Amount of fallen fodder components from *Acacia raddiana*, *Balanites aegyptiaca* and *Ziziphus mauritiana* available to ruminants in selected Sahelian pastures

H O Sanon[1], J A Nianogo[2], N S Nanglem[3] and S Sanou[3]

[1] Institut de l'Environnement et de Recherche Agricole, CRREA de l'Ouest, Station de Farako-ba, BP 910 Bobo-Dioulasso, Burkina Faso
oumou_sanon@hotmail.com
[2] Union Mondiale pour la Nature UICN - Mission Burkina Faso, BP 3133 Ouagadougou, Burkina Faso
[3] Institut de l'Environnement et de Recherche Agricole, CRREA du Sahel, Station de Katchari, BP 80 Dori, Burkina Faso

Abstract

The amount of fallen leaves and fruits (litter), which is available and accessible to animals, was evaluated for three browse species in Sahelian area of Burkina Faso: *Acacia raddiana*, *Balanites aegyptiaca* and *Ziziphus mauritiana*. The amount of leaves and fruits collected on the ground varied with the height and the species of trees. The available amount of leaves and fruits was 1373 g and 4107 g for *Acacia raddiana*, 569 g and 70 g for *Balanites aegyptiaca*, 248 g and 1743 g for *Ziziphus mauritiana respectively*. The availability of browse fodder components lasted 4 months, and was higher in January, mainly due to the highest contribution of *Acacia raddiana* pods.

A significant positive relationship ($R^2 > 0.90$) was found between the available forage of *Acacia raddiana* and physical parameters of the trees. For *Balanites aegyptiaca* and *Ziziphus mauritiana* this relationship was weak.

The contribution of the available browse fodder to the potential production of pasture was important in glacis and sandy soil pasture with regards to the importance of species investigated in the woody flora composition of these pastures.

Chemical analysis of samples from these species showed high content in crude protein (5% to 20.6% of DM) and in minerals (3.31 to 18.18 % of DM; the content in cell wall was low (13.63 to 33.86 % of DM for ADF and 20.20 to 39.56 % of DM for NDF). However, the amount of lignin (5.13 to 15.87 % of DM) and cell wall degree of lignification (25 to 54%) was also high.

Key words: *Acacia raddiana*, amount of leaf/fruit fallen, *Balanites aegyptiaca*, browse fodder, chemical composition, *Ziziphus mauritiana*

Introduction

In the Sahelian area, natural pastures are dominated by annual grasses. During the long dry season, the herbaceous components are in the state of straws with low nutritive value and cannot ensure the maintenance requirement of herbivores. The ligneous family, being less dependent on the short rainy season, represents the only source of green fodder at this period. Leaves, fruits, young branches can constitute 50% to 90% of the diet of cattle and small ruminants respectively (César and Zoumana 1999). However, most of the studies on the ligneous family have been focused on a flora inventory, e.g. chemical composition and digestibility (Le Houérou 1980; Kabore-Zoungrana 1995). Data on browse fodder available and accessible to the ruminants are rare. One of the reasons is the lack of standardized methodologies to evaluate the production of woody forage and their consumption compared to what can be done in corresponding research on herbaceous pasture. Many methodologies have been developed to assess browse production: destructive and non-destructives methods. Direct measures (destructive method) being long and difficult, the classical approach has consisted of establishing predictive equations that allow the estimation of global leaves production. The method has been used in many applications (Cissé 1980, Hiernaux 1980; Cissé and Sacko 1987; Touré and Gillet 1987). Others authors used parameters easily accessible such as density and crow cover to estimate indirectly the production (Breman and de Ridder 1991). However, this global production does not give precision on the proportion really disposable to animals. However, detailed methodologies are lacking. Moreover, the evaluation of this production does not take into account the part of leaves, flowers or fruits/pods fallen, neither the production of fruits/pods, which are rich in protein and energy supply.

Thus, this study was conducted to evaluate the fodder production of some woody species in Sahelian area and particularly the amount of fallen leaves and fruits i.e. litter.

Material and Methods

Location and climate of study area

The study was undertaken in the Sahelian area of Burkina Faso. The mean annual rainfall over the last ten years recorded on the weather station of DORI was 465 mm, with a minimum of 320 mm in 1993 and a maximum of 542 mm in 1994. During the study period (2000), 350 mm of rainfall was recorded. The vegetation of the sites belongs to the Northern Sahelian agro-ecological zone, characterized by shrubby steppes with thorn-bush in the glacis and the sandy soils, savanna vegetation in the depressions and wet and watery meadows around ponds (Fontes and Guinko 1995).

Experimental design

Three species representative of the Sahelian zone of Burkina Faso were investigated: *Acacia raddianaSavi*, *Balanites aegyptiaca (L.)Del. and Ziziphus mauritianaLam.* A random stratified sampling was applied, and three individual trees of each species were randomly selected in the pasture units where the specie is dominant and according to the following classes of height: [< 1m], [1 - 3m], [3 - 5m], [5 - 7m] and [>7m]. In total 15 individuals of *Acacia raddiana* were selected on a pasture of glacis, 15 individuals of *Balanites aegyptiaca* on sandy soil pasture and 12 individuals of *Ziziphus mauritiana* (lack of trees taller than 7m) in the depression pastures. For each individual tree, measurements on the average diameter of the crown cover, the trunk circumference at about 40cm above ground, and the total height were done. The selected trees were protected with wire fencing. The period of measurement lasted December 2000 to April 2001, when the leaves and fruits were falling. Gathering took place every three days. Samples of each component of the species were then analyzed for chemical composition. The dry matter content was determined by oven drying at 100°C and minerals content by ignition at 550°C. The content of crude protein was determined by Kdjeldal method according to procedures described by AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) concentration were determined according to the procedure of Goering and Van Soest (1970).

The data were analyzed using STATVIEW program 2000 and the means were compared by the Fisher test.

Results

The phenological development varied according to the species and the state of maturity of individual plants. Most of the species lost their leaves and fruits between November and March. They restarted the development cycle as soon as the first rains come (June - July) except some individuals of *Balanitesaegyptiaca and Ziziphus mauritiana* which started their foliage in April - May. Also, some *Balanites aegyptiaca* trees did not loose all of their leaves during the dry season (only a decrease in cover density was observed), while insects devoured all leaves of other trees; only 3 of the 15 individual trees did produce fruits.

Effect of species

Acacia raddiana showed the mean production of leaves important with 1373 g during the measurement period; 569 g were collected for *Balanites aegyptiaca* and 247 g for *Ziziphus mauritiana* (table 1). However, the differences between the species were not significant. For the production of fruits, *Acacia raddiana* still showed the highest value with on average 4107 g of pods fallen and collected. This value was significantly different from that of *Balanites aegyptiaca* (70 g). The weak performance of *Balanites aegyptiaca* can be explained by the effect of insects which devoured all leaves of some trees, as stated before.

Table 1. Mean Production of leaves and fruits/pods per specie (dry matter)

Production, g	***Acacia raddiana***	***B aegypyiaca***	***Ziziphus mauritiana***
Leaves	1373a	569a	248a
Fruits/pods	4107a	70b	1743ab

The means value in the same line with different indices are significantly different according to PLSD test of Fisher (p≤ 0.05).

Effect of height of the trees

The average amount of fallen leaves and fruits increased proportionally with the height of the trees (table 2). There were differences among the first two classes (less than 3m) and the fifth (>7 m). In addition, class 1 did not give any fruits and the observed amount of fruits in class 2 comes mainly from *Ziziphus mauritiana*. The interaction between species and height showed that class 5 of *Acacia raddiana* has a production of leaves and pods (5.2 kg and 13.6 kg respectively) significantly different from that of all classes of other species.

Table 2. Influence of height class on the production of leaves and fruits/pods (dry matter)

Production, g	Class 1	Class 2	Class 3	Class 4	Class 5
Leaves	5a	131a	282ab	858ab	3437b
Fruits/pods	0a	20a	1467ab	3134ab	7003b

The means value in the same line with different indices are significantly different according to PLSD test of Fisher ($p \leq 0.05$).

Variations in the amount of fallen leaves and pods with time

Acacia raddiana shows a peak of production in January for the pods and in February for the leaves. These amounts dropped considerably to reach minimum values in March. The amount of fruits from *Ziziphus mauritiana* was highest in December and then decreased, while the amount of leaves increased from December to March, but still remained small. For *Balanites aegyptiaca*, the amount of leaves and fruits were highest in February. The total availability of browse fodder components was highest in January, reaching 43.5 kg/month in total, mainly due to the high contribution of *Acacia raddiana* pods (Figure 1). Then, it decreased quickly and in March only 17% of this maximum production was obtained.

Figure 1. Evolution of leaves and fruits production on ground

Relationship between production of woody components and physical parameters of the trees

For *Acacia raddiana*, the amount of fallen leaves and pods was strongly correlated to trunk circumference ($Y = 954.78 - 100.12X + 1.6X^2$; $R^2 = 0.99$) and average crown diameter ($Y = 3247.65 - 23.68X + 0.03X^2$; $R^2 = 0.92$); the correlation with total height was also positive ($Y = 2093.58 - 30.7X + 0.07X^2$; $R^2 = 0.75$). Table (3) shows available fodder components per unit of area (m^2) of crown according to the classes of height for *Acacia raddiana*. For *Balanites aegyptiaca* and *Ziziphus mauritiana*, the measured parameters had only a weak correlation with the amount of fallen leaves and fruits ($R^2 < 0.25$ and $R^2 < 0.4$ respectively).

Table 3. Amount (g) of fallen leaves and fruits per crown surface (m^2) for *Acacia raddiana*

Classes of height	Class 1 [< 1]	Class 2 [1 - 3]	Class 3 [3 - 5]	Class 4 [5 - 7]	Class 5 [> 7]
Leaves	0	11,56	39,45	143,51	453,26
Fruits	0	1,85	231,15	393,68	1186,47

Contribution of available leaves and fruits in the fodder potential of pastures

Multiplying the average production per specie and per class of height by the proportion of the individual species concerned gives the potential of fallen leaves and pods. The availability was important on sandy soil pastures (98 kg/ha), while depression pastures (35.34 kg/ha) showed the smallest amounts of browse fodder (table 4) in relation with the species investigated. *Acacia raddiana* pods account for 78.24 and 71.23 % of browse fodder components (litter) in glacis and sandy soils respectively. The three species studied constituted 94.14%, 88.94% and 31.32% respectively of the woody plants in glacis, sandy soil and depressions pastures. Consequently, the results from glacis reflect the contribution of browse fodder accessible better.

Table 4. Potential of fallen leaves and fruits per pasture type (/ha)

		Glacis pasture	Sandy soil pasture	Depression pasture
Acacia raddiana	Leaves, g	15185	20479	3134
	Fruits, g	38127	68095	10371
Balanites aegyptiaca	Leaves, g	6	8141	6591
	Fruits, g	-	699	349
Ziziphus mauritiana	Leaves, g	28	466	6119
	Fruits, g	-	52	8778
Total, Kg/Ha		53.346	97.932	35.342

The production of herbaceous biomass was evaluated during the year 2000 to 300 kg/ha on glacis pastures, 550 kg/ha on sandy soil and 1700 kg/ha on the depressions (Sanon 2002). The contribution of available browse fodder in the potential pastures can be estimated at approximately 18% in the pastures of glacis and sandy soil, compared to 2% in the depressions with regards to the browse species studied.

Chemical composition

The dry matter contents in leaves were similar for the three species (Table 5), and in general significantly higher than the dry matter in fruit (except for *Acacia raddiana*).

Table 5. Chemical composition (percent of total DM) of fruits and leaves of species under study

Browse fodder components		DM, %	Minerals	Crude protein	ADF	NDF	ADL
Acacia raddiana	Leaves	97.1 ± 0.96a	28.3 ± 3.27a	6.0 ± 2.59a	25.4 ± 2.18a	24.8 ± 2.26b	12.9 ± 0.87b
	Fruits	96.5 ± 0.68a	5.5 ± 0.25b	20.3 ± 8.67b	26.4 ± 0.92a	34.4 ± 1.99a	8.7 ± 0.72a
Balanites aegyptiaca	Leaves	98.1 ± 0.15a	18.5 ± 0.25c	6.4 ± 2.18a	18.9 ± 1.69b	29.6 ± 0.83b	11.5 ± 1.96bc
	Fruits	91.6 ± 0.26b	5.3 ± 0.08b	6.6 ± 0.37a	21.3 ± 1.18b	34.7 ± 0.71a	8.6 ± 0.79ac
Ziziphus mauritiana	Leaves	97.2 ± 0.23a	10.7 ± 0.25d	5.4 ± 1.67a	24.9 ± 1.65a	29.0 ± 0.30b	11.0 ± 0.58bc

Fruits	92.4 ± 1.07b	4.6 ± 0.24b	12.0 ± 3.56c	18.3 ± 0.67b	27.5 ± 1.18b	8.0 ± 0.50a

The means value in the same column with different indices are significantly different according to PLSD test of Fisher (p≤ 0.05).

The leaves were richer in minerals than the fruits; the leaves of *Balanitesaegyptiaca* have significantly higher minerals content with 18.18 % of DM, and the fruits of *Ziziphus mauritiana* had the smaller rate (4.30 % DM).

Crude protein contents in fruits were significantly higher than in leaves for *Acacia raddiana* (19.61 % DM) and *Ziziphus mauritiana* (11.07% DM). With *Balanitesaegyptiaca* the means were similar in fruits and leaves (6% DM) and significantly smaller than the level in fruits of the two others species. In general, *Acacia raddiana* fruits were richer in protein and leaves of *Ziziphus mauritiana* had the smaller crude protein content.

The content in ADF was higher in fruits than in leaves of *Acacia raddiana* and *Balanitesaegyptiaca*. With *Ziziphus mauritiana*, the leaves contained more ADF than the fruits. Fruits of *Acacia raddiana* had the highest rate. The content in Neutral detergent fiber followed the same tendency as ADF content, with fruits of *Acacia raddiana* richer. ADL content was higher in leaves and *Acacia raddiana* leaves had higher rate.

In general, the content in ADF and NDF of the samples were relatively small, while lignin content (approximately 10 % DM for the whole sample) was high.

Discussion

The difference in physical form of the leaves and their density influences the amount of produced and fallen leaves. The plant phenology which consists of morphological and physiological variations in plants could also bring variation in production and falls of leaves and fruits between species and classes of height.

For *Balanites aegyptiaca*, the results are similar to those of Piot et al (1980) who found a weak production of fruits, a lack of flowering for many individuals and a reduction of the density of foliage in dry season. The effect of insects that reduced the production performance of this species has been also reported by Ickowicz (1995). The amount of pods obtained from *Acacia raddiana* (4 kg/tree) were lower than the result reported by Shayo (Shayo 1998) in Tanzania, who recorded a minimum of 12.9 ± 9.8kg in 1995 (mean of 12 individuals) and 66.2 ± 48.5kg (means of 18 trees) in 1994. However, the production from individuals of the class taller than 7m (13.6 kg) is comparable to the value obtained by Shayo (1998). This author noted also variations according to season, site, age and the height of individuals.

Nevertheless, the availability of fallen leaves should be relative, because all of these components would not be really available to animal for feeding due to the action of wind (which can blow of a part) and trampling by animals and men. Particularly in the case of *Acacia raddiana* which leaves are composed of 6 to 15 pairs of foliollules, when falling they separate into small particles that are easily mixed with sand, rendering their utilisation difficult to animals.

On the other hand, the study on feeding behaviour of goats on pasture (Sanon 2002) showed that the fallen component of browse fodder is well appreciated by these animals that spent 18% to 47% of their grazing time respectively in November and March.

With regard to the allometric relations, Bille (1980) noted that the polynomials of degree 2 or 3 are appropriate to express the relationship between the production of biomass and the physical parameters of the trees, in particular the circumference of the stem and the height of the tree. The results with *Acacia raddiana* confirm this assertion. Cissé (1980) obtained positive correlation coefficients ($0.84 < R < 0.98$) between the logarithm of the foliage production of 6 woody species in the Sahel (*A. albida*, *A. seyal*, *P. lucens*, *Ziziphus mauritiana*, *Commiphora africana, Balanites aegyptiaca*) and the following parameters: the circumference of the trunk, the total height and the crown surface. However in this study, which results are related to the amount of fallen leaves and fruits did not give satisfactory relationship for *Ziziphus mauritiana* and *Balanites aegyptiaca*. Fruits production of *Acacia raddiana* was also positively correlated with trunk diameter in two different sites according to soil deepness (Cissé 1983 in Breman and Kessler 1995).

With regard to production per unit of crown cover, Breman and Kessler (1995) reported a mean of 180 g m^{-2} in the north Sahelian zone.

The assessment of the fodder potential showed different contributions of the ligneous family according to the pasture types (from 2% to 18% on average). Low amounts obtained on the depressions can be explained by the wick contribution of the species investigated in comparison to the existing woody flora. Others species must then be taken into account for the estimation of the potential of browse fodder in this formation. In fact, Hiernaux (1980) noted a potential of browse fodder in the Ranch of Niono equivalent to half of the production of the herbaceous ones; but that was related to the total foliage production.

The results on chemical composition show low crude protein content in leaves of *Acacia raddiana* and *Balanites aegyptiaca* compared to the values given by Touré-Fall (1991), respectively 187 and 195 g/kg DM, but these value concerned green leaves. Thus, the low crude protein content in leaves could be explained by the maturity and senescence, which lead to a decrease in nutritive value compared to green leaves harvested on trees. The same author outlined the influence of age on chemical composition of leaves compared to the pods of legumes. The crude protein content in *Acacia raddiana* pods is similar for the two studies (185 g/kg against 196 g/kg in this study).

For the whole samples crude protein content varies from 5.27 to 19.61% DM, giving a mean value of 9.02%; this mean is smaller than the one reported by Le Houérou (1980) in woody forages of West African (12.5% DM) and East Africa (13.3% DM); however, it is higher than the crude protein in grasses in dry season, which varies between 3 and 5% (Tezenas du Montcell 1991). The results of this study are in the limits obtained by Guinko et al (1989) for some browse species in the Sahel of Burkina Faso (91 to 148.2 g/ kg DM).

Conclusions

- The amount of fallen leaves and fruits/pods varies according to species and classes of height. This production is directly accessible to goats but only available during a part of the dry season (December to March). The results emphasize that fodder of the natural pastures (herbaceous and woody forage) is not available along the year. Thus, it appears necessary to complement with other feed resources for a sustainable livestock production system.

- *Acacia raddiana* shows higher production in terms of leaves and fruits fallen. In addition, previous data (Sanon 1995) showed that this specie is disseminating in the Sahel area of Burkina Faso due to its ability to resist the harsh conditions of the area. This browse fodder could thus be promising specie for improving livestock production in the Sahel.
- The appreciable contribution of fallen browse fodder components and especially of the fruits/pods to the fodder potential of pastures shows the need for rational management of this production. In addition to its accessibility and richness in nutritive elements, the available browse organs on ground should be taken into account by pastoralists in the assessment of available browse production especially and in potential production of pastures in general.

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