Tropical Grasslands (2008) Volume 42, 104–111

Yield and nutritive value of herbaceous and browse forage legumes in the Borgou region of Benin

S. ADJOLOHOUN[1], A. BULDGEN[2], C. ADANDEDJAN[1], V. DECRUYENAERE[3] AND P. DARDENNE[4]

[1] *Faculté des Sciences agronomiques, Université d'Abomey-Calavi, Departement des Productions animales, Cotonou, Benin*

[2] *Faculté universitaire des Sciences agronomiques de Gembloux, Unité de Zootechnie, Gembloux, Belgium*

[3] *Centre wallon de Recherches agronomiques, Section Systémes agricoles, Libramont, Belgium*

[4] *Centre wallon de Recherches agronomiques, Département Qualité des Productions agricoles, Gembloux, Belgium*

Abstract

Four herbaceous (*Aeschynomene histrix, Stylosanthes fruticosa, Centrosema pubescens* and *Mucuna pruriens* var. *utilis*) and 2 browse forage legumes (*Cajanus cajan* and *Leucaena leucocephala*) were tested in a complete randomised block design (4 replicates) on infertile soils in the Borgou region of Benin over 3 consecutive rainy seasons (2000–2002). Leaf and stem production were measured as well as crude protein, crude fibre, ash and mineral concentrations in leaves.

The number of original plants surviving declined in all species except leucaena as the study progressed. Browse legumes produced more leaf material (including stems < 5 mm in diameter; mean of 4450 kg/ha DM) (P<0.05) than herbaceous legumes (mean of 2370 kg/ha). While leaf production of leucaena increased with time, that of the remaining species declined as the study progressed. The lowest production (P<0.05) was recorded for *M. pruriens* (1480 kg/ha DM).

Leaf:stem ratio for the browse legumes (0.35–0.49:1) was lower (P<0.05) than for the herbaceous legumes (0.87–1.10:1). Leaf material for all species was an acceptable source of crude protein (16–28% DM) to complement available forage on natural pastures and savannahs, especially during the dry season. However, concentrations of sodium and zinc in the material were below recommended levels for ruminant feeding.

Correspondence: Dr A. Buldgen, Unite de Zootechnie, Faculte universitaire des Sciences agronomiques, Passage des Deportes 2, 5030 Gembloux, Belgium.
E-mail: buldgen.a@fsagx.ac.be

Introduction

The Borgou region is located in the north of Benin and is characterised by average annual rainfall of 1200 mm (April–October) and infertile soils. In the extensive production systems of the region, natural fallows and savannahs constitute the basic feed for ruminants. Legume species are poorly represented in these grasslands, which are largely dominated by native grasses and weeds (Michiels *et al.* 2000). The irregular distribution of rainfall during the year leads to wide fluctuations in forage production and nutritive value of these natural resources (Adandédjan 1993). As grasses grow rapidly, plentiful biomass is produced after the onset of the rains, but protein concentration declines as grasses grow and mature. During the dry season, the crude protein concentration in the native grasses can drop below 3% DM (Atta-Krah and Reynolds 1989). To solve this problem, farmers can supplement their livestock with agro-industrial by-products such as cottonseed cake and groundnut cake, but this solution is costly. As an alternative, cultivated forage legumes can provide cheap high-quality feed, which can greatly enhance the productivity of traditional agricultural systems. Owing to their higher N content compared with grasses, legumes improve intake of forage by ruminants and digestion of fibre and reduce CO_2 and methane emissions from the rumen, through a more efficient use of the energy content of the ingested forage (Mannetje 2000). Their integration in crop rotations may also increase grain yields of the subsequent food crops (25–136%) and potentially save 50–200 kg/ha N of artificial fertiliser

(Tian *et al.* 2000). Other positive effects of their use are weed suppression and pest and disease reduction (Cullen and Hill 2006).

In Benin, no information is available on the productivity and nutritive value of forage legumes. Therefore, the current study sought to evaluate the yield and nutritive value over 3 years (2000–2002) of 4 herbaceous legumes (*Aeschynomene histrix, Stylosanthes fruticosa, Centrosema pubescens* and *Mucuna pruriens* var. *utilis*) and 2 browse legumes (*Cajanus cajan* and *Leucaena leucocephala*).

These 6 legumes were chosen for their agronomic performance and possible adaptation to the local pedo-climatic conditions. *A. histrix* grows in a range of habitats and shows a remarkable adaptation to marginal acid and infertile soils (CIAT 1979). Its potential as a pasture legume has been recognised since the late 1970s (Bishop *et al.* 1988) and for several years in west Africa (Olanite *et al.* 2004). *S. fruticosa* is native to west Africa, easy to establish by seed and drought-tolerant (Vancoppenolle *et al.* 1984). *C. pubescens* is a vigorous twining perennial legume that persists in dense grass swards, resists weed invasion and tolerates adverse seasonal conditions (Olanite *et al.* 2004). *M. pruriens* is fast-growing and well adapted to the humid and wet-subhumid tropics (Peters *et al.* 2001). Its success lies in its capacity to improve soil fertility and structure, protect soil against erosion and control weed invasion (Buckles *et al.* 1998). *C. cajan* is a productive browse legume with 20–25% crude protein levels (Barnes 1998), but has low palatability before flowering and is highly susceptible to the nematode *Meloidogyne incognita* (Adegbite *et al.* 2002). *L. leucocephala* is adapted to subhumid conditions, produces high yields of nutritious forage (Atta-Krah and Reynolds 1989) and has the potential to improve soil fertility. However, it is susceptible to the psyllid insect (*Heteropsylla cubana*), especially in high rainfall areas, and its productivity declines on acid soils.

Materials and methods

Study area

The study was conducted in northern Benin (2°75′–3°10′W, 9°–9°45′N; elevation 300–400 m asl), near the city of Parakou, on a typical sandy-ferruginous soil of the region. Analyses conducted on 0–10 cm soil samples showed that the substrate contained a high proportion of gravel (30–50%). Sand, loam and clay represented 82, 9 and 9%, respectively. The soil had a low water holding capacity and had suffered a relatively high degree of leaching. The main chemical characteristics of the experimental soil were: $pH_{(2:5\ water)}$ 6.7; N = 0.05%; organic carbon = 0.4%; Ca = 600 mg/kg; Mg = 100 mg/kg; P (extractable) = 2 mg/kg; and K (exchangeable) = 200 mg/kg. The experimental site was previously cultivated without any organic fertilisation, as reflected by the low organic carbon content of the soil.

The mean annual rainfall of the experimental area is about 1200 mm (Climatological station of Parakou), with the rainy season extending from April–May to mid-October. During the rainy season of 2000, rainy episodes were regularly distributed and total rainfall recorded between March and November was 1145 mm. In 2001 (1120 mm), July was particularly wet and September abnormally dry. In the third year (2002), total rainfall was below average (1030 mm), with the beginning and middle of the rainy season particularly dry. Minimum and maximum monthly temperatures occur in December–January (19–20°C) and February–March (30–34°C), respectively. Open pan evaporation averages 4mm/d and the relative humidity varies between 30% (January–February) and 80% (July–August).

Plant ecotypes used

The *A. histrix* accession was ILRI 12463 provided by ILRI Nigeria. In the Borgou area, it grows to 60–120 cm in height, with lateral spread of 70–100 cm. Leaves have 20–50 leaflets, and are 5–10 mm long and 1.5–2 mm wide. *C. pubescens* cv. Belalto was used and has leaflets of 4–5 cm long and 2–3 cm wide, with mean petiole length of 4–6 cm. The *Mucuna pruriens* var. *utilis* (IITA, Bénin) had purple flowers and shiney black seeds. *L. leucocephala* cv. Cunningham from CSIRO (Australia) was used. Mullen and MacFarlane (1998) reported that this cultivar was specially adapted to hot, wet, low-psyllid-pressure environments and was not tolerant of environmental stresses. Seeds of *C. cajan* and *S. fruticosa* were collected in the Borgou region. *C. cajan* was the common type cultivated in west Africa and the accession used had yellow flowers with trifoliate leaflets 5–7 cm long and 3 cm wide. *S. fruticosa* was an autochthonous type common to Africa (Toutain *et al.* 1994).

Establishment and measurements

At the beginning of January 2000, seeds of *L. leucocephala* were oven-treated at 80°C for 2 minutes (Ella *et al.* 1989) and sown into 12 cm diameter plastic bags containing soil collected from the experimental site. The seedlings were transplanted to the field in April 2000. Seeds of *A. histrix* and *S. fruticosa* were immersed in boiling water for 20–30 seconds and 2–3 minutes, respectively, to break their dormancy and ensure uniform germination (based on previous tests). The experimental area was ploughed and harrowed before planting legumes (April 2000) into 5 m × 4 m plots separated by 1 m borders. Plant spacing was 100 cm for *C. cajan* and *L. leucocephala*. *A. histrix* and *S. fruticosa* were seeded (8 kg/ha) in rows with 50 cm inter-rows. Trailing species (*C. pubescens* and *M. pruriens*) were sown with 50 cm inter- and intra-row spacings and were thinned to 1 plant per hole 2 weeks after emergence.

Each legume was considered as a treatment with 4 replications, giving a total of 6 × 4 = 24 plots arranged in a complete randomised block design. Standardisation cuts [5–10 cm high for prostrate species (*M. pruriens* and *C. pubescens*), 10–15 cm for erect herbaceous species (*A. histrix* and *S. fruticosa*) and 30 cm for browse species (*C. cajan* and *L. leucocephala*) (Barnes and Addo-Kwafo 1996; Njarui and Wandera 2004)] were carried out on June 1, 2000. During the 3 rainy seasons, the last harvest was done before the end of the humid season (about October 15) to allow plants to regrow and improve survival during the 6-month dry season. No harvest was performed at the end of each dry season, because the residual edible material at this point was insignificant for all species. All plots were hand-weeded and received no fertiliser during the experiment.

In Year 1 (2000), only 2 harvests of 8-week regrowth (July 28 and September 25, 2000) were made to allow for satisfactory establishment. During the following years (2001 and 2002), the first harvest occurred on June 1 (about 9 weeks after the onset of the rainy season) and 2 successive harvests were carried out on 8-week regrowth (July 29 and September 28, 2001; and July 31 and September 30, 2002). All material on the plots (new plants plus surviving original or 'mother' plants) was harvested. Harvesting ceased in September to allow herbaceous legumes to flower and set seed during the early dry season.

Plant counts on three 0.5 m² quadrats per plot for herbaceous legumes and the whole plot for browse legumes were made 1 month after planting (May 2000), and at the onset of plant growth in the second and third years. Mother plants and seedlings were counted separately.

In all plots, a subplot of 3 m × 3 m was marked for production measurements during the 3-year trial, to avoid border effects. For each cut, the green material collected from the subplots was immediately weighed and a sample was oven-dried for 48–72 h at 60°C for dry matter determination. The dried material was sorted into leaf (leaf + fine twigs, *i.e.,* stems < 5 mm diameter) and stem, oven-dried again for 1 h and the 2 components weighed separately for determining leaf:stem ratio. After each harvest, the remaining material on the plots was cut and discarded.

The forage samples (4 replicates per harvest and legume) were milled to pass a 1 mm screen and were analysed for crude protein (CP, Kjeldahl-method, N × 6.25), crude fibre (CF, Weende method) and ash concentrations, according to the methods of AOAC (1998). Dried samples for each legume were pooled each year and analysed for Ca, Mg, K, Na, Fe, Zn, Mn, Cu and Co concentrations by atomic absorption spectrophotometry using a Perkin Elmer AAS-800 (Wellesley, MA). P concentration was determined by the colorimetric method using molybdovanadate reagent. Se was determined by atomic absorption spectrophotometry coupled to an hydride generator (FIAS-MHS) after reduction in KI solution (Stewart *et al.* 1974). Cl was analysed by titrimetry after fusion of ash with CaO and dilution in 20% HNO_3 (Stewart *et al.* 1974). S was determined by turbidimetry (Stewart *et al.* 1974).

Statistical analyses

Leaf yields (leaf + fine twigs), leaf:stem ratios and crude protein, crude fibre and ash concentrations (n = 4 per legume) were compared using the MIXED procedure of the SAS 8.02 software (SAS Inc., Cary, NC) and the means were compared by the Least Squares Mean method, using the following linear model:

$$Y = \alpha + A_i + B_j + A*B_{(ij)} + e_{(kij)}$$

where Y is the result, α is the overall mean, A_i is the fixed year effect (i = 1, 2 and 3), B_j is the fixed legume effect (j = 1, 2, 3, 4, 5 and 6),

$A*B_{(ij)}$ is the interaction between years and legumes and $e_{(kij)}$ is the error term.

For mineral concentrations (n = 3 per legume), a one-way analysis of variance was performed using the following model:

$$Y = \alpha + A_i + e_{(ij)}$$

where Y is the result of the measurement, α is the overall mean, A_i is the fixed legume effect (i = 1, 2, 3, 4, 5 and 6) and $e_{(ij)}$ is the error term.

Results

Plant establishment and regeneration

All species established well in the first year and their growth (except for *L. leucocephala*) was satisfactory. Plant numbers of erect herbaceous species (*A. histrix* and *S. fruticosa*), trailing species (*C. pubescens* and *M. pruriens*) and browse species (*C. cajan* and *L. leucocephala*) were 200–300, 4 and 1 plant/m^2, respectively (Table 1). During the following years, the numbers of original or mother plants of *A. histrix*, *S. fruticosa* and *C. pubescens* decreased progressively, while all those of *M. pruriens* died in the first dry season. However, for these 4 legumes, regeneration plants (seedlings originating from seed-set of mother plants) were observed in both 2001 and 2002. The number of original mother plants of *C. cajan* had declined to 25% by the third wet season, while all plants of *L. leucocephala* survived.

Dry matter yields

Both year and species had significant effects on leaf yield (P<0.01) with a significant interaction between year and species (P<0.01) (Table 2). While yields of most legumes declined with time (P<0.05), that of leucaena increased (P<0.05) progressively from 2000 to 2002. In the establishment year, highest yield (7265 kg/ha DM) occurred on *C. cajan* with *M. pruriens* and *L. leucocephala* producing the least (2400–2600 kg/ha) (P<0.05). In the final year, leucaena produced 6260 kg/ha and *C. cajan* 2053 kg/ha. Overall, browse legumes produced more leaf material than herbaceous legumes (P<0.05), with *M. pruriens* producing the least DM.

Leaf:stem ratios (Table 3) varied between 0.87:1 and 1.10:1 for herbaceous legumes, while the browse legumes *C. cajan* and *L. leucocephala* produced much lower values (0.49:1 and 0.35:1, respectively) (P<0.05).

Table 1. Plant numbers/m^2 for tested species (n = 4).

Legumes	One month after sowing	June 2001		June 2002	
		Regeneration plants	Mother plants	Regeneration plants	Mother plants
A. histrix	250–300	50–100	20–30	40–60	0
S. fruticosa	200–250	40–50	10–20	30–50	2–5
C. pubescens	4	2	1.75	1	0.5
M. pruriens	4	2.5	0	2	0
C. cajan	1	0	0.75	0	0.25
L. leucocephala	1	0	1	0	1

Table 2. Leaf yields (kg/ha DM) during the 3 experimental years.

Legumes	Years			Mean (n = 12)	s.e.m. (n = 12)
	2000 (n = 4)	2001 (n = 4)	2002 (n = 4)		
A. histrix	4846 Ab[1]	2746 Bbc	1314 Cb	2969 b	356
S. fruticosa	5099 Ab	2270 Bcd	1178 Cb	2849 b	386
C. pubescens	3449 Ac	1905 Bcd	1163 Bb	2172 bc	243
M. pruriens	2594 Acd	1576 Bd	263 Cc	1478 c	213
C. cajan	7265 Aa	4975 Ba	2053 Cb	4764 a	499
L. leucocephala	2429 Cd	3732 Bb	6260 Aa	4140 a	450

[1] Means within rows followed by different upper case letters and within columns followed by different lower case letters are significantly different (P<0.05).

Nutritive values

Highest crude protein concentrations occurred in leucaena and mucuna (Table 4), with all species containing more than 15% CP.

Concentrations of both macro- and micro-minerals varied between species, differences being most pronounced for Ca, P, Cl, Cu, Mn, Se and Co.

Discussion

Plant establishment and forage production

While all species established well, poor survival of the original plants of all species except leucaena and insufficient regeneration from seed were observed in this trial. This outcome is probably a result of a combination of poor tolerance of defoliation, the low cutting heights employed and the annual or weak perennial nature of some species, *e.g. M. pruriens, A. histrix* and *C. cajan*.

In northern Australia, *C. pubescens* cv. Belalto had weak survival under similar cutting height (5 cm *vs* 5–10 cm in our case) (Clements *et al.* 1984). The higher survival of this accession in our study could be a function of better rainfall conditions in our trial (1100 mm *vs* 720 mm), and different plant management in our case, where the final harvest 15–20 days before the end of the rainy season would allow plants to regrow before experiencing the long dry season (6 months).

Table 3. Leaf:stem ratios during the 3 experimental years.

Legumes	Years			Mean (n = 12)	s.e.m. (n = 12)
	2000 (n = 4)	2001 (n = 4)	2002 (n = 4)		
A. histrix	1.01 Aa[1]	0.78 Ba	0.91 Aa	0.90 a	0.04
S. fruticosa	0.81 Aa	0.96 Aa	0.84 Aa	0.87 a	0.03
C. pubescens	1.06 Aa	1.23 Aa	1.03 Aa	1.10 a	0.03
M. pruriens	1.07 Aa	0.96 Aa	0.99 Aa	1.00 a	0.06
C. cajan	0.66 Ab	0.41 Bb	0.39 Bb	0.49 b	0.05
L. leucocephala	0.46 Ac	0.39 Bb	0.21 Cc	0.35 c	0.07

[1] Means within rows followed by different upper case letters and within columns followed by different lower case letters are significantly different (P<0.05).

Table 4. Crude fibre, ash and crude protein concentrations (% DM) in the leaves of tested species, averaged over the 3 experimental years (n = 12).

Parameters[1]	Legumes	(% DM)	
		Mean	s.e.m.
Crude fibre	*A. histrix*	23.35 b[1]	0.50
	S. fruticosa	27.82 a	0.31
	C. pubescens	27.14 a	0.83
	M. pruriens	20.05 c	0.34
	C. cajan	22.47 b	0.59
	L. leucocephala	13.72 d	0.31
Ash	*A. histrix*	7.31 a	0.55
	S. fruticosa	6.85 a	0.34
	C. pubescens	6.95 a	0.63
	M. pruriens	7.73 a	1.53
	C. cajan	6.90 a	0.58
	L. leucocephala	7.49 a	0.51
Crude protein	*A. histrix*	19.40 c	0.37
	S. fruticosa	15.97 e	0.49
	C. pubescens	18.19 d	0.39
	M. pruriens	27.02 a	0.52
	C. cajan	20.79 b	0.41
	L. leucocephala	27.22 a	0.32

[1] Within parameters, species means followed by different letters differ (P<0.05).

Table 5. Macro- and micro-mineral concentrations in leaves compared with ruminant needs (n = 3).

Legumes	Macro-minerals (% DM)							Micro-minerals (g/kg DM)					
	Ca	P	K	Mg	Na	S	Cl	Zn	Cu	Fe	Mn	Se	Co
A. histrix	1.73 a[1]	0.12 cd	1.09	0.25 b	0.01	0.05	0.16 b	28	8 b	131 c	65 b	0.10 ab	0.14
S. fruticosa	1.48 ab	0.10 d	1.06	0.30 b	0.01	0.07	0.41 ab	29	7 b	125 c	89 ab	0.03 b	0.51
C. pubescens	1.05 bc	0.17 ab	1.37	0.27 b	0.01	0.07	0.73 a	29	11a	155 b	92 ab	0.09 ab	0.28
M. pruriens	0.77 c	0.19 a	0.99	0.25 b	0.01	0.07	0.24 b	23	16 a	335 a	126 a	0.03 b	0.36
C. cajan	0.76 c	0.17 ab	0.96	0.24 b	0.02	0.10	0.09 b	23	12 a	181 b	73 b	0.05 b	0.31
L. leucocephala	1.42 ab	0.14 bc	1.14	0.38 a	0.01	0.12	0.21 b	18	18 a	147 b	63 b	0.25 a	0.36
s.e.m.	0.10	0.01	0.06	0.01	0.00	0.01	0.07	1	1	27	7	0.03	0.05
Ruminant requirements(2)	0.24	0.12	0.70	0.10	0.07	0.02	0.07	50	10	50	50	0.1	0.1

[1] Within columns, means followed by the same letter are not significantly different (P>0.05).
[2] Requirements for cattle (200 kg LW) with average liveweight gain of 100 g/d (Rivière 1991 for Ca, P, S, Cu, Fe, Mn, Se and Co; NRC 2000 for K, Na, Cl; and Underwood and Suttle 1999 for Mg and Zn).

The survival rate (about 1.5% in 2002) of *S. fruticosa* in this trial was very similar to that reported for *S. hamata* cv. Verano (1.4%) in Australia after two years (Clements *et al.* 1984) with similar cutting heights. Njarui and Wandera (2004) also observed a progressive decline in plant density for *S. guianensis* cv. Cook and *S. scabra* cv. Fitzroy. To our knowledge, no scientific information is available concerning the survival rate over years for cajanus and leucaena in similar experimental conditions.

Owing to repeated harvests, no seedlings of the browse species regenerated, because only very limited flowering was observed during the dry season. Conversely, for herbaceous species, flowering occurred during the first 2 months of the dry season each year and seedlings were observed in the following rainy seasons (see Table 1). These seedlings were not produced from hard seeds from the original planting, since the original seed of *A. histrix* and *S. fruticosa* had been treated to increase the rate and the uniformity of germination. In the case of *C. pubescens* and *M. pruriens,* the emergence of mother plants in the first year was excellent (over 90%). Therefore, a final harvest in each year can be recommended at least 15–20 days before the end of the rainy season to allow the tested herbaceous legumes to set seed.

This study has shown that browse species, particularly leucaena, have greater potential to produce good quality forage for ruminants than herbaceous species in the Borgou region as reported by Jones and Jones (1982) in subtropical coastal Queensland. However, the data obtained probably underestimate the level of edible material for cattle, especially by the browse species, as these ruminants readily consume stems of leucaena to 5–7 mm diameter in Australia (S. Dalzell, personal communication). In addition, measurements were made only for the 'growing season'. For herbaceous legumes, the leaves fell after the start of the dry season (except for *C. pubescens*), while browse species retained green leaves for most of the dry season, probably through better access to subsoil moisture. However, this production was not measured in our study.

This difference in ability of the different species to retain green leaves has obvious practical implications. Cutting and conserving legumes during the humid season is necessary for *A. histrix, S. fruticosa* and *M. pruriens* to avoid loss of material due to leaf fall, while dry season fodder banks could be envisaged for *C. pubescens, C. cajan* and *L. leucocephala*.

In this trial, none of the species was inoculated with rhizobium. At least for leucaena and to a lesser extent for *A. histrix* and *C. pubescens*, which have specific rhizobial requirements (Lesueur *et al.* 1998), it is likely that productivity would have been improved if appropriate rhizobial strains had been used.

The decline in yield of herbaceous legumes and *C. cajan* during the study is a reflection of poor survival of the original plants and insufficient regeneration from seed. Nutrient depletion over time and the extended dry seasons (particularly for *C. pubescens*) are also possible causes. Yields and persistence of these species might have been better if cutting heights were higher, which would provide more growing points as well as a greater reserve of material to support regrowth. While the yield of *C. cajan* decreased over time, that of *L. leucocephala* increased.

The deeper taproot of leucaena may have allowed it to access moisture and nutrients to a greater depth than *C. cajan* (Ella *et al.* 1989), ensuring survival during the dry seasons.

Nutritive value

Overall, crude protein concentrations in the studied species were close to those reported in the literature (Adjei and Fianu 1985; Paulino 1989; Tarawali *et al.* 1992; Merkel *et al.* 2000) and were much higher than the critical level of 60–80 g/kg DM, below which forage intake is depressed (Minson 1983). This suggests that they have the potential to improve the diets of ruminants in the Borgou region, where CP concentrations of grasses are low during the dry season. However, the presence of tannins or phenols in some species such as *C. cajan* and *L. leucocephala* can lower forage digestibility and intake (Dzowela *et al.* 1995; Vitti *et al.* 2005). They could also have a beneficial effect by enhancing efficiency of protein use through lowering ruminal degradation of the protein and increasing the availability of amino acids in the lower tract.

Phosphorus concentrations in *S. fruticosa* (0.10% DM) and *A. histrix* (0.12%) were low compared with those of the other species (0.14–0.19%) and may be limiting (Rivière 1991), especially for lactating animals. P concentration in *S. fruticosa* was similar to the values reported by Hall (1979) for *S. scabra, S. humilis* and *S. hamata* on soils of similar fertility in Queensland. For *A. histrix*, the values agree with those of Peters *et al.* (1994). All the legumes contained sufficient amounts of macro- and micro-minerals for growing animals, except for zinc and sodium (Underwood and Suttle 1999; NRC 2000).

In brief, the study demonstrates that browse legumes, in particular leucaena, show significant potential as protein sources for ruminants in the Borgou region. Their ability to retain green leaves during the dry season gives them distinct advantages over herbaceous legumes, especially in their potential use as fodder banks. While leucaena cv. Cunningham performed well in the second and third seasons, other more productive cultivars should be evaluated along with promising browse species from other studies. Despite their lower production, herbaceous forage legumes (especially *A. histrix* and *S. fruticosa)* could be used in combination with browse species as supplements to native pastures during the dry season. In other studies conducted in the Borgou region without exploitation during the rainy season (Adandédjan and Adjolohoun**,** unpublished results), *A. histrix* and *S. fruticosa* appeared good and prolific seeders, with high capacity to regenerate from seed each year. However, in grazing or cut-and-carry systems, it is important to provide relief at the end of the rainy season to enable the species to flower and set adequate seed to ensure the survival of the stand. For all the tested legumes, mineral licks containing Na and Zn and possibly P would be needed to optimise ruminant performance. While we did not measure it in our study, supplementing with iodine is recommended when feeding leucaena (S. Dalzell, personal communication). Application of inorganic fertiliser (P and K especially) or manure would be desirable to replace nutrients removed under a cut-and-carry system of forage utilisation. Feeding studies with the most promising species are warranted to ensure that the apparent value of these species can be realised in practice.

References

Adandédjan, C. (1993) Essais et développement des cultures fourragères. *Rapport d'activité mai 1993, Projet de Développement de la Production Animale, Cotonou, Bénin*. pp. 4–5.

Adegbite, A.A., Adesiyan, S.O., Agbaje, G.O. and Omoloye, A.A. (2002) Reaction of fallow crops to root-knot nematodes in south-western Nigeria. *Moor Journal of Agricultural Research*, **3**, 50–53.

Adjei, M.B. and Fianu, F.K. (1985) The effect of cutting interval on the yield and nutritive value of some tropical legumes on the coastal grassland of Ghana. *Tropical Grasslands*, **19**, 164–171.

AOAC (1998) *Official Methods of Analysis*. 16th Edn. 4th Revision. (AOAC International: Gaithersburg, MD, USA).

Atta-Krah, A.N. and Reynolds, L. (1989) Sheep and goat meat production in the humid tropics of West Africa. In: Timon, V.M. and Baber, R.P. (eds) *FAO Animal Production and Health Paper 70. Proceedings of a seminar held in Yamoussoukro, Côte d'Ivoire, 21–25 September 1987*. Available on http://www.fao.org/DOCREP/004/S8374E/S8374E05.htm#ch5 (verified on June 01 2007).

Barnes, P. (1998) Fodder production of some shrubs and trees under two harvest intervals in subhumid southern Ghana. *Agroforestry Systems*, **42**, 139–147.

Barnes, P. and Addo-Kwafo, A. (1996) Research note: Evaluation of introduced forage accessions for fodder production at a subhumid site in southern Ghana. *Tropical Grasslands,* **30**, 422–430.

Bishop, H.G., Pengelly, B.C. and Ludke, D.H. (1988) Classification and description of a collection of the legume genus *Aeschynomene*. *Tropical Grasslands,* **22**, 160–175.

Buckles, D., Triomphe, B. and Sain, G. (1998) *Cover crops in hillside agriculture: Farm innovation with* Mucuna. (IDRC: Canada).

CIAT (1979) Tropical pastures program. *Annual Report 1979*, *CIAT, Cali, Colombia*.

CLEMENTS, R.J., WINTER, W.H. and REID, R. (1984) Evaluation of some *Centrosema* species in small plots in northern Australia. *Tropical Grasslands,* **18**, 83–91.

CULLEN, B.R. and HILL, J.O. (2006) A survey of the use of lucerne, butterfly pea and lablab in ley pastures in the mixed-farming systems of northern Australia. *Tropical Grasslands,* **40**, 24–32.

DZOWELA, B.H., HOVE, L., TOPPS, J.H. and MAFONGOYA, P.L. (1995) Nutritional and anti-nutritional characters and rumen degradability of dry matter and nitrogen for some multipurpose tree species with potential for agroforestry in Zimbabwe. *Animal Feed Science and Technology*, **55**, 207–214.

ELLA, A., JACOBSEN, C., STÜR, W.W. and BLAIR, G. (1989) Effect of plant density and cutting frequency on the productivity of four tree legumes. *Tropical Grasslands,* **23**, 28–34.

HALL, T.J. (1979) Initial evaluation of *Stylosanthes* species on two soils of the Mayvale land system, north-west Queensland. *Tropical Grasslands*, **13**, 9–19.

JONES, R.J. and JONES, R.M. (1982) Observations on the persistence and potential for beef production of pastures based on *Trifolium semipilosum* and *Leucaena leucocephala* in sub-tropical coastal Queensland. *Tropical Grasslands,* **16**, 24–29.

LESUEUR, D., DATE, R.A. and MULLEN, B.F. (1998) *Rhizobium* specifity in *Leucaena*. *Proceedings of a workshop held in Hanoi, Vietnam, 9–14 February, 1998.* pp. 86–95.

MANNETJE, L. 'T (2000) Potencial y perspectivas para la sustentabilidad de las pasturas tropicales. In: Castillo, G.E., Jarillo, R.J. and Concha O.S. (eds) *Producción de leche y carne en el trópico con base en pastoreo.* pp. 1–15.

MERKEL, U., PETERS, M., TARAWALI, S.A., SCHULTZE-KRAFT, R. and BERNER, D.K. (2000) Characterization of a collection of *Aeschynomene histrix* in subhumid Nigeria. Available http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPC/doc/GBASE/Data/pf000513.HTM (verified on July 15, 2007).

MICHIELS, B., BABATOUNDÉ, S., DAHOUDA, M., CHABI, S.L.W. and BULDGEN, A. (2000) Botanical composition and nutritive value of forage consumed by sheep during the rainy season in a Sudano-guinean savanna (central Benin). *Tropical Grasslands*, **34**, 48–55.

MINSON, D.J. (1983) Effects of chemical and physical composition of herbage eaten upon intake. In: Hacker, J.B. (ed.) *Nutritional Limits to Animal Production from Pasture.* pp. 167–182. (CABI: Farnham Royal).

MULLEN, B.F. and MACFARLANE, D.C. (1998) The effect of band-seeding legumes into para grass (*Brachiaria mutica*) on pasture production, sustainability and animal productivity in Vanuata. *Tropical Grasslands*, **32**, 34–40.

NJARUI, D.M.G. and WANDERA, F.P. (2004) Effect of cutting frequency on productivity of five selected herbaceous legumes and five grasses in semi-arid tropical Kenya. *Tropical Grasslands*, **38**, 158–166.

NRC (2000) *Nutrient requirements of beef cattle.* 7th revised Edn. (Academy of Sciences: New York). Available http://www.nap.edu/openbook/0309069343/html/54.html (verified on July 15, 2007).

OLANITE, J.A., TARAWALI, S.A. and AKAN'OVA, M.E. (2004) Biomass yield, quality and acceptability of selected grass-legume mixtures in the moist savanna of west Africa. *Tropical Grasslands*, **38**, 117–128.

PAULINO, V.T. (1989) Liming and phosphate fertilization on forage production, mineral composition and nodulation of pigeonpea (*Cajanus cajan* (L.) Millsp.). *Proceedings of the XVI International Grassland Congress, Nice, France, 1989*. **1,** 49–50.

PETERS, M., TARAWALI, S.A. and ALKÄMPER, J. (1994) Evaluation of tropical pasture legumes for fodder banks in subhumid Nigeria. 1. Accessions of *Centrosema brasilianum, C. pascuorum, Chamaecrista rotundifolia* and *Stylosanthes hamata*. *Tropical Grasslands*, **28**, 65–73.

PETERS, M., HORNE, P., SCHMIDT, A., HOLMANN, F., KERRIDGE, P.C., TARAWALI, S.A., SCHULTZE-KRAFT, R., LASCANO, C.E., ARGEL, P., STÜR, W., FUJISAKA, S., MÜLER-SÄMANN, K. and WORTMANN, C. (2001) The role of forage in reducing poverty and degradation of natural resources in tropical production systems. *Agricultural Research and Extension Network. Network paper No 117.*

RIVIÈRE, R. (1991) *Manuel d'Alimentation des Ruminants Domestiques en Milieu Tropical*. (IEMVT: Paris).

STEWART, E.A., GRIMSHAW, H.M., PARKINSON, J.A. and QUARMBY, C. (1974) *Chemical analysis of ecological materials*. (Blackwell Scientific Publications: Oxford).

TARAWALI, S.A., PETERS, M. and JAMA, A.A. (1992) Species screening and multi-locational testing of *Stylosanthes* species in West Africa. In: de Leeuw, P.N., Mohamed-Saleem, M.A. and Nyamu, A.M. (eds) Stylosanthes *as forage and fallow crop. Proceedings of the Regional Workshop on the use of* Stylosanthes *in West Africa held in Kaduna, Nigeria, 26–31 October 1992.* pp. 81–95. (ILCA: Addis Ababa, Ethiopia).

TIAN, G., KOLAWOLE, G.O., KANG, B.T. and KIRCHHOF, G. (2000) Nitrogen fertilizer replacement indexes of legume cover crops in the derived savanna of west Africa. *Plant and Soil,* **224**, 287–296.

TOUTAIN, B., PEYRE DE FABREÈGUES, B., ROBERGE, G., BIGOT, A. and RIPPSTEIN, G. (1992) Revue des travaux de recherche, de vulgarisation et d'utilisation effectués sur *Stylosanthes* en Afrique de l'Ouest. In: de Leeuw, P.N., Mohamed-Saleem, M.A. and Nyamu, A.M. (eds) Stylosanthes *as forage and fallow crop. Proceedings of the Regional Workshop on the use of* Stylosanthes *in West Africa held in Kaduna, Nigeria, 26–31 October 1992.* pp. 13–22. (ILCA: Addis Ababa, Ethiopia).

UNDERWOOD, E.J. and SUTTLE, N.F. (1999) *Mineral nutrition of livestock.* 3rd Edn. (CAB International: UK).

VANCOPPENOLLE, R., RENARD, C., SOTTIAUX, G. and NYOLE, H. (1984) Comportement de *Stylosanthes guianensis* (Aubl) Sw. dans la basse Ruzizi et le Mosso (Burundi). *Tropicultura,* **2**, 50–55.

VITTI, D.M., ABDALLA, A.L., BUENO, I.C., SILVA FILHO, J.C., COSTA, C., BUENO, M.S., NOZELLA, E.F., LONGO, C., VIEIRA, E.Q., CABRAL FILHO, S.L., GODOY, P.B. and MUELLER-HARVEY, I. (2005) Do all tannins have similar nutritional effects? A comparison of three Brazilian fodder legumes. *Animal Feed Science and Technology*, **119**, 345–361.

(Received for publication April 13, 2007; accepted November 5, 2007)