

Evaluation of tropical pasture legumes for fodder banks in subhumid Nigeria. 1. Accessions of *Centrosema brasilianum*, *C. pascuorum*, *Chamaecrista rotundifolia* and *Stylosanthes hamata*

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Abstract

The potential of 5 forage legume accessions was assessed under cutting, as alternatives to *Stylosanthes hamata* cv. Verano for use in dry season pastures (fodder banks) in Nigeria. Measurements included dry matter yield, nutritive value (crude protein and phosphorus), seed production, drought tolerance and persistence. All accessions had good protein values and could be used to improve the quality of fodder, but their ability to compete with the native vegetation and consistently produce high yields differed.

Chamaecrista rotundifolia cv. Wynn performed well and could be used in fodder banks. Accessions of *Centrosema brasilianum* had poor seed production but warrant further research because of their outstanding ability to remain green and therefore more nutritious in the dry season. *Centrosema pascuorum* accessions yielded well initially but failed to persist.

All accessions showed a decline in the proportion of legume in the third season, supporting the recommendation to crop these areas to reduce grass infestation and exploit the benefits from the legume after 2-3 years.

Introduction

In subhumid West Africa, the low feed quality of the native pasture particularly during the dry season has been identified as the major constraint to livestock production. During the dry season the crude protein (CP) concentration of the native savanna grasses falls below 3% of the dry matter (DM) (Crowder and Chheda 1982; Tarawali *et al.* 1988).

Against this background, ILCA (International Livestock Centre for Africa) working in Kaduna, Nigeria has developed the concept of fodder banks: small areas of legume pastures used as a strategic high protein diet for ruminants to alleviate protein deficiencies during the dry season. Used in a ley system the forage legumes also improve soil properties (Mohamed Saleem and Otsyina 1986; Tarawali 1991a; Tarawali and Pamo 1992). However, there are limited suitable forage legume cultivars; presently, *Stylosanthes hamata* cv. Verano is the only one in use. ILCA, in cooperation with the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit, Germany) developed a special project for the systematic evaluation of tropical forage legumes for subhumid West Africa. The experiments described in this article were part of the evaluation program which has been outlined by Tarawali *et al.* (1989). The objective of these experiments was to compare the performance of promising forage legumes in pure stands and in competition with the native vegetation.

Materials and methods

Site

The experiment was conducted on a ferric luvisol (FAO/UNESCO system) at ILCA's research site,

Kurmin Biri, in the Kachia Grazing Reserve, Kaduna State, Nigeria (10°10'N, 7°55'E). Chemical properties of the surface soil (0–20 cm) prior to the establishment of the experiment at the experimental site are given in Table 1.

Typically, annual rainfall is 1200–1500 mm; the rains begin in April, are steady by early June and finish in October. During the experimental period, annual rainfall was 1257, 1205 and 1694 mm for 1988, 1989 and 1990, respectively. The mean monthly temperature ranges from about 22°C in December–January to 28°C in April. Ecologically, the area belongs to the Northern Guinea Savanna; the main grass species are *Andropogon* spp., *Hyperrhenia* spp. and *Loudetia* spp., and the main tree species are *Isobertinia* spp. and *Terminalia* spp.

Experimental procedure

Accessions selected from earlier screening trials with the ILCA registration numbers are listed in Table 2; where available, alternative CIAT (Centro Internacional de Agricultura Tropical, Colombia) and/or CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia) numbers are also presented.

Stylosanthes hamata cv. Verano and a sward with no legume introduction (subsequently referred to as grassland) were included as “controls”. Each accession was planted on 2 plots per replication; one was weeded throughout the experiment (referred to as W) and one left unweeded, i.e. growing in competition with the native vegetation (NW). The 5 accessions plus *S. hamata* cv. Verano, each W and NW, plus the grassland control gave a total of 13 treatments; each was replicated 3 times giving a total of 39 plots arranged in a randomised complete block design. Plot size was 2 × 3 m.

Land was cleared and the soil prepared to a fine tilth at the start of the experiment. Seeds were scarified mechanically and broadcast on to the plots, on June 2, 1988 at 5 kg/ha with the exception of *Chamaecrista rotundifolia* cv. Wynn (6 kg/ha) and *Stylosanthes hamata* cv. Verano (10 kg/ha seed in pods). Seed rates for Verano were high because of the poor quality of the seeds.

None of the accessions was inoculated with rhizobia. Based on ILCA's recommendation for existing fodder banks, fertiliser application at establishment was 150 kg/ha single superphosphate (SSP: 8% P, 14% S, 20% Ca). The

Table 1. Chemical parameters and texture of the top soil (0–20 cm) at Kurmin Biri.

pH H ₂ O	C	Total N	C/N	Av.P BRAY1	K	Ca	Mg	Na	Sand	Texture* Silt	Clay
	(%)	(%)		(ppm)		(meq/100 g soil)				(%)	
5.7	0.99	0.06	17	2.19	0.18	1.60	0.38	0.04	69.28	15.28	15.44

* Texture: Sand: 2–0.02 mm; Silt: 0.02–0.002 mm; Clay: <0.002 mm

Table 2. Legume accessions used in the trial.

Species	Accession			Cultivar
	ILCA	CIAT	CSIRO	
<i>Centrosema brasilianum</i>	1155	CT5234	CPI87993	
	16773	CT5211	CPI55698	
	16774	CT5284	CPI40060	
	(= 9863)			
<i>pascuorum</i>	19	CT5286	CPI55697	
	(= 9864)			
<i>Chamaecrista rotundifolia</i>	110918 (= 10789)		CPI34721	Wynn
<i>Stylosanthes hamata</i>	175		CPI38842	Verano

annual maintenance dressing was 100 kg/ha SSP applied at the start of the rainy season. Shrubby weeds were slashed in all plots during the rainy season. In 1989 and 1990, at the end of the dry season, all vegetation on the plots was cut to 5 cm above the soil surface.

Plant counts were made in the establishment year, and in the second and third growing seasons; two 0.25 m² quadrats were counted per plot. In the years following establishment, perennating plants and seedlings were counted separately. Beginning of flowering (10% of plants flowering) was recorded for the first 2 growing seasons. Seed production was monitored by visual estimation. Drought tolerance of the sown legumes was visually assessed by recording the percentage of green plants every second week during the dry season.

In the first 2 years of the experiment, at the end of the wet season, 2 random 1 m² quadrats per plot were cut at a height of 5 cm and divided into sown legume, grass and herbaceous weeds (herbs). For the sown legume, leaf/stem ratio was recorded. From each plot a subsample was taken for the determination of the yield, crude protein (CP) and phosphorus (P) concentrations in the whole plant and leaf, stem and litter (e.g. fallen leaves and inflorescences) of the legumes; for comparison, grasses and herbs in the legume plots and the grassland control were analysed as well. Samples were dried immediately after harvest at 65 °C to constant weight, then ground through a 1 mm mesh.

Data were analysed by ANOVA.

Results

Establishment and regeneration

Establishment of Wynn cassia and Verano was good with plant densities of 75 and 59 plants/m², respectively. For the larger-seeded *Centrosema* species, plant densities were 9–13 plants/m². Although no detailed studies were executed, all accessions nodulated readily with the native rhizobia.

Regeneration of Wynn and Verano with 150–550 plants/m² was very high in the following years. *C. pascuorum* had 23–55 plants/m² in the first and 65–86 plants/m² in the second year after establishment. In contrast, *C. brasilianum* had only 2–7 plants/m².

In all species except *C. pascuorum*, some plants survived the dry season. For *C. brasilianum*, 8–9 plants/m² persisted each year, while on average 11 and 23 Wynn plants/m² and 26 and 32 Verano plants/m² survived the first and second dry seasons, respectively.

Flowering

The first accession to flower was Wynn, 43–44 days after planting and 38–40 days after onset of the rains in subsequent years. Verano needed 84–88 days to flower in the establishment year and 55–61 days in subsequent years. *C. pascuorum* 19 reached flowering after 106 days and I6774 after 128–130 days in the first year. In the second and third growing seasons both accessions took 144–152 days. The accessions of *C. brasilianum* flowered last in the establishment year with 120 days for I6773 and 130 days for I155. In subsequent years, because of the high percentage of perennating plants, both *C. brasilianum* accessions had flowered within 60 days of the onset of the rains.

Seed production

In second and subsequent years, seed ripening started with Wynn in August, followed by *S. hamata* 2–3 weeks and the *Centrosema* accessions 8–10 weeks later. Seed ripening of Wynn and Verano was spread over 2–4 months, whereas seed production of *C. pascuorum* was restricted to the transition between the end of the wet and the beginning of the dry season. For *C. brasilianum* there was no obvious peak of seed production.

Drought tolerance

The *C. brasilianum* accessions were most drought tolerant, I155 being slightly better than I6773. About two-thirds of all plants remained green over the dry season. In other species, most plants died before the end of the dry season, with faster senescence of plants in unweeded than in weeded plots. Wynn retained some leaves on the dry plant, while Verano and *C. pascuorum* dropped their leaves as soon as they dried off.

Disease and pest incidence

No severe disease or pest incidences were recorded during the period of observation. *C. pascuorum* showed minor leaf lesions possibly caused by *Macrophomina phaseolina* and *C. brasilianum* had minor leaf lesions possibly caused by *Rhizoctonia* spp. but these were mostly restricted to the peak of the rainy season and did not seriously affect the development of the legumes.

Dry matter yield

1988. All legume plots except the 2 *C. brasilianum* accessions produced higher ($P < 0.05$) DM yields than the grassland control in the establishment year. Only the pure stand of *C. brasilianum* I6773 had a DM yield similar to the grassland control (Figure 1).

In this year, differences in total DM yield between the weeded (W) and not weeded (NW) treatments were variable. Wynn, the *C. pascuorum* accessions and Verano developed well with legume yields ranging between 2–3.5 t/ha.

Legume yields in the unweeded plots relative to the weeded plots were 81% for Wynn and Verano, 78% for *C. pascuorum* I6774, 65% for *C. pascuorum* 19, 16% for *C. brasilianum* I6773 and 34% for *C. brasilianum* I155.

1989. Highest yields (irrespective of treatments) were achieved in the second growing season (1989). Differences between total DM yield of the legume plots and the grassland control were small although those in the pure stands (W) of *C. brasilianum* were lower (Figure 2). Total DM yield of *C. brasilianum* I6773 was higher ($P < 0.05$) in the unweeded plots than in the pure stands (W), whereas weeding had no significant effects on total yield for other accessions.

Competition effects in the plots with companion vegetation (NW) were more pronounced than in 1988, and legume yields in the pure stands were usually much higher than in the unweeded plots. Wynn was the only accession where yields were not significantly ($P < 0.05$) reduced by weed infestation. Legume yields of the unweeded plots (as % of pure-stand yields) were 85% for Wynn, 33% for Verano, 50% for *C. brasilianum* I155,

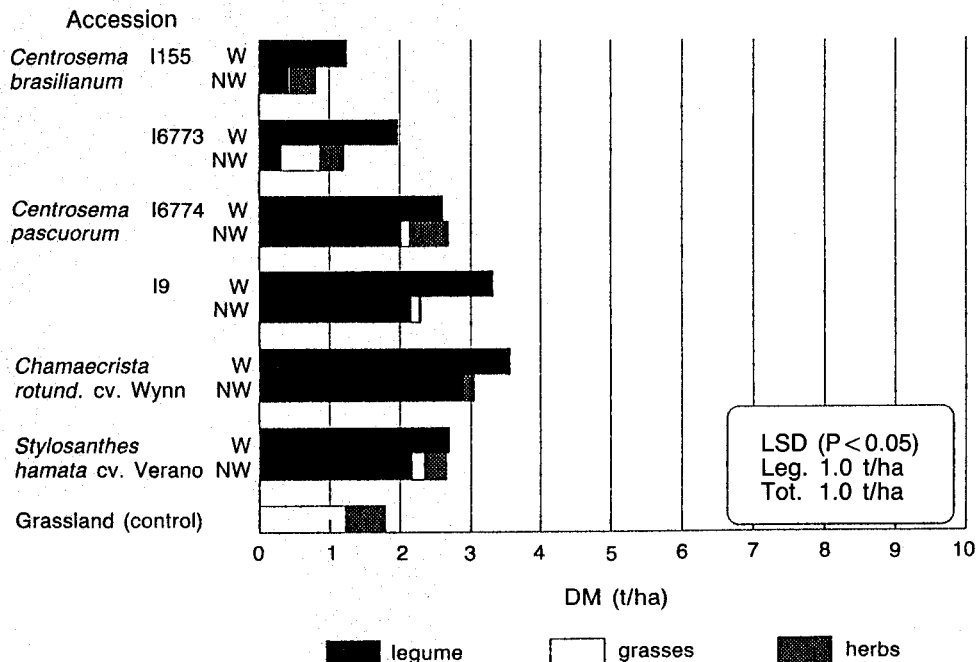


Figure 1. Dry matter yields (t/ha) of different legume accessions and the companion vegetation in the establishment year.

Leg. = legume Tot. = total dry matter
W = weeded NW = not weeded

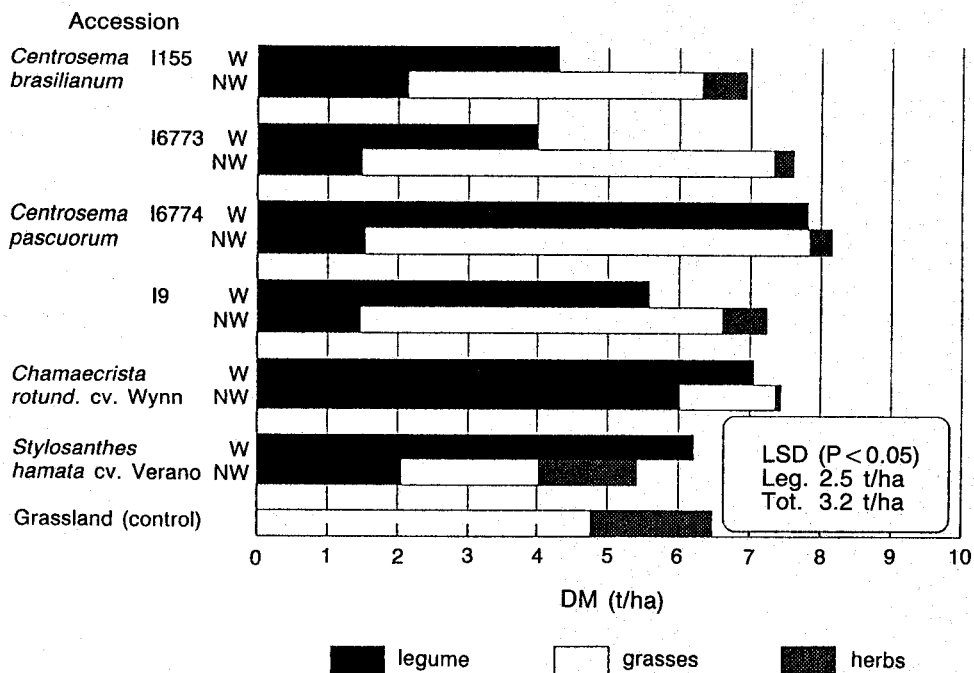


Figure 2. Dry matter yields (t/ha) of different legume accessions and the companion vegetation in the second growing season.

Leg. = legume Tot. = total dry matter
W = weeded NW = not weeded

37% for I6773, 20% for *C. pascuorum* I6774, and 26% for I9.

1990. In the third growing season (1990), total DM yields of the grassland control were slightly lower than in the previous year but still greater than in the establishment year. Herbs had almost disappeared from the sward. Total DM yield of the grassland control was similar to those of the pure legume stands (W), but much lower than in the plots with companion vegetation (NW) (Figure 3). For *C. brasilianum* I6773, *C. pascuorum* I9 and Wynn, total DM yields in the unweeded plots exceeded ($P < 0.05$) yields of the pure stands.

In the unweeded plots, legume yields were much lower than in the pure stands. At this stage, the best performing legume in the NW plots was *C. brasilianum* I6773 which achieved 31% of the pure-stand legume yield. Values for Wynn, *C. brasilianum* I155 and Verano were 27%, 21% and 10%, respectively. Both *C. pascuorum* lines failed to persist in the NW plots.

Nutritive value

Leaf/stem ratio. There were no significant differences ($P > 0.05$) in the leaf/stem ratio between accessions or years. Leaf percentages varied between 53% of DM for *C. brasilianum* I155 and 61.6% for *C. brasilianum* I6773.

Crude protein and phosphorus concentrations. Crude protein (CP) and phosphorus (P) concentrations were similar for the 2 years of data collection (1988 and 1989), and were generally higher in sown legumes than in grasses and herbs (Table 3). Concentrations in grasses and herbs in the legume plots were similar to those in the grassland control and are not presented. CP concentrations in the legumes were lower in unweeded plots than in weeded ones ($P < 0.05$). P concentrations of the *C. brasilianum* lines and Verano were also lower ($P < 0.05$) in unweeded plots. Overall, highest CP concentrations were recorded in *C. pascuorum* I6774 ($P < 0.05$). Highest P concentrations were found in the *C.*

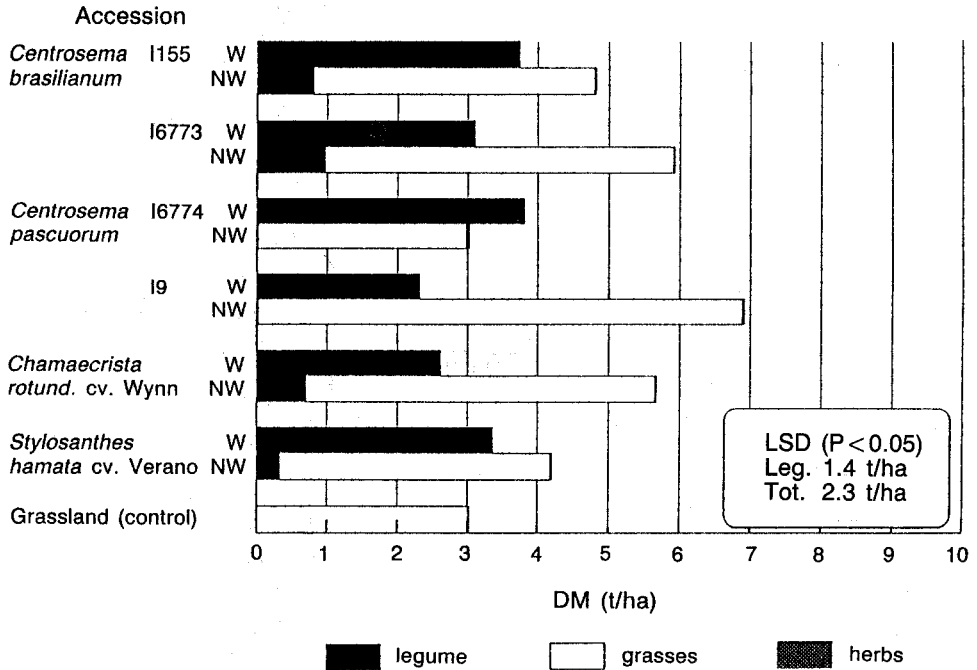


Figure 3. Dry matter yields (t/ha) of different legume accessions and the companion vegetation in the third growing season.

Leg. = legume Tot. = total dry matter
W = weeded NW = not weeded

Table 3. Crude protein (CP) and phosphorus (P) concentrations in sown legumes (whole plant) in weeded (W) and unweeded (NW) plots and in grasses and herbs in control plots at the end of the wet season (mean of first and second year).

		Accession							
		<i>Centrosema</i>			<i>C. rotund.</i>	<i>S. hamata</i>	grasses	herbs	
		<i>brasilianum</i>	<i>pascuorum</i>	19	cv. Wynn	cv. Verano			
		I155	I6773	I6774					
		(%)							
CP	W	11.1	11.1	12.1	10.8	9.8	10.9		
	NW	9.8	8.5	11.3	9.6	8.7	9.3	4.0	6.4
P	W	0.13	0.13	0.11	0.10	0.07	0.10		
	NW	0.12	0.12	0.11	0.10	0.07	0.08	0.06	0.09

brasilianum lines with 0.13% for I6773 and 0.12% for I155, and lowest values in Verano (0.09%) and Wynn (0.07%).

In Table 4, mean values of 2-years data for the CP and P concentrations in leaf, stem and litter at the end of the wet season are shown. Insufficient litter of Verano was present for the collection of a representative sample.

Although the samples were not replicated, some patterns are obvious from the data. CP concentrations of stem and litter were similar but much lower than those of leaf. P concentrations follow a similar pattern with the notable exception of *C. brasilianum* where leaf and stem P concentrations were similar and much higher than in litter. The CP and P concentrations of

Table 4. Crude protein (CP) and phosphorus (P) concentrations in leaf, stem and litter of selected legume accessions at the end of the wet season (mean of first and second year).

		Accession					
		<i>Centrosema</i>		<i>C. pascuorum</i>		<i>C. rotund.</i>	<i>S. hamata</i>
		<i>brasilianum</i>				<i>cv.</i>	<i>cv.</i>
		I155	I6773	I6774	I9	Wynn	Verano
		(%)					
CP	leaf	15.3	15.4	15.2	14.3	16.2	16.3
	stem	6.9	7.6	8.5	7.3	4.1	6.9
	litter	6.4	6.2	8.1	7.3	4.9	
P	leaf	0.15	0.16	0.16	0.14	0.09	0.15
	stem	0.13	0.16	0.07	0.06	0.05	0.05
	litter	0.09	0.08	0.07	0.06	0.03	

stem and litter fractions of Wynn were particularly low, with values lower than for grasses.

Discussion

The value of legumes to supplement tropical grass pastures is well documented (e.g. Norman and Stewart 1967 in Australia; Haggard *et al.* 1971 and Bayer and Waters-Bayer 1989 in Nigeria). Thus, highly productive legumes of good nutritive value which give high legume percentages in the pasture are appropriate. The fodder bank concept is a low-input system. Weeding or herbicide use is not practised so the sown legumes need to be able to compete effectively with the native vegetation. Thus, competitive ability was one of the most important aspects investigated in these experiments.

Of the legumes evaluated, only Wynn cassia achieved high yields of around 3–6 t/ha DM with legume percentages over 80% in unweeded plots at least for the first 2 growing seasons. This accession outperformed *S. hamata* cv. Verano which is presently used in fodder banks. The high competitive ability and persistence of Wynn agrees with results from Strickland and Greenfield (1988) in Australia. All other accessions in this experiment had only low ability to compete with the native vegetation. This is in contrast to other reports where Verano was shown to compete well with grasses. However, in those studies yield percentages above 40% were rarely achieved and were dependent on fertiliser and/or management inputs (Gardener 1980; Winter *et al.* 1989). A high competitive ability in grass-legume mixtures is also reported for *C. brasilianum*, but

good management of the pastures is essential (Anning 1982; Clements *et al.* 1984; Grof 1986; Lascano *et al.* 1990). The main problems for *C. brasilianum* were slow early development and poor regeneration from the soil seed bank. However, preliminary evaluation from South America with a wide range of accessions has indicated that other accessions may be selected with high potential seed production (Schultze-Kraft and Belalcazar 1988).

In the experiment described in this article, the *C. pascuorum* accessions were dominated by the native vegetation and disappeared from the sward after 2 years. Nevertheless, *C. pascuorum* may persist if the pasture is well managed, for example by using early season grazing to control grasses. This has been the case in on-going grazing trials at ILCA, Kaduna, where *C. pascuorum* yielded up to 4.4 t/ha with 44% legume (ILCA 1992). Seemingly contradictory results on the performance and persistence of *C. pascuorum* in the literature (Anning 1982; Clements *et al.* 1984; McCosker 1987; Ross and Cameron 1991) may be a reflection of the degree of pasture management employed.

Grass dominance resulted in poor legume productivity in the third growing season. However, grass yields and total DM yields in the Wynn, *C. brasilianum* I6773 and *C. pascuorum* I9 plots were higher than in the grassland control indicating a positive legume effect on soil fertility. This is in accord with reports of positive effects of forage legumes on cereal crop yields in Nigeria (Mohamed Saleem and Otsyina 1986; Tarawali 1991a; Tarawali and Pamo 1992) and Australia (Vallis and Gardener 1984; McCown *et al.* 1986; Jones *et al.* 1991). To

reduce grass competition and at the same time fully utilise the improvement in soil parameters, cropping the legume areas after 2–3 years is recommended.

The 9.3–11.7% CP in DM of the legumes recorded at the end of the wet season compared favourably with results of Mohamed Saleem and Kaufmann (1986) and Tarawali (1991b) at the same site and for *C. pascuorum* and *Stylosanthes* spp. (including *S. hamata* cv. Verano) in Australia (McCosker 1987; Winter *et al.* 1989). CP concentrations of the legumes were well above the 6–8% DM defined by Minson (1981) and Van Soest (1982) as the minimum needed to ensure maximum forage intake and digestion. Thus all of the tested accessions are capable of improving the protein nutrition of ruminants. The lower CP concentrations in unweeded plots are probably a result of the earlier senescence of the legumes when competing with other species for growth factors rather than a transference of nitrogen from the legume to the grass.

At the end of the wet season, P concentrations were already low for legumes but were comparable with values reported elsewhere, mainly for *Stylosanthes* spp. under similar conditions (McIvor 1979; Mohamed Saleem and Kaufmann 1986; McCosker 1987; Gilbert *et al.* 1989; Winter *et al.* 1989). Only for *C. brasilianum* spp. was the P concentration in the whole plant above the requirement of 0.12% in the diet as reported by Little (1980) for tropical pastures. However leaf P concentrations exceeded this figure even at the end of the wet season. The P concentrations of the native vegetation were also well below animal requirements. With advancing age of the plants and under water stress a further decrease in P concentration is anticipated (Fisher 1980; Legel 1989; Peters 1992). In this context the good drought tolerance, CP concentrations and the comparatively high P values in the stem of the perennial *C. brasilianum* spp. at the onset of the dry season give this species a potential advantage over annuals or short-lived perennials in terms of a high nutritive value in the dry season.

The experiments reported above suggest that Wynn cassia is a suitable legume for fodder bank use in the subhumid zone of Nigeria. Its high competitive ability makes it less sensitive to poor pasture management, an important consideration in view of the farming systems prevalent in Nigeria. Further investigation of a wider range of *C. brasilianum* accessions to identify those

with faster establishment and better seed production is warranted, given the potential of this species to maintain its nutritive value in the dry season. The role of green plants to control soil erosion and maintain soil fertility should also not be underestimated. Although the tested *C. pascuorum* accessions are unsuitable for fodder bank use unless the pasture is very carefully managed, they may be considered for use in a mixed legume pasture where they would provide good quality fodder in the first season when other species would be slow to establish.

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