CANOPY STRUCTURE AND COMPOSITION IN LEGUME SELECTIVITY

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ABSTRACT

To explore possible relationships between canopy structure and composition with forage selectivity, the proportion of legume in the diet of grazing animals (y) and in the available forage (x) were analyzed for contrasting grass-legume pastures. There is evidence that in some temperate and tropical grass-legume pastures, the relative distribution of grass and legume in the sward canopy affects legume selectivity by the grazing animal. Results presented here also suggest that legume selectivity is influenced by growth habit of the grass as it affects sward structure, by relative palatability of the legume and by season of the year. With prostrate grasses in association with a palatable legume, animals selected throughout the year a slightly higher proportion of legume than that available in the total biomass. In contrast, in a prostrate grass in association with an unpalatable legume, animals selected against the legume regardless of stocking rate applied. In the case of associations with a tall-bunch grass, legume selectivity was highly variable, but a tendency existed for selection to occur mainly in the dry season, as has been observed in a number of studies.

These results may have important implications on pasture management requirements of tropical grass-legume pastures exposed to a range of ecosystems with varying climatic conditions.

Introduction

The preferential selection of green leaves by grazing animals has been widely demonstrated in temperate and tropical pastures (Chacon and Stobbs, 1976; Böhnert et al., 1985). Leaf selection and ingestive behavior of animals grazing tropical grasses are generally affected by sward structure. Major factors are leaf bulk density (kg/[ha·cm]), total herbage mass (kg/ha) and sward height (Allden and Whittaker, 1970; Stobbs, 1973; Moore et al., 1985). In the case of grass-legume associations, the legume proportion in the diet of the grazing animal could be influenced by: (1) proportion of the legume in the sward, (2) relative distribution of the morphological components of grass and legume in the sward canopy, and (3) herbage mass, height and density of the pasture (Milne et al., 1982). With temperate grass-legume mixtures, e.g., ryegrass-white clover, a larger proportion of the variation of legume in the diet of sheep was accounted for by considering the legume content in the upper horizons of the sward (linear, $r^2 = .83$) compared with the total sward (linear, $r^2 = .57$; Milne et al., 1982). Also in a tropical grass-legume pasture of <u>Hemarthria altissima</u> cv. Floralta - <u>Aeschynomene americana</u>, the proportion of the legume in the diet of cattle exhibited a quadratic relationship ($R^2 = .79$) with the legume proportion in the upper layer of the pasture (Moore et al., 1985). In both studies, the proportion of the legume in the diet was greater than the proportion in the grazed horizon of the sward, possibly as a result of canopy modification by the grazing animal prior to biting (Moore et al., 1985). More studies involving measurements of the depth of the grazed horizon and the relationship between legume proportion in different strata of the pasture and in the diet selected by grazing animals are needed to improve understanding of factors controlling legume selection in tropical pastures under different climatic conditions. With this objective, the proportions of legume in the diet and in the total biomass were analyzed for different types of grass-legume mixtures in two ecosystems. The possible implications of these results on pasture management are explored.

Experimental Pastures

Pastures with prostrate grasses. Measurements of proportion of legume selected by grazing animals were carried out at the Carimagua Research Station for one year in mixtures of prostrate and semi-erect species of *Brachiaria* (*B. humidicola* [CIAT 679], *B. dictyoneura* [CIAT 6133], *B. brizantha* [CIAT 644], *B. ruziziensis* [CIAT 6291]) with *Arachis pintoi* (CIAT 17434), a stoloniferous legume. The site represented a well drained savanna ecosystem at latitude 4°37' North with an average rainfall of 2100 mm (April-November) and a well defined dry season (December-March). Each association was established in 1227 m^2 plots with two replications. Grazing was across the four mixtures using a rotational scheme of 7/21 days (grazing/rest) with two esophageal fistulated steers (200 kg), resulting in an equivalent stocking rate of 4 A/ha. Measurements of the proportion of legume in the total available biomass and in the diet selected by grazing animals were made on a monthly basis, during the first, third and last day of grazing of each association. A wide range of legume proportion occurred in the available forage because of spittlebug damage to *B. ruziziensis* and *B. brizantha*.

Measurements were also conducted in a different ecosystem at Quilichao, Cauca Valley, Colombia in a *Brachiaria dictyoneura* (CIAT 6133) - *Desmodium ovalifolium* (CIAT 350, a stoloniferous legume) pasture. The site is located at latitude 3°6' North, with an average rainfall of 1772 mm with a bimodal distribution (March-June and September-December). Pastures were again rotationally grazed by Zebu steers (200 kg) at stocking rates of 3.0, 4.0 and 5.5 A/ha, with 7 days of grazing and 21 days of rest. Dietary forage samples from esophageal fistulated steers were obtained every 28 days in the paddocks composing the rotation. During the study (2.5 years), large differences in botanical composition of the available forage have been generated as a result of stocking rate treatments and season of the year.

Pastures with bunch grasses. A grazing trial is in progress at Carimagua involving mixtures of *Andropogon gayanus* cv. Carimagua 1 (an erect, tall bunch grass) with *Centrosema acutifolium* (CIAT 5277 - 5568, a stoloniferous-twining legume). Legume selectivity is being measured on a monthly basis through esophageal collections from steers in pastures continuously grazed at .75, 1.0 and 1.5 A/ha and rotationally grazed at 1.5 A/ha. The proportions of legume in the diet and in the available forage obtained over one rainy season and one dry season were used for the analysis.

Analysis of Results

The proportion of legume in the diet (y) and in the total available forage (x) obtained in the three grazing trials were analyzed using a model which allows the description of animal selectivity with a single parameter. The basic equation used was (Chesson, 1983):

$$\alpha_i = \frac{e_1/q_1}{e_1/q_1 + e_2/q_2}$$

where: α_i = selection index
e_1 = legume amount in the diet
e_2 = grass amount in the diet
q_1 = legume amount in the available forage
q_2 = grass amount in the available forage

To relate the proportion of legume in the diet to proportion in the pasture the above equation was transformed as follows:

$$\frac{e_1}{e_1 + e_2} = [(\alpha_i \frac{q_1}{1 - q_1})/(1 - \alpha_i)]/[1 + (\alpha_i \frac{q_1}{1 - q_1} /(1 - \alpha_i)]$$

The parameter estimated with this equation (α_i) represents selection of the legume component and implies a curvilinear relationship between the proportion in the diet and in the available forage. Estimates of α_i can vary from <0.5 (selection against the legume) to >0.5 (selection in favor of the legume) in the range 0 to 1. The validity of α_i is dependent on two assumptions: (1) that it does not vary with time or, in other words, it is an instantaneous measure of animal behavior, and (2) that it is not dependent on absolute quantities of biomass available.

The function was fitted to the data by minimizing the sum of squared deviations. Because the error distribution changes over the range of 0 1 (error at these points tends to 0) the data were transformed in the y axis using the arcsine transformation. Changes brought about by this transformation were small, but it was conceptually desirable to proceed with this step. A confidence interval at the .01 significance level was calculated for each of the established relationships, assuming a normal error distribution.

Legume Selection and Pasture Type

The grazing trials from which the data for this analysis were derived were not specifically designed to study relationships between legume proportion in the diet and in the available forage. However, the range of data obtained in contrasting grass-legume pastures was thought to be useful for exploring general relationships between legume selected by grazing animals and legume available in the pasture. Extremely limited information of this type is available in the literature for tropical grass-legume pastures.

Legume selection in pastures with prostrate grasses. The relationship between legume proportion in the diet and in the available forage in the Brachiaria spp - A. pintoi pastures (figure 1) was described by an α_i = .523. This indicates that the legume was selected in slightly higher proportion than what was present in the total available forage. In the B. dictyoneura - D. ovalifolium pasture (figure 2), the selection indices (α_i) were .316, .318 and .295 for the high, medium and low stocking rates, respectively, indicating that in the three stocking rates animals selected against the legume in a similar manner, as has been observed in other grazing trials involving D. ovalifolium (CIAT, unpublished results). These results are interesting since they suggest that in this association legume selectivity was not related to forage availability resulting from the three stocking rates imposed, at least with the range of data analyzed. However, it is conceivable that at higher levels of legume availability in the pasture, legume proportion in the diet might be higher than that available in the total biomass, as selection for grass becomes increasingly difficult in a strongly legume dominant pasture. In this case the response function would be described by a curve with a sigmoid shape (Chesson, 1983).

It is postulated that the difference in the selection indices of the legumes in the two associations with prostrate grasses is primarily related to the palatability of the two legumes. The low palatability of D. ovalifolium (CIAT 350) has been associated with high tannin concentration, particularly when grown on sulfur deficient soils (Lascano and Salinas, 1982; Salinas and Lascano, 1982).

Legume selection in pastures with bunch grasses. The proportions of legumes in the diet and available in the forage in the A. gayanus - C. acutifolium pasture were analyzed for the whole year, wet season and dry season (figure 3). The selection indices were .244, .088 and .479 for the entire year, the wet season and the dry season, respectively. Even though the data were extremely variable, there is a tendency for animals to select against the legume in the wet season but in favor of the legume in the dry season. Results from other experiments support this interpretation. In pastures of A. gayanus with Pueraria phaseoloides (CIAT 9900, a twining legume) and Stylosanthes capitata (CIAT 1405, 1019 + 1315, a semierect, sub-shrub legume), animals preferentially selected the legume in the dry season in Carimagua (Böhnert et al., 1985). Work conducted in dry tropical areas of Australia has also indicated higher legume, e.g., S. humilis and S. hamata, selectivity in the dry season than in the wet season (Hunter et al., 1976; Gardener, 1980). In addition, seasonal changes in legume selectivity have also been observed in subtropical areas of Australia (Stobbs, 1977).

It is suggested that with bunch-type grasses, animals can be highly selective with a clear preference for the legume in the dry season. Such does not appear to be the case for legumes grown in association with prostrate grasses.

Legume Selectivity and Grazing Management

A clear understanding of the relationship between legume proportion in the diet of grazing animals and in the available forage, as affected by pasture structure (within or between different sward types), is fundamental for the development of grazing management strategies for different grass-legume mixtures in the tropics.

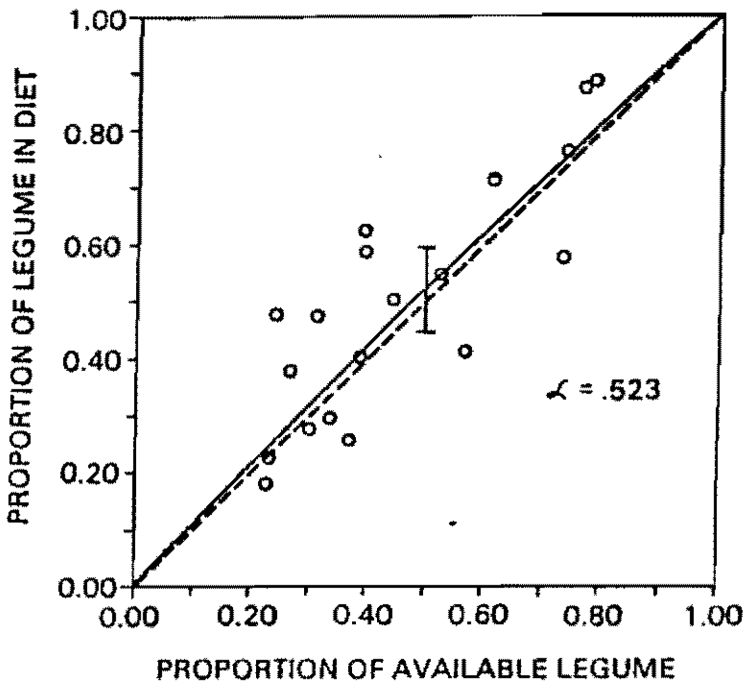

Figure 1. Relationship between legume proportion in the diet and in total available forage in *Brachiaria* spp. *A. pintoi* pastures.

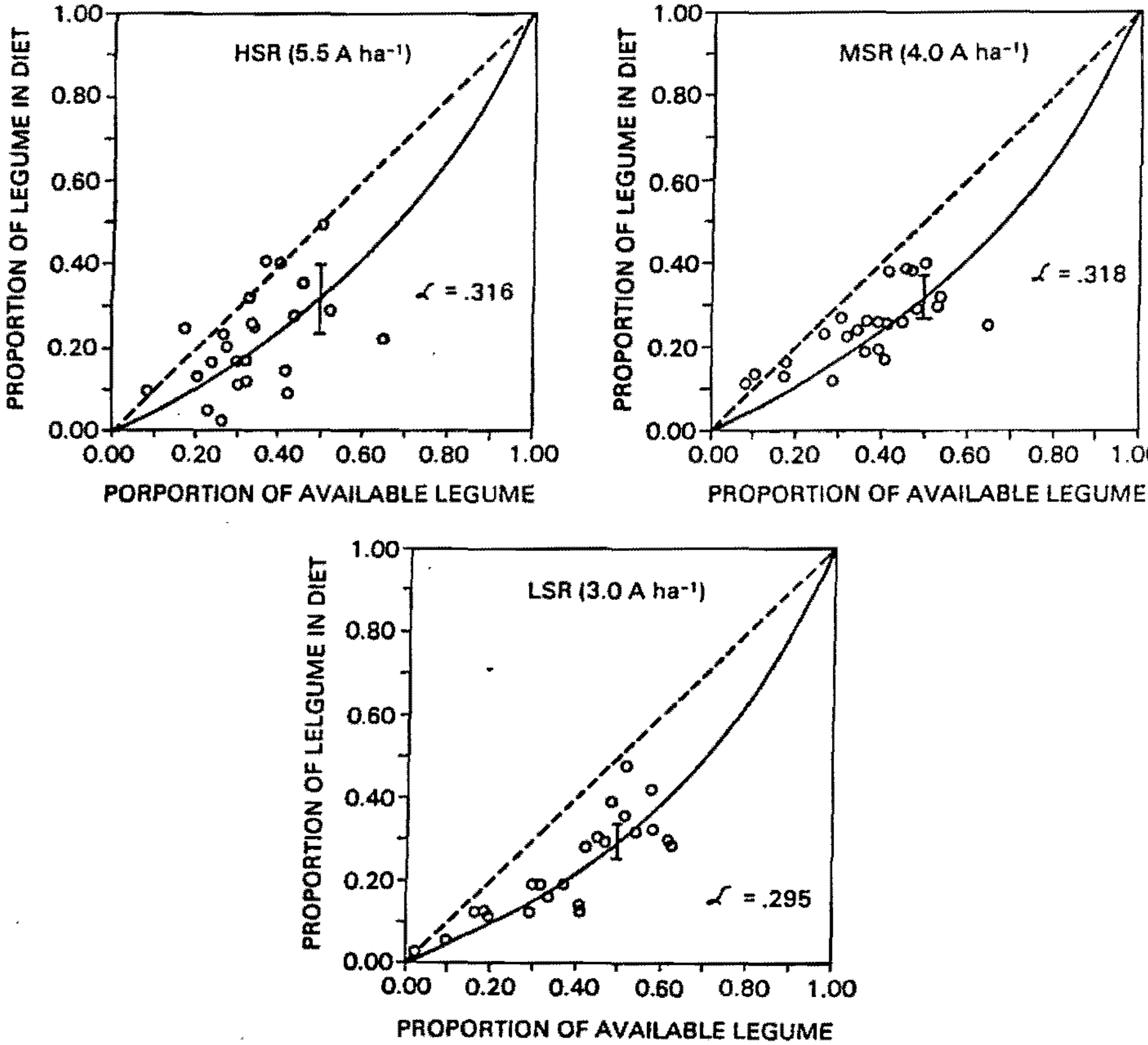

Figure 2. Relationship between legume proportion in the diet and in total available forage in a *Brachiaria dictyoneura* - *D. ovalifolium* pasture at three stocking rates (SR).

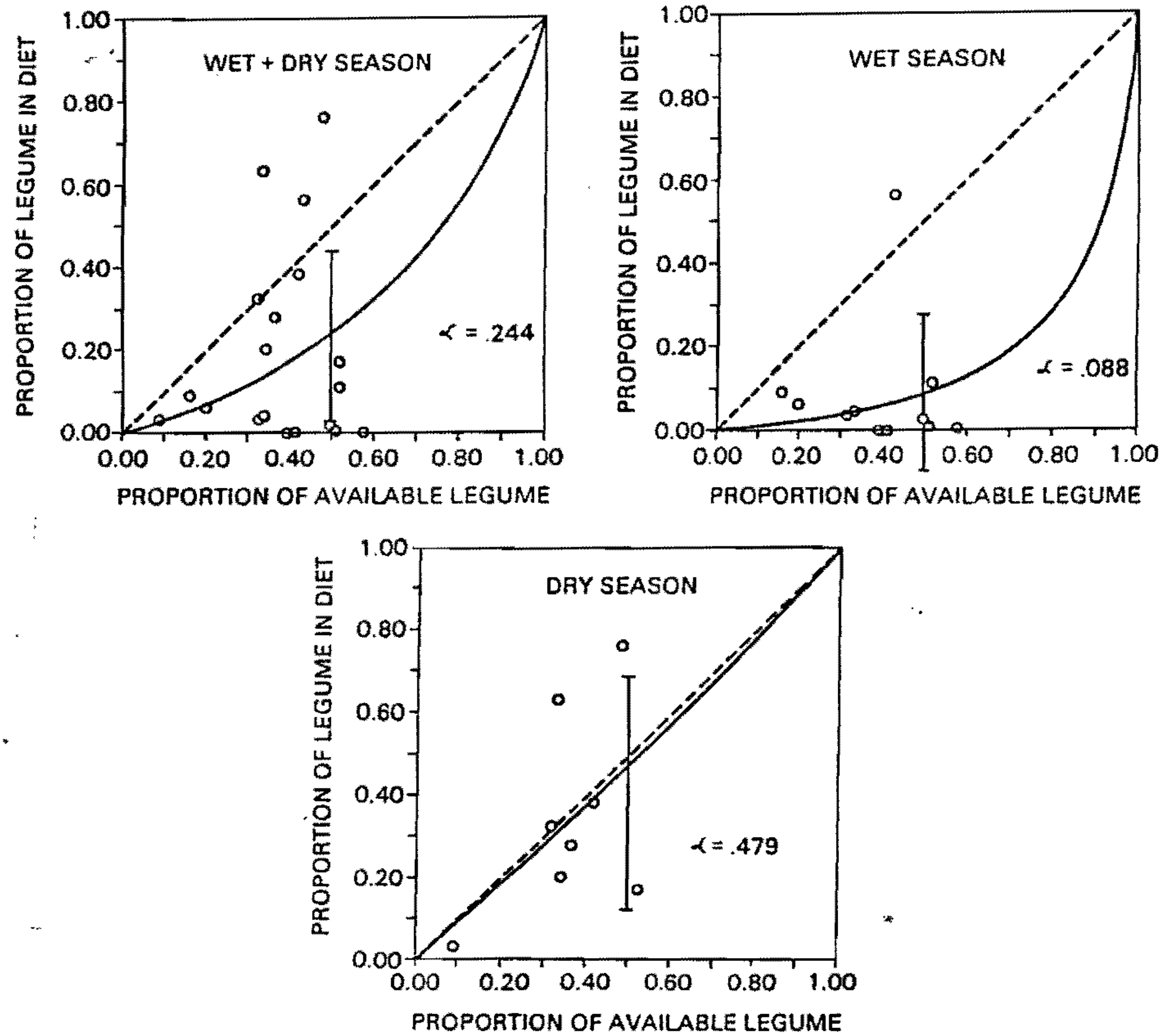

Figure 3. Relationship between legume proportion in the diet and in total available forage in an *Andropogon gayanus - Centrosema acutifolium* pasture in different seasons of the year.

Based on the different selection indices found for the three grass-legume associations considered above, one would expect that management requirements for an adequate grass-legume balance over time would differ between ecosystems. In areas with defined dry season, e.g., savanna ecosystem, associations of palatable legumes, e.g., A. pintoi, with prostrate grasses, e.g., Brachiaria spp., could probably be managed under continuous grazing with seasonal adjustments of stocking rate, since the legume is selected in a similar proportion to what is available. In contrast, in the same environment associations of less palatable and aggressive legumes, e.g., D. ovalifolium, with relatively palatable grasses, e.g., Brachiaria spp., would require some form of deferred grazing to prevent legume dominance or alternatively continuous grazing but with a lower stocking rate. This was partially demonstrated in a grazing trial in the Cerrados of Brazil, characterized by a long dry season (5 to 6 months). In a B. ruziziensis - Calopogonium mucunoides (low palatability) pasture that was legume dominant (30% grass and 70% legume) under continuous grazing, an adequate grass-legume balance (75% grass and 25% legume) was achieved by reducing the stocking rate from 2.5 to 1.5 A/ha (CIAT, unpublished results). In areas with undefined dry season, e.g., tropical rain forest, pastures with prostrate grasses and unpalatable legumes will certainly require rest periods to maintain acceptable grass-legume balance.

Grazing management to keep an adequate balance of grass and legumes in pastures of bunch grass-twining legume associations, e.g., A. gayanus - Centrosema spp., appears to depend on the aggressiveness and relative palatability of the legume as well as on grazing pressure and climate. Pastures based on well adapted and aggressive legumes in areas with short dry seasons are likely to require rotational grazing to prevent legume dominance. Frequency of grazing is also likely to be very critical since animals select against the legume during most of the year, more so if it is of low palatability. With less aggressive legumes, more frequent or continuous grazing may be required to reduce competition from the grass and favor the legume.

Recent experience indicates that rotational grazing is required in some areas. Current available evidence from the tropics indicates that animal performance is as good under continuous grazing with set stocking as with any other grazing management ('t Mannetje et al., 1976). However, pasture management should be viewed not only in terms of animal performance but also in terms of total animal production and pasture stability. One example of this is given by Stobbs (1969) in Uganda with Panicum maximum - Macroptilium atropurpureum grazed continuously and rotationally. Animal gains at the same stocking rate were similar for the continuous and three paddock rotational grazing system but lower for a six paddock rotation. However, after three years of grazing, the proportion of P. maximum was much lower under continuous grazing than under rotational grazing. Pastures under continuous grazing also had more weeds than pastures rotationally grazed. In the long run, it is likely that animal production would have been greater in the more stable pastures under rotational grazing.

If it is accepted that different grass-legume associations have different grazing management requirements for long term persistence, then the question is: "What strategies should be followed to define these requirements?" One approach is the traditional small-plot grazing experiment with a combination of grazing frequencies and grazing pressures in a factorial arrangement (Paladines and Lascano, 1983) or in a central composite design (Mott, 1983). Another alternative is the flexible management approach proposed by Spain et al. (1985). With this strategy, no fixed stocking rates or grazing frequencies are employed. Rather, stocking rate and grazing frequency are adjusted depending on two pasture parameters: (1) stocking rate is adjusted when grazing pressure reaches selected limits, and (2) grazing frequency is adjusted when legume proportion reaches selected limits.

Conclusions

Grass-legume pastures are an important alternative for increasing livestock production in tropical areas. However, to assure success with these pastures grown under different environments it is necessary to develop through well designed experiments appropriate grazing strategies. This in turn requires an understanding of not only how sward structure and composition interact with animal selectivity, but also of how other factors such as competition for soil nutrients, density of growing points, and residual leaf area affect pasture productivity.

Literature Cited

Allden, W.G. and L.A.McD. Whittaker. 1970. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. Australian J. Agr. Res. 21:755.

Böhnert, E., C. Lascano and J.H. Weniger. 1985. Botanical and chemical composition of the diet selected by fistulated steers under grazing on improved grass-legume pasture in the tropical savannas of Colombia. I. Botanical composition of forage available and selected. Sonderdruck aus Zeitschnift fur Tierzuchtung und Zuchtungsbiologie Bd. 102, H.S. 5:385.

Chacon, E. and T.H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behaviour of cattle. Australian J. Agr. Res. 27:709.

Chesson, J. 1983. The estimation and analysis of preference and its relationship to foraging models. Ecology 64:1297.

Gardener, C.J. 1980. Diet selection and liveweight performance of steers on Stylosanthes hamata - native grass pastures. Australian J. Agr. Res. 31:379.

Hunter, R.A., B.D. Siebert and M.J. Breen. 1976. The botanical and chemical composition of the diet selected by steers grazing Townsville stylo-grass pastures during a period of liveweight gain. Proc. Australian Soc. Anim. Prod. 11:457.

Lascano, C. and J.G. Salinas. 1982. Efecto de la fertilidad del suelo en la calidad de Desmodium ovalifolium. Pastos Tropicales. Boletin Informativo 6:4.

Mannetje, L. 't, R.J. Jones and T.H. Stobbs. 1976. Pasture evaluation by grazing experiments. In: N.H. Shaw and W.W. Bryan (Ed.) Tropical Pasture Research: Principles and Methods. pp 194-234. CAB Bulletin 51. Hurley, Berkshire, England.

Milne, J.A., J. Hodgson, R. Thompson, W.G. Souter and G.T. Barthram. 1982. The diet ingested by sheep grazing swards differing in white clover and perennial ryegrass content. Grass Forage Sci. 37:209.

Moore, J.E., L.E. Sollenberger, G.A. Morantes and P.T. Beede. 1985. Canopy structure of Aeschynomene americana - Hemarthria altissima pastures and ingestive behavior of cattle. Proc. XV Int. Grassl. Cong., Kyoto, Japan. p 1126.

Mott, G.O. 1983. Evaluación del germoplasma forrajero bajo diferentes sistemas de manejo del pastoreo. In: O. Paladines y C. Lascano (Ed.) Germoplasma Forrajero bajo Pastoreo en Pequeñas Parcelas. pp 149-163. CIAT, Cali, Colombia.

Paladines, O. and C. Lascano. 1983. Recomendaciónes para evaluar germoplasma bajo pastoreo en pequeños potreros. In: O. Paladines y C. Lascano (Ed.) Germoplasma Forrajero bajo Pastoreo en Pequeñas Parcelas. pp 165-183. CIAT, Cali, Colombia.

Salinas, J.G. and C. Lascano. 1982. Fertilización con azufre y mezcla de la calidad de Desmodium ovalifolium. Pastos Tropicales. Boletin Informativo 5:1.

Spain, J., J.M. Pereira and R. Gualdron. 1985. A flexible grazing management system proposed for the advanced evaluation of associations of tropical grasses and legumes. Proc. XV Int. Grassl. Cong., Kyoto, Japan. p 1153.

Stobbs, T.H. 1969. The effect of grazing management upon pasture productivity in Uganda. III. Rotational and continuous grazing. Trop. Agr. (Trin.) 46:293.

Stobbs, T.H. 1973. The effect of plant structure on the intake of tropical pastures. II. Differences in sward structure, nutritive value and bite size of animals grazing Setaria anceps and Chloris gayana at various stages of growth. Australian J. Agr. Res. 24:821.

Stobbs, T.H. 1977. Seasonal changes in preference by cattle of Macroptilium atropurpureum cv. Siratro. Trop. Grassl. 11:87.