Yield and nutritive value of tropical forage legumes grown in semi-arid parts of Zimbabwe

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Abstract

Four legume species (*Lablab purpureus* cv. Highworth, *Macroptilium atropurpureum* cv. Siratro, *Stylosanthes guianensis* cv. Fine stem and *Desmodium uncinatum* cv. Silverleaf) were grown in experimental plots on 4 soil types in Gokwe South District, Zimbabwe from 1995–1998. The textural classes of the soils were sand, sandy loam, sandy clay loam and clay. The first 3 soil types are regosols formed on Kalahari sands and the clay soils are black vertosols derived from basalt. Legume yield was not significantly affected ($P > 0.05$) by the type of soil. Lablab out-performed the other legumes with a dry matter yield of 5.9 t/ha, compared with 3.1, 2.9 and 3.3 t/ha for Siratro, Fine stem and Silverleaf desmodium, respectively. The corresponding protein concentrations in the legumes were 159, 167, 159 and 134 g/kg DM. The results show that all of these legumes can be grown satisfactorily in areas of high temperature and low rainfall and produce forage with a high protein concentration, with lablab producing the highest DMY.

Introduction

Since 1980, smallholder dairying has become a burgeoning industry in Zimbabwe. This has seen the introduction of temperate dairy breeds such as Friesians and Jerseys into the smallholder farming sector. Traditionally, ruminant animal production in this sector has depended on natural pasture. More recently, improved pastures have been introduced to augment the forage supply from the natural pasture.

The nutritive value of both the natural and planted pastures is not adequate to meet the nutrient requirements of dairy cows. The protein concentration in the natural veld fluctuates with seasonal changes and is often as low as 10–20 g crude protein (CP)/kg dry matter (DM) in the dry season (May–October) (Topps and Oliver 1993). The conventional sources of supplementation of forages are plant proteins, non-protein nitrogen and some animal protein (blood, meat and bone meal) (Ngongoni and Manyuchi 1993). These nitrogen supplements are becoming increasingly unavailable and generally too expensive for smallholder farmers.

Protein-rich forage legumes offer an opportunity to provide a cheap source of quality feed and enhance animal production in the tropics (Mupangwa *et al*. 1997). The protein concentration in legumes ranges from 150–300 g/kg DM (D'Mello 1992; Topps and Oliver 1993). Other important attributes of forage legumes include higher intake, digestibility and mineral status when compared with tropical grasses (D'Mello and Devendra 1995). The performance of forage legumes in the smallholder farming sector, which is characterised by low rainfall, high ambient temperatures and low-fertility soils, is generally unknown. Most studies with forage legumes in Zimbabwe have been conducted on research stations, at higher altitudes and receiving higher rainfall. The objective of this study was to determine the biomass production and nutritive value of 4 common forage legume species: *Lablab purpureus*, *Macroptilium atropurpureum*, *Stylosanthes guianensis* and *Desmodium uncinatum.*

Materials and methods

The study area

Gokwe South District is located in the Midlands region (altitude of 900–1200 m) of Zimbabwe.

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The District lies in the south-west part of the country. Annual rainfall ranges from 450–800 mm, with rainfall increasing from north to south. The District is predominantly a Kalahari sand escarpment, but soils to the north-west are basaltic and shallower. Vegetation types are mainly Tree Savanna and Tree Bush Savanna.

Participating farmers

In 1995, there were 69 smallholder farmers producing milk in the District. The soils in the District were of 4 major textural classes, namely sands (Kalahari sands derived from granite), loamy sands, sandy clay loams and clays. The first 3 soil types are regosols formed on Kalahari sands and clay soils are black vertosols. The farms were stratified into 4 blocks on the basis of the type of soil on each farm. The participating farms were then selected randomly within each soil type. Twelve of the participating farms were on Kalahari sands, and 6 farms on each of the other 3 soil types.

Soil analysis

Five random soil samples were taken from the pasture field on each of the 30 selected farms. The samples were taken using a soil auger to a depth of about 15 cm. The 5 samples from each field were then mixed, and a subsample taken into a polythene bag. The samples were air-dried for 4 days before being taken to the laboratory for analysis for pH, cation exchange capacity, N, P and K. The characteristics of the soils are shown in Table 1.

Table 1. Chemical characteristics of 4 soil types in Gokwe South District, Zimbabwe.

Characteristic	Soil texture			
	Clays	Sandy clay loams	Loamy sands	Sandy soils
pH	6.0	5.8	6.0	5.3
Cation exchange capacity (cmol(+)/kg)	35.9	19.3	13.1	3.3
Nitrogen (ppm)	7.0	12.7	4.3	6.0
Phosphorus (ppm)	0.2	1.3	0.9	0.9
Potassium (cmol(+)/kg)	0.5	0.5	0.5	0.2

Types of legumes

The legume species were: *Lablab purpureus* cv. Highworth, *Macroptilium atropurpureum* cv. Siratro, *Stylosanthes guianensis* cv. Fine stem and *Desmodium uncinatum* cv. Silverleaf.

Experimental design and management of experimental plots

The experiment was carried out from December 1995–March 1998. The 30 selected farms were grouped into 4 blocks according to the 4 soil types. Each of the selected legumes was grown on each farm in duplicate plots measuring 6 m × 6 m in area. Because of limitations of land on some farms, duplicate plots were possible on only 5 farms on the sandy soils, 3 on the sandy clay loams, 4 on loamy sands and 2 on the vertosols. Where duplicate plots were not possible, sites were selected and plots made so as to minimise variations due to nuisance factors such as fertility gradients. The space between plots was 1 m and a path of 2 m was left from the borders of each field. The 4 legume species were randomly allocated to the plots.

The legumes were planted between December 3–10, 1995. Reflecting the most common practice in the district, all legumes were planted without any organic or inorganic fertiliser treatment. The land allocated for the plots on each farm was first ploughed by an ox-drawn mouldboard plough and then harrowed to a fine tilth. The seeding rates for legumes were 3, 4 and 7 kg/ha for Fine stem, Silverleaf or Siratro and lablab, respectively (Grant 1976). The seeds, except for lablab, were placed by hand in furrows about 1 cm deep and lightly covered with soil. Lablab seeds were placed in holes about 3 cm deep, and one seed was placed in each planting station. The inter-row spacing for lablab was 1 m, and that for the other legumes was 0.5 m (Skerman *et al*. 1988). No inoculation with *Rhizobium* was carried out. Seedling establishment was recorded by taking seedling counts 4–6 weeks after the main emergence event. Plot cover was estimated by measuring the amount of bare ground in each plot.

The management of experimental plots, which included seedbed preparation, planting, weeding and harvesting, was done jointly with the farmers and the local extension staff. Hand weeding was done when necessary.

Harvesting

The legumes were harvested post-anthesis at the mid-full bloom stage (physiological maturity) to maximise dry matter yield. Two central quadrats

(1 m × 1 m) from each plot were cut. The cut forage was immediately weighed. After weighing, the forage was chopped using machetes into pieces about 5 cm in length to facilitate mixing so as to obtain a 1 kg representative sample of each forage to be used for laboratory analysis. Duplicate samples were mixed after chopping before taking a 1 kg subsample. The samples were air-dried in-doors for 5 days before being taken to the laboratory for analysis. Harvesting was not possible on one farm each on the sands, sandy clay loams and the clays, due to tampering by animals, giving a total of 27 samples for each legume species.

Sample preparation for analysis

One half of each air-dried sample was dried in a forced-draught oven at 105°C for 24 h for dry matter yield (DMY) determination. The other half to be used for chemical analysis was dried at 60°C in a forced-draught oven for 48 h, ground in a Wiley mill to pass through a 2 mm screen, placed in a plastic sample bottle and stored.

Chemical analysis

The ash content of the samples was determined by igniting the samples in a muffle furnace at 550°C for 8 h. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the method of Goering and Van Soest (1970). Acid detergent fibre samples were used to determine acid detergent insoluble nitrogen (ADIN) concentration. Crude protein and ADIN were analysed by the Kjeldahl method (AOAC 1990). Calcium and phosphorus were determined from ash solutions by an Unicam 701 ICP spectrophotometer (Unicam 1992).

Rumen studies

The forage samples were bulked for each species in each season according to soil types to give a total of 12 samples (4 soil types × 3 seasons) for each legume species. The digestible organic matter (DOM) was measured *in vitro* by the method of Tilley and Terry (1963). The DOM values were used to calculate digestible organic matter yield (DOMY).

Statistical analysis

The data were analysed by the General Linear Models (GLM) procedure of the Statistical Analysis Systems (SAS) package (1990). The following model was fitted to the data:

$$Y_{ijkl} = \mu + A_i + B_j + C_{k(j)} + D_l + A \times D_{(il)} + E_{ijkl}$$

where:

Y_{ijkl} = observation of the l^th grass on the k^th farm on the j^th soil in the i^th season;

μ = overall mean common to all observations;

A_i = effect of the i^{th} season (i = 1,2);

B_j = effect of the j^{th} soil type (j = 1,2,3,4);

$C_{k(j)}$ = effect of the k^{th} farm within the j^{th} soil (k = 1,2…27);

D_l = effect of the l^{th} forage species (l = 1,2,3,4);

$A \times D_{(il)}$ = effect of the interaction between forage type and season; and

E_{ijkl} = random residual error associated with the $ijkl^{th}$ observation.

Farm effects within soil type were used as the error term for testing the effects of the soil type.

Results

Meteorological data

Rainfall data for the 3 years during the growing seasons of 1995–1998 were recorded for the months of December–April for each growing season. These data are shown in Figure 1. The rainfall pattern was normal for the area. Mean maximum and minimum temperatures for the same periods are shown in Figure 2.

Establishment and persistence

The legumes were sown in the first season in 1995 and persisted well throughout the study. Germination rates on all soil types were 95 and 80 percent for Siratro and lablab, respectively. The germination rate of Silverleaf was 65 percent on the sands and loamy sands and about 50 per cent on the sandy clay loams and the clays. However, by mid-season the plot cover for Silverleaf was around 70 per cent. Fine stem stylo had close to 90 per cent germination on all soil types. The stoloniferous and mat-forming legumes managed to cover the experimental plot, achieving 95 per cent plot cover at the end of the first season. Fine stem stylo had about 70 per cent plot cover on the

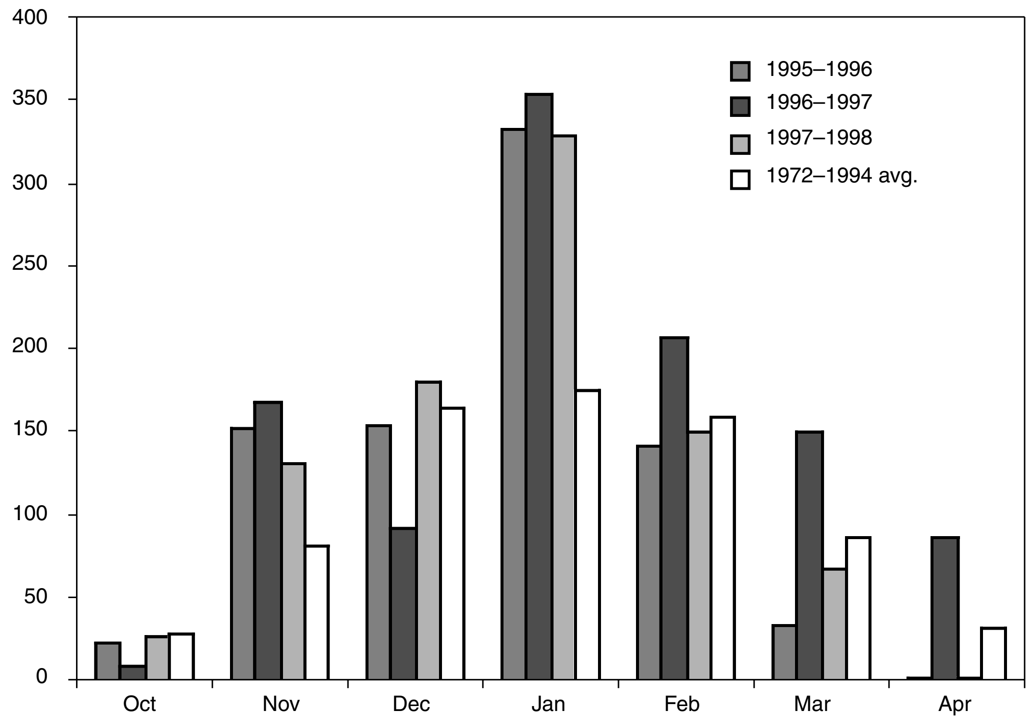

Figure 1. Rainfall data for the rainy seasons of 1995–1998 for Gokwe South District, Zimbabwe.

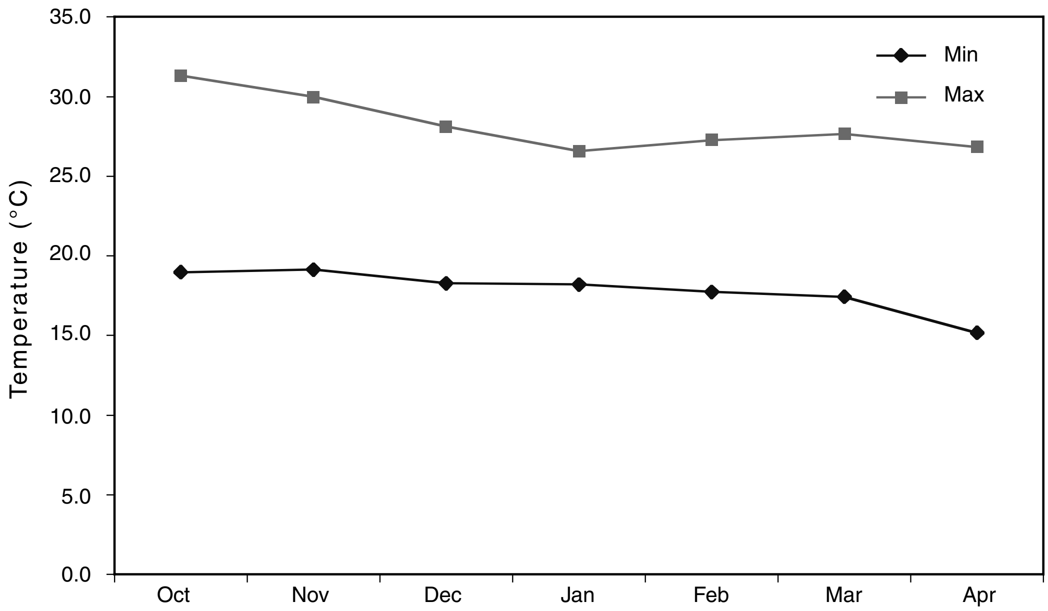

Figure 2. Average monthly minimum and maximum temperatures during the rainy seasons of 1995–1998 in Gokwe South District, Zimbabwe.

sands, sandy clay loams and clays and 80 per cent on the loamy sands at the end of the first growing season. Lablab was re-seeded every season because there were only a few volunteer plants in most plots at the beginning of each new season.

Dry matter and digestible organic matter yield

All legumes were harvested under a single-cut regime. The DMYs of the legumes are shown in Table 2. There was no significant (P > 0.05) species by soil type interaction and as such, main effects only are presented. Lablab produced the highest DMY and DOMY of 5.9 and 3.5 t/ha, respectively. Fine stem stylo had the lowest DMY, but this did not differ significantly (P > 0.05) from Siratro. The DOMYs were 1.9 t/ha for Siratro and Fine stem stylo, and 1.8 t/ha for Silverleaf.

There were significant effects on these parameters due to season of growth and species (P < 0.001). There were no significant soil effects (P > 0.05) on DMY and DOMY. Farm effects were not significant (P > 0.05). There was a significant (P < 0.001) species × season of growth interaction: proportionally more DMY and DOMY were obtained for Siratro, Silverleaf and Fine stem stylo in the second and third seasons of growth than in the first season. There were no differences (P > 0.05) in DMY and DOMY between the seasons for growth for lablab. All other interactions were not significant and were not used in the analysis.

Table 2. Least squares means of dry matter yield of 4 legume species grown in Gokwe South District, Zimbabwe.

Legume	Year 1	Year 2	Year 3	Mean
		(t/ha)		
Siratro	2.2a[1]	3.4b	3.6b	3.1ACD[2]
Lablab	5.7a	6.1a	5.9a	5.9B
Silverleaf	2.3a	3.5b	4.0b	3.3C
Fine stem stylo	2.0a	3.6b	3.1b	2.9D

[1]Values within a row followed by the same lower case letter do not differ significantly (P > 0.05). Standard error of the difference between values = 0.12.
[2]Species means followed by the same upper case letter do not differ significantly (P > 0.05). Standard error of the difference between means = 0.05.

Forage quality

The data on forage quality are shown in Table 3. There were significant effects (P < 0.001) on chemical composition of the legumes due to species. Siratro had the highest (P < 0.05) CP concentration (167.5 g/kg DM) and Silverleaf the lowest (134.5 g/kg DM). Silverleaf and Fine stem stylo were significantly more fibrous (P < 0.05) than Siratro and Lablab. The differences among the legume species in the concentrations of the other constituents were small and likely to be biologically insignificant. Silverleaf had the highest organic matter (OM) digestibility (642.9 g/kg DM) and Fine stem stylo the lowest (541.3 g/kg DM).

Discussion

Establishment and persistence

The differences in establishment rates on the light and heavy textured soils were small for lablab, Fine stem stylo and Siratro, indicating little effect of soil texture. On the contrary, Silverleaf invariably exhibited lower establishment rates on the clay soils. The generally lower establishment rates of Silverleaf could be attributed to poor seed viability. However, the more than 70 per cent plot cover achieved with Silverleaf by the middle of the first season confirms the suggestion by Graham and Muller (1985) that, in drier environments, the problem period is the early seedling survival stage rather than germination failure.

Persistence past the first year of growth is an important consideration for legumes to be used as permanent pastures (Jones and Rees 1997). This attribute was exhibited by Fine stem stylo, Silverleaf and Siratro due to their ability to build soil seed reserves. Highworth is not a good perennial as it failed to persist beyond the year of establishment. This is a well-known attribute of this particular cultivar and cv. Endurance may give better perennation.

Fodder yield and quality

The legumes used in this trial were grown with the aim of optimising yield by harvesting at physiological maturity. This means that the legumes were harvested at different times. All legumes attained physiological maturity late in the season, which did not give time for any meaningful regrowth, allowing for only a single harvest.

Topps and Oliver (1993) reviewed the performance of *Desmodium*, *Macroptilium*, *Stylosanthes* and *Lablab* species in tropical conditions in Southern Africa. However, results have varied

Table 3. Least squares means of chemical composition (g/kg dry matter) of 4 legume species grown in Gokwe South District, Zimbabwe.

	Legume type				SEM
	Siratro (n = 80)[1]	Lablab (n = 77)	Fine stem stylo (n = 77)	Silverleaf desmodium (n = 77)	
Ash	122.9a[2]	100.8b	104.0b	104.0b	1.90
Organic matter	877.1a	899.2b	896.0b	896.0b	1.90
Organic matter digestibility	623.2a	601.7b	541.3c	642.9d	1.35
Crude protein	167.5a	159.0b	159.1b	134.5c	0.90
Neutral detergent fibre	495.4a	465.5b	521.1c	514.2c	4.10
Acid detergent fibre	331.9a	331.4a	414.4b	384.2c	2.30
Acid detergent insoluble nitrogen	2.0a	2.3b	3.0c	2.6d	0.02
Calcium	9.8ab	9.6b	9.2c	9.3bc	0.10
Phosphorus	1.5a	2.1b	2.3c	1.9d	0.04

[1]Number of samples.
[2]Means in the same row followed by different letters are significantly different ($P < 0.05$).

widely due to the heterogeneous production environment found in this region. Many of the results on legume production have varied according to soil type (Jones and Rees 1997), fertiliser application and cutting interval (Mero and Uden 1997). The results obtained in this study fall within some ranges reported in the literature. For example, Jones and Rees (1997) obtained DMYs of 2.4–2.9 and 1.7–8.1 t/ha for lablab cv. Highworth and Siratro, respectively. Where differences occur, these may derive from different conditions in different experiments.

The fodder yield of the legumes was not affected by soil type. Although the plants were not examined for the presence of active nodules, this could have been due to the nitrogen-fixing ability of legumes, which supplies absorbable nitrogen, often the limiting factor in fragile soils. Siratro is widely reported in the literature as being well adapted to light soils (I'ons 1977) but performed equally well on the heavy textured soils in this study. The significant legume × season interaction on fodder yield would be a function of the stands of Silverleaf, Fine stem stylo and Siratro improving with age whereas lablab yields stayed stable. Lablab was established from seed in each season. The increase in plant density, mainly due to free seeding, could explain the increase in yield of Silverleaf desmodium, Siratro and Fine stem stylo in the second and third seasons.

The results of this study show the high biomass production of lablab, in accordance with the findings of Jones and Rees (1997) and Mero and Uden (1997). The major disadvantage of lablab is its failure to persist beyond the season of establishment. Lablab is not a good perennial (Mero and Uden 1997). While other cultivars, for example, Endurance, may give better perennation, the high costs incurred by having to plant this species annually must be weighed against the 44–51% higher yields from this species.

Chemical composition

Legume quality is affected by leaf:stem ratio. The values for quality of legumes shown in Table 3 fall within ranges cited in the literature. Leaf:stem ratios are more valuable in legumes because the leaves are metabolic organs (van Soest 1982). Silverleaf desmodium had the lowest CP concentration, probably due to reduced leaf:stem ratio as a result of poor leaf retention under heat stress. Silverleaf desmodium was adversely affected by high ambient temperature just prior to harvesting, as some of its leaves dropped off. This was not observed with the other species. This leaf fall on *Desmodium* can be managed by harvesting the legume earlier.

It is also important to note that both maturation and ambient temperature will affect various parts of the same plant differently (van Soest 1982). The quality of stems is largely affected because of their structural function. This brings about varying effects of leaf:stem ratios between species. Viewed differently, the ratio of the CP:cell wall (NDF) fractions is roughly 1:3 for lablab, Siratro and Fine stem stylo and 1:4 for Silverleaf desmodium. This indicates a higher proportion of cell wall to CP in Silverleaf desmodium.

The legumes have high OM digestibility except Fine stem stylo. The low OM digestibility of Fine stem stylo would be a function of its high fibre and ADIN concentrations compared with other legumes. High fibre and ADIN concentrations lower digestibility (Van Soest 1982).

Conclusion

The results presented in this study indicate that lablab has great potential, mainly because of its high biomass production. Where seed and labour availability are not limiting, its production is recommended. The poor leaf retention of Silverleaf desmodium under heat stress is an undesirable attribute that makes it unsuitable in this district, unless grown in shady areas or harvested earlier to prevent leaf fall. Fine stem stylo and Siratro are good perennials, but their relatively low yields mean that they require large areas of land to produce adequate quantities required to last a dry season of about 5 months.

The legumes are recommended for use in a cut-and-carry system, and should be grown in the wet season, harvested and conserved to be fed as supplements in the dry season. It is during the dry season that natural pasture is inadequate and of poor quality. The legumes would offer a relatively cheap source of supplementary feeding.

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