Pasture Quality and Nutrition

The Pasture Quality and Nutrition Section was created in January, 1981 as part of the Pasture Evaluation Unit of the Tropical Pastures Program. Its general objective is to evaluate the quality of promising germplasm. Specifically, the section is concerned with:

a) Identifying and characterizing quality factors in germplasm that will aid in the overall screening process;

b) studying quality factors in germplasm assembled in pasture systems as they relate to performance of the grazing animal;

c) identifying alternate uses of germplasm in pasture systems, based on quality related factors.

From the beginning the need for integrating with other sections of the program became evident. This effort is reflected in cooperative research projects carried out with the following sections: Germplasm, Soil and Plant Nutrition, Agronomy-Quilichao, and Pasture Productivity and Management.

Characterization of Quality Factors in Germplasm

Initial evaluation of quality factors in Category III promising germplasm is done in the Palmira laboratory with vegetative material from cutting experiments in Quilichao and Carimagua. In addition, studies with crated wethers are conducted in Quilichao to determine intake and digestibility of grasses and legumes fed alone or in combination, and with grazing animals to determine relative acceptability.

Grasses. Leaf material from nine grasses of 3, 6, 9, 12 and 15 weeks regrowth from a growth curve experiment in the rainy season in Quilichao were evaluated in terms of *in vitro* dry matter digestibility (IVDMD), nitrogen content and rates of decline over time. Summarized results (Table 1) indicate that major differences between grasses were in IVDMD and not so much in nitrogen content. The group of five Brachiaria grasses exhibited higher IVDMD and less rapid decline in digestibility than the four bunch type grasses. Comparisons between the Brachiaria grasses indicate that *B. humidicola* 6013 had a faster decline in IVDMD than *B. decumbens* 606 (-.81% vs -.47% per week). This would explain, as suggested last year (CIAT, 1980), better animal performance observed in Carimagua in *B. decumbens* than in *B. humidicola*.

Recently it has been indicated that one advantage of *B. dictyoneura* over *B. humidicola* is its ability to produce seed under the Carimagua environment. Thus, it became of interest to determine if there was any difference in quality between the two grasses. In a preliminary study crated wethers were offered three-month growth of *B. dictyoenura* and *B.*

humidicola after establishment in Quilichao. Results in Table 2 show no difference in voluntary intake or dry matter digestibility between the two grasses. For both grasses intake of digestible nutrients (43.3 and 39.9 g/kg$^{.75}$ per day) was well above the maintenance requirement cited for this type of animals (25 g/kg$^{.75}$ per day). Future experiments will compare intake and digestibility of the two grasses at three different stages of regrowth.

Table 1. *In vitro* dry matter digestibility (IVDMD) and nitrogen content and their rate of decline in leaf tissue of grasses under cutting (Quilichao).

Accession	Leaf tissue[a]		Rate of decline[b]	
	IVDMD	N	IVDMD	N
	--------%--------		----% per weeks---	
B. decumbens 606	62.1	2.4	- .47	-.11
B. decumbens 6131	64.4	2.4	- .76	-.11
B. ruziziensis 655	62.1	2.3	LF[c]	-.12
B. brizantha 6013	62.6	2.3	- .68	-.12
B. humidicola 6013	63.5	1.9	- .81	-.11
A. gayanus 621	52.6	1.7	-1.16	-.10
P. maximum 604	52.5	2.3	-1.43	-.16
P. plicatulum 600	44.7	1.9	-1.49	-.10
H. rufa 601	48.1	1.6	- .85	-.10

[a] Values reported are the mean of two cycles during the rainy season with 5 cutting frequencies each (3, 6, 9, 12, 15 weeks).
[b] Linear model (y = a-bx).
[c] Lack of fit with model used.

Legumes. As with grasses, leaves of 12 legumes of 3, 6, 9, 12 and 15 weeks regrowth in the rainy season in Quilichao were analyzed for IVDMD and nitrogen content and their corresponding rates of decline over time. Results presented in Table 3 point out the very high nutritive value of *Zornia* sp. 9648 relative to *Z. latifolia* 728 and to the other legumes evaluated. The high IVDMD and nitrogen content of *Zornia* sp. 9648 and of *Zornias* in general would make them ideal legumes for early weaning calves, provided they are palatable enough to ensure high intake.

Of the other legumes evaluated, the two *Desmodium* species, *S. scabra* 1009, *P. phaseoloides* 9900 and *Centrosema* H438 have *in vitro* digestibilities lower than would be expected for legumes. In the case of *D. ovalifolium* 350, *D. gyroides* 3001 and *S. scabra* 1009, the low IVDMD could be related to their tannin content (see footnote Table 3).

Table 2. Preliminary evaluation with crated wethers of the quality of B. dictyoneura as compared with B. humidicola (Quilichao).

Measurement[a]	B. humidicola[b]	B. dictyoneura[b]
Dry matter offered		
(g/kg$^{.75}$ per day)	100.5 ± .73	101.4 ± 1.5
Dry matter refused		
(g/kg$^{.75}$ per day)	33.1 ± -8.8	35.9 ± 8.0
Intake (DM) (g/kg$^{.75}$ per day)	67.4 ± -9.1	65.5 ± 8.0
Feces production (DM)		
(g/kg$^{.75}$ per day)	24.3 ± 3.0	25.6 ± 5.1
Dry matter digestibility (%)	63.9	60.9
Digestible nutrient intake		
(g/DDM/kg$^{.75}$ per day)	43.1	39.9

[a] Six animals per species.
[b] Material fed: green-unchopped 3 months growth after establishment.

It should be mentioned, however, that the in vitro system underestimates the digestibility of legumes containing tannins, such as D. ovalifolium 350. Digestibility values obtained in vivo ($\bar{x}$ 56.9%) in several experiments have been consistently higher than those obtained in vitro ($\bar{x}$ 37.9%) (Table 4). The reason for this large difference, not found with other legumes, is not known.

Differences between the legumes evaluated were also evident in terms of rate of decline in IVDMD (Table 3), which was above 1% per week for Zornia sp. 9648, S. guianensis 184 and G. striata 964 which had higher initial IVDMD values. Except for D. ovalifolium 350, the total nitrogen content of the legumes studied was within the level to be expected. However, closer examination of the nitrogen distribution in the leaf tissue and corresponding solubilities revealed some interesting differences between legumes (Table 5). A great proportion of the nitrogen in the plant cell of the 12 legumes was found in the cell wall (N-NDF), and was particularly high in P. phaseoloides (81.8%) and Centrosema H438 (84.8%). The exact effect of quality of high N-NDF, and low solubility in pepsin present in the two legumes, is not known, but could be related to their relatively low IVDMD reported in Table 3.

Table 3. *In vitro* dry matter digestibility (IVDMD) and nitrogen content and their rate of decline in leaf tissues of legumes under cutting (Quilichao).

Accession	Leaf tissue[a]		Rate of decline[b]	
	IVDMD	N	IVDMD	N
	---------%---------		----% per week----	
Zornia sp. 9648	71.5	5.1	-1.61	-.14
Zornia latifolia 728	65.5	4.3	- .71	-.08
S. guianensis 184	59.4	3.7	-1.04	-.11
S. hamata 147	64.5	3.7	- .61	-.14
S. capitata 1315	57.6	3.3	- .79	-.12
S. scabra 1009[c]	55.8	3.4	- .63	-.11
D. ovalifolium 350[c]	40.1	2.6	- .47	-.05
D. gyroides 3001[c]	35.6	3.5	- .49	-.08
G. striata 964	59.0	4.4	-1.06	-.14
A. histrix 9690	68.4	4.8	- .37	-.13
P. phaseoloides 9900	52.8	4.4	LF[d]	-.09
C. pubescens 438	51.6	4.8	- .86	-.12

[a] Values reported are the mean of two cycles during the rainy season with five cutting frequencies each (3, 6, 9, 12 and 15 weeks).
[b] Linear model (y = a-bx).
[c] Tannin content (catechin equivalent) was 6.6, 19.1 and 8.9 for *S. scabra* 1009, *D. ovalifolium* 350, and *D.* gyroides 3001, respectively.
[d] Lack of fit with model used.

Table 4. Comparative results of dry matter digestibility of *D. ovalifolium* 350 in *in vivo* and *in vitro*[a] studies.

Experiment[b]	Digestibility *D. ovalifolium* 350		
	In vivo	Experiment[c]	*In vitro* (leaf)
1 (wethers)	56.7 ± 3.2	1 (germplasm)	31.6 ± 3.4
2 (wethers)	60.9 ± 2.1	2 (growth curves)	40.9 ± 1.1
3 (wethers)	56.6 ± 1.3	3 (grass/legume mixture)	34.7 ± 2.7
4 (wethers)	55.0 ± 3.9	4 (esophageal forage-Carimagua)	41.4 ± 2.7
5 (wethers)	58.3 ± 1.9	5 (esophageal forage-Carimagua)	38.8 ± 5.1
6 (wethers)	54.0 ± 3.5	6 (fertilization-Carimagua)	40.1 ± 3.6
Average	56.9		37.9

[a] Correction factors in the *in vivo* systems ($\frac{\text{\% IVDMD standard}}{\text{\% in vivo DMD standard}}$) are: .95 for high standard and 1.06 for low standard.
[b] With crated wethers fed *D. ovalifolium* 350 *ad libitum*.
[c] *In vitro* digestibility using leaf material derived from several experiments.

Table 5. Nitrogen fractions and their solubility in the dry matter (DM) and neutral detergent fiber (NDF) of 12 legumes under cutting[a] (Quilichao).

Accession	Nitrogen (%)			Nitrogen solubility (%)		
	N-DM	N-NDF	$\frac{\text{N-NDF}}{\text{N-DM}} \times 100$	Buffer[b] N-DM	Pepsin[c] N-DM	Pepsin[c] N-NDF
Zornia sp. 9648	5.0	2.9	58.0	26.4	79.9	61.0
Zornia latifolia 728	4.4	3.0	68.2	26.8	80.5	64.2
S. guianensis 184	3.7	2.7	73.0	18.4	61.9	64.6
S. hamata 147	3.7	2.6	70.3	18.1	77.9	67.6
S. capitata 1315	3.4	1.9	55.9	19.0	77.3	62.2
S. scabra 1009	3.3	2.0	60.6	15.3	61.4	62.9
D. ovalifolium 350	2.7	1.9	70.4	12.0	48.7	51.7
D. gyroides 3001	3.5	2.4	68.6	11.1	51.0	57.3
G. striata 964	4.5	3.4	75.5	23.7	75.2	63.4
A. histrix 9690	4.8	3.5	72.9	23.0	78.6	65.3
P. phaseoloides 9900	4.4	3.6	81.8	16.3	77.0	56.9
Centrosema sp. 438	4.6	3.9	84.9	18.0	73.0	54.8

[a] Values reported are the mean of two cutting cycles at five frequencies (3,6,9,12 and 15 weeks growth).
[b] Nitrogen in the dry matter soluble in a buffer solution after Wohlt et al. (1973) for 1 hour incubation.
[c] Nitrogen in the dry matter and neutral detergent fiber soluble pepsin 0.2% in .125 N Hcl (.3 g sample/30 ml of pepsin solution) for 48 hours incubation.

The nitrogen soluble in buffer and pepsin was considerably lower in D. ovalifolium 350, D. gyroides 3001, S. guianensis 184 and S. scabra 1009 as compared to the other legumes. This would suggest that the apparent nitrogen digestibility in these four legumes is lower, as compared with the nitrogen digestibility in the other eight legumes. Good agreement has been found between in vivo apparent nitrogen digestibility and nitrogen solubility in pepsin in two legumes in which this relationship has been studied (D. ovalifolium 350, 48% in vivo vs. 51% N solubility; S. capitata 1314, 82.5% in vivo vs. 77.3% N solubility).

The lower nitrogen solubility in the two Desmodium and S. scabra 1009 is associated with tannin content (r = .49) but, as measured in this study (catechin equivalents), it only explains a small proportion of the observed variability. It is possible that more important than the quantity of catechin equivalents present in the tissue is the type of Poliphenol, as suggested in the literature.

As a complement to the evaluation of quality factors in the nine grasses and 12 legumes in Quilichao, an attempt was made to study their relative acceptability to the grazing animal. Both grasses and legumes from the growth curve experiment were given an uniformity cut, and after six weeks of regrowth four replicates were grazed, each one with four animals, from 8 am to 4 pm. Grazing behavior was recorded every five minutes on the third and fourth day on one of the replicates of 162 and 216 m^2 for grasses and legumes, respectively. Samples to estimate dry matter availability and plant part composition were taken with a 1 m^2 quadrat in each species at 8 am, 12 noon, and 4 pm.

Results for grasses obtained on the fourth day (Table 6) indicate that among the Brachiarias included in the test, B. humidicola 6013 had the highest acceptability and B. ruziziensis 655 the least, both in the morning and afternoon observations. Similar preference was observed for the two B. decumbens accessions (606 and 6013) and B. brizantha 665. In the erect group of grasses, A. gayanus 621 was more frequently grazed both in the morning and afternoon as compared to the other three grasses (H. rufa 601, P. maximum 604 and P. plicatulum 600). It is recognized that some of the observed differences in preference for grasses, as measured in this study, could have been influenced by the previous grazing experience of the animals. The test animals had previously grazed B. humidicola 6013, B. decumbens 606, A. gayanus 621 and P. maximum 604. On this basis it can only be stated with a certain degree of confidence that B. humidicola 6013 was more acceptable than B. decumbens 606 and that A. gayanus 621 was preferred over P. maximum 604.

To eliminate previous grazing experience as much as possible, future experiments will allow the animals more days of adjustment on each test material, before grazing behavior is recorded.

In the case of the 12 legumes evaluated for relative preference, only D. ovalifolium 350 had been previously grazed by the test animals. Therefore, the relative ranking of acceptability of the remaining species is done under the same conditions of previous experience: three days in this study.

Table 6. Relative acceptability to grazing animals of six week regrowth of nine grasses (Quilichao).

Grasses	Frequency of time grazing		
	Morning[a]	Afternoon[b]	Total
	%		
B. humidicola 6013	11.2	7.0	18.2
B. decumbens 606	6.7	3.5	10.2
B. brizantha 665	5.1	5.1	10.2
B. decumbens 6131	4.8	4.8	9.6
B. ruziziensis 655	2.6	3.7	6.3
A gayanus 621	8.9	9.2	18.1
H. rufa 601	8.0	2.2	10.2
P. maximum 604	5.7	2.9	8.6
P. plicatulum 600	5.4	3.2	8.6

[a] Values reported are the mean of 183 observations made from 8 am to 12 noon at intervals of 5 minutes on the fourth day of grazing.
[b] Values reported are the mean of 131 observations made from 12 noon to 4 pm at intervals of 5 minutes, after the third day of adjustment.

Results presented in Table 7 clearly show that animals had a greater preference for S. capitata 1315, followed by S. hamata 147, C. pubescens 438 and P. phaseoloides 9900. It was interesting to note the very low acceptability of S. scabra 1009, D. gyroides 3001 and the two Zornias. In the case of S. scabra 1009 and D. gyroides 3001, their low acceptability could be related to tannins present in their leaves (see footnote Table 3) and to lack of previous animal grazing experience, as compared to D. ovalifolium 350. With the Zornias, one could suspect that the little grazing activity observed in the two species was influenced by a limited amount of leaf initially available in the plot (738 and 90 kg/ha for Z. latifolia 728 and Zornia sp. 9648, respectively, as compared with some of the other legumes (leaf availability above 1400 kg/ha). The same could also hold true for G. striata 964 (480 kg/ha of leaves) and A. histrix 3690 (460 kg/ha of leaves), both of which presented low acceptability.

As with grasses, future studies to evaluate relative acceptability of legumes will include more days of adjustment on individual species and, as much as possible, similar amounts of forage on offer.

Table 7. Relative acceptability to grazing animals of six week regrowth of 12 legumes (Quilichao).

Legumes	Frequency of time grazing		
	Morning[a]	Afternoon[b]	Total
	%		
S. capitata 1315	11.8	10.9	22.7
S. hamata 147	9.5	5.3	14.8
S. guianensis 184	5.3	5.6	10.9
S. scabra 1009	0.3	0.7	1.0
D. ovalifolium 350	2.0	4.6	6.6
D. gyroides 3001	0.7	0.0	0.7
Z. latifolia 728	1.6	2.3	3.9
Zornia sp. 9648	0.3	0.7	1.0
C. pubescens H438	8.9	5.6	14.5
P. phaseoloides 9900	4.3	9.2	13.5
G. striata 964	4.0	2.4	6.4
A. histrix 9690	3.0	1.0	4.0

[a] Values reported are the mean of 157 observations made from 8 am to 12 noon at intervals of 5 minutes on the fourth day of grazing.

[b] Values reported are the mean of 147 observations made from 12 noon to 4 pm at intervals of 5 minutes, after the third day of adjustment.

Quality Factors in Germplasm in Pasture Systems

The evaluation of quality related factors of germplasm in pasture systems is done in small plot grass-legume associations in Quilichao and in large grazing trials on legume-based pastures in Carimagua. The main objective is to relate attributes of the forage on offer with that selected by esophageal-fistulated animals, as affected by management, type of association, season of the year and fertilizer treatments. Quantitative relationships between attributes of the forage available and selected by the grazing animal with observed performance are also examined.

Studies on selective grazing -- Quilichao. In last year's Annual Report (CIAT, 1980), the Pasture Utilization Section reported that after 11 months of continuous grazing with variable stocking rates the legume component in a B. decumbens + D. ovalifolium 350 association tended to increase. This was thought to be the result of the higher preference for the grass exhibited by the animals, particularly in the rainy season. After 21 months of continuous grazing, this mixture has remained very productive in terms of animal performance, but with a tendency for the legume component to decline (Figure 1), probably related to overstocking. A greater selection for the legume continued to be observed during the dry season (44.8%), as compared to the rainy season (12.2%).

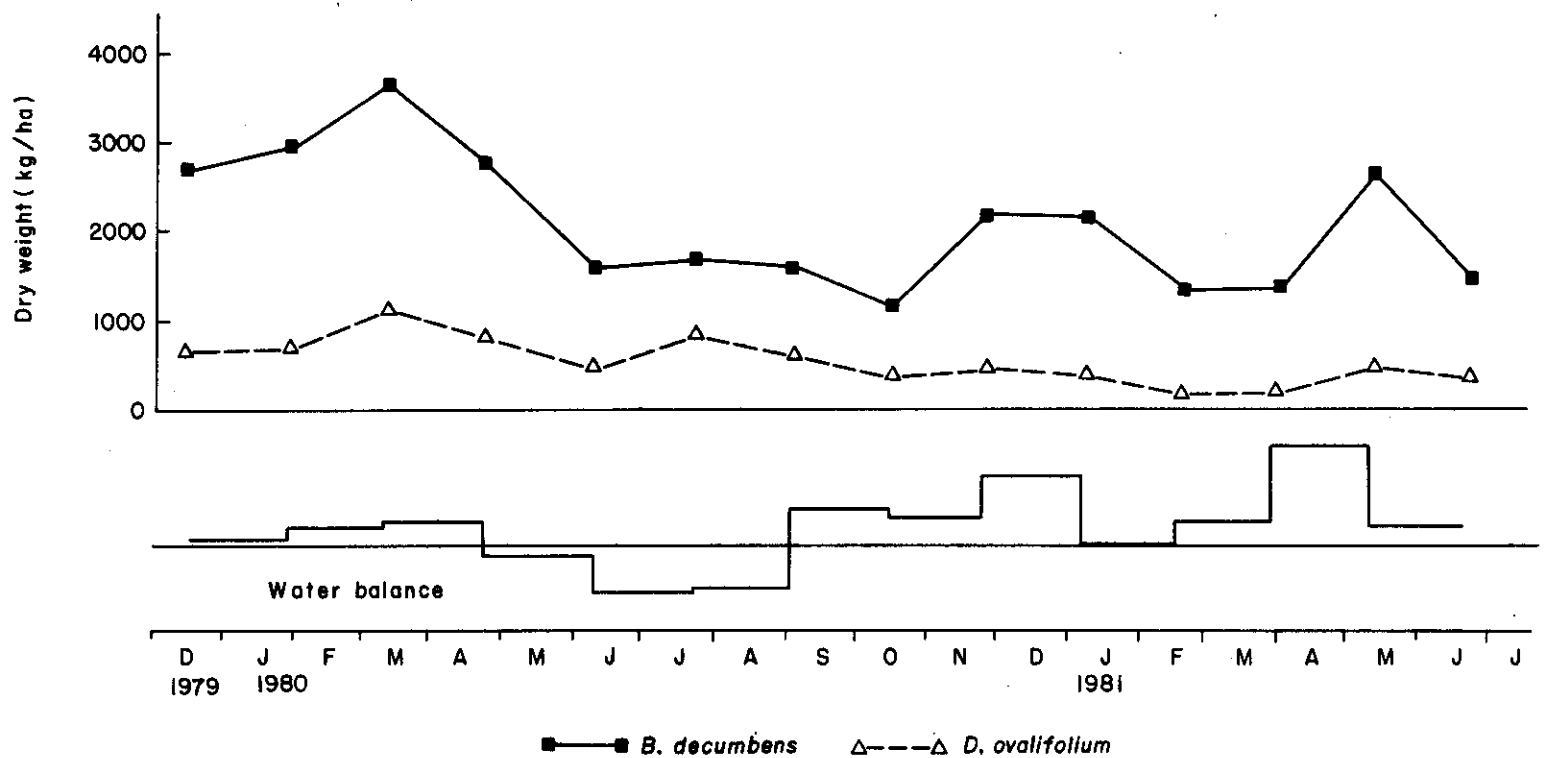

Figure 1. Forage availability of B. decumbens and D. ovalifolium in a mixture under continuous grazing (Quilichao).

The effect of three grazing frequencies (4, 6 and 8 weeks) and two grazing pressures (4 and 8 kg DM/100 kg BW/day) was studied in a mixture of D. ovalifolium with three grasses (A. gayanus + P. maximum and + B. decumbens). Small plots (550 m^2) which had been under grazing with the same treatments for over two years were grazed for five days. Samples of forage available were taken on day 1, 3 and 5 for yield, botanical composition and chemical analysis. Esophageal forage samples were taken daily for botanical composition and chemical analysis. The effect of previous grazing on botanical composition is reflected on day 1 (Table 8). A considerably higher legume proportion was associated with the more frequent grazing (4 weeks - 33.5% L) as compared to the longer rest period (8 weeks - 6.5% L). The effect of grazing pressure from previous years on legume proportion was less evident (23.0% for lower pressure vs. 16.3% L for higher pressure). The proportion of legume selected was not affected by grazing pressure but was influenced by grazing frequency and grazing days (Figure 2). As grazing progressed from day 1 to day 5, the proportion of legume selected increased considerably, particularly in the 6 and 8-week grazing frequencies. This was related to a decline in protein content in the grass available. As a result of legume selection the protein content of the diet selected by the grazing animals was in most cases above 7%, quoted by many as being the critical level in the diet. It is interesting to note that animals grazing the 8-week treatment, with relatively little legume proportion in the forage

Table 8. Changes in legume proportion in an association of D. ovalifolium 350 with A. gayanus + B. decumbens + P. maximum under different grazing frequencies and pressures[a] (Quilichao).

Grazing frequency	Grazing pressure	Days in pasture 1	3	5	Average
Weeks	(kg DM/100 kg/BW per day)	------ % legume available ------			
4	8	38	26	51	38.5
	4	29	38	39	
6	8	22	33	25	26.5
	4	16	30	33	
8	8	9	12	13	8.5
	4	4	7	6	
Average	8	23.0	27.0	27.3	
	4	16.3	25.0	26.0	

[a] Small plots (550 m^2).

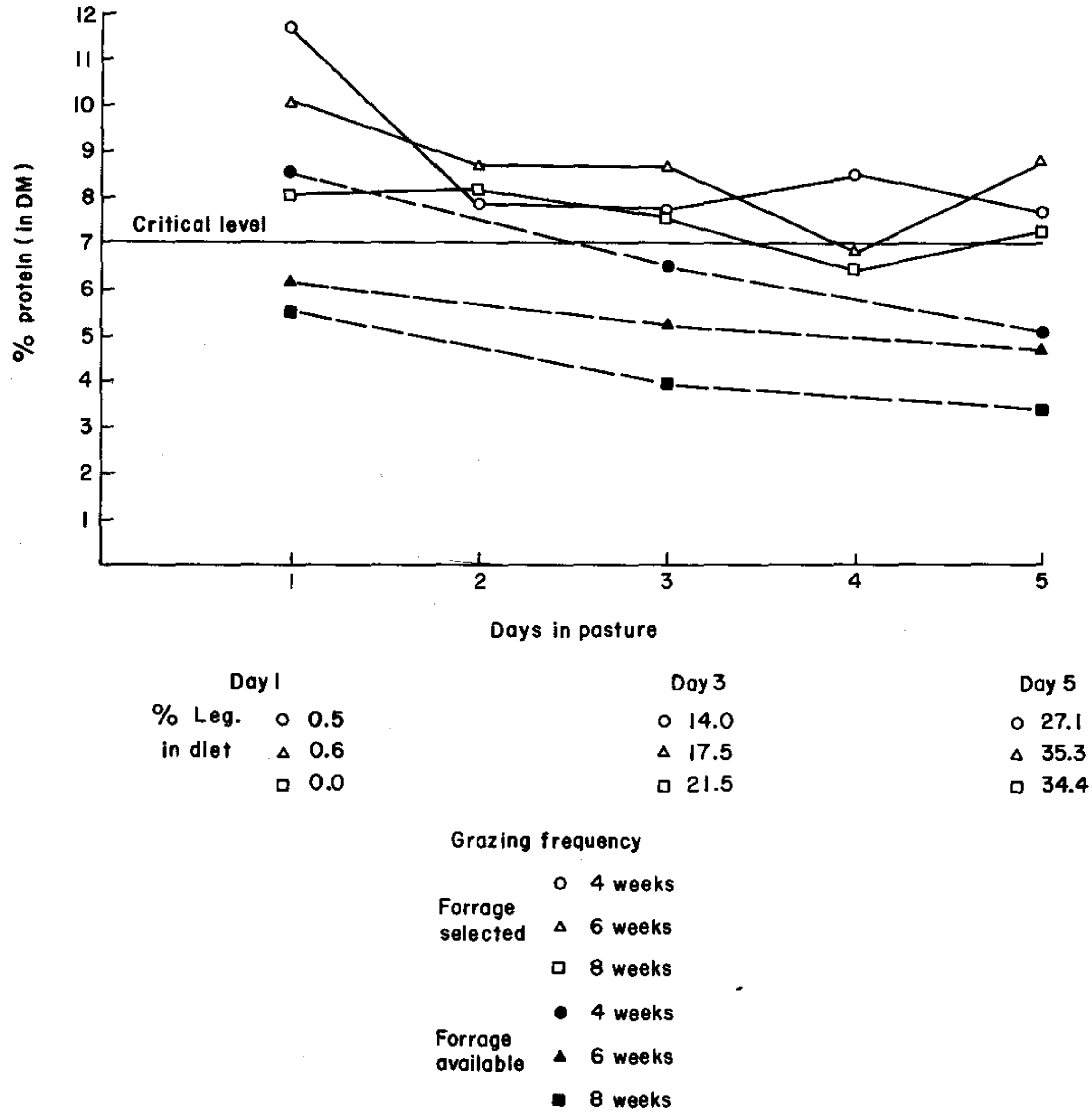

Figure 2. Legume selected and protein content in grass available and selected by esophageal fistulated steers in an association of D. ovalifolium with A. gayanus + B. decumbens + P. maximum under different grazing frequencies (Quilichao).

available, were able to select as much legume as those grazing the 4- or 6-week grazing frequencies, with greater legume availability. This reflects the great selection ability of the grazing animal and would question the need for very high legume proportion in grass/legume associations, at least in the case of D. ovalifolium 350 mixtures.

Studies on selective grazing -- Carimagua. The evaluations of A. gayanus pastures alone and in mixture with ecotypes of S. capitata (1405 and 1019 + 1315) and P. phaseoloides have now been completed. During two dry seasons and one fully rainy season, samples of forage available and selected by esophageal fistulated steers were taken at 2-3 month intervals in each pasture to estimate botanical composition and nutritive value.

The changes over time of the legume proportion in the three pastures and in the diet selected by grazing animals are presented in Figure 3. The proportion of S. capitata in the forage available declined considerably with time, as a consequence of mother plants dying and seedlings lacking vigor. In contrast, the proportion of P. phaseoloides in the forage on offer varied with season of the year, but has remained relatively stable over time. Eventhough the proportion of S. capitata ecotypes was low in the 1981 dry season, the animals were still able to select the legume and gain weight as reported in Table 4 of the Pasture Productivity and Management Section. This points out, once again, that what may be considered by the researcher an insufficient amount of legume in the paddock may not necessarily be the case in the eyes of the animal.

In agreement with observations made last year, the legume selected in the three pastures evaluated continued to be greater in the dry season as compared to the rainy season (Figure 4). It was evident, however, that legume selection in the rainy season could be increased with high stocking rates, as was the case in A. gayanus + S. capitata 1019 + 1315 stocked in July with 4 AU/ha (Figure 4). This was probably the consequence of reducing the ability of animals to select preferred plants in the pasture. The inflorescence of S. capitata and leaves of P. phaseoloides were the legume components most selected in the dry season (Table 9). The high nutritive value of the inflorescence of S. capitata ecotypes and leaves of P. phaseoloides is reflected in their high protein content (Table 10), particularly in the dry season when the grass invariably becomes deficient in protein. The contribution of the legume to the quality of the forage on offer was also evident in the protein content of the A. gayanus leaves (Table 11). Consistently, the leaves of the grass in association with S. capitata 1405 and 1019 + 1315 and P. phaseoloides were higher in protein than the leaves of A. gayanus alone in the rainy season, and to a lesser extent in the dry season. This higher protein content in the A. gayanus leaf could be due to nitrogen transfer from the legume and to a higher proportion of young regrowth as a consequence of greater utilization of the grass, particularly in the P. phaseoloides pasture.

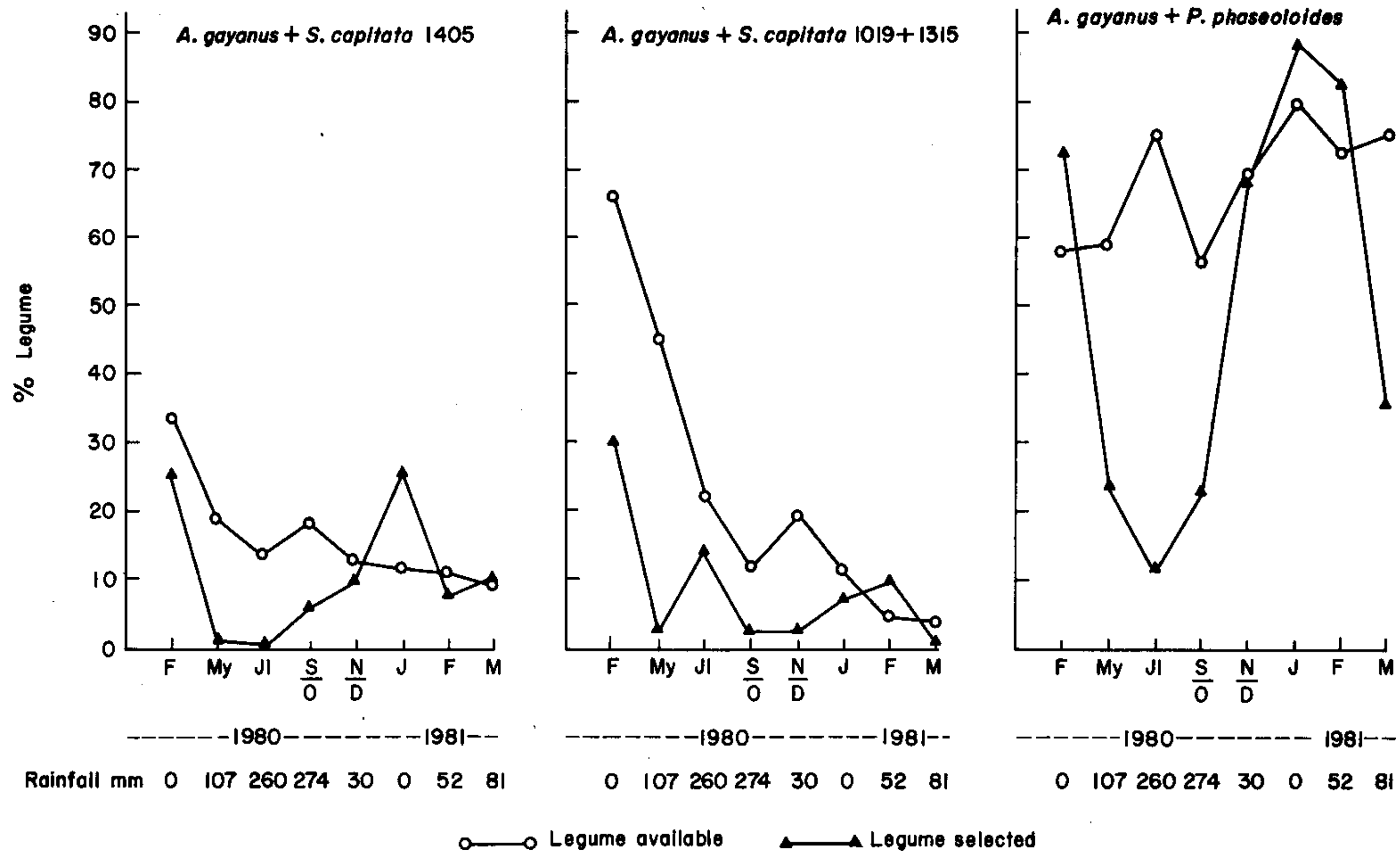

Figure 3. Dynamics of legume available and selected by esophageal fistulated steers grazing mixtures of A. gayanus with ecotypes of S. capitata and P. phaseoloides (Carimagua).

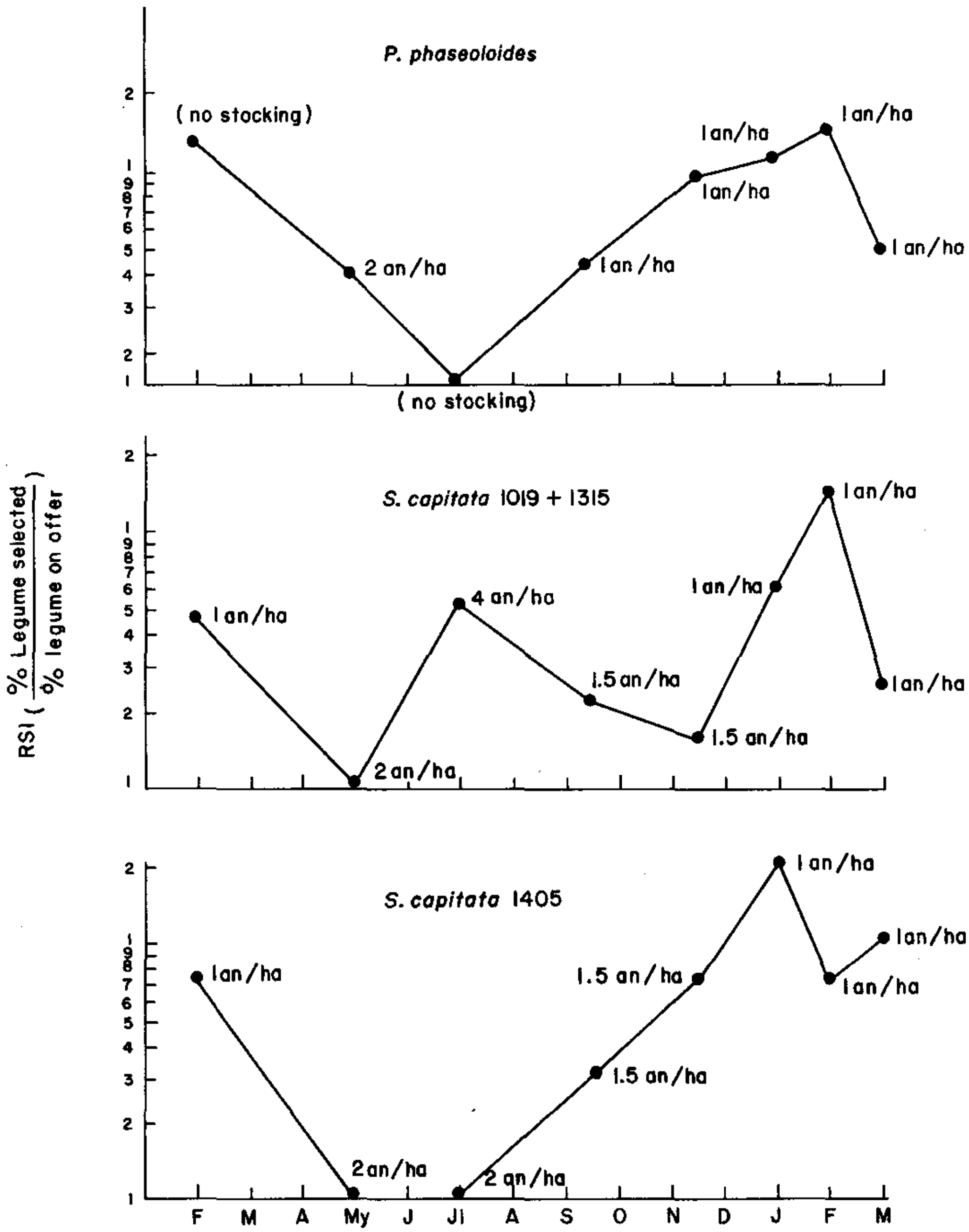

Figure 4. Relative selection index (RSI) for the legume component in associations of A. gayanus with ecotypes of S. capitata and P. phaseoloides under grazing (Carimagua).

Table 9. Plant part composition of legume available and selected by esophageal fistulated steers in the rainy and dry season in associations of A. gayanus with ecotypes of S. capitata and P. phaseoloides under grazing (Carimagua).

Pasture	Season	Legume available				Legume selected			
		Leaf	Stem	Infl.[a]	dm[a]	Leaf	Stem	Infl.[a]	dm[a]
		%							
	Rainy[b]								
+ S. capitata 1405		25.8	47.5	4.4	22.3	54.0	26.0	20.0	-
+ S. capitata 1019 + 1315		29.4	42.3	1.1	27.2	63.0	27.8	9.2	-
+ P. phaseoloides		36.4	41.6	0.0	22.0	86.3	13.7	-	-
	Dry[c]								
+ S. capitata 1405		8.6	50.3	17.6	23.5	17.0	30.2	51.8	1.0
+ S. capitata 1019 + 1315		9.3	39.3	9.8	41.6	22.5	26.3	43.5	7.7
+ P. phaseoloides		19.1	46.7	0.6	33.6	61.4	28.6	-	10.0

[a] Infl = Inflorescence; dm = dead material.
[b] Sampling: May, July, September-October 1980, and March 1981.
[c] Sampling: February and November-December 1980, and January, February 1981.

Table 10. Protein content in plant parts of legumes available in association with A. gayanus under grazing during the rainy and dry seasons (Carimagua).

Pasture of A. gayanus	Season	Legume parts available			
		Leaf	Stem	Infl.	Dead
		% protein			
	Rainy[a]				
+ S. capitata 1405		18.1	7.9	15.7	4.8
+ S. capitata 1019 + 1315		17.1	10.0	14.8	8.7
+ P. phaseoloides		23.5	10.6	-	10.7
	Dry[b]				
+ S. capitata 1405		12.2	7.1	14.2	3.5
+ S. capitata 1019 + 1315		12.4	7.8	13.3	7.7
+ P. phaseoloides		16.7	9.0	15.8	9.4

[a] Sampling: May, July, September-October 1980, and March 1981.
[b] Sampling: February and November-December, 1980, and January and February 1981.

Table 11. Protein content in plant parts of A. gayanus alone and in association with legumes under grazing during the rainy and dry seasons (Carimagua).

Pasture of A. gayanus	Season	Parts of A. gayanus available		
		Leaf	Stem	Dead
		% protein		
	Rainy[a]			
Alone		6.4	3.2	2.7
+ S. capitata 1405		8.1	4.4	3.8
+ S. capitata 1019 + 1315		8.2	4.2	4.1
+ P. phaseoloides		11.0	6.0	5.1
	Dry[b]			
Alone		4.7	2.3	2.2
+ S. capitata 1405		5.2	2.4	3.0
+ S. capitata 1019 + 1315		5.1	2.6	3.3
+ P. phaseoloides		7.7	2.8	3.6

[a] Sampling: May, July, September-October 1980, and March 1981.
[b] Sampling: February and November-December 1980, and January and February 1981.

The legumes' contribution to the nutritive value of the diet selected by the animals in the experimental pastures is summarized in Table 12. During the rainy season, protein in the consumed forage in the legume-based pastures was higher than in the A. gayanus alone, most likely a consequence of the higher protein content in the grass leaves and to legume intake, particularly in the P. phaseoloides pasture. In the dry season the forage selected in the A. gayanus alone was deficient in protein, marginal in the S. capitata pastures, and well above requirements in the P. phaseoloides association. The differences in protein content between forage selected in A. gayanus alone and in legume-based pastures could explain the liveweight changes observed during evaluation of the four pastures, particularly during the dry season (Table 13).

One very promising grass/legume mixture under test in Carimagua is B. humidicola + D. ovalifolium 350. Since February of this year, two 2 ha paddocks have been evaluated for botanical composition of the forage on offer and selected by esophageal fistulated steers at regular intervals. Results (Table 14) indicate that selection of D. ovalifolium has been high in all the sampling periods, independently of grazing systems used. However, a higher legume proportion in the diet has been measured in one of the pastures (OH8) with a relatively higher legume proportion. It is thought that the relatively high selection of D. ovalifolium in this mixture during the rainy season is the consequence of the high stocking rate in the grazing system used, which could be limiting the selection ability of the animals.

Effect of soil fertility on quality of D. ovalifolium 350. In the 1980 Annual Report it was suggested that soil fertility could be an important factor influencing the forage value of D. ovalifolium 350. An experiment was designed in Carimagua, in collaboration with the Soil and Plant Nutrition Section, to study the effect of different fertilizer treatments on the forage quality of D. ovalifolium 350. The experiment was set up in a 2 ha pasture with a pure stand of D. ovalifolium 350 established in 1978 in mixture with B. decumbens and fertilized with 46.2 kg P, 117 kg Ca, 36.52 kg K, 22 kg Mg and 44 kg S/ha. In a completely randomized design with two replications, four fertilizer treatments were established: (T1) control, (T2) + P + Ca, (T3) + P + Ca + K and (T4) + P + Ca + K + Mg + S. The level of each element applied in August, 1980 was: 26.4 kg P, 117 kg Ca, 36.52 kg K, 22 kg Mg and 44 kg S/ha. Soil fertility as affected by treatment and time after fertilizer application is discussed in the Soil and Plant Nutrition Section (see their Figure 2).

Measurements of forage available, forage quality and grazing behavior of four intact animals grazing the entire area were made in the dry season from late November, 1980 until late March, 1981.

Prior to the initiation of the experimental grazing, estimates of forage yield were made in the pasture; results presented in Table 15 show that the yield of D. ovalifolium was considerably higher in the more complete fertilizer treatment (T4) than in the remaining treatments.

Table 12. Protein content of the grass available and forage selected by esophageal fistulated steers grazing *A. gayanus* alone and with legumes during the rainy and dry seasons (Carimagua).

Pasture of *A. gayanus*	Season	Grass available			Forage selected	
		Leaf	Stem	Dead	Legume	Protein
		% protein				
	Rainy[a]					
Alone		6.4	3.2	2.7	-	8.5
+ *S. capitata* 1405		8.1	4.4	3.8	4.3	10.1
+ *S. capitata* 1019 + 1315		8.2	4.2	4.1	5.0	10.2
+ *P. phaseoloides*		11.0	6.0	5.1	23.8	13.1
	Dry[b]					
Alone		4.7	2.3	2.2	-	4.9
+ *S. capitata* 1405		5.2	2.4	3.0	17.1	6.3
+ *S. capitata* 1019 + 1315		5.1	2.6	3.3	12.7	6.4
+ *P. phaseoloides*		7.7	2.8	3.6	77.5	12.0

[a] Sampling: May, July, September-October 1980, and March 1981.
[b] Sampling: February and November-December 1980, and January and February 1981.

Table 13. Liveweight changes of steers grazing A. gayanus alone and in association with ecotypes of S. capitata and P. phaseoloides during the rainy and dry season (Carimagua).

Pasture of A. gayanus	Season	
	Rainy[a]	Dry[b]
	g/an/day	
Alone	454	- 36
+ S. capitata 1405	674	287
+ S. capitata 1019 + 1315	666	147
+ P. phaseoloides	708	570

[a] Values are averages of weighings in: May, June, August, September, November, December 1980, and March 1981.
[b] Values are averages of weighings in: January, February, 1980 and 1981.

Table 14. Relationship between legume on offer and selected by esophageal fistulated steers grazing a B. humidicola + D. ovalifolium 350 mixture (Carimagua).

Date of sampling (1981)	Pasture	Grazing system/ stocking (an/ha)	Legume		RSI[a]
			Available (%)	Selected (%)	
February	OH4[b]	Continuous (3)	21	16	.76
March		Continuous (3)	20	-	
April		Continuous (3)	15	19	1.27
May		Rotational (3.5)	20	26	1.30
July		Rotational (3.5)	22	25	1.14
February	OH8[b]	Continuous (2.0)	43	36	.84
March		Continuous (2.0)	46	37	.80
April		Continuous (2.0)	31	19	.61
May		Rotational (3.5)	27	41	1.52
June		Rotational (3.5)	34	44	1.29

[a] RSI = % legume on forage selected ÷ % legume on forage available.
[b] Grazing system was changed from continuous to rotational (2 pastures) in May starting in OH4.

After three months of grazing, the differences in residual forage between T4 and the other treatments was reduced, as a consequence of greater utilization by the animal. With the onset of the rainy season, which coincided with the last measurement of forage availability, the regrowth in T4 was greater than in the other treatments despite being subjected to heavier defoliation. By the end of February the proportion of leaf in D. ovalifolium was less in the T4 treatment (11%) as compared with T1 (20%), T2 (17%) and T3 (16%), suggesting again greater forage utilization in T4.

Table 15. Forage available in a pasture of D. ovalifolium 350 under different fertilizer treatments and under grazing (1.5 an/ha) (Carimagua).

Sampling date	Fertilizer treatments			
	T1 (Control)[a]	T2 (+P+Ca)[b]	T3 (+P+Ca+K)[b]	T4 (+P+Ca+K+Mg+S)[b]
	forage available (kg DM/ha)			
28-11-80[c]	3.432	3.844	3.424	5.680
27-01-81	2.816	2.548	3.670	5.180
27-02-81	3.206	2.484	4.770	3.574
26-03-81	912	982	1.215	1.440

[a] T1 fertilizer applied at establishment: May 1978 (46.20 kg P, 259 kg Ca, 43.16 kg K, 11 kg Mg and 22 kg S/ha).
[b] T2, T3, T4, fertilizer applied: August 1980 (26.40 kg P, 117 kg Ca, 36.52 kg K, 22 kg Mg and 44 kg S/ha).
[c] Initiation of experimental grazing.

Leaf samples of similar maturity obtained from areas enclosed with cages were taken at monthly intervals for laboratory analysis. Results presented in Table 16 indicate that tannins (catechin equivalents were lower ($P < .05$) in the T4 leaf material as compared with leaf from T1 and T2. In contrast, leaf nitrogen and corresponding solubility in pepsin, and sulfur and potassium concentrations were higher ($P < .05$) in leaves from T4. All treatments receiving phosphorus (T2, T3, T4) had similar P levels in the leaf tissue, but a trend to higher leaf concentration from T4 was apparent.

The four animals grazing the pasture were observed every ½ hour from 8 am to 4 pm twice a week. Recordings were made on where the animals were grazing, resting or ruminating. Summarized results of the observed grazing behavior are presented in Figure 5. It is clear that the animals spent more time grazing the more complete fertilizer treatment (T4). However, it was also evident that as availability of leaves was reduced in T4, the animals increased grazing time in T3. The time spent grazing in T1 and T2 was the result of small areas within these treatments with high residual soil fertility, as was indicated in last year's Annual Report (CIAT, 1980). No clear pattern was observed for the other two animal activities observed.

Table 16. Effect of fertilizer treatments on quality of *D. ovalifolium* 350 under grazing (Carimagua).

Measurement[a] on leaf tissue	Fertilizer treatment			
	T1 (Control)[b]	T2 (+P+Ca)[c]	T3 (+P+Ca+K)[c]	T4 (+P+Ca+K+Mg+S)[c]
Catechin equivalents (%) (Vanillin - Hcl)	37.5[d]	37.0[d]	34.1[d,e]	28.7[e]
Nitrogen (%)	1.99[d]	2.01[d]	2.09[d]	2.59[e]
Nitrogen soluble (%) Pepsin (48 hr)	39.5[d]	39.8[d]	43.4[e]	49.4[f]
Mineral content				
S (%)	.094[d]	.102[d]	.121[e]	.145[f]
K (%)	.617[d]	.643[e]	.707[f]	.740[g]
P (%)	.118[d]	.133[d,e]	.130[d,e]	.140[e]
Ca (%)	1.05	1.13	1.08	1.03
Mg (%)	.245	.239	.232	.246

[a] Values reported are the mean of four evaluations (20-10, 28-11, 1980 and 29-1 and 26-3, 1981).
[b] T1 fertilizer applied at establishment: May 1978 (46.20 kg P, 259 kg Ca, 43.16 kg K, 11 kg Mg and 22 kg S/ha).
[c] T2, T3, T4 fertilizer applied: August 1980 (26.40 kg P, 117 kg Ca, 36.52 kg K, 22 kg Mg and 44 kg S/ha).
[d,e,f,g] Means in the same row with different letters are different ($P < .05$).

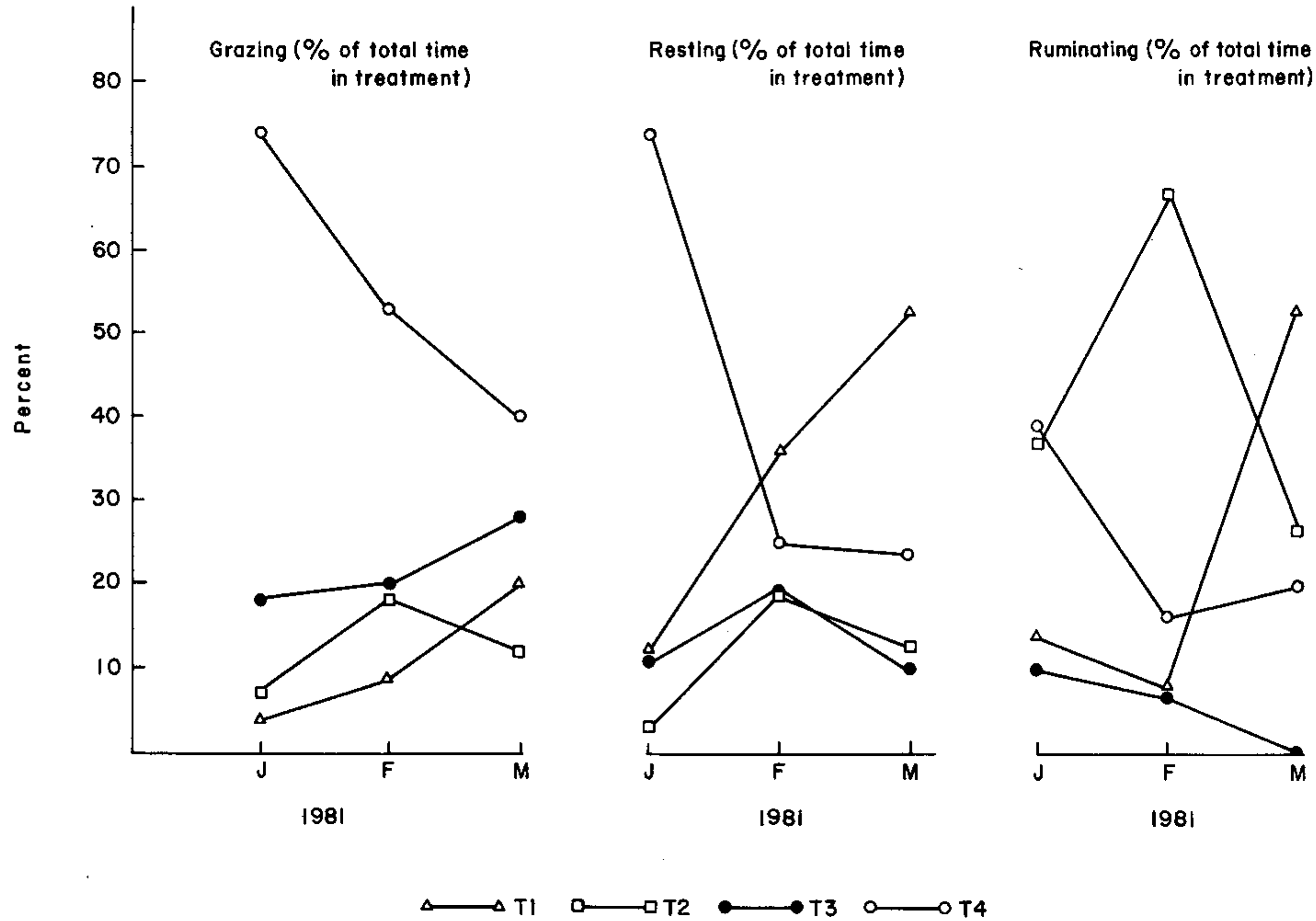

Figure 5. Distribution of activities of animals grazing D. ovalifolium 350 under different fertilizer treatments (T1: control, T2: + P + Ca, T3: + P + Ca + K, T4: + P + Ca + K + Mg + S) (Carimagua).

In general, results from this experiment indicated that the application of Mg and S, in addition to P, Ca and K, to established D. ovalifolium resulted in: (1) increased dry matter on offer; (2) increased nutritive value; (3) increased utilization of the legume by the grazing animal.

The increased nutritive value of D. ovalifolium 350 as a result of fertilization was also observed with crated wethers in Quilichao. Fertilized (44 kg P, 20 kg Mg and 60 kg S/ha) and non-fertilized D. ovalifolium 350 were fed ad libitum to crated wethers. Results (Table 17) indicated that the fertilized D. ovalifolium had less tannins and more protein than the unfertilized legume. The higher protein content resulted in a greater proportion of nitrogen being apparently digested and consequently more digestible protein/100 g of DM in the fertilized D. ovalifolium. No effect of fertilizer treatment on voluntary intake was observed in this study.

Table 17. Results obtained with crated wethers fed D. ovalifolium 350 unfertilized and fertilized (Quilichao).

Measurement	D. ovalifolium 350 offered	
	Non-fertilized	Fertilized[a]
Catechin equivalents (%)		
Vanilin - Hcl	29.8	23.8*
Protein (N x 6.25) (%)		
Leaf	14.7	17.1*
Stem	7.3	7.9
Intake (y) vs. level of offer (x)	y=22.8 +.4687x	y=23.7 + .4612x
Nitrogen intake/100 g DM consumed (g)	21.6	25.0*
Apparent nitrogen digestibility (%)	57.6	65.4*
Apparent protein digestible/100 g DM (%)	6.9	9.0*

[a] Fertilized with: 44 kg P, 20 kg Mg, 60 kg S/ha.
* Significance ($P < .05$).

After analyzing data from the previous experiments, the question of whether the response of D. ovalifolium to fertilizer was due to a specific element or combination, still remained. In an attempt to answer this question, a second trial was set up in Carimagua, again in collaboration with the Soil and Plant Nutrition Section. In the same experimental pasture used in the previous experiment, seven fertilizer treatments were established with two replications. The fertilizer treatments applied in May 1981, at the same level as in the previous experiment, were: (T1) + K + Mg + S, (T2) + Mg + S, (3) + P + K + Ca + Mg, (T4) + P + Ca + S, (T5) + P + Ca + K + S, (T6) + P + K + Ca and (T7) previously T4, + P + K + Ca + Mg + S. In order to arrange these treatments in the pasture, only some elements were applied in May 1981, as indicated in Table 18. To do this, it was assumed and later confirmed by analysis that elements applied in May 1980 would have a residual effect. Preliminary results of leaf material chemical composition (Table 18) indicated that the major responses in leaf nitrogen content and solubility were in the treatments with sulfur (T1, T2, T4, T5 and T7). Also associated with sulfur fertilization, were higher S and lower tannin content in leaves and greater biomass production. Observation of grazing behavior indicates so far that animals are preferentially eating D. ovalifolium in T5.

On the basis of evidence presented, and on the known effects of S on forage quality, it would seem reasonable to assume at this stage that S is the element which mainly affects the forage quality of D. ovalifolium 350 under the Carimagua conditions.

Alternate Uses of Germplasm

It is accepted that legumes result in improved quality of the forage on offer and, as a result, in animal production. As a strategy for increasing livestock production in acid infertile soils, both improved grasses and legumes in association could be introduced to cover a certain proportion of the farm unit. It is conceivable, however, that in the early stages of development of livestock units in these areas, introduced and appropriate legumes could be used in a pure stand to supplement native pastures, particularly during dry periods.

Results obtained by the Pasture Productivity and Management Section in Carimagua indicate that production per animal could be increased in native pastures with the use of blocks of P. phaseoloides as protein banks (see their Table 2). However, to better define appropriate management of a native grass-protein bank system, one would have to study some of the basic factors which could influence the utilization by the animal of the legume and grass component in the system. It is suggested that seasonal variations in protein and digestible energy content of the native grass greatly determine the utilization of the legume in a protein bank. In other words, as quality of the native grass is reduced, particularly during the dry season, more of the legume is consumed, to the point where animals could substitute the native grass for the legume, as has been observed in the Carimagua experiment. Obviously, substitution of grass by legume would defeat the purpose of a protein bank. Other important factors which may affect the productivity of a native pasture-protein bank system are aggressiveness, degree of defoliation in the dry season and quality of the legume used. The first two factors are of agronomic nature and should weigh heavily in the selection of the legume for a protein bank. Obviously, legume quality is important particularly in terms of nitrogen content and its availability to the animal.

Some of the hypotheses stated will be examined in Carimagua in collaboration with the Pasture Productivity and Management Section.

Table 18. Initial characterization of foliar tissue of D. *ovalifolium* 350 under different fertilizer treatments (Carimagua).

Measurement	Fertilizer treatments						
	(K+Mg+S)	(Mg+S)	(P+K+Ca+Mg)[b]	(P+Ca+Mg+S)[b]	(P+Ca+K+S)[b]	(P+K+Ca)[b]	(P+K+Ca+Mg+S)[b]
N-total (%)	2.56	2.57	1.71	2.62	2.61	1.86	2.43
N-soluble (%)	36.02	35.83	23.29	37.00	39.06	22.56	30.65
Sulfur (%)	0.14	0.13	0.09	0.17	0.16	0.10	0.14
Catechin equivalent (%)	5.60	4.90	18.90	4.80	6.50	13.40	8.50
Phosphorus (%)	0.10	0.11	0.11	0.14	0.12	0.12	0.11
Potassium	0.59	0.50	0.53	0.64	0.76	0.59	0.52
Calcium (%)	1.07	1.22	1.17	1.17	1.17	1.19	1.28
Magnesium (%)	0.24	0.23	0.25	0.23	0.20	0.20	0.22

[a] P = 26.40 kg P/ha; K = 36.52 kg K/ha; Ca = 117 kg Ca/ha; Mg = 22 Mg/ha; S = 44 kg S/ha.
[b] Element underlined was applied in August 1980, and all other elements applied in May 1981.

Specifically, measurements will be made of grazing behavior, forage availability and quality. The experiment will use D. ovalifolium as a protein bank, in different proportions of the total area, to supplement native savanna under different stocking rates and burning treatments. These will hopefully result in different degrees of quality of the grass on offer.

This year some preliminary work was done with crated wethers in Quilichao in an attempt to measure effects on intake and digestibility due to quality of grass and legumes offered in a mixture. It is recognized that extrapolation of results obtained with crated wethers to the grazing animal is risky. Nevertheless, it is a fast and unexpensive way to study some of the principles involved in the utilization of legumes as a supplement to low quality grasses.

Results of intake with crated wethers offered different proportions of D. ovalifolium 350 and S. capitata 1315 in combination with mature native savanna and A. gayanus are presented in Table 19. In all cases with the 10% level of legume in the mixture, animals did not substitute grass by legume, and as a result total dry matter intake increased.

Table 19. Voluntary intake of grass and total dry matter by crated wethers offered different legume proportions (D. ovalifolium and S. capitata) in combination with mature native savanna and A. gayanus (Quilichao).

Treatment (% legume offered)	Intake	Savanna[a] + D. ovalifolium 350	A. gayanus[b] + D. ovalifolium 350	A. gayanus[c] + S. capitata 1315
		g DM/hg$^{.75}$ per day		
0% L	Grass	30.0	45.4	50.5
5% L		34.0	-	-
10% L		32.4	45.4	45.9
20% L		18.9	32.5	41.2
30% L		1.8	28.3	41.2
	Total dry matter			
0% L		30.0	45.4	50.5
5% L		40.0	-	-
10% L		45.4	53.7	58.7
20% L		45.0	50.9	64.4
30% L		40.0	53.2	80.8

[a] 2.2% protein in grass and 10% protein in legume.
[b] 4.7% protein in grass and 10% protein in legume.
[c] 4.7% protein in grass and 14.2% protein in legume.

In contrast, at the 20 and 30% legume level, substitution of grass by legume occurred in all treatments, particularly in the savanna + D. ovalifolium 350. The lower substitution observed when A. gayanus was the grass or S. capitata the legume could be due to their higher quality, as reflected by intake and digestibility values in Tables 19 and 20. The lower apparent nitrogen digestibility of D. ovalifolium 350 (48%) as compared to S. capitata 1315 (82.2%) could be related to the low nitrogen high tannin content of this legume, as indicated before.

From previous results, it is clear that, at least with crated wethers, degree of substitution of grass by legume is affected by proportion of legume in the forage offered and by the quality of grasses and legumes fed. This could imply that in order to assure a supplementary effect of the legume to the native grass one would have to control access of the animals to the bank in the dry season or, alternatively, maintain a certain degree of quality on the grass through strategic burning. Furthermore it would appear that in terms of quality, S. capitata 1315 is a better legume for a protein bank than D. ovalifolium 350, and as such it is proposed for testing in the future.

Table 20. Effect of different legume proportions (D. ovalifolium and S. capitata) added to mature A. gayanus on the apparent digestibility of dry matter, cell wall (NDF) and nitrogen with crated wethers (Quilichao).

Treatment (% legume offered)	Apparent digestibility	Mature A. gayanus +		
		D. ovalifolium[a]		+ S. capitata[a]
			(%)	
0% L	Dry matter	40.4		42.0
10% L		44.3		51.3
20% L		47.2		55.8
30% L		47.4		56.6
100% L		56.1	← Δ31.2% →	73.6
0% L	Cell wall (NDF)	45.7		47.4
10% L		45.1		55.7
20% L		45.6		58.1
30% L		47.0		55.5
100% L		52.9	← Δ26.3% →	66.8
0% L	Nitrogen	38.2		40.3
10% L		41.3		51.7
20% L		43.0		61.2
30% L		41.4		63.5
100% L		48.0[b]	← Δ71.2% →	82.2[c]

[a] Legume intake was 60.9 and 108 g DM/kg$^{.75}$ per day for D. ovalifolium and S. capitata 1315, respectively, for the 100% L level.
[b] 10% protein on forage offered.
[c] 14.2% protein on forage offered.