THE EFFECTS OF TROPICAL ENVIRONMENT ON REPRODUCTION EFFICIENCY IN RUMINANTS

Warren C. Foote
G. Simon Riera
Anim. Scientists, Physiology and Reproduction, Ph.D., Utah State University, Logan, Utah, USA.
Aurino A. Simplício
Méd. Vet., Ph.D. EMBRAPA/Centro Nacional de Pesquisa de Caprinos (CNPC), Caixa Postal 10, Sobral, CE

Abstract – A review of the available literature shows that reproductive performance is generally lower among ruminants in the tropics than in more temperate zones. A major limiting factor of most tropical environments is increased temperature which appears to influence reproduction both directly, as well as indirectly through its added stress on production. Age at puberty and fertility are affected, but not the prolificacy or the length of breeding periods where species such as sheep and goats became continuous breeders in tropical environments, because of the minimal changes in photoperiod near the equator. Reproductive performance can be improved in the tropics by modifying the environment primarily to protect against high temperatures and humidity and to provide for a more adequate diet during periods of drought. Shifting reproduction schedules, so that periods of greatest nutritional needs coincides with periods of greatest food production can also improve reproduction performance. However, emphasis should be placed on the successfull adaptation of ruminants to the tropics to assure reproductive success and in some cases to exceed that expressed in temperate zones.

Efeito do clima tropical na eficiência reprodutiva dos ruminantes

Resumo – A bibliografia mostra que a eficiência reprodutiva dos ruminantes é geralmente menor nos animais localizados no trópico que naqueles de zonas temperadas. O principal fator limitante da maioria dos ambientes tropicais é a alta temperatura que afeta os processos reprodutivos diretamente e indiretamente através do estresse na produção. Os parâmetros reprodutivos afetados pelo clima tropical são a idade à puberdade e a fertilidade, não tendo alteração a prolificidade ou o período de reprodução, onde espécies como a ovelha e a cabra apresentam atividade sexual ao longo do ano devido a inexistência de variações anuais significativas no fotoperíodo perto do equador. A eficiência reprodutiva no trópico pode ser melhorada protegendo os animais das altas temperaturas e umidade e providenciando uma alimentação adequada durante os períodos de seca. Também, através de esquemas reprodutivos de forma tal que períodos de maior requerimento nutricional dos animais coincidam com as épocas de maior produção de forragens. Todavia, ênfase deve ser dada na eficiência de adaptação dos animais ao trópico, não somente para assegurar a reprodução das espécies mas também para superar os níveis reprodutivos dos animais de zonas temperadas.

Adaptation of an organism to its environment involves all of its body processes and can be no better than the process most limited by the environment. This is particularly true for the processes of reproduction, because if reproduction fails under the limiting influence of environment or is limited to a level that does not allow propagation at a rate that will maintain a population, then that population becomes extinct. This is true even though other body processes can continue. Reproductive adaptation is essential to genotype survival.

The same principle applies to reproductive efficiency or level of performance in food and fiber producing domestic animals. If reproductive rate is inadequate to provide for production of meat, milk or fiber, the genotype has no value in providing for the needs of man. If the effects of environment can be modified by management to increase reproductive performance to the required level the genotype becomes useful.

Environment, in this paper, is considered to include those physical and biological factors which are a product affect of climate and weather. These include temperature, amount and annual pattern of moisture, altitude, and photoperiod. Tropical environment would include these factors as they exist in the tropical zone surrounding the equator or the occurrence of similar environmental conditions in areas other than the equatorial zone. Tropical environments are usually warm or hot but can be cold. They can be exceedingly arid or rain forest or with dry-wet seasons in semiarid areas such as Northeast Brazil's tropical environments. Tropical environments, by definition to relationship to the equator, involve minimum fluctuations in photoperiod change. They can be at sea level or at 4,500 meters as in the Andean range.

The ancestors of our domestic ruminants evolved beginning millions of years ago in the Pliocene era. The goat, for example, (MacFarlane 1982) probably evolved primarily in South Asia, under the harsh mountain environmental conditions of an arid climate with seasonal changes from hot to cold with accompanying changes in type and amount of feed and with wide photoperiod variation. Their processes of reproduction adapted under the influence of these varying environmental conditions to conceive and produce offspring when the environment including feed was most likely to be available.

Since domestication 12,000 or more years ago, goats have become adapted to widely varying environments by natural and human imposed selection and to production of meat, milk and fiber. And under each environmental condition they have reproduced at a rate and degree of efficiency to provide offspring for production of food and fiber, for increase in numbers, and for genetic selection. MacFarlane (1982) has listed 10 goat ecotypes to demonstrate the extent of this adaptation to varied environment and production systems.

Sheep, which were domesticated about the same time and under somewhat similar environmental conditions (Dixon 1979) as goats, also represent several ecotypes which overlap widely with goats. However, each kind has its own unique adaptation conditions.

Cattle and buffalo were domesticated much later than goats and sheep, and are distributed less broadly, but are adapted to unique environmental conditions. Genotypes of each of these four species are adapted to tropical environments.

Reproductive performance in this paper will be expressed in terms of age at puberty, expression of estrus, ovulation, prolificacy, postpartum interval, parturition interval, weight and viability.

There is relatively little literature published on reproductive performance of ruminants in tropical environments and much of what is published is in more local journals. A review of the available literature shows that reproductive performance is generally low and often limits production performance under tropical conditions. This appears to be partially due to the fact that these animals are often in the hands of small producers with inadequate resources for proper management. However, a major factor is the climate related environment (Table 1).

TABLE 1. Mean age in months at first calving during the years studied at Ridiyagama and Polonnaruwa (from Lundstrom et al. 1982).

Year	Ridiyagama			Polonnaruwa		
	No.	Age	S.D.	No.	Age	S.D.
1968	22	46.3	6.1			
1969	25	46.9	6.0	12	49.3	12.9
1970	26	48.2	9.0			
1971	30	47.3	5.8	24	44.4	5.5
1972	33	43.3	5.0	27	51.0	7.2
1973	35	45.4	4.5	79	47.6	7.6
1974	35	50.9	8.1	48	51.3	7.2
1975	100	50.2	6.4	59	57.6	8.7
1976	38	53.6	6.3	8	55.7	11.3
1977	41	61.6	5.6	17	66.5	18.2
1978/79	39	61.5	8.1	8	56.9	11.2
Total	424	51.0	8.6	282	52.1	10.5

Buffaloes are characteristically late reaching puberty and producing their first calf with subsequent long calving intervals. In the dry zones of Sri Lanka selected reproductive traits were measured from Murrah buffalo cows at two state farms (Lundstrom et al. 1982). Both farms are located near the equator. The Ridiyagama farm is located at 6^{0} North latitude and 81^{0} East longitude with 1,095 mm annual rainfall; the Polonnaruwa farm is located at 8^{0} North latitude and 81^{0} East longitude with 1,427 mm of rainfall. The average age to first calving was 51.0 months (SD = 8.6) and 52.1 (SD = 10.5) months for Ridiyagama and Polonnaruwa farms, respectively. There were large yearly variations. The effect of year and season of year were not clearly defined in this study by Lundstrom (1982). However, Jalatge & Buvanendran (1971) working with the Murrah at one of the farms in Sri Lanka reported an effect of both year and season of birth on the age at first calving. The age at first calving decreased when calves were born in the first quarter compared to the last quarter of the year. Such variations appear to be more closely related to changes in nutrition as a result of the climatic environment than to other factors.

Large variations among calving intervals occurred at both farms; 530.6 days (SD = 168.2) at Ridiyagama and 538.6 days (SD = 166.7) at Polonnaruwa. Parity also greatly affected calving intervals (Table 2). The mean gestation length for buffalo on the Ridiyagama farm has been reported by Jalatage & Buvanendran (1971). This provides an estimate of 225 days for the overall interval from calving to conception. The main causes for this long interval were reported to be period to onset of ovarian activity (100-200 days); (Perera 1981) and to conception. Reports of time from parturition to fertile service in buffalo varies in India from 113 days (Kanujia et al. 1975) to as low as 68 days (Paragaónkar & Kaikini 1977) and 144 days in Egypt (Oloufa & Stino 1979).

TABLE 2. Mean (±SE) calving intervals for parities 2 to 8 in buffalo (from Lundstrom et al. 1982).

Parity no.	Ridiyagama	Polonnaruwa
2	603.8 ± 9.3 (349)[1]	541.3 ± 14.0 (255)
3	494.7 ± 10.7 (254)	492.0 ± 15.9 (191)
4	515.7 ± 12.6 (178)	441.6 ± 18.7 (108)
5	470.3 ± 15.3 (117)	405.9 ± 25.5 (50)
6	479.4 ± 18.9 (75)	397.4 ± 39.0 (18)
7	459.4 ± 25.3 (41)	403.0 ± 65.6 (6)
8	475.3 ± 33.6 (23)	342.4 ± 79.9 (4)

[1] Number of observations.

Differences in these last estimates are due, in large measure, to differences in genetics as well as those associated with environment. The cause for the poor reproductive performance in Sri Lanka was assumed to be related primarily to the female rather than the male. The age at first calving is clearly a function of the female. The long calving interval has been shown (Perera 1981) to result primarily from delay in resumption of ovarian acitivity after parturition rather than infertile services again implicating the female (Table 3).

There appears to have been little work done to determine the influence of better nutrition on improving these reproductive traits. Temperature and photoperiod were considered to have little influence because of the location near the equator compared to seasonal effects reported for India and Pakistan (Siddappa & Patil 1979, and Ahmad et al. 1981).

In Sri Lanka several reports have indicated that variations in rainfall affects feed production as a major cause of poor reproduction in buffalo (Lundstrom et al. 1982, Buvanendran et al. 1971, Jalatge & Buvanendran 1971).

TABLE 3. Pattern of calvings and conceptions (from Elwishy et al. 1984).

Month	Calvings		Conceptions	
	No.	%	No.	%
January	231	12.2	215	11.4
February	213	11.2	190	10.1
March	152	8.1	243	12.9
April	152	8.1	210	11.2
May	134	7.1	160	8.5
June	51	2.7	150	7.9
July	56	3.0	120	6.4
August	87	4.6	40	2.1
September	161	8.5	60	3.1
October	221	11.7	90	4.7
November	212	11.2	180	9.5
December	218	11.5	230	12.2
Total	1888		1888	
Mean	157.3		157.3	
x^2	294.88**		308.88**	

** P < 0.001.

Other studies have been conducted confirming the poor reproductive performance of buffalo (El-sheikh & Mohamed 1965, Ahmad et al. 1981, Jainudeen et al. 1983, Elwishy et al. 1984). Research has also been conducted in areas with greater variation in temperature measuring the effects of season of year on reproduction. In these cases hot temperatures during parts of the year were shown to affect the incidence of estrus (Asker & Elitriby 1958, Roy 1974. Elwisky et al. (1984) reported significant monthly or seasonal variation in calvings; monthly frequencies during October to February were 11.2 - 12.2% compared to frequencies of 2.7 - 8.5% for the remaining months. Consequently conception occurred at higher frequencies during the period of April to December (10.1 - 12.9%)

with lower frequencies from August to October (2.1 - 4.7%) (Table 3). Ovarian acitivity of slaughtered buffalo confirmed these findings.

The time from parturition to conception (postpartum service period) and therefore calving interval were influenced by month of calving (Table 4). Reduced occurrence of estrus and of ovarian activity was considered to be the cause of the seasonal variation. Photoperiod increases together with increased temperatures were considered primary causes of the reduced reproductive performance. Highest fertility occurred during November to February. A reduced level of nutrition during dry periods (Zakari et al. 1981) and the effects of high temperatures on persisting high levels of progesterone (Wiersma & Stott 1969, Stott et al. 1972) were also suggested as factors contributing to the seasonal variation in reproduction.

Libido and presumably semen production of bulls is low during these same periods and if used for natural mating during these same periods would contribute substantially to poor reproduction in the female.

Several reproductive processes have been studied under Amazon conditions (Marajo Island) in Brazil (Vale et al. 1984).

Lengths of the estrous cycle and estrous periods are shown in Table 5. The overall mean estrous cycle length of 23.7 days agrees with most other reports for buffalo (Toelihere 1977, Chien 1979, & Rao et al. 1982, El-sheikh & El-Fouly 1971, Jainudeen 1977). The watter buffalo was reported to be nocturnal in its sexual behavior with 84% occurring during evening, night and early morning hours (14 hour period). The mean time from the end of estrus to ovulation was 19.8 hours. This report did not indicate levels of reproductive performance.

Records from the National Dairy Research Institute, Karmal, India (Madan & Raina 1984) demonstrate that the Murrah buffalo is superior to cattle in production of milk but

TABLE 4. Length (days) of the calving interval and service period (from Elwishy et al. 1984).

Month	No. of obs.	Calving interval		Service period	
		Mean	S.D.	Mean	S.D.
January	187	537	133	220	54
February	156	572	143	255	64
March	116	586	124	269	57
April	107	587	128	270	59
May	96	546	100	229	42
June	33	555	115	238	49
July	49	496	75	179	27
August	62	511	91	194	35
September	119	509	107	192	40
October	197	513	136	196	36
November	185	508	148	191	56
December	178	518	149	201	58
Total or average	1485	535	134	219	55

TABLE 5. Duration of estrous cycle (days) and heat (hours) observed in water buffalo cows (*Bubalus bubalis* Lin.) during a 90 days period (June-August 1982), Marajo-Island-Brazil (from Vale et al. 1984).

Herd	Duration of the estrous cycle (days)			Duration of the heat (hours)		
	n	Mean	S.D.	n	Mean	S.D.
I	41	24.3	6.2	77	23.1	6.2
II	35	23.2	3.4	60	24.3	6.1
Total	76	23.7	4.9	137	23.8	6.2

that comparatively low reproductive performance is a limiting factor in production under the tropical conditions that prevail in that area. These authors compared these two species for several reproductive traits over a seven year period and found the response to be higher in cattle than buffalo in each case (Table 6).

Zebu cattle (*Bos indicus*) are considered best adapted to most tropical conditions and are found in these environments in greatest numbers. However, non Zebu type cattle endogeneous to more local areas exist in some tropical areas of the world.

Reproductive parameters for two breeds of Zebu cattle in Nigeria have been reported by Eduvie (1985) and is summarized in Table 7. Estimates for most traits did not differ between breeds and means, varied from 45-54 days from parturition to detection of first follicle, 43-66 days for interval from parturition to first ovulation and 25 to 26 days for interval from parturition to uterine involution. From these same data it can be observed that under tropical conditions season of year (wet **vs** dry) cows experienced ovarian follicular activity and ovulation earlier during postpartum for cows calving in the dry season than in the wet season. Differences were also shown for parity (or age) of dam but not for suckling. The addition of concentrates (3 kg per day) to pasture tended to shorten all

TABLE 6. Reproductive performance of Murrah buffalo and crossbred dairy cattle in Indian (taken from Madan and Raina 1984).

Process	Ranges between years	
	Crossbred dairy cattle	Murrah buffalo
Service period (days)	105 - 133	104 - 154
No. services/conception	1.6 - 2.2	1.9 - 2.2
Fertility to 1st service (%)	37 - 58	30 - 44
Fertility to three services (%)	76 - 91	60 - 81
Mean age at first conception (months)	22 - 29	30 - 36

TABLE 7. Least squares means of the reproductive traits within each variable (from Eduvie 1985).

Treatments	Interval pp to detection of first follicle (days)	Interval pp to first ovulation (days)	Interval from first follicle to first ovulation (days)	Interval pp to completion of U.I.** (days)
	LSM	LSM	LSM	LSM
SUCKLING				
Suckled	52.77 a (34)	68.11 a (67)	36.08 a (31)	25.64 a (73)
Nonsuckled	23.36 a (10)	34.11 a (15)	26.86 a (10)	25.98 a (15)
FEEDING				
Grazing	47.27 a (22)	68.94 a (52)	58.96 b(21)	26.11 a (56)
Grazing plus concentrate	44.91 a (22)	50.87 a (32)	7.44 c (20)	24.98 a (32)
SEASON				
Dry	46.59 a (14)	49.70 a (36)	17.14 d (14)	26.88 a (38)
Rainy	45.86 a (30)	71.43 a (46)	42.48 d (17)	24.80 a (50)
PARITY				
Two calvings of less	46.44 a (28)	69.78 a (48)	45.01 e (27)	24.92 a (48)
More than two calvings	45.48 a (16)	50.76 a (34)	12.28 f (14)	26.64 a (40)
BREED				
White Fulani	44.91 a (38)	65.85 a (68)	43.30 g (36)	25.94 a (73)
Sokoto Gudali	53.56 a (6)	42.72 a (14)	34.34 h (5)	24.55 a (15)

bc, ef, gh: Means with different superscripts within each treatment group differ significantly (ef, $P < 0.05$; bc, gh, $P < 0.01$).
* pp = Postpartum
** U.I. = Uterine involution.
\+ Ovulation occurred before first follicle was detected.
Values between brackets represent number of animals.

postpartum phenomena with apparent effects of follicular development.

In Northeast Brazil, Weitze & Magalhães (1984) compared age at first calving and calving interval in three herds of purebred Nelore cattle. Herd one was observed under a semiarid condition with long dry periods and little rain; herd two was observed under semihumid conditions with shorter dry season and heavier more regular rainfall; herd three was observed on the margin of a humid region with regular rainfall throughout the year. Age at first calving for all herds averaged 1307 days (43.5 ± 9.53 months) and the calving interval was 456 days (15.2 ± 3.43 months) (Table 8). These variations can be used to estimate these reproductive parameters for this breed. The age at first calving was much shorter in herd three, which was in the best environment for yearround feed production. Differences in calving intervals among herds were less easily

TABLE 8. Mean (±SD) age at 1st calving and calving intervals (days) in 3 Nelore herds under range conditions in Northeast Brazil (from Weitze and Magalhães 1984).

Herd	Age at first calving	Calving interval
1	1369 ± 265 (187)[1]	440 ± 90 (535)
2	1351 ± 277 (468)	476 ± 90 (1496)
3	1115 ± 251 (167)	417 ± 69 (701)
Total	1307 ± 286 (822)	456 ± 103 (2732)

[1] = no. of observations.

interpreted.

Age at first calving and calving intervals limit reproductive efficiency. Calving intervals as long as 15 months greatly reduce management prerogatives where feed cycles are based on annual cycles.

Egbunike (1984) reported comparison of reproductive performance of a native Nigerian breed of cattle, the N'Dama (Bos indus), the German Brown (Bos Taurus) and a cross between the two breeds (N'Dama as dam) over a three year period (Table 9).

The greater adaptability of native N'Dama and the cross is demonstrated in higher fertility and fewer abortions or stillbirths compared to the German Brown. Birth weight was greater in the German Brown because of their greater mature size. Dystocia also occurred in the cross because of relative larger crossbred calves.

Although some parameters such as age at first calving and calving interval are not reported, the level of fertility of approximately 80%, shows relatively high reproductive performance.

Seasonal depression on reproductive performance as a result of high ambient temperatures are well documented (Ulberg 1958, Vincent 1972, Waites 1968). Ulberg & Burfening (1967) found that pregnancy rates dropped 16% (61-45) when rectal temperature increased 1°C measured at 12 hours after insemination. Increased humidity has been shown to greatly increase the effects of increased temperatures. The maximum environmental temperatures the day after insemination was shown to have the greatest effect of all measurements on fertility (Thatcher 1973). Wiesma & Stott (1969) demonstrated that the most temperature critical period on embryo survival was the first 4-6 days following breeding. Dunlap & Vincent (1971) exposed heifers to 32.2°C or 21.1°C temperatures for 72 hours following mating and measured rectal temperatures, percent conceiving and levels of plasma progesterone. The elevated temperature increased rectal temperatures and progestin levels and reduced conception rate to zero (Table 10).

Stott & Williams (1962) working with ambient temperatures in Arizona, demonstrated that low fertility rate and high embryo mortality are major contributors of lowered reproductive performance in Holstein Frezian dairy cattle. They reported a higher proportion of long estrous cycles (longer than 26 days) following infertile mating and with longer duration during the months when cows were under elevated temperature and

TABLE 9. Mean reproductive performance (combined for three years) of the N'Dama, German Brown, and their cross (from Egbunike 1984).

Treatment	Rectal temperature C	Percent conceiving	Plasma progestins b
21.1 C	38.51 (25) a	48 (25)	0.55 (22)
32.2 C	40.00 (23) c	0 (23)	0.97 (13) c

a Value in parentheses represents number of heifers.

b Adjusted means (pretreatment plasma progestin levels used as the covariate).

c Progestins and rectal temperatures for the 32.2 C group were significantly ($P < 0.01$) greater than for the 21.1 C group.

TABLE 10. Rectal temperature, conception rate, and plasma progrestins (ng/ml) in response to thermal stress in bovine (from Dunlap & Vicent 1971).

	N'Dama	German Brown	Crosses
Percent calving (fertility)	78.0	45.4	83.3
Live births (number)	72	94	59
Abortions (%)	0	5.3	0
Stillbirths (%)	0	10.64	0
Dystocia (%)	0	0	11.1
Birth weight (kg)	18.9	32.9	24.02

humidity stress (Table 10). These long cycles can reflect embryonic death and also that high temperatures might also prolong the time to the subsequent estrus and ovulation.

Vaught (1976) reporting on the effects of high summer temperatures in Arizona reported conception to first service of 10% compared to 80% during cooler weather. She reported no effect of elevated temperatures on estrous cycle length, ovulation time or corpus luteum development. However, the duration of estrus was shortened (8.2 - 8.5) hours **vs** 14.0 - 13.5 hours during hot and cooler weather. Progesterone levels were increased in lactating cows during hot weather but not in nonlactating cows not experiencing hypothermia. It was concluded by Vaught (1976) that the corpus luteum was the primary source of increased progesterone while Thatcher (1973) suggested that the adrenal cortex might be a contributing source due to increased steroid production resulting from stress. Vaught (1976) further reported no affect of high temperature on the pre-ovulatory surge of LH or incidence of ovulation.

Seasonal endocrine changes in bulls have been reported for LH, testosterone and prolactin. Tucker et al. (1974) found plasma prolactin levels varied with the season and were influenced by temperature and photoperiod. Gwazdauskas et al. (1980), Welsh et al. (1981), Thibien (1976), Foote et

TABLE 11. Length of estrual cycles (days) by month the animal was bred (from Stott and Williams 1962).

	Estrual intervals greater than 26 days		
Month	No. of intervals	Percent of total intervals	Mean ± SD
May	5	50.0	50 ± 8.6
June	27	47.4	54 ± 20.7
July	37	49.3	56 ± 19.0
August	44	47.3	48 ± 15.8
September	28	28.0	49 ± 13.7
October	37	40.2	43 ± 10.2
November	5	11.9	39 ± 2.1

al. (1976), have reported LH levels during different periods of the year but their results lack agreement.

Downey et al. (1984) in Canada, working with Holstein bulls, reported variations in LH, testosterone and prolactin levels through the year. Prolactin levels were elevated during the summer period and may reflect the effects of temperature stress. Testosterone was elevated in March compared to other periods of the year. LH did not vary throughout the year. Changes in semen characteristics, sperm concentration, ejaculate volume or total sperm were associated with season of year.

De Alba & Riera (1966), working in Costa Rica, subjected Jersey bulls to climatic chambers in which temperature was varied; one group was subjected to 35-36ºC and 80-90% relative humidity for 8 hours during each day. Another group was subjected to heat chambers but with no artificial heating (27º - 29ºC). Light was controlled 12 hours per day. Average exposure times (to fifth successful ejaculate) was 303 and 273 days for the hot and temperate chambers, respectively. The heat treated bulls were older (54.9 **vs** 48.4 weeks) and lighter in weight (171.4 **vs** 182.1 kg) at puberty. Ejaculate volume was not influenced by temperature treatment but percent motility and sperm number was greatly reduced by increased temperature (Table 12). Heat treatment decreased weight and volume of the testis (Table 13). These results confirm the generally accepted detrimental effects of high environmental temperatures on testicular function of the male. However, no detrimental effect on libido was reported.

The literature is replete with references on the influence of environment on reproduction in sheep. They deal mostly, however, with photoperiod and other climatic conditions not directly relevant to the tropics. A large amount of data has been generated at the National Center for Goats and Hair Sheep that define reproductive performance under semiarid tropical conditions. Some of these data – both published and unpublished will be utilized in this paper. Simplício and his associates (unpublished data) have measured the occurrence of estrus and ovulation throughout the year in the endogenous breeds of hair sheep in Northeast Brazil. These results are shown in Table 13 and indicate that they breed with approximately equal frequency throughout the year. This reflects minimum changes in photoperiod characteristic of most tropical regions. Changes in photoperiod as a result of locations, north or south of the

TABLE 12. Average semen characteristics for the first five ejaculates (from De Alba and Riera 1966).

Ejaculate[1]	Hot chamber			Temperature chamber		
	Volume (ml)	Motility (%)	Number (x 104 per mm 3)	Volume (ml)	Motility (%)	Number (x 104 per mm 3)
1st	1.3	0.2	3.4	1.4	20.0	50.0
2nd	1.6	0.8	6.9	2.0	38.5	69.5
3rd	1.9	5.0	11.5	2.1	50.7	123.6
4th	2.1	4.5	4.4	1.9	43.4	117.3
5th	2.3	6.5	19.9	2.5	53.5	103.5
Average	2.0	4.1	9.2	2.0	41.5	92.8

[1] 9-day intervals between ejaculates.

TABLE 13. **Characteristics of segments of the genital tract of bull calves subjected to two temperature regimes (from De Alba and Riera 1966).**

	Hot chamber	Temperature chamber	Significance of difference P =
Testicle[1]			
Gross weight (g)	106.0	149.4	1%
Volume (ml)	105.1	147.3	1%
Total testicular weight (expressed as % of carcass weight)	0.212	0.295	5%

[1] Average of right and left sides.

TABLE 14. **Mean ovulation rate by breed of sheep, month and nutrition-management system (June 1983 - May 1984) (from Diaz Silva et al., unpublished).**

Month	Morada Nova		Santa Ines		B. Somali	
	Confin.	Native pasture	Confin.	Native pasture	Confin.	Native pasture
June	1.2	1.5	1.3	1.3	1.5	1.4
July	1.3	1.4	1.7	1.2	1.0	1.5
August	1.3	1.7	1.0	1.0	1.2	1.3
September	1.0	1.7	1.5	1.0	1.6	2.0
October	1.0	1.5	1.5	1.0	1.0	1.5
November	1.3	2.2	1.0	1.0	1.3	1.3
December	1.5	2.0	1.0	1.0	1.0	1.5
January	2.3	1.5	1.2	1.0	1.2	1.2
February	1.3	1.8	1.4	1.5	1.4	1.8
March	1.3	2.3	1.4	1.5	1.6	1.0
April	1.2	1.7	1.5	1.2	1.3	1.7
May	1.7	2.0	1.4	1.2	1.2	2.0
Mean	1.4	1.7	1.3	1.1	1.3	1.5

equator, interfere with the continuous occurrence of estrus and ovulation. Under some tropical conditions with latitudes of approximately 11° South, seasonal changes do occur in the incidence of estrus and ovulation as demonstrated in the Andian range of Peru. Vivanco et al. (unpublished data) and Bravo et al. (unpublished data) have shown in independent studies that the incidence of both estrus and ovulation is reduced during the period of July to January. This does not appear to be related directly to changes in temperature or rainfall or feed resulting from changes in rainfall. Shifts in time of breeding significantly increase the level of fertility. Prolificacy is low (approximately 1.0) during all parts of the year.

The sheep of the subtropics of Northeastern Brazil are hair sheep; the Morada Nova, Brazilian Somali and the Santa Ines breeds. The National Research Center for Goats and Hair Sheep has collected additional data on their reproductive performance, which is summarized in Tables 15-16. From this information it can be seen that all breeds are well adapted to the environment with fertility ranging from 75 - 92%, prolificacy of 1.36 to 1.96, abortion rates of 4.0 to 9.4%, birth weights of 1.9 - 2.7 kg and weaning weights at 112 days of 12.1 - 16.6 kg. The mortality of

TABLE 15. Reproductive performance of hair tropical sheep in Brazil (from Simplício et al. unpublished).

Variables		Breed			
		Morada Nova 25	Somali 28	Santa Ines 32	
Bred	(%)	100.00	96.42	100.00	NS
Abortions	(%)	4.00	7.14	9.37	NS
Premature parturition	(%)	0.00	0.00	3.12	NS
Parturition at term	(%)	96.00 a	82.14 ab	75.00 b	*
Fertility	(%)	100.00	89.28	87.50	NS
Services/pregnancy	(n)	1.16	1.69	1.41	-
Return[1]	(%)	8.00 a	28.57 b	6.25 a	*
Prolificacy	(n)	1.96	1.34	1.36	-
Sex ratio	(%)	53.06	48.38	70.58	-
Gestation period	(days)	150.29 ± 1.96	149.43 ± 1.50	150.70 ± 1.75	NS

[1] Return to estrus during the breeding season.
($P < 0.05$) for means with different superscript letters among columns.

TABLE 16. Reproductive and productive performance of tropical hair sheep in Brazil (combined from Figueiredo et al. 1983 and Simplício et al. unpublished).

	Morada Nova	Brazilian Somali	Santa Ines
Age at first estrus, days	214.5 ± 38.0 (6)	283.9 ± 53.4 (18)	219.7 ± 64.9 (6)
Weight at first estrus, kg	20.6 ± 0.8 (6)	19.7 ± 2.1 (18)	28.6 ± 3.3 (6)
Age at first mating, days	349.9 ± 68.0 (6)	342.0 ± 32.6 (3)	286.8 ± 59.7 (6)
Weigth at first mating, kg	26.7 ± 2.8 (6)	23.6 ± 0.5 (3)	32.5 ± 3.4 (6)
Estrous cycle duration, days	16.1 ± 1.1 (48)	17.5 ± 5.1(166)	19.6 ± 7.5 (17)
Estrus duration, hours	30.4 ± 13.9 (54)	27.4 ± 7.1 (81)	25.8 ± 7.1 (23)
Age at first parturition, days	497.8 ± 67.0 (6)	490.3 ± 31.1 (3)	450.4 ± 56.1 (5)
Weight at first parturition, kg	28.7 ± 2.7 (6)	28.4 ± 2.2 (3)	39.3 ± 3.3 (5)
Birth weight (kg)	2.0 ± 0.49 a	2.02 ± 0.50 a	2.70 ± 0.64 b
Cummulated birth weight (kg)	3.8 ± 0.82 a	2.70 ± 0.63 b	3.56 ± 1.00 a
Ewe weight at parturition (kg)	28.2 ± 4.50 a	25.50 ± 3.31 a	36.87 ± 6.27 b
kg of lamb born/kg of ewe lambing	13.9 ± 3.94 a	10.64 ± 2.36 b	9.92 ± 3.13 b
kg lamb weaned/ewe exposed to male	16.3	12.07	16.57
kg lamb weaned/kg of ewe at weaning (%)	62.9	57.79	59.78
Mortality until weaning (%)	24.4	13.33	13.33 NS

[1] Number of observations.
($P < 0.01$) for means with different superscript letters among columns.

lambs from birth to weaning is 13.3 to 24.4%. These measurements were made under semiextensive conditions in the center facilities and the responses are probably better than exist under producer conditions.

Postpartum reproductive performance,

which defines the time from parturition to first estrus, is shown in Tables 17 and 18. This parameter varies from 61.3 to 70.9 days for the three breeds. Using the gestation lengths reported in Table 15 the mean lambing or parturition intervals in days are 219.4 for the Morada Nova, 210.6 for the Brazilian Somali and 221.6 for the Santa Ines. These results demonstrate that within the limitations of feed availability which is controlled primarily by the environment that all three breeds of hair sheep are well adapted to the environment with high fertility and prolificacy potential and the ability under proper management to produce lambs at eight month intervals. Their reproductive performance is surprisingly high.

TABLE 17. Interval between parturition and the first postpartum estrus (PPI) in tropical sheep (Brazil) (from Simplício et al. unpublished).

Breed	No. of ewes	PPI (days)
Morada Nova	89	65.0 ± 3.20 a
B. Somali	118	61.9 ± 2.91 a
Santa Ines	72	70.9 ± 4.51 b

P < 0.05 for means with different superscript letters between breeds.

Seasonal variations in the reproductive performance of the male as measured in quantity and quality of semen produced and size and volume of testicles are shown in Tables 19 and 20. These data show that although some seasonal variations occur, rams produce quality semen of adequate fertility to cover fertilization at all periods of the year. Significant differences were not observed between the wet and dry seasons.

The effects of testicular temperatures produced by insulating the scrotum for 28 days against heat loss has been reported by Byers & Glover (1983) in Australia. Prepuberal serum prolactin was elevated after seven days and seminal fructose was increased after 14 days. Testosterone levels were depressed after 14 days of scrotal insulation. No changes were measured in progesterone or estradiol. Prolactin which usually increases in peripheral blood serum may maximize the response to testosterone in accessory glands to maintain a level of accessory gland function.

MacFarlane (1982) estimated that 60% of the goats of the world are located in tropical areas. Their ability to adapt reproductive processes to different tropical environments is demonstrated in reports of reproductive

TABLE 18. Incidence of postpartum estrus in tropical hair sheep (Brazil) (from Simplício et al. unpublished).

Days postpartum	Breed		
	Morada Nova n = 21	B. Somali n = 22	Santa Ines n = 23
0 - 60	7 (33.33)	12 (54.54)	4 (17.39)
61 - 75	13 (61.90)	17 (77.27)	13 (56.52)
76 - 90	17 (80.95)	19 (86.36)	18 (78.26)
91 - 112[1]	19 (90.47)	22 (100.00)	20 (86.95)

[1] Weaning at 112 days.

TABLE 19. Annual means of body weight, semen and testicle characteristics of Brazilian Somali rams (from Simplício et al. unpublished).

Characteristics	Unit	n	Means + SE	Min.	Max.	Diff.	C.V.
Body weight at semen collection	kg	257	38.29 ± 0.32	25.7	46.2	20.5	13.6
Ejaculate volume	ml	257	0.69 ± 0.01	0.1	1.5	1.4	30.0
Color/consistency	0-5	257	3.53 ± 0.04	2.0	5.0	3.0	16.8
Mass motility	1-5	257	3.83 ± 0.02	1.0	5.0	4.0	9.6
Ind. motility	%	257	66.75 ± 0.41	33.2	88.2	55.0	10.0
Forward motility	1-5	257	3.87 ± 0.02	2.0	5.0	3.0	8.3
pH	n	225	6.94 ± 0.03	0.3	7.5	7.2	7.5
Sperm concentration/mm^3	$X10^4$	257	261.78 ± 4.26	96.5	502.0	405.5	26.1
Total sperm number/ejaculate	$x10^8$	257	185.40 ± 4.75	25.2	523.8	498.6	41.1
Dead sperm cells	%	257	21.29 ± 0.44	5.7	71.2	65.5	33.3
Testical volume	ml	129	429.52 ± 5.49	300.0	803.0	503.0	14.5
Scrotal circumference	cm	129	27.50 ± 0.10	25.0	29.0	4.0	4.0

TABLE 20. Least-squares means (s.e.) of seminal and testicular characteristics of Brazilian Somali rams and meteorological ata in different seasons in tropical Northeast Brazil (from Simplício et al. 1982).

Characteristics	Seasons			
	Rainy	Transitional rainy-dry	Dry	Transitional dry-rainy
Ejaculate vol. (ml)	0.669 (0.041) a	0.776 (0.025) b	0.685 (0.028) a	0.632 (0.024) a
Colour-consistency of semen (score 1-5)	3.166 (0.135) a	3.600 (0.084) b	3.667 (0.093) b	3.671 (0.079) b
Mass motility (score 1-5)	3.875 (0.087) b	3.993 (0.051) b	3.880 (0.059) b	3.561 (0.051) a
% individual sperm motility	67.65 (1.25) ab	68.42 (0.77) b	65.97 (0.85) a	65.01 (0.72) a
Forward sperm motility score (1-5)	3.968 (0.075) b	3.934 (0.047) b	3.879 (0.052) b	3.684 (0.044) a
Sperm conc. (x 10/mm)	242.55 (13.82) a	248.44 (8.55) a	278.18 (9.49) b	278.80 (8.04) b
Total sperm no. ejaculate (x 10)	167.24 (15.14) a	202.61 (9.37) a	194.55 (10.39) a	177.31 (8.80) a
% stained sperm	19.8 (1.43) a	20.3 (0.89) a	23.50 (0.98) b	21.4 (0.83) ab
Semen pH	7.11 (0.21) a	7.01 (0.08) a	6.79 (0.09) a	6.87 (0.10) a
Testis volume (ml)	434.7 (13.9) ab	443.2 (8.2) b	427.0 (9.0) ab	408.9 (8.1) a
Testis consistency (score 1-5)	2.99 (0.14) a	3.00 (0.08) a	3.05 (0.09) a	3.00 (0.08) a
Average length of testis (cm) (A)	8.22 (0.05) bc	8.09 (0.03) a	8.30 (0.03) c	8.19 (0.03) b
Average diam. (breadth) of testis (cm) (B)	5.86 (0.06) c	5.56 (0.04) a	5.78 (0.04) bc	5.69 (0.03) b
Testis shape (A x B)	48.29 (0.71) c	45.90 (0.42) a	48.21 (0.46) c	46.74 (0.41) b
Circumference of testis (cm)	27.64 (0.21) bc	27.99 (0.12) c	27.27 (0.14) ab	27.08 (0.12) a
Months	Feb.-Mar.-Apr.	May-Jun.-Jul.	Aug.-Sept.-Oct.	Nov.-Dec.-Jan.
Mean maximum temp. (°C)	32.03	34.50	35.77	35.13
Mean minimum temp. (°C)	23.20	22.50	23.40	23.97
Mean daytime temp. (°C)	26.87	27.83	28.33	28.40
Mean relative humidity (%)	77.00	61.00	55.00	58.67
Total precipitation (mm)	476.70	33.30	0.40	84.40

Means within rows with the same superscript letter are not significantly different ($P < 0.05$).

performance. Extensive information has been provided on four major breeds of goats in India from a research report by Singh & Sengar (1981) (Table 21). From these data it is observed that some breeds such as the smaller Barbari and Black Bengal are highly adapted to the environment with shorter kidding intervals and higher prolificacy. Larger breeds such as the Jamnupari and Beetal had lower reproductive performance,

TABLE 21. Measures of reproductive performance in breeds in Indian goats (taken from Singh and Sengar 1981).

Trait	Breed			
	Jamunapari	Beetal	Barbari	Black Bengal
Duration of estrus (hr)	39.1	48.1	46.70	46.10
Services/conception (no.)	1.64	1.38	1.28	1.37
Fertility (%)	75.2	89.7	88.2	95.8
Abortions (%)	11.6	8.4	8.6	7.5
Postpartum estrus (days)	143	123	76	64
Service period (days)	168	136	79	69
Gestation length (days)	149	149	146	145
Kidding interval (days)	313	289	226	214
Kiddings/doe/year (no.)	0.77	0.97	1.38	1.31
Kidding intervals (days):	1.19	1.29	1.45	1.99
Kids/doe/year(no.)	0.91	1.25	2.00	2.62

but produced heavier offspring so that total weight of offspring produced per doe may have been quite similar.

Haumesser (1975) has reported some parameters of reproductive performance for the Red Sokoto goat of Nigeria (Table 22). These goats are over 14 months of age at first kidding, have an overall prolificacy of 1.47 and an overall kidding interval of 332 days. The occurrence of kidding varies depending on the period of the year with the maximum (52%) occurring from February - April. Kidding interval also varies with period of year (September - October, 343 days and July - August, 266 days).

The reproductive performance of the West African Dwarf goat in Ghana has been measured by Vohradsky & Sada (1973) and is summarized in Table 23. This breed is relatively precocious in terms of age at first kidding (362 days) with a short first kidding interval of 258 days. Subsequent kidding regularity appears to be much lower as indicated by an annual kidding percentage of 39%. The month of highest incidence of kidding was in April and the lowest November.

TABLE 22. Reproductive performance in the Red Sokoto goat (from Haumesser 1975).

		Mean or %		Mean or %
No. does (approx.)		850	Months of maximum occurence of kidding	Feb.-April (51.7%)
Age at first kidding		426.7		
			Kidding intervals (days):	
Litter size at: (prolificacy)	1st kidding	1.08	Overall periods	332.4
	2nd kidding	1.20	September-October	343.2
	3rd kidding	1.72	May-June	302.3
	Overall	1.47	July-August	266.1

TABLE 23. Reproductive performance of the West African Dwarf goat in Ghana (Vohradsky and Sada 1973).

	Mean or %
Number of animals	209
Age at first kidding (days)	362
First kidding interval (days)	258
Kid mortality to 3 months of age (%)	21.4
Month of highest percent of kidding	April
Month of lowest percent kidding	November
Females kidding per year (%)	38.8
Kidding rate (%)	184.0

Prolificacy was high (184%). The ability of endogenous breeds of goats to adapt their reproductive processes to the environment of Northeast Brazil has been shown in research conducted at the National Center for Goat and Hair Sheep Research in Northeast Brazil. Simplício et al. (1985) has shown that all endogenous genotypes of goats demonstrate estrous cycles and ovulations more or less evenly throughout the year. This is shown for the most common genetic types referred to Marota, Moxoto and nondescript type (SDR) which exhibit an average of 46.8 to 92.1% and 56.9 to 86.1% of their estrous periods and ovulations per month (Tables 24 and 25). Annual kidding frequencies (Table 26) based on mixed genetic types of goats from five producer flocks demonstrates year round breeding and kidding under producer management systems (Alves et al. 1986, unpublished).

These results demonstrate the potential of these goats to adapt to reproduction at any time of the year to take the best advantage of feed production or for other production or economic reasons. When reproductive performance was classified into the traditional wet and dry seasons, some diferences were observed but overall similarities were apparent (Table 27). Some differences were minimized because the total reproductive cycle including kid survival and growth to weaning did not occur in the same season.

When the does were classified according to restricted periods of breeding (Nunes et al. 1981), a wet season from January 18 to March 18 and a dry season from August 1 to September 30, a significantly higher proportion became pregnant during the wet than the dry season (96.8 vs 80.0%). There was a higher incidence of abortions from ewes

TABLE 24. Monthly incidence of does showing estrus by genotype during a two year period (from Simplício 1985).

Genotype		Month												Total
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
Marota (36)[1]	n	57	55	58	67	63	69	67	69	62	58	41	38	704
	%	79.2[2]	76.4	80.6	93.1	87.5	95.8	93.1	95.8	86.1	80.6	56.9	52.8	81.5
Moxoto (36)	n	46	49	51	54	56	60	59	62	60	62	28	20	607
	%	63.9	68.1	70.8	75.0	77.8	83.3	81.9	86.1	83.3	86.1	38.9	27.8	70.3
SRD (36)	n	63	68	69	70	64	67	68	68	68	68	43	43	759
	%	87.5	94.4	95.8	97.2	88.9	93.1	94.4	94.4	94.4	94.4	59.7	59.7	87.8
Total (108)	n	166	172	178	191	183	196	194	199	190	188	112	101	2070
	%	76.9 b[3]	79.6 bc	82.4 b	88.4 cd	84.7 c	90.7 cd	89.4 cd	92.1 d	88.0 cd	87.0 cd	51.9 a	46.8 a	79.9

[1] Figures within parentheses indicate number of does.
[2] The percent is based on 36 observations per month for two years.
[3] Total Chi square equal to 332.96, 11 df.
$P < 0.05$ for percentages with different superscript letters between months.

TABLE 25. Monthly incidence of does ovulating by genotype during a two year period (from Simplício 1985).

Genotype		Month												Total
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
Marota (12)[1]	n	17	19	20	19	18	19	18	19	21	20	14	13	217
	%	70.8[2]	79.2	83.3	79.2	75.0	79.2	75.0	79.2	87.5	83.3	58.3	54.2	75.4
Moxoto (12)	n	13	13	14	11	16	16	16	22	19	19	9	11	179
	%	54.2	54.2	58.3	45.8	66.7	66.7	66.7	91.7	79.2	79.2	37.5	45.8	62.2
SRD (12)	n	20	19	21	17	23	19	21	19	22	17	19	17	234
	%	83.3	79.2	87.5	70.8	95.8	79.2	87.5	79.2	91.7	70.8	79.2	70.8	81.3
Total (36)	n	50	51	55	47	57	54	55	60	62	56	42	41	630
	%	69.4 a[3]	70.8 ab	76.4 bc	65.3 a	79.2 bc	75.0 bc	76.4 bc	83.3 bc	86.1 c	77.8 bc	58.3 a	56.9 a	72.9

[1] Figures within parentheses indicate number of does.
[2] The percent is based on 24 observations per month for two years.
[3] Total Chi square equal to 33.27, 11 dif.
1 df, $P < 0.05$.

TABLE 26. Monthly frequency of distribution of kiddings during three years period in five control farms[1] (from J.U. Alves, M.S. Thesis, 1986).

Month			Wet[2]		Dry	
	n	%	n	%	n	%
January	64	4.8				
February	12	0.9				
March	123	9.3				
April	44	3.3				
May	143	10.8	386	29.2		
June	224	16.9				
July	221	16.7				
August	114	8.6				
September	9	6.0				
October	14	11.0				
November	41	3.1				
December	113	8.5			937	70.8
Total	1323	100.0				

[1] One farm from each municipality (Caninde, Granja, Independência, Sobral and Taua).

[2] Wet (January to May) and dry (June to December) seasons.

bred in the dry than the wet season (0. vs 8.0%). A significantly higher proportion of does kidded from the group bred in the wet than the dry season (95.2 vs 69.3%) which appeared to be the result of both a higher proportion conceiving and also a higher proportion of the pregnancies maintained in the group bred in the wet season. This last effect is mostly accounted for in the higher abortion rate in the dry season bred does. There was a higher incidence of kid loss to weaning in does bred in the dry season (16.3 vs 32.9%), resulting in a high proportion of kids weaned at 112 days in the wet, than the dry season (83.7 vs 67.1%). The prolificacy for does bred in the wet season was 153% and in the dry season 157%, based on does kidding (Table 27). These values indicate no affect of season on kidding rate. However, both groups might have been bred following some access to good nutrition since the does assigned to the dry season were bred at the beginning of the dry season.

In another study (Simplício et al. 1982) on

TABLE 27. Reproductive performance of non descriptive (SRD) genotypes of goats under two restricted breeding season during two years (from Nunes et al. 1981).

Variables	1st season (01.18 - 03.18)		2nd season (08.01 - 09.30)	
	n	n (%)	n	n (%)
Does bred	63	63 (100.0)	75	66 (88.0)
Fertility rate	63	61 (96.8) a	75	60 (80.0) b
Abortion	63	0 (0.0) c	75	6 (8.0) d
Premature kidding	63	0 (0.0)	75	1 (1.3)
Does parturating at term	60	60 (95.2) a	75	52 (69.3) b
Kidding rate	60	92 (1.5)	52	82 (1.6)
Kids weaned/does kidding[1]	92	77 (83.7) c	82	55 (67.1) d
Mortality of kids[2]	92	15 (16.3) c	82	27 (32.9) d

a ≠ b ($P < 0.01$) c ≠ d ($P < 0.05$).

[1] Weaning at 112 days of age.

[2] Mortality from birth to weaning.

a small flock of SRD goats managed under traditional conditions on native pasture (Table 28) the fertility was 78.5, the abortions were 24.7% and the prolificacy was 1.3%. This further reported that 33% of the does kidded during the period of one year and 5.2% had three kiddings in a two year period. This does not necessarily indicate that the number of breedings and gestations took place in the one or two year period.

TABLE 28. Reproductive performance of SRD goats (from Simplício et al. 1982).

Characters	n	Percent
Does exposed to male	97	–
Parturitions	76	78.5
Abortions	24	24.7
Two parturitions (1 year)	32	33.0
Three parturitions (2 years)	5	5.2
Parturitions		
Singles	46	54.1
Twins	32	37.1
Triplets	1	1.2
Undetermined	6	7.1

Additional information on reproductive performance is provided for the SRD goat in Northeast Brazil in Table 29. Based on these data the kidding interval is 282.5 days with a postpartum interval for does producing singles of 93.2 days and does bearing twins 104.9 days. There was a great deal of variation in both intervals and likely indicates the role of environment in their determination and therefore the potential role of management in improving these aspects of reproductive performance.

Table 30 provides information on fertility,

TABLE 29. Some reproductive traits in SRD goats (from Simplício et al. 1982).

	Mean ± SRD
Kidding rate	1.3
Kidding interval (day)	282.5 ± 89.9
Postpartum interval (day)	
Singles	93.2 ± 35.2 a
Twins	104.9 ± 23.6 b

The means with different superscripted letters differ significantly ($P < 0.05$).

and prolificacy for four native breeds and two exotic (Anglo Nubian and Bhuj) breeds of goats. Fertility varies from 90.9 to 75% for the native and is 60% for the exotic, the proportion of multiple parturitions was 62.5 to 27.6 for native and 40-33% for exotic, and the kidding rate/doe kidding was 1.65 to 1.30 for native and 1.40-1.33 for the exotic.

The lengths of the estrous cycle and estrous period have also been reported by Simplício et al. (1982) (Table 31). The estrous cycle lengths were divided into short cycles (less than 15 days) 10.6%; normal cycles (15-24 days) 76.9%; and long cycles, (greater than 24 days) 12.5%. Short cycles were found to occur most frequently following parturition and long cycles were assumed to include cycles without the occurrence or detection of estrus at time of ovulation following a normal length luteal phase.

Estrous cycle lengths were reported (Simplício et al. 1982) to be similar for wet (20.6 days) and dry (21.8 days) seasons with an overall mean of 21.2 days. Estrous period length was 62.9 hours for the wet and 51.2 hours for the dry season with an overall mean of 57.8 hours.

One observation made by Simplício (1985) is that 18 month old does that had been reared on native pasture and confined and fed concentrate and chopped elephant grass failed to cycle as regularly or to demonstrate as high an ovulation rate as does from the same group kept on native pasture. The responses were more comparable the second than the first

TABLE 30. Fertility and prolificacy in native goats of Northeast Brazil.

Breed	Fertility	Prolificacy
Caninde[1]	90.91	1.60
Marota[2]	84.43	1.65
Moxoto[2]	80.20	1.30
Repartida[2]	75.00	1.47
Nubian[1]	60.00	1.40
Bhuj[1]	60.00	1.33

[1] Bellaver et al. 1979.

[2] Simplício and Nunes 1979b.

TABLE 31. Frequency of lengths of the estrous cycle and period in SRD goats.

Estrous characteristics	Class interval	Frequency	Percent
Estrous cycle (days)			
	(< 15)	51	10.6
	(15 to 24)	369	76.9
	(> 24)	60	12.5
	Total	480	100.0
Estrous period (hours)			
	(< 15)	1	0.2
	(15 to 29)	6	1.2
	(30 to 44)	108	21.1
	(45 to 59)	141	27.6
	(> 60)	255	49.9
	Total	511	100.0

year. These results were interpreted to reflect problems of adapting to confinement.

Although some variations can be shown to occur under tropical conditions, male goats demonstrate libido and production of sperm of adequate quality and quantity to bring about fertilization throughout the year. Pooled data for wet and dry season in shown in Table 32 for semen production (Nunes et al. 1985). The expression of libido and sperm production are also evident from fertile maturing that occurs during the year.

One possible adaptative morphological trait in the male goat is the divided scrotum which occurs at incidences as high as 25%. Producers in several parts of the world including Northeast Brazil believe that goats with a divided scrotum are more fertile than goats with a single scrotal sack (Robertshaw 1982). Research conducted by Nunes et al. (1985) compared bucks with divided and nondivided scrotums. The results were equivical insofar that most semen traits were similar for the two groups and for subcutaneous scrotal temperatures. Intratesticular temperatures were not measured. Semen from bucks with a divided scrotum had lower percentages of abnormal sperm and their sperm survived longer than bucks with a nondivided scrotum when subjected to thermal stress (Table 33).

The processes of reproduction are a part of and therefore influenced by the total physiology of the organism and its ability to adapt to the environment. Generally reproductive performance is considered to be lower among ruminants in the tropics than in more temperate zones. This is true for age at

TABLE 32. Least square means (SEM) of semen characteristics of Moxoto goats in relation to season (from Nunes et al. unpublished).

Variables	Season	
	Dry	Wet
Ejaculate volume (ml)	0.66 (0.03) a	0.78 (0.02) b
Sperm concentration (x109/ml)	3.12 (0.04) b	2.39 (0.03) a
Mass motility (0-5 score)	3.07 (0.04) b	2.59 (0.05) a
Thermo-stress test[1]		
Motile sperm (%)		
5 minutes	50.6 (0.74) a	56.7 (0.57) b
120 minutes	24.5 (0.75) a	39.7 (0.59) b
Progressive individual motility (0-5 score)		
5 minutes	3.1 (0.03) a	3.2 (0.02) a
120 minutes	2.1 (0.04) a	2.6 (0.04) a
Abnormal sperm (%)	19.2 b	12.0 a

[1] Incubated at 37°C.

$P < 0.05$ for means with different superscript letters among columns within subsets.

TABLE 33. Least square means (SEM) of semen characteristics of Moxoto goats in relation to scrotum morphology (from Nunes et al. unpublished).

Variables	Morphology of scrotum	
	Divided	Non divided
Ejaculate volume (ml)	0.8 (0.02) b	0.6 (0.02) a
Sperm concentration (x109/ml)	2.7 (0.07) a	2.8 (0.06) a
Mass motility (0-5 score)	2.8 (0.04) a	2.8 (0.01) a
Thermo-stress test[1]		
Motile sperm (%)		
5 minutes	54.7 (0.50) a	52.2 (0.87) a
120 minutes	32.8 (0.41) a	30.8 (0.94) a
Progressive individual motility (0-5 score)		
5 minutes	3.2 (0.02) a	3.1 (0.03) a
120 minutes	2.3 (0.12) a	2.3 (0.05) a
Abnormal sperm (%)	7.7 a	23.2 b

[1] Incubated at 37°C.

$P < 0.05$ and $P < 0.01$ for means of volume and abnormal sperm, respectively among columns. $P < 0.05$ for all other means.

puberty and fertility, but not for prolificacy or for length of breeding periods where species such as sheep and goats, which are seasonal breeds in latitudes away from the equator, become continuous breeders at latitudes near the equator. A major limiting factor of most tropical environments is increased temperature. This appears to influence reproduction both directly, as well as indirectly through its added stress on production. This can be observed in the case of milk production in dairy cattle which increases the incidence of reproductive failure. Another major limiting factor of some tropical environments is the lack of moisture. The primary effect in this case appears to be indirectly through reduction in availability or quality of forage.

Another influence of the tropical environments as mentioned above is associated with the equator and is the ability of animals to breed, conceive and produce offspring throughout the year. This is a result of minimal changes in photoperiod. This provides a great deal of flexibility in determination of when breeding and parturition will occur in relation to feed availability and other consequences of annual variations in the environment.

Emphasis is often placed on the limiting effects of the tropics on reproductive performance. More appropriately, emphasis should be placed on the successful adaptation of ruminants to the tropics to assure reproduction to occurs and in some cases to exceed that expressed in temperate zones. This is of particular importance from an adaptation point of view because these species evolved in an environment away from, and very different from, the equator.

An important observation from data collected on animals in the tropics is the great amount of animal to animal variation that occurs in most reproductive processes. This demonstrates that some animals have increased adaptation traits that allow them to reproduce at a higher level and that through genetic selection increased adaptation and therefore reproductive performance can be achieved.

Reproductive performance can be improved in the tropics by modifying the environment primarily to protect against high temperatures and humidity and to provide for a more adequate diet during periods of drought or by shifting reproduction schedules so that periods of greatest nutritional need coincides with periods of greatest food production.

References

AHMAD, N.; CHAUNDBRY, R.A.; KHAN, B.B. Effect of month and season of calving on the length of subsequent calving intervals in Nili. Ravi buffaloes. **Anim. Reprod. Sci.,** 3:301-6, 1981.

ASKER, A.A. & ELITRIBY, A.A. Frequency of using bulls for service and the distribution of calving in the Egyptian buffalo. **Alexandria J. Agric. Res.,** 6:25-38, 1958.

BUVANENDRAN, V.; JALATGE, E.F.A.; GANESAN, K.N. Influence of season on the breeding pattern of buffaloes in Ceylon. **Trop. Agric.,** Trinidad, 48:97-102, 1971.

BYERS, S.W. & CLOVER, T.D. Effect of scrotal insulation on seminal fructose peripheral plasma prolactin, and circulating steroids in rams. **Anim. Reprod. Sci.,** 5:295-301, 1982/83.

CHIEN, W.P. The swamp buffalo and its improvement in the people's Republic of China. In: SEMINAR ON BUFFALO REPRODUCTION AND ARTIFICIAL INSEMINATION. India, 1979. **Proceedings.** Rome, FAO, 1979. p.152-4.

DE ALBA, J. & RIERA, S. Sexual maturity and spermatogenesis under heat stress in the bovine. **Anim. Prod.,** 8:137-44, 1966.

DIXON, K.L. The influence of quaternary environments on the evolution and distribution of wild sheep (*Ovis* spp.). In: WORKSHOP ON THE DOMESTICATION OF SHEEP; their ancestors, geography, time period and people involved. s.l., 1979. **Proceedings.** s.l., Utah State University, 1979. p.1-13.

DUNLAP, S.E. & VICENT, H.D. Influence of postbreeding thermal stress on conception rate in dairy cattle. **J. Anim. Sci.,** 32(6):1216-8, 1971.

EDUVIE, L.O. Factors affecting postpartum ovarian activity and uterine involution in zebu cattle indigenous to Nigeria. **Anim. Reprod. Sci.,** 8:123-8, 1985.

EGBUNIKE, G.N. Reproductive performance of N'Dama (N), German Brown (GB) and NGB cows in a humid tropical environment. In: INTERNATIONAL CONGRESS ON ANIMAL REPRODUCTION AND ARTIFICIAL INSEMINATION, 10. Champaign, Illinois, 1984. **Proceedings.** Champaign, Illinois, University of Illinois at Urbana, 1984, v.2. p.137. Brief Communication.

EL-SHEIKH, A.S. & EL-FOULY, M.A. Estrus, estrous cycle and time of ovulation in a herd of buffalo heifers. **Alexandria J. Agric. Res.,** 19:9-14, 1971.

EL-SHEIKH, A.S. & MOHAMED, A.A. The reproductive performance of the Egyptian buffalo. **J. Anim. Prod.,** 5:99-117, 1965.

ELWISHY, A.G.; GHALLAB, A.M.; ELBAGHDADY, Y.R. Effects of season and feeding schedule on reproductive performance of Buffaloes. In: INTERNATIONAL CONGRESS ON ANIMAL REPRODUCTION AND ARTIFICIAL INSEMINATION, 10. Champaign, Illinois, 1984. **Proceedings.** Champaign, Illinois, University of Illinois at Urbana, 1984. v.4. p.17-24. Plenary & Symposia Papers.

FIGUEIREDO, E.A.P.; OLIVEIRA, E.R. & SIMPLÍCIO, A.A. Hair sheep performance in Brazil. In: FITZHUGH, H.A. & BRADFORD, G.E. **Hair sheep of wertern Africa and the Americas: a genetic resource for the tropics.** Boulder, Colorado, Westview Press, 1983. p.125-40.

FOOT, R.H.; MUNKENBECK, N.; GREENE, W.A. Testosterone and libido in Holstein bulls of various ages. **J. Dairy Sci., 59**:2011-3, 1976.

GWAZDAUKAS, F.C.; BAME, J.A.; AALSETH, D.L.; VINSON, W.E.; SAACKE, R.G.; MARSHALL, C.E. Relationship of plasma hormones and semen quality in bulls. In: TECHINIQUE CONFERENCE ON ARTIFICIAL INSEMINATION AND REPRODUCTION, 8. Columbia, 1980. **Proceedings.** Columbia, USA. Nat. Assoc. of Anim. Breed., In 1980, p.13-20.

HAUMESSER, J.B. Some effects of reproduction in he Red Sokoto goat. Comparison with other tropical breeds. **Revue d'Elevage et de Medecine Veterinaire des pays tropicaux, 28**:225-34, 1975.

JAINUDEEN, M.R. Reproduction in the Malaysian swamp buffalo (*Bubalus bubalis*). In: JOINT CONFERENCE ON HEALTH AND PRODUCTION OF AUSTRALIA AND LOCAL CATTLE IN SOUTHERN ASIA, 1. Kuala Lumpur, Malaysia. 1977. **Proceedings.** Kuala Lumpur, Malaysia, s.ed. 1977. p.162-8.

JAINUDEEN, M.R.; BONGSO, T.A.; TAN, H.S. Postpartum ovarium actitivity and uterine involution in the suckled swamp buffalo (*Bubalus bubalis*). **Anim. Reprod. Sci., 5**:181-90, 1983.

JALATGE, E.F.A. & BUVANENDRAN, V. Statistical studies on characters associated with reproduction in the Murrah buffalo in Ceylon. **Trop. Anim. Health Prod., 3**:114-24, 1971.

KANUJIA, A.S.; BALAINE, D.S.; RATHI, S.S. Effect of some environmental and physiological factors on reproduction and production traits in Indian buffaloes. **Haryana Agric. Univ. J. Res., 5**:179-87, 1975.

LUNDSTROM, K.; ABEYGUANAWARDENA, H.; SILVA, L.N.A. de; PERERA, B.M.A.O. Environmental influence on calving interval and estimates of its repeatability in the Murrah Buffalo in Sri Lanka. **Anim. Reprod. Sci., 5**:99-109, 1982.

MACFARLANE, W.V. Concepts of animal adaptation. In: INTERNATIONAL CONFERENCE ON GOAT PRODUCTION AND DISEASE, 3. Tucson, EUA, 1982. **Proceedings.** Scottdale, EUA, Dairy Goat Journal, 1983. p.375-85.

MADAN, M.L. & RAINA, V.S. Fertility performance of buffaloes under tropical conditions. In: INTERNATIONAL CONGRESS ON ANIMAL REPRODUCTION AND ARTIFICIAL INSEMINATION, 10. Champaign, Illinois, 1984. **Proceedings.** Champaign, Illinois, University of Illinois at Urbana, 1984. v.2. p.142. Brief Communications.

NUNES, J.F.; SILVA, A.E.F.D.; RIERA, G.S.; FOOTE, W.C. Effects of season and scrotal morphology on semen characteristics of Moxoto goats. **J. Anim. Sci., 61**:414, 1985.

NUNES, J.F.; SIMPLÍCIO, A.A.; RIERA, G.S. Eficiência reprodutiva de cabras nativas do tipo sem raça definida (SRD), submetidas a estação de monta em diferentes épocas do ano. In: SIMPÓSIO NACIONAL DE REPRODUÇÃO ANIMAL, 4. Belo Horizonte, 1981. **Anais.** Belo Horizonte, Colégio Brasileiro de Reprodução Animal, 1981. p.37.

OLOUFA, M.M. & STINO, F.K.R. Buffaloes for milk and meat production in Egypt. **J. Anim. Sci., 49**(1):198, 1979. Supplement.

PARAGAONKAR, D.R. & KAIKINI, A.S. Studies on service period and calving interval in Nagpuri buffaloes. **Indian J. Anim. Sci., 47**:822-3, 1977.

PERERA, B.M.A.O. The use of hormone measurement for studying reproductive patterns of buffaloes in Sri Lanka. In: KAMONPATANA, M. ed. **The use of nuclear techniques to improve domestic buffalo production in Asia.** s.l., FAO/IAEA, 1981. p.149-58.

RAO, B.P.; REDDY, B.B.; GOPALAKRISHNA, T. Note on oestrous cycle and time of ovulation in Murrah buffaloes. **Indian J. Anim. Sci., 52**:534-5, 1982.

ROBERTSHAW, D. Concepts in animal adaptation: Thermoregulation of the goat. In: INTERNATIONAL CONFERENCE ON GOAT PRODUCTION AND DISEASE, 3. Tucson. EUA, 1982. **Proceedings.** Scottdale, EUA, Dairy Goat Journal, 1983. p.395-7.

ROY, A. Observations on the physiology of reproduction. In: COCKRILL, W.R. **The husbandry and health of the domestic Buffalo.** FAO, Rome, 1974. p.395-7.

SIDDAPPA, T.N. & PATIL, S.H. Seasonality of breeding and calving of buffaloes. **Indian Vet. J., 56**:122-4, 1979.

SIMPLÍCIO, A.A. **Reproduction in three native genotypes of goats under two feeding-management systems in Northeast Brazil and progesterone and lutenizing hormone profiles during the estrous cycle and seasonal anestrous in Spanish goats in the United States.** Logan, Utah, Utah State University, USA. 1985. 120p. Tese Ph.D.

SIMPLÍCIO, A.A.; FIGUEIREDO, E.A.P.; RIERA, G.S.; LIMA, F.A.M. Reproductive and productive performance of the undefined (SRD) genotype of goats the traditional management system of Northeast Brazil. In: INTERNATIONAL CONFERENCE ON GOAT PRODUCTION AND DISEASE, 3. Tucson, EUA, 1982. **Proceedings.** Scottdale, EUA, Dairy Goat Journal, 1983. p.349.

SIMPLÍCIO, A.A.; RIERA, G.S.; NELSON, E.A.; PANT, K.P. Seasonal variation in seminal and testicular characteristics of Brazilian Somali rams in the hot semiarid climate of Tropical Northeast Brazil. **J. Reprod. Fert., 66**:735-8, 1982.

SIMPLÍCIO, A.A.; RIERA, G.S.; NUNES, J.F. Estrous cycle and periods evaluation in an undefined bread type (SRD) goats in Northeast Brazil. In: INTERNATIONAL CONFERENCE ON GOAT PRODUCTION AND DISEASE, 3. Tucson, EUA, 1982. **Proceedings.** Scottdale, EUA, Dairy Goat Journal, 1983. p.310.

SINGH, S.N. & SENGAR, O.P.S. **Studies on the combining ability of desirable characteristics of important goat breeds for meat and milk separately and in combination.** India, Department of Animal Husbandry and Dairy, 1981. (Final Technical Report, PL-480 - Research Project, A7. AH-89).

STOTT, G.H. & WILLIAMS, R.J. Causes of low breeding efficiency in dairy cattle associated in seasonal high temperature. **J. Dairy Sci., 45**:1369-75, 1962.

STOTT, G.H.; WIERSMA, F.; WOODS, J.M. Reproductive health program for cattle subjected to high environmental temperatures. **J.AM. Vet. Med. Assoc., 161**:1339-44, 1972.

THATCHER, W.W. Effects of season, climate and temperature on reproduction and lactation. **J. Dairy Sci., 57**:360-8, 1973.

THIBIER, M. Diurnal testosterone and 17 - hydroxyprogesterone in peripheral plasma of young post-pubertal bulls. **Acta Endocr., 81**:623-34, 1976.

TOELIHERE, M.R. **Biology and pathology of reproduction in female water buffaloes in Indonesia.** Giessen, German Federal Republic, Justus-Liebig-Universitat, 1977. 93p. Tese.

TUCKER, H.A.; KOPROWSKI, J.A.; BRITT, J.H.; OXENDER, W.D. Serum prolactin and growth hormone in Holstein bulls. **J. Dairy Sci., 57**:1092-4, 1974.

ULBERG, L.C. The influence of high temperature on reproduction. **J. Hered., 49**:62, 1958.

ULBERG, L.C. & BURFENING, P.J. Embryo death resulting from adverse environment on spermatozoa or ova. **J. Anim. Sci., 26**(3):571-7, 1967.

VALE, W.C.; WEITZE, R.F.; GRUNERT, E. Estrus behavior and ovarian function in water buffalo cows (*Bubalus bubalis* Lin.) under amazon condition. In: INTERNATIONAL CONGRESS ON ANIMAL REPRODUCTION AND ARTIFICIAL INSEMINATION, 10. Champaign, Illinois, 1984. **Proceedings.** s.l., s.ed., 1984. v.2. p.154.

VAUGHT, L.K. **Some effects of high environmental temperatures on reproductive, endocrine and physiologic characteristics of lactating and nonlactating Holstein Friesian cows in Arizona.** Utah, Utah State University, USA. 1976. Tese Ph.D.

VINCENT, C.K. Effects of season and high environmental temperature on fertility in cattle: A review. **J. Am. Vet. Med. Assoc., 161**(11):1333-8, 1972.

VOHRADSKI, Y. & SADA, I. West African Dwarf goats in Ghana. 1. Reproduction and death rate of kids. Sbornik Vysoke Skoly Zemedelske V. Praze. **Institut Tropickenko a Subtropickenko Zemedelstvi 6**:161-72, 1973.

WAITES, G.M.H. Temperature and fertility in mamals. In: INTERNATIONAL CONGRESS

ON ANIMAL REPRODUCTION AND ARTIFICIAL INSEMINATION, 6. 1968. **Proceedings.** s.l. s.ed., 1968. v.2. p.235.

WEITZE, K.F. & MAGALHÃES, O. Fertility traits of Nelore beef cattle under range conditions of Northeast Brazil. In: INTERNATIONAL CONGRESS ON ANIMAL REPRODUCTION AND ARTIFICIAL INSEMINATION, 10. Champaign, Illinois, 1984. **Proceedings.** Champaign, Illinois, University of Illinois at Urbana, 1984. v.2. p.156. Brief Communications.

WELSH, T.H.; RADEL JUNIOR, R.D.; JOHSON, B.H. Interrelationships of serum corticosteroids, LH, and testosterone in male bovine. **Archives of Andrology, 6**:141-50, 1981.

WIERSMA, F. & STOTT, G.H. New concepts in the physiology of heat stress in dairy cattle of interest to engineers. **Trans. Am. Soc. Agric. Engineers, 12**:130-2, 1969.

ZAKARI, A.Y.; MOLOKWU, E.C.I.; OSORI, D.I.K. Effects of rectal and ambient temperatures and humidity on conception rates. **Theriogenology, 16**(3):331-6, 1981.