

## Biomass yield, quality and acceptability of selected grass-legume mixtures in the moist savanna of west Africa

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### Abstract

In order to identify options suitable for providing livestock feed in the wetter part of the moist savanna, the DM yield, botanical composition, crude protein, *in sacco* digestibility and neutral detergent fibre of combinations of 4 herbaceous legumes and 2 grasses were evaluated between June 1994 and December 1995 at Ibadan, south-western Nigeria. The legumes, *Stylosanthes guianensis*, *Aeschynomene histrix*, *Centrosema pubescens* and *Chamaecrista rotundifolia*, were each planted in combination with *Brachiaria ruziziensis* and *Cynodon nlemfuensis*. Beginning from one year after planting, the mixtures were mob-grazed 4 times at 8-weekly intervals following DM yield estimation.

Mixtures with *B. ruziziensis* recorded significantly higher dry matter yields at the early stages of evaluation than those with *Cy. nlemfuensis*. Dry matter yield and the legume content of mixtures generally declined with time. *A. histrix*, the most vigorous legume in the early stages, declined rapidly during the course of the experiment and disappeared from the *B. ruziziensis* mixture by the end of the year. In contrast, the proportion of *Ce. pubescens* with the grasses increased over the experimental period so that, by the end of the year, it had the highest yield of all legumes. Variations in quality were less marked than those of biomass yield, but legumes were superior in quality to grasses. No single mixture of grass and legume proved clearly superior to other combinations.

### Introduction

The moist savanna region of sub-Saharan Africa (SSA) covers about 389 M ha, with over 60% falling in the west African region; typically, the region is defined with a length of crop-growing period of 180–270 days per annum (Jagtap 1995). Agriculture in the moist savanna region of west Africa is facing increasing pressure as a result of increases in both human and livestock populations (Smith *et al.* 1997). The introduction of forage legumes has been promoted as a possible option to improve the sustainability of livestock production in the region (Tarawali *et al.* 1999). In the wetter part of the moist savanna, increasing numbers of formerly nomadic herders are settling (Jabbar 1992) and combining arable cropping with cattle husbandry. Apart from the need to provide pasture resources for their livestock, forage species or combinations that could enhance soil fertility for improved crop yield would be appropriate. In this region, the intensity of agriculture does not preclude (except in peri-urban areas) maintaining a pasture. These pasture resources might be used for only a short duration, as most agropastoralists in the area do not have permanent ownership of land. It is therefore appropriate to assess options for pasture establishment, so the present study sought to build upon previous work using grass-legume mixtures and to introduce new options.

Some of the most widely recommended species of forage legumes for animal production in moist savanna regions have become susceptible to diseases, such as anthracnose disease (caused by the pathogen *Colletotrichum gloeosporioides*) in *Stylosanthes* species (Adeoti *et al.* 1994) and leaf blight in *Centrosema* species (Ezenwa 1995). In addition, the number of recommended species is limited and appropriate species have not been identified for every farming system and the range of agroecological conditions found even within the moist savanna ecozone. Efforts to identify other species that could complement or replace the

recommended species since the 1980s have revealed promising accessions with high dry matter yield potential, disease tolerance, high regenerative ability and persistence (Tarawali 1991, 1994; Peters *et al.* 1994a, 1994b; Tarawali *et al.*, 1999). While the indigenous/localised *Panicum maximum*, the dominant natural grass in rangeland, is often of reasonable quality (Aken'Ova and Mohamed-Saleem 1985), other grass species suitable for pasture improvement such as *Brachiaria ruziziensis* and *Cynodon nlemfuensis* (Ademosun 1973; Akinola 1981; Larbi *et al.* 1989) have been identified and included in the present evaluation.

In the majority of evaluation experiments to date, cutting has been used to simulate grazing. However, cutting regimens do not satisfactorily simulate grazing effects (*e.g.* Carlos 1982). In order to establish the suitability of these legumes for grazing, they must be subjected to grazing, especially in mixtures with grasses. This could provide valuable information for identifying appropriate mixtures and developing suitable management practices when the materials are eventually used in pastures. Mob-grazing (the grazing of a limited area of pasture with a much higher than normal stocking density of animals) has been widely used to study the response of forage plants to grazing effects (Mislevy *et al.* 1982). This approach provides information on the responses of the forage materials to various stresses, such as trampling, pulling and deposition of excreta by the grazing animals (Mislevy *et al.* 1982; Rhonda *et al.* 1987). It is assumed that species that are resilient under this relatively intense defoliation when selective grazing is considerably reduced could persist under normal grazing. The short duration provided by the grazing technique could also offer the opportunity to evaluate the performances of the grass-legume combinations if used in a short-term ley.

This study, therefore, further evaluated some promising herbaceous legumes using the mob-grazing approach to determine their agronomic performance and forage potential in grass-legume mixtures. Most evaluation studies in south-western Nigeria have used the locally available *P. maximum* and other tall-growing species due probably, to the relative ease with which the planting materials for such grasses can be sourced. We included other prostrate species in the evaluation in order to widen the available options of forage grasses for animal production in the area.

## Materials and methods

### Site description

The experiment was conducted at ILRI's research site, located at the International Institute of Tropical Agriculture (7°30'N, 3°54'E), Ibadan in south-western Nigeria. The area has a subhumid climate with a mean annual rainfall of 1250 mm with a bimodal distribution lasting from March–October with peaks in June and September. Monthly rainfall at Ibadan during the period of the experiment is as shown in Figure 1. Soil at the experimental site was sandy (86% sand) with a pH of 6.5, organic carbon 1.34%, nitrogen 0.19% and phosphorus (Bray 1) 7.5 mg/kg. Other mineral element concentrations were 0.3 cmol/kg for potassium and sodium, 0.6 cmol/kg for magnesium and 2.1 cmol/kg for calcium, giving an effective cation exchange capacity (CEC) of 3.3 cmol/kg.

### Grass-legume associations

Four legumes: *Stylosanthes guianensis* (accession numbers: ILRI 164; CIAT 184; cv. *Pucallpa*); *Aeschynomene histrix* (ILRI 12463; CIAT 9690; CSIRO CPI 87993); *Centrosema pubescens* (ILRI 152); and *Chamaecrista rotundifolia* (ILRI 10918; CSIRO CPI 34721; cv. Wynn) were planted in association with *Brachiaria ruziziensis* and *Cynodon nlemfuensis* Ib8 to give 8 grass-legume combinations. The legume seeds were supplied by ILRI, Nigeria and the grass cuttings were obtained from established paddocks at ILRI research site.

### Plot establishment and management

Mixtures were planted in 4 m × 5 m plots in July 1994 in a randomised complete block design with 4 replicates. Grasses were planted at a spacing of 25 cm × 50 cm within and between rows, respectively, and legume seeds were broadcast on the same day at seeding rates of 6.0, 3.07, 4.5 and 5.0 kg/ha for *S. guianensis*, *A. histrix*, *Ce. pubescens* and *Ch. rotundifolia*, respectively (Tarawali 1994). As is customary in experiments in south-western Nigeria, the grass-legume mixtures received 200 kg/ha NPK (15:15:15) fertiliser at planting followed by 60 kg/ha single superphosphate (SSP) after cut-back in March 1995. Plots were hand-weeded at 4, 8 and 12 weeks after planting.

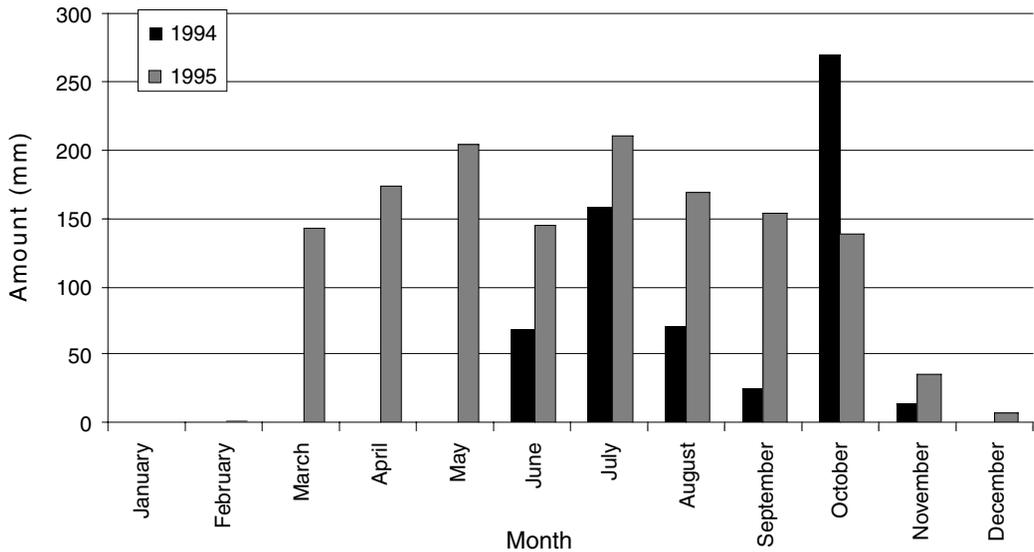


Figure 1. Monthly rainfall at Ibadan, Nigeria during June 1994 to December 1995

#### Forage sampling and grazing

The mixtures were first sampled for estimation of dry matter (DM) yield at the end of the first growing season in the establishment year, in November 1994. Two 1 m<sup>2</sup> quadrats per plot were cut to 30cm stubble height and the cut material was sorted into planted grass, sown legume and weeds, then weighed. Replicates were bulked, and 300g sub-samples were taken and oven-dried at 65°C until weight was constant for percent DM determination and chemical analysis. Subsequently, estimates of DM yields were made immediately before and after each mob-grazing period, using the same method as described above for November 1994, except that the quadrat size was 0.25 m<sup>2</sup>. Dry matter disappearance was calculated as the difference between the pre- and post-grazing values expressed as percentage of the biomass on offer at the start of grazing. Grazing of plots commenced in June 1995. Mob-grazing periods, each lasting 2–3 days, took place at 8-weekly intervals between June–December 1995. Bunaji cattle at a stocking density of 150 TLU/ha (TLU = tropical livestock unit = 250 kg) were allowed to graze the plots for 8 h each day. A 30-minute adjustment period was allowed after animals were introduced, then the number of animals grazing each plot was recorded at 5-minute intervals for 3 h. The number of animals recorded grazing each mixture

during the 3 h was calculated to obtain a value (X) for each pasture treatment, *i.e.*, X<sub>1</sub>, X<sub>2</sub>, ..., X<sub>8</sub> for Treatments 1–8 (*i.e.*, the number of times a given mixture was eaten). A constant value (Y) was obtained as (X<sub>1</sub> + X<sub>2</sub> + ... + X<sub>8</sub>)/8 = Y (*i.e.*, the number of times a given mixture was expected to be eaten if all mixtures had been of equal palatability). Relative palatability indices (RPI) were then obtained for the respective mixtures as:

$$RPI_1 = X_1/Y; RPI_2 = X_2/Y; \dots RPI_8 = X_8/Y$$

(Schultze-Kraft *et al.* 1989).

#### In sacco DM digestibility and chemical analysis

Dried samples of the grass and legume components were ground to pass a 2.5 mm screen and 5 g of each was weighed into 9 cm × 18 cm nylon bags of pore size 41 µm. The bags were incubated for 48 h in rumen-fistulated Zebu castrates. The animals were grazed on *Panicum maximum* pasture throughout the incubation period in order to create a uniform rumen environment for the incubated samples. Bags were withdrawn after the incubation period, washed under running tap water until the rinse water was clear, oven-dried and re-weighed. DM digestibility was estimated as the difference in weight pre- and post-incubation expressed as a percentage of the initial weight (Osuji *et al.* 1993).

For chemical and fibre analyses, samples were ground through a 1.0mm screen. Total N was determined by the Kjeldahl method (AOAC 1990) and crude protein (CP) was calculated as % N  $\times$  6.25. Neutral detergent fibre (NDF), phosphorus (P) and calcium (Ca) were analysed according to Goering and van Soest (1970).

#### Statistical analysis

DM yield and relative palatability data were analysed by the analysis of variance procedure of the Statistical Analysis System package (SAS 1988) and means were separated and compared using the Least Significant Difference (LSD) procedure at a 5% level of significance.

### Results

#### DM yield

Figure 2 shows the DM yields 5 months after establishment (November 1994) and prior to each grazing assessment period (June, August, October and December 1995). In November 1994 (the end of the growing season in the establishment year), yields of mixtures with *B. ruziziensis* were generally higher than those with *Cy. nlemfuensis* with the exception of *Cy. nlemfuensis*-*A. histrix*. During this establishment period, the DM yields consisted almost entirely of the planted grass and legume species, with the former contributing at least half of the total DM with the exception of the *Cy. nlemfuensis*-*A. histrix* mixture, where the grass yield was very low.

Highest yields over the entire period were in June 1995, when the pastures had regrown following the onset of the wet season. At this time, all yield estimates were in excess of 12 t/ha, highest yields ( $P < 0.05$ ) being for *B. ruziziensis*-*S. guianensis* and *Cy. nlemfuensis*-*A. histrix*, both of which yielded more than 19 t/ha. *B. ruziziensis* dominated ( $P < 0.05$ ) in the mixtures, except in combination with *A. histrix* where it contributed about half the DM yield. In mixtures with *Cy. nlemfuensis*, the legumes dominated the mixtures except for *Ce. pubescens*. In general, mixtures with *Cy. nlemfuensis*, except with *S. guianensis*, contained significantly more of other species (weeds) than those with *B. ruziziensis*.

DM yields in August 1995 ranged from 4.1–5.5 t/ha with the exception of *B. ruziziensis*-*A. histrix* which yielded 7.8 t/ha. At this time, the

legume component of the mixtures, except those with *A. histrix*, was small (less than one-third of the total DM yield), and *Ch. rotundifolia* had almost disappeared. Contribution to the DM yield from other species (weeds) was again significantly more in plots with *Cy. nlemfuensis*, but always less than one-third of the total yield.

In October 1995, total DM yields of all mixtures with *B. ruziziensis* exceeded 7.5 t/ha with *B. ruziziensis*-*Ce. pubescens* yielding significantly higher than others. The legume component of these mixtures was negligible for *S. guianensis* and *Ch. rotundifolia* and less than 20% of the total yield for the other 2 species. Mixtures with *Cy. nlemfuensis* yielded between 5.2–6.4 t/ha with the contribution to total yield from the legume component exceeding that in the *B. ruziziensis* plots, with *Ch. rotundifolia* contributing the least. Almost half the DM yield from this treatment was made up of weeds.

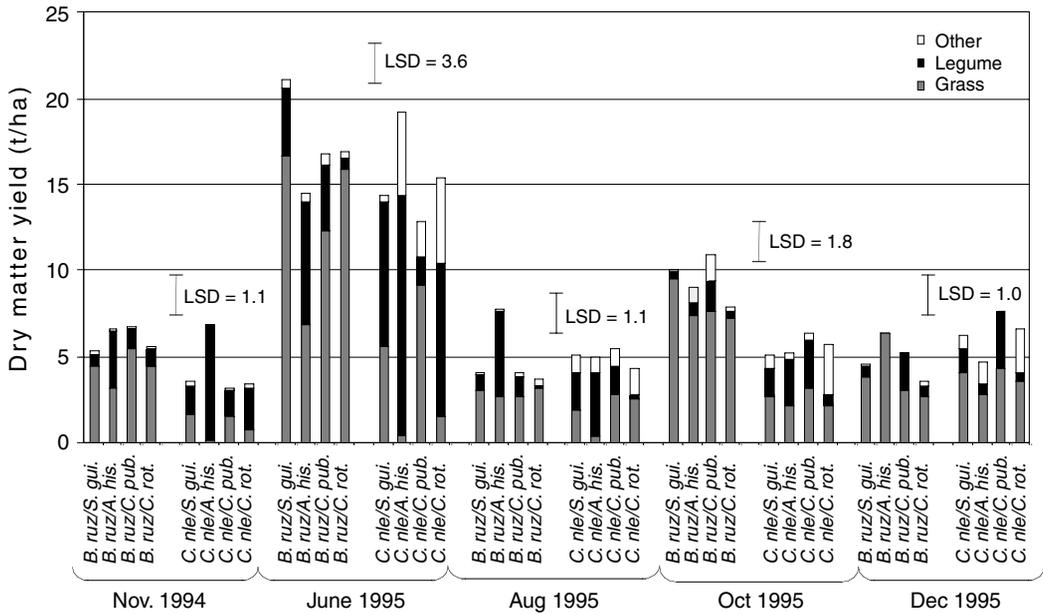
In December 1995, pasture yields were all below 8 t/ha, with the highest yield of 7.7 t/ha for *Cy. nlemfuensis*-*Ce. pubescens* being significantly higher than for other mixtures. *A. histrix* contributed no harvestable yield to the total DM yield in mixture with *B. ruziziensis* and very little with *Cy. nlemfuensis*. *Ce. pubescens* contributed the most ( $P < 0.05$ ) of all legumes to pasture mixtures, about 40% of total DM yield.

#### Palatability and DM disappearance

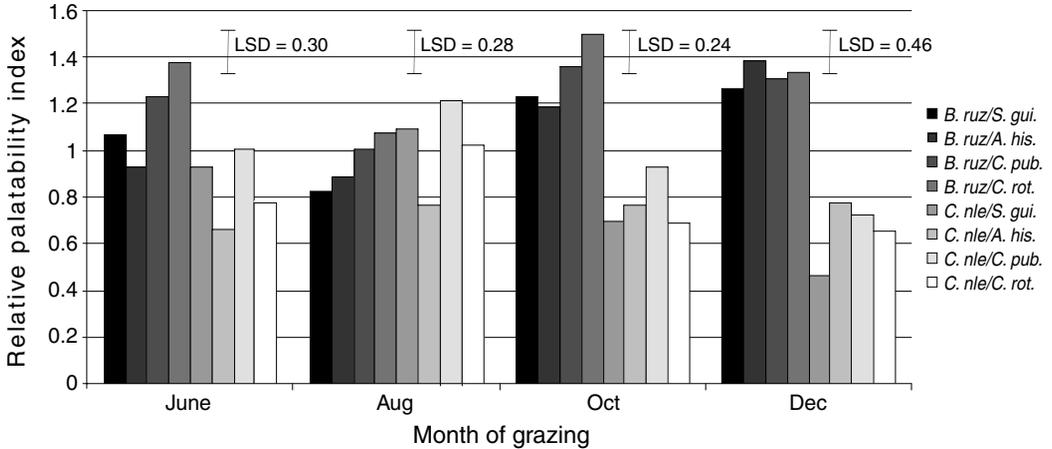
In general, cattle preferentially grazed mixtures with *B. ruziziensis* (Figure 3). Relative palatability indices for the mixtures with *B. ruziziensis* exceeded those for mixture with *Cy. nlemfuensis* with the exception of the mixtures with *S. guianensis* and *Ce. pubescens* in August. Dry matter disappearance during the 4 grazing periods was generally variable with no obvious patterns.

#### Quality

Crude protein (CP), *in sacco* DM digestibility and NDF concentrations were used as measures of quality. Legume CP concentration was higher than that in grass throughout the experiment, with values falling slightly below 7% only for *Ce. pubescens* and *Ch. rotundifolia* in combination with *Cy. nlemfuensis* in October (Figure 4). Legume CP concentrations were highest during the August and October grazing periods. In contrast, CP concentrations for the grass components



**Figure 2.** DM yields (t/ha) of grass-legume mixtures 5 months after establishment in 1994 and before each grazing period in 1995.



**Figure 3.** Relative palatability indices of grass-legume mixtures during each of the 4 grazing periods in 1995.

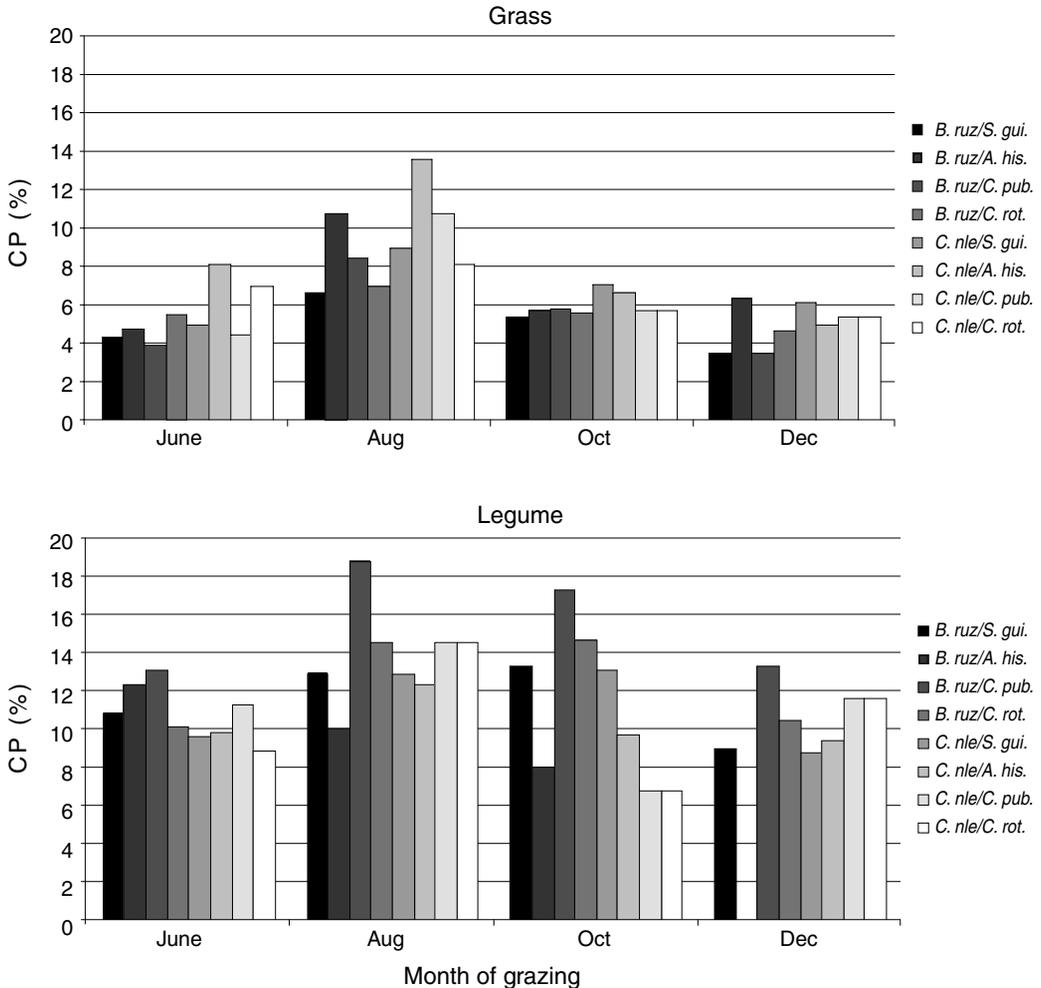
**Abbreviations for bars**

- B. ruz/S. gui.* = *Brachiaria ruziziensis*/*Stylosanthes guianensis*
- B. ruz/A. his.* = *Brachiaria ruziziensis*/*Aeschynomene histrix*
- B. ruz/C. pub.* = *Brachiaria ruziziensis*/*Centrosema pubescens*
- B. ruz/C. rot.* = *Brachiaria ruziziensis*/*Chamaecrista rotundifolia*
- C. nle/S. gui.* = *Cynodon nlemfuensis*/*Stylosanthes guianensis*
- C. nle/A. his.* = *Cynodon nlemfuensis*/*Aeschynomene histrix*
- C. nle/C. pub.* = *Cynodon nlemfuensis*/*Centrosema pubescens*
- C. nle/C. rot.* = *Cynodon nlemfuensis*/*Chamaecrista rotundifolia*

exceeded 7% only at the August measurement. *Ce. pubescens* in combination with *B. ruziziensis* contained the highest legume CP at all measurement periods. For the grass components, *Cy. nlemfuensis* in combination with *A. histrix* had the highest CP concentration for the first 2 grazing periods, but *B. ruziziensis* in combination with the same legume was highest for the dry season

grazing in December. Combining crude protein concentration with DM yield gave an estimate of the production of crude protein which was highest for the June grazing reflecting the high DM yield at that time.

*In sacco* DM digestibility for the legume and grass components of the mixtures during the 4 measurement periods is shown in Figure 5.



**Figure 4.** Crude protein concentration (% DM) in grass and legume components of mixtures at the onset of the 4 grazing periods in 1995.

**Abbreviations for bars**

- B. ruz/S. gui.* = *Brachiaria ruziziensis*/*Stylosanthes guianensis*
- B. ruz/A. his.* = *Brachiaria ruziziensis*/*Aeschynomene histrix*
- B. ruz/C. pub.* = *Brachiaria ruziziensis*/*Centrosema pubescens*
- B. ruz/C. rot.* = *Brachiaria ruziziensis*/*Chamaecrista rotundifolia*
- C. nle/S. gui.* = *Cynodon nlemfuensis*/*Stylosanthes guianensis*
- C. nle/A. his.* = *Cynodon nlemfuensis*/*Aeschynomene histrix*
- C. nle/C. pub.* = *Cynodon nlemfuensis*/*Centrosema pubescens*
- C. nle/C. rot.* = *Cynodon nlemfuensis*/*Chamaecrista rotundifolia*

Digestibility values obtained rarely exceeded 50% for either grass or legume. *B. ruziziensis* tended to be more digestible than *Cy. nlemfuensis*.

Neutral detergent fibre, expressed as percentage of DM, for the grass and legume components at the 4 grazing times periods is shown in Figure 6. Variations between the mixtures and

between measurement times were small with values largely falling between 60–70%. Grass NDF, in general, was slightly higher than that for the legumes.

Phosphorus (P) concentrations (data not shown) varied from 0.10–0.21% over the experimental period, with values in the grass

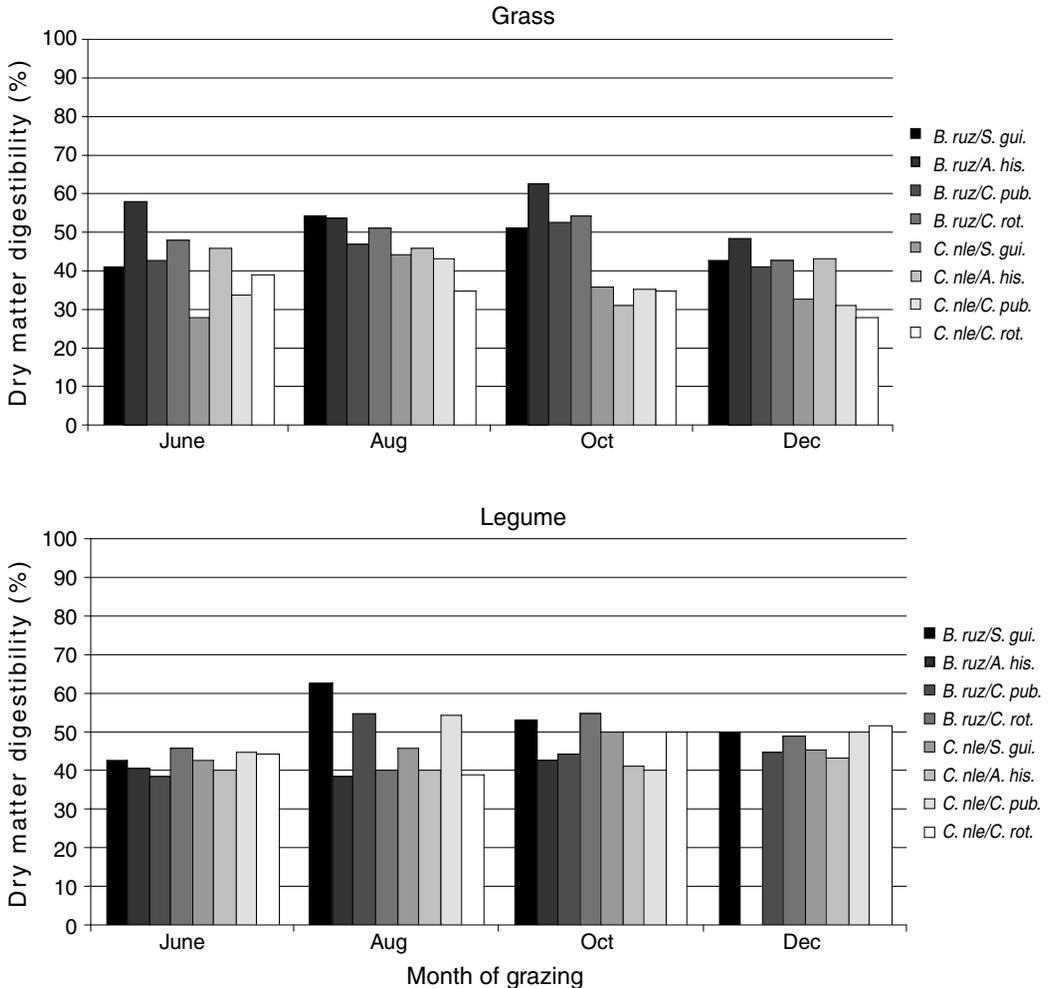
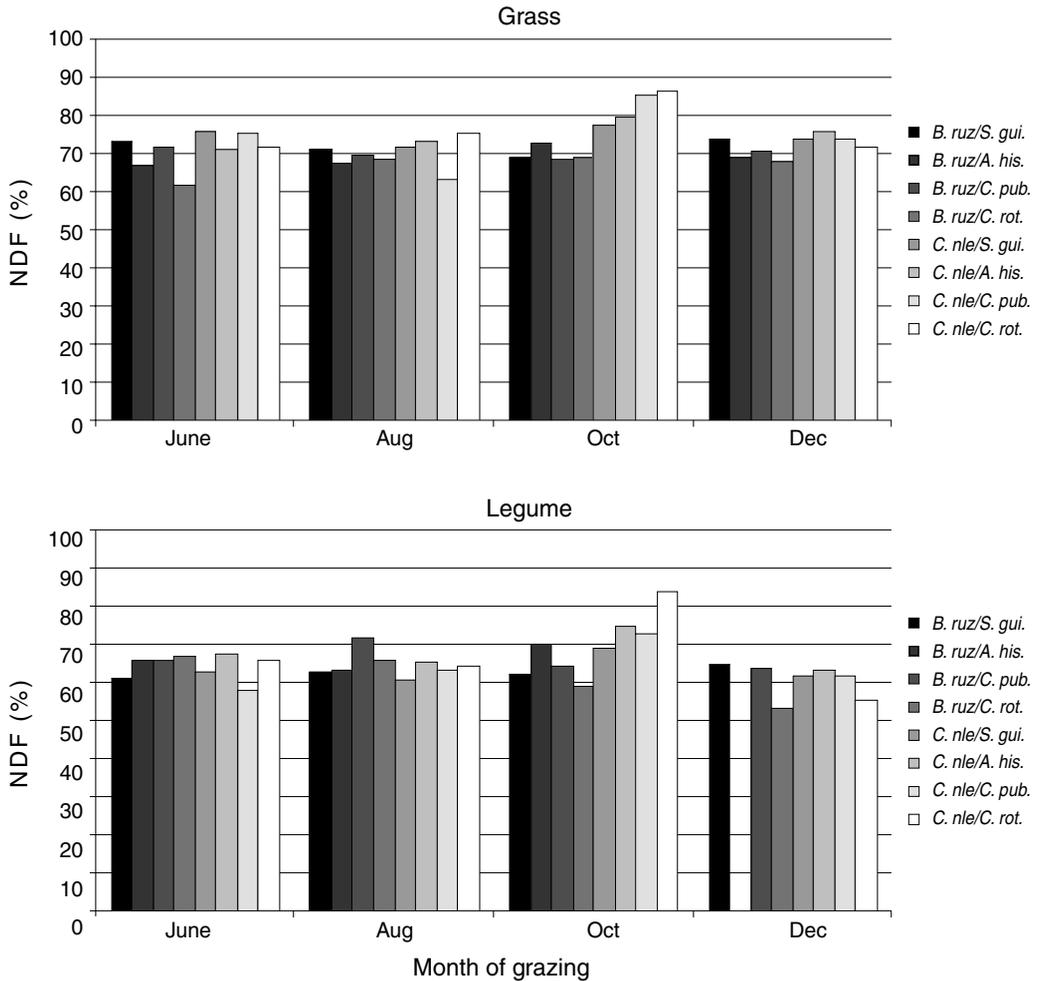


Figure 5. In sacco DM digestibility (%) at 48 h of grass and legume components of mixtures at the onset of each of the 4 grazing periods in 1995.

**Abbreviations for bars**

- B. ruz/S. gui.* = *Brachiaria ruziziensis*/*Stylosanthes guianensis*
- B. ruz/A. his.* = *Brachiaria ruziziensis*/*Aeschynomene histrix*
- B. ruz/C. pub.* = *Brachiaria ruziziensis*/*Centrosema pubescens*
- B. ruz/C. rot.* = *Brachiaria ruziziensis*/*Chamaecrista rotundifolia*
- C. nle/S. gui.* = *Cynodon nlemfuensis*/*Stylosanthes guianensis*
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**Figure 6.** Neutral detergent fibre concentration (% DM) in grass and legume components of mixtures at the onset of each of the 4 grazing periods in 1995.

**Abbreviations for bars**

- B. ruz/S. gui.* = *Brachiaria ruziziensis*/*Stylosanthes guianensis*
- B. ruz/A. his.* = *Brachiaria ruziziensis*/*Aeschynomene histrix*
- B. ruz/C. pub.* = *Brachiaria ruziziensis*/*Centrosema pubescens*
- B. ruz/C. rot.* = *Brachiaria ruziziensis*/*Chamaecrista rotundifolia*
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- C. nle/C. rot.* = *Cynodon nlemfuensis*/*Chamaecrista rotundifolia*

components being slightly higher than in the legumes at all harvest dates. Calcium (Ca) concentration (data not shown) also varied a little, and values for legumes tended to be higher than for grasses. The Ca:P ratio of mixtures ranged between 2.4:1–5.6:1.

**Discussion**

Although *Aeschynomene histrix* and *Chamaecrista rotundifolia* have not been previously reported in grass-legume mixtures from this region, their performances in the present study

were generally comparable with previous reports from elsewhere. The DM yields of mixtures with *Brachiaria ruziziensis* were higher than those with *Cynodon nlemfuensis* at the initial stages, but this situation was reversed towards the end of the study. This confirms other reports that, even though creeping, stoloniferous grasses, such as *Cynodon nlemfuensis* tend to be slow to established, they are more vigorous and productive over time than the tall, upright species (Oyenuga and Olubajo 1975). The legume species also showed varied changes over the trial period, with *Aeschynomene histrix* yielding more than the others during the initial stages and at levels similar to those reported from pure stands (Peters *et al.* 1994b; Tarawali 1994); yields of this species were the lowest of the legumes towards the end of the study. Again, these observations are consistent with previous reports that *Aeschynomene histrix* persisted poorly under cutting regimens (CIAT 1995; Peters *et al.* 1999). Rhonda *et al.* (1987) reported that grazing cattle selected, as for most other legumes, mainly the leaves, seeds and fine stem materials of *Aeschynomene* species, implying that the regrowth points of these legumes are heavily defoliated during grazing. Greater competition from *B. ruziziensis* might also have hastened the disappearance of *A. histrix* from the pasture (Curll and Jones 1989). Generally, the legumes grew better in *Cy. nlemfuensis* than in *B. ruziziensis* especially at the earlier stages of establishment as a result of reduced competition from the former grass at that time.

Performance of *Chamaecrista rotundifolia* was disappointing relative to that in the preliminary evaluation trials at other moist savanna sites (Tarawali 1994; 1995). This could be related to the effects of defoliation and trampling during mob-grazing, which could lead to negative reactions in forage species (Onifade *et al.* 1992). This species performs better in drier environments and tends to behave mostly as an annual, with regeneration from seed being important for persistence in subsequent seasons (Tarawali and Peters 1996).

Although the *Centrosema pubescens* and *Stylosanthes guianensis* accessions used in this study were not those evaluated in grass-legume pasture studies in south-western Nigeria (Akinola 1981; Akinoyemi and Onayinka 1982), their performances are comparable with results of the earlier studies. Unlike the other legumes in the present study, and other reports of legume

suppression by tropical grasses (Kretschmer 1985), DM yield of *Centrosema pubescens* increased over the evaluation period, contributing as much as 40% of total DM yield in December, an indication that it may be more tolerant of the heavy grazing intensity imposed than the other legumes.

From the high DM yields in June, biomass production of the mixtures decreased over the evaluation period, as a result of the grazing pressure imposed. The exceptionally high DM yields of mixtures in June 1995 may be related to the fast growth during the first weeks of the wet season, from March onwards, in combination with the effects of the application of superphosphate early in the wet season which would have especially benefitted the legumes. Increases in DM yield in response to phosphate application to a grass-legume mixture have been attributed to good growth and health of the legume portion (Evans and Bryan 1973).

The P concentrations in the grasses and legumes were generally lower than levels recommended for tropical animals (Minson 1990). However, they were for whole plant samples and animals would select a much higher concentration. The Ca:P ratios were also greater than the 1.5:1–2:1 recommended by NAS (1980) for good animal performance, with the exception of the middle of the rainy season. This may have been related to the earlier application of P, stressing the importance of the addition of this element in maintaining pasture quality.

Both methods of assessing the acceptability of the mixtures for cattle (palatability and DM intake) have their limitations, and are best used in combination to obtain an overall impression (Peters *et al.* 1999). Dry matter intake is often related to the amounts of material on offer, and may be distorted if, for example, there is very little of a particular component present. There seems to be no clear relationship between the measurements of DM intake and relative palatability in the present study although both assessments indicate that mixtures with *Cynodon nlemfuensis* are generally less well consumed, especially towards the end of the evaluation period. Mixtures with *Centrosema pubescens* tended to have the highest DM intake values, and were, to some extent, among the highest in terms of palatability indices. Overall, the DM intake values of mixtures were generally similar to those reported by Okorie *et al.* (1965) and Oyenuga and

Olubajo (1975) for tropical forages. Low DM intake caused by poor quality is advanced as one of the main reasons for poor animal performance in the tropics (Oyenuga and Olubajo 1975).

Crude protein concentrations in the legumes were generally well above 7%, the level below which DM intake becomes depressed (Minson 1981; Humphreys 1991). Higher values during August and October reflect the optimum growth of the legumes during the wet season. By December, many would have commenced drying, hence the lower CP values. The CP concentrations in the grass components especially *B. ruziziensis* were generally lower than this critical level of 7%. Only at the peak of the wet season, in August, when the grass species would have been at maximum growth, was this value exceeded for both species in all mixtures. This partly underscores the importance of the complementary roles of grass-legume mixtures, as do the CP yields (data not presented), where the legume contribution to the total became more important as the experimental period progressed. The higher CP values of the grasses in mixture with *A. histrix* indicate that the legume probably had a positive effect on the quality of the associated species. Similar beneficial effects on quality have been reported by Peters *et al.* (1999). The mean CP concentrations in *C. rotundifolia* and *A. histrix* were similar to those reported by Peters *et al.* (1994a; 1994b). *C. pubescens* maintained the highest CP level among the legumes throughout the trial period as earlier reported for *Centrosema* species (Ademosun and Kolade 1973; Adjei and Fianu 1985); this may, in turn, be linked to the better acceptance of mixtures with this species by the grazing animals. Reports have indicated that livestock are able to select positively for better quality feed (Joblin 1962).

Positive effects of *A. histrix* on the associated grass are again indicated by *in sacco* digestibility, although these are less marked as the differences between mixtures and harvest times for this value are not clearly apparent. Ndlovu (1992) noted that legumes when mature are higher in lignin than grasses and grass cell walls are thus more degradable than those of non-grass forages (van Soest 1982). Ademosun and Kolade (1973) reported an average digestibility value of 60% for *C. nlemfuensis* with a cutting interval of 6 weeks. Overall, legumes had somewhat better quality values and *B. ruziziensis* was of better quality (lower NDF and higher *in sacco* digestibility)

than *C. nlemfuensis*. The generally low *in sacco* digestibility values for the mixtures were an indication that the materials were highly fibrous before the animals were introduced. Even though the presence of legumes in mixtures would enhance protein concentration in forage on offer, the limited legume DM yields as the season advanced would have limited this effect for most of the mixtures when the nitrogen contribution would be most needed. A general overview of the performances of the legumes showed that *A. histrix* was vigorous early but was less prominent as the season advanced and grazing intensified. *Ch. rotundifolia* was generally disappointing as it grew well early with *Ce. nlemfuensis* but produced insignificant yields late in the season. *C. pubescens* improved with time and showed considerable promise, especially as the plots were also well grazed by the animals. *S. guianensis* was also present in significant amounts late in the season.

Amongst the 8 mixtures evaluated, no single one was outstanding in terms of biomass and quality for the entire trial period. Initially, mixtures of *B. ruziziensis* and *A. histrix* were superior, but these were superseded towards the end of the study by the more persistent *C. nlemfuensis* and better quality *C. pubescens*. The results suggest, therefore, that the intended duration of the pasture needs to be taken into account when selecting species, and that, for a persistent pasture over varied conditions, a mixture of options, including for instance, the 2 grasses with both *A. histrix* and *C. pubescens* would be a good option. Mixtures of species have been shown to be more successful in terms of persistence as well as being able to withstand variations in microenvironment and management (Peters *et al.* 1999; Tarawali *et al.* 1999). Meanwhile further studies would be needed to further assess the promising species over an extended period under normal grazing in this region, especially to ensure that the legume-grass balance could be maintained.

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## References

- ADEMOSUN, A.A. (1973) Nutritive evaluation of Nigerian forages. 4. The effect of stage of maturity on the nutritive value of *Panicum maximum* (Guinea grass). *Nigerian Agricultural Journal*, **10**(2), 170–177.
- ADEMOSUN, A.A. and KOLADE, J.O.Y. (1973) Nutritive evaluation of Nigerian forages. 3. A comparison of the chemical composition and nutritive value of two varieties of *Cynodon*. *Nigerian Agricultural Journal*, **10**, 160–169.
- ADEOTI, A.A., TARAWALI, S.A. and MOHAMED-SALEEM, M.A. (1994) Development and management strategies for Stylo with emphasis on pests and diseases. In: de Leeuw, P.N., Mohamed-Saleem, M.A. and Nyamu, A.M. (eds) *Stylosanthes as a 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*. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 123–128.
- 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**, 164–170.
- AKEN'OVA, M.E. and MOHAMED-SALEEM, M.A. (1985) Screening of Guinea grass (*Panicum maximum* Jacq.) accessions for forage value in the low latitude humid tropics. *Nigerian Agricultural Journal*, **19**, 88–93.
- AKINOLA, A.O. (1981) Growth of signal grass (*Brachiaria decumbens*) alone and with legumes in Northern Nigeria. *Tropical Grasslands*, **15**, 130–134.
- AKINYEMI, A.A. and ONAYINKA, E.A.O. (1982) The productivity and carrying capacity of *Panicum maximum* planted with or without *Centrosema pubescens*. *Nigerian Journal of Agricultural Science*, **4**, 33–38.
- AOAC (Association of Official Analytical Chemists) (1990) *Official Methods of Analysis*. 15th Edn. (AOAC: Washington, DC, USA).
- CARLOS, E.L. (1982) Edaphic and climatic factors that affect intake and selectivity of forage plants under grazing. In: Paladines, O. and Carlos, E.L. (eds) *Forage Germplasm Under Small Plot Grazing: Evaluation of Methodologies. Proceedings of a workshop held in Cali, Colombia, 22–24 September 1982*. CIAT (Centro Internacional de Agricultura Tropical), Cali, Colombia. pp. 61–79.
- CIAT (1995) Réseau de recherche en alimentation du bétail en Afrique occidentale et centrale (RABAOC). Results 1990–1994. Working document 145. CIAT (Centro Internacional de Agricultura Tropical), Cali, Colombia.
- CURLL, M.L. and JONES, R.M. (1989) The plant-animal interface and legume persistence — An Australian perspective. In: Marten, G.C., Matches, A.G., Barnes, A.F., Brougham, R.W., Clements, R.J. and Sheath, G.W. (eds) *Persistence of Forage Legumes. Proceedings of a trilateral workshop held in Honolulu, Hawaii, 18–22 July 1988*. Madison, Wisconsin, USA. pp. 339–359.
- EVANS, T.R. and BRYAN, W.W. (1973) Effects of soils, fertilizers and stocking rates on pastures and beef production on the Wallum of south-eastern Queensland. II. Liveweight change and beef production. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **13**, 530–536.
- EZENWA, I.V. (1995) *Forage Production Potentials of Herbaceous and Tree Legumes in Mixtures with Grasses in Oyo State, Nigeria*. Ph.D. Thesis. University of Ibadan, Nigeria.
- GOERING, H.K. and VAN SOEST, P.J. (1970) Forage fiber analysis. *Agriculture Handbook No. 379*. USDA, Washington, DC, USA.
- HUMPHREYS, L.R. (1991) *Tropical Pasture Utilization*. (Cambridge University Press: UK).
- JABBAR, M.A. (1992) Evolving crop-livestock farming systems in the humid zone of West Africa: Potential and research needs. *Outlook on Agriculture*, **22**, 13–21.
- JAGTAP, S.S. (1995) Environmental characterization of the moist lowland savanna of Africa. In: Kang, B.T., Akobundu, I.O., Manyong, V.M., Carsky, R.J., Sanginga, N. and Kueneman, E. (eds) *Moist Savannas of Africa: Potentials and Constraints for Crop Production*. [International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria in cooperation with Food and Agriculture Organization (FAO): Rome, Italy].
- JOBLIN, A.D.H. (1962) The use of grazing-animal observations in the early stages of pasture evaluation in the tropics. I. The measurements of relative palatability. *Journal of the British Grassland Society*, **17**, 171–177.
- KRETSCHMER, A.E. (1985) Tropical legumes: A brief review. *Proceedings of Annual Beef Cattle Short Course, Florida, University of Florida/IFAS*. pp. 56–66.
- LARBI, A., MISLEVY, P., BROWN, W.F. and ADEJI, M.B. (1989) Evaluation of three tropical perennial grasses for beef production in south central Florida. *Proceedings of the XVI International Grassland Congress, Nice, France, 1989*. pp. 1215–1216. (French Grassland Society: Versailles, Cédex, France).
- MINSON, D.J. (1981) Nutritional differences between tropical and temperate pastures. In: *Grazing animals: Disciplinary approach*. *World Animal Science*, **34**, 143–147. (Elsevier: Amsterdam, The Netherlands).
- MINSON, D.J. (1990) Chemical composition and nutritive values of tropical legumes. In: Skerman, P.J. and Riveros, F. (eds) *Tropical legumes*. (Food and Agriculture Organization of the United Nations: Rome). *FAO Plant Production and Protection Series No. 23*. pp. 163–180.
- MISLEVY, P., MOTT, G.O. and MARTIN, F.G. (1982) Screening perennial forages by mob-grazing technique. *Proceedings of the XIV International Grassland Congress, Lexington, Kentucky, USA, 1981*. pp. 516–519.
- NAS (National Academy of Science) (1980) *Mineral Tolerance of Domestic Animals*. (NAS: Washington, DC, USA).
- NDLOVU, L.R. (1992) Complementarity of forages in ruminant digestion: Theoretical considerations. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds) *The Complementarity of Feed Resources for Animal Production in Africa. Proceedings of the Joint Feed Resources Network Workshop held in Gaborone, Botswana, 1991*. pp. 17–23.
- OKORIE, I.I., HILL, D.H. and MCLROY, R.J. (1965) The productivity and nutritive value of tropical grass-legume pastures rotationally grazed by N'dama cattle at Ibadan, Nigeria. *Journal of Agricultural Science*, **64**, 235–245.
- ONIFADE, O.S., ADU, I.F. and AKINOLA, J.O. (1992) Performance and management of sheep on Rhodes grass-stylo pasture in Nigeria. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds) *The Complementarity of Feed Resources for Animal Production in Africa. Proceedings of the Joint Feed Resources Network Workshop held in Gaborone, Botswana, 1991*. pp. 85–94.
- OSUJI, P.O., NSAHLAI, I.V. and KHALILI, H. (1993) *Feed evaluation. ILCA Manual 5*. [ILCA (International Livestock Centre for Africa): Addis Ababa, Ethiopia].
- OYENUGA, V.A. and OLUBAJO, F.O. (1975) Pasture productivity in Nigeria. I. DM production and chemical composition of herbage. *Journal of Agricultural Science*, **85**, 1–10.

- PETERS, M., TARAWALI, S.A. and ALKÄMPER, J. (1994a) Evaluation of tropical pasture legumes for fodder banks in subhumid Nigeria. 1. Accessions of *Centrosema brasilianum*, *Centrosema pascuorum*, *Chamaecrista rotundifolia* and *Stylosanthes hamata*. *Tropical Grasslands*, **28**, 65–73.
- PETERS, M., TARAWALI, S.A. and ALKÄMPER, J. (1994b) Evaluation of tropical pasture legumes for fodder banks in subhumid Nigeria. 2. Accessions of *Aeschynomene histrix*, *Centrosema acutifolium*, *C. pascuorum*, *Stylosanthes guianensis* and *S. hamata*. *Tropical Grasslands*, **28**, 74–79.
- PETERS, M., TARAWALI, S.A., SCHULTZE-KRAFT, R., SMITH, J.W. and MUSA, A. (1999) Performance of legume-legume mixtures under small-plot periodic grazing. *Journal of Agronomy and Crop Science*, **182**, 25–35.
- RHONDA, R.G., OCUMPAUGH, W.R., QUESENBERRY, K.H. and MOORE, J.E. (1987) Mob-grazing of morphologically different *Aeschynomene* species. *Tropical Grasslands*, **21**, 123–132.
- SAS (1988) *User's Guide: Statistics*. (Statistical Analysis System Institute Inc.: Cary, North Carolina, USA).
- SCHULTZE-KRAFT, R., LASCANO, C., BENAVIDES, G. and GOMEZ, J.M. (1989) Relative palatability of some little-known tropical forage legumes. *Proceedings of the XVI International Grassland Congress, Nice, France, 1989*. pp. 785–786.
- SMITH, J.W., NAAZIE, A., LARBI, A., AGYEMANG, K. and TARAWALI, S.A. (1997) Integrated crop-livestock systems in sub-Saharan Africa: an option or imperative? *Outlook on Agriculture*, **26**, 237–246.
- TARAWALI, S.A. (1991) Preliminary agronomic evaluation of forage legumes for subhumid West Africa. *Tropical Agriculture (Trinidad)*, **68**, 88–94.
- TARAWALI, S.A. (1994) The yield and persistence of selected forage legumes in subhumid and semi-arid West Africa. *Tropical Grasslands*, **28**, 80–89.
- TARAWALI, S.A. (1995) Evaluation of *Chamaecrista rotundifolia* accessions as a fodder resource in sub-humid Nigeria. *Tropical Grasslands*, **29**, 129–133.
- TARAWALI, S.A. and PETERS, M. (1996) The potential contribution of selected forage legume pastures to cereal production in crop-livestock farming systems. *Journal of Agricultural Science*, **127**, 175–182.
- TARAWALI, S.A., PETERS, M. and SCHULTZE-KRAFT, R. (1999) Selecting and testing forage legumes for sustainable agriculture and livestock production in subhumid west Africa. *ILRI Project Report. ILRI (International Livestock Research Institute), Nairobi, Kenya*.
- VAN SOEST, P.J. (1982) *Nutritional Ecology of the Ruminants*. (D&B Books: Corvallis, Oregon, USA).

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