INFLUENCE OF GRAZING REGIMES ON CATTLE NUTRITION AND PERFORMANCE AND VEGETATION DYNAMICS IN SAHELIAN RANGELANDS

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Propositions

Stellingen

1. Additional grazing time at night leads to increased forage intake and consequently, better performance by cattle, but reduces collectable manure for cropping. *This thesis*

2. Sight does not play a major role in diet selection of grazing ruminants. *This thesis*

3. When cattle in the Sahel are night-corralled to collect manure for arable cropping, supplementation is necessary in the critical late dry season to limit weight losses. *This thesis*

4. Grazing ruminants tend to make better use of Sahelian rangelands than predicted on the basis of pasture evaluation (quantity and quality) alone. *This thesis*

5. Indigenous (herders') knowledge and herd management strategies should be considered in the development of any animal- or ecologically-related innovation. *This thesis*

6. Technical innovations for animal husbandry systems in the Sahel should be flexible enough to deal with existing diversity in the pastoral community in terms of environmental, social, economic and political conditions. *This thesis*

7. Sustainable increases in agricultural production in the West African Sahel requires not only an optimal use of manure, but also external inputs such as fertilizer. *H. van Keulen and H. Breman. 1990. Agriculture, Ecosystems and Environment 32:177-197; Breman, 1998. African Fertilizer Market 11 (5):2-10.*

8. The dedicated scientist is like the obsessed lover: he never knows when to stop.

9. It aren't so much the things we don't know that get us in trouble. It's the things we know that aren't so.

10. It is much easier to be critical than to be correct. *Benjamin Disraeli. 1805-1881.*

11. All proofs rest on premises. *Aristotle. 384-322 BC.*

12. No pleasure is comparable to the standing upon the vantage-ground of truth. *Francis Bacon. 1561-1626.*

13. Whatever makes men good Christians, makes them good citizens.
Daniel Webster. 1782-1852.

14. Nothing is seen in its own light - not even a visible thing. Every sight of nature is tinged with the light of memory. *George Matheson. 1842-1906.*

Augustine Abioye Ayantunde *-Influence of grazing regimes on cattle nutrition and performance and vegetation dynamics in Sahelian rangelands. Wageningen, 1 December 1998.*

INFLUENCE OF GRAZING REGIMES ON CATTLE NUTRITION AND PERFORMANCE AND VEGETATION DYNAMICS IN SAHELIAN RANGELANDS

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Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus,
van de Landbouwuniversiteit Wageningen,
dr. C.M. Karssen,
in het openbaar te verdedigen
op dinsdag 1 december 1998
des namiddags te vier uur in de aula.

Printed by: Ponsen & Looijen BV, Wageningen

ISBN: 90-5485-989-X

Key Words: Cattle, Diet selection, Forage intake, Night grazing, Herd management, Vegetation dynamics, Sahelian rangelands

Ayantunde, A.A. 1998. Influence of grazing regimes on cattle nutrition and performance and vegetation dynamics in Sahelian rangelands.

In the West African Sahel, common herd management practices such as night grazing and corralling influence time available for grazing. When animals are used to deposit manure in the cropping fields, conflicts often arise between the need for animals to graze long enough for adequate feed intake, especially in the dry season, and the need to collect manure. Grazing trials were carried out in Sadoré (13° 14'N and 2° 16'E) and Toukounous (14° 30'N and 3° 17'E), Niger, to determine the effects of timing (day or day-and-night) and duration of grazing on cattle nutrition and performance, and to quantify the short-term effects of grazing by cattle on vegetation dynamics in Sahelian rangelands. In addition, a survey was conducted among livestock herders in two villages of Niger, Kodey and Toukounous, on their perceptions of night grazing with the aim of identifying constraints to the practice of night grazing and opportunities to apply relevant experimental results in the management of herds in the region. There were no differences in the quality of the diet selected during the day and at night, but the quality of the available and ingested forage declined as the season progressed from wet to dry. During the dry season, there was a trend for day-and-night grazing cattle to be more selective during the day, than animals that grazed only during the day. Animals that had additional grazing time in the night consistently had higher forage intake and consequently, higher average daily gain than those that grazed only during the day in all seasons. However, additional grazing at night reduced the amount of manure that could be collected for crop fields. When animals are supplemented, night grazing appears less relevant as the length of night grazing time did not significantly affect average daily gain in the critical late dry season. Annual herbage production of four paddocks used in Toukounous was 1893 kg DM ha^{-1}. Of this amount, consumption by cattle accounted for 48% on a year-round basis. The quality of the diet selected by the animals was consistently higher than that of the herbage grazed in all seasons. These results indicate that grazing ruminants tend to make better use of Sahelian rangelands than often predicted on the basis of pasture evaluation alone. The response of herders interviewed on their perceptions of night grazing indicates that ethnic group and herd size are critical characteristics for the decision on the practice of night grazing. Herders' perceptions of night grazing with respect to animal production parameters such as weight development, water consumption, faecal output and feeding behaviour are consistent with available experimental results. Therefore, the herders' current knowledge and herd management strategies need to be considered in the development of any animal or ecological innovation.

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Acknowledgements

First and foremost, I am grateful to God who has made all things beautiful in His own time. But for His grace, power and interventions at sundry times, this dissertation would not have been possible.

I am very grateful to Prof. Herman van Keulen and Dr. H.M.J. Udo for their thorough supervision, constructive criticism, and stimulating discussions at different stages of my programme. I am particularly encouraged by their unwavering enthusiasm and unflinching support for my work. Special thanks are due to Ing. F.A. Steenstra for her invaluable input in setting the layout of this thesis and Dr. G. Zemmelink for his critical review of some chapters of this dissertation. I am also indebted to Mrs. Clara van Keulen for her invaluable support to my family in making our stay in Wageningen a pleasure.

The studies reported in this thesis were carried out under the auspices of the International Livestock Research Institute (ILRI), Niger. I am grateful to ILRI for the scholarship granted to me and the enthusiasm showed for my programme. Worthy of distinctive recognition are the enormous contributions of Dr. S. Fernández-Rivera, Dr. P. Hiernaux and Dr. T.O. Williams to the design and implementation of my field work in Niger, and the writing of the thesis. Their professional tutelage, support and enthusiasm at different stages of my programme are highly appreciated. I am also grateful for the friendly and supportive climate they provided in the conduct of my research and writing. I am also indebted to all the staff of ILRI-Niger for their untiring assistance with respect to the nitty-gritty of the work. My special thanks are due to Harouna Garba, Adamou Kalilou, Mamoudou Issa-Koukou and Robert A.B.C. for their assistance with management of experimental animals, vegetation measurement, laboratory analyses of the herbage and extrusa samples and computer graphics, respectively. I also do appreciate the companionship and encouragement of Mamadou Sangaré, Dr. Eva Schlecht and Dr. E. Owusu. I am also grateful to Dr. M. Chanono, director of Station Sahelienne expérimentale de Toukounous, Niger, for the permission to carry out most of the studies in this thesis at the station and other people at the station who were involved with management and herding of the animals.

My profound gratitude is directed to my wife and my mistress, Oluremi, for her moral support and sacrifice which eased my task considerably. You had painfully endured my long hours of work. My Precious, I thank you for your support and love.

Finally, I acknowledge with gratitude the moral and spiritual support of Pastor Ojo and his family. I am equally indebted to the brethren who has directly or indirectly contributed to the successful completion of this thesis. They include brothers James Sangodokun, Bayo Sofidiya, Sola Idowu and Tunrayo Alabi. May God remember you for good and perfect that which concern you.

What in me is dark
Illumine, what is low raise and support,
That to the height of this great arguement
I may assert Eternal Providence,
And justify the ways of God to men.

Line 22-26, Paradise Lost, John Milton. 1608-1674.

Contents

Chapter 1

General Introduction

General Introduction

The role of livestock in the Sahel

The Sahelian zone of Africa is delineated approximately by the 100 mm isohyet in the north and the 600 mm isohyet in the south (Penning de Vries and Djitèye, 1982). The zone is characterized by a tropical climate with a monomodal rainfall regime of irregular inter-annual intensity and one dry season of 8 to 9 months (Penning de Vries and Djitèye, 1982). Three phyto-geographical sub-zones can be distinguished: The Saharan-Sahel between 100 and 200 mm, the 'typical Sahel' from 200 to 400 mm, and the Sahelo-Sudanian zone between 400 and 600 mm (Bernus, 1988). West African Sahelian countries include Burkina Faso, Chad, Gambia, Mali, Mauritania, Niger and Senegal. These countries support approximately 51% of the 37 million Tropical Livestock Units (TLU is a standard animal with a body weight of 250 kg) of West Africa and 20% of the human population on 71% of the land in the region (Jahnke, 1982; ILCA, 1993). So, livestock keeping constitutes the main land use form in the Sahel and the only means of livelihood for millions of the inhabitants (Penning de Vries and Djitèye, 1982). The Sahelian zone occupies 50 % of the land surface in Niger, 40 % in Mali, 39 % in Mauritania, 32 % in Chad, 27 % in Senegal and 7 % in Burkina Faso (Anonymous, 1986).

In the Sahel, livestock form a key element in food security strategies. They provide meat, milk, skins, draught power, transport and manure, and fulfill various socio-cultural functions such as payment of dowry, establishment and reinforcement of relationships and source of prestige within the pastoral society (Anonymous, 1986; Winrock International, 1992). For farmers and pastoralists livestock serve as a productive asset to generate income, reduce risks and mitigate the effects of drier than average years. Livestock provide an opportunity to invest surplus funds following a good crop harvest. In climatically unfavourable years, animals may be sold and the proceeds used to buy grain for human consumption (Sandford, 1989). Dicko (1986; cited by Sandford, 1989) reported that in South-West Niger during the drought of 1984/1985, about 75% of the proceeds of livestock sales were used to purchase cereals. For pastoralists, milk is a vital food commodity. It is either consumed fresh or processed (Bernus, 1988). For farmers, livestock serves as cash generator for seasonal requirements of agricultural activities, for example, purchase of inputs such as seed and paying the initial labour requirements for weeding. Livestock production in the Sahel is almost exclusively associated with exploitation of the natural rangelands (Breman and de Ridder, 1991). Livestock contribute substantially to the economies of the region (Table 1) and together with farming form the economic base of the West African Sahel.

Table 1. Value of agriculture and livestock products in West African Sahelian countries, 1988.

Country	Value[a] ($ millions)		Livestock share of agricultural output (%)
	Agriculture	Livestock	
Burkina Faso	671	183	27
Chad	554	216	39
The Gambia	99	15	15
Mali	835	368	44
Mauritania	188	158	84
Niger	667	314	47
Senegal	817	172	21

Source: Winrock International, 1992 (after U.S. Department of Agriculture 1990).

[a]Based on total output of agriculture and livestock products (meat, milk, eggs, wool, hides and skins).

Problems facing livestock production in the region include low and variable forage availability and poor quality, water scarcity, low animal production, high mortality rates, low and declining soil fertility and land degradation, declining grazing area principally due to expansion of cultivated land, increasing sedentarization of the pastoral population, inadequate and poor infrastructures for transportation, processing and marketing, institutional constraints (weak and ineffective extension agencies, poorly funded animal health services) and inconsistent government policies which too often favour urban consumers at the expense of rural producers (Penning de Vries and Djitèye, 1982; van Keulen and Breman, 1990; Breman and de Ridder, 1991;Winrock International, 1992). Low available forage is principally due to low biomass production from the rangelands (Penning de Vries and Djitèye, 1982) which is a reflection of poor soil fertility, and inadequate and erratic rainfall. All the above authors and many others also mention drought as a problem to livestock production in the region. Drought affects livestock production through reduced herbage production and water scarcity which often lead to death of animals.

Livestock production systems in the Sahel

Two main forms of livestock production systems exist in the West African Sahel, i.e. pastoralism and mixed crop-livestock farming (de Leeuw, 1984; Traoré and Breman, 1993). Pastoralism connotes specialized livestock keeping, which in the region is associated with movement of herds in search of forage and drinking water. Pastoralism takes the form of nomadism or transhumance (de Leeuw, 1984). The former implies constant movement of the herds, whereas the latter is characterized by more or less regular seasonal migrations from a permanent homestead. Nomadism is however decreasing in importance in the region (Powell et al., 1996). Pastoralism is the major livestock production system in the northern part of the Sahel, especially in areas with an annual rainfall below 300 mm and poor soils (Penning de Vries and Djitèye, 1982; Traoré and Breman, 1993). It is labour-intensive compared to the ranching system in the USA and Australia, and extensive in terms of external inputs (Traoré and Breman, 1993). Divergent opinions exist with respect to the biological and ecological sustainability of pastoralism (de Leeuw, 1984; Behnke and Scoones, 1993; Hiernaux, 1993; Traoré and Breman, 1993). Pastoralism is, however, an adaptive strategy that enables livestock holders to subsist and exploit the Sahelian resources. Herd size varies strongly among pastoral systems. It is often positively correlated to the degree of mobility (de Leeuw, 1984). In general, agro-pastoral households own smaller herds, either because of the competitive demands for labour for cropping, but more often because they operate in densely populated areas where grazing land is becoming increasingly scarce.

Crop-livestock farming systems are characterized by keeping of cattle, sheep or goats, in combination with cultivation of crops. Animal husbandry is mostly sedentary in crop-livestock systems. These livestock production systems are common in the southern (wetter) part of the Sahel. In these systems, crop residues, pastures and forage crops on fallows and communal lands are feed resources for the animals. Common constraints to crop-livestock systems include inadequate feed resources in terms of quantity and quality, reduced fallow periods, low and declining soil fertility, soil erosion, lack of access to agricultural inputs and encroachment of cropping onto grazing lands (Powell et al., 1996).

Integration of crop and livestock production

In crop-livestock farming systems, the integration of crops and livestock is characterized by the use of crop residues as animal feed, and the use of manure and animal power for crop production (Powell and Williams, 1993; Traoré and Breman, 1993; Williams et al., 1997). The degree of crop-livestock interaction, however, varies widely. Crop residues are feed resources, especially in the dry season which lasts for 7 to 9 months (Sandford, 1989; Williams et al., 1997). Most cereal stovers are grazed freely in fields or harvested for feed, fuel, or construction material, while groundnut and cowpea hays are stored for feeding during the dry season to selected animals, or they are sold (Powell and Williams, 1993; Powell et al., 1996). In mixed farming systems, livestock derives up to 45% of their total annual feed intake (DM) from crop residues and up to 80% during critical periods (Sandford, 1989). The propotion of crop residues in the animal's diet is related to annual rainfall, the intensity of cropping, and the available forage during the dry season. However, natural rangelands form the main feed resource for livestock.

Rapid population growth and increasing urbanization in the Sahelian countries have contributed significantly to the increased integration of crop and livestock production and to competition between the two sectors (van Keulen and Breman, 1990; Ramaswamy and Sanders, 1992; Traoré and Breman, 1993). The consequence of population growth is extension of arable farming to marginal lands, thereby reducing communal pasture areas for livestock. In addition, the fallow periods are shortened or eliminated and crop yields per unit area have declined (Ramaswamy and Sanders, 1992). Cultivation of more land and shortening of fallow periods promote soil depletion, thereby exacerbating the problem of land degradation (van Keulen and Breman, 1990). The introduction of animals in arable farming for draught power and manure is therefore necessary to improve soil fertility and crop yield. The combination of population growth and periodic droughts has increased pressure on the natural resource base in the zone (van Keulen and Breman, 1990), which is further threatened by increasing sedentarization of the previously pastoral population (Traoré and Breman, 1993) and the growing number of absent livestock owners, who entrust their animals to paid herders. This increased pressure on natural resource base in the region not only affect the direction and magnitude of nutrient flows, but also the spatial distribution of grazing in the rangelands.

Influence of herd management practices on livestock production

The nutrient flows in the Sahelian landscape and the spatial distribution of grazing are also influenced by herd management practices. Common herd management practices in the Sahel such as herding type (shepherding or free-ranging), night grazing, watering (frequency and location) and corralling affect time available for grazing by the animals (Breman et al., 1978; Dicko-Touré, 1980; Bayer, 1990; Powell et al., 1996). By corralling animals on cultivated land the nutrients in faeces and urine especially nitrogen and phosphorus, are transferred from rangeland to cropland (Powell et al., 1996). Herding of grazing ruminants allows a highly flexible use of land for grazing, as close supervision of the animals permits grazing of unfenced areas of fallow amidst cultivated fields and the grazing of crop residues (Bayer, 1990). However, herded, as opposed to free-ranging cattle, have access to pasture for only a limited time, normally only during the daylight hours. Restriction of grazing time may limit animal production. For instance, grazing trials in Uganda (Joblin, 1960), Zimbabwe (Smith, 1961) and Tanzania (Kyomo et al., 1972; Wigg and Owen, 1973) have shown that weight gains were higher in animals given the opportunity to graze at night in addition to grazing during the day than in those that grazed only during the day (Table 2).

Night grazing is a common practice in the West African Sahel, especially at the end of the dry season (Breman et al., 1978; Dicko-Touré, 1980). This practice has also been reported for herded animals in East Africa (Joblin, 1960; Smith, 1961; Kyomo et al., 1972; Wigg and Owen, 1973; Nicholson, 1987); grazing cows in Cuba (Senra et al., 1992; Senra et al., 1994), Nigeria (Breinholt et al., 1981), Brazil (Visela et al., 1974), Philippines (Hebron et al., 1981) and for free ranging sheep and cattle in the USA and Australia (Arnold and Dudzinski, 1978; Vallentine, 1990). Apart from sheep and cattle, horses have also been reported to graze at night (Hayakawa, 1991). An ancient Chinese proverb that says "Horses cannot be rich if not allowed to graze in the night" also suggests that horses graze at night. The literature review on night grazing in Table 2 shows that benefits of night grazing include increased grazing time, higher manure deposition on rangelands, increased forage intake and milk production, and higher weight gains. Arguably, the value of night grazing varies with environmental and pasture conditions and production objectives. Night grazing is labour-intensive especially when the animals are herded in the night and there is danger of predators to the stock and that of snake bite to the herdsmen (King, 1983). In the tropics and subtropics and during prolonged periods of hot weather in temperate zones, night grazing may account for up to 80% of the total grazing time by cattle (Vallentine, 1990). Breinholt et al. (1981) observed that the duration of night grazing was postively related to hours of sunshine and Arnold and Dudzinski (1978) reported that the proportion of night grazing was significantly related to total grazing time. These findings suggest that time spent on night grazing varies with environmental conditions, especially ambient temperature. The effect of moonlight on grazing time at night is unclear. Visela et al. (1974) reported that moonlight increased night grazing time, whereas Vallentine (1990) observed that the presence or absence of a moon had no effect. Manuring crop land in the Sahel includes night time corralling of animals, especially cattle, directly on fields and/or hauling manure from homesteads (Powell and Williams, 1993). The advantage of corralling animals on cropland is that it returns both manure and urine to soils and requires little additional labour in animal management and no labour in manure handling, storage and

Table 2. Summary of various studies on night grazing.

Site/Country	Animal species	Conclusion	Source
Uganda	Cattle (bulls)	Animals with access to night grazing gained 30% or 13 kg more during a 10-month trial period than day-grazers.	Joblin, 1960
Zimbabwe	Cattle (oxen and heifers)	Cattle that are not kraaled (day-and-night grazers) had a higher weight gain than those that were kraaled. Night grazing accounted for 20% of total grazing time.	Smith, 1961
Tanzania	Cattle (heifers)	Zebu heifers with access to night grazing were 25-110 kg heavier at the age of 120 weeks than day grazing heifers.	Kyomo et al., 1972
Tanzania	Cattle (steers)	Steers with access to night grazing had higher weight gain than those that grazed only during the day	Wigg and Owen, 1973
Nsukka, Nigeria	Cattle (cows)	Night grazing in addition to day-time grazing significantly increased milk production of imported Friesian breed.	Breinholt, 1979
Mali	Cattle (bulls and cows)	Cattle spent longer time grazing in the night in the dry season than in the wet season. The animals were unherded in the night.	Dicko-Touré, 1980
Nsukka, Nigeria	Cattle, Nigeria	Cows spent more time grazing in the night than during the day in the dry season. Duration of night grazing was positively related to length (hours) of sunshine.	Breinholt et al., 1981
Laguna, Philippines	Cattle (cows)	Cows that grazed in the night in addition to stall feeding with maize silage during the day had higher intake than those that had 24 h access to maize silage. The former also performed better.	Hebron et al., 1981
Japan	Horses	Night grazing provides good exercise for race horses.	Hayakawa, 1991
Cuba	Cattle (cows)	No differences in feed intake, milk yield and weight gain between cows on restricted day grazing and those on day and night grazing in the wet season.	Senra et al., 1992
Cuba	Cattle (cows)	Day and night grazing cows had longer total grazing time than day-grazers.	Senra et al., 1994
Belgium	Cattle (cows)	N content of the cow faeces and the grass and the urea content of the milk were significantly higher in day-and-night grazers than in day-grazers.	Carlier and Verbruggen, 1996

spreading. The practice of corralling cattle at night for manuring is an important soil fertility improvement strategy (Khombe et al., 1992; Powell et al., 1996). Application of manure results in increased the cation exchange capacity, exchangeable bases and pH of the soil (Khombe et al., 1992). Powell and Williams (1993) reported that in areas of western Niger, between 30 and 50% of the cultivated areas is manured annually at a rate of 1.3 tonnes per hectare. Fernández-Rivera et al. (1995) reported mean faecal excretions of 8.5, 9.7 and 10.1 g DM per kg body weight for cattle, sheep and goats, respectively. The amounts of nutrients (nitrogen and phosphorus) excreted in urine and faeces depend on animal diet (Powell et al., 1996), animal management and season (Romney et al., 1994). Although most of the nutrients excreted in urine may be lost, either through volatilization or leaching (Romney et al., 1994), urine deposited on crop fields may increase soil pH and hence the availability of phosphorus. When animals are used to deposit manure in the crop fields, conflicts arise between the need for animals to graze long enough to have adequate feed intake and the need to improve soil fertility of the arable land.

Forage intake by grazing animals and impact of grazing on vegetation

Studies on animal nutrition in the Sahel have reported wide seasonal variation in forage intake by grazing ruminants (Dicko-Touré, 1980; Guerin et al., 1988; Schlecht, 1995). This variation could be explained by fluctuation in supply and quality of available feeds. These studies, however, failed to consider the influence of herd management practices on ruminant nutrition, even though practices such as night grazing and corralling affect grazing time, which in turn influence the nutrition of the animals and nutrient transfer processes. Generally, forage ingestion by grazing ruminants depends on feed availability and quality. Most literature points to digestibility, rate of ingesta passage and reticulo-rumen fill as primary factors that determine intake in range ruminants (Ellis, 1978; Allison, 1985; Hodgson, 1985). Body size and physiological status are major animal-related factors that affect intake. However, Ketelaars and Tolkamp (1991) proposed an alternative model of oxygen efficiency theory as being responsible for the regulation of feed intake. Range and/or herd management strategies such as supplementation, species combination of the grazing animals and grazing intensity also influence voluntary intake by grazing ruminants. As grazing intensity increases, opportunities for selective grazing decrease and consequently, herbage intake (Allison, 1985; Cordova et al., 1978).

An extensive discussion on Sahelian rangelands: potential and actual production, and limiting factors to rangeland production, is given in the report of the Malian-Dutch project edited by Penning de Vries and Djitèye (1982). The Sahelian rangelands are dominated by annual plants with a short growing cycle (Penning de Vries and Djitèye, 1982). Growth of these annual plants and the associated forage production are determined by amount and distribution of rainfall, nutrient availability in the soil and grazing management (Le Houérou and Hoste, 1977; Penning de Vries and Djitèye, 1982; Hiernaux and Turner, 1996). Biomass yield per year and forage quality of the rangelands are low and vary markedly across seasons and from year to year (Penning de Vries and Djitèye, 1982; Behnke and Scoones, 1993; Hiernaux, 1993).

Grazing animals affect plant communities in several interrelated ways including plant defoliation, nutrient removal and redistribution through excreta, and mechanical impacts on soil and plant material through trampling (Vallentine, 1990; Matches, 1992; Hiernaux, 1993). The impact of grazing on a vegetation depends on frequency, timing and intensity of grazing, species of animal, season, soil type and the amount of excreta deposited on the pasture (Matches, 1992; Hiernaux, 1993). Grazing may result in substantial changes in persistence, productivity, and botanical composition of the sward and the subsequent regrowth rate of plants. However, different forage species vary in their response to grazing (Coleman, 1992). Highly preferred species decline as they are selectively grazed and are replaced by less preferred vegetative types as grazing pressure increases (Mwendera et al., 1997). The short-term or immediate effects of grazing on a plant can (1) be detrimental, i.e., reduced plant vigour or even death, (2) be beneficial, i.e., increased size or growth rate, or (3) have no apparent beneficial or negative efffect. The short-term effects of grazing on the vegetation include reduction in standing herbage mass through consumption by animals, transformation of standing herbage to litter and acceleration of litter decomposition by trampling (Hiernaux and Turner, 1996). Trampling by grazing ruminants may affect biomass yield: It may directly damage or destroy vegetative parts, leaves, stems and roots, which in turn may cause reduced regrowth, and changes in botanical composition (Matches, 1992). Indirect effects of trampling include soil compaction and with the associated reduction in soil aeration and soil infiltration, increased soil erosion and possibly changes in soil-water relationships, all of which may affect plant growth. The long-term effects of grazing largely depend on the adaptation of the plant to local and changing biotic and abiotic factors. In the long-term, floristic composition of the vegetation may be modified (Breman and Cissé, 1977; Dormaar et al., 1990) and this in turn may affect herbage production and feed value (Milchunas et al., 1995). However, the botanical composition of annual Sahelian pastures under non-disturbed conditions is highly variable from year-to-year and this may makes it difficult to establish long term changes in the vegetation.

Objectives and outline of the thesis

The studies reported in this thesis were carried out under the auspices of the International Livestock Research Institute (ILRI), Niger, in the framework of the project

"Livestock-mediated nutrient transfers in Semi-Arid West Africa". They originated from recognition of the conflict between the time animals are "used" for manuring and the time they need for foraging, with the aim of identifying management practices that optimise the animals' time for the two purposes, i.e. manuring to sustain soil fertility and hence crop production and foraging to maintain or increase livestock output in terms of meat and/or milk. Thus, the grazing trials were designed to examine the effects of the traditional practice of night corralling for manure collection (i.e. no night grazing) on animal production and the potential impact on nutrient transfer from rangeland to cropland. Effects of livestock grazing on vegetation were studied to increase understanding of forage ingestion by grazing cattle and the associated nutrient cycling within rangelands.

The specific objectives of the studies reported in this thesis were: (1). To determine the effects of timing (day or day and night) and duration of grazing on diet selection, feeding behaviour, forage and water consumption, faecal excretion and weight changes of cattle in Sahelian rangelands. (2). To quantify the short-term effects of grazing by cattle on vegetation dynamics in Sahelian rangelands. (3). To identify constraints to the practice of night grazing and the opportunities to apply relevant experimental results in the management of herds in the region.

In Chapters 2 to 5, grazing trials examining the effects of night grazing on cattle nutrition and performance are presented. Chapter 2 reports results of a preliminary study on the influence of night grazing on feeding behaviour, diet selection, forage and water intake, faecal output and weight changes of cattle. This trial was designed to provide information on night grazing to be used in the design of more complex and longer grazing trials. Chapters 3 and 4 report on more elaborate and complex experiments on the effects of timing and duration of grazing on nutrition and performance of cattle lasting for a year and with more animals. Aspects of diet selection, weight changes and faecal output are presented in Chapter 3 while feeding behaviour, forage and water consumption are treated in Chapter 4. In Chapter 5, effects of nocturnal grazing and supplementation on diet selection, eating time, forage intake and weight changes are reported.

In Chapters 6 and 7, effects of grazing by cattle on vegetation are presented. In Chapter 6, the short term effects of grazing by cattle on herbage growth and disappearance in Sahelian rangelands are quantified and discussed. Chapter 7 reports on utilization by grazing cattle of the spatially heterogeneous and seasonally variable range resources and the annual nutrient balances of a Sahelian rangeland.

Chapter 8 presents a case study from Niger on herders' perceptions, practice and problems of night grazing. It provides anthropogenic explanation on the practice of night grazing and a comparison of herders' perceptions and research results.

Finally, in the general discussion, the major findings from the previous chapters are discussed in an integrative way and their possible impact for practical recommendations for herd management in the Sahel.

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Chapter 2

The influence of night grazing on feeding behaviour, diet selection, forage and water intake, faecal output and weight changes of cattle in the Sahel

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Submitted to Journal of Range Management

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Abstract

Night grazing is a common herd management practice in the West African Sahel, especially at the end of the dry season. The influence of night grazing on feeding behaviour, nutrition and performance of cattle was studied. Twenty-four steers weighing 367 kg (SD=76) grazed either from 0900 to 1900 h (day-grazers), 2100 to 0700 h (night-grazers) or 0900 to 1900 h and 2400 to 0400 h (day-and-night grazers) during 13 weeks. Four esophageally fistulated steers were used in a cross-over design to sample the diet selected during the day and at night. No differences ($P>0.05$) were observed in the diet selected in the day or at night. As the season progressed the fiber components of the diet increased ($P<0.01$) significantly while nitrogen and *in sacco* dry matter disappearance declined ($P<0.01$). Actual grazing (i.e. eating) time (min d^{-1}, SEM=16) were 352, 376 and 476 for day, night, and day-and-night grazers, respectively. Day-and-night grazers had a higher intake of organic matter than either day- or night-grazers. Night-grazers had the lowest forage intake and also the slowest rate of consumption. Steers that grazed in the night had the lowest water intake: 22.7 l d^{-1} (SEM=1.5) in week 4; 19.9 l d^{-1} (SEM=1.1) in week 8. Average weight changes (g d^{-1}, SEM=62) were -435, -548 and -239 for day, night, and day-and-night grazers, respectively. These results show that during the dry season, grazing exclusively in the night cannot substitute for day time grazing, but that it is rather complementary to the latter. Timing (day or night) of grazing did not affect diet selection but nocturnal grazing decreased the need for water.

Key Words: Cattle, Forage intake, Night grazing, Sahelian rangelands

Introduction

Night grazing is a common herd management practice in the West African Sahel, especially at the end of the dry season (Breman et al., 1978; Dicko-Touré 1980). This practice has also been reported for herded animals in the sub-humid zone of West Africa (Bayer, 1986), East Africa (Wigg and Owen, 1973; Nicholson, 1987) and for free ranging sheep and cattle in the USA and Australia (Arnold and Dudzinski, 1978; Vallentine, 1990). In addition to the advantage of increased grazing time, King (1983) reported that night grazing helps to reduce heat stress on the animals and may increase forage intake. It has the benefit of manure deposition on rangelands rather than in the enclosed sites (Wigg and Owen, 1973). However, this is in conflict with the practice of corralling the animals on cropland for depositing manure (Powell et al., 1996). Arguably, the value of night grazing varies with environmental and pasture conditions, and production objectives. Previous research (Fernández-Rivera et al., 1998) on night grazing by cattle showed that diet selection during the day and at night were not different. However, the steers that grazed during the day consumed more forage and water than those that grazed in the night. Further studies on the influence of night grazing on feeding behaviour, nutrition and performance of cattle are needed to improve understanding of the nutrition of grazing cattle and cattle's role in nutrient transfer processes in the landscape.

The objective of this study was to determine the effects of night grazing on diet selection, forage and water intake, faecal excretion, feeding behaviour and performance of cattle.

Material and Methods

Study site

The experiment was conducted over 13 weeks at the end of the dry season (February to May) of 1995 at International Crop Research Institute for the Semi-Arid Tropics (ICRISAT-SC) in Sadoré (Lat 13° 14' N and Long. 2° 16' E), Niger.

Treatments, pasture and animals

Twenty-four intact steers with a body weight (BW) of 367 (SD=76) kg were randomly allotted to three treatments: grazing either from 0900 to 1900 h (day grazing), 2100 to 0700 h (night grazing) or 0900 to 1900 h and 2400 to 0400 h (day-and-night grazing). After return from the pasture, the steers were kept in individual pens in a barn located 150 m from the paddock. The animals grazed the same pasture in the day and at night, i.e. a fallow of 5.5 ha, dominated by annual grasses mainly *Ctenium elegans*, *Diheteropogon hagerupii*, *Pennisetum pedicellatum* and forbs mainly *Borreria stachydea* and *Hibiscus sabdariffa*. At the beginning of the trial, the standing herbage mass and litter mass of the pasture were estimated at 828 and 1070 kg DM per ha, respectively (Table 1). The herbage mass consisted of standing hay composed of 59% grasses and 41% forbs.

The study included two periods of collection of faeces and extrusa which started in weeks 4 and 8 of the experiment. Each of these periods included nine days of data collection. The animals were accustomed to carrying faecal collection bags during the last week before the data collection started. Water intake was also measured in weeks 4 and 8 of the trial. In each collection period, faecal bags were emptied and the faeces weighed, before and after grazing. Ten percent of the faecal excretion was sampled and frozen for subsequent analysis. All the animals were watered in the morning (0800 h) before grazing started. In week 8 of the experiment all steers were observed for the following activities: searching for food, prehending, masticating, ruminating, walking, drinking, sleeping and idling. Eating time was defined as the time spent prehending, masticating and searching

Table 1. Nutritional quality (g/kg DM) of standing herbage and litter mass at the beginning of the experiment (March 1995).

Component	Standing herbage	Litter	SEM
Organic matter	949	938	6
Nitrogen	3.5	3.4	0.5
Phosphorus	1.2	1.1	0.2
DMD[1]	426	412	18
OMD[2]	400	391	19
DOM[3]	380	367	13

[1]DMD = Dry matter digestibility. [2]OMD = Organic matter digestibility.
[3]DOM = Digestible organic matter (i.e. OMD x OM).

for food. Idling included time spent neither for eating, ruminating, sleeping, walking nor drinking. Activities such as drinking, fighting and socializing were referred to as 'other'. Observation was made every 5 min (24 h/d) for 3 consecutive days.

In the two collection periods, four esophageally fistulated steers were randomly grouped into two pairs and were used in a cross-over design for sampling the diet selected during the day and at night. The two pairs either grazed in the day (0900 to 1900 h) or at night (2100 to 0700 h). During the data collection period in weeks 4 and 8, samples of the diet selected by the fistulated steers (extrusa) were collected in the morning (1000 h) and afternoon (1500 h) for the day grazing pair, and at night (2200 h) and at dawn (0300 h) for the night grazing pair, for 3 consecutive days. At the end of the three day collection period, the two groups were switched. After switching the grazing schedule, the animals were allowed three days for adaptation after which extrusa samples were collected for another three days following the same collection schedule. The extrusa samples were frozen immediately after collection.

Sample processing and laboratory analyses

The daily faecal sub-samples were bulked by time of collection (before or after grazing) and analyzed for dry (DM) and organic matter (OM). The extrusa samples were dried at 55 °C for 48 h and were ground to pass a 1-mm screen. They were analyzed for DM, OM, nitrogen (N), ashless neutral detergent fiber (NDF), ashless acid detergent fiber (ADF) and ashless lignin (Van Soest et al., 1991). Hemicellulose and cellulose were calculated as the differences NDF-ADF and ADF-lignin, respectively. Samples ground to pass a 2-mm screen were incubated in duplicate for 48 h in three ruminally fistulated steers to determine *in sacco* DM (DMD) and OM (OMD) disappearance, treating the residues from the nylon bags in a HCl-pepsin solution for 24 h. Samples collected from vegetation mass measurement, representing the available feed, were subdivided by facies (grasses or forbs), strata (low, medium and high cover density) and dominant species for standing herbage and litter separately. These were analyzed for DM, OM, N, phosphorus (P), DMD and OMD.

Animal measurements

Animals were weighed every two weeks for three consecutive days. Average daily gain (ADG) was estimated by regression of individual body weight (BW) data over time. Forage intake was determined from individual data on faecal output and group (day or night schedule) means of OMD. Water intake was measured daily during the collection periods, for which all animals had access to water for 30 min.

Statistical analyses

Data analysis were performed with SAS (Statistical Analysis System Institute, 1987) using the General Linear Model (GLM) procedure for the variance and regression analyses. An analysis of variance model including treatments as fixed effects, was used to analyze data on faecal output, forage and water intake, and animal behaviour (time spent eating, ruminating, idling, walking, sleeping and drinking). Multiple comparisons of treatment means within and between the collection periods (weeks 4 and 8) were performed by contrasts. Extrusa components of diet selected in the day and at night were analyzed using the Cochran procedure for the *t* test.

Results

There were no differences ($P>0.05$) in the quality of diet (extrusa) selected (Table 2) in the day or at night for both collection periods (weeks 4 and 8), the only exception was observed in week 4 when the NDF (SEM=6) of the diet selected by night-grazers (675 g kg^{-1} DM) was significantly ($P<0.05$) higher than that of the day-grazers (649g kg^{-1} DM). As the dry season progressed (week 4 vs week 8, Table 3) diet's (g kg^{-1} DM) NDF, ADF, cellulose, hemicellulose and lignin increased significantly ($P<0.01$) while nitrogen concentration (SEM=0.4) declined ($P<0.05$) from 8.5 in week 4 to 7.3 g kg^{-1} DM in week 8 and DMD (g kg^{-1} DM, SEM=8) also declined significantly (week 4 = 529; week 8 = 482).

Steers grazing in the day, night, and day-and-night spent 352, 376 and 476 min/d respectively for eating (Table 4). Night-grazers spent less time ($P<0.05$) ruminating and walking than day-grazers. Day-and-night grazers spent 124 minutes eating more than

Table 2. Chemical composition (g/kg DM) of forage selected (extrusa) by esophageally fistulated steers grazing in the day or at night.

Component	Week 4				Week 8			
	Day	Night	SEM	P [t][1]	Day	Night	SEM	P [t]
Organic matter	894	883	5	0.12	881	889	4	0.18
Nitrogen	9.0	8.1	0.5	0.27	7.5	7.1	0.4	0.60
NDF	649	675	6	0.04	817	821	7	0.70
ADF	507	521	5	0.20	635	637	8	0.86
Lignin	134	129	9	0.62	178	187	11	0.49
Cellulose	373	393	7	0.12	460	450	8	0.42
Hemicellulose	143	154	5	0.10	182	184	6	0.87
DMD[1]	533	524	8	0.61	486	478	10	0.64
OMD[2]	469	455	10	0.41	459	444	13	0.39
DOM[3]	419	402	8	0.25	404	395	7	0.18

[1]P [t] = Probability of Type I Error. [2]DMD = Dry matter digestibility.
[3]OMD = Organic matter digestibility. [4]DOM = Digestible organic matter (i.e. OMD x OM).

Table 3. Diet (extrusa) quality (g/kg DM) with the progression of dry season in week 4 (March 1995) and week 8 (May 1995).

Component	Week 4	Week 8	SEM	P [t][1]
Organic matter	889	885	4	0.38
Nitrogen	8.5	7.3	0.4	0.02
NDF	662	819	5	<0.01
ADF	514	636	6	<0.01
Lignin	131	183	5	<0.01
Cellulose	383	455	6	<0.01
Hemicellulose	148	183	5	<0.01
DMD[2]	529	482	8	<0.01
OMD[3]	462	451	8	0.35
DOM[4]	411	399	6	0.36

[1]P [t] = Probability of Type I Error. [2]DMD = Dry matter digestibility.
[3]OMD = Organic matter digestibility. [4]DOM = Digestible organic matter (i.e. OMD x OM).

day-grazers ($P<0.05$). The hourly distribution of time expenditure (Figure 1) for different activities showed that day-grazers had two distinct grazing (eating) periods with the first in the morning till mid-day and the second before the sunset. The second grazing period accounted for over 60% of total time spent grazing. Day-and-night grazers also had two grazing periods in the day similar to day-grazers with one additional period in the night of about 2 h. Night-grazers had two grazing periods with the initial period accounting for about 75% of the total grazing time. Steers that grazed in the day-and-night had lower time for resting (time spent sleeping + idling) than steers that grazed in the day (421 vs 560, SEM=25, $P<0.05$) but there was no difference in resting time by day-grazers compared to night-grazers (560 vs 614, SEM=25, $P>0.05$).

Day, and day-and-night grazing steers consistently consumed more forage than steers that grazed at night (Table 5). In weeks 4 and 8, day-and-night grazers consumed daily 93.2 and 67.1 g DM $kg^{-0.75}$ BW respectively whereas night-grazers consumed 62.5 g DM $kg^{-0.75}$ BW in week 4 and 53.6 g DM $kg^{-0.75}$ BW in week 8. Day-grazers consumed significantly ($P<0.05$) more digestible organic matter (g DOM $kg^{-0.75}$ BW) than night-grazers (Week 4: 30.2 vs 20.4, SEM=1.6; week 8: 22.7 vs 18.3, SEM=1.4), but the differences between day-grazers and day-and-night grazers were not statistically significant ($P>0.05$). Forage intake (g DM $kg^{-0.75}$ BW) declined significantly ($P<0.05$) from week 4 to week 8 for day-grazers, and day-and-night grazers. Intake rate (mg OM $kg^{-0.75}$ BW min^{-1}) in week 8 (SEM=7) were 142 for day-grazers, 110 for night-grazers and 113 for day-and-night grazers.

Table 4. Time expenditure (minute/day) on different activities in Week 8 (May 1995) of the experiment of day, night, and day-and-night grazing steers.

Activity	Day	Night	Day-and-night	SEM
Eating[1] ▲	352	376	476	16
Ruminating #	463	389	447	21
Sleeping ▲	88	99	50	12
Walking # ▲	37	28	55	3
Idling[2] ▲	472	519	371	27
Other[3]	30	29	43	10

Day vs Night, $P<0.05$. ▲ Day vs Day-and-night, $P<0.05$.

[1] Eating includes prehension, mastication and search for food.

[2] Idling includes time spent neither for grazing, ruminating, sleeping, walking nor drinking.

[3] Other includes activities such as drinking, fighting and socializing.

Table 5. Daily intake of dry (DM), organic (OM) and digestible organic (DOM) matter, and intake rate (intake per actual grazing time) by day grazing, night grazing and day-and-night grazing steers in the dry season in the Sahel.

Forage intake	Day	Night	Day-and-night	SEM
Week 4:				
g DM animal^{-1} d^{-1} #	7081 †	5132 ¶	7329 ‡	242
g DM kg$^{-0.75}$ BW #	86.3 †	62.5	93.2 ‡	4.8
g DOM kg$^{-0.75}$ BW #	30.2 †	20.4	31.9 ‡	1.6
Week 8:				
g DM animal^{-1} d^{-1} #	4967 †	4164 ¶	5242 ‡	209
g DM kg$^{-0.75}$ BW #	62.9 †	53.6	67.1 ‡	4
g DOM kg$^{-0.75}$ BW #	22.7 †	18.3	24.3 ‡	1.4
g DM min^{-1} # ▲	14.4	11.2	11.0	0.7
mg OM kg$^{-0.75}$ BW min^{-1} # ▲	142	110	113	7

Day vs Night, $P<0.05$. ▲ Day vs Day-and-night, $P<0.05$.
† Values in Week 4 vs Week 8, $P<0.05$ for the same variable for day grazing steers.
¶ Values in Week 4 vs Week 8, $P<0.05$ for the same variable for night grazing steers.
‡ Values in Week 4 vs Week 8, $P<0.05$ for the same variable for day-and-night grazing steers.

There was a significant ($P<0.05$) difference in water intake between steers that grazed in the night and those that grazed either in the day or in the day-and-night in both periods of measurement (Table 6). As the season progressed water intake of day-grazers (week 4 = 35.5, week 8 = 27.6 l d^{-1}) and day-and-night grazers (week 4 = 35.5, week 8 = 27.6 l d^{-1}) declined significantly ($P<0.05$) but that of night-grazers (week 4 = 22.7, week 8 = 19.9 l d^{-1}) remained fairly constant. Relative to forage intake water consumption (l kg^{-1} forage DM) was constant for all treatments regardless of the period of measurement. Regression analyses of water intake on metabolic weight ($BW^{0.75}$) and dry matter intake (DMI, kg DM d^{-1}) showed that water intake (WI, ml d^{-1}) was correlated with BW in all treatments and with DMI for day-grazers, and day-and-night grazers but not for night-grazers. The following regression equations were estimated from the pooled data of weeks 4 and 8:

Day-grazers: $WI = 148\ (SEM=26)\ BW^{0.75} + 3243\ (SEM=343)\ DMI$ ($r^2 = 0.99$, $P<0.01$)

Night-grazers: $WI = 263\ (SEM=6)\ BW^{0.75}$ ($r^2 = 0.99$, $P<0.01$)

Day-and-night grazers: $WI = 126\ (SEM=34)\ BW^{0.75} + 3412\ (SEM=429)\ DMI$ ($r^2 = 0.99$, $P<0.01$)

In week 4, faecal excretion by day-grazers, night-grazers, and day-and-night

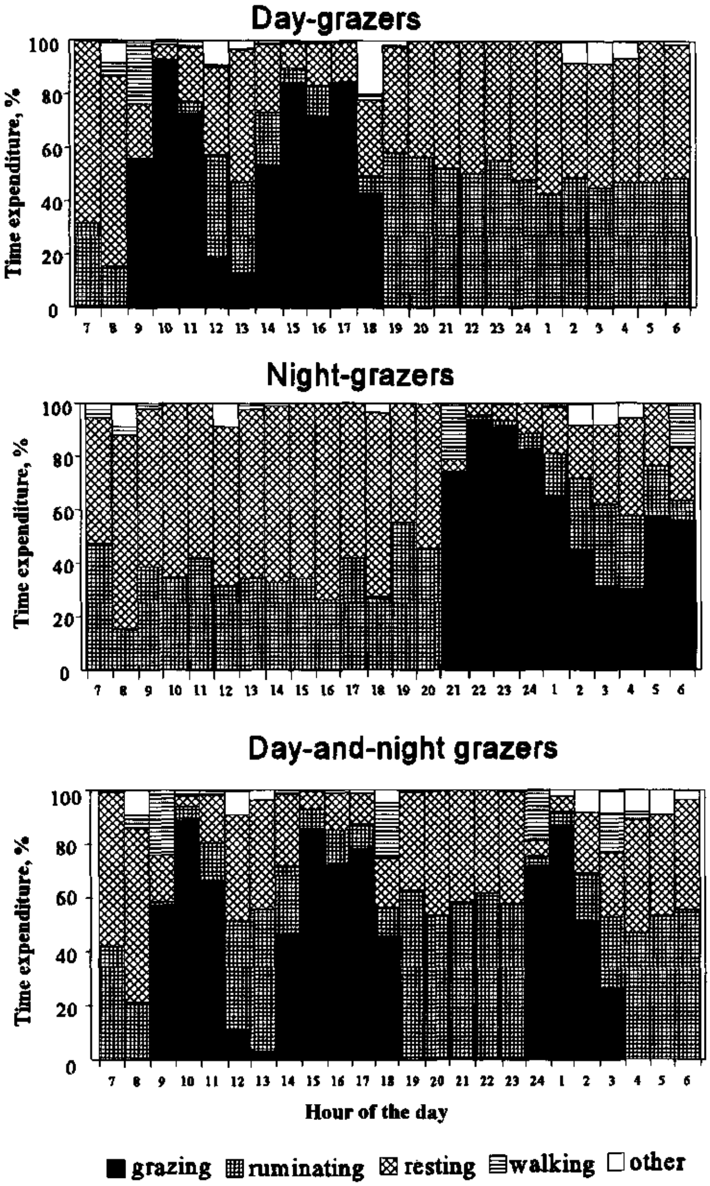

Figure 1. Hourly distribution of time expenditure for different activities by day, night, and day-and-night grazing steers in the dry season in the Sahel.

grazers were 9.3, 6.9 and 10.3 g DM kg^{-1} BW d^{-1} (SEM=0.7), respectively. In week 8 (SEM=0.6), day-grazers excreted 7.6 g DM kg^{-1} BW d^{-1}, the faecal output by night-grazers was 6.9 g DM kg^{-1} BW d^{-1} and day-and-night grazers voided 8.3 g DM kg^{-1} BW d^{-1}. A significant ($P<0.05$) decrease in faecal excretion was observed in day-grazers, and day-and-night grazers as the season progressed, whereas that of night-grazers remained essentially the same.

Average weight changes (g d^{-1}, SEM=62) was -435 for day-grazers, -548 for night-grazers and -239 for day-and-night grazers. There was no significant difference ($P>0.05$) in weight changes between day-grazers and night-grazers.

Discussion

The results on diet (extrusa) quality show that the time (day or night) of grazing had no significant influence on dietary selection, which supports the findings by Arnold (1966) that sight does not play a major role in the selection of plant parts by grazing animals. Similar results were observed by Fernández-Rivera et al. (1998). However, there may be differences between the quality of diet selected during the day and at night if the grazing sites and species composition are different, which is often the case when the animals are herded during night grazing. The declining quality of the diet selected as the

Table 6. Water consumption by day, night and, day-and-night grazing steers in the dry season in the Sahel.

Water intake	Day	Night	Day-and-night	SEM
Week 4:				
l $animal^{-1}$ d^{-1} #	36.0 †	22.7	35.5 ‡	1.5
l kg^{-1} forage DM #	5.1	4.4	4.9	0.2
ml kg^{-1} BW d^{-1} #	100 †	62	105 ‡	5
Week 8:				
l $animal^{-1}$ d^{-1} #	27.1 †	19.9	27.6 ‡	1.1
l kg^{-1} forage DM #	5.5	4.8	5.3	0.3
ml kg^{-1} BW d^{-1} #	80 †	59	82 ‡	3

Day vs night, $P<0.05$.
† Values in Week 4 vs Week 8, $P<0.05$ for the same variable for day grazing steers.
‡ Values in Week 4 vs Week 8, $P<0.05$ for the same variable for day-and-night grazing steers.

season progressed, as observed in this study, has also been reported by Schlecht (1995) for steers and by Becker et al. (1996) for zebu cows grazing natural pastures in the region. Nitrogen concentration (7.1 to 9.0 g kg^{-1} DM) in the diet selected was similar to values reported in the dry season by Pratchett et al. (1977) in Botswana (5.7% CP) and Schlecht (1995) in Mali (53 to 82 g CP kg^{-1} OM) and Becker et al. (1996) in Niger (64 to 75 g CP kg^{-1} OM) for extrusa samples taken in the same season. The digestibility of OM (444 to 469 g kg^{-1} DM) was similar to that observed by the latter authors and by Fernández-Rivera et al. (1998) in the region.

Regardless of the time of grazing, the steers spent about 60% of the time allowed for grazing for eating (i.e. prehension, mastication, and searching for food). The actual grazing times of 5.9, 6.3 and 7.9 hours for day, night, and day-and-night grazing, respectively, compare well with reported values in the dry season of 6.3 h for a day grazing herd in Kenya by Coppock et al. (1988); 7 to 8 h for day-and-night grazers in Uganda by Harker et al. (1954) and 7.4 to 10.4 h reported by Dicko-Touré (1980) for day-and-night grazers in Mali. The ruminating time (6.5 to 7.7 h) also agrees with those reported by Dicko-Touré (1980) and Harker et al. (1954). Night-grazers spent less time ruminating than either day-grazers or day-and-night grazers, because they had a lower forage intake. This might also be associated with the natural inclination to ruminate in the night. The lower walking time for steers that grazed in the night compared to the other groups, even though they grazed in the same pasture, supports the findings of Arnold (1966) that sight impairment (poor visibility) causes orientation problems, which limits the area for selective grazing by the animals. The cost of grazing in the night, in addition to day grazing is a reduction in resting time as observed for day-and-night grazers. The general pattern of two grazing periods during the day, separated by a mid-day rest observed in day-grazers, and day-and-night grazers has also been reported by Coppock et al. (1988) for Turkana cattle in Kenya. Night-grazers had a longer initial grazing period (4.5 vs 2.7 h) than day-grazers, probably because they were not constrained by heat and high radiation. Resting between the grazing periods by night-grazers may likely be induced by rumen fill or fatigue. Similar findings were reported by Fernández-Rivera et al. (1998) in a preliminary study on nocturnal grazing by cattle in the region.

Forage intake, in both weeks 4 and 8, was lower for night-grazers than day-grazers, which supports previous findings by Fernández-Rivera et al. (1998). This was due to a slow intake rate. Forage intake by day-grazers (64.6 g OM $kg^{-0.75}$ BW), and day-and-night grazers (69.0 g) in week 4 falls within the range of 63 to 83 g reported by Schlecht (1995) for unsupplemented steers in Mali and the values reported by Becker et al. (1996) for unsupplemented cows in Niger. The intake values in week 8, however, are lower than those reported by these authors. Day-and-night grazers spent longer time eating than day-grazers but intake was not different. This means that in the day-and-night grazing group, intake (and intake rate) during the day decreased due to night grazing. The faecal excretion values found in this study (6.3 to 11.0 g DM kg^{-1} BW d^{-1}) is similar to those reported by Schlecht (1995). Collectable manure, i.e. the amount of faeces excreted while not in the pastures (manure excreted while in the corralling site), was higher than the faeces deposited in the rangelands by day-grazers (week 4: 1786 vs 1521, week 8: 1322 vs 1236 g DM $animal^{-1}$ d^{-1}). The reverse was the case for the animals that grazed in the night, i.e. night-grazers (week 4: 1058 vs 1385, week 8: 953 vs 1304 g DM $animal^{-1}$ d^{-1}) and day-and-night grazers (week 4: 1126 vs 2326, week 8: 932 vs 1836 g DM $animal^{-1}$ d^{-1}). This shows that more manure could be collected from animals that did not graze in the night compared to those that did. The amounts of collectable manure estimated in this study fall within the range of 600 to 1500 g DM TLU^{-1} (TLU is Tropical Livestock Unit, animal of 250 kg body weight) reported by Khombe et al. (1992) and Fernández-Rivera et al. (1995).

Consumption of water relative to forage intake (l kg^{-1} forage DM) found in this study agrees with the value of 4.5 l kg^{-1} forage DM reported by King (1983). The day, and day-and-night grazers, that consumed more forage drank more water than the night-grazers. High water consumption by the former could also be associated with high temperatures during the day, as reported by Fernández-Rivera et al. (1998), Nicholson (1987) and King (1983), the latter suggesting an extra water cost of 0.35 l km^{-1} for walking in high solar heat. The range in water consumption (56 to 110 ml kg^{-1} BW d^{-1}) observed in this study is below the theoretical maximum (160 ml kg^{-1} BW d^{-1}) suggested by King (1983) for cattle grazing tropical pastures. The lower water intake observed in the second period of measurement (week 8) could be attributed to an unexpected rainfall during the period and the concomitant fall in daily temperature for some days and the low ingestion of forage. Low water consumption by the night-grazers observed in this study and the previous one (Fernández-Rivera et al., 1998) suggests that during a period of water scarcity, the water needs of grazing cattle could be reduced if nocturnal grazing is practiced without day grazing and the animals are restricted and protected from sunlight during the day.

Steers that grazed in the day-and-night had lower weight loss (239 g d^{-1}) than either day-grazers (435 g d^{-1}) or night-grazers (548 g d^{-1}). Similar results were reported by Wigg and Owen (1973) and Khombe et al. (1992) for steers that grazed day and night. These findings and that of the present study show that grazing exclusively in the night cannot substitute for day grazing. It rather complements day grazing and leads to better animal performance especially in the dry season.

The results also show that the traditional practice of night corralling (i.e. no night grazing) of cattle in West African Sahel put a nutritional stress on the animals (by decreasing forage intake), thereby increasing weight losses especially in the dry season. It also increases the needs for supplementation. To resolve the conflict between night grazing and night corralling, it is necessary to determine the optimum use of the animal's time for grazing and manuring. Therefore, further research on combinations of timing (day and/ or night) and duration of grazing is needed to identify practical and feasible recommendations on how to resolve the conflict.

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Chapter 3

Effect of timing and duration of grazing on nutrition and performance of cattle. I. Diet selection, weight changes and faecal output

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Submitted to Journal of Animal Science

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Abstract

Sixty-four Azawak male calves were allotted to eight treatments (T) in each of two trials to study the effect of timing (day and (or) night) and duration of grazing on cattle's diet selection, weight changes and faecal output. Grazing time during the day was 6 h for T 1, 2 and 3; 9 h for T 4, 5 and 6; and 12 h for T 7 and 8. Night grazing time was 0 h for T 1, 4 and 7; 3 h for T 2, 5 and 8; and 6 h for T 3 and 6. The two trials were carried out from July 1995 to May 1996 covering the wet (WS), early dry (EDS) and late dry (LDS) seasons. Eight esophageally fistulated steers were used in a cross-over design to sample the diet selected by day-grazers (D1) and by day-and-night grazers during the day (D2) and at night (N2). Animals were weighed for three consecutive days every two weeks. Faecal output was collected with faecal bags for 9 days. In WS there were no differences ($P>0.05$) in the quality of the diet (extrusa) selected for D1, D2 and N2. However, in EDS and LDS day-and-night grazers selected a diet of lower ($P<0.05$) NDF and ADF (g kg^{-1} DM) content during the day than day-grazers (in EDS, NDF: 576 vs 592, SEM=13; ADF: 451 vs 465, SEM=10; in LDS, NDF: 732 vs 746, SEM=4; ADF: 570 vs 582, SEM=4). In LDS, crude protein content for D1 was lower than for D2 (73 vs 79, SEM=2, $P<0.05$). In WS, EDS and LDS, there were no differences in *in vitro* organic matter digestibility of the diet selected by day-grazers and by day-and-night grazers. In WS, an additional 6 h of night grazing increased average daily gain (ADG) by 92 g d^{-1} ($P<0.05$). An interaction between day and night grazing times on ADG was observed in the wet season but not in the dry season. Faecal output increased with increase in total grazing time. However, there were no differences ($P>0.05$) in nitrogen and phosphorus concentration (g kg^{-1} DM) in faeces between day-and-night grazers and day-grazers (in WS, N: 26.7 vs 27.3, SEM=0.8; P: 5.5 vs 5.5, SEM=0.3; in EDS, N: 16.6 vs 16.5, SEM=0.7; P: 2.4 vs 2.4, SEM=0.1; in LDS, N: 13.9 vs 14.0, SEM=0.2; P: 1.9 vs 1.8, SEM=0.7). Across treatments, more faeces were voided per kg of live weight in the dry season than in the wet season. These results suggest that the quality of the diet selected during the day and at night was not significantly different in all seasons. However, during the dry season there was a trend for day-and-night grazers to be more selective during the day than day-grazers. Allowing additional grazing time during the night led to better animal performance, particularly in the dry season.

Key Words: Cattle, Diet selectivity, Animal performance, Night grazing, Sahelian rangelands

Introduction

Management practices that affect grazing time are likely to influence forage consumption and consequently performance of grazing cattle. In the West African Sahel, ruminants are generally corralled overnight to collect manure (Powell et al., 1996). Alternatively, they may be allowed to graze during the night, especially at the end of the dry season (Breman et al., 1978; Dicko and Sangaré, 1986). In addition to management related factors, forage availability and perhaps, quality also affect grazing time. In general, time spent grazing increases as quantity and quality of available forage decrease (Arnold, 1960; Dicko-Touré, 1980).

Wigg and Owen (1973) and Ayantunde et al. (1998) showed that allowing day grazing cattle additional grazing time during the night improved animal performance. Preliminary studies on night grazing by Fernández-Rivera et al. (1998) and Ayantunde et al. (1998) suggest that diet selection by cattle is little or not affected by timing (day or night) of grazing. Night grazing may influence not only animal nutrition but also the spatial distribution of nutrients excreted through faeces and urine. Thus, studies on timing and duration of grazing by cattle can lead to a better understanding of nutrient constraints and cattle's role in the transfer of nutrients across the landscape. The objective of this study was to determine the effect of timing (day and (or) night) and duration of grazing on cattle's diet selection, weight changes and faecal excretion.

Materials and Methods

Study site

Two grazing trials were carried out between July 1995 and May 1996 in Toukounous (Lat. 14° 30' N and Long. 3° 17' E), Niger. Trial 1 was conducted between July and November 1995 and Trial 2 between February and May 1996. Both trials included the same experimental treatments and design but Trial 1 was executed during the period of the year when forage availability is highest covering wet (WS) and early dry (EDS) seasons, whereas Trial 2 was conducted when forage availability is low (late dry season, LDS). For simplicity, these seasons are referred to in this paper as "wet" (WS) and "dry" seasons (DS).

Animals and treatments

Sixty-four Azawak male calves with an average body weight of 222 (SD=78) and 274 (SD=75) kg in trials 1 and 2 respectively were randomly allotted to 8 treatments defined by different combinations of timing (day and (or) night) and duration of grazing (Table 1). Animals grazed in the same paddock either during day and night or during the day only according to their treatments. After returning from the pasture the animals were

Table 1. Treatments and grazing schedules.

Treatment	Grazing time (h)		Total duration (h)	Grazing schedule	
	Day	Night		Day (h)	Night (h)
1	6	0	6	1200 -1800	-
2	6	3	9	1200 - 1800	0200 - 0500
3	6	6	12	1200 - 1800	2300 - 0500
4	9	0	9	0900 - 1800	-
5	9	3	12	0900 - 1800	0200 - 0500
6	9	6	15	0900 - 1800	2300 - 0500
7	12	0	12	0600 - 1800	-
8	12	3	15	0600 - 1800	0200 - 0500

confined in a barn located about 1 km from the experimental paddock. The pasture grazed was dominated by annual grasses, namely *Brachiara xantholeuca*, *Cenchrus biflorus*, *Schoenefeldia gracilis* and forbs mainly *Indigofera senegalensis*, *Sesbania leptocarpa* and *Corchorus olitorius*.

Diet selection

In both experiments, eight esophageally fistulated steers of the same breed and age as the intact animals were randomly divided into two groups and were used in a cross-over design for sampling the diet selected during the day and at night. One group grazed during the day only (0900 to 1800 h) while the second group grazed during day and night (0900 to 1800 h and 2300 to 0500 h). Samples of the diet selected (extrusa) by the day-grazers (D1) and by day-and-night grazers during the day (D2) and at night (N2) were collected in August (WS) and November (EDS) 1995 in trial 1 and in March and May (LDS) 1996 in trial 2. During the collection period, extrusa samples were collected during the day at 1000 and 1500 h from both groups and at night at 2400 and 0300 h from the day-and-night grazing group. In each season, after a three-day collection period, the day-grazing group was switched to day-and-night grazing and the day-and-night group to day-grazing. After switching, the animals were allowed 10 days for adaptation, after which extrusa samples were collected for a second period of three days. The extrusa samples were put in ice and subsequently frozen until they were processed. Esophageal samples of each collection period were composited per time of collection and animal, dried at 55°C and ground to pass 1 mm screen for laboratory analyses. They were analyzed for dry matter (DM), organic matter (OM), nitrogen (N), ashless neutral detergent fiber

(NDF), ashless acid detergent fiber (ADF), ashless lignin (Van Soest et al., 1991) and crude protein was calculated as 6.25 x N. Hemicellulose and cellulose were calculated as the differences NDF - ADF and ADF - lignin respectively. Organic matter digestibility (OMD) was determined by the *in vitro* gas production technique calibrated with standards obtained *in vivo* (Menke et al., 1979).

Faecal output

In August and November 1995 and in March and May 1996, the sixty four calves were fitted with faecal collection bags for total collection. In each collection period, the animals were accustomed to carrying the bags for 7 to 10 days before the nine days of faecal collection. Because of the relatively high number of animals, faeces were collected in two lots each including four animals per treatment. The bags were emptied in the morning and evening before and after day grazing. The faeces were weighed immediately after collection and 10% of the fresh faeces were taken and sun-dried for each steer, collection day and collection time (morning and evening). The sun-dried samples for the nine-day collection periods were weighed, bulked, pounded, mixed and sub-sampled per animal. The sub-samples were ground to pass 1 mm screen for determination of DM, OM, N and P concentration.

Collectable manure

Collectable manure is defined as the amount of faeces excreted while not in the pasture, i.e. the manure that could be collected through its deposition while cattle are corralled on cropland. For the animals that did not graze at night (day-grazers), the amount of faeces (dry matter) excreted while resting at the camping site, i.e. the faecal output collected before day grazing started was the amount of collectable manure. For the animals that grazed during the night, the difference between the amount of faeces excreted during the night (which was measured) and the faeces excreted while grazing during the night was assumed to be the collectable manure. The amount of faeces excreted while grazing during the night was calculated as the product of faecal excretion rate per hour and the number of hours of night grazing. The excretion rate per hour of day grazing was assumed to be valid for the night. Faecal N and P that could be collected for manuring was calculated as the product of estimated collectable manure and the concentration of N and P (g kg^{-1} DM) in faeces.

Body weight (BW)

Animals were weighed every two weeks for three consecutive days during the two trials.

Statistical Analyses

Data analyses were performed separately for each trial with SAS (1987) using the General Linear Model (GLM) procedures for the variance and regression analyses. Average daily gain (ADG) per animal was estimated by regression of individual BW data on time. Weight changes data (ADG) were analyzed using a model including the effect of initial weight as covariate, the main effect of day grazing time (HD) and night grazing time (HN), and the interaction HD x HN. In the late dry season, HD x HN interaction was removed from the model because of its non-significant effect (P>0.05). Data on faecal output and collectable manure were analyzed using a model including the effects of HD, HN and HD x HN interaction. These analyses were performed considering HD and HN as continuous variables (linear and quadratic effect) and also as classes. In the latter case, multiple comparisons of treatment means were performed with contrasts. Contrasts of interest were: 1. Day vs Day + 3 h night-grazers (T 1, 4, 7 vs 2, 5, 8); 2. Day vs Day + 6 h night-grazers (T 1, 4 vs 3, 6); 3. Six vs 9 h day grazing (T 1, 2, 3 vs 4, 5, 6); 4. Six vs 12 h day grazing (T 1, 2 vs 7, 8); 5. Nine vs 12 h day grazing (T 4, 5 vs 7, 8). Seasonal variation in faecal output and collectable manure across treatments was examined by using a model including the effects of season, treatment and season x treatment interaction. The hypothesis that diet selection differs during the day and at night was tested with a model including the effect of period, time of collection (i.e. day or night) and hour of collection nested within time of collection. The hypothesis that night grazing affects diet selection during the day was tested by including in the model the effect of period of collection (PER), group of the esophageally fistulated steers (GP), hour of collection (HR) and GP x HR, using only the data collected during the day. Seasonal variation in diet selection was tested with a model that included the effects of season, GP and season x GP interaction.

Results

Diet quality

In all seasons the chemical composition of the diet selected during the day (D2) by day-and-night grazers was not different (P>0.05) from that selected at night (N2). However, in the wet season ADF of extrusa selected at night tended to be higher than that selected during the day (414 vs 391, SEM=8). Differences (P<0.05) in OM content were observed in the early and late dry seasons, possibly reflecting variation in sand contamination of extrusa. Time of grazing (day or night) had no influence on CP and *in vitro* OMD in all seasons (Table 2). No differences were observed in the diet selected during the day between animals that were allowed to graze during the night (D2) and those that were not (D1). However, during the dry season there was a trend for day-and-night grazers to be more selective (i.e. ingesting a diet of better quality) during the day

Table 2. Diet (extrusa) quality (g kg^{-1} DM) selected by day-grazing (D1) and day-and-night grazing esophageally fistulated steers during the day (D2) and at night (N2).

Component	Wet season				Early dry season				Late dry season			
	D1	D2	N2	SEM	D1	D2	N2	SEM	D1	D2	N2	SEM
Organic matter	802	797	785	7	830	827†	846†	6	854	853†	830†	4
Crude protein	199	194	192	6	115	121	119	6	73‡	79‡	80	2
NDF	581	572	584	7	592‡	576‡	580	13	746‡	732‡	729	4
ADF	415	391†	414†	8	465‡	451‡	459	10	582‡	570‡	577	4
Lignin	131	131	134	4	141	136	139	8	152	143†	160†	5
Hemicellulose	166	181	170	10	127	125	120	5	164	162	152	3
Cellulose	284	273	280	7	324	315	321	10	431	424	418	5
OMD	608	622	635	10	557	558	543	11	510	515	523	10

‡D1 vs D2, $P<0.05$. †D2 vs N2, $P<0.05$

than animals that grazed only during the day (Table 2). For instance, in EDS and LDS the day-and-night grazers selected a diet of lower ($P<0.05$) NDF and ADF (g kg^{-1} DM) content during the day (D2) than the day-grazers (in EDS, NDF: 576 vs 592, SEM=13; ADF: 451 vs 465, SEM=10; in LDS, NDF: 732 vs 746, SEM=4; ADF: 570 vs 582, SEM=4). In LDS, crude protein content for D2 was higher than for D1 (79 vs 73, SEM=2, $P<0.05$). In all seasons, there were no differences in *in vitro* OMD, hemicellulose and cellulose concentration between the diet selected by day-grazers and day-and-night grazers. As the season progressed, CP and OMD in the diet selected by both groups declined ($P<0.05$), while the fibre components (NDF, ADF, lignin and cellulose) increased ($P<0.05$).

Weight changes

In both trials, there was a positive relationship between grazing time and weight gain (Figure 1). In the season with high forage availability, the treatment with 9 h day grazing time and 6 h night grazing time had the highest ADG (539 gd^{-1}), while animals grazing for 6h during the day and no grazing at night had the lowest ADG (368 g d^{-1}). Given the same day grazing time, an increase in night grazing time resulted in higher weight gains in the wet season (trial 1) and lower weight losses in the dry season (trial 2). In trial 1, ADG (SEM=35) was 368 for 6 h, 480 for 9 h, 520 for 12 h and 539 g d^{-1} for 15 h grazing time. In trial 2, ADG (SEM=25) was -288 for 6 h, -238 for 9 h, -185 for 12h and -136 g d^{-1} for 15 h. In the wet season, an additional 6 h of night grazing gave

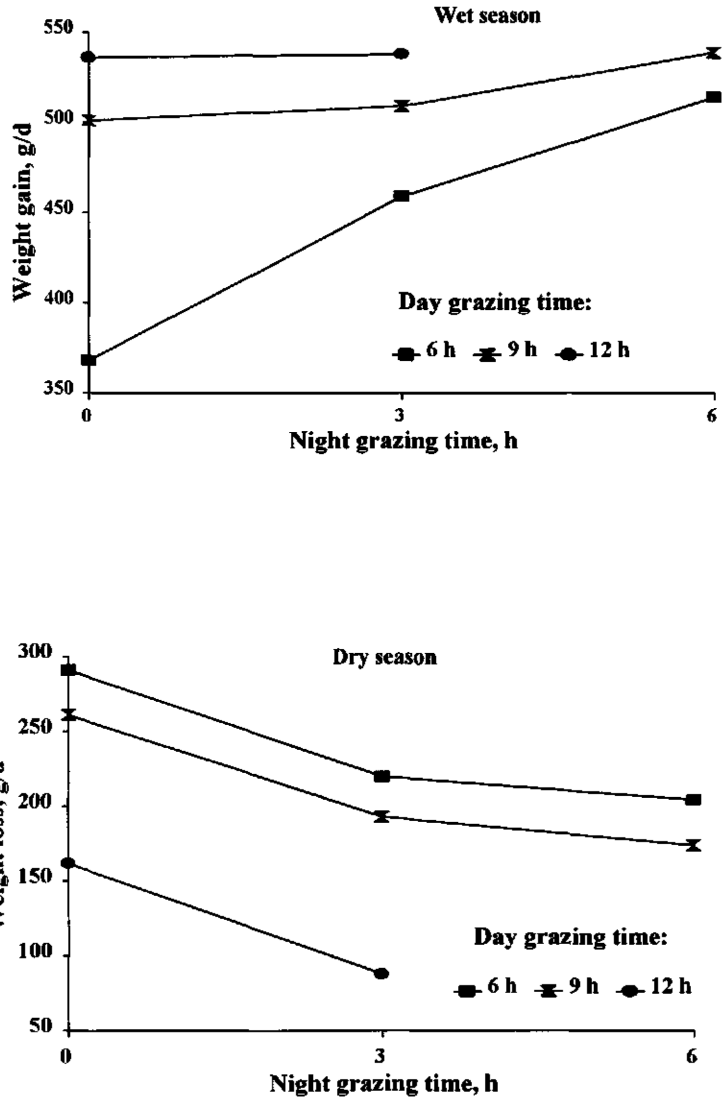

Figure 1. Weight changes in the wet (SEM=35) and dry (SEM=25) seasons for different combinations of day and night grazing times.

(in wet and early dry seasons) of the diet selected by day-grazers and that selected during the day by day-and-night grazers suggests that night grazing has no effect on diet selection during the day.

Table 3. Faecal dry matter (DM), nitrogen (N) and phosphorus (P) excretion by day and (or) night grazing cattle in the wet, early dry and late dry seasons.

Treatment (T)	1	2	3	4	5	6	7	8	SEM	Contrast[a]
Day grazing time, h	6	6	6	9	9	9	12	12		
Night grazing time, h	0	3	6	0	3	6	0	3		
Wet season:										
g DM animal^{-1} d^{-1}	1629	1819	1956	1742	1932	2206	1776	2041	134	2
g DM kg BW d^{-1}	7.1	7.7	8.2	7.3	7.8	9.0	7.6	8.7	0.5	2
g DM kg BW$^{-0.75}$ d^{-1}	27.5	30.1	32.1	28.7	30.8	35.4	29.4	33.9	1.4	1, 2, 4
g N kg^{-1} DM	29.4	30.0	26.8	26.8	25.7	26.7	25.6	24.5	0.8	3, 4
g P kg^{-1} DM	5.8	6.2	5.4	5.2	5.3	5.1	5.6	5.6	0.3	3
Early dry season:										
g DM animal^{-1} d^{-1}	2120	2557	2871	2388	2650	3070	2562	2825	207	2
g DM kg BW d^{-1}	8.4	9.7	9.9	8.9	9.9	11.1	9.3	10.6	0.3	1,2,3,4
g DM kg BW$^{-0.75}$ d^{-1}	33.3	38.7	40.7	35.8	39.7	45.1	37.7	42.7	1.2	1,2,3,4,5
g N kg^{-1} DM	16.2	16.4	15.7	17.2	17.4	16.5	16.2	17.3	0.7	NS[b]
g P kg^{-1} DM	2.6	2.4	2.3	2.4	2.5	2.3	2.3	2.5	0.1	NS[b]
Late dry season:										
g DM animal^{-1} d^{-1}	2234	2575	2739	2397	2698	2979	2623	3106	145	1, 2, 4, 5
g DM kg BW d^{-1}	9.0	9.9	10.5	9.5	10.1	11.1	10.0	10.6	0.3	1,2,3,4
g DM kg BW$^{-0.75}$ d^{-1}	35.6	39.6	41.8	37.7	40.7	44.7	40.0	43.8	1.0	1,2,3,4,5
g N kg^{-1} DM	14.6	14.4	13.8	13.6	13.5	13.7	13.9	14.1	0.2	3, 4, 5
g P kg^{-1} DM	1.8	1.8	1.9	1.9	1.9	2.0	1.9	1.8	0.7	3, 5

[a]Contrast (P<0.05), Contrast 1 = T 1, 4, 7 vs 2, 3, 8; 2 = T 1, 4 vs 3, 6; 3 = T 1, 2, 3 vs 4, 5, 6; 4 = T 1, 2 vs 7, 8; 5 = T 4, 5 vs 7, 8.
[b]NS = None of the contrasts was significant (P>0.05).

Table 4. Collectable amounts of faecal dry matter (DM), nitrogen (N) and phosphorus (P) by day and (or) night grazing cattle in the wet, early dry and late dry seasons.

Treatment (T)	1	2	3	4	5	6	7	8	SEM	Contrast[a]
Day grazing time, h	6	6	6	9	9	9	12	12		
Night grazing time, h	0	3	6	0	3	6	0	3		
Wet season:										
g DM animal^{-1} d^{-1}	955	712	433	813	649	372	801	746	57	1,2
g DM kg BW d^{-1}	4.3	3.0	2.0	3.4	2.6	1.5	3.4	3.1	0.2	1,2,3
g DM kg BW$^{-0.75}$ d^{-1}	16.3	11.8	7.51	13.6	10.4	6.0	13.3	12.2	0.7	1,2,3
g N animal^{-1} d^{-1}	28.2	21.4	11.9	21.9	16.8	9.9	20.2	18.3	1.7	1,2,3,4
g P animal^{-1} d^{-1}	5.7	4.5	2.4	4.1	3.5	1.9	4.6	4.2	0.5	2,3
Early dry season:										
g DM animal^{-1} d^{-1}	1344	1154	847	1230	955	634	1261	1071	85	1,2,3
g DM kg BW d^{-1}	5.4	4.5	3.0	4.6	3.6	2.3	4.6	4.0	0.2	1,2,3,4
g DM kg BW$^{-0.75}$ d^{-1}	21.2	17.8	12.4	18.4	14.3	9.4	18.5	16.2	0.7	1,2,3,4
g N animal^{-1} d^{-1}	21.6	19.0	13.3	20.8	16.3	10.4	20.6	18.3	1.4	1,2
g P animal^{-1} d^{-1}	3.6	2.9	1.9	3.0	2.4	1.4	2.9	2.7	0.2	1,2,3
Late dry season:										
g DM animal^{-1} d^{-1}	1331	978	534	1142	840	496	1216	1082	54	1,2,3,5
g DM kg BW d^{-1}	5.4	3.9	2.1	4.5	3.2	1.8	4.6	3.7	0.2	1,2,3,4,5
g DM kg BW$^{-0.75}$ d^{-1}	21.3	15.4	8.4	17.9	12.7	17.4	18.6	15.1	0.5	1,2,3,4,5
g N animal^{-1} d^{-1}	19.5	14.1	7.4	15.5	11.3	6.9	16.9	15.1	0.7	1,2,3,5
g P animal^{-1} d^{-1}	2.4	1.8	1.0	2.2	1.6	1.0	2.3	1.9	0.2	1,2

[a]Contrast ($P<0.05$), Contrast 1 = T 1, 4, 7 vs 2, 3, 8; 2 = T 1, 4 vs 3, 6; 3 = T 1, 2, 3 vs 4, 5, 6; 4 = T 1, 2 vs 7, 8; 5 = T 4, 5 vs 7, 8.

However, during the late dry season there was a trend for day-and-night grazers to be more selective during the day than day-grazers. This may be due to a different intensity of browsing of woody forage which may contribute 22 to 64% of the ingested crude protein by cattle grazing on Sahelian rangelands in the late dry season (Ickowicz, 1995).

The sharp decline in crude protein of the diet selected as the season progresses, observed in this study, has also been reported by Schlecht (1995) in Mali. The relatively low variation in digestibility of the forage selected across seasons was also reported by Schlecht (1995). This is often typical of annual grasses dominated vegetation, whose fiber characteristics are essentially unchanged in most of the dry season because they mature rapidly and uniformly (Coppock et al., 1987). The sharp decline in crude protein between the wet and early dry season compared to the late dry season is probably due to shedding of leaves and fruits and dispersal of seeds in the early dry season (October and November), especially by dicotyledonous plants.

In this study, the crude protein content and organic matter digestibility of the diet selected are consistently above 7 and 48% respectively, suggested as the minimum values for a maintenance ration of grazing cattle (Breman and De Ridder, 1991), assuming feed availability is not a constraint. This is not consistent with the general assumption that on tropical pastures in regions with more than 250 mm of annual rainfall, poor animal nutrition is mainly due to poor forage quality (Breman and De Wit, 1983). Schlecht (1995) found a trend in quality (crude protein and digestibility) of diet selected by unsupplemented grazing cattle in Mali similar to the one in this study. In the present study, the animals were able to select relatively good quality (in terms of crude protein and digestibility) diet, even in the late dry season due to browsing of woody forage, which is moderately available in the experimental paddocks. In addition, the vegetation of the paddocks is dominated by annual grasses, which are highly palatable and nutritively above average.

Recorded weight changes in both wet and dry seasons demonstrate that allowing additional grazing time at night improves animal performance. With long day grazing time (up to 10 h) in the wet season, night grazing is less critical for animal performance. This is further demonstrated by the increasing night grazing time required to compensate for a one hour reduction in day grazing time as the latter increases. However, night grazing may still be critical in the wet season for better animal performance in the West African Sahel because most herders allow their herds to graze for 6 to 9 h during the day (Dicko and Sangarè, 1986). In the dry season, for a given ADG a one-hour reduction in day grazing time, irrespective of its length, was compensated for by 1.5 h night grazing time. This indicates that night grazing is a perfect complement to day grazing for better animal performance, especially in the late dry season.

Across treatments, the ADG values found in this study are consistent with the range of 370 to 500 g d^{-1} reported by Achard and Chanono (1995) for free-ranging bulls of the same breed in the wet seasons of 1987, 1989 and 1991. Average daily gain of day-grazers in this study is also the same as that of unsupplemented day grazing bulls in Mali (Schlecht, 1995) for wet and dry seasons. The performance of day-and-night grazers in the present study is, however, better than ADG of -240±61 g d^{-1} for day grazing bulls in the dry season of 1991 reported by the same author. Similar performance was reported by Wigg and Owen (1973) and Ayantunde et al. (1998) for steers that grazed during day and night.

Higher faecal output by day-and-night grazers compared with day-grazers observed in this study is consistent with results from Ayantunde et al. (1998). Lower faecal excretion in the wet season is due to a significantly higher dietary digestible organic matter content at a comparable level of intake. This suggests that faecal output is not constant over a wide range of digestibilities as assumed by Kahn and Spedding (1984). Non-significant differences in faecal nitrogen and phosphorus between day-grazers and day-and-night grazers suggest that concentrations of N and P in faeces are not affected by night grazing. This can also be attributed to little or no difference in the quality of the diet selected by day- and day-and-night grazers. The declining trend in faecal N and P with the advancement of the season is a reflection of fall in digestibility of the forage (Cordova et al., 1978).

More faecal dry matter, N, and P could be collected for manure depositing on crop fields from animals that did not graze during the night. The amount of collectable manure estimated in this study falls within the range of 600 to 1500 g DM TLU^{-1} (TLU is Tropical Livestock Unit, a 'standard' animal of 250 kg body weight) reported by Fernández-Rivera et al. (1995) when cattle were used for manuring for 14 h d^{-1}. Also, the amount of faecal N that could be collected for manuring in the dry season agrees with the value of 15 g TLU^{-1} reported by Schlecht (1995) as faecal excretion during the night. The actual amount of N that can be collected on croplands will exceed the values estimated in this study, when urinary N is included. The need for depositing manure on crop fields in the dry season necessitates night corralling of the animals, a common practice in the Sahel, but this reduces available grazing time and consequently, the amount of forage consumed and weight gain, as found in this study. For example, with the animals that had the shortest grazing time (6 h only in the day) the collection of manure was highest (Table 4) but ADG was lowest in both the wet and dry seasons (Figure 1). This indicates that long night corralling has a negative effect on animal performance, particularly in the dry season. The results from this study suggest that the animals can graze during the night for 3 h in addition to at least 9 h during the day and still allow the collection of an appreciable amount of manure (about 1 kg DM d^{-1}).

Implications

This study demonstrates that the quality of the diet selected during the day is not different from that selected at night. Also, night grazing does not affect diet selection during the day in the wet season. However, during the dry season day-and-night grazers tend to be more selective during the day than day-grazers. Allowing additional grazing time during the night improves animal performance in the wet and dry seasons. With long day grazing time in the wet season, night grazing is less critical. In the dry season, night grazing is absolutely essential for better animal performance but this is in conflict with the need for night corralling of cattle to deposit manure on croplands.

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Effect of timing and duration of grazing on nutrition and performance of cattle. II. Eating time, forage and water intake

A.A. Ayantunde, S. Fernández-Rivera, P.H.Y. Hiernaux, H. van Keulen, H.M.J. Udo and M. Chanono

Abstract

Sixty-four Azawak male calves were allotted to eight treatments (T) in each of two trials to study the effect of timing (day and (or) night) and duration of grazing on cattle's forage and water intake and feeding behaviour. Grazing time during the day was 6 h for T1, 2 and 3; 9 h for T4, 5 and 6; 12 h for T7 and 8. Night grazing time was 0 h for T1, 4 and 7; 3 h for T2, 5 and 8; and 6 h for T3 and 6. The two trials were carried out from July 1995 to May 1996 covering the wet (WS), early dry (EDS) and late dry (LDS) seasons. Forage intake was determined from individual data on fecal output and means of extrusa *in vitro* organic matter digestibility. Water intake and eating time were measured in LDS. Eating time was determined by recording animal's activities every 5 min. Total time spent eating increased with increasing total time allowed for grazing. Day-and-night grazers consumed more ($P<0.05$) forage (g DM kg $BW^{-0.75}$ d^{-1}) than day-grazers in all seasons. In WS, forage intake (g DM kg $BW^{-0.75}$ d^{-1}) by day-and-night grazers was 110 compared to 89.7 for day-grazers. Day-and-night grazers consumed 102.2 g DM kg $BW^{-0.75}$ d^{-1} in EDS and 96.9 g DM kg $BW^{-0.75}$ d^{-1} in LDS, whereas day-grazers consumed 91.1 and 82.1 in the same seasons, respectively. In WS, EDS and LDS, increased night grazing time led to an increase ($P<0.05$) in consumption of digestible organic matter. Forage intake increased by 8.8 g DM kg $BW^{-0.75}$ h^{-1} of total duration of grazing in WS (SEM=0.2) and by 8.3 g DM kg $BW^{-0.75}$ h^{-1} in EDS (SEM=0.2), while it increased by 7.8 g DM kg $BW^{-0.75}$ h^{-1} in LDS (SEM=0.1). Water consumption by day-and-night grazers was significantly lower ($P<0.05$) than for day-grazers (4.7 vs 5.3 l kg^{-1} forage DM). The animals consumed 10.5 ml kg BW^{-1} (SEM=0.4) per hour of day grazing and 5.7 ml kg BW^{-1} (SEM=0.9) per hour of night grazing. These results reaffirm that additional grazing time during the night leads to increased forage intake and consequently provides an opportunity for better animal production, especially in the dry seasons when available forage is low.

Key Words: Cattle, Forage intake, Feeding behaviour, Night grazing, Sahelian rangelands

Introduction

Generally, when time available for grazing is not limiting, forage ingestion depends mainly on forage availability and quality. Herd management strongly influences time available for grazing (Bayer, 1986). In the Sahel, corralling grazing ruminants on cultivated land, especially at night, for depositing manure on cropland is a common practice (Powell et al., 1996). This practice is often in conflict with the need for cattle to graze at night particularly as the season progresses from wet to dry, and both forage quantity and quality decrease. In addition to the advantage of increased grazing time, King (1983) reported that night grazing helps to reduce heat stress on the animals. Despite the importance of night grazing or corralling for manuring purpose in the Sahel, information on the potential impact of these practices on cattle nutrition and nutrient cycling in the landscape is limited.

The objective of this study was to determine the effect of timing (day and (or) night) and duration of grazing on cattle's forage and water intake, and eating time.

Materials and Methods

The study location and detail of the experimental design were described by Ayantunde et al. (1998a).

Animals and treatments

Sixty-four Azawak male calves with average body weights of 222 (SD=78) and 274 (SD=75) kg in trial 1 and 2 respectively were randomly allotted to 8 treatments (T) characterised by different timing (day and (or) night) and duration of grazing. Grazing time during the day was 6 h for T 1, 2 and 3; 9 h for T 4, 5 and 6; and 12 h for T 7 and 8. Night grazing time was 0 h for T 1, 4 and 7; 3 h for T 2, 5 and 8; and 6 h for T 3 and 6. Animals grazed in the same paddock either during the day and night or during the day only according to treatment. Additional detail of experimental procedures were given by Ayantunde et al. (1998a).

Forage and water intake

Forage intake was determined from individual data on faecal output and means of extrusa *in vitro* organic matter digestibility for the diet selected by day-grazers and by the day-and-night grazers during the day and at night (Ayantunde et al., 1998a). In the late dry season, water consumption was measured daily during the data collection periods in March and May 1996, when all animals had access to water for 30 min in the morning before day grazing commenced.

Feeding behaviour

Grazing activities were observed in March and May 1996 (trial 2) on four animals selected per treatment every 5 min for 8 days for a length of time defined by their respective treatments. That is, the animals were observed only during the grazing times during the day and at night. The observation was instantaneous and the recording included one of the following activities: prehension, mastication, searching for food, resting (while in the pasture), walking, drinking and others (e.g. fighting). Eating time was defined as the time spent prehending, masticating and searching for food.

Statistical Analyses

Data analyses were performed with SAS (1987) using GLM procedures for the variance and regression analyses. Data on forage and water intake and feeding behavior were analyzed using a model including the effects of day grazing time (HD), night grazing time (HN) and HD x HN. The model for water intake also included body weight of the animals. The quadratic effect of HD was included in the model for feeding behaviour because of its significance. These analyses were also performed considering HD and HN as classes. In this case, multiple comparisons of treatment means were performed by contrasts. Contrasts of interest were: 1. Day vs Day + 3 h night-grazers (T 1, 4, 7 vs 2, 5, 8); 2. Day vs Day + 6 h night-grazers (T 1, 4 vs 3, 6); 3. Six vs 9 h day grazing (T 1, 2, 3 vs 4, 5, 6); 4. Six vs 12 h day grazing (T 1, 2 vs 7, 8); 5. Nine vs 12 h day grazing (T 4, 5 vs 7, 8). Seasonal variation in forage intake by the animals across treatments was examined using a model including the effects of season, treatment and season x treatment interaction.

Results

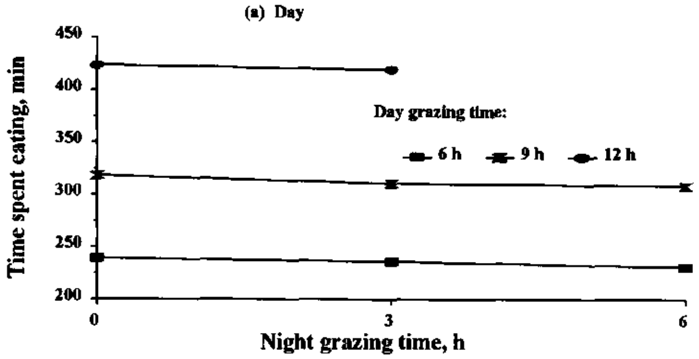
Time spent eating

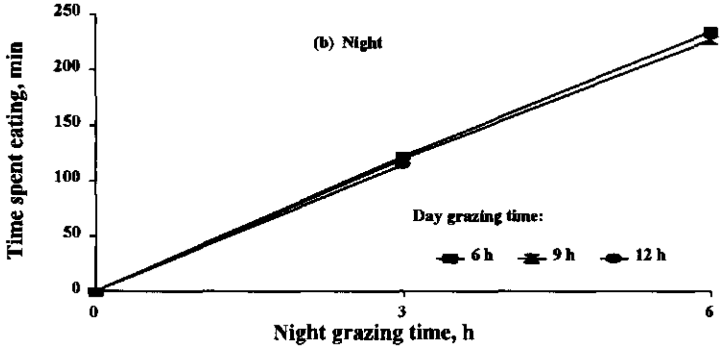
Time spent eating during the day was 239, 236, 231, 318, 310, 309, 423, 419 minutes for T1, 2, 3, 3, 4, 5, 6, 7 and 8 respectively (Figures 1a, b, c). Total time spent eating increased linearly with increasing total time allowed for grazing. Treatments with the same day grazing time (HD) spent almost the same time eating during the day regardless of night grazing time (HN). Increasing day grazing time only resulted in a small non-significant decrease in time spent eating during the night. Animals in the treatment with 6 h total grazing time spent the highest proportion (66 %) of their time eating, whereas the animals in treatments with 15 h total grazing time spent 59 % of their time eating. Time spent eating during the day (EATDAY), at night (EATNITE) and in 24-h period (EATTOT) were best described by the following equations (only parameters that were significant ($P<0.05$) were included in the model):

EATDAY (min) = 40.90 (SEM=1.02) x HD - 0.53 (SEM=0.10) x HD^2, r^2 =0.99
EATNITE (min) = 38.75 (SEM=0.29) x HN, r^2 =0.99
EATTOT (min) = 43.29 (SEM=1.57) x HD - 0.73 (SEM=0.14) x HD^2 + 36.84 (SEM=1.08) x HN, r^2 =0.99

Forage intake

In all seasons (wet, early dry and late dry), day-and-night grazers (T2, 3, 5, 6, 8) consumed more ($P<0.01$) forage than day-grazers (T 1, 4, 7; Table 1 and Figure 2). In the wet season, forage intake (g DM kg $BW^{-0.75}$ d^{-1}) by day-and-night grazers was 110 compared to 89.7 for day-grazers. Day-and-night grazers consumed on average 102.2 g





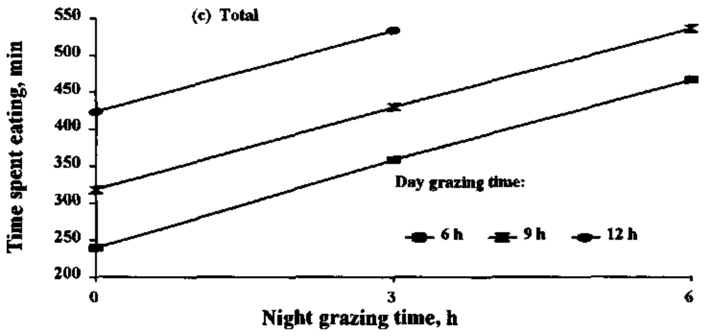


Figure 1. Actual time spent eating (a) during the day (SEM=4), (b) during the night (SEM=3) and (c) in 24-h period (SEM=6) for different combinations of day and night grazing times in the late dry season by day and (or) night grazing cattle.

DM kg $BW^{-0.75}$ d^{-1} in EDS and 96.9 g DM kg $BW^{-0.75}$ d^{-1} in LDS whereas day-grazers consumed 91.1 in EDS and 82.1 in LDS. In all seasons, increased night grazing time resulted in increased ($P<0.05$) consumption of digestible organic matter (Table 1). For instance, in the WS (SEM=2.2) digestible organic matter (DOM) intake was 35.4, 41.3 and 45.7 g DM kg $BW^{-0.75}$ d^{-1} for 0, 3 and 6 h of night grazing respectively. Digestible organic matter intake by all animals was significantly lower ($P<0.05$) in LDS than in WS and EDS. In all seasons forage intake increased with increase in total duration of grazing (Figure 3). For instance, in the WS (SEM=4.5) forage intake was 86.6 for 6 h, 96.0 for 9 h, 101.9 for 12 h and 117.4 g DM kg $BW^{-0.75}$ d^{-1} for 15 h total duration of grazing. As the season progressed, forage intake declined. Intake rate (mg OM $kgBW^{-0.75}$ min^{-1} of eating time) in the late dry season decreased as total grazing time increased. The treatment with shortest total grazing time (6 h) had the highest eating rate

Table 1. Forage dry matter (DM) and digestible organic matter (DOM) intake of day and (or) night grazing cattle in the wet, early dry and late dry season.

Treatment (T)	1	2	3	4	5	6	7	8	SEM	Contrast[a]
Day grazing time, h	6	6	6	9	9	9	12	12		
Night grazing time, h	0	3	6	0	3	6	0	3		
Wet season:										
g DM $animal^{-1}$ d^{-1}	5121	6166	6632	5468	6549	7480	5586	6918	440	1, 2
g DOM $kgBW^{-.75}$ d^{-1}	33.5	38.6	42.6	36.2	40.9	48.7	36.5	44.5	2.2	1, 2, 4
Early dry season:										
g DM $animal^{-1}$ d^{-1}	5423	6314	7091	6109	6544	7580	6554	6975	519	2
g DOM $kgBW^{-.75}$ d^{-1}	36.6	41.3	43.1	39.6	42.9	48.4	40.9	45.3	1.4	1, 2, 3, 4
Late dry season:										
g DM $animal^{-1}$ d^{-1}	4853	5939	6310	5213	6221	6868	5711	7145	341	1, 2, 4, 5
g DOM $kgBW^{-.75}$ d^{-1}	31.0	37.3	38.7	34.4	38.1	41.7	35.8	41.1	1.2	1, 2, 3, 4
Intake rate in late dry season (per min of eating time):										
g DM min^{-1}	20.4	19.3	15.7	16.8	15.5	13.5	14.3	13.2	1.2	2, 3, 4
mg OM $kgBW^{-.75}$ min^{-1}	318	270	215	257	223	194	206	179	9	1, 2, 3, 4,5

[a]Contrast ($P < .05$), Contrast 1 = T 1, 4, 7 vs 2, 5, 8; 2 = T 1, 4 vs 3, 6; 3 = T 1, 2, 3 vs 4, 5, 6; 4 = T 1, 2 vs 7, 8; 5 = T 4, 5 vs 7, 8.

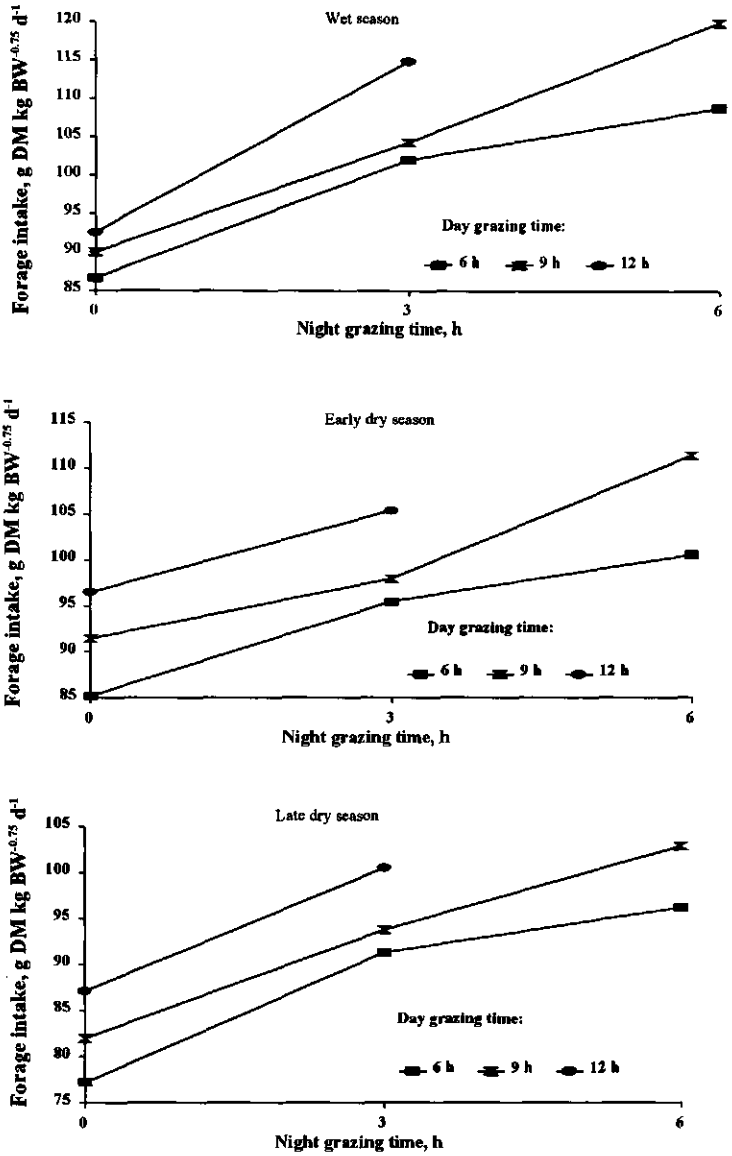


Figure 2. Forage intake for different combinations of day and night grazing times in the wet (SEM=4.5), early dry (SEM=2.9) and late dry (SEM=2.2) seasons by day and/or night grazing cattle.

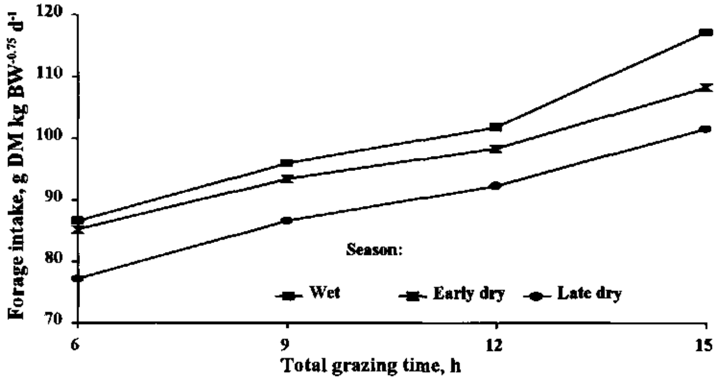


Figure 3. Forage intake for different total grazing times in the wet (SEM=4.5), early dry (SEM=2.9) and late dry (SEM=2.2) seasons by day and/or night grazing cattle.

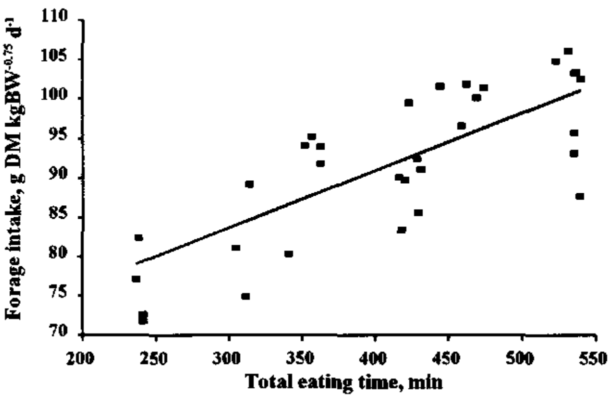


Figure 4. Relationship between forage intake and total eating time (min) by day and/or night grazing cattle in the late dry season.

(318 mg OM kg BW$^{-0.75}$ min^{-1} of eating time). Daily forage intake (g DM kg BW$^{-0.75}$) by the animals increased linearly as total eating time (EATTOT, min) increased (Figure 4):

Intake (g DM kg BW$^{-0.75}$ d^{-1}) = 61.93 (SEM=5.21) + .07 (SEM=0.01) x EATTOT, r^2 =0.36

Table 2. Water intake by day and (or) night grazing cattle in the late dry season.

Treatment (T)	1	2	3	4	5	6	7	8	SEM	Contrast[a]
Day grazing time, h	6	6	6	9	9	9	12	12		
Night grazing time, h	0	3	6	0	3	6	0	3		
l animal^{-1} d^{-1}	27.2	29.4	28.9	27.9	29.9	30.4	29.7	29.1	1.0	2
ml kg BW^{-1} d^{-1}	105	110	111	108	112	115	113	109	4	2
l kg^{-1} forage DM	5.4	4.9	4.6	5.2	4.8	4.5	5.2	4.5	0.3	1, 2

[a]Contrast (P < .05), Contrast 1 = T 1, 4, 7 vs 2, 5, 8; 2 = T 1, 4 vs 3, 6; 3 = T 1, 2, 3 vs 4, 5, 6; 4 = T 1, 2 vs 7, 8; 5 = T 4, 5 vs 7, 8.

Water intake

Water intake (l animal^{-1} d^{-1}) in the late dry season ranged from 27.2 to 30.4 (SEM=1.0; Table 2). Animals that grazed 6 h during the night in addition to day grazing (T3 and 6) drank 2.1 l water more ($P<0.05$) than those that grazed only during the day (T1 and 4). However, there was no significant difference ($P>0.05$) in water intake by the animals that grazed for 3 h during the night in addition to day grazing (T2, 5 and 8) compared with the day-grazers (T1, 4, and 7). Relative to forage intake, water consumption (l kg^{-1} forage DM) by day-and-night grazers was significantly lower ($P<0.05$) than by the day-grazers (4.7 vs 5.3, SEM=0.3). Regression analysis of water intake as dependent variable on HD and HN as independent variables gave:

$$\text{Water intake (ml kg BW}^{-1}\text{ animal}^{-1}\text{ d}^{-1}) = 10.5\ (\text{SEM}=0.4) \times \text{HD} + 5.7\ (\text{SEM}=0.14) \times \text{HN}, \quad r^2 = 0.94$$

Regression analysis of water intake as dependent variable on metabolic weight ($BW^{.75}$) and dry matter intake (DMI, kg DM animal^{-1} d^{-1}) as independent variables showed that the animals drank 492 ml of water per kg DM consumed in addition to 397 ml per kg $BW^{0.75}$:

$$\text{Water intake (ml animal}^{-1}\text{ d}^{-1}) = 397\ (\text{SEM}=34) \times BW^{0.75} + 492\ (\text{SEM}=366) \times \text{DMI}, \quad r^2 = 0.98$$

Discussion

Day-and-night grazers spent an additional 117 and 231 min eating for 3 and 6 h of night grazing. This advantage of additional grazing time during the night has been reported for herded cattle in the subhumid zone of Nigeria (Bayer, 1986), East Africa

(Wigg and Owen, 1973; Nicholson, 1987), and also for free-ranging sheep and cattle in the USA and Australia (Arnold and Dudzinski, 1978; Vallentine, 1990). The small difference in time spent eating during the night for a given night grazing time irrespective of day grazing time may be due to low heat stress during the night, which might have favored the animals to continue eating (King, 1983). Besides, the animals needed to spend long time eating at night in the late dry season (the season of observation) when available forage is low. In the wet season, different results are to be expected since grazing time is inversely related to the availability of forage (Osuji, 1974; SCA, 1991). Day-grazers tried to compensate for their lower total grazing time compared with day-and-night grazers through increased ingestion rate (260 vs 216 mg OM kg $BW^{-0.75}$ min^{-1} of eating time). Eating rate in the treatment with 6 h total grazing time was twice that in the treatment with 15 h total grazing time (318 vs 187 mg OM kg $BW^{-0.75}$ min^{-1}). Similar behavior has been reported for goats that had restricted access to pasture (Romney et al., 1996).

The advantage of increased forage intake through additional grazing time during the night (King, 1983; Ayantunde et al., 1998b) is reaffirmed by the positive relationship between forage intake and grazing time observed in all seasons. Forage consumed (g DM kg $BW^{-0.75}$ d^{-1}) by the animals in this study is comparable to values reported by Schlecht (1995) for unsupplemented grazing bulls in Mali, but is higher than values reported by Fernández-Rivera et al. (1998) for day- and (or) night-grazers in the late dry season at another site in Niger. This may be attributed to differences in herbage mass and species composition of the vegetation between the study sites. The decline in forage intake as the season progresses is an indication of the decrease in forage availability and quality (Ayantunde et al., 1998a). However, forage intake in the early dry season when cattle have access to harvested millet fields in addition to the natural pasture can be higher than in the wet season.

Water consumption in the late dry season by the animals was positively related to forage intake, i.e. day-and-night grazers drank more water than day-grazers. From the regression analysis of water intake on day grazing time and night grazing time, 10.5 ml kg BW^{-1} was drunk per hour of day grazing whereas 5.7 ml kg BW^{-1} was drunk per hour of night grazing. High water consumption during the day can be attributed to high ambient temperatures during the day (Nicholson, 1987), as walking in the sun increases water intake. Similarly, King (1983) observed an extra water cost of 0.35 l km^{-1} for walking in high solar radiation. Water consumption by the animals (overall mean=110 ml kg $BW^{-0.75}$ d^{-1}, SEM=4) in this study is well below the theoretical maximum (160 ml kg $BW^{-0.75}$ d^{-1}) suggested by King (1983) for cattle grazing tropical pastures. Regression analysis of water intake on metabolic weight and dry matter intake showed that 492 ml of water was drunk per kg of dry matter consumed in addition to 397 ml per metabolic weight. Lower water consumption relative to forage intake by day-and-night grazers compared with day-grazers further confirms that water intake is lower during the night than during the day. Thus, a longer duration of night grazing may be necessary in a period of water scarcity to meet livestock water need.

Implications

This study suggests that the traditional practice of corralling cattle at night limits forage intake. Additional grazing time during the night leads to increased forage intake and consequently provides an opportunity for better animal production, especially in the dry season when available forage is low. Longer grazing times during the night in periods of water scarcity may lead to lower drinking water requirement.

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Chapter 5

Effect of nocturnal grazing and supplementation on diet selection, eating time, forage intake and weight changes of cattle

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Effect of nocturnal grazing and supplementation on diet selection, eating time, forage intake and weight changes of cattle

A.A. Ayantunde, S. Fernández-Rivera, P.H.Y. Hiernaux, H. van Keulen, H.M.J. Udo and M. Chanono

Abstract

Sixty-four Azawak male calves (BW=224 kg, SD=58) were used to study the effect of nocturnal grazing (HN) and supplementation (SUP) on forage intake, faecal output, water intake, feeding behaviour and weight changes of cattle in the dry season in the Sahel. Treatments were factorial combinations of four levels of HN (0, 2, 4 and 6 h d^{-1}) and two levels of SUP (0 and 565 g DM millet bran $animal^{-1}$ d^{-1}). All calves were allowed to graze 10 h during the day and were weighed every 2 weeks during the 70 d experimental period. Faeces were collected during 9 d from all animals. Eating time was determined in four animals per treatment by recording their activities every 5 min during 8 d. Eight steers fitted with esophageal cannulas were randomly divided into two groups (with and without SUP) and used in a cross-over design for sampling the diet (forage) selected. Both groups grazed 10 h during the day and 4 h at night. Extrusa crude protein (No SUP vs SUP; 64 vs 68 g kg^{-1} DM, SEM=3) and *in vitro* organic matter digestibility (518 vs 509 g kg^{-1} DM, SEM=11) were not influenced by supplementation (P>0.05). Time spent eating during the day (310 vs 307 min d^{-1}, SEM=2) or at night (97 vs 96 min d^{-1}, SEM=1) were also not affected by supplementation. Total (day-and-night) eating time increased by 39.4±2.3 min h^{-1} of HN and decreased by 1.9±.4 min h^{-2} of HN. In non-supplemented calves forage intake (SEM=3) was 75.9, 78.1, 86.4 and 89.1 g DM kg $BW^{-0.75}$ d^{-1} for 0, 2, 4 and 6 h of HN, respectively, and for supplemented animals was 78.6, 79.7, 83.5 and 83.5. There was no difference (P>0.05) in faecal output associated with range forage between non-supplemented and supplemented animals (44.3 vs 43.7 g DM kg $BW^{-0.75}$ d^{-1}, SEM=0.8). The supplemented animals drank more water than the non-supplemented (26.2 vs 24.8 l $animal^{-1}$ d^{-1}). In non-supplemented cattle, average daily gain (ADG) increased by 24.4±8.7 g h^{-1} of HN, and in supplemented animals by 9.3±6.2 g h^{-1} of HN. The response in ADG tended to decrease with more than 4 h of HN. Supplementation improved ADG (-107 vs 99 g d^{-1}, SEM = 14, P<0.01). Supplementation did not affect quality of the diet selected or eating time but substitutes forage consumption at long periods of night grazing. Night grazing improves dry season performance and its effect decreases when cattle are supplemented.

Key Words: Cattle, Forage intake, Night grazing

Introduction

Nocturnal grazing and night-time corralling of grazing ruminants on crop fields are alternative herd management practices in the West African Sahel (Dicko-Touré, 1980;

Fernández-Rivera et al., 1995; Powell et al., 1996). Results from previous studies (Fernández-Rivera et al., 1998; Ayantunde et al., 1998) have demonstrated that night corralling (i.e., no night grazing) of cattle limits forage intake, thus leading to increased weight losses during the dry season and an increased need for supplementation. Night grazing stimulates animal production (King, 1983; Khombe et al., 1992), however, it reduces the amount of collectable manure for cropping (Ayantunde et al., 1998). In addressing this conflict it is necessary to determine the interactions between night grazing and supplementation. This would allow estimation of the need for supplementary feeding when no night grazing is practised and, perhaps, identification of categories of animals according to their nutrient requirements that are least affected by night corralling.

The objective of this study was to determine the effect of night grazing and supplementation on diet selection, forage intake, faecal output, water intake, feeding behaviour and weight changes of cattle.

Materials and Methods

Study site

A grazing trial was carried out for 70 days between April and June 1997 (late dry season) in Toukounous, Niger (14° 30' N and 3° 17' E). The vegetation of the paddock grazed was dominated by annual grasses, i.e. *Brachiara xantholeuca, Cenchrus biflorus, Schoenefeldia gracilis*, forbs such as *Indigofera senegalensis, Sesbania leptocarpa* and *Alysicarpus ovalifolius*, and trees such as *Maerua crassifolia, Acacia laeta*, and *Salvadora persica.*

Animals and treatments

Sixty-four Azawak male calves with an average body weight of 224 kg (SD=58) were randomly allotted to eight treatments (Table 1) defined by a factorial combination of four different durations of grazing in the night (0, 2, 4 and 6 h) and two levels of supplementation (0 and 608 g DM d^{-1}; Table 2). All the animals had 10 h of day grazing time. Animals grazed in the same paddock during the day and at night. After returning from day grazing at 1800 h, animals in the corresponding treatments were given supplement individually. The quantity of millet bran fed was calculated as the dry matter needed to meet the daily energy deficit of 3 to 8 MJ if the animals were only grazing natural pasture in the dry season at the same site, based on recommendations by AFRC (1993) for maintenance requirement of grazing steers.

Diet selection

Eight esophageally fistulated steers were randomly divided into two groups and

Table 1. Treatment and grazing schedules.

Treatment (T)	Grazing time, h		Total grazing time, h	Level of supplement, g DM d^{-1}	Grazing schedule, h	
	Day	Night			Day	Night
1	10	0	10	0	0800 - 1800	-
2	10	0	10	608	0800 - 1800	-
3	10	2	12	0	0800 - 1800	0400 - 0600
4	10	2	12	608	0800 - 1800	0400 - 0600
5	10	4	14	0	0800 - 1800	0200 - 0600
6	10	4	14	608	0800 - 1800	0200 - 0600
7	10	6	16	0	0800 - 1800	0000 - 0600
8	10	6	16	608	0800 - 1800	0000 - 0600

Table 2. Nutritional composition of the supplement used.

Ingredient or nutrient	Per kg DM	Per day
Millet bran, g DM	929	565
Superphosphate, g DM	59	36
Salt, g	12	7
Total, g	1000	608
Protein, g	140	85
ME, Mcal	2.55	1.55

used in a cross-over design for sampling the diet selected during the day and at night. Both groups grazed in the day (0800 to 1800 h) and at night (0200 to 0600 h). One group was given supplement as in the supplementation treatments while the second group received no supplement. After three weeks of adaptation to supplement and grazing regimes, samples of the range forage selected (extrusa) were collected for three days during the day at 0900 and 1500 h and at night at 0300 and 0500 h. At the end of three days collection, the two groups were switched and after 10 days of adaptation extrusa samples were collected for three days similar to the first sampling period. The extrusa samples were placed in a container with ice and kept frozen until they were processed.

The samples were dried at 55°C and ground to pass a 1 mm screen. They were analyzed for dry (DM) and organic (OM) matter, and nitrogen (crude protein (CP) = N x 6.25). Organic matter digestibility (OMD) was determined by the *in vitro* gas production technique calibrated with standards obtained *in vivo* (Menke et al., 1979).

Faecal output

In May 1997, the sixty four male calves were fitted with canvas faecal collection bags for total collection. Faeces were collected for nine days, after an accustomization period of 7 to 10 days. The bags were emptied at the onset and end of the day grazing period. The fresh faeces were weighed immediately and 10% of the fresh faeces were taken and sun-dried for each animal, collection day and collection time (morning and evening). The sun-dried samples for the nine days were then weighed, bulked per animal, pounded, mixed and sub-sampled. The sub-samples were ground to pass a 1 mm screen for determination of DM, OM, nitrogen and phosphorus.

Measurements

Animals were weighed every two weeks for three consecutive days. Average daily gain (ADG) was estimated by regression of individual body weight over time. The amount of supplement fed and its digestibility were used to determine supplement contribution to faecal output. Faecal output attributed to supplement was subtracted from total faecal output to determine faecal output from range. Range forage intake was determined from individual data on faecal output from range and means of extrusa *in vitro* OMD of the diet selected in each treatment. The *in vitro* OMD for each treatment was calculated as a function of the number of hours grazed at night because of significant differences ($P<0.05$) between day and night. Water intake of the animals was measured daily during the data collection period in May, for which all animals had access to water for 30 min in the morning before day grazing time. The grazing activities of the animals such as eating (prehension, mastication and searching for food), resting while in the pasture, walking and drinking were also monitored in May 1997. Four steers were randomly selected per treatment and their grazing activities, while at pasture, were recorded every 5 min for eight days.

Statistical analyses

Data analyses were performed with SAS (1987) using General Linear Model (GLM) procedures for the variance and regression analyses. Extrusa variables were analysed with a model including the fixed effect of animals, period of collection, level of supplement (S), time of collection (T), and S x T. Contrasts were used to compare quality of diets selected during day (0900 and 1500 h) and night (0300 and 0500 h). Feeding behaviour (i.e., eating time), forage intake and faecal output were analysed with a model including night grazing time (HN), level of supplement (S) and HN x S. The significant quadratic effect of HN was included in the model for feeding behaviour. The model for analysis of water intake included body weight of the animals in addition to the factors studied. Multiple comparison of treatment means was performed by contrast statement using GLM procedure. Body weight data were analyzed with a model including HN, S, HN x S, and initial body weight of the animals with ADG as the response variable.

Results

Diet quality

Extrusa crude protein (No supplement vs supplement; 64 vs 68 g kg^{-1} DM, SEM=3) and *in vitro* organic matter digestibility (518 vs 509 g kg^{-1} DM, SEM=11) were not influenced by supplementation (P>0.05; Table 3). However, crude protein content of the diet selected in the day was higher (P<0.05) than that selected at night (No supplement: 72 vs 56, SEM=3; With supplement: 77 vs 59, SEM=3), whereas the reverse was the case for *in vitro* OMD.

Time spent eating

Time spent eating during the day (310 vs 307 min d^{-1}, SEM=2), at night (97 vs 96 min d^{-1}, SEM=1) and in total (407 vs 403 min d ;$^{-1}$ SEM=2) was not affected by supplementation (Figure 1). However, time spent eating during the day decreased as night grazing time increased (0 h = 314, 2 h = 308, 4 h = 307, and 6 h = 305 min d^{-1}, SEM=3). Total eating time for day-and-night increased by 39.4±2.3 min h^{-1} of HN and decreased

Table 3. Diet (extrusa) quality (g kg^{-1} DM) selected by esophageally fistulated steers at different collection time (h) with or without supplement in the dry season.

Component	Without supplement					With supplement				
	0900	1500	0300	0500	SEM	0900	1500	0300	0500	SEM
Organic matter	841	848	848	843	6	854	851	856	840	6
Crude protein	76[a]	68[a]	55[b]	57[b]	3	79[a]	76[a]	57[b]	62[b]	3
OMD[c]	503[a]	490[a]	545[b]	533[b]	13	468[a]	488[a]	539[b]	541[b]	11
DOM[d]	388[a]	386[a]	436[b]	415[b]	11	374[a]	386[a]	432[b]	419[b]	11

[a,b] Differing superscripts denote significant differences between means within rows (P<0.05).

[c] OMD = in vitro Organic Matter Digestibility.

[d] DOM = Digestible Organic Matter (OMD x Organic matter).

long term, floristic composition of the vegetation may be modified (Breman and Cissé, 1977; Dormaar et al., 1990) and this in turn may affect herbage production and feed value (Milchunas et al., 1995).

Most reports on the influence of livestock grazing on Sahelian rangelands are either based on description of sites of different grazing histories (Breman and Cissé, 1977; Breman et al., 1980; Granier, 1975) or on clipping experiments (Hiernaux and Turner, 1996). There has been very little controlled experimental work involving grazing ruminants over a large area of pasture and a long period to quantify the effect of livestock grazing on the vegetation (Ickowicz, 1995; Thébaud et al., 1995). The objective of this study was to determine the short term effects of grazing by cattle on herbage growth and disappearance, and spatial heterogeneity of the herbage mass.

Materials and Methods

Site description

The study was carried out from July 1995 to July 1996 at a ranch at Toukounous, situated at 14° 30' N and 3° 17' E at an altitude of 290 m above sea level. The ranch covers 4474 ha and is partitioned into fenced paddocks of varying size of which four were used in this experiment. The climate is typical Sahelian with monomodal rainfall

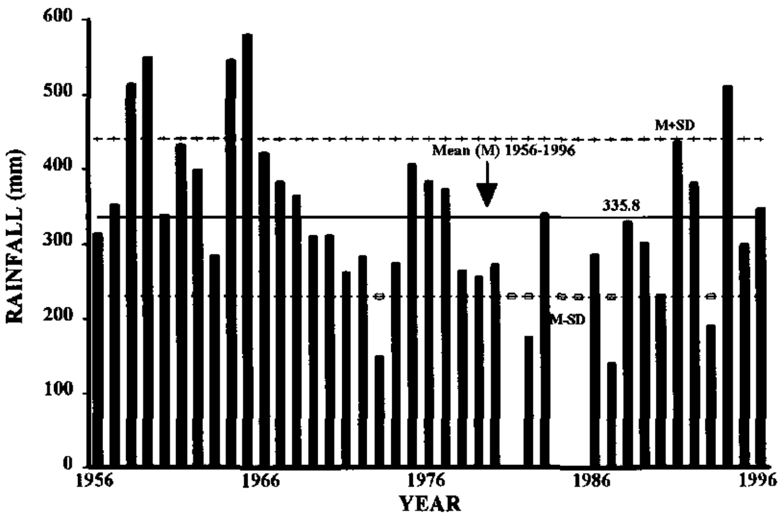

Figure 1. Annual rainfall (mm) from 1956 to 1966 for Toukounous, Niger.

from July to September. Annual rainfall during the year of this study was 300 mm (Figure 1) which is close to the site average of 336 mm (SD=105) for the period 1956 to 1996 (data for 1981, 1984 and 1985 are not available, Sivakumar et al., 1993). The vegetation is an open annual savanna with annual grasses and forbs, scattered shrubs and small trees. The vegetation on the ranch (Achard, 1992) is dominated by annual grasses such as *Cenchrus biflorus* Roxb., *Brachiara xantholeuca* Stapf, and *Schoenefeldia gracilis* Kunth, and annual forbs which include *Indigofera senegalensis* Lam., *Sesbania leptocarpa* DC., and *Corchorus olitorius* Linn. (plant species are named according to Hutchinson and Dalziel, 1954-72).

Experimental paddocks and grazing schedule

Two of the four paddocks (II4 and II5, Table 1) of similar size (75 ha) and similar proportions of alluvial plain (clay soil) and fixed dunes (sandy soil) were rotationally grazed (Figure 2) every month from August to November 1995. These paddocks were grazed by seventy two young bulls with an average body weight 222 kg (SD=78). From December 1995 to March 1996, the animals were moved to another two paddocks (II2 and II3) of similar soil features where grazing was rotated bimonthly. From April to July 1996, the animals were moved back to paddocks II4 and II5 where they were also rotated bimonthly.

Vegetation mass measurement

In each of paddocks II4 and II5, five transects of 200 m each were defined for vegetation mass measurements, based on the results of soil mapping carried out at the beginning of the experiment. Four of these transects were located systematically, starting at the cardinal points of the paddock from the fence inward, while the fifth transect was laid out in the clay depression. For II2 and II3, only four 200 m transects were used, two of them in the clay depression and two on sandy upland in accordance with the almost

Table 1. Area (ha) and contribution (%) of different soil types to the experimental paddocks.

Paddock	% of the paddock		Total area (ha)
	Clay flat	Sand dunes	
II2	57.4	42.6	98.4
II3	49.0	51.0	63.8
II4	5.6	94.4	74.9
II5	10.4	89.6	75.3

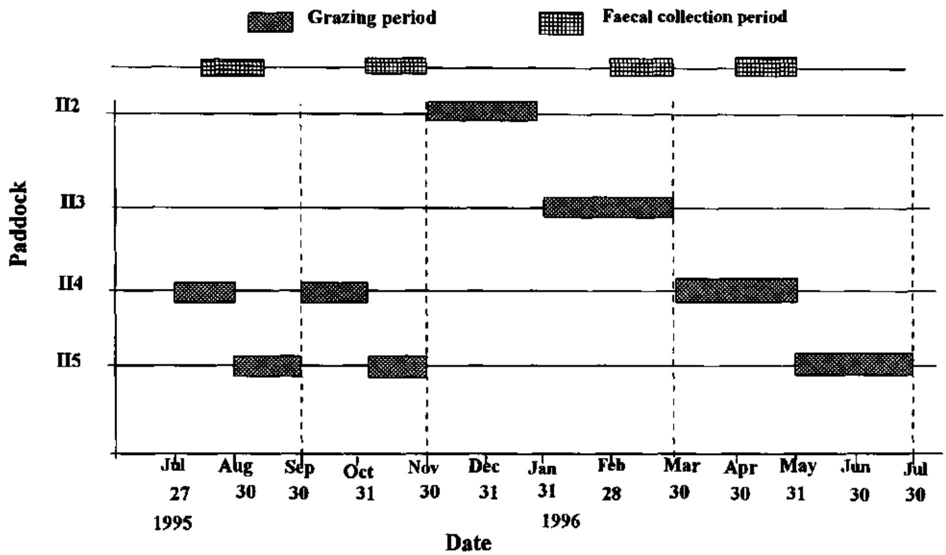

Figure 2. Grazing schedule for the experimental paddocks.

equal proportions of the two soil types in the two paddocks. Standing and litter mass of the herbage was measured by destructive harvest of forty 1 x 1m plots per paddock, randomly stratified along the transects. Standing herbage inside the quadrat was clipped at about 2 cm above soil surface and litter was collected separately except during the wet or growing season (July to September). The harvested herbage samples were sun-dried and weighed to determine dry matter. Organic matter, nitrogen and phosphorus content were determined in sub-samples. Weighted average and variance of sun-dried standing herbage and litter masses at different dates of measurement were calculated for each paddock, using equations suggested by Cook and Stubbendieck (1986) for stratified random sampling. Simple statistical analyses (mean, variance, SEM, CV) of the data collected were performed with SAS (Statistical Analysis System, 1987).

Herbage growth and disappearance

Herbage growth (accumulation) in the growing season and disappearance in dry season were estimated by changes in total herbage mass between two measurement dates.

Rate of accumulation (kg ha^{-1} d^{-1}) = $[(M_i - M_{i-1}) + I_i] / (t_i - t_{i-1})$,

Rate of disappearance (kg ha^{-1} d^{-1}) = $(M_i - M_{i-1}) / (t_i - t_{i-1})$,

where M_i = total herbage mass at date t_i

M_{i-1} = total herbage mass at date t_{i-1}

I_i = Intake by cattle during time $t_i - t_{i-1}$

Standing herbage and litter masses reported for July 1995 in this study were the remnants from the previous season (1994 vegetation) and were disregarded in calculating the rate of herbage mass change between 1 July and 30 August 1995. Herbage growth in 1995 started after germination, following the rain of 1 July, thus herbage mass for the current season was zero at that moment. Forage intake by the animals was estimated from faecal output and mean *in vitro* digestibility of the diet selected. Faeces were collected by faecal bags for nine days in August and November 1995 and in March and May 1996 (Figure 2), while diet selection was sampled through eight esophageally fistulated steers during the same periods.

Spatial heterogeneity of the herbage mass

To determine the spatial heterogeneity of the herbage mass, a random sample of 100 plots was created using a random generator for a normal distribution applied to the mean and standard deviation of each stratum sampled, the number of samples being proportional to the area covered by the strata. The coefficient of variation of the mean of the random sample for each date of vegetation mass measurement was used as an indicator of spatial heterogeneity of the herbage mass (Hiernaux, 1995).

Results

Standing herbage and litter mass

When animals entered the paddocks II4 and II5 on 27 July 1995, the mass (kg DM ha^{-1}, mean±SEM) of standing herbage was 256±10 and 178±26 for II4 and II5, respectively (Table 2) while litter mass in both paddocks exceeded one ton ha^{-1}. At the end of August, 1256 kg DM ha^{-1} (SEM=115) of the current season standing herbage had accumulated in II4 (excluding intake by cattle) whereas the ungrazed paddock (II5) at that time had 1800 kg DM ha^{-1} (SEM=140) of standing herbage. Consumption by cattle during the period in II4 was 186±13 kg DM ha^{-1}, i.e. about 6 kg DM d^{-1}. Peak herbage yield (kg DM ha^{-1}) was recorded in September for both paddocks (II4: 1777±100; II5: 1772±131) followed by a steady decline till the end of the dry season. There was an accumulation of litter from October onward. The litter mass remained essentially stable till March 1996 after which it declined steadily during the second half of the dry season. At the end of the dry season less than 100 kg DM ha^{-1} of standing herbage mass remained in both paddocks, while litter mass was 246 for II4 and 352 for II5. These paddocks were almost bare, with cover density for standing herbage of 0.2±0.1 and 0.3±0.1 % for II4 and II5 respectively.

Table 2. Mass (kg DM ha^{-1}) and cover (%) for the standing herbage and litter, and consumption (kg DM ha^{-1}) by animals at different dates of measurement (Mean±SEM).

Paddock	State	Date	Season	Mass (kg/ha)			Cover (%)	
				Standing herbage	Litter	Intake	Standing herbage	Litter
II4	U[1]	1/7/95[4]	wet	256±10	876±17	0	0.8±0.1	2.4±0.1
II5	U	1/7/95[4]	wet	178±26	1314±31	0	1.0±0.1	2.5±0.1
II4	G[2]	29/8/95	wet	1256±115	nm[3]	186±13	16.2±0.5	nm
II5	U	29/8/95	wet	1800±140	nm	0	14.0±1.0	nm
II4	U	29/9/95	wet	1777±100	nm	0	8.6±0.3	nm
II5	G	29/9/95	wet	1772±131	nm	179±11	8.2±0.6	nm
II4	G	30/10/95	dry	758±43	701±69	196±16	5.2±0.3	nm
II5	U	30/10/95	dry	1170±54	677±51	0	5.6±0.2	nm
II4	U	29/11/95	dry	740±41	711±16	0	5.1±0.3	9.2±0.2
II5	G	29/11/95	dry	650±29	794±16	189±14	4.5±0.3	5.2±0.2
II2	U	28/11/95	dry	1213±86	954±96	0	7.0±0.6	nm
II3	U	28/11/95	dry	1594±121	549±122	0	12.6±1.0	nm
II2	G	30/1/96	dry	444±61	984±38	327±25	2.1±0.2	4.2±0.2
II3	U	30/1/96	dry	1283±173	658±18	0	7.6±0.9	2.2±0.1
II2	U	30/3/96	dry	380±29	800±30	0	1.5±0.1	6.6±0.3
II3	G	30/3/96	dry	319±37	860±25	371±29	2.3±0.2	5.7±0.2
II4	U	29/3/96	dry	487±39	550±12	0	3.9±0.3	6.5±0.1
II5	U	29/3/96	dry	575±50	314±11	0	4.4±0.3	2.9±0.1
II4	G	30/5/96	dry	122±17	436±10	332±21	1.2±0.2	3.1±0.1
II5	U	30/5/96	dry	429±35	386±11	0	2.7±0.2	2.8±0.1
II4	U	29/7/96[5]	wet	99±12	246±9	0	0.2±0.1	0.9±0.1
II5	G	29/7/96[5]	wet	80±12	352±12	330±19	0.3±0.1	0.8±0.1

[1]U = Ungrazed during the previous 1 or 2 months.

[2]G = Grazed during the previous 1 or 2 months. [3]nm = Not measured.

[4]Values reported for standing herbage and litter mass, and cover refer to the previous season before the study started.

[5]Values reported for standing herbage and litter mass, and cover refer to the remaining herbaceous materials at the end of current season.

Effect of grazing on herbage growth

In the first two months of the growing season (July and August), the rates of herbage mass accumulation were 24.0 and 30.0 kg ha^{-1} d^{-1} for paddocks II4 and II5, respectively (Figure 3). Hence, it was lower for paddock II4 which was grazed in August 1995. If intake by cattle during this period is added to herbage accumulation, growth under grazing equals growth in ungrazed control indicating that rate of growth during this period was not affected by grazing. The rates of herbage accumulation declined in September to values of 11.2 and 10.9 kg ha^{-1} d^{-1} for II4 and II5, respectively (including consumption by the animals).

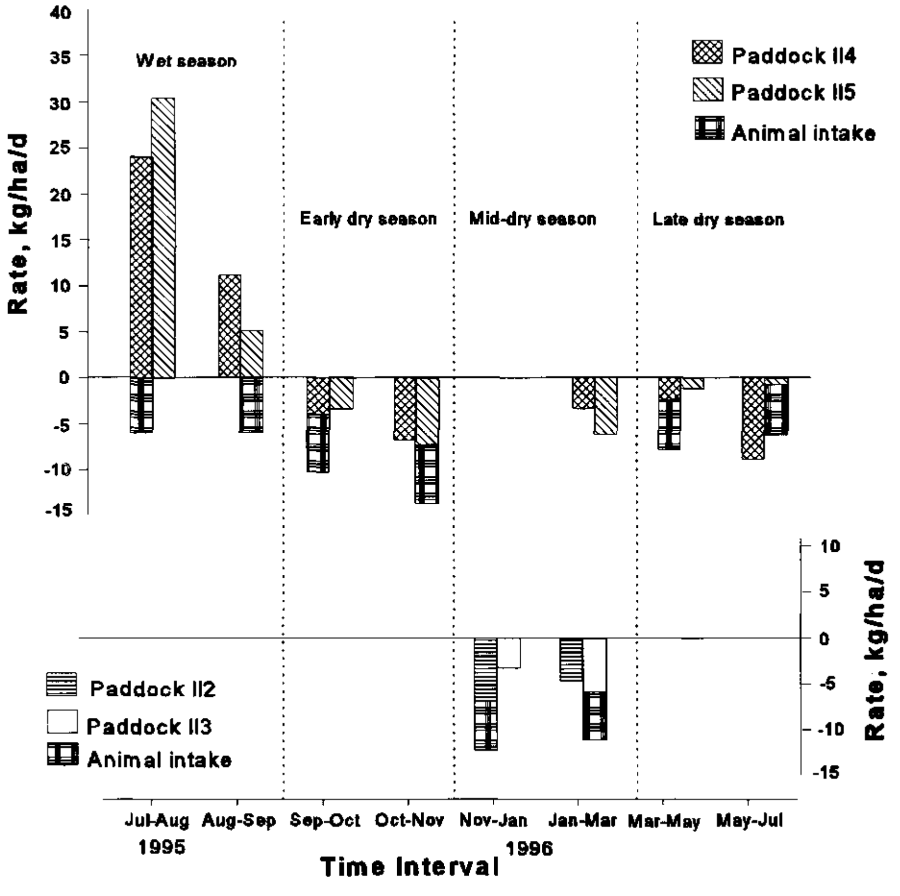

Figure 3. Rate of herbage mass change and intake by cattle in time interval of one or two months in the Sahelian rangelands.

Effect of grazing on herbage disappearance

In the first month of the dry season (October) the rate of herbage disappearance (Figure 3) was higher in paddock II4 that was grazed, than in II5 which was ungrazed (3.9 vs 3.4 kg ha^{-1} d^{-1}). Taking into account consumption by the animals, the disappearance rate would be three times higher than in II5. In paddocks II2 and II3, the rate of herbage disappearance above consumption by cattle ranged from 3.4 to 6.9 kg ha^{-1} d^{-1}. Higher rates of herbage disappearance above consumption when the paddock was grazed were observed throughout the dry season except in July 1996. Litter mass was consistently higher in the grazed than in the ungrazed paddock at the same period (Table 2). From September to October, the rates of degradation of standing herbage to litter were 11.7 and 11.3 kg ha^{-1} d^{-1} for II4 and II5 respectively, whereas from September to November the rates were 10.6 and 6.1 kg ha^{-1} d^{-1} for paddocks II2 and II3 which had not been grazed. Over the dry season, herbage disappearance due to consumption by cattle accounted for 59% of total herbage disappearance.

Effect of grazing on spatial heterogeneity of herbage mass

The spatial heterogeneity of the herbage mass at a scale of $1m^2$ assessed by the coefficient of variation (CV) of herbage mass mean increased as the season progressed from 48.5 in the wet season to 246.4 % in late dry season (Figure 4), with a sharp

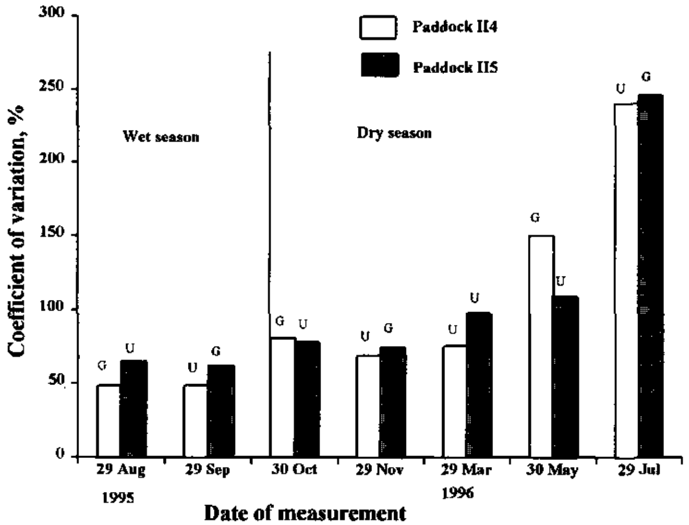

Figure 4. Spatial heterogeneity of herbage mass when the experimental paddocks were grazed (G) or ungrazed (U) in the previous one or two months as indicated by coefficient of variation of standing herbage mass.

increase at the end of the dry season from May to July. In August, the grazed paddock (II4) had a lower CV than II5 which was ungrazed during the period. However, the reverse was the case in September and throughout the dry season, grazing consistently resulted in higher spatial heterogeneity of the herbage mass.

Discussion

The peak standing herbage mass of about 1.8 ton ha^{-1} measured in II4 and II5 is similar to the 1.8 to 2.2 ton ha^{-1} reported by Breman and Cissè (1977) for the Niono ranch in Mali with an annual rainfall of 500 mm in the areas lightly grazed. Peak herbage production found in this study also agrees with the theoretical production suggested by Breman and de Wit (1983) for the Sahelian zone with about 300 mm of annual precipitation. However, if the relationship between annual rainfall and rangeland production for the African Sahelo-Sudanian zone suggested by Le Houérou and Hoste (1977) was applied to the study site which received 300 mm of rainfall in the study year (1995), herbage mass should have been 750 kg DM ha^{-1}, far below actual production. This shows that annual rainfall alone is inadequate to predict herbage yield in Sahelian rangelands. Edaphic and land use factors, and rainfall distribution pattern should be taken into account for a realistic estimate of rangeland production.

The lower rate of herbage accumulation of the grazed paddocks compared to the ungrazed ones agrees with the observation that grazing before the end of the growing season reduces herbage yield (Cissé and Breman, 1975; Matches, 1992; Hiernaux, 1995). However, plant response varies depending on the timing of grazing. The results show that grazing is more likely to stimulate regrowth at early stages of plant development (before heading). This confirms the report by Hiernaux and Turner (1996) that grazing in the early part of the wet season (July to August) triggered regrowth which compensated forage intake by livestock. In the later part of the growing season (September) the regrowth triggered by grazing fall short of forage intake by 0.2 kg ha^{-1} d^{-1} (Figure 3). However, the effect of grazing on herbage growth and production also depends on animal species and stocking rate (Hiernaux and Fernández-Rivera, 1995) and past grazing history of the site (Milchunas et al., 1995).

High rates of herbage disappearance (Figure 3) as observed at the onset of the dry season in October to November in both the grazed and the ungrazed paddocks can be attributed to shedding of leaves, especially by dicotyledonous plants and dispersion of seeds, fruits and/or inflorescences. This indicates a slight acceleration in herbage disappearance due to trampling (Hiernaux and Fernández-Rivera, 1995). Rates of herbage disappearance are moderate and constant during the following months and accelerated in the last month of the dry season, litter decomposition being enhanced by the first rains

(107 mm in July). Grazing in the dry season leads to a higher rates of herbage disappearance (Figure 3). However, when the herbage consumed by cattle is accounted for, the disappearance rate under grazing is only slightly higher than in the ungrazed paddocks. The effect of trampling is shown by the higher rates of degradation of standing herbage to litter in paddocks II4 and II5 which had been grazed between August and November than in II2 and II3 which were not grazed until December.

At the stocking rate of 0.23 animal ha^{-1}, 48% of the dry matter produced was consumed by cattle on a year-round basis. Given 3 and 9 months of wet and dry seasons respectively in the Sahel, consumption by cattle is thus 12 and 36% of the annual herbage production in the wet and dry seasons respectively. The fraction consumed in the dry season is higher than the 22.5% suggested by Le Houérou and Hoste (1977) but in line with 35% reported by Breman and de Ridder (1991). The value for the wet season is lower than the 17.5% suggested by Le Houérou and Hoste (1977). These results suggest a relatively efficient use of range resources by the animals in Toukounous ranch compared to other sites in the Sahel. This may be attributed to favourable nutritional quality of the herbage for most of the year, high herbage production, species diversity of the vegetation on the ranch, and a relatively low stocking rate (Achard and Chanono, 1995).

In the early wet season, grazing slightly reduced spatial heterogeneity of the herbage mass but in September the effect was reverse (Figure 4). The reduction in spatial heterogeneity of the herbage mass in the early wet season may be attributed to low selectivity by the animals during this period. In the dry season, grazing reinforces the spatial heterogeneity of the herbage mass (Hiernaux, 1995). The effect of grazing is more noticeable in May than in other months of the dry season. At the end of the dry season (July 1996) CV of standing herbage mass was two times higher than in May for both the grazed and ungrazed paddocks while the CV of the two paddocks was similar. This may be attributed to a rather high rate of herbage disappearance in the ungrazed paddock due to rainfall-accelerated decomposition of herbaceous materials in that month. Factors other than grazing such as wind erosion, plant dominant species, and land use systems can significantly affect spatial heterogeneity in Sahelian rangelands (Hiernaux, 1995).

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The selective use by grazing cattle of spatially heterogeneous and seasonally changing range resources in the Sahel

A.A. Ayantunde, P. Hiernaux, S. Fernández-Rivera, H. van Keulen and H.M.J. Udo

Abstract

The selective use by cattle of range resources in the Sahel was assessed in terms of quantity and nutritional quality of the herbage grazed and diet selected. Peak available forage was 1951 kg ha^{-1} dry matter (DM) with 47.9 kg nitrogen ha^{-1} and 7.4 kg phosphorus ha^{-1}. The diet selected was consistently higher in nitrogen, phosphorus and organic matter digestibility than the herbage grazed. Consumption by cattle accounted for 48% of the annual herbage production. The results suggest that grazing ruminants tend to make better use of Sahelian rangelands than often predicted on the basis of pasture evaluation alone.

Key words Sahelian rangelands, Forage availability, Nutritional quality, Selective grazing, Diet selectivity.

Introduction

Rangeland production in the Sahel is characterized by seasonal, interannual and spatial variation (Le Houérou and Hoste, 1977; Breman and de Wit, 1983; Ickowicz 1995; Hiernaux, 1996). In an average year, primary production ranges from 600 kg DM ha^{-1} in the northern Sahel with 200 mm of rainfall to 2400 kg DM ha^{-1} in the southern Sahel with 600 mm rainfall (Glatzle, 1991). Added to this, wide local variation in herbage production has been reported within a region (Wylie et al., 1995). For example, the authors reported primary production in the administrative district of Diffa in Niger to vary from 305 to 936 kg DM ha^{-1} from one site to another in 1989. And within site, herbage production and quality also varies depending on soil type, redistribution of run-off water in relation to topography and geomorphology, and plant species (Breman and de Ridder, 1991). The feed quality of the herbage produced is often inversely proportional to soil water availability during the growing season for a given soil type (Breman and de Wit, 1983). As a consequence of the spatial heterogeneity in herbage mass and quality, grazing by cattle is selective. This is demonstrated by the animals through choice of feeding or foraging station, avoidance of certain plant species and preference for others (Guerin et al., 1988), and selection among different parts of a plant (leaves, stem, seed and fruit; Stobbs, 1973; Manser and Brotherton, 1995; Diarra et al., 1995). However, the selective ability of the animals cannot compensate for poor forage quality by eating more in the dry season (Stobbs, 1973).

Strong dietary selectivity by cattle grazing Sahelian rangelands has been reported in the few studies on feeding behaviour of ruminants (Diallo, 1978; Dicko and Sangaré, 1986; Diarra et al., 1995). The objective of this study was to assess the selective use by cattle of range resources in the Sahel in terms of quantity and nutritional quality of the herbage grazed and diet selected in a controlled grazing experiment.

Materials and Methods

Study site

This study was carried out from July 1995 to July 1996 on a ranch at Toukounous, situated at 14° 30' N and 3° 17' E at an altitude of 290 m above sea level. The ranch covers 4474 ha and is partitioned into fenced paddocks of varying size of which four were used in this experiment. The climate is typical Sahelian: semi-arid tropics with monomodal rainfall from July to September. Annual rainfall during the study year was 300 mm, which is close to the site average of 336 mm (SD=105) for the period 1956 to 1996 (data for 1981, 1984, and 1985 are not available, Sivakumar et al., 1993). The vegetation is an open savannah dominated by annual grasses such as *Cenchrus biflorus*, *Brachiara xantholeuca* and *Schoenefeldia gracilis*; annual forbs which include *Indigofera senegalensis*, *Sesbania leptocarpa* and *Corchorus olitorius*, and scattered shrubs and small trees including good value browse such as *Maerua crassifolia*, *Acacia laeta*, and *Salvadora persica* (plant species are named according to Hutchinson and Dalziel, 1954 to 1972).

Pasture, animals and grazing schedule

Two of the four paddocks (II4 and II5, Table 1) of similar size (75 ha) having similar proportions of alluvial plain (clay soil) and fixed dunes (sandy soil) were rotationally grazed (Figure 1) every month from August to November 1995 by seventy two Azawak young bulls with average body weight of 222 kg (SD=78). From December 1995 to March 1996, the animals were moved into the other two paddocks (II2 and II3) of similar soil features where grazing was rotated bimonthly. From April to July 1996, the animals were moved back to paddocks II4 and II5 where they were also rotated bimonthly. The animals were weighed every two weeks for three consecutive days throughout the study period.

Herbage mass measurement

The main soil and related vegetation types of the four paddocks were mapped at the beginning of the experiment using a portable Geographic Position System (Trimble Pathfinder). In each of the paddocks II4 and II5, five transects of 200m each were defined

Table 1. Area (ha) and contribution (%) of different soil types to the experimental paddocks.

Paddock	Total area (ha)	% of the paddock	
		Clay flat	Sand dunes
II2	98.4	57.4	42.6
II3	63.8	49.0	51.0
II4	74.9	5.6	94.4
II5	75.3	10.4	98.6

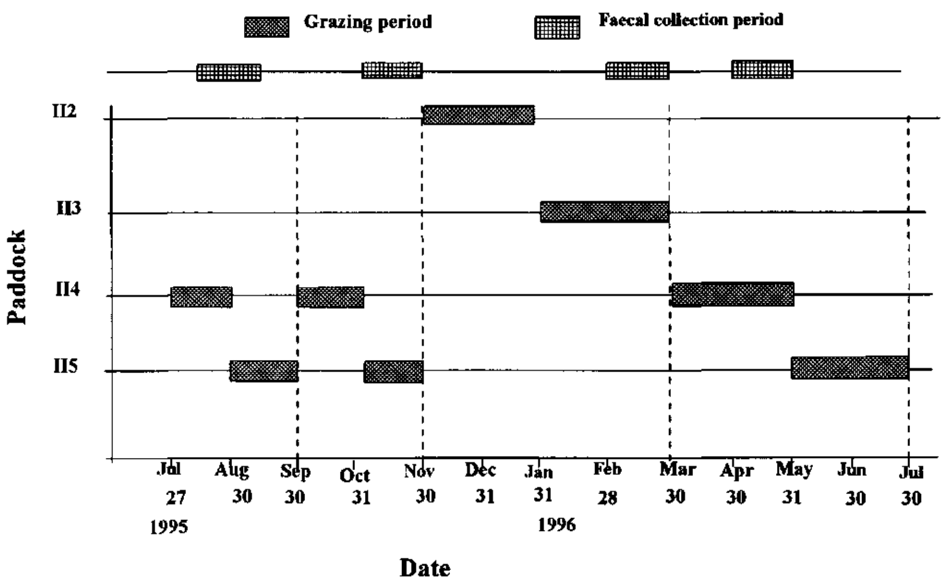

Figure 1. Grazing schedule for the experimental paddocks.

for herbage mass measurements. Four of these transects were located systematically starting at the cardinal points of the paddock from the fence inward, while the fifth transect was laid out in the clay depression. For II2 and II3, only four 200m transects were used, two of them in the clay depression and two on sandy upland in accordance with the almost equal proportions of the two soil types in the two paddocks (Table 1). Standing and litter mass of the herbage was measured by destructive harvest of forty 1 x 1m plots per paddock, randomly stratified along the transects. Standing herbage inside the quadrat was clipped at about 2 cm above soil surface and during the dry season litter was collected separately. The harvested herbage samples were sun-dried and weighed to determine dry matter and sub-samples were taken for chemical analysis. Weighted average and variance of sun-dried standing herbage and litter mass were calculated for each paddock, using equations given by Cook and Stubbendieck (1986) for stratified random sampling. Simple statistical analyses (mean, variance, SEM) of the data on herbage mass and nutritional quality of the herbage sample were performed with SAS (Statistical Analysis System, 1987). Total herbage mass consisting of standing herbage and litter is referred to as available forage. The floristic composition of the vegetation in paddocks II4 and II5 was determined at the end of August 1995 (peak vegetative stage) by estimating the cover of each species in the sampled plots and relating these to the dominant species in the plot. Species dominance was described for all the 1 x 1m plots along each 200m transect. The contribution of each species to the total cover was weighted by the relative importance of the dominant species.

Diet selection, faecal sampling and forage intake

Diet selection by the animals was sampled with eight esophageally fistulated steers that grazed the same pasture as the rest of the herd. Extrusa samples were collected in the day and at night for three consecutive days in August and November 1995, and March and May 1996. The extrusa samples were frozen immediately after collection and stored for laboratory analyses. Forage intake (I) by the animals was estimated from faecal output (F) and mean *in vitro* organic matter digestibility (D) of the diet selected by the equation $I = F\ (1\text{-}D)^{-1}$. Faeces were collected by faecal bags for nine days each in August and November 1995, and in March and May 1996 (Figure 1). The forage intake values (Table 2) estimated at these dates were also assumed for the grazing periods that intake was not measured.

Table 2. Forage intake and faecal excretion (g DM d^{-1}; mean±SEM) values determined in the grazing trials with cattle which are assumed for the months when there were no measurement.

Date of measurement	No of animals	Body weight (kg ±SD)	Dry matter intake	Faecal excretion	Months assumed for
Aug. 95	72	243±63	6240±440	1888±134	Sep.
Nov. 95	72	275±67	6574±519	2631±207	Oct., Dec.
Mar. 96	71	278±65	5652±437	2645±219	Jan., Feb
May 96	71	256±60	5738±527	2692±205	Apr. Jun.

Laboratory analyses

The extrusa samples were dried at 55°C for 48 h and ground to pass through 1-mm mesh screen. Sun-dried herbage samples were also milled to pass a 1-mm mesh screen. Both extrusa and cut herbage samples were analyzed for DM, organic matter (OM) and nitrogen. Digestibility was determined by the *in vitro* gas production technique calibrated with standards obtained *in vivo* (Menke et al., 1979). Phosphorus concentration in cut herbage samples was also determined. Because of saliva contamination that may interfere with chemical analysis, phosphorus content of extrusa was derived from nitrogen content using a linear regression established on 703 standing herbage and litter samples collected during the study year:

$$P\ (g\ kg^{-1}\ DM) = N\ (g\ kg^{-1}\ DM) \times 0.151\ (\pm 0.008),\ r^2 = 0.864.$$

Results

Structure of the vegetation

The vegetation in both paddocks (II4 and II5) was dominated by annual grasses (Table 3). At peak vegetative stage, about 70 and 65% of the plant species found on sandy soils in paddocks II4 and II5 respectively were grasses, while dicotyledons constituted about 25 % of the cover in both paddocks. In paddocks II4 and II5 clay soil was dominated by dicotyledons. About 12 % of the total number of species encountered at peak vegetative stage in both paddocks (Appendix 1) were refused by ruminants (Figure 2) while 68 and 62% were highly preferred in II4 and II5, respectively.

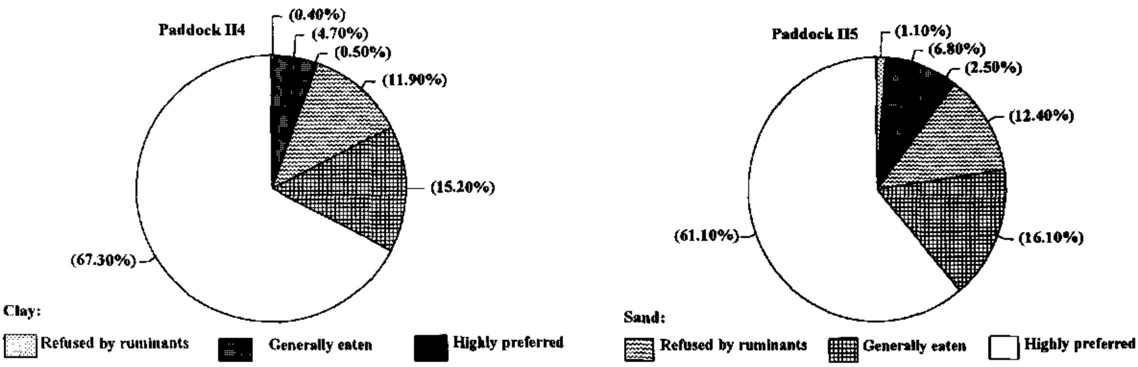

Figure 2. Palatability of plant species present per total number encountered in each paddock for each soil type at the peak vegetative period.

Herders' perceptions, practice and problems of night grazing in the Sahel: Case studies from Niger

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Abstract

A survey was conducted from February to June 1997 among livestock herders in two villages of Niger, Kodey and Toukounous, on their perceptions, practice and problems of night grazing. Cattle and sheep were the species that were taken out for night grazing by the herders. Small herd size and labour constraints were mentioned as the principal reasons for not practising night grazing. Major benefits of night grazing included good body condition, herd growth, increased milk production, prevention of diseases and reduction in herd mortality. Insecurity, difficulty in staying awake at night, labour constraints and damage to crops by animals were given as problems of night grazing. According to the herders, grazing time (duration) during the day and night was shorter in the wet season than in the dry season. In the wet season animals were herded (followed and closely supervised by herders), whereas in the dry season, animals were mostly left to range freely in both villages. In general, children herded the animals during the day, while adults were responsible for night time herding. Herders' perceptions on night grazing as regards animal production parameters such as weight development, water consumption, faecal output and feeding behaviour are consistent with available experimental results. Therefore, technical research need to recognize the constraints faced by herders and determine how to overcome them so that technical and economic efficiency will not be impeded by these constraints.

KEY WORDS: Herders, Night grazing, Perceptions; herd management; Sahel.

Introduction

In the West African Sahel, natural rangelands form the main feed resources for livestock (Breman et al., 1978). The quantity (herbaceous mass) and quality (crude protein and digestibility) of the available forage vary markedly with seasons (Breman et al., 1978; Dicko-Touré, 1980; Schlecht, 1995). In addition to feed-related factors, some herd management practices affect the nutrition of livestock by influencing the timing and duration of grazing. For example, night grazing and corralling of grazing ruminants on crop fields for manuring, which are common practices in the region (Breman et al., 1978;

Powell and Williams, 1993). When animals are used to deposit manure in the cropping fields, conflict often arises between the need for the animals to graze long enough to have adequate feed intake and the need to improve soil fertility through manure collection. Night grazing in addition to grazing during the day is important especially in the dry season, when available forage is low and the quality is poor, for improved animal performance (Bayer et al., 1987). In addition to the advantage of increased forage intake, King (1983) reported that night grazing helps to reduce heat stress on the animals. The extent to which night grazing is practised may be influenced by species composition of the herd, pastoral system (nomadic, transhumance or sedentary), livestock ownership pattern, household labour availability, season and production objectives (Maaliki, 1981; de Verdière, 1994).

The limited information on the practice of night grazing in the West African Sahel (Breman et al., 1978; Dicko-Touré, 1980; Fernández-Rivera et al., 1996; Ayantunde et al., 1997) reflects the scientists' perceptions derived through conventional scientific methods (observational studies and experiments). To complement this scientific research and to benefit from herders' professionalism in animal husbandry (Thébaud et al., 1995), a better understanding of the indigenous knowledge on this herd management practice is essential. This can help to assess the potential benefits of the practice for low external input and sustainable agriculture (Chamber et al., 1989; Reijntjes et al., 1992).

This survey complements the grazing trials that have been conducted on night grazing by cattle in Sahelian rangelands (Fernández-Rivera et al.,1996; Ayantunde et al., 1997). The objectives of this study were: (i) to learn how herders practise night grazing and the reasons behind it; (ii) to identify constraints to night grazing and the opportunities to apply relevant experimental results in the management of herds in the region.

Materials and Methods

Study site

A survey on herders' perceptions of night grazing was conducted from February to June 1997 in two villages (Kodey and Toukounous) in Niger. Kodey (13° 23' N and 2° 51' E) has a population of about 1050 inhabitants (ILRI 1997, unpublished). The inhabitants of Kodey mainly belong to the Djerma and Fulani ethnic groups with a minority of Hausa. The Djermas and Hausas are mainly land cultivators while the Fulanis are livestock keepers. Sixty-two percent of the village land is cropped (Hiernaux et al., 1998). The climate is characterised with a monomodal annual rainfall of 450 mm between June and September. The second village, Toukounous (14° 30' N and 3° 17' E) has similar population as Kodey. The dominant ethnic groups in the village are Hausa and Fulani with Djerma and Tuareg minorities. The Fulani and Tuareg are traditional livestock keepers. However, the Fulani in Toukounous are increasingly settling down to cultivate land within the past 30 years (de Verdière, 1994). The percentage of the land cropped is 27 % as reported by de Verdière (1994). The village is situated within the Sahelian zone with an annual rainfall of 330 mm (Sivakumar et al., 1993).

Survey on herders perceptions

In each village, preliminary group interviews (a group usually comprised of three to eight herders) were conducted to familiarize the villagers with the objectives of the survey, to select herders and to have a better understanding of the herders' definition of terminologies to be used in the survey such as agricultural season and time. In total, 71 herders were randomly selected and interviewed in Kodey and 46 in Toukounous. Of this number, those that practise night grazing (Table 1) were individually interviewed using a detailed questionnaire developed after the group interviews. From the group interviews, four seasons were identified by the herders namely wet (July to September), harvest (September and October), cold dry (November to February) and hot dry (March to June). The two enumerators who conducted the interviews with the herders are resident of the villages and they belong to the ethnic groups which predominate in each village. The questionnaire was administered in the languages of the interviewees (Fulfulde, Djerma and Hausa) which the interviewers speak fluently and included questions on herding practices, grazing schedules, herd size, animal behaviour in the night, problems encountered during night grazing and the benefits from the practice.

Table 1. Ethnic composition of the herders interviewed in Kodey and Toukounous, Niger, 1997.

SITE	No. of herders in each ethnic group				TOTAL
	Djerma	Hausa	Fulani	Tuareg	
Kodey (n = 71)					
Night grazing	3	0	54	0	57
No night grazing	12	1	1	0	14
Toukounous (n = 46)					
Night grazing	0	1	13	0	14
No night grazing	0	9	22	1	32

Analysis of survey data

Data analysis was performed with SAS (1987) using frequency procedure for the description of the data and to analyse the relationships among various variables for each site. The logistic procedure (SAS, 1987) for binary response was used to investigate the probability of practising night grazing (binary response variable) given the ethnic group of the herders and the size of cattle and sheep (explanatory variables) in the herd. Goat size was excluded as an explanatory variable as goats are not taken out for night grazing according to the herders.

Results and Discussion

Ethnic composition of the herders interviewed

In Kodey, 14 of the 71 herders interviewed did not practise night grazing (Table 1) of which 12 belonged to the Djerma. Historically, the Djerma are not pastoralists (Dietvorst and Kerven, 1992). It is then not a surprise that majority of herders that did not practise night grazing in Kodey belonged to this group. However, there are some livestock owners in this ethnic group who entrusted their animals to herdsmen (mainly the Fulani), especially during the wet (growing) season when they do not have sufficient labour for both herding and farming tasks (Zuppan, 1994).

In Toukounous, 32 of the 46 herders interviewed did not practise night grazing (Table 1), of which the Fulani accounted for 69 %. Surprisingly, the majority of the herders from this ethnic group that were interviewed did not practise night grazing. This can be attributed to lower herd size in Toukounous compared with Kodey, differences in area of land cropped between the two sites (62 % in Kodey and 27 % in Toukounous), and access to grazing area which is more restrictive in Kodey than in Toukounous. Nevertheless, in both villages night grazing was practised virtually only by the Fulani. They have been described as the most highly specialized among West African pastoralists (Dietvorst and Kerven, 1992). The principal reasons given by the herders that did not practise night grazing (Table 2) included labour constraints, small herd size, strangeness of the practise to the respondent's culture (this reason was given only by the Djerma) and laziness. Forty four percent of the herders in Toukounous gave labour constraints as the main reason followed by small herd size. This order was reversed in Kodey. Availability of labour is often a problem in herd management, when herders are also farmers (Zuppan, 1994) especially in the wet (growing) season. An additional reason is the seasonal migration of adult men to coastal countries in West Africa such as Côte-d'Ivoire, Nigeria, Ghana and Benin (Faulkingham and Thorbahn, 1975; Lamers and Feil, 1995).

Table 2. Principal reasons given by the herders for not practising night grazing in Kodey and Toukounous, Niger.

Reason	Kodey (n=14)	Toukounous (n=32)
	% of the respondents	% of the respondents
Small herd size	35.8	21.8
No cattle in the herd	7.1	3.1
Alien to the respondent's culture	35.8	15.6
Supplements fed to animals and thus no need for night grazing	7.1	3.1
Animals herded by professional herders	7.1	6.3
Labour constraint	7.1	43.8
Laziness	0	6.3

Perceived benefits and problems of night grazing

Good body condition, prolificacy and herd growth were the principal benefits given by the herders for practising night grazing (Table 3). Other benefits included disease prevention and reduction in herd mortality, increased milk production and additional grazing time. The advantage of additional grazing time as identified by the herders agree with the experimental results by Fernández-Rivera et al. (1996) and Ayantunde et al. (1997). Through additional grazing time, night grazing leads to increased forage intake (King, 1983; Fernández-Rivera et al., 1996; Ayantunde et al., 1997) and consequently increased weight gain (Wigg et al., 1973; Nicholson, 1987). This may then account for good body condition, increased milk production and reduction in herd mortality. In both villages, at least 50 % of the respondents gave insecurity, which include snake bites, attacks by evil spirit and cold, as the main problem during night grazing (Table 4). Danger of predators and hazards for herdsmen and the stock have been reported by Bayer (1986) and Coppock et al. (1988) as major problems during night grazing. Other problems reported by the herders included difficulty in staying awake at night, risk of damage to crops, fatigue, labour constraint (i.e. lack of household labour for herding) and insufficient grazing area. The latter was mentioned only in Kodey probably due to large extent of land cropped.

Table 3. Benefits of practising night grazing as perceived by herders in Kodey and Toukounous, Niger.

Benefit	Kodey (n=57)	Toukounous (n=14)
	% of the respondents	% of the respondents
Animals are calm and controllable after night grazing	8.8	0
Good body condition, prolificacy and herd growth	38.6	78.7
Increased milk production	15.8	0
Prevention of diseases and reduction in herd mortality	17.5	7.1
Animals are able to resist hard times (e.g., drought)	5.3	7.1
Additional grazing time	12.3	7.1
Access to grazing areas not allowed for use during the day	1.7	0

Table 4. Major problems encountered during night grazing by herders in Kodey and Toukounous, Niger.

Problem	Kodey (n=57)	Toukounous (n=14)
	% of the respondents	% of the respondents
Insufficient grazing area	21.1	0
Difficulty in staying awake at night	12.3	28.6
Insecurity (e.g. snake bite, cold, attack by evil spirits)	54.4	64.3
Labour constraint	1.7	0
Damage to crops by animals at night	7.0	7.1
Herder fatigue	3.5	0

Herd size and night grazing

In both villages, herders that practised night grazing had higher numbers of cattle, sheep and goats than those who did not (Figure 1). Average herd size for cattle in Kodey exceeded 20 for those that practised night grazing while it was between 11 and 20 in Toukounous. The number of sheep and goats were about the same in both villages. It is rather speculative to comment extensively on herd size of the pastoralists because they usually underreport their animal numbers to limit taxation (Pouillon, 1988). The number of animals reported by the herders often depends on who is asking. In addition, there are taboos strongly believed by the herders that discourage counting of the animals, for example, divine wrath if they boast about herd size (Pouillon, 1988). Nevertheless, it was clear from the herders' response that large herd size (> 10) of cattle and sheep encourages night grazing. As all the herders in both villages listed cattle and sheep as species that grazed in the night, only these species and the ethnic group of the herders were included in the logistic regression model to predict the probability of practising night grazing. For both sites combined:

$$\text{Logit}(p) = -3.37\ (\text{SEM} = 0.82) + 2.19\ (\text{SEM} = 0.71) * \text{Ethnic} + 0.14\ (\text{SEM} = 0.04) * \text{Cattle} + 0.01\ (\text{SEM} = 0.01) * \text{Sheep}$$

($R^2 = 0.53$; log likelihood function = 98.26, $p < 0.05$; proportion of observations correctly classified = 75.2 %).

Logit (p) = Logarithmic probability of practising night grazing

SEM = Standard Error of the Mean

Ethnic = Ethnic group of the herders (Fulani = 1, others = 0)

Cattle = Number of cattle in the herd

Sheep = Number of sheep in the herd

The significance ($P<0.05$) of "log likelihood function" shows that the ethnic group, and the number of cattle and sheep in the herd are critical to night grazing. The herders in both villages confirmed this (the significance of herd size) by identifying small herd size as one of the principal reasons for not practising night grazing (Table 2). In both villages, calves and lambs, newly acquired animals and sick ones were not taken out for night grazing.

Age class of the herders during the day or night grazing

Seventy four and 50 % of the respondents in Kodey and Toukounous, respectively (Table 5), mentioned that only children herded animals during the day while 17 and 29%

Table 6. Grazing schedules during the day and at night in different seasons in Kodey and Toukounous, Niger[1,2]

Season	Village	Day Grazing							Night Grazing[3]						
		Departure time (h)			Returning time (h)				Departure time (h)			Returning time (h)			
		0700	0800	0900	1000	1700	1800	1900	2300	2400	0100	0200	0400	0500	0600
Wet (Jul.- Sept.)	Kodey	12.3	56.1	31.6	0.0	1.8	61.4	36.8	33.3	45.6	12.3	8.8	63.2	26.3	7.0
	Toukounous	7.1	28.6	42.9	21.4	20.2	78.6	1.2	7.1	21.4	28.6	42.9	28.6	21.4	35.7
Harvest (Sept. -Oct.)	Kodey	14.0	71.9	14.1	0.0	0.0	19.3	80.7	24.6	38.6	8.8	7.0	29.8	38.6	19.3
	Toukounous	0.0	28.6	50.0	21.4	7.1	85.7	7.2	14.3	7.1	28.6	50.0	28.6	28.6	35.7
Cold dry (Nov. - Feb.)	Kodey	22.8	57.9	19.3	0.0	0.0	22.8	77.2	40.4	26.3	10.5	3.5	26.3	50.9	22.8
	Toukounous	14.3	42.9	28.5	14.3	7.1	28.6	64.3	14.3	35.7	21.4	21.4	21.4	28.6	42.9
Hot dry (Mar. - Jun.)	Kodey	29.8	63.2	7.0	0.0	0.0	8.8	91.2	40.4	26.3	8.8	5.3	21.1	49.1	24.6
	Toukounous	21.4	52.9	25.7	0.0	14.3	28.6	57.1	42.9	14.3	7.1	7.1	14.3	21.4	64.3

[1] Values are % of total respondents per site (Kodey, n = 57; Toukounous, n = 14).

[2] The hour specified as departure or returning time covers 30 min before and after the time, e.g. 0900 h means 0900 h ±30 min.

[3] For night grazing, few respondents gave time outside the range indicated above such as 2200 h as departure time and 0300 as returning time.

started day grazing an hour later (0900 h) than in Kodey in the wet and harvest seasons and at the same time in the cold dry and hot dry seasons. Over 50 % of the respondents gave 1900 h as the returning time from day grazing for all the seasons at both sites except in the wet and harvest seasons.

In the wet season, 46 % of the respondents in Kodey started night grazing at 2400 h in Kodey compared with 21 % in Toukounous (Table 6). The highest proportion of the respondents (43 %) in Toukounous gave 0200 h as the departure time. However, the duration of night grazing was about 4 h at both sites. The duration of night grazing as that of day grazing increased as the season progressed from wet to dry in both villages. Results from observations of feeding activities of cattle by Dicko-Touré (1980) and Bayer (1986) support the response of the herders. Time spent grazing, either in the day or at night generally increases with decline in available forage. Moreover, herding practices also affect duration of grazing: Bayer (1986) observed that herded cattle spent less time grazing than did the free-ranging animals. Short grazing time in the wet season may also be due to labour competition for cropping and herding (Bayer et al., 1987). Ninety one

Table 7. Grazing orbits during the day and at night and night camping sites in different seasons in Kodey and Toukounous, Niger[1].

Season	Grazing site					Camping site		
	Day		Night					
	Range & Fallow	Cropland	Range & Fallow	Cropland	Village[2]	Range & Fallow	Cropland	Villag
Kodey								
- Wet	100	0	98.2	0	1.8	96.5	3.5	0
- Harvest	94.7	5.3	72.8	25.4	1.8	47.4	52.6	0
- Cold dry	48.2	51.8	61.4	38.6	0	1.7	98.3	0
- Hot dry	73.1	26.9	77.2	22.8	0	0	100	0
Toukounous								
- Wet	92.9	7.1	100	0	0	71.4	21.4	7.1
- Harvest	78.6	21.4	46.4	53.6	0	28.6	71.4	0
- Cold dry	64.3	35.7	78.6	21.4	0	14.3	78.6	7.1
- Hot dry	100	0	100	0	0	21.4	78.6	0

[1] Values are % of total respondents per site (Kodey, n=57; Toukounous, n=14).

[2] Village includes the surrounding areas.

and 86 % of the herders interviewed watered their animals between 1000 and 1300 h in Kodey and Toukounous, respectively.

In the wet season, over 90 % of the respondents in both villages (Table 7) grazed their herds on the range and fallow land during the day or at night. After the harvest of millet, the crop fields become accessible to livestock grazing. In the dry season, crop residues are an important feed resource for the grazing ruminants in the Sahel. Observations from Bayer et al. (1987), Sandford (1989) and Williams et al. (1997) that crop residues contribute substantially to dry season grazing confirm the herders' response. Cereal stovers are generally grazed communally by cattle, sheep and goats. Sometimes, all cereal stovers may be harvested from fields for stall-feeding and/or for sale like cowpea and groundnut residues (Powell and Williams, 1993). Grazing site can be influence by location of water points (Thébaud et al., 1995), especially in the dry season.

The camping site (Table 7) in the wet season was mainly range and fallow land in both villages. However, 4 and 21 % of the respondents in Kodey and Toukounous, respectively mentioned cropland as the camping site in the wet season. In this case, the animals were either tethered or camped in an enclosed area on the crop field to prevent damage to crops. In Toukounous, 7 % of the respondents camped their animals in the precinct of the village in the wet and cold dry seasons. In the dry season, most of the herders camped their animals on the cropland in both villages. Corralling of livestock on cropland is an important part of the 'symbiotic' farmer-herder relationships (Toulmin, 1983; Bayer et al., 1987; Powell and Williams, 1993 and Zuppan, 1994) in the Sahel.

Herding practices in the day and at night

During day grazing, animals were generally herded (followed and supervised by the herders) in Kodey, irrespective of the season (Figure 2). In Toukounous, 100 and 79 % of the herders shepherded their animals in the wet and harvest seasons, respectively during day grazing (Figure 2). However, in the cold dry and hot dry seasons, over 70 % of the herders in Toukounous allowed their animals to range freely. In the wet (growing) season, there is need for tight control and supervision of herds that are close to cultivated fields to prevent damage to crops (Bayer et al., 1987). Herding allows for flexible movement of the herd (Bayer, 1995) which is vital to optimal exploitation of the spatially heterogeneous and temporally changing range resources in the Sahel (Thébaud et al., 1995). During night grazing, herding and tethering were the herd management practices in the wet season in both villages. As the season advanced from wet to dry, orientating of the animals and free-ranging became the dominant herding practices. Orientating implies that the herders followed the animals to the grazing site and then returned to the village, leaving the animals to forage on their own whereas in free-ranging, the departure

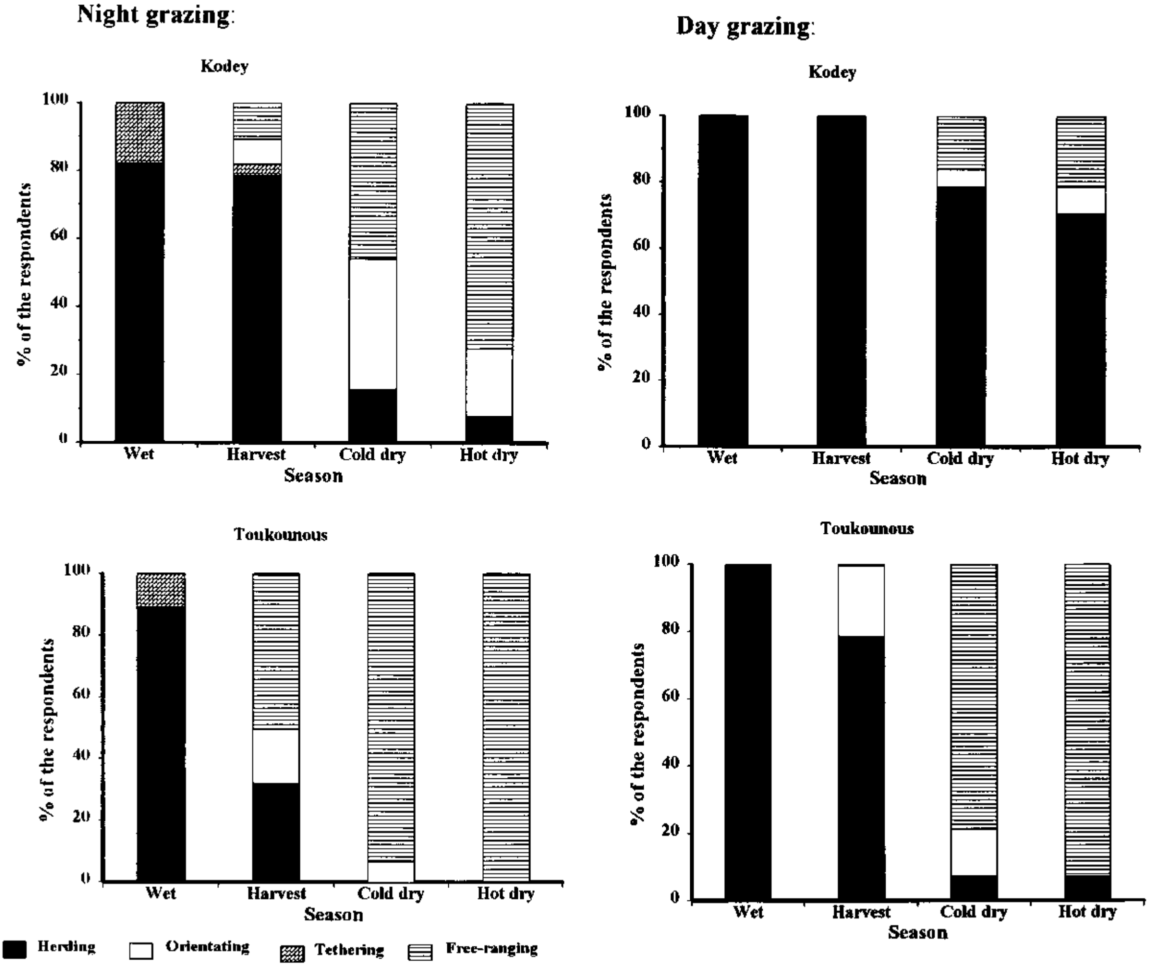

Figure 2. Herding practices in different seasons in Kodey and Toukounous, Niger.

to the grazing site, choice of grazing site and return to the camping site is left to the initiative of the animals. The prevalence of free-ranging in the dry season during night grazing, has also been reported by Dicko-Touré (1980) for grazing cattle in Mali.

Supplementation of cattle

In Kodey, 74 % of the herders interviewed supplemented their animals in the wet season and none in Toukounous (Table 8). Insufficient grazing area in Kodey due to the

Table 8. Proportion of herders that feed supplement, types of supplements and category of animals supplemented at different seasons in Kodey and Toukounous, Niger.

Season	Proportion	Types of supplement[1]	Animals supplemented[1]
Kodey			
- Wet	73.7	Millet bran	Lactating cows, old animals
- Harvest	75.4	Millet bran, millet stover	Lactating cows, old animals
- Cold dry	98.3	Millet bran, cowpea hay, millet stover, cut tree leaves	Lactating and pregnant cows, sick animals
- Hot dry	100	Millet bran, cowpea hay, cut tree leaves, millet stover	Lactating cows, old and sick animals, pregnant cows
Toukounous			
- Wet	0	None	None
- Harvest	7.1	Millet stover	Lactating cows
- Cold dry	50.0	Millet bran, millet stover	Lactating cows, old animals
- Hot dry	50.0	Millet bran, millet stover	Lactating cows, old animals

[1] Types of supplement and animals supplemented are listed in order of decreasing importance.

high cultivation density may be the reason for the wet season supplementation of cattle. With the advance of the season from wet to dry, more herders supplemented their stocks (Table 8). Even then, the proportion of the respondents that fed supplements in Toukounous was lower than in Kodey in all seasons. Millet bran and stover were the common supplements in both villages irrespective of the season. This is expected because millet is the staple food crop in Niger and in most other West African Sahelian countries. Other common supplements in the region include cowpea hay, bush hay, rice feed meal, cottonseed cake and groundnut cake (Schlecht, 1995). Supplementary feeding is often necessary in the dry season when available forage is low and of poor quality. In both villages, lactating cows were the focus of supplementary feeding, presumably because of the importance of milk and milk products in the herders' diet. Apart from the milking cows, old animals, pregnant cows and sick animals were also supplemented. Draught

Table 9. Herders' perceptions and researchers results on the influence of night grazing on different animal production parameters.

Parameter	Herders' perceptions	Researchers results
- Weight development	- Good body condition and positive weight changes.	- Grazing in the night in addition to day grazing led to better weight development (Wigg and Owen, 1973; Nicholson, 1987; Fernández-Rivera et al., 1996; Ayantunde et al., 1997).
- Milk production	- Increased milk production.	- Not available
- Water consumption	- Increased water intake and animals are eager to drink after night grazing.	- Grazing only in the night by steers reduced animals' water need compared to day time grazing. However, grazing in the day and at night led to increased water intake (Fernández-Rivera et al., 1996).
- Diet selection	- Animals are less selective in the night than in the day.	- No significant differences between the quality of diet selected in the day and at night by grazing steers (Fernández-Rivera et al., 1996; Ayantunde et al., 1997).
- Faecal output	- More faecal output with additional grazing time in the night.	- Herders' perceptions confirmed by Wigg and Owen (1973) and Fernández-Rivera et al. (1996).
- Animal health	- Reduced herd mortality.	- Not available
- Feeding behaviour	- Animals are calm and concentrate more on grazing than during the day.	- Night grazing steers spent more time grazing than day-grazers (Fernández-Rivera et al., 1996).
- Grazing time	- Provides additional grazing time.	- Confirmed by King (1983), Fernández-Rivera et al. (1996) and Ayantunde et al. (1997).
	- Night grazing time is longer in the dry season than in the wet season.	- Confirmed by Dicko-Touré (1980) and Bayer (1986).

animals have also been reported to be given supplements (Fall et al., 1997), but this was not observed in the study villages.

Herders' perceptions and researchers results on night grazing

Herders' perceptions on night grazing in both villages with respect to animal production parameters such as weight development, faecal output, water consumption and feeding behaviour mostly agree with available experimental results on night grazing (Table 9). The main difference between herders' perceptions and research results was on diet selection by the animals. The herders indicated that animals were less selective in the night compared to day time grazing but experimental results from grazing cattle in the region by Fernández-Rivera et al. (1996) and Ayantunde et al. (1997) showed no significant differences in quality of the diet selected during the day and during the night. The differences perceived by the herders could be associated with differences in grazing sites between day and night which is often the case for the pastoral herds. There are no experimental results to confirm or refute the herders' perceptions on the influence of night grazing on milk production and animal health. However, it sounds logical that increased forage intake or better nutrition through additional grazing time will lead to improved animal health, thereby reducing herd mortality and may also lead to increased milk production. The agreement between herders' perceptions and research results on night grazing reaffirms the professionalism of the pastoralists (Thébaud et al., 1995) and it also re-emphasize the importance of indigenous knowledge in the design and implementation of agricultural research in the region (Oostrum and Peters, 1995).

Implications for animal production and technology innovation

The response of the herders in both villages indicates that night grazing is an important herd management strategy that can lead to improved animal production in the region. Herders' experience with night grazing suggests that the practice has evolved over time in adaptation to social, environmental and perhaps, political circumstances and pressures. Therefore, the herders' current knowledge and herd management strategies need to be considered in the development of any animal or ecological related innovation. Moreover, social acceptability of an innovation should be seriously considered alongside with its technical feasibility and economic viability. In addressing the problems of night grazing, there is need to focus on the constraints enumerated by the herders such as insecurity and labour constraints. This implies that technical research need to recognize the constraints faced by herders and determine how to overcome them so that technical and economic efficiency will not be impeded by these constraints. Appropriate government policy on land use and effective national extension services are also necessary in addressing the herders' problems. Government policy that protects the right of herders to communal grazing land will lessen the problem of insufficient grazing area as cited in Kodey and this may reduce the outflow of young people to the urban areas. Supply of protective shoes e.g., boots, by the government will address the problem of snake bite during night grazing.

Table 3. Quality of the herbage grazed and diet (extrusa) selected (g kg^{-1} DM; mean±SEM) by esophageally fistulated steers.

Site	Date	Season	Crude Protein		Organic matter digestibility	
			Herbage	Extrusa	Herbage	Extrusa
Sadoré	Mar. 95	late dry	22±3	53±3	396±19	462±11
Toukounous	Aug. 95	wet	166±25	197±6	580±29	621±10
	Nov. 95	early dry	71±13	117±6	487±21	554±11
	Mar. 96	late dry	62±8	81±3	466±32	542±10
	May 96	late dry	41±6	73±2	445±28	494±10

especially in the dry season (Dicko-Touré, 1980; Ickowicz, 1995). Even though we did not estimate the contribution of browse to the diet of the animals, but its rather high value of crude protein (above 7 %) in the late dry season suggest the effect of browsing of woody forages. The dominance of palatable annual grasses such as *Cenchrus biflorus*, *Schoenefeldia gracilis* and *Brachiaria xantholeuca* in the study site could also have contributed to the relatively high crude protein in the late dry season.

The nutritional quality (nitrogen and phosphorus concentrations, and dry matter digestibility) of these species and that of dicotyledonous plants (Chapter 7) showed the normal seasonal variation in quality of standing biomass. Peak N and P concentrations were observed in the wet season (August) and subsequently the concentrations declined. A similar trend was observed in their dry matter digestibility. However, dicotyledonous species that had higher digestibility than annual grasses in the wet season had lower values in the dry season, indicating that the magnitude of reduction in digestibility differs between the two classes of species (grasses and dicotyledons). This implies that the grasses, though lower in N and P concentrations throughout the year, were more digestible than the dicotyledons in most part of dry season. Interestingly, some of these dicotyledons like *Tephrosia purpurea* though higher in N and P concentrations are refused by cattle. Therefore, palatability of plant species cannot be solely explained by their chemical composition, but is also dependent on plant morphology, animal factors and experience (Vallentine, 1990; Hiernaux and Turner, 1996; Kaitho, 1997). Since species composition plays a major role in determining the distribution of biomass quantity and quality, and palatability to the animals, pasture evaluation should distinguish among different classes of species (e.g. grasses, leguminous and non-leguminous dicotyledons). This distinction may provide a better indication of the nutritional quality of a rangeland and its utilization by grazing ruminants than the mean chemical composition of the composite herbage samples. Wide differences in animal productivity from Sahelian rangelands may also be better understood if the differences in nutritional value of different species are known and the foraging behaviour of the grazing animals is considered.

The results we obtained in our studies on utilization of Sahelian rangelands by grazing cattle may not be representative for sites under high grazing pressures and different grazing management practices, because the stocking rate in our studies was moderate (3 ha TLU^{-1}) and the paddocks were rotationally grazed. The high weight gains in the wet season and low weight losses in the dry season by the animals compared to results from studies by Wilson (1986) and Schlecht (1995) in the region (see Chapter 7), suggest that at low to medium stocking rates, increased animal growth rates can be obtained on Sahelian rangelands. This implies that at the current stocking rates the range is "overstocked", and that lower animal densities would result in increased production per animal, a view commonly held by the animal scientists and ecologists (Penning de Vries and Djitèye, 1982; Ketelaars, 1984; Breman and de Ridder, 1991). It is beyond the scope of this thesis to comment on the effects of reduced animal densities on animal production per unit area. In addition to the benefit of increased production per animal, the detrimental effects of increased defoliation intensity on the vegetation and the associated negative consequences for the soil (soil compaction and the associated reduction in soil aeration and infiltration, increased soil erosion) will be significantly reduced. However, reducing herd size is an unpopular option to the livestock-keepers in view of the multi-functional roles of the animals in the pastoral households. Hence, the objectives of the pastoral production are to satisfy nutritional and social needs and not primarily profitability i.e., monetary returns (Bourgeot, 1981).

Herders' perceptions of night grazing

The response of herders interviewed on their perceptions of night grazing (Chapter 8) in Kodey and Toukounous, Niger, indicates that night grazing is an important herd management strategy in the region. In both villages, most of the herders were of the opinion that night grazing, in addition to grazing during the day, has a positive effect on weight changes of both adult animals and their offspring, milk production, reproductive performance and faecal output (Table 4). However, the herders observed that night grazing prevented manure collection in the corral, i.e. manure that could be deposited in the corral is deposited on the rangelands. The perceived benefits of night grazing by the herders are consistent with experimental results that night grazing increase total grazing time and consequently forage intake, increased weight gains in the wet season and

Table 4. Influence of night grazing on animal productivity as perceived by the herders in Kodey and Toukounous, Niger (values are % of the total respondents per site).

Parameter	Kodey (n=57)				Toukounous (n=14)			
	Pos.[1]	Neg.[2]	None[3]	Don't know[4]	Pos.	Neg.	None	Don't know
Weight change in adults	98.3	0	1.7	0	92.9	0	7.1	0
Weight change in offspring[5]	63.2	0	29.8	7.0	92.9	0	0	7.1
Milk production	98.3	0	1.7	0	92.9	0	0	7.1
Reproductive performance	71.9	0	17.6	10.5	50.0	0	21.4	28.6
Faecal output	79.0	0	12.3	8.7	57.2	0	35.7	7.1
Recuperation of faeces on corral	31.5	24.6	24.6	19.3	28.6	7.1	28.6	35.7

[1]Pos. = Positive effect; [2]Neg. = Negative effect; [3]None = No effect; [4]Don't know = The herders could not judge; [5]Weight change in offspring refers to the influence of night grazing by dam (adult female) on the weight change (development) in the offspring.

reduced weight losses in dry seasons (Wigg and Owen, 1973; Dicko-Touré, 1980; Nicholson, 1987; Fernández-Rivera et al., 1996; Ayantunde et al., 1997). The agreement between herders' perceptions and research results on night grazing reaffirms the professionalism of the pastoralists (Thébaud et al., 1995) and it also re-emphasizes the importance of indigenous knowledge in the design and implementation of agricultural research in the region (van Oostrum and Peters, 1995). Therefore, the herders' current knowledge and herd management strategies need to be considered in the development of any animal- or ecologically-related innovation.

The response of the herders in both villages suggests that night grazing is ethnic-related. Night grazing was practised virtually only by the Fulani, who are the most highly specialized among West African pastoralists (Dietvorst and Kerven, 1992). However, the Fulani are increasingly settling, a general trend among the pastoral population in Africa (Toulmin, 1992a; de Verdière, 1994). Sedentarization of pastoral people is perhaps a reaction to the variable climatic, economic and political circumstances. For example, Kirk (1991) observed that drought and the associated loss of animals, forced some pastoralists to become sedentary in the West African Sahel. The decline in rangeland production in the region and loss of communal grazing lands through the expansion of arable farming may also play a role in the sedentarization of the pastoralists. Associated with sedentarization is the diversification of vocation to farming and trading which tends to weaken the pastoralists' culture of full devotion to livestock keeping. Farming by the herders places demands on household labour and often limits herd mobility, thereby increasing grazing pressure around the homesteads (Zuppan, 1994). This extra-demand for farming labour on the herders may be responsible for labour constraints mentioned as one of the major problems of night grazing (Table 5). Without farming, pastoral production is already labour-intensive (Traoré and Breman, 1993; Sieff, 1997). Labour is required for herding duties, digging of wells, milking of cows, collecting water and building of huts. Dahl and Hjort (1976) observed that available labour set limits to herd growth. However, Scoones (1992) argues that once minimum labour requirements are met, livestock productivity appears insensitive to labour inputs and that household labour availability is not necessarily related to livestock performance.

Generally, labour demand varies according to overall size of herds, number of separate grazing units and distance from the homesteads, condition of the grazing resources and herd management practices. For instance, night grazing places a strong demand on household labour. The problem of labour constraints for night grazing, and herding in general, can be addressed through appropriate government policies that discourage urban migration (Table 5), like provision of electricity, water and primary health care clinics in the rural areas. Apart from interventions from the government, the herders can also hire labour or entrust their animals to professional herders (Toulmin, 1992b). Hired herdsmen can be paid in cash or in kind through either livestock offspring or derivatives of pastoral production (mostly milk), tea, sugar and clothes (Bourgeot, 1981; Toulmin, 1992b; Thébaud et al., 1995). However, the emergence of absent livestock owners (mostly urban dwellers), having their herds tended by paid herdsmen has increased the cost of hiring paid herdsmen (Kirk, 1991). Besides, pastoralists are usually unwilling to hire non-family labour, because hired herdsmen are thought to care less about the animals (Sieff, 1997). This is also a major problem in entrusting animals to professional herders (Toulmin, 1992b). This author observed that problems in entrusting animals to other herders often arise because the owners cannot monitor carefully enough how their animals are cared for. As a result, herd-owners rarely allow the paid herdsmen to take their animals to a great distance from the village and consequently, the paid herder cannot take advantage of pasture variation over a wide area.

The problem of insufficient grazing areas as mentioned by the herders in two villages is a global problem in the West African Sahel (Kirk, 1991; Traoré and Breman, 1993) and the solution mainly depends on government land tenure policies. The increasing cultivation of communal grazing areas has been driven principally by high

Table 5. Major problems encountered during night grazing by herders, possible interventions and the constraints in implementing the suggested interventions.

Problem	Intervention	Constraint in implementation
Insecurity (e.g. snake bite, cold, attack by evil spirits)	- Joint herding (2 or more herders in charge of the herd) - Grazing within the vicinity of the village - Wearing protective shoes (e.g. boots) and clothes (e.g. sweater) - Using head lamps or torch light	- High grazing pressure around the village - Costs in procuring boots, sweaters, head lamps etc.
Labour constraints	- Hiring labour (paid herders) - Entrusting the animals to professional herders - Drilling wells in the grazing area to reduce labour needs for watering - Appropriate government policies that discourage urban migration, like provision of basic infrastructures (electricity, water, primary health care clinic)	- Costs in paying hired labour - Trust in confiding animals to professional herders - Lack of priority by the government for rural dwellers - Farming by the herders
Insufficient grazing area	- Protection of communal pastures from cropping - Establishment of dry season grazing reserves - Grazing of crop residue fields in the dry season	- Inappropriate and inconsistent government policies on land tenure - Weak bargaining power vis-à-vis the government - Sedentarization of pastoral population - Harvest of crop residues for stall-feeding and/or for sale
Damage to crops	- Herding of the animals during the growing season - Grazing in areas far from the crop fields	- Additional demand on labour - Restriction of grazing time for the animals
Herders' fatigue	- Cooperative herding[1] of the animals - Herding of the animals at certain time interval instead of every day	- Problem of trust in cooperative herding - Animals may not return to corral for manure collection if left alone - Risk of damage to crops in the growing season

[1]Cooperative herding refers to an arrangement between two or more herders whereby each of the herders takes care of the animals in turn for an agreed number of days or weeks.

population growth in the region (van Keulen and Breman, 1990; Ramaswamy and Sanders, 1992). The weak bargaining position of the pastoralists (mostly Fulani) because they are in the minority in all countries in the West African Sahel (Dietvorst and Kerven, 1992), allowed farmers to extend the cropland into the more marginal areas. Gilles and Jamtgaard (1981) reported that the claims of farmers for land have been honoured by most governments despite the objections of pastoralists. These authors also observed that the policies of most governments in Africa to settle pastoralists and to reduce their mobility have contributed to increased cultivation of marginal lands and the associated decline in grazing areas.

Other problems associated with night grazing such as insecurity, damage to crops and herders' fatigue (Table 5) can be handled by the herders. Joint herding could be arranged to minimize the risk of insecurity, especially from predators while cooperative herding (an arrangement between two or more herders whereby each of the herders takes care of the animals in turn for an agreed number of days or weeks) is a feasible strategy to reduce herders' fatigues. However, the poor financial base of the herders may be a problem in procuring protective shoes, sweaters and head lamps as security measures during night grazing.

In addressing the problems of night grazing, there is a need to focus on the constraints enumerated by the herders such as insecurity, labour constraints and insufficient grazing areas. This implies that technical research needs to recognize the constraints faced by herders and suggest measures to alleviate them to improve technical and economic efficiency. In addition, technical innovations should be flexible enough to deal with diversity and variability of the pastoral community and their social, economic and political conditions.

General conclusions

The major conclusions of the studies described in this thesis are:

- The quality of the diet selected during the day and at night is not different but rather the quality of the available forage declined as the season progressed from wet to dry. During the dry season, there was a trend for day-and-night grazing cattle to be more selective (i.e. ingesting a diet of better quality) during the day than animals that grazed only during the day.

- Night corralling of cattle puts nutritional stress on the animals because of lower forage intake, thereby increasing weight losses in the dry season. It also increases the need for supplementation.

- Weight gain and grazing time are positively related. Additional grazing time at night, especially in the dry season, improves animal performance.

- Additional grazing time at night leads to an increase in forage intake and faecal output but to a decrease in collectable manure for cropping.

- Day grazing with sufficient supplementation is adequate for cattle to maintain their body weight in the critical late dry season in the Sahel. Thus, when animals are denied night grazing (i.e. night corralled) supplementation is necessary to reduce weight losses in the dry season.

- Day-and-night grazers consume less water than day-grazers per kg forage DM ingested. Thus, night grazing reduces livestock water needs.

- Ethnic group and herd size are critical to the practice of night grazing. Night grazing is practised virtually only by the Fulani in the two villages surveyed.

- In the wet season, the animals are generally herded (i.e. closely followed and supervised) to prevent damage to crops but in the dry season night grazing is left to the initiative of the animals.

- Children are the herders during the day, while adults are responsible for night-time herding of the animals.

- Herders' perceptions of night grazing with respect to animal production parameters such as weight development, water consumption, faecal output and feeding behaviour are consistent with available experimental results. Therefore, the herders' current knowledge and herd management strategies need to be considered in the development of any animal- or ecologically-related innovation.

- Grazing by cattle stimulates regrowth in the early part of the wet season which compensates for consumption by cattle, later, grazing reduces the rate of herbage accumulation.

- Grazing in the dry season increases the rate of herbage disappearance. However, when the fraction consumed by cattle is accounted for, the disappearance rate is only slightly higher than in ungrazed paddocks.

- Leguminous and non-leguminous dicotyledons have higher nitrogen and phosphorus concentrations than grasses throughout the year, but grasses are more digestible in most of the dry season.

- Grazing ruminants tend to make better use of Sahelian rangelands than predicted on the basis of pasture evaluation alone.

Practical recommendations

From an animal production point of view the following practical recommendations can be made:

- Allow cattle to graze as much as they can in the day and at night especially in the dry season.

- In the wet season, allow cattle to graze for up to 10 h during the day and night grazing will be unnecessary.

- Cattle being used for corralled have need for extra supplementation to compensate for lack of night grazing especially in the dry season or animals with lower nutrient needs for corralling, e.g. young calves, bulls, non-working bullocks, should be used.

- Long night grazing is advisable in periods of water shortage to reduce water needs of the animals.

- Leave crop residues in the fields for animals to graze, which will increase manure deposition on the cropland and reduces the need for herding labour at night.

- Evaluation of Sahelian rangelands should not only focus on biomass production, but also on the quality of the herbage produced and the utilization by grazing animals.

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Summary

In the West African Sahel (zone with annual rainfall between 100 and 600 mm), natural rangelands form the main feed resource for livestock. The quantity (herbaceous mass) and quality (nitrogen content and digestibility) of the available forage vary markedly over the seasons and from year-to-year. In addition to feed-related factors, management practices affect the nutrition of cattle, by influencing timing and duration of grazing. For instance, night grazing and corralling, which are common practices in the zone, affect time available for grazing. When animals are used to deposit manure in the cropping fields conflicts often arise between the need for animals to graze long enough for adequate feed intake and the need to collect manure. These herd management practices may also affect the direction and magnitude of nutrient flows, and the spatial distribution of grazing in the landscape. The studies reported in this thesis originated from recognition of the conflict between the need for night grazing, especially in the dry season, and night-time corralling for manure collection. They aimed at identifying management practices that optimise the animals' time for the two objectives, i.e. manuring to sustain soil fertility and hence crop production, and foraging to maintain or increase livestock output in terms of meat and/or milk.

The specific objectives of the studies were: (1) To determine the effects of timing (day or day and night) and duration of grazing on diet selection, feeding behaviour, forage and water consumption, faecal excretion and weight changes of cattle in Sahelian rangelands; (2) To quantify the short-term effects of grazing by cattle on vegetation dynamics in Sahelian rangelands; (3) To identify constraints to the practice of night grazing and opportunities to apply relevant experimental results in the management of herds in the region. The grazing trials were designed to examine the effects of the traditional practice of night corralling for manure collection (i.e. no night grazing) on animal production and the potential impact on nutrient transfer from rangeland to cropland. Effects of livestock grazing on the vegetation were studied to increase understanding of forage ingestion by grazing cattle and the associated nutrient cycling within rangelands.

The studies were carried out under the auspices of the International Livestock Research Institute (ILRI), Niger, within the framework of the project "Livestock-mediated nutrient transfers in semi-arid areas of West Africa. The grazing trials were carried out at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT-Niger) in Sadoré (13° 14' N and 2° 16' E) and in Toukounous (14° 30' N and 3° 17' E), Niger, between February 1995 and June 1997. The survey on herders' perceptions of night grazing was conducted from February to June 1997 in Toukounous and Kodey (13° 23' N and 2° 51' E), Niger.

The studies on night grazing show that there are no differences in the quality (crude protein and digestibility) of the diet selected during the day and at night, but the quality of the available and ingested forage declined as the season progressed from wet to dry. These results show that sight does not play a major role in diet selection. These results may be not hold under pastoral systems where the grazing sites during the day and at night are often different as in our studies where animals grazed the same paddocks. During the dry season, there was a trend for day-and-night grazing cattle to be more selective (i.e. ingesting a diet of better quality) during the day, than animals that grazed only during the day. It is concluded that grazing cattle are less selective when their grazing time is restricted.

Our results also showed that night corralling, especially during the dry season, not only leads to nutritional stress on the animals (by reducing forage intake) and consequently reduced performance, but also increased the need for supplementation. Animals that had additional grazing time in the night consistently had higher forage intake than those that grazed only during the day in all seasons. Consequently, day-and-night grazers had higher weight gains in the wet season and lower weight losses in the dry season than animals that were corralled in the night. However, additional grazing at night reduces the amount of manure that can be collected for crop fields. The collectable manure decreased linearly with increase in duration (total time) of grazing, suggesting that more of the faecal output by the animals was deposited on the rangelands. The animals with the shortest grazing time (6 h only in the day) produced the highest amount of manure, but had the lowest weight gain in the wet season and highest weight loss in the dry season. However, we found that the animals that grazed during the night for 3 h in addition to 9 h during the day still produced an appreciable amount of manure (about 1 kg DM d^{-1}) in the dry season. Thus, grazing cattle can be allowed to graze in the night and still deposit an appreciable amount of manure in the corral. This, however, requires additional labour for herding in the night, especially to guarantee return of the animals to the crop fields to be manured.

In the absence of herding labour for night grazing, so that the animals have to be corralled (i.e. not allowed to free-range in the night), supplements have to be fed to ensure that their nutritional requirements are met and performance is not jeopardised, especially in the dry season. When animals are supplemented night grazing appears less relevant as the length of night grazing time did not significantly affect average daily gain in the late dry season. Even though supplementation seems justified from an animal production point of view, the benefits in terms of crop yield from using the supplemented animals in manuring crop fields is a decisive factor in opting for night corralling with supplementation, instead of night grazing.

Annual herbage production of the four paddocks used in Toukounous was 1893 kg DM ha^{-1}. However, lower values may be observed at other sites in the Sahel with similar annual rainfall as at our study site because of considerable spatial variation in Sahelian rangeland production. Of the herbage produced, consumption by cattle accounted for 48 % on a year-round basis. This reaffirms that consumption by livestock is one of the major factors in herbage disappearance. Nevertheless, our study on the short term effects of grazing by cattle on herbage growth and disappearance shows that grazing in the early growing season (before heading) stimulates regrowth, subsequently in the wet season there was a decline in rate of herbage accumulation. During the season, grazing leads to higher rates of herbage disappearance. However, when the fraction consumed by cattle is accounted for, the disappearance rate is only slightly higher than in the ungrazed paddocks. The quality (crude protein and digestibility) of the diet selected by the animals (esophageally fistulated steers) was consistently higher than that of the herbage grazed in all seasons, which demonstrated the selective ability of the animals. These results indicate that grazing ruminants tend to make better use of Sahelian rangelands than often predicted on the basis of pasture evaluation alone. Thus, evaluation of the nutritive value of forages should not only focus on their chemical composition, but should also consider the foraging strategy of the animals. The nitrogen and phosphorus concentrations, and digestibility of the dominant annual grasses and dicotyledonous species of the pastures reached their peak in the middle of the wet season (August) and subsequently declined. However, dicotyledonous species that had higher digestibility than the annual grasses in the wet season were less digestible in most of the dry season. Some of these dicotyledonous plants though higher in N and P concentrations are refused by cattle. It is concluded that palatability of plant species cannot be solely explained by their chemical composition. Hence, pasture evaluation should distinguish among different classes of species (e.g. annual grasses, leguminous and non-leguminous dicotyledons) as this may provide a better indication of the nutritional quality of a rangeland and its utilization by grazing ruminants than the mean chemical composition of the composite herbage samples.

The response of herders interviewed on their perceptions of night grazing (Chapter 8) in Kodey and Toukounous, Niger, indicates that night grazing is an important herd management strategy that can lead to increased animal production in the region. Ethnic group and herd size are critical characteristics for the decision on the practice of night grazing. Night grazing is practised virtually only by the Fulani in the two villages surveyed. Large herd size promotes night grazing. In the wet season, the animals are generally herded (i.e. closely followed and supervised) to prevent damage to crops, but in the dry season night grazing is left to the initiative of the animals. Children are the herders during the day while adults are responsible for night-time herding of the animals.

Herders' perceptions of night grazing with respect to animal production parameters such as weight development, water consumption, faecal output and feeding behaviour are consistent with available experimental results. Therefore, the herders' current knowledge and herd management strategies need to be considered in the development of any animal or ecological innovation. In addressing the problems of night grazing, there is a need to focus on the constraints enumerated by the herders such as insecurity, labour constraints and insufficient grazing areas.

Résumé

Dans le Sahel ouest-africain (zone comprise entre les isohyètes 100 et 600 mm de pluviométrie annuelle), les pâturages naturels constituent la principale source d'alimentation du bétail. La quantité (biomasse herbacée) et la qualité (taux d'azote et de digestibilité) du fourrage disponible varie remarquablement de saison en saison et d'année en année. En plus des facteurs d'alimentation, les pratiques de gestion affectent aussi la nutrition du bétail, en influenceant le rythme et la durée de la pâture. Par exemple la pâture de nuit et le parcage qui sont des pratiques répandues dans la zone influencent le temps disponible pour la pâture. Quand les animaux sont utilisés pour enfumer les champs de culture avec leurs fécès, les conflits arrivent souvent entre le besoin des animaux d'avoir un temps de pâture assez long pour une ingestion adéquate et le besoin de collecter du fumier. Ces pratiques de gestion du troupeau peuvent aussi influencer la direction et l'ampleur des flux des nutrients, ainsi que la distribution spatiale des pâturages dans le terroir. Les études réalisées dans cette thèse ont été initiées sur la base de la reconnaissance de la compétition entre le besoin de pâture nocturne particulièrement en saison sèche et le temps de parcage nocturne pour la collecte du fumier. Elles visent à identifier les pratiques qui optimisent le temps des animaux pour les deux objectifs, c'est-à-dire la production de fumier pour maintenir la fertilité du sol et par conséquent la durabilité de la production agricole, et en essayant de maintenir ou d'accroitre la production animale en termes de quantité de lait et/ou de viande.

Les objectifs spécifiques de ces études étaient (1) Déterminer les effets du rythme (par jour ou jour et nuit) et de la durée de la pâture sur la sélection du fourrage, le comportement fourrager, la consommation de fourrage et d'eau, l'excrétion de fécès et le changement de poids des bovins sur les pâturages sahéliens; (2) Quantifier les effets à court terme de la pâture des bovins sur la dynamique de la végétation dans les pâturages sahéliens; (3) Identifier les contraintes de la pâture de nuit et les opportunités pour appliquer les résultats expérimentaux rélevants dans la gestion des troupeaux dans la région. Les essais de pâture étaient éxécutés pour examiner les effets de la pratique traditionnelle de parcage nocturne pour la collecte de fumier (c'est-à-dire pas de pâture nocturne) sur la production animale et l'impact potentiel sur le transfert de nutrient des pâturages aux champs de culture. Les effets de la pâture des animaux d'élevage sur la végétation étaient étudiés pour avoir plus de connaissances sur l'ingestion du fourrage des bovins en pâture et le cycle associé des nutrients dans les pâturages naturels.

Les études ont été menées sous les auspices du Institut international de recherche sur l'élevage (ILRI), Niger dans le cadre du projet sur les transferts des nutrients dans l'élevage dans les zones semi-arides de l'Afrique de l'Ouest. Les essais de pâture ont été menées à l'Institut international de recherche agricole pour les zones tropicales semi-