Forage Legumes for Sustainable Agriculture and Livestock Production in Subhumid West Africa
Forage Legumes for Sustainable Agriculture and Livestock Production in Subhumid West Africa

S.A. Tarawali, M. Peters and R. Schultze-Kraft

1. International Livestock Research Institute (ILRI), Ibadan, Nigeria
2. University of Hohenheim (380), Stuttgart, Germany
Table of Contents

List of Tables .......................................................... vi
List of Figures .......................................................... viii
Acknowledgements ...................................................... x
Preface ................................................................. xi
Summary ................................................................. 1
1. Introduction and background ........................................... 4
   Introduction ................................................................ 4
   Agro-ecology of the research sites .................................. 5
   Experimental sites ...................................................... 7
   Plant material ........................................................... 8
2. Collecting and screening herbaceous legume germplasm .................... 10
   Introduction ................................................................ 10
   Experiment 1: Evaluation of the world collection of *Centrosema brasiliense* ...... 11
     Materials and methods .............................................. 11
     Results ....................................................................... 13
     Discussion ................................................................... 15
   Experiment 2: Evaluation of *Aeschynomene histrix* ......................... 16
     Materials and methods .............................................. 16
     Results ....................................................................... 18
     Discussion ................................................................... 21
   Experiment 3: Collection of indigenous herbaceous legume species in northern Nigeria .................................................... 23
     Materials and methods .............................................. 23
     Results ....................................................................... 23
     Discussion ................................................................... 25
3. Selected grass-legume mixtures for calf supplementation .................... 27
   Introduction ................................................................ 27
   Experiment 1: Evaluation of selected grass-legume combinations for supplementation of young calves ........................................ 29
     Materials and methods .............................................. 29
     Results ....................................................................... 31
     Discussion ................................................................... 36
   Experiment 2: Small-plot mob grazing trial to assess the potential of selected grass-legume mixtures for cattle supplementation ......................... 39
     Materials and methods .............................................. 39
     Results ....................................................................... 40
     Discussion ................................................................... 45
   Experiment 3: Assessment of the problems of and opportunities for calf rearing: The perceptions of farmers in Oyo State, Nigeria .................................................... 48
     Materials and methods .............................................. 48
     Results ....................................................................... 48
Discussion ....................................................... 49

4. Evaluation of selected legume-legume mixtures for supplementation of dairy cattle .................................................... 50
   Introduction .................................................... 50
   Experiment 1: Relative palatability and seasonal agronomic performance of selected pasture legumes for species mixtures in subhumid West Africa .... 51
      Materials and methods ........................................ 51
      Results ........................................................ 52
      Discussion ....................................................... 53
   Experiment 2: Evaluation of the agronomic performance of selected forage legumes in sole and mixed plots ........................................ 55
      Materials and methods ........................................ 55
      Results ........................................................ 56
      Discussion ....................................................... 59
   Experiment 3: Utilisation of legume mixtures for year-round supplementation of Bunaji heifers ...................................... 61
      Materials and methods ........................................ 61
      Results ........................................................ 62
      Discussion ....................................................... 69

5. Evaluation of selected forage legumes for forage and subsequent cereal production .................................................... 73
   Introduction ....................................................... 73
   Experiment 1: Performance of selected legumes, their effect on subsequent maize yield and potential for forage regeneration ...................... 74
      Materials and methods ........................................ 74
      Results ........................................................ 76
      Discussion ....................................................... 83
   Experiment 2: Effect of forage legumes on maize production and soil nitrogen (N) mineralisation with different levels of N to maize ................ 86
      Materials and methods ........................................ 86
      Results ........................................................ 87
      Discussion ....................................................... 87
   Experiment 3: Effect of length of forage legume fallow on maize yield, maize nutrient uptake and soil mineral nitrogen (N) dynamics ....... 88
      Materials and methods ........................................ 88
      Results ........................................................ 88
      Discussion ....................................................... 89
   Experiment 4: Preliminary observations on the potential of forage legumes in south-west Nigeria ................................................. 89
      Materials and methods ........................................ 89
      Results ........................................................ 90
      Discussion ....................................................... 91
   Experiment 5: Cereal production on grazed forage legume pastures ............ 92
      Materials and methods ........................................ 92
List of Tables

Table 1.1. Forage legume material used for experiments described in this report .................................................... 9

Table 2.1. Centrosema brasiliannum Group A: Accessions from cluster 1 with very high initial dry-matter yields, good regrowth, good drought tolerance and low incidence of anthracnose and Cercospora ........................................... 14

Table 2.2. Centrosema brasiliannum Group B: Accessions with high yields both in 1993 and 1995, good regrowth during the dry season and good drought tolerance ....................................... 14

Table 2.3. General soil parameters of the site used to establish Aeshynomene histrix accessions ......................................... 16

Table 2.4. Summary of genera and tendency of species to be found in particular agro-ecological zones ........................................ 24

Table 2.5. Numbers of species found at two sites on three dates in the dry season .......................................................... 25

Table 3.1. Soil characteristics of the experimental site at Ibadan for the Panicum maximum plots before introduction of legumes ...... 30

Table 3.2. Soil characteristics of the experimental site at Ibadan for the small-plot grass-legume trial ........................................... 39

Table 3.3. Legume germination and total plot soil cover of selected grass-legume mixtures during the 12-week establishment period .......................................................... 41

Table 3.4. Quality parameters of grass and legume components during the establishment period ........................................... 41

Table 3.5. Quality parameters of grass and legume components for the four grazing periods ........................................... 44

Table 3.6. Intake, expressed as a percentage of the dry forage on offer consumed on grass-legume plots ........................................... 45

Table 4.1. Soil characteristics of the Mando Road experiment site .......................................................... 51

Table 4.2. Dry-matter yields (kg/ha) of legume plots before grazing .......................................................... 53

Table 4.3. Soil features of the experimental site at Fashola (small plots) .......................................................... 55

Table 4.4. Soil features of the experiment site at Fashola (grazing trial) .......................................................... 61

Table 4.5. Percentage greenness of the various components of the pastures during the 1994/95 and 1995/96 dry season .................. 66

Table 4.6. Defoliation (% consumption) estimates of pasture components during the grazing period ........................................... 67

Table 4.7. Average daily liveweight gains (ADG) of animals on various pasture treatments ........................................... 69

Table 5.1. General soil properties of the sites used for experiments to assess the potential of selected forage legumes for forage and subsequent cereal production ........................................... 75

Table 5.2. Soil cover of sown legume components in April 1996 ................ 81
Table 5.3. Range of forage yields obtained from forage legumes planted in farmer’s fields, dry season 1995/96 ........................................ 91
Table 6.1. Seed yields from Abuja Road seed multiplication plots ............ 97
Table 6.2. Forage legume seed distribution, 1993 to mid-1996 .................. 98
Table 6.3. Forage dry-matter and grain yields and dry forage losses for three harvest dates ......................................................... 100
**List of Figures**

Figure 1.1. Map of Nigeria showing experimental sites collection trip routes and major ecological zones in the moist savannah. .......... 6
Figure 1.2. Monthly rainfall for the main experimental sites. .......... 7
Figure 2.1. Diagrammatic representation of the arrangement of *Striga hermonthica* seeds and roots of test plant in petri dish to determine the ability of root exudate to stimulate suicidal germination of *S. hermonthica* seeds. .............. 18
Figure 2.2. Schematic representation of the five growth habit groups identified for *Aeschynomene histrix* accessions, with CIAT accession numbers shown (ILRI = ILRI 12463). .......... 19
Figure 3.1. Estimated dry-matter productivities of grass–legume pastures during the dry season after the establishment phase, before grazing trials .......... 32
Figure 3.2. Estimated dry-matter productivities of grass–legume pastures during the grazing period in the 1995 wet season (June–September) .......... 33
Figure 3.3. Estimated dry-matter productivities of grass–legume pastures during the grazing period in the 1996 dry season (January–April) .......... 34
Figure 3.4. Cumulative liveweight gains (LWG) of calves grazing grass–legume, or grass alone (with or without supplement) pastures for a 15-week period during the 1995 wet season .......... 35
Figure 3.5. Cumulative liveweight gains (LWG) of calves grazing grass–legume, or grass alone (with or without supplement) pastures during the 1996 dry season .......... 36
Figure 3.6. Dry-matter yields of various components in small plot grass–legume mixtures during the establishment phase .......... 42
Figure 3.7. Estimated dry-matter yields of grass and legume components of small plots before mob grazing .......... 43
Figure 4.1. Dry-matter yields of small plots of selected legumes before mob grazing at four harvest dates .......... 58
Figure 4.2. Crude protein (CP) values of individual legume species in single and mixed species plots .......... 59
Figure 4.3. Soil cover estimates (%) of components of legume mixtures during the establishment phase (1994) and after the onset of the rains in 1995 .......... 63
Figure 4.4. Dry-matter yields of treatment paddocks during the grazing period (November 1994 to March 1996) .......... 64
Figure 4.5. Dry-matter yields of adjacent native paddocks during the grazing period (November 1994 to March 1996) .......... 65
Figure 4.6. Cumulative liveweight gains for heifers with and without access to mixed legume pastures .......... 68
Figure 5.1. Soil cover estimate for sown legumes at Ibadan and Fashola following establishment in 1994 .......... 77
Figure 5.2. Dry-matter yields of sown legumes and associated components at the end of the 1994 wet season .................................. 78
Figure 5.3. Dry-matter yields of sown forage legumes and associated components, mid-dry season 1994/95 ....................... 79
Figure 5.4. Dry-matter yields of forage legumes and associated components in the early wet season, 1995, immediately before maize planting .......... 80
Figure 5.5. Dry-matter yields of forage legumes and associated components at the end of the 1995 wet season, 3 months after maize harvest ........ 81
Figure 5.6. Maize grain yield following forage legumes ........................................ 82
Figure 5.7. Maize grain yield on natural fallow plots with various applications of nitrogen (N) to maize ......................... 83
Figure 5.8. Maize grain yields following grazed pastures with various histories and with applications of three levels of nitrogen (N) to maize ........ 93
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Preface

This report presents the results of a special project funded by Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung and Deutsche Gesellschaft für Technische Zusammenarbeit, Germany (BMZ/GTZ) (Special project 223-K8064-3/92). The project was carried out by the International Livestock Research Institute (ILRI) in collaboration with the University of Hohenheim (380), Stuttgart, Germany.

Much of the data presented in this report has been generated by field work forming part of diploma and doctoral theses. The majority of the research has also been written up as papers which are published, or are in the process of being reviewed for publication in peer-reviewed journals. For clarity, the major publications (including theses) relating to each section of this manuscript are indicated in each section and listed in the references.
Summary

Results of a three-year research project conducted in the subhumid region of Nigeria are presented. To promote the use of forage legumes for sustainable agriculture, a number of research aspects were addressed including screening collections of the promising pasture legumes *Centrosema brasilianum* and *Aeschynomene histrix* and small-scale collection of herbaceous forage species in northern Nigeria. Studies to optimise the utilisation of selected forage legumes included the use of material in combination with grasses for calf supplementation and combining selected legumes to give stable, year-round pastures. Considering the importance of integrating crop and livestock production, studies were also carried out to investigate the potential of selected forage legumes to contribute to both fodder and crop production. Forage seed production and collaboration with national and international institutes in West Africa have also featured.

Evaluation of a collection of 257 *Centrosema brasilianum* accessions identified two groups of 10 and 11 accessions suitable for fallow systems and longer-term pastures, respectively. Sixty-five *Aeschynomene histrix* accessions were screened and those with potential to contribute to both fodder production and soil improvement were identified. A particularly interesting feature of this material was the ability to stimulate *in vitro* suicidal germination of *Striga hermonthica* seeds, thereby offering the opportunity to reduce the seedbank of this devastating parasitic weed of cereals. Eleven accessions of *A. histrix* with promising features were selected for further evaluation and seed multiplication.

Almost 600 accessions of indigenous herbaceous forages were collected from northern Nigeria, making a substantial contribution towards the conservation of the genetic resource, and indicating the potential for both evaluation of the material collected, and further, targeted collection in the region.

Small-plot evaluation of selected grass-legume mixtures indicated that those containing *Brachiaria ruziziensis* were generally preferred by cattle although *Cynodon nlemfuensis* persisted better in pastures over a longer period. *B. ruziziensis* established faster and showed better nutritional quality. *Centrosema pubescens* and *Aeschynomene histrix* were the most appropriate legumes in combination with these grasses, with *Centrosema pubescens* showing better persistence and nutritional qualities. Using a mixture of these two grasses and two legumes is proposed as an appropriate approach to providing a good quality, persistent pasture. In grazing studies with young calves, the native grass *Panicum maximum* was grazed alone or combined with either a wheat bran supplement or oversown with *Stylosanthes guianensis* or *Centrosema pubescens*. In two short-term grazing experiments, higher weight gain of calves was achieved with the combination of *Panicum maximum/Centrosema pubescens* pastures in both the wet season and the stressed part of the dry season, before the onset of the rains.

Evaluation of selected forage legumes for use in legume-legume mixtures indicated that there is potential for such pastures to overcome the limitations of individual species. Legumes in the mixtures were selected to include *Centrosema pascuorum* (known
to grow well only in the establishment year), either *Stylosanthes guianensis* or *Aeschynomene histrix* (for persistence and yield in subsequent years) and either *C. macrocarpum* or *C. pubescens* (to provide green fodder in the dry season). *Arachis pintoi* was included in all mixtures, but showed poor establishment and persistence. In small-plot grazing studies, the ability of different legumes in mixtures to compensate for the failure, slow establishment or lack of persistence of other species was apparent. This meant that legume yields were sustained, albeit with different components, and therefore indicates that such legume mixtures have the potential to minimise the risks associated with pasture establishment and management. Nutritive values of individual legume species were enhanced when grown in combination with other legumes, suggesting a synergistic effect.

In a large-scale grazing trial, the effects on young heifers of supplementation with pastures containing a mixture of legumes were compared with supplementation with pasture containing no legume and with native range grazing. Botanical composition, yield and defoliation of the pastures were also monitored. Pastures were grazed as supplements from November 1994 to March 1996 (two dry seasons and one wet season). During the course of the experiment, the proportion of legume in the pastures remained relatively constant (confirming the concept of legume mixtures providing sustained yields), but the individual legumes making up this proportion varied. *Centrosema macrocarpum* and *C. pubescens*, present in low amounts initially, were the dominant species at the end of the trial period. *C. pascuorum* disappeared almost entirely by the second season but *Aeschynomene histrix* and *Stylosanthes guianensis* remained, albeit at fairly low levels, with *A. histrix* showing an impressive ability to regenerate from seed. Supplementing animals with legume mixtures had a dramatic effect on liveweight gain. In the first harsh dry season animals with access to these pastures continued to gain weight, whereas those on native range lost weight. These differences were maintained throughout the trial period. Animals receiving legume mixture pastures gained five to six times as much weight daily in the dry season as those without; there were no marked differences between the treatments in the wet season. Pastures containing legume mixtures were estimated to be able to maintain stocking rates of four to eight times as high as those estimated for the native range. The implications of such results in terms of animal performance, in particular growth and maturity of female animals in the herd are discussed.

*Centrosema macrocarpum, C. pubescens, Stylosanthes guianensis, Aeschynomene histrix* and the shrub *Flemingia macrophylla* were able to provide good quantities of fodder and to significantly increase the subsequent yield of maize (without added nitrogen) up to 145% compared to native fallow plots. The effect was more dramatic on degraded soils where some legume plots yielded twice as much maize as natural fallow plots, being equivalent to an application of about 90 kg nitrogen/ha to maize. These species were also able to regenerate well in the season after maize cropping, thereby contributing to the continued promotion of such a sustainable system. *Mucuna pruriens* was able to cover the soil extremely fast during the establishment phase, providing effective weed suppression, but the subsequent fodder production was generally poor. *Arachis pintoi*, whilst having low fodder yields, had an excellent forage quality especially in terms of
digestibility, and a positive effect on subsequent maize yield. In grazed forage legume pastures differences between species were observed, the annual Centrosema pascuorum making a negligible contribution to subsequent maize yield after three years' grazing, in contrast to Chamaecrista rotundifolia or Stylosanthes hamata pastures which, after three years grazing had significant effects on the yield of a maize crop. The importance of selecting the most appropriate legume to contribute to crop and livestock enterprises in various farming systems is considered, including aspects such as length of fallow period, cultivation methods, forage requirements and extent of soil degradation. In an on-farm study, farmers responded positively to forage legumes, with the majority requesting more seeds in the following season.

Small-scale forage legume seed multiplication for both on-station experiments, and distribution to national and international institutes and non-governmental organisations in West Africa was implemented, and over 300 kg of forage seed distributed. Implications for continued seed production by national institutes and, subsequently, farmers, is discussed. Collaborative efforts with the International Institute of Tropical Agriculture (IITA) to investigate the potential of dual-purpose grain legumes are also reported, with selected cowpea accessions having good grain and fodder production.

Major conclusions, strategies for appropriate targeting of herbaceous legume-based interventions and suggestions for future research, based on these findings are presented.
1 Introduction and background

Introduction

Ruminant production in sub-Saharan Africa is constrained by health problems and nutritional limitations (ILCA 1979). In the subhumid zone of West Africa, cattle populations are increasing due to migration and settlement of previously nomadic pastoralists encouraged by reductions in tsetse flies as their habitats are destroyed by intensive cultivation (Jabbar 1992; Bourn et al. 1994). However, nutrition, especially in the dry season, has been identified as a major constraint to cattle productivity. Wet season nutrition, when animals are tethered to prevent them damaging growing crops, limits small ruminant performance (Ikwuegbu et al. 1995). In the late 1970s the International Livestock Centre for Africa, working in the subhumid zone of Nigeria, began to search for solutions to the nutritional constraints which were limiting ruminant production. A forage legume technology to improve the poor quality of the native range was developed in the form of the ‘fodder bank’ package (Otsyina et al. 1987). Initially, Stylosanthes species, previously selected by the national research institutes, were used to improve pasture. However, all but one of the recommended cultivars, Stylosanthes hamata cv Verano, were found to be susceptible to a fungus disease, anthracnose, caused by the pathogen Colletotrichum gloeosporioides (Mohamed-Saleem and Adeoti 1989; Adeoti et al. 1994). Concurrently, it was recognised that the package needed to be more flexible and able to address the needs of a wide range of production systems in the region (Tarawali et al. 1989). A forage legume evaluation programme was therefore initiated to identify species or cultivars which could complement or replace S. hamata cv Verano in fodder banks.

Initially, the investigations focused on other species and accessions of Stylosanthes (Mohamed-Saleem and Otsyina 1984). However, in 1988, the German Government provided funds for a five-year project that included screening of other genera. During the course of this project, over 1000 accessions of herbaceous forage legumes were tested, mainly in subhumid Nigeria (Tarawali et al. 1989; Tarawali 1991b; Tarawali et al. 1994; Tarawali 1994a; Tarawali 1995a; Tarawali 1995b). To facilitate the process, a stepwise evaluation procedure was developed, with a progression of stages from preliminary screening in small plots through to grazing and seed multiplication trials of the most suitable material (Tarawali et al. 1989; Tarawali et al. 1995). A number of promising accessions were identified, including Aeschynomene histrrix, Centrosema brasiliarum, C. macrocarpum, C. pascuorum, C. pubescens, Chamaecrista rotundifolia, Stylosanthes guianensis and S. hamata (Tarawali 1991b; Peters 1992; Peters et al. 1994a; Peters et al. 1994b; Tarawali 1994a; Tarawali 1995a; Tarawali 1995b). At the end of the project, it was apparent that it would be appropriate to develop the best options for management and utilisation for farmers to use the accessions identified. At the same

1. The International Livestock Centre for Africa (ILCA) and the International Laboratory for Research on Animal Diseases (ILRAD) were subsumed into one centre, the International Livestock Research Institute (ILRI), from January 1995.
time, increased awareness of problems associated with the on-going agricultural intensification in the region (Jabbar 1992; Bourn et al 1994) made it necessary to investigate the use of these and other species to promote crop as well as livestock production in a sustainable manner. On this basis, the German government funded a further three-year project with the following objectives:

- to screen world collections of germplasm of species identified as promising for the subhumid environment to identify the most appropriate accessions of each species
- to test the potential (quantity and quality) of promising accessions in grass-legume and legume-legume mixtures for year-round production of high quality feed for cattle
- test the contribution of promising legumes to soil improvement, especially in relation to cropping systems in order to identify material which would be appropriate for crop-livestock farming systems
- to provide moderate quantities of seed, together with advice and contacts for national agricultural research systems (NARS) and international agricultural research centres (IARCs) throughout the region.

This report documents the major findings of the three-year project. The research was conducted from 1993 to 1996 at four main sites, all located within the lowland moist savannah region of Nigeria. A fifth site, Minjibir, was included for part of one experiment (Chapter 6).

Agro-ecology of the research sites

The lowland moist savannah region of sub-Saharan Africa covers a land area of 389 million hectares, making it the largest of the three moist savannah regions (viz. the mid-altitude savannah with 169 million and the highland moist savannah with 57 million hectares; Jagtap 1995). The region is classified on the basis of the length of the growing period (LGP) per annum which ranges between 151 and 270 days; thus, the region has marked wet (growing) and dry seasons. The lowland moist savannah can be divided into three strata, the northern Guinea savannah, with LGP of 151-180 days, the southern Guinea savannah with 181-210 days and the derived/coastal savannah with 211-270 days. These three strata are shown for Nigeria in Figure 1.1. It should be noted that these strata do not correspond to the savannah descriptions based on vegetation proposed by Keay (1959), although similar nomenclature was used.

Total annual rainfall decreases from the south to the north, and the pattern of precipitation changes from bimodal in the derived/coastal savannah to monomodal in the southern and northern Guinea savannahs. Agroclimatically, the region is well suited to crop production but the soils, mostly Alfisols, are very poor and often limit agricultural productivity. The main cropping enterprises are cereals (maize, rice and sorghum),

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2. The lowland moist savannah zone and the subhumid zone are considered synonymous for this document, although in the strictest sense, the lowland moist savannah represents the subhumid zone plus the coastal savannah.
grain legumes (groundnut, cowpea and soyabean) and root crops (yam, cassava and some sweet potato). The northern Guinea savannah, with monomodal rainfall, is favoured for the production of medium duration cereal and grain legume crops, with a shift towards root crops as one moves towards the more southerly derived savannah where the growing period is longer and the rainfall bimodal. Small ruminants feature throughout the region, whereas cattle keeping is more common in the north where there is less threat from trypanosomosis. This, however, is an evolving situation, with more cattle owners settling in the southern and derived savannahs as the tsetse fly habitats are reduced because of increasing cultivation (Jabbar 1992; Bourn et al 1994).

The moist savannah region has a high agricultural potential (Okigbo 1995), especially with the increasing integration of crops and livestock, making it an appropriate region for this research project. Research was mainly carried out at four locations in the lowland moist savannah of Nigeria: Kurmin Biri and Mando Road in Kaduna State, and Fashola and Ibadan in Oyo State (Figure 1.1). Rainfall for the years of experiments were based at the various sites is shown in Figure 1.2. A brief description of the general features of each experimental site is given in this section; further details including soil parameters of each planting site are presented together with the respective experimental details in each chapter.
Figure 1.2. Monthly rainfall for the main experimental sites.

Experimental sites

Kurmin Biri

Located at lat 10°10' N, long 7°55'E in the northern Guinea savannah, this site has unimodal rainfall with, on average, 1200 mm per annum, 95% of which falls between April and October. The dry season can be harsh, often lasting at least 6 months. Rainfall during 1993 totalled 1564 mm. The soil is poor and shallow with a ferrallitic hardpan (Adeoye 1988) 15 to 20 cm below the surface.

Mando Road

The site at Mando Road was on the premises of the College of Agriculture and Animal Science, Ahmadu Bello University, Kaduna, Nigeria (lat 10°36’N, long 7°27’E), in the northern Guinea savannah. The soil is a poor tropical ferruginous type, classified as Alfisol (USDA 1975) with pH c. 5. Annual rainfall is monomodal and averages 1200 mm with 95% falling between April and October; the dry season is harsh, lasting at least 6 months. Total rainfall for 1993 and 1994 was 1242 and 1106 mm, respectively.
Fashola

Fashola is located 80 km north-west of Ibadan (lat 7°53'N, long 3°46'E) in the derived savannah ecozone. Rain usually starts in March/April and continues until early November; it is often bimodal with the major wet season (March to July) being followed by a decrease in rainfall in August (sometimes referred to as the minor dry season), then the minor wet season through to October. The distinction between major and minor wet seasons (March to July and August to October, respectively) is not always evident (Figure 1.2) and for this reason, except where experiments were specifically aimed at major or minor wet seasons (for example in Chapter 5), the period from March to October is referred to as the wet season. Occasional showers may occur during the dry season (November to March). Annual rainfall during 1994 and 1995 was 1282 and 1430 mm, respectively. The soils are generally classified as plinthic oxic Haplustoll (USDA 1975; Fasehun 1980), slightly acidic sandy soils with low nitrogen (N), carbon (C), phosphorus (P) and exchangeable cations.

Ibadan

Trials at Ibadan were planted within the IITA (International Institute of Tropical Agriculture) campus (lat 7°30'N, long 3°54'E) in the derived savannah, where the annual rainfall is, on average, 1300 mm. Rainfall is often bimodal, with peaks in June and September, and a dip in August. As for Fashola, the distinction of major and minor wet seasons is not always clear (Figure 1.2), and the period from March to October is referred to as the wet season. Occasional showers can occur during the dry season, between November and March.

Minjibir

This site is IITA’s research station located to the north of the northern Guinea savannah, in the semi-arid region of Nigeria (lat 12°03'N, long 8°36'E). Rainfall is typically monomodal with extremely harsh dry seasons lasting over 6 months. Although not within the focal region of the moist savannah, this site was used as a comparison for trials of grain and herbaceous legumes with the on-going research in the northern Guinea savannah (Chapter 6). Rainfall was 675 mm in 1993.

Plant material

The forage legume materials used for the studies described in this report are listed in Table 1.1. For those that were multiplied in Nigeria, original accession numbers and their equivalents are shown according to Kidest et al (1991) and Schultze-Kraft et al (1989a). However, multiplication over a number of years at Nigerian research sites means that some outcrossing may have occurred, and the material used may no longer be strictly equivalent to the original accession.
Table 1.1. Forage legume material used for experiments described in this report.

<table>
<thead>
<tr>
<th>Species</th>
<th>Accession(s)</th>
<th>Source</th>
<th>Other numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeschynomene histrix</td>
<td>64 accessions</td>
<td>CIAT genebank</td>
<td></td>
</tr>
<tr>
<td>Aeschynomene histrix</td>
<td>ILRI 12463</td>
<td>Multiplied in Nigeria</td>
<td>CIAT 9690</td>
</tr>
<tr>
<td>Arachis pintoi</td>
<td>CIAT 17434</td>
<td>CIAT genebank</td>
<td>Cv Amarillo (Australia)</td>
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<tr>
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<td>CIAT 812311</td>
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<td>ILRI 14924</td>
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<tr>
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<td>IITA</td>
<td>IITA farm</td>
<td></td>
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1. This term is used to refer to the accession number when originally received by ILRI.
2 Collecting and screening herbaceous legume germplasm

Introduction

Whilst promising germplasm had been identified for use in sub humid West Africa, e.g. Centrosema brasillianum (Peters 1992; Tarawali 1996) and Aeschynomene histrrix (Tarawali 1994a), in some cases the material was identified on the basis of the performance of one or two accessions of the species. Evaluation of collections of Stylosanthes hamata (Tarawali 1995a) and Chamaecrista rotundifolia (Tarawali 1995b) had shown that often, there are other accessions that could perform better than the commercial cultivars, or the few that happen to have been included in screening programmes. Hence, it was appropriate to look for other accessions of some identified promising species; this situation particularly applied to Centrosema brasillianum and A. histrrix.

Centrosema brasillianum was identified as promising in earlier evaluation trials in West Africa, mainly in the northern Guinea savannah (Tarawali 1991b; Peters 1992) as well as in other regions of the world (Clements 1990; Schultze-Kraft 1990). It has an outstanding and valuable ability to remain green and therefore of high nutritive value during the dry season (Clements et al 1984; Grob 1986; Lascano et al 1990; Peters 1992; Peters et al 1994a). However, seed production, especially in the establishment year, was not good (Tarawali 1991b) and flowers were readily attacked by blister beetles (Mylabris pustulata) which migrated from surrounding sorghum fields after cereal harvest in the early dry season. Another potential drawback to this promising species was the incidence of foliar blight, a fungus disease caused by pathogens of the genus Rhizoctonia (Lenne et al 1990). Observations in northern Nigeria, however, were made only on a few accessions of the species (Tarawali 1991b; Peters 1992) and, in view of its valuable potential as dry season fodder, it was appropriate to investigate the world collection, comprising 257 accessions from the Centro Internacional de Agricultura Tropical (CIAT) genebank. This investigation was also intended to facilitate better understanding of the genetic diversity of the species, especially when compared with results from evaluation of a subset of the collection in South America (Schultze-Kraft and Belalcázar 1988).

Aeschynomene histrrix had been identified as a promising species in the northern Guinea savannah of Nigeria (Tarawali 1994a). It is a prostrate to semi-erect, perennial herbaceous legume originating from savannah, pine woods, rocky hillsides and waste places below 1400 m above sea level in Central and South America (Rudd 1955). The species had also been identified as having good potential in tropical America (Bishop et al 1988), with high crude protein content (Peters 1992) and ability to compete with weeds (Peters et al 1994b). Another important feature of the species is its apparent potential to act as a trap crop (Robson and Broad 1986) with the ability to reduce infestation of crop fields with the parasitic weed Striga hermonthica (Weber et al 1995) by

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Herbaceous legume germplasm

stimulating suicidal germination of the weed seeds. However, in northern Nigeria only two accessions of Aeschynomene histrix were included in the agronomic evaluation trials (Tarawali 1994a). It was therefore important to determine if accessions with good forage potential as well as the ability to improve crop production could be identified, hence a collection of 64 accessions was obtained from CIAT for evaluation. The accession ILRI 12463, originally imported from ILRI’s genebank in Addis Ababa, Ethiopia, in 1987 (Tarawali 1994a) and subsequently evaluated and multiplied locally, was also included in the experiments as a standard for comparison.

Most of the material tested during the evaluation programmes in subhumid West Africa was imported (exogenous accessions) with few exceptions (e.g. Alysicarpus, Chamaecrista; Tarawali 1991b); these indigenous accessions generally did not perform well. Nevertheless, there are many indigenous forage legumes in the subhumid and semi-arid regions of Nigeria which represent a potentially important source of material that could be developed for forage production (Agishi 1983; Bayer 1990). It is also important, in the face of increasing genetic erosion caused by population pressure, pollution and climatic changes, to attempt to conserve the genetic diversity of such species (Marshall and Brown 1983; Cremer-Bach 1992). At present, 25–30% of the total world genepool of legumes used for forage is of African origin (le Houérou 1991).

Nigeria has a wide range of agro-ecological zones, stretching from humid and coastal savannas in the south, to Sudan savannah in the north, meaning that there should be an equally wide variety of indigenous legume species. Despite this apparent potential only a few, isolated collections have been made in the country, focusing on wild relatives of crop plants such as Vigna (Ng 1991) or a single legume species, Alysicarpus glumaceous (Foster 1961). It was therefore appropriate to conduct a preliminary investigation into the availability of indigenous legume plants with forage potential. In order to focus the collection missions, this study concentrated on the northern regions of the country, on the basis that the more severe dry season in these regions increases the likelihood that any material collected would be adapted to such conditions where the need for additional forage is also greater. It was also decided to limit the collection to herbaceous legume material of less than 1.5 m in height.

Experiment 1: Evaluation of the world collection of Centroserma brasiliunum

Materials and methods

Plant material

In 1993 CIAT provided 257 accessions of Centroserma brasiliunum, representing the world collection. ILRI accession 155, multiplied in the northern Guinea savannah of Nigeria over several years and used for a number of previous experiments, was also included for comparison.
Establishment and management

The trial was established in June 1993 at the beginning of the rainy season at Kurmin Biri in the northern Guinea savannah of Nigeria. Soil at the site used for the trial had average pH 5, total nitrogen 0.07%, organic carbon 0.97% and available phosphorus (Bray 1) 4.40 ppm. The 257 accessions, plus 13 randomly distributed plots of ILRI 155, were established on well-tilled soil in a randomised complete block design with two replications. Plot size was 0.5 x 1.0 m with 2.5 m between plots. Seeds were scarified with sandpaper and 20 seeds were sown in a row in the centre of each plot. All plots received a basal dressing of single super phosphate (SSP) at a rate giving 27 kg/ha P2O5. Inoculum was not used. Plots were hand weeded until the end of the 1993/94 dry season, after which there was no further weeding. Plots were grazed by cattle in the 1994/95 dry season.

Data collection

In 1993 the following parameters were recorded (Peters et al 1998a): viability, per cent germination, leaf colour, soil cover, lateral spread, growth habit, leaf area/shape, adventitious roots, time of peak flowering, flower colour and incidence of diseases and pests. Productivity was estimated by harvesting half of each plot at the end of the 1993 wet season. Cut samples were weighed and dried at 65°C then ground and analysed for crude protein (CP). Regrowth of the cut parts and drought tolerance was estimated in the middle of the 1993/94 dry season. In the 1995 wet season, the plots were again assessed and the following parameters recorded (Peters et al 1998a): spread, presence of adventitious roots, dry-matter yield (visual estimates using BOTANAL according to Campbell and Arnold 1973; Tothill et al 1992; Waite 1994), vigour and competitiveness with native vegetation.

Data analyses

Principal component analyses with selected variables and factor analysis with the complete data set were carried out, followed by a hierarchical cluster analysis using the average linkage method of SAS (1988) to identify interesting clusters. For each parameter assessed, all the accessions were also grouped in order to describe the variability of the whole collection. The values for ILRI 155 were excluded from these analyses because of confounding effects, but results for these plots were separately compared with the original equivalent accession CIAT 5234. CIAT accessions 5180, 5211, 5222, 5420, 5471, 5531, 5700, 5819, 5824 and 5882 were also excluded from the analyses because they did not persist up to 1995.

2. Crude protein analyses were carried out at the IITA analytical laboratory using the Micro-Kjeldahl technique unless indicated otherwise.
Results

Germination was 85% in the laboratory, but only 41% measured as emerged seedlings in the field. Only 24 accessions did not have dark green leaves within a few weeks of planting. Eighty-one per cent of the accessions attained soil cover over 70% within 17 weeks of planting; this parameter was positively correlated with field establishment at 8 weeks. Lateral spread was positively correlated with soil cover, dry-matter yield in 1993 and regrowth. Spread in 1995 was positively correlated with dry-matter yield in 1995 and leafiness, but spread in the two years was not related.

Most of the material (77%) had a prostrate-trailing growth habit in 1995, but in 1993 only 57% were classified in this group, the remainder being classified as semi-erect or climbing. Adventitious roots (medium to high tendency) were found in 36% of the accessions in 1993; none were found in 1995. The majority of accessions were classified as having elliptic to oval leaves (73%).

The peak flowering time varied between 102 and 197 days after planting with 19.4%, 27.1%, 38.1%, 14.2% and 1.2% of accessions classified as very early, early, intermediate, late and very late flowering groups, respectively. Most accessions had blue to lilac-violet flowers, with up to 57% showing mixed colours on the same plot.

Three main fungal diseases were observed, namely, anthracnose (Colletotrichum spp), rhizoctonia (Rhizoctonia spp) and cercospora (Cercospora spp). Incidences of cercospora and anthracnose were positively correlated. Disease incidence above 25% (of any or a mixture of these diseases) was recorded for CIAT accessions 5553, 5703, 5709, 15273, 15404, 25110 and 25172. Foliar beetles (Ootheca mutabilis) were observed during the establishment phase but did not cause severe damage to any accession. In contrast, 15.4% of accessions were damaged more than 10% by sucking insects. Blister beetles (Mylabris sp) caused damage to flowers of 16.6% of the accessions but only CIAT 571 and 25123 were severely damaged.

Most of the accessions (94.7%) were drought tolerant to the extent that more than 50% of the plants on the plot remained green in the dry season. The majority of accessions (88%) maintained high CP values of between 13% and 16%.

Comparing accession ILRI 155 (average of the 13 planted plots) with the theoretical equivalent, CIAT 5234, indicated that the two accessions were similar for all parameters except 1995 values relating to productivity for which ILRI 155 had higher values.

From the principal component analyses, 1995 dry-matter yields were positively correlated with vigour, competitiveness and percentage Centrosema brasiliannum and were therefore used to represent these parameters in the cluster analysis. Likewise, days to peak flower was used to represent days to peak seeding. Soil cover at 17 weeks also represented germination and lateral spread in 1993. Variables used for the cluster analysis were: dry-matter yields 1993 and 1995, ability to regrow in the dry season, CP content, soil cover 17 weeks after planting, drought tolerance, anthracnose incidence, cercospora incidence and days to peak flowering; the clusters were truncated at the 9-group level. Three clusters were of particular agronomic interest, and could be classified into groups A (Table 2.1) and B (Table 2.2). Group A consists of accessions in cluster 1 characterised by fast establishment, high yields in 1993, good regrowth, good drought
Table 2.1. Centrosema brasilianum Group A: Accessions from cluster 1 with very high initial dry-matter yields, good regrowth, good drought tolerance and low incidence of anthracnose and Cercospora.

<table>
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<tr>
<th>ACC</th>
<th>COV</th>
<th>DM₁</th>
<th>DM²</th>
<th>REG</th>
<th>DRO</th>
<th>CP</th>
<th>FLO</th>
<th>ANT</th>
<th>CER</th>
<th>RFB</th>
<th>PER</th>
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<th>LEF</th>
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ACC = accession; COV = soil cover 17 weeks after planting; DM = dry-matter yield; REG = regrowth after the dry season; DRO = drought tolerance; CP = crude protein; FLO = peak flower (50% of plants in plot flower) in days after planting; ANT = anthracnose incidence; CER = Cercospora incidence; RFB = Rhizoctonia foliar blight incidence; PER = percentage of Centrosema brasilianum on total dry matter of plot; GRO = growth habit as assessed during the 1995 evaluation; LEF = leaf form as assessed in 1993; LEA = percentage leaf; SP93 = lateral spread in 1993; RAI = annual rainfall at the collection site.


Table 2.2. Centrosema brasilianum Group B: Accessions with high yields both in 1993 and 1995, good regrowth during the dry season and good drought tolerance.

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<th>CER</th>
<th>RFB</th>
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</table>

1. Clusters 2 and 3 plus two selected accessions from cluster 5 (15192 and 15389) and one accession from cluster 6 (25210); 2. 1993; 3. 1995.

ACC = accession; COV = soil cover 17 weeks after planting; DM = dry-matter yield; REG = regrowth after the dry season; DRO = drought tolerance; CP = crude protein; FLO = peak flower (50% of plants in plot flower) in days after planting; ANT = anthracnose incidence; CER = Cercospora incidence; RFB = Rhizoctonia foliar blight incidence; PER = percentage of Centrosema brasilianum on total dry matter of plot; GRO = growth habit as assessed during the 1995 evaluation; LEF = leaf form as assessed in 1993; LEA = percentage leaf; SP93 = lateral spread in 1993; RAI = annual rainfall at the collection site.


tolerance, low disease incidence and low/average yields in 1995. Group B contains 6 accessions representing cluster 2 with high dry-matter yields in both years, good drought
Herbaceous legume germplasm
tolerance and low disease incidence. To these were added two early flowering accessions forming cluster 3, together with two accessions from the variable cluster 5 and one from cluster 6 which showed exceptionally high yields in 1995.

Discussion

Establishment of the accessions was generally good and leaf colour observations suggest that nodulation was not a limiting factor. Morphological descriptions tended to agree with those of a subset of this material (Schultze-Kraft and Belalcázar 1988) with few exceptions, the main one being that these authors classified all the accessions as prostrate whereas in this study some erect and semi-erect forms were described. This may be related to the accompanying vegetation since there was some variation in this classification between 1993 and 1995. Adventitious roots were recorded only in 1993 where, in weeded plots, the plants were in contact with the soil in contrast to the observation in 1995 when companion vegetation meant that most plants were climbing, thereby reducing soil contact and resulting in no adventitious root formation. Schultze-Kraft and Keller-Grein (1985) also reported that Centrosema brasilianum had virtually no ability to root on trailing stems in trials conducted in South America.

Flower colour variations similar to those found in this study had also been previously reported (Schultze-Kraft and Belalcázar 1988) and interpreted as an indication of out-crossing. This is further supported by the observation that accession ILRI 155 and its supposed ‘equivalent’, CIAT 5234, showed differences in persistence. This may be related to the fact that the ILRI 155 had been multiplied over many years in Nigeria and was therefore more adapted. Yields of ILRI 155 were similar to those reported earlier for the region (Tarawali 1991b; Peters et al 1994a).

In contrast to other studies where C. brasilianum was reported to be very susceptible to Rhizoctonia solani (Schultze-Kraft and Keller-Grein 1985; Lenné et al 1990), disease and insect attacks were not major problems throughout this study. Other reports of the drought tolerance and persistence of the species (Clements et al 1984; Lascano et al 1990; Peters et al 1994a) were confirmed. However, Grof (1986) reported that C. brasilianum persisted poorly under grazing in combination with Andropogon gayanus. All the accessions were well able to withstand drought, retaining green leaves right through the dry season. Ludlow et al (1983) reported that C. brasilianum has strong stomatal control over water loss, being very responsive to changes in leaf water potential (ψH) and this may contribute to the apparent drought tolerance of the species. Ability of the roots to penetrate the soil may also be involved in the drought tolerance mechanisms of this species.

The two groups of accessions identified on the basis of pattern analyses (Tables 2.1 and 2.2) may be used as a basis for selecting material for particular farming system requirements. Group A accessions performed well in the establishment year and had good drought tolerance, but did not persist in terms of high yield. Nevertheless, such material could be appropriate for a short fallow system, where good productivity and cover in the first year would be important, and lower persistence would mean subsequent cultivation would not be impaired by the legume’s presence. Group B
accessions showed good persistence for a number of years, even after grazing and these could therefore be suitable for a longer term pastures. Accessions from both groups came from a wide range of environments, emphasising the need to evaluate over varying conditions to obtain maximum utility of available material. The 21 accessions forming groups A and B, plus ILRI 155 are being multiplied by the National Animal Production Institute (NAPRI), in preparation for further evaluation studies.

Experiment 2: Evaluation of Aeschynomene histrix

Materials and methods

Plant material

Sixty-four accessions of Aeschynomene histrix, representing the material collected in South America and stored by CIAT since the early 1980s, were obtained from the CIAT genebank in 1995; 0.2 to 1.0 g of each accession (140 to 500 seeds) were provided. Seeds of the locally multiplied accession ILRI 12463 were also included as ‘standards’ for comparison.

Seed quality

Thousand-seed weight (i.e. the weight in grams of 1000 seeds by extrapolation) was estimated by accurately weighing two lots of approximately 200 seeds of each accession.

Germination and viability of the 64 seedlots was estimated using 30 seeds of each accession. These were placed on moist filter paper in a petri dish; germinated seeds were counted after 2, 4 and 6 days. Germinated seeds were transferred to jiffy pots and raised in a screen house to be used for replanting poorly established plots in the field. Seeds were also examined for fungal and bacterial infection by the IITA seed pathology laboratory.

Trial establishment and management

The trial was established at the beginning of the wet season (May 1995) on the IITA campus, Ibadan, in the derived savannah of Nigeria. The design was a randomised complete block with four replications. Plot size was 2.0 x 1.0 m with a space of 1.0 m between plots. Soil features of the experimental site are shown in Table 2.3.

Table 2.3. General soil parameters of the site used to establish Aeschynomene histrix accessions. 1

<table>
<thead>
<tr>
<th>pH (H₂O)</th>
<th>Organic C (%)</th>
<th>Kjeldahl N (%)</th>
<th>C/ N ratio</th>
<th>P (Bray1) (mg/kg)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.85</td>
<td>0.092</td>
<td>9.2</td>
<td>6.8</td>
<td>85</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

1. Values are the means for four replications.
C = carbon; N = nitrogen; P = phosphorus.

The soil was ploughed and harrowed to give a fine tilth before sowing 50 seeds in the centre of each plot as a single row, 2.0 m in length. Fertiliser and inoculant were not
used. Two to three weeks after sowing, plots with poor germination were replanted with 3-week-old seedlings raised in jiffy pots. Plots were weeded throughout the evaluation period.

The number of plants per plot was counted 2, 4, 6 and 8 weeks after planting. Soil cover, estimated as the percentage of the plot covered, was assessed 4, 8, 10 and 12 weeks after planting.

**Morphology and phenology**

The number of leaflets on the first leaf were counted 3 weeks after planting. Height and spread were measured using 3 plants per plot, 12 weeks after planting; growth habit was also assessed according to the following 5 categories: prostrate, decumbent, semi-erect/decumbent, semi-erect, semi-erect/erect. Other features such as adventitious roots and stickiness were also noted.

Flowering was monitored by recording days after planting to peak flower (50% of plants per plot with flowers). Flower colour, assessed as white, orange or bright yellow was recorded. Ripe seeds were collected twice a week through to the end of the 1995/96 dry season.

**Diseases**

Diseases were assessed according to incidence (percentage of plants on a plot affected) and severity (percentage of affected plants showing symptoms) 7, 8, 9, 10, 11 and 12 weeks after planting.

**Productivity**

Each plot was divided into two equal parts: the first part was cut 13 weeks after planting (middle of the wet season) and then both parts were cut 21 weeks after planting (end of the wet season). Field fresh weight was measured and subsamples of about 200 g were taken, separated into leaf and stem and dried in an oven at 65°C to determine dry weight. Dry samples were divided into two parts: one part was ground through a 2.5 mm sieve and analysed for 48-hour in sacco digestibility (Osuji et al 1993) while the other part was ground through a 1 mm sieve and analysed for nitrogen (micro-Kjeldahl).

**Ability to stimulate *Striga* germination**

The laboratory test used to determine the potential of root exudates to stimulate suicidal germination of *Striga hermonthica* has been described by Berner et al (1995). About 0.5 g of fresh, washed, chopped roots from each accession were placed in the centre of a petri dish. Pre-conditioned seeds of *S. hermonthica* were placed around the roots (Figure 2.1); three replicates of each accession were prepared in this way. Germination was estimated by observing *S. hermonthica* seeds under a dissecting microscope after 48 hours incubation at 28°C. The test was also carried out using
Forage Legumes in Subhumid West Africa


**Figure 2.1.** Diagrammatic representation of the arrangement of *Striga hermonthica* seeds and roots of test plant in petri dish to determine the ability of root exudate to stimulate suicidal germination of *S. hermonthica* seeds.

Distilled water or GR 24 (germination releasing compound, a synthetic *Striga* germination stimulant based on the structure of a natural stimulant from the roots of cotton plants). The ability of different accessions to stimulate *S. hermonthica* germination was estimated using an analysis of variance with germination of *Striga* seeds using distilled water and using GR 24 as covariates and comparing with germination of 0%.

**Data analysis**

Principal component analyses, followed by a hierarchical cluster analysis using the average linkage method of SAS (1988) was carried out to identify interesting clusters.

**Results**

**Seed quality and establishment**

Germination in the laboratory averaged 46%; seeds inspected at the IITA seed health laboratory revealed no fungal or bacterial infections. Thousand-seed weight ranged from 0.98 to 2.10 g. Establishment in the field was generally poor with 28 accessions having
an average germination, estimated from numbers of emerged seedlings, below 10%.
Likewise soil cover 5 weeks after planting was, for most plots, less than 5% but plants
subsequently established well so that by 12 weeks after planting average soil cover was
50% and after 20 weeks at least 14 accessions had soil cover of 90% or more.

**Morphology and phenology**

Observations of the first leaf revealed that 29 accessions had 5 leaflets on the first leaf;
20 had 7 and the remaining 16 accessions had varying numbers (5 to 9). Average plant
height and spread were 18 and 37 cm, respectively, 12 weeks after planting. Height
ranged from 1 to 40 cm and spread from 10 to 70 cm. Growth habit was classified into
5 groups (Figure 2.2). The majority of accessions in growth habit groups 4 and 5 had
leaves longer than 4 cm and wider than 1.5 cm with leaflets longer and wider than 1
and 0.3 cm, respectively. Accessions in growth habit groups 2 and 3 had short, narrow
leaves. Leaf shape in growth habit group 1 was variable.

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Figure 2.2. Schematic representation of the five growth habit groups identified for Aeschynomene histrix
accessions, with CIAT accession numbers shown (ILRI - ILRI 12463).

The earliest accessions to flower at 41 days after planting were CIAT 7884 and 9686.
Twenty-three accessions failed to flower and produce seeds and a further 10 produced
the equivalent of less than 10 kg/ha. Ten accessions produced more than 100 kg/ha of seeds, and 3 of these had seed yields over 400 kg/ha (ILRI 12463, CIAT 7255 and 9690).

Fifteen accessions showed the presence of adventitious roots. Six accessions were sticky to touch, four of which were in growth habit group 1.

Diseases

A number of fungal diseases were recorded, the major ones being Rhizoctonia solani, Colletotrichum spp and Fusarium spp. Rhizoctonia occurred mostly after periods of heavy rainfall but the affected plants seemed to recover during drier intervals; nevertheless, CIAT accessions 7575, 8581, 8928, 9691, 18541 and ILRI 12463 showed particularly good tolerance of this disease. Colletotrichum seemed to affect mainly the older leaves and, although it was recorded on most plants, severity and incidence remained low. Fusarium caused wilting and in some cases dead plants, with accessions 7555, 7884, 8247, 8487, 8595, 8581 and 8941 being the most severely affected; all these accessions had erect growth habits. 'Little leaves' were observed for seven accessions (CIAT 7561, 7572, 7578, 8493, 9033, 18537 and 18541).

Productivity

Thirteen weeks after planting, in the middle of the wet season, average dry-matter yield was 94 g/m² (25 g/plant) with a range of 12 to 294 g/m² (5 to 97 g/plant); average stem:leaf ratio was 1:1.1. Average 48-hour in sacco digestibilities of leaf and stem were 65% and 40%, respectively. Twenty-one weeks after planting, at the end of the wet season, dry-matter yields ranged from 24 to 1776 g/m² (6 to 328 g/plant) with an average of 490 g/m² (139 g/plant) and stem:leaf ratio of 1:0.6. The plants cut at 13 weeks regrew to give an average dry-matter yield of 126 g/m² with a maximum of 360 g/m² and the same stem:leaf ratio (1:0.6) as the first cut. At all harvests, CIAT 8911 had the highest productivity.

Values of CP were generally high, ranging between 13% and 28% for leaf and 9% and 15% for stems. Digestibility values were more variable, with values between 45% and 76% for leaf and 31% and 50% for stems; leaf:stem ratios were positively correlated with digestibility.

Ability to stimulate Striga germination

Thirteen accessions showed a significant effect on Striga seed germination in the in vitro petri-dish test (P<0.05); these were CIAT 7267, 7563, 7576, 7587, 7884, 8267, 8487, 8941, 9690, 18539, 18974, 19470 and ILRI 12463. CIAT 8487 had the highest effect (125%) on germination.
Analyses

Principal component analyses indicated that the growth habit group and soil cover at 12 weeks after planting were positively correlated, plant height and disease incidence were negatively correlated while plant spread and disease incidence were positively correlated. The first four principal components described more than 75% of the variability, and these were based on establishment and biomass parameters. Six cluster groups were identified, with the majority of accessions in the variable cluster 6. Other clusters were:

cluster 1: CIAT 8911—outstanding biomass production
cluster 2: CIAT 8581, 9690, 18539, ILRI 12463—good establishment and biomass production
cluster 3: CIAT 9033—very poor establishment and biomass production, high disease incidence
cluster 4: CIAT 7884—poor establishment and biomass production, high incidence of Fusarium disease
cluster 5: CIAT 7565, 7575, 9668—poor biomass production in the first cut, but good regrowth.

Discussion

Although germination percentages and initial establishment (cover) in the field were poor for the majority of accessions tested, a number were able to recover and produce well, indicating their potential for use in farming systems in the region. The poor germination is likely to be related to the age of the seeds, some of which were from collections dating back as far as the early 1980s. More than half of the accessions fell into the erect or semi-erect groups, with those in the groups with growth near the ground generally having the poorest productivity and highest disease incidences. Nevertheless, some of these accessions had good ability to cover the soil, and CIAT 7587 also had reasonable productivity and Striga hermonthica germination. Productivity was higher if the plants were cut once, 21 weeks after planting, than if they were cut twice. This confirms other results, that indicated that Aeschynomene hisrix does not yield well under cutting regimes (CIAT 1995a). Yields for the 21-week cut were generally compatible with other results; even the very highest (CIAT 8911), which represents 17,000 kg/ha is not unreasonable, as Tarawali (1994a) has reported almost 14,000 kg/ha from Aeschynomene hisrix in northern Nigeria. The somewhat higher yield in this study may be related to both the different climate and soil and to the fact that this yield has been estimated from a smaller plot, with the inevitable potential for ‘border effects’. On a small plot, plants near the edge (border) often grow better than those in the middle. If the plot is large enough this ‘distortion’ can be avoided by harvesting only the central part, but this was not possible with those tiny plots.

The ability of some accessions to stimulate suicidal germination of S. hermonthica is of interest. Aeschynomene hisrix has the potential, as a legume, to improve the fertility of the soil and therefore increase subsequent crop yields (Tarawali 1994a); the additional ability
Forage Legumes in Subhumid West Africa

to reduce infestation by this devastating parasitic weed is an attractive advantage and suggests that the species could have an excellent potential for use in crop-livestock systems. Weber et al (1995) reported the use of *A. histrix* ILRI 12463 on *S. hermonthica* infested farmers' fields in rotation with maize in northern Nigeria. Maize yields were increased 83% when *A. histrix* was used in the rotation, comparing well with soybean rotation which gave an increase of 75%. Numbers of emerging *S. hermonthica* plants were also reduced. In the context of our study, it would be appropriate to initiate seed multiplication and subsequent field testing of the selected accessions for their *Striga* control abilities. Whilst the laboratory tests are a reliable indicator of the potential of suicidal germination abilities, it is always necessary to follow up with field testing to verify the results.

Forage production of several of the accessions was good, and CIAT 7576, 7587, 8262, 9690, 18539 and 18974 and ILRI 12463 have both good forage and good *S. hermonthica* germination ability. Further seed multiplication and larger-scale evaluation of these accessions would be worthwhile, with the exception of CIAT 8262 which failed to produce seeds. CIAT 8487 would also warrant further investigation since this accession had an exceptionally high *S. hermonthica* germination ability, although dry-matter productivity under conditions at Ibadan in 1995 was not high. CIAT 8911, although the best in terms of dry-matter productivity, had a low ability to stimulate *S. hermonthica* germination. However, this accession should be multiplied and tested further as it may have potential as a forage in situations where *S. hermonthica* control is not mandatory. The accessions proposed here for further multiplication all had acceptable seed production except CIAT 8262 and this is an important criterion in the selection process; material that has seed production problems will be hard to disseminate to farmers.

Bishop et al (1988) evaluated a collection of over 300 *Aeschynomene* accessions, including 8 accessions of *A. histrix*. In contrast to our study, all these *A. histrix* accessions were classified as having prostrate growth habit, but the potential of the *A. histrix* for good herbage production was acknowledged as was the slight incidence of anthracnose disease. Kretschmer and Bullock (1980) also classified *A. histrix* accessions as prostrate or semi-erect and reported the natural habitat to be savannah or well-drained soil, but recorded later flowering than that observed in this study. These authors also indicated the potential of the species to form adventitious roots, as observed for 15 accessions in our study. It is not apparent how the accessions used by these authors correspond to those in our study, although they are from a similar region, covering several countries in tropical South America (CIAT forage germplasm database information).

ILRI 12463 is classified as equivalent to CIAT 9690 (Kidest Shenkoru et al 1991), and in this study, the two accessions behaved very similarly in terms of the parameters assessed. This suggests that the accession ILRI 12463 had retained its genotypic composition, despite having been multiplied in Nigeria over a number of years.

*A. histrix* ILRI 12463 has been reported as having good CP and phosphorus contents (Peters et al 1994b; Tarawali 1994a) and these features were confirmed for this study.

On the basis of the parameters evaluated, 20 accessions were identified with promising characteristics (Merkel et al 1998). Of these, 11 (CIAT 7267, 7884, 8487, 8581,
8907, 8911, 8928, 9690, 18539, 19470 and ILRI 12463) had adequate seed production features making them suitable for further evaluation and multiplication.

Experiment 3: Collection of indigenous herbaceous legume species in northern Nigeria

Materials and methods

In collaboration with scientists from the National Animal Production Research Institute (NAPRI), Zaria, Nigeria, four collection trips were made in the northern Guinea savannah and semi-arid regions of Nigeria, during the middle of the 1993/94 dry season (November to February) (Figure 1.1). Each trip lasted five to six days. Over the four trips, collections were made at 67 sites, covering a range from lat 9°N to 13°N, long 4°E to 14°E. Preference was given to interesting or representative sites likely to have the greatest variety of legume species, hence, distances between sites were not regular, and ranged from 50 to 200 km. The selection criteria applied were to select only herbaceous and subshrub legumes (height less than 1.5 m) and to collect a maximum of four plants of each ecotype at each site. These were placed in separate paper bags (since outcrossing potentials were unknown).

Each site was characterised by recording the location, topography and surrounding vegetation; 10 g of soil from the upper 1–2 cm was sampled and used to estimate pH with a field pH meter. Locations were classified at two levels, firstly into bush, trial path or roadside; these were then subdivided into a total of 25 habitats, according to land use (e.g. farm land, forest edge, former road etc). Data on length of growing period, potential evapotranspiration and agro-ecological zone were added later using information from the Agroecological Studies Unit of IITA.

The plants from which seeds were collected were also described, using a scale of 0 to 5 (where 0 = least) to rank for number of flowers, mature seeds, relative abundance, drought tolerance (% green leaves), grazing intensity and leafiness. Diseases and pests were noted only when the damage was severe.

To gain some understanding of how the vegetation changes as the dry season progresses, two sites were visited on three occasions during the 1993/94 dry season (18/11/93; 23/12/93 and 26/1/94). On each occasion, sites and plant species were described as above.

Results

Material collected

A total of 600 accessions were collected comprising 73 identified species (and a few unidentified), most of which belonged to the family Papilionaceae, with the remaining being from Caesalpinaceae or Mimosaceae. Seventeen species were found more than 10 times and 6 of these were found 30 or more times (Abyssicarpus rugosus, A. glumaceus, Tephrosia linearis, T. pedicellata, Indigofera secundiflora, Zornia glochidiata); 22 species were found only once.
Species presence in relation to the environment

Over the 67 sites, pH varied from 3.3 to 7.9, with the majority being between pH 5.5 and 6.5. Low or high pH values were often associated with specific habitats such as fallow land and woodlands, respectively. Some species seemed to show a relationship with pH: Desmodium velutinum, Crotalaria macrocalyx and Indigofera paniculata were associated with high pH while Desmodium barbatum, Mimosa pigra and Tephrosia purpurea were associated with low pH. Chamaecrista rotundifolia was found in soils with pH ranging from 4.5 to 7.9. The location of some genera was related to specific agro-ecological zones (Table 2.4). There were very few species and ecotypes in the arid/semi-arid zone; the majority were found in the northern Guinea savannah.

<table>
<thead>
<tr>
<th>Genus</th>
<th>No. of species</th>
<th>Agro-ecological zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Papilionoideae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrus</td>
<td>1</td>
<td>WS</td>
</tr>
<tr>
<td>Adenodolichos</td>
<td>1</td>
<td>no tendency</td>
</tr>
<tr>
<td>Aeschynomene</td>
<td>2</td>
<td>A/S, NGS</td>
</tr>
<tr>
<td>Alysicarpus</td>
<td>4</td>
<td>A/S, NGS</td>
</tr>
<tr>
<td>Calopogonium</td>
<td>1</td>
<td>no tendency</td>
</tr>
<tr>
<td>Clitoria</td>
<td>1</td>
<td>SGS</td>
</tr>
<tr>
<td>Crotalaria</td>
<td>12</td>
<td>NGS</td>
</tr>
<tr>
<td>Desmodium</td>
<td>7</td>
<td>NGS</td>
</tr>
<tr>
<td>Eriosema</td>
<td>1</td>
<td>NGS, SGS</td>
</tr>
<tr>
<td>Glycine</td>
<td>2</td>
<td>NGS, SGS</td>
</tr>
<tr>
<td>Indigofera</td>
<td>17</td>
<td>NGS</td>
</tr>
<tr>
<td>Macrotyloma</td>
<td>1</td>
<td>NGS</td>
</tr>
<tr>
<td>Pseudarthria</td>
<td>1</td>
<td>NGS</td>
</tr>
<tr>
<td>Rhyynchosia</td>
<td>1</td>
<td>WS</td>
</tr>
<tr>
<td>Sesbania</td>
<td>3</td>
<td>A/S</td>
</tr>
<tr>
<td>Stylosanthes</td>
<td>2</td>
<td>NGS</td>
</tr>
<tr>
<td>Tephrosia</td>
<td>6</td>
<td>NGS</td>
</tr>
<tr>
<td>Vigna</td>
<td>2</td>
<td>SGS</td>
</tr>
<tr>
<td>Zomia</td>
<td>1</td>
<td>A/S</td>
</tr>
<tr>
<td>Caesalpinioideae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassia</td>
<td>2</td>
<td>NGS</td>
</tr>
<tr>
<td>Chamaecrista</td>
<td>3</td>
<td>NGS</td>
</tr>
<tr>
<td>Mimosoideae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acacia</td>
<td>1</td>
<td>A/S</td>
</tr>
<tr>
<td>Mimosa</td>
<td>1</td>
<td>A/S</td>
</tr>
</tbody>
</table>

A/S = arid/semi-arid; NGS = northern Guinea savannah; SGS = southern Guinea savannah; WS = mid-altitude woodland savannah.

Plant descriptions and relationship to habitat

The majority of the accessions (438) were collected from 22 habitats defined in the category 'bush' and there were relationships between both the number and type of
different species found, and the habitat. Incidences of *Zornia*, *Tephrosia pedicellata*, *Indigofera secundiflora*, *I. dendriodes* and *Cassia mimosoides* were high on roadsides where, generally, there were many different species. *Alysicarpus* spp were common in areas where land was influenced by cropping; *Zornia glochidiata* and *Stylosanthes fruticosa* were frequent on trial paths. Sites prone to grazing tended to have more species with prostrate or creeping growth habits. Grazing also influenced the number of ripe seeds, leafiness and apparent drought resistance because grazing stimulated regrowth of young shoots. Few herbaceous legume species were found in National Parks.

Pests or disease damage were recorded for only 69 of the 600 accessions, and incidence of these was extremely variable, even at a single site. Notable were *Crotalaria* spp which had flowers damaged by beetles and *Indigofera pulchra* which was damaged by a fungus disease.

*Mimosa pigra*, *Crotalaria naragutensis*, *C. retusa*, *C. senegalensis*, *Macroptilium* sp, *Tephrosia purpurea* and *Indigofera priureana* showed good drought tolerance, with green leaves remaining on the plants well into the dry season.

**Vegetation changes in the dry season**

By visiting two sites on three separate occasions as the dry season progressed, it was possible to obtain an impression of the on-going vegetation changes (Table 2.5).

<table>
<thead>
<tr>
<th>Site</th>
<th>November 93</th>
<th>December 93</th>
<th>January 94</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDZ I (natural pasture, trail path, shrub)</td>
<td>6</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>KDZ II (natural pasture, shrub, further shrub)</td>
<td>9</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: Kaleja (1994).

Both sites were influenced by grazing cattle and there was a lot of firewood collection at the second site meaning that by the third visit there were no small shrubs or trees (hence the classification 'further shrub'). Species that were not yet flowering did not start during the study period, and those that were flowering on the first visit had stopped by the third, expect for *Indigofera macrocalyx* which continued to flower. Presence of ripe seeds (for those species that flowered) increased over the period. Leafiness and greenness decreased over time. Grazing preferences varied, with the most grazed species being *Zornia glochidiata*, *Crotalaria macrocalyx* and *Chamaecrista rotundifolia* on the first visit; *Stylosanthes fruticosa* and *Desmodium hirtum* on the second and *Chamaecrista rotundifolia* on the third. For *Chamaecrista rotundifolia* this observation may be related to the observed increase in abundance.

**Discussion**

The influences of both human and animal activity on occurrence of herbaceous legume species were apparent as a result of this study; both these activities had positive and
negative effects on species presence. For example, animals may decrease species diversity by overgrazing, leading to monocultures of unpalatable species. However, livestock can also distribute seeds, and passage through animals is known to encourage germination of some seeds (Foster 1961). In human-designated protected areas such as national parks, herbaceous legumes were few because of the dominance of vigorous grasses. Logging also decreased species presence. In contrast, cropping activities favoured legume divergence, especially annual species. These observations confirm the importance of such collecting trips for the conservation of genetic diversity. Even in the space of a few months, changes in vegetation could be observed suggesting that this diversity is being rapidly eroded by the activities of humans and their livestock. Similar findings were reported from Oman, where grazing activities were having a dramatic effect on the genetic resources (Guarino 1990; Prendergast 1992). At the same time, through the collection, evaluation and subsequent appropriate use of both indigenous and exogenous forage legumes could discourage over- and indiscriminate grazing.

Asare et al (1984) observed indigenous herbaceous and shrubby plants at a single site near Zaria in northern Nigeria. They reported that *Isoberlinia doka* is the dominant species, and this may be because it was not eaten by cattle. In contrast, *Parinari curatellifolia* was highly palatable, and these authors reported an obvious lack of this around trail paths frequented by nomadic cattle herds. Other promising indigenous species reported by these authors included *Desmodium velutinum*, *Sphenostylis schweinfurthii*, *Desmodium scorpiurus* (a naturalised species) and *Flemingia macrophylla*. Accessions of the two *Desmodium* species were collected in our study (Kaleja 1994), but other species may be classified as shrubs and are therefore outside of the target group. Nevertheless, this serves to emphasise that a similar collection focusing on browse plants would be worthwhile since they form such an important fodder resource (Bayer 1990).

This study has enabled a collection of indigenous herbaceous legume material to be assembled, together with information on site of origin and preferred habits for a number of species. Whilst the study did not apply rigorous principles of forage plant collection in terms of number of ecotypes collected at each site (e.g. Marshall and Brown 1983), sites were chosen to be representative and to cover as wide a range of variation as possible within the time available. It would now be appropriate to evaluate the material collected in a small-plot observation trial (Tarawali et al 1995), while at the same time multiplying seeds to enable further identification and characterisation of species with promising attributes; this research has started at NAPRI. Such an evaluation could then be followed up by more targeted collection missions, possibly extending to other West African countries, to obtain more material of promising species. Forage plant collection is not only more likely to yield fruitful results in terms of better performing and more useful accessions for development and introduction into farming systems, but is considerably more feasible than conventional plant breeding using forage species (Harlan 1983). It also has the advantage of contributing towards conservation of rapidly disappearing genetic resources.
3 Selected grass–legume mixtures for calf supplementation

Introduction

The subhumid region of sub-Saharan Africa has a cattle population in excess of 37 million head, about 30% of which are found in West Africa (Winrock 1992). Whilst many are managed as nomadic herds, there is an increasing trend towards sedentarisation (Jabbar 1992). In the last half-century, formerly nomadic families have begun to settle, often on the outskirts of villages, where they begin some cropping enterprises. Their cattle continue to be of major importance, although herd size often reduces with sedentarisation. The herds have fairly typical dairy herd structures with 50% or more cows, 20% or less males and 30% heifers with suckling calves (Mohammed 1990). Nevertheless, productivity of the cattle, the majority of which are Bunaji (Bos indicus, White Fulani/Zebu) is generally poor (Rege et al 1993a; Rege et al 1993b). Amongst the factors contributing to the low productivity of such Bunaji cattle herds in subhumid Nigeria, are low milk offtake, high calf mortality and low fecundity rates; these in turn are related to the low quality and quantity of the feed resource for much of the year (McDowell 1972; Mohamed-Saleem 1986). Current husbandry practices, including daily herd management and late calf weaning, probably designed to cope with the feed constraint, also contribute to the low productivity (Otcche 1986; Ogunsiji et al 1988).

On a daily basis, lactating animals are usually milked in the morning when calves are allowed to suckle briefly to stimulate the ‘let down’ response (Mukasa-Mugerwa 1989). Once milking is over, young animals are generally kept at the homestead, with none or very little feed while the rest of the herd, including their dams, go out grazing. When the herds return in the evening, the calves are again allowed to suckle. The unweaned calves therefore drink at least 30% of what would otherwise be saleable milk (Mohammed 1990) between birth and 7 or 8 months of age, the age at which weaning usually occurs, although there is rarely any attempt to enforce this (Otcche 1986). Despite such a scenario, the nutritional requirements of the young animals are rarely met and calves are often undernourished making them slow to mature and prone to disease; this contributes significantly to the high calf mortality.

The main forage resource is the natural vegetation, with limited grazing of crop residues at certain times of the year (early to mid-dry season); purchased supplements, except salt licks, are rarely used for any class of animal (Mohammed 1990). During the peak (late) of the dry season, browse species, notably Pterocarpus erinaceus and Daniella olivera may be lopped to provide supplemental feed for adult animals. If feed supplements were available for the young calves which remain at the homestead, they would take less milk from the dams, would probably survive better and (for females) subsequently have improved reproductive performance. Whilst reducing suckling in this

1. The results presented in this chapter have previously been reported in Olanite (1998).
way may shorten the lactation period because of the adverse effect on the let down response (Mukasa-Mugerwa 1989), the milk offtake per day would be higher, and the dams would be likely to start cycling sooner, thereby increasing total herd productivity. Milk is becoming an increasingly important commodity in much of subhumid West Africa and this trend is likely to continue, given the positive effects of urbanisation on the demand for milk products (Winrock 1992). A survey of peri-urban farmers in southwestern Nigeria (Saki, Fashola, Oyo and Ogbomoso local government areas, Figure 1.1) indicated that milk production was important for about 50% of the farmers in all four areas surveyed (Mohammed 1990). The research described in this chapter aimed to explore some options for providing better nutrition for young calves which could have beneficial effects on both total herd productivity and milk output. Whilst concentrate feeds (mainly agro-industrial by-products) or even milk replacers may be the ideal candidates for supplementary calf feeding, in most of West Africa such resources are scarce, expensive or both. This study therefore focused on identifying appropriate forage material that could be easily grown by farmers near their homesteads, to provide a ready supplement for the young animals. Research in the humid and subhumid regions of Nigeria and elsewhere in West Africa has identified both forage legumes and grasses which may be suitable in this respect.

*Panicum maximum* is one of the most common grasses in the derived savannah region of Nigeria. Research has shown that, under good conditions, its nutritional value is high, having up to 12.5% crude protein (CP), total digestible nutrients (TDN) of 10.2% and good calcium (Ca), phosphorus (P) and magnesium (Mg) (McDowell et al 1974; Crowder and Chheda 1977; Akinwumi and Onayinka 1982; Aken'Ova and Mohamed-Saleem 1985). Whilst improved varieties of this species, such as cv Nchisi (S.112) have been identified from on-station research (Aken'Ova 1993), they are generally not available for distribution to extension services or farmers. This study therefore focused on the indigenous *P. maximum* that is endemic in most of the rangelands of Nigeria's derived savannah region. Other improved grasses may subsequently be of use for such interventions, if appropriate extension methods are in place and, in this context, *Cynodon nlemfuensis*, *Brachiaria ruzicetiensis* or *B. decumbens* could be potential candidates, as they have good dry-matter and CP yields (Ademosun 1973; Ademosun and Chheda 1974; Bogdan 1977; Akinola 1981; Larbi et al 1989).

Although certain grasses can give good forage yields, the quality of a pasture can be further improved and assured by the inclusion of forage legumes which, although not always so bulky, retain higher quality throughout the year. *Centrosema pubescens* and *Stylosanthes guianensis* have both been recommended for use in mixtures with grasses (Ademosun 1973; Mislevy 1985) and have been shown to improve animal performance (Adegbola and Onayinka 1968). These researchers used commonly available Centro and Cook stylo. However, further evaluation, mainly in the northern and southern Guinea savannas has shown that different accessions of *Stylosanthes* or other forage species may be able to perform even better (Tarawali 1991b; Tarawali 1994a; Tarawali 1995a), although such, more recently identified material has not been tested in grass-legume mixtures. Included here are *Chamaecrista rotundifolia* (cv Wynn; ILRI 10918), *Aeschynomene histrix* (ILRI 12463), *Centrosema brasilianum* (ILRI 155), *Stylosanthes*
Grass-legume mixtures for calf supplementation

Based on this previous research, grass-legume mixtures using appropriately selected species were considered to have good potential for providing a feed resource for young calves. To identify the most appropriate species combinations and explore their potential as feed resources for young calves, two types of trial were initiated. A large-plot trial using, as described in the preceding two paragraphs, the most obvious species candidates, *Stylosanthes guianensis* or *Centrosema pubescens* oversown into indigenous *Panicum maximum* was established to investigate the effects of grazing such sown pastures on young calves, and the performance of these pasture species combinations under grazing. This experiment also included a positive control of the best available concentrate at the time of the study, wheat bran, as well as a treatment consisting of *Panicum maximum* with no legume or concentrate. Once established, these grass pastures, with or without forage legume or wheat bran, were used for grazing studies to compare their effects on the liveweight gains of calves. Two short-term studies were carried out, the first using weaned calves of about one year old, and the second with weaned calves aged about 4 months.

The second trial was designed to investigate other potential resources, namely, *Cyndon niemfuensis*, *Brachiaria ruzizensis*, *Chamaecrista rotundifolia* and *Aeschynomene histrîx*. These species, together with *Stylosanthes guianensis* and *Centrosema pubescens* were used for a smaller plot experiment, to investigate their performance in grass-legume mixtures, in terms of persistence under grazing, and quality parameters that could be used to estimate their potential value as a resource for young calves. Including close monitoring of the nutritive value of the forage resources was important especially in the context of calf nutrition, where forage with good digestibility, low fibre, high CP and adequate Ca and P are particularly vital.

**Experiment 1: Evaluation of selected grass-legume combinations for supplementation of young calves**

**Materials and methods**

**Establishment**

The trial was established in the early part of the wet season (June) in 1994 using existing plots of *Panicum maximum* on the ILT campus, Ibadan, in the derived savannah of Nigeria. Soil parameters are presented in Table 3.1.

The trial was a randomised complete block design with four 0.1-ha plots demarcated per replicate and a total of three replicates. In each replicate, the *P. maximum* was mowed and harrowed, then one plot was oversown with scarified seed of *Stylosanthes*...
guianensis ILRI 164 and one with Centrosema pubescens ILRI 152. A third plot was used as a P. maximum alone pasture and the remaining plot again used as P. maximum alone, but with a supplement of wheat bran\(^2\) (18.3% CP, 0.16% P, 0.14% Ca, 80% in sacco digestibility 48 hours). A basal dose of 200 kg/ha NPK (15:15:15) was applied to all plots at the time of legume planting. Throughout the establishment period, before grazing started, the plots were mowed down to 0.5 m at intervals using a tractor-mounted mower to keep the P. maximum below 1.0 m high.

Table 3.1. Soil characteristics of the experimental site at Ibadan for the Panicum maximum plots before introduction of legumes.

<table>
<thead>
<tr>
<th>pH</th>
<th>N (%)</th>
<th>OM (%)</th>
<th>P (ppm)</th>
<th>Ca</th>
<th>Mg</th>
<th>Mn</th>
<th>K</th>
<th>Na</th>
<th>EfCEC</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
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<td>6.2</td>
<td>0.094</td>
<td>0.95</td>
<td>6.6</td>
<td>1.28</td>
<td>0.28</td>
<td>0.12</td>
<td>0.18</td>
<td>0.25</td>
<td>2.09</td>
<td>92</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Values are in cmol+/kg unless otherwise indicated; N = nitrogen; OM = organic matter; P = available phosphorus, Bray I; Ca = calcium; Mg = magnesium; Mn = manganese; K = potassium; Na = sodium; EfCEC = effective cation exchange capacity.


Data collection

Plots were assessed for number of legume seedlings, grass stands and soil cover using twenty 1 m\(^2\) quadrats systematically located over each plot 4, 8 and 12 weeks after legume planting. Flowering, seeding, disease incidence and dry season drought tolerance were estimated at each of the sampling dates (December 1994, February 1995 and April 1995).

Productivity/botanical composition and forage quality

Dry-matter productivity and botanical composition of the pastures were assessed in the middle of the 1994/95 dry season (December 1994), the peak of the 1994/95 dry season (February 1995) and the beginning of the 1995 wet season (April) using the yield estimate and percentage-rank method with the BOTANAL programme described by Tothill et al (1992). On each occasion 40 quadrats per plot (5 transects with eight 1 m\(^2\) quadrats each) were sampled. Forage quality was assessed by sampling the major species found in each treatment, bulking over replicates, drying and grinding through 1 mm or 2.5 mm sieves for analyses of chemical composition (CP, neutral-detergent fibre (NDF), acid-detergent fibre (ADF), P and Ca) and in sacco digestibility, respectively.

Grazing periods

Two grazing trials were carried out on the same pastures. The first was for 15 weeks in the wet season of 1995 (June to September), the second for 12 weeks in the 1995/96 dry season (January to April 1996). For each grazing period, three calves were allocated

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2. The amount of wheat bran provided per day was calculated as 30% of the daily dry-matter requirement, assuming a total of 3% of body weight (total of all calves on the treatment) would be consumed.
to each treatment, with the distribution of the animals taking into account breed, age and sex. Calves used for wet season grazing were about 1 year old (average live weight at the start of the trial, 106 kg) while those used during the dry season were about 4 months old (average live weight at the start of the trial, 70 kg). At any time only one replicate of each treatment was being grazed by the appropriate group of calves; the animals were moved to the same treatment in a different replicate at weekly intervals. Pasture composition and productivity were assessed as described above using BOTANAL for each plot immediately before and after grazing. Calves were weighed between changing paddocks.

**Results**

**Establishment and phenology**

*Panicum maximum* averaged between 6 and 8 tillers/m² 12 weeks after plots were harrowed. Germination of *Centrosema pubescens* was good, with 80% of the sown seeds germinating 12 weeks after establishment. *Stylosanthes guianensis* seeds had lower germination, with 40% of the sown seeds germinating. Soil cover was between 49% and 78% for *P. maximum*/*S. guianensis* and *P. maximum*/*C. pubescens*, respectively, 12 weeks after planting.

In the dry season (February 1995), plots with either of the two legumes showed significantly (P<0.05) higher greenness than those without. Following the onset of the wet season, all pastures responded well, with soil cover above 60% for all treatments. Plots with either of the two legumes generally had higher soil cover, although not significantly so. Average numbers of legume plants following the onset of the rains were 45 and 13 plants/m² for *S. guianensis* and *C. pubescens*, respectively, with the majority of *S. guianensis* being new seedlings.

**Pasture productivity, quality and botanical composition**

Establishment phase. Before starting the grazing trials, pasture productivity and botanical composition were monitored (Figure 3.1). Yields of the *P. maximum* alone pastures were generally higher than those with introduced legume when the first measurements were made, six months after establishment of the trial, but by the onset of the second wet season (April 1995) all treatments had similar total yields, between 6000 and 7000 kg/ha. The amounts of other grasses and forbs in the *P. maximum* alone plots was about double that for plots with introduced legumes, and these components decreased throughout this measurement period. Yield of *C. pubescens* was 2000–3000 kg/ha during the measurement period, with *S. guianensis* being similar, although higher in the dry season, (February 1995) at almost 4000 kg/ha. During this period, the 'other grasses' consisted mainly of *Panicum repens* with some *Pennisetum polystachion*, whilst the forbs were dominated by *Syndrella nodiflora*.

Analysis of CP and in *sacco* digestibility for the first two measurement periods showed that *P. maximum* in all treatments had the lowest CP, ranging between 4% and
### Estimated Dry-Matter Productivities of Grass-Legume Pastures during the Dry Season after the Establishment Phase, before Grazing Trials

<table>
<thead>
<tr>
<th>Date</th>
<th>DM Yield Estimate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early dry 94/95</td>
<td>15,000</td>
</tr>
<tr>
<td>Mid-dry 94/95</td>
<td>10,000</td>
</tr>
<tr>
<td>Late dry 94/95</td>
<td>5,000</td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Early dry 94/95</td>
<td>0</td>
</tr>
<tr>
<td>Mid-dry 94/95</td>
<td>0</td>
</tr>
<tr>
<td>Late dry 94/95</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 3.1.** Estimated dry-matter productivities of grass-legume pastures during the dry season after the establishment phase, before grazing trials.

5.5%. The highest CP recorded was for ‘other legumes’; *C. pubescens* and *Stylosanthes guianensis* had values of 11% and 13%, respectively. The majority of components showed a slight decrease in CP between the first and second measurements. Forty-eight-hour in sacco digestibility was fairly variable, with the grasses and *Syndrella nodiflora* generally having the lowest values and the two introduced legumes and other legumes having the highest. The values ranged from 27% for *Syndrella nodiflora* in the dry season (February 1995) to 69% for other legumes at the same time.

**Wet season 1995.** Pasture productivity for the 15-week period of the first grazing trial is shown in Figure 3.2. Yields at the start of the grazing trial in the early wet season (June 1995) were not vastly different from those recorded at the onset of the wet season in April 1995; all followed a similar decline over the period. Both plots with *P. maximum* only initially had lower total yields than the two plots which contained legumes, and the difference consisted of the legume component. All plots had similar yields of *P. maximum*. The two legume plots had generally lower yields of other grasses and forbs.
Total yields for the legume plots were generally higher throughout the period, especially for the P. maximum/C. pubescens which seemed to decline slower. Both P. maximum alone plots had less than 2000 kg/ha at the end of the period, with the plots containing legume producing about 0.5 t/ha more.

All treatments showed an increase in CP value with grazing, with a peak around the middle of the grazing period. C. pubescens had the highest value of 18.5%. Forty-eight-hour in sacco digestibility increased over the grazing period with the highest values for Panicum species in combination with S. guianensis or C. pubescens. The ratio of Ca to P was below 4 for all treatments except P. maximum/C. pubescens where the values were over 10 for both the grass and legume component of the mixture. At the start of the grazing period, NDF values for the P. maximum alone plots were over 70% whilst in plots with introduced legumes, the values were at least 10% lower. By the middle of the grazing period, values reduced more dramatically in the P. maximum alone plots, and increased slightly towards the end of the 15-week period, so that there was very little difference in these values between the various components and treatments by this time.
Dry season 1996. Dry-matter productivities of the *P. maximum*, sown legumes and associated components are shown in Figure 3.3. At the start of the grazing period (January 1996) the plots with sown legume had significantly fewer other grasses and forbs than those with *P. maximum* alone. This difference was maintained throughout the trial, remaining significant for the *C. pubescens* treatment. For the first one-third of the grazing period, yields declined, and these declines were more marked in the treatments without sown legume. The *C. pubescens* treatment declined less than the *S. guianensis*. Throughout the trial, the *C. pubescens* had higher yields than *S. guianensis* (about 25% of total dry-matter yield vs 12%). The *C. pubescens* yield actually increased slightly even during the first third of the grazing period when all other components decreased. Total yield variations were, however, largely related to changes in the amount of *P. maximum*. Before the middle of the grazing period, yields began to increase slightly, with a more marked increase during the last third of the period. At the end of the 12-week grazing period, the two *P. maximum* alone plots had the highest yields of about 2500 kg/ha, while the two treatments with sown legume had yields of about 500 kg/ha less.

![DM yield estimate (kg/ha)](image1)

![DM yield estimate (kg/ha)](image2)


**Figure 3.3.** Estimated dry-matter productivities of grass-legume pastures during the grazing period in the 1996 dry season (January–April).
Calf performance

Wet season 1995. Liveweight gains of the animals on the four treatments are shown in Figure 3.4. At the end of the period, the total liveweight gain for calves grazing the *P. maximum/C. pubescens* mixture was significantly (P<0.05) higher than for all the other treatments, including the wheat bran. Lowest gains were recorded for *P. maximum* alone, although this was not significantly different from the *P. maximum/wheat bran* or *P. maximum/S. guianensis* treatments. Average daily gains (ADG) over the 15-week period for the four treatments were 317, 365, 531 and 385 g/day for *P. maximum* alone, *P. maximum/S. guianensis*, *P. maximum/C. pubescens* and *P. maximum/wheat bran*, respectively.

![Cumulative Liveweight Gains](image)


Figure 3.4. Cumulative liveweight gains (LWG) of calves grazing grass-legume, or grass alone (with or without supplement) pastures for a 15-week period during the 1995 wet season.

Dry season 1996. Cumulative liveweight gains for the calves grazing the four treatments during the 1996 dry season are shown in Figure 3.5. Up to week 8, the animals grazing *P. maximum/C. pubescens* had higher gains than those on the other treatments. For the
last 4 weeks of the trial, animals on the *P. maximum/S. guianensis* treatment gained faster, but all treatment groups showed a sharper increase in weight gain. Animals receiving wheat bran showed a variable response, with weight losses between weeks 4–5 and 7–8. At the end of the period, the calves on *P. maximum/C. pubescens* had the highest weight gain, followed by those on *P. maximum/S. guianensis*, but these were not significantly (P<0.05) different from those on *P. maximum/wheat bran* or *P. maximum* alone. ADG for these four treatments, over the 12-week period were 399 g/day, 384 g/day, 335 g/day and 310 g/day for *P. maximum/C. pubescens*, *P. maximum/S. guianensis*, *P. maximum/wheat bran* and *P. maximum* alone, respectively.

**Discussion**

In this study establishment was generally comparable to that reported from other studies (e.g. Lazier and Clatworthy 1990; Mendoza et al 1990), although that of *Stylosanthes*
Grass-legume mixtures for calf supplementation

S. guianensis was initially slow. Yields before the start of the grazing study related to the management of the pastures: those with no introduced legume were not harrowed and therefore had higher productivities. Mowing to maintain the pastures was used to prevent the grass becoming dominant, and from reaching maturity and causing a related decline in quality. Obviously, mowing would not be feasible for farmers. However, it is anticipated that with a pasture close to the homestead, a farmer’s animals could be used to graze off the grass and maintain the necessary balance. In our trial, with repeated mowing the taller grasses were reduced more than the legumes, accounting for the relative similarity in productivity by the start of the grazing period. The introduced legumes seemed to out-compete the native forbs, as productivities of introduced legumes were considerably lower than in plots with Panicum maximum alone. Centrosema pubescens had slightly higher yields than S. guianensis at the end of the grazing period, but the difference was not as dramatic as that reported by Lascano et al (1990) where C. pubescens remained at 10–17% of the dry matter whereas S. guianensis was completely grazed out. Quality parameters before the onset of the grazing study were fairly typical (e.g. Lascano et al (1990) reported C. pubescens with 15–25% CP and 50–55% dry-matter digestibility), with the CP for P. maximum being rather low. The legumes had a positive effect on the drought tolerance of the various mixtures, and for C. pubescens this was reflected in a positive effect on the CP of the associated P. maximum.

During the 15-week grazing period in the 1995 wet season, the positive effect of grazing on the nutritive values of both grass and legume components was apparent, although this declined by the end of the period, suggesting that the pastures really were being grazed to their limit by this time. The decline in quality towards the end of the grazing period was lower for the mixture with C. pubescens and this was reflected in the liveweight gains of the animals on that pasture, which were superior to those of the other treatments. The sown legumes had a positive effect on both the quantity of herbage available and the quality, since the increased quantity comprised partly of sown legume which had higher quality values than the P. maximum that dominated the grass component. Variations in Ca/P ratios were slight except for the P. maximum/C. pubescens mixture which had higher initial values, declined towards the middle of the period then rose again. This change was caused by exceptionally high Ca values at the end of the grazing period; P values were not vastly different from other treatments, and all components maintained P above the critical 0.12% (Little 1980) throughout the trial period.

During the wet season grazing, animal liveweight gains showed a clear advantage of the P. maximum/C. pubescens mixture over the other three treatments. This is most likely related to the quantity and quality of this treatment, which did not decline as much as others. Average daily gains ranged between 317 and 531 g/day which compare well with results from similar trials. A range of animal liveweight gains has been reported for grazing trials with similar materials in the area, from 190 to 490 g/day (Aken’Ova 1993). Adegbola and Onayinka (1976) reported ADG of up to 700 g/day for adult cattle at Fashola, compared with 150 g/day on range; in a 12-year study in a wetter region of South America, Lascano et al (1990) reported that pastures based on C. pubescens gave ADGs of 400 g/day. While both these studies report higher values, they were conducted...
for longer periods and used adult cattle. The very high Ca/P ratios, although outside the recommended range (Peters 1992), appear not to have had any detrimental effect on animal performance. The wheat bran had very good nutritive value, especially in terms of CP and digestibility which were better than any of the legumes; however, the performance of animals on this was still surpassed by the P. maximum/C. pubescens mixture. Although the animals gained more weight on wheat bran than on S. guianensis, the difference was not significant.

In the dry season, the effect of the fairly sudden onset of the rain (Figure 1.2), just before the middle of the trial was apparent from both the pasture performance and the subsequent effect on the liveweight gain of the calves (Figures 3.3 and 3.5). The effect of the initial harsh dry period is also apparent, as well as the dramatic effect of the treatment with C. pubescens in overcoming this limitation. During this stressful period, calves on this treatment gained significantly more weight than those on the other treatments; this can be related to the amount of sown legume that was maintained in these pastures. The animal response to wheat bran was very varied, again indicating that, whilst it has high nutritive value, it may not be appropriate for very young animals which weigh less than 100 kg (Little et al 1994); in the first grazing period, the older animals responded better with 385 g/day compared with 335 g/day for the younger animals. Average daily gains were comparable to those recorded in other studies in the region. The C. pubescens accession used in our study differs from the locally found ‘Centro’ (a naturalised/indigenous C. pubescens) in that it seems to remain greener and more persistent in the dry season (M. Peters and S.A. Tarawali, unpublished); this may well have contributed to its outstanding performance in these studies.

There have been a number of recommendations concerning the use of improved grasses in the region, including cv Nchisi for P. maximum and an improved Cynodon hybrid, lb8 (Aken’Ova 1993). However, this study has indicated that if appropriate forage legumes are introduced and managed in the indigenous P. maximum, good results can be obtained. This is encouraging since dissemination of such improved grasses to farmers seems not to have occurred (possibly partly because they rely on cuttings); distribution of smaller quantities of legume seeds is more feasible. These results therefore suggest that introducing a forage legume into the native P. maximum pasture can be used to provide a calf supplement as good as or better than the best available concentrate, wheat bran.

Whilst the economic implications of using grass-legume pastures rather than concentrates have not been investigated in this study, it is known that supplies of concentrates such as wheat bran are very unreliable and often inaccessible for farmers in rural areas, even if they could afford to purchase such inputs on a regular basis. Utilisation of a forage-legume enriched P. maximum pasture would therefore appear to be an attractive option to improving calf nutrition. Once the establishment costs have been met, yearly inputs into such a system would also be minimal, thereby releasing participating farmers from relying on inputs that depend on the vagaries of the economic environment.
Experiment 2: Small-plot mob grazing trial to assess the potential of selected grass–legume mixtures for cattle supplementation

Materials and methods

Establishment

The trial was established in the early part of the wet season (June 1994) on the IITA campus, Ibadan, in the derived savannah of Nigeria. The land was ploughed and harrowed to give a fine soil tilth. Soil parameters at the experimental site are given in Table 3.2.

Table 3.2. Soil characteristics of the experimental site at Ibadan for the small-plot grass–legume trial.

<table>
<thead>
<tr>
<th>pH</th>
<th>OM (%)</th>
<th>P (ppm)</th>
<th>Ca</th>
<th>Mg</th>
<th>Mn</th>
<th>K</th>
<th>Na</th>
<th>EfCEC (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
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<tbody>
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<td>6.5</td>
<td>0.191</td>
<td>1.34</td>
<td>7.5</td>
<td>2.12</td>
<td>0.64</td>
<td>0.17</td>
<td>0.32</td>
<td>0.28</td>
<td>3.32</td>
<td>89</td>
<td>4</td>
</tr>
</tbody>
</table>

Values are in cmol+/kg unless otherwise indicated; N = nitrogen; OM = organic matter; P = available phosphorus, Bray I; Ca = calcium; Mg = magnesium; Mn = manganese; K = potassium; Na = sodium; EfCEC = effective cation exchange capacity.


The eight treatments were laid out in a randomised complete block design with four replicates. Plot size was 4.0 x 5.0 m with 1.0 m between plots. Two grasses (Cynodon nlemfuensis IB 8 and Brachiaria ruvicaulis) were used in combination with each of four legumes (Stylosanthes guianensis ILRI 164, Aeschynomene histrrix ILRI 12463, Chamaecrista rotundifolia ILRI 10918 and Centrosema pubescens ILRI 152). Grasses were established by transplanting cuttings and planting at 0.25 and 0.5 m within and between rows, respectively, on each plot. Legume seeds were scarified using sandpaper and broadcast using seed rates of 9.8, 7.2, 13.4 and 8.7 kg/ha for S. guianensis, A. histrrix, C. rotundifolia and C. pubescens, respectively. At the time of planting a basal fertiliser dressing of 200 kg/ha NPK (15:15:15) was applied. To ensure good establishment of the trial, plots were weeded twice, 4 and 8 weeks after planting.

Data collection

Germination of the legumes was estimated by counting seedlings 4, 8 and 12 weeks after planting in the establishment year, and at the same intervals after the rains started in the second year.

Two randomly located 1 m² quadrats were used per plot. The number of grass tillers was also estimated. Soil cover was estimated at the same time, as a percentage of the soil in the quadrat covered by the respective grass–legume mixtures.

Drought tolerance was estimated at 6-weekly intervals during the 1994/95 and 1995/96 dry seasons, using a scale of 1 (10–25% of plants in plot green) to 5 (100% of plant in plot green).
Productivity and forage quality

Productivity was estimated at the end of the wet season (November 1994) and in the mid-dry season (January 1995). On each occasion two 1 m² quadrats were cut from each plot at a height of approximately 10 cm. The cut material was divided into sown legume, planted grass, other grasses and other forbs. Subsamples were taken and dried in an oven at 65°C to obtain dry weights. Dry samples were bulked according to treatments and ground through 1 mm or 2.5 mm sieves for analyses of chemical composition (CP, NDF, ADF, P and Ca) and 48-hour in sacco digestibility, respectively.

Mob grazing

Mob grazing commenced in the early part of the wet season in the second year (June 1995). Productivity was estimated before and after grazing as described above. Adult N’Dama cattle were allowed to graze the plots freely for 6 hours a day for 2 days at a stocking density of 150 animals/ha. Grazing was repeated in the middle of the wet season (August), the end of the wet season (October) and the middle of the 1995/96 dry season (December 1995). During each grazing period, palatability was estimated by recording the number of grazing animals per plot every 5 minutes, following a one-hour adjustment period.

Results

Establishment and phenology

Both Brachiaria ruziziensis and Cynodon nlemfuensis established well, maintaining 7 to 9 tillers/m² during the establishment period; a few stands of Cynodon nlemfuensis had to be replanted initially. Legume establishment was more varied with 26 to 127 plants/m² after 12 weeks. Germination, expressed as a percentage of the sown seeds that emerged, ranged from 38% to 79% (Table 3.3). Total soil cover was poor during the first 4 weeks, with all plots below 20%, but by 12 weeks after establishment, most treatments had over 50% soil cover, reaching 70% for B. ruziziensis/Aeschynomene histrix.

Assessment of the ability of the various mixtures to remain green (drought tolerant) in the dry season showed that plots with Chamaecrista rotundifolia were the first to be affected, being the only plots to have less than 50% green during the 1994/95 dry season (December 1994). Later in the same dry season (February 1995), only plots with Centrosema pubescens or Stylosanthes guianensis had over 45% green, with the maximum being 65% for Cynodon nlemfuensis/Centrosema pubescens.

All plots retained similar numbers of grass tillers into the second wet season, with a slight increase for Cynodon nlemfuensis because of its stoloniferous growth habit. Regeneration/germination of the legumes, monitored soon after the onset of the rains in the second year, was generally good; Chamaecrista rotundifolia had the highest number

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3. To prevent damage to too much of the plots during this sampling, quadrats of 0.5 x 0.5 m were used to sample before and after grazing.
of new seedlings and Centrosema pubescens the lowest. Soil cover was over 50% for all treatments 12 weeks after the rains started, reaching 88% for B. ruizien.sis/Centrosema pubescens; again, plots with Chamaecrista rotundifolia had the lowest soil cover.

Table 3.3. Legume germination and total plot soil cover of selected grass-legume mixtures during the 12-week establishment period.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Legume germination (%)</th>
<th>Soil cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 wap</td>
<td>8 wap</td>
</tr>
<tr>
<td>Brachiaria ruizien.sis/Stylosanthes guianensis</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>B. ruizien.sis/Aeschynomene histrix</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>B. ruizien.sis/Centrosema pubescens</td>
<td>68</td>
<td>72</td>
</tr>
<tr>
<td>B. ruizien.sis/Chamaecrista rotundifolia</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Cynodon nlemfuensis/S. guianensis</td>
<td>13</td>
<td>29</td>
</tr>
<tr>
<td>C. nlemfuensis/A. histrix</td>
<td>38</td>
<td>46</td>
</tr>
<tr>
<td>C. nlemfuensis/Centrosema pubescens</td>
<td>62</td>
<td>68</td>
</tr>
<tr>
<td>C. nlemfuensis/Chamaecrista rotundifolia</td>
<td>32</td>
<td>36</td>
</tr>
</tbody>
</table>

Least significant difference (P<0.05)

1. Estimated from comparing emergence with seeds sown.
wap = weeks after planting.

Pasture productivity and quality

Dry-matter productivity during the establishment period at the end of the wet season (November 1994) and in the middle of the 1994/95 dry season (January 1995) is shown in Figure 3.6 with quality parameters in Table 3.4. Treatments with Cynodon nlemfuensis had generally lower productivity than those with B. ruizien.sis except for the mixture with A. histrix where the legume produced far more than any other component, meaning this mixture had good productivity at both harvest dates. A. histrix yield with B. ruizien.sis was less than with Cynodon nlemfuensis, but was still the highest yielding legume.

Table 3.4. Quality parameters of grass and legume components during the establishment period.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>End of wet season 1994</th>
<th>Middle of 1994/95 dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass CP</td>
<td>Legume CP</td>
</tr>
<tr>
<td></td>
<td>Di</td>
<td></td>
</tr>
<tr>
<td>Brachiaria ruizien.sis/Stylosanthes guianensis</td>
<td>7.5</td>
<td>51</td>
</tr>
<tr>
<td>B. ruizien.sis/Aeschynomene histrix</td>
<td>5.6</td>
<td>41</td>
</tr>
<tr>
<td>B. ruizien.sis/Centrosema pubescens</td>
<td>4.7</td>
<td>46</td>
</tr>
<tr>
<td>B. ruizien.sis/Chamaecrista rotundifolia</td>
<td>5.2</td>
<td>45</td>
</tr>
<tr>
<td>Cynodon nlemfuensis/S. guianensis</td>
<td>8.1</td>
<td>46</td>
</tr>
<tr>
<td>C. nlemfuensis/A. histrix</td>
<td>6.8</td>
<td>46</td>
</tr>
<tr>
<td>C. nlemfuensis/Centrosema pubescens</td>
<td>8.9</td>
<td>nd</td>
</tr>
<tr>
<td>C. nlemfuensis/Chamaecrista rotundifolia</td>
<td>8.3</td>
<td>52</td>
</tr>
</tbody>
</table>

CP = crude protein %; Di = % 48-hour in sacco digestibility; nd = no data.
Forage Legumes in Subhumid West Africa

Productivities at the second harvest date were lower than at the first with the most marked reduction in yield recorded for the Cynodon nlemfuensis/Chamaecrista rotundifolia treatment. The proportion of Brachiaria ruziziensis was greater in all mixtures at the second harvest, with the exception of the A. histrix mixture where it remained at about 50%. At the end of the wet season all grasses had lower digestibility than legumes in the respective mixtures. By the middle of the dry season, grass digestibility was similar to the first harvest, or had increased slightly; most of the legumes showed similar digestibility values or a slight decrease, with the exception of Centrosema pubescens which showed an increase in both combinations. The digestibility values of Chamaecrista rotundifolia were the lowest with both grasses.

Estimates of dry-matter productivity before mob grazing in the early wet season (June 1995), mid-wet season (August 1995), end of wet season (October 1995) and mid-1995/96 dry season (December 1995) are shown in Figure 3.7.
Grass-legume mixtures for calf supplementation

B. ruzi = Bracharia ruziensis; S. gui = Stylosanthes guianensis; A. his = Aeschynomene histrix; C. pub = Centrosema pubescens; C. rot = Chamaecrista rotundifolia; C. nle = Cynodon nlemfuensis; LSD = least significant difference.

For all treatments and harvests, the productivities of associated grasses and other forbs were less than 15% of the totals, these are therefore excluded from the figure for clarity.


Figure 3.7. Estimated dry-matter yields of grass and legume components of small plots before mob grazing.

With the exception of Centrosema pubescens, in the early wet season legumes had higher productivities in the mixtures with Cynodon nlemfuensis and again, A. histrix had the highest legume yields with both grasses. Highest total yield at this time was for B. ruziensis/S. guianensis. Chamaecrista rotundifolia had low yield with B. ruziensis at this time and subsequently produced poorly in both mixtures. Regrowth after grazing, up to the next period in the middle of the wet season, was generally poor for all mixtures, with only B. ruziensis/A. histrix exceeding 5000 kg/ha. Regrowth of the grasses was better during the latter part of the wet season. By the end of the wet season, all mixtures with B. ruziensis had yields of almost 10,000 kg/ha, although the legume percentage in these mixtures was lower than in the Cynodon nlemfuensis mixtures. Centrosema pubescens had the highest legume yields with both grasses. By the middle of the dry season (December)
the highest legume yields with both grasses were for *Centrosema pubescens* and this was the only legume to maintain at least 50% composition in the mixture.

Selected quality parameters for the four grazing periods are shown in Table 3.5. Digestibility values are generally low for all harvests, especially for *A. histrix*. *Cynodon nlemfuensis* had lower digestibility values than *B. ruzizensis*. Crude protein values were generally higher in the wet than dry season and legumes had higher values than grasses, particularly at the end of the wet season (October). *Centrosema pubescens* had the highest CP values, and retained these into the dry season. During the wet season (June and August measurements), *A. histrix* seemed to have a positive effect on the CP value of the associated grass, although the CP value for the legume alone was not the highest; by the end of the wet season, this effect was less apparent. There was little variation in the P values, with a range between 0.10% and 0.21% over all the treatments from the early part to the end of the wet season. Grasses generally had higher P values than legumes, with the grass associated with *A. histrix* being among the highest at all harvest dates. *Centrosema pubescens* had the highest CP values among the legumes. Legumes had higher Ca than grasses at all harvest dates with *S. guianensis* often having the highest value. Ca/P ratios were mostly high with only *B. ruzizensis* with all legumes in the mid-wet season and with *S. guianensis* or *A. histrix* at the end of the wet season having values between 1.0–2.0. Only *A. histrix* at the end of the wet season had a value less than 1.0 (0.81) and values of this parameter for legumes were generally higher (about double) than those for grasses. The highest value was recorded for *Cynodon nlemfuensis/* *Chamaecrista rotundifolia* at the end of the wet season (20.5).

Table 3.5. Quality parameters of grass and legume components for the four grazing periods.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grass CP</td>
<td>Legume CP</td>
<td>Grass CP</td>
<td>Legume CP</td>
</tr>
<tr>
<td>Brachiaria ruzizensis/Stylosanthes guianensis</td>
<td>4.4 41</td>
<td>10.9 43</td>
<td>6.7 54</td>
<td>12.9 53</td>
</tr>
<tr>
<td>B. ruzizensis/Aeschynomene histrix</td>
<td>8.8 58</td>
<td>12.4 41</td>
<td>10.8 54</td>
<td>10.1 39</td>
</tr>
<tr>
<td>B. ruzizensis/Centrosema pubescens</td>
<td>4 43</td>
<td>13.1 39</td>
<td>8.5 47</td>
<td>18.8 55</td>
</tr>
<tr>
<td>B. ruzizensis/Chamaecrista rotundifolia</td>
<td>5.5 48</td>
<td>10.2 46</td>
<td>7 50</td>
<td>14.6 40</td>
</tr>
<tr>
<td>Cynodon nlemfuensis/S. guianensis</td>
<td>5 nd</td>
<td>9.6 43</td>
<td>9 44</td>
<td>12.9 45</td>
</tr>
<tr>
<td>C. nlemfuensis/A. histrix</td>
<td>8.2 46</td>
<td>9.8 40</td>
<td>13.6 46</td>
<td>12.4 39</td>
</tr>
<tr>
<td>C. nlemfuensis/Centrosema pubescens</td>
<td>4.5 nd</td>
<td>11.3 45</td>
<td>10.8 43</td>
<td>18.4 54</td>
</tr>
<tr>
<td>C. nlemfuensis/Chamaecrista rotundifolia</td>
<td>7 39</td>
<td>8.9 44</td>
<td>8.2 nd</td>
<td>14.6 38</td>
</tr>
</tbody>
</table>

CP = crude protein %; Di = % 48-hours in sacco digestibility at 48 hours; nd = no data.

Variations in NDF and ADF were not marked, especially for NDF where the range for all treatments at any harvest date never exceeded 10%. NDF values were higher for grasses at all harvest dates; *Cynodon nlemfuensis* had higher values than *B. ruzizensis* and all values (grass or legume) were highest at the end of the wet season when *Cynodon*
Grass-legume mixtures from calf supplementation

nlemfuensis with Chamaecrista rotundifolia reached 86% and 83% for the grass and legume, respectively. Lowest values were recorded in the middle of the wet season with several components recording 63% and S. guianensis reaching 61%.

Intake, calculated as the difference between the forage on offer and that remaining after the grazing period, is shown in Table 3.6. Zero intake is related to the absence of a particular component (Figure 3.7). For the first grazing period legumes were preferred to grass, except for A. histrix and the one Centrosema pubescens plot where productivity was very low. Total intake was highest for Cynodon nlemfuensis/Chamaecrista rotundifolia. In the middle of the wet season, legumes were again favoured over grasses, with the exception of B. ruizienisi/Chamaecrista rotundifolia plots. Intake for B. ruizienisi plots was generally higher than for Cynodon nlemfuensis except in the mid-wet season grazing; B. ruizienisi/A. histrix had the highest total intake. By the end of the wet season total intake declined, but the pattern was similar to that found earlier in the season. In the middle of the 1995/96 dry season, for those plots with legume present (i.e. not A. histrix), intake of this component was high, with all exceeding 50%. The highest total intake was for plots with Centrosema pubescens. Palatability indices generally showed little variation or trends; however, plots with Cynodon nlemfuensis were generally less palatable than those with B. ruizienisi for all measurement periods.

Table 3.6. Intake, expressed as a percentage of the dry forage on offer consumed on grass-legume plots.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Early wet season</th>
<th>Mid wet season</th>
<th>Late wet season</th>
<th>Mid 1995/96 dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachiaria ruizienisi/Stylosanthes guianensis</td>
<td>47 67 50</td>
<td>20 36 24</td>
<td>67 63 54</td>
<td>7 71 17</td>
</tr>
<tr>
<td>B. ruizienisi/Aeschynomene histrix</td>
<td>46 2 26</td>
<td>36 65 54</td>
<td>56 0 53</td>
<td>44 0 44</td>
</tr>
<tr>
<td>B. ruizienisi/Centrosema pubescens</td>
<td>42 85 54</td>
<td>23 55 36</td>
<td>57 78 64</td>
<td>23 73 62</td>
</tr>
<tr>
<td>B. ruizienisi/Chamaecrista rotundifolia</td>
<td>33 76 38</td>
<td>45 2 48</td>
<td>53 26 46</td>
<td>43 67 47</td>
</tr>
<tr>
<td>Cynodon nlemfuensis/S. guianensis</td>
<td>45 64 57</td>
<td>41 49 48</td>
<td>14 60 18</td>
<td>23 64 11</td>
</tr>
<tr>
<td>C. nlemfuensis/A. histrix</td>
<td>50 63 58</td>
<td>44 47 48</td>
<td>30 80 13</td>
<td>14 50 33</td>
</tr>
<tr>
<td>C. nlemfuensis/Centrosema pubescens</td>
<td>58 11 58</td>
<td>26 44 42</td>
<td>15 82 36</td>
<td>62 97 73</td>
</tr>
<tr>
<td>C. nlemfuensis/Chamaecrista rotundifolia</td>
<td>48 95 73</td>
<td>8 23 20</td>
<td>27 0 24</td>
<td>5 75 22</td>
</tr>
</tbody>
</table>

G = grass; L = legume.

Discussion

Some of the grasses and legumes used in this study had been used in grass-legume grazing trials before, although in different combinations (e.g. Oyenuga and Olubajo 1975; Adegbola and Onayinka 1976; Akinola 1981; Lazier and Clatworthy 1990). Aeschynomene histrix and Chamaecrista rotundifolia had not previously been reported in
combination with grasses in this region. Establishment of all components was generally comparable with other reports. *A. histrix* had particularly good establishment, especially in the *Cynodon nlemfuensis* plots, and this was reflected in the high yields of *A. histrix* during the initial assessment of productivity. Performance of the legumes and grasses in the dry season was also similar to previous reports; Oram (1984) reported that *Chamaecrista rotundifolia* is not drought tolerant while Mendoza et al. (1990) reported that *Stylosanthes guianensis* and *Centrosema pubescens* have good drought tolerance. *Brachiaria ruziziensis* seemed to be the more vigorous of the two grasses, having the highest grass and lowest legume yields during the initial productivity assessments. Oyenuga and Olubajo (1975) also reported that tall grasses tended to be higher yielding than creeping types but that the creeping types tend to persist better eventually because their stoloniferous habit is more tolerant of grazing. This was observed in our study where the *Cynodon nlemfuensis* yielded higher than *B. ruziziensis* at the end of the experiment but the *B. ruziziensis* out-competed the legumes and had the highest yield in the initial stages. This may be related to the more upright and faster growth habit of *B. ruziziensis*, meaning it would have shaded out the legumes more quickly than the *C. nlemfuensis* which, although it has a stoloniferous, creeping growth habit, tends to grow slower and was itself out-competed by the *A. histrix* especially during the establishment phase (Figure 3.6).

Typically, grasses were of lower quality in terms of crude protein and digestibility than the legumes, although *Chamaecrista rotundifolia* had low CP by the middle of the dry season, reflecting the fact that it was very dry by this time. Oram (1984) reports that *C. rotundifolia* is persistent under grazing, but relates this to seedling recruitment, a feature not assessed in our study. Indeed, several authors have reported that this species has a relatively low palatability, as observed in this study, and that this may contribute to its persistence (Ahn et al. 1988; Partridge and Wright 1992).

The seemingly high dry-matter yields recorded for the first period of mob grazing may well be related to the sampling procedure, where 0.25 m\(^2\) quadrats were used. These are known to easily give over-estimates, especially in dense stands, and comparing a series of regressions on similar grass-legume pastures using both 1.0 m\(^2\) and 0.25 m\(^2\) quadrats indicated that this was indeed the case (S.A. Tarawali, unpublished). If these regression equations were applied to the data in this study, the yields for the first harvest in the early wet season would be reduced, but there were little differences for the other three sampling dates, when the yields were lower and therefore easier to assess with the smaller quadrats; the relative proportions of the legume and grass components were not affected. On this basis, the yields presented can be considered acceptable, with the proviso that they are likely to be overestimates for the first harvest.

Repeated mob grazing over the 6-month period led to an inevitable decline in productivity (Oyenuga and Olubajo 1975), especially of the legumes, which virtually disappeared in most plots, with the exception of *Centrosema pubescens*. *A. histrix*, vigorous and the most productive in the early stages, maintained its presence for the first two grazing periods, but had almost disappeared by the third in the *B. ruziziensis* mixture and by the fourth grazing in the *Cynodon nlemfuensis* mixture. Similar lack of persistence under constant cutting pressure for *A. histrix* has been reported (CIAT 1995a) although
Grass-legume mixtures for calf supplementation

it would be interesting in our case to assess the regeneration in the following wet season, since this species seeds profusely (Tarawali 1994a) and has persisted, largely through seedling recruitment, in other studies in the region (Chapter 4; Peters et al 1998b; Peters et al 1999b). *Cynodon nlemfuensis* constantly had lower quality parameters than *B. ruizienis*, and this is even suggested by the morphology of the two species, *B. ruizienis* being more lush and green. *Centrosema pubescens* maintained the best quality and was the most persistent, a result that is consistent with that of similar studies where the species remained at least 31% of the total pasture yield under grazing pressure (Akinola 1981; Lazier and Clatworthy 1990). *A. histrix* seemed to exert a positive effect on the quality of the associated grass, even though the intrinsic quality values of the legume alone were not exceptional. Similar, apparently synergistic effects of legumes in combination with other plants have been reported (Peters et al 1997c; G. Tarawali personal communication). The low CP of *Chamaecrista rotundifolia* amongst the legumes is again not surprising when compared with previous results (Ahn et al 1988), and with its inability to resist drought, as evidenced by the dramatic drop in CP by the end of the wet season in 1995.

Legumes tended to have lower P and higher Ca than the associated grasses in this study, and this resulted in generally high Ca/P ratios, outside of the recommended range for livestock nutrition (0.5–2.0, cited in Peters 1992). Only in the middle of the wet season were the ratios within the recommended range, and this may have been related to the application of a top dressing of P some weeks before this assessment period as well as the favourable growth conditions around this time of the year. This lends support to the concept that P fertilisation of such pastures is important to maintain the nutritive balance of the herbage on offer, as well as to encourage plant growth.

Measurements of intake, as carried out in our study, give an indication of the relative palatability of the various species; however, the method used to make the measurements makes intake a function of availability. When a species is present in very small amounts, intake can easily present a distorted impression of potential palatability. Such values should therefore be interpreted with caution, especially for the two last grazing periods. Nevertheless, the study can give some indications. Generally, *A. histrix* seemed not to be preferred in the early wet season, and *Chamaecrista rotundifolia* was less acceptable in subsequent periods. Towards the end of the study, *Cynodon nlemfuensis* seemed to be the less favoured of the two grasses, except when in combination with *Centrosema pubescens* which may be related to the quality differences. Several authors have reported that livestock are able to select the most nutritious forage (e.g. Joblin 1962). A combination of both intake and relative palatability assessments may be more useful in determining the animals' preferences (Peters et al 1998b).

Small-plot grazing trials, such as described here, can be used to provide useful information on the potential of grass-legume combinations. Nevertheless, the complex of interrelated factors governing the outcome needs to be carefully considered (Paladines and Lascano 1993). In our study, albeit short term, the indications are that different species have advantages at different times, and under various conditions. For example, *B. ruizienis/A. histrix* could be a very productive combination for fast establishment and low grazing pressure, but this grass with *Centrosema pubescens* could have better nutritive value, especially in the dry season. *Cynodon nlemfuensis/Centrosema*
pubescens would be less productive in the initial stages, but could provide a more sustained pasture over a longer grazing period. Factors such as these need to be considered in relation to the farming system and the particular problem to be addressed by introducing grass-legume mixtures. In the context of providing year-round calf supplementation, a mixture of the two grasses with possibly A. histrix and Centrosema pubescens may be a good option, although some attention would need to be given to pasture dynamics if such mixtures were used.

Experiment 3: Assessment of the problems of and opportunities for calf rearing: The perceptions of farmers in Oyo State, Nigeria

Materials and methods

Three areas for survey were selected to represent the northern, central and southern parts of Oyo State, namely, Saki, Ogbomoso and Oyo, respectively (Figure 1.1). Fifteen farmers in each area were interviewed, making a total of 45 farmers. Each farmer was visited only once, and a questionnaire administered. This brief survey was carried out during July and August 1995.

Results

All the 45 farmers interviewed owned cattle, with a mean herd size of 19 and a range of 4 to 45 animals; Bunaji and N'Dama phenotypes were found. Most (80%) of the calves were born in the wet season, with an average of 7 calves born alive during the 12 months before the survey, of which at least 1 died before reaching the age of 4 months. Farmers reported that, on average, 3 calves would die each year, with a range of 0 to 8 deaths. The majority of deaths were in the wet season and all farmers attributed death to diseases, but most failed to acknowledge the relationship between disease and poor nutrition. Estimates of calf mortalities ranged between 14% and 42%. All farmers allowed their calves to wean naturally and weaning age varied from 7 to 12 months, with an average of 10 months. All farmers gave calves feed supplements in both wet and dry seasons, but this consisted of mineral salt lick and browse for 60% of those interviewed, with the remaining 40% giving only salt lick. Farmers spent on average 51.00 Naira (₦) per month on supplement for calves. Calves were allowed to follow the herd for grazing from about 9 months of age, although they started nibbling grass around the homestead from about 3 months old.

Discussion

The brief on-farm survey seems to largely confirm results obtained in previous surveys in this and other similar regions with respect to the reproductive performance of cattle on

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4. At the time of the survey ₦ 80.00 = US$ 1.00.
Grass-legume mixtures for calf supplementation

farm. In general, the poor condition of calves and the overall effects on herd productivity were clearly indicated with low calf production, probably reflecting the poor nutrition condition of the female animals and high mortality. Late and indiscriminate weaning, as currently practised by the local farmers, is probably a strategy to try and ensure maximum calf survival in the absence of alternative nutrition for the young animals. Most reports emphasise not only the importance of calf nutrition and weaning practices, but also that of the dam, an aspect addressed to some extent by studies on legume mixtures (Chapter 4; Peters et al. 1998b). Little et al. (1994) reported mortalities of 14–24% for N'Dama calves in The Gambia, with weaning as late as 14 months. De Jode et al. (1992) reported that calf mortalities in the Oyo area were greatest at 2–4 months of age with up to 29% recorded in the wet season. Rege et al. (1993b) also reported higher mortality (up to 15%) for Bunaji calves in the wet season in northern Nigeria, and showed on-farm evidence for the effects of poor calf nutrition of the subsequent reproductive performance of female animals. Slow early growth of female calves, whether weaned or not, results in late onset of oestrus and therefore low herd productivity (Mukasa-Mugerwa 1989). Tegegne et al. (1994) recommended restricted suckling and early weaning with appropriate supplements for calves and dams to increase productivity for peri-urban dairy systems using crossbred animals. Albospino and Labato (1993) showed that weaning as early as 100 days had no detrimental effects on crossbred calf performance in Brazil.

This study indicates that farmers are aware of the problems but not of the solutions, although their attitude towards providing salt licks suggests that they would not be averse to supplementation practices, if available. The experiments reported above on the use of grass-legume mixtures for calf supplementation suggest that this may be a viable approach towards alleviating the constraints limiting the growth and performance of young cattle.
4 Evaluation of selected legume-legume mixtures for supplementation of dairy cattle

Introduction

Earlier forage legume screening work identified accessions with good potential as forage material for the moist savannah regions of West Africa (see Chapter 1). These included Aeschynomene histrix, Centrosema brasiilianum, C. pascuorum, C. pubescens, Chamaecrista rotundifolia, Stylosanthes guianensis and S. hamata (Mohamed-Saleem and Otsyina 1984; Tarawali et al 1989; Tarawali 1991b; Peters 1992; Peters et al 1994a; Peters et al 1994b; Tarawali 1994a; Tarawali 1994b; Tarawali 1995b). However, none of the selected accessions had all the desired properties of an 'ideal' legume: Centrosema pascuorum was good in the establishment period, but disappeared subsequently (Peters 1992); Centrosema brasiilianum and C. pubescens were slow to establish, but remained green in the dry season (Tarawali 1991b; Peters 1992); Aeschynomene histrix, Stylosanthes guianensis and S. hamata could provide good fodder for a number of years, but did not remain green throughout the dry season (Peters 1992; Peters et al 1994a; Peters et al 1994b; Tarawali 1994a; Tarawali 1995a). Mixtures of legumes therefore have the potential to overcome the limitations of single-species stands in several respects including establishment (Aiken et al 1991a; Aiken et al 1991b); weed suppression and disease tolerance (Walker and McKeague 1985; Chakrabarty et al 1991); quality maintenance (Brown et al 1991) and soil fertility (Oyer and Touchton 1990). With this background, in order to provide a sustainable, year-round legume-rich pasture, studies were initiated to test complementary mixtures of these previously identified accessions.

Several experiments were established to investigate the potentials of various forage legume accessions in mixtures. These included palatability evaluation of the various species to provide backup information for mixing species together, small-plot trials comparing the performance under grazing of sole species and combinations and a large grazing trial where selected combinations were established for use as supplementary pastures for young heifers on a year-round basis so that the effects of such species combinations on animal growth could be monitored. The large grazing trial included four legume-legume mixtures, each consisting of four species. Centrosema pascuorum and Arachis pintoi were included in all the mixtures on the basis that C. pascuorum was known to give excellent establishment cover and yields, although without persistence, and A. pintoi had been shown to provide a stable ground cover for a number of years in similar environments in South America (Lascano 1994). Each mixture also contained either Stylosanthes guianensis or Aeschynomene histrix, included to give good biomass yields for a number of years, and either Centrosema pubescens or C. macrocarpum to give green forage C. macrocarpum had shown an excellent potential in similar environments in South America (Schultze-Kraft 1990). C. brasiilianum was not included because this trial was established in the derived savannah region, and the somewhat wetter conditions may

1. The results presented in this chapter have been previously reported in Peters et al (1997, 1998b, 1999a, 1999b).
have increased the risk of *Rhizoctonia* disease, to which this species is prone (Lenné et al 1990).

**Experiment 1: Relative palatability and seasonal agronomic performance of selected pasture legumes for species mixtures in subhumid West Africa**

**Materials and methods**

**Establishment**

The trial was established at the onset of the wet season (June 1993) at Mando Road in the northern Guinea savannah. Soil characteristics of the experiment site are shown in Table 4.1.

<table>
<thead>
<tr>
<th>Soil characteristics of the Mando Road experiment site.</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Values are in cmol+/kg unless otherwise indicated; N = nitrogen; OM = organic matter; P = available phosphorus, Bray 1; Ca = calcium; Mg = magnesium; Mn = manganese; K = potassium; Na = sodium; Tot acid = total acidity; EfCEC = effective cation exchange capacity.


Three adjacent ‘blocks’ were established, each consisting of nine accessions (*Aeschynomone histrix* ILRI 12463, *Centrosema brasilianum* ILRI 155 and 6773, *Centrosema pascuorum* ILRI 9857, *Chamaecrista rotundifolia* ILRI 10918, *Stylosanthes guianensis* ILRI 164 and 15557, *Stylosanthes hamata* ILRI 75 and 15876) planted on 4 x 5 m plots in a randomised complete block design with 3 replications (27 plots). One block served as an adjustment block before each grazing period, the other two were used for alternate grazing periods. Seeds were sown into well prepared soil, with 150 kg/ha SSP at planting and a top dressing of 100 kg/ha at the start of the following wet season. Plots were maintained weed-free throughout the experiment.

**Data collection**

Establishment was monitored by counting seedlings and estimating soil cover 4, 8 and 12 weeks after planting. Diseases, pests and drought tolerance (leafiness and greenness) were estimated by ‘scoring’. Dates of peak flowering and seeding were recorded.

Dry-matter productivity was estimated by cutting two 1 m² quadrats from each plot before and after grazing at the beginning and end of the 1993/94 dry season, in the middle of the 1994 wet season and in the middle of the 1994/95 dry season. Dry samples were ground and assessed for crude protein (CP) and 48-hour in sacco digestibility (Osuji et al 1993).
Before each grazing period, three Bunaji steers were allowed to graze the adjustment block freely for one week. Grazing on the experimental blocks was for 4 hours a day after overnight fasting; the grazing periods lasted for 15, 18, 13 and 9 consecutive days for the four measurement periods, respectively. Plots were cut to a uniform 15 cm above ground level after each grazing and assessment period. During grazing, preference was estimated every 5 minutes and a relative palatability index calculated using the cafeteria method (Schultze-Kraft et al 1989b), where a score of 1.00 means no positive or negative selection. This method of assessment was compared to the difference method, based on the forage consumed (Warmke et al 1952).

Results

Establishment and phenology

All the legumes established well: the highest seedling densities were for *Stylosanthes guianensis* and *Aeschynomene histrix* accessions (over 35 plants/m²). Following the onset of the rains in the second year, few new seedlings were found, but all accessions except *C. pascuorum* had some perennating plants. Soil cover in the establishment year was initially slow, but after 16 weeks ranged from 25–28% (*C. brasiliianum* and *S. hamata* accessions) to 42–46% (*S. guianensis* and *C. pascuorum* accessions). Different accessions had varying rates of soil cover; but by the end of the second wet season, soil cover was 57% to 72%, except for *C. pascuorum* (37%). Grazing in the 1994 wet season resulted in higher soil cover than in the ungrazed plots.

Accessions flowered between 84 and 133 days after planting, with *Chamaecrista rotundifolia* and *Centrosema brasiliianum* having the earliest and latest flowering dates, respectively. All accessions had low leafiness at the end of the first dry season, but *Centrosema brasiliianum* had the best and *Centrosema pascuorum* the least ability to remain green throughout the dry season. Disease and pest incidences and severities were minimal, never exceeding 15% for any disease on any accession.

Productivity and palatability

Dry-matter yields before the four grazing periods are shown in Table 4.2. *S. guianensis* accessions had the highest yields while *Chamaecrista rotundifolia* and *S. hamata* had the lowest; *Centrosema pascuorum* yields declined sharply in the second year.

Nutritive value, in terms of CP and 48-hour in sacco digestibility was highest for all accessions in the middle of the 1994 wet season. *S. guianensis* ILRI 15557 consistently had the highest values at all four measurement periods, reaching a maximum of 12.1% CP and 60% digestibility. The lowest digestibilities were recorded for *C. brasiliianum* ILRI 6773 and *A. histrix* at the end of the 1993 dry season, *C. brasiliianum* in the 1994 wet season and *A. histrix*, *C. pascuorum* and *Chamaecrista rotundifolia* in the middle of the 1994 dry season. Crude protein and digestibility values were linearly related for each of the three dry season periods, but not for the wet season.
Table 4.2. Dry-matter yields (kg/ha) of legume plots before grazing.

<table>
<thead>
<tr>
<th>Accession</th>
<th>Dry-matter yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start dry season</td>
</tr>
<tr>
<td>Aeschynomene histrix112463</td>
<td>697</td>
</tr>
<tr>
<td>Centrosema brasiliannum 1155</td>
<td>1163</td>
</tr>
<tr>
<td>C. Brasiliannum 16773</td>
<td>963</td>
</tr>
<tr>
<td>C. pascuorum19857</td>
<td>1029</td>
</tr>
<tr>
<td>Chamaecrista rotundifolia 110918</td>
<td>487</td>
</tr>
<tr>
<td>Stylosanthes guianensis 1164</td>
<td>2304</td>
</tr>
<tr>
<td>S. guianensis 115557</td>
<td>2591</td>
</tr>
<tr>
<td>S. Hamata 157</td>
<td>799</td>
</tr>
<tr>
<td>S. Hamata 115876</td>
<td>1197</td>
</tr>
<tr>
<td>Standard error (SE)</td>
<td>471</td>
</tr>
</tbody>
</table>


Intake, measured as a percentage of forage on offer that was eaten, was highest for all four grazing periods for the S. guianensis accessions; other accessions were eaten to significantly different extents, depending on the grazing period. For example, the intake value was high for C. pascuorum at the end of the 1993 dry season, but, together with S. hamata ILRI 15876 had the lowest intake values in the 1994 wet season. More than 88% of all accessions were eaten during the final grazing period. S. hamata ILRI 15876 had consistently higher intake values than S. hamata ILRI 75.

Palatability indices again indicated positive selection for the S. guianensis accessions for all grazing periods. C. pascuorum, S. hamata ILRI 75 and A. histrix were never positively selected for. C. brasiliannum was selected for in the middle of the 1994 dry season.

A series of regressions indicated that, whilst there were no significant relationships between the two methods of palatability assessment, linear relationships did exist between the palatability indices and leafiness estimates in the dry seasons.

Discussion

This study was designed to provide information on the yield, persistence of and animal preferences for selected legume accessions, as a prelude to using them in mixtures for pasture establishment.

Performance of most of the accessions was as reported in previous trials in the region. Centrosema pascuorum grew well initially, but dried up quickly and did not persist in the second year (Peters et al 1994a; Peters et al 1994b). Stylosanthes guianensis accessions gave consistently good yields of high quality and persisted well (Tarawali 1994a). Yields of Chamaecrista rotundifolia, Aeschynomene histrix and Stylosanthes hamata accessions were generally lower than previously reported (Peters et al 1994a; Peters et al 1994b; Tarawali 1994a, Tarawali 1995a) in the region, and this may be related to the extremely poor soil conditions at the trial site. Such somewhat unexpected variations in
performance by some, but not all, species strengthens the concept that mixtures of legume species would offer a better opportunity of having good productivity regardless of micro-environment variations. In contrast to most of the material, Centrostepha brasiiliunum had good greenness, drought tolerance and persistence during the dry season (Peters 1992; Peters et al 1994a) and therefore, this or similar species would be an important component of a mixture to ensure that legume was available for the whole year.

The different species varied in their soil cover rates at different times during the experiment lending support to the idea that mixtures of legume species would be able to provide a more stable cover throughout the year, with different components contributing at various times. This has important implications not only for ensuring a year-round fodder supply, but also for maintaining soil cover and arresting erosion (Clements et al 1984).

The results showed differences between the two accessions of Stylosanthes hamata and of S. guianensis in terms of intake and quality. These differences indicate that the performance of a single accession of a species should not be interpreted as entirely representative of all the available variation and that, once interesting species are identified, it may be appropriate to test as many accessions as possible. The S. hamata ILRI 15876 was identified as a result of such an evaluation of a collection of 163 accessions of this species (Tarawali 1995a). Intra-species variations, especially in forage quality also offer new opportunities for plant breeding using biotechnology approaches to identify molecular markers for quality traits (Singh and Tarawali 1997).

The two methods of assessing palatability provide different types of information and results from the two were therefore not correlated. The intake (difference) method indicates whether an accession is eaten or not and results from such assessments may be influenced by the amount of forage on offer. In this study, the apparent high intake of S. guianensis could be related to its high productivity, but this is unlikely since the cafeteria method of assessment also indicated preference for this species. The cafeteria method, which gives a palatability index, provides more information on the relative preferences for the different accessions. Information from both methods is useful when considering the use of legume mixtures as well as other pasture situations. The positive correlation between relative palatability and leafiness is not surprising, but does not mean that material that dries up will not be eaten, only that it is likely to be eaten after the green material has been exhausted. Dry C. pascuorum or S. hamata in pastures were readily eaten by cattle (Mani 1992).

Chamaecrista rotundifolia generally had fairly low palatability and this has been indicated in several other studies (Partridge and Wright 1992; Quirk et al 1992) although in our study, and in other similar work in the region, the palatability of this species seems to be more related to the quantity of forage on offer. There is some evidence to suggest that cattle become used to grazing A. histrix such that it changes from being selected against to becoming a preferred species (Experiment 3, this chapter; Peters et al 1998b; Peters et al 1999b). Such 'adaptation' to 'new' species has been reported in other instances (Marten 1978; Lascano et al 1985; Carulla et al 1991).

Nutritive values obtained in this study were generally comparable to results from this region (Peters 1992; Tarawali 1994a; Tarawali 1995a). The values for Stylosanthes and
Legume-legume mixtures for dairy cow supplementation

Centrosema, were also comparable to those from other regions (McCosker 1987; Winter et al 1989). *Stylosanthes guianensis* ILRI 15557 is particularly interesting because of its high nutritive value, good productivity and palatability; it is also known to show good tolerance of anthracnose disease (Tarawali 1994a). The positive correlation between CP and digestibility agrees with that reported by Minson (1990) for the dry season values; the variance when applied to wet season results may be related to the large variations in quality at this time of year, but further research would be required to clarify this.

Many of the results obtained support the idea that legume mixtures are likely to be more stable and ultimately more beneficial than single species which may have predictable (such as susceptibility to drought) as well as unpredictable (such as reactions to variations in micro-environment or management) limitations.

**Experiment 2: Evaluation of the agronomic performance of selected forage legumes in sole and mixed plots**

**Materials and methods**

**Establishment**

The trial was established at the beginning of the wet season (May 1994) at Fashola in the derived savannah. General soil features of the experimental site are shown in Table 4.3. The 10 treatments consisted of four mixtures of legumes (Mix 1: *Centrosema pascuorum*, *Stylosanthes guianensis*, *C. pubescens*, *Arachis pintoi*; Mix 2: *C. pascuorum*, *Aeschynomene histrix*, *C. pubescens*, *Arachis pintoi*; Mix 3: *C. pascuorum*, *S. guianensis*, *C. macrocarpum*, *Arachis pintoi*; Mix 4: *C. pascuorum*, *Aeschynomene histrix*, *C. macrocarpum*, *Arachis pintoi*) plus six sole legume plots (*Centrosema pascuorum* ILRI 9857; *Stylosanthes guianensis* ILRI 164; *Centrosema pubescens* ILRI 152; *Arachis pintoi* CIAT 17434; *Aeschynomene histrix* ILRI 12463 and *Centrosema macrocarpum* CIAT 5713).

<table>
<thead>
<tr>
<th>Total N (%)</th>
<th>OM (%)</th>
<th>P (ppm)</th>
<th>Ca (ppm)</th>
<th>Mg (ppm)</th>
<th>Mn (ppm)</th>
<th>K (ppm)</th>
<th>Na (ppm)</th>
<th>Cu (ppm)</th>
<th>Zn (ppm)</th>
<th>Tot acid (ppm)</th>
<th>EfCEC (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.082</td>
<td>0.66</td>
<td>6.73</td>
<td>3.11</td>
<td>1.22</td>
<td>0.29</td>
<td>0.23</td>
<td>0.23</td>
<td>1.2</td>
<td>2.7</td>
<td>0.38</td>
<td>5.46</td>
<td>7</td>
</tr>
</tbody>
</table>

Values are in cmol +/kg unless otherwise indicated; N = nitrogen; OM = organic matter; P = phosphorus; Ca = calcium; Mg = magnesium; Mn = manganese; K = potassium; Na = sodium; Cu = copper; Zn = zinc; Tot acid = total acidity; EfCEC = effective cation exchange capacity.


Scarified legume seeds were broadcast onto well prepared soil on 4 × 5 m plots in a randomised complete block design with 4 replications. Sowing rates of the legumes were adjusted in the mixtures to give one-quarter of the recommended rate for each component. At planting, 200 kg/ha SSP was applied, with a top dressing of 100 kg/ha at the start of the 1995 wet season. Plots were hand-weeded only twice, about 3 and 6 weeks after planting to ensure good establishment.
Numbers of sown legume plants were counted in two randomly located 1 m² quadrats per plot 4, 8 and 12 weeks after planting, and at similar intervals after the onset of the rains in 1995. Soil cover of the sown legumes was estimated using the two 1 m² quadrats per plot, at the same time. Flowering, seeding, disease incidence and drought tolerance were estimated as described for Experiment 1.

**Productivity and forage quality**

Dry-matter productivity was assessed by cutting two 1 m² quadrats per plot towards the end of the minor wet season in 1994 (October), in the middle of the 1994/95 dry season (January 1995), in the early wet season of 1995 (June) and at the end of the 1995 minor dry season (August). At each harvest date, dry-matter yields of the sown legumes, other grasses and herbs were determined and samples of each component analysed for 48-hour in sacco digestibility (Osuji et al 1993) and CP (micro-Kjeldahl).

**Palatability and intake**

After each of the four harvest dates, three White Fulani heifers grazed on the plots for 7 h/day until most vegetation was 15–25 cm above ground level. Samples were again harvested as above to determine the remaining dry-matter yields of the various components then the plots were all cut down to 10–15 cm above the ground. During the grazing period, the number of animals on each plot was recorded every 5 minutes and used to calculate a palatability index using the cafeteria method (Schultze-Kraft et al 1989b; Peters et al 1999a).

**Results**

**Establishment and phenology**

*Arachis pintoi* did not establish in any plot, mainly due to predation by birds and rodents, but also because of the slow growth of the few seeds that did germinate. For the other treatments, plant densities ranged from 12 to 18 plants/m² in the mixture plots, and 7 (C. pascuorum) to 33 (S. guianensis) plants/m² in the single species plots in the establishment period. Twelve weeks after planting, all plots had soil cover of 88% or more. During the first 8 weeks of establishment, mixture plots had higher soil cover than single species plots, except for *C. pascuorum* which was as high as the mixtures.

All species flowered towards the end of the rains (November 1994) but seed production was low for *S. guianensis* and negligible for *C. macrocarpum. Aeschynomene histrix*, *C. pascuorum* and *C. pubescens* all had high total seed yields. These seeding patterns were generally reflected in the composition of the plots at the onset of the following wet season, notably for *Aeschynomene histrix* plots which had very high numbers (up to 100 plants/m²) of new seedlings, although *C. pascuorum* failed to persist at all. *C. macrocarpum* and *C. pubescens* had the best ability to perenniate, with 10 or more plants/m² surviving the dry season. Soil cover was generally slower in the second season,
and, in contrast to the establishment year, the mixtures were slower than the single species in covering the soil. Nevertheless, all plots had soil cover over 50% by 12 weeks after the onset of the rains, except for S. guianensis (33%); cover continued to increase up to 24 weeks by which time all plots had soil cover over 70%, with, again, S. guianensis lower at 55%. After 24 weeks, the percentage of legume in all plots was similar and there was very little native vegetation (grasses or herbs).

Drought tolerance, estimated as percentage greenness during the two dry seasons, indicated that C. pascuorum dried up almost as soon as the rain stopped while Aeschynomene hisrix and S. guianensis remained green well into the dry season, but less so in the second dry season. C. pubescens and C. macrocarpum had the best drought tolerance, and this was higher in the second dry season when both had over 65% green at the end of the dry season.

Disease did not present a major problem for any of the species under evaluation in this experiment. Anthracnose and Rhizoctonia were recorded, but incidence and severity were rarely above 5%, and never over 15%.

**Productivity and forage quality**

Dry-matter productivities are shown in Figure 4.1 for the four harvest dates. At the first harvest, S. guianensis had the highest yield of about 8000 kg/ha. Mixture plots yielded between 3000 and 4000 kg/ha and the lowest yields were recorded from C. pubescens and C. macrocarpum single species plots. Regrowth was good for all plots by the second harvest, and legume litter was also present in amounts ranging from 500 to 2000 kg/ha. The highest yield was again from S. guianensis with lowest from C. pascuorum. Mixture plots all yielded over 6000 kg/ha (including litter). By the third harvest, grasses and herbs had increased; these components were negligible in earlier harvests. The highest legume yields were for Aeschynomene hisrix and C. macrocarpum single species. Total yields of all other treatments consisted of less than 50% legume. Mixtures yielded between 1500 and almost 3000 kg/ha legume; the lowest yield was recorded for mixture 1. Yields were slightly higher by the fourth harvest, with a similar pattern to that of the third harvest, with increased legume percentages in the treatments, with only mixture 1 having less than 50% legume. The legume component in mixtures 3 and 4 consisted almost entirely of C. macrocarpum, whereas in mixtures 1 and 2 C. pubescens made up about half the legume component with S. guianensis and Aeschynomene hisrix, respectively.

Crude protein values for the legumes in single species and mixture plots are shown in Figure 4.2. All values decreased in the dry season, but did not fall below 7% at any time. The values of individual legume species in mixtures were generally higher than those for the respective species in single legume plots and this effect was most dramatic for C. macrocarpum (Figure 4.2). C. pubescens had the highest values. In the major dry season, litter for all treatments had CP values over 10% whereas at the same time, CP values for the associated grasses fell below 6.5%.

In *sacco* digestibility at 48 hours was highest for the first harvest and lowest for the major dry season harvest for all species. Maximum values, reaching 69%, were obtained.
Forage Legumes in Subhumid West Africa

Figure 4.1. Dry-matter yields of small plots of selected legumes before mob grazing at four harvest dates.

M1 = Mix 1; M2 = Mix 2; M3 = Mix 3; M4 = Mix 4; C. pa. = Centrosema pascuorum; S. g. = Stylosanthes guianensis; C. pu. = C. pubescens; A. h. = Aeschynomene histrix; C. m. = C. macrocarpum.
Source: Peters et al. (1999b).

for associated grasses at the first harvest, but generally values ranged between 40% and 55% with no clear pattern.

Palatability and intake

Mixtures 2, 3 and 4 were positively selected for at all times. Mixture 1 was generally not selected for except during the first 5 days of the first harvest, when there was a very high...
positive selection. *C. pascuorum* was selected positively in the dry season, but since it did not persist, was not analysed subsequently. *S. guianensis* was selected against in the dry season, but positively at other times; the other single legume species had very low palatability indices at all times.

Variations in intake were slight, with totals ranging between 62% and 83% of the dry matter on offer. There was some indication of higher intake of grasses than legumes in the wet season measurement periods. *C. pubescens* and *S. guianensis* had slightly lower intakes at all times, especially in the early wet season.

**Discussion**

Performances of the legume species used in this experiment were generally similar to those recorded previously (Peters et al 1994a; Peters et al 1994b; Tarawali 1994a) in the region. *C. pascuorum*, with an annual growth habit, dried up as soon as the rains ceased and did not persist into the second year. *Aeschynomene histrix* and *S. guianensis* showed...
some drought tolerance and excellent seed production and consequently, seedling recruitment the following season, especially for *Aeschynomene histrix*. The other *Centrosema* accessions perennated well, with good drought tolerance. *Arachis pintoi* had not been previously tested in the region, but had been reported to perform well in pastures in similar ecologies in South America (Carulla et al 1991); its failure in our study was, however, compensated for in the mixture plots by the other species present. By the end of the study, all mixture plots had maintained at least 50% legume, although the composition of this had changed over the course of the experiment. In contrast, plots with *C. pascuorum* or *Arachis pintoi* single species had no legume at all, thereby emphasising the value of using legume mixtures for their ability to compensate for failure of any component of the mixture. Although in this study, single species yields of *C. pubescens*, *C. macrocarpum* and *Aeschynomene histrix* were higher than those of the mixture plots at the end of the experiment, yields of the mixture plots tended to be more stable than those of the single species plots. Mixture plots also seemed to be more palatable throughout the year than most of the single species plots which showed much more varied, and usually lower, palatability.

The apparent synergistic effect of the legume mixtures on crude protein concentration in the component species is of interest. This may be related to *Rhizobia* interactions, or other nutrient factors. Similar findings were reported by Peters et al (1997) with different species combinations, and by G. Tarawali (unpublished) where the combination of a freely nodulating legume, *Stylosanthes hamata*, with a non-nodulating species, *S. capitata*, showed that the CP content of *S. hamata* was increased by at least 2% when grown in combination than when grown as the sole species. Mixtures of the two species also gave higher forage and subsequent maize yields, further supporting the concept that legumes in mixtures exert synergistic effects.

*Centrosema macrocarpum* showed an outstanding performance, both in single species and mixture plots, with the exception of its ability to produce seeds. Whilst this was not a drawback in our study since the plants perennated and regrew well the following season, it does represent a potential limitation to the adoption of the species in the region, since seeds need to be available for technology dissemination. In view of the apparent potential of the species, further studies targeted at understanding and improving seed production may be worthwhile. Observations of limited pod formation under certain conditions in South America prompted further studies of the flowering/seeding physiology of the species in this region, and indicated that insect pollination is obligatory, with most accessions showing preference for cross pollination (Escobar and Schultze-Kraft 1990).

The implication of the results from this study is that mixtures of legumes are easier to establish and manage for maintenance of a stable legume component in pastures than are single species stands. This means such mixtures are more flexible in response to environmental and management variations and would therefore be more likely to succeed with farmer management. Reátegui et al (1995) reported similar findings in an on-farm situation in Perú where, despite varying farmer management practices, by using a combination of legumes with contrasting establishment and persistence features, stable pastures were maintained.
Experiment 3: Utilisation of legume mixtures for year-round supplementation of Bunaji heifers

Materials and methods

Establishment and grazing management

The trial was established at Fashola in the derived savannah in May 1994 at the beginning of the wet season. Average soil features of the experiment site are shown in Table 4.4. The soil is generally classified as a plinthic oxic Haplustoll (Fasehun 1980).

Table 4.4. Soil features of the experiment site at Fashola (grazing trial).

<table>
<thead>
<tr>
<th>Total N</th>
<th>OM</th>
<th>P</th>
<th>pH (%)</th>
<th>Ca</th>
<th>Mg</th>
<th>Mn</th>
<th>K</th>
<th>Na</th>
<th>Cu (ppm)</th>
<th>Zinc (ppm)</th>
<th>Tot acid</th>
<th>EfCEC</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.082</td>
<td>0.66</td>
<td>6.73</td>
<td>2.97</td>
<td>1.1</td>
<td>0.22</td>
<td>0.18</td>
<td>0.18</td>
<td>1.35</td>
<td>1.45</td>
<td>0.27</td>
<td>4.9</td>
<td>88</td>
<td>8</td>
</tr>
</tbody>
</table>

Values are in cmol+/kg unless otherwise indicated; N = nitrogen; OM = organic matter; P = phosphorus; Ca = calcium; Mg = magnesium; Mn = manganese; K = potassium; Na = sodium; Cu = copper; Zn = zinc; Tot acid = total acidity; EfCEC = effective cation exchange capacity.


Treatments consisted of four legume mixtures (as in Experiment 2) oversown onto tilled native pasture and a fifth treatment of native pasture with no added legume. All plots were fenced and each treatment consisted of a 0.3 ha treatment paddock with an adjacent 1.02 ha native pasture paddock. Three replications were planted in a randomised complete block design. Treatment paddocks were sprayed with the herbicide RoundUp (containing 360 g/litre of glyphosate) at an application rate of 5 litres/ha and harrowed before broadcasting the legume seeds. At the time of planting 200 kg/ha SSP was applied and a top dressing of 100 kg/ha was applied at the onset of the rains the following year. Grass was controlled by a single application of Fusilade at 6 litres/ha 8 weeks after sowing the legumes. Shrubs were slashed occasionally throughout the trial. Legume establishment was assessed by counting numbers of plants and estimating soil cover in fifty 1 m² quadrats arranged in 5 transects per treatment paddock 4, 8, and 12 weeks after planting and at similar intervals after the onset of the rains the following year.

Grazing commenced at the beginning of the dry season in November 1994. Three Bunaji heifers, within the weight range of 132 to 142 kg (stocking density of 1.2 TLU (Tropical Livestock Unit)/ha, where 1 TLU = 250 kg) were allocated to each plot.

Animals remained on their respective 1.02 ha native pasture plot except for 2–4 hours each morning when they were allowed free access to the appropriate adjacent treatment plot. Another group of animals (sixth treatment) were taken out to graze the range from about 0700 to 1700 hours daily, covering a radius of about 4 km every day; these animals were confined at night. All animals had water and salt lick² supplied ad libitum. Animals were weighed fortnightly and received routine veterinary care.

² Salt lick: 0.18% P; 0.25% Ca; 0.25% Mg; 0.06% K; 447 ppm Na; 159 ppm Mn; 451 ppm Fe; 188 ppm Cu and 103 ppm Zn.
At the beginning of the dry season in November 1995, because of the increase in animal live weight, the number of animals per treatment was reduced to two, retaining a stocking density of 1.2 TLU/ha. The experiment was concluded towards the end of the 1995/96 dry season, in March 1996, after data for two dry (1994/95 and 1995/96) seasons and one wet (1995) season were collected. Animals remained on the treatments from the start of the grazing in November 1994 through to March 1996 with the exception of a 3-week period in October 1995.

Animal liveweight changes were analysed separately for each season, using repeated measurement analysis and lsmeans (SAS 1988), with live weight at the beginning of the season as a covariance.

**Pasture performance**

From the beginning of the dry season (November 1994) the percentage rank method with direct yield estimation of the BOTANAL program (Tothill et al. 1992) was used to assess both the treatment and adjacent native range pastures at six-weekly intervals. The 16 most common species (including the sown legumes) were identified, with other material classified as other grasses, other forbs, leguminous shrubs or other shrubs. Fifty 1-m² quadrats distributed over 5 transects were used for each treatment and adjacent native paddock. A further 50 quadrats over 3 transects were assessed in the same way from areas representative of the free range grazing. At each sampling date, 12 quadrats from treatment and native pasture were clipped, dried and weighed to produce appropriate calibration curves.

Greenness and defoliation (scored as: 0 = no grazing; 1 = a trace; 2 = 5-25% removed; 3 = 25-50% removed; 4 = 50-75% removed and 5 = over 75% removed; Andrew 1986) were also estimated in the same quadrats used for the BOTANAL. Defoliation scores were converted into percentage consumption.

Pasture establishment data were assessed using conventional ANOVA. Yield and botanical composition were assessed as split plots, with treatments as main plots and time of harvest as subplots significant effects were assessed with lsmeans test (SAS 1988).

**Results**

**Pasture establishment and performance**

With the exception of *Arachis pintoi*, all sown legumes established well, with plant densities of 10-18 plants/m² 12 weeks after planting. Soil cover of the sown legumes increased over the 16-week establishment period (Figure 4.3) and at this time, paddocks with *C. macrocarpum* (mixtures 3 and 4) had significantly (P<0.05) higher cover than those without.

After the onset of the rains in the second year (May 1995), *Aeschynomene histrix* had substantial regeneration from seed and this was reflected in significantly higher total plant numbers (17-18 plants/m²) of this legume in mixtures 2 and 4, 16 weeks after the onset of the rains. The plant number variations were not reflected in total soil cover by the sown legumes at this time, with no significant differences in the range of 42-56%
Legume-legume mixtures for dairy cow supplementation

Figure 4.3. Soil cover estimates (%) of components of legume mixtures during the establishment phase (1994) and after the onset of the rains in 1995.

Source: Peters et al. (1998b).

Part of mixture 4 was destroyed by fire during the 1994/95 dry season and this treatment was therefore excluded from the analyses for that season. It was included again from the beginning of the 1995 wet season. The yield and botanical composition of the pastures for the duration of the grazing trial are shown in Figure 4.4. At the outset, total pasture yield of the treatment plots ranged between 4500 and 5200 kg/ha with 48–61% sown legume species. Total dry-matter yields decreased over the dry season, increasing again with the onset of the rains with another decrease towards the end of the 1995 wet season. There were no significant differences in total yields or total proportion of sown legumes for the treatment paddocks, but the proportions of the individual legumes did vary significantly. *C. macrocarpum* and *C. pubescens* increased significantly whereas *C. pascuorum* almost disappeared completely; *Arachis pintoi* persisted at a low level. Total dry-matter yield of the native pasture treatment paddocks
The numbers on the x-axis represent the 6-weekly periods of assessment, numbers 1–4 being dry season 1994/95, 5–8 wet season 1995 and 9–12 dry season 1995/96. The area between the dotted lines was excluded because of fire damage.
Source: Peters et al (1998b)

Figure 4.4. Dry-matter yields of treatment paddocks during the grazing period (November 1994 to March 1996).

did not differ significantly from the paddocks with legume mixtures, until the end of the 1996 dry season when total yields declined more sharply, but this treatment had a lower legume percentage. Other legume species comprised about 20% of the total yield, and consisted mainly of naturalised *Calopogonium mucunoides*. The amount of other ‘legume’ varied according to season, but was roughly the same proportion in all treatment and adjacent native pasture plots (Figures 4.4 and 4.5) and was less than 10% of the total dry matter by the end of the measurement period.
Assessment of the attached native range paddocks for all treatments showed similar total yield patterns in relation to season as the treatment paddocks and there were no significant variations in total dry-matter yields between treatments at each harvest date (Figure 4.5). However, seasonal variations were observed at the beginning and end of

![Graphs showing dry-matter yields for different treatments and years](image)

The numbers on the x-axis represent the six weekly periods of assessment, numbers 1-4 being dry season 1994/95; 5-8 wet season 1995 and 9-12 dry season 1995/96. The area between the dotted lines was excluded because of fire damage.


Figure 4.5. Dry-matter yields of adjacent native paddocks during the grazing period (November 1994 to March 1996).
the 1995 wet season. The proportion of legume in these paddocks remained below 25% for the entire period, with especially low values at the end of both dry seasons; this component was, again, mainly *Calopogonium mucunoides*.

In all paddocks, the grass component consisted mainly of *Panicum maximum* with some *Andropogon* spp.

The ability of the various components of the pastures to remain green during the dry season is presented in Table 4.5. *C. macrocarpum* and *C. pubescens* had the best drought tolerance, especially for the 1995/96 dry season when the plants were well established. *S. guianensis*, although not as drought tolerant as the two *Centrosema* species, was, in addition to these, better at remaining green in the dry season than the associated grasses.

Table 4.5. Percentage greenness of the various components of the pastures during the 1994/95 and 1995/96 dry seasons.

<table>
<thead>
<tr>
<th>Species</th>
<th>1994/95 dry season</th>
<th>1995/96 dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early</td>
<td>Mid</td>
</tr>
<tr>
<td>Sown legumes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aeschynomene histrix</em></td>
<td>59</td>
<td>46</td>
</tr>
<tr>
<td><em>Arachis pintoi</em></td>
<td>78</td>
<td>58</td>
</tr>
<tr>
<td><em>Centrosema macrocarpum</em></td>
<td>76</td>
<td>59</td>
</tr>
<tr>
<td><em>Centrosema pascuorum</em></td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td><em>Centrosema pubescens</em></td>
<td>79</td>
<td>55</td>
</tr>
<tr>
<td><em>Stylosanthes guianensis</em></td>
<td>85</td>
<td>52</td>
</tr>
<tr>
<td>Other legumes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calopogonium mucunoides</em></td>
<td>66</td>
<td>22</td>
</tr>
<tr>
<td>Other legumes</td>
<td>74</td>
<td>52</td>
</tr>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Andropogon</em> spp</td>
<td>55</td>
<td>31</td>
</tr>
<tr>
<td><em>Brachiaria</em> spp</td>
<td>58</td>
<td>22</td>
</tr>
<tr>
<td><em>Panicum maximum</em></td>
<td>57</td>
<td>26</td>
</tr>
<tr>
<td>Other grasses</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td><em>Cyperus</em> spp</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>Forbs</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Boereria</em> spp</td>
<td>55</td>
<td>28</td>
</tr>
<tr>
<td><em>Tridax procumbens</em></td>
<td>69</td>
<td>63</td>
</tr>
<tr>
<td><em>Celosia</em> spp</td>
<td>54</td>
<td>32</td>
</tr>
<tr>
<td>Other forbs</td>
<td>62</td>
<td>41</td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chromolaena odorata</em></td>
<td>65</td>
<td>54</td>
</tr>
<tr>
<td>Leguminous shrubs</td>
<td>83</td>
<td>66</td>
</tr>
<tr>
<td>Other shrubs</td>
<td>79</td>
<td>62</td>
</tr>
</tbody>
</table>

*nd = no data.*


Digestibilities of the dominating grasses decreased from 55% to over 60% at the beginning of the wet season to values of 45–50% six weeks later and for the remainder of the wet season, with legumes (with the exception of *Arachis pintoi*) having digestibilities of 45–50% throughout the wet season.
The defoliation estimates for the components of the pastures during the grazing period are shown in Table 4.6. Although all sown legume species were well consumed, there were variations over time for *A. histrix*, *C. macrocarpum* and *C. pascuorum* which were poorly consumed at the start of the 1995 wet season, whereas *C. pubescens* and *S. guianensis* were more evenly consumed throughout. *Calopogonium mucunoides* was consumed only at the end of the 1994/95 dry season. Many other components also had peak consumption at this time, but were consumed more than *Calopogonium mucunoides* at other times, making the difference less dramatic. Forbs, shrubs and *Chromolaena odorata* had very low consumption in the 1995 wet season. Defoliation of most components was highest at the end of the 1994/95 dry season. Grasses had higher values than the other components during the wet season.

Table 4.6. Defoliation (% consumption) estimates of pasture components during the grazing period.1

<table>
<thead>
<tr>
<th>Species</th>
<th>1994/95 dry season</th>
<th>1995 wet season</th>
<th>1995/96 dry season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 3 4 5 6 7</td>
<td>8 9 10 11 12</td>
<td></td>
</tr>
<tr>
<td><strong>Sown legumes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aeschynomene histrix</em></td>
<td>28 24 33 15 14</td>
<td>42 31 14 40 57</td>
<td></td>
</tr>
<tr>
<td><em>Arachis pintoi</em></td>
<td>14 33 28 6 5</td>
<td>22 15 5 22 24</td>
<td></td>
</tr>
<tr>
<td><em>Centrosema macrocarpum</em></td>
<td>26 55 57 2 14 17</td>
<td>35 19 11 33 40</td>
<td></td>
</tr>
<tr>
<td><em>Centrosema pascuorum</em></td>
<td>24 37 nd 2 9 11</td>
<td>35 26 12 55 nd</td>
<td></td>
</tr>
<tr>
<td><em>Centrosema pubescens</em></td>
<td>31 50 42 12 17 26</td>
<td>33 28 14 35 45</td>
<td></td>
</tr>
<tr>
<td><em>Stylosanthes guianensis</em></td>
<td>37 45 47 19 22 31</td>
<td>40 30 19 42 55</td>
<td></td>
</tr>
<tr>
<td><strong>Other legumes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Calopogonium mucunoides</em></td>
<td>7 37 55 1 11 14 40</td>
<td>6 1 3 9 9</td>
<td></td>
</tr>
<tr>
<td><em>Other legumes</em></td>
<td>15 33 55 11 14 40</td>
<td>33 14 12 31 40</td>
<td></td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Andropogon spp</em></td>
<td>31 37 47 33 28 15</td>
<td>47 28 12 26 52</td>
<td></td>
</tr>
<tr>
<td><em>Brachiaria spp</em></td>
<td>19 35 nd 57 11 9</td>
<td>40 17 76 15 24</td>
<td></td>
</tr>
<tr>
<td><em>Panicum maximum</em></td>
<td>42 47 62 40 35 35</td>
<td>47 37 22 45 52</td>
<td></td>
</tr>
<tr>
<td><em>Other grasses</em></td>
<td>14 33 60 28 15 24</td>
<td>37 24 10 17 28</td>
<td></td>
</tr>
<tr>
<td><em>Cyperus spp</em></td>
<td>1 47 nd 2 2 5</td>
<td>14 7 2 12 22</td>
<td></td>
</tr>
<tr>
<td><strong>Forbs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Boereria spp</em></td>
<td>2 22 62 2 7 7</td>
<td>28 11 2 10 12</td>
<td></td>
</tr>
<tr>
<td><em>Tridax procumbens</em></td>
<td>1 22 67 1 1 5</td>
<td>17 15 11 28 33</td>
<td></td>
</tr>
<tr>
<td><em>Celosia spp</em></td>
<td>2 19 24 2 2 5</td>
<td>22 15 7 14 17</td>
<td></td>
</tr>
<tr>
<td><em>Other forbs</em></td>
<td>2 24 37 1 1 7</td>
<td>9 5 2 12 11</td>
<td></td>
</tr>
<tr>
<td><strong>Shrubs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chromolaena odorata</em></td>
<td>2 19 42 11 4 2</td>
<td>2 1 1 1 1 2</td>
<td></td>
</tr>
<tr>
<td><em>Leguminous shrubs</em></td>
<td>17 33 47 22 26 15</td>
<td>22 11 6 5 4</td>
<td></td>
</tr>
<tr>
<td><em>Other shrubs</em></td>
<td>2 12 24 22 9 6</td>
<td>12 1 1 1 1 1</td>
<td></td>
</tr>
</tbody>
</table>

1. Numbers refer to the 6-weekly assessment periods as in Figures 4.4 and 4.5.

nd = no data.

Animal performance

Cumulative liveweight gains are shown in Figure 4.6. Data analysis by season indicated that animals grazing legume mixtures gained significantly more weight in the two dry seasons, but there were no differences between liveweight gains on the various treatments with or without sown legume during the wet season. During the 1994/95 dry season, animals on the free range grazing and on the native pasture (i.e. no sown legume) lost weight, with the free-grazing animals losing significantly more. Following this weight loss, the free-grazing animals showed fast growth at the start of the wet season, but the differences accumulated over the preceding dry season remained and the overall average daily gain (ADG) was not higher than that of the other treatments for the wet season (Table 4.7).


Figure 4.6. Cumulative liveweight gains for heifers with and without access to mixed legume pastures.

Differences in ADG between treatments were slight in the wet season, but pronounced in both dry seasons (Table 4.7) when animals with access to legume mixture plots gained considerably more than those without (native pasture or free range grazing). In the first dry season, animals on the native pasture treatment fared better than those on free range grazing, in terms of weight change, but in the second dry season (1995/96) this was reversed, with the free range grazing animals gaining slightly more weight than those on the confined native pasture.
Table 4.7. Average daily liveweight gains (ADG) of animals on various pasture treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1994/95 dry season ADG (g/day/animal)</th>
<th>1995 wet season ADG (g/day/animal)</th>
<th>1995/96 dry season ADG (g/day/animal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixture 1</td>
<td>110</td>
<td>364</td>
<td>206</td>
</tr>
<tr>
<td>Mixture 2</td>
<td>201</td>
<td>468</td>
<td>254</td>
</tr>
<tr>
<td>Mixture 3</td>
<td>110</td>
<td>458</td>
<td>206</td>
</tr>
<tr>
<td>Mixture 4</td>
<td>-</td>
<td>377</td>
<td>214</td>
</tr>
<tr>
<td>Confined native</td>
<td>46</td>
<td>416</td>
<td>32</td>
</tr>
<tr>
<td>Free range</td>
<td>-58</td>
<td>435</td>
<td>40</td>
</tr>
</tbody>
</table>


Discussion

The results of this large-scale grazing trial have generally confirmed the findings from the two small-plot trials, that appropriate mixtures of forage legumes can provide a stable, year-round pasture supplement. The behaviour of the individual species in the large-scale trial was largely as reported previously (Peters et al 1994a; Peters et al 1994b; Tarawali 1994a), and the mixtures behave similarly to those in small plots with periodic grazing. In mixture plots where a species failed to establish (Arachis pintoi) or persist (Centrosema pascuorum) other components of the mixture compensated so that the total legume percentage was not decreased. Arachis pintoi has been highly recommended for pastures in tropical South America (Kerridge and Hardy 1994; Hernandez et al 1995), but its slow establishment combined with predation by rodents and birds seem to preclude its use as a major pasture component in this region of Nigeria. Since this species, however, does have an exceptionally high digestibility it may be worthwhile to initiate studies of some other accessions of Arachis pintoi that have recently become available at CIAT (CIAT 1995b). This could be complemented by preliminary evaluation of accessions of Arachis glabrata to investigate the potential of this species in the moist savannahs of West Africa. The use of suitable Arachis species may be particularly beneficial in situations where both energy and protein seem to be the limiting nutritional constraints, i.e. for the early weaning of calves or as supplement in the wet season. C. pascuorum behaved largely as expected, and contributed only during the establishment year when some of the other, slower to establish, mixture components produced less. On the various treatment blocks, C. macrocarpum and C. pubescens persisted best and had the best ability to remain green in the dry seasons; this C. pubescens accession ILRI 152 stays greener and grows better than the naturalised local ‘Centro’. Sown legumes maintained a fairly constant level between 30% and 50%, with these proportions (i.e. the 30% and 50%) consisting of about two-thirds Centrosema species and the remainder Stylosanthes guianensis or Aeschynomene histrix, depending on the mixture. Aiken et al (1991a, 1991b) reported similar changes in legume species composition in pasture mixtures, but with a fairly constant proportion of sown legume in the total pasture.

Contents of naturalised legume (10-15%) were similar in the legume and range paddocks. Thus the total (sown and naturalised) legume contents in the legume pastures
Forage Legumes in Subhumid West Africa

were in the range (or above) of 13–45% legume in a pasture required to maintain the nitrogen balance in the soil of tropical pastures and thus, sustain the productivity of the system (Cadisch et al 1994; Thomas and Lascano 1995). Equally, the supplementation with the sown legume pastures raised total legume contents in the forage on offer to levels within the range of 20–40% reported to be needed for optimal animal production (Simpson and Stobbs 1981; Crowder and Chedda 1982).

The loss of mixture 4 from a fire incident in the 1994/95 dry season, whilst accidental, did give further support to the robust nature of legume mixtures; by the middle of the 1995 wet season, this treatment had as much overall productivity and legume component as the others. Indeed, C. macrocarpum in this plot started to regrow even before the onset of the rains, but the plants themselves, although still green at the time of the fire, did not persist per se: Mendoza et al (1990) reported that C. pubescens is more tolerant of fire than S. guianensis although Tarawali and Pamo (1992) indicated that a thick stand of S. guianensis was fire-resistant. In our study, the Aeschynomene histrrix was able to regenerate from seeds after the fire. Thus, including species which can both regenerate from plants or seeds enabled the legume-rich pasture to be sustained, even after the fire.

Whilst the sown legumes were all eaten by cattle, there were variations with season, similar to those reported for legume mixtures with grasses by Norton et al (1990). Grasses were clearly preferred to legumes in the wet season, although C. pubescens and S. guianensis were less discriminated against. Lascano et al (1990) reported a similar preference of cattle for C. macrocarpum in the dry season. The effect of the harsh 1994/95 dry season is apparent when, towards the end of this stressful period, animals were seemingly forced to eat Calopogonium mucunoides, Tridax procumbens and Chromolena odorata, species which were hardly eaten throughout the rest of the grazing period (Figure 1.2). Aeschynomene histrrix seemed to be more readily eaten in the second dry season, suggesting a possible adaptation to the previously unfamiliar species as suggested by several authors (e.g. Marten 1978; Lascano et al 1985).

The detrimental effect of the dry season on animal liveweight gain is apparent from this study, and supplementation with legume pastures was able to overcome this shortcoming. The 1994/95 dry season was harsher than that of 1995/96 (Figure 1.2) in that there was no rain at all from November 1994 to March 1995 whereas in the second dry season there were some isolated showers during this period. The effects of this are evident in terms of the animal performance. In 1994/95 the animals on the free range grazing treatment actually lost weight. This was undoubtedly related not only to the quantity of forage available (compare periods 3 to 5 with 10 to 12 in Figure 4.5), but also to the quality; the range consisted largely of grasses, and at this time these were completely dry and fibrous and therefore of limited nutritive value. The reduced quantity of feed also meant that the animals had to walk further for grazing, again contributing to their weight loss. During this severe period, animals with access to the native pasture treatment paddock also lost some weight, but less than those on the range; this is probably related to the better quality of the native pasture (and reduced walking to find fodder) caused by regular grazing. All animals with access to legume mixture treatments continued to gain, or remained stable in terms of weight. The
Legume-legume mixtures for dairy cow supplementation

differences accumulated during this initial grazing period were maintained throughout the rest of the trial, despite some compensatory growth by the range animals at the start of the wet season. No differences were observed between treatments during the course of the wet season, with the highest gains being achieved at the beginning of this season, results that agree with those of Okorie et al (1965) and Olubajo and Oyenuga (1971) working in the same region. The lower gains and lack of effect of legume supplementation during the rest of the wet season suggest that during this season, not protein but energy, or possibly, minerals were limiting. There may be an opportunity to increase wet season gains by mineral supplementation or by utilising legumes of high digestibility like *Arachis pintoi*.

Differences between treatments were maintained during the second dry season, although these were not as dramatic as during the first. Animals without legume pastures remained at constant weight whereas those with access to legume paddocks continued to increase in weight. Mixture 2 (*C. pascuorum, Aeschynomene histrix, C. pubescens, Arachis pintoi*) although not significantly different to other legume treatments, remained the best in terms of its effect on animal liveweight gain throughout the trial period.

The effects of the various pasture treatments on animal weight gain are best illustrated by the average daily gains for each of the two dry seasons and the one wet season (Table 4.7). Animals with access to legume pastures gained five to six times as much weight as those without. These results are comparable with weight gains achieved on improved *Stylosanthes* and *Centrosema* pastures under continuous grazing in the wet–dry tropics (Gillard and Winter 1984; Lescano et al 1990) but higher than weight gains achieved with complementary grazing of legume pastures as in our study (Norman and Stewart 1967; Haggar et al 1971). In Fashola, Adegbola and Onayinka (1976) reported ADG of 700 g/day for adult cattle on *P. maximum/C. pubescens* pasture, and compared this with 150 g/day for native range. The value for ADG on natural range was much higher in the study by Adegbola and Onayinka (1976) than the value in our study (150 vs 40 g/day per animal). However, the difference between this and the supplemented animals (in the dry season) was less than in our study even though in the reported study the animals had 24-hour access to the improved pasture as opposed to only 2–4 hours access in our study.

The findings of this study indicate the potential of mixed legume pastures for year-round cattle supplementation and have important implications for cattle productivity in the subhumid region of West Africa. It is well documented that poor nutrition, especially in the dry season, limits the general performance of cattle (e.g. ILCA 1979; Rege et al 1993a; Rege et al 1993b). There is also evidence to suggest that poor nutrition of young females results in late oestrus, and the subsequent poor calf nutrition and long calving intervals (Mukasa-Mugerwa 1989; Rege et al 1993b). The introduction of legume mixtures to provide supplements for such animals provides an exciting option towards alleviating such constraints and increasing cattle productivity per head and per unit area. Stocking densities maintained throughout the year in this trial were between 1.2 and 2.2 TLU/ha as compared to a carrying capacity of 0.27 TLU/ha reported for range pastures in the derived savannah (Adegbola and Onayinka 1968) and an estimated
Forage Legumes in Subhumid West Africa

carrying capacity for the entire subhumid zone of between 0.17 and 0.45 TLU/ha (Winrock 1992). Utilisation of a mixture of legumes would be more robust, as shown by this study, and therefore more likely to succeed in the hands of farmers who are largely inexperienced in growing and managing forage plants, as well as being responsive to environmental variations.
5 Evaluation of selected forage legumes for forage and subsequent cereal production

Introduction

The first forage legume evaluation programmes in Nigeria were targeted at identifying species that would be particularly useful as dry season feed resources for ruminant livestock. However, population growth, demographic shifts and their resultant influences on livestock populations are forcing a closer integration of crop and livestock enterprises (McIntire et al. 1992). In the moist savannah, intensification of agriculture coupled with increased livestock numbers, particularly cattle (increased cropping results in fewer habitats for tsetse fly so cattle are no longer at such high risk from trypanosomosis), mean that marginal lands are no longer available for grazing (Jabbar 1992; McIntire et al. 1992; Bourn et al. 1994). If synergistic management approaches are not sought, the two production systems will be competing for and degrading the scarce land resources. Intensified cropping reduces or eliminates the possibility of restoring soil fertility through long fallow periods. In view of this, it is no longer appropriate to view forage legume evaluation in isolation, for livestock use alone, since it is well known that tropical forage legumes can also contribute to maintaining soil fertility with a short fallow period (Wilson et al. 1982; MacColl 1990; Tarawali 1991a; Tarawali and Pamo 1992; Tarawali and Peters 1996). Indeed, such plants may hold the key to preventing destruction of the environment by promoting the sustainable integration of livestock and crop production.

Although some studies of the effects of forage legumes on subsequent cereal production have been reported (Mohamed-Saleem and Otsyina 1986; Tarawali 1991a; Tarawali 1994a), most have focused on only a few forage species. None of these studies have attempted to quantify both the legume contribution to the soil and the forage production in the same system. This study was therefore designed to use forage legumes recommended for the region, and to investigate both the forage quantity and quality as well as the potential benefits to cereal production. The species used were selected on the basis of their previous performance as fodder or soil restoration plants in Nigeria or under similar climatic conditions in tropical South America. *Aeschynomene histris* (Peters et al. 1994b; Tarawali 1994a), *Stylosanthes guianensis* (Wilson et al. 1982; Mohamed-Saleem et al. 1985; Pizarro et al. 1985; Suarez and Machado 1988; Amezquita et al. 1991; Tarawali and Pamo 1992; Aken’Ova 1993; Peters et al. 1994b; Tarawali 1994a), *Centrosema pubescens* (Tarawali and Pamo 1992; Aken’Ova 1993), *Centrosema macrocarpum* (Schultze-Kraft and Keller-Grein 1985; Schultze-Kraft et al. 1985; Villaquiran and Lascano 1986; Valero et al. 1987; Suarez and Machado 1988), *Desmodium ovalifolium* (Ghof 1982; Gonçalves et al. 1986; Thomas and Grof 1986; Valero et al. 1987; Hernandez et al. 1995), *Pueraria phaseoloides* (Wilson et al. 1982; IITA 1993), and *Arachis pintoi* (Lascano and Thomas 1988; Carulla et al. 1991) have been shown to

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1. The results presented in this chapter have previously been reported in Tarawali and Peters (1996), Muhr et al. (1997), Muhr (1998) and Muhr et al. (1998).
have potential as fodder and soil improvement species in Nigeria or South America. *Mucuna pruriens* (IITA 1993), *Dioclea guianensis* (Lascano and Thomas 1988; Carulla et al 1991), *Zornia glabra* (Thomas and Grof 1986) and *Calopogonium caeruleum* have shown good potential with respect to soil maintenance/improvement. Two shrubby legume species, *Flemingia macrophylla* and *Cratylia argentea* (Thomas and Schultze-Kraft 1990) which have shown good fodder and soil-improving attributes were also included.

Three trials were established to investigate the potential of these promising legumes for forage production and subsequent cereal production, and to study the effects of length of fallow period on forage production and maize grain yields and the nitrogen dynamics of such systems. The latter two aspects were focused on only two accessions, *Centrosema macrocarpum* and *S. guianensis*.

Some consideration of the potential benefit of forage legumes used for grazed pasture to subsequent cereals is also pertinent. *Stylosanthes hamata* cv Verano and, to a lesser extent, *S. guianensis* cv Cook have been used for pastures, and some instances of the benefits of these to subsequent cereal crops have been reported (Mohamed-Saleem and Otsyina 1986; Tarawali 1991a; Tarawali and Pamo 1992). However, most reports on the soil improving effects of other legumes have been from small experimental plots that were usually weeded and ungrazed (Tarawali 1994a; Tarawali 1995a). In this context, pastures established with forage legumes selected in previous trials (*S. hamata*, *Chamaecrista rotundifolia*, *Centrosema pascuorum*) and grazed as a dry season supplement for three dry seasons were cropped with maize, in an effort to investigate the dual purpose of such species in a more 'realistic' situation (Tarawali and Peters 1996).

**Experiment 1: Performance of selected legumes, their effect on subsequent maize yield and potential for forage regeneration**

**Materials and methods**

**Establishment**

The trial was established at two sites in the derived savannah: one on the IITA campus, Ibadan, and the other on a farmer's field adjacent to Fashola. Trial design and data collection were identical at both sites unless indicated otherwise. The soil properties of the experimental sites are described in Table 5.1.

The trial was a randomised complete block design with 4 replications and 14 treatments consisting of 11 herbaceous legumes (*Aeschynomene histrix* ILRI 12463, *Arachis pintoi* CIAT 17434, *Calopogonium caeruleum* CIAT 812311, *Centrosema macrocarpum* CIAT 5713, *Centrosema pubescens* ILRI 152, *Dioclea guianensis* CIAT 7801, *Desmodium ovalifolium* CIAT 13089, *Mucuna pruriens*, *Pueraria phaseoloides*, *Stylosanthes guianensis* ILRI 164 and *Zornia glabra* CIAT 8279) two shrubs (*Cratylia argentea* CIAT 18516 and *Flemingia macrophylla* CIAT 17403) and a control treatment with no added legume (natural fallow).
Table 5.1. General soil properties of the sites used for experiments to assess the potential of selected forage legumes for forage and subsequent cereal production.

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>(%)</th>
<th>C/N ratio</th>
<th>ppm</th>
<th>K</th>
<th>Na</th>
<th>Ca</th>
<th>Mg</th>
<th>Mn</th>
<th>Ex Ac</th>
<th>EfCEC</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ibadan</td>
<td>5.1</td>
<td>1.4</td>
<td>0.12</td>
<td>4.21</td>
<td>0.47</td>
<td>0.42</td>
<td>6.45</td>
<td>77</td>
<td>10</td>
<td>13</td>
<td></td>
<td>74</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Fashola</td>
<td>6.1</td>
<td>0.64</td>
<td>0.05</td>
<td>4.23</td>
<td>0.22</td>
<td>0.33</td>
<td>4.7</td>
<td>82</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Unless otherwise indicated, units are cmol+/kg. Org. C = organic carbon; N = nitrogen; P = phosphorus; K = potassium; Na = sodium; Ca = calcium; Mg = magnesium; Mn = manganese; Ex Ac = exchangeable acidity; EfCEC = effective cation exchange capacity.

Sources: Muhr (1998).

Sources of the seeds are indicated in Table 1.1. Plot size was 4.0 x 5.0 m with 1.0 m between plots; establishment took place at the beginning of the wet season, in May 1994. With the exception of the shrubs, seeds were broadcast at 200-280 seeds/m² for small seeds and 4 seeds/m² for the large-seeded species. Shrubs were sown at a spacing of 30 x 30 cm with 3 seeds per hill, and later thinned to one plant, giving about 11 plants/m². A basal dressing of 16 kg/ha phosphorus (P), was applied as SSP at the time of planting. Plots were only weeded during the establishment period 3, 6 and 9 weeks after planting; bare patches were resown as appropriate. Twenty adjacent natural fallow plots were demarcated at the time of establishing legume plots, in readiness for maize planting the following season. These were control plots for nitrogen (N) applications to maize, in the form of five N levels and four replicates in a randomised complete block design. Two complete areas with this design were allocated, one for the major and one for the minor wet season maize planting, to act as controls for all experiments.

Establishment of the legume species was monitored by counting seedlings 6 weeks after planting, and estimating soil cover 6, 10 and 20 weeks after planting. For each measurement, two 1 m² quadrats were used per plot and disease and pest incidence were also recorded. An estimate of nodulation was made 10 weeks after planting by digging out one soil core per plot (Sarrantonio 1991) and noting the number of nodules, their size (small, medium or large) and activity (red, red-grey, grey). Onset of flowering, peak seeding and leaf drop were also noted.

Forage potential

Biomass production was estimated at the end of the wet season (November 1994), in the middle of the dry season (January 1995) and at the beginning of the wet season in the second year (May 1995). In November 1994 two 1 m² quadrats were sampled from the plot borders; in the middle of the dry season, the central part of the plot was sampled for both biomass and litter and all plots were cut down to about 10 cm (herbaceous plants) or 50 cm (shrubs) stem height (to simulate removal of fodder for livestock). On each occasion, material was cut, separated into sown legume, other legumes, grasses and herbs; these components were weighed and their dry weights determined. Selected forage biomass samples were analysed for N, P and potassium (K) to estimate nutrient oftake during the dry season harvest, and nutrient input into the soil before maize planting. Before the harvest at the beginning of the 1995 wet season (May), just before maize planting, the soil cover of the regrowing legumes was also estimated.
Biomass yields of the plots were estimated in the same way three months after harvesting the maize in 1995; at the same time, an assessment was made as to whether the legume regrowth was from seeds or old stems. In April 1996, the beginning of the wet season one year after maize planting, the percentage soil cover of each plot by the original legume component was estimated.

**Maize production**

At the beginning of the 1995 wet season (May), maize was planted on all the legume plots, and in the natural fallow control (14 plots per replicate). The biomass from legume regrowth since the mid-dry season harvest was incorporated into the soil before planting maize, using a rotor-tiller at Ibadan and a hand-hoe at Fashola. Maize was planted on ridges 60 cm apart to give a plant density of 55,555 plants/ha. At the time of maize planting, decomposition studies (Anderson and Ingram 1993) were established for *Centrosema macrocarpum*, *S. guianensis*, *Centrosema pubescens*, *Aeschynomene histrix*, *Calopogonium caeruleum*, *F. macrophylla* and the natural fallow plots by placing air-dried material (representing an area of 30 x 30 cm) into a nylon mesh bag with 2 mm pore size. Six bags per plot were buried and removed 13, 22, 30, 42, 61 and 95 days after maize planting at Ibadan and 8, 16, 24, 35, 54 and 89 days after maize planting at Fashola. After removal, the litter from the bags was washed with tap water, oven dried and milled through a 1 mm sieve before ashing at 550°C to determine ash-free dry matter, samples were then analysed for nitrogen.

Maize was weeded once, 5 weeks after planting, and monitored for height and stem diameter every 10 days; days to onset of silking and tasseling were also recorded. The central 2–3 rows of each plot were harvested and used to determine grain yield.

Maize was also planted on the natural fallow plots demarcated the previous season, with treatments in the form of N level to maize imposed as 0, 30, 60, 90, 120 kg/ha N applied as urea in a split dose, half at planting and half 5 weeks later. One control trial was planted at the beginning of the 1995 wet season in May and one at the onset of the minor wet season in August 1995.

All plots received a basal dressing of 60 kg/ha each of phosphorus as P<sub>2</sub>O<sub>5</sub> and potassium as K<sub>2</sub>O at the time of maize planting.

**Results**

**Establishment and phenology of forage legumes**

Germination was generally poor with only *Mucuna pruriens* and *Flemingia macrophylla* at Ibadan, and *M. pruriens*, *Arachis pintoi*, *Calopogonium caeruleum* and *Cratylia argentea* at Fashola exceeding 50% germination. *Desmodium ovalifolium* (Ibadan and Fashola) and *C. argentea* (Ibadan) had to be replanted. The germination was, to some extent, reflected in the soil cover measurements (Figure 5.1). *M. pruriens* and *Centrosema macrocarpum* had the fastest soil cover, but most accessions had 80% or more soil cover at both sites by 20 weeks after planting. Soil cover was generally faster at Fashola than Ibadan.
Legumes for forage and cereal production

All accessions had root nodules 10 weeks after planting with *S. guianensis* and *Desmodium ovalifolium* having exceptionally high numbers. In general, nodule numbers were higher, and their colours suggested more activity at Ibadan than at Fashola.

Only *Aeschynomene histrix*, *Z. glabra* and *Arachis pintoi* had set seeds before the first harvest, but by the mid-dry season all accessions had seeded except *Centrosema macrocarpum*, *Desmodium ovalifolium*, *Dioclea guianensis* and *Cratylia argentea*; the latter three did not flower at all during the first year.

**Forage potential**

At the end of the wet season, dry-matter production showed similar patterns at the two sites, with *S. guianensis* and *A. histrix* showing significantly higher (P<0.05) biomass yields (Figure 5.2) than the other accessions. By the middle of the dry season *S. guianensis* again had the best biomass production (Figure 5.3) at both sites. *Aeschynomene histrix*
productivity was high at Ibadan, but less so at Fashola. *Centrosema macrocarpum* also produced well at Ibadan. At this second harvest, litter was assessed; *M. pruriens* and *Centrosema pubescens* had the highest litter yields at Ibadan and at Fashola, respectively. Quality of the forage, in terms of 48-hour in sacco dry-matter (DM) digestibility was slightly higher at Ibadan than at Fashola. *Arachis pintoi* had consistently high values, even for litter, although for all other accessions, litter values were about 10% lower than standing material. The two *Centrosema* species, *S. guianensis* and *Dioclea guianensis* were the most drought tolerant of the legumes tested with over 40% green material on the plots at the peak of the dry season.

Regrowth of the cut plots from the mid-dry season cut in January through to mid-May, just before maize planting showed that the different accessions varied in their potentials to regenerate. There was a marked difference in soil cover between the two sites, with Fashola having less than 40% for all plots in contrast to Ibadan where cover (of weeds plus sown legume) exceeded 50% for 10 of the 14 treatments. Soil cover estimates showed that the material could be grouped into two: accessions with good soil

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**Figure 5.2.** Dry-matter yields of sown legumes and associated components at the end of the 1994 wet season.

C. mac = *Centrosema macrocarpum*; C. pub = *Centrosema pubescens*; S. gui = *Strychosanthes guianensis*; A. his = *Aeschynomene histrix*; C. cae = *Calopogonium caeruleum*; F. mac = *Flemingia macrophylla*; F. pha = *Fueraria phaseoloides*; M. pru = *Mucuna pruriens*; D. ova = *Desmodium ovalifolium*; Z. gla = *Zornia glabra*; D. gui = *Dioclea guianensis*; A. pin = *Arachis pintoi*; C. arg = *Cratylia argentea*; N. fal = natural fallow.

Legumes for forage and cereal production

Dry matter (kg/ha)

![Chart showing dry matter yields of sown forage legumes and associated components, mid-dry season 1994/95.]

C. mac = Centrosema macrocarpum; C. pub = Centrosema pubescens; S. gui = Stylosanthes guianensis; A. his = Aeschynomene histris; C. cae = Calopogonium caeruleum; F. mac = Flemingia macrophylla; P. pha = Pueraria phaseoloides; M. pru = Mucuna pruriens; D. ova = Desmodium ovalifolium; Z. gla = Zornia glabra; D. gui = Dioclea guianensis; A. pin = Arachis pintoi; C. arg = Cratylia argentea; N. fal = natural fallow.


Figure 5.3. Dry-matter yields of sown forage legumes and associated components, mid-dry season 1994/95.

cover (60% and above at Ibadan, 20-40% at Fashola) and those with poor cover (less than 20% at Ibadan; less than 10% at Fashola). *Centrosema macrocarpum*, *Centrosema pubescens*, *F. macrophylla* and *P. phaseoloides* were in the good soil cover group at both sites; *Calopogonium caeruleum* was in the good soil cover group at Ibadan only. Accessions with good soil cover also had the best forage yields (Figure 5.4) which were higher at Ibadan than at Fashola. *Desmodium ovalifolium* (none), *M. pruriens* and *Arachis pintoi* had the lowest regrowth at both sites.

Estimates of nutrient offtake, from analysis of plant samples taken in the mid-dry season harvest indicated that up to 120 kg N/ha, 10 kg P/ha and 135 kg K/ha could be removed in the biomass, with the highest values recorded for *S. guianensis*. The regrowth between this harvest and maize planting in the early wet season could contribute up to 150 kg N/ha, 18 kg P/ha and 140 kg K/ha (maximum values, not all for one species).

After the maize harvest, regrowth of both sown legumes and associated vegetation (grasses, herbs and other legumes) was higher at Fashola than at Ibadan (Figure 5.5). At Fashola *Centrosema macrocarpum*, *Centrosema pubescens*, *Aeschynomene histris*, *F. macrophylla* and *M. pruriens* had over 1000 kg/ha sown legume; this was true only for *Centrosema*.
pubescens, F. macrophylla and M. pruriens at Ibadan. At Ibadan, the total forage yield was very variable, with the natural fallow plot having one of the highest yields. The yield of the natural fallow was among the lowest at Fashola, where total forage yields were at least 1000 kg/ha more for all plots except Cratylia argentea, Arachis pintoi, Dioclea guianensis and Desmodium ovalifolium. Legume regeneration appeared to be mainly from seeds for S. guianensis, Centrosema pubescens, Aeschynomene histrix, P. phaseoloides, M. pruriens, Calopogonium caeruleum and Arachis pintoi, with Centrosema pubescens, Centrosema macrocarpum, F. macrophylla and Arachis pintoi also showing regrowth from old plant parts.

At both sites, several of the legumes were able to regenerate successfully in the wet season a year after maize planting (April 1996; Table 5.2). F. macrophylla, Aeschynomene histrix, Centrosema pubescens and S. guianensis all had soil covers exceeding 50% of the plot. Desmodium ovalifolium and Dioclea guianensis failed to re-establish, whilst Calopogonium caeruleum, M. pruriens and Z. glabra had less than 5% soil cover at Fashola and very low values at Ibadan. Generally the pattern was similar at both sites; Centrosema macrocarpum had lower cover at Ibadan, whilst P. phaseoloides and M. pruriens had better cover at Ibadan than at Fashola.
Legumes for forage and cereal production

Dry matter (kg/ha)

Ibadan

Dry matter (kg/ha)

Fashola

LSD (sown legume) = 530 kg/ha

LSD (sown legume) = 650 kg/ha

C. mac = *Centrosema macrocarpum*; C. pub = *Centrosema pubescens*; S. gui = *Stylosanthes guianensis*; A. his = *Aeschynomene hisrix*; C. cae = *Calopogonium caeruleum*; F. mac = *Flemingia macrophylla*; P. pha = *Pueraria phaseoloides*; M. pru = *Mucuna pruriens*; D. ova = *Desmodium ovalifolium*; Z. gla = *Zornia glabra*; D. gui = *Dioclea guianensis*; A. pin = *Arachis pintoi*; C. arg = *Cratylia argentea*; N. fal = natural fallow.


**Figure 5.5.** Dry-matter yields of forage legumes and associated components at the end of the 1995 wet season, 3 months after maize harvest.

**Table 5.2.** Soil cover of sown legume components in April 1996.

<table>
<thead>
<tr>
<th>Component</th>
<th>Ibadan (%)</th>
<th>Fashola (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Centrosema macrocarpum</em></td>
<td>26</td>
<td>34</td>
</tr>
<tr>
<td><em>C. pubescens</em></td>
<td>87</td>
<td>77</td>
</tr>
<tr>
<td><em>Stylosanthes guianensis</em></td>
<td>70</td>
<td>59</td>
</tr>
<tr>
<td><em>Aeschynomene hisrix</em></td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td><em>Calopogonium caeruleum</em></td>
<td>17</td>
<td>81</td>
</tr>
<tr>
<td><em>Flemingia macrophylla</em></td>
<td>80</td>
<td>91</td>
</tr>
<tr>
<td><em>Pueraria phaseoloides</em></td>
<td>46</td>
<td>12</td>
</tr>
<tr>
<td><em>Mucuna pruriens</em></td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td><em>Desmodium ovalifolium</em></td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td><em>Zornia glabra</em></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Dioclea guianensis</em></td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td><em>Arachis pintoi</em></td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td><em>Cratylia argentea</em></td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>LSD (P&lt;0.05)</td>
<td>18</td>
<td>11</td>
</tr>
</tbody>
</table>

1. Mean values as % of each plot.
   LSD = least significant difference.
Maize production

Maize grain yields for the two sites are shown in Figure 5.6. The effect of the legumes on the subsequent maize yield was more marked at Fashola than at Ibadan where only *Z. glabra* plots had significantly higher (P<0.05) maize yields than the natural fallow plot, although six other accessions also had higher maize grain yields, these were not significant (P<0.05). In contrast, at Fashola, seven accessions had higher maize grain yield (P<0.05) than the natural fallow, representing as much as 145% increase for *S. guianensis*.

![Grain yield (kg/ha) Ibadan](image1)

![Grain yield (kg/ha) Fashola](image2)

For the adjacent control trials on natural fallow, with five N-levels to maize (Figure 5.7), maize yields at Ibadan were not affected by N level, with even the 0 kg/ha N plot giving 3300 kg/ha grain. At Fashola, maize grain yield increased almost linearly with increase in N. At Ibadan, the maize plants between 37 and 68 days after planting were significantly taller for plots that received N than for those that did not, but there were no differences between the N levels. Comparing these control trials with the legume plots indicated that, at Fashola, *S. guianensis*, *Aeschynomene histrix*, *Calopogonium caeruleum*...
Legumes for forage and cereal production

Grain yield (kg/ha)

\[ y = 3090 + 7x \]
\[ (r = 0.891; P < 0.016) \]

Grain yield (kg/ha)

\[ y = 1610 + 280x \]
\[ (r = 0.980; P < 0.001) \]


Figure 5.7. Maize grain yield on natural fallow plots with various applications of nitrogen (N) to maize.

and *Arachis pintoi* plots gave maize grain yields equivalent to at least 80 kg/ha N whereas at Ibadan this applied only to the *Z. glabra* plot (50 kg/ha N).

Decomposition studies indicated that the decomposition rate (in terms of dry-matter disappearance) was somewhat higher at Ibadan with 50-70% loss during the first 3 weeks of incubation. At Ibadan the estimated half-lives of the material assessed varied between 14 days for the natural fallow and 33 days for *F. macrophylla*. Half-lives were longer at Fashola, with a range of 14 days for *Aeschynomene histrix* to 56 days for *F. macrophylla*. Material from *S. guianensis*, *Aeschynomene histrix* and natural fallow plots had the fastest decomposition rates during this period. Measurements of N release from the plant residues ranged between 26-88 kg N/ha and 19-52 kg N/ha at Ibadan and Fashola, respectively.

**Discussion**

Establishment of the legumes at both sites was generally slow. This was related to poor germination and growth during a dry spell following planting and, at Ibadan in particular, high weed pressure. Despite this, *Mucuna pruriens* covered the soil very fast, reaching over 60% within 6 weeks of planting. The high weed pressure at Ibadan is reflected in the composition and yield of the natural fallow plot at the end of the wet season where over 6000 kg/ha of herbs were recorded. In contrast, the Fashola site had
Forage Legumes in Subhumid West Africa

a lot more grass. Despite these differences in the natural vegetation, yield patterns at the two sites were similar, with *Stylosanthes guianensis* and *Aeschynomene histrix* producing highest. However, these species were not among those with the best regeneration ability before planting maize. *Centrosema macrocarpum*, *Centrosema pubescens*, *Flemingia macrophylla* and *Pueraria phaseoloides* seemed to have the advantage, probably as a result of their better ability to perennate. This harvest may have been too early for good establishment from newly germinated seeds to have taken place. Similar variations, reflecting the different growth habits of the various species, were evident following the maize harvest where the after-effects of the different cultivation methods at the two sites were also apparent. This was because the rotor-tiller destroyed perennating plants at Ibadan whereas many were able to survive the hand-cultivation at Fashola. Several of the species were also able to regenerate well the following wet season, supporting the concept that with appropriate species and management cereal cropping will not cause deterioration in the quality of legume pastures (Tarawali and Pamo 1992). Some species, such as *M. pruriens* behaved strictly as annuals, although this would not preclude its use as a short fallow where self-regeneration is not important. Indeed MacColl (1990) advocated for such species in fallow systems in order to reduce problems of cultivating the land if persistent perennials remained. It should, however, be noted that such problems should not arise if livestock graze the forage plants before maize cropping, with the manure being returned to the plot to ensure minimal loss of nutrient benefits.

Cobbina (1992) reported an assessment of selected forage legumes in a similar environment, and accessions of *Centrosema macrocarpum*, *Centrosema pubescens*, *P. phaseoloides* and *S. guianensis* had high herbage productivity with good N content, as in our study.

The effects of the various species on subsequent maize yield seemed to be related to the soil fertility at the two sites (Table 5.1). The response at Ibadan was very limited, even to different levels of N on the control plots. In contrast, on the more degraded Fashola soils, the legumes had a dramatic effect on maize production with many giving the equivalent of about 80 kg N/ha on the control plots. This ‘N equivalent’ is within the range reported by many authors for forage legume contributions to subsequent cereals (e.g. Jones et al 1991; Mohamed-Saleem and Fisher 1993; Tarawali and Mohamed-Saleem 1995). This stresses the potential of legumes in situations where the need is greatest—where soil is very degraded. There was no apparent relationship between the previous forage yield and the subsequent effect on maize production, although MacColl (1989) reported that nitrogen contribution of legumes to maize yield was related to vigour the previous season as well as time of seeding relative to vegetative growth. Nevertheless, there are likely to be innumerable interrelated plant and environmental factors that influenced the final maize yields, including soil physical and chemical changes. Although appreciable amounts of N, P and K were estimated to have been removed in the dry season biomass, this did not seem to affect maize yields, and many of the species were also able to accumulate considerable amounts of these nutrients in the period between dry season harvest and maize planting. In a farmer situation, removal of such large amounts of nutrients as fodder for livestock, may to some extent be compensated for by returning manure to the plots.
There may be some relationship between subsequent maize yield and forage quality (Tian et al 1993). *Arachis pintoi* plots yielded low amounts of forage but had good quality, and one of the best maize yields; this may be related to observations that plant residue quality can affect N mineralisation (Rubaduka et al 1993). In our study, there were indications that the decomposition rate was affected by the lignin:N ratio and amount of dry matter incorporated (Muhr 1998). Thomas and Lascano (1995) also found a good correlation between decomposition rates and lignin:N ratios for selected forage legumes.

The decomposition studies on selected material indicated that the half-lives were generally low, even for legumes. Thomas and Lascano (1995) reported a half-life of 47 days for *Arachis pintoi* in studies in South America, with several other legumes, and grasses having half-lives of over 100 days. Whilst it is important that decomposition takes place fairly fast so that nutrients are available to the maize during the crucial, early stages of growth, the rapid decomposition found in this study may mean that mineralised N was leached to lower soil layers before it could be used by the cereal crop (Jones et al 1991). This, in addition to the soil and weed factors discussed above, may also account for the observed greater response to both legumes and N at Fashola.

Nevertheless, such studies have indicated that these legumes can make important contributions to the soil N, and stress the need to consider the synchrony between crop requirements and release from leguminous plant parts.

In this study, *Desmodium ovalifolium, Dicloea guianensis* and *Cratylia argentea* generally performed poorly; they had low herbage yields, a negligible effect on maize yield and little ability to persist. *Calopogonium caeruleum* and *Zornia glabra* had poor herbage yields and persistence after maize cropping, but both seemed to have a positive effect on maize yield. *Arachis pintoi* had low herbage yield, but the quality was good (especially the very high digestibility, which would also have implications for energy availability). The species had a positive effect on subsequent maize yield and persisted well. Herbage yields of *Arachis pintoi* tend to be low partly because of its prostrate growth habit, but its fodder quality, persistence and soil improving properties are well recognised in South America and other tropical regions (Kerridge and Hardy 1994). It may be worth investigating *Arachis pintoi* further in the moist savannah regions of Nigeria along with other accessions of the species with greater drought tolerance which have recently become available (CIAT 1995b). *Centrosema macrocarpum, Centrosema pubescens, Stylosanthes guianensis, Aeschynomene histrix* and the shrub *Flemingia macrophylla* all performed well in this study, although each species has to be considered for its ability to fit into a particular farming system niche. The *Centrosema* accessions persist well under conditions where perennation is possible while *S. guianensis* and *Aeschynomene histrix* can regenerate from seeds. *F. macrophylla* is difficult to establish and may be harder to remove after some time and therefore may be better in an alley farming context. *Mucuna pruriens* and *Pueraria phaseoloides* behave essentially as annuals, especially *M. pruriens* which, with its outstanding ability to cover the soil and smother weeds, has an obvious advantage in certain situations. Indeed, in the Republic of Bénin farmers are adopting *M. pruriens* fallows to restore soil fertility, especially where the land is infested with *Imperata cylindrica* (IITA 1995). It is evident that the use of forage species for both fodder and
crop production is possible, and a number of the species tested in this study would be suitable for such systems. Selection of the most appropriate species needs to be carefully targeted at the farming and management system to be used (Tarawali and Peters 1996). Considerations here include length of the fallow period, cultivation method, labour available for weeding, requirement for forage the following season and extent of soil degradation.

Experiment 2: Effect of forage legumes on maize production and soil nitrogen (N) mineralisation with different levels of N to maize

Materials and methods

Establishment

This experiment was established at Ibadan using two forage legumes, *Centrosema macrocarpum* CIAT 5713 and *Stylosanthes guianensis* ILRI 164, in a split-plot design with nitrogen level to maize as the main plot (0, 30 or 60 kg/ha) and the two legumes as subplots. The trial was established at the beginning of the wet season, in May 1994, by establishing and monitoring the legumes as described in Experiment 1.

Forage potential

Biomass production by the two legumes was monitored as described in Experiment 1.

Maize production

At the beginning of the wet season, in May 1995, maize was planted and monitored as described in Experiment 1, with the central two rows of each subplot being harvested to estimate grain yield.

Soil analyses

To assess nitrogen (N) mineralisation of legumes during maize growth, the field incubation method was used (Raison et al 1987; Anderson and Ingram 1993). A pair of soil samples was taken from each plot at weekly intervals for the first 6 weeks after maize planting, and fortnightly for the next 6 weeks. One sample of each pair was analysed immediately for mineral N, and the other after 1 week incubation in the field.

Results

Establishment of legumes/forage potential

The two legumes established and produced essentially as in the first trial, with *C. macrocarpum* yielding 4500 kg/ha, 6000 kg/ha and 5300 kg/ha biomass dry matter in
November 1994, January 1995 and May 1995, respectively. Biomass dry-matter yields for *S. guianensis* were 12,500 kg/ha, 8000 kg/ha and 1700 kg/ha in November 1994, January 1995 and May 1995, respectively.

**Maize production**

At 0 kg N/ha maize grain yield after *C. macrocarpum* (3800 kg/ha) was significantly higher than the natural fallow control (2400 kg/ha) and was not affected by N application. Maize grown after *S. guianensis* responded to 30 or 60 kg/ha N but the effects of the two were not significantly different.

**Soil analyses**

Nitrate-N (NO\(^{-3}\)) in the soil during maize growth following *C. macrocarpum* was not affected by the N application but was higher than for *S. guianensis* at all N levels. At 0 kg N/ha, nitrate-N reached a maximum of 40 and 50 µg N/g soil 2 weeks after planting maize for *C. macrocarpum* and *S. guianensis*, respectively. For *S. guianensis*, for both N applications, maximum nitrate-N was 35 ppm, reached at 2 and 3 weeks after maize planting for 30 kg/ha and 60 kg/ha, respectively. For both legumes, nitrate-N declined to less than 10 µg N/g soil 8 weeks after maize planting.

**Discussion**

At Ibadan, where soil nitrogen was not considered to be a major limiting factor contributing to maize growth, the forage legumes had more effect on cereal growth than the N levels applied in this experiment. This may be related to nutrient release, as shown by the higher nitrate-N in the soil following *Centrosema macrocarpum* than following *Stylosanthes guianensis* which was reflected in the differences in the effects of the two species on maize yield in this experiment. Tian et al (1993) reported that plant residues affect the uptake of nutrients by maize plants. Rubaduka et al (1993) indicated that age of plant parts and hence quality affect the mineralisation of plant residues. Kachaka et al (1993) showed that lignification also has a significant effect on decomposition and N mineralisation. In our study this was indicated by the apparent lower soil N from *S. guianensis* which is more woody (meaning more lignified) than *C. macrocarpum*. Several authors have indicated that the effects of leguminous plant residues on subsequent cereal yields relate to more than soil N, and include both chemical and physical soil improvements (e.g. Mohamed-Saleem and Otsyina 1986; Tarawali and Mohamed-Saleem 1995).

Nitrogen losses through leaching of nitrate and ammonium produced by mineralisation of plant residues are thought to be small since mineralisation is stimulated by conditions that also increase plant growth and nutrient uptake (Alves et al 1993). Nevertheless, introducing forage legumes, especially in grazed pastures, is a good option to stabilise such systems.
Experiment 3: Effect of length of forage legume fallow on maize yield, maize nutrient uptake and soil mineral nitrogen (N) dynamics

Materials and methods

Establishment

This experiment was established at Ibadan using two forage legumes, *Centrosera macrocarpum* CIAT 5713 and *Stylosanthes guianensis* ILRI 164 in a split-plot design with length of fallow period (i.e. forage legume growth before maize planting in either the major wet season, May 1995, or the minor wet season, August 1995) as the main plot and the two legumes as subplots. The trial was established at the beginning of the wet season in May 1994 by establishing and monitoring the legumes as described in Experiment 1.

Forage potential

Biomass production by the two legumes was monitored as described in Experiment 1. Legumes on the plots planted with maize in the minor wet season were sampled again four weeks before planting the maize (July 1995) and again immediately before maize planting (August 1995).

Maize production

At the beginning of the major or minor wet season in May or August 1995, respectively, maize was planted and monitored as described in Experiment 1, with the central two rows of each subplot being harvested to estimate grain yield.

Results

Establishment of legumes/forage potential

Legume dry-matter yields in the mid-dry season were 7300 and 10,600 kg/ha for *C. macrocarpum* and *S. guianensis*, respectively. Thirty-eight per cent of the *C. macrocarpum* yield was shed leaves whereas this component was 23% of the *S. guianensis* yield. Before maize planting, in the major wet season, dry-matter yields were 4000 and 2500 kg/ha for *C. macrocarpum* and *S. guianensis*, respectively. In the minor wet season, after a longer regrowth period, biomass dry-matter yields were 6500 and 7700 kg/ha for *C. macrocarpum* and *S. guianensis*, respectively. Just over half the *C. macrocarpum* yield was shed leaves whereas this figure was about one-third of the total for *S. guianensis*. 
Maize production

On the control plots, maize production in the second wet season was generally lower than in the first, with 2300 kg/ha yield at 0 kg N/ha increasing to a maximum of 3300 kg/ha at 90 kg N/ha. Yields at 90 and 120 kg N/ha were significantly higher than those at 0 or 30 kg N/ha. Maize grain yield at 0 kg N/ha in the first wet season was not significantly different from that after either of the forage legumes. In the second wet season, both legumes gave higher maize grain yields than the 0 kg N/ha control, but did not differ significantly from each other. Analysis of the plant biomass indicated that more N was removed in S. guianensis herbage at the dry season harvest, but more was accumulated in C. macrocarpum plants between the dry season harvest and maize planting in the early wet season. Maize height and stem diameter measurements indicated that maize grown after C. macrocarpum may have a higher yield potential, since they were greater than those for maize grown after S. guianensis. However, this yield was not realised because the maize was attacked by stem borers.

Discussion

Whilst the best maize yields were obtained by planting the cereal in the major wet season, the effects of the forage legumes were more marked when cereal planting took place in the minor wet season. Planting at the beginning of the minor wet season also meant that more forage was available before maize planting, but the relative benefits of the two systems needs to be questioned. Is better maize yield, or better forage yield the main concern? Planting in the first wet season would seem to be favoured since maize yield would be likely to be the main concern at this time when forage supply from the surrounding vegetation is likely to be plentiful. Retaining the forage legumes for a longer period did confer some increase in subsequent maize yield as compared to natural fallow. Therefore if a farmer were forced to consider growing second season maize, there would be the benefit of having had legumes present, even on the apparently less degraded soil. These results suggest again, that the use of forage legumes for fallow and fodder needs to be carefully tailored to meet farmers' requirements. Studies such as this can indicate which options will give optimum results.

Experiment 4: Preliminary observations on the potential of forage legumes in south-west Nigeria

Materials and methods

Twenty-one farms of settled Fulani agropastoralists in the local government area of Oyo, south-western Nigeria (Figure 1.1), were selected from an earlier group of 63 crop-livestock farmers surveyed by Okoruwa (1994). The 21 farmers were visited in January 1995 and a short questionnaire was administered to determine their representativeness of the crop-livestock system(s) in the area with respect to resource endowment, and
their potential interest in improving dry season feed resources and soil fertility. These preliminary interviews were used to select 8 farmers who were interviewed in more depth to assess their willingness to participate in a 'planted fallow' trial before introducing the concept of on-farm establishment of selected forage legumes.

On-farm establishment of forage legumes

Eight farms were selected for on-farm establishment of legumes. On each farm only one replicate was planted, with four treatments—sole *Centrosera macrocarpum*; sole *Stylosanthes guianensis*; a mixture of *Centrosera macrocarpum, Stylosanthes guianensis, Centrosera pubescens, Aeschynomene histrix, Arachis pintoi, Desmodium ovalifolium, Dicloea guianensis, Zornia glabra, Flemingia macrophylla* and *Cratyli argentea*; and natural fallow (no planted legume). The total area planted ranged from 72 to 100 m², depending on the farmer's resources. Land clearing before legume planting was minimal and related to the farmer's interest and decision. Researchers visited the farmers and discussed how to establish the legume seeds; a consensus was reached that the legumes should be sown in strips of 50 cm wide with 50 cm in between. Plots were established at the start of the 1995 major wet season. Farmers' perceptions of the legumes and their approach to establishment and management were monitored during regular farm visits. The legumes were also monitored by seedling counts and biomass production estimates in the middle and at the end of the dry season.

Results

Preliminary survey

The preliminary survey of 21 farmers in January 1995 indicated that average farm size was 3.5 ha, cassava and maize were the predominant crops in the main wet season, and cassava and sorghum/yam were predominant in the minor wet season. About 40% of the total farm was left fallow during any one wet season, with fallow periods averaging 2.5 years. Average number of cattle per household was 25: more than half of these belonged to the Fulani while the remainder were given to the Fulani by arable farmers for 'caretaking'. Herd grazing was estimated to cover a radius of 3 and 9 km in the wet and dry seasons, respectively, with calves younger than 6 months remaining at the homesteads.

These interviews indicated that farmers perceived input costs and labour availability as the most limiting factors to agricultural productivity. Credit facilities to allow hiring labour/tractor at critical times were options that could boost cropping. Farmers felt that introducing legumes would be influenced by availability of labour, land, and seeds (in decreasing order of importance). Diseases were unanimously identified as the major limitation to cattle rearing, but farmers did not link these to inadequate nutrition; 20% of the farmers did recognise this as an additional problem. Availability of quality drugs at subsidised prices was considered important if cattle productivity was to be increased.
On-farm establishment of forage legumes

Most of the 8 selected farmers opted to plant the forage legumes on land where cassava or melon were being grown, but which had poor yields, declining yields being the best indicator that the land was due for fallowing. All except one of the participating farmers opted to plant the forage legumes more than 100 m from the homestead, although they acknowledged this distance may necessitate some protection in the dry season.

Table 5.3 shows the range of forage yields recorded in the farmers' fields 8 months after planting; yields for only S. guianensis and Aeschynomene histrix in the mixture plots

<table>
<thead>
<tr>
<th>Fallow</th>
<th>Dry-matter yield (range, kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrosema macrocarpum</td>
<td>580</td>
</tr>
<tr>
<td>Stylosanthes guianensis</td>
<td>1710-8500</td>
</tr>
<tr>
<td>S. guianensis in mixture</td>
<td>1110-2280</td>
</tr>
<tr>
<td>Aeschynomene histrix in mixture</td>
<td>340-700</td>
</tr>
<tr>
<td>Natural fallow (herbs)</td>
<td>0-440</td>
</tr>
<tr>
<td>Natural fallow (grasses)</td>
<td>0-2690</td>
</tr>
</tbody>
</table>


are given, since the other components originally planted did not give any measurable yields. The high yield of 8500 kg/ha for S. guianensis was from a farm where the plots were weeded twice. This species still gave reasonable yields (1710 to 3580 kg/ha) even in the absence of weeding. Establishment of Centrosema macrocarpum was generally poor: although the plants germinated, they were yellow and stunted until the end of the 1995 dry season, when the farmers reported that with the onset of the rains they became greener and started to grow better.

Five of the seven farmers who participated in the on-farm trial requested more forage legume seeds the following planting season, with one increasing the land under legumes to 0.25 ha. The most commonly requested species were S. guianensis and Aeschynomene histrix with one request for Mucuna pruriens and one for Desmodium ovalifolium.

Discussion

The initial survey revealed that farmers in the Oyo area did not rank limited nutrition of cattle as a major factor limiting productivity and nor did they perceive land degradation or lack of fallow to be serious problems. Nevertheless, the subsequent participation and discussions with farmers who agreed to test the forage legumes gave some clear indications that not only were the participants ready to learn new approaches but they quickly perceived the potential benefits to both crop and livestock production. Farmers who initially showed little interest in the forage plots by lack of weeding, were
subsequently impressed by the potential of the species. This resulted in requests for more seeds and farmers indicating they intended to collect seeds from their existing plots. Indeed, the interest was such that a demonstration of seed scarification was arranged at the spontaneous request of farmers on one of the field days!

The performance of the legume species was variable, with *Centrosema macrocarpum* initially performing poorly, in contrast to its on-station performance. This may have been related to local soil/rhizobia conditions, especially as plants seemed to recover the following year, and farmers were very interested in the drought tolerance ability of this species. Reports from South America have indicated that this species can be very poor if a specific *Rhizobium* strain is not applied (R. Schultze-Kraft, unpublished). *C. macrocarpum* is known to show reduced nitrogen fixation when P or K are low under field conditions (Cadisch et al 1992). *Stylosanthes guianensis*, however, grew well, even in the absence of weeding and has good potential for introduction into these farming systems.

Whilst of a very preliminary nature, the surveys, on-farm trials and field days conducted indicated that, with some initial explanation and demonstration, farmers appreciate the potential of forage legumes to contribute to their farming systems and are ready to provide inputs such as labour and land to ensure they obtain maximum benefits from such an intervention. On this basis, the onus is on the research community (Mohamed-Saleem and Fisher 1993) to ensure that appropriate material and instruction can be provided either directly or via national research and extension services. The studies described above, provide a useful basis for further developing appropriate strategies for the on-farm integration of forage legumes.

**Experiment 5: Cereal production on grazed forage legume pastures**

**Materials and methods**

Established, grazed pastures oversown with *Stylosanthes hamata*, *Chamaecrista rotundifolia* cv Wynn, *Centrosema pascuorum* cv Cavalcade or no added legume were used for this trial. The pastures were originally established in 1990 and managed as for fodder banks (Otsyina et al 1987), with 2 heifers grazing each paddock in the early wet (6 h/day) and mid-late dry seasons (2.5 h/day) for 3 years. In the 1993 wet season, plots of 48 × 22 m were demarcated in three replicates of each treatment. Each plot was divided into three equal subplots for N applications of 0, 60 or 120 kg/ha. Maize was planted on all subplots, with 60 kg/ha each P₂O₅ and K₂O. Planting and weeding were done according to traditional local practices (Tarawali 1991a) and the time taken for establishment, fertiliser application and harvesting operations was recorded. Ripe maize was harvested from the centre of each subplot, dried and threshed. Herbage biomass and botanical composition were assessed before and after maize cropping using the percentage rank and comparative yield estimate methods (Tothill et al 1992).
Results

Labour (man days) required to establish, maintain and harvest the maize crop on the pastures of different histories (Stylosanthes hamata, Chamaecrista rotundifolia, Centrosema pascuorum or native pasture) was not significantly different. Maize yields are shown in Figure 5.8. Chamaecrista rotundifolia and S. hamata paddocks gave maize yields significantly higher than native pasture or Centrosema pascuorum. Yields at the different N levels were significantly different for all pasture treatments, and maize yield per kg of N applied was about double that for native pasture for S. hamata and Chamaecrista rotundifolia. Forage yields at the end of the wet season, after maize harvest were about double those at the beginning. S. hamata and Chamaecrista rotundifolia yields increased proportional to this, but Centrosema pascuorum yield was halved, with the increased total yield in these plots consisting of grasses.

![Grain yield graph](image)


Figure 5.8. Maize grain yields following grazed pastures with various histories and with applications of three levels of nitrogen (N) to maize.

Discussion

Chamaecrista rotundifolia and Stylosanthes hamata improved maize yield, even after 3 years of grazing. In contrast, Centrosema pascuorum behaved as an annual and did not...
contribute significantly to maize yield after this longer fallow period, but it could function effectively in a one year fallow system, where its annual behaviour could be advantageous (MacColl 1990; Jones et al 1991). Since labour requirements to cultivate land that had previously been under legumes did not differ from natural fallow, farmers should not fear that the improved vegetation from legumes will subsequently present a labour problem; this confirms results on similar Stylosanthes pastures (Tarawali et al 1987). The forage legumes regenerated after the cropping phase and for S. hamata and Chamaecrista rotundifolia the proportion of legume in the pastures actually increased after cropping. This may have been related to the reduction of N in the pastures, which could reduce the invasion by nitrophilous grasses. Such observations have encouraged the recommendation that periodic cropping of such forage legume pastures should be used as a management practice to reduce grass invasion in the pasture (Tarawali and Pamo 1992). Increases in maize grain are likely to be matched by increases in the residue quantity (Powell 1984) and this, combined with the understorey of regenerating legumes, would contribute positively to the dry season forage resource after the cropping period. The positive benefits were more apparent for S. hamata and Chamaecrista rotundifolia partially because the length of pasture period before cropping suited the growth patterns of these plants better than the Centrosema pascuorum, although this species could be appropriate in other situations, for example where an annual fallow is required. Thus, these studies again stressed the importance of selecting the appropriate legume species for the farming system in question.
6 Seed production, distribution and collaboration with other institutes in subhumid West Africa

Introduction

Small-scale production of forage seed is important as a back-up to provide seed for experiments. It also facilitates the distribution of such materials to other national and international institutes for both research and seed multiplication. As such, forage legume seed multiplication has been an integral part of the ongoing project and consequently, methods for small-scale seed production, especially appropriate for national agricultural research systems (NARS) with limited resources have been developed (Tarawali 1994c).

With the promotion and initial success of forage plant use, comes the problem of seed supply. Seed for preliminary screening experiments may be available from international genebanks, but quantities are usually small and the material needed for larger experiments of promising material, and subsequent on-farm testing needs to be produced in the respective countries. For most West African countries, importation is costly, time consuming and may involve elaborate quarantine procedures. Large-scale commercial production of forage seed is often portrayed as a complex enterprise, requiring detailed knowledge of plant physiology with appropriate equipment for establishing, managing, harvesting, cleaning and storing the seed crops. However, experience in this project has shown that it is possible to produce reasonable quantities of basic seed with fairly limited resources and using mainly manual labour.

Collaboration with Nigerian NARS has been mainly with the National Animal Production Research Institute (NAPRI), Zaria, with particular focus on collection and preliminary evaluation research, as outlined in the various experimental descriptions. However, seed has been distributed by ILRI-Nigeria to other NARS and non-governmental organisations (NGOs) in both Nigeria and other West African countries.

Interaction with NARS has also taken place in the form of participation in a forage evaluation network, Recherche en alimentation du bétail en Afrique occidentale et centrale (RABAOC), a project within ILRI's African Feed Resources Network (AFRNET; ILCA 1991). The project involves CIRAD-EMVT (Centre de coopération internationale en recherche agronomique pour le développement-Élevage et médecine vétérinaire), CIAT and ILRI. Evaluation of forage material was carried out in 10 West and central African countries and has been reported (CIAT 1995a).

In addition to the RABAOC project, collaboration with CIAT has been in the form of germplasm exchange, with the collections of Centrosema brasilianum and Aeschynomene histrix being provided by their Genetic Resources Unit. The other major international institute with which collaboration has been developed is IITA. Collaboration here was twofold: firstly, provision of scientific advice and forage legume

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1. Some of the results presented in this chapter have previously been reported in Tarawali et al (1997).
development of projects with the cowpea breeders to investigate the forage potential of this crop. In this chapter, examples of the herbaceous legume seed multiplication and distribution are given, together with some of the work being developed on multi-purpose cowpeas.

Cowpea, *Vigna unguiculata* L. Walp., is a major fodder resource in the drier subhumid and semi-arid regions of West Africa. Farmers deliberately opt for varieties and crop geometries that will permit them to harvest cowpea haulms to conserve as fodder at the end of the wet season (Tarawali et al. 1997). As soon as the rains stop, the dry fodder is rolled up and stored on roof tops or in tree forks for feeding or sale later in the dry season, when prices of such a commodity are high. Indeed, farmers in Niger may derive up to 25% of their annual cash income from sales of cowpea fodder (ICRISAT 1991). Recognising the importance of fodder as well as grain from cowpea, IITA scientists commenced breeding efforts to identify dual-purpose varieties that would provide both grain and fodder (Akudabweni et al. 1990). In collaboration with ILRI scientists, experiments were also conducted in subhumid and semi-arid Nigeria to compare cowpea fodder with the identified forage legumes; these trials are summarised here.

**Small-scale forage legume seed production**

**Materials and methods**

Seed production plots established in 1988 on the premises of a commercial farm on the outskirts of Kaduna in the northern Guinea savannah were maintained until 1994 when a new, smaller multiplication facility was established on the research farm in the derived savannah at Fashola. The methods used to establish and maintain these plots were essentially the same at both sites, as described here.

**Site selection, establishment and maintenance**

Land was cleared and soil prepared to a fine tilth. A basal dressing of 200 kg/ha SSP was applied, with subsequent annual dressings of 100 kg/ha SSP. Forage legume accessions were established at the beginning of the wet season, by sowing scarified seed in rows at approximately double the recommended seed rates (Humphreys 1980) with 2.0 m between rows to facilitate weeding and harvesting. Rows were maintained weed free by hand hoeing as necessary. The rows were arranged so that different accessions of the same species were separated by at least 50 m, to minimise the risk of cross pollination.

Trellises, consisting of metal poles spaced 5.0 m apart with smooth wire at 0.5 and 1.0 m from the ground, were used for climbing species, and the young plants twined onto the wires initially.

At the end of each dry season, the plots were cut down to encourage good growth in the following wet season. In most instances, even annual species did not have to be resown because germination from dropped seed was sufficient.
Harvesting, cleaning and storage

All seeds were manually harvested by hand picking every 2–3 days once the seeds started to ripen. For species with large pods (Calopogonium, Centrosema, Chamaecrista, Clitoria, Lablab, Macroptilium, Pueraria etc), this consisted of picking the pods and threshing them later. For species with small pods (Aeschynomene, Desmodium, Stylosanthes and Zornia) plants were shaken over a container so that the ripe seeds fell from them. The seeds collected were then winnowed using local methods usually used for crop plants. Seeds were dried and stored in the active storage facilities of the IITA Genetic Resources Unit.

Results

Seed yields from Abuja Road seed multiplication plot (Kaduna) during the 1992/93 and 1993/94 dry seasons are shown in Table 6.1. For comparison, yields reported for the first dry season (1988/89) after the plots were established are also shown. Clearly, well established plots yield better than those newly planted, whether the species are annuals or perennials. Once established, Lablab purpureus consistently gave the best seed yields, with most of the other accessions showing some variation from year to year although Aeschynomene histrich also yielded well.

Table 6.1. Seed yields from Abuja Road seed multiplication plots.

<table>
<thead>
<tr>
<th>Species</th>
<th>Accession</th>
<th>1988/89 (kg/ha)</th>
<th>1992/93 (kg/ha)</th>
<th>1993/94 (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeschynomene histrich</td>
<td>ILRI 12463</td>
<td>260</td>
<td>600</td>
<td>417</td>
</tr>
<tr>
<td>Calopogonium mucunoides</td>
<td>ILRI 6750</td>
<td>44</td>
<td>350</td>
<td>737</td>
</tr>
<tr>
<td>Centrosema brasilianum</td>
<td>ILRI 155</td>
<td>45</td>
<td>703</td>
<td>315</td>
</tr>
<tr>
<td>Centrosema brasilianum</td>
<td>ILRI 6773</td>
<td>8</td>
<td>1209</td>
<td>360</td>
</tr>
<tr>
<td>Centrosema pascuorum</td>
<td>ILRI 9857</td>
<td>46</td>
<td>129</td>
<td>890</td>
</tr>
<tr>
<td>Centrosema pascuorum</td>
<td>ILRI 9858</td>
<td>49</td>
<td>495</td>
<td>292</td>
</tr>
<tr>
<td>Centrosema pascuorum</td>
<td>cv Cavalcade</td>
<td>n/p</td>
<td>63</td>
<td>625</td>
</tr>
<tr>
<td>Centrosema pubescens</td>
<td>ILRI 152</td>
<td>11</td>
<td>285</td>
<td>175</td>
</tr>
<tr>
<td>Chamaecrista rotundifolia</td>
<td>ILRI 10915</td>
<td>117</td>
<td>140</td>
<td>498</td>
</tr>
<tr>
<td>Chamaecrista rotundifolia</td>
<td>ILRI 10918</td>
<td>26</td>
<td>168</td>
<td>570</td>
</tr>
<tr>
<td>Chamaecrista rotundifolia</td>
<td>cv Wynn</td>
<td>n/p</td>
<td>180</td>
<td>76</td>
</tr>
<tr>
<td>Lablab purpureus</td>
<td>ILRI 147</td>
<td>92</td>
<td>1869</td>
<td>1555</td>
</tr>
<tr>
<td>Stylosanthes capitata</td>
<td>ILRI 9052</td>
<td>74</td>
<td>485</td>
<td>195</td>
</tr>
<tr>
<td>Stylosanthes guianensis</td>
<td>ILRI 164</td>
<td>57</td>
<td>272</td>
<td>80</td>
</tr>
<tr>
<td>Stylosanthes guianensis</td>
<td>ILRI 15557</td>
<td>n/p</td>
<td>541</td>
<td>170</td>
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<tr>
<td>Stylosanthes hamata</td>
<td>ILRI 15868</td>
<td>n/p</td>
<td>300</td>
<td>380</td>
</tr>
<tr>
<td>Stylosanthes hamata</td>
<td>ILRI 15876</td>
<td>n/p</td>
<td>350</td>
<td>77</td>
</tr>
<tr>
<td>Stylosanthes humilis</td>
<td>ILRI 7363</td>
<td>142</td>
<td>634</td>
<td>312</td>
</tr>
<tr>
<td>Stylosanthes scabra</td>
<td>ILRI 140</td>
<td>41</td>
<td>61</td>
<td>200</td>
</tr>
<tr>
<td>Stylosanthes scabra</td>
<td>ILRI 441</td>
<td>136</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

n/p = not planted.
Source: Modified from Tarawali (1994c).
A summary of the forage legume seed distribution to various institutes in West Africa is presented in Table 6.2. Over 300 kg of seeds, has been distributed for use in ILRI on-farm and on-station experiments and studies by IITA and national institutes in both Nigeria and other West African countries (Cameroon, The Gambia, Ghana and Mali). Seed has also been provided to NGOs, most of whom were working directly with farmers, meaning these seeds were immediately introduced into farming systems. This category also includes seed supplied to two commercial farms, one a large dairy farm interested in developing forage for the dairy cattle, and the other an arable farm concerned with introducing a livestock component to promote sustainability and optimise crop residue use on the farm.

Table 6.2. Forage legume seed distribution, 1993 to mid-1996.

<table>
<thead>
<tr>
<th>Institutes</th>
<th>Years</th>
<th>Number of accessions</th>
<th>Total weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILRI experiments</td>
<td>1993–95</td>
<td>37</td>
<td>129</td>
</tr>
<tr>
<td>IITA</td>
<td>1993–96</td>
<td>67</td>
<td>95</td>
</tr>
<tr>
<td>National institutes (Nigeria)</td>
<td>1993–95</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>National institutes (West Africa excluding Nigeria)</td>
<td>1993–96</td>
<td>36</td>
<td>13</td>
</tr>
<tr>
<td>Non-governmental organisations</td>
<td>1993–95</td>
<td>40</td>
<td>52</td>
</tr>
</tbody>
</table>


**Discussion**

The results from simple, on-station seed multiplication plots have demonstrated that seed multiplication of forage legumes is feasible, using locally available inputs. This should continue to provide an impetus for scientists of national research and extension programmes to develop in-country programmes for the production of basic quantities of forage seed for both research and subsequent dissemination to farmers. The importance of appropriate selection of material is apparent. Accessions with poor seed yields are likely to be very expensive to produce, and therefore would be of limited value to either researcher or farmer.

The availability of such seed means that, as appropriate technologies are developed for specific farming systems, farmers themselves could become involved in seed production, possibly using contract growing approaches. In this instance, farmers would be provided with appropriate seed by the national programme, together with technical expertise and advice on seed production. The farmer would be mandated to provide a specified quantity of clean seed for the national programme (Mengistu 1994). A more opportunistic approach (HSU 1994) is to adapt on-farm utilisation of forage species to allow for seed collection. With both approaches land and labour requirements and gender implications need to be taken into account when considering the development of on-farm forage seed production. For example, in some regions women have a central role in selecting and presenting crop seeds. Attention should also be paid to seed cleaning and storage, and here, a combination of modern technical knowledge and traditional methods may be the optimum approach (Agishi 1994; de Brujin et al 1994).
The summary of forage seed distribution probably presents a fairly accurate impression of the areas of collaboration, since provision of seeds is often the end result of a number of discussions or meetings to decide upon the most appropriate material for each situation. The information presented does not represent the total picture of forage research collaboration in West Africa. Indeed, the majority of forage seeds were distributed to national programmes in this region before 1993 meaning that, in most countries, it was no longer necessary to import seed from Nigeria. Some of the material included in the RABAOC network evaluation trials (CIAT 1995a) and now being multiplied and disseminated on farm by various national programmes, originated from trials in Nigeria. Seed originally provided for research by national or international institutes is also subsequently multiplied and passed on by them, both in the form of research trials, and in response to requests from individuals.

Preliminary investigations into the forage potential of dual-purpose cowpea

Materials and methods

Experiments to compare potential dual-purpose cowpeas with forage legumes were established at ILRI’s Kurmin Biri site in the northern Guinea savannah and at the IITA station at Minjibir in the semi-arid zone.

At the beginning of the 1993 wet season, a trial was established to investigate the potential fodder quality and quantity and grain yields from selected cowpea lines (Kanannado and IT89KD-288), Lablab purpureus ILRI 147, Centrosera pascuorum ILRI 9857 and Stylosanthes guianensis ILRI 164. The trial was a split-plot design with four replicates. Main plots were harvest dates, (H1 = end of the wet season; H2 = 8 weeks later, H3 = 16 weeks later) and subplots were the five legume accessions. Subplots were 5.0 x 2.0 m in size and consisted of four rows spaced 0.5 m apart, the central two rows being used for sampling. The two forage legumes were sown at 6 kg/ha, evenly distributed along the rows; the grain legume seeds were spaced at 20 cm intervals along the rows. A basal dressing of NPK fertiliser (15:15:15) was applied at planting and plots were weeded throughout the trial. At H1 and H2, two 1 m² quadrats were cut and weighed from the sampling area, one was tied and stored on a roof top, the other was dried at 65°C and ground through 1 mm or 2 mm sieves for crude protein (CP) and 48-hour in sacco digestibility analyses, respectively. At H3 samples were cut for dry-matter determination and quality analyses but no material was stored. At H3 seed yields were also estimated (by picking ripe pods, threshing, drying and weighing seed) from the central sampling area. At the same time, the material from H1 and H2 that had been cut and stored was reweighed, dried and ground as above for quality analyses.
Results

Forage dry-matter yields were generally higher at Minjibir than at Kurmin Biri (Table 6.3, with the exception of *S. guianensis* which did not germinate well at Minjibir. Cowpea forage and grain yields were very low at Kurmin Biri and although higher at Minjibir, they were superseded by the *Lablab purpureus* which had good forage and grain yields. Forage yield losses were lower for the first than for the second harvest, and were considerably higher at Kurmin Biri for the second harvest. Analysis of CP and in sacco digestibility indicated that material retained the same quality once harvested, but the later harvests had much lower values for these two parameters (about half the CP% and 10% to 15% lower digestibility) for both sites.

**Table 6.3. Forage dry-matter and grain yields and dry forage losses for three harvest dates.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Accession</th>
<th>H1 DM</th>
<th>H1 % loss</th>
<th>H2 DM</th>
<th>H2 % loss</th>
<th>H3 DM</th>
<th>H3 Grain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kurmin Biri</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Centrosema pascuorum</em></td>
<td>ILRI 9857</td>
<td>3875</td>
<td>8</td>
<td>2657</td>
<td>74</td>
<td>1783</td>
<td>256</td>
</tr>
<tr>
<td><em>Stylosanthes guianensis</em></td>
<td>ILRI 164</td>
<td>4663</td>
<td>10</td>
<td>6540</td>
<td>40</td>
<td>3964</td>
<td>0</td>
</tr>
<tr>
<td><em>Lablab purpureus</em></td>
<td>ILRI 147</td>
<td>3663</td>
<td>10</td>
<td>2432</td>
<td>42</td>
<td>1813</td>
<td>383</td>
</tr>
<tr>
<td>Cowpea</td>
<td>Kanannado</td>
<td>886</td>
<td>0</td>
<td>128</td>
<td>46</td>
<td>180</td>
<td>0</td>
</tr>
<tr>
<td>Cowpea</td>
<td>IT89D-288</td>
<td>537</td>
<td>10</td>
<td>167</td>
<td>37</td>
<td>229</td>
<td>18</td>
</tr>
<tr>
<td><strong>Minjibir</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Centrosema pascuorum</em></td>
<td>ILRI 9857</td>
<td>4465</td>
<td>2</td>
<td>4605</td>
<td>37</td>
<td>4975</td>
<td>0</td>
</tr>
<tr>
<td><em>Stylosanthes guianensis</em></td>
<td>ILRI 164</td>
<td>1489</td>
<td>12</td>
<td>476</td>
<td>0</td>
<td>3191</td>
<td>0</td>
</tr>
<tr>
<td><em>Lablab purpureus</em></td>
<td>ILRI 147</td>
<td>5295</td>
<td>8</td>
<td>4340</td>
<td>7</td>
<td>8190</td>
<td>869</td>
</tr>
<tr>
<td>Cowpea</td>
<td>Kanannado</td>
<td>2572</td>
<td>8</td>
<td>1599</td>
<td>46</td>
<td>3480</td>
<td>12</td>
</tr>
<tr>
<td>Cowpea</td>
<td>IT89D-288</td>
<td>1923</td>
<td>5</td>
<td>1336</td>
<td>28</td>
<td>3201</td>
<td>84</td>
</tr>
</tbody>
</table>

H1 = end of wet season; H2 = 8 weeks later; H3 = 16 weeks later; DM = dry matter.


Discussion

Dry-matter yields of the forage legume species were generally comparable with results from similar regions in Nigeria (e.g. Tarawali 1994a; Tarawali 1994b), however, forage and grain yields from the cowpea accessions were extremely low at Kurmin Biri. The generally poor performance of the grain legumes at Kurmin Biri is probably related to a combination of factors. These include variety selection (for resistance to insects and diseases), but especially the extremely poor and shallow soils which account for the somewhat surprising observation that in this wetter environment yields were lower than in the drier, but with deeper soils, site of Minjibir where yields of fodder compared favourably with those from a more humid environment (Akundabweni et al 1990). The low grain yields of cowpea were probably related to the fact that no insecticides were used, even though these were monocultures (the commonest practice amongst farmers being to intercrop with cereal so as to reduce insect pressure). This study has indicated
that the dual-purpose grain legumes have a good potential to contribute to fodder supplies in semi-arid regions where farmers are already familiar with the concept of fodder conservation. In wetter, subhumid areas, use of forage legumes may be more appropriate. The fodder availability from dual-purpose cowpeas can be further improved by appropriate breeding and selection programmes and crop management practices such as strip cropping rather than alternate row planting (Singh and Tarawali 1997; Tarawali et al 1997). A further improvement may also be achieved by new initiatives currently being developed by ILRI and IITA to improve the quality of the crop residue (Singh and Tarawali 1997).
7 Conclusions and recommendations

In sub-Saharan Africa annual population growth rates are about 3%, meaning that by 2020, the population will have increased fivefold from 1960. This is coupled with a demographic shift in population from rural to urban areas, meaning that the increase in urban population is likely to be nearer twentyfold (Club du Sahel 1995). Such changes mean there will be an increase in the demand for agricultural products, and the shift from rural to urban areas is likely to result in an increase in the demand for livestock products (Winrock 1992). The inevitable result of such increases in population will be an increase in agricultural activity in an attempt to meet the rising demands. However, much of the arable land is already being utilised (Alexandratos 1995); increased productivity must therefore come from either improving the productivity per unit area of land or expanding to marginal areas, traditionally a grazing resource for livestock. Expanding crop production and the concurrent reduction in fallow periods will lead to competition between crop and livestock ventures and subsequent degradation of the environment if appropriate interventions are not sought. Herbaceous legumes offer an attractive option in this context, being able to provide both fodder for livestock whilst at the same time improving soil fertility and promoting the sustainable use of land resources.

Over the course of at least 40 years, many experiments using forage legumes have been reported, but with little adoption by farmers (Thomas and Sumberg 1995); this is mainly because such material is not tested in farming systems. In contrast, and against the background of evolving crop-livestock integration, this project has attempted to evaluate and develop management and utilisation strategies for using forage legumes in current farming systems in subhumid West Africa. A number of promising opportunities to realise these strategies have been identified along with appropriate areas for future research and development foci. These include:

- Accessions of *Centrosema brasi!ianum* with potential to contribute to specific farming systems of either short fallow or longer-term pasture. This material needs to be characterised and evaluated further in readiness for dissemination.

- *Aeschynomene histrix* accessions with potential to provide nutritious ruminant fodder, contribute to soil improvement by maintaining soil fertility and to decrease the seed population of the parasitic weed *Striga hermonthica*. Further on-farm testing of such material is warranted.

- The potential of the indigenous forage resource has been indicated by collection in a limited area. This aspect of research requires further targeted collection throughout the region to conserve this valuable genetic resource.

- Forage legumes, in particular *Centrosema pubescens* ILRI 152, may be introduced into native *Panicum maximum* to provide a pasture supplement for young calves thus reducing their nutritional stress. This potential now needs to be exploited by increasing awareness amongst farmers, probably through on-farm trials and subsequent extension.

- Mixtures of forage legumes, selected to produce complementary combinations, have a tremendous potential to provide stable legume-rich pastures for cattle supplemen-
Conclusions and recommendations

tation. This approach can be used wherever forage legumes have been tested to enable appropriate accessions to be identified. Such mixtures minimise the risks usually associated with pasture establishment and management and are therefore appropriate for on-farm testing and subsequent wider extension. The potential of such mixtures for subsequent crop production, and their subsequent sustained forage production needs to be investigated.

- Selected forage legumes including accessions of Centrosema macrocarpum, C. pubescens, Aeschynomene histrix and Stylosanthes guianensis, and the shrub Flemingia macrophylla have the potential to contribute to both crop and livestock production in a sustainable manner. Farmers are already showing interest in using S. guianensis in particular. The use of these species for sustainable food and fodder production needs to be further promoted, especially as farmers becoming increasingly aware of the need to arrest land degradation.

- Forage legumes of particular interest, and with specific researchable topics have been identified. These include Centrosema macrocarpum, an extremely promising species for fodder and soil improvement but the limitations of seed production and micronutrient/Rhizobia requirements need investigation. Arachis pintoi, has the potential to contribute, especially in terms of energy because of its very high digestibility; it may be pertinent to investigate other accessions of this and related species of the same genus (e.g. Arachis glabrata) now available (CIAT 1995b). Similarly, new material of the promising species Stylosanthes guianensis is also available (CIAT 1995b) and studies of this could be appropriate.

- To promote the appropriate utilisation of forage legumes, seed production is mandatory and needs to be encouraged by national institutes, non-governmental organisations and, eventually, farmers themselves throughout the sub humid zone of West Africa.

- Dual-purpose legumes offer a good opportunity to integrate livestock and crop production, whilst optimising the returns from inputs. Further studies in this area should include evaluating fodder and grain production of appropriate breeders' lines, with emphasis on fodder quality.

Whilst this project has facilitated the promotion of forage legume utilisation for sustainable farming in subhumid West Africa, possible limitations include the relatively short time frame, meaning that long-term persistence could not be studied. In-depth economic studies were not implemented at this stage, but should certainly be included as the interventions are disseminated to farmers as proposed above. Nevertheless, the results of this project have a valuable role to play in contributing to the challenge portrayed by Tribe (1994):

> The challenge we all face today is learning how to produce higher yields of crops and livestock while still conserving essential natural resources, like soil, water, forests and biodiversity which will be needed for the survival of future generations.

In the context of this project, this challenge could be expanded with particular reference to the current limitations of adoption of herbaceous legumes. The results of
on-station research and some researcher-controlled trials on farmers' fields have clearly demonstrated the potential of such species to contribute to, if not play an essential role in, sustainable agriculture for the next decades. However, the awareness of the farmers and their readiness to adopt such technologies will continue to limit the expansion of this work if not appropriately addressed. There is a need to look for 'windows' in the farmers' perceptions of their needs, into which herbaceous legumes could fit. An example of this is the potential of herbaceous legumes, such as Aeschynomene histrix to reduce Striga hermonthica infestation in cereal fields. This would be a dramatic and visible demonstration of a legume's contribution that would make it immediately attractive to farmers for whom S. hermonthica represents a major problem. Such appropriate targeting of legume-based technologies will ensure their successful adoption by farmers (Weber 1996). Studies such as those reported here provide essential information on a range of species that will enable the selection of material that is best able to address the needs which the farmers in diverse situations perceive as paramount.
References


Guarino L. 1990. Collecting wild species in Dhofar, Southern Region of the Sultanate of Oman. *Plant Genetic Resources Newsletter* 81/82:41–44. FAO (Food and Agriculture Organization of the United Nations) and IPGRI (International Plant Genetic Resources Institute), Rome, Italy.


References


References


References


Forage Legumes in Subhumid West Africa


References


Thomas D. and Grof B. 1986. Some pasture species for the tropical savannas of South America. II. Species of *Centrosema, Desmodium* and *Zornia*. *Herbage Abstracts* 56:511-517.


Scientific and Industrial Organisation) Division of Tropical Crops and Pastures, St. Lucia, Brisbane, Queensland, Australia.


## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>Acid-detergent fibre</td>
</tr>
<tr>
<td>AFRNET</td>
<td>African Feed Resources Network</td>
</tr>
<tr>
<td>CIAT</td>
<td>Centro Internacional de Agricultura Tropical, Cali, Colombia</td>
</tr>
<tr>
<td>CIRAD-EMVT</td>
<td>Centre de coopération internationale en recherche agronomique pour le développement–Elevage et médecine vétérinaire</td>
</tr>
<tr>
<td>ICRISAT</td>
<td>International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India</td>
</tr>
<tr>
<td>IITA</td>
<td>International Institute of Tropical Agriculture, Ibadan, Nigeria</td>
</tr>
<tr>
<td>ILCA</td>
<td>International Livestock Centre for Africa, Addis Ababa, Ethiopia (now ILRI)</td>
</tr>
<tr>
<td>ILRAD</td>
<td>International Laboratory for Research on Animal Diseases, Nairobi, Kenya (now ILRI)</td>
</tr>
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<td>ILRI</td>
<td>International Livestock Research Institute</td>
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<td>National Animal Production Research Institute, Zaria, Nigeria</td>
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<td>National agricultural research systems</td>
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<td>NGO</td>
<td>Non-governmental organisation</td>
</tr>
<tr>
<td>RABAOC</td>
<td>Recherche en alimentation du bétail en Afrique occidentale et centrale</td>
</tr>
<tr>
<td>SAS</td>
<td>Statistical Analysis Systems</td>
</tr>
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<td>SSP</td>
<td>Single superphosphate</td>
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