Selectivity of resident and oesophageal fistulated steers grazing *Arachis pintoi* and *Brachiaria dictyoneura* in the Llanos of Colombia

J.E. CARULLA,[1] C.E. LASCANO[2] AND J.K. WARD[1]
[1]*Animal Science Department, University of Nebraska, Lincoln, Nebraska, USA and*
[2]*Tropical Pastures Program, CIAT, Cali, Colombia.*

Abstract

Measurements were carried out at the Carimagua Research Station in the Llanos of Colombia, to (1) further characterize the nutritional value of *A. pintoi* (CIAT 17434) in association with *B. dictyoneura* cv. Llanero during the rainy (RS) and dry (DS) season, and (2) assess legume selectivity of resident and oesophageal fistulated steers grazing the pasture. Four paddocks (0.5 ha each) were rotationally grazed (7 days on/21 days rest) by 4 (group 1) or 3 (group 2) resident crossbred zebu steers in the RS and DS, respectively. In addition, 4 oesophageal fistulated steers were used to measure quality of ingested forage and legume selectivity during 5 periods of the year. The quality of the grass and legume on offer was determined in each of the 5 periods. Legume proportion in the diet of resident and fistulated steers was estimated using $\delta\,^{13}C$ in the faeces and extrusa as well as by readings of extrusa by the microscope point technique. Crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) of *A. pintoi* leaves on offer were 18.5% and 61.2% in the RS and 15.8% and 65.3% in the DS. Leaves of *B. dictyoneura* averaged 9.7% CP and 58.1% IVDMD in the RS and 7.1% CP and 54% IVDMD in the DS. The IVDMD of the diet selected by oesophageal fistulated steers (56%) was similar throughout the year, whereas the CP varied between seasons, being higher in the RS (12.3%) than in the DS (9.1%). Resident steers in group 1 and fistulated steers selected similar proportions of legume (42% and 47%, respectively). In contrast, resident steers in group 2 selected a lower ($P < .001$) proportion of legume (19%) than fistulated steers (34%). The results of this study confirm that *A. pintoi* is a high quality legume and that it is well consumed by previously adapted animals.

Correspondence: Dr C.E. Lascano, Tropical Pastures Program, CIAT, A.A. 6713, Cali, Colombia, S.A.

Resumen

En la estación Carimagua en los Llanos de Colombia se llevó a cabo un experimento bajo condiciones de pastoreo para (1) determinar el valor nutritivo de A. pintoi *(CIAT 17434) en asociación* B. dictyoneura *cv. Llanero durante la época lluviosa (ELL) y época seca (ES) y (2) determinar la selectividad de leguminosa en la asociación por novillos residentes y novillos fistulados del esófago. En cuatro potreros (0.5 ha/potrero) se realizó un pastoreo rotacional (7 días de ocupación/21 días de descanso) utilizando 4 novillos residentes (grupo 1) o 3 novillos residentes (grupo 2) en ELL y en ES, respectivamente. Adicionalmente, se utilizaron novillos fistulados en el esófago para medir calidad y proporción de leguminosa en la dieta seleccionada durante 5 períodos en el año. La calidad de la gramínea y leguminosa en oferta se determinó en cada uno de los 5 períodos de muestreo. La proporción de leguminosa en la dieta de novillos residentes y fistulados del esófago se estimó en base a* $\delta\,^{13}C$ *en heces y extrusa y mediante lecturas de la extrusa con un estereoscopio. La proteína cruda (PC) y digestibilidad* IN VITRO *de la materia seca (DIVMS) de las hojas en oferta de* A. pintoi *fue de 18.5% y 61.2% en ELL y 15.8% y 65.3% en ES. Las hojas de* B. dictyoneura *en oferta promediaron 9.7% PC y 58.1% DIVMS en la ELL y 7.1% y 54% en la ES. La DIVMS de la dieta seleccionada por fistulados del esófago (56%) varió poco entre épocas del año, mientras que la PC fue mayor en ELL (12.3%) que en ES (9.1%). Los novillos residentes en el* *grupo 1 seleccionaron una proporción de leguminosa (42%) similar a los animales fistulados (47%). En contraste, los novillos residentes en el grupo 2 seleccionaron menos (P<.001) leguminosa (19%) en comparación con los novillos fistulados (34%). Los resultados de este estudio confirman que el* A. pintoi *es una leguminosa de alta calidad y que es bien consumida por novillos con acostumbramiento previo.*

Introduction

Between 1976 and 1978 accessions of several species of *Arachis* were introduced in the Llanos of Colombia by the Centro Internacional de Agricultura Tropical (CIAT) (Grof 1985). Among the accessions introduced, *Arachis pintoi* (CIAT 17434) exhibited tolerance to heavy grazing, and good compatibility with aggressive grasses of the genus *Brachiaria* (Grof 1985). In addition, grazing studies using oesophageal fistulated animals showed that *A. pintoi* in association with several grasses was selected in high proportions and that the legume contributed significantly in improving the quality of the diet selected (Lascano and Thomas 1988). However, recent work by Coates *et al.* 1987, has indicated that extrusa samples collected from oesophageal fistulated animals may not necessarily reflect the selectivity exhibited by resident animals grazing legume-based pastures.

The objectives of this research were: (1) to further characterize the nutritional value of *A. pintoi* (CIAT 17434) in association with *Brachiaria dictyoneura* cv. Llanero and (2) to assess if selectivity of *A. pintoi* by oesophageal fistulated steers reflected the selectivity of resident steers.

Materials and methods

Location

The experiment was conducted at the Carimagua Research Station (N 4°34′, W 71°20′ and 160 masl) in the Eastern plains of Colombia. The station is located in a region classified as isohyperthermic well drained savanna, which accounts for 3,488,000 ha (Cochrane 1986). Annual rainfall is distributed mainly from April through November. Rainfall during the experimental period (June 1988–June 1989) was 2798 mm, of which 242 mm were recorded during the dry season (Dec–Apr). Year round temperature is >23.5 °C. Soils are classified as Oxisols (Tropic Haplustox Isohyperthermic) with pH 4.5 of low base status and deficient in P and with high Aluminium saturation (86%). The site where the experiment was conducted has soils with clay-loam texture.

Pasture establishment

Vegetative material (stolons) of the grass *B. dictyoneura* and legume *A. pintoi* (CIAT 17434) were planted in alternate rows 1 m apart in 2 ha, then divided into four paddocks of 0.5 ha each. Vegetative material of the legume was inoculated with rhizobium at planting. Fertilizer for establishment was applied at the rate of 20 kg of P, 20 kg of K, 12 kg of Mg and 12 kg of S/ha. Half of this fertilizer rate was applied after the second year under grazing.

Grazing management

The four paddocks were rotationally grazed (7 days on/21 days rest) by two groups of growing-crossbred zebu resident steers. The first 4 steers (group 1 — average 208 kg liveweight) were introduced in May 1988 and were replaced on December 22, 1988 by 3 steers (group 2 — average 161 kg liveweight). In addition, 4 oesophageal and rumen-fistulated crossbred zebu steers were introduced at day one of each of 5 grazing cycles. These steers grazed the pasture together with the resident steers for a complete cycle of 28 days.

Measurements

In order to assess selectivity of resident and fistulated steers in the mixture of *A. pintoi* and *B. dictyoneura* in different seasons of a year, five grazing cycles of 28 days each and 35 days apart were considered in the study. Two techniques to estimate selectivity were used: (1) readings of extrusa by the microscope point-hit technique (Harker *et al.* 1964) and (2) by determination of the ratio of the natural isotopes of carbon ^{12}C and ^{13}C ($\delta^{13}C$) in extrusa and faeces (Jones *et al.* 1979; Coates *et al.* 1987). The latter technique was used to estimate the proportion of legume eaten by both fistulated and resident animals of group 1 and 2.

Faeces and extrusa samples were collected on days 7, 10, 14 and 21, 24, 28 of each grazing cycle. To determine the proportion of legume in diet by $\delta^{13}C$ in faeces, sub-samples of dry faeces (60 °C) from days 7, 10, 14 and 21, 24, 28 were mixed and a composite sample by sampling period was made for each animal. Extrusa, faeces and forage samples were finely ground to a powder and sent to the Division of Tropical Crops and Pastures, CSIRO, in Australia for $\delta^{13}C$ determination. To estimate percent legume in diet with $\delta^{13}C$ values in faeces and extrusa, the equations proposed by Coates *et al.* (1987) were used.

The quantity and botanical composition of the forage on offer were determined on days 7, 10, 14, 21, 25 and 28 of each grazing cycle. Ten quadrats of 1.05 m² (1.5 × 0.67 m) were placed in the pasture by dividing the paddock into 10 imaginary squares and in each square a sampling site was selected at random. The forage in each quadrat was hand clipped at ground level and samples were hand separated into grass, legume and senescent material of the grass.

To determine forage quality and leaf to stem ratio, 30 samples in points randomly chosen were cut at 6 cm above ground level and at ground level for the grass and legume, respectively, on days 7, 10, 14 and 21, 24, 28 of each grazing cycle.

Dry forage samples and sub-samples of ground extrusa were used to determine Nitrogen by Microkjeldahl (Chapman and Pratt 1961) and IVDMD (Tilley and Terry 1963; modified by Moore and Mott 1974). Additional analysis for neutral detergent and acid detergent fibre (Van Soest 1963) were carried out for the legume plant parts.

Statistical analysis

The differences in selectivity between fistulated and resident animals during the different periods of the year were studied using the following model:

$$\text{Response}_{ijk} = \mu + \text{Time}_i + \text{Treat}_j + \text{Int(Time,Treat)}_{ij} + E_{ijk}$$

where μ = General mean

Time_i = Sampling period effect

Treat_j = Treatment effect

$\text{Int(Time,Treat)}_{ij}$ = Interaction between treatment and sampling period

E_{ijk} = Experimental error

The effects of season and day of grazing on animal selectivity were analyzed using a nested model:

$$\text{Response}_{ijk} = \mu + \text{Time}_i + \text{Days(Time)}_{ij} + E_{ijk}$$

where μ = General mean

Time_i = Sampling period effect

Days(Time)_{ij} = Days within sampling period effect

E_{ijk} = Experimental error

Differences between means from the ANOVA test were determined by Duncan's multiple range test. Correlation analysis was done for animal selectivity determined by different methods.

Results

Forage availability

As expected, the total forage on offer varied with season of the year, being lowest at the end of the dry season (2162 kg/ha) and highest at the middle of the rainy season (Sept–Oct) (3248 kg/ha) (Table 1). The variation in forage on offer due to season, was mainly due to a reduction of legume on offer (1750 to 663 kg/ha). The grass on offer did not vary greatly (1345 ± 114 kg/ha) between seasons, with the exception of the last grazing cycle (May to June) where it was higher (2011 kg/ha).

Table 1. Forage availability and leaf to stem ratio of *B. dictyoneura* and *A. pintoi*

Grazing cycle	Season	Forage availability			Leaf:Stem	
		Grass		Legume		
		Green	Senescent		Grass	Legume
		(kg/ha DM)			(ratio)	
Aug–Sep	Rainy	830	666 (44)[1]	1750 (54)[2]	1.6	1.4
Nov–Dec	Rainy	732	529 (41)	1620 (56)	2.9	1.2
Jan–Feb	Dry	669	804 (54)	869 (37)	2.1	0.2
Mar–Apr	Dry-Rainy	680	820 (55)	663 (30)	2.2	0.6
May–Jun	Rainy	1538	856 (32)	856 (32)	2.5	2.1

[1] Figures in parenthesis represent the senescent material as a percent of total grass available.
[2] Figures in parenthesis represent the legume as a percentage of total forage available.

The proportion of legume in the forage on offer declined (54% to 30%) as the dry season progressed (Table 1). This reduction was associated with heavy defoliation of *A. pintoi* leaves, as reflected by a low leaf to stem ratio (0.25) during the dry season as compared with the rainy season (1.8) (Table 1). Similar changes in leaf to stem ratio in *A. pintoi* between the dry and rainy season were reported by Lascano and Thomas (1988), indicating that this legume is very sensitive to drought stress.

The leaf to stem ratio in the grass showed small variation due to season of the year (Table 1); however, changes between grazing cycles were observed in the grass in terms of the proportion of senescent material. In the late rainy season the grass had 44% of dead material, which increased to 54% in the dry season but later dropped to 24% at the beginning of the rains (Table 1). The increase in the proportion of senescent material in the grass on offer during the dry season has been observed in other grasses in the Llanos of Colombia (Grof 1985; Lascano and Thomas 1988).

Forage quality

The IVDMD and CP values in leaves and stems of *B. dictyoneura* and *A. pintoi* are presented in Table 2. The IVDMD values for the grass leaves and stems were lowest during the driest months of the year and highest at the beginning of the rainy season (Table 2). Decreases in the IVDMD of plant parts due to water stress have been observed in other tropical grasses grown in the Llanos of Colombia such as *Brachiaria decumbens* (69 to 61%), *Brachiaria humidicola* (64 to 55%), *Andropogon gayanus* (53 to 44%) and *Panicum maximum* (52 to 40%) (CIAT 1980). As expected, the CP % of leaves and stems of *B. dictyoneura* were lowest during the dry season (Table 2). Critical CP levels in the grass leaves (7%), where intake may be depressed (Minson and Milford 1967), were observed only during part of the dry season (Jan–Feb).

The IVDMD of *A. pintoi* leaves (mean = 63.1%) and stems (mean = 63.6%) was high throughout the year (Table 2). Leaves of *A. pintoi* had the highest IVDMD value (66.9%) during the beginning of the dry season (Jan–Feb). Similar results were reported by Lascano and Thomas (1988) who found IVDMD values of *A. pintoi* leaves of 67% and 60% for dry and rainy season, respectively. The stem fraction of the legume showed the opposite trend from that in leaves, since the lowest IVDMD values were observed at the end of the dry season (Table 2). The CP content of leaves of *A. pintoi* was lowest (13.2%) at the beginning of the dry season and highest (21.8%) at the beginning of the rainy season (Table 2). On the other hand, the CP content of stems of *A. pintoi* was similar throughout the year, with the exception of the last grazing cycle in which CP increased. The decrease in CP of *A. pintoi* leaves during the dry season was also observed by Lascano and Thomas (1988) and by Böhnert *et al.* (1986) in *Stylosanthes capitata* and *Pueraria phaseoloides* in the Llanos of Colombia.

The neutral detergent (NDF) and acid detergent fibre (ADF) content of the plant parts of *A. pintoi* are presented in Table 3. As expected, the NDF and ADF of leaves was lower than in stems, with no clear trend due to season of the year.

Table 2. *In vitro* Dry Matter Digestibility (IVDMD) and Crude Protein (CP) content of leaves of *B. dictyoneura* and *A. pintoi*

Grazing cycle	Season	Grass				Legume			
		Leaf		Stem		Leaf		Stem	
		IVDMD	CP	IVDMD	CP	IVDMD	CP	IVDMD	CP
		(% DM)				(% DM)			
Sep–Oct	Rainy	59.1	8.7	48.2	4.6	63.7	16.8	69.4	9.4
Nov–Dec	Rainy	56.5	8.8	56.4	5.7	61.0	16.7	63.3	9.0
Jan–Feb	Dry	53.1	6.6	48.2	4.7	66.9	13.2	63.5	9.3
Mar–Apr	Dry-Rainy	55.5	7.5	51.4	5.2	63.6	17.2	59.3	9.7
May–Jun	Rainy	59.9	9.3	54.3	8.5	60.4	21.8	62.7	13.5
Mean		56.8	8.2	51.7	5.7	63.1	17.9	63.6	10.1

Table 3. Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) in leaves and stems of *A. pintoi*

Grazing cycle	Season	Leaves		Stems	
		NDF	ADF	NDF	ADF
		(% DM)			
Sep–Oct	Rainy	—	—	49.6	41.7
Nov–Dec	Rainy	47.2	26.9	51.3	39.9
Jan–Feb	Dry	50.5	30.9	55.3	39.1
Mar–Apr	Dry-Rainy	48.5	27.4	59.4	42.7
May–Jun	Rainy	54.9	34.5	52.3	43.8
Mean		50.3	29.9	53.6	41.4
CV (%)		6.7	11.7	7.1	4.6

Diet quality

The *in vitro* dry matter digestibility (IVDMD) and crude protein (CP) content of extrusa are presented in Table 4. The IVDMD (mean = 56.1%) was similar throughout the year, whereas the CP content changed and was lower during the dry season as compared with the rainy season (Table 4). Higher IVDMD values (61%) for extrusa collected in pastures associated with *A. pintoi* were reported by Lascano and Thomas (1988). However, the CP content in the diet was similar to what was found in this study (11.0 *vs* 12.6%).

Table 4. Crude Protein (CP) and *In Vitro* Dry Matter Digestibility (IVDMD) of extrusa

Grazing cycle	Season	IVDMD	CP
		(% DM)	
Sep–Oct[1]	Rainy	58.5	11.3
Nov–Dec	Rainy	56.0ab[2]	12.9a
Jan–Feb	Dry	56.3ab	8.3c
Mar–Apr	Dry-Rainy	54.7b	10.0b
May–Jun	Rainy	57.3a	12.8a
Mean		56.1	11.0
s.e.		1.07	2.21

[1] Data of this grazing period were not included in the statistical analysis, different methodology was used to collect extrusa.
[2] Values with different letters within a column are significantly different ($P<0.05$).

The quality of the diet changed with day of occupation of the paddock (Table 5). The CP content in extrusa increased (10.2 to 11.6%) whereas the IVDMD decreased (58.9 to 53.6%) as the grazing progressed from day 1 to 7. The increase in CP as days of grazing advanced was associated with a parallel increase in legume proportion in the extrusa (Table 5). In contrast, the decrease in IVDMD of diet as grazing progressed

Table 5. Legume proportion (Leg), Crude Protein (CP) and *In vitro* Dry Matter Digestibility (IVDMD) of extrusa by day of occupation of the paddocks

Day	Leg	CP	IVDMD
		(% DM)	
1	23.5b[1]	10.2b	58.9a
4	51.3a	11.2a	55.6b
7	57.4a	11.6a	53.6c
Mean	44.1	11.0	56.1
s.e.	18.1	0.7	2.6

[1] Values with different letters within a column are different ($P<0.05$).

was negatively related to the increment of legume in the diet. This seemed contradictory, considering that the legume had higher digestibility than the grass and therefore a higher digestibility of the extrusa should be expected as the legume increased in the diet. It is possible that the lower digestibility of the extrusa as the proportion of legume increased, was due to heat damage since extrusa samples were not freeze dried. Narváez and Lascano (1989) found that legumes were more susceptible than grasses to the method of drying.

Legume selectivity

Methods: Legume proportion in the diet of bifistulated animals estimated through readings of extrusa and proportions of $\delta^{13}C$ in extrusa and faeces are presented in Figure 1. The average legume proportion in the diet estimated from stereoscope readings of extrusa (45%) and $\delta^{13}C$ in extrusa (44%) and faeces (41%) were similar and not statistically different ($P>0.05$). A high correlation coefficient (0.95) was observed between the two methods to estimate percent

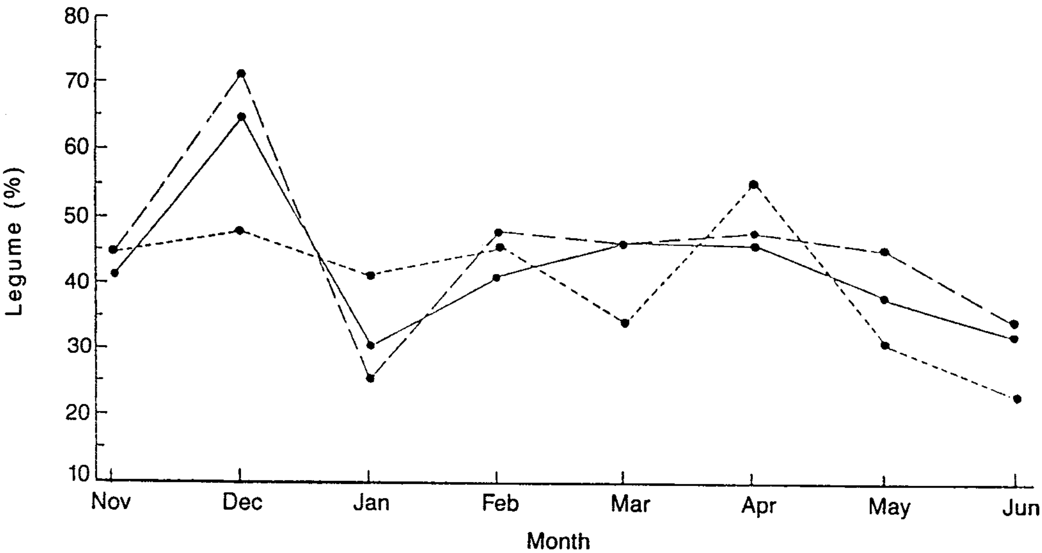

Figure 1. Legume in the diet of oesophageal fistulated steers estimated by microscope readings of extrusa (— — —), $\delta^{13}C$ in extrusa (———), and $\delta^{13}C$ in faeces (----).

legume in extrusa. However, correlation coefficients between estimates of percent legume in the diet determined with $\delta^{13}C$ faeces and $\delta^{13}C$ extrusa (0.55), and with $\delta^{13}C$ faeces and point-hit readings of extrusa (0.44) were low. Similar results were reported by Coates *et al.* (1987) who observed poor agreement between the percent legume in the diet estimated by readings of extrusa and $\delta^{13}C$ in faeces, but good agreement between readings in extrusa and $\delta^{13}C$ in extrusa. The proportion of legume in the faeces represents a longer period of consumption than that sampled over a shorter interval in the extrusa.

Legume in diet: Legume in the diet of fistulated and resident steers estimated with $\delta^{13}C$ in faeces is presented in Table 6. Resident animals of group 1 selected high proportions of legume during the first two grazing cycles (September to December). During the following cycles, the legume proportion in the diet of resident animals of group 2 dropped, being lowest in January and February.

Table 6. Legume in the diet of resident (groups 1 and 2) and fistulated steers estimated with $\delta^{13}C$ in faeces

Period	Group 1	Group 2	Fistulated
		(% DM)	
Sep	57	—	—
Oct	57	—	—
Nov	43a[1]	—	46a
Dec	42a	—	48a
Jan	—	9b	41a
Feb	—	6b	44a
Mar	—	22b	34a
Apr	—	20b	56a
May	—	20b	31a
Jun	—	10b	23a

[1] Values with different letters within a row are different ($P<0.01$).

The drop in the proportion of legume selected coincided with a new set of resident steers grazing the pasture, as well as with a reduction of legume on offer (Table 1). How much of the change observed in the legume selected could be attributed to the change of animals and how much to a reduction of legume on offer cannot be determined with the data available. However, it is clear that resident steers in group 2 did not show the same behaviour in terms of legume selectivity as the fistulated animals, that continued to select high proportions of legume during the dry season (Table 6). Thus, results suggest that the new set of resident steers had a different preference for the legume than those used previously.

Discussion

The results confirm that *A. pintoi* (CIAT 17434) is a legume with high CP content and high digestible matter. The CP and IVDMD levels observed in *A. pintoi* during the different seasons of the year were higher than those observed by Böhnert *et al.* (1986) at the Llanos in *Stylosanthes capitata* and *Pueraria phaseoloides*. As a result, the quality of the diet selected in the *A. pintoi* based pasture was high throughout the year, as was also observed by Lascano and Thomas (1988) in similar conditions.

In this study *A. pintoi* was well accepted by the oesophageal fistulated animals and consumed in greater proportions than that present in the pasture during the dry season, which was also found by Lascano and Thomas (1988). However, there were large differences in legume selectivity between resident steers in group 2 and the fistulated animals and resident steers in group 1. These differences cannot be easily explained, but may be the result of fistulated animals and resident steers in group 1 being previously exposed to the legume. The oesophageal fistulated and the resident steers in group 1 had been exposed to the *A. pintoi* based pasture before the experiment began (at least for 4 months). On the other hand, the second group of resident steers had only one month of exposure to the pasture before the measurements began. Evidence of the importance of previous exposure to a diet in the selective behaviour of ruminants has been recently presented by Squibb *et al.* (1990). The authors observed that prior exposure to the shrub *Cercocarpus montanus* enhanced subsequent consumption of that shrub by sheep. Other workers have also observed differences in grazing behaviour and forage intake between experienced and inexperienced calves (Hodgson and Jamieson 1981) and between experienced and inexperienced sheep (Curll and Davidson 1983).

Differences in legume selectivity between fistulated steers and the second group of resident steers suggest that grazing animals need a period of time to learn to consume *A. pintoi*. This would not be a problem in commercial pastures where animal management could be adjusted over space and time, but it does have research implications. The adaptation period needed by the animals of at least four to six months suggested by this study could result in an underestimation of the potential productivity (e.g. animal gains) of *A. pintoi* based pastures. Possible solutions would be the use of the same animals for longer periods of times or to expose them to the legume prior to the initiation of the experiment.

Results from this trial also stress the importance of the management of oesophageal fistulated steers to evaluate animal selectivity. Animals should be managed in a similar manner to those animals to which inference is to be made.

Acknowledgements

We wish to thank the University of Nebraska and the Centro Internacional de Agricultura Tropical for their economic support through the development of this project. Also, we thank all the people at the Carimagua Research Station who made this project possible.

References

Bohnert, E., Lascano, C. and Weniger, J.H. (1985) Botanical and chemical composition of the diet selected by fistulated steers under grazing on improved grass-legume pastures in the tropical savannas of Colombia. I. Botanical composition of forage available and selected. *Journal of Animal Breeding and Genetics*, **102**, 385-394.

Bohnert, E., Lascano, C. and Weniger, J.H. (1986) Botanical and chemical composition of the diet selected by fistulated steers under grazing on improved grass-legume pastures in the tropical savannas of Colombia. II. Chemical composition of forage available and selected. *Journal of Animal Breeding and Genetics*, **103**, 69-79.

Chapman, H.D. and Pratt, P.F. (1961) *Methods of Analysis for Soils, Plants and Water*, pp. 56-65. (Division of Agricultural Sciences: University of California.)

CIAT (1980) Pasture utilization. In: Tropical Pastures Program 1980 Report, pp. 85-89. (CIAT: Cali, Colombia.)

Coates, D.B., Schachenmann, P. and Jones, R.J. (1987) Reliability of extrusa samples from steers fistulated at the oesophagus to estimate the diet of resident animals in grazing experiments. *Australian Journal of Experimental Agriculture*, **27**, 739-745.

Cochrane, T.T. (1986) Soils, climate and vegetation in rangeland of Tropical America. In: Kalmbacher, R.S., Coleman, S.S., Lewis, C.E. and Tanner, G.W. (eds) pp. 1-10. *Tropical American Lowland Range Symposium.* Proceedings of the Society for Range Management, Kissimmee, Florida.

Curll, M.C. and Davidson, J.C. (1983) Defoliation and productivity of a *Phalaris* - subterranean clover sward, and the influence of grazing experience on sheep intake. *Grass and Forage Science*, **38**, 159-167.

Grof, B. (1985) Forage attributes of the perennial groundnut *Arachis pintoi* in a tropical savanna environment in Colombia. *Proceedings of the XV International Grassland Congress, Kyoto, Japan*, pp. 168-170.

Harker, K.M., Torrel, D.T. and Van Dyne, G.M. (1964) Botanical examination of forage from oesophageal fistulas in cattle. *Journal of Animal Science*, **23**, 465-469.

Hodgson, J. and Jamieson, W. (1981) Variations in herbage mass and digestibility and the grazing behaviour and herbage intake of adult cattle and weaned calves. *Grass and Forage Science*, **36**, 39-48.

Jones, R.J., Ludlow, M.M., Troughton, J.H. and Blunt, C.G. (1979) Estimation of the proportion of C3 and C4 plant species in the diet of animals from the ratio of natural ^{12}C and ^{13}C isotopes in the faeces. *Journal of Agricultural Sciences*, (Camb.), **92**, 91-100.

Lascano, C.E. and Thomas, D. (1988) Forage quality and animal selection of *Arachis pintoi* in association with tropical grasses in the eastern plains of Colombia. *Grass and Forage Science*, **43**, 433-439.

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

MOORE, J.E. and MOTT, G.O. (1974) Recovery of residual organic matter from *in vitro* digestion of forages. *Journal of Dairy Science*, **57**, 1258-1259.

NARVAEZ, N. and LASCANO, C. (1989) Digestibilidad *in vitro* de especies forrajeras tropicales. 2. Factores asociados con su determinación. *Pasturas Tropicales*, **11**, 19-23.

SQUIBB, R.C., PROVENZA, F.D. and BALPH, D.F. (1990) Effect of age of exposure on consumption of a shrub by sheep. *Journal of Animal Science*, **68**, 987-997.

TILLEY, M.A. and TERRY, R.A. (1963) A two-stage technique for the *in vitro* digestion of forage crops. *Journal of the British Grassland Society*, **18**, 104-111.

VAN SOEST, P.J. (1963) Use of detergent analysis of fibrous feeds. II. A rapid method for determination of fiber and lignin. *Journal of the Association of Official Analytical Chemist*, **46**, 829-835.

(Received for publication April 30, 1991; accepted October 26, 1991)