PRODUCTIVITY OF GRASS-LEGUME PASTURE AND ITS CONTRIBUTION TO ANIMAL PRODUCTION IN THE TROPICS

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ABSTRACT

Major constraint to animal production in the tropics is the deficiency of year-round supply of feed, in quantity and quality, in particular during the dry season. And one of the strategies to overcome this problem is to introduce improved pastures based on legumes that are well-adapted to the edaphic and climatic conditions prevailing in the tropics.

In the context of the collaborative research program on the "Improvement of Tropical Pastures" between TARC and CIAT, the author had the opportunity to carry out experiments showing that grass-legume pastures offer a great potential in animal production. Cattle grazing on grass-legume mixture usually select grass species although legume intake tends to increase during the dry season, presumably due to seasonal changes in legume quality. Such intake enables to minimize the weight loss observed in the dry season while increasing animal productivity as a whole. This is one of the important attributes of legumes.

However, the utilization of local feed resources available is also important and relevant from the economic and ecological points of view, and improved pastures should be used strategically to provide supplemental feed during the critical stage of animal nutrition. Therefore, the development of a production system aiming at integrating the utilization of local feed resources and improved pastures is essential if animal production is to be increased in the tropics.

Introduction

Livestock production is an important component of tropical agriculture (Hutton, 1974; Maeno, 1982; Perez, 1977; Sanchez, 1976; Sanchez and Tergas, 1979). Approximately half of the world's permanent pastures and more than half of the cattle population are located in the tropics (Table 1). However, productivity is very low (Table 2), and only 20%of the world's beef is produced in this region (Table 3).

Most of the cattle raising in the tropics is based on native pastures, and low productivity

Table 1 Importance of pastures and animal husbandry in the tropics (1980)

Region	Permanent pastures	Cattle population
	1,000ha	1,000head
Tropical Africa	631,134	148,220
Tropical America	370,287	194,816
Tropical Asia	50,457	244,085
Australia* and Oceania	452,333	26,765
Total	1,504,211(48.3%)	613,886(51.1%)
World	3,116,685(100 %)	1,201,810(100 %)

Source : Based on FAO Production Yearbook, 1981.
* : Includes temperate Australia.

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Table 2 Productivity of beef in the tropics
(1980)

Region	Carcass weight	Extraction rate
	kg	%
Tropical	162	8.9
Temperate	209	29.4
World	198	19.0

Source : Based on FAO Production Yearbook, 1981.

Table 3 Beef production in the tropics
(1980)

Region	Beef and veal production
	1,000ton
Tropical Africa	1,942
Tropical America	4,556
Tropical Asia	807
Australia* and Oceania	1,577
Total	8,882(19.7%)
World	45,130(100 %)

Source : Based on FAO Production Yearbook, 1981.
* : Includes temperate Australia.

of cattle in the tropics is attributed to many factors such as low reproductive performance, low annual weight gain and high susceptibility to diseases. However, the major constraint to animal production is the deficiency of year-round supply of feed, in quantity and quality, in particular during the dry season (Brumby, 1974; Hutton, 1970; Perez, 1977; Sanchez, 1976; Stonacker, 1975).

Table 4 shows the productivity of tropical pastures in the Colombian Llanos (CIAT, 1981). Native pasture of savanna, even if well managed, produced only 90 kg of liveweight per animal per year. In particular. weight gain per unit land area is as low as 20 kg, due to the low carrying capacity or stocking rate of native pasture (4-5 ha/animal). Cattle weight gain during the rainy season and weight loss during the dry season are well illustrated in this table, too.

Table 4 Productivity of tropical pastures

	Dry season	Wet season	Total year	
	(g/animal/day)		(kg/animal)	(kg/ha)
Best managed savanna	−167	449	90	22
Savanna+Protein Bank*	126	537	147	74
B. decumbens	− 50	506	118	147
A. gayanus+*S. capitata*	303	656	201	330

Source : Adapted from CIAT REPORT, 1981.
* : *P. phaseoloides*.

One of the strategies to overcome this problem is to introduce improved pastures based on legumes (Brumby, 1974; CIAT, 1978; Hutton, 1970, 1974, 1978; Mannetje, 1978; Sanchez and Tergas, 1979; Stonaker, 1975). As shown in Table 4, introduction of legumes, simply as protein bank, increased the productivity of native pasture more than three times in terms of weight gain per hectare while weight gain per animal increased more than 50%. Also weight gain during the dry season was particularly evident, suggesting that the weight loss observed in the dry season can be attributed to the deficiency of feed, in particular protein (Perez, 1977; Sanchez and Tergas, 1979), and can be minimized by the introduction of legumes, as mentioned before.

Deficiency of protein is also encountered in the case of improved grass pastures. As shown in Table 4, *B. decumbens* pasture induced a 2-and 7-fold weight gain per hectare of native pasture with and without protein bank, respectively. However, weight gain per animal did not increase significantly, and weight loss in the dry season was still observed. Introduction of improved grass pastures contributed to the increase of the productivity per unit land area through the increase of the carrying capacity. However, feed quality was not appreciably improved, particularly in the dry season, hence the introduction of legumes is essential for increasing the productivity of pastures.

As shown in the case of *A. gayanus* + *S. capitata* pasture (Table 4), productivity of improved grass-legume pasture increased remarkably. Compared with the native pasture, weight gain per animal doubled,and weight gain per hectare increased 15 times. And weight gain both per animal and per hectare in grass-legume pasture was twice that in grass alone pasture.

Contribution of legumes to the increase in productivity

As mentioned before, introduction of grass-legume pastures is very effective and relevant for the "Improvement of Tropical Pastures". Therefore, evaluation and screening of promising grass and legume species that are well-adapted to the edaphic and climatic conditions prevailing in the tropics are most important (Hutton, 1970, 1974, 1978; Sanchez and Tergas, 1979).

In the context of the collaborative research program on the "Improvement of Tropical Pastures" between TARC and CIAT, the author had the opportunity to carry out some experiments in Colombia. The results of one of these experiments are presented in this report.

Brachiaria decumbens is one of the promising grasses that are well-adapted to infertile, acid soils in Tropical Latin America, although it has several shortcomings. One of the problems is its low compatibility with legumes due to its aggressive growth habit. Thus it is necessary to identify legumes which can be associated with this grass species (Hutton, 1978; Sanchez and Tergas, 1979).

Recently, *Desmodium ovalifolium* which was introduced from Southeast Asia, and shows a prostrate and vigorous growth habit, could be used in association with *B. decumbens* (Hutton, 1978).

Therefore, to obtain information on the productivity and performance of both pasture and animal, a mixture of these two species was established and grazing experiments were conducted. To compare pasture performance under the same grazing pressure, forage availability in this mixture was estimated every 6 weeks, and the number and/or weight of grazing steers was adjusted so as to offer the animals the same amount of forage (4 kg DM/100 kg Bw/day) using the "Put and Take Method" (Blaser *et al.*, 1974; Mott, 1960). Animal production (body weight gain) was also determined every 6 weeks.

As shown in Table 5, this mixture was found to be highly productive (animal weight gain: 1,100 kg/ha/year, 240 kg/animal/year, 660 g/animal/day). This remarkable weight gain, in

Table 5 Liveweight gain under put and take grazing *Brachiaria decumbens+Desmodium ovalifolium* **(19 December, 1979 6 August, 1981. Quilichao)**

	1st period	2nd period	3rd period	Total period	Adjusted to 1 year
	19 December-11 June (171 days)	12 June-2 April (288 days)	3 April-6 August (125 days)	19 December-6August (584 days)	(365 days)
g/animal/day	781	604	635	662	662
kg/animal/period	133	174	79	386	242
Steers/ha	5.2	3.8	5.1	4.5	4.5
kg/ha	694	661	403	1,758	1,099

particular per unit area, was obtained with a high stocking rate of 4.5 steers/ha owing to the high carrying capacity, i.e. forage availability in this mixture (Fig. 1).

Figure 1 also shows the seasonal changes of forage availability as affected by the rainfall distribution which were reflected in the seasonal changes of animal weight gain. Liveweight gain in the rainy season was very high, but was low in the dry season although no weight loss was observed. And as expected, there was a positive correlation between forage availability and liveweight gain per hectare (Fig. 2).

Rainfall distribution had also affected the protein content of grass and legume, and as shown in Figure 3, there was a positive correlation between protein content in diet and daily weight gain of animal. There was no weight loss associated with the dry season, because the dietary protein content had never fallen below the critical level (7%) (Hutton, 1978; Perez, 1977) for maintenance of cattle body weight (Fig. 3).

High productivity of this mixture is attributed to its high forage quantity and quality, and these attributes tend to fluctuate with the season due to the changes in the rainfall distribution.

Rainfall distribution affected not only forage availability but also the botanical composition of this mixture, as shown in Figure 1. During the rainy season, the proportion of legumes was very low, but it increased gradually from the onset of the rainy season to

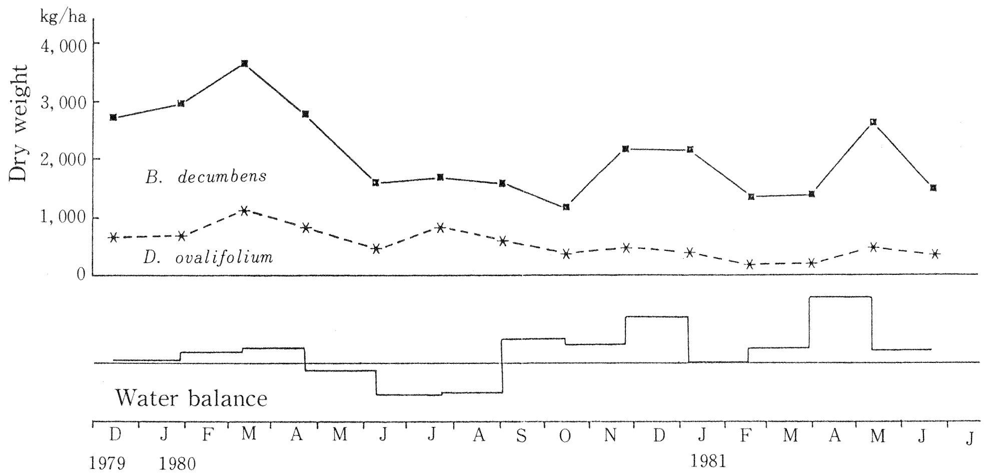

Fig. 1 Forage availability of *B. decumbens+D. ovalifolium* **mixture under continuous grazing.**

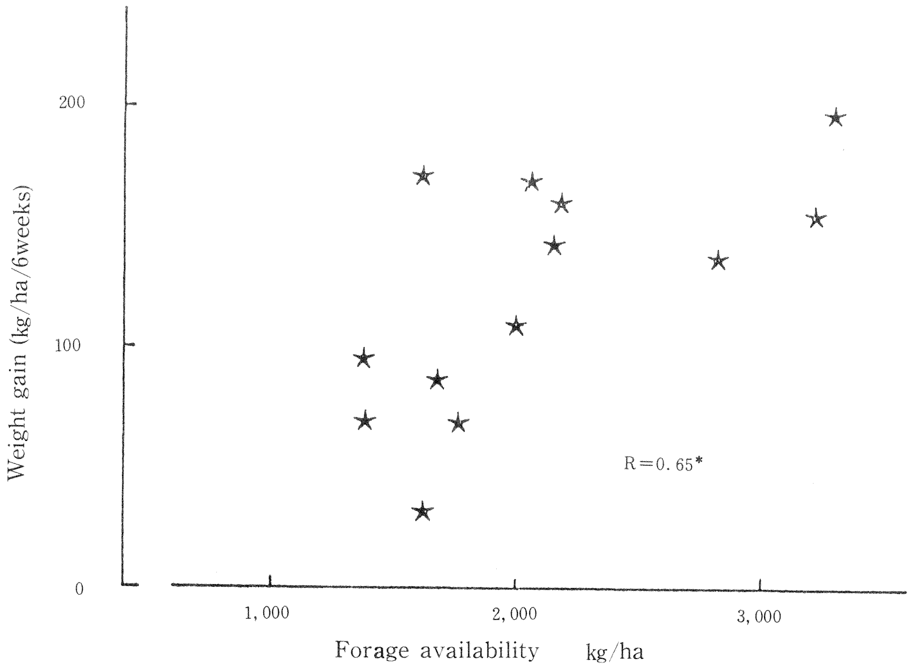

Fig. 2 Relationship between forage availability and animal weight gain (*B. decumbens*+*D. ovalifolium*).

the onset of the dry season, and in this case reached values of around 50% of the total.

This seasonal change of botanical composition undoubtedly affected the grazing performance of cattle, in particular the selection of forage (Stobbs, 1977). Detailed knowledge on the performance of cattle grazing on grass-legume pastures is valuable to understand the changes in animal weight gain and also in the botanical composition of pastures. Such data could be useful in the management of pastures and animals (Gardener, 1980). Therefore, using animals with an esophageal fistula, forage selection was analysed.

Figure 4 shows the botanical composition of forage on offer and selected by cattle. During the rainy season, cattle selected *B. decumbens* and the legume proportion in the diet was very low, However in the dry season selection of *D. ovalifolium* increased gradually. Selection of a component is partly influenced by the amount available in the pasture. Thus apparently, there was a highly positive correlation between the proportion of legume in forage on offer and selected (Fig. 5).

However, when the ratio of the legume proportion in forage selected and on offer was compared, differences were observed (Fig. 4). To interpret these differences, the Relative Selection Index (RSI) was determined. This RSI (also called the Relative Preference Index (Gardener, 1980) or the Selection Ratio) (Mc Lean *et al*., 1981) is defined as the ratio of % Herbage in the Diet/%Herbage on Offer. Indices above 1 show preference and below 1 rejection.

As shown in Figure 4, the RSIs of *B. decumbens* were always above 1 and there were few differences throughout the season. In the case of *D. ovalifolium,* however, the RSIs were always below 1 and large seasonal variations (0.14-0.98) were observed. This pattern of variation seems to be associated with the rainfall distribution, and as shown in Figure 6, there was a negative correlation between water balance and the RSIs of *D. ovalifolium*. That is, the Relative Selection Indices of legume were very low during the rainy season and

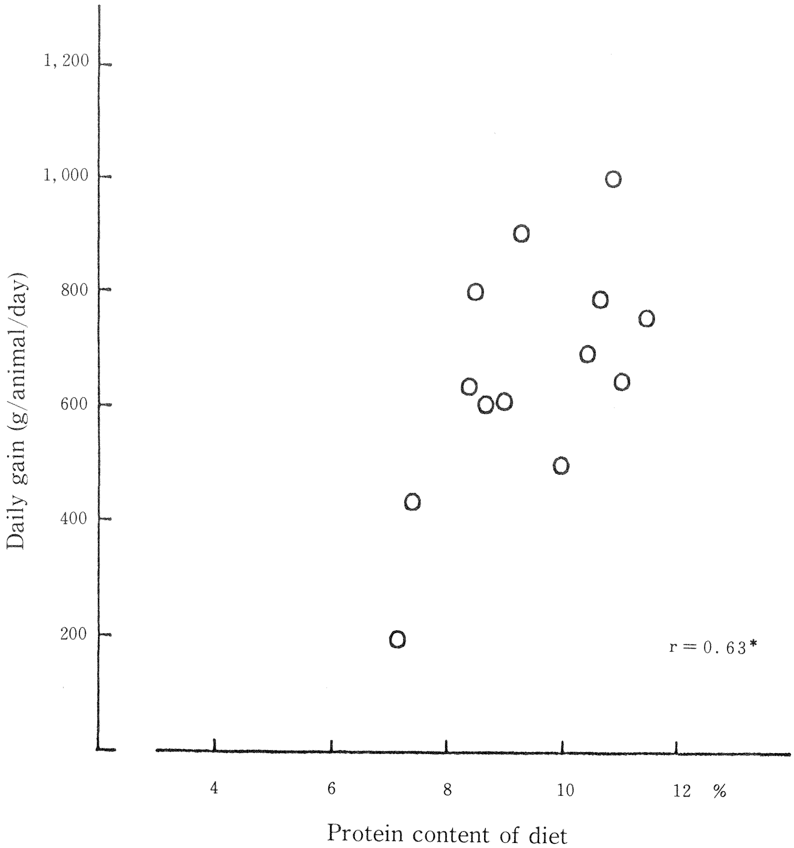

Fig. 3 Relationship between protein content of diet and animal weight gain (*B. decumbens* + *D. ovalifolium*).

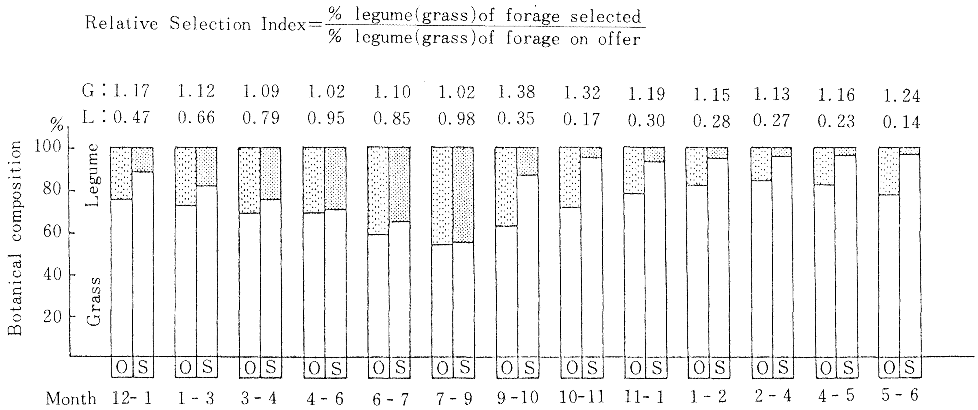

Fig. 4 Botanical composition of forage on offer and selected by steers with esophageal fistula in a *B. decumbens* + *D. ovalifolium* mixture under continuous grazing.

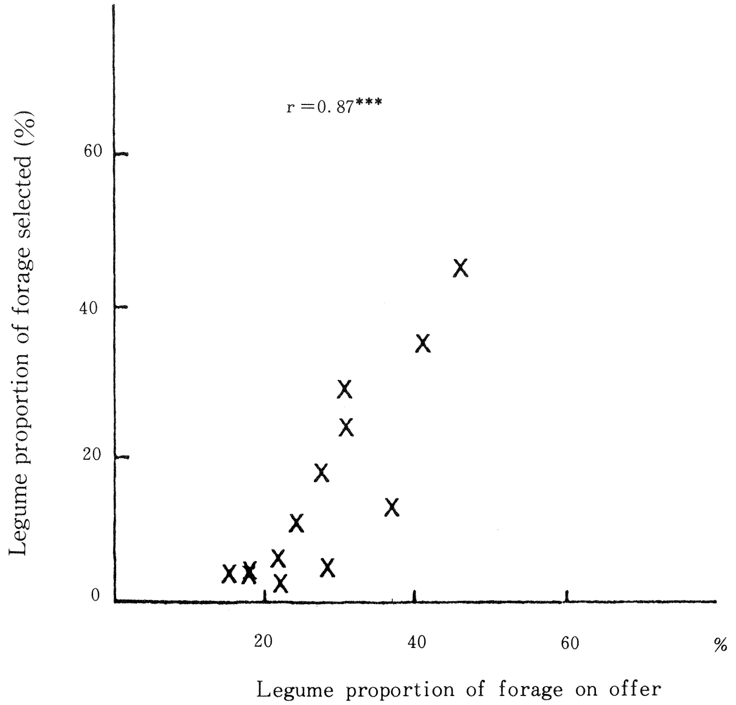

Fig. 5 Relationship between legume proportion of forage on offer and selected by steers with esophageal fistula (*B. decumbens* + *D. ovalifolium*).

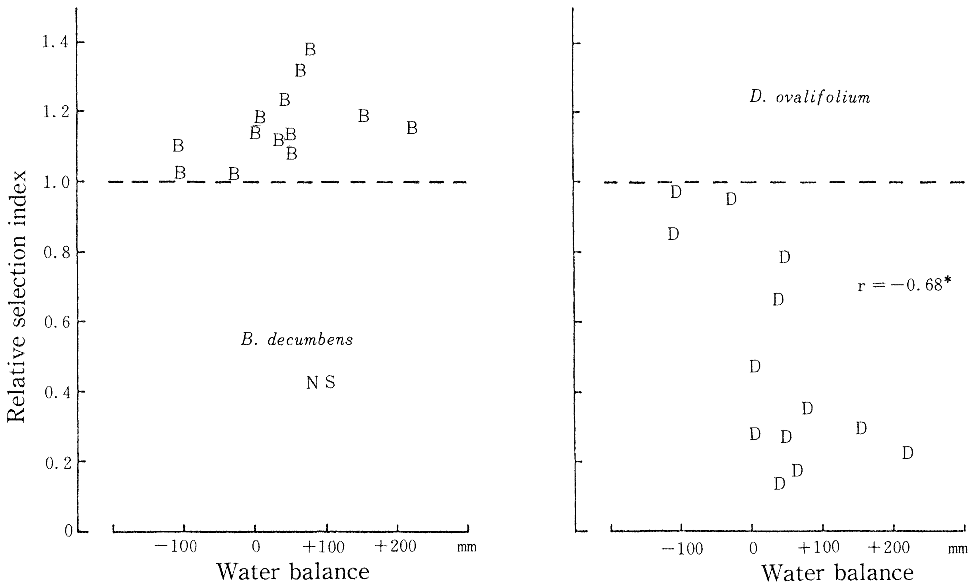

Fig. 6 Relationship between water balance and relative selection index of grass and legume (*B. decumbens* + *D. ovalifolium*).

increased in the dry season, although still remaining at values below 1. However, the RSIs of *B. decumbens* were always above 1, regardless of the season.

This access to legumes in the dry season is a well-known phenomenon, but the reason why animals select legume during the dry season remains poorly documented (Gardener, 1980; Mc Lean *et al.*, 1981) and is presumably related to the botanical and chemical composition of forage on offer, as discussed below.

Figure 7 shows the relationship between the grass proportion of forage on offer and the RSIs of grass and legume. The Relative Selection Indices of *B. decumbens* were always above 1, regardless of the proportion of forage on offer, suggesting that cattle select *B. decumbens* at any time.

In the case of *D. ovalifolium*, however, there was a negative correlation between the grass proportion of forage on offer and the RSIs of legume. When the grass proportion of forage on offer decreased, the RSIs of *D. ovalifolium* increased. That is, cattle selected legumes only when the proportion of grass on offer was low. Since the grass proportion decreased (legume proportion increased) during the dry season (Fig. 8), apparently there was a negative correlation between the water balance and the RSIs of *D. ovalifolium*, and the RSIs increased during the dry season, as shown before (Fig. 6).

However, the data should be interpreted with caution since the increase in the selection (preference) of legumes does not necessarily imply that there is a concomitant increase in the legume proportion of forage on offer. As shown in Table 6, for an identical proportion of legume in forage on offer, the legume proportion of forage selected and then the Relative Selection Indices were low in the rainy season, compared with the dry season. And this difference appeared to be related to the difference in the forage quality of legume (for example, K content of *D. ovalifolium,* as shown in the parenthesis).

Figure 9 shows the relationship between K content of forage on offer and the RSIs of grass and legume. Potassium content of *B. decumbens* was always higher than that of *D. ovalifolium*, and the RSIs of *B. decumbens* were also high. On the contrary, K content of *D. ovalifolium* was low, and was positively correlated with the RSIs of legume.

In vitro digestibility tests of grass and legume showed that the digestibility of the plants also affected the Relative Selection Index. Digestibility of *B. decumbens* was higher than of *D. ovalifolium* (Fig. 10).

These differences in the forage quality of grass and legume could presumably account for the preference of grazing animals. Figure11 shows diagrammatically the probable reason for

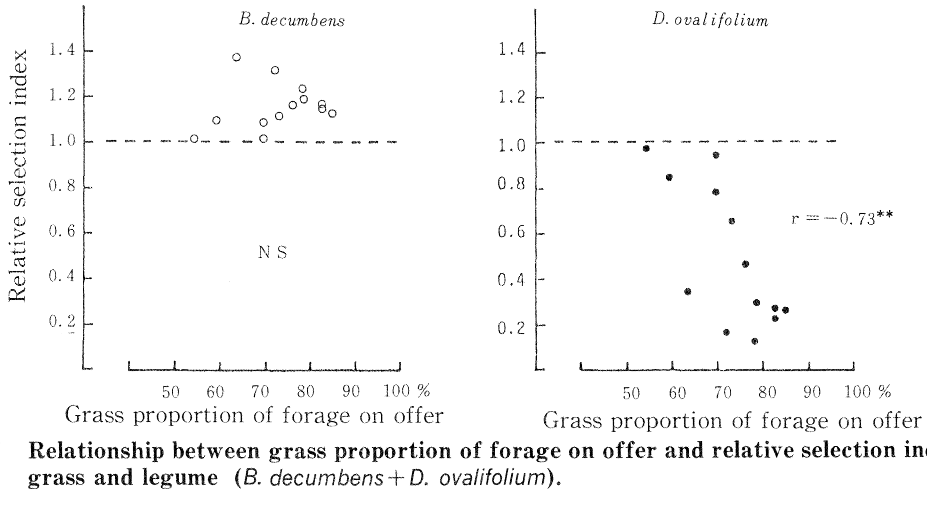

Fig. 7 Relationship between grass proportion of forage on offer and relative selection index of grass and legume (*B. decumbens* + *D. ovalifolium*).

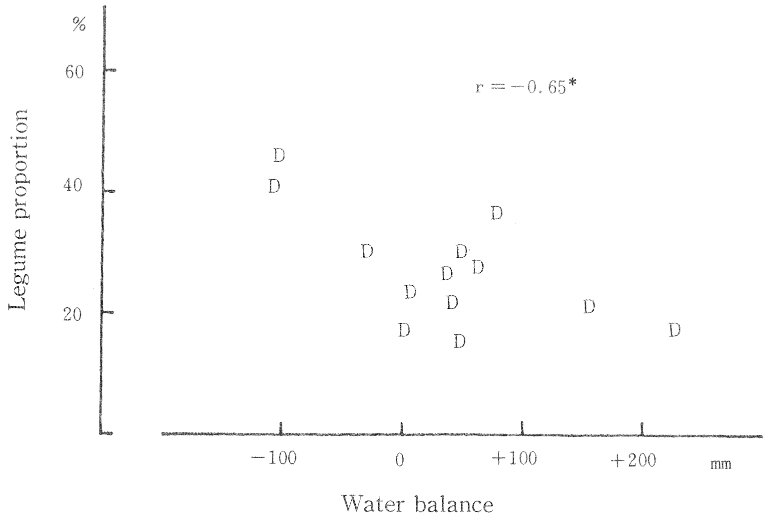

Fig. 8 Relationship between water balance and legume proportion in a mixture of *B. decumbens* + *D. ovalifolium*.

Table 6 Comparison of relative selection index* of legume in dry and rainy season (*B. decumbens* + *D. ovalifolium*)

	Legume proportion of forage		Relative selection index	
	Un offer	Selected		
Dry season	45.8%	44.8%	0.98	(0.68%)**
Rainy season	43.8	12.2	0.28	(0.48%)

*R.S.I. = % legume in diet/% legume on offer.
**Figures in parenthesis show potassium content of legume.

dry season access to legume. Grazing animals always prefer *B. decumbens* because of its high quality. During the rainy season when grass is abundant, cattle consume this grass mainly with a resultant decrease in the grass proportion from the rainy season to the dry season. Thus, cattle are forced to consume legumes in the dry season because of the shortage of grass, and then consumption of legumes increases gradually. This relative increase in the consumption of legumes leads to the improvement of legume quality due to plant renewal, which in turn promotes the consumption of legumes. Then the legume proportion decreases (grass proportion increases) until the next rainy season, hence the decrease in the selection of legumes. This may presumably be the reason why cattle select legumes (the Relative Selection Index of legume increases) during the dry season. However, more experiments should be performed to explain this phenomenon (Mc Lean et al., 1981; Stobbs, 1977).

In any case. the selection of legume by grazing cattle in the dry season is advantageous from the view point of productivity. Because, as shown before (Fig. 1), in the dry season more than half of the forage available consists of legume, and the increased consumption of legume enables to minimize the dry season-weight loss, and to obtain a high liveweight gain per year (Table 5).

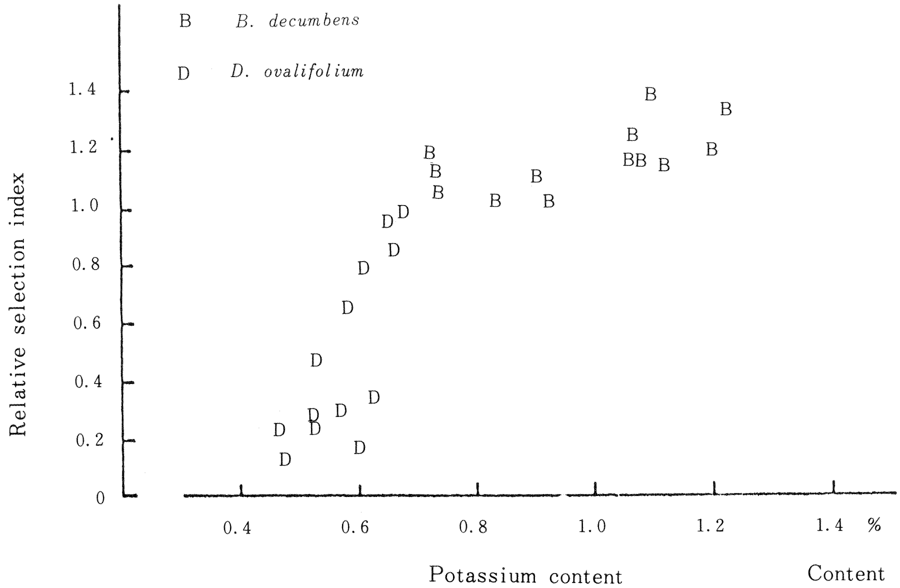

Fig. 9 Relationship between potassium content and relative selection index of *B. decumbens and* **and** *D. ovalifolium.*

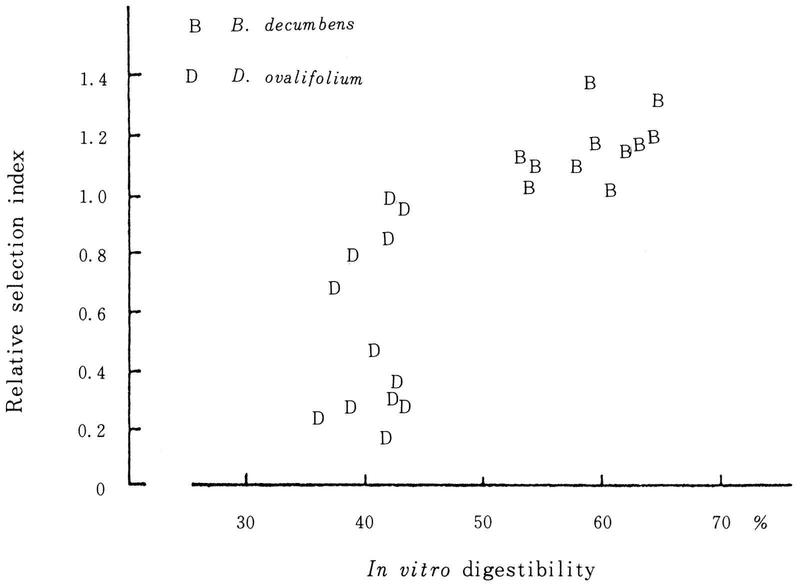

Fig. 10 Relationship between *in vitro* **digestibility and relative selection index of** *B. decumbens* **and** *D. ovalifolium.*

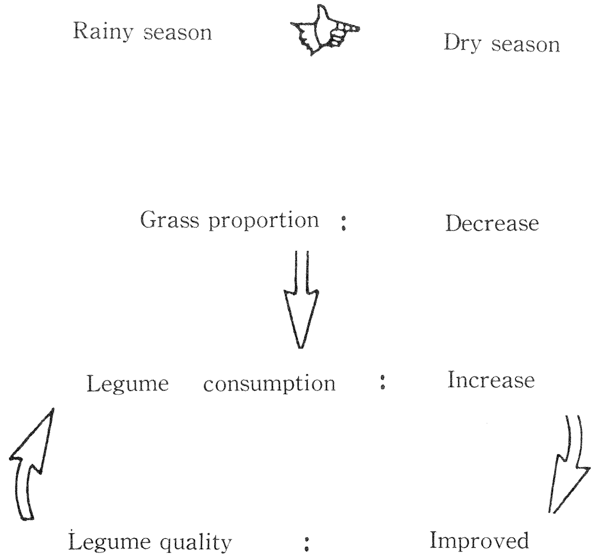

Fig. 11 Reason for dry season access to legumes.

This dry season access to legume and contribution to animal production are also observed in mixtures of other grasses and legumes. And this is one of the reasons why legumes should be introduced to increase the productivity of tropical pastures, in particular during the dry season.

One important role of legumes is their contribution to the improvement of the forage quality of companion grasses through the fixation and transfer of nitrogen (Sanchez, 1976; Sanchez and Tergas, 1979; Shaw and Bryan, 1976). However, as shown in this report, legumes also contribute to animal production through direct consumption of legumes by cattle, particularly in the dry season.

Figure 12 shows the relationship between protein availability (protein content of grass × grass availability + protein content of legume × legume availability) and animal weight gain. As expected, there was a positive correlation between these parameters. Protein availability was affected by the rainfall distribution (Fig. 13). During the rainy season, most of the protein available was derived from *B. decumbens,* but in the dry season the contribution of *D. ovalifolium* increased gradually.

As shown in Figure 14, contribution of *D. ovalifolium* to total protein availability was around 20% in the rainy season, but it increased up to 60% in the dry season. And this seasonal change of legume contribution was due to the legume proportion of forage on offer rather than to the protein content of legume. Therefore, as mentioned previously, dry season access to legume is a significant factor for increasing the productivity.

Since the mixture had been established only three years before, experiments should be carried out over a period of several years, to obtain information on persistency (Hutton, 1970, 1978; Sanchez and Tergas, 1979; Shaw and Bryan, 1976) in particular. Also large scale grazing trials with various stocking rate treatments should be undertaken. Thus it is evident that grass-legume pastures show a great potential for increasing the productivity.

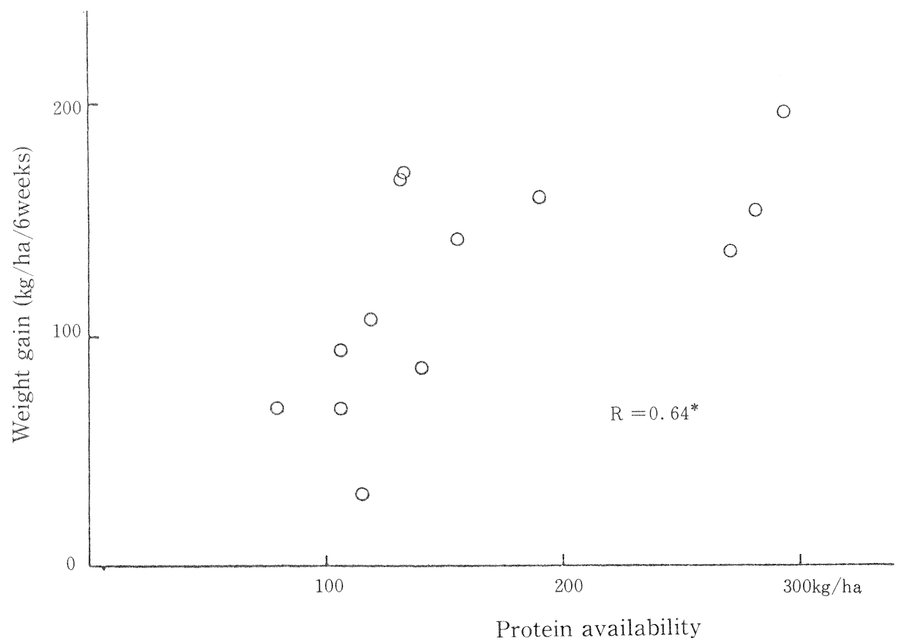

Fig. 12 Relationship between protein availability and animal weight gain (*B. decumbens* + *D. ovalifolium*).

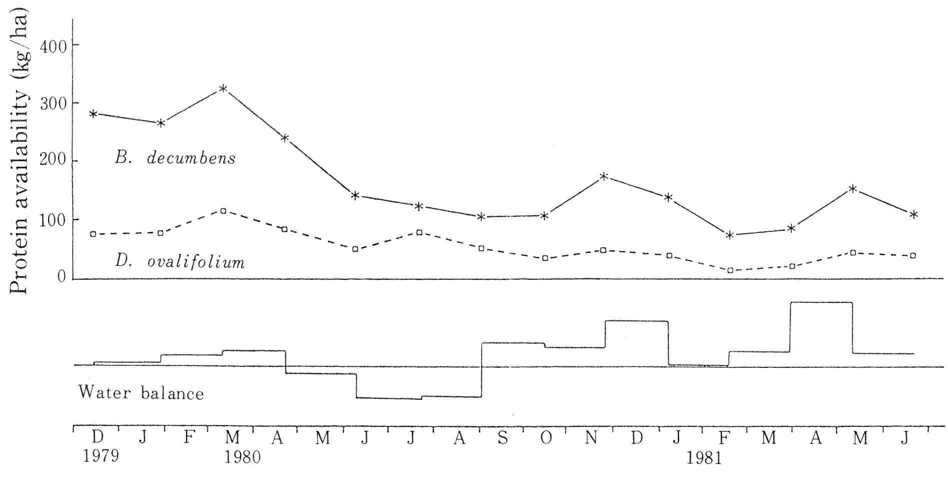

Fig. 13 Protein availability of *B. decumbens* + *D. ovalifolium* mixture under continuous grazing.

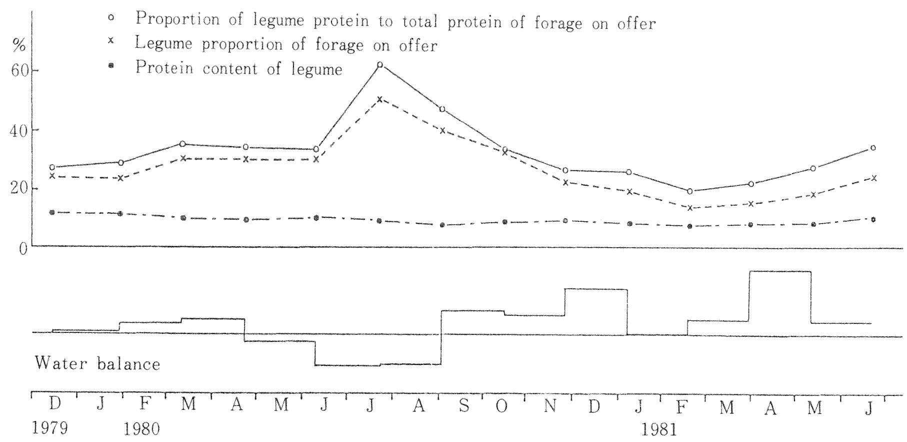

Fig. 14 Seasonal change of legume contribution to total protein availability, legume composition, and protein content of legume in a mixture of *B. decumbens*+*D. ovalifolium*.

Problems to be solved for increasing animal production

As mentioned in this report, animal husbandry is an important component of tropical agriculture. And for increasing productivity, improvement of tropical partures by introducing grasses and legumes is essential (Brumby, 1974; CIAT, 1978; Hutton, 1970, 1974, 1978; Maeno, 1982; Mannetje, 1978; Perez, 1977; Sanchez, 1976; Sanchez and Tergas, 1979).

In this regard, some of the problems which should be overcome are summarized as follows (Hutton 1978; Maeno, 1982; Preston, 1977; Sanchez, 1976; Sanchez and Tergas, 1979):

1 Grass and legume species that can be well adapted in the tropics are site-specific. Therefore, trials for introduction and evaluation of promising germplasm should be conducted on a regional basis.

2 However, improvement of grasslands with grass-legume mixtures is comparatively expensive under the conditions prevailing in the tropics.

Therefore, the utilization of adequate local feed resources available in each region is also important and relevant from the economic and ecological points of view. And improved pastures should be used strategically to provide supplemental feed during the critical stage of animal nutrition.

3 Finally, the development of a production system aiming at integrating the utilization of local feed resources and improved pastures is essential for increasing productivity as a whole.

This is an economically and ecologically sound technology which should be adopted in the tropics.

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Discussion

Siregar, M.E. (Indonesia): You mentioned that the mixture of *Andropogon gayanus* and *Stylosanthes capitata* is very good. However you placed emphasis on the combination of *Brachiaria decumbens* and *Desmodium ovalifolium*. Which combination would you recommend ?

Answer: Above all I wanted to emphasize the importance of combining grasses and legumes to achieve a better level of nutrition in cattle. The choice of a combination will depend essentially on the location. Materials should be evaluated on a regional basis. Each species has advantages and disadvantages. For example *Brachiaria decumbens* may induce symptoms of photosensitization in cattle. In the case of *Andropogon gayanus*, it is difficult to maintain a dense pasture due to the growth habit of the grass.