

Copyright 1995

The CIAT Library would like to thank the publisher of ***Tropical Grasslands*** for giving us permission to include the full text of this article on our website.

Derechos de autor 1995

La Biblioteca del CIAT agradece al editor de ***Tropical Grasslands*** el permiso de incluir el texto completo de este artículo en nuestra pagina web.

Dry season performance of four tropical pasture legumes in subhumid west Africa as influenced by superphosphate application and weed control

M. PETERS^{1,2}, S.A. TARAWALI¹ AND J. ALKÄMPER²

¹International Livestock Centre for Africa (now International Livestock Research Institute), Subhumid Research Site, Kaduna, Nigeria

²Justus-Liebig-Universität, Wissenschaftliches Zentrum Tropeninstitut, Giessen, Federal Republic of Germany

Abstract

The productivity and nutritive value of *Chamaecrista rotundifolia* cv. Wynn, *Centrosema pascuorum* cv. Cavalcade, *Stylosanthes guianensis* cv. Pucallpa and *S. hamata* cv. Verano as affected by single superphosphate fertilisation (SSP) and weed control were measured during the dry season in subhumid Nigeria. Wynn, when growing in competition with the native vegetation, had the highest dry matter yields. During the dry season, legume yields were more stable than those of the associated grasses and herbs. Fertilisation with SSP at low levels of available soil phosphorus increased legume productivity but native grasses and herbs did not respond to the fertiliser applied.

The nutritive value of all legume species was low for most of the dry season, with crude protein concentrations, *in vitro* dry matter digestibility, and phosphorus concentrations ranging between 5–7%, 40–50% and 0.02–0.05%, respectively. The decline of nutritive value during the dry season was largely a function of changes in leaf/stem/litter proportions. It is suggested that drought tolerance and capacity to retain leaf should receive more attention when evaluating forage species to be used in the dry season.

Despite these limitations, Wynn has potential to complement the widely used *Stylosanthes hamata* cv. Verano in drier subhumid west Africa.

Correspondence: Dr M. Peters, University of Hohenheim (380), D-70593 Stuttgart, Germany. e-mail: michael.peters-vilbel@t-online.de

The other species tested could be successfully used in legume mixtures.

Introduction

In subhumid west Africa, the low quality and quantity of the native pasture in the dry season (November–April) is the major constraint to livestock production. The most critical period is January–April, when available feed from the native range often falls below 500 kg/ha (Mohamed Saleem 1986), and other feed sources such as crop residues are exhausted or become scarce (Bayer and Waters-Bayer 1989). Crude protein (CP) concentrations of the grasses dominating the native range in the dry season are as low as 2–3% (Crowder and Chheda 1982). Grazing legume-based pastures in the dry season can maintain continuity of forage supply in such wet/dry climates, where suitable legumes exist (Humphreys 1991).

Against this background, the ILCA (International Livestock Centre for Africa, now ILRI, International Livestock Research Institute) Subhumid Zone Programme in Kaduna, Nigeria developed the concept of fodder banks, fenced legume pastures used as a strategic high protein supplement to the native savanna vegetation. This approach is limited by the lack of suitably adapted forage legumes to complement *Stylosanthes hamata* cv. Verano, the only cultivar widely used in existing fodder banks. Therefore, an evaluation programme with emphasis on dry season performance of selected legume accessions was developed. This paper describes the dry season performance of 3 of the most promising accessions (Peters *et al.* 1994a; 1994b), *Chamaecrista rotundifolia* cv. Wynn, *Centrosema pascuorum* cv. Cavalcade and *Stylosanthes guianensis* cv. Pucallpa (ILRI 164) in comparison with *Stylosanthes hamata* cv. Verano, as affected by management of the associated vegetation and different levels of single superphosphate (SSP).

Materials and methods

Site

The experiments were carried out at ILCA's sub-humid zone research site at Kurmin Biri (10°10' N, 7°55' E) in central Nigeria. Average annual rainfall is about 1400 mm (Table 1), of which 95% falls between April and October. During the period of the experiment, annual rainfall was 1258 mm in 1988, 1205 mm in 1989 and 1694 mm in 1990. The mean monthly air temperature ranged from about 22°C in December–January to 28°C in April. According to the classification of D'Hoore (1964), the soil is a ferruginous tropical soil and the vegetation is northern guinea savanna characterised by *Andropogon* spp., *Hyperrhenia* spp. and *Loudetia* spp. as the dominant grasses, with *Isobertinia* spp. and *Terminalia* spp. as the main tree species. This soil type covers about 58% of the west African savanna (Jones and Wild 1975). Prior to planting, soils at the experimental sites had a pH (H₂O) ranging between 4.7 and 5.4, organic carbon concentrations (Walkley-Black) of 1.2–1.4%, total nitrogen (Kjeldahl) concentrations of 0.07–0.08%, available phosphorus (P) concentrations (BRAY I) of 0.4–2.2 ppm, and potassium, calcium, magnesium and sodium concentrations of 0.1–0.2, 1.6–2.4, 0.3–0.8, and 0.04–0.05 meq/100 g soil, respectively. The soil had 65–72% sand, 14–16% silt and 13–19% clay (Hydrometer method).

Experimental design

The 4 species (Wynn, Cavalcade, Pucallpa and Verano) were evaluated in separate experiments. The trials were split-plot designs with 4 replications. Main plot treatments (3) were different levels of single superphosphate (SSP; 8% P, 14% S, 20% Ca) in the establishment year only, *i.e.* 0 (P0), 150 (P1) and 300 (P2) kg/ha SSP, respectively. Fertiliser rates were based on experience

with established *Stylosanthes* fodder banks (Otsyina *et al.* 1987). In subsequent years, no fertiliser was applied so that the residual effects of the initial application could be measured. Subplots (3) were assigned to management options, *i.e.* W = weed-free (hand weeding; to compare results with previous preliminary evaluations mainly done in weed-free plots); C = cutting vegetation down to the height of the legume through the first half of the wet season (as a simulation of early season grazing); and NW = no weeding (legume plus the upcoming vegetation). Subplot size was 2 × 5 m. Planting dates were June 2, 1988 (Wynn), June 4, 1988 (Verano) and June 9, 1989 (Cavalcade and Pucallpa).

Soil in the plots was prepared to a fine tilth; seeds were scarified with sandpaper and broadcast. Seeding rates were 6 kg/ha for Wynn, Cavalcade and Pucallpa and 10 kg/ha for Verano; the higher rate for Verano was necessary because of impurity and poor quality of the available seed. No inoculum was applied as earlier experience in the area showed that the species nodulated freely with the native cowpea rhizobia. Legumes were allowed to seed before the first harvest of haylage in the dry seasons.

Measurements

Seedling counts were done 4 and 8 weeks after planting and 4 and 8 weeks after the start of the rains in subsequent years. Two 0.25 m² quadrats were counted per subplot. In the years after establishment, perennating plants were also counted to determine dry season survival.

Diseases and pests were monitored regularly throughout the experimental period and visually assessed for incidence (area of plot affected) and severity (damage to individual plants) when infestations were observed. Greenness of the legumes was estimated by visually assessing the

Table 1. Rainfall distribution (mm) at the experimental site between 1988 and 1990 compared with the 9-year average (1985–1993).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1988	—	1	18	19	237	242	183	278	264	18	—	—	1258
1989	—	—	—	41	133	178	167	368	208	111	—	—	1205
1990	—	—	—	127	255	155	255	494	321	88	—	—	1694
Average	—	2	19	66	178	216	245	392	240	72	5	—	1436

ability of the plants to maintain green leaves over the dry season.

Four harvests were made at 6-weekly intervals from the start of the dry season, with samples being collected in two 0.5 m² quadrats per subplot (cutting height about 10 cm above ground level). When present, litter (mainly fallen leaves) was collected from the ground. After sampling, the remainder of the subplot was cut back to about 10 cm above ground level. Samples were divided into sown legume, grass and herbs to determine both absolute and relative contributions of the different sward components to total dry matter yield as the dry season progressed. Leaf/stem/litter proportions of the legumes were also determined. For chemical analysis of fodder over the dry season, bulked samples of about 200 g of whole plant and leaf/stem/litter fractions from the 4 replications per subplot were taken and dried immediately after harvest at a temperature of 65°C until a constant weight was reached. Afterwards, samples were ground through a 1 mm mesh and analysed for crude protein (CP; micro-Kjeldahl), fibre (Goering and Van Soest 1970), *in vitro* dry matter digestibility (IVDMD; Tilley and Terry 1963) and phosphorus (P; colorimetric), calcium (Ca), sodium (Na), potassium (K) and magnesium (Mg) concentrations (Atomic Adsorption Spectrophotometer). As differences between years were small, values averaged over years are presented.

Statistical analysis

Data were analysed by ANOVA and means were compared by LSD ($P < 0.05$) for a split-plot design. For comparison of changes over the dry season, harvests were treated as sub-subplots and data analysed as a split-split-plot design (Gomez and Gomez 1984).

Results

Stylosanthes hamata cv. *Verano*

Establishment, regeneration and disease. Only 7–15% of the sown *Verano* seeds established in the field; however, due to the high seeding rate, plant densities were satisfactory. Fertilisation had a positive effect on legume establishment ($P < 0.05$) with 40–60 plants/m² in the fertilised plots (P1 and P2) and 25–30 plants/m² in the non-fertilised

plots (P0). Regeneration in the following years was good with average plant densities of 238 plants/m² and 430 plants/m² in Years 2 and 3, respectively. Plant densities were higher ($P < 0.05$) in subplots harvested after November (1st harvest) in the previous year.

Though there were slight symptoms of anthracnose (*Colletotrichum gloeosporioides*), development of *Verano* was not seriously affected.

Dry season survival and greenness. *Verano* dried off in the middle of the dry season between November and beginning of February. SSP fertilisation had a positive effect; in fertilised plots, 30–60% of plants were green until the end of December, whereas only 10–30% of plants in non-fertilised plots were green at that time. Once plants had dried off, they shed their leaves. Survival of plants was affected by harvest date in the preceding dry season; harvesting in the 2nd half of the dry season significantly ($P < 0.05$) increased perennating plants from 16–17 plants/m² to 28–38 plants/m².

Dry matter yield. In the establishment year (Year 1), SSP increased *Verano* yield significantly ($P < 0.05$) only at the 2nd and 3rd harvest dates for P2 and at the 3rd harvest for P1 (Figures 1a and 1b; for clarity of presentation, only data for the 1st and 3rd harvest dates for each species and year are presented). Grasses and herbs did not react to P fertilisation ($P > 0.05$). The associated vegetation in the C and NW plots reduced legume yields only at the 1st and 2nd harvests ($P < 0.05$), with *Verano* percentages increasing from 50–65% at the beginning of the dry season (Figure 1a) to usually higher than 80% in the 2nd half of the dry season (Figure 1b). SSP fertilisation had no effect on legume percentages.

Although no fertiliser was applied in Year 2, residual effects of SSP fertilisation on legume yield were still observed, though these were significant ($P < 0.05$) only for the 2nd to 4th harvest and the 2 P levels (P1, P2) could not be differentiated (Figures 1c and 1d). Legume yields in the W plots were higher than in the C and NW plots. No differences in legume yields were observed between the latter two, but legume percentage was higher in the C than in the NW treatment. Legume yields remained stable throughout the dry season, in contrast to grass and herb yields.

In Year 3, DM yields were lower than in previous years, and no residual effect of the SSP applied at planting was detectable (Figures 1e

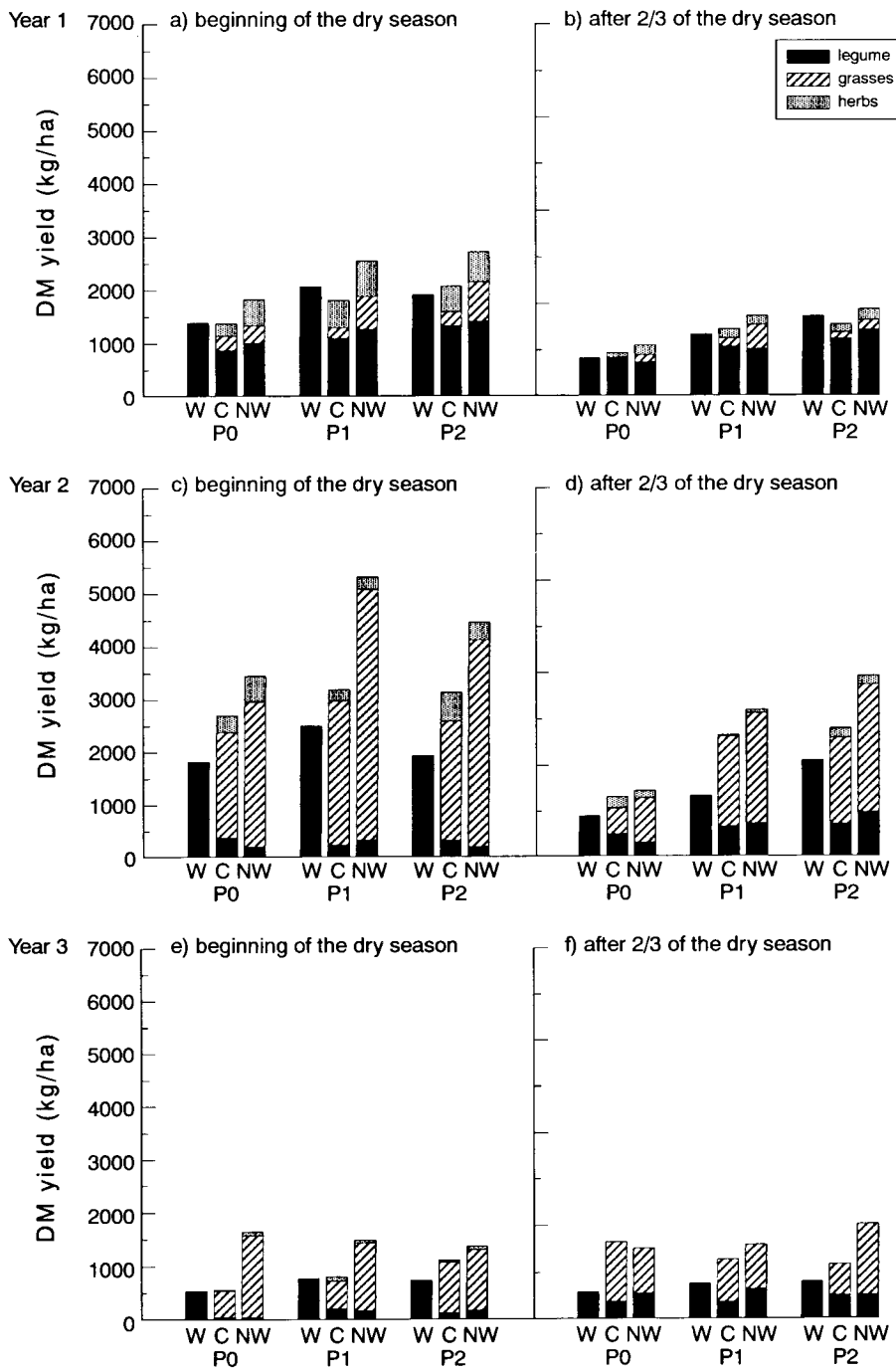


Figure 1. Dry season dry matter yields of *Stylosanthes hamata* cv. Verano as affected by P fertilisation in the establishment year and weed control.

P0 = without fertilisation; P1 = 27 kg/ha P₂O₅; P2 = 54 kg/ha P₂O₅ as SSP.
 W = weed free; C = cutting in the early rainy season; NW = no weed control.

and 1f). By now, competition from nitrophilous grasses like *Pennisetum pedicellatum* and *Andropogon* spp. was much stronger than in earlier years, and hence, legume dry matter yields in the C and NW treatments were much lower than in the W treatment ($P < 0.05$). Cutting (C) in the wet season had no positive effect on legume yields in comparison with the NW treatments, but grass growth was reduced. No effect of harvest date on yields was found.

Nutritive value. Verano shed most of its leaves at the beginning of the dry season, and by the 2nd harvest date in mid-December, leaves accounted for less than 6% of dry matter. Litter percentage, mainly fallen leaves, increased correspondingly, while stem proportions remained fairly constant until the end of the dry season, when there was a

sharp decrease from 50% to 35% of total legume dry matter.

CP concentrations of whole plant (including litter) and leaf samples decreased sharply between the 1st and 2nd harvest dates from 10.4% and 16.8% to 5.5–6.7% and 9.3–11.3%, respectively, for the remainder of the dry season (Table 2). CP concentrations of stem and litter were more stable, with litter having higher concentrations than stem. Digestibility did not vary much over the dry season, with leaf and litter (56–61%) being much more digestible than the stem fraction (31–46%). Fibre and mineral concentrations remained relatively constant during the dry season, though the P concentrations, already low at the onset of the dry season, decreased further as the dry season progressed.

Table 2. Crude protein, *in vitro* dry matter digestibility (IVDMD), fibre and mineral concentrations of different legume species in the dry season. (Ranges over the dry season are shown in brackets).

Species	Verano	Wynn	Pucallpa	Cavalcade
<i>Crude protein (%)</i>				
whole plant	7.2 (5.4–10.4)	5.6 (4.3–7.2)	6.2 (5.4–8.3)	6.5 (4.5–11.4)
leaf	11.8 (9.3–16.8)	11.3 (9.4–13.5)	11.2 (9.7–14.2)	6.7 (4.1–14.1)
stem	5.4 (4.3–6.0)	4.8 (4.1–5.3)	5.6 (5.1–6.0)	5.2 (4.6–6.0)
litter	6.6 (5.9–7.0)	4.4 (3.7–4.9)	5.9 (5.7–6.0)	5.2 (4.9–5.7)
<i>IVDMD (%)</i>				
whole plant	49.8 (47.1–53.1)	48.7 (45.0–50.1)	41.4 (39.8–45.1)	44.0 (38.4–52.6)
leaf	58.6 (56.0–61.0)	58.7 (55.7–60.4)	59.9 (58.4–61.9)	44.7 (38.9–58.8)
stem	39.9 (30.7–46.1)	40.0 (36.9–43.1)	36.1 (33.8–38.8)	30.9 (26.7–35.0)
litter	59.0 (55.8–60.9)	53.6 (49.3–56.1)	63.8 (61.8–65.7)	50.4 (48.2–54.5)
<i>Fibre (whole plant)</i>				
NDF (%)	53.8 (49.5–57.7)	52.6 (50.7–55.5)	63.4 (59.7–66.7)	65.2 (56.7–69.2)
ADF (%)	47.7 (45.7–49.5)	45.8 (43.4–47.4)	56.4 (53.2–60.0)	52.0 (43.1–56.1)
ADL (%)	11.1 (10.2–12.4)	13.3 (12.5–13.7)	12.1 (10.9–12.8)	12.0 (9.9–13.1)
<i>Minerals (whole plant)</i>				
Ca (%)	0.93 (0.78–1.06)	0.78 (0.69–0.87)	0.8 (0.54–1.10)	0.9 (0.73–1.1)
P (%)	0.05 (0.03–0.07)	0.03 (0.03–0.04)	0.05 (0.02–0.09)	0.05 (0.02–0.09)
K (%)	0.87 (0.74–0.94)	0.68 (0.52–0.82)	1.04 (0.51–1.51)	1.05 (0.73–1.19)
Mg (%)	0.15 (0.12–0.20)	0.11 (0.09–0.12)	0.17 (0.11–0.23)	0.23 (0.16–0.24)
Na (ppm)	62.5 (48.2–77.1)	51.7 (28.2–64.4)	25.5 (21.2–29.5)	29.9 (24.4–24.8)

Chamaecrista rotundifolia cv. Wynn

Establishment, regeneration and disease. Establishment of Wynn was good, with average plant densities of 80 plants/m². Regeneration in subsequent years was also good, with average plant densities of 298 plants/m² and 516 plants/m² in Years 2 and 3, respectively. Higher plant densities were recorded in the fertilised plots and in plots harvested later in previous years ($P < 0.05$). Throughout the experimental period, no diseases were observed for Wynn.

Dry season survival and greenness. Greenness of Wynn was related to SSP fertilisation. In the P0 plots, most plants had dried up by mid-January (15% of plants still green), whereas in the P1 and P2 plots, about 30% and 50%, respectively, of the plants were still green in mid-February. Wynn retained leaves for some weeks after drying off. Each year, about 30 plants/m² survived the dry season, independent of harvest date.

Dry matter yield. In the establishment year, Wynn responded ($P < 0.05$) to SSP fertilisation, with a bigger increase between P2 and P1 than between P1 and P0 (Figures 2a and 2b). Legume yields were more stable over the dry season than grass and herb yields. Grasses and herbs were not affected by fertilisation. Legume percentages were high throughout the dry season (56–97%) and were not significantly ($P > 0.05$) affected by fertilisation or weeding.

The SSP fertilisation from the previous year continued to have an effect on legume yields in Year 2 (Figures 2c and 2d). As in the previous year, differences between the P1 and P2 treatments were greater than between P0 and P1 treatments ($P < 0.05$). In contrast, grass yields were independent of P levels, and legume percentages increased from 46–63% in the P0 to 62–86% in the P2 treatments. Neither cutting nor time of harvest influenced legume percentage. Legume yields were more stable over the dry season than grass and herb yields.

No residual effect of SSP fertilisation at planting was found in Year 3 (Figures 2e and 2f). Cutting (C) in the wet season did not affect legume yields, but grass growth was reduced and legume percentage in the C plots ranged between 39–72% compared with 18–49% in the NW plots. As in previous years, legume percentage in the forage on offer increased over the dry season ($P < 0.05$).

Nutritive value. Leaf percentages fell steadily over the dry season from more than 30% at the beginning to less than 10% at the end of the dry season. However, leaf drop was slower than for Verano. Litter percentages increased in relation to leaf drop, while stem percentages remained relatively constant until the end of the dry season.

CP concentrations of whole plant samples (7%) were already low at the beginning of the dry season, and decreased further to below 5% at the end of the dry season (Table 2). A similar pattern was found for the leaf fraction with CP concentrations falling from 13.5% at the beginning to 9.4% at the end of the dry season. CP concentrations in stem were always between 4.1 and 5.3%, and litter CP concentrations ranged between 3.7 and 4.9%. Digestibility remained relatively constant over the dry season with values between 45 and 50%, with leaves having the highest and stem the lowest digestibilities. Fibre and mineral concentrations did not change much over the dry season, with P and Mg concentrations being very low.

Stylosanthes guianensis cv. Pucallpa

Establishment, regeneration and disease. Establishment and regeneration of Pucallpa were good, with average plant densities of 40 plants/m² and 260 plants/m², respectively. Regeneration of plants was better in subplots harvested after November (1st harvest). Anthracnose was found, but did not seriously affect plant growth.

Dry season survival and greenness. Pucallpa dried off mainly in January and shed its leaves immediately. P fertilisation had a positive effect on greenness. As for Verano, survival of Pucallpa was dependent on harvest date in the preceding dry season. In plots harvested in the 1st half of the dry season, only 10 plants/m² survived, in comparison with 16 plants/m² in plots harvested in the 2nd half.

Dry matter yield. In the establishment year, SSP fertilisation led to substantially higher legume yields at all harvest dates (Figures 3a and 3b), with significant ($P < 0.05$) differences between all levels of P. Usually, legume yields were highest in the W treatment and lowest in the NW treatment. Legume yields were more stable through the dry season than grass and herb yields. Grass and herb yields were not affected by SSP fertilisation. As only the legume responded

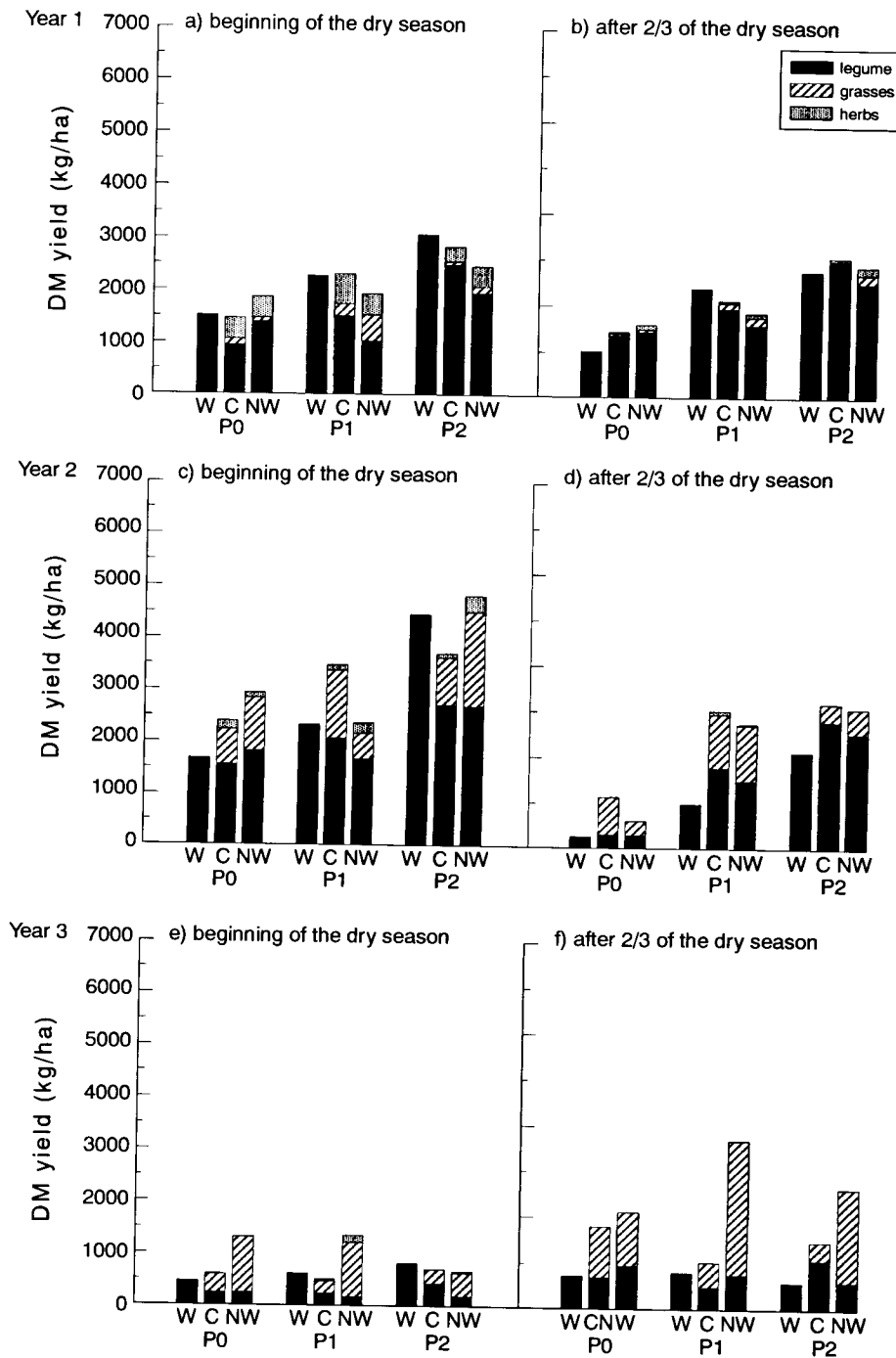


Figure 2. Dry season dry matter yields of *Chamaecrista rotundifolia* cv. Wynn as affected by P fertilisation in the establishment year and weed control.

P0 = without fertilisation; P1 = 27 kg/ha P₂O₅; P2 = 54 kg/ha P₂O₅ as SSP.
 W = weed free; C = cutting in the early rainy season; NW = no weed control.

to SSP fertilisation, legume percentages were higher in the fertilised plots ($P < 0.05$), with 73–100% legume in the P2 plots compared with 40–65% legume in the P0 plots. Legume percentages were higher at later harvests than at the beginning of the dry season.

In Year 2, the initial SSP dressing still had a positive effect on Pucallpa, especially at the higher P level (P2), and legume percentages were increased from 24–50% in the P0 plots to 50–100% in the P2 plots (Figures 3c and 3d). Grass yields were not affected by P level and herbs had almost disappeared, so legume percentages were increased in the P1 and P2 treatments. The associated vegetation had no consistent effect on

Pucallpa yields, but cutting reduced grass yields and thus increased legume percentages. However, only the early harvests were significantly different. In contrast to grass yields, legume yields remained stable over the dry season, raising legume percentages at later harvests.

Nutritive value. Leaf percentages declined from over 50% at the onset of the dry season to 37% 6 weeks later and less than 10% at the end of the dry season. As leaf percentage decreased, litter percentage (mainly fallen leaves) increased, and stem percentage remained relatively constant.

CP concentrations of whole plant samples and leaves decreased from 8.3% and 14.2%, respectively, at the beginning of the dry season, to 5.6%

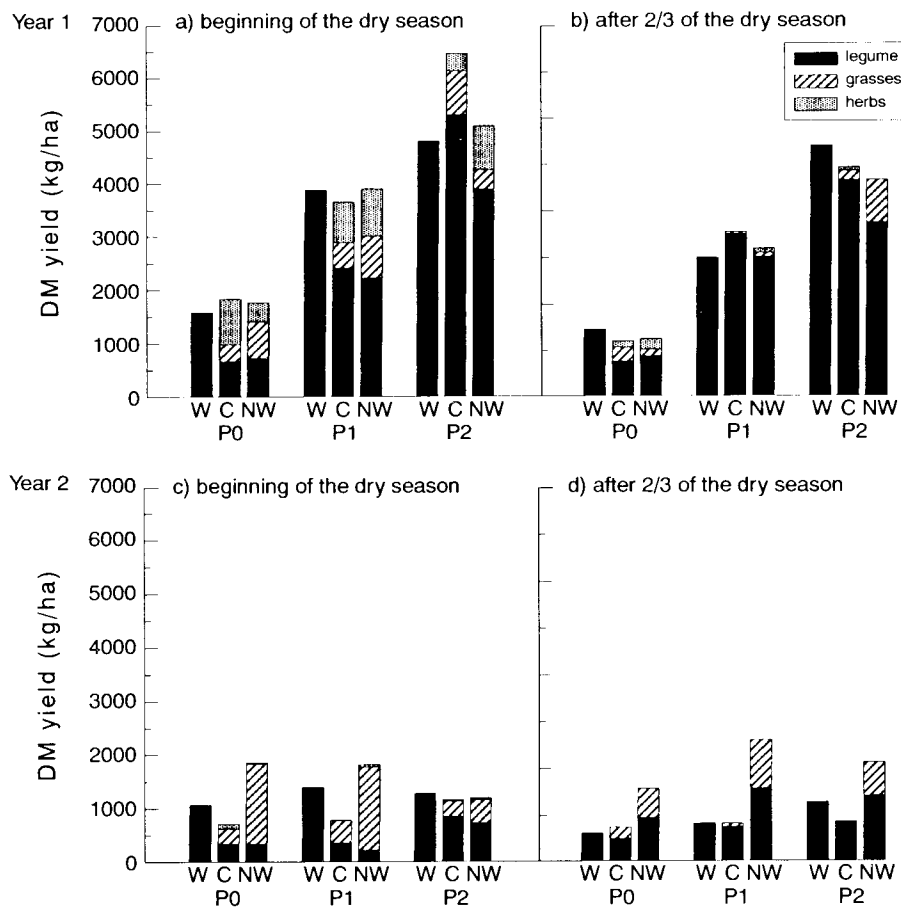


Figure 3. Dry season dry matter yields of *Stylosanthes guianensis* cv. Pucallpa as affected by P fertilisation in the establishment year and weed control.

P0 = without fertilisation; P1 = 27 kg/ha P_2O_5 ; P2 = 54 kg/ha P_2O_5 as SSP.

W = weed free; C = cutting in the early rainy season; NW = no weed control.

and 10.7%, respectively, 6 weeks later (Table 2). Stem and litter CP concentrations showed little variation over the dry season. Digestibility of whole plant samples was low, with an average of 41% over the dry season. Leaf and litter were much more digestible than the stem fraction. Fibre and mineral concentrations remained constant, but P and Mg levels declined from 0.09% and 0.23% at the beginning to 0.02% and 0.11% at the end of the dry season, respectively.

Centrosema pascuorum cv. *Cavalcade*

Establishment, regeneration and disease. Establishment and regeneration of *Cavalcade* were satisfactory to good with average plant densities

of 10–20 plants/m² and 150 plants/m², respectively, with no effect of treatments or harvesting date in the previous dry season. *Cavalcade* showed slight symptoms of *Macrophomina phaseolina* and *Cercospora* spp., but these were not an impediment to plant development.

Dry season survival and greenness. *Cavalcade* dried off as early as November, but retained leaves for some weeks after drying off. As it behaved strictly as an annual, none of the original plants survived the dry season.

Dry matter yield. Although P fertilisation increased legume yields of *Cavalcade*, differences were usually not significant ($P>0.05$) and no difference existed between the P1 and P2 fertiliser levels (Figures 4a and 4b). Legume yields in

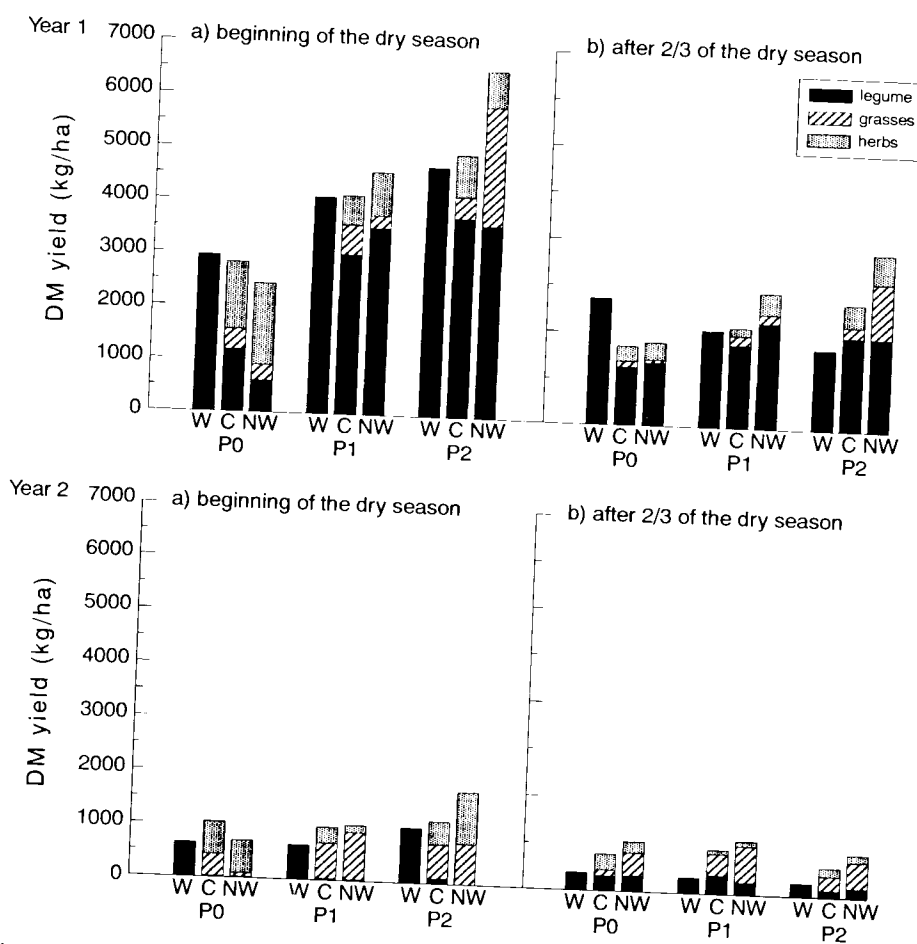


Figure 4. Dry season dry matter yields of *Centrosema pascuorum* cv. *Cavalcade* as affected by P fertilisation in the establishment year and weed control. P0 = without fertilisation; P1 = 27 kg/ha P₂O₅; P2 = 54 kg/ha P₂O₅ as SSP. W = weed free; C = cutting in the early rainy season; NW = no weed control.

the weeded plots were higher than in C and NW treatments, but differences between the latter two were negligible. Over the dry season, yields of legumes, grass and herbs decreased, but legume percentages increased from 30–40% to 50–75% in the non-fertilised plots. In the fertilised plots, legume percentages were always above 58% and up to 83%.

Although regeneration had been good, Cavalcade yields in Year 2 were poor, and in the C and NW treatments, Cavalcade almost disappeared. No response to SSP fertilisation in the previous year and weeding practice could be determined.

Nutritive value. As stem percentage remained relatively constant over the dry season, the change in leaf/stem/litter proportions was mainly expressed by a shift between leaf and litter fractions. Leaf percentage of Cavalcade fell from over 70% at the beginning of the dry season to 20% 6 weeks later and about 10% at the end of the dry season, while litter percentages increased correspondingly.

CP concentrations of whole plant samples and leaf samples fell from 11.4% and 14.1% at the onset of the dry season to 4.1–5.3% 6 weeks later. CP concentrations in litter, containing a lot of seeds and pods, and stem were 4.6–5.7% higher than leaf CP concentrations. A similar pattern existed for digestibilities, declining sharply from values above 50% for the whole plant and leaf samples to 38.4–44.6% for the remainder of the dry season. Litter digestibility remained relatively high at 48.2–54.5% over the dry season, while digestibility of the stem was low at 26.7–35%. Fibre and mineral concentrations remained relatively constant, but P concentrations declined from 0.09% at the beginning to 0.02% at the end of the dry season.

Discussion

In subhumid west Africa, conserved legume pastures (fodder banks) grazed for 2–4 hours per day could improve not only the quality but also the quantity of available fodder in the dry season. The legumes tested maintained growth and retained green foliage longer into the dry season than the native grasses dominating the native savanna and thus are less subject to processes of dry matter destruction. This also explains the increase in legume percentages in the plots with

associated vegetation as the dry season progressed.

According to Salinas *et al.* (1990), *Centrosema* accessions can be distinguished in their P requirement by responsiveness (responsiveness = the increase in yield to applied P) and efficiency (efficiency = the yield at nil P). Under the extensive conditions in subhumid Nigeria, a similar classification seems to apply to other legume species and other nutrients. Thus, Pucallpa had the greatest response to fertilisation, but the lowest efficiency. Cavalcade and Verano had only a low responsiveness, but high efficiency. Wynn was more responsive than these 2 accessions and also very efficient. Moreover, Wynn had the greatest ability to use residual fertiliser. This flexibility of Wynn in its reaction to a varying P supply and its capacity to utilise residual P is of particular interest in a suggested extensive ley farming system with a varying, and often hardly quantifiable, nutrient supply. Under the present socio-economic conditions in Nigeria and west Africa in general, it is also likely that, with limited resources, crops rather than fodder plants will be fertilised, especially as growing the latter has no tradition in tropical Africa (Peters and Tohill 1988). Generally, 150 kg/ha SSP was sufficient to achieve satisfactory productivity of all species in the year of establishment. This is in agreement with results from Haggard *et al.* (1971) with other *S. guianensis* cultivars and Peters (1992) with Wynn and Cavalcade at other sites in the same region. However, the residual effect of the fertilisation lasted for only 2 years. Hence, legumes would need to be topdressed to remain productive, if they are used for a longer time as recommended for the management of fodder banks (Otsyina *et al.* 1987). Though not investigated, the nutrient return by the animal is likely to be limited at grazing times of 2–4 hours per day in the dry season. Grasses and herbs showed little or no response to SSP fertilisation, confirming results from Nigeria, Australia and South America that, in P-deficient soils, P fertilisation enhances legume growth (Haggard *et al.* 1971; Serrao *et al.* 1979; Whiteman 1980). Thus, with responsive legumes, fertilisation increases legume percentage in the forage on offer and could be used as a management tool.

As the legumes are intended as a dry season supplement to the native pasture, highly competitive legumes forming stands with a high legume percentage are ideal. Such legumes are

also likely to be tolerant of suboptimal pasture management, an important aspect under the prevalent extensive farming systems in subhumid Nigeria, and Wynn is a viable alternative to Verano for the drier subhumid zone. Its high competitive ability and high persistence confirm results from Australia (Strickland and Greenfield 1988; Partridge and Wright 1992).

Cavalcade and Pucallpa, with their ability to establish quickly, could be used as components in legume mixtures currently being tested in Nigeria. The competitive ability of Cavalcade and its lack of persistence need to be investigated further as reports in the literature differ (Anning 1982; Clements *et al.* 1986; Ross and Cameron 1992). In this context, reducing competition from native grasses by grazing seems to improve establishment and growth of legumes such as Verano and *Stylosanthes scabra* cv. Fitzroy in a semi-arid environment in Australia (Stockwell 1993). In contrast, in the present study, cutting the vegetation in the early wet season reduced grass competition, but this did not lead to an increase in legume productivity. Further studies including the grazing animal are recommended. In view of the high costs of grazing trials, the use of small-plot grazing techniques as early as possible in the evaluation process is recommended (Thomas and De Andrade 1986). Of concern are the declining yields of Wynn and Verano in Year 3, probably caused by depletion of nutrients from the poor soils, combined with the increase in nitrophilous grasses. Similar observations have been made in other trials in the region, and the cropping of fodder banks to enhance crop yields and to reduce grass competition is recommended (Tarawali *et al.* 1988). After the cropping phase, *Stylosanthes* fodder banks readily re-establish. Because of their prolific seed production, Wynn and, to a lesser extent, Pucallpa have potential in a similar system.

CP concentrations ranged between 5 and 7% of dry matter after 1/3 of the dry season (mid-December). Similar dry season CP concentrations of *Centrosema pascuorum* and *Stylosanthes* spp. (including *Stylosanthes hamata* cv. Verano) were recorded in Australia (McCosker 1987; Winter 1988; Winter *et al.* 1989a, 1989b). These values are close to the 6–8% CP defined by Minson (1981) and Van Soest (1982) as the minimum needed for cattle to ensure that no reduction in intake occurs and digestion is not impaired. However, the legume pastures are used only as a

supplement to the native range and CP concentrations are well above the 2–3% CP reported for the grasses dominating the native range in the dry season in savanna areas (Crowder and Chheda 1982; Peters 1992).

With IVDMD values around 50% for the legumes (whole plant), animal productivity could be impaired by the digestibility of the fodder (Squires 1981). However, with the exception of Pucallpa, digestibilities were higher than for the native vegetation in the dry season (40–45%; Peters 1992) and are comparable with values found in the literature (McIvor 1979; Gardener *et al.* 1982; McCosker 1987). The lower digestibilities of Pucallpa and Cavalcade in comparison with Verano and Wynn can be explained by the consistently higher NDF/ADF concentrations of the former species. The much higher digestibility of the leaf relative to the stem confirms the results of McIvor (1979) and Gardener *et al.* (1982) working with *Stylosanthes* and *Centrosema* species, but the similar values of litter and leaf are in contrast to the findings of Gardener *et al.* (1982). The higher digestibility of the litter than the leaf of Cavalcade can be explained by the high proportion of seeds and pods in litter.

Among the minerals, P (0.02–0.05% after 1/3 of the dry season) and Na (28–77 ppm) concentrations were particularly low and were well below animal requirements. However, in standover feed on tropical pastures, P is only one of the limiting essential nutrients and seldom the cause of low animal productivity, as in the dry season, animals usually lose weight and thus mineral requirements are reduced (McDowell *et al.* 1993). If protein and energy supply are improved, minerals can become a limiting factor to animal production on tropical pastures.

Generally, the nutritive value of the legumes in the dry season was independent of the presence or absence of the companion vegetation and fertiliser application. Similarly, McIvor (1979) in Australia could not detect an effect of the associated grasses on CP and P concentrations of *Stylosanthes* spp. or *Centrosema pubescens* and Winter (1988) and Winter *et al.* (1989b) report that a fertiliser effect on CP and P concentrations is restricted to the wet season.

In accordance with a review by Bayer (1986), the decreasing nutritive value of the whole plant over the dry season is mainly a result of the changes in the leaf/stem ratio caused by falling leaves. In this context, there is a need for species

with a longer growing season and a slower rate of maturity (Stobbs 1975). Considering the limitations of grazing time and DM intake of animals, more emphasis should be placed on the nutrient concentration of the legumes at the intended time of use. This is becoming even more important when smaller areas of legumes are used as a supplement to the existing native vegetation to ensure year-round availability of high quality fodder. Such fodder banks are usually exhausted by the end of the dry season, with cattle even licking litter from the ground, and hence experiencing limited opportunities for selection.

The species described in this paper are self-regenerating annuals or short-lived perennials. Although their nutritive value is higher than that of the native grasses, perennial species remaining green and retaining nutritious leaves under drought conditions are probably of higher value as a dry season feed. On the other hand, these species are often slow to establish. Annuals and biennials as a group germinate more quickly and colonise gaps in pasture and thus reduce risk in pasture establishment (Cook *et al.* 1993). Therefore, legume mixtures with components to ensure good establishment, with a high ability to suppress weeds and potential to provide high quantities of forage year-round, combined with species which remain green in the dry season are advocated. The legume species tested in the present study could be of particular value in such mixtures intended to maintain the continuity of forage supply year-round.

Acknowledgements

Messrs S. Akusu and A.D. Agu were a valuable help in field data collection and sample preparation. The authors thank Dr G. Tarawali for his advice and constructive criticism of the manuscript. The opportunity to use ILCA field and laboratory facilities and the financial support by GTZ/BMZ (Deutsche Gesellschaft für Technische Zusammenarbeit and Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung, Germany) are gratefully acknowledged.

References

- ANNING, P. (1982) Evaluation of introduced legumes for pastures in the dry tropics of North Queensland. *Tropical Grasslands*, **16**, 146–155.
- BAYER, W. (1986) Weidewirtschaft und Futternutzung. In: Cesar, K. (ed.) *Einführung in den Tropischen und Subtropischen Pflanzenbau*. pp. 173–189. (DLG-Verlag: Frankfurt).
- BAYER, W. and WATERS-BAYER, A. (1989) Adapting tropical pasture research to the production system: From Australian ranching to African pastoralism. *Experimental Agriculture*, **25**, 277–289.
- CLEMENTS, R.J., WINTER, W.H. and REID, R. (1984) Evaluation of some *Centrosema* species in small plots in Northern Australia. *Tropical Grasslands*, **18**, 83–91.
- COOK, S.J., GILBERT, M.A. and SHELTON, H.M. (1993) Tropical pasture establishment. 3. Impact of plant competition on seedling growth and survival. *Tropical Grasslands*, **27**, 291–301.
- CROWDER, L.V. and CHIHEDA, H.R. (1982) *Tropical Grassland Husbandry*. (Longman: London and New York).
- D'HOORE, J.L. (1964) *Soil Map of Africa*. Scale 1 to 5 000 000. Joint Project no. 11. (Commission for Technical Cooperation in Africa: Lagos).
- GARDENER, C.J., MEGARRITY, R.G. and MCLEOD, M.N. (1982) Seasonal changes in the proportion and quality of plant parts of nine *Stylosanthes* lines. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **22**, 391–401.
- GOERING, H.K. and VAN SOEST, P.J. (1970) *Forage Fiber Analysis*. Agriculture Handbook No. 379. (USDA: Washington, DC).
- GOMEZ, K.A. and GOMEZ, A.A. (1984) *Statistical Procedures for Agricultural Research*. (John Wiley and Sons: New York).
- HAGGAR, R.J., DE LEEUW, P.N. and AGISHI, E. (1971) The production and management of *Stylosanthes gracilis* at Shika, Nigeria. II. In savanna grassland. *Journal of Agricultural Science, Cambridge*, **77**, 437–444.
- HUMPHREYS, L.R. (1991) *Tropical Pasture Utilisation*. (Cambridge University Press: Cambridge, New York, Melbourne, Port Chester, Sydney).
- JONES, M.J. and WILD, A. (1975) *Soils of the West African Savanna*. (Commonwealth Agricultural Bureaux: Farnham Royal).
- MCCOSKER, T.H. (1987) Agronomic and grazing evaluation of 3 lines of *Centrosema pascuorum* under seasonally flooded conditions in the Northern Territory. *Tropical Grasslands*, **21**, 81–91.
- MCDOWELL, L.R., CONRAD, J.H. and HEMBRY, F.G. (1993) Minerals for grazing ruminants in tropical regions. *Bulletin, 2nd Edn.* University of Florida, Gainesville.
- MCIVOR, J.G. (1979) Seasonal changes in nitrogen and phosphorus concentrations and *in vitro* digestibility of *Stylosanthes* species and *Centrosema pubescens*. *Tropical Grasslands*, **13**, 92–97.
- MINSON, D.J. (1981) Nutritional differences between tropical and temperate pastures. In: Morley, F.H.W. (ed.) *Grazing Animals*, World Animal Science B 1. (Elsevier Scientific Publishing Company: Amsterdam).
- MOHAMED SALEEM, M.A. (1986) The ecology, vegetation and land use of subhumid Nigeria. In: von Kaufmann, R., Chater, S. and Blench, R. (eds) *Livestock Systems Research in Nigeria's Subhumid Zone*. Proceedings of the second ILCA/NAPRI symposium held in Kaduna, Nigeria, 30 October–2nd November, 1984. pp. 59–84 (ILCA: Addis Ababa).
- OTSYINA, R.M., VON KAUFMANN, R.R., MOHAMED SALEEM, M.A. and SULEIMAN, H. (1987) Manual on fodder bank establishment and management. *Subhumid Zone Programme, ILCA, Kaduna*.
- PARTRIDGE, I.J. and WRIGHT, J.W. (1992) The value of round-leaved cassia (*Cassia rotundifolia* cv. Wynn) in a native pasture grazed with steers in south-east Queensland. *Tropical Grasslands*, **26**, 263–269.
- PETERS, K.J. and TOTHILL, J.C. (1988) Strategy of ILCA to improve productivity of pasture and forage resources in Africa. In: Alkämper, J. (ed.) *Tropische Weiden und Futter-*

- resourcen. pp. 35–49. (Giessener Beiträge zur Entwicklungsforschung; Giessen).
- PETERS, M. (1992) *Evaluation of tropical pasture legumes for fodder banks in subhumid Nigeria*. Ph.D. Thesis. Justus-Liebig-Universität, Giessen, Germany.
- 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.
- ROSS, B.J. and CAMERON, A.G. (1991) Pasture legume evaluation on seasonally flooded soils in the Northern Territory. *Tropical Grasslands*, **25**, 32–36.
- SALINAS, J.G., KERRIDGE, P.C. and SCHUNKE, R.M. (1990) Mineral nutrition of *Centrosema*. In: Schultze-Kraft, R. and Clements, R.J. (eds) *Centrosema: Biology, Agronomy and Utilisation*. pp. 119–149. (CIAT: Cali).
- SERRAO, E.A.S., FALES, I.C., DA VEIGA, J.B. and TEIXEIRA NETO, J.F. (1979) Productivity of cultivated pastures on low fertility soils of the Amazon of Brazil. In: Sanchez, P.A. and Tergas, L.E. (eds) *Pasture Production in Acid Soils of the Tropics*. Proceedings of a Seminar held at CIAT, Cali, Colombia, 17–21 April, 1978. pp. 195–225. (CIAT: Cali).
- SQUIRES, V. (1981) *Livestock Management in the Arid Zone*. (Inkata Press: Melbourne).
- STOBBS, T.H. (1975) Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. *Tropical Grasslands*, **9**, 141–150.
- STOCKWELL, T.G.H. (1993) A comparison of establishment and growth of two *Stylosanthes* species with eight grass species sown on cultivated and uncultivated seedbeds at three sites in the semi-arid tropics of the Northern Territory. *Tropical Grasslands*, **27**, 1–10.
- STRICKLAND, R.W. and GREENFIELD, R.G. (1988) Forage species adaptation to red earth soils in southern Queensland. *Tropical Grasslands*, **22**, 39–48.
- TARAWALI, G., MOHAMED-SALEEM, M.A. and VON KAUFMANN, R. (1988) Legume based cropping: a possible remedy to land tenure constraint to ruminant production in the subhumid zone of Central Nigeria. In: Dzowela, B.H. (ed.) *African Forage Plant Genetic Resources, Evaluation of Forage Germplasm and Extensive Livestock Production Systems*. Proceedings of the Third Workshop held at the International Conference Centre, Arusha, Tanzania, 27–30 April 1987. pp. 417–429. (ILCA: Addis Ababa).
- THOMAS, D. and DE ANDRADE, R.P. (1986) The evaluation under grazing of legumes associated with *Andropogon gayanus* in a tropical savannah environment on the central plateau of Brazil. *Journal of Agricultural Science, Cambridge*, **107**, 37–41.
- TILLEY, J.M.A. and TERRY, R.A. (1963) A two-stage technique for the *in vitro* digestion of forage crops. *Journal of the British Grassland Society*, **18**, 104–111.
- VAN SOEST, P.J. (1982) *Nutritional Ecology of the Ruminant*. (Durham and Downey: Portland, Oregon).
- WHITEMAN, P.C. (1980) *Tropical Pasture Science*. (Oxford University Press: Oxford).
- WINTER, W.H. (1988) Supplementation of steers grazing *Stylosanthes hamata* pastures at Katherine, Northern Territory. *Australian Journal of Experimental Agriculture*, **28**, 669–682.
- WINTER, W.H., MOTT, J.J., MCLEAN, R.W. and RATCLIFF, D. (1989a) Evaluation of management options for increasing the productivity of tropical savanna pastures. 1. Fertiliser. *Australian Journal of Experimental Agriculture*, **29**, 613–622.
- WINTER, W.H., MOTT, J.J., MCLEAN, R.W. and RATCLIFF, D. (1989b) Evaluation of management options for increasing the productivity of tropical savanna pastures. 2. Legume species. *Australian Journal of Experimental Agriculture*, **29**, 623–630.

(Received for publication May 4, 1994; accepted January 8, 1997)