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Food intake, milk production and growth of kids of local, multipurpose goats grazing on dry season natural Sahelian rangeland in Mali

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Abstract

A study was carried out in the dry season, from October 1993 to May 1994 at an institutional farm in Niono (14º5'N, 6ºE, 295 m), on the Sahelian border of Mali with a semi-arid climate. Thirty-four local Sahelian goats in their first to fifth lactation weighing about 27 kg were used. Eleven of them suckled twin and 23 suckled single kids. The does were herded on natural rangeland for 8 to 9 h/day and received no food supplements. Dry season forage mass, intake and nutritive value of diets selected by goats, milk yield and effects on kids' growth were measured.

The vegetation cover consisted of a herbaceous stratum dominated by annual gramineae plants and a woody stratum composed of 26 species of plants, whose relative abundance varied according to the topography and soil type. The goats spent between 0·126 (early dry season) and 0·004 (late dry season) of grazing time on herbaceous cover and the remaining time on consuming leaves, flowers and fruits of woody plants. The phytomass decreased as the dry season advanced. However, nutrient intake was relatively constant during the course of the study period, as the goats compensated for low biomass by walking more and grazing larger areas and for longer periods. On average, goats selected diets with 121 g crude protein and 7·6 MJ metabolizable energy per kg dry matter.

The milk yield and milk fat were measured weekly for 29 weeks but data for only 12 weeks are interpreted and discussed. Mean daily actual and fat-corrected milk (40 g fat per kg milk) production for the first 12 weeks of lactation was 692 (s.e. 139) g and 627 (s.e. 73) g respectively. The milk yield was maximum in the 1st week of lactation followed by a gradual decline. Milk yield was affected by litter size, number of lactation, weight and age of does at parturition. The does with twin kids produced significantly more milk (762 (s.e. 110) g/day) than the does with singles (656 (s.e. 158) g/day) ($P < 0·05$*). The milk yield increased from the first lactation (542 (s.e. 49) g/day) to the third lactation (739 (s.e. 49) g/day) (*$P < 0·05$*) with no difference between the third and fifth lactation. Does over 27 kg produced more milk than those under 27 kg (*$P < 0·001$*) and does over 2·5 years produced more milk than younger does (*$P < 0·01$*). Milk fat was inversely related to milk production. Kids born as singles were heavier (2194 (s.e. 76) g) than those born as twins (1966 (s.e. 78) g) (*$P < 0·05$*). The kid growth rate was affected by birth weight (*$P < 0·001$*) and milk yield of dams (*$P < 0·01$*). Within litter size (single or twins), sex had no significant effect on the growth rate of kids, however the singles grew faster than twins (*$P < 0·001$*) throughout the 12 weeks of measurement. Single kids were 1·41 times as heavy as twins at 12 weeks.*

It is concluded that, the milk yield of does and weight gain of kids under the precarious feeding conditions of the study indicate that the local goats monitored were adapted to local harsh conditions. Nutrition has been regarded as the main constraint to goat production from the range in the dry season. Further specific studies are needed to overcome the dry season nutritional stress and to improve goat production.

Keywords: *food intake, goats, kids, milk yield, rangelands, Sahelian zone.*

Introduction

Small ruminants are an integral part of the agro-pastoral system in the Sahelian region. In Central Mali, 0·75 and 0·95 of families possess goats and sheep respectively, with an average of 30 head per family (Wilson and Light, 1986). Despite their high number (over 12 million; Direction Nationale de l'Elevage du Mali, 1988), small ruminant meat and milk represent proportionately only 0·51 and 0·40 of local meat and milk production respectively (Institut d'Economie Rurale, 1992). This denotes their low meat and milk yield. One of the major constraints in animal production in Sahelian areas is the precarious food situation during the long dry season (Glatzle, 1991). In these areas, goats eat mainly natural pasture composed of herbaceous and woody strata which are subject to great seasonal and interannual variations in quality and quantity (Penning de Vries and Djitéye, 1982; Hiernaux *et al*., 1994). Although the contribution of the woody stratum within the pasture phytomass is considered to be modest (Le Houérou, 1980; Piot *et al*., 1980; Breman and De Ridder, 1991), it may be an important resource in some areas, especially during the dry season (Belsky, 1989; Coughenour *et al*., 1990) and for goats (Pfister and Malechek, 1986; Ramìrez *et al*., 1991).

The objectives of the present study were, to evaluate the herbaceous and woody biomass available for grazing local Sahelian non-dairy goats during the dry season in a semi-arid zone of Mali and to estimate voluntary food intake and nutritive value of selected diets and their effect on milk yield and growth of kids.

Material and methods

Study site

The study was carried out in the dry season, from October 1993 to May 1994 at the Sahelian Research Station, Niono (14º5'N, 6ºE, 295 m), Mali. Niono has a semi-arid climate with 3 to 4 months of rainy wet season (June-September) and 8 to 9 months of dry season. The dry season is cold from October/November to February and hot from March to May/June. The long-term average annual rainfall is 583 mm but only 350 mm of precipitation occurred during the year of the present study. The Station has a protected natural rangeland of 12000 ha of which 4000 ha was allowed to be grazed by goats in the present study. The forage on this natural rangeland consists of an herbaceous stratum dominated by annual leguminous plants and a woody stratum consisting of trees and shrubs. The topography of pastured areas consists of sandy dunes, loamy depressions and borders of a drainage canal running through the Station. This drainage canal contains water all year round and is used as a watering place especially in the dry season. The details of vegetation of the station have been described earlier by Penning de Vries and Djitéye (1982).

Animals

The goats used in the present study were of Sahelian type (Charray *et al*., 1980) locally known as 'Peul goats'. They were vaccinated against peste des petits ruminants (rinderpest of small ruminants) and pasteurellosis and treated against internal and external parasites. Thirty-four goats in their first to fifth lactation with an average body mass (M) of 27 kg at kidding were selected from a flock of 58 adult goats. Twenty-three of them suckled single and 11 suckled twin kids (total kids = 45). Four of the does were fitted with faecal collection bags. The goats were herded on natural pastures for 8 to 9 h/day and received no food supplements. Goats had free access to water in the drainage canal during the day. After grazing during the day they were penned during the night and received only mineral blocks based on sodium chloride and bone meal.

Determination of forage mass

Preliminary observations had revealed that the goats grazed on the sandy dunes, in the loamy depressions and along the borders of the canal. Therefore biomass dry matter (DM, kg/ha) was estimated in these areas only. Herbaceous phytomass was measured in October and February, as after February the diet of goats included only a negligible amount of dry herbaceous plants. The vegetation within 1·0 m^2 quadrats was harvested with scissors to ground level at regular intervals of 100 m on a transect of 1000 m. This operation was repeated three times in every area (3 × 10 quadrats per area per period). The foliage mass of woody stratum was estimated monthly in all the three areas. At the beginning of the study an inventory of all the plants was made and their density (number of plants of a given species per ha), as well as the circumference of plants at 40 cm of height estimated. The total foliage mass was calculated by using the allometric regression of Cissé (1992) and Hiernaux *et al*. (1994).

Food intake

The voluntary food intake was estimated indirectly by collection of total faeces from four lactating does fitted with faecal bags. These does were choosen because of their docility. Two of them suckled twins and two suckled single kids. After 3 days of adaptation to the collection bags, the total amount of faeces produced was measured each month for a period of 5 days. The faecal DM (F) was obtained by oven drying the faeces at 105ºC. Food intake (I) was calculated by the relation: $I = F/1 - D$ where

D = digestibility of selected diets (mean of 5 days / month).

Food sampling and grazing behaviour

Each month food samples were collected continuously for 5 days. These samples, called 'hand samples', were obtained by observing what the animals were selecting, and collecting, every 15 min, similar parts of plants to those eaten by each of the four does fitted with faecal collection bags. The time spent eating each type of plant was also observed during these 5 days by one of us (MS). These observations were made simultanously with faecal collection. The feeding behaviour of these four does was assumed to be that of the flock.

Laboratory analysis

Forage and faeces DM was determined by oven drying 5 g of air-dried samples at 105ºC for 4 h. Crude ash (CA) was determined by incinerating 5 g of air-dry samples at 550ºC for 4 h. Organic matter (OM) was determined by subtracting CA from sample DM. Nitrogen (N) was determined by the standard Kjeldahl method and the crude protein (CP) by N × 6·25. Organic matter digestibility (OMD), dry matter digestibility (DMD) and metabolizable energy (ME) of forage were determined according to Menke *et al*. (1979).

Walking distance

The distance covered by does for grazing was measured by a pedometer attached to one of the does of the flock with a single kid. The pedometer used was a commercial model, 'Evertrust', commonly used by athletes. It was calibrated according to manufacturer's instructions, by walking a measured known distance with pedometer attached to waist and then adjusting to an exact accuracy.

Milk yield and milk fat

The milk yield and milk fat contents were measured weekly. Two complementary methods were used simultaneously. Every Thursday morning to Friday morning, kids were separated from their dams. Does were hand milked on Thursday evening and Friday morning and milk yield was measured. After milking, kids were allowed to suck their mothers and the milk consumed was estimated by difference in weight of kids before and after suckling. This supplementary method was used because the hand milking did not provide the true total estimate of milk yield of does as all the milk could not be milked out. The total milk yield in 24 h was calculated by addition of the amount milked by hand and the amount consumed by the kids. Raw milk was converted to fat-corrected milk (40 g fat per kg) by the relation: $Q = 0{\cdot}4 \times M_i + 0{\cdot}15 \times F \times M_i$ (Gaines, 1927).

Q = kg milk with 40 g fat; M_i = kg raw milk; F = g fat per kg raw milk.

The milk fat was determined by the standard Gerber method. The does were considered dry when the milk production fell to less than 150 g / day.

Body weight

Does were weighed at kidding and subsequently once a month after 12 h fasting. The kids were weighed at birth and subsequently once a week after 12 h fasting.

Determination of nutrient requirements

(a) Energy for maintenance for does (according to Sauvant *et al*., 1991): 0·444 MJ ME per kg $M^{0.75}$ per day; (b) energy for milk production (according to Sauvant *et al*., 1991): 4·95 MJ ME per kg fat corrected-milk; (c) energy for walking (according to Becker and Lohrmann, 1992): 2 kJ / km per kg live weight; (d) crude protein for maintenance (according to Sauvant *et al*., 1991): 4 g CP per kg $M^{0.75}$ per day; (e) crude protein for milk production (according to Sauvant *et al*., 1991): 76 g CP per kg fat-corrected milk.

Data analysis

Initially the food intake data of does with twins and singles within a month were compared as repeated measures (BMDP statistical software Los Angeles USA, 1988). As there were no significant differences found between the intakes with twins and singles, the data were pooled and the effect of month compared by Duncan's multiple comparison test.

The effects of milk yield of dam, litter size and kid birth weight on growth of kids were analysed by linear regression. The effect of sex and litter size on growth rate of kids was analysed by regressing the live weight of each kid against time (for 12 weeks) and then comparing the mean slopes of regressions (i.e. live-weight gains).

Results

Forage biomass

The areas were characterized by their vegetation cover which varied according to the season, the type of soil and topography. The vegetation cover was highest along the canal and lowest in the sandy dunes.

The herbaceous stratum was composed principally of annual gramineae and leguminous plants, the most important being *Schoenfeldia gracilis*, *Diheteropogon hagerupii*, *Zornia glochidiata*, *Cassia tora*

Table 1 *Woody forage plants found in three formations of range grazed by goats (+ = present; – = absent)*

Family	Species	Formations		
		Sandy dune	Depressions	Borders of canal
Anacadiaceae	*Sclerocaria birrea*	+	+	+
Bombacaceae	*Adansonia digitata*	+	–	–
	Bombax costatum	+	–	+
Burcseraceae	*Commiphora africana*	+	+	+
Caesalpiniaceae	*Bauhinia rufescens*	–	–	+
	Piliostigma reticulata	–	–	+
Capparidaceae	*Boscia angustifolia*	+	+	+
	B. senegalensis	+	–	–
	Cadaba farinosa	+	+	–
	Caparis tomentosa	–	–	+
Combretaceae	*Anogeissus leiocapus*	–	+	+
	Combretum ghazalense	–	–	+
	C. glutinosum	+	–	–
	C. micrantum	+	–	+
	Guiera senegalensis	+	+	+
Mimosaceae	*Acacia ataxacantha*	–	+	–
	A. senegal	+	+	+
	A. seyal	+	+	+
	Dichrostachys glomerata	+	–	+
Oleaceae	*Ximinia americana*	+	+	–
Papillionaceae	*Pterocarpus lucens*	+	+	+
Rhamnaceae	*Ziziphus mauritiana*	+	+	+
Rubiaceae	*Feretia apodenthera*	–	+	+
Simaroubiaceae	*Balanites aegyptiaca*	–	+	+
Tiliaceae	*Grewia bicolor*	+	+	+
	G. flavescens	–	–	+

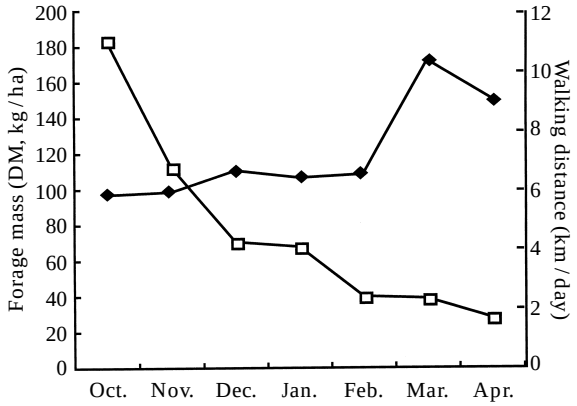

Figure 1 The biomass (□) of ligneous (woody) plants (dry matter (DM), kg/ha) and the walking distance (◆) (km/day) of Sahelian goats grazing dry season natural rangeland in Mali.

and *Ipomea* spp. The herbaceous mass decreased as the dry season advanced. In sandy dunes it decreased by proportionately 0·65 between October (950 (s.e. 741) kg DM per ha) and February (334 (s.e. 207) kg DM per ha). In the depressions the decrease was 0·35 during the same period (999 (s.e. 269) to 650 (s.e. 439) kg DM per ha).

The range inventory revealed the presence of 26 species of ligneous (woody) plants in the grazed area (Table 1). Nine species were shared by all the areas (i.e. sandy dunes, loamy depressions and borders of

Table 2 *Proportion of grazing time spent by goats on different plants and their fractions between October and April*

Forages		Oct.	Nov.	Dec.	Feb.	March	April
A. seyal	Green leaves	0·298	0·122	0·242	0·156	0·093	0·047
	Dead leaves		0·103				
	Flowers			0·218	0·622	0·273	
	Fruits					0·459	0·753
Z. mauritiana	Green leaves	0·199	0·074	0·063	0·065		
	Dead leaves					0·037	0·078
	Fruits			0·211			
A. senegal	Green leaves	0·115					0·030
	Fruits			0·120	0·050	0·041	
P. lucens	Green leaves	0·082	0·058				
D. glomerata	Green leaves	0·029	0·057				
B. aegyptiaca	Green leaves						0·019
C. tomentosa	Green leaves				0·022		
Other woody plants	Green leaves	0·181	0·462	0·136	0·072	0·093	0·072
All woody plants		0·904	0·874	0·990	0·987	0·996	1·00
Herbaceous plants		0·096	0·126	0·010	0·013	0·004	
Grazing time (min/day)		435	405	360	330	361	376
Time spent on the pasture (min/day)		540	525	495	465	510	510

canal). Three species were found on sandy dunes only, one in the depressions only, five on borders of canal only and eight species at least in the three formations. There was a rapid decrease in the ligneous plants foliage mass from 183·7 kg DM per ha in October to 26·9 kg DM per ha in April (Figure 1). This trend was observed in all formations as the foliage mass decreased from 121·3 to 19·7 kg DM per ha on the borders of canal, from 54·1 to 5·7 kg DM per ha in the depressions and from 8·3 to 1·5 kg DM per ha on the sandy dunes.

The proportion of grazing time spent on different plants and their parts is presented in Table 2. Grazing the herbaceous stratum represented proportionately up to 0·126 of total grazing time in November and less than 0·013 from December to April. During the whole study period, 0·88 to 0·99 of grazing time was spent in grazing green leaves, dead leaves, flowers and fruits of various ligneous plants. There were large variations both in plant type and their fractions consumed by goats during the different months. Nevertheless, during the period of study *Acacia seyal* was the most important plant where goats spent from 0·225 of grazing time in November, consuming green or dead leaves, to 0·825 in March, consuming mainly the fruits.

The goats spent daily 465 to 540 min (7·75 to 9·0 h) on pasture, of which proportionately 0·71 to 0·81 was spent on grazing.

Distance covered for grazing

The distance covered by goats for grazing varied from 5·83 km / day in October to 10·40 km / day in March and 9·10 km / day in April. There was an inverse relationship between total phytomass and distance covered by goats (Figure 1).

Table 3 *Estimated daily nutrient intakes during the dry season*

Month	Dry matter (g / kg M)	Dry matter (g / kg $M^{0·75}$)	Metabolizable energy (kJ $M^{0·75}$)	Crude protein (g / kg $M^{0·75}$)
October	28^{c}	$63·8^{c}$	442^{b}	$8·6^{b}$
November	33^{b}	$75·9^{b}$	495^{b}	$8·7^{b}$
December	36^{ab}	$80·6^{b}$	670^{a}	$9·7^{b}$
January	34^{b}	$78·1^{b}$	677^{a}	$9·8^{b}$
February	36^{ab}	$79·2^{b}$	674^{a}	$9·4^{b}$
March	35^{ab}	$79·8^{b}$	636^{a}	$9·8^{b}$
April	40^{a}	$92·6^{a}$	628^{a}	$12·2^{a}$
s.e.	3	7·0	7·2	0·7

^{a,b,c} Means in the same column with different superscripts are statistically different ($P < 0·05$).

Table 4 *Nutritive value of the diets selected by goats*

Month	Nutritive value† DMD (g / kg)	OMD (g / kg)	CP (g / kg OM)	ME (MJ / kg OM)
October	471^{c}	509^{c}	134^{a}	$7·5^{c}$
November	447^{d}	498^{c}	128^{a}	$7·2^{c}$
December	554^{a}	591^{b}	128^{a}	$8·9^{b}$
January	574^{a}	641^{a}	137^{a}	$9·7^{a}$
February	564^{a}	641^{a}	134^{a}	$9·7^{a}$
March	532^{b}	611^{b}	140^{a}	$9·1^{b}$
April	463^{cd}	506^{c}	144^{a}	$7·4^{c}$
s.e.	9	10	8	0·3

^{a,b,c,d} Means in the same column with different superscripts are significantly different ($P < 0·05$).
† DMD = dry matter digestibility; OMD = organic matter (OM) digestibility; CP = crude protein; ME = metabolizable energy.

Intake and nutritive value of diets selected by the goats

The voluntary food intake and nutritive value of diets are presented in Tables 3 and 4, respectively.

Table 5 *Metabolizable energy (ME) (MJ/day) and crude protein (CP) (g/day) balance of does and amount of forage (dry matter (DM), g/day) needed for equilibrium*

	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
ME required							
Maintenance	5·30	5·25	5·20	5·19	5·09	5·10	5·24
Milk	3·40	3·24	2·68	2·86	2·94	2·82	2·21
Walking	0·32	0·33	0·36	0·34	0·34	0·54	0·49
Growth						0·74	0·95
Total	9·02	8·82	8·24	8·39	8·37	9·20	8·89
ME ingested	5·28	5·82	7·82	7·88	7·72	7·30	7·43
ME balance	–3·74	–3·0	–0·42	–0·51	–0·65	–1·9	–1·46
CP required							
Maintenance	48	47	47	47	46	46	47
Milk	52	50	41	44	45	43	40
CP ingested	103	103	114	115	108	113	144
CP balance	+3	+6	+26	+24	+17	+24	+57
Forage needed (DM g / day)	540	463	50	60	80	241	254

Except in October when it was lower ($P < 0{\cdot}01$), the daily DM intake was on average 35 g/kg M (80·7 g/kg $M^{0{\cdot}75}$). Intake was not affected by lactation stage. Does ingested 825 (s.e. 63) g, 887 (s.e. 52) g and 950 (s.e. 56) g DM per day during the 1st, 2nd and 3rd month of lactation respectively. The highest levels of CP intake ($P < 0{\cdot}05$) were recorded in March and April (Table 3), usually regarded as the start of the period of nutritional deficiencies. Likewise, the CP content of diets in March and April (Table 4) was the highest in the dry season ($P < 0{\cdot}05$). DMD (Table 4) was much lower ($P < 0{\cdot}001$) in October, November and April (<475 g/kg DM) than that in December to March (>530 g/kg DM), leading to a significant difference in ME content of diets selected during these two periods ($P < 0{\cdot}001$). Goats were in negative ME balance throughout the dry season (Table 5), whereas CP requirements seemed to be achieved. Based on ME content of diets selected during the different months, 50 g DM (December) to 540 g DM (October) was needed to balance the ME deficit of does in the dry season (Table 5).

Milk yield and milk fat

The mean daily actual and fat-corrected milk production for the first 12 weeks of lactation was 692 (s.e. 139) g and 627 (s.e. 73) g respectively. The mean daily milk production on a metabolic weight basis was 61 g/kg $M^{0{\cdot}75}$ for actual and 56·4 g/kg $M^{0{\cdot}75}$ for fat-corrected milk. Mean milk production (Figure 2) was highest in the 1st week, decreased progressively thereafter to week 9 and then remained stationary to week 12.

Four factors related to does influenced the milk production. Does with twins produced more milk (762 (s.e. 110) g/day) than the does with single kids (656 (s.e. 158) g/day), ($P < 0{\cdot}05$). Does weighing over 27 kg at kidding produced 764 (s.e. 123) g of milk compared with 610 (s.e. 86) g of milk per day by does weighing less than 27 kg ($P < 0{\cdot}001$). Does aged over 2·5 years produced more milk (742 (s.e. 124) g/day) than younger ones (638 (s.e. 100) g/day), ($P < 0{\cdot}01$). Milk production increased from the first to the third lactation ($P < 0{\cdot}05$) and thereafter remained the same (Table 6).

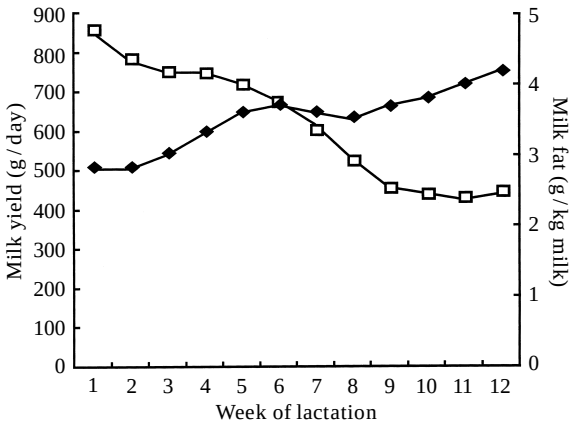

Figure 2 Milk yield (□) and milk fat content (◆) produced by Sahelian goats in Mali.

Table 6 *Milk production of goats according to the lactation number*

Lactation number	Number of does	Milk production (g/day) Mean	s.e.
1	6	542	49
2	5	652	53
3	6	739	49
4	12	738	34
5	5	734	53

During this study, 22 does were monitored until they were considered dry (yielding less than 150 g milk per day). Twelve of the 22 dried at week 26 and produced on average 108 kg of milk during the 26 weeks; the other 10 produced on average 109 kg during 29 weeks of lactation.

Milk fat content was inversely related to milk production (Figure 2).

Growth of kids

Figure 3 shows the weekly body weights of single and twin born kids.

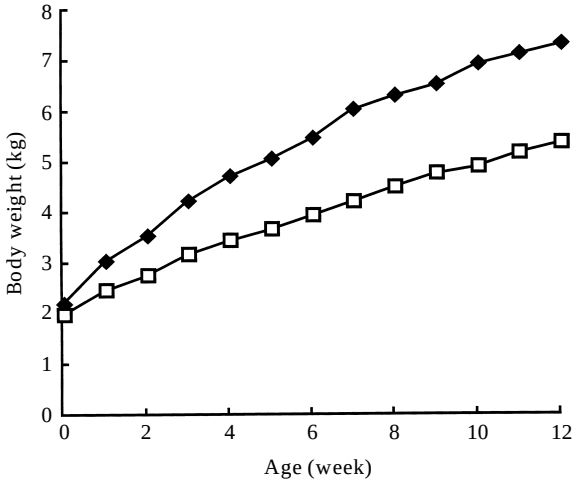

Figure 3 Growth of single (◆) and twin (□) kids of Sahelian goats in Mali grazing rangeland during the dry season.

The single kids were born heavier (2194 (s.e. 76) g) than each of the twin kids (1966 (s.e. 78) g), ($P < 0{\cdot}05$). At 12 weeks of age single kids had higher live weight (7461 (s.e. 256) g) than the twins (5411 (s.e. 276) g), ($P < 0{\cdot}001$), with a daily weight gain of 62·7 g for single kids and 41·0 g for twin kids. The growth rate of kids was influenced significantly by the milk production of their dams ($P < 0{\cdot}01$).

Sex had no significant effect ($P > 0{\cdot}05$) on growth rate of kids within single or twin born groups. However the difference between the growth rate of single and twin kids was highly significant ($P < 0{\cdot}001$) throughout the 12 weeks of measurement.

Discussion

The change in biomass of the herbaceous stratum observed between October and February was influenced mainly by climatic conditions, topography and soil type. At the end of the rainy season in October, both on the dunes (sandy soil) and depressions (loam) the herbaceous mass was of similar level. During the dry season, the contrast between the formations became apparent, primarily due to the differences in the topography and moisture content of the soils. Large variations in herbaceous mass between wet and dry seasons in the Sahel region have also been reported in other studies in Senegal and Mali (Guérin *et al*., 1986; Dicko and Sangaré, 1984). As the rainfall in Niono during the rainy season prior to the study was only proportionately 0·6 of the long-term average rainfall, the productivity was much lower than reported from the same locality by Penning de Vries and Djitéye (1982).

The foliage mass of the ligneous (woody) stratum also decreased as the dry season advanced and was again influenced by the soil type and availability of moisture. This decrease is explained, in large part, due to the drop of leaves during the dry season. These leaves and other plant matter that had fallen on the ground have not been taken into account in the calculation of phytomass. However, leaves, flowers and fruits of the ligneous plants were major components of the diet during the dry season as proportionately 0·87 to 1·00 of grazing time of goats was spent on these parts (Table 2). Although 26 species of woody plants were present on the site, *Acacia* spp., mainly *A. seyal* and to a lesser extent *A. senegal*, and *Z. mauritiana* were the most important contributors of aerial pastures, in the form of green leaves in the early dry season and dead leaves, flowers and fruits in the late dry season. The strategic importance of such plants in the goat husbandry in the Sahelian region is of paramount importance although large variations between years are noted (Hiernaux *et al*., 1994).

The relatively constant level of forage intake during this study, in spite of a large variation in available herbaceous and aerial woody plants foliage mass, may be explained by feeding behaviour of goats and an increase of fallen plant matter mass (leaves, flowers, fruits). Goats are known to discriminate between the available foods and to regulate the type and the quantity of food ingested (Morand-Fehr *et al*., 1991). Another regulating factor was the walking behaviour of goats. As the amount of phytomass decreased the goats walked longer distances (Figure 1) and grazed longer to cover their nutrient requirements.

The daily DM intake of lactating Sahel does in the present study (64 to 93 g DM per kg $M^{0.75}$) (Table 3) was generally less than that reported for lactating Alpine does (181 g DM per kg $M^{0.75}$; Sauvant *et al*., 1991) or lactating Jamnapari does (98 to 131 g DM per kg $M^{0.75}$; Maheshwari and Talapatra, 1975). The intakes in the present study may be explained by the nature of the diets which were mainly composed in the early dry season of green leaves of *Acacia* spp. (Reed *et al*., 1990) and in the late dry season of bulky roughage of low degradability such as dead leaves and seed pods. In studies with dairy (Sauvant *et al*., 1991) and multipurpose goats, such as Maradi (Red Sokoto) goats of Niger (Djibrillou *et al*., 1998), DM intake was directly related to milk yield. However in the present study, there was no such correlation.

The low intake by goats affected their ME intake. The relatively high and constant CP value of the goats' diet throughout the dry season may be accounted for by the fact that a large proportion of the food ingested came from woody plants with a high CP content (Becker and Lohrmann, 1992; Ramìrez *et al*., 1991). These CP contents are considered adequate for tropical range animal requirements in the dry season (Norton, 1994; Breman and De Ridder, 1991). However some studies (Barry and Manley, 1984; Woodward and Reed, 1989) have reported that intake of tannin-rich forage may have negative effects on diet protein utilization. Thus Ramìrez *et al*. (1991) found that proportionately only 0·513 of the CP content of range goats' diets was available in the gastro-intestinal tract. When these criteria are applied to the CP value found in our study, the goat diets became slightly protein deficient.

The large intake of deciduous and dead leaves of woody plants in October and November, and of seed pods of *A. seyal* (very fibrous when ripe) in April led to a high acid-detergent fibre (ADF) and lignin

content of the goats' diets (Ramìrez *et al*., 1991). Moreover, intake of tannin-rich forage like *A. seyal* may have negative effects on digestion of neutral-detergent fibre (NDF) and ADF fractions of the diet (Reed *et al*., 1990) and may explain the low digestibility and low ME content of diets selected in the present study in October, November and April. However, these data were similar to those reported by Becker and Lohrmann (1992) (DMD = 380 to 650 g, ME = 7·2 MJ), but higher than those of Ramìrez *et al*. (1991) (DMD = 341 g, ME = 4·6 MJ), with goats on woody pasture. The low ME content of diets and low intake led to the unbalanced ME supply for does in the dry season.

The milk yield of does in the present study was similar to those reported from some Sahelian breeds, such as Massakory, Maure, Touareg and Voltaique (Charray *et al*., 1980) and superior to other Sahelian breeds such as Fouta Djallon (Charray *et al*., 1980), Red Sokoto of Nigeria (Akinsoyinu *et al*., 1981; Ehoche and Buvanendran, 1983) or other non-Sahelian breeds such as local goats of Burundi (Farina, 1987) and Galla goats of Kenya (Blackburn and Field, 1982). It is known that milk production is related to the breed but also to the level of energy intake (Hadjipanayiotou and Morand-Fehr, 1991). The curve of milk production (Figure 2) with the peak in the 1st week followed by a decline seems to be common in low milk yielding tropical breeds as observed by Blackburn and Field (1982), Farina (1987) and Djibrillou *et al*. (1998). This trend is different for dairy breeds who attain the peak of milk production much later, sometime at 6 to 8 weeks of lactation (French, 1970).

The milk fat content of Sahelian goats in the present study was, in general, similar to those reported for some other non-dairy breeds of goats (Devendra and Burn, 1983; Morand-Fehr *et al*., 1991). The fat content increased as the milk production decreased with advancing lactation (Figure 2). Such relationships between milk yield and fat content have been observed also by Mba *et al*. (1975), Castellanos and Valencia (1982) and Djibrillou *et al*. (1998).

The birth weights of single kids were similar to those reported earlier but the birth weights of the twins were higher in the present study than in the Sahelian breed of Mali (Wilson, 1983) and other breeds of goats of Central and West Africa (Charray *et al*., 1980). The growth rate of single kids was higher than the twin kids and the difference in weight increased with advancing lactation (Figure 3). This tendency is a reflection of the milk production and sharing of milk by twin kids.

It can be concluded that the ME supply was the major constraint for Sahelian goats during the dry season. However, one should take into account the effects of high ingestion of tannin-rich forage by goats which may also hamper protein utilization. Hence determination of secondary compounds of the major woody plants of goats' diets and their effects on rumen function, food intake and goat production is in need of research. The milk production reached by Sahelian goats in the present study indicates their adaptation to the local harsh environment and suggests that further research to conserve and improve them should be undertaken. The results also indicated that kid growth during the first 3 months of life is largely determined by the milk production of their dams. Methods to reduce this dependency are needed.

References

Akinsoyinu, A. O., Tewe, O. O., N'Gere, L. O. and M'Ba, A. U. 1981. Milk composition and yield of the Red Sokoto (Maradi) goat in Nigeria. *Tropical Animal Production* **6:** 186.

Barry, T. N. and Manley, T. R. 1984. The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. 2. Quantitative digestion of carbohydrates and proteins. *British Journal of Nutrition* **51:** 493-504.

Becker, K. and Lohrmann, J. 1992. Feed selection by goats on tropical semi-humid rangeland. *Small Ruminant Research* **8:** 285-298.

Belsky, A. J. 1989. Landscape patterns in a semi-arid ecosystem in East Africa. *Journal of Arid Environments* **17:** 265-270.

Blackburn, H. D. and Field, C. R. 1982. The performance of Somalia Blackhead sheep and Galla goat in Nothern Kenya. In *Integrated Project in Aridlands (IPAL); technical report E-8, programme on Man and the Biosphere (MAB)*. UNESCO.

Breman, H. and de Ridder, N. 1991. *Manuel sur les pâturages tropicaux*. ACCT-CTA, Paris.

Castellanos, R. and Valencia, Z. 1982. Quantitative and qualitative study of milk production of the Pelibuey sheep. *Tropical Animal Production* **7:** 232-240.

Charray, J., Coulomb, J., Haumesser, J. B., Planchenault, D. and Pugliese, P. L. 1980. *Les petits ruminants d'Afrique Centrale et d'Afrique de l'Ouest. Synthèses des connaissances actuelles*. IEMVT, Ministère de la Coopération, Paris.

Cissé, M. I. 1992. *Relevé du peuplement ligneux et évaluation du potentiel fourrager aérien des parcours.* Document de travail, Institut d'Economie Rurale, Bamako, Mali.

Coughenour, M. B., Coppock, D. L. and Ellis, J. E. 1990. Herbaceous forage variability in an arid pastoral region of Kenya: importance of topographic and rainfall gradients. *Journal of Arid Environments* **19:** 147-159.

Devendra, C. and Burn, M. 1983. *Goat production in the tropics.* Commonwealth Agricultural Bureau, Slough, UK.

Dicko, M. S. and Sangaré, M. 1984. Le comportement alimentaire des ruminants domestiques en zone sahélienne. In *Proceedings of the second international rangeland congress, Adelaide.*

Direction Nationale de l'Elevage du Mali. 1988. *Rapport annuel 1988.* Direction Nationale de l'Elevage du Mali, Bamako, Mali.

Djibrillou, O. A., Pandey, V. S., Gouro, S. A. and Verhulst, A. 1998. Effect of urea-treated or untreated straw with cotton seed on performances of lactating Maradi (Red Sokoto) goats in Niger. *Livestock Production Science* **55:** 117-125.

Ehoche, P. W. and Buvanendran, V. 1983. Yield and composition of milk and pre-weaning growth rate in goats. *World Review of Animal Production* **19:** 19-24.

Farina, L. 1987. La chèvre locale du Burundi: production laitière et croissance du chevreau pendant la période néonatale. *Thesis M.Sc. no. 3, Prince Leopold Institute of Tropical Medicine, Antwerp, Belgium.*

French, M. H. 1970. *Observations on goats.* FAO Agricultural studies no. 80. Food and Agriculture Organization, Rome.

Gaines, W. L. 1927. Milk yield in relation to recurrence of conception. *Journal of Dairy Science* **10:** 117.

Glatzle, A. 1991. Feed resources in the Sahel. *Animal Research and Development* **35:** 43-58.

Guérin, H., Richard, D., Friot, D. and MBaye, Nd. 1986. Les choix alimentaires des bovins et des ovins sur pâturages sahéliens. *Reproduction, Nutrition, Development* **26:** 269-270.

Hadjipanayiotou, M. and Morand-Fehr, P. 1991. Intensive feeding of dairy goats. In *Goat nutrition* (ed. P. Morand-Fehr), pp. 197-208. Pudoc, Wageningen, The Netherlands.

Hiernaux, P. H. Y., Cissé, M. I., Diarra, L. and de Leenw, P. N. 1994. Fluctuations saisonnières de la feuillaison des arbres et des buissons sahéliens. Conséquences pour la quantification des ressources fourragères. *Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux* **47:** 117-125.

Institut d'Economie Rurale. 1992. *Plan stratégique de la recherche aronomique au Mali.* Programme Productions Animales, Vol. II, doc. 5; Février 1992. Institut d'Economie Rurale, Mali

Le Houérou, H. N. 1980. Composition chimique et valeur nutritive des fourrages ligneux en Afrique tropicale occidentale. In *Les fourrages ligneux en Afrique: etat actuel des connaissances* (ed. H. N. Le Houérou) pp. 259-284. CIPEA, Addis Ababa.

Maheshwari, M. L. and Talapatra, S. K. 1975. Stall feeding of Jamnapari with cowpea fodders. *Indian Veterinary Journal* **52:** 30-33.

Mba, A. U., Boyco, B. S. and Oyenuga, V. A. 1975. Studies on the milk composition of West African Dwarf, Red Sokoto and Saanen goats at different stages of lactation. I. Total solids, butterfat, solid-non-fat, protein, lactose and energy content of milk. *Journal of Dairy Research* **42:** 217-226.

Menke, K. H., Raab, L., Salewski, A., Steingass, H., Fritz, D. and Schneider, W. 1979. The estimation of digestibility and metabolizable energy content of ruminant feeding stuffs from gas production when they are incubated with rumen liquor *in vitro*. *Journal of Agricultural Science, Cambridge* **93:** 217-222.

Morand-Fehr, P., Bas, P., Blanchard, G., Daccord, R., Giger-Riverdin, S., Gihad, E. A., Hadjpanayiotou, M., Mowlem, A., Remeuf, F. and Sauvant, D. 1991. Influence of feeding on goat milk and technological characteristics. In *Goat nutrition* (ed. P. Morand-Fehr), pp. 209-224. Pudoc, Wageningen, The Netherlands.

Norton, B. W. 1994. The nutritive value of tree legumes. In *Forage tree legumes in tropical agriculture* (ed. R. C. Gutteridge and H. M. Shelton), pp. 177-191. CAB International, Wallingford, UK.

Penning de Vries, F. W. T. and Djitéye, M. A. 1982. *La productivité des pâturages sahéliens, une étude des sols, des végétations et de l'exploitation de cette ressource naturelle.* Agricultural research report no. 918. Pudoc, Wageningen.

Pfister, J. A. and Malechek, J. C. 1986. Dietary selection by goat and sheep in deciduous woodland of northern Brazil. *Journal of Range Management* **39:** 24-28.

Piot, J., Nebout, J. P., Nanot, R. and Toutain, B. 1980. *Utilisation des ligneux sahéliens par les herbivores domestiques. Etude quantitative dans la zone sud de la mare d'Oursi.* GERDAT, Paris.

Ramìrez., R. G., Loyo, A., Mora, R. M., Sanchez, E. M. and Chaire, A. 1991. Forage intake and nutrition of range goats in shrubland of northeastern Mexico. *Journal of Animal Science* **69:** 879-885.

Reed, J. D., Soller, H. and Woodward, A. 1990. Fodder tree and straw diets for sheep: intake, growth, digestibility and the effects of phenolics on nitrogen utilisation. *Animal Feed Science and Technology* **30:** 39-50.

Sauvant, D., Morand-Fehr, P. and Giger-Riverdin, S. 1991. Dry matter intake by adult goat. In *Goat nutrition* (ed. P. Morand-Fehr), pp. 25-36. Pudoc, Wageningen, The Netherlands.

Wilson, R. T. 1983. Productions animales. In *Recherches sur les systèmes de productions des zones arides du Mali* (ed. R. T. Wilson, P. N. de Leeuw and C. de Haan), pp. 63-94. CIPEA, Addis Ababa.

Wilson, R. T. and Light, D. 1986. Livestock production in Central Mali: economic characters and productivity indices for traditionally managed goat and sheep. *Journal of Animal Production Research* **62:** 567-575.

Woodward, A. and Reed, J. D. 1989. *The influence of polyphenolics on the nutritive value of browse: a summary of research conducted at ILCA.* ILCA bulletin no. 35, pp. 2-10.

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