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RELATIVE PALATABILITY AND SEASONAL AGRONOMIC PERFORMANCE OF SELECTED PASTURE LEGUMES FOR SPECIES MIXTURES IN DRY-SUBHUMID WEST AFRICA

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SUMMARY

Relative palatability and some agronomic traits were studied for nine legumes including *Aeschynomene histrix*, *Centrosema brasilianum* (two accessions), *Centrosema pascuorum*, *Chamaecrista rotundifolia*, *Stylosanthes guianensis* (two accessions) and *Stylosanthes hamata* (two accessions). All species were consumed by cattle but the relative palatability varied according to season. Only the two *S. guianensis* accessions were positively selected throughout the year. A positive relationship was established between the ability to retain green leaves in the dry season and palatability. Once established, the two *C. brasilianum* accessions out-performed the other legumes in their ability to stay green and retain leaves in the dry season; related to the ability to retain green leaves under drought conditions, *C. brasilianum* ILRI 155 was among the most palatable legumes in the dry season. *S. guianensis* accessions had the highest dry matter (DM) yields and one of them (ILRI 15557) had the highest nutritive value. In contrast with earlier results in the same environment, *C. rotundifolia* and *A. histrix* performed poorly in terms of DM productivity. The implications of the agronomic characteristics of the legumes for the management of legume-based pastures in crop/livestock systems are discussed and the concept of legume–legume mixtures, composed of several compatible species, is advocated.

INTRODUCTION

In subhumid West Africa, legume-based pastures have been shown to be beneficial to both crop and livestock production (Tarawali, 1994) and a number of species and accessions were identified as appropriate for the environment (Peters *et al.*, 1994a; b; Tarawali, 1994). However, information on the relative palatability of these species is limited; knowledge of palatability and how it changes over seasons, is essential if such legumes are to be managed and utilized efficiently (Joblin, 1962; Lascano *et al.*, 1990), especially if several are combined in one pasture.

The concept of using mixtures of compatible legumes is currently being investigated by the International Livestock Research Institute (ILRI) in Nigeria

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as such mixtures are seen to have the potential to overcome limitations of individual species and genotypes with regard to ease of establishment, persistence (Aiken *et al.*, 1991a; b), suppression of weeds and disease tolerance (Chakrobarty *et al.*, 1991). In addition, year-round high levels of herbage production from a mixture of N-fixing legumes should have a positive effect on soil fertility maintenance (Oyer & Touchton, 1990). Species combinations are also more flexible than pure legume stands in their reaction to variations in environmental conditions, management practices, and farming systems (Reátegui *et al.*, 1995); they can therefore increase the stability of pastures and reduce the risk of losing the investment in costly pasture establishment.

This study was initiated to fill the gap in information on the relative palatability of selected legumes in order to provide basic background information for the subsequent design and implementation of trials using legume combinations.

MATERIAL AND METHODS

Site characteristics

The experiment was established on 17 June 1993 on the outskirts of Kaduna (lat 10°36′N, long 7°27′E) in dry-subhumid northern Nigeria. The site has a unimodal rainfall pattern, with 95% of the rain falling between April and October when precipitation exceeds evapotranspiration. Average annual rainfall is 1200 mm, rainfall in the two experimental years (1993 and 1994) was 1242 and 1106 mm respectively. Relative humidity varied from less than 40% (December to March) to 80–90% (June to September). Mean daily temperatures ranged from 18–23 °C in December/January to 28–30 °C in March/April. The soil at the experimental site is considered an Ultisol according to the USDA classification. It is a sandy clay loam with low levels of total nitrogen, organic matter and available phosphorus. Details of the soil analysis are presented in Table 1.

Trial establishment and design

The experiment included three independent grazing paddocks. Within each of these paddocks, nine legumes (Table 2) were arranged in a randomized complete block design with three replications; plot size was 4 × 5 m, so there were 27 plots in each paddock. Paddock 1 was used for a one-week adjustment period before experimental grazing, the two other paddocks were grazed alternately during the

Table 1. Soil characteristics at the experimental site. (me = milliequivalents.)

pH H_2O	5.0	Potassium (me 100 g^{-1})	0.23
Total nitrogen (%)	0.051	Sodium (me 100 g^{-1})	0.38
Organic matter (%)	0.99	Total acidity (me 100 g^{-1})	1.75
Available phosphorus (Bray-I) ppm	1.06	Effective cation exchange capacity (me 100 g^{-1})	4.47
Calcium (me 100 g^{-1})	1.64	Sand (%)	50.0
Magnesium (me 100 g^{-1})	0.44	Silt (%)	22.0
Manganese (me 100 g^{-1})	0.03	Clay (%)	28.0

Table 2. Legumes tested in the trial.

Species	Accession numbers†			Cultivar
	ILRI	CIAT	CPI	
Aeschynomene histrix	12463	9690	87993	
Centrosema brasilianum	155	5234	87993	
Centrosema brasilianum	6773	5211	55698	
Centrosema pascuorum	9857	5924		Cavalcade
Chamaecrista rotundifolia	10918		34721	Wynn
Stylosanthes guianensis	164	184		Pucallpa
Stylosanthes guianensis	15557			
Stylosanthes hamata	75		38842	Verano
Stylosanthes hamata	15876			

† The ILRI numbers refer to accession numbers from the International Livestock Research Institute (ILRI), Kenya, the CIAT numbers to accession numbers from the Centro Internacional de Agricultura Tropical (CIAT), Colombia and the CPI numbers to accession numbers from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. In subsequent tables accession numbers are all ILRI numbers, abbreviated to I.

four measurement phases; this meant that paddock 2 was grazed at the beginning of the dry season 1993–94 and in the middle of the wet season 1994, while paddock 3 was grazed at the end of the dry season 1993–94 and in the middle of the dry season 1994–95.

Before sowing, the land was cleared and prepared to a fine tilth; legumes were sown at 200 seeds m^{-2} for the small seeded accessions (*A. histrix*, *C. rotundifolia*, *Stylosanthes* spp.) and at 50 seeds m^{-2} for the larger seeded *Centrosema* spp. Rhizobial inoculum was not used, but prior to sowing all plots received 150 kg single superphosphate (8% P, 14% S, 20% Ca) ha^{-1}, and a maintenance dressing of 100 kg single superphosphate ha^{-1} at the onset of the following rainy season. Plots were kept free of weeds throughout the experimental period; at the end of each dry season all plots were cut to 15 cm above ground level.

Data measurements

Population density was measured in two 1-m^2 quadrats per plot at 4, 8 and 12 weeks after sowing in the establishment year (Year 1), and 4 and 8 weeks after onset of the rains in the second year (Year 2). Soil cover was estimated visually at 12, 16 and 20 weeks after sowing in Year 1, and 4, 8, 12 and 20 weeks after the onset of the rains in Year 2. Incidence and severity of diseases and pests were rated visually on scales ranging from 0 to 9 (incidence: 0 – no diseases or pests, 9 – all plants affected; severity: 0 – no disease or pest symptoms, 9 – death of plant) whenever visible incidence of diseases or pests occurred. Flowering and seed production were monitored throughout the experiment; date of peak flowering and seeding were recorded when 50% of plants on the plot had reached the flowering or seeding stage. Drought tolerance was assessed every four weeks during the dry season, using two parameters, the ability of plants to retain leaves (leafiness: 0 – no leaves dropped, 9 – all leaves dropped), and of the leaves to stay green (greenness: 0 – all plants dried, 9 – all plants green). All scales were subsequently converted to percentage values (percentage of leaves still on plants and percentage of leaves still green).

Dry matter (DM) production (cutting height 15 cm above ground level) before and after grazing was determined at the beginning and end of the dry season (Year 1), in the middle of the wet season and middle of the dry season (Year 2). Samples were taken before grazing for the determination of DM content (drying at 65 °C for 48 h), crude protein (CP) concentration (Micro-Kjeldahl) and digestibility (nylon bag method, 48-h incubation (Osuji *et al.*, 1993)).

After exposure to the same species on the adjustment paddock for one week, three Bunaji steers (4–5 years old) were allowed to graze freely on the measurement paddock for 4 h every day (0800–1200 hours) after overnight fasting until animals showed little grazing activity due to lack of palatable forage. This point was reached after 15 d at the beginning of the first dry season, 18 d at the end of the first dry season, 13 d in the middle of the wet season and 9 d in the middle of the second dry season. After data recording in the morning, animals had free access to the adjacent native range until they were kraaled in the evening around 1700 hours. After each grazing period, the plots were cut back to a uniform height of approximately 15 cm above ground.

The relative palatability of the legumes was assessed in two ways:

(1) The Difference method (Warmke *et al.*, 1952) was used to determine the difference between the forage on offer before grazing and the residual forage after grazing.

(2) A Cafeteria approach recording grazing preference every 5 min. A relative palatability index was calculated by dividing the number of times a given legume treatment was eaten by the number of times the legume could be expected to be eaten if all treatments were of equal palatability (Schultze-Kraft *et al.*, 1989). Using this method legumes not selected for or against would score 1.00, whereas lower palatability would be indicated by values <1 and higher palatability by values >1. The beginning of the grazing period, when forage availability is not limiting, is considered the most sensitive indicator of palatability; material not consumed at the end of the grazing period indicates highly unpalatable species.

Data analysis

Data was analysed by Analysis of Variance (ANOVA) for randomized complete block designs; for comparison between treatment means, standard errors of the mean (s.e.m.) are presented. The data set was subjected to a range of regression procedures to find out if relationships exist between the two methods of measuring relative palatability (Cafeteria method versus Difference method), and between relative palatability and forage on offer, drought tolerance or nutritive quality (crude protein concentration and digestibility).

RESULTS

Establishment and regeneration

Data on establishment and regeneration were averaged over the two measurement paddocks. All legumes had satisfactory germination with both *S. guianensis* accessions and *A. histrix* having the highest and *S. hamata* ILRI 75, *C. brasilianum* ILRI 6773 and *C. pascuorum* having the lowest population densities at eight weeks after sowing (Table 3). In Year 2, regeneration from the seed bank was poor but for all accessions some plants survived the dry season except for *C. pascuorum* which behaved as a strict annual. Total plant densities (that is perennating plants plus seedlings) in Year 2 were low especially for the small-seeded legumes.

Soil cover measurements showed that initial establishment was slow but 16 weeks after sowing, the two *S. guianensis* accessions and *C. pascuorum* covered 42–46% of the soil. Slowest to cover were *C. brasilianum* ILRI 155 and *S. hamata* ILRI 75 with only 25–28% cover. At the end of the wet season (20 weeks after sowing) all legumes had established well with soil cover between 44% and 78%. There were interactions between species or accessions and time of measurement ($p < 0.05$) indicating that species differ regarding times of maximum growth rate. For example, *C. pascuorum* and *S. guianensis* had rapid early growth (first 12 to 16 weeks after establishment) while *A. histrix* or *C. brasilianum* were initially slow but grew at a faster rate later in the wet season. In Year 2, *S. guianensis* ILRI 164 was the fastest, whereas the two *S. hamata* accessions and *C. pascuorum* were the slowest to re-establish. At the end of the second wet season all legumes had re-established well with soil covers between 57% and 72%, with the exception of *C. pascuorum* (37% soil cover). In the paddock that was grazed in the wet season of Year 2, average soil cover at the end of the wet season was higher ($p < 0.05$) than in the ungrazed plots (data not shown). As in the year of establishment, there were significant ($p < 0.05$) interactions between legumes and time of measurement.

Flowering and seeding

The earliest legume to flower was *C. rotundifolia* at 84 d after sowing, the other species flowered 106–133 d after sowing. Most species had mature seeds 150–183 d after sowing, although *C. rotundifolia* had mature seeds already at day 105 after sowing.

All legumes except *C. pascuorum* had some flowers throughout the dry season. In Year 2 most legumes flowered towards the end of the wet season (141 to 173 d after onset of the rains) with the exception of the early flowering *C. rotundifolia* which reached peak flowering 94 d after the onset of the rains (middle of the wet season). As in the previous year, the earliest to reach maturity was *C. rotundifolia* 160 d after the onset of the rains; *C. brasilianum* was the latest (225–232 d after onset of the rains).

Table 3. Establishment of legumes eight weeks after sowing (Year 1), regeneration and plant survival eight weeks after onset of the rains (Year 2) and soil cover 12, 16 and 20 weeks after sowing (WAS) (Year 1), and 8 and 24 weeks after onset of the rains (AOR) (Year 2).

	Population density (plants m^{-2})			Soil cover (%)				
	Year 1	Year 2		Year 1			Year 2	
Legume†	Seedlings	Seedlings	Old plants	12 WAS	16 WAS	20 WAS	8 AOR	24 AOR
A. histrix I 12463	37	3	10	16	29	59	24	72
C. brasilianum I 155	26	2	8	15	25	50	24	64
C. brasilianum I 6773	11	3	8	15	34	53	29	61
C. pascuorum I 9857	14	4	0	16	46	57	14	37
C. rotundifolia I 10918	29	8	12	24	39	54	30	58
S. guianensis I 164	42	2	9	29	42	78	38	74
S. guianensis I 15557	41	2	14	28	44	65	25	66
S. hamata I 75	13	11	6	12	28	44	18	57
S. hamata I 15876	31	7	5	15	38	63	16	59
s.e.m.	6.1	2.2	2.0	3.9	7.8	7.5	3.7	6.1

† Legumes are listed in Table 2; I numbers are ILRI accession numbers; s.e.m. = standard error of the mean.

Table 4. Leafiness (% of leaves retained) during the 1993–94 (Year 1) and 1994–95 (Year 2) dry seasons.

	Year 1 dry season			Year 2 dry season		
Legume†	Start	Middle	End	Start	Middle	End
A. histrix I 12463	53	9	1	94	10	7
C. brasilianum I 155	58	26	9	97	53	47
C. brasilianum I 6773	53	27	8	100	50	31
C. pascuorum I 9857	44	1	1	89	9	1
C. rotundifolia I 10918	44	24	10	86	25	17
S. guianensis I 164	81	33	16	100	31	23
S. guianensis I 15557	86	30	10	100	36	23
S. hamata I 75	32	1	1	86	25	3
S. hamata I 15876	56	5	1	97	25	7
s.e.m.	6.0	6.3	2.0	4.4	3.1	2.9

† Legumes are listed in Table 2; I numbers are ILRI accession numbers; s.e.m. = standard error of the mean.

Drought tolerance

In Year 1, *C. rotundifolia*, *S. guianensis* and *C. brasilianum* had a greater ability to retain leaves as the dry season progressed than *S. hamata*, *A. histrix* and *C. pascuorum*; the last dropped its leaves immediately after drying off (Table 4). In general, leaf percentages at the end of the dry season were low. In Year 2, *C. brasilianum*, in particular accession ILRI 155, held its leaves for a much longer time into the dry season ($p < 0.05$) than in Year 1.

C. brasilianum had the greatest, *S. hamata* and *C. pascuorum* the lowest ability to stay green over the dry season (Table 5). Generally, with the exception of *A. histrix*, plants remained greener in Year 2 than in Year 1 ($p < 0.05$).

Table 5. Drought tolerance (% greenness) during the 1993–94 (Year 1) and 1994–95 (Year 2) dry seasons.

	Year 1 dry season			Year 2 dry season		
Legume†	Start	Middle	End	Start	Middle	End
A. histrix I 12463	47	27	13	94	25	8
C. brasilianum I 155	61	44	30	97	72	47
C. brasilianum I 6773	53	48	31	94	61	42
C. pascuorum I 9857	31	0	0	97	18	1
C. rotundifolia I 10918	44	36	18	75	47	22
S. guianensis I 164	78	50	20	100	53	33
S. guianensis I 15557	72	39	15	100	58	31
S. hamata I 75	26	1	1	94	50	7
S. hamata I 15876	50	7	1	89	47	13
s.e.m.	6.0	4.6	1.7	4.1	4.1	3.8

† Legumes are listed in Table 2; I numbers are ILRI accession numbers; s.e.m. = standard error of the mean.

Table 6. Dry matter yields (kg ha^{-1}) before grazing at the beginning and end of the dry season (Year 1), and in the middle of the wet season and the middle of the dry season (Year 2).

	Year 1		Year 2	
Legume†	Beginning dry season	End dry season	Middle wet season	Middle dry season
A. histrix I 12463	697	523	2142	688
C. brasilianum I 155	1163	739	1869	873
C. brasilianum I 6773	963	1069	2204	764
C. pascuorum I 9857	1029	1676	191	286
C. rotundifolia I 10918	487	329	1297	246
S. guianensis I 164	2304	3783	3273	1230
S. guianensis I 15557	2591	2032	2472	1892
S. hamata I 75	799	803	722	389
S. hamata I 15876	1197	1413	2325	804
s.e.m.	471	405	653	541

† Legumes are listed in Table 2; I numbers are ILRI accession numbers; s.e.m. = standard error of the mean.

Diseases and pests

No severe damage from diseases or pests was observed throughout the duration of the experiment. During the establishment phase, leaf-sucking insects were seen on all species and anthracnose (*Colletotrichum gloeosporioides*) was detected on *C. brasilianum* and both *Stylosanthes* species, but incidence and severity were less than 5%. Anthracnose symptoms were also detected in Year 2, particularly on *S. hamata* and *C. rotundifolia*; however, incidence and severity were below 10% (typically < 5%). *C. brasilianum* showed signs of Rhizoctonia Foliar Blight (RFB) but incidence or severity did not exceed 15%.

Dry matter yield

S. guianensis accessions had the highest DM yields at all harvest dates (Table 6). Differences between Year 1 and Year 2 were significant ($p < 0.05$) only for *C. pascuorum* where yields in the second year were much lower.

Nutritive value

With 91 and 97 g kg^{-1} DM, *S. guianensis* had the highest CP concentrations at the beginning of the dry season; the other legumes ranged between 64 and 79 g kg^{-1} DM (Table 7). At the end of the dry season, CP values ranged between 49 and 63 g kg^{-1} DM, except for *S. guianensis* ILRI 15557 (87 g kg^{-1} DM). In the wet season, at an advanced stage of growth, CP concentration was 94–121 g kg^{-1} DM with the exception of *C. pascuorum* (184 g kg^{-1} DM). Dry matter digestibility (DMD) at the end (Year 1) and middle (Year 2) of the dry season ranged between 0.33 and 0.60, with *S. guianensis* ILRI 15557 having the highest values; DMD was below 0.40 for *A. histrix* and *C. brasilianum* ILRI 6773 at the end (Year 1) and for *A. histrix*, *C. pascuorum* and *C. rotundifolia* at the middle

Table 7. Crude protein concentrations (CP, g kg^{-1}DM) and dry matter digestibility (DMD) at the beginning and end of the dry season (Year 1) and in the middle of the wet and dry seasons (Year 2).

	Year 1				Year 2			
	Beginning dry season		End dry season		Middle wet season		Middle dry season	
Legume†	CP	DMD	CP	DMD	CP	DMD	CP	DMD
A. histrix I 12463	79	0.52	49	0.39	115	0.54	61	0.37
C. brasilianum I 155	70	0.48	57	0.45	104	0.43	87	0.45
C. brasilianum I 6773	70	0.47	57	0.38	119	0.40	86	0.42
C. pascuorum I 9857	60	0.51	63	0.46	184	na	50	0.33
C. rotundifolia I 10918	63	0.47	50	0.47	117	0.45	69	0.37
S. guianensis I 164	91	0.52	61	0.50	99	0.50	89	0.49
S. guianensis I 15557	97	0.59	87	0.60	121	0.57	113	0.56
S. hamata I 75	64	0.49	58	0.45	104	0.44	61	0.41
S. hamata I 15876	65	0.48	56	0.48	94	0.48	67	0.41

† Legumes are listed in Table 2; I numbers are ILRI accession numbers; na = not available.

(Year 2) of the dry seasons. Corresponding values for the wet season and the early dry season varied between 0.40 and 0.59, *S. guianensis* ILRI 15557 again having the highest values.

Palatability

Dry matter intake (Difference method). All legumes were consumed by the test cattle. However, dry matter intake (DMI) varied between seasons and species or accessions. Both *S. guianensis* accessions were well consumed throughout the year, with ILRI 15557 being more acceptable than ILRI 164. DMI of the other species was affected by season; noteworthy is the consistently higher DMI of *S. hamata* ILRI 15876 compared with ILRI 75 and the very low DMI of *S. hamata* ILRI 75 and *C. pascuorum* ILRI 9857 in the wet season (Table 8). No significant differences between legumes were detected in the middle of the dry season (Year 2).

Cafeteria method. Palatability varied among species and seasons (Table 9). Considering the mean index for the entire grazing periods, both *S. guianensis* accessions were the only legumes positively selected (values > 1) throughout the year. In the early dry season (Year 1) *S. hamata* ILRI 15876 was also positively selected, whereas in the middle of the dry season (Year 2) both *C. brasilianum* accessions and at the end of the dry season (Year 1) *C. brasilianum* ILRI 155 and *C. rotundifolia* were positively selected. In the wet season (Year 2), *C. brasilianum* ILRI 6773 was positively selected in addition to the two *S. guianensis* accessions. *C. pascuorum*, *S. hamata* ILRI 75 and *A. histrix* were never positively selected, and *A. histrix* had the lowest overall selection.

Differences in relative acceptability of legumes within the same grazing period were most obvious at the beginning of the dry season (Year 1) and in the middle of

Table 8. Dry matter intake (DMI) in % of forage on offer at the beginning and end of the dry season (Year 1) and in the middle of the wet and dry seasons (Year 2).

Legume†	Year 1		Year 2	
	Beginning dry season	End dry season	Middle wet season	Middle dry season
A. histrix I 12463	69.8	74.0	83.3	88.0
C. brasilianum I 155	94.6	68.3	80.1	93.7
C. brasilianum I 6773	69.0	62.3	82.3	94.3
C. pascuorum I 9857	66.5	91.4	46.1	86.5
C. rotundifolia I 10918	78.0	62.3	83.6	92.7
S. guianensis I 164	89.7	76.4	82.8	93.3
S. guianensis I 15557	95.6	84.1	84.2	96.3
S. hamata I 75	92.8	67.3	45.6	88.3
S. hamata I 15876	95.2	83.6	70.2	90.7
s.e.m.	8.8	7.7	12.1	3.7

† Legumes are listed in Table 2; I numbers are ILRI accession numbers; s.e.m. = standard error of the mean.

the wet season (Year 2). At the beginning of the early dry season grazing period (Year 1) animals selected strongly the two *S. guianensis* accessions and *S. hamata* ILRI 15876 whereas *C. pascuorum* and *C. rotundifolia* were positively selected only at the end of this grazing period. In the wet season *C. brasilianum* ILRI 6773, initially not among the relatively preferred legumes, was positively selected towards the end of the grazing period.

Regression analyses

No consistent relationships were found between the palatability estimated using the Cafeteria and the Difference methods, or between relative palatability and forage on offer or greenness. However, in the dry season there was a positive linear relation between leafiness and relative palatability (measured by the Cafeteria method): the higher the ability to retain green leaves, the higher the preference for the accession. Coefficients of determination (r^2) between leafiness and palatability indices (at the beginning of the respective grazing periods) were 0.70, 0.67 and 0.60 ($p < 0.05$) for the beginning (Year 1), middle (Year 2) and end (Year 1) of the dry season respectively.

The estimated regression line between palatability (indices) and leafiness is

palatability = a + b*leafiness, where

a = −0.895 (s.e.m. 0.489), and b = 0.034 (s.e.m. 0.008) for the beginning of the dry season,

a = −0.457 (s.e.m. 0.509), and b = 0.050 (s.e.m. 0.016) for the middle of the dry season,

a = 0.789 (s.e.m. 0.082), and b = 0.033 (s.e.m. 0.010) for the end of the dry season respectively.

Table 9. Palatability indices at the beginning and end of the dry season (Year 1) and in the middle of the wet and dry seasons (Year 2).†

Legume†	Year 1						Year 2					
	Beginning dry season			End dry season			Middle wet season			Middle dry season		
	First	Last	Average	First	Last	Average	First	Last	Average	First	Last	Average
A. histrix I 12463	0.56	0.74	0.57	0.65	0.90	0.73	0.44	0.53	0.54	0.92	0.70	0.81
C. brasilianum I 155	0.54	0.98	0.83	1.06	1.22	1.21	0.68	0.63	0.63	3.18	1.11	2.14
C. brasilianum I 6773	0.71	0.92	0.75	0.89	0.48	0.70	0.87	1.30	1.34	1.43	0.89	1.16
C. pascuorum I 9857	0.47	1.12	0.70	0.92	1.13	0.95	0.44	0.67	0.69	0.13	0.86	0.50
C. rotundifolia I 10918	0.45	1.25	0.74	1.24	1.18	1.24	0.25	0.67	0.71	0.35	0.94	0.64
S. guianensis I 164	1.72	0.86	1.31	1.38	1.40	1.36	1.98	1.82	1.78	0.92	1.14	1.03
S. guianensis I 15557	2.45	1.36	1.96	1.02	1.10	1.15	3.23	2.03	2.05	1.62	2.10	1.86
S. hamata I 75	0.76	0.60	0.81	0.72	1.05	0.92	0.87	0.74	0.72	0.00	0.43	0.22
S. hamata I 15876	1.42	1.18	1.34	1.08	0.79	0.85	0.50	0.67	0.68	0.45	0.85	0.65
s.e.m.	0.37	0.27	0.17	0.29	0.29	0.13	0.50	0.52	0.16	0.75	0.51	0.29

† Indices are for the first and last four days of grazing and average values represent the mean index for the entire grazing period; s.e.m. = standard error of the mean.

When pooling the whole data set, it was not possible to define a relationship between CP concentration and DMD; however, when the data were analysed separately for each harvest date, highly significant ($p < 0.01$) linear relations between CP concentration and DMD could be established for the beginning, middle and end of the dry season ($r^2 = 0.69$, 0.86 and 0.66 respectively); no relation was found between the CP concentration and DMD for the wet season harvest.

The estimated regression line between DMD and CP is

DMD = a + b*CP, where
a = 32.17 (s.e.m. 4.653), and b = 2.463 (s.e.m. 0.627) for the beginning of the dry season,
a = 17.45 (s.e.m. 3.860), and b = 3.261 (s.e.m. 0.495) for the middle of the dry season,
a = 18.73 (s.e.m. 7.617), and b = 4.634 (s.e.m. 1.255) for the end of the dry season respectively.

DISCUSSION

According to Gardener (1981) plant densities of 30–100 plants m^{-2} are needed for the maximum production of *Stylosanthes* pastures. Stockwell *et al.* (1986) regard plant densities of 10–30 plants m^{-2} as good, and 20–50 plants m^{-2} as excellent for the establishment of *C. pascuorum*. In the present trial plant densities in Year 1 fell in this range except for *S. hamata* ILRI 75; the low plant densities, in particular of the small-seeded legumes in Year 2, may have a negative effect on legume persistence. Legumes varied with respect to the time of maximum growth during the wet season and their ability to cover the soil. Initial soil cover is an important indicator of the ability of a plant to protect the soil after sowing or onset of the rains. Soil cover a few months after sowing or onset of the rains shows the general ability of the species to establish or re-establish. Legume mixtures offer the possibility of utilizing the differences in establishment and regeneration characteristics of different species. Combining relatively fast establishing species like *C. rotundifolia*, *S. guianensis* and *C. pascuorum* with slower establishing, but persistent species such as *C. brasilianum* is likely to ensure high overall plant densities and a good soil cover year round. This strategy may improve the success of legume establishment and persistence, enhance weed suppression and protect the soil from wind and water erosion.

DM yields, especially of *C. rotundifolia* and *S. hamata* ILRI 75, were lower than reported elsewhere for subhumid Nigeria (Peters *et al.*, 1994a; b; Tarawali, 1994). This could be attributed to the poor chemical characteristics and low depth of the soil and, in the case of *S. hamata* ILRI 75, to the poor establishment of this accession. The two *S. guianensis* accessions were the most productive, although once established, that is, in Year 2, both *C. brasilianum* accessions were superior in their ability to retain leaves and stay green over the dry season. Combining species such as *S. guianensis* and *C. brasilianum* in a pasture mixture seems to be an attractive option to utilize the positive characteristics of the respective species which can lead to an overall more productive and stable pasture. The disappointing performance of *C. rotundifolia*, *S. hamata* ILRI 75 and *A. histrix*, previously reported to be well adapted to dry-subhumid Nigeria (Peters *et al.*, 1994a; b; Tarawali, 1994) strengthens the concept of having complementary legumes grown in mixtures since these can be expected to react better to differences in the environment and management practices (Reátegui *et al.*, 1995).

Only whole plant samples were taken for the determination of nutritive quality as most plant parts are readily consumed. This is particularly true in the dry season, when animal production is limited most. CP concentrations and digestibility were generally comparable with results reported by Peters (1992) and Tarawali (1994) for a similar environment. The lower CP concentrations at the beginning of the dry season seem to have been a function of the low water-holding capacity of the soil resulting in rapid senescence and consequent rapid decline in nutritive quality. Information from other parts of the world on the nutritive quality of legumes in the dry season is scarce, but McCosker (1987) and Winter *et al.* (1989) reported similar dry season CP concentrations for *C. pascuorum* and *Stylosanthes* spp. in Australia. The relatively high digestibility of *S. guianensis* ILRI 15557, which at the end of the dry season was almost 0.60, is noteworthy. This accession is therefore of special interest as a dry-season supplement, particularly when other positive characteristics such as rapid establishment, high dry matter production and palatability, and anthracnose tolerance (Tarawali, 1994) are taken into account.

In agreement with a review of the world literature by Minson (1990), analysis of the data showed a relationship between CP concentration and DMD in dry-season samples; this did not apply to the wet-season samples. This can be explained by the considerable digestibility variation among species and accessions during the wet season, in contrast with the CP values which varied much less. With maturation, digestibility seemed to decrease more rapidly than CP concentration (Minson, 1990). In the dry season, digestibility and crude protein values had already reached low levels and changes were comparatively small. These results may need to be confirmed as wet-season samples were taken at only one date.

The positive relationship between leafiness and palatability in the dry season is important when selecting accessions for dry-season supplementation. Accessions staying green and maintaining a high leaf content over the dry season are also likely to control soil erosion and to maintain soil fertility better than plants that dry up. Such plants should therefore receive particular attention in selection programmes (Clements *et al.*, 1984; Peters, 1992).

Information on the differences between species or accessions regarding their relative palatability as affected by season is important for the management of pastures (Joblin, 1962). This applies not only to the productivity of the pasture and resulting animal production, but is also important for the inclusion of legume-based pastures in crop-livestock systems. Combining several legume species or accessions of varying seasonal palatability would allow resting periods for the different components in the mixtures, thus improving legume persistence in the pasture and at the same time ensuring a diet of high quality throughout the year. Relatively low acceptance of some of the species in a mixture could be an advantage in crop–livestock systems as a considerable amount of high-quality DM will be left for the improvement (either by incorporation or by decomposition) of organic matter content and nutrient status of the soil.

In general, all legumes were consumed although the acceptability varied among species and accessions. *Chamaecrista rotundifolia* cv. Wynn has been reported to be of low palatability at some sites (Quirk *et al.*, 1992; Partridge and Wright, 1992) and this agrees with the low initial palatability of *C. rotundifolia* at three of the four harvest dates in the present trial. However, other results from the present trial and information from a grazing experiment in northern Nigeria (Jama, 1998) suggest that the intake of *C. rotundifolia* is a function of the forage on offer and the stocking rate applied. The initial relatively low acceptability of *A. histrix* by animals never exposed to this species is in agreement with observations in other trials. However, after a long enough adaptation period, *A. histrix* is readily eaten and becomes seasonally one of the most preferred species in a sward (M. Peters, unpublished data). The increase in DMI of this species over time seems to confirm this trend. Such preconditioning of animals to species of initially lower palatability has been reported elsewhere (Marten, 1978; Lascano *et al.*, 1985), although no general definition was given of the time of adaptation needed. Carulla *et al.* (1991), working with *Arachis pintoi*-based pastures suggest that an adaptation period of at least 4 to 6 months is needed. This should be taken into account when considering relative palatability derived from small plot trials, as such trials might not expose the animals for a time long enough to adapt to all potentially palatable species.

There was no consistent relationship between the results from the Cafeteria method (overall palatability) and the Difference method. This seems to relate to the fact that it was not possible to measure the amount of forage consumed over time. It is likely that at the beginning of the grazing period the preferred species were consumed in large quantities; at later times when there was less possibility for selection it is likely that DMI per unit time declined. In conclusion, based on the present study, the two methods provide different information and therefore should be used concurrently. The Cafeteria method measures the relative palatability of the different legumes over time, whereas the Difference method is an indicator of whether a particular legume is consumed or not.

In contrast to Valderrama (1988) it was not possible to determine a consistent relationship between DM yield and palatability. Therefore palatability differences between the legumes tested do not seem to depend on the forage on offer; as reported above, legumes initially negatively selected were consumed once DM of the more palatable species was depleted. At the end of the dry season, palatability differences between species and accessions were less pronounced; nor was there much difference between the palatability at the beginning and the end of a grazing period. This implies less difference in the relative palatability of the drier material or less possibility for selection or both.

This paper has presented a large body of information on the performance of particular legumes in order to facilitate management decisions. Attention needs to be drawn to possible site-specific performances of some of the species dealt with here. Although reported to be highly productive in the environment, the DM yields of *C. rotundifolia* and *A. histrix* were low. To overcome such unpredictable, site-specific limitations of species or accessions, the utilization of mixtures of complementary legumes adapted to the environment is advocated. On the basis of the results reported here and obtained in pure stands, experiments to develop such combinations are now in progress.

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