ORSKOV R

Animal Science 1996, **63**: 381-388

1357-7298/96/56950381$20·00

The effects of supplementation with *Gliricidia sepium* or *Leucaena leucocephala* forage on intake, digestion and live-weight gains of *Bos taurus* × *Bos indicus* steers offered napier grass

S. A. Abdulrazak[1]†, R. W. Muinga[2], W. Thorpe[3] and E. R. Ørskov[1]

[1]*Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB*
[2]*Kenya Agricultural Research Institute, Regional Research Centre, Mtwapa, PO Box 10275, Bamburi, Kenya*
[3]*International Livestock Research Institute, PO Box 30709, Nairobi, Kenya*

Abstract

Two experiments were carried out to evaluate the effect of incremental levels of Gliricidia sepium *(gliricidia) and* Leucaena leucocephala *(leucaena) on forage intake, diet apparent digestibility, microbial nitrogen supply and live-weight changes in cattle. In each experiment, 20 intact and five fistulated crossbred steers (*Bos taurus × Bos indicus*) were used. Napier grass basal diet was offered* ad libitum *alone or supplemented with 7·5, 15, 22·5, or 30 g dry matter (DM) per kg metabolic body weight ($M^{0.75}$) gliricidia (experiment 1) or leucaena (experiment 2). In experiment 1, total DM intake increased but not significantly with gliricidia supplementation (5·2, 5·1, 5·2, 5·4, 5·7 (s.e.d. 0·21) kg/day) while intake of napier grass was depressed linearly (5·2, 4·7, 4·5, 4·3, 4·2 (s.e.d. 0·21) kg/day; $P < 0·05$). In experiment 2, supplementation with leucaena increased the total DM intake linearly without depressing the intake of napier grass (5·2, 5·8, 6·2, 6·6, 6·7 (s.e.d. 0·31) kg/day; $P < 0·001$ and 5·2, 5·3, 5·3, 5·3, 5·0 (s.e.d. 0·21) kg/day respectively). Neither gliricidia nor leucaena supplementation affected the apparent digestibility of the diet or* in sacco *DM degradation characteristics of the forages. Rumen ammonia and live-weight gain were increased linearly ($P < 0·05$) by supplementation from 130 to 215 mg/l (experiment 1) and 75 to 113 mg/l (experiment 2), from 306 to 478 g/day (experiment 1) and from 538 to 850 g/day (experiment 2), respectively. However, since the responses were linear, further experiments are required to quantify the responses to higher levels of these legume supplements.*

Keywords: *gliricidia, leucaena, purines, steers, supplements, tropical Africa.*

Introduction

In tropical regions, grass forages grown with minimal application of fertilizers are generally low in nitrogen (N) and digestible organic matter (Leng, 1990). Cattle offered such forages are therefore unlikely to consume adequate nitrogen for efficient rumen digestion and resultant intake and animal performance, particularly for dairy production, will be low. Protein supplementation of grass diets containing less than 70 g crude protein per kg dry matter (DM) has increased DM intake and animal performance (Minson and Milford, 1967). A wide variety of legume trees grow in the tropics and their protein-rich forage can improve the production of ruminants consuming low quality grasses (Devendra, 1993). One of the most widely used legumes is *Leucaena leucocephala*. Supplementation of tropical grass with leucaena forage has been shown to improve the lactation performance of dairy cows (Muinga *et al.*, 1995). However, the psyllid pest has greatly reduced the productivity of leucaena in coastal Kenya (Reynolds and Bimbuzi, 1993) and alternative sources of legume forages are required. *Gliricidia sepium*, a legume tree producing high quality fodder, is a potential substitute (Bennison and Paterson, 1993).

Estimates are required for animal performance and rumen characteristics when these legumes are given

† Present address: S. A. Abdulrazak, Kilifi Institute of Agriculture, Department of Animal Science, PO Box 195, Kilifi, Kenya.

as supplements to low-nitrogen basal diets. Recommendations can then be developed for feeding systems that utilize optimal levels of the forages for growing cattle, and subsequently for dairy production. To contribute to those objectives, two experiments reported in this paper were carried out to measure voluntary food intake, diet apparent digestibility, rumen characteristics and live-weight changes in *Bos taurus* × *Bos indicus* steers given a basal diet of napier grass (*Pennisetum purpureum*, var. bana) supplemented with incremental levels of gliricidia (local accession) or leucaena (accession K28) forage.

Material and methods

The experiments were conducted at the Kenya Agricultural Research Institute (KARI), Regional Research Centre, Mtwapa (3° 56'S, 39° 44'E) in the coastal lowland coconut-cassava agro-ecological zone (Jaetzold and Schmidt, 1983). Experiment 1 was conducted between 1 May and 9 July 1993, and experiment 2 between 24 July and 1 September 1993. The monthly rainfall during May, June and July was 272, 185 and 79 mm respectively, and July, August and September was 79, 62, 71 mm respectively.

Animals

The same 20 crossbred (*Bos taurus* × *Bos indicus*) steers were used in both experiments to measure voluntary food intake, diet apparent digestibility and to estimate live-weight change and rumen microbial yield. At the start of experiments 1 and 2, the mean age and live weight of the steers were 12 months and 173 (s.d. 17·9) kg and 15 months and 208 (s.d. 18·1) kg, respectively. Before the commencement of the experiments the steers were drenched with an anthelmintic and blood obtained from the caudal vein to screen for trypanosomes. Five crossbred (*Bos taurus* × *Bos indicus*) steers each fitted with a flexible rubber cannula, were used to estimate changes in rumen ammonia nitrogen (NH_3-N) and *in sacco* degradation characteristics of forages. They had an initial mean live weight of 391 (s.d. 45·9) kg and 406 (s.d. 45·1) kg at the start of experiments 1 and 2, respectively. All the steers were confined in individual, well ventilated stalls, and each week were weighed and sprayed with an acaricide.

Diets

Napier grass was harvested daily at about 1·0 m height; it was chopped with a motorized cutter to pieces of about 50 mm which limited preferential selection of forage components. Gliricidia and leucaena were harvested daily in the morning for feeding the same afternoon, with some allowed to wilt overnight for the feed offered the next morning. Stems thicker than 50 mm were removed from the legume forages to ensure that the fodder composition was uniform. Gliricidia forage was harvested after 8 weeks regrowth, while leucaena foliage was harvested from mature plants (flowering stage). Five amounts of gliricidia (experiment 1) or leucaena (experiment 2) were offered: 0, 7·5, 15, 22·5 or 30 g DM per kg metabolic body weight ($M^{0.75}$).

Experimental procedure and design

The napier grass was offered twice or three times daily to ensure constant availability of fodder. Food refusals were weighed in the morning before fresh forage was offered. Animals with refusals of less than 5 kg fresh weight were offered 5 kg more forage than the total amount offered the previous day. The leguminous forage was offered daily at 06.00 h and 15.00 h in two equal parts by weight. The forages offered were sampled for DM determination once per week. The live weights recorded at the end of each week of the experiment were used to calculate the amount of legume forage to be offered during the subsequent week. Water and a mineral lick which contained 189 g Ca, 110 g P, 130 g Na, 4 g S and 1·6 g Cu per kg, were on offer at all times. The five diets were offered in a randomized design for the 20 steers, i.e. four animals per treatment; measurements were recorded for 7 weeks. The same experimental diets were offered in a 5 × 5 Latin-square design to the five steers fitted with rumen cannula; each period of the experiment consisted of a 10-day adaptation and a 4-day data collection period.

Rumen pH, NH_3 and in sacco *degradation*

To determine the *in sacco* degradation characteristics of the forages, 5 g of dry sample milled through a 3·5-mm screen were placed in nylon bags (140 × 75 mm, pore size 40 to 60 μm). During the last 4 days of each period, nylon bags in duplicate containing napier grass and gliricidia (experiment 1) or leucaena (experiment 2) were placed in the rumen. The bags were removed after 6, 12, 24, 48, 72, and 96 h and stored in a freezer. The 0-h measurement was obtained by soaking the bags in warm water (37°C) for about 15 min. At the end of the degradability trial the bags were hand-washed under running water until the water coming out of the bags was clear. The samples were then dried in an oven at 85°C to determine DM disappearance. The DM disappearance values were then fitted to the exponential equation of McDonald (1981). The degradation curve is described as: within a lag time T, $y = A$, i.e. the initial washing loss; beyond the time T, $y = a + b\,(1 - e^{-ct})$ where a, b and c are degradation constants.

During the last 2 days of the degradability study, about 100 ml rumen liquor were collected at 0, 1, 2, 3, 4, 6, 8, 10 and 12 h after the morning supplement was offered. The pH of the sample was determined

immediately, using a pH stick. The sample was strained using a clean cotton cloth and the liquid fraction acidified with HCl acid and stored at −20°C for later analysis of rumen NH_3-N.

Urine and faeces collection

The total daily faecal output of the 20 steers were collected by stationing an attendant with a bucket by each animal to collect all excreta voided during the last 7 days of the trial. Similarly, spot urine samples in experiment 1 were collected in a similar manner, between 09.00 and 13.00 h for 5 days. Daily urine samples were weighed and 100 ml urine were stored in small plastic bottles containing 7 ml 10% H_2SO_4 to give a pH below 3. The urine samples were stored at −20°C to be analysed for purine derivatives (PD) (allantoin and uric acid) and creatinine (C). After recording the weight, a proportion (0·10) of the 24-h faecal collections was stored at 5°C. At the end of the collection period the faecal samples were bulked, mixed and a sample obtained for DM and ash determinations.

Analytical methods

DM of foods and faeces was determined by drying the sample in the oven at 105°C for 24 h, ash by ashing at 550°C for 8 h, crude protein (CP) by the official methods of the Association of Official Analytical Chemists (1984) and neutral-detergent fibre (NDF) was determined by the method of Goering and Van Soest (1970). Rumen NH_3-N was determined as described by Preston and Leng (1987). Purine derivatives were analysed according to the method of Chen *et al.* (1990b). Microbial purine absorbed (MPA) by the animals was estimated from the daily excretion of PD based on the model described by Chen *et al.* (1990a). The ratio PD : C (mmol : mmol) concentration in spot urine samples was corrected for metabolic body weight ($M^{0.75}$), since daily creatinine excretion in urine appears as a function of the metabolic weight of the animal. The calculation was made as: PD : C = PD concentration/(creatinine concentration/$M^{0.75}$).

Calculation of PD excretion on spot samples of urine was based on the finding of Mejia (1992), that the ratio of PD : C was positively related to daily output of PD.

$$PD : (C/M^{0.75}) = 1.79\ X + 4.51\ (r^2 = 0.84),$$

where = X is daily excretion of PD (mmol/day).

The supply of microbial N entering the small intestine was calculated from MPA using the following factors: digestibility of microbial purine 0·83; and, purine-N : total microbial-N ratio 0·116 : 1·00. Thus microbial N supply (g/day) = MPA × 70/0·83 × 0·116 × 1000 = 0·727 × MPA, where 70 is the N content (mg/mmol) of purine (Chen, 1989).

Statistical analysis

Data from the experiments were subjected to analysis of covariance using the General Linear Model (GLM) of the SAS computer package (Statistical Analysis Systems Institute (SAS), 1987). Initial live weight was a covariate in the analysis of DM intake and live-weight changes, the model for which included the effects of breed (0·25 to 0·42 or 0·50 to 0·67 Sahiwal genes) and orthogonal polynomial contrasts to estimate the effect of the level of supplement (Snedecor and Cochran, 1980). In the analysis of the Latin-square experiment, the effect of diet, period and animal were fitted.

Results

The animals remained healthy throughout the experiment. The chemical compositions of foods used in the experiments are presented in Table 1. The values given are the means of seven observations. The legume forages had higher DM and CP but lower NDF contents than napier grass. Gliricidia contained relatively more NDF (493 *v.* 469 g/kg DM) than leucaena forage. In the two experiments, napier grass had similar DM and CP content, but in experiment 1 a higher NDF (753 *v.* 678 g/kg DM) content.

Table 1 *Chemical composition of food used in experiments*

	Dry matter (DM) (g/kg)		Ash (g/kgDM)		Crude protein (g/kgDM)		Neutral-detergent fibre (g/kgDM)	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Experiment 1								
Napier grass	176	24·0	141	1·8	76	5·3	753	13·0
Gliricidia	260	11·8	106	9·9	214	8·1	493	21·3
Experiment 2								
Napier grass	164	27·9	130	1·1	79	9·6	678	12·7
Leucaena	300	27·0	90	5·9	218	3·4	469	4·9

Table 2 *Mean daily dry-matter intake (DMI), apparent digestibility of dry matter (DMD) and organic matter (OMD) and live-weight gains (ADG) in steers given napier grass* ad libitum *alone or with 7·5, 15, 22·5 or 30 g DM per kg $M^{0.75}$ of gliricidia (experiment 1) or leucaena (experiment 2)*

	Level of supplement (g DM per kg $M^{0.75}$)						
	0		15	22·5	30	s.e.d.	Significance of linear response
Experiment 1							
DMI (kg/day)							
Napier	5·2	4·7	4·5	4·3	4·2	0·21	
Gliricidia	0	0·4	0·7	1·1	1·5		
Total	5·2	5·1	5·2	5·4	5·7	0·21	
DMD (g/kg)	608	610	592	578	606	16·6	
OMD (g/kgDM)	638	653	631	625	661	11·6	
DOM† (g/kgDM)	554	569	551	548	581	14·6	
ADG (g/day)	306	358	429	371	478	53·5	
Experiment 2							
DMI (kg/day)							
Napier	5·2	5·3	5·3	5·3	5·0	0·21	
Leucaena	0	0·5	0·9	1·3	1·7		
Total	5·2	5·8	6·2	6·6	6·7	0·31	
DMD (g/kg)	598	611	616	616	590	45·1	
OMD (g/kgDM)	657	695	650	657	712	51·5	
DOM† (g/kgDM)	563	605	566	572	621	44·5	
ADG (g/day)	538	711	719	789	850	76·5	

† DOM = digestible organic matter.

Table 3 *Rumen pH, NH_3-N and* in sacco *dry matter (DM) degradation of napier grass and gliricidia in steers given napier grass* ad libitum *alone or with 7·5, 15, 22·5 or 30 gDM per kg $M^{0.75}$ of gliricidia forage*

	Level of gliricidia (gDM per kg $M^{0.75}$)						
	0	7·5	15	22·5	30	s.e.d.	Significance of linear response
Rumen pH	6·62	6·65	6·60	6·60	6·61	0·07	
NH_3-N (mg/l)	130	162	150	188	215	27·9	
DM degradation constants†							
Napier							
A	20·5	20·1	20·1	19·6	22·1	2·34	
B	59·1	58·0	55·7	56·5	54·6	4·97	
A + *B*	79·6	78·1	75·7	76·2	76·7	4·50	
c	0·032	0·036	0·040	0·038	0·032	0·0106	
Gliricidia							
A	31·5	32·4	31·1	31·6	30·7	1·84	
B	48·7	48·1	47·4	47·5	47·6	2·62	
A + *B*	80·2	80·6	78·5	79·1	78·3	1·83	
c	0·052	0·058	0·076	0·062	0·066	0·0135	

† *A* is the water-soluble component and *B* the insoluble but fermentable component; $B = (a + b) - A$. *a*, *b* and *c* are constants in the exponential $p = a + b\,(1 - e^{-ct})$.

Table 2 presents daily dry-matter intake (DMI), diet apparent digestibility, and live-weight gain data for experiments 1 and 2. Low acceptability of gliricidia was recorded during the 1st week of the experiment. During the subsequent weeks all gliricidia offered was consumed. While napier grass DMI decreased linearly ($P < 0·01$) with increased level of gliricidia, the total DMI was increased but not significantly, by about 0·18 kg/day for every 10 gDM per kg $M^{0.75}$ increment of the supplement. In experiment 2, incremental supplementation with leucaena increased total DMI of the 20 steers ($P < 0·001$) linearly without affecting the intake of the napier grass (Table 2). The response in total DMI with

Table 4 *Rumen pH. NH_3-N and* in sacco *DM degradation of napier grass and leucaena in steers given napier grass* ad libitum *alone or with 7·5, 15, 22·5 or 30 gDM per kg $M^{0·75}$ of leucaena forage*

	Level of leucaena (gDM per kg $M^{0·75}$)						
	0	7·5	15	22·5	30	s.e.d.	Significance of linear response
Rumen pH	6·56	6·52	6·52	6·51	6·41	0·09	
NH_3-N (mg/l)	75	91	105	97	113	1·93	**
DM degradation constants†							
Napier grass							
A	18·4	18·5	18·1	18·2	18·6	0·74	
B	59·8	59·6	64·4	61·3	59·4	3·49	
A + *B*	78·1	78·3	82·5	79·5	78·0	3·04	
c	0·040	0·042	0·034	0·040	0·038	0·0081	
Leucaena							
A	30·5	31·0	30·7	30·8	31·3	0·95	
B	43·5	37·1	41·0	38·0	38·4	4·55	
A + *B*	74·0	68·1	70·3	68·8	69·7	4·83	
c	0·040	0·050	0·044	0·052	0·044	0·0146	

† *A* is the water-soluble component and *B* the insoluble but fermentable component; $B = (a + b) - A$. *a*, *b* and *c* are constants in the exponential $p = a + b\,(1 - e^{-ct})$.

leucaena supplementation was such that, for every 10 gDM per kg $M^{0·75}$ increment, the steers consumed an extra 0·52 kg DM per day. Supplementation with either of the legumes had no significant effect on the apparent digestibility of the mixed diet. The total DMI of fistulated steers was also linearly ($P < 0·001$) increased (data not shown). In both experiments, incremental levels of the legumes increased the mean live weight linearly ($P < 0·05$). Live-weight gains were relatively higher with leucaena than gliricidia supplementation, such that for each increment of 10 gDM per kg $M^{0·75}$, of gliricidia or leucaena, the steers gained approximately 49 and 96 g/day, respectively.

Tables 3 and 4 present the results of the rumen pH, NH_3-N concentration and *in sacco* DM degradation characteristics. The incremental supplementation of gliricidia or leucaena did not affect rumen pH or change the *in sacco* degradation of the napier grass, but increased rumen NH_3-N linearly ($P < 0·01$) by about 27 mg/l and 11 mg/l for every increment of 10 gDM per kg $M^{0·75}$ of gliricidia and leucaena offered, respectively.

Table 5 shows the estimates of urinary PD, absorbed purine and microbial N supply. Gliricidia supplementation increased the daily excretion of PD quadratically ($P < 0·05$). The estimated purine

Table 5 *Urinary purine derivatives excretion, estimated absorbed purine, and microbial nitrogen (N) supply† in steers given napier grass* ad libitum *alone or with 7·5, 15, 22·5 or 30 gDM per kg $M^{0·75}$ of gliricidia forage*

	Level of gliricidia (gDM per kg $M^{0·75}$)						Significance	
	0	7·5	15	22·5	30	s.e.d.	Linear	Quadratic
Purine derivatives excreted (mmol/day)	68·6	80·4	79·3	81·9	70·6	6·32		*
Estimated absorbed purine (mmol/day)	57·8	70·9	69·4	73·5	68·5	7·19		
DOMI‡ (g/day)	2824	2789	2988	2951	3165	98·1	*	
Calculated microbial N supply								
gN/day	41·4	50·7	49·6	52·6	49·0	5·14		
gN/kg DOMI	14·7	18·4	16·6	18·0	15·5	1·24		

† Calculated microbial N = 0·715 × estimated absorbed purine.
‡ DOMI = digestible organic matter intake.

absorption and calculated microbial N supply was lowest in the control group, but not significantly increased with gliricidia supplementation. When expressed on the basis of digestible organic matter intake (DOMI), the estimated efficiency of microbial N production ranged between 14·6 and 18·4 g N per kg DOMI (Table 5) with no statistically significant pattern to the change.

Discussion

The effects of gliricidia and leucaena on steer responses are reported in two successive experiments, and the comparison between the two legumes is only made to facilitate the discussion. The DM and CP content of napier grass used in this study were similar to those reported in the earlier studies at the centre (Muinga *et al.*, 1992). NDF content of napier grass used in experiment 2 was lower (678 *v.* 753 g/kg DM) than napier grass in experiment 1. The legumes had a lower NDF content compared with napier grass. The mean CP content of leucaena and gliricidia were 218 and 214 g/kgDM, which is in the range reported in the literature (Topps, 1992) but higher CP values in leucaena have been reported (van Eys *et al.*, 1986; Kamatali *et al.*, 1992; and Muinga *et al.*, 1992). Leucaena used in this study was harvested from mature plants which might have resulted in lower N content in these studies. Also the attack by the psyllid may have resulted in forage with a lower proportion of leaflets and therefore lower N content.

Animals in the control group consumed on average 105 and 91 g DM per kg $M^{0.75}$ per day of napier grass in experiments 1 and 2, respectively. These intakes were above the standard forage intake suggested by Crampton *et al.* (1960). They suggested 80 gDM per kg $M^{0.75}$ as standard forage intake using tropical forages which were proportionately 0·70 digestible.

As supplementation with leucaena did not depress the intake of napier grass diet, it led to a significant linear increase ($P < 0.001$) in total DMI. The increase in total DMI results are consistent with the results of Bonsi *et al.* (1994) and Muinga *et al.* (1995) with leucaena supplementation.

Supplementation of gliricidia from 7·5 to 30 g DM per kg $M^{0.75}$ depressed the napier grass intake linearly ($P < 0.01$) but tended to increase total DMI. Similarly in the study by van Eys *et al.* (1986) in which gliricidia was offered as a supplement to napier grass, the DMI of napier grass was depressed and total DMI did not increase. These results, however, contrast with those of Ash (1990), who reported no depression of the basal diet intake when guinea grass diets were supplemented with gliricidia.

In other studies, intake and apparent digestibility of mature pangola grass (Minson and Milford, 1967) and rice straw (Pathirana *et al.*, 1992) were increased with legume forage supplementation. However the CP (~36 g/kg DM) contents of the basal diets in their study (Minson and Milford, 1967; Pathirana *et al.*, 1992) were lower than in this study. Egan (1986) indicated that legume supplements are usually most effective when offered with roughage containing less than 20 g N per kg digestible organic matter because they increase the rumen ammonia concentration by providing ruminally fermentable N. The lack of response in the increase of the basal diet in this study suggests that the CP content of the basal diet (76 and 79 g/kg DM) did not limit the intake and that once the rumen microbial requirements for N had been met, additional high quality forage, in this case leucaena and gliricidia, did not have any stimulating effect on the basal diet.

The difference in the response of basal diet intake between gliricidia and leucaena supplements on the DMI of napier grass is difficult to explain. It is unlikely that the substitution effect resulting from increasing levels of gliricidia supplement was due to decreased cellulolysis because supplementation did not depress degradability of napier grass. Minson and Milford (1967) indicated that legume forage supplements will have a stimulating effect due to supply of N but a substituting effect due to their 'bulk effect'. Smith and van Houtert (1987) suggested that, when readily consumed, the gliricidia distends the rumen, reducing intake of the basal diet.

In this study gliricidia was readily consumed but also extensively degraded in the rumen, hence the bulkiness is unlikely to have contributed to depressing the intake of the basal diet. Low acceptability of gliricidia has been suggested as a contributing factor towards lower intake (Tjandraatmadja *et al.*, 1993) due to distinctive odour in the forage. In this study, low intakes of gliricidia were observed during the 1st week of the experiment but thereafter all the gliricidia offered was consumed. The forage was offered some hours after harvesting which allowed it to wilt, eliminating its distinctive odour.

Possibly the relatively higher total DMI with leucaena was associated with faster outflow rate of particulate matter. Retention time of particulate matter has been reduced following supplementation with leucaena (Bamualim *et al.*, 1984). The other possible explanation to the increase in total DMI with leucaena might be due to the nature of the

legume protein. *In sacco* N degradation results (unpublished data) suggested that, compared with gliricidia, a smaller proportion of the N in leucaena was ruminally degraded (*B* fraction), and this ruminally degradable N was degraded at a slower rate. Leng and Preston (1983) indicated that supplementing roughage with rumen undegradable digestible protein generally results in improvements of DMI and this type of protein is more efficiently utilized than the rumen degradable protein (Ørskov, 1992).

Apparent digestibility of the diet was not increased significantly with either legume supplement, results consistent with those of van Eys *et al.* (1986) and Ash (1990). By contrast, supplementation of rice straw with legumes which comprised proportionally 0·30 of the diet, significantly increased apparent digestibility (McMeniman *et al.*, 1988). In agreement with similar studies (van Eys *et al.*, 1986 and Muinga *et al.*, 1995), the DM *in sacco* degradation of the basal diet remained unchanged with increasing level of either gliricidia or leucaena supplementation.

Rumen NH_3-N in the unsupplemented animals was 130 and 75 mg/l in experiments 1 and 2 respectively, and increased linearly and significantly with gliricidia and leucaena, to 215 and 113 mg/l ($P < 0·01$) respectively at the highest level of supplementation. The difference in NH_3-N in the control groups given napier grass with similar CP content could not be explained, but both values were above the recommended 50 mg/l (Satter and Slyter, 1974) for maximum microbial growth. Rumen NH_3-N generated in the rumen may reflect the degradability of N in the legume, implying that the N in leucaena was less degraded than that in gliricidia. Richards *et al.* (1994) reported that N in gliricidia was degraded faster than in leucaena and that *in situ* N degradation was greater in leguminous forages than in king grass (napier grass).

Live-weight gains increased linearly ($P < 0·05$) with incremental supplementation (Table 2 and 3). In both experiments the inclusion of legume with napier grass at proportionally 0·26 of the total DM increased the live-weight gains of steers by proportionally 0·57 compared with that of steers offered napier grass alone. Improved live-weight performance when legumes supplement roughage diets low in N have been reported (van Eys *et al.*, 1986; Ash, 1990; and Mtenga and Shoo, 1990). The relatively faster gains in experiment 2 could be attributed to higher ruminal turn-over rate (Thornton and Minson, 1973), more N (particularly rumen undegradable N) in the form of amino acids, and an increase in total DMI.

In conclusion, for every 10 g DM per kg $M^{0·75}$ supplement to napier grass diet, the legume forages gliricidia and leucaena increased total DMI by 0·18 and 0·52 kg/day, rumen NH_3-N by 27 and 11 mg/l, and live weight by 49 and 96 g/day, respectively. Since animal performance increased linearly, further experiments are required to quantify the response to higher levels of these legume supplements as well as to evaluate responses to energy-rich supplements for these napier-legume diets.

Acknowledgements

The authors wish to thank the Director of KARI for the provision of facilities, and the staff of Regional Research Centre, Mtwapa for assistance during the experiment. Financial assistance for this research from International Livestock Centre for Africa (now the International Livestock Research Institute) and the Natural Resources Institute, UK, is gratefully acknowledged. Abdulrazak is grateful to the Director, Ministry of Agriculture, Livestock Development and Marketing, for granting him study leave to carry out these studies.

References

Ash, A. J. 1990. The effect of supplementing with leaves from the leguminous trees *Sesbania grandiflora, Albizia chinesis* and *Gliricidia sepium* on the intake and digestibility of Guinea hay by goats. *Animal Feed Science and Technology* **28:** 225-232.

Association of Official Analytical Chemists. 1984. *Official methods of analysis. 14th edition.* Association of Official Analytical Chemists, Washington, DC.

Bamualim, A., Weston, R. H., Hogan, J. P. and Murray, R. M. 1984. The contributions of *Leucaena Leucocephala* to post ruminal digestible protein for sheep fed tropical pasture hay supplemented with urea and minerals. *Proceedings of the Australian Society of Animal Production* **15:** 255-258.

Bennison, J. J. and Paterson, R. T. 1993. *Use of trees by livestock. Gliricidia.* Natural Resources Institute publication, Chatham, U.K.

Bonsi, M. L. K., Osuji, P. O., Nsahlai, I. V. and Tuah, A. K. 1994. Graded levels of *Sesbania sesban* and *Leucaena leucocephala* as supplements to teff straw given to Ethiopian Menz sheep. *Animal Production* **59:** 235-244.

Chen, X. B. 1989. Excretion of purine derivatives by cattle and sheep and its use for the estimation of absorbed microbial protein. *Ph.D. thesis, University of Aberdeen.*

Chen, X. B., Hovell, F. D. DeB., Ørskov, E. R. and Brown, D. S. 1990a. Excretion of purine derivatives by ruminants: effect of exogenous nucleic acid supply on purine derivatives excretion. *British Journal of Nutrition* **63:** 131-142.

Chen, X. B., Mathieson, J., Hovell, F. D. Deb. and Reeds, P. J. 1990b. Measurements of purine derivatives in urine of ruminants using automated methods. *Journal of the Science of Food and Agriculture* **53:** 23-33.

Crampton, E. W., Donefer, E. and Llory, L. E. 1960. Nutritive value index for forage. *Journal of Animal Science* **19:** 538-544.

Devendra, C. 1993. Trees and shrubs as sustainable feed resources. *Proceedings of the seventh world conference on animal production, Edmonton, vol. 1,* pp. 119-136.

Egan, A. R. 1986. Principles of poor quality roughage with nitrogen. In *Ruminant feeding system utilization of fibrous agricultural residues 1985* (ed. R. M. Dixon), pp. 49-57. ACT, Canberra, Australia.

Eys, J. E. van, Mathius, I. W., Pongsapan, P. and Johnson, W. L. 1986. Foliage of the tree legumes gliricidia, leucaena, and sesbania as supplement to napier grass diets for growing goats. *Journal of Agricultural Science, Cambridge* **107:** 227-233.

Goering, H. K. and Van Soest, P. J. 1970. *Forage fibre analysis.* United States Department of Agriculture, A.R.S. handbook no. 379.

Jaetzold, R. and Schmidt, H. 1983. National conditions and farm management information. In *Farm management handbook of Kenya.*

Kamatali, P., Teller, E., Vanbelle, M., Collignon, G. and Foulon, M. 1992. *In situ* degradability of organic matter, crude protein and cell wall of various tree forages. *Animal Production* **55:** 29-34.

Leng, R. A. 1990. Factors affecting the utilization of 'poor quality' forages by ruminants particularly under tropical conditions. *Nutrition Research Review* **3:** 277-303.

Leng, R. A. and Preston, T. R. 1983. Nutritional strategies for the utilization of agro-industrial by-products by ruminants and the extension of the principles and technologies to the small farmer in Asia. *Proceedings of the fifth world conference of animal production, vol. 1, Tokyo, Japan.*

McDonald, I. 1981. A revised model for estimation of protein degradability in the rumen. *Journal of Agricultural Science, Cambridge* **96:** 251-252.

McMeniman, N. P., Elliott, R. and Ash, A. J. 1988. Supplementation of rice straw with crop by-product. 1. Legume straw supplementation. *Animal Feed Science and Technology* **19:** 43-53.

Mejia, A. T. 1992. Diurnal changes in urinary and plasma urine derivatives in sheep fed *ad libitum. M.Sc. thesis, University of Aberdeen.*

Minson, D. J. and Milford, R. 1967. The voluntary intake and digestibility of diets containing different proportions of legumes and mature Pangola grass (*Digitaria decumbens*). *Australian Journal of Experimental Agriculture and Animal Husbandry* **7:** 546-551.

Mtenga, L. A. and Shoo, R. A. 1990. Leucaena leucocephala as a supplement feed for black herd Persian lambs. *Bulletin of Animal Production in Africa* **38:** 119-126.

Muinga, R. W., Thorpe, W. and Topps, J. H. 1992. Voluntary food intake, live-weight change and lactation performance of crossbred dairy cows given *ad libitum Pennisetum purpureum* (napier grass var. Bana) supplemented with leucaena forage in the lowland semi-humid tropics. *Animal Production* **55:** 331-337.

Muinga, R. W., Topps, J. H., Rooke, J. A. and Thorpe, W. 1995. The effect of supplementation with *Leucaena leucocephala* and maize bran on voluntary food intake, digestibility, liveweight and milk yield of *Bos indicus* × *Bos taurus* dairy cows and rumen fermentation in steers offered *Pennisetum purpureum ad libitum* in the semi-humid tropics. *Animal Science* **60:** 13-23.

Ørskov, E. R. 1992. *Protein nutrition in ruminants.* Academic Press, London.

Pathirana, K. K., Mandalita, U. L. P. and Gunaratne, S. S. N. 1992. *Straw based supplementation of low output system for zebu heifers. International Atomic Energy Agency, TEC document 691.* International Atomic Energy Agency, Vienna, Austria.

Preston, T. R. and Leng, R. A. 1987. *Matching livestock systems to available feed resources in the tropics and sub-tropics.* Penambul Books, Armidale, Australia.

Reynolds, L. and Bimbuzi, S. 1993. The leucaena psyllid in the coast Province of Kenya. *Agroforestry Today* **5:** 21.

Richards, D. E., Brown, W. F., Ruegsegger, G. and Bates, D. B. 1994. Replacement value of tree legumes for concentrates in forage-based diets. II. Replacement value of *Leucaena leucocephala* and *Gliricidia sepium* for lactating goats. *Animal Feed Science and Technology* **46:** 53-65.

Satter, L. D. and Slyter, L. L. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. *British Journal of Nutrition* **32:** 199.

Smith, O. B. and Houtert, M. F. J. van. 1987. The feeding value of *Gliricidia sepium*: a review. *World Animal Review* **57:** 57-68.

Snedecor, G. W. and Cochran, W. G. 1980. *Statistical methods. Seventh edition.* The Iowa State University Press, Ames, Iowa, USA.

Statistical Analysis Systems Institute. 1987. *Guide for personal computers, version 6 edition,* pp. 551-640. Statistical Analysis Systems Institute Inc., Cary, NC.

Thornton, R. F. and Minson, D. J. 1973. The relationship between apparent retention in the rumen, voluntary intake and apparent digestibility of legumes and grass diet in sheep. *Australian Journal of Agricultural Research* **24:** 889-898.

Tjandraatmadja, M., Macrae, I. C. and Norton, B. W. 1993. Digestion by sheep of silages prepared from mixtures of tropical grasses and legumes. *Journal of Agricultural Science, Cambridge* **120:** 407-415.

Topps, J. H. 1992. Potential, composition and use of legume shrubs and trees as fodder for livestock in the tropics. *Journal of Agricultural Science, Cambridge* **118:** 1-8.

(*Received* 22 *May* 1995—*Accepted* 1 *June* 1996)