand, growth rate between the 10th and the 30th days of age ranged between 170 and 220 g/day and between 150 and 180 g/day (Table 1) for single males, single females and twins (Khaldi, 1980).

Table 1: Birth weight (g) and growth rate (g/day) of Barbary lambs

	Single males	Single females	Twins
Birth weight (kg)	3.6	3.4	3.1
At 10-30 d (g)	220	200	170
At 30-90 d (g)	180	170	150

In a recent study, Khaldi et al. (1987) analysed the gentlc and phenotypic variation factors of the growth parameters of Barbary lambs. These lambs issued from the flock at Ousseltia Station during the period 1963-79. The total number of lambs used was 3 653. The variables analysed were birth weight and weight at 10, 30 and 90 days of age and growth rate between 10 and 30 days and between 30 and 90 days.

The results of the study show that under the harsh conditions of central Tunisia, all these parameters are closely related to the effect of the year (Figures 5, 6, 7). Because of these harsh environmental conditions, lamb growth is below their real potential since growth rates of 250 g/day are often obtained under experimental conditions or in rainy years (Khaldi, 1984).

The growth potential of lambs is difficult to assess during the suckling period as it is closely related to pregnancy and milk production of the ewe for the first three months. Thus, selection for growth will depend on greatly changed production methods (Khaldi, 1979, 1983, 1984).

1.4.4. Mortality rates

The mortality rate of lambs in the study varied from 0 to 34 percent according to year and management conditions. The mortality rate of adult animals ranged between 0 and 21 percent. The mean mortality rate of all the flocks was 8 and 5 percent for the two categories of animals respectively. It is evident that these two parameters are significantly higher in dry years than when rainfall does not represent a limiting factor.

In the Experimental Stations of the National Institute of Agricultural Research of Tunisia, the mortality rate of lambs and adults does not exceed 5 percent whatever the annual rainfall may be (Khaldi, unpublished data). This result is evidently related to forage availability.

2. CARCASS QUALITY

Increased meat production in Tunisia and Libya is a priority item in their agricultural policy to satisfy the animal protein needs of their people. To reach this objective, the number of newborn lambs has to be increased together with an improved growth rate and dressing percentage, so that a heavier carcass is obtained. Actually, lambs are slaughtered at a mean liveweight of 25 g when they are 4 to 6 months old.. If this liveweight were increased to about 35 g it would certainly be one of the best ways to increase national meat production. However, carcass quality could be lowered by increasing the liveweight of Barbary lambs due both to the fat-tail and its subcutaneously deposited fats.

The relationship of carcass quality with liveweight was studied in Barbary ram lambs by Atti and Khaldi (1987). In this study, 10 ram lambs were slaughtered at a liveweight of 25 g and 10 others were slaughtered at a liveweight of 35 g. The dressing percentage was 43 percent in light lambs and 48 percent in heavy lambs. The weight of the fat-tail represented 6.3 and 7.2 percent of the carcass weight when lambs were slaughtered at 25 and 35 g liveweight respectively. Similarly, the animals slaughtered at 35 g exhibited significantly larger amounts of internal and external fat than light lambs. In effect, the thickness of the dorsal fat was 1.65 mm in lambs slaughtered at 25 g and 4.67 mm when the liveweight increased to 35 g. On the other hand, the pelvic and renal fat weight increased from 90 to 140 g when liveweight at slaughter increased from 25 to 35 g. The carcass composition was as follows:

- at 25 g: 66 percent muscle + 24 percent bone + 10 percent fat
- at 35 g: 64 percent muscle + 19 percent bone + 17 percent fat.

3. MILK PRODUCTION

Growth of lambs depends essentially on the milk production of the ewes and their maternal qualities, especially during the first four weeks of age, when the lamb's nourishment is exclusively milk. It is therefore essential to estimate the quantity of milk furnished by the ewe and consumed by the lamb until weaning to perfect new management techniques leading to the improvement of flock productivity.

Milk production was studied in housed (Bonsma, 1939; Wallace, 1948; Hugo, 1952; Thomson and Thomson, 1953; Gyer and Dyer, 1954) and in grazing ewes (Barnicoat et al . 1949; Owen, 1957). Moreover, it has been demonstrated that ewe milk yield can be affected by many factors such as breed, age, sex, birth weight and number of suckled lambs (Bonsma, 1939; Wallace, 1948; Owen, 1953; Munro, 1955; RIcordeau et al. 1960; Folman et al. 1966; Peart et al. 1972). On the other hand, high correlations between dam milk production and lamb growth rate were found by Wallace (1948), Ricordeau and Boccard (1961), Doney and Munro (1962) and Poujardieu (1969).

Two experiments on the Barbary breed at the Experimental Station of Ousseltia studied the effects of age of ewes, sex of lambs and milk yield under grazing conditions (Khaldi, 1979) and the influence of nutrition in late pregnancy and in lactation on milk production of ewes and growth rate of their progeny (Khaldi, 1983).

3.1 Grazing ewes

The aim of this experiment was to study the effect of the age of ewes and the sex of lambs on the milk yield of the former and the growth rate of the latter. Fourty red-race females were used and divided into 4 groups:

- 10 adult ewes suckling single male lambs
- 10 adult ewes suckling single female lambs
- 10 yearlings suckling single male lambs
- 10 yearlings suckling single female lambs

Adult and young females (yearlings) were 5 and 2 years old respectively. The animals were grazed on natural pastures of mainly couch-grass and did not receive any supplementation, the year having been particularly favourable. Ewes were weighed monthly and lambs weighed at birth just after parturition and then weekly. The ewe milk yield was estimated indirectly by weighing lambs before and after suckling (Ricordeau et al. 1960) during the first 13 weeks of lactation.

3.1.1 Changes in ewe weight

The change in ewe weight (Figure 8) showed clearly that they were undernourished during both pregnancy and the suckling period. This is the case of all flocks managed under extensive management conditions. In fact, adult ewes were heavier than yearlings at mating in May (55 vs 45 g). Figure 8 shows that all the females kept a constant liveweight during the first 3 months of pregnancy and then gained weight until lambing.

Nevertheless, this weight gain in late pregnancy resulted exclusively from the growth of the pregnant uterus since all females lost about 4.2 g between mating and parturition (liveweight after lambing - liveweight at mating). Furthermore, the liveweight of all the suckling females decreased during lactation but the weight loss was significantly higher (P < 0.05) in adult than in young ewes (11.8 vs 8.7 g).

3.1.2 Milk production

The sex of lambs had no significant effect on ewe milk yield. However, total milk production was significantly affected (P < 0.05) by the age of the females (Figure 9; Table 2). Milk production was estimated at about 91 and 80 g in adult and young ewes respectively.
The relationship between the liveweight of the females at mating and their milk production was significant (P < 0.05) only during the last 4 weeks of lactation (r = 0.50).
Table 2: Comulative milk production (g)

Period (weeks)	Adult with single males	Adult with single females	Yearling with single males	Yearling with single females
0-4	34.64	35.24	30.91	31.85
5-8	29.83	28.67	26.63	26.45
9-12	23.92	21.75	19.14	19.12
0-13	92.79	89.82	79.93	81.32

Source: Khaldi (1979).

3.1.3 Growth of lambs

The mean growth rate of lambs was not significantly affected either by their sex or the age of their ram. Nevertheless, male lambs issued from adult ewes tended to have a higher growth rate than the other lamb categories during the first 9 weeks of age (Table 3).
Table 3: Growth rate of Barbary lambs (g/day)

Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13
Single males of adults	227	247	256	255	224	201	207	196	187	127	127	138	114
Single females of adults	220	239	212	223	195	178	189	180	151	143	105	100	104
Single males of yealings	217	234	211	232	222	174	183	182	148	143	87	128	69
Single females of yearlings	196	217	223	228	206	185	187	182	162	144	87	119	93

Source: Khaldi (1979).
Lamb growth rates were relatively high (about 230 g/day) during the first month after birth but they decreased dramatically to 180 g/day during the

following two weeks and to only 95 g/day between the 8th and the 13th week. These data reflect the insufficiency of natural pastures available to the lactating females and the necessity of supplementation by concentrates, at least after lambing.

Contrary to growth rate, lamb liveweight was significantly ($P < 0.05$) affected by both their sex and age of the dam. Male lambs were heavier at birth and subsequent ages than ewe-lambs with both adult and young mothers (Figure 10). The effect of sex became more pronounced with age only in lambs produced by adult ewes. On the other hand, lambs issued from ewes were significantly ($P < 0.05$) heavier at birth than those issued from yearlings. However, the maternal influence, of great importance during the first month of life, decreased in relative value with age of lambs.

Phenotypic correlations between lamb birth weight and liveweight at different ages were high and significant ($P < 0.01$), but the higher correlation coefficients were obtained during the first 4 weeks of age ($r = 0.80$ to 0.90). This result demonstrates the close relationship between pre-natal and post-natal lamb growth when extensively managed.

3.1.4 Relationship between milk yield and lamb growth

The correlation coefficient between dam milk production and lamb weight gain during the first 6 weeks of age was 0.722. It increased slightly to 0.732 when weight gain was substituted by the corresponding liveweight. These two similar values are statistically significant ($P < 0.01$). Thus, the liveweight of lambs at this age is a good means to estimate milk production of ewes as well as their weight gain since birth. Linear regressions connecting these different variables are:

$Y = 5.406\ X_1 - 2.944$

and $Y = 4.498\ X_2 - 12.173$

with:

Y = ewe milk production during the first 6 weeks of lactation (g)

X_1 = lamb weight gain between birth and 6 weeks of age (g)

X_2 = lamb liveweight at 6 weeks of age (g).

The sex of lambs had no significant effect on their milk-to-weight-gain ratio, but males tended to convert better maternal milk to meat than females (Table 4). This ratio decreased slightly during the first 2 weeks and then increased until the 6th week. This increase was certainly related to the increase of lamb liveweight and nutritional requirements. It decreased again after six weeks probably because the lamb started to graze and was no longer dependent on the dam.

Table 4: Milk-to-weight-gain ratio of Barbary lambs

Weeks	Single males of adults	Single females of adults	Single males of yearlings	Single females of yearlings
1	5.4	6.1	5.6	6.1
2	5.0	5.5	4.8	5.1
3	4.9	6.0	5.0	5.0
4	5.1	5.5	4.6	5.3
5	5.4	6.0	4.9	6.1
6	5.5	6.4	5.9	5.8

7	4.8	5.4	5.0	4.6
8	4.9	4.9	4.3	4.9

Source: Khaldi (1979).

3.2 Effect of nutrition in late pregnancy and in lactation on ewe milk yield and lamb growth

Ewe nutritional requirements increase rapidly in late pregnancy and in lactation and it is often difficult to cover them. Generally, these two physiological stages occur in late summer or in autumn, which frequently are the dry seasons in North Africa when sheep are undernourished.
An experiment was peformed at the Experimental Station of Ousseltia on 80 red-head females to study the influence of nutritional level in late pregnancy and in lactation on the performances of Barbary ewes (Khaldi, 1983). Two nutritional levels, high (H) and low (L), were used during the last 6 weeks of pregnancy and the first 13 weeks of the suckling period on 4 groups of 20 adult ewes: LL, LH, HL and HH. During all the experimental period, the females were grazed on dry natural pastures and only the well-fed animals received lucerne hay ad libitum supplemented by 400 g of concentrate/ewe/day. Ewes were weighed weekly, just before lambing and one day after. Lambs were weighed at birth and then every week. Ewe milk production was estimated weekly by weighing lambs before and after suckling according to the method of Ricordeau et al. (1960).

3.2.1 Supplementary feed consumption of ewes

In late pregnancy, the quantity of hay consumed by the well-fed ewes (HH and HL) decreased progressively until parturition (Table 5). During the first 13 weeks of lactation, and in addition to pastures, the females of the HH and HL supplemented groups consumed 110.13 and 114.90 hg of dry matter of hay/ewe. In both periods, the supplemented animals consumed all the concentrate they received (400 g/ewe/day).

Table 5: Quantities of supplementary feed intake consumed by groups HH and HL in late pregnancy (kg/ewes/day)

Weeks prepartum	6	5	4	3	2	1
Hay	0.46	0.42	0.42	0.40	0.33	0.26
Dry matter of hay	0.43	0.40	0.42	0.38	0.31	0.24
Concentrate	0.40	0.40	0.42	0.40	0.40	0.40
Dry matter of concentrate	0.36	0.36	0.36	0.36	0.36	0.36
Total dry matter	0.79	0.76	0.76	0.74	0.67	0.60

Source: Khaldi (1983).

3.2.2 Changes in ewe weight

Ewe weight gains during the last 6 weeks of pregnancy were higher in well-fed (HH and HL) than in under-fed groups (LL and LH) , but the difference between the values of these weight gains was not significant. Nevertheless, the effect of feed intake level in late pregnancy became more important ($P < 0.05$) when the proper weight change of ewes was considered (weight 24 hours after parturition - weight 6 weeks before parturition). In fact, a weight gain of 3.6 and 2.1 g was recorded in supplemented ewes (HH and HL) with 1 and 2 foetuses respectively. In contrast, all the under-fed females lost between 2.0 and 5.3 g of their body mass during the same period according to litter size.
The average weight loss of ewes during the first 13 weeks of the suckling period was 4.05, 8.01, 9.90 and 14.10 in groups LH, HH, LL and HL respectively. This weight loss was not significantly affected by the number of suckled lambs. The differences were only significant ($P < 0.05$) between groups LH and HL on the one hand and beween groups HH and HL on the other.

3.2.3 Milk production

Whatever the nutritional level and the number of suckled lambs, the milk production peak was recorded during the first week of lactation (Figures 11and 12). The nutritional level in late pregnancy had no significant effect on ewe milk yield. In contrast, this milk yield was significantly ($P < 0.05$) affected by the post- partum feed level. In effect, total milk production was similar in groups HH and LH on the one hand and in groups HL and LL on the other (Table 6). Milk production was higher, but not significantly, in ewes suckling twins than in those suckling single lambs, especially in well-nourished lactating females.
Table 6: Total milk production (g)

Groups	LL	LH	HL	HH
Singles	61.720	98.060	65.730	103.790
Twins	67.800	88.420	69.130	91.400

Source: Khaldi (1983).

3.2.4 Lamb growth

The birth weight of lambs issued from well-fed ewes in late pregnancy was higher than the birth weight of those produced by under- fed ewes during the same period (Table 7). However, the effect of the pre-partum nutritional level of dams on the birth weight of their progeny was only significant ($P < 0.05$) with twins.
Table 7: Effect of pre-partum nutritional level of Barbary ewes on lamb birth weight (g)

Nutritional level	High	Low
Single males	3.99	3.56
Single females	3.55	3.32
Twins	3.39	2.48

Source: Khaldi (1983).

In both single and twin lambs, the growth rate was significantly ($P < 0.05$) affected by post-partum nutritional level of ewes. This growth rate was higher in groups HH and LH than in groups LL and HL (Table 8).
At 10 days of age, the liveweight of single lambs was statistically similar in the 4 groups. At this age, only twins of group HH were significantly ($P < 0.05$) heavier than those of group LL (Figures 13 and 14). When they were 35 days old, single lambs of both groups HH and LH became significantly ($P < 0.05$) heavier than those of groups LL and HL. In twins, the sole significant difference ($P < 0.05$) was recorded between groups HH and LL. When lambs reached the age of 90 days, their liveweight was higher in groups HH and LH than in groups LL and HL, but the differences were significant ($P < 0.05$) only in the case of single lambs.
Table 8.: Growth rate of lambs (g/day)

Groups		LL	LH	HL	HH
Single	10-30	130	220	140	230
males	30-90	120	160	130	180
Single	10-30	140	180	140	200
females	30-90	110	150	120	150
Twins	10-30	80	110	70	100
	30-90	80	100	80	100

Source: Khaldi (1983).

3.2.5 Relationship between milk production of ewes and growth of lambs

Lamb birth weight has very little influence on dam milk production. In fact, the correlation coefficient between these two parameters was at its maximum during the first week ($r = 0.28$). It then decreased rapidly to reach 0.03 only at the end of the 4th week of lactation. This can probably be related to the high vigour of the Barbary lamb at birth which allows it to suck all the milk present in the dam's mammary gland. On the other hand, there was a high correlation between lamb weight at 35 days of age and ewe milk production during the first 5 weeks of lactation ($r = 0.90$). Linear regression is:
$Y = 4.49 X - 9.17$ with:
Y = milk production during the first 5 weeks (g)
X = liveweight of lambs at 35 days of age (g)
The highest correlation coefficient between daily milk production of the ewe and lamb growth rate was observed at the 5th week for singles ($r = 0.80$) and at the 3rd week for twins ($r = 0.59$).
The pattern of milk-to-weight-gain ratio is given in Table 9 which shows that the utilization of milk is more efficient in twins than in single lambs on the one hand and in males than in females on the other. Meanwhile, the differences between these three categories of young animals are not significant.
Table 9: Milk-to-weight-gain ratio of Barbary lambs (g milk/1 g gain)

Weeks	Single males	Single females	Twins
1	4.50	4.85	4.43

2	5.32	5.49	5.26
3	5.58	5.71	5.69
4	5.61	6.02	5.18
5	5.87	5.43	7.07
6	5.33	5.37	6.11

Source: Khaldi (1983).

4. REPRODUCTION

4.1 Reproduction of Barbary ewes

The seasonal character of sexual activity in sheep has long been known. Among the factors controlling seasonal reproduction, photoperiod is without doubt the most important component (Yeates, 1949; Hafez, 1952; Menaker, 1971; Follett, 1978; Legan and Karsh, 1980; Goodman and Karsh, 1981; Thimonier, 1981).

Generally, cyclic oestrous activity appears in ewes when the daily clear photoperiod decreases and seasonal anoestrus occurs when this photoperiod begins to increase (Ortavant et al. 1964; Fraser and Laing, 1969; Thimonier and Mauleon, 1969; Ducker and Bowman, 1970; Newton and Betts, 1972; Dyrmundsson, 1978; Lax et al. 1979). The traditional mating season of Barbary females in Tunisia is in spring (Tchamitchian and Sarson, 1970; Sarson, 1972; Khaldi, 1980). Reasons to explain this contradiction could be:

- existence of continued sexual activity;
- presence of two breeding seasons, one in autumn, and the other in spring (Hafez, 1954);
- displacement of the natural breeding season under the effects of flock management and nutritional and genetic factors (Robinson et al. 1970). In fact, the reduced importance of photoperiod variations under low latitudes increases dramatically the effect of climate and nutritional level.

It is therefore essential to know the seasonal variations in the oestrous and ovarian activity of Barbary females in their natural environment to specify adequate reproduction periods.

On the other hand, in a favourable environment, where nutrition does not represent a limiting factor, the acceleration of lambing rate can be an efficient means to increase the number of lambs produced by ewes every year, but these intensive techniques depend on the aptitude of the female to become pregnant rapidly after parturition.

Many studies have shown that the resumption of ovarian and oestrous activities during the post-partum period can be affected by the lambing season, lactation, nutrition and breed (Mauleon and Dauzier, 1965; Hunter, 1968; Restall, 1971; Joubert, 1972; Shevah et al. 1974; Restall and Starr, 1977). After the lambing season, Hunter (1968) concluded that the nutritional level of ewes is an important factor which could affect their post-partum fertility. Rhind et al. (1980) came to a similar conclusion. Likewise, our own observations (Khaldi, unpublished data) showed a great variation in fertility rate of Barbary ewes managed in a 3 lambing/2 year system, especially when females were mated in December-January (35 to 85 percent). In this case, and for different reasons, feed availability was sometimes limited in autumn and winter, which led to more or less severe under-nutrition of females in late pregnancy and in lactation.

A series of experiments was thus performed to study the reproductive aspects of Barbary females.

4.1.1 Seasonal variations of ovarian and oestrous activity

A trial was performed at the Experimental Station of Bou-Rebiaa to specify the age at puberty and the seasonal variations of ovarian and oestrous activity of Barbary females. It started with 26 5-month old ewe-lambs and 25 4 to 5-year old ewes. The mean liveweight varied from 25 to 52 g in the ewe-lambs and from 41 to 62 g in the ewes during the 16 months of the experiment. Oestrus was checked twice daily and ovarian activity was controlled by regular coelioscopies every 17 days.

4.1.1.1 Breeding season and seasonal anoestrus

The onset of the breeding season of the ewe-lambs born in autumn occurs during the first half of September of the following year when they reach puberty at 10 months old weighing on average 34.7 g. This latter value represents about 65 percent of the adult ewe weight. This weight at puberty is a common characteristic in most animal species. The duration of the breeding season of ewe-lambs is short (104 days) since their last oestrus occurs in early December (Figure 15).

The breeding season of adult ewes is significantly ($P < 0.01$) longer. Its mean duration is 242 days and it extends from mid-July to late February (Figure 16). Evidence exists which indicates that the intensity of seasonal anoestrus is also related to female age. In effect, 25 to 40 percent of adult ewes ovulate and exhibit oestrus regularly in spring when, during the same period, the termination of the oestrous activity in young females is almost complete.

4.1.1.2 Ovarian activity

As with oestrous activity, cyclic ovarian activity is not a continuous phenomenon throughout the year, but is characterized by its seasonality and follows closely the changes of the former.

Irrespective of age, the results of this experiment show the existence of an oestrus-ovulation dissociation during some periods of the year. Thus, during a period of 12 months, 32.1 percent of ovulations are not accompanied by oestrous behaviour in ewe-lambs. The percentage of silent ovulations during the same period is only 22.6 percent in adult ewes. This phenomenon of silent ovulation is not peculiar to the Barbary breed, since it has been reported in many other breeds by Thimonier and Mauleon (1969), Van Niekerk (1972), Land et al. (1973), Hulet et al. (1974), Dyrmundsson (1981) and Thimonier (1981). Silent ovulation occurs throughout the four seasons but especially before the onset of the sexual season, after its termination and during April-May.

In contrast, the occurrence of oestrus without ovulation is very rare since the frequency of such a phenomenon represents only 2.6 percent of the total number of oestrouses recorded during all the experimental period.

The mean ovulation rate of the ewe-lambs is low (1.08) and remains relatively constant throughout the year (Figure 17). In contrast, the ovulation rate of adult ewes undergoes important seasonal changes with the highest

ovulation rate being observed in September-October (1.60) and the lowest in March-April.
When a period of 12 months is taken into consideration (1 July - 30 June), the mean ovulation rate is significantly ($P < 0.05$) higher in ewes (1.32) than in ewe-lambs (1.08). On the other hand, this ovulation rate decreases in the case of silent ovulation, in both adult and young females, from 1.38 and 1.12 when they display oestrus, to 1.16 and 1.05.

4.1.1.3 Duration of oestrus and oestrous cycle

The mean duration of oestrus is estimated at 26.2 hours in ewe- lambs and 28.3 hours in adult ewes. The difference between the two categories of females is significant ($P < 0.05$). In both cases, the duration of oestrus is lower in spring than in summer and autumn (Figure 18). On average, the oestrus duration is longer more especially as the ovulation rate is higher (Table 10).

Table 10: Relationship between ovulation rate and oestrus duration (hours)

Number of ovulations	Oestrus duration	
	Yearlings	Ewes
0	12.0	27.6
1	26.0	27.0
2	29.5	30.6
3	36.0	42.0

Source: Khaldi (1984).
The mean interoestrous interval is estimated at 17.7 days in both young and adult females and seasonal changes in oestrus cycle do not occur.

4.1.2 Post-partum anoestrus

4.1.2.1 Effects of suckling duration and lambing season

To study the effects of suckling duration and lambing season on the resumption of post-partum ovarian and oestrous activities, an experiment was performed on 131 adult females, 3 to 5 years old, at the Experimental Station of Bou-Rebiaa (Khaldi, 1984). Fifty-three ewes had lambed between 14 and 30 October, 35 between 12 and 26 February and 43 between 2 and 28 June. For each of these lambing periods, the mean prolificacy rate was 120, 140 and 126 percent respectively. The mean liveweight of ewes 48 hours after parturition was about 50 g.
In each lambing season, weaning of lambs was accomplished in half of the ewes 45 or 90 days post-partum except for October lambing ewes where a third group dried off only 2 days after parturition.
Animals were grazed on natural pastures in autumn, winter and spring and on cereal stubble in summer. In addition, they received hay *ad libitum* and 300 g of concentrate/ewe/day. Ovarian activity was controlled by coelioscopy every 17 days from the 5th day post-partum and oestrus was checked twice daily for 8 months.
4.1.2.1.1 Effects of suckling duration

Irrespective of the lambing season, the suckling duration (45 or 90 days) had no significant effect on the post-partum resumption of ovarian activity of ewes. On the other hand, drying off of autumn lambing ewes 48 hours after parturition did not lead to a significant decrease in interval between parturition and the occurrence of the first post-partum ovulation (Table 11). In this case, the intervals were 15.1, 16.5 and 17.6 days when the females dried off 2, 45 or 90 days after lambing.

Table 11: Effects of lambing season and suckling duration on parturition post-partum first ovulation interval

Suckling duration	Lambing month		
	February	June	October
2 days	-	-	15.1 ± 5.5
45 days	43.4 ± 19.8	30.3 ± 14.9	16.5 ± 9.1
90 days	51.4 ± 14.8	33.3 ± 9.8	17.6 ± 8.1

Source: Khaldi (1984).

In a given lambing season, suckling duration (45 or 90 days) was of no consequence on those ewes displaying at least one oestrus during the 8 months following parturition and the mean interval between parturition and the occurrence of the first oestrus in these ewes during the same period (Table 12). In contrast, the precocious drying off of ewes (48 hours after lambing) in October reduced their post-partum period by about 25 days.

Table 12: Percentage of ewes displaying at least one oestrus within the first 240 days post-partum and parturition-oestrus interval (days)

Suckling duration		Lambing month		
		February	June	October
2 days	%	-	-	100
	duration	-	-	32.1 ± 12.9
45 days	%	82.3	100	100
	duration	97.7 ± 12.4	73.5 ± 21.4	59.0 ± 24.9
90 days	%	77.7	90.0	77.7
	duration	103.9 ± 8.2	76.2 ± 30.3	60.0 ± 49.7

Source: Khaldi (1984).

4.1.2.1.2 Effects of lambing season

The lambing season had a considerable effect on the first post- partum ovulation interval as well as suckling duration which was 45 or 90 days. In fact, this interval was on average 17 days in October lambing ewes, and about twice (32 days) and three times (47 days) longer in females lambing in June and February respectively.

The first post-partum ovulation was silent (without oestrus) in 95 percent ewes. The phenomenon was observed during the three lambing seasons which were considered.

As the resumption of cyclic oestrous activity during the post- partum period was not affected by suckling duration (45 or 90 days), the effect of lambing season on the interval between parturition and first oestrus was calculated for all the ewes of each group (Table 12). The average values of the post-partum anoestrus duration (50 percent of females displaying oestrus) were 55, 68 and 108 days in ewes lambing in October, June and February respectively. The percentage of females presenting at least one oestrus during the experiment (8 months) was 90.3 in the first group, 85.7 in the second group and 80.0 in the third group (P < 0.05).

4.1.2.2 Effects of nutritional level on pregnancy and lactation

The influence of the pre-partum and post-partum nutritional levels of Barbary ewes was studied by Khaldi (1984) at the Experimental Station of Bou-Rebiaa. The experiment concerned 164 adult females mated between 12 and 19 May after oestrous synchronization (30 mg of FGA and 400 IU of PMSG). At the start of the trial, the mean age and liveweight of ewes were 4.6 ± 1.3 years and 55.5 ± 5.3 g. All the females were housed and they were divided into 4 groups of 41 ewes according to their nutritional level (Table 13) during the last 12 weeks of pregnancy and the first 18 weeks of lactation:

- HH: ewes receiving a high nutritional level before and after parturition
- HL: ewes receiving a high nutritional level before parturition and a low level during lactation
- LH: ewes receiving a low nutritional level before parturition and a low level during lactation
- LL: ewes receiving a low nutritional level before and after paturition.

Table 13: Quantities of feed distributed to ewes (g/ewe/day)

Groups	Pregnancy		Lactation		
	Hay	Concentrate	Hay	Concentrate	Soya cake
HH	ad libitum	0.4	ad libitum	0.8	0
HL	ad libitum	0.4	1.0	0	0.2
LH	1.0	0	ad libitum	0.8	0
LL	1.0	0	1.0	0	0.2

Source: Khaldi (1984).

All the ewes were weighed every week and 24 hours after parturition. Maximum tail perimeter was also recorded at the beginning of the experiment, at parturition, and 4 and 18 weeks post- partum. The lambs were weighed at birth and then every week.

The post-partum ovarian activity was controlled by coelioscopy every week and the dosage of the plasmatic progesterone level in blood samples 3 times/week until the occurrence of the second post-partum oestrus for each ewe. Oestrus was checked twice daily be entire rams.

4.1.2.2.1 Feed intake

The mean quantity of hay dry matter (DM) ingested during the last 12 weeks of pregnancy was 1.30 g/ewe/day in the HH and HL groups. Its weekly variation was negligible. The ewes of these two groups consumed all the concentrate distributed (400 g/ewe/day). Groups LH and LL consumed only 0.87 g of hay DM ewe/day during the same period. Total energy intake of the underfed females before parturition represented only 44.4 percent of the well-nourished ewes.

During lactation, and over and above the 800 g of concentrate, the ewes of groups HH and LH consumed on average 1.56 and 1.47 g of hay DM ewe/day. These intake levels did not vary considerably during the 18 weeks of suckling. The underfed females of groups HL and LL consumed only 200 g of soya cake and 0.87 g of DM of hay/animal/day Their energy intake represented only 42.5 percent of consumption of well-nourished ewes.

4.1.2.2.2 Liveweight changes

The pre-partum nutritional level of ewes had a highly significant (P < 0.01) effect on the evolution of their liveweight during the last 12 weeks of pregnancy. In fact, the liveweight of the well-fed ewes (HH and HL) increased dramatically (9.4 g) until parturition while the underfed females (LH and LL) kept a constant liveweight during the same period in spite of the growth of their pregnant uterus. Thus, the latter lost at least 6.50 kg of their own liveweight (liveweight 24 hours after lambing - liveweight 12 weeks before lambing) (Figure 19).

After parturition, the principal factor influencing liveweight changes in suckling ewes was certainly their post-partum feed intake level. The well-nourished females did not lose much body mass (HH) or kept a constant liveweight (LH) during the first 18 weeks of suckling. On the other hand, the weight loss of the under-nourished females during the same period was significant since it represented between 21 and 29 percent of their liveweight 24 hours post-partum in groups LL and HL, respectively.

4.1.2.2.3 Caudal perimeter changes

During the last 12 weeks of pregnancy, the overnourished ewes (HH and HL) maintained a constant caudal perimeter but this perimeter decreased from 3.4 to 6.0 cm during the same period in the underfed animals (Table 14). Further, the effect of post-partum nutritional level on the caudal perimeter during lactation was highly significant (P < 0.001). This perimeter showed a reduction of more than 24 cm in the underfed females of groups LL and HL which lost about 50 and 43 percent respectively of the perimeter of their fat-tail during the suckling period.

Table 14: Effect of nutrition on the evolution of the caudal perimeter (cm) of Barbary ewes

Litter size	Groups	-12 weeks	+ 1 day	+18 weeks
1	HH	63.0 ± 4.6	63.3 ± 4.9	53.5 ± 7.7
	HL	65.1 ± 6.5	65.9 ± 7.2	40.2 ± 9.7
	LH	61.3 ± 5.2	56.6 ± 4.8	52.2 ± 7.0
	LL	62.7 ± 5.4	59.3 ± 4.6	34.7 ± 11.7
2	HH	64.1 ± 5.7	63.4 ± 6.2	53.4 ± 7.6
	HL	63.9 ± 4.1	64.3 ± 4.0	34.3 ± 12.0
	LH	59.3 ± 7.3	53.4 ± 7.9	50.8 ± 9.0
	LL	61.7 ± 5.1	55.7 ± 5.8	25.4 ± 8.0

Source: Khaldi (1984).

Irrespective of the physiologial stage of the ewes, there was a highly significant (P < 0.001) correlation between their caudal perimeter (Y, cm) and their liveweight (X, g). Nevertheless, the correlation coefficient (r) between these two criteria was higher at the end of lactation than at parturition or during the prior 12 weeks. Regressions obtained at these three stages were the following:

- at 12 weeks before parturition:

$Y = 0.54 X + 32.20$ (r = 0.50)

- at 1 day post-partum:
  $Y = 0.74 X + 18.52$ (r = 0.70)
- at 18 weeks post-partum:
  $Y = 1.62 X - 28.61$ (r = 0.85)

The correlation between caudal perimeter variations (Y, cm) and proper liveweight changes (X, g) during the last 12 weeks of pregnancy or the first 18 weeks of lactation were also very significant (P < 0.001). Reressions of the two criteria are:

- pregnancy:
  $Y = 0.53 X + 0.51$ (r = 0.68)
- lactation:
  $Y = 1.62 X + 4.15$ (r = 0.87)

4,1.2.2.4 Ovarian activity

Irrespective of litter size, pre-partum nutritional level had no significant effect on the date of first post-partum ovulation.

The effect of post-partum nutritional level on parturition-first ovulation interval was only significant (P < 0.05) in ewes suckling single lambs. In this case, the first post-partum ovulation occurred on average 9 days sooner in groups HH and LH than in groups LL and HL (Table 15). The resumption of ovarian activity of twins suckling ewes took place about 30 days after parturition in the 4 groups. Interval parturition first ovulation was significantly (P < 0.05) affected by the number of suckled lambs only in group HH where it was shorter in single mothers than in twin mothers.

Table 15: Effect of nutrition and number of suckled lambs on parturition first post-partum ovulation interval (days)

	Suckled lambs	
Groups	1	2
HH	17.1 + 4.0	30.4 ± 21.0
HL	30.9 + 23.5	30.2 ± 23.5
LH	24.2 ± 10.5	28.8 ± 20.5
LL	28.1 ± 18.5	30.1 ± 8.5

Source: Khaldi (1984).

The first post-partum ovarian cycle was not always of a normal duration (Figure 20). For all ewes, this duration varied from 5 to 79 days. Only 49.6 percent of the first ovarian cycle had a normal duration ranging between 15 and 20 days (17.2 ± 1.21 days). The first post-partum ovarian cycle was short (8.1 ± 2.5 days) or long (37.2 ± 17.1 days) in 30.6 and 19.8 percent of ewes respectively. The incidence of abnormal cycles occurred more frequently when the resumption of ovarian activity was pecocious. In fact, the duration of post-partum interval to ovulation was significantly (P < 0,05) longer in ewes with a normal cycle (30.0 ± 18.8 days) than in those with an abnormal cycle (23.0 ± 16.0 days).

The most important factor influencing the duration of the first ovarian cycle was the post-partum nutritional level of ewes. The frequency of short cycles was significantly (P < 0.001) higher in the well-nourished females of groups HH and LH (about 22 percent) than in the underfed ewes of groups LL and HL (about 13 percent).

Frequency of abnormal corpus lutea decreased significantly (P < 0.001) at the second post-partum ovulation. Thus, most females (83.8 percent) had a second ovarian cycle of a normal duration (17.9 ± 1.2 days). The premature regression of the second corpus luteum was observed in 13.5 percent of ewes and its persistence in only 2.7 percent.

4.1.2.2.5 Oestrous activity

Resumption of post-partum oestrous activity was less precocious than ovarian activity since the first ovulation was silent in 99 percent of ewes. On the whole, the number of silent ovulatiHons ranged from 0 to 5 with a mean of 1.5 ± 0.8. This number was significantly (P < 0.001) affected by post-partum nutritional level. It was higher in the well-nourished ewes after lambing (HH and LH: 1.3 to 3.3) than in the underfed females during the post-partum period (LL and HL: 1.1 to 1.2). The prepartum nutritional level and the number of suckled lambs had no significant effect on the frequency of silent ovulation.

The occurrence of first oestrus depended upon the life span of the previous corpus luteum since 91 percent of oestrus was displayed after a normal or a long luteal phase and in 9 percent only of ewes with a preceding short luteal phase.

The percentage of ewes displaying at least one oestrus during the first 18 weeks of lactation depended essentially upon their pre- partum nutritional level. This percentage was significantly (P<0.05) higher in ewes receiving a high feed level in pregnancy (HH and HL: 89 percent) than in those suffering from under-nutrition during the same period (LL and LH: 66 percent). In the same way, this percentage was significantly (P<0.05) affected by the number of suckled lambs. It was higher in ewes suckling single lambs (67 to 100 percent) than in those suckling twins (50 to 84 percent). The post-partum nutritional level had no significant effect on the occurrence of oestrus in ewes.

Post-partum interval to first oestrus was not significantly affected by the feed intake level before or after parturition. In return, this interval was influenced (P<0.01) by the number of suckled lambs (Table 16), being about 10 days shorter in single suckling ewes than in those suckling twins.

Table 16: Effect of nutritional and number of suckled lambs on interval parturition - first oestrus (days)

Groups	Suckled lambs	
	1	2
HH	40.0 ± 12.7	56.1 ± 27.6
HL	49.5 ± 20.4	53.2 ± 26.2
LH	45.5 ± 11.5	56.7 ± 18.4
LL	43.2 ± 14.6	53.2 ± 14.6

Source: Khaldi (1984).

The duration of the first oestrous cycle was not affected by the nutritional level before and after lambing or by the number of suckled lambs. This duration was normal (18.0 + 1.1 days) in 94.3 percent of females displaying at least two successive oestrus. The other cycles were short (6 to 7 days) or long (21 to 22 days). The second oestrus duration was always normal (18.2 + 0.8 days).

4.1.3 Response to ram exposure

In some animal species, the reproductive function of females can be modified by exposing them to males (goat: Shelton, 1960; sow: du Mesnil, du Buisson and Signoret, 1962; mouse: Whitten, 1958).
In most sheep, the sudden introduction of rams to previously isolated anoestrous females induces a synchronized appearance of oestrus with two peaks of activity around the 18th and 23rd days after being run with males (Schinckel, 1954; Fairnie, 1976). The use of the endoscopy technique (Thimonier and Mauleon, 1969) demonstrated that contact with rams causes the ewe to show silent ovulation within the first 4 days of teasing; the first induced ovarian cycle can be of a normal (17 days) or a short (6 days) duration (Oldham *et*_ al_., 1979; Knight et al_., 1981).
The application of teasing techniques can be useful in North Africa to obtain group lambing in the rainy season (autumn) when feed availability is important. Therefore, the response of Barbary females to rams according to age and nutritional level was studied (Khaldi, 1984).

4.1.3.1 Effect of age

An experiment was performed at the Experimental Station of Ousseltia on 160 adult ewes (5.1 ± 1.6 years) and 40 yearlings (1.5 ± 0.1 years). Adult females had lambed in autumn and had been dry for more than 75 days. The flock was kept on natural pastures and did not receive any supplementation. It had been completely isolated from rams for about 9 months. Entire rams were introduced in the flock on 5 May with a ratio males/females of 1/10. The occurrence of oestrus was checked twice daily until 10 July and females were mated only at their second oestrus. Ovaries of all females were examined by laparoscopy the day the males were introduced (Day 0) and 9 days later for those without any corpus luteum on Day 0.

4.1.3.1.1 Ovarian activity

The age of females had a high significant (P<0.01) influence on spontaneous ovarian activity before the introduction of rams into the flock. Effectively, about half the adult ewes (50.6 percent) were cycling spontaneously whereas 22.5 percent of yearlings only had corpus lutea the day the males were introduced.
The stimulation of ovarian activity of the non-cycling females by the introduction of rams was very intense. Ovulation was induced in practically all anoestrous ewes (97.5 percent) and in 74.2 percent of yearlings. The difference between the two categories of females was significant (P<0.01). The ram-induced ovulations seemed to occur during the first 4 days of contact with males (Figure 21).
Whatever the age of the females, the duration of the first ram-induced ovarian cycle was not always normal. The percentage of females with a short first ovarian cycle (about 6 days) was 23.4 percent in adult ewes and 34.8 percent in yearlings, but the difference between the two percentages was not significant. Ovarian activity was not controlled beyond the nineth day after introduction of rams; nevertheless, the dates of oestrous

occurrence seemed to indicate that the corpus lutea formed after the short cycle persisted normally (Figure 21).
Ovulation rates were similar (1.22) in spontaneously cycling adult ewes and yearlings before teasing. In contrast, the ram-induced ovulation rate was significantly ($P<0.05$) higher in ewes (1.42) than in yearlings (1.09). The induced ovulation rate of adult ewes was higher (1.47) when their first ovarian cycle was of a normal duration than if this latter were short (1.22).
4.1.3.1.2 Oestrous activity
Eighty-seven percent of stimulated adult ewes showed oestrus before Day (D) 26. This percentage was 73.9 only in ovulating young females by the male effect, but the difference between the two percentages is not significant.
Irrespective of age of females, the ram-induced ovulation or that occurring after a short ovarian cycle was generally silent (without oestrus).
In adult ewes, 71.6 percent of oestrus was observed between D 13 and D 19, with a maximum frequency at D 17. This oestrus was related to the ovulation occurring after a first normal ovarian cycle. About 21 percent of oestrus occurred between D 21 and D 25. It coincided with the ovulation occurring after a first short ovarian cycle followed by a normal cycle. In this case, the oestrous peak activity was observed at D 22. The mean interval between the introduction of males and the occurrence of oestrus was 16.5 ± 1.2 and 23.1 ± 1.4 days in the two categories of ewes respectively.
Oestrus was observed in 52.9 percent of yearlings between D 16 and D 21 and in 47.1 percent between D 22 and D 24. Thus, the mean interval between the introduction of rams and the occurrence of oestrus was 18.0 ± 1.6 in the former and 22.9 ± 0.7 days in the latter.
Sexual receptivity was observed at least twice in 82 percent of spontaneously cycling adult ewes before the introduction of rams into the flock and in 43 percent only in those ovulating by the ram effect. The other ewes had fallen again into anoestrus.
All ewes cycling before stimulation by the presence of rams had a normal oestrous cycle (17 days), but this duration was normal in less than 80 percent of the ram-stimulated ewes.

4.1.3.2 Effect of nutrition

This experiment studied the response of anoestrous Barbary ewes to ram effect according to their liveweight and their feed level between weaning of lambs and introduction of males to the flock (Khaldi, 1984).
The trial took place in the Experimental Station of Bou-Rebiaa. It involved 122 dry ewes of 3 to 6-years old (mean age: 4.1 ± 1.1 years). Nine weeks before rams were introduced (9 May), lambs ere weaned and ewes were divided into three lots according to their liveweight:

- lot L: light ewes (39.3 ± 2.6 g)
- lot H: heavy ewes (52.5 + 3.5 g)
- lot M: middle ewes (45.8 ±1.2 g)

A different feeding ration was therefore distributed to the ewes to keep their liveweight constant, to decrease or to increase it before the introduction of rams. Five groups were formed:

- group LL: 25 light ewes keeping a constant liveweight

- group LH: 24 light ewes gaining liveweight
- group HH: 24 heavy ewes keeping a constant liveweight
- group HL: 25 heavy ewes losing liveweight
- group MM: 24 middle ewes keeping a constant liveweight

The amount of distributed and refused feed was controlled daily for each group and the amount of forage was adapted weekly according to the mean liveweight change of each group.

Ovarian activity during the 21 days preceding the introduction of males was controlled by estimating the progesterone level in ewe plasma with a frequency of 3 samples/week. After the introduction of rams (Day 0), ovarian activity was controlled by laparoscopy at day 4, day 9 and 4 to 7 days after the occurrence of oestrus. This latter was checked twice daily with 4 entire rams per group and females were mated 12 and 24 hours after the onset of oestrus.

4.1.3.2.1 Feed intake and liveweight changes

Ewes of groups LH and HH consumed 400 and 200 g of concentrate/head/day respectively. Quantities of hay infested were 1.2, 1.4, 1.0 and 1.1 g/head/day in groups LL, LH, HH and MM respectively. Mean intake of straw was about 0.8 g/head/day in group HL.

Liveweights of ewes remained practically constant in groups HH, LL and MM until the introduction of rams (Figure 22). Females of group HL, suffering from under-nutrition, lost 7.3 g (- 116 g/day) between the onset of the experiment and the introduction of rams. In contrast, ewes of group LH gained livesweight (+ 105 g/day) during the same period. Their mean liveweight gain was 6.6 g.

Despite their very different body conditions at the onset of the experiment, the females of groups MM, LH and HL had a very similar liveweight (about 45 g) when males were introduced.

4.1.3.2.2 Ovarian activity

Initial liveweight at the onset of the experiment affected significantly ($P<0.01$) the proportions of ewes with spontaneously active ovaries before the introduction of males (LL and LH: 6.1 percent; HH and HL: 40.8 percent). The percentage of cyclic females in group MM (12.5 percent) was not significantly different from those of the other groups. Liveweight changes between weaning and the introduction of rams (9 weeks) had no significant effect on the cyclic ovarian activity of ewes before the onset of teasing.

Ovulation was induced in most non-cyclic ewes of groups HH (88.5 percent), LH (91.3 percent) and MM (90.5 percent) within the first 4 days of contact with males. Ho' ver severe, more or less prolonged under-nutrition decreased the response of females to ram effect (Table 17). Thus, ovulation was induced only in 76.9 percent of females of group HL and 65.2 percent of females of group LL, but only the latter percentage was significantly ($P<0.05$) lower than that of groups LH and MM.

Table 17: Percentage of anoestrous ewes responding to ram effect

Groups	Non-cyclic females	Ovulating	females
		N	%
LL	23	15	65.2
LH	23	21	91.3
HL	13	10	76.9
HH	16	14	87.5
MM	21	19	90.5

The ram-induced ovluation was followed in the quasi-totality of ewes by a second ovulation within the first 24 days of mating. Only 2 females of group HL did not reovulate during the same period, but the life span of their corpus lutea was normal. The first induced ovarian cycles did not always have a normal duration. Some females developed corpus lutea which regressed prematurely and thus had short Induced ovarian cycles (5.3 ±0.7 days) but their subsequent ovarian cycle was of a normal duration (17.0 ± 2.0 days) and similar to that of ewes in which the first induced ovarian cycle was normal (16.5 ± 1.5 days).

The liveweight of ewes 9 weeks before teasing had a considerable influence on their induced ovulation quality. In effect, the short ovarian cycle frequency was significantly (P<0.01) higher in groups LL (53.3 percent) and LH (76.2 percent) than in groups HH (21.4 percent) and HL (20.0 percent). The percentage of ewes showing a short induced ovarian cycle in group MM was intermediate (31.6 percent).

In contrast, liveweight changes of ewes had no significant effect on the duration of their first ovarian cycle. On the other hand, whatever the liveweight changes, there was a threshold liveweight of 42.7g 9 weeks before teasing (calculated by discriminant analysis) by which the proportion of females with a short induced ovarian cycle can be estimated. Under this threshold liveweight, 67 percent of females would have a short cycle. Above this threshold, the first induced ovarian cycle would be of a normal duration in 73 percent of ewes.

Liveweight of ewes 9 weeks before teasing did not seem to affect their induced ovulation rates (Table 18). In fact, they were very similar in groups LL (1.27) and HH (1.29). The ovulation rate of group MM was slightly higher (1.42). In contrast, the liveweight changes of females between drying off and the introduction of rams (9 weeks) had a dramatic effect on their induced ovulation rates. This effect appeared through the difference observed between groups LH (1.43) and HL (1.10). The influence of liveweight changes on ovulation rate of ewes at first oestrus was less clear. Nevertheless, the same tendencies concerning induced ovulation were found. This ovulation rate at first oestrus varied from 1.00 in group HL to 1.24 in group LH.

Table 18: Ovulation rate of stimulated ewes

Groups	Induced ovulation	First oestrus
LL	1.27	1.07
LH	1.43	1.24
HL	1.10	1.00
HH	1.29	1.08
MM	1.42	1.11

Source: Khaldi (1984).

4.1.3.2.3 Oestrous activity

The occurrence of oestrus. in ewes ovulating by ram effect was not significantly affected by their liveweight and its changes. The percentage of females which displayed oestrus within the first 27 days of mating varied in fact from 80 to 100 percent according to groups.

4.1.3.2.4 Fertility and prolificacy

Only apparent fertility (number of lambing females per 100 females present in the flock at mating), real fertility (number of lambing females per 100 mated females) and prolificacy (number of born lambs per 100 lambing females) resulting from the first 27 days of mating were considered (Table 19). The liveweight of females had a marked influence on apparent fertility. This latter was significantly ($P<0.01$) lower in group LL (26.1 percent) than in groups HH (62.5 percent) and MM (66.7 percent). It was also affected by the liveweight changes before mating. In effect, the liveweight gain of group LH resulted in a significant ($P<0.01$) increase of apparent fertility of ewes (78.3 percent) compared with ewes of group LL (26.1 percent). Likewise, the liveweight loss of ewes of group HL decreased their apparent fertility rate (38.5 percent) compared to the females of group HH. However, the difference between these two latter groups was not significant.

Table 19: Fertility and prolificacy of ram-stimulated ewes

Groups	Apparent fertility	Real fertility	Prolificacy
LL	26.1	42.9	100.0
LH	78.3	85.7	116.7
HL	38.5	62.5	100.0
HH	62.5	83.3	110.0
MM	66.7	73.7	114.3

Source: Khaldi (1984). !

The real fertility of ewes was equally affected by their liveweights. It was significantly ($P<0.05$) higher in group HH (83.3 percent) than in group LL (42.9 percent). That of group MM was intermediate (73.7 percent). In the same way, liveweight changes had an important effect on real fertility which was twice as high in group LH than in group LL ($P<0.01$). Moreover, liveweight loss of ewes in group HL decreased their real fertility rate by 25 percent compared with group HH ($P<0.05$).

Severe, prolonged (LL) or more recent (HL) under-nutrition of females affected their prolificacy. All ewes of groups LL and HL had single lambs. In the other 3 groups, the prolificacy varied from 110 to 116.7 percent. No significant difference was evident.

4.2 Reproduction in Barbary rams

The seasonality of semen production in Barbary rams was studied by Mehouachi and Khaldi (1987). Sperm was collected using an artificial vagina from 6 rams during a 13 month period with a rate of 2 x 2 collections per week. The results of this study showed that the Barbary rams ejaculated on average 11 x 10^9 spermatozoa per week. Semen production was higher in summer and autumn than in spring.
The epididymal reserves seemed to be low as a result of decrease in sperm production between two ejaculates.
The volume of semen ejaculated by rams was significantly ($P<0.001$) affected by the season. Higher production was observed during summer (1.05 ml) and lower during winter (0.65 ml). The quality of ejaculated sperm was
also greatly influenced by season. However, variation of different parameters controlling this quality was not the same during the year:

- The proportion of dead spermatozoa was at its highest level (98 percent) in summer, from mid-July to mid-August;
- the number of spermatozoa with morphological abnormalities was higher in autumn (34 percent) and winter (32 percent) than in spring (26 percent) and summer (27 percent);
- the decapitated spermatozoa and head abnormalities were present at a low level, but the proportion of these malformations was higher in spring than in autumn.

The Barbary rams were sexually active throughout the year, but their libido decreased strongly during winter.

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