CIAT

beef program

1978

Beef Program

CIAT's Beef Program became fully operational this year, with field research activities at CIAT-Quilichao, Carimagua, Brasilia and a network of 14 established regional trials throughout the target area. Following the objectives and work plan described in the 1977 Annual Report, the main accomplishments can be summarized in terms of developing germplasm, technology components and setting the stage for technology transfer activities.

Germplasm

Andropogon gayanus CIAT 621 has shown outstanding performance as a highly productive forage grass for Oxisol-Ultisol regions. It has entered the Category 5 (pre-release) stage, which includes large-scale seed production. Its principal attributes are: (1) excellent growth and dry matter production in acid, infertile soils with minimum inputs; (2) exceptional tolerance to drought stress, burning and high levels of Al saturation; (3) low P and N requirements; (4) no known disease or insect attacks; (5) excellent seed producing ability; (6) compatibility with legumes; (7) adaptability to low-cost pasture establishment systems; (8) acceptable nutritional quality and high intake due to very high palatability; (9) high animal production levels during the first year.

Its principal unknown characteristics are its tolerance to Brazilian spittlebug species, animal production during the dry season, and its weed potential in crops. The Instituto Colombiano Agropecuario (ICA) and CIAT have agreed to a joint release as "Pasto Carimagua cv. 621" by early 1980, provided the unknown questions are satisfactorily resolved and no significant negative factors are found during the 1979 experiments.

Seven accessions of three forage legume species, *Zornia latifolia* (CIAT 728), *Desmodium ovalifolium* (CIAT 350) and *Stylosanthes capitata* (CIAT 1019, 1078, 1097, 1315 and 1405) continue to show promise for potential release and have entered animal production trials at the Category 4 level. At this time it is not possible to ascertain which species is superior. All are showing good persistence during their second year under grazing pressure trials, are adapted to acid, infertile soils, have good self-propagation mechanisms, show no major insect or disease attacks, and have good nitrogen fixation potential.

In addition, *Z. latifolia* has a very high protein content and grows vigorously during the dry season. *D. ovalifolium* is aggressive enough to form good mixtures with *Brachiaria decumbens* but is susceptible to a nematode attack and its seed production potential at low latitudes is unproven. Some *S. capitata* accessions show three persistence mechanisms: abundant seedling production, regrowth from the crown nodes (like alfalfa), regrowth from axillary and terminal buds. All three legume species were found tolerant to burning, which may add to their persistence in cases of accidental burning or a need for periodic burning of some associations.

The germplasm evaluation process continues to funnel a large number of legume and grass accessions through Categories 1, 2, 3, and 4 evaluations at CIAT-Quilichao, Carimagua and Brasilia. Two browse-type, shrubby legume species have been promising under acid soil conditions: *Desmodium gyroides* 3001 and several lines of *Leucaena leucocephala* resulting from selection or breeding for acid soil tolerance, coupled with adapted acid-tolerant rhizobia. Also several late-flowering *Stylosanthes guianensis* types from the Cerrado appear to show promise for anthracnose tolerance.

Technology Components

Several sections of the Program are developing technology components to turn acid soil infertility, and plants adapted to it, into assets rather than liabilities. Low density space-planting systems provide significant savings in seed, fertilizer and machinery, and have produced pastures ready for grazing within a year. Low soil fertility inhibits weed growth while the pastures establish themselves, either from reseeding or stolon growth. Low reactivity rock phosphates, abundant in tropical America, are efficiently utilized because soil acidity dissolves the rocks rapidly and makes them available to pasture species tolerant to high levels of Al.

Carrying this thinking to the laboratory, a new acid media was developed to screen *Rhizobium* strains for acid soil tolerance. This facilitates the selection for *Rhizobium* persistence on acid soils, since lime pelleting is only effective for the first generation of nodules.

Other significant technology developments include the discovery that the type of trichoma and secretions on *Stylosanthes* stems may explain their tolerance or susceptibility to stemborer attacks, the design of simple mechanisms for estimating root length and leaf water potential in tropical grasses, the development of an *Andropogon* de-awner, the effectiveness of rock phosphate minigranules in providing better handling properties without affecting reactivity, and the verification of simulation models described last year by actual data gathered this year. In addition grass/legume pasture persistence was defined by economic analysis to be at least six years.

Putting some of the available technology together as a practical package, a breeding herd systems trial in Carimagua showed that the strategic use of improved grass legume pastures occupying 10% of the grazing area increased beef production by 250% during its first year of operation, and appears to be highly profitable.

Knowledge of the Target Area

Although the research results are most encouraging, more time is needed to determine whether the new grass/legume pastures are significantly persistent in order to be truly profitable. While research continues, advances have been made in understanding the target area both physically and production-wise, and in developing cooperative relationships with national institutions.

Interpretation of a wealth of climatic, soil and landscape data shows that the potential evapotranspiration during the rainy season effectively separates savannas from two types of forested areas. Interpretation of the target area survey strongly suggests that two evaluation sites for Category 2 and 3 germplasm should be established in jungle areas.

The in-depth study of beef production farms in the Llanos and the Cerrado (ETES project) is providing reliable quantitative data on actual production systems and excellent opportunities for validating new pasture technology at the farm level. Animal health surveys show significant differences in the extent and importance of diseases in different parts of the target area. Meetings with collaborators from many national research and development institutions helped develop a manual for forage germplasm collection and evaluation, and brought together much of the present knowledge on soil/pasture/cattle relationships in the target area. For the first time, a tropical forages research network began to function in Latin America.

Fourteen regional trials have been planted in Bolivia, Peru, Ecuador, Colombia, Venezuela and Nicaragua to test the adaptability of promising germplasm. Fifteen additional trials are to be planted in Brazil in December 1978, and additional trials in Central America and the Caribbean are projected for 1979. The first 6-month forages course trained 21 collaborators from research and development institutions of Brazil, Colombia, Bolivia, Peru, Ecuador, Venezuela, Panama, Nicaragua and Cuba. The second course is scheduled to start in February 1979.

TARGET AREA SURVEY

In mid-1977 a survey of the Beef Program's target area, the Oxisol and Ultisol regions of tropical America, was initiated in order to classify the land resources in terms of climate, landscape, and soils, and provide a geographically oriented economic synthesis of the region, which would serve as the basis for the Program's transfer of technology strategy. The methodology used and initial results were described in the 1977 Annual Report.

During 1978 the analysis of climatic data was completed, as was aerial reconnaissance and field work in South America. A total of 237 land systems have been identified so far, in the areas where work has been completed (Fig. 1). The collated data for each land system are being stored in a computerized retrieval system, which also has the capability of drawing special purpose maps.

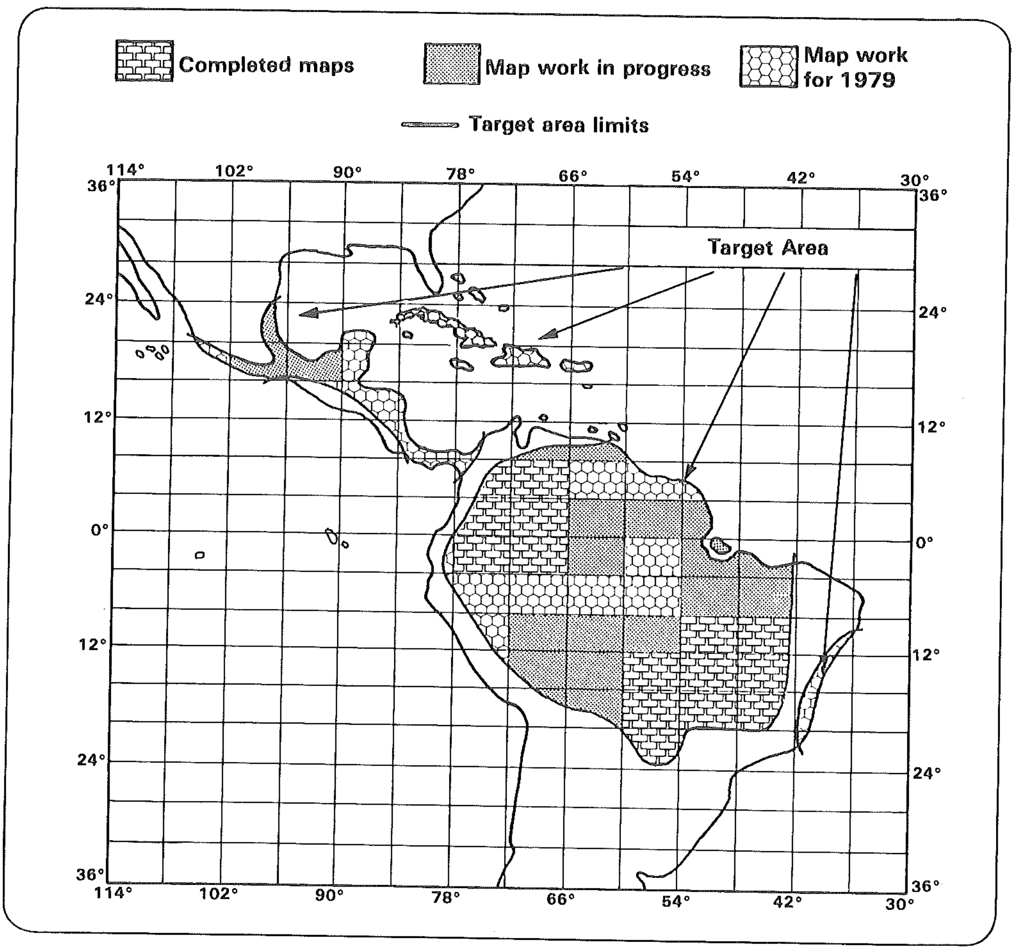

Figure 1. Status of land systems map work for the target area of the CIAT Beef Program.

Climate

Long-term climatic data of meterological stations in the target area were assembled and analyzed. Figure 2 shows the approximate locations of the stations and Figure 3, an example of the data output of one, including a definition of the parameters. The moisture availability index (MAI) predicts the probability of drought stress. When MAI $<$ 0.34 serious drought stress is highly probable. MAI values between 0.34 and 0.67 show stress, a MAI between 0.68 and 1.0 little stress and MAI values $>$ 1.00 no water stress.

With the completion of the water balance analyses, it was decided to map and collate climatic parameters. Data from the central savannas of Brazil showed that the total wet season (months with MAI $>$ 0.33) potential evapotranspiration throughout that region was remarkably constant. A map of lowland tropical South America was then made where four major regions with total wet season

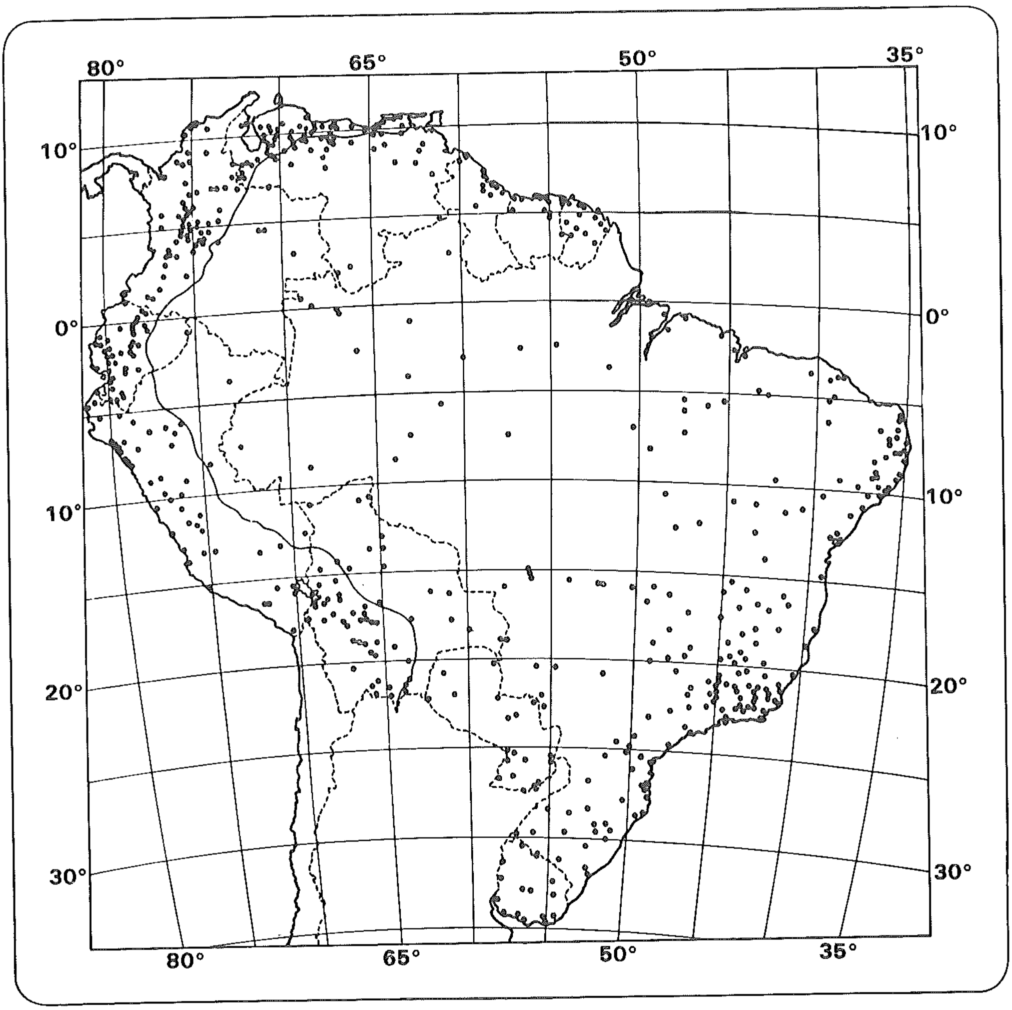

Figure 2. Locations of meteorological stations in the South American region

FORMOSA LAT 15 32 LON 47 18 912. METROS

	JAN	FEV	MAR	ABR	MAI	JUN
TEMP MED	22.0	22.1	21.9	21.5	20.1	19.0
H.R. MED	84.	78.	77.	64.	52.	38.
PCT SOL	44.	52.	53.	66.	76.	87.
RS MED	494.	523.	492.	486.	459.	452.
PRECIP.	252.	204.	227.	93.	17.	3.
ET POT	141.	135.	140.	132.	125.	115.
DEF PREC	-111.	-69.	-87.	39.	108.	112.
DEP PREC	176.	138.	157.	51.	0.	0.
MAI	1.25	1.02	1.12	.38	.00	.00

JUL	AGO	SET	OUT	NOV	DEZ	ANUAL
18.9	20.7	22.8	22.9	21.9	21.6	21.3
36.	41.	59.	78.	88.	91.	66.
88.	85.	61.	51.	38.	33.	61.
471.	522.	507.	510.	460.	430.	484.
6.	3.	30.	127.	255.	343.	1560.
123.	144.	143.	149.	127.	121.	1596.
117.	141.	113.	22.	-128.	-221.	35.
0.	0.	1.	78.	179.	248.	
.00	.00	.01	.52	1.41	2.04	

1 Mean temperature in °C.
2 Mean % relative humidity.
3 Mean % possible sunshine.
4 Incident mean solar radiation (Langleys/day) estimated from PCT SUNSHINE
5 Mean rainfall in mm.
6 Estimated potential evapotranspiration by Hargreaves method, in mm.
7 Precipitation deficit ≡ POT ET - PRECIP (water balance) in mm.
8 Dependable precipitation (in mm) ≡(PRECIP x 0.7) - 10
9 Moisture availability index $= \frac{\text{DEP PREC}}{\text{POT ET}}$

Figure 3. Example of the computer printout of climatic data for a representative meteorological station used in land systems classification, with definitions of the parameters used.

evapotranspirations of less than 910, 910-1060, 1061-1300 and greater than 1300 mm were easily delineated, as these classes followed the natural clustering of the potential evapotranspiration figures (Fig. 4). The 910-1060 mm class had a mean of 987 mm, an SD of 54 mm and a CV of 5.5%; the 1061-1300 mm class had a mean of 1178 mm, an SD of 71 mm and a CV of 6%. The <910 mm region, encompasses areas with more than six months dry season with "caatinga" or other forms of semi-arid or arid vegetation. These are largely outside of the target area, although they include some Oxisols and Ultisols. The 910-1060 mm areas correspond neatly to savanna vegetation regions such as the Cerrado and the Llanos, with four to six months dry season. The 1061-1300 mm belt encompasses areas under semi-evergreen seasonal vegetation which experience three to four months of dry season. The areas with more than 1300 mm are the tropical rain forest regions with less than three months dry season. The similarity between the total wet season potential evapotranspiration map (Fig. 4) and the length of the dry season map (Fig. 5) is clear. This parameter, therefore, apart from equating usable energy for plant growth, provides for a broad first approximation of the length of water stress in the target area. Potential evapotranspiration during the rainy season is clearly a most useful parameter for classifying climate for growth of perennial species such as pastures.

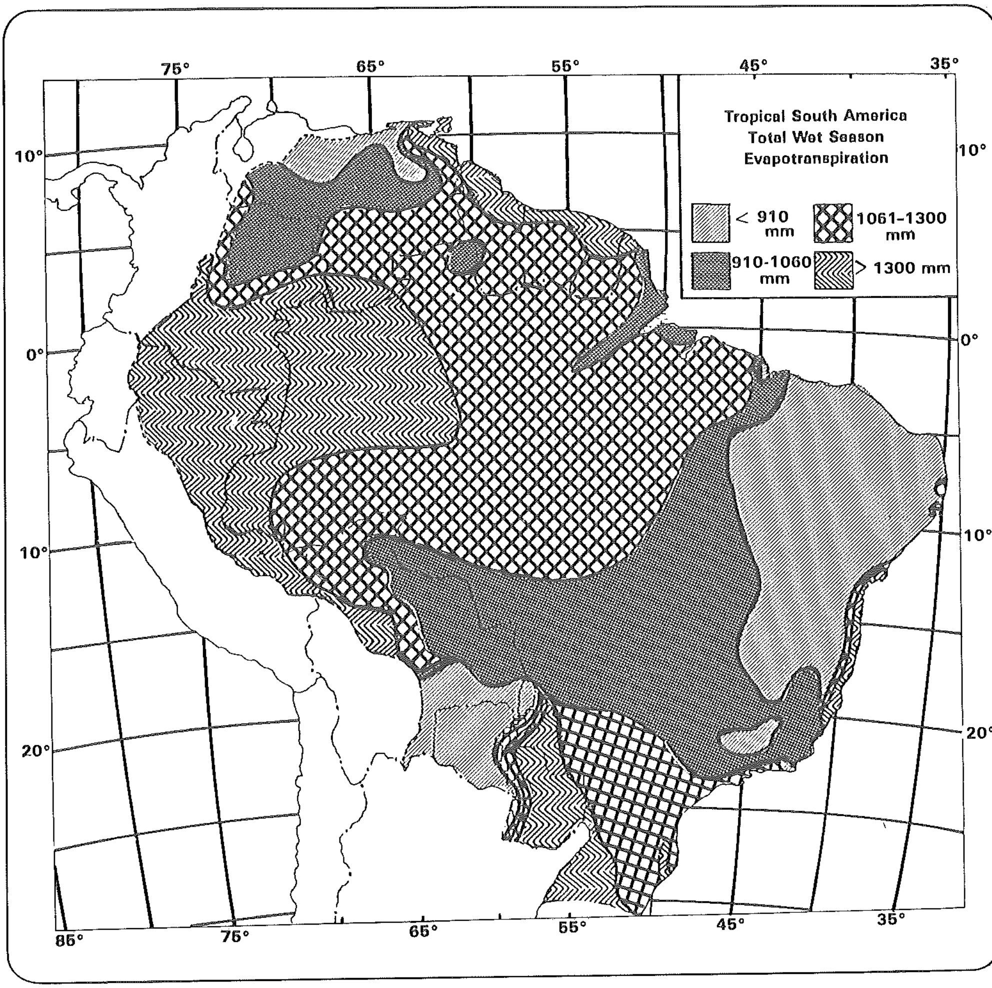

Figure 4. Total wet season evapotranspiration in tropical South America.

Landscape

It was shown that there are two completely different circumstances for cattle production in the savannas of Brazil. The first is characterized by well-drained lands, principally Oxisols, where the major limiting factor is lack of pastures during the dry season. The second is characterized by poorly drained lands, mainly Ultisols (Aquults) with flat topography. These soils have a heavy texture horizon that impedes drainage under a lighter texture topsoil. With the onset of the wet season the topsoil very quickly becomes saturated with water and the land generally inundates to the extent that cattle must be shifted to higher lands. Often the availability of higher lands within a reasonable distance is limited and a shortage of wet season pasture results. Nevertheless, at the present time, such lands carry more stock per unit area than the well-drained lands, and are well thought of by cattle producers.

In central-west Brazil, 52% or 126 million ha would classify as well-drained (mainly Oxisol) savannas, 8% or 20 million

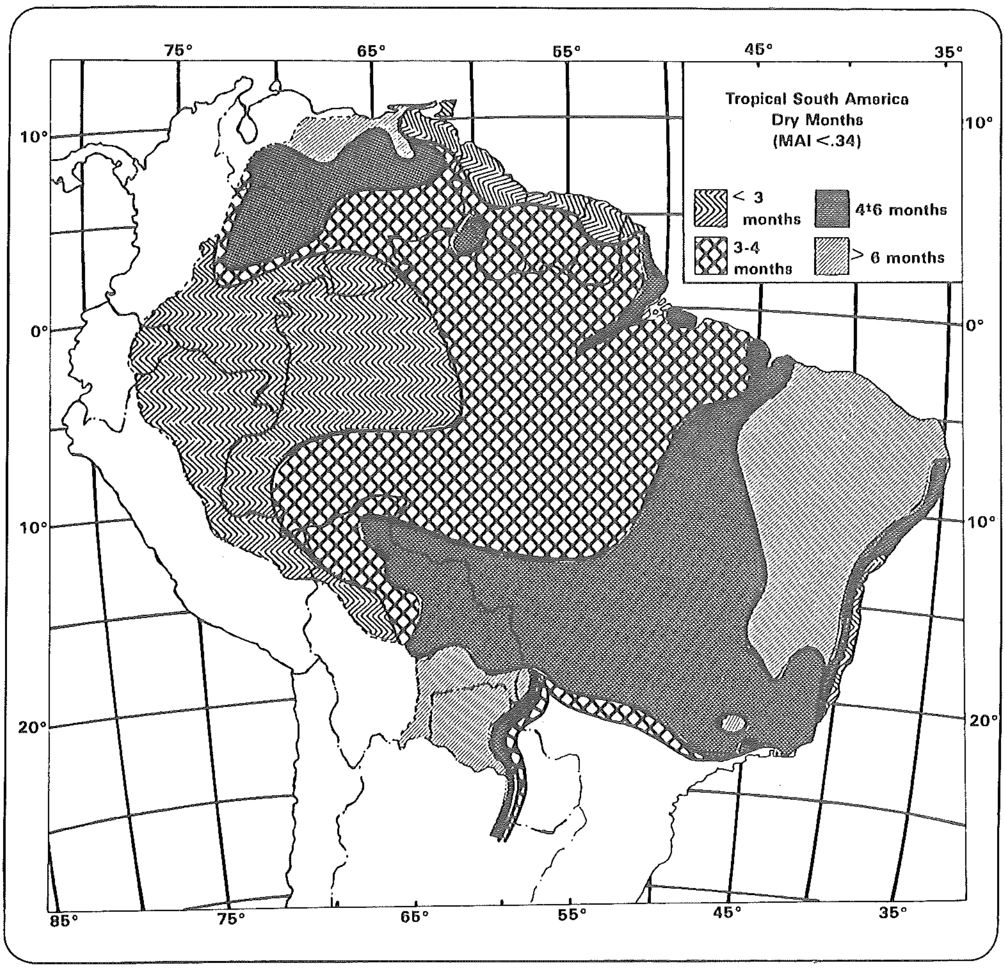

Figure 5. Dry months (Moisture Availability Index <.34) in tropical South America.

ha as seasonally flooded (mainly Ultisol) savannas and the remaining lands as other formations including 21 million ha of Entisol (sandy soil) savannas.

In lowland eastern Colombia 20% or 12 million ha would classify as well-drained (Oxisol) savannas and 7% or 4.5 million ha as seasonally flooded (Ultisol) savannas, and the remaining 46 million ha or 73% as other formations, mainly forests.

The delineation of land systems, especially in central Brazil, has emphasized the exciting contrasts between flat tablelands, hills and valleys and lowland plains. Many systems are well-watered with perennial streams dissecting the countryside at regular intervals. All contain areas of contrasting soils, and these have been summarized and separately described as land facets within land systems. This variability is clearly very important to practical farming.

Vegetation

The vegetation throughout the study region ranges from deciduous forests, to savannas, semi-evergreen seasonal forests and finally, to tropical rain forests. This gradient follows the broad classification of total wet season potential evapotranspiration (Fig. 4). However, within these areas, variations occur due to differences in soil physical and chemical properties. The physiognomic forms of Brazilian Cerrados described as "campo limpo" (grassland), "campo sujo" (grassland with occasional shrubs), "campo cerrado" (open savanna), "cerrado" (intermediate) and "cerradão" (closed savanna with continuous forest canopy) have been shown by Lopez and Cox of North Carolina State University to follow a fertility gradient. Therefore, the considerable controversy in the Brazilian literature concerning the origin of the Cerrado vegetation has been effectively resolved: the Cerrados may be considered as one climatic zone, with a constant total wet season potential evapotranspiration that ranges from 910 to 1060 mm within which the fertility gradient will determine the physiognomic form of the vegetation.

It was interesting to observe in the well-drained savannas that beef cattle actively browse shrubs and trees, especially during the dry season. Brazilian workers have shown that at the height of the dry season, over 60% of animal intake comes from shrub and tree browsing in the Cerrados. The availability of protein-rich forage during the dry season is critical on the well-drained lands, thus the attention being given to selection of grass and legume cultivars that can maintain forage quality well into the dry season is well-justified. Deep rooting species such as the grass *Andropogon gayanus* and the legume *Stylosanthes capitata* were seen to maintain forage quality during the dry season when introduced to these areas. The evaluation of total wet season as opposed to total dry season evapotranspiration will help to locate sites that will give a realistic selection pressure on forage cultivars thought suitable for improving cattle feeding. Clearly, these sites should be on representative soils from a physical and chemical point of view.

Soil

In the delineation of the land systems, soil physical characteristics have played a predominant role, particularly with respect to slope, drainage and water-holding capacity. As already noted, soils have been described separately in the land facet descriptions within a given land system. It was observed that the water-holding capacity of many clay Oxisols approaches that of sands.

In assessing soil fertility characteristics, the procedure followed was that of: (1) identifying toxicity problems, particularly Al and Mn and, (2) subsequently identifying deficiency problems.

Throughout much of the region studied, exchangeable Al levels were found to be high. In Brazil particularly, it was observed that farmers often apply massive, and costly quantities of lime assuming that the Al should be neutralized completely to overcome toxicity problems. However, crops vary in their tolerance to high levels of exchangeable Al, the degree of which may be expressed approximately in terms of the percentage Al saturation of the effective cation exchange capacity. Consequently, for many crops it is not necessary to neutralize all the exchangeable Al, but merely to apply enough lime to decrease the percentage Al saturation to levels that do not affect production. Therefore, an equation to estimate lime requirements at a specific level of Al saturation was developed:

$$\frac{\text{meq Ca/100 g soil}}{\text{required for liming}} = 1.5\left[\text{Al} - \text{RAS}\,(\text{Al} + \text{Ca} + \text{Mg})/100\right]$$

The values for the elements on the right side of the equation are expressed in terms of meq/100 g soil in the original exchange complex of the unlimed soil. RAS is the required percentage Al saturation. When the estimated lime requirement using the factor 1.5 is greater than the chemical lime equivalent of the exchangeable Al, a closer agreement to measured data is obtained by substituting this by 2.

The equation can be used for estimating approximate field lime requirements by simply changing the expression meq Ca/100 g soil to tons of lime/ha and multiplying the other side of the equation by the apparent specific gravity of the soil. The use of the equation requires no special soil analyses, only a 1*N*KCl extraction for the determination of exchangeable Al, Ca and Mg. When tested against experimental data from Brazil, Colombia and the U.S., the estimated lime requirement by the equation showed correlation coefficients above 0.99** when compared with actual data. Its use could lead to considerable savings in lime applications not only in the region of interest but also in the rest of the world. It is a practical development of CIAT's stated low input philosophy.

It is possible that some areas are affected by Mn toxicity problems, but little information was available relevant to the area studied.

The most common nutrient deficiency throughout the region, apart from N, is undoubtedly P. However, for the forage species seen growing, relatively small applications of P_2O_5 (50 kg/ha or less) appear to give satisfactory response once Al toxicity problems are overcome, preferably by cultivar tolerance.

Zinc deficiency has been reported, but only with excessive lime applications. Nevertheless, Zn levels in soils are often low as are Mg, P, and S levels. Molybdenum and B levels may prove deficient in some soils for some crops. Exchangeable Na levels are often very low in the savanna regions, and this undoubtedly points to the need for common salt in helping to improve beef cattle nutrition in those regions.

In order to facilitate indentifying possible toxicity and deficiency conditions, a procedure of carrying out a regression analysis on the chemical analyses of 15 to 20 soil samples was followed wherever sufficient data could be found.

Bibliographic References

To date, some 4500 bibliographic references and abstracts of work relevant to the impact area have been incorporated into a card system.

The entire study is scheduled to be completed by mid-1979, after which additional efforts will start in the interpretation of the data collected by Program soil scientists, agronomists, animal scientists and economists.

PLANT INTRODUCTION

During 1978, this Section continued its focus on: (1) assembling germplasm through direct collection and exchange with other institutions; (2) initial increase and maintenance of germplasm; (3) preliminary evaluation of germplasm; and,(4) identification and classification of germplasm through a reference herbarium.

Collection and Introduction of Forage Germplasm

Three major germplasm collection expeditions were conducted in 1978: in Panama, in collaboration with the Instituto de Investigación Agropecuaria de Panama (IDIAP) and the Banco Nacional de Panama (Fig. 6); in Venezuela, in collaboration with the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP) (Fig. 7); and in Brazil, in collaboration with the Centro Nacional de Recursos Genéticos of the Empresa Brasileira de Pesquisa Agropecuaria (CENARGEN-EMBRAPA) (Fig. 8). During these systematic expeditions and several occasional collections (mainly in Colombia) a total of 1458 accessions were assembled. Furthermore, 416 accessions were acquired through germplasm exchange with other institutions (Table 1). With these additions during the year, CIAT's tropical forage germplasm collection, specializing in materials originating from regions with acid, infertile savanna and jungle soils, increased to a total of 4781 accessions (Table 1).

Initial Germplasm Increase and Maintenance

Much of the Section's work during 1978 consisted of germplasm multiplication, to produce sufficient seed or vegetative material for preservation, preliminary evaluation and distribution. Under screenhouse and field conditions in CIAT-Palmira and CIAT-Quilichao, for almost 2000 accessions seed was harvested or plants are presently still in pots or in the field (Table 2).

Preliminary Evaluation of Germplasm

Preliminary evaluations in CIAT-Quilichao during the year since October 1977 provided the following results.

From among 53 *Zornia* spp. accessions, seven were selected which proved to be more vigorous than or as vigorous as the control (CIAT 728) (Table 3). All seven ecotypes are native to and were collected in the Colombian Llanos Orientales. Selected

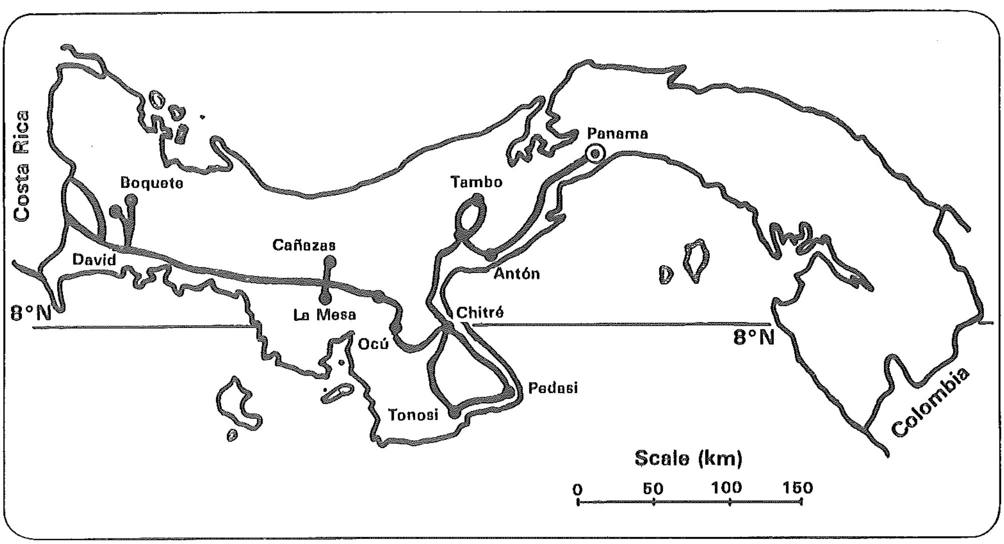

Figure 6. Routes of systematic forage germplasm collection in Panama (CIAT/IDIAP/Banco Nacional de Panama), January 1978.

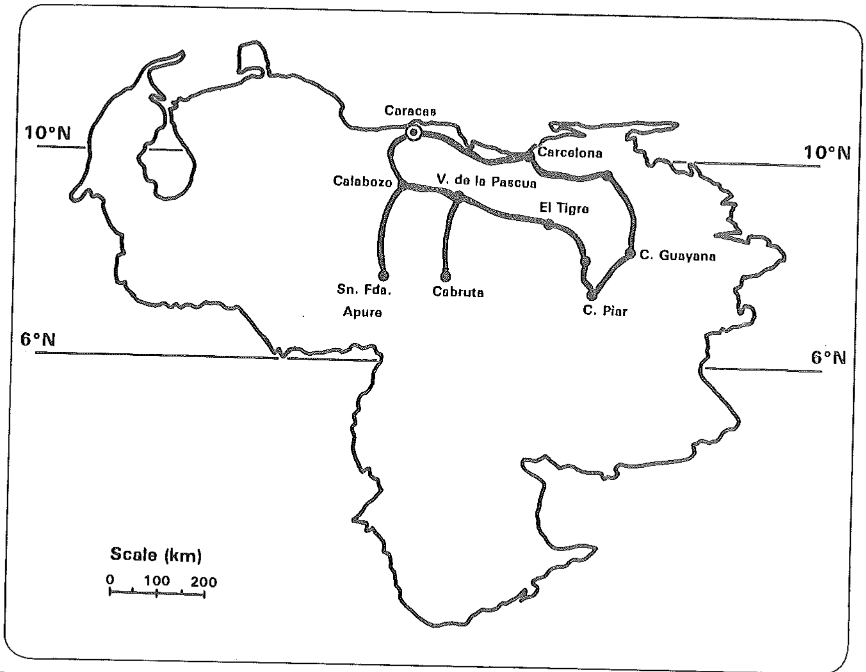

Figure 7. Routes of systematic forage germplasm collection in Venezuela (CIAT/FONIAP), February 1978.

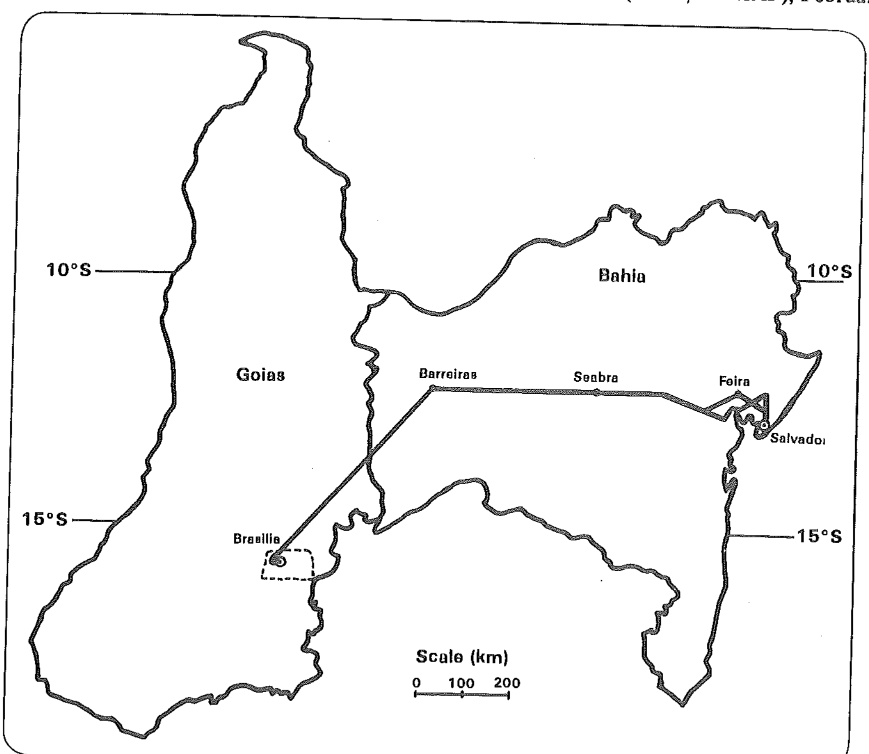

Figure 8. Routes of systematic forage germplasm collection in Brazil (CIAT/CENARGEN-EMBRAPA), September-October 1978.

Table 1.

Introduction of forage germplasm through direct collection and exchange with other institutions during 1978 and total accessions in the forage germplasm bank as of Nov. 1, 1978.

	Introductions during 1978						
	Direct collections						Total
Genera	Panama	Venezuela	Brazil	Occasional collections	Exchange	Total	accessions in bank
Stylosanthes	39	57	190	43	53	382	1204
Desmodium	56	42	33	68	32	231	670
Zornia	21	29	76	27	22	175	316
Aeschynomene	32	36	46	30	16	160	255
Macroptilium/ Vigna	21	24	14	44	42	145	401
Centrosema	21	37	23	18	38	137	325
Galactia	12	25	18	26	7	88	168
Arachis			1		2	3	48
Miscellaneous legumes[1]	111	83	48	104	47	393	1110
Grasses				3	157	160	284
Total	313	333	449	363	416	1874	4781

1 *Calopogonium, Pueraria, Teramnus, Glycine, Rhynchosia, Cassia, Crotalaria, Tephrosia, Eriosema, Clitoria, Indigofera, Leucaena* and others.

Table 2.

Forage germplasm under initial seed increase for maintenance and working collection, during 1978.

Genera	No. of accessions
Stylosanthes	469
Desmodium	247
Zornia	178
Aeschynomene	107
Macroptilium/ Vigna	176
Centrosema	125
Galactia	72
Arachis	47
Miscellaneous legumes[1]	289
Grasses[2]	248
Total	1958

1 *Calopogonium, Pueraria, Teramnus, Glycine, Rhynchosia, Cassia, Crotalaria, Tephrosia, Eriosema, Clitoria, Indigofera, Leucaena,* and others.
2 Also for preliminary evaluation.

material is classified in Category 2 by the Program's Germplasm Committee.

Of 13 *Centrosema* spp. accessions, three were selected as superior to the control (CIAT 438) (Table 4). While two of them are genetically improved materials introduced from Brazil (*Centrosema pubescens* CIAT 5122 and CIAT 5124, bred by Dr. Aryno Serpa, Unidade de Execução de Pesquisa de Ambito Estadual (UEPAE) at Itaguaí), the most outstanding ecototype was CIAT 5065, an accession from a 1977 collection expedition to the Colombian Llanos Orientales.

Within a group of 26 accessions of several *Aeschynomene* species, wide variation was observed with regard to plant type, longevity, growth habit, leafiness, drought resistance and adaptation to the Ultisol (pH 4.0 in the introduction plots) at CIAT-Quilichao. The species *Aeschynomene histrix, Aeschynomene*

Table 3.

Preliminary evaluation of 54 *Zornia* spp. accessions for vigor/productivity as rated during monthly evaluations in CIAT-Quilichao[1].

CIAT No.	Origin	Estab-lish-ment	Mean vigor during: 1st dry season	Re-growth	2nd dry season	Obser-vations
728	Meta, Col.	3.0	3.0	3.0	3.0	Control
9203	Meta, Col.	1.3	2.0	2.2	2.0	
9214	Meta, Col.	1.3	2.0	2.4	2.0	
9215	Meta, Col.	2.0	1.5	2.0	3.0	
9220	Meta, Col.	4.0	4.0	3.4	3.0	Selected
9225	Meta, Col.	2.7	2.0	3.0	3.0	
9245	Meta, Col.	3.0	3.0	4.0	3.0	Selected
9258	Meta, Col.	3.7	3.0	4.6	4.0	Selected
9260	Meta, Col.	3.7	4.0	4.4	4.0	Selected
9270	Meta, Col.	4.0	4.0	4.6	4.0	Selected
9286	Meta, Col.	3.0	3.0	4.0	4.0	Selected
9295	Meta, Col.	3.7	4.0	3.8	4.0	Selected
9164	Vichada,Col.	1.3	2.0	2.0	1.0	
9179	Vichada,Col.	3.0	4.0	3.0	4.0	
9278	Vichada, Col.	1.3	2.0	2.0	2.0	
9190	Valle, Col.	3.7	3.0	2.2	2.0	
9518	Valle, Col.	2.3	2.0	1.6	1.0	
9559	Cauca, Col.	3.0	3.0	2.4	2.0	
9576	Cauca, Col.	3.3	4.0	3.4	2.0	
9577	Nariño, Col.	3.0	3.0	2.0	2.0	
9304	Tolima, Col.	4.0	3.0	2.2	2.0	
9307	Amazonas, Braz.	2.0	2.0	1.8	2.0	
9208	Amazonas, Braz.	2.0	1.5	1.0	1.0	
9309	Dist. Federal, Braz.	2.3	2.0	1.4	1.0	
9646	Goiás, Braz.	1.3	2.0	2.0	2.0	
5 access.	Mato Grosso, Braz.	2.7-3.3[2]	0	0	0	Annual ecotypes
24 access.	Mato Grosso, Braz.	1.3-2.7	1.0-3.0	1.2-2.8	1.0-2.0	

1 Rating from 0 to 5 in comparison with control accession CIAT 728: 0 = dead plants; 1 = much less and 2 = less vigor than control; 3 = same vigor as control; 4 = more and 5 = much more vigor than control.
2 Range between lowest and highest individual ratings.

brasiliana and *Aeschynomene paniculata*, which so far have been unknown agronomically, were identified as potentially promising forage species for acid soil conditions. Four accessions (CIAT 9665, 9666, 9681 and 9690) were selected for further evaluation in Category 2.

Out of a group of 31 accessions of several *Macroptilium* and *Vigna* species, after one year of observations none of the materials tested could be considered well-adapted to the CIAT-Quilichao environment. Most of the accessions behaved as annuals, and those with a longer life cycle were severely

Table 4.

Preliminary evaluation of 14 *Centrosema* spp. accessions for vigor/productivity as rated during monthly evaluations in CIAT-Quilichao.[1]

			Mean vigor during			
CIAT No.	Origin	Estab-lish-ment	1st dry season	Re-growth	2nd dry season	Obser-vations
438	Hybrid	3.0	3.0	3.0	3.0	Control
5122	Hybrid	5.0	4.0	4.0	4.0	Selected
5123	Hybrid	3.0	2.0	3.0	3.0	
5124	Hybrid	5.0	4.0	4.0	4.0	Selected
5052	Vichada, Col.	3.7	4.0	3.0	2.0	
5063	Meta, Col.	2.7	3.0	2.5	2.0	
5065	Meta, Col.	4.0	4.0	4.5	5.0	Selected
5105	Cauca, Col.	2.3	2.0	2.3	2.0	
5106	Cauca, Col.	2.7	3.0	3.0	2.0	
5130	Valle, Col.	2.7	2.0	2.0	2.0	
5125	Antioquia, Col.	3.3	3.0	2.8	2.0	
5109	Mato Grosso, Braz.	3.0	3.0	3.0	2.0	
5111	Mato Grosso, Braz.	1.7	1.0	0	0	
5114	Mato Grosso, Braz.	2.7	3.0	3.0	2.0	

1 Rating from 0 to 5 in comparison with control accession CIAT 728: 0 = dead plants; 1 = much less and 2 = less vigor than control; 3 = same vigor as control; 4 = more and 5 = much more vigor than control.

Table 5.

Forage legume germplasm under preliminary evaluation in CIAT-Quilichao during 1978.

Species	No. of accessions
Stylosanthes capitata	87
Stylosanthes bracteata	20
Zornia spp.	231
Desmodium spp. (erect browse types)	24
Desmodium barbatum	129
Aeschynomene spp.	36
Centrosema spp	43
Macroptilium/*Vigna* spp.	62
Calopogonium spp.	82
Galactia spp.	79
Pueraria phaseoloides	11
Total	804

Table 6.

Specimens of tropical forage plants, savanna vegetation and weeds in CIAT's reference herbarium, as of November 1, 1978.

	No. of specimens
CIAT forage germplasm	
Gramineae	51
Leguminosae	194
Savanna vegetation	
Gramineae and *Cyperaceae*	35
Leguminosae	55
Other families	60
Weeds	96
Total	491

affected by fungal and bacterial diseases. Furthermore, during 1978 new preliminary evaluation plots with a total of 804 accessions from 10 genera, were established (Table 5). In these experiments, special emphasis was given to genera and species which already have been identified as promising for the Beef Program's target area.

Reference Herbarium

Development of a reference herbarium continued with the specimen collection increasing to 491 exsiccates through October 1978 (Table 6). A major acquisition was the weeds collection previously held by CIAT's former Weed Control Section.

Plans for 1979 include decreased field collecting and concentration on characterizing and cataloguing existing accessions. The rate of collecting is expected to increase again in 1980, particularly in Africa and Southeast Asia.

FORAGE BREEDING

The objective of the Forage Breeding Section is to breed for specific combinations of desirable characteristics not likely to be obtained via plant exploration. Initial crossing was aimed at: (1) recombining certain desirable characteristics of *Stylosanthes capitata;* and, (2) introducing or strengthening acid soil tolerance in *Centrosema, Leucaena* and *Panicum maximum.*

Stylosanthes capitata

Twelve promising ecotypes of *S. capitata* were selected in conjunction with the legume agronomists for inclusion in the half-diallel crossing program. The ecotypes represent a range of vigor, maturity, seed production and adaptation. The aim is to combine high yield and seed production, ability to grow in the dry season, active nodulation, high anthracnose and stemborer resistance and adaptability to soils with pH values from 4.2 to 6.0. It is of interest that central Brazilian ecotypes appear intolerant of higher pH's, while the Venezuelan ecotypes used in the program are tolerant.

Only a few of the diallel combinations (about 6 of 78) have not been obtained by crossing as yet. The F_1 plants are being raised and some are already producing F_2 seed. By February 1979 it is hoped that quantities of F_2 seed of all diallel combinations will be available for planting out populations at CIAT-Quilichao. The plant populations will be oversown with *Andropogon gayanus* and selections will be made under periodic grazing.

Centrosema pubescens

Eight diverse ecotypes of *Centrosema* (one proved not to be *Centrosema pubescens)* were selected for vigor and high tolerance in a pot experiment with Carimagua Oxisol (pH 4.5, 90% Al saturation). These are now entered in a half-diallel crossing program to combine vigor and tolerance to grazing (in conjunction with a suitable grass), insects and diseases, with high tolerance to very acid soils, as well as adaptability to soils of higher pH. With the aim of overcoming the slow early growth of *Centrosema,* active early nodulation and efficient P uptake will be important selection criteria.

A number of the crosses have been achieved and F_2 seeds should be available in February 1979 for plant populations to be grown at CIAT-Quilichao and evaluated in conjunction with *A. gayanus* under periodic grazing.

Leucaena

Populations of fertile progenies from several backcrosses between *Leucaena leucocephala* (cv. Cunningham) with 104 chromosomes and *Leucaena pulverulenta* with 56 chromosomes were screened for vigor and tolerance in a pot experiment with Carimagua Oxisol. A number of intolerant plants were retained as control material, and a range of promising well-nodulated plants with vigorous root development selected. Six *L. leucocephala* varieties were also grown in the Carimagua Oxisol.

All the above *Leucaena* plants are now growing at CIAT-Palmira for studies of edible forage and seed production, mimosine levels and chromosome numbers. An important aim is to obtain sufficient quantities of seed for screening large populations for acid tolerance in a sand culture system. It is hoped that some of the vigorous plants from the preliminary screening in the Carimagua Oxisol will combine high edible forage production with low mimosine levels and high tolerance to acid soils. Selected lines from this material will be grown at CIAT-Quilichao, Carimagua and Brasilia.

Desmodium ovalifolium

Desmodium ovalifolium flowers need to "trip" to form seed, so it is possible its plant populations vary to a degree. A preliminary screening of a large *D. ovalifolium* population for acid tolerance is in progress in the sand culture system.

A number of *Desmodium heterocarpon* introductions have been obtained for crossing studies. It may be possible to incorporate greater drought resistance and better seed production in the current CIAT 350 accession of *D. ovalifolium* which associates so well with *Brachiaria decumbens*. Breeding could markedly increase the range of adaptability of this valuable legume and adaptation to the Brazilian Cerrado would be very important.

Panicum maximum

Sexual plants propagated from a selection made by Dr. Wayne Hanna, Coastal Plain Research Station, Tifton, Georgia, U.S.A., have been planted at CIAT-Palmira. In addition, several plant populations derived from crossed seed from the same station are available. Numbers of plants of each of CIAT's *P. maximum* introductions are also established in the block.

Several crosses are being made using the better apomictic *P. maximum* introductions (e.g., Makueni) as the pollen parents and the sexual material as the females. Good quantities of crossed seed are being produced and germination of some will be attempted soon. *P. maximum* seed has a dormancy period of several months but it may be possible to break this dormancy by germinating in Petri dishes with 0.2% KNO_3. Plant populations from the crosses will be grown out for: (1) selection for tolerance to acid conditions (low pH, high Al, low Ca, low P) in the sand culture system; (2) selection for drought tolerance and dry season growth; and (3) selection for disease resistance. Once a superior apomictic plant has been identified it is "fixed" because of the nature of apomixis. It can then be multiplied and evaluated without delay.

A number of selections made from the populations raised from the crossed seed from the Coastal Plain Station are already being evaluated for drought resistance, etc. at Carimagua, in collaboration with the Grass Agronomy Section. A cytological method for rapidly identifying sexual and apomictic plants in hybrid populations is being investigated. This will obviate the need for time-consuming progeny testing.

LEGUME AGRONOMY

During 1978, ecotype evaluation of promising legume germplasm continued at Carimagua and CIAT-Quilichao, and started in Brasilia, with the arrival of the Forage Agronomists at the Cerrado Center.

At Carimagua, as a result of systematic evaluation of 177 accessions in introduction plots during 1976-77, 32 lines were selected for observations under grazing (Table 7). Those accessions which had shown outstanding promise, were sown in larger areas. A total of 12 ha were established with the selected lines in associations with two grasses *(Brachiaria decumbens* and *Andropogon gayanus);* grazing started in December 1977, using a flexible grazing system with an average stocking rate of 3.5 animals/ha.

Data taken during nine months in this grazing area as well as in parallel cutting experiments confirm *Zornia latifolia* (CIAT 728), *Desmodium ovalifolium* (CIAT 350) and several *Stylosanthes capitata* accessions (CIAT 1019, 1078, 1097, 1315, 1405), as highly promising legumes for conditions of the Colombian Llanos Orientales and similar areas.

Zornia latifolia

Out of five *Zornia* spp. accessions, the late-flowering ecotype CIAT 728 *(Z. latifolia)* proved the most productive, in terms of both dry matter and protein production (Table 8). The superiority of this accession was not only evident during the establishment phase but also during and after grazing (Table 9). Active growth during the dry season with abundant production of nutritionally valuable leaves is one of its most important characteristics (Fig. 9). Occasionally, insect and disease attacks produced severe defoliation, but plants recuperated completely within a few days.

Desmodium ovalifolium

After a somewhat slow initial growth, *D. ovalifolium* 350 has a great potential of producing dry matter during the rainy and early dry seasons, outyielding other promising species such as *S. capitata.* Later in the dry season, however, production of *D. ovalifolium* drops sharply due to defoliation (Fig. 10). This lack of resistance to very severe drought limits its potential to areas with a dry season not longer than three to four months. However, regrowth and production of nutritious dry matter starts immediately after the onset of the rainy season, and regrowth is faster than in the case of *S. capitata* (Fig. 11).

Due to its stoloniferous growth habit, *D. ovalifolium* is aggressive enough for association with stoloniferous prostrate grasses such as *Brachiaria decumbens* which is known to be legume suppressing. Figure 12 shows that under cutting, it is possible to maintain stable grass/legume mixtures of *D. ovalifolium* and *B. decumbens.* In mixtures with a tufted grass such as *A. gayanus,* the persistence of *D. ovalifolium* indicates a good shade tolerance. Under grazing, however, due to an apparently higher palatability of *A.*

Table 7.

Evaluation of legume accessions in introduction plots at Carimagua.[1] (Summary of selected lines).

Species	CIAT No.	Origin	Adaptation to Soil Stress	Dry Season Performance	Self-Propagation	Disease Tolerance	Pest Tolerance	Seed Production	Productivity	Promising Status[2]
Stylosantes										
humilis	1222	Maranhão, Braz.	2	3	4	1	3	4	2	b
	1303	Maranhão, Braz.	2	1	4	1	3	4	2	b
humata	147	Guárico, Ven.	2	2	3	1	1	2	2	b
	1040	Magdalena, Col.	2	3	4	3	3	2	4	b
capitata	1007	CPI, Braz.	2	3	3	4	4	2	3	b
	1019	Minas Gerais, Braz.	4	3	4	4	4	4	2	a
	1078	Bahía, Braz.	4	4	2	2	3	2	2	a
	1097	Bahía, Braz.	2	4	2	2	3	2	2	a
	1315	Maranhão, Braz.	2	3	4	2	2	4	2	a
	1318	Maranhão, Braz.	2	3	4	2	2	4	2	a
	1323	Maranhão, Braz.	2	3	4	4	2	4	2	a
	1325	Maranhão, Braz.	2	3	2	2	3	2	2	b
	1328	Maranhão, Braz.	2	3	4	2	2	2	2	a
	1338	Piauí, Braz.	2	3	4	2	2	4	2	a
	1339	Piauí, Braz.	2	3	4	4	2	4	2	a
	1342	Piauí, Braz.	2	2	4	2	2	4	2	a
	1405	Mato Grosso, Braz.	2	3	2	2	2	2	3	b
bracteata	1281	Dist. Fed., Braz.	2	3	2	2	2	4	3	b
sp.	1093	Bahía, Braz.	2	4	3	2	2	3	1	b
Desmodium										
barbatum	3040	Maranhão, Braz.	4	2	1	2	2	2	2	b
	3063	Cauca, Col.	4	2	1	2	2	2	2	b
canum	367	Unknown	3	3	3	2	4	2	3	b
	388	Bahía, Braz.	3	2	3	2	4	2	3	b
	3005	Guiana Fr.	3	2	1	4	4	2	3	b
	3033	Maranhão, Braz.	2	2	3	2	2	2	3	b
	3042	Monagas, Ven.	3	2	4	2	4	3	1	b
ovalifolium	350	Malaysia	2	2	4	4	4	1	4	a
Zornia										
latifolia	728	Meta, Col.	4	4	4	3	3	2	2	a
sp.	802	Brazil	4	1	4	2	4	2	3	b
	883	Goiás, Braz.	4	3	4	2	2	2	2	b
	897	Mato Grosso, Braz.	4	3	4	2	2	2	2	b
Macroptilium sp.	535	Barinas, Ven.	3	4	3	3	2	4	4	b

1 Rating system: 4 = very positive to factor; 3 = positive; 2 = intermediate; 1 = negative.
2 Status: a = very promising; b = promising.

Table 8.

Dry matter yields, protein content (%N x 6.25) and protein yields of five *Zornia* accessions in Carimagua. (Six months after sowing.)

CIAT No.	DM (kg/ha)	Protein (%)	Protein (kg/ha)
728	4917	16.3	801.5
883	3564	10.9	388.5
897	3389	11.4	386.3
802[1]	1883	9.2	173.2
814[1]	617	9.8	60.5

1 Annual ecotypes.

gayanus during the rainy season, *D. ovalifolium* tends to dominate the grass. With *B. decumbens*, however, a stable grass/legume mixture was maintained under grazing (Table 10).

Of six *Desmodium* accessions tested in mixed swards with *B. decumbens, Brachiaria humidicola, A. gayanus* and *Panicum maximum* at CIAT-Quilichao, *D. ovalifolium* 350 was the most productive and most persistent legume, mainly in association with the prostrate *Brachiaria* spp. accessions (Figs. 13 and 14). In mixtures with tufted grasses *(Andropogon* and *Panicum),* yield and persistence of CIAT accession 3063 of *D. barbatum* (a species native to the Quilichao area) were about equal to those of *D. ovalifolium.* In all cases the lowest yielding species was *D. scorpiurus* which disappeared completely.

Stylosanthes capitata

According to differences in flowering time, the two previously identified *S. capitata* types (an early-flowering ecotype from central Brazil and a late-flowering ecotype from the coastal region of Bahia) performed differently during the dry season (Fig. 10). Mid-season ecotypes were also identified.

Whereas the early flowering ecotype CIAT 1019 stops growing at the onset of the dry season and drops its seed heads (which at the end of the rainy season represent 60-70% of the total dry matter), the late-flowering CIAT 1078 continues growing actively and its leaves and seed heads represent a valuable source of protein during the dry season (Fig. 11).

Grazing experiments showed that the high seed production potential of the early and mid-season flowering *S. capitata* types (CIAT 1019 and CIAT 1315, respectively), through spontaneous generation of large

Table 9.

Available forage of five *Zornia* accessions under grazing in Carimagua.

CIAT No.	Dec. 1977 (before first grazing)	Sept. 1978 (after last grazing)	Oct. 1978 (after 4 weeks resting period)
	Dry matter (kg/ha)		
728	4917	848	1990
883	3564	203	516
897	3388	425	723
802[1]	1883	493	1493
814[1]	617	-	-

1 Annual ecotypes.

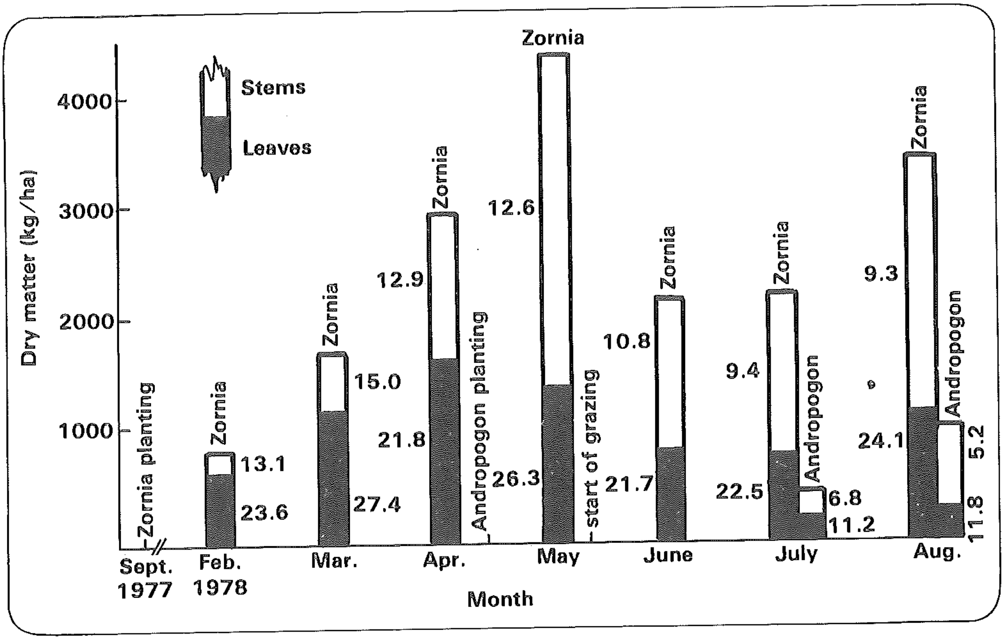

Figure 9. Dry matter yields of leaves and stems of *Zornia latifolia* CIAT 728 associated with *Andropogon gayanus* during establishment at Carimagua. (Figures along bars represent protein percentages.)

quantities of seedlings, represents an important self-propagation mechanism of these accessions (Table 11), thus contributing to a stable grass/legume mixture.

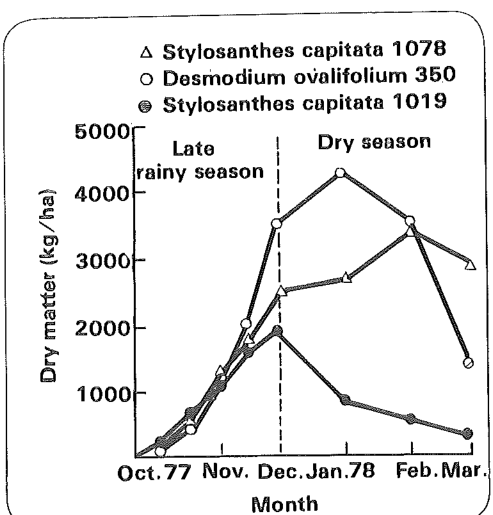

Figure 10. Dry matter production of three selected legume accessions in pure swards, during eight sequential growth periods after a standardization cut in the late rainy season at Carimagua.

Although this seems to be true also for an association with *B. decumbens* (Fig. 15),

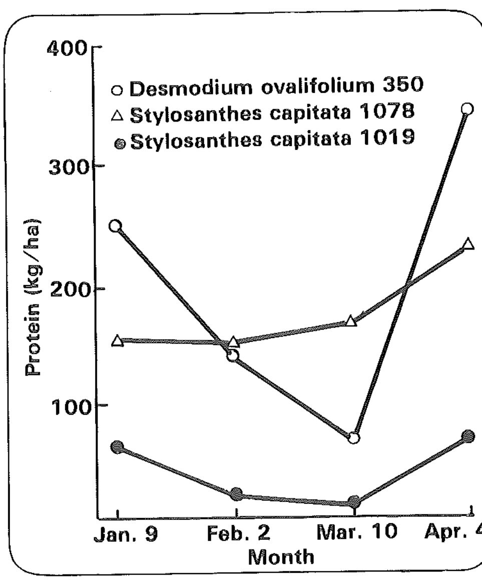

Figure 11. Changes in protein yield of inflorescences/seed heads and leaves of three selected legumes in a pure sward during the dry season (January-March) and at the beginning of the rainy season (April) at Carimagua.

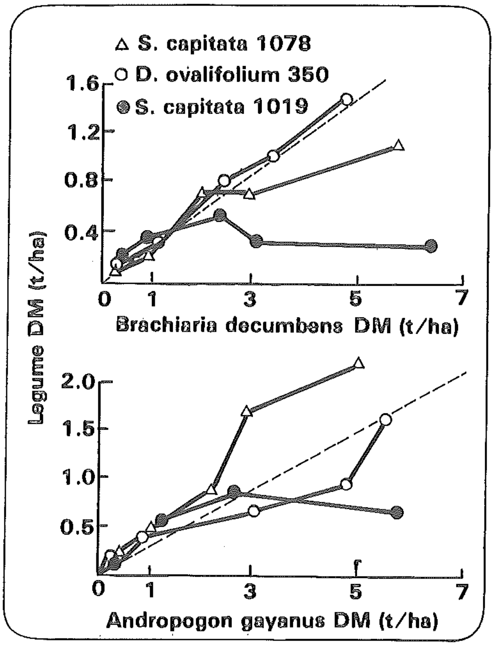

Figure 12. Relationship between three selected legume accessions and two grasses *(Brachiaria decumbens* and *Andropogon gayanus)* in mixed swards at Carimagua.

further conclusions can only be drawn after evaluating the persistence of the new plant generation. To date, observations indicate that maintaining a stable mixture with *A. gayanus* under grazing is feasible.

In connection with its high seed production potential, *S. capitata* has another characteristic. Due to hard seed coats, cattle apparently cannot digest all the seeds and these are dispersed through the feces (Fig. 16).

On the basis of these data, *Z. latifolia* CIAT 728, *D. ovalifolium* CIAT 350, and *S. capitata* CIAT 1019, 1315, 1405, 1078 and 1097 (the latter also a late-flowering type from Brazil) have been included in Category 4 (animal production experiments) of the Beef Program's list of promising legume germplasm (Table 12).

Evaluations of new germplasm (material collected or introduced in 1977) were initiated by establishing space-planted introduction plots with a total of 350 new accessions. After initial observations of their adaptation to the Carimagua environment, these accessions will be grazed.

Stylosanthes guianensis

Species evaluation in mixed swards under cutting and grazing continued in

Table 10.

Available forage of *Desmodium ovalifolium* 350 and two associated grasses *(Andropogon gayanus* and *Brachiaria decumbens)* under grazing in Carimagua.

Species	Dec. 1977 (before first grazing)	Jan. 1978 (after first grazing)	Mar. 1978 (end of dry season)	Sept. 1978 (after last grazing)
	Dry matter (kg/ha)			
D. ovalifolium	3639 (59)[1]	1854 (77)	680 (68)	2660 (74)
A. gayanus	2527	541	318	929
Total	6166	2395	998	3589
D. ovalifolium	2147 (28)	1107 (45)	853 (41)	2390 (56)
B. decumbens	5429	1332	1196	1845
Total	7576	2439	2049	4235

1 Numbers in parentheses are the percentage legume dry matter in the sward.

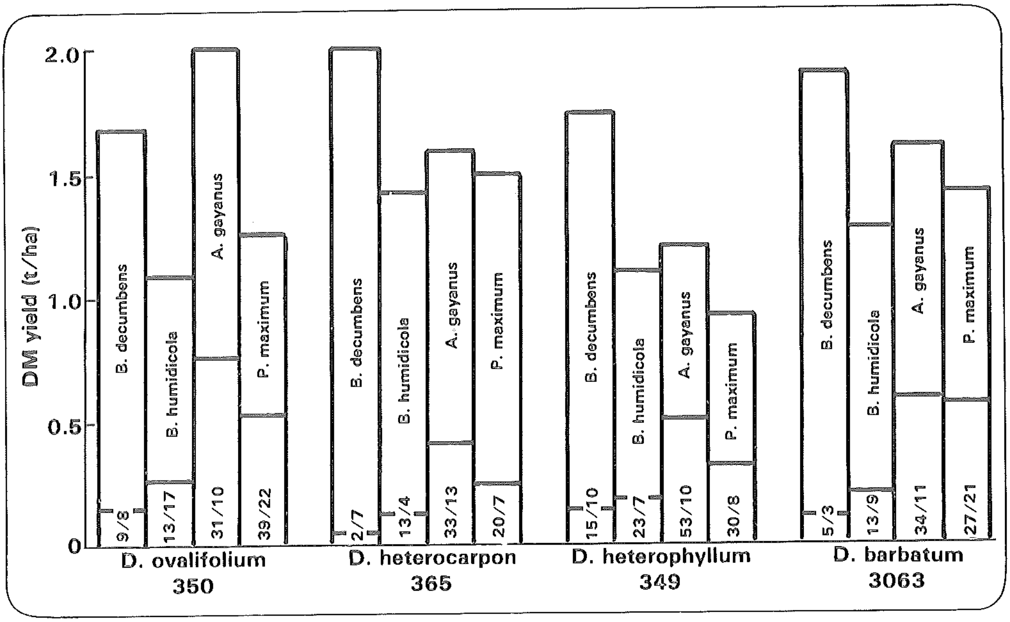

Figure 13. Dry matter yields (means of four cuts) of four *Desmodium* species in mixed swards with four grasses under a six-week cutting regime at CIAT-Quilichao. (Figures in bases of bars are the percentage legume at first and last cuts.)

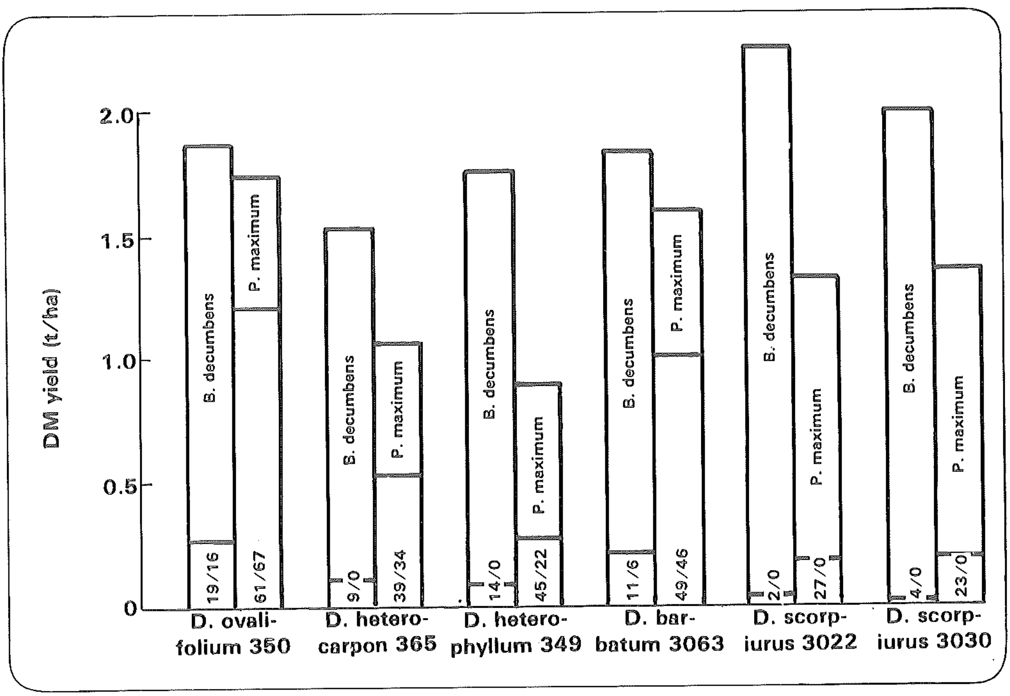

Figure 14. Dry matter yields (means of four cuts) of six *Desmodium* accessions in mixed swards with *Brachiaria decumbens* and *Panicum maximum* under a six-week cutting regime at CIAT-Quilichao. (Figures in bases of bars are the percentage legume at first and last cuts.)

Table 11.

Self-propagation of three *Stylosanthes capitata* ecotypes associated with two grasses under grazing in Carimagua.

S. capitata accession	Associated with	March 1978	June 1978	Sept. 1978
		(seedlings/m²)		
1019	*Brachiaria*	2341	165	135
(early)	*Andropogon*	1188	187	141
1315	*Brachiaria*	266	116	68
(midseason)	*Andropogon*	140	56	35
1078	*Brachiaria*	0	0	5
(late)	*Andropogon*	0	0	8

CIAT-Quilichao and El Limonar (near Quilichao) with germplasm that had previously been identified as potentially promising for the Quilichao environment.

The grazing trial with two *Stylosanthes guianensis* accessions (CIAT 136 and 184) in mixtures with *B. decumbens, A. gayanus, Hyparrhenia rufa* and *P. maximum* entered its third year (second year of grazing). Since the first two years were extremely dry, anthracnose had not been important. In 1978, however, there was a severe outbreak of anthracnose. Furthermore, as *S. guianensis* plants grew older, stemborer infestations increased considerably. Mainly due to these factors,

Figure 15. Self-propagation of *Stylosanthes capitata* through seedlings in a grazed mixture with *Brachiaria decumbens* at Carimagua.

Figure 16. Self-propagation of *Stylosanthes* through animal feces at Carimagua.

Table 12.

CIAT forage legume accessions classified as promising Categories 4 and 3 (materials for animal production and grazing pressure trials, respectively), as of November 1, 1978.

Category	Species	CIAT No.	Adaptation to Carimagua	Adaptation to Quilichao	Auto-propagation	Disease tolerance	Insect tolerance	N fixation potential	Seed production potential	Water stress tolerance	Al and low P tolerance	Nutritional quality	Ease of management	Animal production	Persistence under grazing
			Selection criteria (blanks represent unknown)												
4	*Zornia latifolia*	728	+	+	+	+	+	+	+	+	+	+			
	Desmodium ovalifolium	350	+	+	+	+	+	+	-	+	+				
	Stylosanthes capitata	1019	+	+	+	+	+	+	+	+	+				
	Stylosanthes capitata	1078	+	+	+	+	+	+	+	+	+				
	Stylosanthes capitata	1097	+	+	+	+	+		+	+	+				
	Stylosanthes capitata	1315	+	+	+	+	+		+	+	+				
	Stylosanthes capitata	1405	+	+	+	+	+		+	+	+				
	Pueraria phaseoloides	9900	(+)[1]	+	-	+	+	+		+	+				
3	*Centrosema* hybrid 17-33	438	-	+		+	+	+	+	+	+	+			
	Desmodium heterophyllum	349	(+)	+	+	+	+	+	+	-		+			
	D. (= Codarocalyx) gyroides	3001	(+)	+		+	+		+	+					
	Stylosanthes hamata	147	(+)	+	+	-	-		+	+	+				
	Stylosanthes capitata	1318	+	+	+	+	+		+	+	+				
	Stylosanthes capitata	1323	+	+	+	+	+		+	+					
	Stylosanthes capitata	1325	+	+	+	+	+		+	+					
	Stylosanthes capitata	1342	+	+	+	+	+		+	+					

1 (+) Adapted at a higher soil fertility level.

plants of both accessions tended to disappear. This tendency was somewhat stronger for CIAT 136 than for CIAT 184, and more accentuated in mixtures with *B. decumbens* and *A. gayanus* than with the other two less vigorous grasses (Fig. 17). Consequently, further evaluations of these accessions have been discontinued in areas where anthracnose and stemborer are important. It is also important to note that it took two grazing years to determine the persistence of these legumes.

This finding in effect downgraded *S. guianensis* from the Program's promising categories list but does not mean that the species is discarded as such. Future work with this species will concentrate on the late-flowering, fine-stemmed ecotypes which have shown good anthracnose and drought tolerance (CIAT Annual Report, 1977, p. A-22). According to preliminary evaluations, these latter *S. guianensis* types are also showing promise at the Cerrado Center.

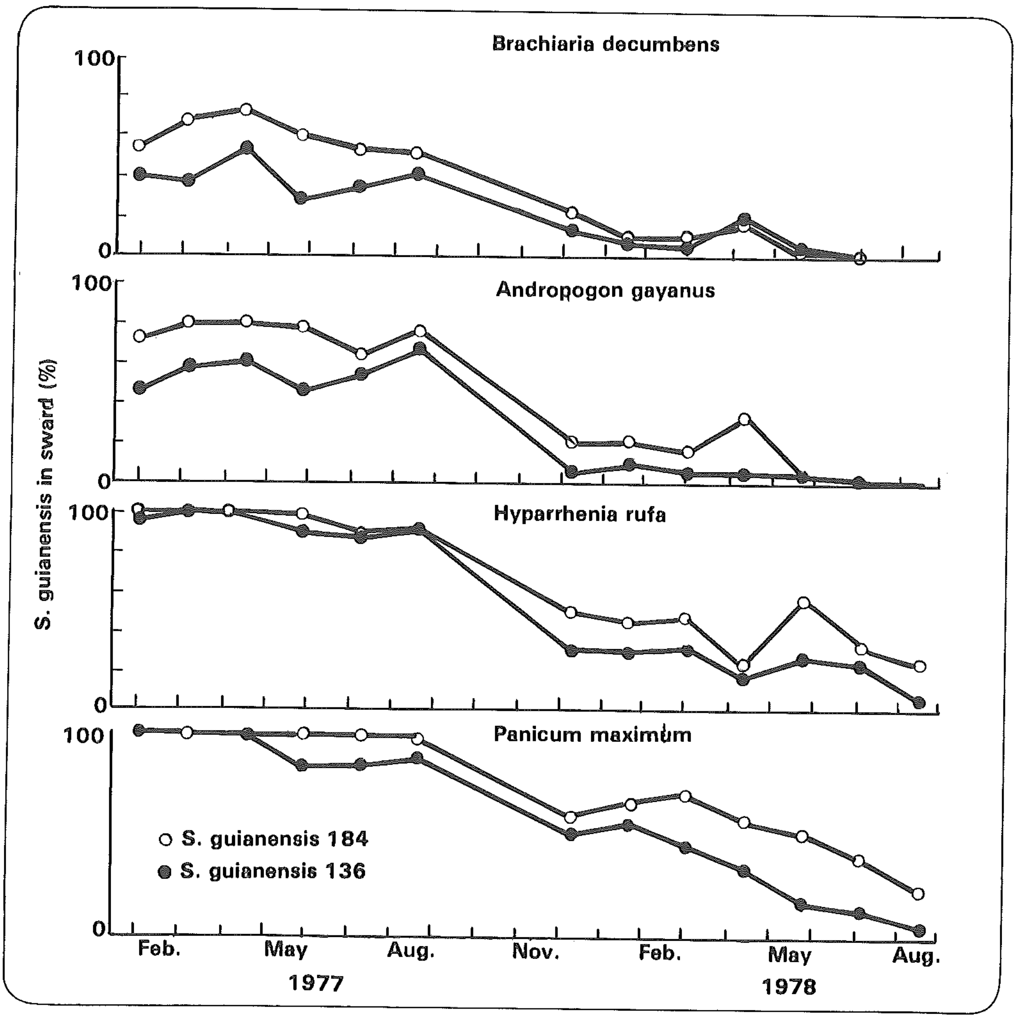

Figure 17. Botanical composition of two *Stylosanthes guianensis* spp. accessions in association with four grasses during the first two years under grazing at El Limonar (near CIAT-Quilichao).

Centrosema hybrid 438

The *Centrosema* grazing experiment, with five accessions, entered its second year under grazing in mixture with *A. gayanus* at El Limonar. With the exception of the low-yielding local accession CIAT 456, no differences were observed between the tested lines. Although the percentage of *Centrosema* diminished considerably during the second year of grazing, mixtures tended to stabilize at a low value of 10% botanical composition (Fig. 18).

An interesting finding was that *Andropogon gayanus,* when associated with *Centrosema* had higher protein contents than when associated with *S. guianensis* (Fig. 19). A similar tendency also was evident in a cutting experiment where *Centrosema* had considerably higher protein contents than *Z. latifolia* and *D. ovalifolium* (Table 13).

In another cutting experiment, in which productivities of three *Centrosema* lines in association with *A. gayanus* and *P. maximum* were compared, a mixture of the hybrids 438 and 442 outyielded the other two accessions in either association (Table 14).

Browse Legumes

Species with an erect growth habit, such as *Desmodium (= Codarocalyx) gyroides* 3001 and *Desmodium* sp. 3019 have significant potential as browse plants. In a

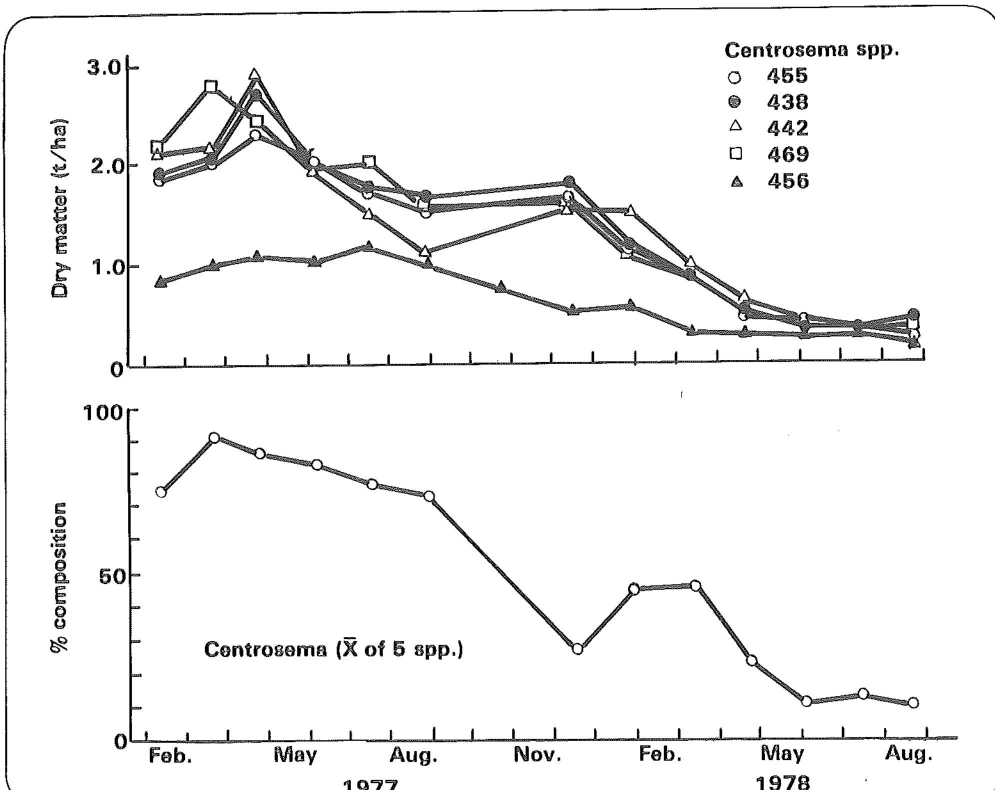

Figure 18. Presentation yields and botanical composition of five *Centrosema* spp. accessions grown with *Andropogon gayanus* during the first two years under grazing at El Limonar (near CIAT-Quilichao).

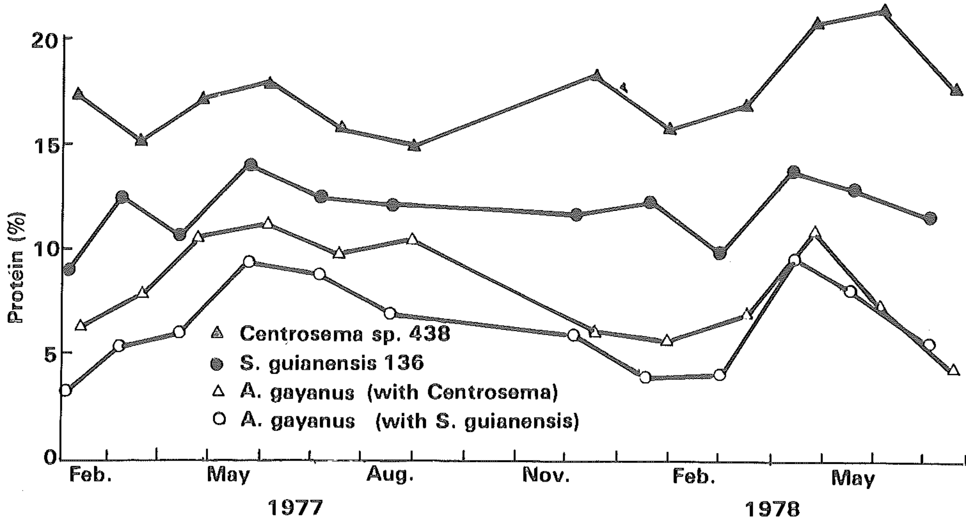

Figure 19. Protein content of *Centrosema* spp., *Stylosanthes guianensis* and *Andropogon gayanus* under grazing at El Limonar (near CIAT-Quilichao).

cutting experiment where no major effects of different cutting heights and intervals were observed at CIAT-Quilichao, *D. gyroides* 3001 yielded considerably more dry matter but only slightly more protein than 3019. Over a 40-week period, both species produced very high levels (1000-1500 kg) of protein/ha (Fig. 20).

The leguminous shrub *Leucaena* is potentially capable of producing high yields of dry matter and crude protein, far in excess of the best herbaceous species. However, previous experience with this plant has shown it to be of poor productivity on acid soils. Consequently, large quantities of lime are necessary for establishment and maintenance. As soon as seed of *Leucaena leucocephala* x *Leucaena pulverulenta* populations from

Table 13.

Protein content (%N x 6.25) of three legumes in association with *Andropogon gayanus* at CIAT-Quilichao. (Means of 6 cuts.)

Accession	% Protein of regrowth after		
	4 weeks	6 weeks	8 weeks
Desmodium ovalifolium 350	13.0	11.8	12.1
Zornia latifolia 728	13.0	15.5	18.8
Centrosema sp. 845	20.5	21.6	22.1
Andropogon gayanus 621			
growing with:			
D. ovalifolium	11.3	9.2	8.1
Z. latifolia	11.5	9.4	8.1
Centrosema sp.	12.5	9.6	10.5

Table 14.

Dry matter production of three *Centrosema* lines in mixture with *Andropogon gayanus* and *Panicum maximum* at CIAT-Quilichao. (Means of 5 cuts).

Mixture	Dry matter yield (kg/ha)			
	Grass	Legume	Total	% legume
A. gayanus + CIAT 438/442	1244	258	1502	17
A. gayanus + CIAT 845	1188	148	1336	11
A. gayanus + CIAT 413	1463	110	1573	7
P. maximum + CIAT 438/442	775	357	1132	31
P. maximum + CIAT 845	714	189	903	21
P. maximum + CIAT 413	813	212	1025	21

the Forage Breeding Section are available, the CIAT Forage Agronomist at the Cerrado Center will begin research to select acid-tolerant, vigorous, low-mimosine lines. Hopefully, this new material will be available for evaluation on the Cerrado during the 1979-80 rainy season. Meanwhile, an attempt will be

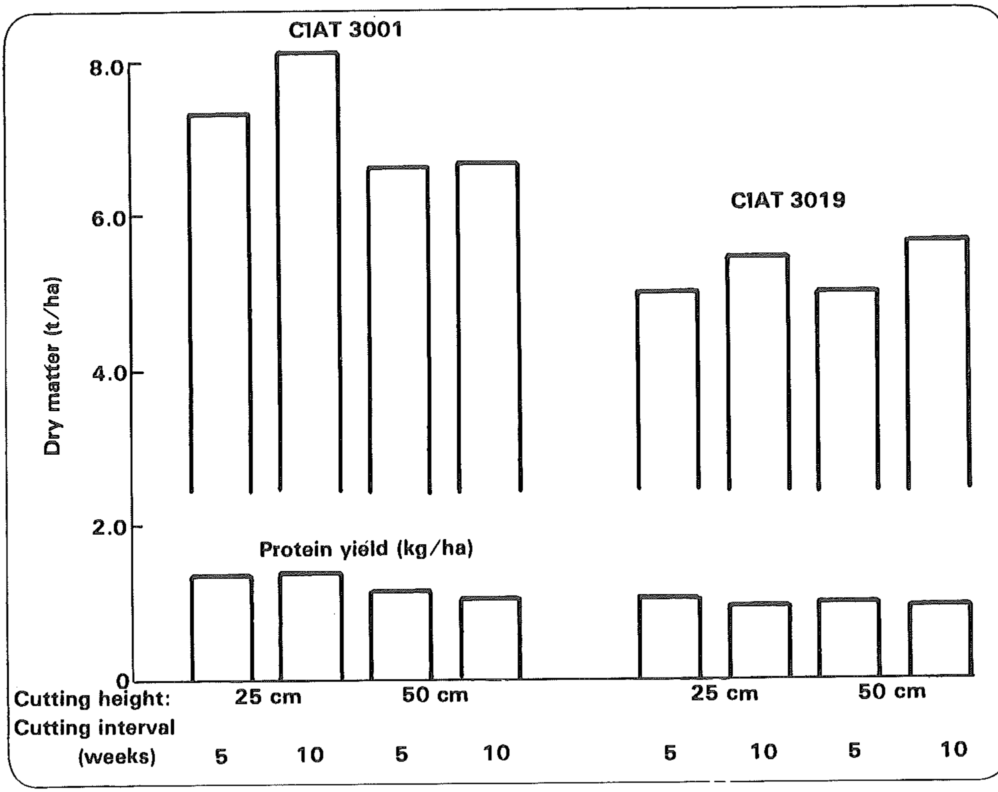

Figure 20. Total yields of dry matter and protein of two *Desmodium* browse-type species under different cutting regimes, over 40 weeks, at CIAT-Quilichao.

made to improve the productivity of existing cultivars utilizing a combination of inoculation/pelleting techniques. Three important *Leucaena* cultivars, Peru, Cunningham, and Giant Hawaii, will be inoculated with new *Rhizobium* strains collected on acid soils and pelleted with rock phosphate or lime. The present commercial *Rhizobium* strains NGR 8 and CB 81 will be used as controls. The most promising treatment or treatments will become the controls against which new lines of *Leucaena* will be screened.

In the future, legume bacteriology studies will be extended to include field testing of new *Rhizobium* strains for herbaceous legumes. However, first it will be necessary to identify the promising species before attempting to increase productivity still further by inoculation and pelleting techniques.

New Activities

Systematic evaluation of Category 2, 3 and 4 germplasm was initiated at the Cerrado Center in late 1978. A total of 352 accessions of Category 2 material of *Stylosanthes, Aeschynomene, Calopogonium, Macroptilium, Centrosema, Galactia, Zornia, Pueraria, Desmodium, Teramnus, Vigna, Soemmeringia,* and *Leucaena* were planted in triple replicates. Two replicates (one grazed) mixed with *A. gayanus* will be sited on a Dark Red Latosol (Oxisol), and one replicate, on a Red-Yellow Latosol (also an Oxisol). These two soil types represent 58% of all Cerrado soils. A similar program with grasses will begin during the 1979-80 rainy season when CIAT will have expanded its collection of *Panicum* and *Andropogon* ecotypes.

Fourteen highly promising legumes that have performed well will be evaluated under grazing as Category 3 materials. These include an anthracnose-resistant *S. guianensis,* four lines of *S. capitata, Stylosanthes bracteata,* two lines of *Centrosema, D. ovalifolium* and *Z. latifolia.* Where possible, Brazilian commercial varieties will be used as controls. These activities mark the initiation of the Beef Program's third major research site in germplasm evaluation, at the Cerrado Center.

New experiments established during 1978 in CIAT-Quilichao included a *Macroptilium atropurpureum* evaluation project, selected for acid soil tolerance in Australia and planted with *A. gayanus.*

Germplasm Classification

The germplasm classification scheme developed by the Beef Program's Germplasm Committee essentially followed the selection criteria established in 1977 (CIAT Annual Report, 1977, p. A-15), with two modifications. These include: (1) the elimination of the selection criteria "Adaptation to medium soil fertility" and "Adaptation to high soil fertility", and, (2) the addition of a new criterion "Autopropagation" (AP). Based on experiences with germplasm evaluation under grazing, this plant characteristic was considered an important part of a forage legume's ability to survive and/ or to spread under grazing in mixtures with grasses. Autopropagation may be due to aggressive stoloniferous growth or free-seeding habit coupled with ready germination of fallen seeds or seeds passed through animals' digestive tracts.

With data expected from the Program's regional trials and work at Brasilia, major changes in the classification scheme will be necessary to account for environmental differences between the various sites. Plans for 1979 include the quantification and sub-division of several criteria.

Present status of promising germplasm included in the two most advanced categories (Category 3 — grazing pressure trials, and Category 4 — animal production trials) is shown in Table 12. Blanks in the selection criteria for Category 4 germplasm (in which *Pueraria phaseoloides* is included as a commercial control) refer mainly to "Nutritional quality" and "Nitrogen fixation potential", which need to be quantified. However, considerable liveweight gains obtained during the various grazing experiments, and in-field observations on nodulation, indicate that these factors are not limiting. If Category 4 germplasm continues to show good persistence during present grazing experiments described in the Pasture Utilization Section, pre-cultivar release (Category 5) will be considered in the near future.

At this point it is not possible to predict which accessions of the three most promising species — *Z. latifolia, D. ovalifolium* and *S. capitata* — will be the best under specific environmental conditions. Work planned for 1979 at the three main research sites, and throughout the target area via regional trials, are expected to provide much of the additional information needed before the technology transfer process begins.

GRASS AGRONOMY

The major research activities of the Grass Agronomy Section during 1978 were: (1) to determine the drought tolerance, response to defoliation, response to fertility, and nutritional quality of selected promising accessions; (2) to classify grass accessions according to their relative promise; and, (3) to develop techniques to facilitate future research activities. Criteria for classifying grass accessions are given in Table 17, page B-43. Table 18, page B-44 shows the current classifications based on 1978 results reported in this section.

Drought Tolerance

The drought tolerance of 17 accessions in Categories 3 and 4 were studied in CIAT-Quilichao. Figure 21 shows the dry matter poduction of the 12 most important ones averaged across eight fertility treatments at the end of the April-June rainy season and early and late in the June-September dry season. Erect species were generally more productive than prostrate species early in the dry season, probably because of their reduced water use due to lower mean leaf area indices (LAI). Mean LAI's were lower because more drastic clipping reduced the LAI's of erect species (see Fig. 27).

Figure 22 shows that although the soil was at field moisture capacity (FMC) on May 11 (following heavy rains), by the end of the first growth period (June 15), *Brachiaria decumbens* 606 had reduced the soil profile water content of the top 2 m by 62 mm, and *Andropogon gayanus* 621 had reduced it 44 mm. By the end of the second growing period (August 2), *B. decumbens* had reduced the profile water content a total of 141 mm, and *A. gayanus,* a total of 101 mm. By September 7, the difference in profile water content was calculated to be 33 mm, 187 mm below FMC for *B. decumbens* and 154 mm below FMC for *A. gayanus.*

Table 15 gives typical values of plant water potential and leaf diffusive resistance on the abaxial surface measured in *A. gayanus* 621, *B. decumbens* 606, *Panicum maximum* 604 and *Hyparrhenia rufa* 601 during the June-August dry season in

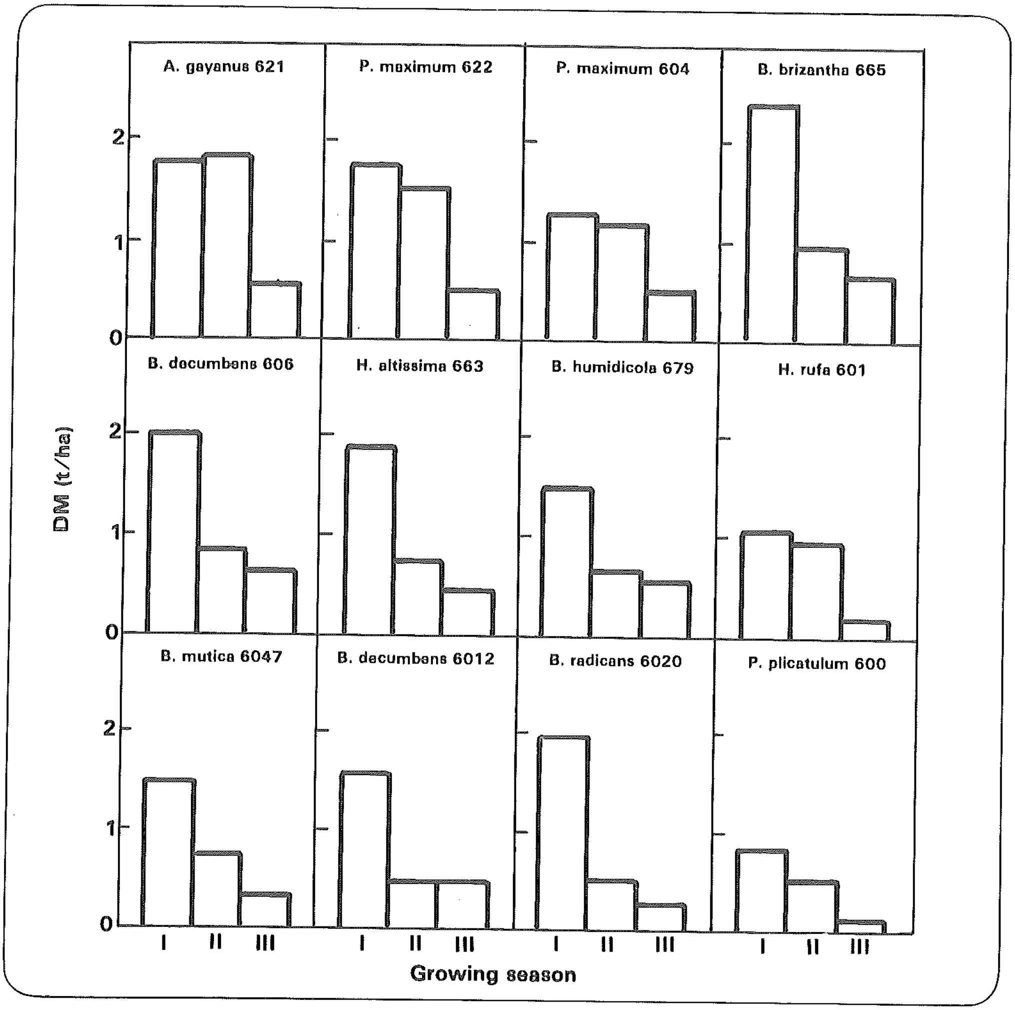

Figure 21. Dry matter (DM) yield of 12 grass accessions averaged across eight fertility treatments and cut at six-week intervals at the end of the April-June 1978 rainy season (I), and early (II) and late (III) in the June-September 1978 dry season, at CIAT-Quilichao.

CIAT-Quilichao. Although differences were not always significant, in both CIAT-Quilichao and Carimagua, *A. gayanus* and *P. maximum* normally maintained a higher plant water potential relative to *H. rufa* and *B. decumbens.* In contrast, *A. gayanus* and *B. decumbens* tended to maintain lower diffusive resistance values than the other two species.

These data suggest that the four species do not close their stomata at the same level of plant water potential. This is shown in more detail in Figure 23. The diffusive resistance of the abaxial leaf surface appears to be most sensitive to plant water potential in *P. maximum,* where stomata always closed before plant water potential reached -20 bars. The diffusive resistance of *B. decumbens* is apparently the least sensitive to low leaf water potential since relatively low abaxial leaf water potentials were observed even when plant water potential approached -30 bars. *A. gayanus*

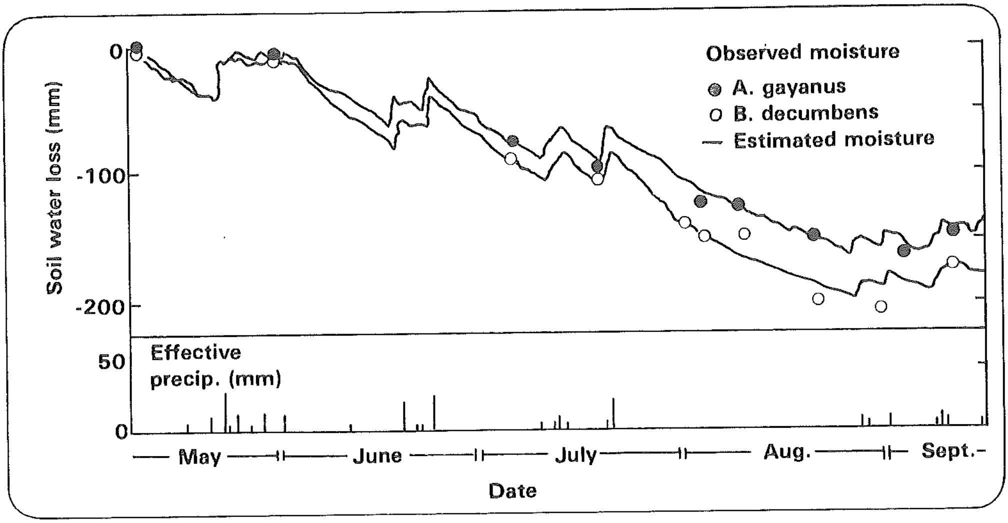

Figure 22. Observed and estimated soil profile moisture content at CIAT-Quilichao. (Soil profile water content was at field capacity on the first sampling date in May).

and *H. rufa* were intermediate in their sensitivities to plant water potential.

Table 16 shows the rooting density and rooting density per unit LAI in the same four species. Although no significant differences in rooting density were observed, the rooting density per unit LAI of *B. decumbens* was notably inferior to the other species.

In summary, the yield advantage of erect species over prostrate species during the early part of the dry season (Fig. 21) was probably due to their conservation of soil water because of lower mean LAI's (Fig. 22). By the late dry season this advantage appears to have disappeared, and *B. decumbens* 606 yielded slightly more than *A. gayanus* 621 and *P. maximum* 604, and much more than *H. rufa* 601. This was

Table 15.

Plant water potential and leaf diffusive resistance in four grass species on two dates during the June-September 1978 dry season at CIAT-Quilichao.

Ecotype		3 Aug. 1978[1] Water potential (bars)	3 Aug. 1978[1] Diffusive resistance (sec/cm)	10 Aug. 1978[2] Water potential (bars)	10 Aug. 1978[2] Diffusive resistance (sec/cm)
Panicum maximum	604	-13.42 a[3]	26.41 b	-10.38 ab	15.84 a
Andropogon gayanus	621	-15.50 a	13.45 a	- 9.51 a	12.36 a
Hyparrhenia rufa	601	-18.96 b	36.72 c	-13.13 b	37.45 b
Brachiaria decumbens	606	-19.08 b	16.34 a	-12.43 ab	14.06 a

1 Experiment 1, 6 weeks of regrowth, LAI > 1.5
2 Experiment 2, 3 weeks of regrowth, LAI < 1.0 except in *B. decumbens*, LAI > 3
3 Means within columns followed by the same letter are not significantly different at P = 0.05.

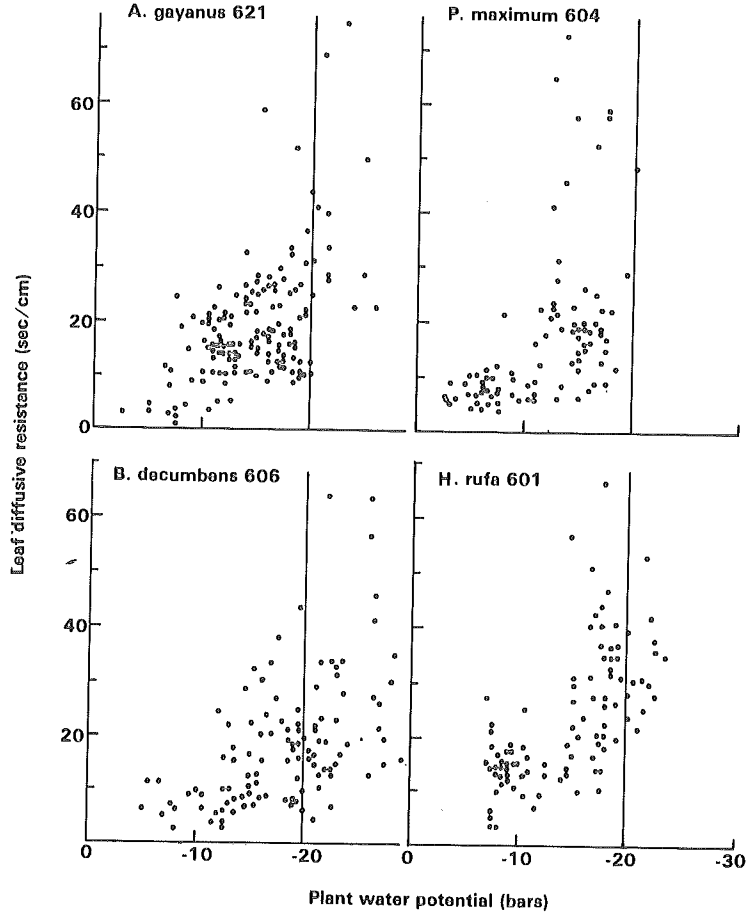

Figure 23. Relationships between plant water potential and leaf diffusive resistance of the abaxial leaf surface in four grass species at CIAT-Quilichao.

Table 16.

Leaf area index (LAI) and root density at 40-80 and 80-120 cm soil depths, for four grass species grown at CIAT-Quilichao.

Ecotype		LAI	Roots 40-80 (cm/cm³)	Roots 80-120 (cm/cm³)	Roots/LAI 40-80 ((cm/cm³)/LAI)	Roots/LAI 80-120 ((cm/cm³)/LAI)
Panicum maximum	604	1.2	1.5 a[1]	0.7 a	1.3 ab	0.61 a
Andropogon gayanus	621	1.3	2.2 a	0.3 a	2.5 a	0.36 ab
Hyparrhenia rufa	601	1.0	2.3 a	0.5 a	2.4 a	0.51 a
Brachiaria decumbens	606	2.0	1.2 a	0.4 a	0.4 b	0.11 b

1 Values in the same column followed by the same letter are not significantly different at the 0.05 level.

probably due to its ability to maintain open stomata under drought stress (Fig. 23). Since *B. decumbens* 606 also had the lowest mean values of rooting density and rooting density per unit LAI, rooting density probably is not a major determinant of drought tolerance in these species.

Response to Defoliation

Twelve accessions were evaluated to determine the effect of clipping height on regrowth. Figure 24 shows their response to a single clipping to 0, 5, 10 and 15 cm. Of the prostrate species, *Brachiaria radicans*

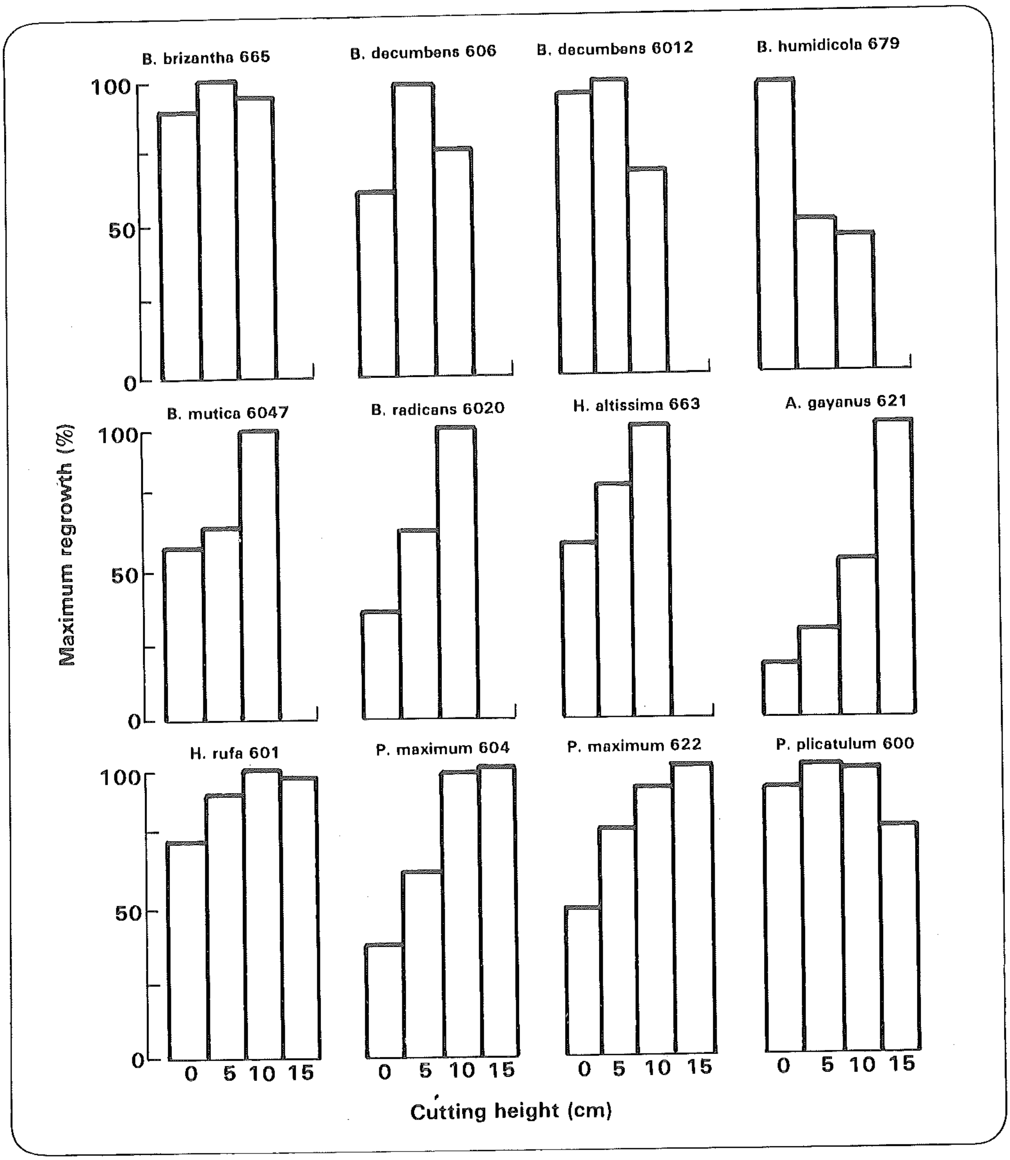

Figure 24. Response of 12 grass accessions to clipping height at CIAT-Quilichao.

6020, *Brachiaria mutica* 6047 and *Hemarthria altissima* 663 were most susceptible to clipping to ground level or 5 cm. Of the erect species, *A. gayanus* 621 and *P. maximum* 604 were the most susceptible.

Since defoliation by burning is common in tropical savannas it is important to know how promising accessions respond to this practice. Figure 25 shows that *A. gayanus* 621 and both accessions of *P. maximum* (604 and 622) were very resistant to burning. Although *Brachiaria* species recovered from burning, they did so more slowly than erect species, and burning could not be recommended as standard practice.

Considerable controversy has been centered on the relative importance of reserve carbohydrates and residual leaf area in determining the regrowth rate of tropical grasses. Regrowth in the dark (regrowth potential) has been shown to be positively correlated with the amount of reserve carbohydrates in the stubble. No correlation was found between regrowth potential and either total regrowth or the mean relative regrowth rate of 11 grass accessions. However, data in Figure 26 show that in the three most productive erect and three most productive prostrate accessions a positive correlation existed between either residual dry matter or residual LAI and regrowth. Regrowth in erect species was more sensitive to the amount of residual material than was regrowth of prostrate species. There were negative relationships between either residual dry matter or residual leaf area and the mean relative regrowth rate. These data illustrate the importance of maintaining sufficient residual dry matter and

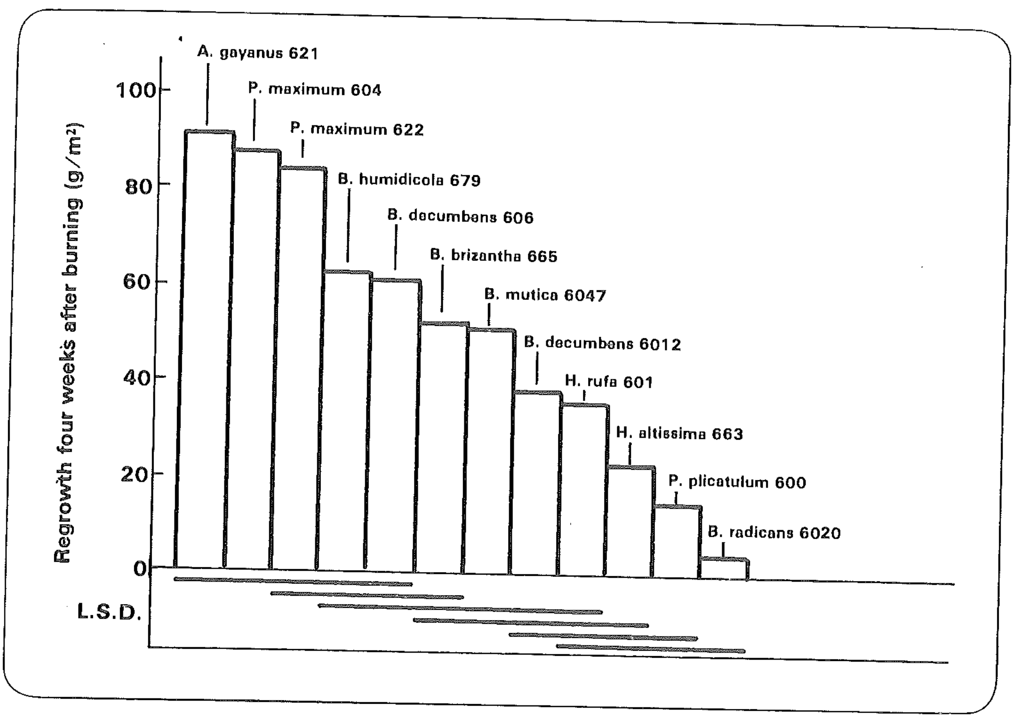

Figure 25. Response of 12 grass accessions to a standard burning treatment at the beginning of the dry season at CIAT-Quilichao.

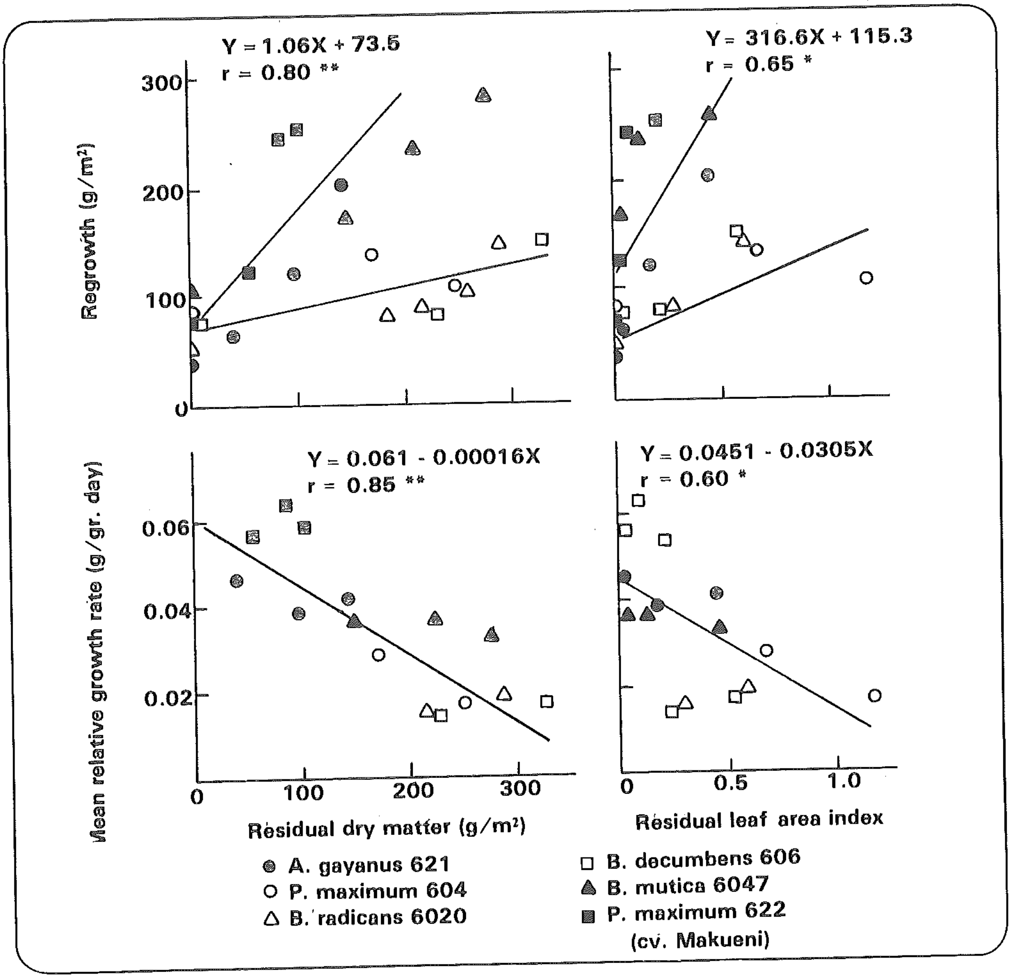

Figure 26. Effects of residual dry matter and residual leaf area index on regrowth and mean relative growth rate in six grass accessions.

leaf area after grazing, especially in erect grasses. Figure 27 shows that after severe defoliation (clipping to 10 cm) two erect and two prostrate accessions had similar relative growth rates, but because erect accessions were left with much less residual dry matter, their actual regrowth rates were lower for the first few weeks.

Fertility Response

Knowledge of the fertility response of grass accessions is important in determining the minimum fertility levels necessary to produce adequate growth. Figures 28 and 29 show first-year rainy season growth response curves of selected accessions to varying levels of N and P fertility in Carimagua. Accessions are arranged in decreasing order of fertilizer response. With high rates of N, *Brachiaria brizantha* 665, *B. decumbens* 606, *Brachiaria humicola* 679 and *A. gayanus* 621, produced over 2.5 t/ha dry matter (DM) basis during an 18-week period without application of fertilizer P, and

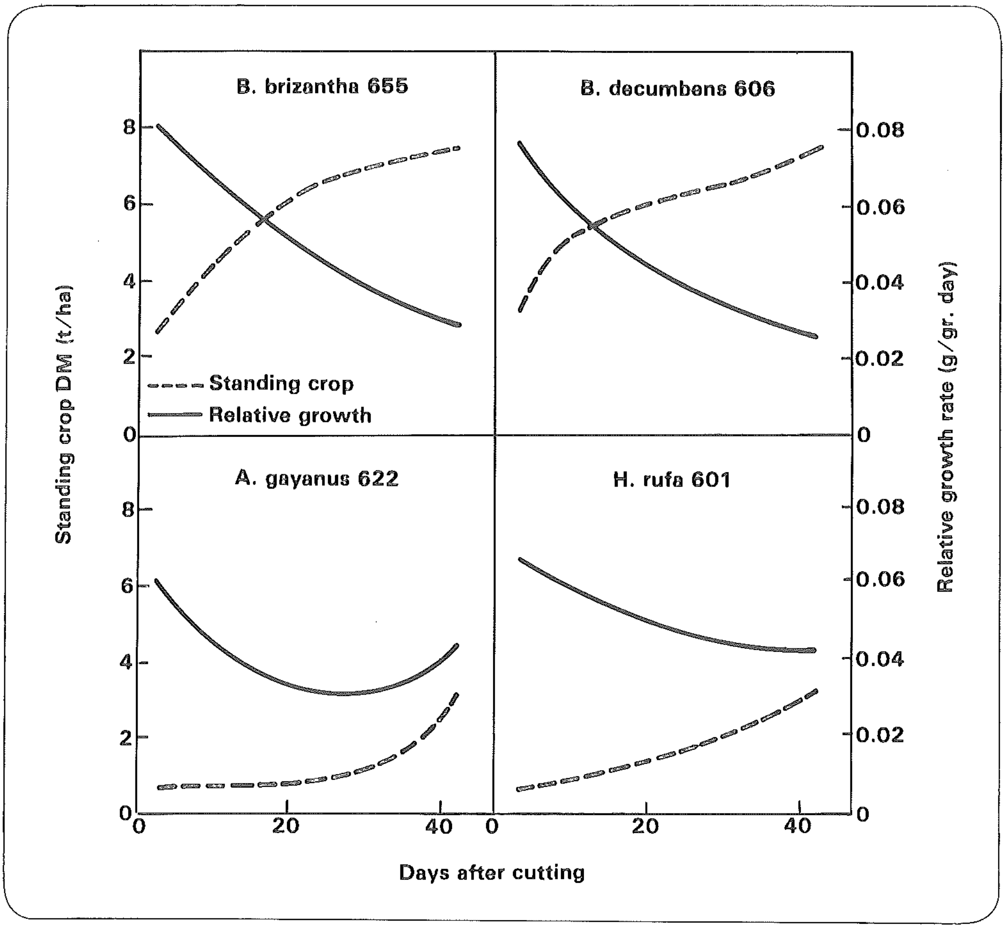

Figure 27. Standing crop and relative growth rate in four grass accessions after severe defoliation at CIAT-Quilichao.

produced over 5 t/ha DM with the application of 50 kg P_2O_5/ha.

In most regions of the Beef Program's target area the routine application of fertilizer N is not economically feasible. It therefore becomes important to identify accessions which have adequate growth rates with minimal inputs of N. Figure 28 shows that *B. brizantha* 665, *B. decumbens* 606, *A. gayanus* 621, *H. rufa* 601, and *P. maximum* 604 yielded at least 4 t/ha DM without fertilizer N, but with adequate P. *A. gayanus* 621, *B. decumbens* 606, and *B. brizantha* 665 performed best under conditions of both low N and low P fertility.

Nutritional Quality

The nutritional quality of tropical grasses is often limited by the DM digestibility or the crude protein (CP) content of material consumed. Figure 30 shows the mean rainy season DM digestibility of 12 accessions. It is notable that even when grab samples are taken to eliminate the error associated with whole-plant samples, *A. gayanus* 621 and *B.*

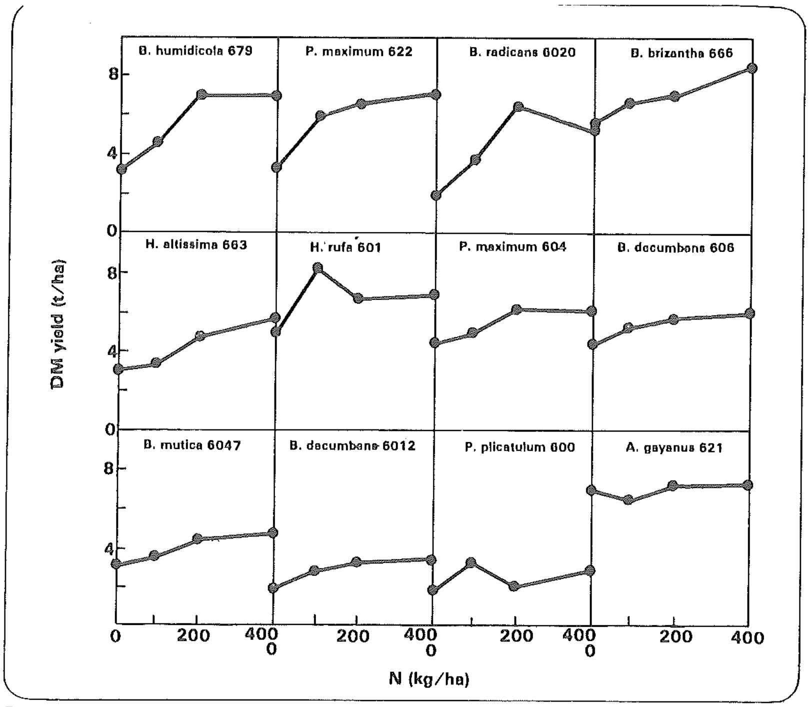

Figure 28. Response of 12 grass accessions to N fertilization at Carimagua. (Sums of three cuts in rainy season; all treatments received 200 kg P_2O_5/ha.)

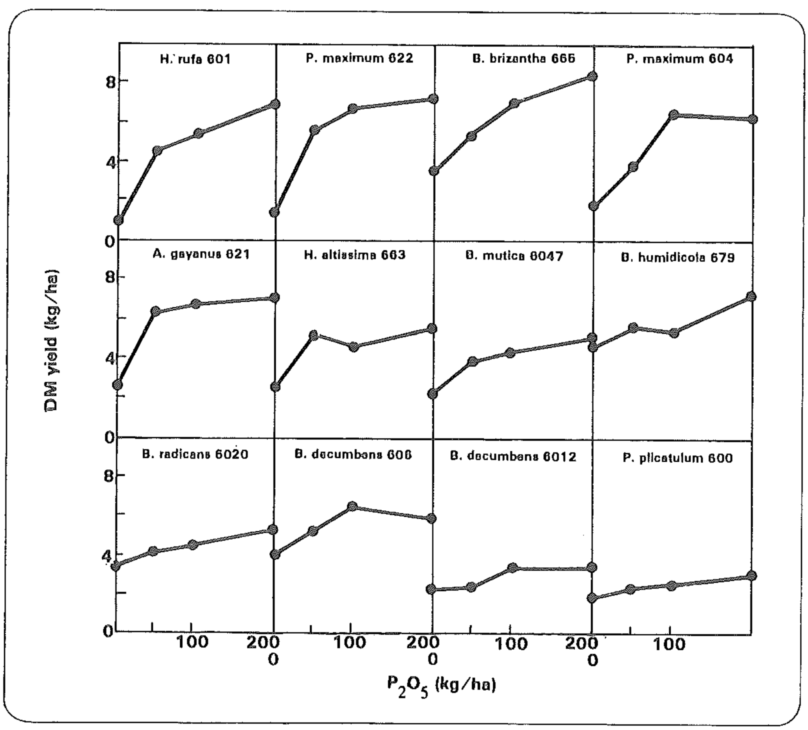

Figure 29. Response of 12 grass accessions to P fertilization at Carimagua. (Sums of three cuts in rainy season; all treatments received 400 kg N/ha/year).

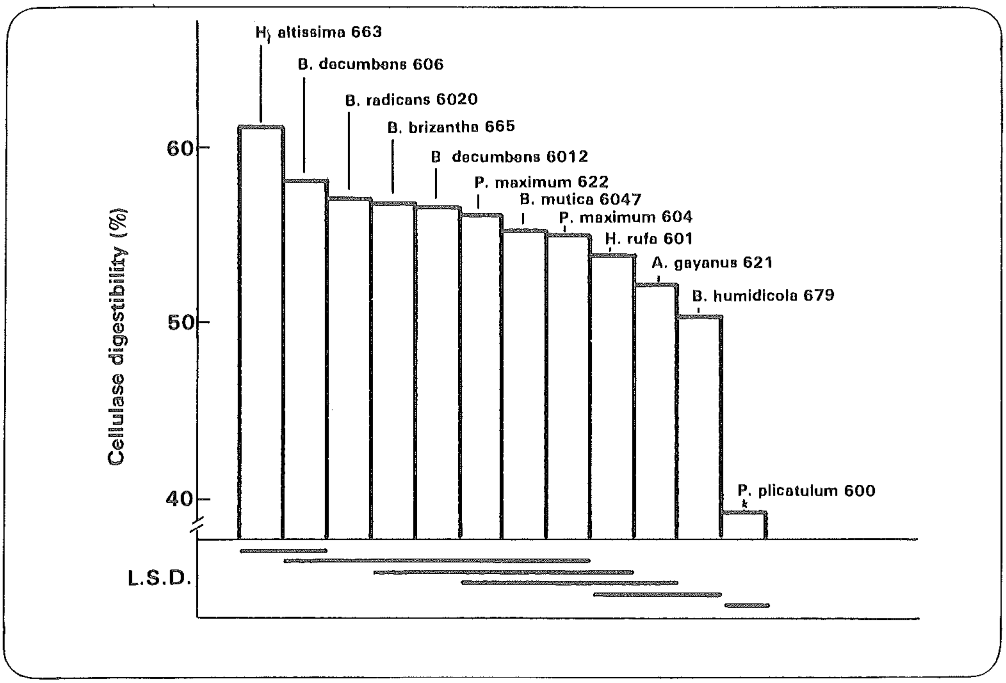

Figure 30. Mean dry matter digestibility by cellulase assay of grab samples of six-week-old regrowth in the rainy season and under eight fertility treatments at Carimagua.

humidicola 679, are among the lowest in DM digestibility.

The N or CP content of grasses growing on soils low in N often limits animal growth in the tropics. Figure 31 shows the mean N content of grab samples of the six-week regrowth of 12 accessions taken from low-N treatments. *A. gayanus* 621, although relatively low in DM digestibility, has relatively high levels of N. *H. altissima* 663, although the highest in DM digestibility, is low in N. *B. humidicola* is low in both DM digestibility and N.

Improvements in Methodology

Other activities during the year involved adapting the Campbell-Brewster hydraulic press (Fig. 32) to estimate leaf water potential in tropical grasses. This method is about twice as rapid as the Scholander pressure chamber and allows up to four treatments to be measured simultaneously. Its ease of construction and handling in the field are additional advantages. The correlation coefficient between measurements with the hydraulic press and the pressure chamber was 0.90.

Root length per unit volume of soil (rooting density) is a widely accepted measure of root system "activity". One of the most time-consuming steps in measuring rooting density is measuring the root length of the samples of roots. A technique was developed whereby root samples are passed by the sensing head of an automatic leaf area meter, and the root "area" of the sample is correlated with root length estimated by conventional means. The regression coefficient between the conventional technique and the root area technique was 0.85. The root area technique requires approximately one-tenth the time of conventional measuring techniques.

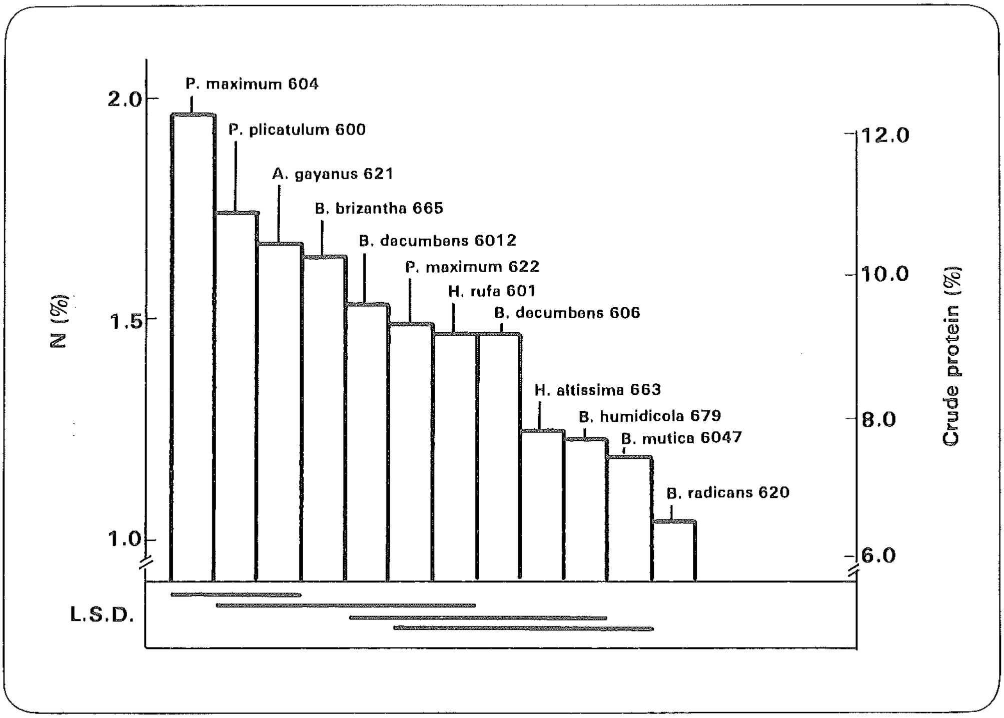

Figure 31. Mean N and crude protein contents of grab samples of six-week-old regrowth in the rainy season at Carimagua and CIAT-Quilichao in treatments having 0 or 50 kg N/ha/year.

In cooperation with the Climatology Unit, a computerized soil water balance model utilizing soil, plant, and climatic inputs and developed for use in a humid sub-tropical environment was adapted for use in the tropics. In CIAT-Quilichao the model predicted the water content of profiles under *B. decumbens* and *A. gayanus* with an error of less than ± 15 mm throughout the period from May to September 1978 (see Fig. 22).

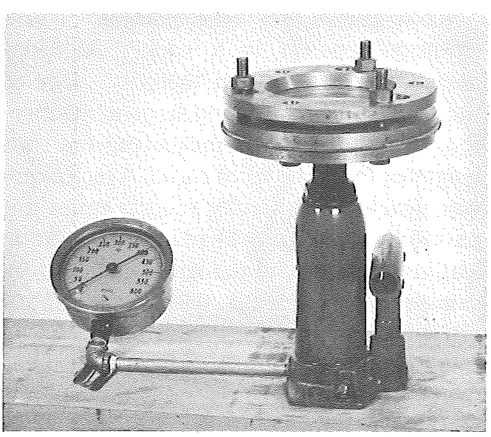

Figure 32. Adapted Cambell-Brewster hydraulic press.

The soil water balance model was used to estimate the transpiration from a clipping frequency experiment conducted by the Legume Agronomy Section. When transpiration calculated by the model was regressed on dry matter yield, a high correlation (0. 95) was observed. Although the relationship between transpiration and dry matter production must be determined at a given location, the technique could be very valuable for the simulation of seasonal growth or growth during years with different precipitation totals.

Table 18.

Summary of evaluations of promising grass accessions included in Categories 3, 4 and 5. (Blanks indicate unknown reactions to conditions.)

Species and CIAT No.	Acid soil tolerance	Vigor in CIAT-Quilichao	Vigor in Carimagua	Drought resistance	Disease resistance	Insect resistance	Nutritional quality	Tolerance to burning	Seed production	Ease of management	Compatibility with legumes	Animal productivity	Tolerance to flooding	Category in 1978	Recommendation for 1979
Andropogon gayanus 621	+	+	+	+	+	+	-	+	+	-	+	+	-	4	5
Brachiaria brizantha 665	+	+	+	+	+	-	+	+	+				-	3	3
Brachiaria decumbens 606	+	+	+	+	+	-	+	-	+	+	-	+	-	4	4
Brachiaria decumbens 664	+	-	-	-	+	-	+	-					-	3	S[1]
Brachiaria decumbens 6012	+	-	-	-	+	-	+	-					-	3	S
Brachiaria humidicola 679	+	+	+	+	+	+	-	-	-				+	3	4
Brachiaria humidicola 6013	+	+	+	+	+	+	-	-	-					3	S
Brachiaria mutica -	+	+	-	-	+	+	+	-	-				+	3	3
Brachiaria radicans 6020	+	+	-	-	+	+	-	-					+	3	3
Brachiaria ruziziensis 6019	+	-	-	-	+	+	+	-	-					3	S
Eriochloa polystachya 6017	+								+				+	3	3
Hemarthria altissima 663	+	+	-	-	+	+	+	-	-				+	3	3
Hyparrhenia rufa 601	+	-	+	-	+	+	-	-	+		+		-	3	S
Melinis minutiflora 608	+		-	-				-	+	+			-	3	S
Panicum maximum 604	+	+	+	-	-	+	+	+	+	+	+	+	-	3	4
Panicum maximum 622	+	+	+	-	+	+	+	+	+		+		-	3	4
Paspalum plicatulum 600	+	-	-	-	-	-	-	+	+	+			+	3	S

1 S = suspended from further evaluation

Classification of Grass Accessions

All grass accessions were classified according to our knowledge of their agronomic behavior and their promise within the Program. Table 17 is a summary of the evaluations used for each category. Table 18 summarizes current evaluations of accessions in Categories 3, 4, and 5 according to the selection criteria established in 1977. Approximately 40 accessions are currently in Category 2 and are being evaluated under common grazing and in association with a common legume in Carimagua and CIAT-Quilichao.

Table 17. Categories of promise and their implications for grass germplasm evaluation.

Category	Type of evaluation
1	1. Botanical characterization 2. Adaptation to soil and climate in CIAT-Quilichao 3. Disease and insect resistance
2	1. Response to 2 fertility levels in Carimagua 2. Persistence and compatibility with legumes under common grazing 3. Drought resistance 4. Disease and insect resistance 5. Nutritive value
3	1. Regional trials 2. Fertility requirements
4	1. Systems of establishment 2. Seed production systems 3. Systems of utilization and management (animal production trials
5	1. Multiplication of basic seed 2. Completion of research prior to release

Andropogon gayanus

In 1973 *Andropogon gayanus* 621 was introduced from Shika, Nigeria by Dr. Bert Grof of the CIAT Beef Program. It has been extensively evaluated at CIAT-Palmira, Carimagua, El Limonar and CIAT-Quilichao. It is included in the Beef Program's regional trials, and as a result of its promise for the acid, infertile soils of the target area it was promoted this year to Category 5 (Tables 17 and 18).

Preliminary rainy season animal gain data are also promising, but adequate dry season data are not yet available. Nevertheless, *A.gayanus* 621 is sufficiently promising that basic seed production will begin in 1979, and a final decision regarding a joint release with the Instituto Colombiano Agropecuario (ICA) will be made in late 1979.

SEED PRODUCTION

This Section continued to meet two basic objectives: (1) seed production for experimental purposes and production of foundation seed of new cultivars, and (2) development of relevant technology for commercial forage seed production.

Primary emphasis has been upon seed increase of experimental lines with seeds being used within the Beef Program. However, with increasing emphasis upon certain species, an expanded research effort was defined, collaborators identified and projects initiated both in Colombia and in locations at higher latitudes.

Seed Increase

Seed increase is confined to accessions nominated to the promising list by the Program's Germplasm Committee. Initial seed production targets are consistent with the five categories assigned. Seed was produced from 35 accessions at three locations in Colombia during the year.

A large part of this seed increase effort is plant propagation. Seed production plots are established either by vegetative propagation, single plant transplanting or direct field seeding. A total of 12 ha of new crop area was established and the average total area under seed increase was 15 ha during 1978. CIAT-Quilichao was the principal location with 10 ha of crops while 3 ha were maintained at Palmira and 5 ha of new plots were established at Carimagua. The transition from the rainy season to dry season at CIAT—Quilichao during December 1977 was prolonged, causing adverse effects upon flowering synchronization, especially in *Centrosema, Pueraria* and *Stylosanthes capitata.* With few exceptions, harvesting was done manually to avoid contamination and for greater efficiency of recovery when working with relatively small crop areas. Harvesting was during January-February and again during July-August at CIAT-Quilichao and Palmira, and during November at Carimagua. Total production amounted to 2468 kg of graded seed (Table 19), with emphases upon *Andropogon gayanus* and accessions of *S. capitata.*

The present production locations all share the restriction of little variation in dry season length due to their low latitude. Palmira and Quilichao have bi-modal rainfall patterns and the effective natural growing season is restricted to three months—insufficient for all species within the establishment year. The longer growing season available at Carimagua is therefore an advantage within the establishment year but is basically a disadvantage in the following years. Plans were made to initiate seed increase at Brasilia (17°S latitude), both to exploit the higher latitude and to help fulfill the expanding seed requirements for experimentation in the Cerrado.

Seed Production Technology

Crop Maturity Patterns and Harvest Methodology

Brachiaria decumbens. A crop was sampled over a one-month period extending from early seed maturity until complete seed shattering (Fig. 33). The objective was to record hand-harvested seed yield and quality and to identify the optimum harvest period.

This seedling crop of relatively low plant density flowered over an extended period commencing in early July. As a result, seed maturity showed a very broad peak in that more than 50 kg/ha of pure seed was harvestable for a two-week period and even 75% of maximum yield of pure seed was recoverable over seven days. After the total population of inflorescences reached a plateau by August 2, a maximum yield of 89 kg/ha of pure seed was recorded by August 9. This coincided with marked changes in the relative proportion of "immature", "mature" and "shattered" inflorescences. At maximum yield of pure seed, the percentage of mature inflorescences declined markedly from a peak of approximately 70% while percentage shattered inflorescences increased markedly above 10%. The unit weight of pure seed was approximately 400 mg/ 100 seeds at maximum yield of pure seed but continued to increase for another eight days to a maximum of 450 mg/ 100 seeds. Seed germination data are needed to

Table 20.

Comparison of manual and direct combine harvesting of three commercial lots of *Brachiaria decumbens.*

Comparison	Direct combine	Manual
Pure seed yield (kg/ha)	35	59
Percent recovery (on pure seed basis)	59	100
Unit weight of pure seed (mg/100)	457	388

harvest maturity. Therefore, the method of recovery from the ground was obviously not at its maximum potential. The traditional manual method provided highest yields of pure live seed, 34 kg/ha. A re-threshing step added to the manual method provided 10% more pure live seed, but this seed had a low germination capacity (25%), and probably a short storage life; thus, re-threshing is not recommended. Even at this time, the recollection from ground was the next most efficient method, recovering 24 kg/ha of pure live seed mainly because of the very high (74%) seed germination. Direct combining versus windrow pick-up by the combine four days after cutting recovered 13 and 17 kg/ha pure live seed, respectively, indicating the combine recovered at best 50% of yields obtainable by the traditional manual method. Comparison of the traditional method versus windrow pick-up indicates that 50% losses can be made by the combine during threshing alone, even after sweating.

Yields in the July crop were higher than the January crop. The manual method was initiated on July 7 but a mechanical problem delayed combine treatments until July 11. During this period there was a very significant increase of seed recovered from the ground (over 100 kg/ha), indicating a high degree of seed shattering. Thus, when compared to the manual method, two methods including the combine (3 and 4) confound methodology and time of harvest and reduce the interpretations which can be made. The potential of recovering seed from the ground becomes more apparent as sampling was continued for 12 days after the point of optimal plant harvest and a maximum of 100 kg/ha of pure live seed was collected on July 19. Again, very high seed germination was recorded, 43% compared to an average of 20% for other methods. It is not valid to compare the combine-involved methods 3 and 4 to the traditional hand-harvest method. Comparing methods 1 and 5 indicates 30% losses due to threshing by the combine after sweating as opposed to manual threshing. Again, there was a small advantage to windrow pick-up as opposed to direct combining.

Overall, it appears that the cheapest and most efficient harvest method for *A. gayanus* is the traditional manual method. In regions where crop maturity coincides with a dependable dry season that reduces the risk of damage from unseasonal rainfall, recovery of shattered seed from the ground appears very feasible and would be facilitated by row spacings of approximately 1.5 m. Obviously, with large crop areas, combining would become feasible even with lower efficiency of recovery. These investigations will be continued.

The traditional hand-harvest method used with many tropical grasses including *A. gayanus,* includes a field sweating phase where flowering stems are cut and stacked in heaps for three to four days. Concern is often expressed that conditions within the heap may adversely affect seed germination. Tests conducted upon hand-harvested seed with post-harvest

Table 21.

Results of evaluations of harvest methodology for *Andropogon gayanus*.

		Expt. 1, January			Expt. 2, July		
		Pure seed		Pure live seed	Pure seed		Pure live seed
Harvest method	Date 1978	Yield (kg/ha)	Germination 7 mo. (%)	Yield 7 mo. (kg/ha)	Yield (kg/ha)	Germination 3 mo. (%)	Yield 3 mo. (kg/ha)
1. Traditional manual cutting, field stacking, and threshing	Jan. 23	69	50	34	-	-	-
	July 7	-	-	-	262	18	47
1a. Same as 1, plus re-threshing	Jan. 23	11	25	3	-	-	-
2. Recovery from ground	Jan. 23	32	74	24	-	-	-
	July 7	-	-	-	104	27	28
	July 12	-	-	-	208	35	73
	July 19	-	-	-	232	43	100
3. Direct combining	Jan. 23	32	41	13	-	-	-
	July 11	-	-	-	47	25	12
4. Manual cutting, *in situ* wind-rowing and combine pick up	Jan. 23	33	50	17	-	-	-
	July 12	-	-	-	64	22	14
5. Manual cutting and field stacking with combine threshing	Jan. 23	32	52	17	-	-	-
	July 7	-	-	-	233	14	33

treatments of 0, 3, 6 and 9 days sweating, resulted in 83, 78, 63 and 44% germination, respectively, at 10 months. These results indicate that while sweating in properly constructed heaps for three days has no adverse effects, longer periods can reduce germination.

Regional Seed Production Potentials

Identifying appropriate geographic regions for seed production is of fundamental importance to the development and economics of commercial seed production and any research effort to support this enterprise. Geographic regions where seed (not forage) production is optimized provide favorable combinations of climatic, edaphic, agronomic and economic factors to consistently promote both high yield and quality of seed, plus consistent recovery at harvest. Generally, the legumes are more demanding in this regard than most grasses. CIAT, as an international institution, is well-suited to coordinate such a widespread project, one which will also assist the development of seed supplies required for the Beef Program's experimental activities.

A formal project proposal was developed and sent to potential collaborators at locations over a range of latitudes, total annual precipitation and seasonal temperature regimes but emphasizing regions with marked seasonal distribution of rainfall and low or zero incidence of frost. Plantings of a variety of legumes and grasses, nominated by the collaborators at CIAT, were made beginning in November 1978 to define phenology, seed yields, incidence of pests and diseases, and other parameters relating to commercial production potentials. Collaboration has been confirmed with the Centro de Pesquisa Agropecuaria de Cerrados (CPAC) at Brasilia, 17°S; the Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG) at Sête Lagoas, 18°S, and Felixlandia, 17°S, in Brazil; at Santa Cruz, 17°S, with the Centro de Investigación Agrícola Tropical (CIAT), Santa Cruz, and at Valle de Sajta, 17°S, with the Cooperación Técnica del Gobierno Suizo (COTESU) in Bolivia; and with the Instituto Colombiano Agropecuario (ICA), at Valledupar, Colombia.

A preliminary experiment conducted in collaboration with the Beef Program Forage Agronomist at CPAC, Brasilia during 1978 indicated the potential severity of weed problems in legume establishment (especially *Pennisetum setosum, Cenchrus* sp. and *Acanthosperum australe)* and the presence of the budworm *Stegastra bosqueella* in all *Stylosanthes* species. High first-year, hand-harvested, pure seed yields were recorded in *A. gayanus,* 290 kg/ha; *B. decumbens,* 96 kg/ha; *Brachiaria ruziziensis,* 160 kg/ha; and *Calopogonium muconoides,* 900 kg/ha.

Andropogon gayanus. Nitrogen response: An established stand at El Limonar (near CIAT-Quilichao) provided an experimental area to investigate effects of N rates and application methods on yield of pure seed. The stand was burned on August 25, received adequate rainfall after September 14, commenced flowering in mid-October and matured in mid-December. Nitrogen applications are described in Table 22. Considerable difficulty was encountered in determining the optimal harvest date. One replication was harvested on December 19 and the remainder on December 27. There were no differences between treatment means based upon data from all four replications. However, there was a significant difference between repetitions related to date of harvest, clearly indicating that the December 27 harvest was too late and that any possible treatment differences could not be recorded at that time. Therefore, the unreplicated data from the December 19 harvest warrants independent comment. These data indicated a strong trend for pure seed yield to increase with levels of increasing N. A pure seed yield of more than 200 kg/ha was recorded with both 200 and 300 kg N/ha applied in two split applications. These investigations will be continued.

De-awning: With the *A. gayanus* spikelet being very hairy and having a long awn, seed masses naturally tend to clump and do not flow easily. A de-awner or de-bearder was developed to overcome this

Table 22.

Effect of N applications upon pure seed yield of *Andropogon gayanus* at El Limonar.

Nitrogen application (kg/ha)			Yield of pure seed (kg/ha)	
Sept. 20	Oct. 14	Total	Dec. 19	Dec. 27
0	0	0	111	68
100	0	100	134	66
200	0	200	163	60
50	150	200	206	80
50	250	300	225	80

difficulty which complicates seed processing.

Basically, this machine includes a metal cylinder 71 x 30 cm with protruding rubber fingers, an upper concave with a ribbed rubber surface, and a curved semi-cylindrical lower concave made up of screens with variable apertures. A range of cylinder speeds from 250 to 750 rpm are available from three pulleys and clearance between the drum fingers and the curved concave screen is adjustable from 1 to 5 cm. Seed is fed manually from a small hopper into the central revolving cylinder and are withdrawn by a basal auger. The machine has a capacity of approximately 50 kg/hr.

Purity analysis: Determinations of both yield in standard terms of pure seed and of germination of the pure seed fraction require a standardized method of purity analysis.

A "quick" or "Irish" purity test was developed using a 10-g sample and defining a pure seed as any basal spikelet plus appendage. The main value of this test is its speed and the fact that 100 minus Irish purity equals the minimum level of inert matter as would be defined by the International definition of purity. The Irish purity test, therefore, provides an easy check on the minimum quantity of inert matter present in a seed sample but does not define the real nature of the pure seed fraction.

An International purity test (where the pure seed fraction is only those spikelets which contain a confirmed caryopsis) was developed defining the pure seed fraction as the basal spikelet containing a caryopsis but excluding the awn, any free caryopsis or parts thereof and germinated spikelets excluding the awn. Inert material includes basal spikelets without caryopsis, all upper spikelets, all awns, as well as soil, sand and vegetative plant parts, etc. The separation of a 6-g sample into its three component fractions — pure seed, inert matter and weeds — is very laborious and requires approximately four hours.

An attempt was made to develop a more rapid indirect means of estimating International purity, exploiting the relationship between caryopsis content (expressed as a percent based on number) and International purity (expressed as a percent based on weight) of the Irish pure seed fraction of any sample. Using a wide range of samples a linear regression equation of $Y = 1.099 X$, ($R^2 = 0.993$), was defined where Y = International purity of the Irish pure seed fraction and X = caryopsis content of the Irish pure seed fraction. For a given seed sample the procedure to calculate International purity indirectly is: (1) determine Irish purity and caryopsis content; (b) from the equation determine the International purity of the Irish pure seed fraction; and (c) multiply this value by percentage Irish purity. While this method is providing data closely approximating values derived by direct determinations of International purity, its utility remains under investigation.

PLANT PATHOLOGY

The Plant Pathology Section commenced activities in July 1978. The major aims of this section are to detect, identify and assess diseases of germplasm under evaluation and to develop control measures for damaging diseases of promising forage species.

The primary activity this year was initiation of extensive microflora surveys of germplasm currently under field evaluation and of related indigenous species to determine the incidence and severity of pathogenic organisms.

Anthracnose

Anthracnose is the most damaging disease of tropical forage legumes in Central and South America, Australia and Florida. In Central and South America, this disease had been reported to be caused by one fungus, *Colletotrichum gloeosporioides,* and only *Stylosanthes* species have been reported to be affected.

Because of its importance, a specific survey to determine the occurrence and severity of anthracnose at Carimagua, El Limonar (near CIAT-Quilichao) and the Quilichao sub-station was initiated. Fifteen random isolations were made from accessions with suspected anthracnose lesions. To date, results have emphasized the widespread occurrence of anthracnose (Tables 23, 24 and 25). Most legume genera currently under evaluation, as well as members of the indigenous flora, were hosts to anthracnose at the three locations. In addition, two species of *Colletotrichum* were involved, *C. gloeosporioides* and *C. dematium,* and on any particular accession, symptoms caused by both fungi were identical.

Although anthracnose was widespread, its severity varied considerably among genera and accessions. At all locations, anthracnose, primarily caused by *C. gloeosporioides,* was severe on *Stylosanthes guianensis* accessions. Most *Stylosanthes capitata* plantings at Carimagua and Quilichao were only slightly infected or unaffected. At El Limonar, although stem lesions were numerous in 2.5-year-old plantings of *S. capitata* (CIAT 1019, 1078, 1097 and 1405), their effects appeared minor. Past screening of stylo accessions to *C. gloeosporioides* (CIAT Annual Report, 1976 and 1977), together with field observations, had shown *S. capitata* to be highly tolerant to anthracnose. A study of this tolerance is being initiated.

On *Zornia* accessions, slight to moderately severe leaf spotting was caused by *C. dematium* at Carimagua and by both *Colletotrichum* spp. at Quilichao. *C. gloeosporioides* caused die-back in several plantings of *Pueraria phaseoloides* at Carimagua. Anthracnose fungi caused minor leaf and stem lesions on other legumes. *Desmodium ovalifolium* was the

Table 23.

Frequency of occurrence on tropical forage legumes of anthracnose-causing fungi (*Colletotrichum* spp.) at Carimagua. (Mean of 15 random isolations per accession).

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes capitata		
No occurrence	1342, 1497, 1504, 1520, 1533, 1535, 1642, 1728	1342, 1497, 1535, 1728
Slight occurrence	1019, 1315[1], 1499	1504, 1520, 1533, 1642
Moderate occurrence	1078	1019, 1078, 1499
Severe occurrence	-	1315
Stylosanthes guianensis		
No occurrence	1533, 1551, 1569	136, 1553, 1569, 1571
Slight occurrence	1486, 1578	1480, 1486, 1503, 1533, 1549, 1551, 1562, 1565, 1573, 1649
Moderate occurrence	1480, 1503, 1549, 1565, 1571, 1573	1578
Severe occurrence	136, 1553, 1562, 1649	
Stylosanthes hamata		
No occurrence	-	147
Severe occurrence	147	-
Stylosanthes humilis		
No occurrence	1303	-
Moderate occurrence	-	1303
Stylosanthes ingrata		
No occurrence	-	1604
Severe occurrence	1604	-

1 Sexual state production.

continued

Table 23. (continued)

Species	Accessions showing occurrence of *C. gloeosporioides*	*C. dematium*
Stylosanthes scabra		
No occurrence	1583	1583
Aeschynomene sp.		
No occurrence	9874	-
Slight occurrence	-	9874
Cassia sp.		
No occurrence	Native	-
Slight occurrence	-	Native
Centrosema spp.		
No occurrence	5061	5061
Moderate occurrence	438	-
Severe occurrence	-	438
Desmodium barbatum		
No occurrence	Native	-
Slight occurrence	-	Native
Desmodium heterophyllum		
No occurrence	349	-
Slight occurrence	-	349
Desmodium heterocarpon		
No occurrence	365	365
Desmodium ovalifolium		
No occurrence	350	350

continued

Table 23. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Galactia spp.		
No occurrence	964, 9152	9152
Moderate occurrence	-	964
Indigofera sp.		
No occurrence	Native	-
Severe occurrence	-	Native
Macroptilium spp.		
No occurrence	-	4049
Slight occurrence	4115	4115
Moderate occurrence	4049	-
Pueraria phaseoloides		
No occurrence	-	9900
Severe occurrence	9900	-
Soemmeringia spp.		
No occurrence	9471, 9844	-
Slight occurrence	Native	9471, 9844
Moderate occurrence	-	Native
Zornia spp.		
No occurrence	9166, 9199, 9203, 9225, 9226, 9245, 9258, 9284, 9292, 9602, 9644, 9915	9258
Slight occurrence	728	9166, 9203, 9225, 9226, 9245 9602, 9644, 9915
Moderate occurrence	-	728, 9199, 9284
Severe occurrence	-	9292

Table 24.

Frequency of occurrence on tropical forage legumes of anthracnose-causing fungi *(Colletotrichum* spp.) at El Limonar, near CIAT-Quilichao. (Mean of 15 random isolations per accession).

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes capitata		
No occurrence	-	1078, 1097, 1342
Slight occurrence	1342	1405
Moderate occurrence	-	1019
Severe occurrence	1019[1], 1078[1], 1097[1], 1405[1]	
Stylosanthes guianensis		
No occurrence	1200	64-A, 151-A, 184, 191-B, 1135, 1152, 1175, 1200 1705
Slight occurrence	1152, 1175,	191-A
Moderate occurrence	151-A, 1135[1]	-
Severe occurrence	64-A, 184, 191-A, 191-B 1705[1]	-
Stylosanthes hamata		
No occurrence	-	118, 147
Moderate occurrence	118	-
Severe occurrence	147[1]	-
Stylosanthes humilis		
Slight occurrence	1304	-
Moderate occurrence	-	1304
Stylosanthes sympodialis		
No occurrence	-	1043, 1044
Moderate occurrence	1043, 1044	

1 Sexual state production.

continued

Table 24. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Stylosanthes viscosa		
No occurrence	-	1074-A, 1132
Slight occurrence	1132	-
Severe occurrence	1074-A	-
Calopogonium muconoides		
No occurrence	-	Sp.
Moderate occurrence	Sp.[1]	-
Desmodium ovalifolium		
No occurrence	350	350
Desmodium heterocarpon		
No occurrence	365	365
Desmodium canum		
No occurrence	367	367
Desmodium barbatum		
Slight occurrence	Native	Native

1 Sexual state production.

Table 25.

Frequency of occurrence on tropical forage legumes of anthracnose-causing fungi (*Colletotrichum* spp.) at CIAT-Quilichao. (Mean of 15 random isolations per accession).

	Accessions showing occurrence of	
Species	*C. gloeosporioides*	*C. dematium*
Stylosanthes capitata		
No occurrence	1325, 1495, 1499, 1520, 1728	1315, 1325, 1342, 1405
Slight occurrence	1342[1], 1497, 1516, 1519, 1535	1019, 1078, 1097, 1497, 1535,
Moderate occurrence	1019. 1097, 1315[1],	1499, 1520
Severe occurrence	1078[1], 1405	1495, 1516, 1519, 1728
Stylosanthes guianensis		
No occurrence	1062, 1175, 1825, 1829, 1832, 1833, 1838, 1842, 1856, 1871, 1905	64-A, 184, 1062, 1135, 1175, 1698, 1735, 1749, 1755, 1763 1825, 1826, 1829, 1830, 1832 1833, 1838, 1842, 1846, 1856, 1863, 1867, 1871, 1902, 1905,
Slight occurrence	1135, 1698[1], 1830	136
Moderate occurrence	1826	-
Severe occurrence	64-A, 136, 184, 1735, 1749, 1755, 1763, 1846, 1863[1], 1867, 1902	-
Stylosanthes hamata		
No occurrence	-	118, 147
Slight occurrence	147	-
Severe occurrence	118	-
Centrosema spp.		
No occurrence	4042, 5175, 5177, 5196	438, 4042, 5062, 5107, 5108, 5175, 5177, 5196
Slight occurrence	5062, 5108	-
Severe occurrence	438, 5107	-

1 Sexual state production

continued

Table 25. (continued)

Species	Accessions showing occurrence of	
	C. gloeosporioides	*C. dematium*
Desmodium ovalifolium		
No occurrence	350	350
Desmodium barbatum		
Slight occurrence	-	Native
Severe occurrence	Native[1]	-
Galactia striata		
Slight occurrence	-	964
Severe occurrence	964	-
Macroptilium spp.		
No occurrence	4014, 4015, 4050, 4133	535, 4009, 4014, 4015, 4050 4133
Slight occurrence	535	-
Moderate occurrence	4009	-
Vigna spp.		
No occurrence	4188, 9546	4120, 4139, 4188, 9546
Moderate occurrence	4120[1], 4139	-
Zornia spp.		
No occurrence	9472, 9651, 9925	9166, 9292, 9472, 9651, 9771, 9925
Slight occurrence	9166	-
Moderate occurrence	728, 9292, 9771	728

1 Sexual state production.

only promising forage legume not affected by anthracnose.

Colletotrichum isolates are being collected from most-affected accessions. Screening trials to evaluate resistance of promising legumes to anthracnose fungi and to determine host ranges are in progress. If legume mixtures are used, it is essential to determine whether *Colletotrichums* pathogenic to one legume could affect other legumes.

At Carimagua, newly established *S. guianensis* germplasm accessions from Colombia were more susceptible to anthracnose than germplasm from Venezuela and Brazil (Table 26). These observations suggest that further collections of *S. guianensis* should be made in Venezuela and Brazil where anthracnose pressures appear to be more selective than in Colombia.

The importance of evaluating germplasm under a variety of ecosystems is stressed.

Table 26.

Evaluation of anthracnose on *Stylosanthes guianensis* in introduction plots (for grazing) at Carimagua.

CIAT No.	Origin	Date planted 1978	Preliminary anthracnose evaluation[1] 11 October
136	Meta, Col.	April 29	3
1562	Meta, Col.	April 29	3
1578	Meta, Col.	April 29	2
1571	Meta, Col.	April 29	3
1563	Meta, Col.	June 3	3
1549	Meta, Col.	June 3	3
1577	Meta, Col.	June 3	2
1564	Meta, Col.	June 3	1
1551	Meta, Col.	June 3	1
1552	Meta, Col.	June 3	3
1572	Meta, Col.	June 3	3
1573	Meta, Col.	June 3	2
1566	Meta, Col.	June 3	3
1557	Meta, Col.	July 20	2
1568	Meta, Col.	July 20	4
1574	Meta, Col.	July 20	1
1553	Meta, Col.	July 20	4
1560	Meta, Col.	July 20	1
1561	Meta, Col.	July 20	1
1565	Meta, Col.	July 20	2
1559	Meta, Col.	July 20	1
1480	Vichada, Col.	June 3	2
1483	Vichada, Col.	June 3	3

1 Anthracnose rating: 0 = no anthracnose; 1 = minor leaf and/or stem spotting; 2 = moderate leaf and/or stem spotting; 3 = severe spotting; defoliation; 4 = severe defoliation; plant death.

(continued)

Table 26 (continued)

CIAT No.	Origin	Date planted 1978	Preliminary anthracnose evaluation[1] 11 October
1484	Vichada, Col.	June 3	0
1481	Vichada, Col.	June 3	3
1482	Vichada, Col.	June 16	0
1479	Vichada, Col.	July 8	3
1575	Vichada, Col.	August 8	4
1478	Vichada, Col.	August 8	4
1477	Cauca, Col.	June 3	0
1648	Cauca, Col.	July 20	1
1649	Cauca, Col.	August 8	4
1580	Tolima, Col.	July 20	3
1539	Venezuela	April 29	1
1523	Venezuela	June 3	1
1503	Venezuela	June 3	3
1491	Venezuela	June 16	0
1533	Venezuela	July 20	1
1521	Venezuela	July 20	0
1531	Venezuela	July 20	0
1508	Venezuela	July 20	0
1507	Venezuela	August 8	0
1500	Venezuela	August 8	0
1498	Venezuela	August 8	0
1335	Brazil	June 16	0
1678	Brazil	July 20	0
1633	Brazil	July 20	0
1741	Brazil	July 8	0
1604	Brazil	August 8	0
1640	Brazil	August 8	0
1681	Brazil	August 8	0
1486	Panama	April 29	1
1600	Belize	June 3	1
1602	Belize	July 20	0
1609	Belize	July 20	1
1599	Belize	July 8	0
1598	Belize	July 8	0
1611	Belize	July 8	0
1585	Belize	July 8	0
1622	Belize	August 8	0
1591	Belize	August 8	0
1589	Guatemala	July 20	3
1948	Ecuador	August 8	2

1 Anthracnose rating: 0 = no anthracnose; 1 = minor leaf and/or stem spotting; 2 = moderate leaf and/or stem spotting; 3 = severe spotting; defoliation; 4 = severe defoliation; plant death.

Blight

Blight, caused by *Sclerotium rolfsii,* was first detected in Carimagua in 1977 and was again observed from August to October 1978. The fungus attacks two- to three-month-old *S. capitata* plants near the soil surface, causing wilting and plant death. CIAT 1019 was the most susceptible while 1078, 1315 and 1328 were occassionally affected. Although, at present, disease incidence is low, blight is a potentially important disease due to the ability of fungal sclerotia to survive in the soil for many years. Experiments have been initiated to screen promising legume accessions against *S. rolfsii* and to study variation in susceptibility with age of accession 1019.

Root-knot Nematode

Several plantings of *D. ovalifolium* CIAT 350 at Carimagua, El Limonar and CIAT-Quilichao were affected by the root-knot nematode, *Meloidogyne javanica.* Large galls developed on roots of infected plants which were chlorotic and stunted. Severely infected plants died. Only vegetatively propagated plantings of *D. ovalifolium* at Carimagua and Quilichao were affected. Surveys of indigenous legumes, including *Desmodium* species, at Carimagua, El Limonar and Quilichao failed to detect root-knot nematodes, with one exception. At Carimagua, one indigenous *Desmodium,* growing near an infected *D. ovalifolium* planting, was infected. It appears that introduced infected *D. ovalifolium* material and/or soil, possibly from soil used in Jiffy pots from CIAT-Palmira where cassava and the composite *Bidens pilosa* are hosts to this nematode, are responsible for the presence of root-knot nematode at Carimagua and Quilichao. Screening of all promising legumes and many accessions of *Desmodium* species for resistance to *M. javanica* is in progress.

Camptomeris Leaf Spot

This disease, caused by *Camptomeris leucaenae,* is specific to *Leucaena* species. Previously, it has been recorded only from Caribbean islands, Venezuela and, in February 1978, from Mexico, where its incidence was sporadic but its effect often severe. Newly established plots of *Leucaena leucocephala* CIAT 734 were severely affected by *C. leucaenae* at CIAT-Quilichao in September 1978. Small brownish spots or chlorotic patches appeared on the upper surface of diseased leaflets while the fungus sporulated profusely as black pustules on the lower surface. Heavily infested leaflets turned yellow and there was considerable defoliation. Periods of dry weather favored the disease. This potentially damaging disease will require basic study if *Leucaena* is further considered as a tropical forage legume for this region.

Cercospora Leaf Spot

At CIAT-Quilichao and Carimagua, most plantings of *Panicum maximum* were affected by *Cercospora* leaf spot. Infestations were more severe in the wetter environment of Carimagua. The reddish brown spots enlarged and coalesced on leaves of all ages, producing extensive areas of necrotic tissue. Studies on the effect of *Cercospora* sp. on yield of *P. maximum* and field evaluations for resistance are being initiated.

Rust

Accessions of *Macroptilium* and *Vigna* species were moderately to severely affected by the rust, *Uromyces appendiculatus,* at CIAT-Quilichao. Large reddish brown sori containing uredospores developed profusely on both leaf surfaces. *Macroptilium* sp. CIAT 4050 was severely affected with many leaves turning yellow and falling. This disease will warrant investigation if *Macroptilium* and *Vigna* are further evaluated as forages.

Powdery Mildew

Powdery mildew, caused by *Oidium* sp., was observed on accessions of *Macroptilium* and *Vigna* species at CIAT-Quilichao. Several plants of *Macroptilium* sp. CIAT 4195 were killed. At present, however, disease incidence is low.

Other Potentially Important Fungi

Legumes

Moderately severe spotting of leaves and stems was caused by *Alternaria alternata* on *Zornia* sp. CIAT 9203; by *Cercospora* spp. on accessions of *Centrosema, Galactia, Macroptilium* and *Vigna;* by *Cercosporidium* sp. on several *Aeschynomene* accessions and by *Dreschslera* sp. on several *Zornia* accessions. Other fungi commonly isolated from leaf spots included *Curvularia* spp., *Drechslera* spp., *Leptosphaerulina* spp., *Pestalotia* spp., *Phoma* spp., *Phomopsis* sp., and *Stemphylium* spp.

Grasses

Potentially pathogenic fungi isolated from leaf spots on grasses included *Alternaria* spp., *Curvularia* spp., *Drechslera* spp., and *Colletotrichum graminicola*. Inflorescens of *P. maximum* were sporadically affected by *Fusarium* spp. and a smut *(Ustilago* sp.). No potential plant pathogens have been identified as attacking *Andropogon gayanus* 621.

ENTOMOLOGY

The objective of the Entomology Section is to develop pest management systems for tropical forages in the Beef Program's Target Area. These systems are designed to avoid or minimize chemical controls.

Studies this year concentrated on the biology, ecology and population dynamics of insect pests together with the development of a screening system for host plant genetic resistance to the stemborer. In addition, biological control agents and forage and animal management practices were identified and evaluated as components of integrated control systems.

Life Cycle Studies

Stemborer

The stemborer, tentatively identified as *Zaratha* sp. in last year's report, was now identified as *Caloptilia* sp. by D.R. Davis of the Beltsville Agricultural Research Center, U.S.A. *Caloptilia* sp. attacks *Stylosanthes* species at the three major field research sites of the Beef Program, in the Colombian Llanos and Cauca Valley of Colombia and in the Cerrado of Brazil. The female oviposits on the plant stem; eggs are red, elongated and about 0.42 mm long with a corrugated surface. The incubation period is approximately 11 days at 25°-30°C. Newly emerged larvae are about 0.6 mm long, of a creamy white color with a very well differentiated anal plate. Larvae then penetrate into the stem and continue their development attaining a length of about 7.5 mm. The larval stage averages about 58 days. Pupation occurs inside the stem and after 18 days the adult emerges. The adult stemborer is a microlepidoptera, brown-grey in color, 5 mm long with very long filiform antennae. The life cycle of this stemborer is shown in Figure 34.

Budworm

Information on the biology of the stylo budworm, *Stegasta bosqueella* Chambers, was obtained under field conditions from *Stylosanthes capitata* 1019. Females lay their eggs on the trichomes of the external bracts of the inflorescences. Eggs are elongated and creamy white in color with a corrugated surface. The incubation period is about five days; at the time of hatching larvae are creamy yellow with a dark reddish pro- and mesothorax and are 0.5 mm long. Last instar larvae grow to 6 mm, becoming pinkish in color. The larval period lasts about 18 days and the pupal stage, 9 days. Under field conditions the budworm is found feeding on terminal branches, before the plant starts flowering. The budworm's life cycle is shown in Figure 35.

Biological Control

Larval Parasitism

Stemborer larval populations are parasitized by wasps identified as a Hymenoptera, family Eupelmidae, *Anastatus* sp. and Hymenoptera, family Braconidae, *Bracon* sp. (both determined by Paul M. Marsh of the Beltsville Agricultural Research Center). Although

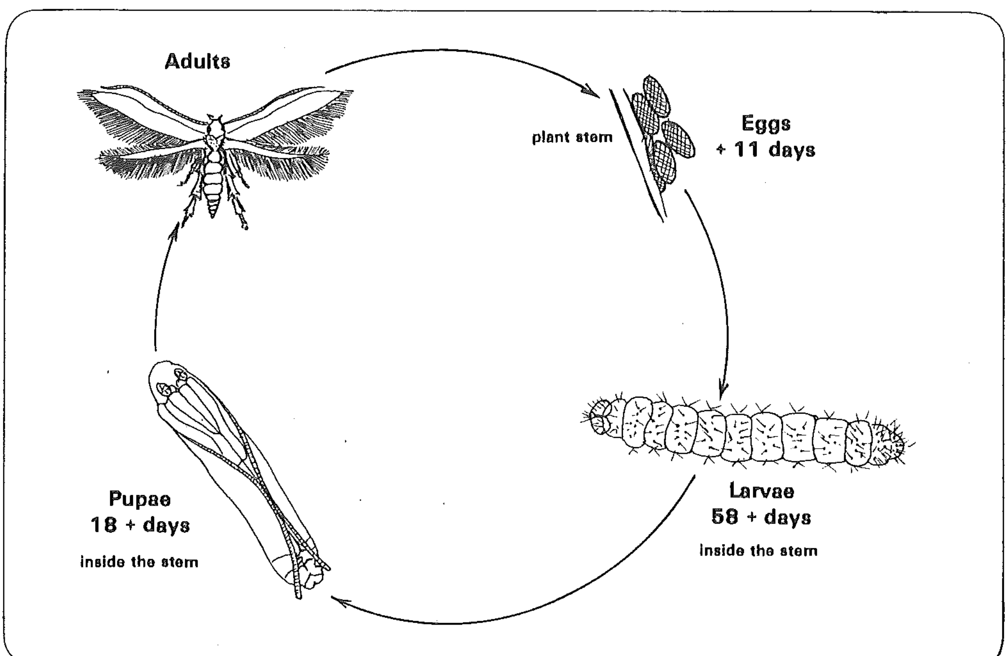

Figure 34. Life cycle of the stemborer *(Caloptilia* sp.) attacking *Stylosanthes.*

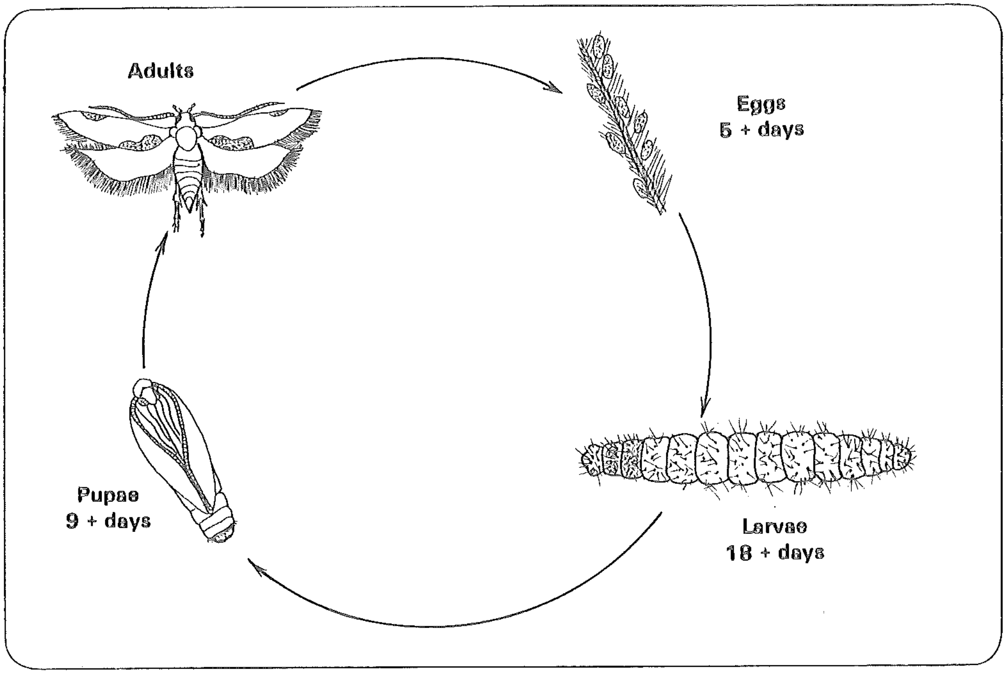

Figure 35. Life cycle of the budworm *(Stegasta bosqueella* (Chambers)) attacking *Stylosanthes*.

both species are found parasitizing the stemborer under natural conditions, apparently *Anastatus* sp. (Figure 36) is more specific than *Bracon* sp. (Figure 37). Both species oviposit in the stemborer larvae where the parasite larvae develop.

Further studies will be conducted to determine the efficiency and functional and numerical response of these parasites as potential components of an integrated control system. *Bracon* sp. is found in CIAT-Quilichao and Carimagua, but *Anastatus* has only been found at El Limonar, near CIAT-Quilichao, where populations are established. At Quilichao

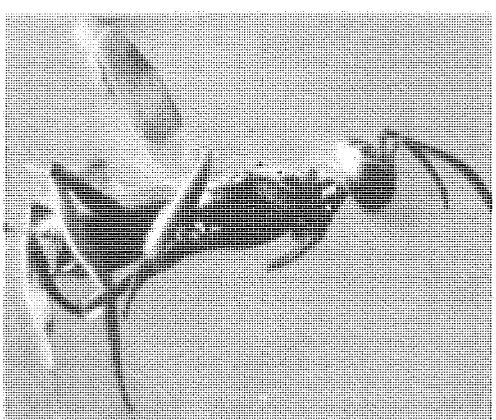

Figure 36. Stemborer parasite *Anastatus* sp. (Hymenoptera; family: Eupelmidade).

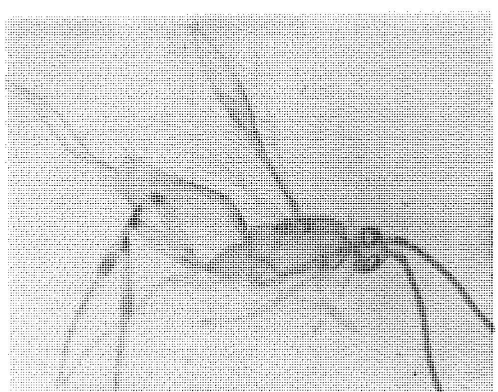

Figure 37. Stemborer parasite *Bracon* sp. (Hymenoptera; family: Braconidae).

the stemborer infestation is presently very low.

Stemborer Pathogen

A fungi affecting stemborer larvae was found in the field at CIAT-Quilichao. The fungi is probably *Spicaria* and studies of its influence on the stemborer will be continued.

Budworm Parasitism

Three different parasites have been found attacking budworm larvae: *Bracon* sp. (same as the stemborer parasite); a Hymenoptera, family Braconidae, *Chelonus* sp.; and a Hymenoptera, family Braconidae, *Orgilus* sp. (Figures 38 and 39).

Host Plant Resistance

Screening System

Since the stemborer is the most important pest affecting *Stylosanthes* accessions, emphasis has been given to developing a screening system to evaluate CIAT forage germplasm for tolerance or resistance as quickly as possible. The system consists of three steps.

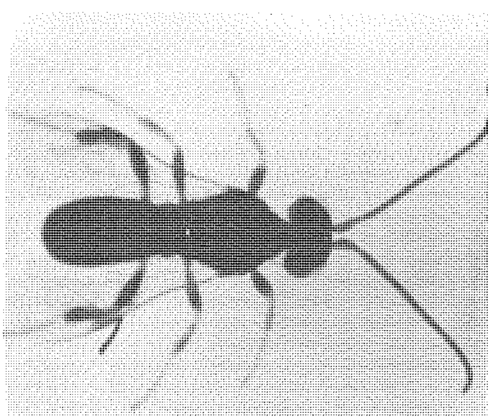

Figure 38. Budworm parasite *Chelonus* sp. (Hymenoptera; family: Braconidae).

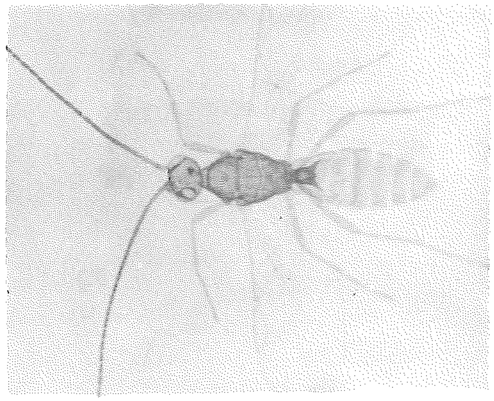

Figure 39. Budworm parasite *Orgilus* sp. (Hymenoptera; family: Braconidae).

(1) Field Screening. Using germplasm material planted at CIAT-Quilichao, Carimagua and elsewhere by other sections of the Beef Program, evaluations are made throughout the year. During natural outbreaks, data on tunnel length, larvae size and numbers, and plant phenology are recorded.

(2) Oviposition Preference Test. For this test cages were designed in which *Stylosanthes* plants are randomly placed. Plant material is infested with males and females of *Caloptilia* sp. The plants remain in the cages three to four days under stemborer stress; afterwards they are removed and replaced by another set which is infested with a new group of males and females. Oviposition evaluations are made by recording the numbers of eggs found per plant ecotype tested.

(3) Feeding Preference Test. Stems of several promising *Stylosanthes* accessions are placed on Petri dishes infested with stemborer larvae, providing the larvae with the opportunity to infest and penetrate the ecotype preferred.

Population Dynamics

A study was initiated to identify the

orders, families and species of insects found more frequently on the different ecotypes of legumes and grasses, and to understand insect population flows and preferences. An insect collection and a catalog of the main insects found on forages and legumes were developed. High populations were recorded during the first year of sampling; species of Homoptera appear to be potential pests at both CIAT-Quilichao (Figure 40) and Carimagua. Figure 40 shows insect orders to be more evenly distributed on *Andropogon gayanus* than on other species. Many of these insects are beneficial ones (Hymenoptera, Diptera including insect pollinators, some Hemiptera and Coleoptera).

Characterization of Effects of Anthracnose/Stemborer Attacks

In order to understand and to differentiate the effects of anthracnose and stemborer on *Stylosanthes guianensis* 136 pastures an experiment with either fungicide (benomyl), insecticide (carbofuran) or fungicide/insecticide treatments was designed. The experiment was located in an *S. guianensis* paddock at Carimagua. Data from one year of observations (Table 27) showed: (1) that reduced forage production was due to anthracnose attacks and not to stemborer infestations; (2) that defoliation was

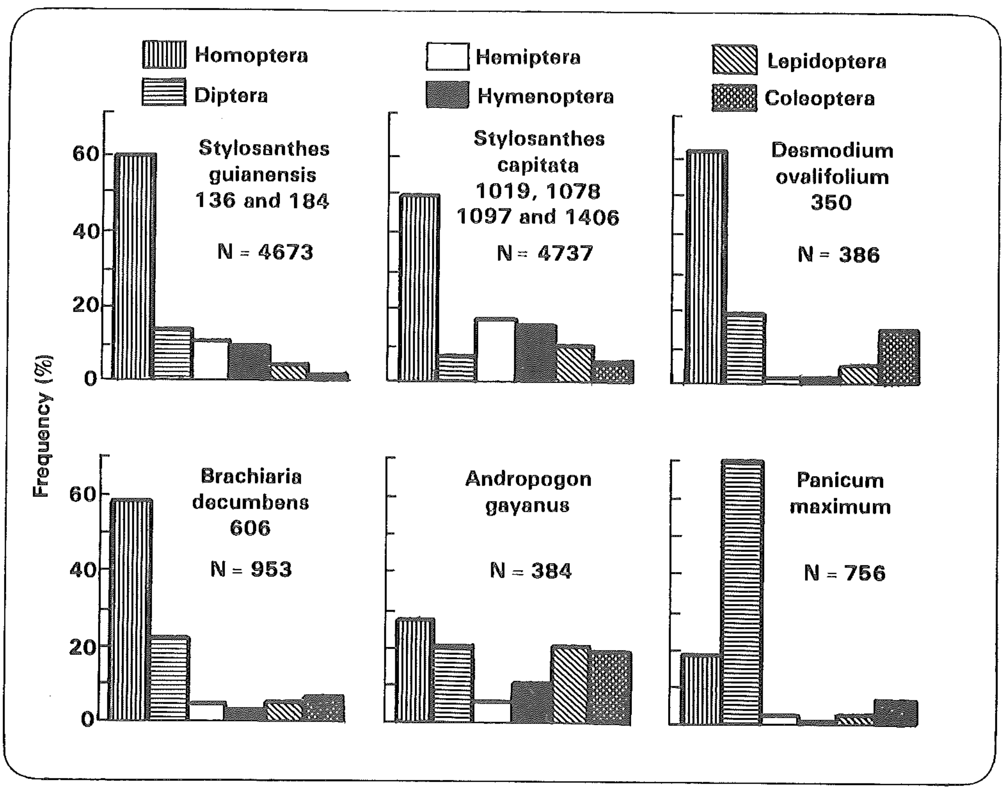

Figure 40. Frequency of appearance of different insect orders on some legumes and grasses in samplings at CIAT-Quilichao, 1978. (N= number of insects observed.)

Table 27.

Effects of fungicide, insecticide and fungicide/insecticide treatments on the incidence of anthracnose and stemborer infestations on *Stylosanthes guianensis* 136 pasture yields at Carimagua during 1978.

	Treatments[1]				
Parameter	Check	Insecticide	Fungicide	Insecticide/ fungicide	Grazed
Stemborer infestation (%)	8.0	5.3	7.8	4.5	3.3
Defoliation (%)	53.7	51.7	43.4	44.1	54.9
Fresh matter[2] (kg/ha)	2041	2100	3740	3780	-
Dry matter[2] (kg/ha)	660	667	1180	1172	-

1 Insecticide: carbofuran; fungicide: benomyl.
2 At first cutting, August 1978.

greater on treatments not receiving the fungicide; and (3) the treatments receiving the fungicide provided the highest forage production. The percentage of stemborer infestation throughout the year was low, and the infestation level was less than one larvae per plant. Based on these preliminary results stemborer cannot be considered a limiting factor in forage production, at least during the establishment year. This experiment will be maintained two more years.

Field Evaluations

Stemborer infestation was monitored at Carimagua throughout the year. Field plots of *Stylosanthes* accessions planted alone or associated with grasses, and with or without grazing were evaluated.

Comparing *S. capitata* 1019 against *S. capitata* 1078, in association with *Brachiaria decumbens* and *A. gayanus* and with and without grazing, accession 1019 showed less infestation than the latter under both situations (Figure 41). Also, 11 ecotypes in association with grasses and under grazing were evaluated during the year. Results showed some variability in infestation among the ecotypes. *S. capitata* 1019 had the lowest percentage of infestation, while *S. capitata* 1078 showed the highest (Figure 42). However, the infestation levels (number of larvae per plant) were low in all cases except for 1078 which showed more than one larvae per plant (Figure 43). When both the percentage and level of infestation were recorded for *Stylosanthes* plants in pure stands without grazing, *S. capitata* 1097 and *S. guianensis* 1200 showed the highest percentage and level of infestation (Figure 44).

Bases for Host Plant Resistance

As a result of field evaluations certain *S. capitata* ecotypes have been identified which consistently show low stemborer damage; these include accessions 1019, 1405, 1342, 1339, 1338 and 1325.

Most Lepidoptera, when reaching the adult stage, search for food sources of nectars and honeydew and insects are frequently found visiting plants that provide these foods. It is possible that female stemborers are being attracted by stylo accessions that have morphological characteristics of the stem with glandular trichomes having exudations on the tip of the hair. Usually, these exudations contain

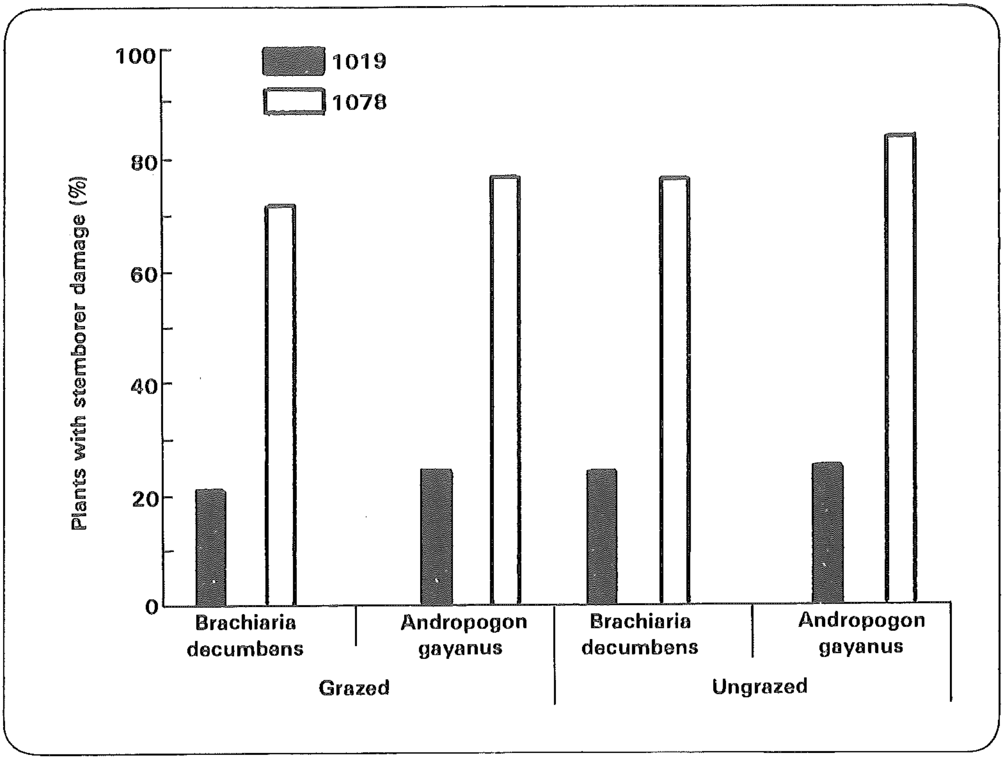

Figure 41. Infestation percentages of stemborer *(Caloptilia* sp.) on two ecotypes of *Stylosanthes capitata* in association with two grasses, with and without grazing, at Carimagua, 1978.

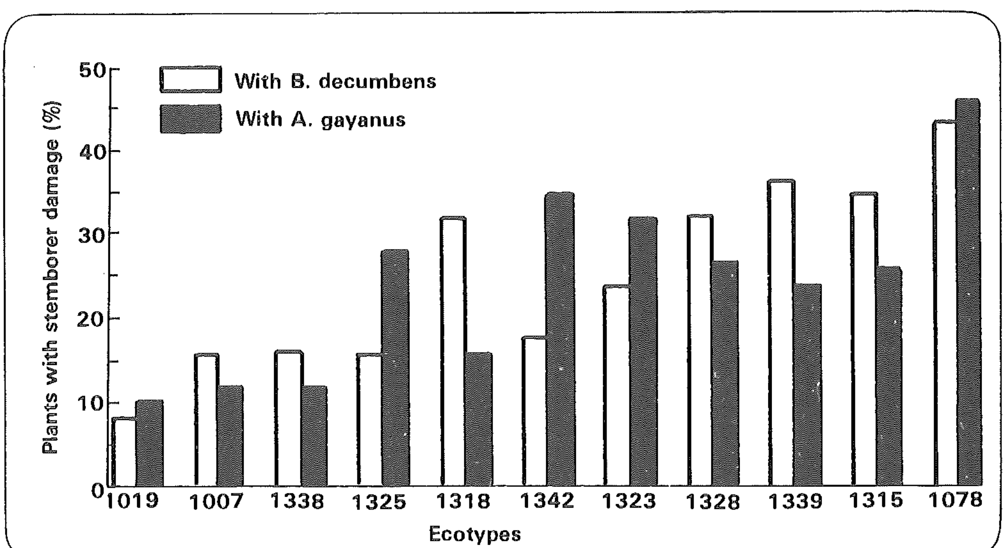

Figure 42. Infestation percentages from the stemborer *(Caloptilia* sp.) found on some ecotypes of *Stylosanthes capitata* in association with grasses under grazing at Carimagua, 1978.

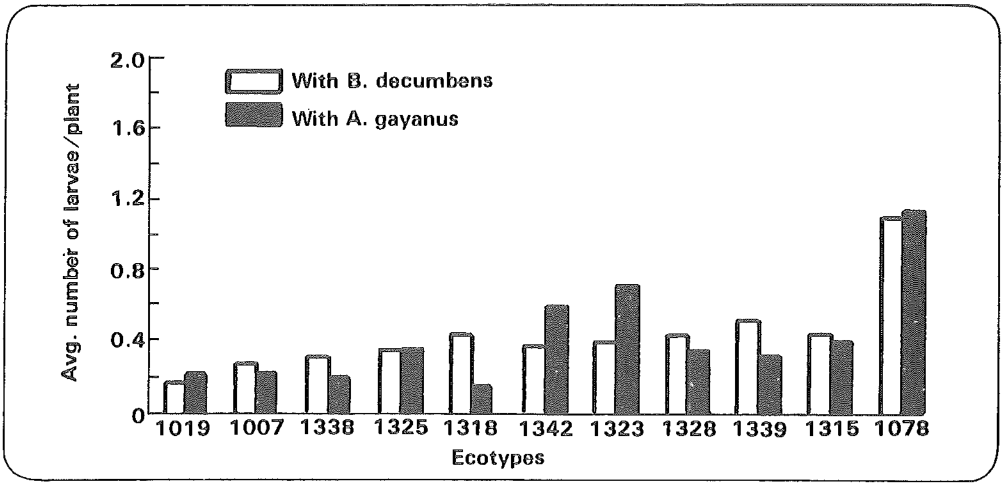

Figure 43. Numbers of stemborer *(Caloptilia* sp.) larvae found on some ecotypes of *Stylosanthes capitata* in association with grasses under grazing at Carimagua, 1978.

sugars that act as insect attractants and often serve as stimuli to oviposition. This morphological characteristic of the plant could be used as a tool in selecting accessions resistant or tolerant to stemborer attack.

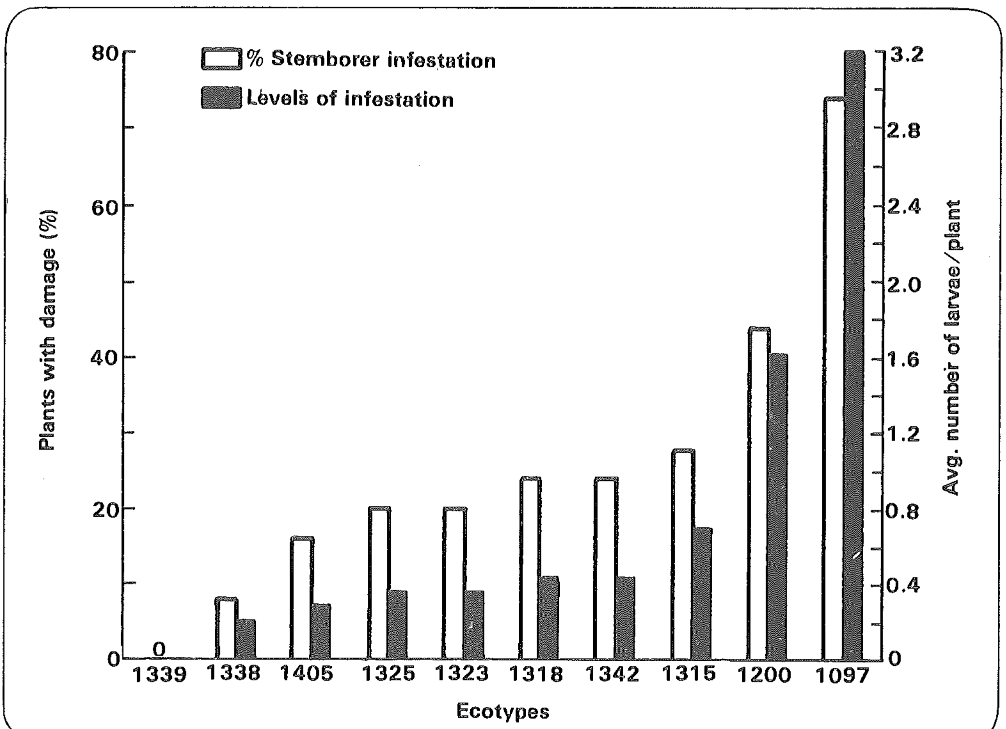

Figure 44. Percentages of plants with damage and numbers of stemborers recorded on ecotypes of *Stylosanthes* in pure stands, without grazing at Carimagua, 1978.

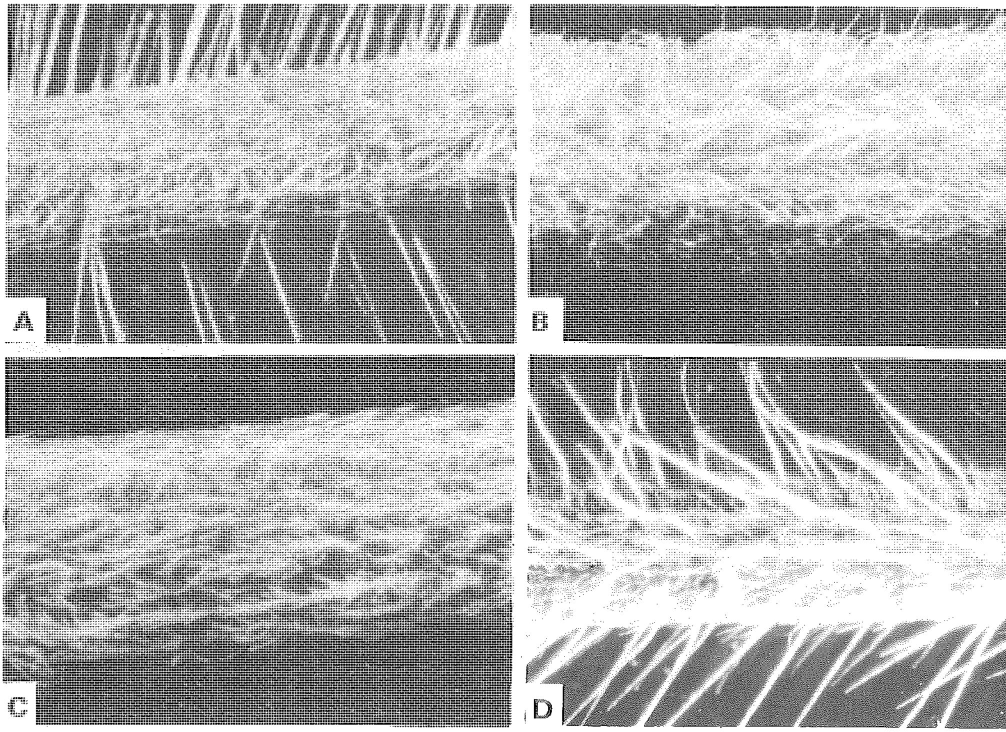

Figure 45. Four *Stylosanthes* ecotypes with varying trichome structures. (A) *S. guianensis* 136 with glandular trichomes; (B) *S. guianensis* 184 with glandless trichomes; (C) *S. capitata* 1019 with glandless trichomes; and, (D) *S. capitata* 1078 with glandular trichomes.

Also, by crossing hairy with glabrous types it might be possible to obtain plants with desirable forage production qualities that also feature this morphological factor for resistance to stemborer.

In preliminary research, the stemborer has been observed to prefer accessions with glandular trichomes (*S. guianensis* 136 and *S. capitata* 1097 and 1078) while *S. guianensis* 184 and *S. capitata* 1019 and 1405 which do not have glandular trichomes have shown less stemborer damage (Figure 45).

Based on these results chemical analyses of total carbohydrate and protein contents between the two types of plants have been initiated to better identify causes of resistance or tolerance to stemborer damage.

SOIL MICROBIOLOGY

The objective of the Soil Microbiology Section is to maximize the benefits of biological nitrogen fixation to adapted forages in the acid, infertile soils of tropical Latin America. Priority has been given to the legume/*Rhizobium* symbiosis. The research strategy is: (1) to maintain and augment the CIAT *Rhizobium* germplasm resource; (2) to evaluate the symbiotic nitrogen fixation potential of *Rhizobium* strains with adapted legumes; and, (3) to test the symbiotic potential of selected strains in field situations, initially at CIAT-Quilichao, Carimagua and Brasilia, and then in regional trials throughout the Beef Program's target area.

Rhizobium Collection

The number of strains in the CIAT *Rhizobium* collection for tropical forages doubled during 1978 to 2043 through donations by collaborators (principally R. A. Date of the Commonwealth Scientific and Industrial Research Organization (CSIRO), Brisbane, Australia) and through collecting trips to eastern Venezuela (CSIRO/CIAT), Ecuador (CSIRO/CIAT), and northeastern Brazil (EMBRAPA/CSIRO/CIAT). The second edition of the catalog of strains of *Rhizobium* for forage legumes was published and is available.

Research on collection methodology revealed that although silica gel and $CaCl_2$ do not differ significantly in the rate at which they dessicate nodules in storage vessels, the viability of rhizobia in stored nodules is greater and the level of contaminating organisms on primary isolation plates is reduced when $CaCl_2$ is used.

It is now known that a key factor in past failures of isolating *Rhizobium* from nodules of plants (especially *Stylosanthes* spp.) growing in acid soils was because many such strains have an acid requirement for growth and cannot grow on the standard medium (pH 7) used for isolation. This implies that the search for acid-adapted *Rhizobium* in existing collections of strains which were originally isolated onto routine, non-acid media may not be the most valid nor fruitful approach. Collecting activities have been increased using acid media to isolate and maintain cultures.

Strain Selection

Strains of *Rhizobium* for forage legumes which are nominated as promising by the Beef Program's Germplasm Committee continue to be selected by the five-stage program outlined last year, (CIAT Annual Report, 1977). One change from previous methodology is that the soil used in pot trials at Stage III is not sterilized.

Stage I (Aseptic Tube Culture)

Stylosanthes capitata. Forty-three strains of *Rhizobium* isolated from root nodules of *Stylosanthes* species from various soil types were tested with two *S. capitata* genotypes (CIAT 1019 and 1078). Nodulation did not occur in any host genotype by strain combination. When the standard agar rooting medium was acidified to pH 4.9, however, 15 strains produced nodulation on *S. capitata* 1019. It is concluded that *S. capitata* has an acid requirement for nodulation. *S. capitata* exhibited greater specificity in its strain requirement than *S. guianensis* CIAT 136, *S. hamata* PI 40264A and *S. hamata* PI 38842, each of which nodulated with all 43 strains.

Zornia spp. Eight out of 15 strains of *Rhizobium* tested with *Zornia* sp. CIAT 728 formed nodules under the test conditions.

Macroptilium sp. CIAT 535. Only half of the *Rhizobium* strains tested with this host formed nodules, indicating a much higher degree of specificity of strain requirement than occurs with the very promiscuous *Macroptilium atropurpureum* cv. Siratro.

Stage II (Sand Culture with pH 7 Nutrient Solution)

Desmodium ovalifolium CIAT 350. The

ranking of 39 strains of *Rhizobium* in order of their nitrogen fixing potential with this host is given in Figure 46. The best non-CIAT isolate was 26th in effectiveness. Variation in strain effectiveness can be attributed mainly to differences in the mass of nodules formed (Fig. 47) rather than the rate at which the nodules function (specific nodule activity).

Stylosanthes capitata CIAT 1019. The result of this experiment (Fig. 48A) indicated that growth requirements of the plant have not been met satisfactorily by the medium used routinely in this stage. CIAT 71, a strain known to be effective with *S. capitata,* was ineffective. Work continues to develop a nutrient solution suitable for sand culture of *S. capitata.*

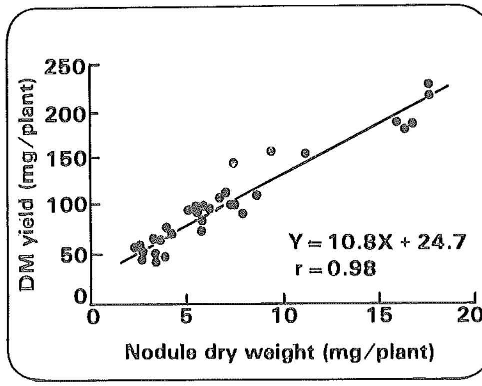

Figure 47. Correlation between nodule mass and dry matter production by *Desmodium ovalifolium* 350 in symbiotic associations with 35 strains of *Rhizobium.*

Macroptilium sp. CIAT 535. The wide spectrum strain CB 756 was moderately effective with this host (Fig. 48B). The

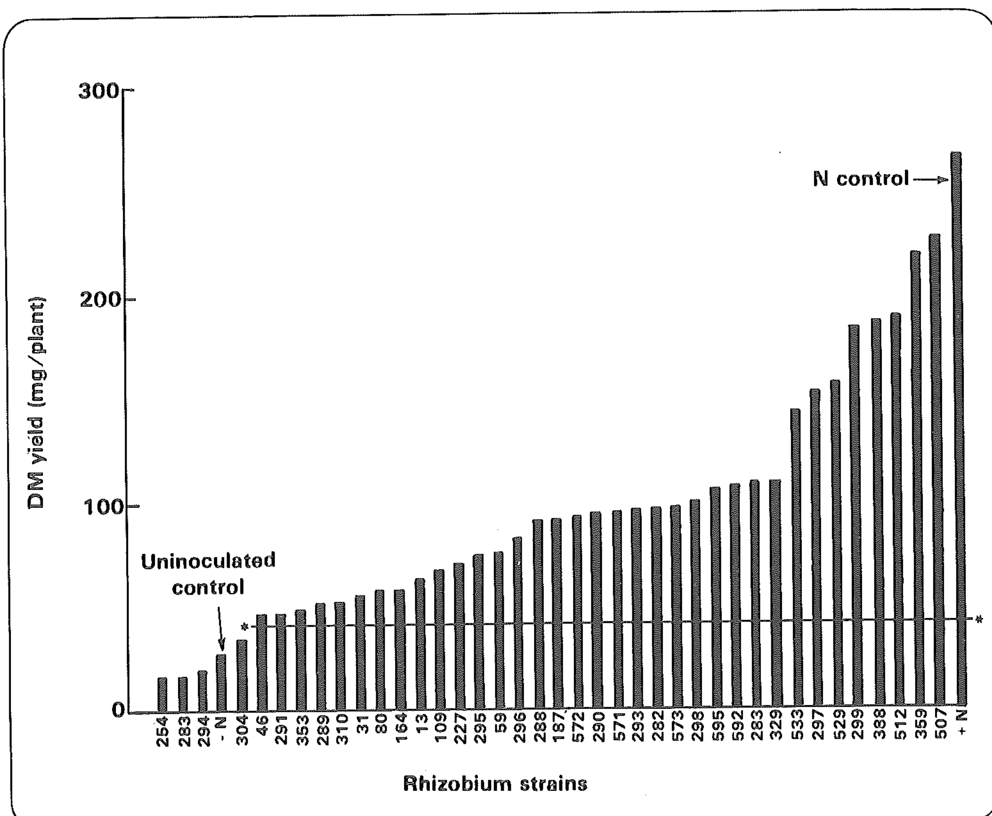

Figure 46. *Rhizobium* strain selection for *Desmodium ovalifolium* 350 (during Stage II). (* = upper confidence limit (95%) to mean of uninoculated control.)

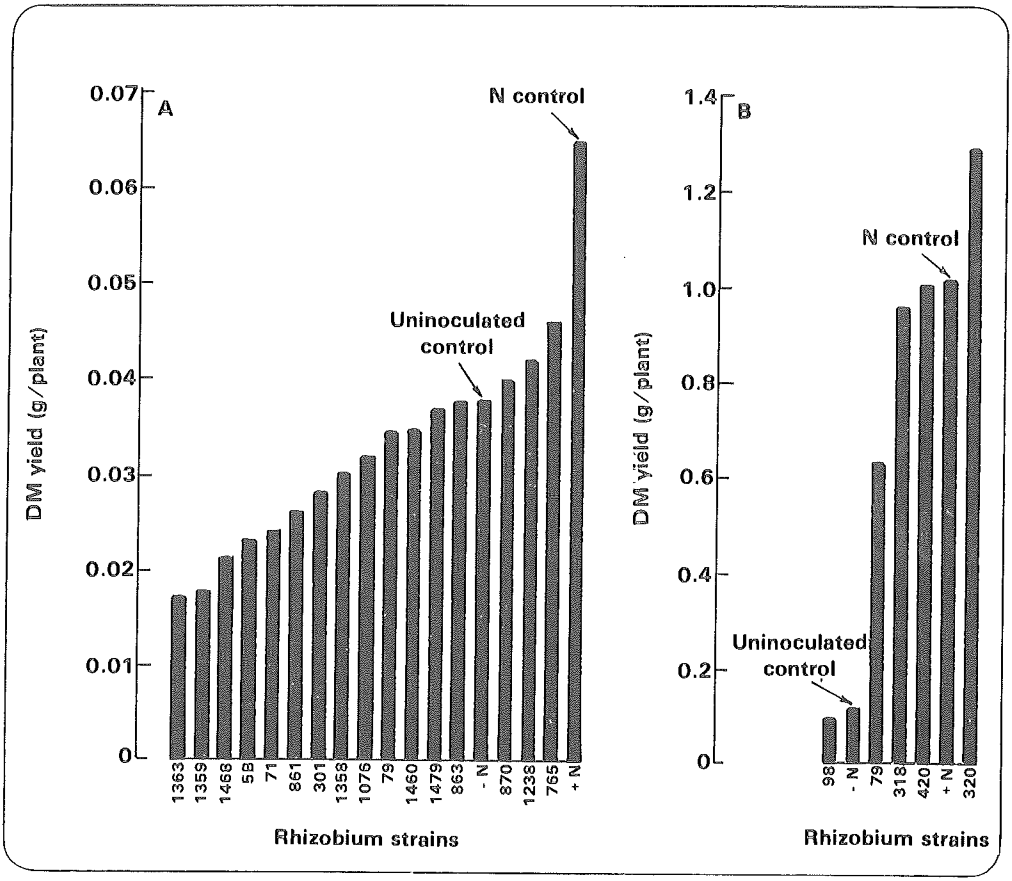

Figure 48. *Rhizobium* strain selection for (A) *Stylosanthes capitata* 1019, and (B) *Macroptilium* sp. 535, during Stage II.

strains CIAT 320, 420 and 318 were more effective.

Stage III (Pot Culture in Site Soil)

Stylosanthes capitata CIAT 1019. Plants inoculated with the best strain in this trial yielded double the dry matter of uninoculated control plants (Fig. 49A). The strain CIAT 71, which to now has been recommended for *S. capitata* only on the basis of high effectivity with *S. guianensis* and genetic compatability with *S. capitata,* was confirmed as a highly effective nitrogen fixing symbiont for this host and has increased attractiveness as a wide spectrum inoculant strain for acid soils. CB 756, a strain often used to inoculate *Stylosanthes,* was confirmed to be ineffective with this *S. capitata* accession.

Zornia sp. CIAT 728. Strain CIAT 71, originally isolated from *Stylosanthes* nodules, proved to be one of the most effective strains on this taxonomically closely related genus (Fig. 49B). Strain CIAT 103, which had been recommended previously for *Zornia* on the basis that it was a *Zornia* isolate, is only moderately effective with this accession.

Desmodium distortum CIAT 335. Only 3 of 12 strains of *Rhizobium* that were

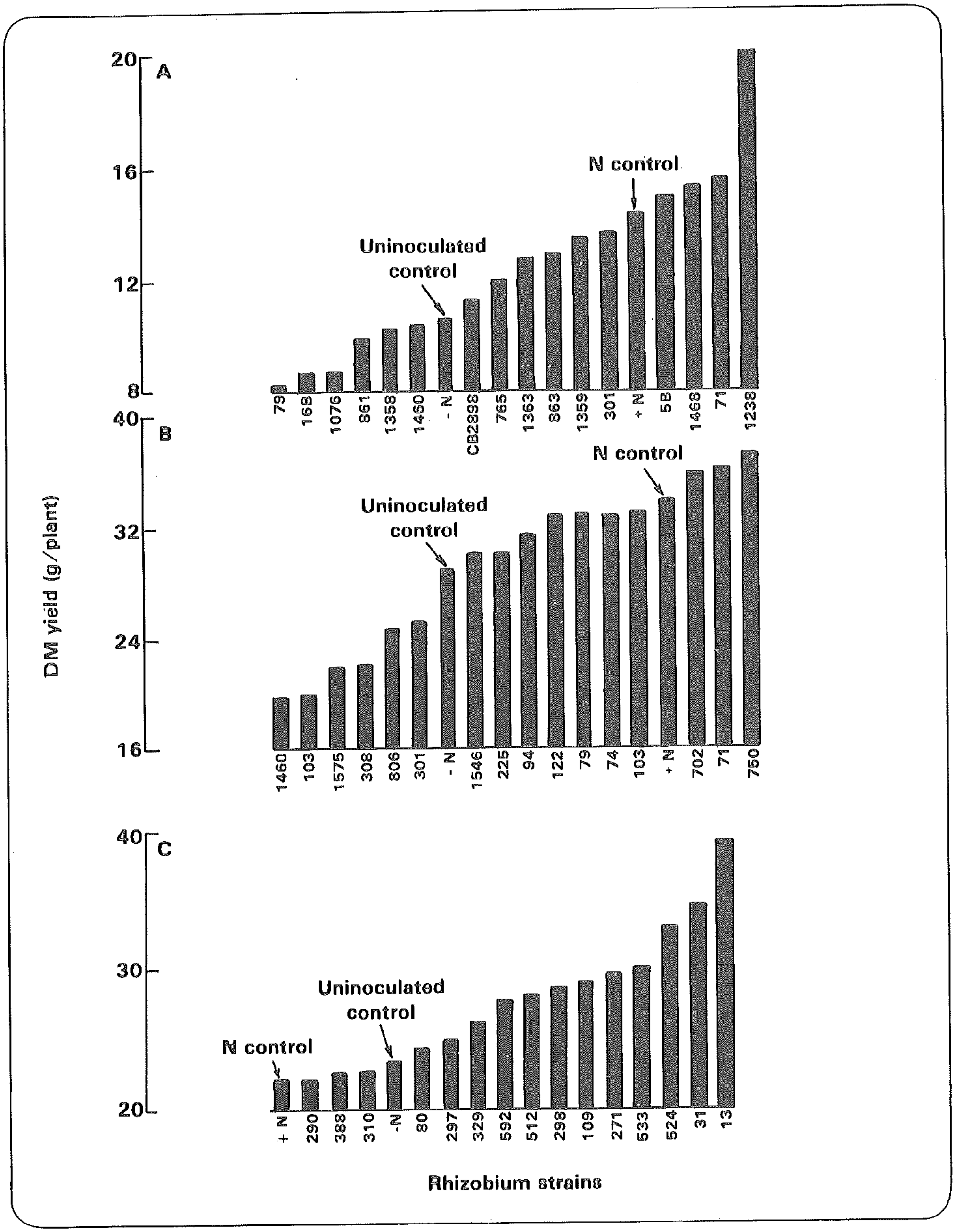

Figure 49. *Rhizobium* strain selection at Stage III for (A) *Stylosanthes capitata* 1019; (B) *Zornia* sp. 728; and, (C) *Desmodium distortum* 335.

highly effective in nitrogen fixation in sand jars were capable of nodulating and fixing nitrogen under acid soil stress (Fig. 49C).

Centrosema hybrid brasilianum x virginianum CIAT 438. The ranking of effectiveness in nitrogen fixation in acid soil in the presence of competing native strains of *Rhizobium* for the best 10 strains from Stage II (CIAT Annual Report, 1977) differs from the order of merit under optimal plant growth conditions (Fig. 50A). The best strain under stress in site soil was eighth in effectiveness in sand jars. Also, several strains that were very effective in sand jars fixed no nitrogen in acid soil. It was particularly surprising that strain CIAT 324 which was 49th among 50 strains in sand jars gave the second highest yield in the Stage III trial.

Desmodium heterophyllum CIAT 349. Only 1 out of 10 strains of *Rhizobium* that were fully effective in nitrogen fixation at Stage II was fully effective in nitrogen fixation under stress in acid soil (Fig. 50B)

Stage III results emphasize the important modifying role which the soil can play on the legume/*Rhizobium* symbiosis and urges caution in over-dependence on the standard sand jar test to select strains of *Rhizobium* for a stress condition.

Stage IV (Field Trials)

CIAT-Quilichao. Data from the field trials with *Desmodium ovalifolium* 350, *S. guianensis* 136, *Centrosema* hybrid *brasilianum* x *virginianum* 438, *Galactia striata* 964, *D. distortum* 335, *Macroptilium* sp. 535, *D. heterophyllum* 349, *S. capitata* 1019, *S. capitata* 1078 and *Pueraria phaseoloides* 9900 are summarized in Table 28.

Carimagua. Results of the field trials with *D. ovalifolium* 350, *S. capitata* 1019,

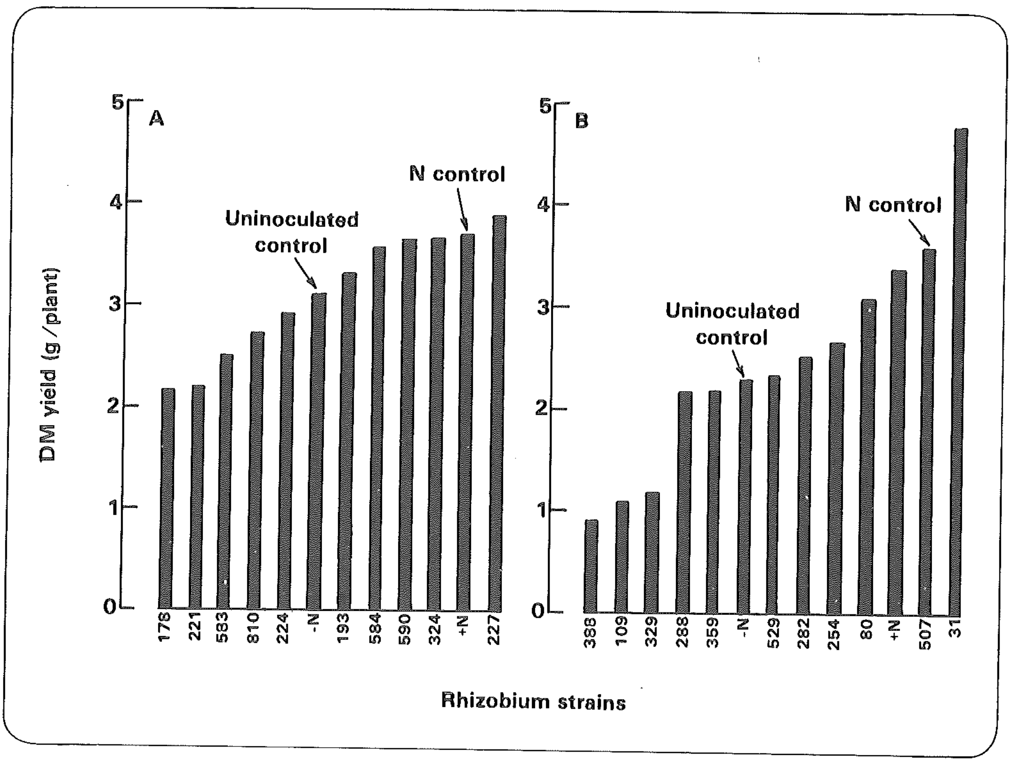

Figure 50. Rhizobium strain selection for Stage III for (A) *Centrosema* hybrid 438 and (B) *Desmodium heterophyllum* 349.

Table 28.

Summary of field trials of *Rhizobium* strains and inoculation technologies at CIAT-Quilichao.

Species and accession number		Best treatment[1]	Inoculation response (as % of uninoculated control)			
			1st cut[2]	2nd cut	3rd cut	4th cut
Stylosanthes guianensis	136	CIAT 79 lime pellet	52.5	28.3	43.3	14.8
Centrosema hybrid	438	CIAT 590 lime pellet	17.4	0	5.1	-[4]
Galactia striata	964	CIAT 378 RP[3] pellet	19.7	0	0	0
Desmodium ovalifolium	350	CIAT 299 lime pellet	101.0	35.6	-	-
Desmodium distortum	335	CIAT 299 no pellet	34.1	20.3	3.2	-
Macroptilium sp.	535	CIAT 319 lime pellet	70.9	-	-	-
Desmodium heterophyllum	349	CIAT 80 RP pellet	48.8	-	-	-
Pueraria phaseoloides	9900	CIAT 79 RP pellet	61.1	3.3	-	-
Stylosanthes capitata	1019	CIAT 71 RP pellet	0	-	-	-
Stylosanthes capitata	1078	CIAT 71 RP pellet	12.5	-	-	-

1 Standard field trial of three selected strains and three inoculation technologies.
2 Cutting interval depended on the production by each species, but was usually around 3 months.
3 Rock phosphate.
4 Blanks indicate data are not yet available.

S. capitata 1078 and *Macroptilium* sp. 535 are summarized in Table 29. The experiment with *Macroptilium* has been terminated due to lack of host plant adaptation to the soil, climatic, insect and disease stresses of the region. With *S. capitata* accessions neither 1019 nor 1078 survived into the second year under small plot, pure sward conditions. Adult plants of 1019 were virtually eliminated by spider mites

Table 29.

Summary of field trials of *Rhizobium* strains and inoculation technologies at Carimagua.

Species and accession number	Best treatment[1]	Inoculation response (as % of uninoculated control)		
		1st cut[2]	2nd cut	3rd cut
Desmodium ovalifolium 350	CIAT 46 RP pellet	22.3	0	-
Stylosanthes capitata 1019	CIAT 71 lime pellet	39.5	-	-
Stylosanthes capitata 1078	CIAT no pellet	15.1	0	4.1
Macroptilium sp. 535	CIAT 318 lime pellet	98.3	41.3	1.6

1 Standard field trial of three selected strains and three inoculation technologies.
2 Cutting interval depended on the production by each species, but was usually around 3 months.

and in 1078 stemborer reduced the population of mature plants to near zero. These results are inconsistent with the observed behavior of these accessions in mixed pasture with grasses. Some useful data may be obtained on the persistence of introduced strains in soil and their ability to nodulate new seedlings but it is not possible to study the inoculation response for more than one growing season with this experimental design. Future experiments with these accessions will be performed in larger plots with mixed swards.

Acid Tolerance by Rhizobium

Results for field and pot trials show that a response to inoculation with selected strains of *Rhizobium* is the rule rather than the exception although response tends to be reduced over time. It is likely that protecting the inoculant strain with pelleting at the time of sowing permits an early and high percentage infection by the effective introduced strain thus giving a marked initial response. A critical point is reached when the primary nodule population decomposes (after 2-3 months) and the rhizobia must survive in the acid soil as free-living soil saprophytes. Multiplication at low pH is extremely important for reinfection of the legume root, competition with native strains of *Rhizobium* for nodule sites and persistence in the soil microflora. Research was therefore directed at developing a medium to test for this character.

Alkali production by tropical rhizobia has been an obstacle to developing such a test causing the pH to rise from its initial value of around pH 4 to above pH 8, thereby confusing interpretation of the results. A stable acid medium which eliminates the ability of *Rhizobium* to produce alkali was developed (Table 30). The medium permits selection of strains genuinely capable of multiplication at low pH (Fig. 51) and will enable the effect of Al and other acidity stresses on *Rhizobium* to be determined.

Table 30.

Liquid medium for selecting acid-adapted strains of *Rhizobium*.[1]

Ingredient	Quantity
KH_2PO_4	68 mg
K_2HPO_4	87 mg
$CaCl_2.2H_2O$	39.4 mg
$MgSO_4.7H_2O$	74 mg
$Fe^{+++}Na$ EDTA	36.8 mg
$MnCl_2.4H_2O$	0.49 mg
$ZnSO_4.7H_2O$	0.29 mg
$CuCl_2.2H_2O$	43 μg
$Na_2MoO_4.2H_2O$	12 μg
$CoCl_2.6H_2O$	1.2 μg
Sodium glutamate	220 mg
Thiamine[2]	100 μg
Biotin[2]	250 μg
Arabinose	10 g
Distilled water	to one liter

1 Acidified with 0.1 *N* HCl (before autoclaving).
2 Filter sterilized and added after autoclaving the medium.

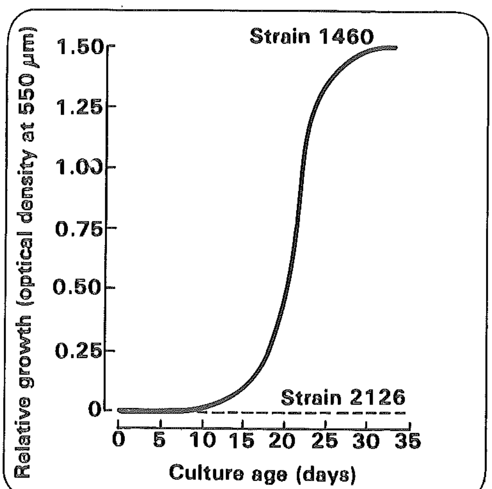

Figure 51. Relative growth of *Rhizobium* strains CIAT 1460, originating from an acid soil (pH 4.5), and CB 2126, from an alkali soil (pH 8.5), in a defined, acid medium (initial pH 4.2).

Demonstration that alkali production by the tropical rhizobia depends on the culture medium reopens the debate over whether these microorganisms actually produce alkali in the rhizosphere of their host and whether it was correct to attribute an evolutionary and ecological role to the process. It has been considered that lack of alkali production by the non-typical *Rhizobium* for *Leucaena leucocephala* is the prime reason for this species' lack of adaptation to acid soils. Parallel experiments at CIAT-Quilichao and Carimagua employing identical treatments and a recently assembled collection of strains of *Rhizobium* isolated from *Leucaena* has revealed that there is not, as was thought, a block of nodulation of *Leucaena* below pH 5.0. A wide array of strains from differing soil types were capable of forming effective symbioses in acid conditions (Fig. 52). A few strains were exceptionally effective and are being investigated further.

Inoculation Recommendations

The inoculation recommendations for promising legume accessions (as of Oct. 31, 1978) are given in Table 31. In some cases there is a change (improvement) from last year's list. During 1978, 86 kg of peat-

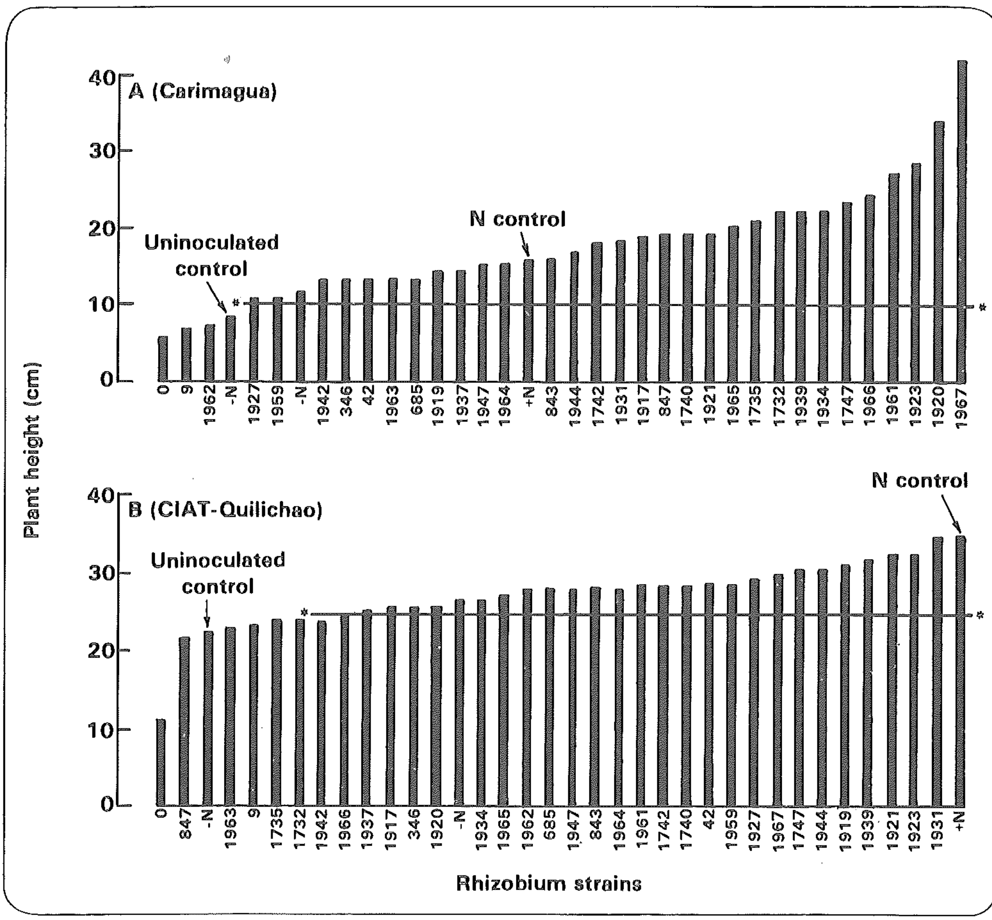

Figure 52. Response by *Leucaena leucocephala* to inoculation with strains of *Rhizobium* at two acid soil sites. (* = upper confidence limit (95%) to mean of uninoculated control.)

Table 31.

Current inoculation recommendations developed for certain promising forage legumes.

Species	CIAT No.	*Rhizobium* strain	Technology
Category 4			
Desmodium ovalifolium	350	CIAT 299	lime pellet
Pueraria phaseoloides	9900	CIAT 71	lime pellet
Stylosanthes capitata	1019/1078	CIAT 71	lime pellet
Zornia aff *latifolia*	728	CIAT 71	lime pellet
Category 3			
Centrosema hybrid	438	CIAT 590	lime pellet
Desmodium heterophyllum	349	CIAT 31	rock phosphate pellet
Category 2			
Stylosanthes guianensis	136/184	CIAT 71	lime pellet

based inoculum were produced; 45 kg were used for research in Colombia by CIAT and the Instituto Colombiano Agropecuario (ICA), and 10 kg and 6 kg were requested by national and international research institutes, respectively, while 25 kg were sent to private entities.

SOIL FERTILITY AND PLANT NUTRITION

Research on the nutritional requirements of promising grass and legume germplasm, and fertilization technology designed to efficiently meet such requirements was conducted CIAT-Palmira, CIAT-Quilichao, Carimagua and Brasilia. Emphasis this year was on: (1) N requirements of the main tropical grasses, and the N contribution of associated legumes; (2) P requirements of the main grasses; (3) more efficient use of cheap sources of P, primarily rock phosphates and its alteration products; and, (4) development of systematic techniques for estimating nutritional requirements of promising germplasm accessions. The properties of the main soils used, the Quilichao Ultisol and the Carimagua and Brasilia Oxisols,were described in the 1977 CIAT Annual Report (pages A44 and A45). Data from Brasilia are reported in the Pasture Development section.

Nitrogen Requirements of Forage Grasses

Although nitrogen fertilization of forage grasses is not considered feasible for the target area, basic information is needed to quantify their N needs and to ascertain the potential contribution of legumes in mixtures.

The N responses of *Andropogon gayanus* 621, *Brachiaria decumbens* 606 and *Panicum maximum* were determined in a small plot experiment at Quilichao, where the grasses received a basal application of 150 kg P_2O_5/ha and 60 kg K_2O/ha, followed by a maintenance application of 50 kg P_2O_5/ha, 50 kg K_2O/ha and 50 kg $MgSO_4$ six months later, thus satisfying the plant's nutritional requirements while maintaining an acid soil environment (pH 4.5, 67% Al saturation, with no lime applied).

Response to N is shown in Figure 53, where the contrasting behavior of the three grasses is evident. *B. decumbens* and *P. maximum* produced significantly less dry matter than *A. gayanus* without N (13.6 vs 21.3 t/ha/year). *B. decumbens* responded positively to the highest rate of 400 kg N/ha, while *P. maximum* required 200 kg N/ha for maximum growth. In sharp contrast, *A. gayanus* showed a significant response only to 50 kg N/ha. The dry matter yields of *A. gayanus* were significantly superior to those of *B. decumbens* at all N rates, suggesting that the former utilizes available soil N better than the latter.

Table 32 shows the N uptake values for the first five cuts. The high N-supplying power of this Ultisol is evident from the high uptake values without fertilization and is probably due to its high organic matter content (about 7%) and the fact that this trial was initiated in the first year after plowing. Uptake of native soil N, measured in check plots, was about 200 kg N/ha/year, with no significant differences

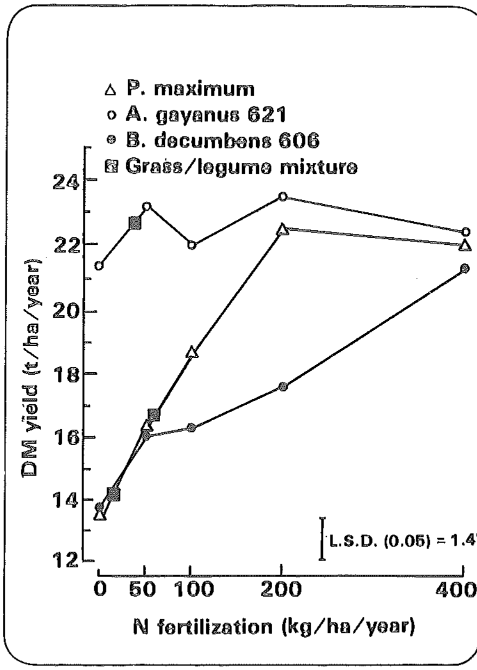

Figure 53. Nitrogen responses of three forage grasses grown alone and in association with *Stylosanthes guianensis* 184, in an Ultisol from CIAT-Quilichao. (Sum of 6 cuts per year.)

Table 32.

Nitrogen uptake of three grasses during the first 10 months of growth (5 cuts), at CIAT-Quilichao.

N applied (kg/ha/year)	*Andropogon gayanus* 621	*Panicum maximum* (kg/N/ha)	*Brachiaria decumbens* 606
0	225	184	192
50	268	234	243
100	315	291	249
200	323	355	264
400	294	336	374

between grass species. The superior behavior of *Andropogon,* therefore, does not appear to be due to its higher capacity to take up native soil N, but rather to a more efficient use of N in dry matter production. Table 33 shows the lower overall plant N content of *A. gayanus.*

The black squares of Figure 53 indicate the estimated N contributions of *Stylosanthes guianensis* 184. By placing the dry matter yield of the association of the N response curve and extrapolating to the X-axis, it is estimated the legume contributed the following amounts of N, expressed in equivalent amounts of in-organic fertilizer N applied: 40 kg N/ha with *A. gayanus,* 60 kg N/ha with *P. maximum* and only 15 kg N/ha with *B. decumbens,* (due to its aggressive growth habit).

Another N experiment was established on 0.25-ha enclosures in *B. decumbens* grazing trials of different ages in Carimagua. Several N rates were applied. All treatments received a basal application of 50 kg P_2O_5/ha, 60 kg K_2O/ha, 20 kg S/ha and 20 kg Mg/ha, except for an unfertilized "absolute or negative check" and a "positive" check which received 0.5 t lime, 700 kg N, 100 kg P_2O_5, 100 kg K_2O, 20 kg S, 20 kg Mg, 10 kg Zn, 5 kg Cu, 1 kg B, and 0.2 kg Mo/ha.

Table 33.

Plant nitrogen content and protein equivalent of three forage grasses under cutting regimes at Quilichao. (Mean of 5 N rates and 5 cuttings in 10 months.)

Species	N (%)	Protein (%)
Andropogon gayanus 621	1.58	9.9
Panicum maximum	1.75	10.7
Brachiaria decumbens 606	1.93	12.1

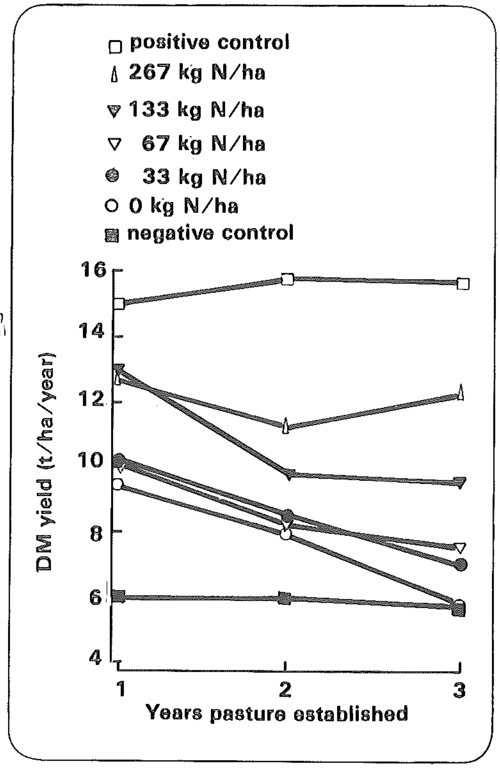

Figure 54. Effects of N fertilization and pasture age on dry matter production of *Brachiaria decumbens* in grazing paddocks at Carimagua. (Positive control: 700 kg N/ha, 0.5 t lime/ha + basal treatment + micronutrients; negative control: no fertilizers or lime.)

Figure 54 shows the first year's results (4 cuttings). Urea was the N source. Dry matter production in the negative check averaged 6 t/ha/year. Yields from plots receiving moderate levels of P, K, S and Mg, but no N, sharply decreased with increasing age of the pastures. This result correlates with the decrease in liveweight gains shown in Tables 43 and 44 and gains shown in Tables 43, 44 and 45 of the Pasture Utilization Section.

These differences in pasture age were gradually offset by N fertilization, there being no difference at 267 kg N/ha/year with a dry matter production of 12 t/ha, twice that of the negative control. This shows that N is limiting *B. decumbens* production in Carimagua grazing trials and that the N deficiency increases with increasing age of the pasture. The positive control with heavier fertilization plus lime and micronutrients increased dry matter production to about 15 t/ha/year, almost three times the negative control. Since 1 kg of liveweight gain pays for only 1 kg of N at Carimagua, N fertilization is not presently economical. These results point out the need for associating legumes with grasses as a cheap source of N.

Phosphorus Requirements of Forage Grasses

Two experiments were established in the Quilichao Ultisol and the Carimagua Oxisol to provide a sufficiently wide range of P rates to determine the external (soil test) and internal (% plant P) critical levels during the establishment year. Although both experiments include different rock phosphate sources only the triple superphosphate (TSP) data are presented here.

The Quilichao experiment consisted of two mixtures: *A. gayanus* 621 and *P. maximum*, each associated with *Centrosema* hybrid 438.

Figure 55 shows the growth rates of the two grasses for four cuts as a function of P rate. *P. maximum* showed a fast initial growth rate with maximum at 200-400 kg P_2O_5/ha with growth decreasing afterwards, particularly during the two dry

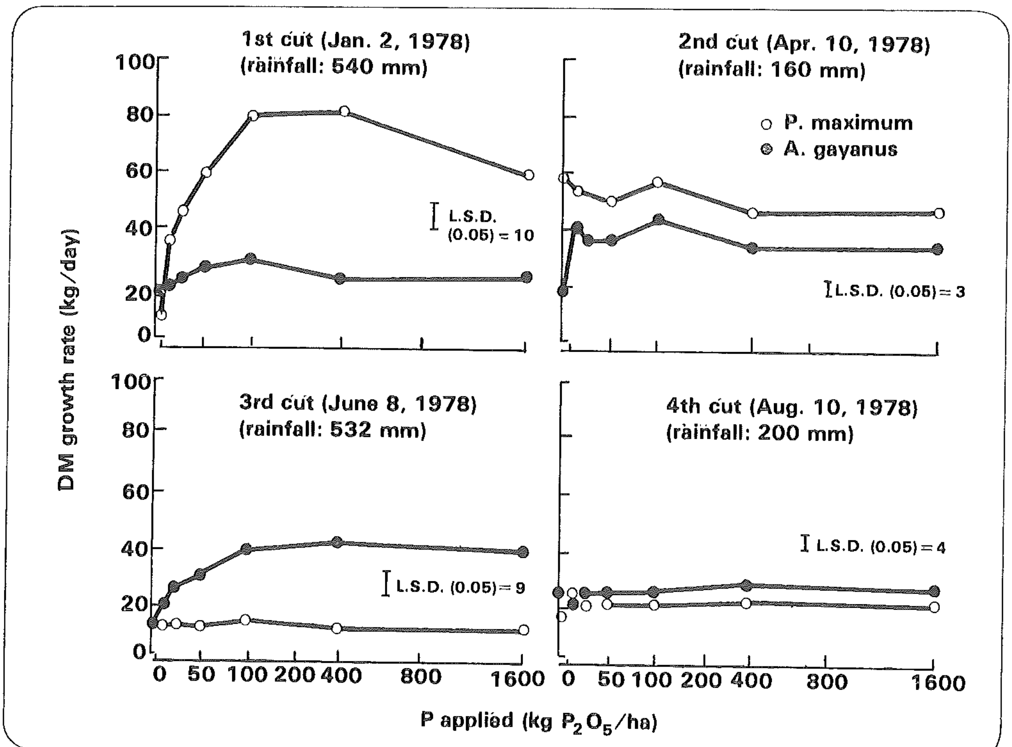

Figure 55. Effects of P on growth rates of two grasses associated with *Centrosema* hybrid 438 during the establishment year at CIAT-Quilichao.

season harvests (2 and 4). *A. gayanus* started very slowly, but gradually surpassed *P. maximum* in growth rates. Figure 56 shows the overall effect of the establishment year. *P. maximum* responded positively up to 70 kg P_2O_5/ha/year, while *A. gayanus* produced its maximum yield at 0 kg P_2O_5/ha.

Figure 56 also shows the effects on the associated legumes. *Centrosema* produced much more dry matter with *A. gayanus* than with *P. maximum*, showing a clear response up to 80 kg P_2O_5/ha. When mixed with *Panicum*, *Centrosema*'s response to P was negative, probably because of excessive competition by the grass which increased sharply with increasing P level. These preliminary data show that *A. gayanus* has lower P requirements than *P. maximum*, and therefore may be more compatible with a legume like *Centrosema* hybrid 438.

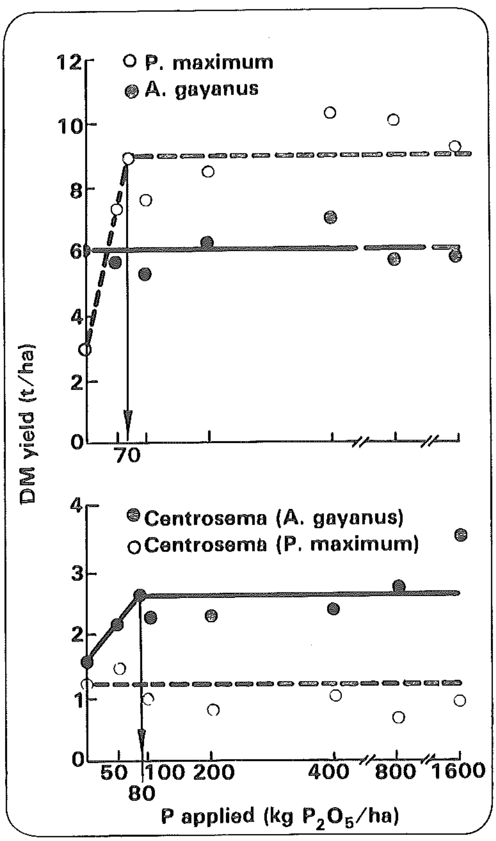

Figure 56. Phosphorus response of *Andropogon gayanus* and *Panicum maximum* in CIAT-Quilichao and its contrasting effect on the associated legume (*Centrosema*).

In Carimagua, a similar experiment including *B. decumbens* was established with *Desmodium ovalifolium* 350 as the associated legume. The P rates were lower because P fixation in the Carimagua Oxisol is about half that of the Quilichao Ultisol. Figure 57 shows that *B. decumbens* responded much more to P than the other two species. *B. decumbens* and *A. gayanus* reached maximum yields at 50 kg P_2O_5/ha while *P. maximum* responded positively up to 100 kg P_2O_5/ha.

The internal and external critical levels of P calculated for three species on the Carimagua Oxisol are shown in Table 34. This confirms the similar critical levels of P for *A. gayanus* and *B. decumbens*, which

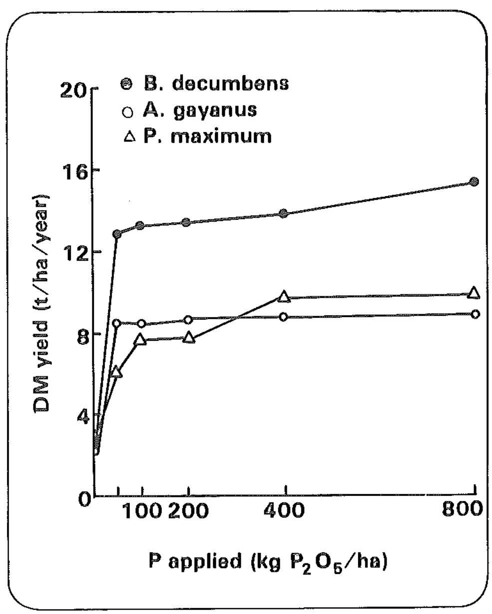

Figure 57. The effect of P on dry matter production of three tropical grasses grown in an Oxisol, at Carimagua.

Table 34.

External and internal critical levels of P for three grass species during the establishment year under a cutting regime on a Carimagua Oxisol.

Species	Critical levels: external avail.P (Bray II) (ppm)	internal P in tissue (%)
Andropogon gayanus 621	5	0.11
Brachiaria decumbens	7	0.12
Panicum maximum	6-10[1]	0.15

1 Not well-defined.

are lower than those of *P. maximum*. The Carimagua data indicate that *B. decumbens* may utilize P more efficiently than *A. gayanus*, although both species are well-adapted to low P availability.

The Phosphorus Project

The overall objective of this project is to develop a P management strategy for the principal cropping systems of acid soils of the Latin American tropics.

The high P fixing capacity and low total and available P in these soils in tropical Latin America are well-documented in the 1977 CIAT Annual Report. Although low P status predominates in vast areas of tropical Latin America, the region is blessed with known major phosphate rock deposits (Fig. 58). In order to characterize these rocks according to their relative agronomic effectiveness, samples from most of the major known deposits are being screened and compared in greenhouse trials with *P. maximum* as the test

Figure 58. Major known phosphate rock deposits in tropical South America.

crop. In addition, many of these phosphate rocks are being altered chemically and thermally to ascertain if the agronomic effectiveness of the materials can be significantly increased. Preliminary indications are that phosphate rocks which are partially acidulated (20%) with H_3PO_4 and those which are fused with magnesium silicates show very good potentials from both an initial and a residual standpoint. In addition, the physical mixtures of powdered phosphate rock and TSP also appear quite promising.

Soil Test Calibration

Although many of the acid, infertile soils of tropical Latin America are classified differently, their P status is relatively the same. As a result, it has generally been assumed that these soils would react about the same to similar applications of fertilizer P. To validate this, several soil samples were taken from selected field experiments with known amounts of added TSP, from both the CIAT-Quilichao Ultisol and Carimagua Oxisol, and Bray II P measured. Figure 59 illustrates the similar behavior of the two soils to all levels of applied P. In addition, it should be noted that even species requiring low P (2.5 to 6 ppm P, Bray II) will likely need P applications of from 50 to 100 kg P_2O_5/ha.

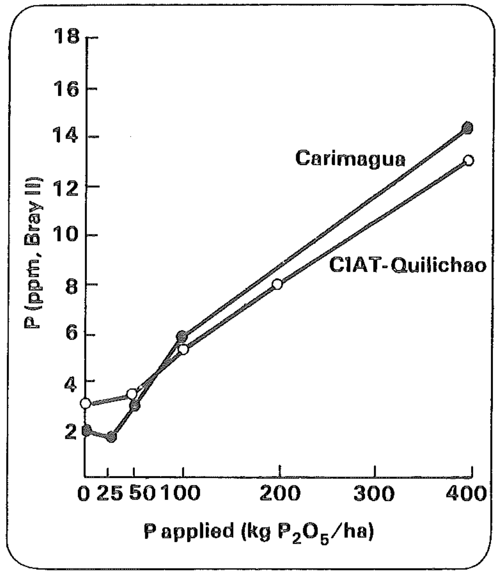

Figure 59. Effect of triple superphosphate additions on soil test P, for soils from two locations in Colombia.

Lime/Phosphorus Experiments

An incubation experiment was conducted with the Quilichao and Carimagua soils to determine the effect of varying levels of lime and P, as single superphosphate (SSP), on the availability of P as determined by Bray II. Generally, there was no apparent interaction except at the highest rate of applied P (400 kg P_2O_5/ha) and lower rates of lime where the P availability appeared to increase markedly on the Carimagua soil (Fig. 60). In all cases, however, the available soil P increased with each increment of applied P. It is also interesting to note how similarly the two soils reacted to the varying lime rates when soil pH and percentage Al saturation of the effective cation exchange capacity were considered (Fig. 61).

A greenhouse experiment was also conducted to determine the effect of rate and source of P on yield of *P. maximum* grown on two limed and unlimed Colombian soils. The amount of lime added was that calculated to neutralize 80% of the exchangeable Al. This amount was underestimated for the Quilichao soil because of the influence of the high organic matter content. Lime did not generally influence the yield of *P. maximum*, however, yields did increase with increasing increments of P up to a rate of about 300 ppm P for all carriers except TSP, which leveled off at about 150 ppm P (Fig. 62 and 63).

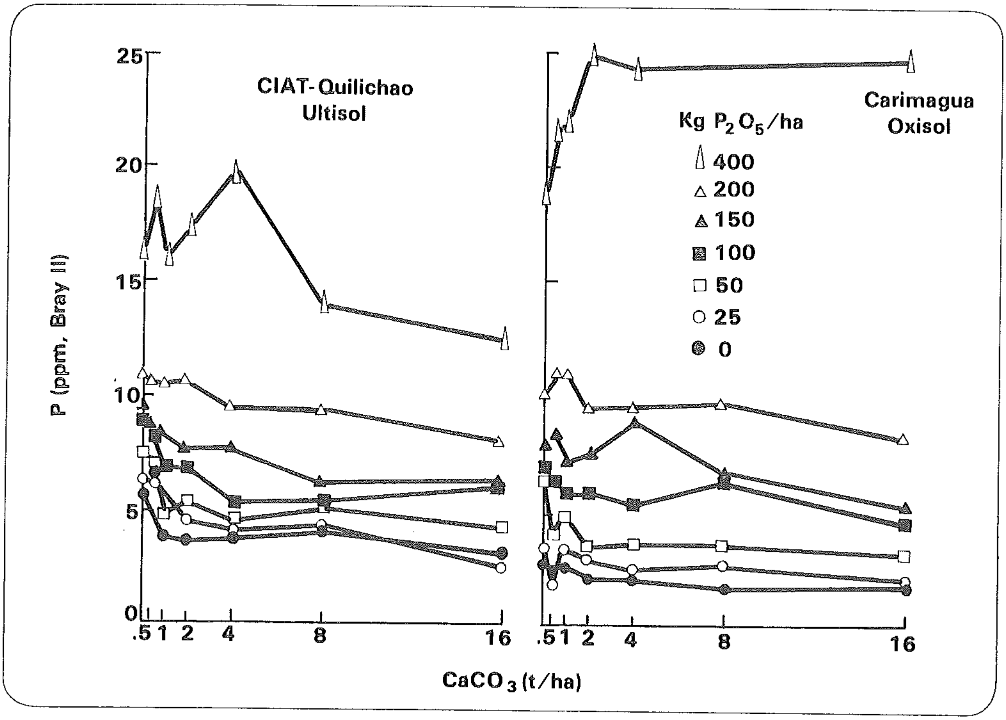

Figure 60. Effect of varying levels of applied single superphosphate and lime on availability of soil P on two soils from Colombia, after 30 days incubation.

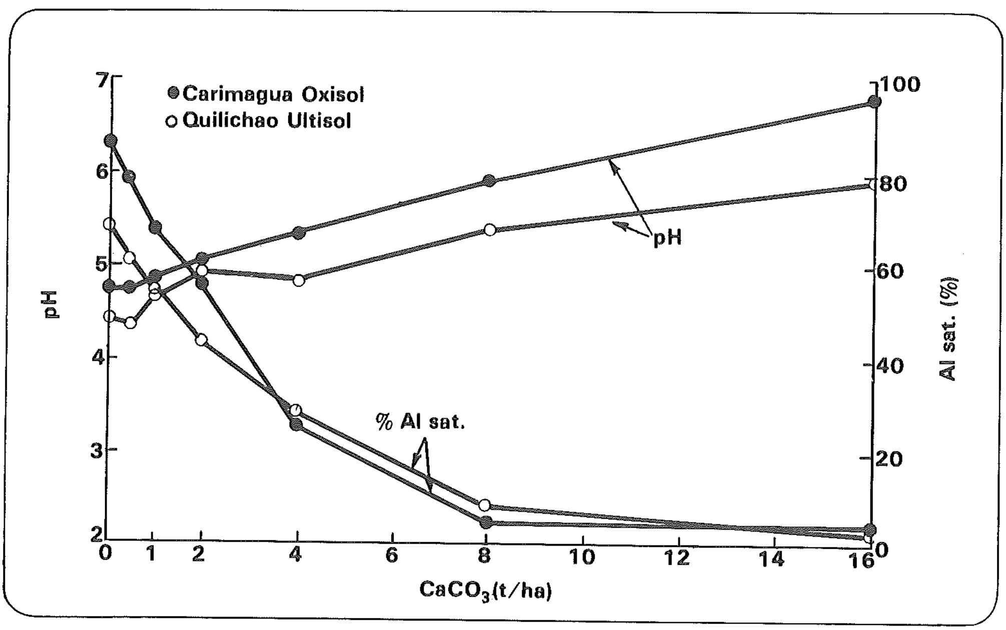

Figure 61. Effect of varying rates of lime on soil pH and percentage Al saturation on two soils from Colombia, after 30 days incubation.

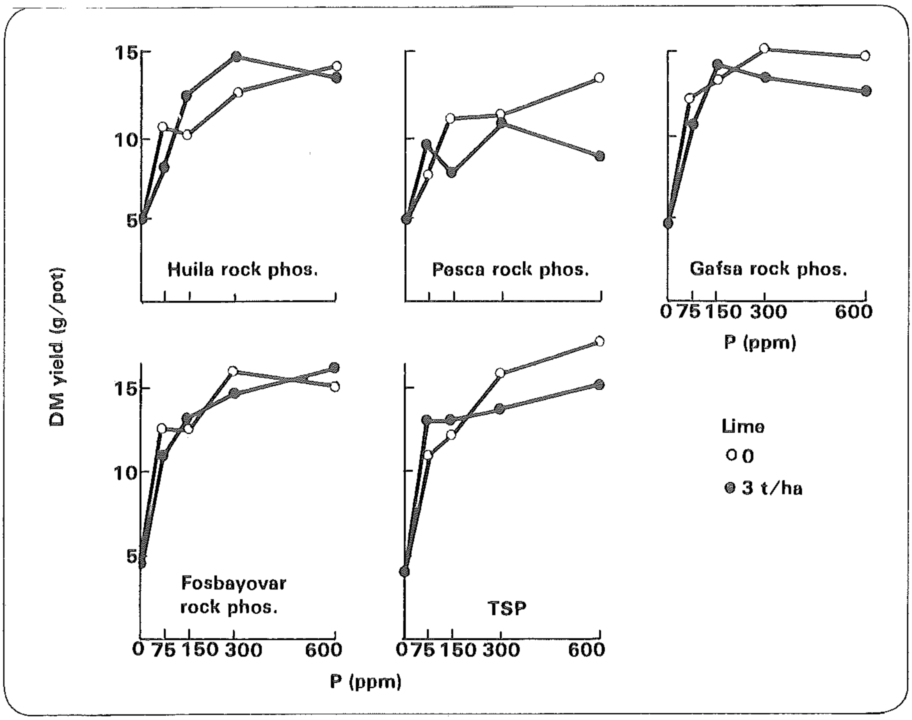

Figure 62. Effect of rate and source of P on yield of *Panicum maximum* grown in the greenhouse on a limed and unlimed Ultisol from CIAT-Quilichao. (Average of 5 cuts.)

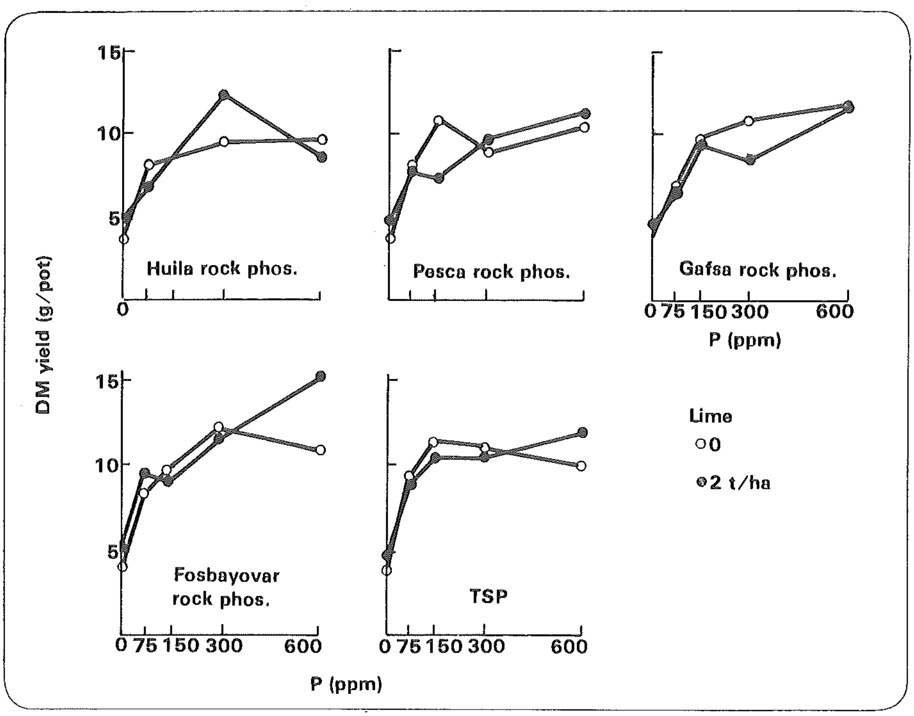

Figure 63. Effect of rate and source of P on yield of *Panicum maximum* grown in the greenhouse on a limed and unlimed Inceptisol from Popayan, Colombia. (Average of 5 cuts.)

Phosphorus Incubation Experiment

An incubation experiment was conducted with a Carimagua Oxisol to determine the changes in P availability (Bray I) due to rate and time of reaction of six different P carriers. Available P dropped markedly during the first incubation period (16 days) and remained relatively constant thereafter, regardless of the P carrier (Fig. 64). This was somewhat surprising as one would expect the more soluble TSP and basic slag to decrease in available P with time due to fixation. Apparently, a state of equilibrium is reached and the levels of available P remain constant, the level of which is determined by the rate of applied P and relative solubility of the P carrier.

Mixtures of Phosphate Rock and Triple Superphosphate

One possibility for improving P availability in phosphate rocks is to mix them with an acid-forming material such as TSP. By using a material such as TSP there is also the added advantage of supplying P in an immediately available form. Accordingly, a greenhouse experiment was established to study the effect of ratio of TSP to phosphate rock on yield of *P. maximum*, grown on a Carimagua Oxisol. Results would indicate that the ratio of P as TSP to phosphate rock varies markedly as far as availability of P to the *P. maximum* is concerned, especially at the lower rate of applied P (Fig. 65). For Pesca phosphate rock, a 75:25 ratio of TSP to rock is superior, whereas with Huila

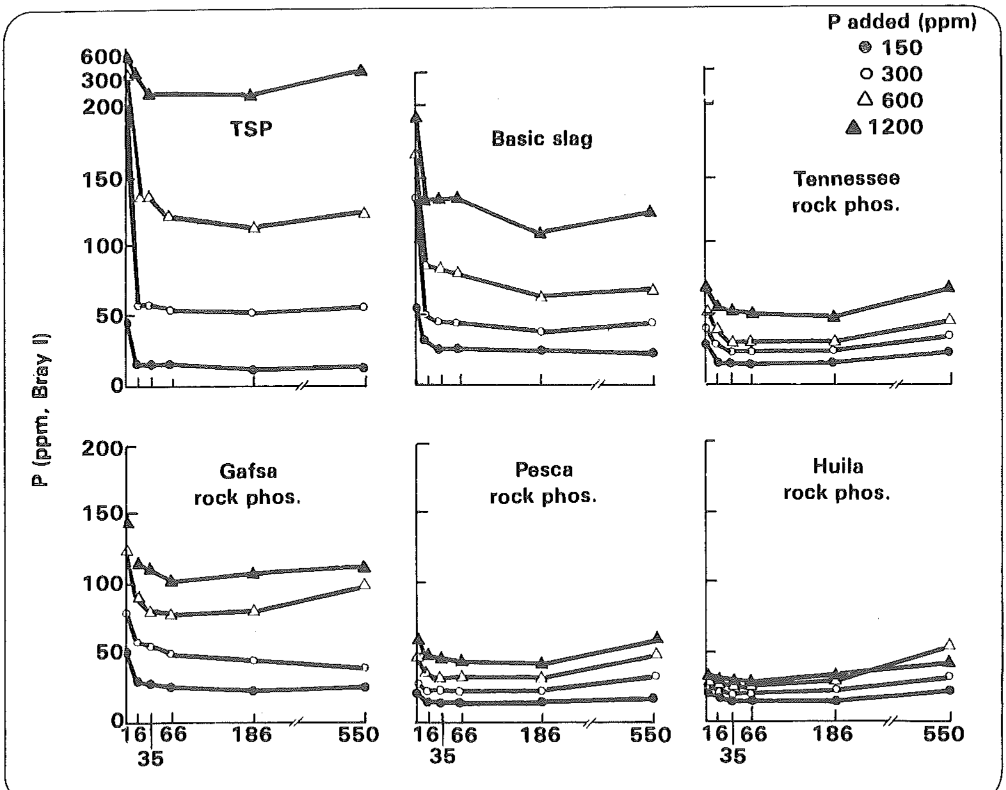

Figure 64. Changes in P availability (Bray I), due to time of reaction of six different P carriers with a Carimagua Oxisol.

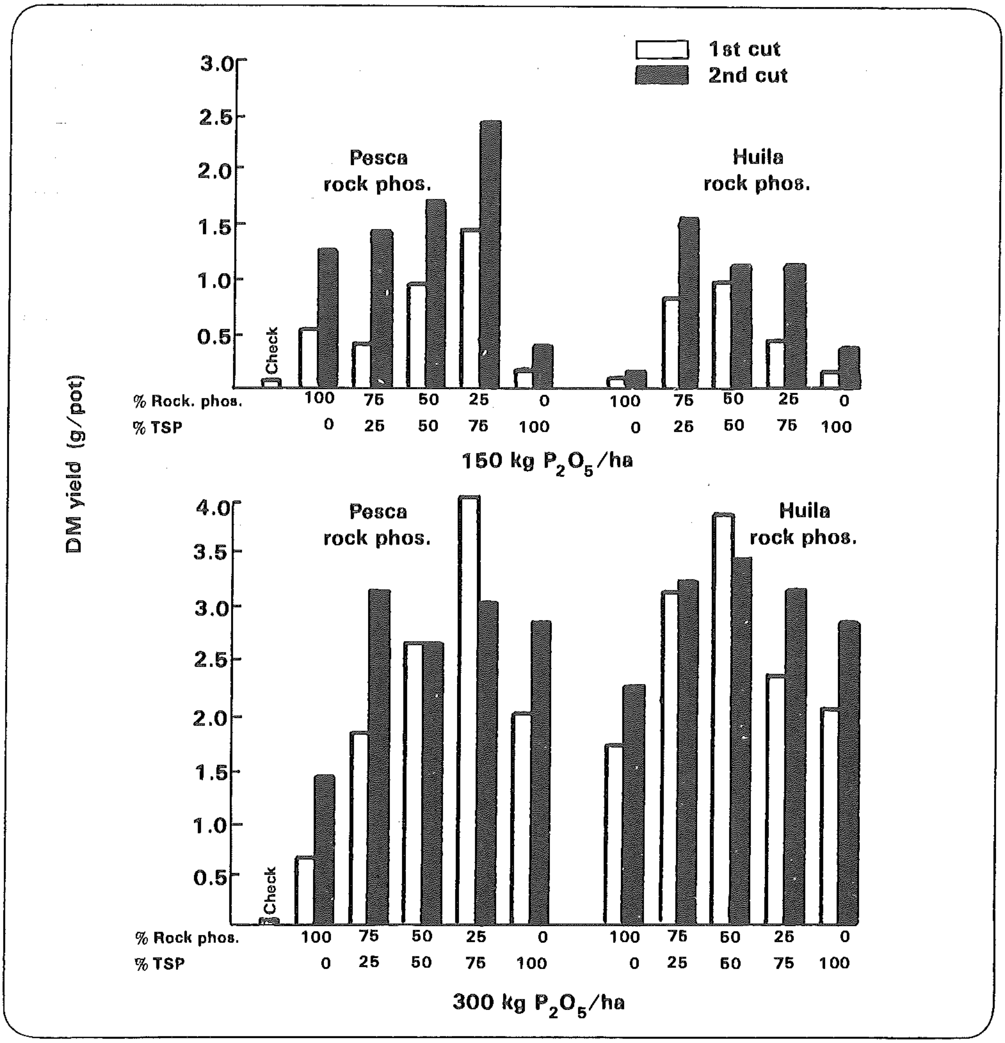

Figure 65. Effect of ration of TSP to rock phosphate and P rate on yield of *Panicum maximum* grown in the greenhouse on a Carimagua Oxisol.

phosphate rock a 25:75 ratio appears optimum. At the higher rate of applied P the ratio effect was not so clear, probably due to increased amounts of TSP.

It is difficult to explain why, at the lower rate of P, the 100% TSP did so poorly (Fig. 65). Since all sources were finely ground, perhaps the soluble TSP was fixed and therefore unavailable to the plant. Results of this experiment do suggest, however, that a similar trial should be conducted in which finely ground materials are granulated to determine the effect of aggregate size. Furthermore, granulation of these mixtures would insure intimate contact between the phosphate rock and the TSP so that acid from the TSP would be more likely to react with the rock and not be dissipated in the soil.

Long-term Effects of Different Phosphate Rocks

A long-term field experiment with *B. decumbens* was established in 1976 at

Carimagua to compare effects of six phosphate rocks with TSP. Application rates range from 0 to 400 kg P_2O_5/ha, all broadcast and incorporated into the topsoil. To date the grass has been cut seven times; results are given in Figure 66. Although yields differed markedly at first, due to the P carrier, after seven cuts total yields are remarkably similar for all carriers at any given rate of applied P. Figure 67 shows excellent performance of the phosphate rocks when compared with TSP. In any given time the phosphate rocks appear equal to and, in many instances, superior to the TSP, especially from a residual standpoint. The overall performance of the P carriers is given in Table 35.

It might be concluded that with time one

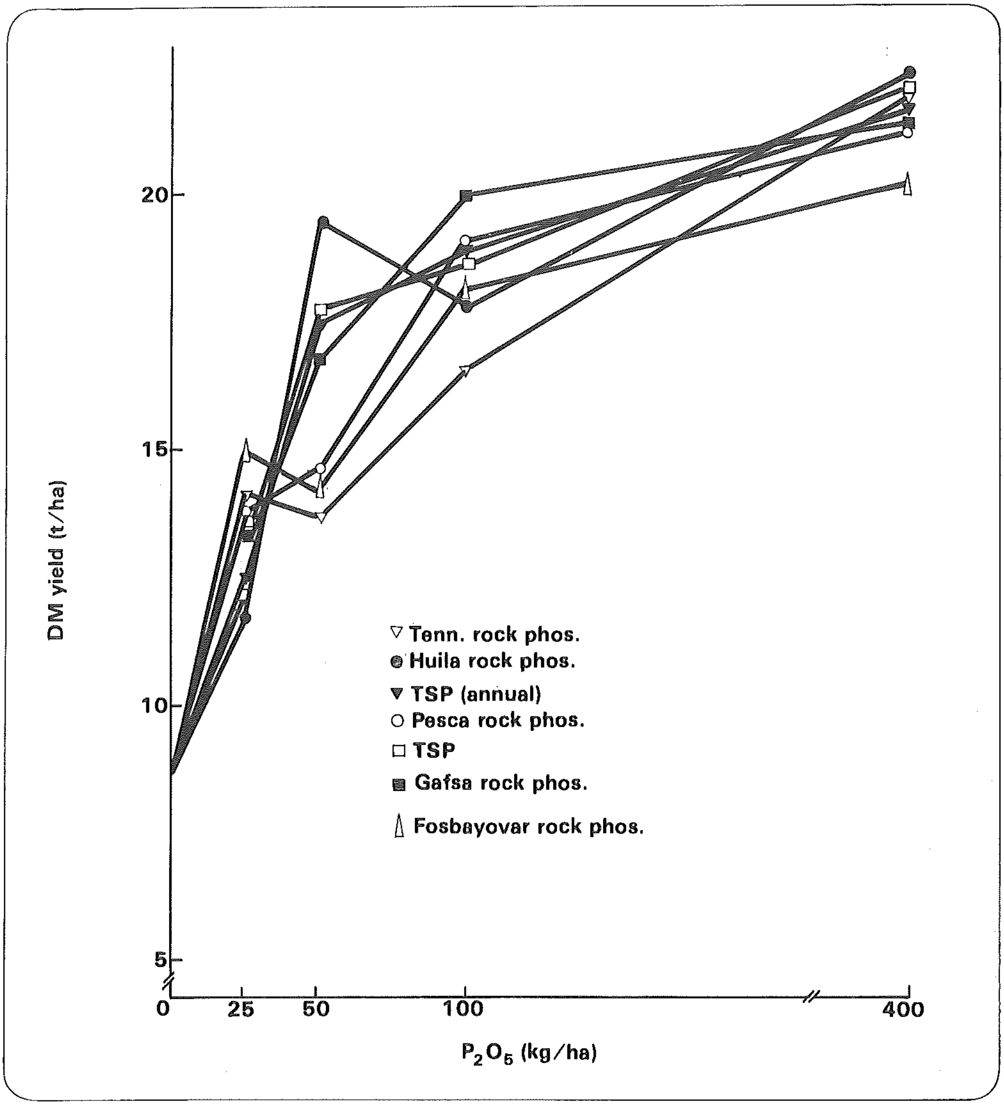

Figure 66. Effect of P carrier and rate of application on yield of *Brachiaria decumbens* grown on a Carimagua Oxisol. (Total of 7 cuttings.)

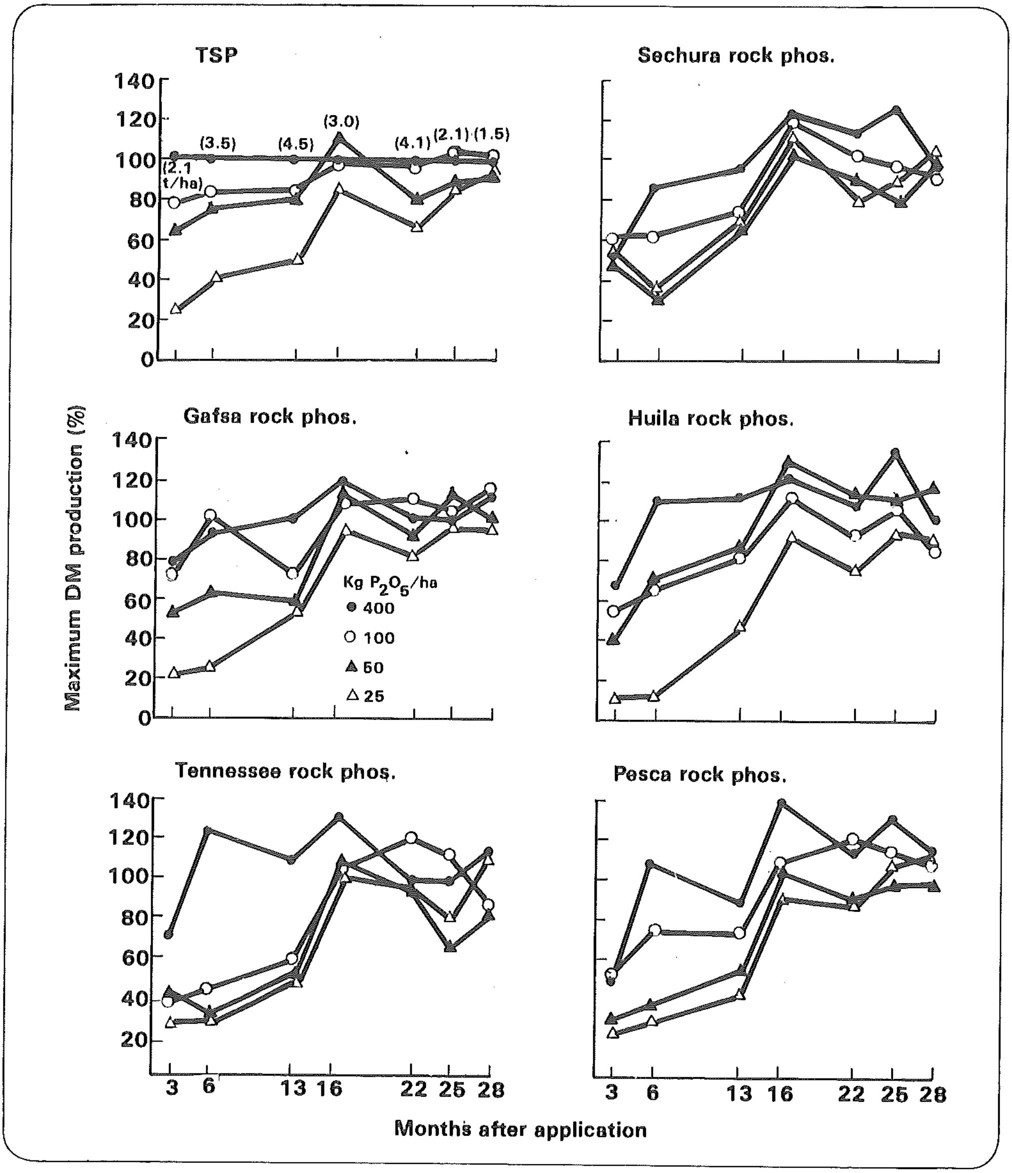

Figure 67. Initial and residual effects of five phosphate rocks relative to TSP applications on *Brachiaria decumbens* yields on a Carimagua Oxisol. (TSP considered as 100%, with actual yields given in parentheses.)

P source is just as effective as another in a long-term forage production scheme. However, this may not be true since other essential nutrients probably became more limiting than P, thus creating this leveling effect. Figure 68 illustrates quite vividly the extreme K deficiency which occurred between the second and fourth cuts. There are indications that Zn might also be reaching deficiency levels in the plant tissue (Fig. 68). To insure validity of experimental results, it would appear that a complete tissue analysis monitoring scheme must become an integral part of the on-going P research program.

Table 35.

Relative agronomic effectiveness of phosphate rocks from several sources as determined by yield of *Brachiaria decumbens* grown in the field at Carimagua.(Sum of 7 cuts taken over a 28-month period.)

P source	Relative effectiveness (%) P_2O_5 applied (kg/ha)			
	25	50	100	400
Triple superphosphate	100	100	100	100
Huila rock phosphate	96	110	96	109
Pesca rock phosphate	111	81	101	104
Gafsa rock phosphate	110	75	108	99
Tennessee rock phosphate	112	78	88	106
Sechura rock phosphate	125	90	87	98

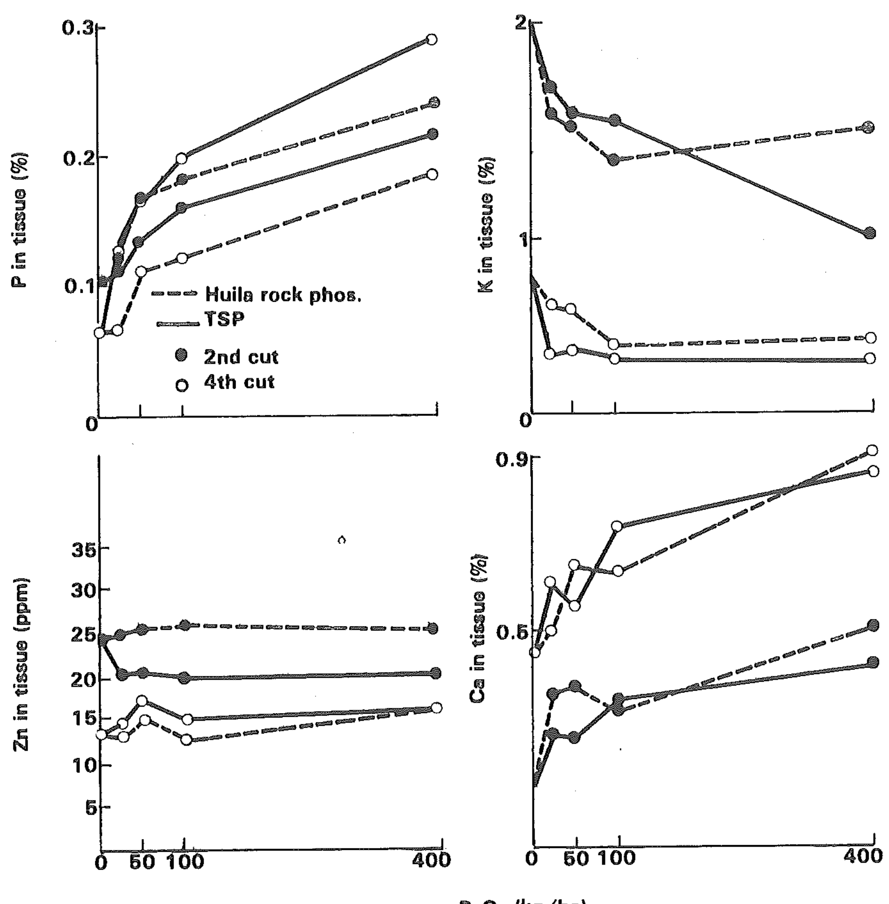

Figure 68. Effect of two P carriers and application rates on selected essential elements in *Brachiaria decumbens* grown on a Carimagua Oxisol.

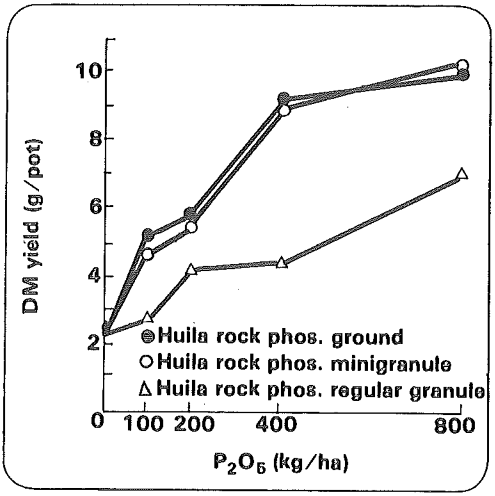

Figure 69. Effect of rate and granule size of Huila phosphate rock on yield of *Panicum maximum* grown on a Carimagua Oxisol in the greenhouse. (2 cuttings).

Granule Size of Phosphate Rock

In general, phosphate rock must be finely ground to be most effective. This

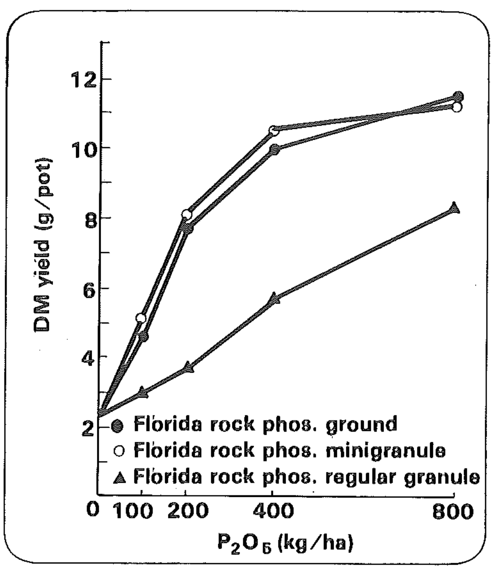

Figure 70. Effect of rate and granule size of Florida phosphate rock on yield of *Panicum maximum* grown on a Carimagua Oxisol in the greenhouse. (2 cuttings).

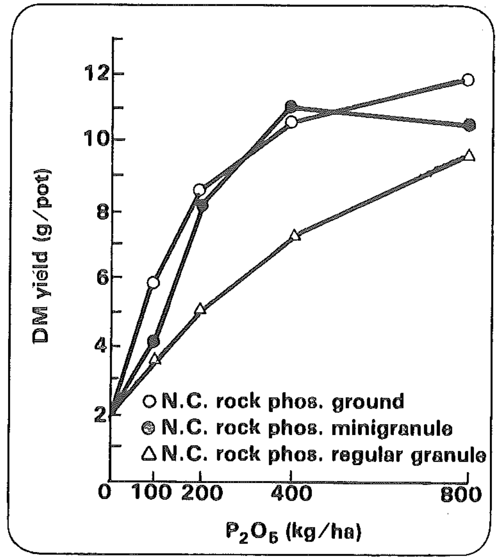

Figure 71. Effect of rate and granule size of North Carolina rock phosphate on yield of *Panicum maximum* grown on a Carimagua Oxisol in the greenhouse. (2 cuttings).

creates certain problems since the product is usually quite dusty and hard to spread evenly on the field. A greenhouse experiment was established to determine the effect of granule size of phosphate rock on yield of *P. maximum* grown on a Carimagua Oxisol. The granules were made by granulating finely ground phosphate rock with a 3.3% KCl binder. Three particle sizes were used: powdered (< 200 mesh), minigranules (- 48 + 140 mesh) and regular fertilizer granules (-16 + 16 mesh). Figures 69-71 illustrate quite clearly that the minigranules are as effective as the powdered materials at all application rates. The use of minigranules would eliminate most of the physical problems of handling finely ground phosphate rocks.

Developing a Phosphorus Research Network

To date, 16 field experiments have been established with several crops on representative sites throughout Colombia, and at

Table 36.

List of established and proposed field experiments of the Phosphorus Project.

Location	Crops	Status[1]	No. of exper.	Cooperators
Colombia				
Popayán	Beans	E	1	
Carimagua	*B. decumbens*	E	1	
	Cassava	E	1	
	Peanuts/Rice	E	1	
	P. maximum	P	1	
Quilichao	Cassava	E	2	
	B. decumbens	E	2	
	Rice/Peanuts	E	1	
	Maize/*D. ovalifolium*/ *P. maximum*	P	1	
Villavicencio	Lowland rice/Peanuts	E	1	ICA
	Upland rice/Peanuts	E	1	ICA
	B. decumbens	E	1	ICA
	P. maximum	P	1	ICA
Peru				
Pucallpa	*B. decumbens*	E	2	IVITA
	P. plicatulum/ *C. pubescens*	E	1	IVITA
Yurimaguas	Rice/Peanuts/Soybeans	E	1	CRIA I-NCSU
Brazil				
Cerrado Center	Cassava	P	1	EMBRAPA-CPAC
	Soybeans	P	1	EMBRAPA-CPAC
Venezuela				
Jusepin	Maize/Peanuts	P	1	U. ORIENTE

1 E = established, P = proposed.

Pucallpa, Perú. Early in 1979 several additional field experiments will be established in Brazil, Colombia, Perú, and Venezuela (Table 36). In addition, greenhouse and laboratory studies are underway to screen for promising phosphate materials which will then be field-tested.

Although the Phosphorus Project is an integral part of the Beef Program, it also has equal research responsibility to other crops, most of which are preceeded by or grown in rotation with tropical pastures in Oxisols and Ultisols.

Systematic Estimation of Nutrient Requirements

The Soil Fertility and Plant Nutrition Section was established in June 1978. Its fundamental objective is to understand, within an acceptable level of precision, nutrient requirements of forage species grown under acid, infertile soil conditions.

In most cases, nutritional requirements of the promising grasses and legumes accessions have not been determined and this lack of information presents an important gap. The specific objectives of this section are the following: (1) to characterize and define analytical methods for acid soils and plant tissue; (2) to evaluate the introduced germplasm by a rapid method which will determine preliminary selection criteria; (3) to determine the critical nutritional requirements of the promising germplasm.

Activities began with an evaluation of the CIAT soil and plant analyses laboratories, including the analytical methods used for soils and plant tissue.

For routine soil analysis from CIAT-Quilichao and Carimagua the extraction methods adopted are: 1*N* KCl for exchangeable Al, Ca and Mg, Bray II extractant for P and K, and finally the double acid extract for micronutrients. At the moment, the analytical laboratory is adapting to a system for analyzing a large volume of samples.

Keeping in mind that the grass and legume germplasm has been classified in categories based on previous evaluations, an evaluation system has been adopted which is compatible with the established categories. The preliminary selection which has been used in the Grass and Legume Agronomy sections (CIAT Annual Report 1977), represents the established selection criteria. Within this parameter, the Plant Nutrition section will use the following criteria for selecting new germplasm:

1. An evaluation based on visual symptoms of deficiencies or mineral toxicity. The objective is to characterize the factors contributing to general adaptation to conditions at CIAT-Quilichao and Carimagua.

2. Selection for tolerance to Al by simple and rapid techniques. The objective is to characterize the factors contributing to Al tolerance.

Existing material in introduction gardens at Quilichao and Carimagua and newly introduced material will be evaluated by assigning values for visual symptoms of deficiencies or toxicity; these will be confirmed with foliar analysis including controls. In addition to providing information for selecting tolerant species, this system will allow charting of symptoms of foliar deficiencies and mineral toxicities which will facilitate future evaluations.

Germplasm will be screened for tolerance to Al by using the differential correlation of the radicular system technique. This technique uses a hematoxilin solution having a high affinity for Al and permits the differentiation of the meristematic tissues which also have a direct affinity for Al.

The original hematoxilin method was modified slightly to adjust for the germination characteristics of forage seeds and the initial growth of the forage plants. This technique should permit evaluating a large proportion of the Category 1 material in a relatively short time.

For materials in categories 2, 3 and 4, a quantitative determination of nutritional requirements has been adopted using the critical concentration method. This method uses the Cate-Nelson interpretation technique, which is widely accepted for its simplicity and acceptable precision.

Since research in the area of fertilizer requirements is dynamic, it is convenient to use an easy model to manage where the results are easily calculated and can be interpreted rapidly. Once data are analyzed, it will then serve as a basis to revise and make necessary adjustments for succeeding experiments. Also, this method will be useful for readjusting previous results.

Studies on nutritional requirements will be initiated in 1979. To facilitate rapid interpretation these studies will be done in the glasshouse using soils from Carimagua, with most of the nutrients to be studied. To study Mn toxicity, soils from Quilichao will be used.

At each nutritional level it will be possible to study various species which will be subjected to the following evaluation: (1) production of dry matter (aerial part and roots); (2) rate of growth (GR, RGR); (3) foliar analysis; and (4) rate of nutrient translocation.

Once these parameters have been determined they will be subjected to two types of evaluation to determine the critical nutritional requirements: (a) dispersion diagrams, and (b) linear discontinuous models.

Finally, the results will be interpreted by multiple nutrients through the combination of linear discontinuous models by individual nutrients. For each species, these criteria will be used to formulate the fertilizer requirements which will be initially evaluated in CIAT-Quilichao and Carimagua and later in regional trials throughout the Program's target area.

PASTURE DEVELOPMENT

Research on pasture development was conducted at CIAT-Quilichao, Carimagua and Brasilia with the overall objective of developing low-cost methods of establishing and maintaining improved pastures. Advances were made in: (1) using crops as precursors to pasture establishment; (2) low density seedings; (3) determining components of conventional establishment methods; (4) strip plantings; and (5) introducing legumes into native Cerrado.

Crops as Precursors for Pasture Establishment

The possibilities of establishing pastures while growing crops were studied at Quilichao and Carimagua. The intercropping potentitals of key grass and legume pasture species were tested with crops having a wide range in growth habit, growth duration, plant architecture and fertility requirements. An experiment on the Quilichao Ultisol tested the establishment of pure *Stylosanthes guianensis* 184, and mixed swards of that legume with *Brachiaria decumbens* or *Panicum maximum* under stands of cassava, beans, rice, corn, sorghum and peanuts. The combinations were planted in October 1977 at two soil fertility levels: "low" 0.5 t/ha of dolomitic lime, and 100 kg P_2O_5/ha as triple superphosphate, and "high" with 4 t/ha of lime, 400 kg P_2O_5/ha and 100 kg K_2O/ha, all broadcast and incorporated into the top 15 cm of the soil. The crops were sprinkle-irrigated when required. The results with cassava, rice and beans at Quilichao are summarized below.

Cassava

The variety Chiroza planted at 1.2 x 0.8 m grew very well and yielded up to 53 t/ha of fresh roots in 12 months when grown in monoculture (Table 37). When the three pastures were planted at the same time as the cassava, *S. guianensis* decreased cassava yields about 20% but established itself well, reflecting a positive intercropping effect. Mixed grass/legume pastures proved too competitive for cassava. Root yields decreased drastically and the pasture had to be cut while cassava was growing, an unlikely practical situation. *P. maximum* depressed cassava yields more than *B. decumbens*, presumably because of its erect growth habit. There were no significant differences due to fertility. When pastures were planted 60 days after the cassava, growth of both grasses and legumes was poor, probably due to low light intensity and anthracnose attacks in *S. guianensis*. Likewise, when pastures were broadcast 210 and 300 days after cassava planting, stands were poor. The only practical alternative seems to be simultaneous planting of the pasture legume with cassava.

Rice

The variety CICA 8 was drilled in 30-cm

Table 37.

Effect of simultaneous intercropping of cassava (cv. Chiroza Gallinaza) and pasture production (3 cuts) on the Ultisol at CIAT-Quilichao.

Fertility level	Species[1]	Cassava (roots) Mono-culture (t/ha)	Inter cropped (t/ha)	RY[2] (%)	Pastures (dry matter) Mono-culture (t/ha)	Inter-cropped (t/ha)	RY (%)
Low	Cassava + Sg	45.6	38.2	84	2.1	1.0	48
	Cassava + Sg + Pm	50.8	8.9	17	6.0	6.2	103
	Cassava + Sg + Bd	42.4	17.0	40	7.0	6.4	92
High	Cassava + Sg	53.0	34.4	65	2.7	1.5	56
	Cassava + Sg + Pm	42.7	10.2	24	9.6	8.6	89
	Cassava + Sg + Bd	46.6	23.9	51	8.5	7.7	91

1 Sg = *Stylosanthes guianensis* 136; Pm = *Panicum maximum;* Bd = *Brachiaria decumbens.*

2 RY = Relative yield = $\frac{\text{Intercropped yield}}{\text{Monoculture yield}} \times 100$

rows and managed as an upland crop but without serious water stress due to frequent sprinkle-irrigation. Rice growth was so vigorous that the pastures performed poorly (Table 38). When planted at the same time, forage grasses did establish themselves, but produced only about 32% of the dry matter of pastures without rice.

S. guianensis alone produced very little. It was affected by anthracnose when grown with rice, but much less severely when grown alone. When pastures were planted 45 and 60 days after rice, so few plants established themselves that measurable dry matter was not produced. Rice yields were high, particularly at high fertility. At the low fertility level, rice yields actually increased about 27% when pastures were interplanted; this effect practically disappeared at the high fertility level. The reasons for this unexpected observation are not understood.

A second experiment was established in July 1978 with the same rice variety planted at two row spacings (30 and 45 cm) to provide less competition for the pastures used. *Desmodium ovalifolium* 350 replaced *S. guianensis* because of its better anthracnose and shade tolerance. The legume was planted with *B. decumbens,* each between alternate rice rows at 14, 30, 45 and 120 days after rice planting. Rice was harvested 180 days after seeding. Rice yields were even higher than before, reaching a maximum of 7.7 t/ha. Figure 72 shows that rice yields were severely affected by interplanting pastures 15 days after rice seeding, but rice yields approached maximum when interplanting was delayed to 45 days and pasture growth was still reasonable. The optimum point for the intercropping system seems to be between 30 and 45 days. This figure also shows the highly competitive nature of this intercropping system. The wider row is better for pastures and *vice versa.* The results indicate that with vigorous, short-statured, high-yielding rice varieties, pasture establishment is feasible.

Beans

Beans were also tested, to evaluate the potential of an early maturing crop with high fertility requirements. The results of the first crop (Table 39) showed high yields at the high fertility level and no effect on bean yields of interplanting pastures roughly halfway in the bean life cycle. Pasture production was decreased by about half in the presence of beans. Nevertheless, the fact that the pastures had no detrimental effect on bean yields indicates that pasture establishment via intercropping is highly desirable in this short season crop.

Pasture Development in the Llanos

The Carimagua Pasture Development unit initiated a number of new trials during 1978 primarily emphasizing low input pasture establishment methods and pasture maintenance and management systems. This expanded effort was made possible by the addition of a plant nutrition specialist who has assumed responsibility for much of the liming and nutrient requirement research previously done by this group.

During establishment of a number of new trials, some important lessons have been learned relative to establishment methods. A number of new trials were planted where native savanna had been grazed rather intensively, resulting in changes in botanical composition and the presence of many more weeds than are normally encountered in virgin native savanna. Serious problems with weed competition occurred in several trials where P was applied broadcast prior to or

Table 38.

Intercropping effects of rice (var. CICA 8) and pastures (3 cuts) planted at different times on CIAT-Quilichao Ultisol. (First rice experiment planted 12 October 1977).

Days of pasture seeding after rice	Fertility level	Species[1]	Rice (grain) Mono-culture (t/ha)	Rice (grain) Inter-cropped (t/ha)	Rice (grain) RY[2] (%)	Pastures (dry matter) Mono-culture (t/ha)	Pastures (dry matter) Inter-cropped (t/ha)	Pastures (dry matter) RY (%)
0	Low	Rice + Sg	2.27	2.80	123	2.15	0.04	2
		Rice + Sg + Pm	2.65	3.38	128	5.97	2.31	39
		Rice + Sg + Bd	3.06	3.82	125	6.99	1.96	28
		Mean	2.66	3.33	125	5.04	1.44	29
	High	Rice + Sg	4.59	5.04	110	2.67	0.02	1
		Rice + Sg + Bd	4.54	4.18	92	9.60	3.98	41
		Rice + Sg + Bd	6.53	4.80	74	8.96	2.03	23
		Mean	5.22	4.67	90	6.98	2.01	28
45	Low	Rice + Sg	2.27	3.19	140	2.15	0.00	0
		Rice + Sg + Pm	2.65	3.82	144	5.97	0.00	0
		Rice + Sg + Bd	3.06	4.32	141	6.99	0.00	0
		Mean	2.66	3.78	142	5.04	0.00	0
	High	Rice + Sg	4.59	5.14	112	2.67	0.00	0
		Rice + Sg + Pm	4.54	6.37	140	9.60	0.00	0
		Rice + Sg + Bd	6.53	6.20	95	8.96	0.00	0
		Mean	5.22	5.90	113	6.98	0.00	0
60	Low	Rice + Sg	2.27	3.61	159	2.15	0.00	0
		Rice + Sg + Pm	2.65	2.40	91	5.97	0.00	0
		Rice + Sg + Bd	3.06	3.10	101	6.99	0.00	0
		Mean	2.66	3.04	114	5.04	0.00	0
	High	Rice + Sg	4.59	5.23	114	2.67	0.00	0
		Rice + Sg + Pm	4.54	4.90	108	9.60	0.00	0
		Rice + Sg + Bd	6.53	6.20	105	8.96	0.00	0
		Mean	5.22	5.44	104	6.90	0.00	0

1 Sg = *Stylosanthes guianensis* 136; Pm = *Panicum maximum;* Bd = *Brachiaria decumbens.*

2 RY = Relative Yield $= \frac{\text{Intercropped yield}}{\text{Monoculture yield}} \times 100$

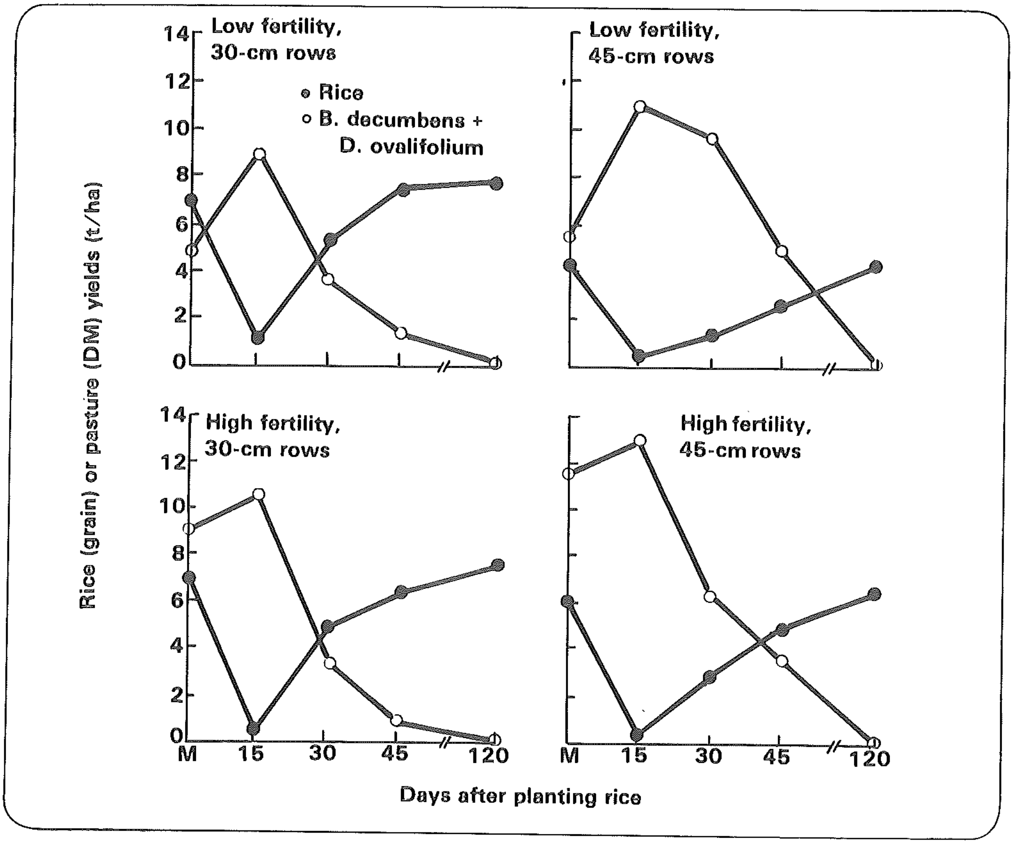

Figure 72. Effects of time of intercropping rice (var. CICA 8) with *Desmodium ovalifolium* and *Brachiaria decumbens* as affected by fertility level and rice row spacing, at CIAT-Quilichao. (July 1978 planting. M = monocultures for rice or pasture species.)

at planting time, thus necessitating either chemical or manual post-planting weed control. In contrast, trials that were row-seeded with band-applied fertilizer had no serious weed problems during the establishment phase. The most severe weed problems were encountered when both seed and fertilizer were broadcast. This experience emphasizes the importance of band or localized placement of fertilizer applied at seed time. After the pasture is established, broadcast fertilizer applications are appropriate.

Several observations during the season underscore the importance of competition of grass and legume seedlings with established grasses and legumes. For example, new seedlings of *A. gayanus* rarely survived or grew appreciably in the presence of a rather thinly established stand (about 20,000 plants/ha) of *A. gayanus*. In a low-density seeding trial (1000 plants/ha) with *A. gayanus*, a radius of approximately 1 m around mother plants (originally seeded plants) was essentially free of any new seedlings. Beyond that point the stand of new seedlings was excellent. Another example is that of *Stylosanthes capitata* seedlings. In the presence of established plants of *S. capitata*, seedlings developed in a moderately vigorous manner, but in the presence of established grasses, the

Table 39.

Effects of intercropping beans (var. ICA-Tui) with pastures (1 harvest) planted 45 days after beans at CIAT-Quilichao. (Oct. 17, 1977 planting.)

Fertility level	Species[1]	Bean grain yields: Monoculture (t/ha)	Bean grain yields: Intercropped (t/ha)	Bean grain yields: RY[2] (%)	Pasture DM yields: Monoculture (t/ha)	Pasture DM yields: Intercropped (t/ha)	Pasture DM yields: RY (%)
Low	Beans + Sg	1.08	1.08	100	0.80	0.37	46
	Beans + Sg + Pm	1.06	0.91	86	2.03	1.27	62
	Beans + Sg + Bd	1.22	1.24	102	1.70	0.93	55
	Mean	1.12	1.08	96	1.51	0.86	57
High	Bean + Sg	1.57	1.58	100	1.40	0.85	61
	Bean + Sg + Pm	1.63	1.47	90	6.06	2.19	36
	Bean + Sg + Bd	1.67	1.84	110	2.29	2.11	92
	Mean	1.62	1.63	100	3.25	1.72	53

1 Sg = *Stylosanthes guianensis* 136; Pm = *Panicum maximum*, Bd = *Brachiaria decumbens*.

2 $RY = \text{Relative yield} = \frac{\text{Intercropped yield}}{\text{Monoculture yield}} \times 100$

seedlings were dwarfed and exhibited severe K and Mg deficiency symptoms. It is well-known that pasture plants generally have higher nutrient requirements (nutrient concentration in soil solution) in the seedling phase than after establishment. It seems logical that competition from established plants would aggravate this situation, thus requiring special maintenance when seedling survival is required to thicken stands.

Pasture Establishment

Work continued in low-density seeding experiments which were previewed last year (CIAT Annual Report, 1977,pp. A 61-63). Ten species were planted at 1000 hills/ha with initial fertilizer applied only in the hill. After establishment was assured, fertilizer was broadcast between hills. Preliminary establishment data were presented last year. Percentage coverage of the plot area, used as a measure of establishment, is shown in Figure 73. Complete coverage had been achieved by May with *Brachiaria humidicola*,

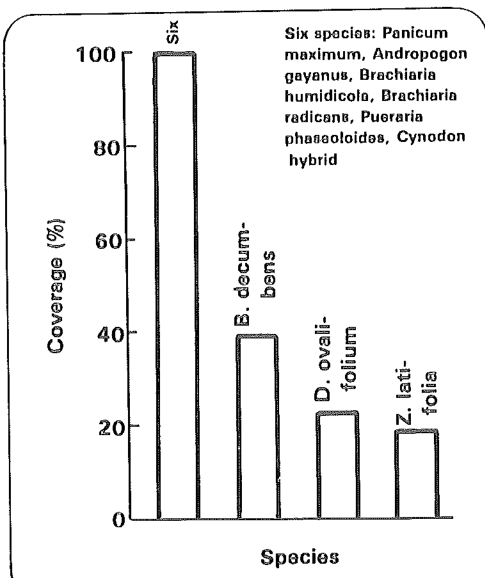

Figure 73. Percentage coverage provided by stolons and/or seedlings in May 1978 from a low-density planting (1000 hills/ha) made in September 1977.

Brachiaria radicans, a *Cynodon* hybrid, *A. gayanus*, *P. maximum* and *Pueraria phaseoloides*. The extremely low fertility of the soil was an effective weed control mechanism and almost none were present. Initial stands of *S. capitata* 1078 were very poor and reseeding was not successful, therefore reliable data are unavailable for that species.

By June, nine months after seeding, *B. humidicola, B. radicans, P. maximum, A. gayanus* and *P. phaseoloides* (kudzu) were ready for grazing. At that time, the kudzu mat was not well-rooted but after grazing, it was thoroughly anchored to the soil. The *Cynodon* hybrid provided cover but is too poorly adapted to be considered for this ecosystem.

By September 1978, i.e., one year after establishment, all species excepting *S. capitata* had provided essentially complete cover. Figure 74 shows the condition of *A. gayanus* in May, shortly after the beginning of the rainy season. Stand counts, shown in Table 40, averaged over 150 plants/m^2 for *A. gayanus* developed from the 1000 plants/ha in the original seeding. Stand counts for *P. maximum* were much lower, ranging from 5 to 15 plants/m^2, but entirely adequate for pasture establishment.

The low density planting system of pasture establishment shows considerable promise for reducing initial investment in fertilizer, labor, and seed which are all often critically limiting resources in developing areas. From this early experience a number of new trials have been established. In one, the interaction of

Figure 74. *Andropogon gayanus* established via low-density seeding method at Carimagua. The large "mother" plants were planted in September 1977, spaced 3.16 m apart (1000 hills/ha). They began seeding in November at the end of the rainy season and germination occurred after first rains of the next rainy season in March 1978. Seed settled to bottom of furrows left by field cultivator and appear to have been seeded in rows. Stand counts in April 1978 averaged 150 plants/m^2.

Table 40.

Effects of P and K on stand counts from low density seeding of *Andropogon gayanus* and *Panicum maximum* at Carimagua, 1978.

	P_2O_5 kg/ha			
	0.5	1	3	9
	(plants/m²)			
A. gayanus	97	170	144	176
P. maximum	4.8	6.3	6.6	13.2
	K_2O kg/ha			
	0	0.5	1.5	
A. gayanus	136	160	146	
P. maximum	6.4	7.3	9.5	

tillage methods with planting density of *A. gayanus* is studied. In another, the effect of the stage of development of native savanna (burned and unburned) on establishment of three legumes *(D. ovalifolium, S. capitata* and *P. phaseoloides)* associated with *A. gayanus* will be evaluated. Another trial tests the interaction of tillage methods and grass species.

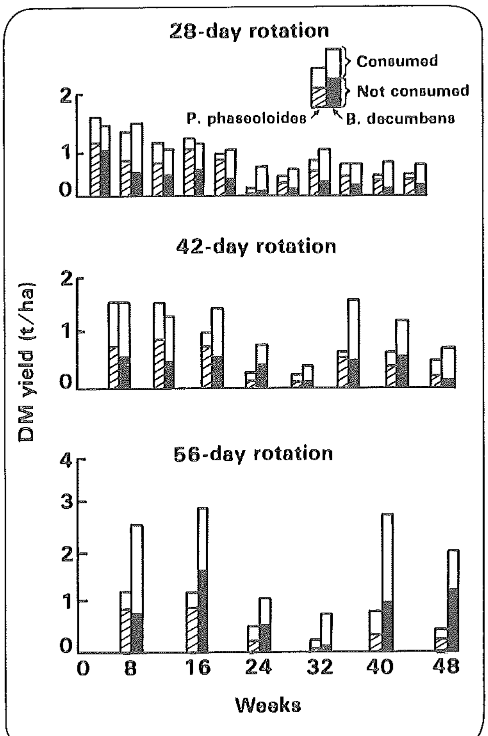

Figure 75. Effect of grazing frequency on dry matter production and forage consumption of *Pueraria phaseoloides* and *Brachiaria decumbens* seeded in alternate 2.5-m strips, at Carimagua.

Conventional establishment methods are also being studied in trials planted during the year. The interaction of tillage x species x date of seeding includes conventional seed bed preparation and the stubble mulch sweep method of controlling native savanna and preparing the seed bed. Another trial is designed to test the interaction of methods of seeding and time of seeding of legumes relative to time of seeding of grasses. Four associations composed of *S. capitata, P. phaseoloides. A gayanus* and *P. maximum* are included. Early evaluation indicates that seeding in alternate rows or alternate pairs of rows provides the best balance. Broadcast seeding and fertilizer application has resulted in excessive weeds and poor species balance.

Pasture Maintenance and Management

The kudzu/grass strip seeding experiment initiated in 1975-76 and described in the 1977 Annual Report continued in 1978 with some modifications. *B. decumbens* remains strongly competitive in 56- and 42-day rotations and maintains good stands even in the 28-day rotation (Fig. 75 and 76). It has invaded the kudzu strips, especially in the 56-day rotation. This is sufficient time for *B. decumbens* to produce seed and most of the invasion appears to be via new seedlings. There is much less invasion in the 42- and 28-day rotations.

On the other hand, *Melinis minutiflora* and *Hyparrhenia rufa* began to decline in the very early grazing cycles under all three

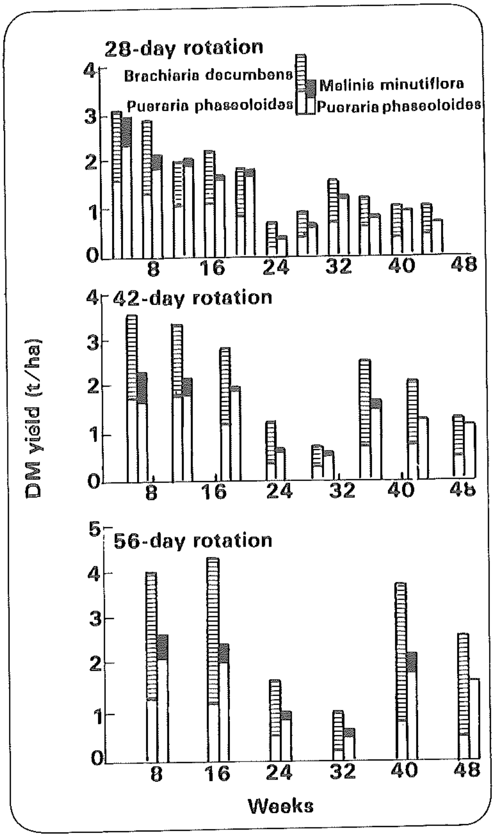

Figure 76. Effect of grazing frequency on total dry matter production of two pasture associations, at Carimagua.

rotations, and had essentially disappeared by mid-1978 from the 2.5-m strips where they were initially seeded. They were displaced by kudzu from the alternate 2.5-m strips. The failure of these two grasses was due to a number of factors. Initial stands of all species were good with the exception of *H. rufa,* which was handicapped from the outset. Both species have relatively slow growth rates under Carimagua conditions, compared to *B. decumbens* which recovers rapidly after grazing and produces much more dry matter in a given rest period than the others. The design of the experiment did not permit separate grazing of the three associations and as a consequence, preferential grazing of *M. minutiflora* and *H. rufa* also contributed to their failure. Both are relatively palatable in the rainy season. The rapid decline of *M. minutiflora* is shown in Figure 76. The data for *H. rufa* are almost identical.

The two grasses which were displaced by kudzu were replaced late in the year by *B. humidicola* and *P. maximum* after disking the grass strip to control the invading kudzu. Both species are expected to be sufficiently aggressive to maintain stands with kudzu. They appear to be much more like *B. decumbens* in vigor and rate of dry matter production, based on observations in a number of other trials at Carimagua.

Figure 75 shows that legume production is negatively correlated with grass production. Total legume production to date has been greatest in the 28-day rotation and least in the 56-day rotation. Total grass production has tended in the opposite direction with greatest production in the 56-day rotation. Total combined production was greatest for the 28-day rotation and least for the 56-day rotation. It appears that the 42-day rotation would result in the best compromise for production and persistence of both *B. decumbens* and kudzu.

During the 1978 grazing season, it was observed that *B. decumbens* within the kudzu strip benefited greatly from the improved fertility environment whereas *B. decumbens* only 2.5 m away in the middle of the grass strip is grossly N-deficient. The grass appears to be improving at the expense of the legume in the legume strip and declining rapidly for lack of N in the grass strip. It is possible that the legume will now rapidly improve in the grass strips as grass competition decreases. There may be (in space) an example of ascending grass/declining legume and subsequently, declining grass/ascending legume cycles that are observed in time under field conditions. It may be possible to design a paddock with spatial distribution which would encourage this cyclic change in balance but with the cycles out of phase from one strip to the other, providing for a more continued availability of forage and more constant pasture quality within the paddock.

The kudzu in this experiment was established in 1975 and the grasses were established in early 1976. Although the legume is declining in the *B. decumbens* association (Figure 75) it has persisted through three dry seasons and appears to be a productive, rather long-lived pasture species for savanna ecosystems similar to that of Carimagua. It does require higher fertilizer input than *S. capitata* and *Zornia latifolia*.

The validity of this type of rotational grazing experiment is subject to question and it is difficult to extrapolate from the research experience to farm conditions. Based on the promising results with *B. decumbens* and kudzu and the apparent longevity of kudzu, we have initiated a new trial on spatial distribution of the two species in which the strip width of each species is varied from 0 to 8 m while maintaining the strip width of the associated species constant at 4 m. The new trial will be grazed continuously with grazing pressure adjusted to forage availability. Data will be taken on persistence of species, invasion of strips, weed incidence and efficiency of N transfer to the grass.

An additional trial related to maintenance and pasture management was initiated in 1978 to study the interaction of

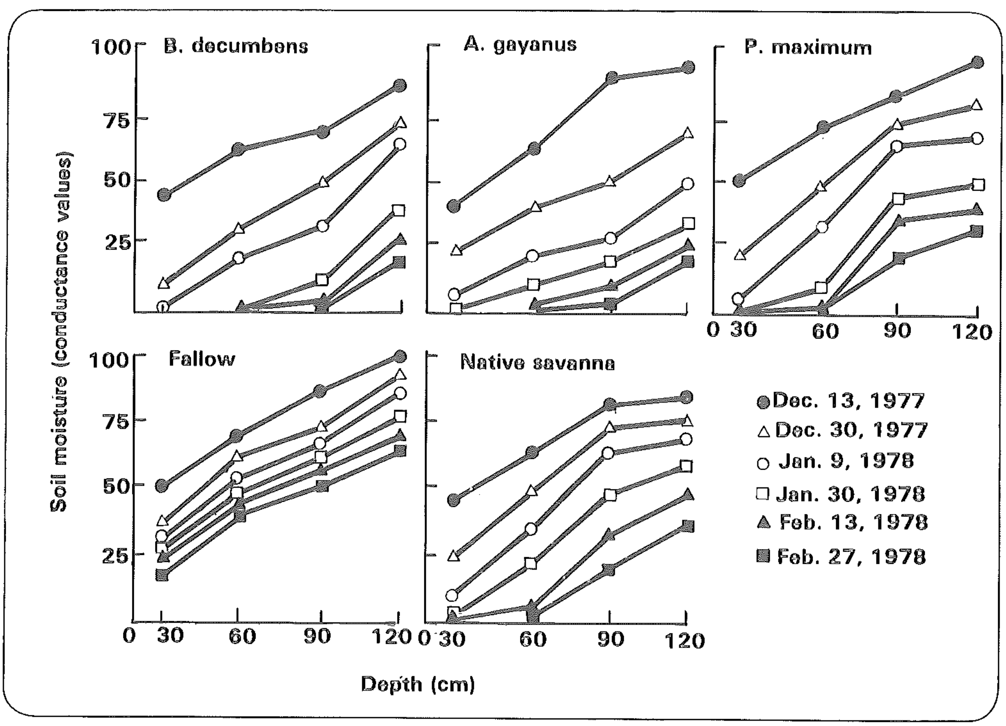

Figure 77. Moisture extraction profiles under fallow, ground, native savanna, *Brachiaria decumbens, Andropogon gayanus* and *Panicum maximum* during the 1977-78 dry season at Carimagua.

P levels and pasture associations. Two grasses and two legumes *(P. maximum, A. gayanus, S. capitata, P. phaseoloides)* are combined in four associations which are each fertilized at three different P levels. The grasses and legumes included differ markedly in their P requirement, thus P level should have a strong effect on relative competitiveness and productivity of the components of the associations.

Subsoil Moisture Availability to Pasture Species

At the beginning of the 1977-78 dry season sets of Bouyoucos blocks were installed in a number of different profiles to a depth of 1.20 m to follow the extraction of subsoil moisture by several grasses. The results are preliminary and additional work will be undertaken in the coming dry season. In Figure 77 it can be seen that *P. maximum* and the native savanna displayed almost identical moisture extraction capabilities. Both pastures were relatively inefficient at extracting moisture at the 90- and 120-cm depths compared with *A. gayanus* and *B. decumbens,* both of which dried the profile completely to the 90-cm depth and apparently dried it somewhat greater at 120 cm than did the other two pastures. Under fallow, although some moisture was lost from the subsoil it remained quite moist throughout the dry season, even at the 30- cm depth. It should be noted that the values obtained are not soil moisture content but are conductance values and therefore, should not be taken as precise moisture measurements.

These observations correlate well with apparent drought resistance of the species observed. *A. gayanus* and *B. decumbens* are both noted for their good performance during the dry season. This may be largely due to their ability to root deeply, taking advantage of stored moisture in the subsoil. *P. maximum* is a relatively poor summer performer and is apparently unable to utilize subsoil moisture as effectively as the other two grasses.

It is speculated that for legume/grass associations for savanna ecosystems where the dry season is severe and long, the most drought-tolerant grasses may not be the most desirable since they would obviously compete more strongly with the legume for limited moisture. A less competitive grass that tolerates the dry season well and recovers quickly in the following rainy season may in fact be a more desirable companion grass for legumes.

Fertilizer Maintenance Requirements under Grazing

Small enclosures in grazing paddocks are used for testing for nutrient responses in *B. decumbens* grazed at three stocking rates. A large N response has been observed, but we are still unable to show responses to P and K treatments using two replicates of a complete 3 x 3 factorial.

Pasture Development in the Cerrado

A review of available edaphic and nutrient response data for crops and forages shows that little information is available for predicting the most important soil limiting factors for forage grasses and legumes of interest for this area. Phosphorus fertilization requirements for establishment is well-known for some crops and possibly *B. decumbens* but little is known regarding establishment and maintenance requirements for forage legumes or grass/legume associations. Most of the work in 1978 related to establishment methods has been done with cultivated pastures. There is little information on native pasture improvement, including legume introduction in native savannas. Traditionally, improved pastures in the Cerrado of Brazil have been developed by expensive mechanized clearing, plowing, liming and complete seed bed preparation for pure stands of grasses or grass/legume associations. Legume persistence has always been a problem and at present most farmers and research workers are pessimistic about the potential of grass/legume associations. Maintenance fertilization and better grazing management would probably overcome some of the problems of persistence.

Limiting Fertility Factors

To identify these factors a series of exploratory pot experiments was initiated. All major, secondary and micronutrients except N, P, Cl and Fe were included in a 2^8 factorial with one-quarter of a replication. Phosphorus and Fe were considered in satellite experiments, P being applied as a constant in the factorial experiments. Two test plants representing high and low fertility requirements were used in two experiments with two Oxisols, the Latosol Vermelho Escuro (LVE) and a Latosol Vermelho Amarelo (LVA). A striking visual plant response to S was observed in both soils with both test plants. Plant response data in terms of dry matter are available only for the LVA. They confirm the S deficiency observations and show other deficiencies as well.

The dry matter production of the *Centrosema* hybrid 448 was doubled when 30 kg S/ha was applied. *Calopogonium mucunoides* also responded significantly to S. Both legumes responded to Ca when 500 kg/ha was added as $CaCO_3$. This has been interpreted as a nutrient response more than a liming effect of $CaCO_3$. Plant and soil analyses are being performed to check this hypothesis.

Potassium has also been identified as limiting for both legumes in the LVA soil. A significant response to Mo was observed with *Centrosema*. Other deficiencies will probably show up as nutrients are extracted by additional harvests.

Based on these findings, experiments with S, Ca, K and Mo have been initiated. Spray application of other nutrients will be tested if they are identified in the pot experiment as potentially limiting.

Establishment Requirements

Cerrado soils are typically P-deficient but the amount of P required for pasture legume establishment and maintenance is not well-defined. As a basis for selecting P levels to be used in field experiments, a preliminary pot trial was performed with the same legumes and soils previously described. An additional objective was to check the validity of the P and Ca levels chosen for the previous experiment.

Four levels of P equivalent to 50, 100, 200 and 400 kg P/ha as calcium monophosphate and 0, 100, 500 and 1000 kg $CaCO_3$/ha were used. Plant responses are shown in Figures 78 and 79 for the LVA soil. Plant response to $CaCO_3$ was

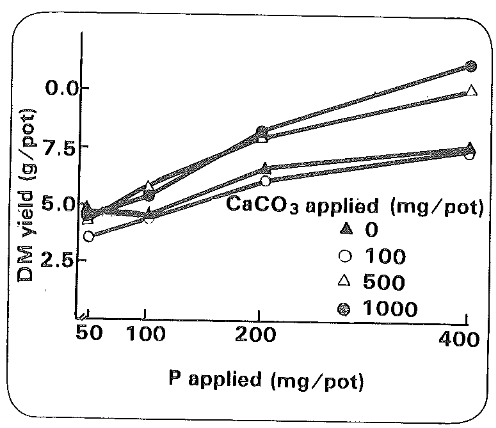

Figure 78. *Calopogonium muconoides* response to lime and P on a Red-yellow Latosol at Brasilia, Brazil.

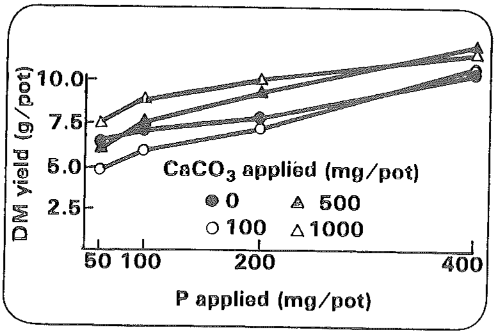

Figure 79. *Centrosema* hybrid 438 response to lime and P on a Red-yellow Latosol at Brasilia, Brazil.

detected for both species at levels equivalent to 500 kg $CaCO_3$/ha but not above this level. Response to P was high even at levels as high as 200 and 400 kg P/ha. This indicates that large amounts of P are necessary for maximum seedling growth in the field.

Based on previous results a field experiment was initiated this year to evaluate three sources and several rates of P. Sulphur, Ca, K, Zn, and Mo were included at uniform levels, based on results of the 2^8 factorial experiment and information available for other crops. The objective is to determine P fertilization requirements for establishment of an *A. gayanus*/*S. capitata* association using triple superphosphate, Araxá rock phosphate and Yoorin, a thermal rock phosphate. Main plots will be divided next year to determine residual effects and optimum maintenance rates.

Establishment Methods

A field experiment was established in January 1978 to test several methods of legume introduction into native savanna with various degrees of tillage. Three legume species — *S. capitata, C. mucunoides* and *Glactia striata* — were selected, based on previous information available at CPAC. Burning was included as a treatment to eliminate excessive mature vegetation accumulated in previous years and improve seed/soil contact.

A 20-day drought followed planting and growth was reduced by the short rainy season but establishment was successful with some species and methods. Stand counts are shown in Table 41 for April and August observations.

Table 41.

Effects of establishment methods on stand counts of three legumes introduced in native savanna (Brazilian Cerrado, LV soil). (Means of 20 observations in April and 40 observations in August.)

	Stylosanthes capitata 1405		*Calopogonium mucunoides*		*Galactia striata*	
	April 78	August 78	April 78	August 78	April 78	August 78
Method	(plants/m²)					
Oversowing	<1	<1	<1	<1	3	1
Burning & oversowing	2	1	8	3	2	<1
Disking & oversowing	2	2	31	12	13	4
Burning, disking & oversowing	4	2	29	16	10	5
Sod-seeding	2	1	32	17	12	4
Burning & sod-seeding	3	<1	40	16	8	4

Pasture Renovation

There are vast areas of pure grass pastures as well as grass/legume associations in which the legume component has disappeared in the Cerrado of Brazil. The dominant species are *B. decumbens, H. rufa* and *M. minutiflora.* These pastures decline in productivity after a few years, probably due primarily to low soil N availability as a result of a low rate of organic matter mineralization under grazing. In addition, forage quality declines, especially during the dry season in pure stands of these species. Legume introduction in grass swards is known to increase total production, improve forage quality and incorporate N into the system as well.

B. decumbens dominates almost all other species in association. There is a clear need to identify adequate species and methods of establishing legumes in old *Brachiaria* swards.

A field experiment was started this year to test several methods and species for renovating a three-year-old *Brachiaria* pasture. The renovation methods tested in 8 x 12 m plots in a randomized complete block design are the following: (1) oversowing *Brachiaria;* (2) oversowing *Brachiaria* after disking; (3) sod-seeding (1-in wide furrows 50 cm apart); (4) planting in strips (1.50-m wide rotovated band); and (5) N fertilizer application after disking, with no legume introduction.

Three species were planted for each establishment method. *C. mucunoides,* a well-known legume adapted to Cerrado conditions; *Centrosema* hybrid CIAT 438, more productive at relatively higher soil fertility levels and *D. ovalifolium* CIAT 350, probably the legume best-equipped to compete with *Brachiaria.*

The experiment will provide information on adaptation of species for association with existing *Brachiaria* and on methods most suitable for legume introduction. The grass/legume associations which succeed will be compared to N fertilized *Brachiaria.*

Other Experiments

Additional field and pot experiments designed to help interpret the experiments outlined above have been initiated. Two pot experiments are in progress to study Fe, Ca and Mn and sources of S in two major soils using two test plants. Two field experiments have been established on old experimental sites with contrasting levels of available P and pH, to study the effect of these factors on grass/legume associations.

PASTURE UTILIZATION

The Units of the Pasture Utilization Section of the Beef Program conducted activities at Carimagua, CIAT-Quilichao and Brasilia. All activities are related to evaluating Category 4 material from the standpoint of the use that animals can make of this promising germplasm.

Nutritive Value of Andropogon gayanus

Intake and digestibility trials were conducted with several promising forages at Quilichao, employing crated wethers offered forage in increasing quantities.

The digestibility of *Andropogon gayanus* CIAT 621 was determined using hay cut during the dry season after 44 days of regrowth. The hay was offered at four levels between 50 and 200 g of DM/W$^{.75}$/day. Figure 80 shows a quadratic relationship between forage consumption and digestibility. Maximum digestibility of 60% was attained at a level of consumption of 60 g. Moreover, Figure 81 shows that the consumption of digestible DM was above maintenance at forage levels of 50 g and over, indicating a good degree of utilization.

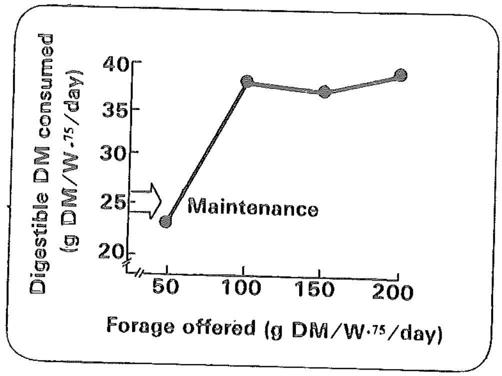

Figure 81. Effect of amount of forage offered on consumption of digestible DM of *Andropogon gayanus* 621 hay made from a 44-day regrowth cut during the dry season and fed to crated wethers.

Nutritive Value of Desmodium Species

Desmodium ovalifolium 350 was fed fresh, unchopped at levels between 30 and 240 g of DM/W$^{.75}$/day, and at five plant ages averaging 50, 80, 100, 125 and 145 days of regrowth. The last trial coincided with the beginning of the dry season at Quilichao.

Figure 82 shows the relationship between the amount of *D. ovalifolium* offered and its consumption. The relationship is clearly asymptotic and very similar for all forage ages. Maximum DM intake was reached between 80 and 90 g of DM/W$^{.75}$ offered, including the forage cut during the dry season. Digestibility increased as the level of consumption increased, reaching levels of around 60% in all cuts, which can be considered adequate for tropical forage legumes (Fig. 83). The increase in digestibility with increasing forage consumption can be explained by the increase in leaf consumption as shown in Figure 84. It is important to observe that the intake of digestible dry matter was above the approximate maintenance level of 25 g/W$^{.75}$/day (Fig. 85).

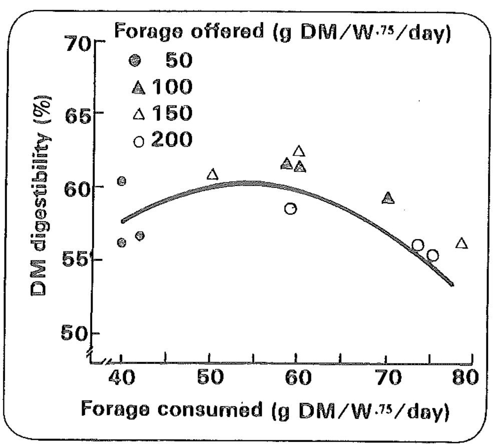

Figure 80. Relationship between forage offered, forage consumed and digestibility of *Andropogon gayanus* 621 hay made from 44-day regrowth during the dry season.

Figure 86 shows the average crude protein (CP) and P contents of leaf and stem at each age. Protein is not particularly high, but its level in the leaves is quite adequate for animal growth and reproduction. Leaf P is insufficient for growth or reproduction in spite of the application of 200 kg P_2O_5/ha at establishment. The critical levels of protein and P are generally considered to be 7-10% and 0.2%, respectively.

The digestibility and intake of three *Desmodium* species were compared when

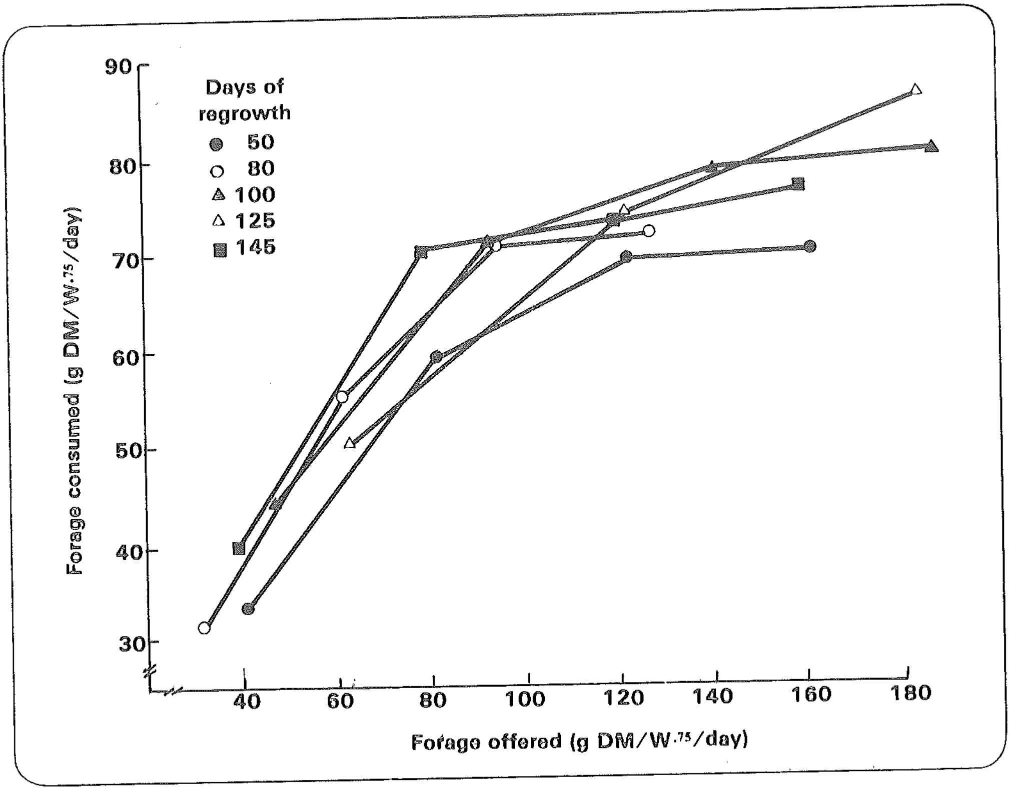

Figure 82. Relationship between stage of regrowth, forage on offer and consumption of green *Desmodium ovalifolium* 350 fed to crated wethers.

cut for hay, during the dry season. *D. ovalifolium* 350 and *Desmodium heterophyllum* 349 are species of interest for Oxisol and Ultisol areas. *Desmodium distortum* 335 was included as a positive control since it has been previously found to be of high nutritive value although not adapted to acid soils. Figures 87 and 88 show the intake and digestibility values of the three legumes with increasing levels of forage offered. The high nutritive value of *D. distortum* is again demonstrated by its linear increase in intake and digestibility up to the highest level offered. *D. heterophyllum* had higher consumption than *D. ovalifolium* but both reached near maximum intake at 80 g of offer. Digestibility of the latter two legumes did not change with increased forage offer or consumption, in marked contrast with *D. distortum*. The difference reflects the much more drastic selection for leaves occurring as forage availability increased; at 40 g of DM offered the low digestibility of *D. distortum* was associated with near total consumption of the woody main stems of the legume. *D. heterophyllum* and *D. ovalifolium* appear to be very palatable species of high intake potential in spite of decreased possibility of selection for leaves.

Grazing Management of Legume/Grass Associations

The effect of the rotation interval on the survival and productivity of *Centrosema* hybrid 438, was studied in two experiments at Quilichao. In one experiment, *Centrosema* was mixed with *Panicum max-*

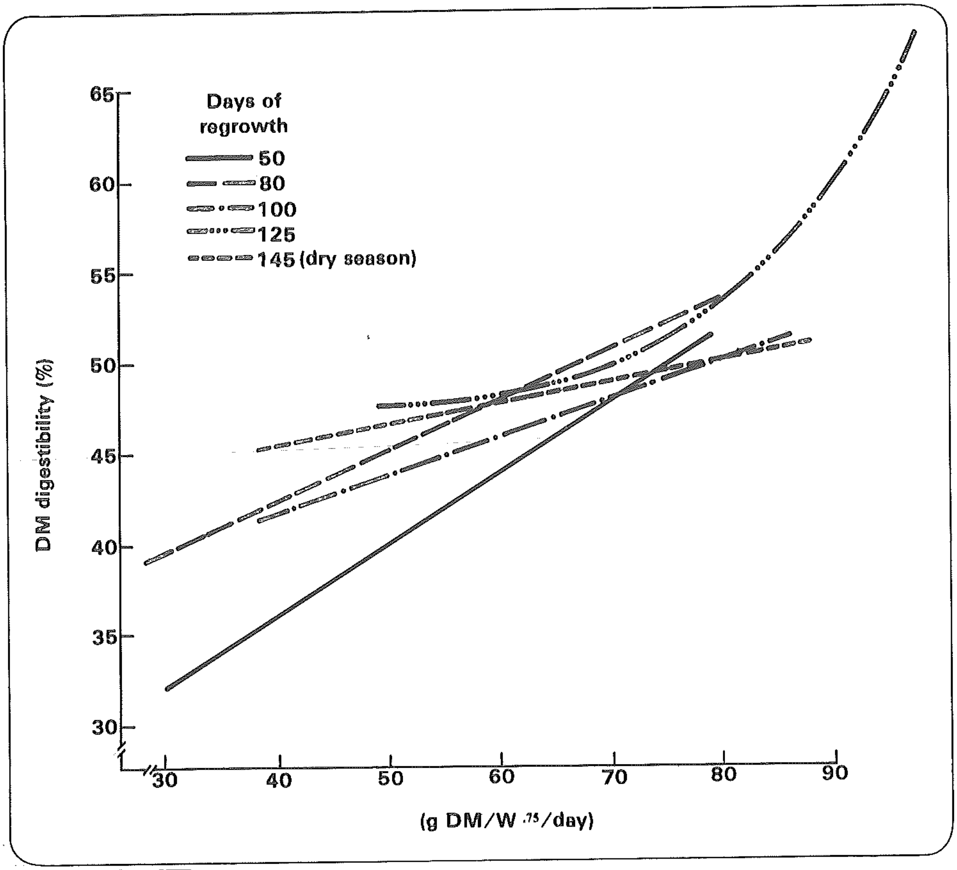

Figure 83. Relationship between stage of regrowth, forage consumption and digestibility of green *Desmodium ovalifolium* 350 fed to crated wethers.

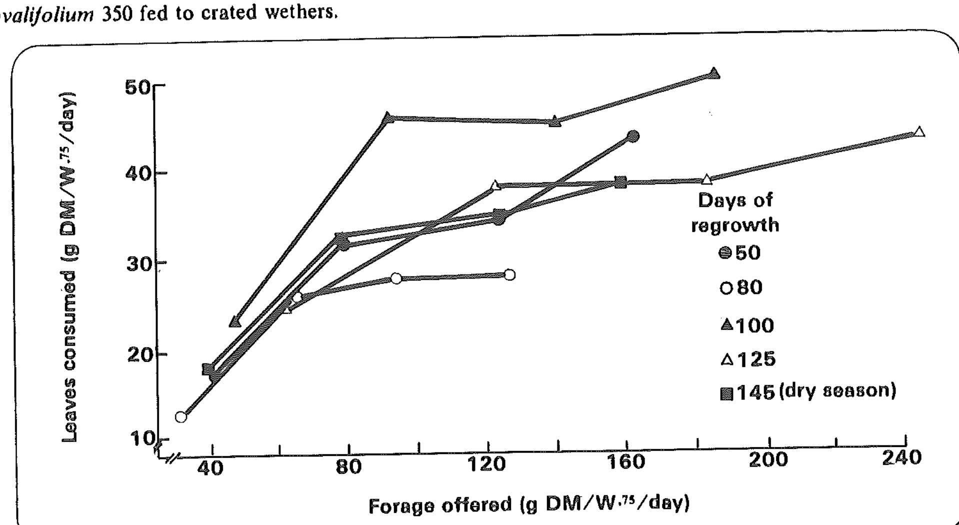

Figure 84. Relationship between stage of regrowth, forage on offer and leaf consumption by crated wethers fed green *Desmodium ovalifolium* 350.

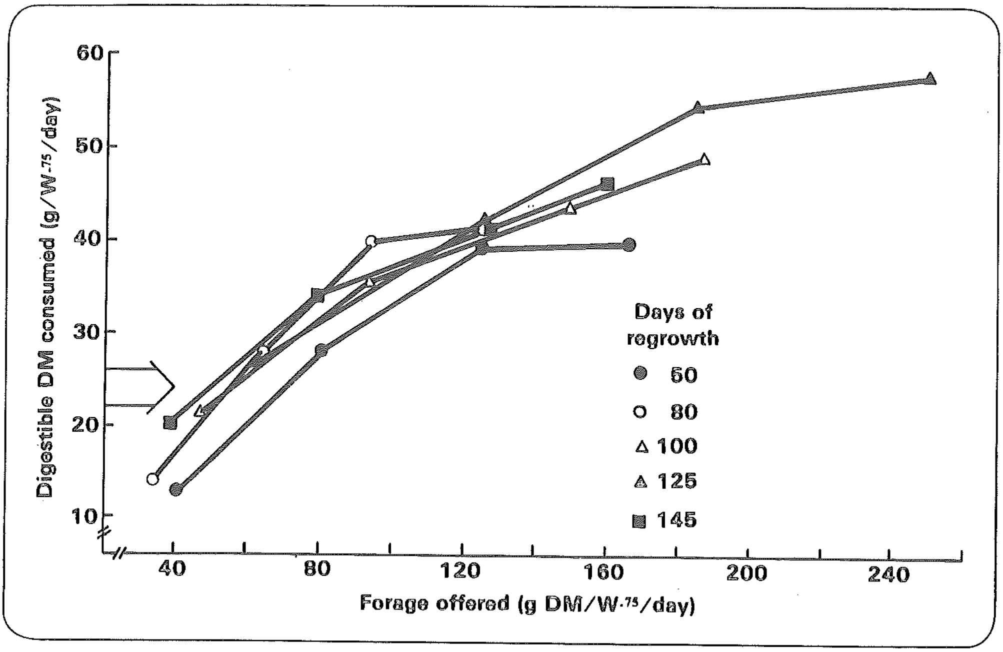

Figure 85. Effect of amount of forage on offer and stage of regrowth on consumption of digestible dry matter by crated wethers.

imum var. Common, *Brachiaria decumbens* and *A. gayanus* 621 and grazed at three intervals — 4, 6 and 8 weeks — at low and high grazing intensities. In all mixtures, forage yield tended to increase as the rest periods increased, the increase

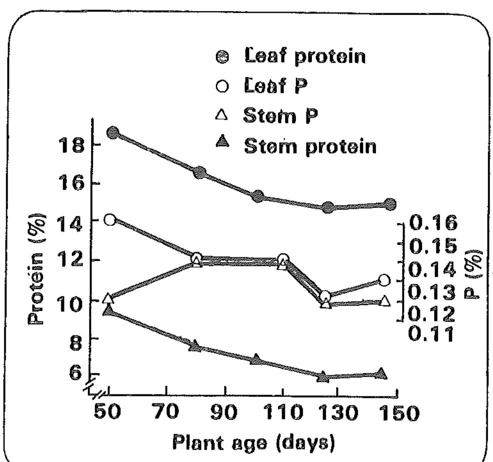

Figure 86. Effect of plant age on protein and P content of leaves and stems of *Desmodium ovalifolium* 350.

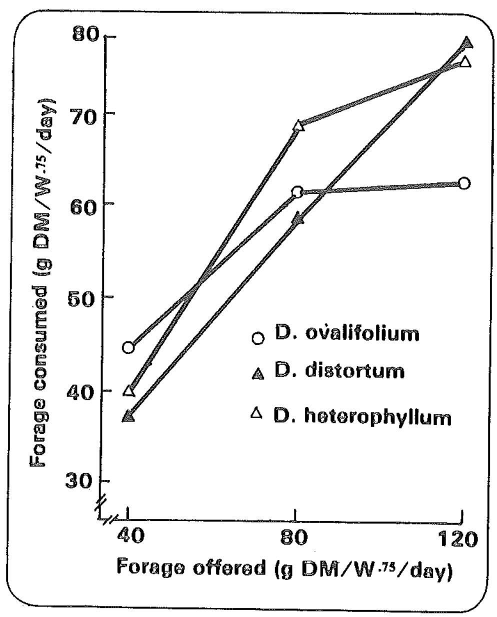

Figure 87. Effect of amount of forage offered on consumption of *Desmodium ovalifolium*, *Desmodium distortum* and *Desmodium heterophyllum* hay cut in the dry season and fed to crated wethers.

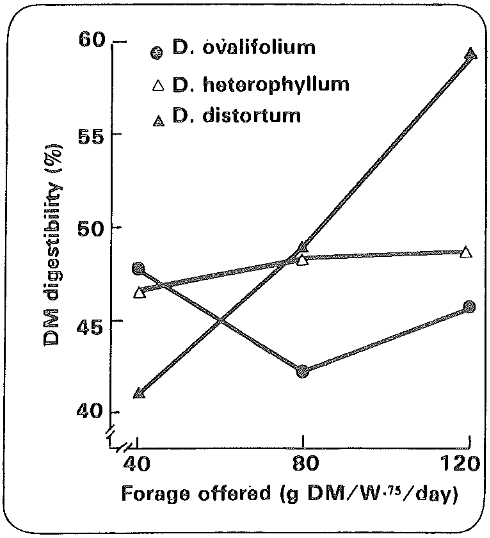

Figure 88. Effect of amount of forage offered on DM digestibility of *Desmodium ovalifolium, Desmodium distortum* and *Desmodium heterophyllum* hay cut in the dry season and fed to crated wethers.

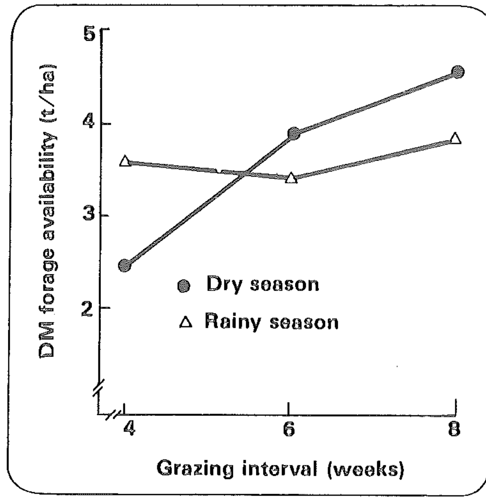

Figure 90. Effect of grazing interval on dry matter availability of mixtures of Centrosema hybrid 438 and the grasses *Panicum maximum* var. Common, *Brachiaria decumbens* and *Andropogon gayanus* 621 during the rainy and dry seasons, at Carimagua.

being more pronounced in the *Centrosema/Andropogon* mixture and less in *B. decumbens* (Fig. 89). This increment was not observed in in the first rainy season

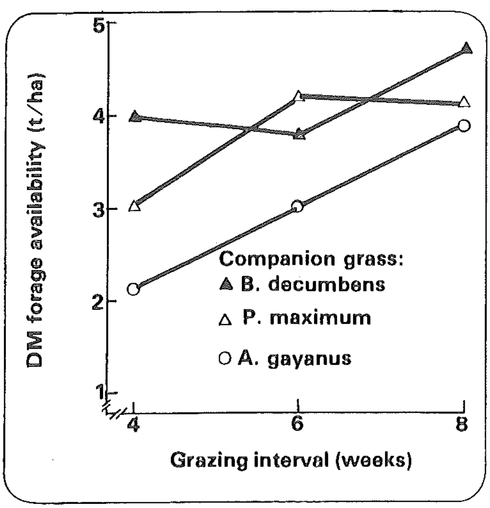

Figure 89. Effect of grazing interval on mixtures of *Centrosema* hybrid 438 and each of three grasses, *Panicum maximum* var. Common, *Brachiaria decumbens* and *Andropogon gayanus* 621.

but was large in the following dry season (Fig. 90).

The effect of the companion grass on legume content of the mixtures is presented in Figures 91 and 92 for the rainy and dry seasons, respectively. The legume content was low in the mixture with *B. decumbens* and *P. maximum* in the first rainy season and decreased to nearly nil in the following dry season. *A. gayanus,* on the other hand, allowed good legume persistence while still maintaining a reasonable DM yield, particularly with the longer rest periods (Fig. 89). The data from the first two grazing seasons indicate that only *A. gayanus* will allow this legume to persist under the conditions of the experiment.

In the second experiment, legume/grass associations are being continuously grazed at a stocking rate of 2 animals/ha. All mixtures contain *Centrosema,* one of the two *Stylosanthes guianensis,* 136 and 184, and one of the grasses *P. maximum* var. Common, *B. decumbens* and *A. gayanus*

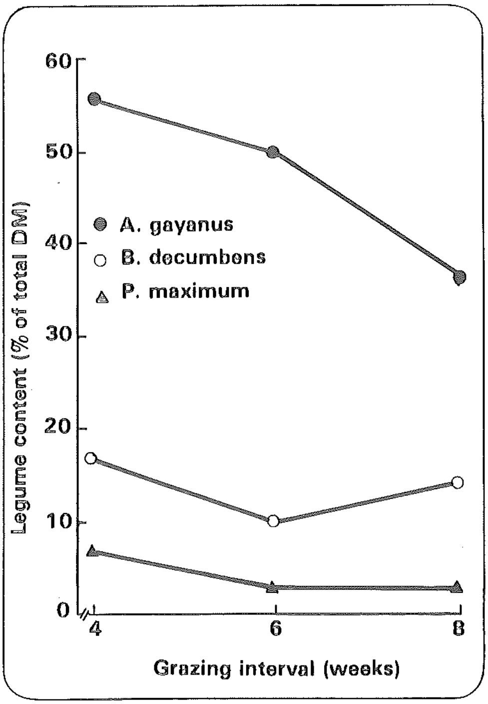

Figure 91. Effect of grazing interval on legume content of pastures containing mixtures of *Centrosema* hybrid 438 and one of the grasses *Panicum maximum, Brachiaria decumbens* or *Andropogon gayanus* 621, during the rainy season at CIAT-Quilichao.

621. Table 42 shows the available DM for each of the mixtures during the first rainy season and the following dry season. In all cases DM availability decreased, but the

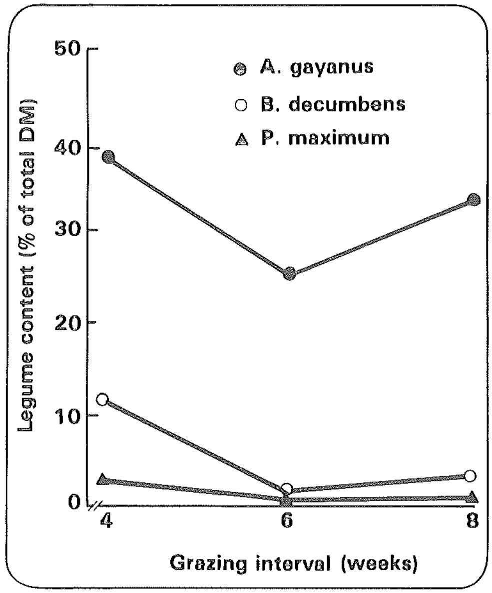

Figure 92. Effect of grazing interval on legume content of pastures containing mixtures of *Centrosema* hybrid 438 and one of the grasses *Panicum maximum, Brachiaria decumbens* or *Andropogon gayanus* 621, during the dry season at CIAT-Quilichao.

quantities are large, indicating a problem of understocking. This will be corrected by increasing to 3 animals/ha in subsequent years. Under continuous grazing, yield of *A. gayanus* has been severely reduced. This can be partly explained by insufficient initial stand resulting from vegetative

Table 42.

Forage availability of mixtures of *Centrosema* CIAT hybrid 438, *Stylosanthes guianensis* 136 and 184 and one of the grasses *Panicum maximum, Brachiaria decumbens* and *Andropogon gayanus* 621 in continuously grazed plots at CIAT-Quilichao.

	DM yield in rainy season (t/ha)			DM yield in dry season (t/ha)		
Component	*P. maximum*	*B. decumbens*	*A. gayanus*	*P. maximum*	*B. decumbens*	*A. gayanus*
Centrosema	2.5	3.8	3.4	0.9	0.5	2.4
S. guianensis	1.5	2.8	2.9	0.2	0.2	0.8
Grass	3.9	3.2	1.2	3.3	2.6	0.2
Total	9.3	11.6	9.0	5.2	3.7	3.6

propagation, and by a strong preference of the steers for this species. By the end of the dry season the contribution of *A. gayanus* had decreased to less than 5% (Fig. 93). The other two grasses have become dominant and the legume has decreased to 10 to 20% of the stand. Both introductions of *S. guianensis* are rapidly disappearing.

From results obtained thus far, it appears that *A. gayanus* should not be grazed when initial plant populations are low because it can be grazed out rather rapidly.

Two animals continuously grazing a 1-ha paddock have gained 164 kg each during 233 days of grazing for an average daily weight gain of 704 g/steer.

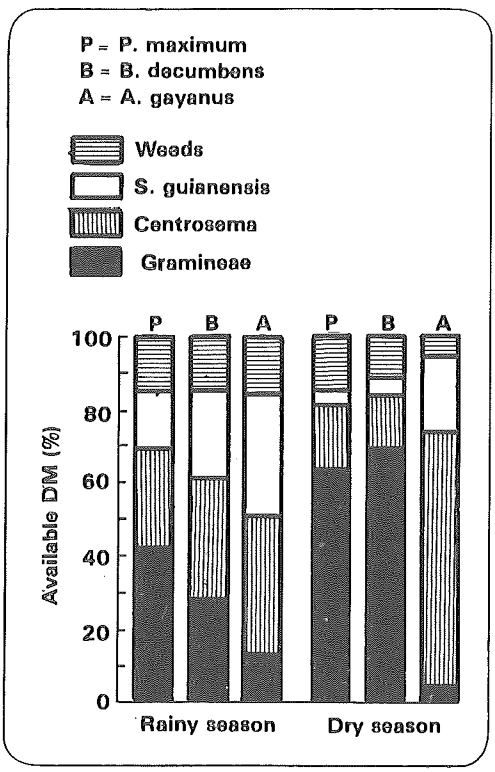

Figure 93. Botanical composition of plots comprised of mixtures of *Centrosema* hybrid 438, *Stylosanthes guianensis* 136 and 184 and one of the grasses *Panicum maximum, Brachiaria decumbens* and *Andropogon gayanus* 621 under continuous common grazing, at CIAT-Quilichao.

Two new experiments, similar to those above, have been established at Quilichao to determine the most adequate grazing management for mixtures of *D. ovalifolium* 350 and two of the grasses. Under continuous grazing, *B. decumbens* will not be included and *A. gayanus* will occupy most of the area in the mixture to avoid its elimination by preferential grazing.

Animal Production Potential of Pure Grass Pastures

Brachiaria decumbens

The *B. decumbens* trials at Carimagua continued into their fourth year in order to determine the most appropriate year-round management. This year's results are presented in Tables 43 to 45. Liveweight gains are similar to previous years with the exception of certain treatments with variable dry season/rainy season stocking rates. It is important to note that *B. decumbens* is capable of producing as much as 260 to 280 kg of liveweight gain/ha/yr. Forage availability ranged from 1 to 2 t/ha of green DM during the rainy season and 0.2 to 0.5 t/ha during the dry season. Recovery at the beginning of the rainy season (April) is rapid, but as shown in Figure 94, it is slower at the higher stocking rate. Rainy season forage availability had been restored by May, in every case. Figure 95 shows a similar situation when stocking rates are higher in the rainy season, clearly demonstrating the need to wait at least one month after rains start to establish rainy season stocking rates.

Pasture productivity in Carimagua is fairly stable over time in spite of large seasonal variations. Differences tend to

Table 43.

The effect of stocking rate on liveweight changes of steers grazing *Brachiaria decumbens* at constant stocking rates throughout the year at Carimagua. (Fourth year of grazing).

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
Dry season[1]	Rainy season[2]	Dry season	Rainy season	Total	Dry season	Rainy season	Total
0.9	0.9	-8	86	76	-7	77	70
1.3	1.3	2	71	73	3	92	95
1.7	1.7	3	73	77	5	124	129

1 83 days of grazing, December to March.
2 251 days of grazing, March to November.

cancel out in consecutive seasons due to compensatory gains as shown in Figure 96 for continuously grazed and set-stocked *B. decumbens*.

Panicum maximum

Panicum maximum var. Common was sown July 1977, with the application of 140 P_2O_5/ha as basic slag, and has been continuously grazed at 0.9, 1.3 and 1.7 steers/ha since February 1978. At that time, the pasture was already tall with an excess of dry, old material. It was necessary to increase stocking rates in May and June 1978 to reduce the forage available. Nevertheless, weight gains during the dry and rainy seasons were excellent, reaching a maximum of 314 kg/ha and gains per animal of 114 kg at 1.7 animals/ha stocking rate (Table 46). These are only first year results and as such are of limited value because it is well-known that *P. maximum* is a fast-growing, nutritious grass with high nutrient requirements, particularly for N, which is usually depleted rapidly in tropical soils.

Andropogon gayanus

An experiment was seeded with *A. gayanus* 621 in August 1976. Vegetative

Table 44.

The effect of rainy season stocking rates on liveweight change of steers grazing *Brachiaria decumbens* at low stocking rates during the dry season.(Third year of grazing.)

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
			Rainy season				
Dry season[1]	Rainy season[2]	Dry season	Early	Late	Dry season	Rainy season	Total
0.7	1.62	15	36	63	11	127	138
0.7	2.34	10	25	55	7	146	153
0.7	3.06	37	45	66	26	233	259

1 83 days, from December to March.
2 Rainy season stocking rates were not re-established until May 5, 1978 to allow recovery of the pastures. Early rainy season from March to May, 57 days and late rainy season from May to November, 194 days.

Table 45.

The effect of dry season stocking rate on liveweight change of steers grazing *Brachiaria decumbens* at medium stocking rate during the rainy season. (Second year of grazing.)

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
Dry season[1]	Rainy season[2]	Dry season	Rainy season Early	Rainy season Late	Dry season	Rainy season	Year
0.72	2.16	20	29	49	14	127	141
1.03	2.08	27	38	104	28	255	283
1.36	204	13	24	87	18	210	228

1 83 days, from December to March.
2 167 days. Rainy season stocking rates were not re-established until May 5, 1978 to allow recovery of the pastures. Early rainy season from March to May, 57 days and late rainy season from May to November, 194 days.

material was taken from this planting and used in May-August 1977 to plant two more similar experiments. The first experiment was stocked in December 1977, at 0.9, 1.3, and 1.7 steers/ha, and the other two in June 1978, at 0.9, 1.3, 1.7 and 1.63, 2.34 and 3.06 steers/ha. Grazing management of these experiments was not easy because the plants were slow to establish, particularly when vegetative material was used. Almost a year was required to accumulate sufficient growth for safe grazing. Once established however, *A. gayanus* grows very rapidly, requiring high stocking rates to maintain reasonable pasture height.

Table 47 summarizes the comparison of the forage availability of the three main grass species presently being used in Carimagua. Care must be used in interpreting those data, since the ages of the pastures are different, but they serve to point out the large biomass production in

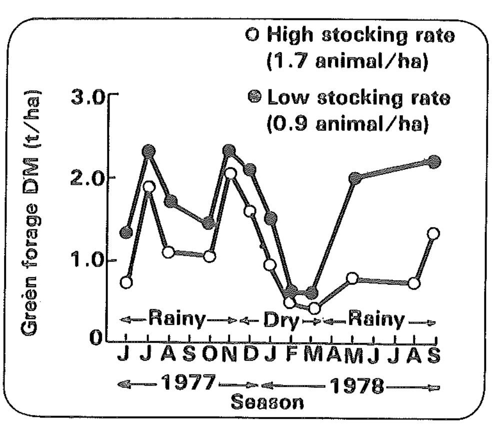

Figure 94. Effect of stocking rate and season on amount of forage on offer in *Brachiaria decumbens* pastures grazed continuously at constant year-round stocking rates (medium stocking rate not shown).

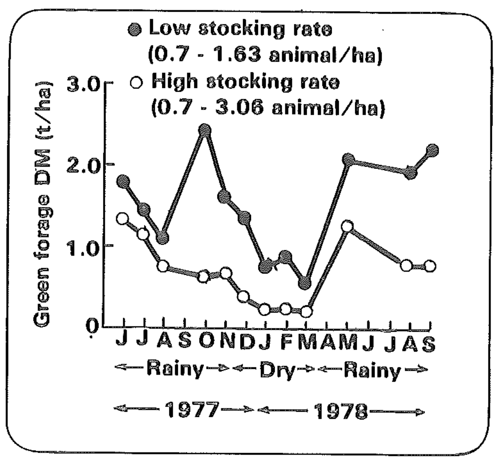

Figure 95. Effect of rainy season stocking rates and season on amount of forage on offer in *Brachiaria decumbens* pastures grazed continuously at low (0.7 animal/ha) stocking rates during the dry season.

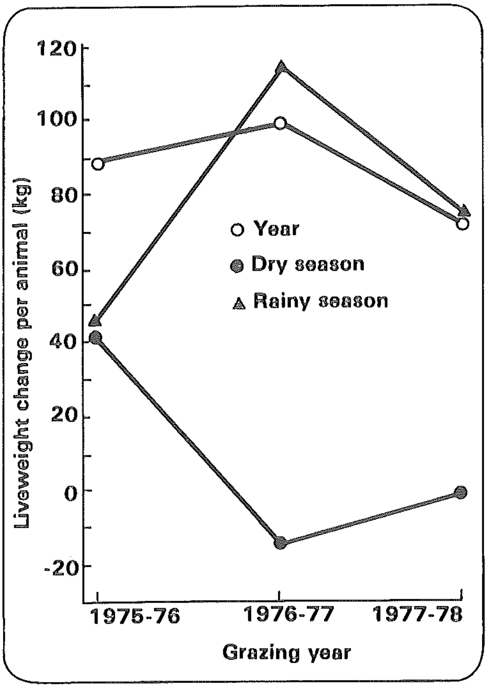

Figure 96. Effect of year on liveweight changes of steers grazing *Brachiaria decumbens*. Data are averages of three set stocking rates, 0.9, 1.3 and 1.7 steers/ha.

A. gayanus and the difficulties in grazing it properly.

Tables 48 and 49 show the protein and P content of *B. decumbens* and *A. gayanus* to be fairly similar during the rainy season. During the dry season, however, *B. decumbens* has 1% more protein and P at equivalent stocking rates (1.7 animals/ha). Protein content of the green forage of *B. decumbens* during the dry season was much higher when it was grazed during the previous rainy season at 3.06 animals/ha than at lower stocking rates. This explains the higher dry season weight gains observed for animals grazing at the highest stocking rate.

Brachiaria humidicola

Brachiaria humidicola, a grass well-known in Brazil and other areas of the world, has been incorporated in the list of promising species for Carimagua. *B. humidicola* is a strongly stoloniferous plant, which by virtue of its ability to root at stolon nodes, covers the ground rapidly and competes particularly well with weeds. *B. humidicola* was planted at Carimagua in May-June 1978 and will be grazed beginning in 1979.

Table 46.

The effect of stocking rate and season on liveweight gains of steers grazing *Panicum maximum* in first grazing year at Carimagua.

Stocking rate (animal/ha)		Gain per animal (kg)			Gain per hectare (kg)		
Dry season[1]	Rainy season[2]	Dry season	Rainy season	Total	Dry season	Rainy season	Total
0.9	0.9	9	127	135	8	172	180
1.3	1.3	11	111	121	15	232	247
1.7	1.7	13	96	114	23	291	314

1 27 days, February to March.
2 251 days. Stocking rate was increased from May 4 to June 21, 1978 to 2.7, 3.9 and 5.1 steers/ha, respectively, to reduce the excessive accumulation of forage.

Table 47.

The effect of season forage availability and stocking rate on three grasses continuously grazed in Carimagua[1].

Stocking rate (steers/ha)	Dry season *A. gayanus*	Dry season *B. decumbens*	Rainy season *A. gayanus*	Rainy season *B. decumbens*	Rainy season *P. maximum*[2]
	(t dry green forage/ha)				
0.9	3.7	2.1	7.7	1.6	2.4
1.3	3.3	1.4	4.2	1.1	1.6
1.7	5.5	1.6	4.7	0.8	1.7

1 Number of years under grazing: *A. gayanus* and *P. maximum*, one year; *B. decumbens*, four years.
2 Not sampled in the dry season. Grazing started in February 1978.

Animal Production Potential of Grass/Legume Pastures

Seven legumes have reached Category 4 of the Program's germplasm classification system: *Pueraria phaseoloides* (kudzu), *D. ovalifolium* CIAT 350, *S. capitata* (CIAT 1019, 1315, 1405, 1078) and *Zornia latifolia* CIAT 728. Replicated 2-ha plots of each species were sown at Carimagua in combination with *A. gayanus* to measure animal production potential. Grazing started in November 1978.

For areas of extensive or semi-intensive grazing where native savanna is plentiful, the concept of establishing a limited area of legume/grass pasture seems the most logical and feasible technique for increased reproductive performance and calf growth (see the Animal Management Section report). Another alternative is to establish

Table 48.

The effect of stocking rate and season on the chemical composition of *Brachiaria decumbens* at Carimagua, 1978.

Stocking rate (steers/ha) Dry season	Stocking rate (steers/ha) Rainy season	Season	Plant part	Protein (%)	P (%)
1.7	1.7	Rainy	Green	7.00	0.15
			Dead	1	-
		Dry	Green	3.50	0.13
			Dead	0.82	0.10
0.7	3.06	Rainy	Green	6.70	0.16
			Dead	-	-
		Dry	Green	6.61	0.20
			Dead	2.03	0.08

1 Samples not available for analysis.

Table 49.

Chemical composition of *Andropogon gayanus* 621 in two seasons of the year. (Stocking rate 1.7 animals/ha all year.)

Season	Plant part	Protein (%)	P (%)
Rainy	Green	7.04	0.16
	Dead	2.94	0.05
Dry	Green	2.43	0.09
	Dead	1.82	0.02

small areas of pure legume as protein banks to be used during times of protein stress, particularly in the dry season. *P. phaseoloides* is a legume which normally does not thrive under continuous grazing but which covers the ground rapidly and effectively competes with weeds. It was planted at Carimagua as a protein bank in combination with native savanna and *B. decumbens*. Grazing started in November 1978.

Animal Production Trials at Brasilia

One grazing trial was started at the beginning of the rainy season, utilizing a legume-based pasture *(Brachiaria ruziziensis* x *Stylosanthes guianensis* cv. Endeavour) which had been established the previous year as part of a larger experiment designed to study methods of managing the Cerrado for agriculture. The effect of two levels of P_2O_5 (120 and 240 kg/ha applied during establishment) and stocking rate on animal performance are being studied. The experiment was grazed from one month after the rains began until the animals began losing weight in the following dry season.

Animal gains were inversely related to stocking rate with the lowest stocking rate (1.5 animals/ha) resulting in gains of 582 g/day as compared to gains of 343 g/day at the highest stocking rate (2.7 animals/ha) (Fig. 97).

Neither stocking rate nor P_2O_5 level resulted in differences in average daily gains at the two intermediate stocking rates (1.9 or 2.3 animals/ha). The gains of both these groups were superior to those from the highest stocking rate (Table 50) and nearly equal to gains of the lowest stocking rate. Thus, their gain/ha/day was greater than that of the low stocking rate, especially at the 2.3 animals/ha stocking rate. The relationship of individual and per hectare gains are shown in Figure 98.

At the beginning of the experiment, the pasture was estimated to contain 40% legume and 60% grass. As the rains began to diminish, the availability of *B. ruziziensis* decreased with increased stocking rate and paddocks with 2.7 animals/ha appeared to be almost pure *S. guianensis*, indicating a preference for *Brachiaria* over *Stylosanthes* during the rainy season.

The number of grazing days (Table 50) was directly related to the stocking rate, i.e., as the stocking rate increased the number of grazing days increased even though the higher stocking rates were removed from the experiment first. When the number of grazing days is multiplied by average daily gain, there is no difference in total weight gain between the highest and lowest stocking rates and the two intermediate stocking rates are superior to both high and low stocking rates in total weight gain.

As in Colombia, anthracnose has destroyed about 90% of the *S. guianensis* plants during this trial, confirming the need to eliminate susceptible cultivars from the germplasm evaluation flow.

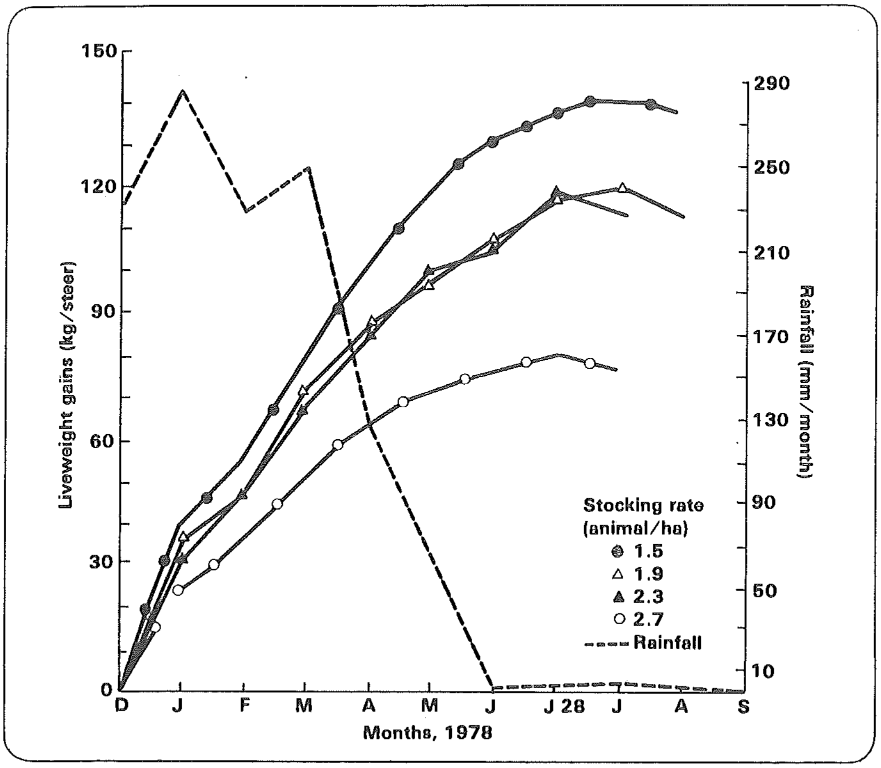

Figure 97. Effect of stocking rate and season on distribution of steer gains on a *Brachiaria ruziziensis/Stylosanthes guianensis* pasture in the Cerrado.

Table 50.

The effect of stocking rate and P fertilization on growth of Zebu steers in *Brachiaria ruziziensis/Stylosanthes guianensis* pastures at the Cerrado Center, Brazil. (December 1977 to August 1978).

	Stocking rate (steers/ha)					
	1.5	1.9		2.3		2.7
	(kg P_2O_5/ha)					
Parameters	120	120	240	120	240	240
Days on experiment	238	238	238	224	224	224
Daily gains per animal (g)	582	492	481	514	519	343
Daily gains per hectare (g)	878	934	913	1177	1188	929
Total weight gain/ha during experiment (kg)	209	222	217	264	266	208

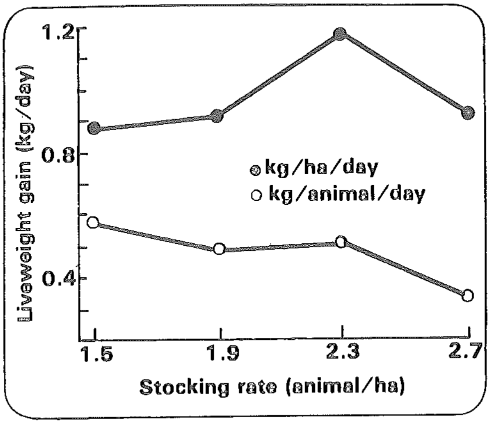

Figure 98. Effect of stocking rate on steer gains on *Brachiaria decumbens/Stylosanthes guianensis* mixed pasture in the Cerrado.

Unlike Colombia, however, there is vigorous new seedling growth at the start of the 1978-79 rainy season, which should extend the life of the legume component.

Three new experiments were initiated during the year. One is designed to compare the effect of grass alone plus N versus grass/legume associations for growing weaned beef calves. Grasses and legumes to be used are *B. decumbens, A. gayanus, S. capitata* and *Calopogonium mucunoides*. *Brachiaria* and *Calopogonium* are the most commonly found improved pasture species in the Cerrado. They are being compared with two relatively new species.

A second experiment is designed to study the effect of different levels of pasture nutrition and weaning age on reproductive performance of lactating cows.

A long-term experiment which began in the last quarter of the year is designed to study the effects of: (1) the length of the breeding season; (2) strategic use of improved pasture during the breeding season; and, (3) weaning ages on the reproductive performance of beef cattle in the Cerrado.

ANIMAL MANAGEMENT

The two units of the Animal Management Section of the Beef Program, at CIAT and Brasilia, are developing improved beef production systems utilizing the improved pasture technology being developed by other sections. Activities during 1978 concentrated on: (1) evaluation of existing beef production systems in Colombia, Brazil and Venezuela; (2) the strategic use of improved pastures in Colombia; and (3) management of test herds. Herd management experiments in Brasilia were started during the year but no results are yet available.

Evaluation of Beef Production Systems

The Beef Production Systems Evaluation project (ETES) is being conducted jointly by the Animal Management and Economics sections, with support of Animal Health and in collaboration with EMBRAPA's Cerrado Center (CPAC) in Brazil, and FONAIAP's Centro de Investigaciones Agropecuarias del Nororiente (CIARNO) in Venezuela. The prevailing beef production systems of the Colombian and Venezuelan Llanos and the Cerrado of Brazil are being evaluated in technological and economic terms.

Within each region, farms representing different technology levels have been selected and monitored in relation to natural resources, applied management, physical inputs, production, animal health and economic conditions. Three regional teams visit the selected farms three or four times a year to collect data.

Llanos of Colombia

In this region, on-farm data collection started in October 1977. Up to October 1978, four periodic studies at 17 farms (out of 20 initially), have been done. Two studies, corresponding to late rainy and early rainy seasons, provided a full set of data on animal performance. The other two served as follow-ups, mainly for updating of records.

Another major activity in cooperation with the CIAT Data Services Unit, was the development of a computerized data processing system to store and analyze a data bank of: (1) non-varying farm descriptors; (2) variable farm descriptors; (3) pasture utilization (animal inventory by paddock); (4) individual performance of female stock; (5) individual performance of male stock; and (6) expenditures and income. Final analyses will be made after two years of observation. Preliminary analyses have been run for files 3, 4 and 5.

Table 51 shows pasture availability on the selected farms. Average farm size is about 2900 ha, of which 5% is sown pastures and the rest, native savanna. A high variation of total sown pasture area and of the three species have been found. *Brachiaria decumbens* is the predominant grass, while *Melinis minutiflora* and, particularly, *Hyparrhenia rufa* are decreasing in importance. This confirms experimental results from Carimagua, which show low productivity during the dry season of both *Melinis* and *Hyparrhenia* and poor adaptation to acid soil conditions of the latter. In almost all cases, *H. rufa* is found on land which was originally forest. The area under *B. decumbens* is increasing rapidly, since it has shown good adaptability, high production and relative superiority during the dry season. High interest for this latter species is rather disturbing, because establishment costs are high and its productivity over time (productive persistence) is unknown. Also, the spittlebug risk and related management problems are often overlooked.

In general, there is a lack of knowledge of how to manage this pasture. Data in Table 51 summarize pasture utilization in terms of stocking rate. Farms show highly variable stocking patterns. Stocking rates vary from 2.9 to 12.5 ha/A.U./ha (0.08-0.34 A.U./ha).

The mean figure observed, 5.9 ha/A.U., is considered adequate and is contrary to the general opinion that Llanos farms are understocked. The optimum stocking rate on native savanna for maximum animal performance is not precisely known, but at Carimagua breeding herds are managed under similar stocking rates, 6 to 7 ha/A.U.

The mean availability of sown pastures per animal unit is 0.36 ha/A.U. In general, farmers give breeding stock little access to sown pastures, but prefer to utilize them with male stock or cows culled for sale. In most cases, sown pastures are also used for recovery of cows in extremely poor condition, such as those lactating during the dry season. This "strategic" use to avoid cow losses during the dry season is a common management practice.

Table 52 shows the herd structure, i.e.,

Table 51.

Pasture inventories and animal stocking in relation to amounts of sown pastures on 16 farms in the Colombian Llanos.

Farm No.	Total area[1] (ha)	Sown pastures: Total sown area (ha)	Sown pastures: % of total area	Species (%): *Brachiaria decumbens*	Species (%): *Melinis minutiflora*	Species (%): *Hyparrhenia rufa*	Cattle stock (A.U.)	Overall stocking rate (ha/A.U.)	Sown pasture availability (ha/A.U.)	Sown pastures per breeding cow (ha)[2]
2	1060	272	26	62	20	18	292	3.7	0.93	0.1
4	3050	22	1	27	73	0	610	5.0	0.04	0.0
5	810	143	18	50	0	50	238	3.4	0.60	0.5
6	1590	231	15	47	5	48	398	4.0	0.58	0.3
7	4950	457	9	27	25	48	969	5.3	0.47	0.0
8	380	162	43	100	0	0	130	2.9	1.25	3.0
9	470	0	0	0	0	0	131	3.6	0.00	0.0
11	5250	52	1	0	0	100	436	12.5	0.12	0.0
12	4430	161	4	94	6	0	558	8.3	0.29	0.0
13	1410	0	0	0	0	0	258	5.6	0.00	0.0
14	1700	30	2	17	83	0	325	5.3	0.09	0.0
15	3580	164	5	21	79	0	930	3.8	0.18	0.0
17	2240	321	14	1	99	0	329	6.7	0.98	0.0
18	8890	144	2	38	33	29	1101	8.3	0.13	0.0
19	3950	20	1	0	0	100	377	11.1	0.05	0.0
20	2860	65	2	77	23	0	559	5.3	0.12	0.0
Mean	2910	140	5	35	28	25	488	5.9	0.36	0.06

1 Includes native savanna, gallery forests and sown pastures.
2 Dependent on degree of utilization by breeding cows.

Table 52.

Herd structure of 16 farms in the Colombian Llanos.

Farms	Animal categories (%)				Total No.
	Breeding cows	Bulls	Heifers[1]	Steers[1]	
2	36	2	24	38	315
4	49	3	33	15	674
5	50	3	31	17	265
6	46	4	34	15	460
7	40	3	35	23	1038
8	37	3	36	24	145
9	43	4	31	22	145
11	36	5	33	27	517
12	24	2	26	48	603
13	44	2	35	19	282
14	44	3	34	19	369
15	34	2	37	25	1046
17	33	3	34	22	369
18	40	4	30	26	1219
19	40	2	30	27	412
20	33	2	32	33	627
Overall mean	39	3	33	25	530
Total	3324	258	2833	2779	9194

1 Heifers and steers include suckling calves and steers include cull cows for fattening.

the proportion of animals in each major category. Approximately 39% of the total stock are breeding cows (females which have calved). This figure is typical for a cow-calf and stocker operation, with low reproductive rates, advanced age of heifers at first calving, and advanced marketing age of steers.

Farms 4, 5 and 6 have a well-above-average percentage of breeding cows (and a low proportion of steers) indicating operations tending towards the cow-calf type and selling steers at a rather young age.

The farm sample includes one case (farm 10) of management oriented towards fattening (on *Brachiaria)* and is thus not representative of the Llanos. Seven farms (e.g., farm 12) are also engaged with fattening, but as a rather marginal or tentative operation.

A high proportion of heifers, which are kept for replacement, are common in the herds. This explains the age structure of the breeding stock given in Table 53.

The average age of cows is 76 months, indicating a relatively short productive life. Only 8% of total breeding stock has been classified as old cows (over 9 years of age).

In the total sample of 196 palpated heifers, between 2 and 4 years of age, only

Table 53.

Relative age structure of breeding cows in 16 farms of the Colombian Llanos.

Farm No.	No. of observa-tions	Age classes: Young <60 months (%)	Medium 60-108 months (%)	Old > 108 months (%)	Mean age (months)
2	55	44	42	14	74
4	0	–[1]	–	–	–
5	73	37	62	1	71
6	46	46	46	8	68
7	79	4	96	0	73
8	49	18	79	3	71
9	44	25	68	7	71
11	73	45	55	0	59
12	65	25	69	6	75
13	72	26	74	0	70
14	56	22	71	7	78
15	0	–	–	–	–
17	47	9	55	36	106
18	73	14	74	12	84
19	43	25	70	5	80
20	50	26	52	22	84
Overall mean	825[2]	26	66	8	76

1 Information not available.
2 Total number of observations.

37% were pregnant. These 72 pregnant heifers were 38 months old, with average weights of 305 kg. These figures generally indicate that replacement heifers produce their first calf at more than 4 years of age. Therefore, the average productive lifetime of a cow, including first gestation, can be estimated to be 4 to 5 years, not much longer than the raising period. If these results are confirmed next year, together with the calculated average calving rate of 50%, one can expect a cow to produce 2 to 2.5 calves during her lifetime. It has to be considered that young cows, particularly first calvers, are less efficient than old cows. Therefore, the age structure shown in Table 53 may explain the low reproductive indices.

The low proportion of old cows is probably not related to longevity of the female population as such, although continuous nutritional stress may have an effect. The main reason for short lifetimes of cows is their high beef value, i.e., if cash is needed, farmers prefer to sell old cows (rather than young steers, which next year might have a higher value). This culling of heavy (often pregnant) cows, has an adverse effect on the herd's reproductive level.

Table 54 summarizes the adoption of herd management technology by the farms. Application of techniques 1 to 4 has a direct (active) effect on herd output, while the others may have an indirect

Table 54.

Frequency and degree of adoption[1] of herd management techniques on 16 farms of the Colombian Llanos.

Technology component	Farm																Relative adoption (%)
	2	4	5	6	7	8	9	11	12	13	14	15	17	18	19	20	
1. Mineral supplementation	4	8	10	4	8	10	8	8	6	4	8	4	10	10	8	4	70
2. Animal health program	6	8	8	6	8	10	6	10	4	4	6	8	10	6	-	8	70
3. Culling	-	10	10	2	2	2	2	2	-	-	2	2	5	2	-	2	30
4. Weaning	4	10	4	8	4	10	8	10	4	4	4	4	10	4	-	10	60
5. Herd subdivision	4	10	4	10	4	10	-	10	4	-	-	4	8	4	-	4	50
6. Production records	-	5	5	-	-	5	-	2	2	-	2	2	-	-	-	-	20
7. Seasonal mating	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8. Technical assistance	-	5	3	-	1	-	3	-	-	-	3	1	3	-	-	-	20
9. Dehorning	-	-	5	-	-	-	-	-	-	-	5	-	5	-	-	-	20
10. Animal identification	-	5	5	-	5	5	-	5	5	-	5	5	5	5	-	5	60
Relative management level (%)	24	81	72	40	43	70	36	63	33	16	47	40	75	41	10	44	46

1 Techniques 1 to 5 had a maximum rating of 10 points; techniques 6 to 10 a maximum of 5 points. Therefore, a total maximum of 75 points can be achieved.

(passive) effect. A maximum of 10 points (according to degree of adoption) was computed for techniques 1 to 5, and a maximum of 5 points to techniques 6 to 10. This quantification does not imply application of *appropriate* technology.

Contrary to general opinion, mineral supplementation is quite common on the farms, i.e., all farms supplement animals with minerals, although mostly in a more or less restricted manner. An overall average estimated daily intake of 48.6 g/A.U./day (17.7 kg/A.U./year) was recorded, with a mineral mixture of about 5% P, equivalent to 2.8 g P/A.U./day. It is interesting to note that most owners and even cowboys are well aware of mineral deficiency and its relation to abortions and low fertility. The degree of adoption of mineral supplementation is mainly limited by cash availability.

Animal health practices (vaccination, parasite control, navel disinfection of newborne calves) also show a relatively high adoption level, although most of the technology has not been developed for the Llanos and therefore may be inappropriate.

The culling of unproductive cows is seldom practiced because it requires some basic techniques such as individual animal identification and production (abortion, calving, calf mortality) records that imply a high overall management level. The potential of adopting this management practice is considered high, because it could be done relatively cheaply and would assure a strong, immediate impact on reproductive efficiency of breeding herds.

Little systematic weaning is practiced on the farms; in many cases weaning occurs naturally (cows stop producing milk). This is related to the continuous mating used on all farms, with calves being born throughout the year. Most ranchers are aware of a natural concentration of calving during late dry season, consistent with Carimagua findings. Since ranchers commonly gather their herd only once or twice a year, during early and late rainy season, ages of nursing calves vary widely, complicating weaning at a given age. In this case, farmers prefer to wean calves at a rather old age, approximately 10 months.

Restricted or seasonal mating is not practiced on the sampled farms, nor has it been heard of outside the sample. Ranchers believe that "it doesn't work", because "cows will fail to conceive". This is consistent with the fact that successful adoption of seasonal mating requires good managerial skill. This knowledge gap emphasizes the importance of the Carimagua experiment, described later in this section.

While individual animal identification and branding is quite common, individual performance records are seldom kept except for controlling the cattle inventory.

Data in Table 54 show an enormous potential to increase herd productivity by transferring known management technology such as culling and seasonal mating, which can be adopted at a low cost. On most farms, the existing infrastructure (e.g., corrals and fences) would need only minor improvement for these practices.

Table 55 gives an estimate of the reproductive performance of the breeding herds, in relation to the body weight of cows according to lactation status. Since farmers do little to improve pastures, the nutritional condition of the cows, and the resulting reproductive indices, are expressions of the forage production potential of the savanna. According to results obtained at Carimagua, the mature body weight of a dry cow commonly found in the

Table 55.

Reproductive performance[1] of breeding stock in 16 farms of the Colombian Llanos.

Farm No.	Cow age (months) $\overline{X}$	Body weight of cows (kg) Dry cows No.	Dry cows $\overline{X}$	Lactating cows No.	Lactating cows $\overline{X}$	Estimated calving rate[2] (%)	Reproductive index[3] (%)
2	74	29	317	26	302	45	0.78
4	–[4]	107	320	-	-	34	0.85
5	71	39	297	33	284	57	0.74
6	68	25	348	22	299	77	0.94
7	73	58	303	25	290	42	0.67
8	71	15	410	31	356	67	1.09
9	71	21	344	20	313	54	0.85
11	59	44	326	29	298	51	0.96
12	75	50	308	16	283	38	0.59
13	70	45	344	27	285	59	0.79
14	78	42	306	14	272	48	0.73
15	–	32	303	26	289	56	0.85
17	106	23	337	23	310	52	0.91
18	84	31	298	41	261	44	0.83
19	80	28	279	16	264	30	0.56
20	84	23	312	26	276	45	0.92
Overall mean	76	622	318	375	293	49	0.81

1 Based on data obtained in May - June, 1978.
2 Calculated from lactation and pregnancy status (see text).
3 Sum of proportion of lactating and pregnant cows.
4 Information not available.

Llanos under adequate pasture-based feeding conditions for satisfactory reproductive performance is about 400 kg. On the farms, average weight of dry cows was 318 kg (in the early rainy season), approximately 20% below the estimated optimum. On some farms, the nutritional stress appeared to be extremely high. For example, in farms 18 and 19 lactating cows averaged only 262 kg. On only four farms did lactating cows weigh more than 300 kg. These inadequate feeding conditions are the main cause of poor reproductive performance in the Colombian Llanos.

The estimated calving rates in Table 55 correspond to the period from November 1977 until October 1978. The following formula was used: Number of lactating (1-6 months) cows plus number of pregnant (3-9 months) cows divided by total number of cows in the sample.

Because of the known natural within herd variation of calving rates between years, these figures have to be complemented with one more year of observation. However, the average rate of 49% appears reliable and agrees well with the 52% reported from a former survey (CIAT Annual Report, 1974). According to the initial hypothesis, variation between farms is high, ranging between 30 and 77%. The close relationship between nutritional condition (body weight) and reproduction is evident.

Table 55 also shows values for the reproductive index, obtained by adding together all lactating and pregnant cows (lactating pregnant cows are rated twice) and dividing by the total number of cows in the sample. This index quantifies the proportion of actively reproducing cows over a period of approximately 18 months, and is therefore a better parameter to compare the reproductive status of a herd than the estimated calving rate based on single observations.

The best and worst reproductive indices (farms 8 and 19, respectively) coincide with the highest and lowest cow weights. Based on this index, it is estimated that approximately 10 to 15% of the cow population should be culled, because of extremely poor reproduction or infertility.

The relative distribution of breeding cows, according to pregnancy and lactational status, of a total sample of 988 observations is shown in Table 56. Only 2% of lactating cows were found to be pregnant. The survey reported in 1974 indicated 9%. This finding again confirms that the vast majority of lactating cows are not able to reconceive, primarily due to nutritional stress. The average cow has to recover for several months from lactation after weaning, resulting in an average calving interval of approximately 24 months and corresponding to 50% calving rates.

Table 57 gives the average body weight of young stock, within age categories. Fattening operations are excluded so results refer to cattle grazing savanna only. Also, the results of the two weighing seasons are shown. No significant differences were found in age within

Table 56.

Distribution of breeding cows in relation to pregnancy and lactation status, based on 988 observations in the Colombian Llanos.

Pregnancy	Dry	Lactating ≤6 months	Lactating >6 months	Mean
	(%)			
Open	21	23	13	57
Pregnant ≤3 months	16	-	1	17
Pregnant >3 months	25	-	1	26
Mean (lactation)	62	23	15	100

Table 57.

Body weights of animal stock, by age categories, on sampled farms of the Colombian Llanos.

Age categories	Overall mean			Early dry season		Early rainy season	
	No.	Age (months)	Weight (kg)	No.	Weight (kg)	No.	Weight (kg)
Female stock							
Weaners	195	8	138	87	129	180	145
1 - 2 years	267	16	185	89	191	178	182
2 - 3 years	226	27	250	105	245	121	254
3 - 4 years	193	38	267	118	259	75	279
>4 years[1]	100	52	280	62	272	38	294
Cows (dry)	1245	76	309	632	300	613	318
Male stock[2]							
Weaners	187	8	136	111	138	76	132
1 - 2 years	273	16	184	125	178	148	189
2 - 3 years	90	26	232	38	240	52	227
>3 years	23	49	259	19	259	4	258

1 Have not yet calved.
2 Castrated and uncastrated.

categories during these seasons. While the data have not been fully analyzed, sex and seasonal effects appear not to be important. Females in category over 4 years of age are heifers which have not calved yet.

Cerradò of Central Brazil

Four major ecologically homogeneous sub-regions of the Brazilian Cerrado were identified by the Target Area Survey Section and are: (1) Central-west Minas Gerais; (2) Southern Goiás; (3) Northern Goiás; and (4) Central Mato Grosso.

Activities started in January 1978, as the CIAT special-funded Animal Scientist joined the CIAT-CPAC team. Due to physical limitations to cover these four vast sub-regions, an initial screening was necessary. For this purpose, extensive recognition trips were made. Based on the findings that in sub-regions 1 and 2 dairy ranching prevails (60 to 80% of the farms use beef cows for milk production), it was decided to concentrate efforts and resources on sub-regions 3 and 4, where beef production systems definitely predominate. Nevertheless, the increasing importance and trend toward dual-purpose ranching may have implications with the Program's orientation.

From May onward, farms were pre-selected, and by September, eight farms in Central Mato Grosso area and seven farms in Northern Goiás were identified and initial data collections to characterize the farms were concluded. For records of individual animal performance a sample of

1900 head of cattle was identified and numbered. The selected farms are shown in Table 58.

Table 58 shows a relatively high variation in farm size, herd size, and actual stocking rates, ranging from 2 to 5 ha/head of cattle. Nevertheless, it is interesting to note that the mean figures for both regions are very similar. Also, the herd structure is comparable, with breeding stock representing 45-47% of the total stock.

The main difference between the two sub-regions appears to be the proportion of planted pastures on the farms, being higher in Mato Grosso (24% of total pastures) than in Goiás (14%). Nevertheless, in both regions the only two important species, *Hyparrhenia rufa* and

Table 58.

Characteristics of selected farms in the Cerrado of Brazil.

Farm No.	Technology level[1]	Type of operation[2]	Area (ha) Total[3]	Area (ha) Sown past.	Cattle Cows	Cattle Total	Stocking rate[4] (ha/animal)
Sub-region: Central Mato Grosso							
1	M	C/R	2000	400	-	-	-
2	M	C	1700	310	88	300	5.6
3	M	C	2000	550	300	503	3.9
4	H	C/R	5450	1200	520	1200	4.1
5	L	C/R	990	250	305	442	1.9
6	L	C/R	4400	800	460	1135	3.4
7	M	C	1126	215	210	419	2.4
8	M	C/R	1467	220	120	307	4.2
Mean: Mato Grosso			2400	500	290	615	3.6
Sub-region: Northern Goias							
9	H	C/R	1630	288	200	593	2.0
10	L	C	700	250	120	255	2.2
11	L	C	870	50	90	244	3.6
12	M	C/R	3100	500	348	661	4.6
13	M	C/R	3560	100	308	791	4.4
14	H	C	3370	300	300	540	4.0
15	M	C	2100	275	420	816	1.9
Mean: Northern Goias			2200	250	255	560	3.2

1 H: High, M: Medium, L: Low
2 C: Cow-calf, R: Raising
3 Includes crops and forest
4 Overall stocking rate: Savanna + Sown pasture/Total No. of cattle.

Brachiaria decumbens, have been found in the same two-thirds: one-third proportion, respectively.

Comparing these findings with results from the Colombian Llanos, there appear to be no major differences in farm area and herd size. Cerrado farmers appear to have a higher stocking rate (3-4 ha/head in Brazil), than in the Llanos of Colombia (5-6 ha/head). A significant difference can also be observed in the proportion of sown pastures on the farms (Cerrado 14-24%, Llanos 5%). While in Brazil the most important sown pasture species is *H. rufa*, *B. decumbens* and *M. minutiflora* predominate in the Llanos. In both Cerrado regions, almost all farms do some cropping (rice mainly), although at a relatively small scale. On the Llanos farms, commercial crops were not found.

Also some differences can be observed in herd structure. While on the Cerrado farms over 45% of the total stock are breeding cows, on the Llanos farms only 36% are cows. This indicates that Brazilian ranchers sell their stock at a younger age than their Colombian counterparts.

Eastern Llanos of Venezuela

During 1978 an agreement with FONAIAP was signed. Among other collaborative research activities, the ETES Project will be carried out as a joint venture. In October, a CIAT Animal Scientist joined the multidisciplinary team assigned to the project at the CIARNO regional center in Maturín. Initially, the northeastern Llanos region has been selected, with possibilities to expand into the central Llanos later. Pre-selection of farms has been concluded, providing a basis for final selection. Data collection concerning animal performance will start early in 1979.

Breeding Herds Management Systems

The main objective of this large experiment is to evaluate the strategic use of improved pastures on cow-calf type production systems in tropical savanna regions.

Strategic use is defined as a temporary access of the breeding stock to improved pastures, during critical periods of the reproductive cycle (calving, early lactation, reconception). For a rational strategic use of improved pastures, a seasonal restricted mating appears to be essential.

The experimental objectives were described in the 1977 Annual Report. The final design is shown in Table 59.

Approximately 10% of the total area utilized by Herds 2, 4 and 6 is improved pastures, i.e., 120 ha of grasses (mainly *B. decumbens,* but associated with *M. minutiflora* and partially with *A. gayanus)* and 30 ha of *Stylosanthes guianensis* 136 planted in August-September 1977, with low fertilizer inputs (47 kg P_2O_5/ha, to all plus 10 kg S/ha on legumes).

Strategic use with 20 high-priority (early lactating) cows per Herds 2, 4 and 6 started in the late dry season (February 15 till April 30, 1978). During this period, stocking rate of the legume paddock was 1.6 A.U./ha, and in the grass paddocks (during establishment), 0.36 A.U./ha.

From May until September, grass and legume paddocks were grazed intermittently, at an average stocking rate of 1.6 A.U./ha. The periods during which Herds 2, 4 and 6 had access to the improved pastures are shown in Table 59.

The native savanna pastures had an average stocking rate of 0.15 A.U./ha.

Table 59.

Treatments in breeding herds management systems experiment, during 1978 at Carimagua.[1]

Herds	No. of Cows	Pastures: Type	Pastures: Time on improved pastures (days)	Mating periods: Months	Mating periods: Duration (days)
1	54	Savanna only	0	Jan-Dec.	365
3	54	"	0	June-Sept.	120
5	54	"	0	May-July[2]	90
2	54	Savanna +	114	Jan-Dec.	365
4	54	Improved pastures	155	June-Sept.	120
6	54		91	May-July[2]	90

1 Within herds, 50% of calves will be weaned at 6 months and 50% at 9 months.
2 A second mating period of 90 days, during December 1978-January 1979 is planned.

These pastures are burned in sequence (within paddocks) 2 or 3 times per year. Some of them include a high proportion of good, productive low areas (up to 50%). In an attempt to eliminate paddock effects, all herds on savanna are rotated monthly throughout all paddocks.

The experimental herds were formed in December 1977. Cows were selected with the only criterion being proven fertility—at least two calves for old (born in 1969) cows and one calf or pregnant for young cows. Replacement heifers must weigh 280 kg by 3 years of age. Culling of infertile cows is routine. All herds are comparable in age and physiological (lactation and pregnancy) status. In August 1978, another 16 heifers were included so that each herd now has 56 breeding females.

The routine management program for the six herds includes: (1) Year-round *ad libitum* mineral supplementation. Phosphorus content in the mixture varies from 7 to 8%. Average consumption has been 58 g/A.U./day (21 kg/A.U./year); (2) A complete animal health program, including control of infectious diseases (foot-and-mouth, brucellosis, malignant edema, pasteurellosis and black leg), external (every two months) and internal parasites (calves twice a year, adults once a year), and care of newborne calves (particularly navel disinfection). (3) All bulls are supplemented with 0.6 kg of cottonseed meal during the dry season and are kept on improved pastures during rest periods. (4) Individual animal checks every two months, during data collection.

Therefore, general herd and pasture management is near feasible optimum, in relation to the environment and present state of knowledge.

From September 1977 to August 1978, the experimental breeding herds had the following average performance: calving rate, 72.5%; preweaning calf mortality, 9.9%; adult mortality, 1.5%; and, abortions, 0.6%.

In the same period, these traits were not yet influenced by experimental treatments. But the high calving rate, due to selection and culling in December 1977, resulted in a high proportion of lactating cows during mating periods, thus permitting the study of reconception during lactation.

A significant effect of the pasture treatment on weaning weight of calves was observed from June onwards. All calves that conceived during 1977 (with continuous mating in all herds) were weaned at 9 months of age. In Table 60 the results of June and August are shown. Although cows from Herds 2, 4 and 6 had access to improved pastures during late lactation for only an average of 160 days, they weaned 11% (18 kg) heavier calves than cows grazing only native savanna.

The effect of pastures on body weight of cows, according to their lactation status is shown in Figure 99. While dry cows with access to improved pastures showed an almost constant, positive difference compared to the cows with access to native savanna only, there are continuously increasing differences between lactating cows.

In October, lactating cows of Herds 2, 4 and 6 were 31 kg heavier than comparable cows of the savanna herds.

In analyzing the effect of pastures on body weight of cows by lactation periods, it becomes evident that improved pasture supplementation is particularly effective during early lactation, when nutritional requirements are highest. Figure 100 shows the weights taken in June and August. Although all differences are significant, differences due to improved pastures during the first half of lactation is about 30 kg, and only 10 kg during the second half.

Table 61 provides results of the weighing in October. The difference between early lactating cows has increased to 43 kg, to 23 kg for late lactating and only 18 kg for dry cows.

A pregnancy diagnosis was done at the end of October (Table 62). Conception rates were calculated over total cows, and over "able" cows, defined as cows which calved 90 days or less before the end of the mating season, and therefore have recovered from normal lactation anestrus. The conception rate for able cows is approximately equivalent to overall conception rate, once the reproductive cycles of the breeding herds are adjusted to the respective mating seasons.

Table 60.

Pasture effect on weaning weight of calves during the rainy season.

	Calf weight (kg)						
	Overall mean		Savanna only		Savanna + 10% sown pasture		
Weaning month	No. of observ.	Mean	No. of observ.	Mean	No. of observ.	Mean	Difference
June	56	176	26	166	30	185	19
August	28	179	15	171	13	189	18
Total	84	177	41	168	43	186	18

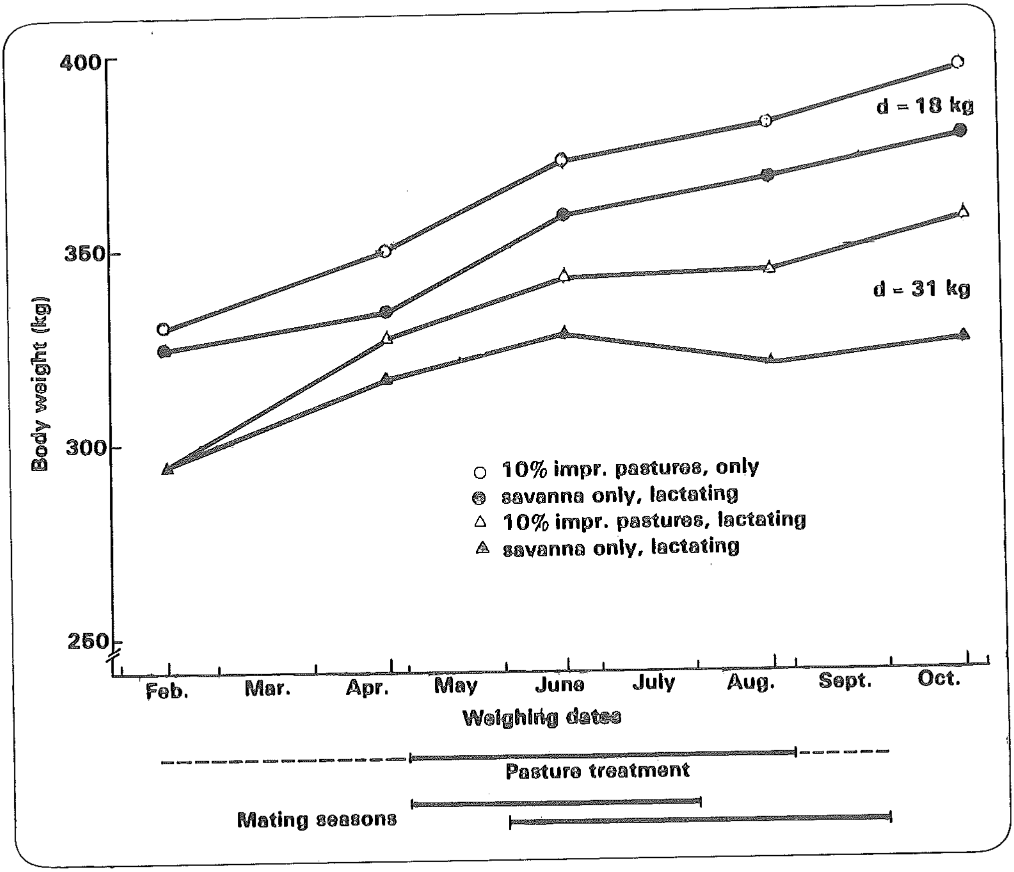

Figure 99. Efect of pasture systems on body weight of cows, according to lactation status, in the Breeding Herds Management Systems, Carimagua.

Of particular interest is the reconception rate of lactating cows, since low reproduction rates generally found under tropical savanna conditions are closely related to the fact that most cows will not conceive until after weaning.

The pasture effect on conception rates is shown in Table 63. The savanna herds also show relatively high indices as a result of high management level. Nevertheless, a 25% increase in herds supplemented with improved pastures can be observed. This is explained through the high (68%) reconception rate of lactating cows, due to better nutritional condition.

In Table 64, conception rates in relation to mating periods are given. Possibly pregnancies in Herds 1 to 4 are slightly underestimated. Although results are not quite conclusive, it appears that a 3-month mating period (Herds 5 and 6), during the early rainy season (May - July), particularly in combination with improved pastures (see Herd 6 in Table 62) assures a high conception ability, possibly due to the "flushing" effect. Adoption of restricted mating periods appears feasible, and does not necessarily have a negative effect on reproductive rates during the first year of adoption. The adoption of short mating periods makes possible the practical

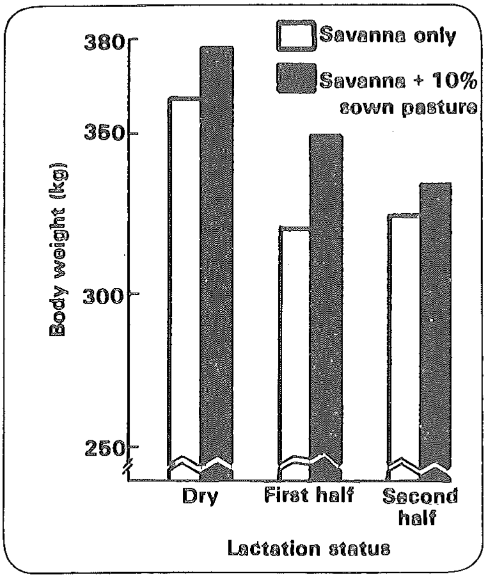

Figure 100. Effect of strategic use of sown pastures on body weight of cows in relation to lactation status, during the rainy season at Carimagua (means for June-August).

strategic management of improved pastures.

The results obtained during this first experimental year were used for an overall evaluation of the two basic systems: "A" on savanna only with the best possible management, and "B", savanna plus 10% of improved grass plus legume pasture. Analysis of the 1978 data showed that 10% improved pastures increased the annual liveweight output to 23 kg/ha, that is 2.5 times that from system A (9 kg/ha).

There are indications, however, that the stocking rates of the improved pasture can be increased from 1.6 to 2.0 A.U./ha, that the age of heifers at first calving can decrease to 3 years and pre-weaning calf mortality can decrease to 5%. In this case, system B could produce an output of 30 kg/ha/year, or 3.5 times more than system A.

Corresponding economic analyses presented in the Economics Section suggest that the limited strategic use of improved pastures with breeding herds is an attractive alternative for beef producers, once legume-based pastures become available and persist for at least six years under Colombian Llanos conditions.

Test Herd

At Carimagua, the Section manages the ICA-CIAT Test Herd, with the major objective of producing suitable cattle for grazing experiments. At the same time, new management techniques, adapted to the environment, can be validated under practical, extensive, commercial production conditions.

The Test Herd uses about 5900 ha, of which 160 ha (3%) are planted with *B. decumbens*. Average stocking rate of the savanna pastures varies between 6 to 7 ha/head. The present cattle stock includes 267 breeding females (158 cows and 109 mated heifers), and 11 bulls (3 San Martinero and 8 Zebu). The project also receives weaners from Carimagua experiments and raises them until they are used again in grazing experiments or are sold.

Cows are mated from April 1 until November 30. All animals are supplemented *ad libitum* with minerals. Bulls are supplemented daily with 500 g cottonseed meal during the dry season. Soft culling based on reproductive performance is practiced. The herds are gathered three times a year. At this time animals are vaccinated, dipped, weighed, identified, males are castrated, calves near 9 months of age are weaned and, once a year, cows are palpated for culling.

Overall mortality was 1.8% and of calves before weaning, 5.4%. Due to extensive management, the latter figure might be

Table 61.

Body weight of cows according to lactation status and herds (October 1978).

	Dry		Lactation status: First half		Lactation status: Second half	
Herd	(No.)	(kg)	(No.)	(kg)	(No.)	(kg)
Savanna only						
1	29	391	9	330	18	326
3	38	373	7	335	11	325
5	32	370	11	301	13	336
Savanna + improved pastures						
2	27	407	10	365	19	345
4	37	395	9	367	9	358
6	39	387	7	351	10	360
Means						
Savanna only	99	377	27	320	42	329
Savanna + improved pastures	103	395	26	362	38	352

Table 62.

Conceptions in breeding herds management systems experiment according to palpation done at end of October 1978.

	Herds: Savanna only			Herds: Savanna + 10% improved pasture		
Parameters	1	3	5	2	4	6
Total cows	54	54	53	52	52	52
Able cows[1]	50	47	38	49	43	44
Pregnant cows	30	28	26	39	31	37
Overall conception (%)	56	52	49	75	60	71
Conception of able cows (%)	60	60	68	80	74	84
Conception over total lactating cows (%)	22	6	21	62	28	53
Conception over lactating able cows (%)	25	9	38	69	56	78

1 Able to conceive, with more than 90 days between calving and end of mating season.

Table 63.

Pasture effect on conception rates.

Pasture treatment	Overall conception (%)	Conception, able cows[1] (%)	Conception lactating able cows[1] (%)
Savanna only	52	63	24
Savanna + 10% improved pastures[2]	69	79	68

1 Able to conceive (over 90 days between calving and end of mating period).
2 Average of 120 days on improved pastures.

underestimated. The average weaning weight of 67 calves (weaning in November not included) was 143 kg (males 144 kg, females 139 kg) at an average of 9 months of age. Eight abortions (5%) were recorded.

For the period between October 1977 and September 1978, the calvings registered are shown in Table 65. For Herds 1 to 3, average calving rate was 58%, similar to that reported last year. The 109 heifers of Herds 4 and 5 were tentatively mated for 45 days only during October-November 1977, resulting in 34% calving and indicating that, although body weight was satisfactory, the mating period and particularly the season of the year were not adequate.

The following numbers of animals were provided to other research projects at Carimagua during the year: Legume Agronomy Section, 20 female weaners; Animal Management Section, 55 female weaners; Pasture Utilization Section, 160 steers and male weaners; Mineral Supplement Studies (ICA), 335 heifers; and Beef Production Studies (ICA), 114 steers. In addition, the Test Herd handles calves

Table 64.

Effect of mating periods on conception rates.

Mating periods	Overall conception (%)	Conception, able cows (%)	Conception, able lactating cows (%)
Continuous (Herds 1 + 2)[1]	65	70	47
4 Months (Herds 3 + 4)[2]	56	66	32
3 Months (Herds 5 + 6)[3]	60	77	58

1 Since May 1978.
2 During June, July, August, September 1978.
3 During May, June, July 1978.

Table 65.

Calvings recorded in Carimagua Test Herds.

Herds	Mated cows/ heifers	Parturitions	Calving rate (%)
1	61	35	57.4
2	47	30	63.8
3	50	27	54.0
4[1]	52	(20)[2]	(38.5)[2]
5[1]	57	(17)	(29.8)
Total	267	129	(48.3)

1 Heifers mated only during Oct.-Nov. 1977.
2 Values in parentheses are low reflecting the short mating period for heifers in Herds 4 and 5.

from other projects. A main calf producer was the Breeding Herd Management Systems experiment. Another 68 non-suitable animals were sold, and 56 animals were consumed at the Center.

ANIMAL HEALTH

This section continued the monitoring and surveillance of animal health problems at three levels of intensity. The macro-level consists of an animal disease inventory of the target area and is an integral part of the Target Area Survey. Macro-level studies will provide general background information for any condition that could affect cattle productivity in the area.

Intermediate level work comprises the surveillance at Carimagua, the ETES Project, miscellaneous surveillance from the Cerrado Center in Brazil and an area in Paraguay, and a description of problems arising from pasture toxicity (toxic plants.).

At the micro-level, studies were conducted on a parasite profile at Carimagua, the epidemiological study of a natural leptospirosis infection in the Colombian Llanos and a report on the artificial leptospira infection in well-nourished cows. The micro-level studies are directed to obtaining information for devising a practical preventive medicine approach for control of specific conditions already defined as important.

Macro-monitoring

Animal Disease Inventory

Data has been obtained from regions of the target area, especially in Brazil, Colombia and Paraguay.

Brazil has considerably more information on disease aspects than any other country in the target area. The information, however, is in the hands of local institutions, individuals and private practitioners and will require considerable effort to collect and assemble.

Table 66 describes conditions found in the states of Mato Grosso and Goiás with priorities as they appear now, with limited data. As more quantitative data are collected, the information will be more dependable.

Four conditions merit attention. First, considerable numbers of tuberculosis lesions are found at slaughterhouses in beef cattle from this area of Brazil. In Mato Grosso only, 1166 carcasses were condemned in 1977 because of TB. This infection is important not only from the standpoint of meat loss, but also because of dangers of human infections.

Second, brucellosis infections appear very high (15-18% prevalence) in some regions, however, the high figures come from specific farms and the disease is not randomly distributed. The official prevalence figures for the Mato Grosso show 9.43% reactors and for Goiás, 11.60% reactors, the latter figure being the highest for the country.

A third important condition is bursitis, an infection of the bursa underneath the hump in *Bos indicus* cattle. Its nature has not yet been determined. Bursitis has increased considerably in the last two

Table 66.

Some conditions affecting beef cattle health in the states of Mato Grosso and Goiás, Brazil. (Preliminary information for the Animal Disease Inventory of the Target Area Survey.)

Conditions	Observations	Tentative priority
Tuberculosis	1116 carcasses condemned in Mato Grosso in 1977.	1
Brucellosis	Some regions with 15-18% prevalence.	1
Bursitis	91 cases at slaughterhouse in Mato Grosso in 1977.	1
Internal parasites	Mainly *Cooperia* and *Haemonchus* species (treated during dry season).	1
Botulism	Produced as a consequence to mineral deficiencies.	2
Toxic plants	Six outstanding: Anilão, Dama da noite, Erva Café, Faveira, Barbatinão, Piriquiteira.	2
"Espichamento"	Due to *Solanum malacoxica* (toxic plant).	2
"Peste Secar"	Blamed mostly on Co deficiency.	2
Anaplasmosis	Primarily in calves.	3
"Peste Rachar"	Probably nutritional (25% deaths in Northern Goiás in 1-4 months old calves).	3
Rabies	From vampire bats, in outbreaks (15 cases in Goiás in one month)	3

years, causing some meat losses. The last condition is internal parasites, which are seriously impairing calf growth in the area. Problems are being produced by parasites of the *Cooperia* and *Haemonchus* species. Two treatments during the dry season are being advanced as efficacious.

The information from Colombia will come primarily from previous studies reported in CIAT Annual Reports, data that is being obtained from the ETES and other projects described below, and information that is being collected from Colombian institutions.

Data from Paraguay to be used for this disease inventory is described below under miscellaneous surveillance; these are results from direct laboratory examination of serum samples sent to CIAT laboratories.

Intermediate Monitoring

Carimagua Surveillance

The main health problems occurring in Carimagua are calf mortality and malnutrition.

Calf mortality is most common in the first few days of life; many calves just disappear and are not even seen in closely observed and managed herds. It appears that some animals are born prematurely, some at full term but weak and others are lost inside bushy areas. Data from two herds (64 calvings) showed 9.6% mortality in calves under one month of age. The breeding experiment herd showed 23 deaths from 233 calvings, a 9.9% mortality rate. Most of this calf mortality is registered as unknown (Table 67) for the reasons given. A stronger effort should be made to analyze these cases better.

Table 67. **Causes of cattle mortality in the Carimagua Research Station in 1978.**

Condition	No. of cases
Malnutrition (clinical)	27
Unknown	26
Sinking in mud or watering holes	17
Bone fractures	15
Snake bite	6
Polyarthritis	4
Photosensitization	1
Total reported deaths	96[1]
Total animals in station	2600
Mortality rate	3.7%

1 Only from animals that had been ear tagged. Some calves that died before they were branded are not included.

Malnutrition causes deaths in cattle of all ages but is most common in cows over 8 years and in weaners from 12 to 18 months.

Two other factors affecting mortality are cattle becoming mired in mud and quicksand at water holes, which accounted for 17 cases during 1978, and bone fractures, which caused 15 deaths in the same period (Table 67).

The conditions responsible for treatment procedures are mainly uterine infections, polyarthritis and malnutrition.

ETES Project

The second visit to the 17 farms of the ETES Project (see sections of Animal Management and Economics) was useful for gathering the first set of information on internal and external parasites. There are observations for assessment of infestations due to *Dermatobia hominis*, ticks, Stephanofilaria, internal parasites, and lice (Table 68).

Table 68.

Summary data of internal and external parasites identified from animals in farms of ETES Project in the Colombian Llanos, examined at beginning of the rainy season.

Infection level	Internal parasites[1] (No. of animals)	(%)	Interpretation (egg/g feces)	*Dermatobia hominis* (No. of animals)	(%)	Stephanofilaria (No. of animals)	(%)
Clean	85	61.1	0	1.430	96.3	487	38.7
Low	38	27.3	1-500	44	2.9	589	46.8
Medium	10	7.1	501-5500	4	0.2	103	6.3
High	6	4.3	> 5500	7	0.4	80	6.3
Total animals examined	139			1485		1259	

1 Includes nematodes and protozoa.

The criteria for the evaluations has come from previous work at Carimagua and in some Llanos farms. It is continuously tested for improvement.

In tests for internal parasites, 10% of the adult animals and 20% of the calves going through the chute are sampled. Levels of infestation are classified as clean, low, moderate and high. From 139 animals examined, only 4.3% had high infections (over 5500 eggs per gram of feces), 61.1% were clean, and 10 farms had animals classified only in the low infection level (50 to 500 eggs per gram of feces). It appears that internal parasites, at the beginning of the rainy season, produced mainly low infection levels on these farms and do not constitute a herd problem. However, there are individual animals that would have benefited from treatment at this time. The results of this preliminary sampling will be evaluated against the data obtained from further samplings and with data from the parasites profile being constructed at Carimagua and reported below.

External parasites showed low levels of infestation. In 8 of the 15 farms sampled, no ticks were found and in the rest only 10% of the animals had low infestation levels. This will have to be further evaluated against the level of hemoparasites. For the fly, *D. hominis,* at this sampling 96% of the 1430 animals were clean and only 0.7% had medium to high infestations requiring treatment. Stephanofilaria is a cutaneous microfilaria that produces a verminous dermatitis. Forty-eight percent of 1259 animals examined had at least one focus of infection on the underside of the abdomen and 6.3% had more than three foci. The significance of this infection in relation to productivity has not been evaluated, and it might be worthwile to look into its relation with other external parasites.

One farm which had continuous reports of calf and weaner losses was followed in-depth to monitor the problem. Fifty animals were examined for ecto- and endoporasites, urinalysis, hematology, blood chemistry and antibodies for infectious diseases. In general, the exams revealed animals at a low nutritional level and severe management deficiencies, since salt offered did not contain minor mineral elements, calves' navels were not disinfected and dead animals were not buried.

There was a complex mixture of disease problems with inadequate handling. Six calves had high counts for Coccidia, a protozoan that accounts for a bloody diarrhea. Two calves had high counts for round-worm of the family Trichostrongylidae and one calf had a high count for Ascaris round-worm.

In relation to hemoparasites, *Anaplasma* is not a problem on this farm, however *Babesia argentina* is highly endemic. Twenty animals had strong antibody reactions, and this could account for clinical cases of babesiosis. Tick counts at the end of the dry season were high for two animals. Together with the low nutritional levels, all of these parasite burdens are contributing to the low productivity.

The overall health status revealed 25 of the 50 animals examined to be in bad clinical condition. Twelve animals (24%) had low hemoglobin and hematocrit levels, and 6 had low total protein blood plasma levels; these were animals with anemia and hypoproteinemia. SGOT enzyme was high in 9 animals and indicates critical energy supply or a hepatic lesion. Two animals showed an obvious infectious disease at the moment of examination as indicated by the high neutrophil blood cell count. Mean blood parameters in this herd were low in comparison to means from cows of the experimental herd in Carimagua, reported last year.

For this farm, the procedure described to evaluate nutritional and health status, using as standards previously obtained mean values, is working satisfactorily, for blood parameters. Better standards are required for evaluating internal and external parasite burdens, including their antibody reactions.

Miscellaneous Surveillance

Cooperative work with the Veterinary Diagnostic Laboratory of the Ministry of Agriculture in Paraguay and Cerrado Center of EMBRAPA in Brazil, was initiated last year. Work was started to gather some information on animal health problems of beef cattle. Serum samples for detection of infections associated with reproductive and nutritional problems were received from those laboratories this year. As was decided previously, samples were used for the following serologic tests: plaque micro-agglutination for *Leptospira* spp., passive hemo-agglutination for infectious bovine rhinotracheitis (IBR) virus, complement fixation antibodies for *Anaplasma marginale,* and indirect immunofluorescent test for *B. argentina* and *Babesia bigemina.*

Paraguay

A total of 274 serum samples from four different areas of Paraguay were tested for any evidence of infection in beef cattle with the agents mentioned above. Table 69 shows the results of the serologic survey of the bovine serum samples tested against different reference antigens. The prevalence of IBR antibodies in beef cattle from those areas of Paraguay was very low (2.5%) which could indicate that IBR virus activity is also of low importance there. However, the disease has been found in beef cattle of tropical America (Target Area), so this information should be considered for further studies.

With the exception of *Leptospira*

Table 69.

Antibody prevalence for different infectious agents in beef cattle from Paraguay and Brazil.

Antigen	Paraguay[1] (P/T)[3]	Paraguay[1] (%)	Brazil[2] (P/T)	Brazil[2] (%)
IBR virus	4/274	1.5	6/165	3.6
Leptospira spp.				
L. hebdomadis	86/274	31.4	40/167	23.9
L. hardjo	112/274	40.9	58/166	34.9
L. pomona	0/274	0.0	3/167	1.8
L. wolffi	82/274	29.9	22/167	13.2
L. sejroe	106/274	38.7	64/167	28.3
Anaplasma marginale	4/274	1.5	0/166	0.0
Babesia argentina	12/274	4.8	14/166	8.4
Babesia bigemina	9/274	3.3	9/166	5.4

1 Paraguay: Diagnostic Laboratory of the Ministry of Agriculture.
2 Brazil: Cerrado Center (EMBRAPA).
3 P/T: Positives/Total tested.

pomona (0% prevalence) antibody prevalences for the other leptospiras tested were rather high. *Leptospira hardjo* should be of some consideration because it had the highest antibody prevalence (46.9%) of the leptospiral agents and 27 animals showed titers ≥ 1:800 for it which means that disease prevalence for chronic cases was 9.8%. Titers higher than 1:800 were also detected for the other leptospiras tested.

The antibody prevalence for *A. marginale, B. argentina* and *B. bigemina* was relatively low, however, results indicate that diseases caused by these agents are present in those areas of Paraguay and probably in an enzootic form.

Future studies over time should be developed in beef cattle in Paraguay in order to get more information about the epidemiological implications of these and other infectious agents in that area.

Brazil

Sera from 167 cattle from the Cerrado Center were tested against the aforementioned antigens to evaluate antibody prevalences. Results are summarized in Table 69. IBR antibody prevalence was 3.6%, a very low figure possibly reflecting a low activity of IBR virus in the specific area or herd where the samples originated. A wider survey may be indicated to get more dependable figures. Considering the different species of leptospiras tested, all demonstrated infectious activity among beef cattle of this specific area. *Leptospira sejroe* and *L. hardjo* were notoriously more prevalent than the others while *L. pomona* had a very low prevalence rate. Twelve animals had titers ≥1:800 for *L. hardjo* but only two animals showed titers ≥1:800 for *L. sejroe*.

There was no indication of infection for *A. marginale* but *B. argentina* and *B. bigemina* showed antibody prevalences of 8.4% and 5.4%, respectively, suggesting that babesiosis is present in the area and may be enzootic.

Further studies should also be considered for this area in Brazil.

Brachiaria decumbens Toxicity

There were two reports of *Brachiaria decumbens* photosensitization during the year; one occurred at Carimagua where two heifers (18-24 months old) of a group of 20 in the pasture showed marked lesions in the skin. They were pasturing *B. decumbens* and the lesions started to recede after the animals were removed from the pasture. One heifer died and the lesions found at necropsy were of a liver tissue damage and skin necrosis. The cultures from pasture material revealed mostly saprophytic species but also one possible animal pathogen, *Fusarium,* described below.

The second documented report of *B. decumbens* toxicity was on a farm 50 km west of Carimagua, where 123 sheep were introduced into a *B. decumbens* pasture. Sixteen animals died within three weeks with swollen faces, edema, weakness and anemia. When the animals were taken from the pasture no more deaths occurred. The lesions in one animal necropsied were liver necrosis and facial edema.

Five farms in the Colombian Llanos with previous reports of photosensitivity were followed to study possible relationship with pasture. All had *B. decumbens* pastures. Vegetative material (stems and leaves) with lesions (dead material) was collected and transferred with adequate humidity to the laboratory where direct observations and cultures for fungi were conducted.

Principal fungi obtained were *Fusarium, Helminthosporium, Curvularia* and *Nigrospora.* It appears that *Fusarium* (detected in three farms) could be a possible agent of toxicity in cattle, however, extracts of this fungus were injected intradermally in rabbits and no toxin was detected. It is interesting to note that *Phytomices chartarum,* the fungus reported in some areas of Brazil, was not detected although sampling may not have been repeated long enough.

Data obtained from the National Beef Center of EMBRAPA, in Campo Grande, shows that 252 sick animals and 57 deaths were found in a population of 1950 animals pasturing *B. decumbens* from seven municipalities in the State of Mato Grosso do Sul, in 1977.

Despite these and other reports, and considering that large numbers of cattle are pasturing *B. decumbens,* it appears that the intoxication produced by this forage affects only a very small proportion of animals exposed (1 to 5%). It occurs primarily in cattle under 14 months of age and if affected animals are moved to other pastures soon after showing signs of intoxication they will gradually recover. There is a neglibible figure of animals that die, primarily from liver tissue damage. The symptoms and lesions indicate a photosensitization, and the ultimate cause is not known.

Micro-monitoring

Internal Parasite Profile

Work began on the study of the natural evolution of internal parasites in the savannas of the Colombian Llanos. The result of this work will be preventive medicine control procedures specifically adapted to the prevailing ecological conditions. Control procedures should consequently be less costly. Two herds of 50 pregnant cows each (6-9 months of pregnancy) were chosen for monitoring. The animals were placed in a native savanna pasture at a stocking rate of 6.5 to 7 ha/A.U.

Proportionate areas of savanna have

Table 70

Average fecal egg counts for internal parasites in calves from Carimagua, 1978.

Date	No. animals examined	Fecal content (eggs/g)						
		Total all species	Trichostron-gylidae	*Ascaris*	Strongy-loides	*Eimeria*	*Moniezia*
March 6	8	373.4	0	42.4	331.0	0	0
April 5	18	141.2	35.1	76.1	30.0	0	0
May 9	15	612.7	540.3	12.3	42.6	30.8	0
June 6	29	338.4	197.6	0.9	77.6	54.6	0
July 5	31	912.2	198.7	78.7	120.8	513.8	0
Aug. 2	36	2 457.4	459.9	74.1	32.3	1 862.3	28.6
Sept. 1	34	556.7	302.3	24.0	27.0	173.7	29.1
Oct. 2	37	416.2	238.9	0	12.1	149.4	15.7

been burned sequentially and the management is generally similar to that used by farmers in the area. Animals receive a complete mineral supplement. No treatment is applied to control internal parasites. The animals are subjected to the standard vaccination scheme for the farm. In group I, the calves were born from March through July and have been sampled monthly by complete fecal examinations and blood parameters. The cows are also being studied through fecal examinations. Fecal samples are being analyzed for total egg counts (Sloss test) and lung-worm larvae counts (Baerman test).

The results of the first eight months of sampling showed that calves are affected rapidly in the first few days of life with parasites of the genus *Strongyloides.* Larvae of this parasite penetrate readily through the skin. The infestation however appears to be under control at this time (Table 70 and Fig. 101). This parasite is responsible for nearly all of the compounded average egg counts for several parasites from April through June. The second parasite affecting calves in early life in this region is of the family Trichostrongylidae (several genera). They reach a peak in May at the beginning of the rainy season, but seem to be well-controlled by the calves until the October sampling.

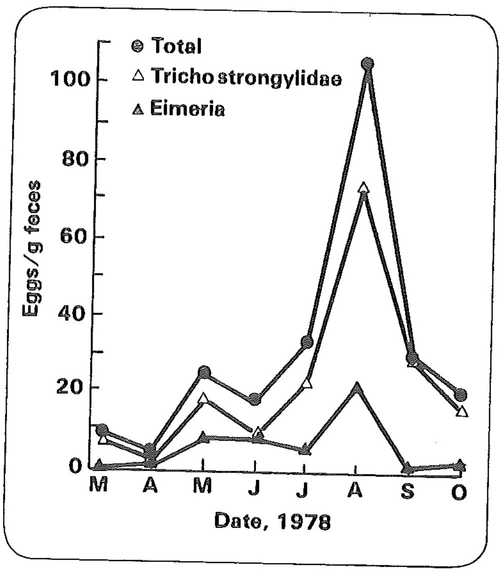

Figure 101. Averages of total fecal egg counts for internal parasites in cows from Carimagua.

The *Eimeria* protozoa (at least four species identified so far) are beginning to emerge as the most pathogenic internal parasite for calves in this area. The calves are gradually being invaded by this protozoan which reached the highest level in August, two months after the peak of the rainy season. The infection level, however, has decreased considerably in the last two samplings. The Coccidias are responsible for most of the compounded average egg counts for several parasites from June through September (Fig. 101). The levels of infection reached by *Eimeria* (Coccidias) in this period goes well beyond the levels considered in other regions as producing clinically sick animals (>500 egg/g feces). However, none of the affected calves had died yet from this infection, even though they have not been treated. On the other hand, figures given in Table 70 are averages, and there are individual calves that are beginning to show marked anemia as a consequence of high Coccidial infections. It will be interesting to see the pattern of this infection as the calves get older and other parameters are analyzed. They will be monitored after weaning up to 18 months of age. The analysis and evaluation of blood parameters in these animals is underway. The second group of calves is being formed with animals calved at the end of the rainy season and these examinations are in progress.

The results of the cow exams revealed, in general, low parasite burdens for most of the sampling period. In March and April, the first examinations, parasite counts were very low. They increased gradually reaching their highest level in August (Table 71) at the same time that the compounded egg counts from the calves reached their peak. In fact the shape of the curve (Fig. 102) is very similar to the one for the calves, although the scale is much smaller for the cows. Parasites of the Trichostrongylidae family are mostly responsible for the compounded average of internal parasites for the cows.

In one of the samplings, a 9-year-old cow showed several eggs with characteristics of a Trematode. Later an 11-year-old cow also showed some eggs with identical conformation. With this lead a search was made in animals slaughtered for meat at

Table 71.

Average fecal egg counts for internal parasites in cows from Carimagua.

Date	No. animals examined	Fecal content (eggs/g) Total all species	Trichostrongylidae	*Eimeria*	*Moniezia*	*Capillaria*
March 6	5	9.8	8.6	0	0	1.2
April 5	47	4.3	3.2	0	1.1	0
May 9	47	25.8	19.7	4.8	0.9	0.25
June 6	47	18.6	9.4	8.6	0.3	0.17
July 5	48	35.7	22.6	7.7	5.3	0.06
Aug. 2	45	103.1	74.3	23.3	5.2	0.1
Sept. 1	45	29.9	28.1	0.5	1.3	0.02
Oct. 2	51	20.5	17.1	2.9	0.3	0.07

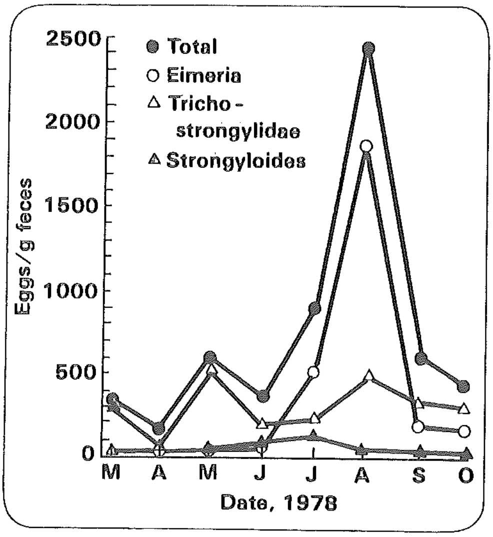

Figure 102. Averages of total fecal egg counts for internal parasites in calves from Carimagua.

the Carimagua Experimental Station. From 35 apparently healthy animals observed from May through August, 14 (40%) had in the rumens several adult forms of a Trematode classified as *Paramphistomum* spp. The parasite was also found in the rumen of a 14-month-old steer at the same time that a *B. bigemina* infection was diagnosed. This is the first time this parasite has been described in cattle grazing tropical savannas in Colombia, and probably in similar savannas of South America. The significance of the infection in relation to productivity will be further evaluated.

Natural Leptospira Infection under High Nutritional Stress

The purpose of this study was to understand better the pathogenesis, epidemiological diagnosis and effect on productivity of leptospira infections while at the same time observing the effects of antibiotic treatment.

Observations were started in July 1976 and completed in July 1978 on the commercial herd used for this study. The observation period started with 100 cows and 7 bulls and ended with 83 cows and 6 bulls. The herd grazed continuously on 400 ha of native savanna in a farm 65 km east of Puerto López in the Meta region of Colombia.

Four isolations of *L. hardjo* were obtained from urine cultures performed under field conditions. Serum antibodies to *L. hardjo* were used to evaluate evolution of the infection and one-third of the animals were given two injections of Streptomycin (October and December 1976), a second third of the cows received Streptomycin once (April 1977) and the remainder did not receive any antibiotic.

The infection was reported last year to have diminished considerably as a whole in the herd from July 1976 through July 1977. However, comparing the number of animals that previously had low infections with the new chronic infections occurring in both the untreated and treated groups (Fig. 103), one can see an overall increase in the latter. Although the infection generally decreased in the herd in the first year, this appears to be not only a reflection of the treatment, but also a result of the natural evolution of the disease. Curves of the untreated group and the two treated groups have the same shapes and do not differ markedly, except for group II that had new chronic infections from July 1976 through February 1977. A reduction of chances of acquiring the infection could have occurred in the untreated groups as a result of fewer *Leptospira* being eliminated by the treated groups, since all animals were in the same pasture.

In relation to abortions, 11 occurred from September 1977 through July 1978, 3 in Treatment I, 3 in Treatment II and 5 in the untreated group. Some abortions

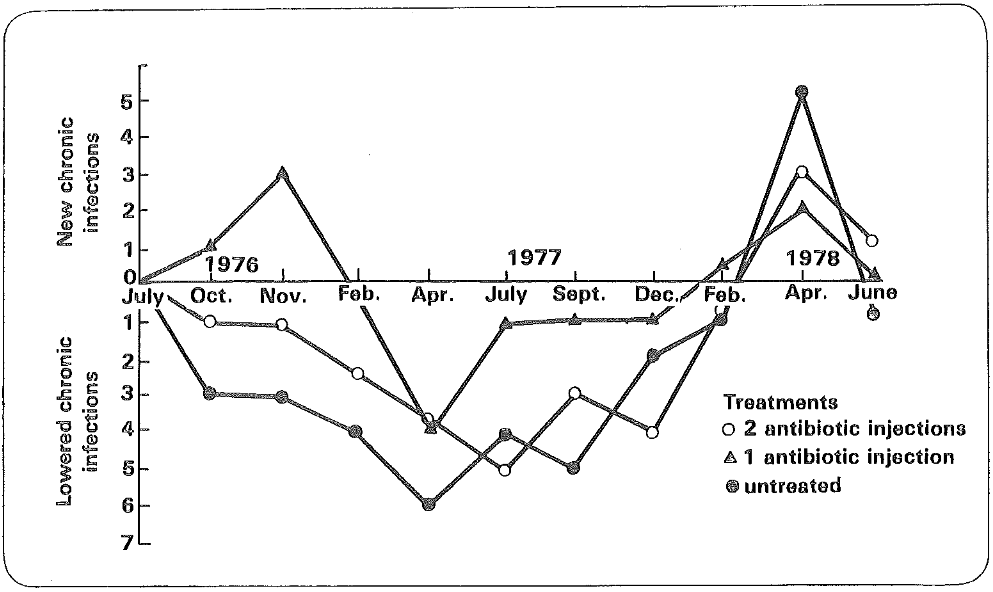

Figure 103. Cows naturally infected with *Leptospira hardjo* that had high levels of reaction over two years (July 1976-June 1978), on a commercial farm in the Colombian Llanos.

occurred in animals not showing evidence of *Leptospira* infection. It might be that management factors accounted for some of these losses. Moreover, animals whose infections, detected by serology, had high titers initially ended the two-year observation period with very similar high reactions. It appears then, that treatment with antibiotics as used in the trial does not eliminate the infection from chronically affected animals (ones with high titers). There is evidence that more frequent antibiotic treatments will reduce the infection, however, this is not practical in the field.

At the beginning of the observation period it was thought that some blood parameters were useful to detect affected animals. However, variations tend to be cyclical and in the final analysis, there are no differences between infected animals and cattle with no detectable infection (Table 72). In fact, all values for the herd as a total, and values from infected animals are within the mean values reported last year for breeding cows in the Colombian Llanos. Consequently, it appears that animals with chronic *Leptospira* infections do not have blood changes resembling those of malnutrition. The disease is masked by deficient nutrition due to its effects but with appropriate tests could be readily differentiated.

Studies on Pathogenicity of Leptospira hardjo

To test the ability of *L. hardjo* as a pathogen, an intensive study was started in 1977 to evaluate its infectivity and its pathogenicity by experimental inoculation into carefully selected pregnant cows. A strain of *L. hardjo* isolated from naturally infected cows from the Colombian Llanos was adapted to laboratory conditions and used for these experiments. Levels of 6 x 10^8 cells of *L. hardjo* were inoculated intravenously into each of 10 animals. Two more pregnant cows were used as non-inoculated controls. Urine samples for

Table 72.

Mean values of five blood parameters of beef cattle from the Colombian Llanos in a herd naturally infected with *Leptospira hardjo*.

Animals	Parameters				
	Packed cell volume (%)	Hemoglobin (g %)	Total protein (g %)	Creatinin (mg %)	Phosphorus (mg/100 ml)
Herd total	38.6	13.2	7.3	2.3	4.7
Infected cows[1]	41.2	14.0	8.1	2.5	4.0

1 Chronic infections with serological titers <1:800.

isolation of *Leptospira* were taken periodically from all animals and inoculated into hamsters and tubes containing artificial media. Serum samples were also taken during the experimental period to determine the antibody levels that animals developed after the challenge with *L. hardjo*. Clinical and pathological observations were described for each cow during the experiment. Blood samples were used to determine packed cell volume (PCV), hemoglobin, total protein, albumin, urea, ureic nitrogen (BUN) and creatinin.

L. hardjo was detected in 9 of the 10 cows inoculated. The leptospira were mainly detected by urine cultivation but also, by direct examination of urine under dark ground illumination. Shedding of leptospiras in urine was detected from four days to 10 months post-inoculation. Six of the cows shed leptospiras in the urine for less than five months after the challenge. Two cows stopped shedding leptospiras for two months, after which leptospiras were detected for several days and disappeared again. One cow shed the bacteria in urine from 23 days to 10 months post-inoculation with only a short period of time (seven months into the experiment) when leptospiras were not found. The results suggest that cows get re-infected within a short period of time with *L. hardjo* and may be chronically infected, or that a latent infection may be established in cattle.

All inoculated cows reacted against the *L. hardjo* antigen and developed a serologic response with variable levels during the time post-inoculation. Figure 104 shows the mean antibody levels (reciprocal logarithm) throughout 302 days post-inoculation for the group of animals challenged. Antibody response was detected at the first sampling (four days) after challenge. The antibody level peaked sharply at 13 days (mean titer 1:700), then decreased to the lowest level at 73 days. After that time the mean antibody titers oscillated within a narrow range, varying between 1:40 to 1:115 for two months. The antibody response after 142 days slowly increased to intermediate antibody levels (1:200) which continued until the end of the experiment. The second rise of the curve indicates that re-infection of the animals occurred and this is explained by the shedders (in the urine)

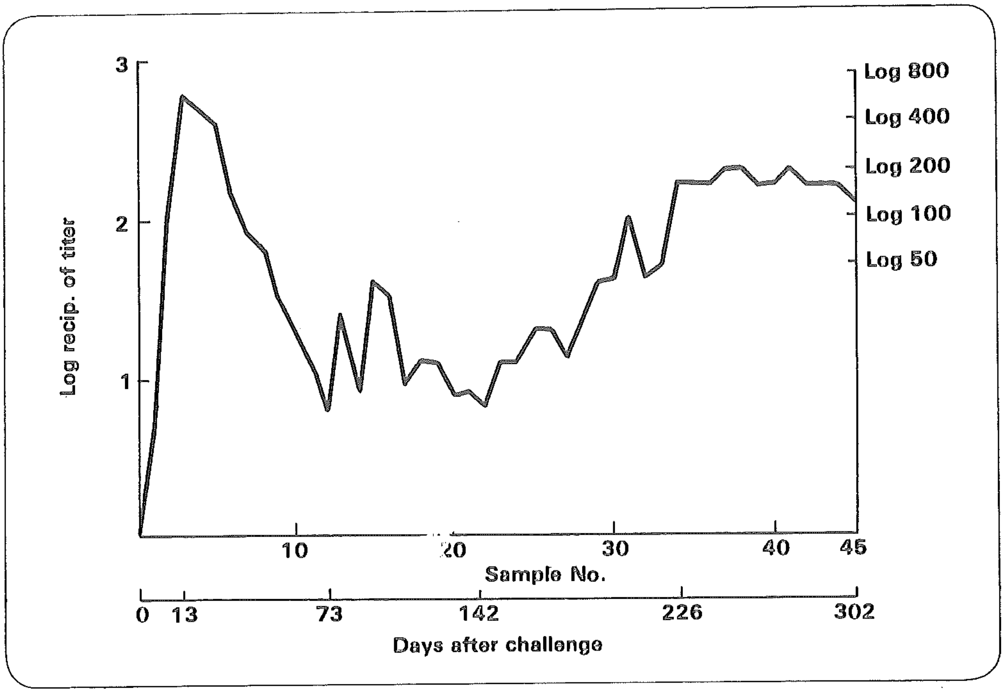

Figure 104. Mean serologic titer for 10 pregnant cows inoculated with *Leptospira hardjo*, at Carimagua.

described above. A latent infection established in these animals could also show a similar serologic response. If animals remain infected as has been seen in the last period of the experiment, a chronic form of the disease caused by *L. hardjo* should be possible.

Table 73 shows the alterations observed in cows inoculated with *L. hardjo*. The most significant lesions from the standpoint of productivity are the retained placentas and metritis which occurred in half of the exposed cows. However, the effect on the neonate is also highly significant. Eight calves were born weak and three had edema and icterus in the internal surfaces.

Mean values of some blood parameters were established for control and experimental animals. Hemoglobin, PCV, total protein, albumin, and urea mean values for both experimental and control animals were within the range determined last year for Zebu breeding cows on the experimental station at Carimagua with an adequate nutritional level. Mean values for BUN and creatinin were 4.6 mg/100 and 2.3 mg/100, respectively. These results suggest that the nutritional level has little influence on the level of *Leptospira* infection. However, they could be additive as explained before.

Immunoglobulin G (IgG) and immunoglobulin M (IgM) concentrations were determined in sera from the group of cows experimentally inoculated with *L. hardjo*. A chromatographic column with DEAE-Cellulose for extraction of immunoglobulins, the method described by Lowry, *et al.* for protein quantification and the method of electrophoresis for protein identification, were used for determinations of immunoglobulin in the serum

Table 73.

Clinico-pathological alterations observed in pregnant cows after challenge with *Leptospira hardjo*.

	Gross lesions			Histopathology		
Cow No.	Retained placenta	Metritis	Kidney	Nefritis	Perimetritis, Parametritis	Calf condition
1 (Control)	-	-	-	-	-	Normal
3 (Control)	-	-	+	+	-	Normal
24	+	+	+	+	+	Weak
10	+	+	+	+	-	Weak
20	-	-	-	+	-	Weak
6	+	+	+	+	-	Weak
33	-	-	+	+	-	Weak
64	-	-	-	+	-	Weak
5	-	-	+	+	-	Normal
36	-	-	+	+	-	Weak
42	+	+	+	+	-	Weak
71	+	+	+	+	-	Not determined

samples. Concentrations of IgG and IgM among inoculated animals tended to be higher than concentrations of Ig's in the control group. There is some relationship between the antibody level for *L. hardjo* detected by the microscopic agglutination test and the concentrations in the serum of IgG and IgM.

A test vaccine is currently being tried to evaluate its effect in controlling some of the clinical signs of the disease.

ECONOMICS

In 1978 the Economics Section was engaged in: (1) evaluation of improved beef production technology components: (2) anticipation of the expected profitability of legume-based pastures on cow-calf farms in the Colombian Llanos through simulation; and, (3) anticipation of the expected distribution of benefits of increased beef production among consumers of different income levels in urban areas of Latin America.

Costs of Pasture Establishment

Costs of different pasture establishment methods in the Carimagua region were estimated using 1978 prices. The methods considered were: (1) plowing plus two diskings; (2) three diskings; (3) two diskings; (4) stubble mulch sweeps used once; (5) low density seeding with stubble mulch sweeps; and (6) low density (or spaced planting) with two diskings.

Methods 1 through 3 are conventional. For a description of methods 4 through 6 see Pasture Establishment Section of the CIAT Annual Reports for 1976, 1977 and 1978.

The following criteria were used in estimating the costs for each method:

- A tractor of 75-78 HP with no alternative use on the farm except for pasture establishment and maintenance.
- Direct labor costs were charged according to *time* worked in each method, plus equipment preparation and transportation time required.
- Depreciation of equipment was charged according to *use*.
- Depreciation of facilities (shelter) and tools according to *time*.
- Interest (10%) on equipment was charged according to *time*.
- Maintenance of equipment according to *use*.
- Repairs of equipment according to *use*.
- Coefficients of time/ha and fuel consumption/hr or each activity were direct estimates obtained from the CIAT-Quilichao and Carimagua stations.

Costs presented in this report correspond to Methods 1, 3, 4, and 6. The cost of Method 2 falls consistently between those of Methods 1 and 3. The cost of Method 5 consistently falls slightly below that of Method 6.

The pasture establishment cost is divided into: land preparation cost, fertilizer cost and seed cost. Due to the influence of fixed costs, land preparation cost per hectare varies according to the area worked per year. These are depicted in Figure 105 for every method.

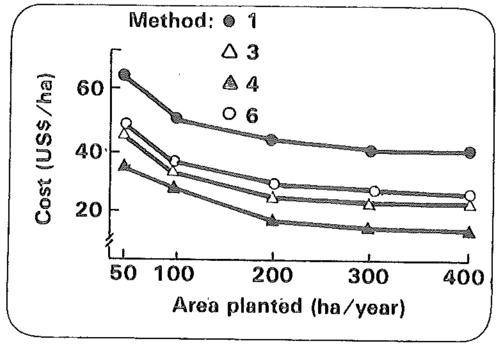

Figure 105. Land preparation costs using alternative pasture establishment methods, as a function of the area planted per year.

Since each system has a different establishment period, in order to make the systems comparable, all cost items in each system are capitalized up to the moment the pasture is at its full carrying capacity. Capitalized establishment costs for 100 ha/year and two alternative fertilizer and seed costs are reported in Table 74. Note that for the currently recommended levels of fertilizer for legume/grass mixtures (medium: 50 kg of P_2O_5 + 25 kg of K_2O + 20 kg of S + 20 kg of Mg/ha), the fertilizer cost accounts for 42 to 60% of total cost, depending on the establishment method.

In Figures 106 and 107, the total capitalized cost of each method is depicted for medium and low fertilizer and seed costs, respectively. These figures clearly show that establishment cost varies greatly among the methods considered. Second, economies of scale exist for each establishment method. However, alternative methods could compensate this bias, resulting in an overall "scale-neutral" technology. The lower seed costs of the low density or spaced planting system (Method 6), have this effect.

Since in its present stage of development this method appears to be more feasible for planting small areas, it partially compen-

Table 74.

Pasture establishment costs[1] using alternative methods, for 100 ha/year.

Method	Establishment costs (US$/ha) Land preparation	Fertilizer	Seed	Capitalized total
1- Medium	48	64	34	153
Low	48	45	17	116
3- Medium	30	64	34	133
Low	30	45	17	96
4- Medium	20	64	34	122
Low	20	45	17	86
6- Medium	32	64	3	106
Low	32	45	2	84

1 Prices of 1978.

sates the economies of scale present in the other systems. This is especially so when seed costs are high. It should be kept in mind that smaller and less expensive equipment would also reduce unit costs, although not necessarily proportionately i.e., the cost of a 35-HP tractor is more than half that of a 70-HP tractor. Hence, the development of establishment methods appropriate for small farms is a reasonable objective. In this way alternatives which compensate the within-method economies of scale are developed.

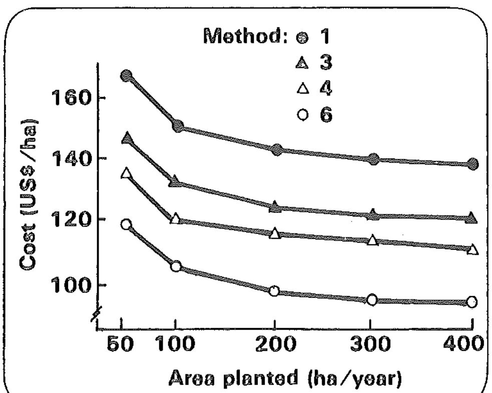

Figure 106. Total establishment costs using alternative pasture establishment methods, assuming medium fertilizer (US$64/ha) and seed (US$34/ha) costs.

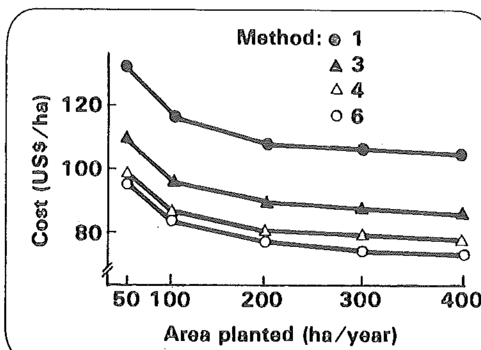

Figure 107. Total establishment costs using alternative pasture establishment methods, assuming low fertilizer (US$45/ha) and seed (US$16/ha) costs.

Selected Parameters of Herd Systems

In Table 75, selected parameters of several herd systems for the Llanos are presented for comparative purposes. They correspond to the Herd System Experiment (HSE) reported in CIAT's 1977 Annual Report, to the Breeding Herd Management System (BHMS), the ETES project, and the Carimagua Test Herd described in the Animal Management Section of this report, and to the systems which were simulated in 1977. In Systems 1 through 6, cows graze native savanna, and in Systems 3 and 4, some animals also occasionally graze introduced grasses.

System 1 results in a decreasing herd over time. System 2 simulated in 1977, was considered more representative of production systems in the Llanos. Results obtained during 1978 in the ETES project (averages of 16 farms monitored in the area) yielded similar calving and adult mortality rates to those in System 2, but greater calf mortality. Results obtained this year in the BHMS (System 8) with strategic grazing of *Brachiaria decumbens* and *Stylosanthes guianensis* (10% of total area) are similar to those of System 9, a simulated breeding herd strategically grazing a legume-based pasture.

Body weights of cows and calves for all systems are presented in Table 76. The low body weights of lactating cows in Systems 1 through 3 explain the low calving rates

Table 75.

Selected parameters of actual and simulated herd systems in the Colombian Llanos.

System	Observation period (years)	Calving rate (%)	Mortality rates (%)	
			Calves	Adults
Savanna only				
1. HSE[1] (Herds 2-3)	4	46	26	5
2. Simulated[2] (native)	-	50	8	5
3. ETES[3] (farms)	1	49	13-14	4-5[4]
4. Test herd	2	58	6	2
5. HSE (Herds 4-5)	4	65	12	5
6. BHMS[5] (Herds 1-3-5)	1	63	10	1.5
Introduced Pastures				
7. HSE (Herds 6-7) *Melinis minutiflora* + savanna	4	64	10	5
8. BHMS (Herds 2-4-6) 10% *Brachiaria decumbens* + *Stylosanthes guianensis* + savanna	1	79	10	1.5
9. Simulated[2] legume-based pasture	-	77	7	3

1 Herd Systems Experiment.
2 In 1977.
3 ETES: Technic-Economic Study of Systems.
4 Preliminary estimates.
5 BHMS: Breeding Herd Management Systems.

Table 76.

Body weight of cows and calves in selected systems in the Colombian Llanos.

System[1]	Cows (kg) Dry	Cows (kg) Lactating	Calves (kg) Age in months 9	Calves (kg) Age in months 18
Savanna only				
1. HSE (Herds 2-3)	302	272	117	150
2. Simulated (native)	302	272	117	150
3. ETES (farm)	318	293	136	184
4. Test herd	n.a.	n.a.	143	n.a.
5. HSE (Herds 4-5)	334	305	147	175
6. BHMS (Herds 1-3-5)	377	320	168	n.a.
Introduced pastures				
7. HSE (Herds 6-7) *Melinis minutiflora* + savanna	325	297	132	165
8. BHMS (Herds 2-4-6) 10% *Brachiaria decumbens* + *Stylosanthes guianensis* + savanna	395	363	186	n.a.
9. Simulated legume-based pasture	370	330	170	210

1 For explanation of systems, see footnotes to Table 75. Source: CIAT Annual Reports, 1977 and 1978.

observed. The *average* body weight for 375 lactating cows in the ETES project is 293 kg. Many of the animals in this sample have a low probability of reconception during lactation since their weight is substantially below the sample average.

Calving frequencies as a function of cow weights at mating, for 2-month intervals in HSE, are presented in Table 77. The adjusted frequency figures could be interpreted as the percentage probability that an open cow within a given weight interval could calve if exposed to the bull for a period of two months. In this sense, probabilities increase rather markedly up to weights of 280-299 kg. Reduced probabilities beyond the 360-379 kg weight interval are due to the fact that no culling based on reproductive performance was made in the HSE. Infertile but otherwise healthy cows did not suffer lactational stress and therefore tended to be in the heavier weight intervals.

These probabilities help explain the observed calving rates obtained in the different systems and give support to the practice of strategically grazing improved pastures to increase body weights of individuals cows beyond the critical conception weight of 300 kg. For heifers, the equivalent critical conception weight is approximately 270 kg.

Simulation of Strategically Used Legume-based Pastures

Even though there is as yet no proven persistent legume-based pasture available for the Llanos, there are some issues that could be addressed in anticipation of such

Table 77.

Calving frequency as a function of cow weight at mating, at two-month weighing intervals, Herd Systems Experiment.

Weight interval (kg)	No. of observations	No. of births	Adjusted frequency (%)	Relative frequency (%)
<220	300	1	0.1	0.1
220-239	137	9	6.6	2.8
240-259	229	34	14.8	6.3
260-279	414	105	25.4	10.7
280-299	402	125	31.1	13.1
300-319	358	105	29.3	12.4
320-339	282	97	34.4	14.5
340-359	124	37	29.8	12.6
360-379	106	31	29.2	12.4
380-399	59	9	15.3	6.4
400-419	32	1	3.1	1.3
420-440	23	4	17.4	7.3
Totals	2466	558	236.8	100.0

a package. Would the target legume-based pasture be profitable at the farm level? How many years should it persist in order to be profitable? How is its profitability affected by establishment and maintenance costs?

Obviously, the exact answer to these questions will depend on the particular circumstances of each farm, farmers' access to resources, the opportunity cost of capital and management, and the attitude of farmers toward risk. However, a tentative answer could still be obtained in terms of expected profitability of moving from the "typical native system" to the "target system". For this purpose, both systems were simulated over a 22-year period, starting with the same initital herd of 190 cows for a commercial ranch of 2500 ha. Once the herd is stabilized, the target system produces nearly 300% more output per hectare than the native system.

The parameters of the native system are those of System 2 described in Tables 75 and 76. The parameters of the target system are roughly those of System 8, in the same tables, except for slightly lower body weights of weaners and culled cows. Such parameters correspond to a system in which a legume-based pasture (10% of the farm's area) is grazed strategically by lactating cows and replacement heifers. Although based on experimental results of only one year, these parameters are considered feasible as a target at the farm level. In addition, the following were assumed for this system: (a) heifers reach mating weight (270 kg) at 2.5 years of age; (b) stocking rates of 1.0 and 2.0/A.U./ha are feasible for improved pasture in the dry and rainy season, respectively; (c) intake of mineral mixtures of 21 kg/A.U./year; (d) bull:cow ratio of 1:20; (e) hard culling during the first 2 years; (f) 20% annual culling rate of cows and bulls for the

Table 78.

Establishment cost[1] estimates used in simulation of strategic legume-based pastures.

	Fertilizer (kg/ha)				Costs (US$/ha)			
Levels	P_2O_5	K_2O	S	Mg	Fertilizer	Tillage	Seed	Total
High	100	25	20	20	94	42	34	170
Medium	50	25	20	20	64	42	34	140
Low	30	15	10	10	41	42	17	100

1 1976 prices.

remaining years; (g) the farm could not buy replacement heifers or cows; and, (h) 1976 prices.

In order to perform a sensitivity analysis, three levels of pasture establishment and maintenance costs were considered (Tables 78 and 79). The "medium" levels correspond to current costs, and to current (tentative) fertilizer recommendations.

The results of the sensitivity analysis, expressed in terms of rates of return to incremental capital and management of alternative pastures with different fertilizer requirements, but yielding the same animal output per hectare, are presented in Table 80. Such rates of return are to be compared with that obtained with the native system (System 2), which was estimated at 8.1% per year (CIAT Annual Report, 1977, pp. A-102).

These results are encouraging. Strategically grazing a legume-based pasture which persists for at leat six years, with medium establishment and maintenance costs, appears to be economically attractive for cow-calf operations. As anticipated in the 1977 Annual Report, pasture persistence beyond six years is of less economic importance when grazed strategically, compared to continuous grazing by a large number of animals.

Figure 108 through 111 illustrate the

Table 79.

Maintenance cost[1] estimates used in simulation of strategic legume-based pastures.

	Fertilizer (kg/ha)				Total
Levels	P_2O_5	K_2O	S	Mg	cost[2] (US$/ha)
High	40	20	10	10	50/year
Medium	20	10	5	5	28/year
Low (every 2 years)	20	10	5	5	14/year

1 1976 prices

2 Including application costs.

Table 80.

Returns to incremental capital and management of improved pastures having identical animal performance with the same stocking rate, but requiring different fertility levels, and of varying persistence.

Cost (US$/ha)		Pasture persistence (years)			
		6	8	10	12
Establishment	Maintenance	Return (%)			
	50/year	10.1	11.1	11.8	12.6
170	28/year	15.3	16.0	17.2	17.8
	14/year	17.9	19.1	20.5	21.3
	50/year	12.7	13.0	13.5	14.2
140	28/year	17.3[1]	18.1	19.0	19.5
	14/year	20.5	21.8	22.9	23.7
	50/year	15.1	15.3	15.9	16.1
100	28/year	20.9	21.7	22.1	22.2
	14/year	25.0	26.0	26.8	27.2

1 Decreases to 10.9 if pastures persist only 3 years.

cash flows for selected situations. It can be seen that reducing establishment costs, and especially maintenance cost, would substantially affect profitability. Farm cash flow is improved, and due to probable difficulties of farmers in obtaining supplies of the appropriate fertilizer mix, adoption becomes more likely.

A word of warning is in order. The above simulated results have ignored production and market risks, and hence may overestimate the expected returns. Also the technology has yet to be validated at the farm level. Hence, it is reasonable to conclude that for cow-calf operations, the current strategy of the Program of screen-

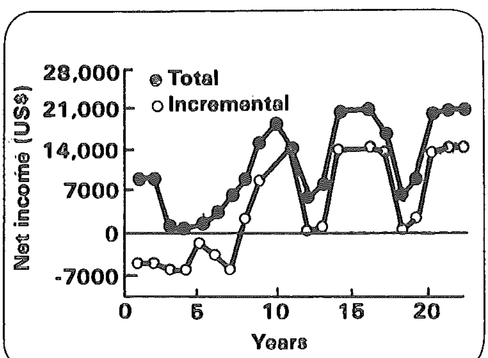

Figure 108. Total and incremental annual net income for high establishment and maintenance costs, for pasture persistence of six years.

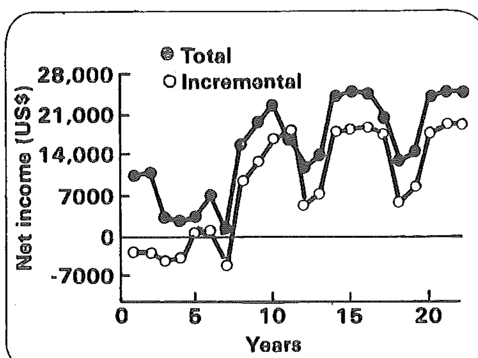

Figure 109. Total and incremental annual net income for medium establishment and maintenance costs, for pasture persistence of six years.

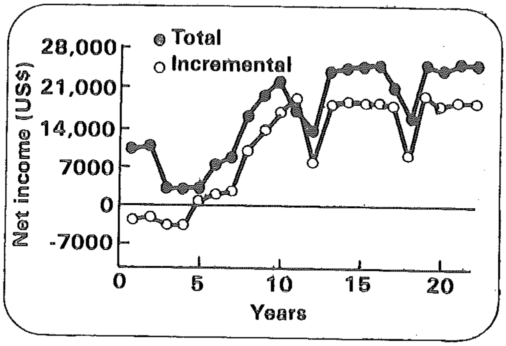

Figure 110. Total and incremental annual net income for medium establishment and maintenance costs, for pasture persistence of 12 years.

ing selected species for the Llanos which require low inputs is appropriate. For other regions with less fertility stress, selection of species of low fertility requirements will be less critical, provided that: (a) on-farm input: output price ratios are equal to or more favorable than in the Llanos; and, (b) that there are no serious problems in the supply of inputs.

Distribution of Benefits among Consumers from Increased Beef Production

11 A feature common to most Latin American countries during the last 15 years is the fact that demand for beef (at constant real prices) has been growing at a faster rate than production. As shown in Table

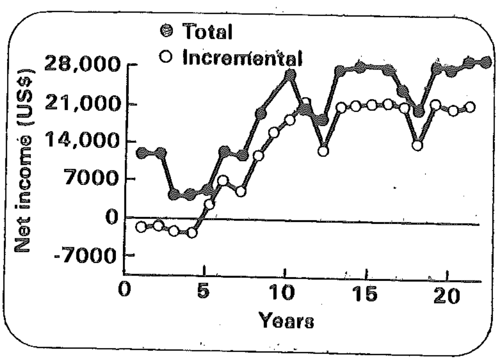

Figure 111. Total and incremental annual net income for low establishment and maintenance costs, for pasture persistence of 12 years.

81, demand for beef in tropical Latin America during 1960-1975 grew at an average annual rate of 5.6%. Except for Central America, production increases during that same period lagged significantly behind, averaging 3.6% per year in the tropics. Future trends, based on the observed growth rates of population, per capita real income and beef production project a very large "potential" increase in beef consumption for the next decade and a half[1]. While Central America and the temperate region are expected to continue as net exporters, Mexico and the rest of tropical Latin America will likely become net importers by 1990. This projected gap between the supply and the demand for beef in the tropics would imply an increasing trend in the real price of beef. Due to the importance of this commodity in the budget of low-income families in these countries, price increases would have a considerable effect on income distribution and in total protein intake of these groups.

Objectives of the Study

In view of the above analysis, it was considered important to study the potential *(ex ante)* economic benefits to be expected from increased beef production due to research in pastures and forages for the acid infertile soils of tropical Latin America, their distribution between producers and consumers, and among consumers of different income strata. The study dealing with the latter aspect of distribution of benefits among urban consumers was initiated in 1978. A previous CIAT study had dealt with this question for the case of Cali, Colombia; a summary of the results pertinent to beef is shown in Table 82.

1 See Valdés, A. and G. Nores, "Growth Potential of the Beef Sector in the Economic Context of Latin America," *In* Proceedings of the IV World Conference on Animal Production, Buenos Aires, Argentina, August 1978. In press.

Table 81.

Growth of demand at constant real prices and production of beef in Latin America, 1960-1975.

Region and Country	Growth rate of Demand[1] (%)	Growth rate of Production[2] (%)
Tropical Latin America	5.6[3]	3.6
Mexico	5.3	5.2
Venezuela	6.9	5.1
Ecuador	7.5	4.2
Brazil	6.9	3.9
Dominican Republic	5.8	3.7
Colombia	5.2	2.0
Peru	4.7	1.4
Bolivia	4.0	0.0
Surinam	6.2	0.0
Paraguay	3.1	-1.1
Central America	5.2[3]	5.8
Honduras	4.6	8.3
Costa Rica	5.2	7.1
Nicaragua	5.2	6.7
Panama	5.9	5.3
Guatemala	5.6	4.6
El Salvador	4.8	1.8
Caribbean	3.7	1.0
Guyana	4.1	2.6
Haiti	3.3	1.2
Jamaica	4.4	0.4
Temperate Latin America	2.0[3]	0.3
Argentina	1.7	0.5
Chile	3.0	0.2
Uruguay	1.3	-1.2
Latin America	5.1[3]	2.2

1 $\dot{d} = \dot{P} + \dot{Y}\,\varepsilon_y + \dot{P}\,\dot{Y}\,\varepsilon_y$
where:
$\dot{d}$ = growth rate of demand
$\dot{P}$ = growth rate of population
$\dot{Y}$ = growth rate of real income per capita
ε_y income elasticity of demand
2 Slaugther only
3 Average weighted by population

Table 82.

Budget allocation and elasticities of demand for beef by income strata, Cali, Colombia.

Income strata	Per capita income (US$/ month)	Family size (persons)	Income spent on beef (%)	Income elasticity (%)	Price elasticity (%)
I	5	5.9	10.5	1.52	1.46
II	9	6.3	10.1	1.35	1.31
III	13	6.8	12.1	0.99	0.99
IV	26	6.3	9.5	0.67	0.69
V	59	6.7	10.3	0.47	0.50

Sources: P. Pinstrup-Andersen, "Decision-making on Food and Agricultural Research Policy: The Distribution of Benefits from New Agricultural Technology Among Consumer Income Strata", *Agricultural Adm.* (4), 1977.

P. Pinstrup-Andersen and Elizabeth Caicedo, "The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition", *A.J.A.E.*, August 1978.

A question arises as to whether the proportion of total income spent in beef could indeed be expected to remain constant across income groups, as was observed in that study, and yet income elasticity decreases as a function of income. Also, the fact that average family size varied without a consistent pattern among income strata, could have been due to the grouping criteria, to sample design, or was simply a peculiar characteristic of the population of Cali. Therefore, there was a need to verify whether the results for beef consumption previously obtained for Cali were equally valid for other urban areas of tropical Latin America, and if not, what implications this would have on the results and conclusions which had been derived earlier.

Preliminary Results

The data used are from consumer expenditure surveys which were undertaken in several Latin American urban centers between late 1966 and late 1969 by Estudios Conjuntos sobre Integración Económica Latinoamericana (ECIEL), and coordinated by the Brookings Institution. The data refer to a large number of families interviewed in the following cities and countries: Bogotá, Cali, Medellín, and Barranquilla, Colombia; Rio de Janeiro, Recife, and Porto Alegre, Brazil; Caracas and Maracaibo, Venezuela; Quito and Guayaquil, Ecuador; Lima, Peru; Asunción, Paraguay; and Santiago, Chile. In addition, data became available from a similar family budget survey for São Paulo, Brazil, which was carried out in 1971-72 by the Fundação do Instituto de Pesquisas Economicas (FIPE) of the University of São Paulo, and which included 2380 families. All of these surveys contain information on family income and expenditures, plus several socio-demographic characteristics of the households.

Preliminary results were obtained for the four Colombian cities as well as for São Paulo. Table 83 contains a selection of descriptive characteristics of the sample of

Table 83.

Selected descriptive characteristics of the sample of families in a survey on distribution of benefits from increased beef production among urban consumers.

Country, city and income quartile[1]	Per capita expenditure range	Average per capita: Total expen-diture	Average per capita: Total monetary income	Average per capita: Food expen-diture	Average family size	Number of persons in families interviewed
	(US$/month)				(persons)	
Colombia[2]						
Bogotá:						
I	3.9 - 16.6	12.0	11.0	6.3	7.5	1427
II	16.7 - 27.9	22.0	21.4	10.9	5.8	1103
III	28.0 - 62.0	40.8	39.8	16.1	4.7	894
IV	62.3 - 514.0	137.1	143.2	37.0	4.0	761
Barranquilla:						
I	4.2 - 17.8	12.6	10.1	7.9	7.4	1262
II	17.9 - 28.0	22.0	19.0	13.3	5.7	972
III	28.3 - 56.5	40.5	42.0	19.0	4.9	835
IV	56.7 - 399.5	105.5	113.1	32.5	4.0	682
Cali:						
I	3.3 - 15.6	10.5	9.7	6.5	6.9	1019
II	16.0 - 29.6	22.2	20.6	12.5	5.5	813
III	29.7 - 61.2	41.9	38.8	19.0	4.4	650
IV	61.4 - 541.7	129.6	136.5	37.0	3.5	517
Medellín:						
I	2.0 - 13.0	8.9	9.1	5.1	8.1	1492
II	13.1 - 26.2	18.5	18.4	6.6	5.9	1087
III	26.3 - 56.7	38.8	41.0	16.8	4.4	811
IV	56.8 - 721.2	124.7	151.2	31.9	3.9	718
Brazil[3]						
Sao Paulo:						
I	5.1 - 28.0	21.2	25.4	11.1	5.5	3273
II	28.1 - 44.8	37.6	45.2	17.1	4.4	2618
III	44.9 - 75.6	60.9	76.1	23.3	4.1	2440
IV	75.8 - 642.0	147.2	179.5	39.5	3.7	2202

1 Families are classified into income quartiles according to average per capita expenditure; each quartile represents 25 percent of the families.

2 At prices of 1967; 1 dollar=Col.$15.82. Source: CIAT, estimated from Family Budget Survey (CEDE-Brookings Institution 1966 - 1967).

3 At prices of 1971; 1 dollar= Cr.$5.72. Source: CIAT, estimated from Family Budget Survey (FIPE-University of Sao Paulo 1971-1972).

Table 84.

Allocation of family income and expenditures to beef consumption and income elasticity of demand for beef, by city and income strata.

Country, city and income quartile[1]		Food/ total expen- diture (%)	Expenditure in beef as percentage of: Food expen- diture	Total expen- diture	Total income	Income elas- ticity (%)
Colombia[2]						
Bogotá:	I	54.1	18.6	10.0	10.6	1.09
	II	49.9	18.4	9.2	9.4	0.83
	III	40.2	18.5	7.5	7.5	0.52
	IV	28.0	14.3	4.0	3.7	0.20
	Total	36.3	16.5	6.0	5.8	-
Barranquilla:	I	64.0	23.1	14.8	18.0	1.01
	II	60.6	24.8	15.2	17.3	0.62
	III	47.3	23.3	11.0	10.6	0.58
	IV	33.7	21.2	7.1	6.1	0.52
	Total	45.7	22.7	10.4	9.9	-
Cali:	I	64.6	24.2	15.6	16.4	1.28
	II	56.5	24.3	13.7	14.7	0.77
	III	45.2	23.3	10.5	11.4	0.42
	IV	31.2	18.6	5.8	5.5	0.41
	Total	42.4	21.6	9.1	9.0	-
Medellín:	I	57.9	23.1	13.3	12.9	0.79
	II	50.8	23.0	11.7	11.3	0.88
	III	43.9	23.1	10.2	9.5	0.64
	IV	27.8	15.8	4.4	3.3	0.38
	Total	37.6	19.8	7.4	6.3	-
Brazil[3]						
Sao Paulo	I	52.5	9.5	9.0	6.7	0.86
	II	45.5	12.5	8.8	7.0	1.18
	III	38.3	12.8	6.5	4.8	0.47
	IV	26.8	13.4	4.6	3.6	0.43
	Total	40.8	12.0	6.0	4.6	-

1 Families are classified into income quartiles according to average per capita expenditure; each quartile represents 25% of the families.
2 CIAT: estimated from Family Budget Survey (CEDE-Brookings Institution, 1966-1967)
3 CIAT: estimated from Family Budget Survey (FIPE-University of Sao Paulo, 1971-1972).

families included in each of the surveys. Families are classified into income quartiles, each one containing 25% of the households in the sample. In Table 84 the main preliminary estimates obtained from the survey data are presented. These consist of a set of descriptive statistics along with econometric estimates obtained by fitting Engel curves or expenditure functions. The figures shown for income elasticity were estimated by fitting double-log regressions between *per capita* beef expenditure and total *per capita* expenditure. In all cases elasticity estimates were significant at P = 0.05.

As may be noted, beef expenditure comprises approximately 20% of the food budget in the Colombian cities and 12% in São Paulo, with slightly higher figures for lower than for higher income strata. The proportion of total family income devoted to beef consumption is also high, indicating the importance of this commodity for consumers of all income groups. This is particularly so for the low income stratum, which spends no less than 7% (São Paulo) and as much as 18% (Barranquilla) of its total income on beef. With respect to income elasticities of demand for beef, it may be seen that in general these figures are high, especially in the case of the low income quartiles which reflect a high preference for beef consumption. The elasticity decreases towards the higher socio-economic strata, as is expected for a food item.

The results for Cali may be compared to the previous estimates shown in Table 81. Earlier, families were classified according to their total income, and emphasis was placed on separating low income consumers, in such a way that strata I, II, and III show relatively small differences in total per capita income. Instead, the new results are obtained from classifying families into income groups according to average *per capita* expenditure of each family, resulting in sharp differences between strata, and a clear pattern in family size, which diminishes as income increases. With respect to beef consumption by income strata, the new results show a larger share of the budget devoted to beef in Cali, Medellín, and Barranquilla compared with the previous estimate of 10 to 12%. More important is the fact that the proportion of the total budget spent in beef clearly decreases as income increases, and thus is consistent with a decreasing income elasticity of demand.

Preliminary Conclusions

Although the two CIAT studies on the distribution of benefits among consumer income strata from increased beef production present certain differences, the following conclusions based on the earlier estimates for Cali still stand and, on the basis of these preliminary estimates, seem to be applicable to other urban areas in the region:

1. If the supply of any one of the 17 food commodities (considered in the previous CIAT study) is increased by 10%, the largest absolute consumer benefit is obtained from beef. It should be pointed out, however, that this conclusion ignores the costs involved in increasing supply;
2. A 10% increase in beef supply provides a larger net impact on protein intake among protein deficient groups than a similar increase in the supply of any other single food. This conclusion now seems even more strongly supported.
3. Consumer benefits from an expanding beef supply are expected to be distributed less regressively than current income distribution. This conclusion is also reinforced by the study underway.

TRAINING AND REGIONAL TRIALS

Activities of the Training and Regional Trials Section concentrated on efforts of developing and strengthening a network of scientists and technicians working on the production and utilization of forages on acid soils with low native fertility in the tropics. This network will validate, adopt and assist in the transfer of technology developed by CIAT and national research institutions. At the same time, contacts were established with national research and development institutions for all collaborative activities of the Program, especially those related to regional trials.

Training

During 1978, 39 professionals received training in the various disciplines of the Program. By selecting technicians from national institutions that work in Latin American countries comprising the Target Area of the Beef Program, strengthening of the research capacity for validation of technology at the regional level is being accomplished.

From among these professionals, eight visiting research associates are participating in research projects in several disciplines of the Program in collaboration with universities in Canada, France, Mexico, the United States and Western Germany. This work fulfills some of the requirements for obtaining the MS, PhD or equivalent degrees. In this manner the Beef Program is contributing to preparing research leaders who will strengthen collaborative links with national institutions and the universities in countries having the most advanced technology.

The First Course on Research for the Management of Tropical Pastures was held during the second semester of 1978. Twenty technicians from eight countries in the Target Area participated, representing research and development institutions as shown in Table 85. Principal objectives of the course were to offer specific training in: (1) the identification, interpretation and validation of new forage production technologies; and, (2) the development of strategies for the introduction of adequate management practices for improved pastures to assist beef producers. Course participants spent 25% of the time at CIAT-Palmira, on the theoretical phase, and another 60% on practical training at CIAT-Quilichao and selected farms in the surrounding area. The remainder of the time, including course evaluations, was spent on study trips to the Colombian North Coast and the Llanos, especially at the Carimagua station.

Regional Trials

Table 86 shows the locations and edaphic and climatic characteristics for sites where regional trials for the adaptation of forage species selected by CIAT were established or projected for planting in 1978. Twenty-five localities, throughout the Target Area and with varying levels of fertility and soil moisture, offer the Program an excellent opportunity to verify the production potential of promising forage legume and grass species, in comparison with check species considered most productive in each locality (Tables 87 and 88). Evaluations will be for periods of at least two years under conditions of cutting and grazing that are common for each site, in order to select the most productive species to be evaluated for their

Table 85.

Distribution by countries and institutions of research and development of participants in the First Course on Research in the Management of Tropical Pastures.

Country	National institution for: Research	Development	Total
Bolivia	1	0	1
Brazil	3	4	7
Colombia	1	3	4
Cuba	1	0	1
Nicaragua	1	1	2
Panama	0	1	1
Peru	2	1	3
Venezuela	1	0	1
Total	10	10	20

animal production potential when associated with grasses and legumes. Preliminary results indicate that the promising grass *Andropogon gayanus* 621 is performing well at all sites where it is being evaluated.

Conferences

The Beef Program assisted in sponsoring two important conferences in April 1978, with a total attendance of 257 scientists and other professionals.

The first conference was a Workshop on the Collection, Preservation, Distribution and Characterization of Forage Plant Genetic Resources, organized in collaboration with the University of Florida (U.S.A.) and sponsored by the U.S. Agency for International Development. Sixty-eight persons representing 40 institutions in 20 countries attended this workshop.

Its principal objective was to produce a manual that would serve as a guide for establishing a coordinated system of collecting, classifying, preserving, distributing and evaluating native tropical forage species. The manual will be published in Spanish, Portuguese and English, during 1979.

The second conference, a Seminar on the Production and Utilization of Forages in Acid, Infertile Soils of the Tropics, had

Table 87.

Accessions of grasses under evaluation in regional trials for adaptation of forage species selected by CIAT.

Species	CIAT No.	No. of locations
Andropogon gayanus	621	25
Brachiaria decumbens	606	25
Panicum maximum (Common)	604	25
Hyparrhenia rufa	Check	12
Melinis minutiflora	Check	1
Paspalum plicatulum	Check	1
Digitaria decumbens	Check	1
Digitaria unfolozi	Check	1
Cenchrus ciliaris	Check	1

Table 86.

Locations, collaborators and characteristics of the zones where regional trials for adaptation of forage germplasm are established.

Location	Institution	Principal collaborator	Date of planting	Annual precip. (mm)	Climate[1] (mm)	Soil	Soil characteristics[2]		
							pH	Avail. P (ppm)	Al satur. (%)
Bolivia									
San Ignacio	CIAT	G. Sauma	Jan. 18	1142	II	Ultisol	5.5	5	19
Ecuador									
Santo Domingo	INIAP	R. Santillán	Feb. 15	3230	III	Alfisol	5.7	5	0
Peru									
Pucallpa	IVITA	V. Morales	Feb. 28	1708	III	Ultisol	(4.2)	2	61
Yurimaguas	CRIA-III	D.E. Bandy	May 9	2002	IV	Ultisol	4.0	2	85
Tarapoto	CRIA-III	H. Schiere	May 9	1150	(III)	Ultisol	4.5	4	88
Venezuela									
Jusepín	Univ. Oriente	C. Alcalá	June 1	1052	I	Ultisol	5.8	(7)	(20)
El Tigre	CIARNO	O. Parra	June 8	1234	II	Oxisol	5.1	(3)	(70)
Atapirire	IUTET	O. Parra	June 9	1023	II	Oxisol	5.1	(6)	(25)
Calabozo	CIARLLACEN	D. Escobar	June 12	1326	II	Inceptisol	(6.0)	(8)	(0)
Uracoa	FUSAGRI	N. Tafur	June 13	1325	II	Ultisol	-	-	-
Guachi	Univ. Zulia	I. Urdaneta	June 15	2740	I	Ultisol	4.0	3	52

1 Based on potentital evapotranspiration during the rainy season: I <910; II = 910-1060; III = 1060-1300; IV > 1300.
2 Numbers in parentheses are estimated. Data for P are variable extractants.

Table 86.(continued)

Location	Institution	Principal collaborator	Date of planting	Annual precip. (mm)	Climate[1] (mm)	Soil	Soil characteristics[2] pH	Avail. P (ppm)	Al satur. (%)
Colombia									
Santander de Quilichao	CIAT	-	Mar. 20	1845	-	Ultisol	3.8	4	70
La Libertad	ICA	R. Pérez	July 13	2639	IV	Oxisol	4.7	11	78
El Nus (Medellin)	ICA	S. Monsalve	Sept. 21	2200	-	Oxisol	4.9	4	15
Nicaragua									
Nueva Guinea	INTA	D. Padgett	July 26	2894	IV	Ultisol	-	-	-
Brazil[3]									
Sête Lagoas	EPAMIG	N. Costa	December	1209	III	Oxisol	(4.8)	(2)	(75)
Goiania	EMGOPA	M. Sobrinho	"	1487	II	Oxisol	(5.0)	(5)	(70)
Belém	CPATU	A. Serrão	"	2762	IV	Oxisol	(4.8)	(2)	(75)
Paragominas	CPATU	A. Serrão	"	1068	III	Oxisol	6.4	6	2
Marabá	CPATU	A. Serrão	"	1988	III	Oxisol	5.4	5	14
S. do Araguia	CPATU	A. Serrão	"	1727	III	Ultisol	5.2	5	0
Marajó	CPATU	A. Serrão	"	(2000)	III	Ultisol	5.1	5	83
Macapa	CPATU	A. Serrão	"	1309	II	Oxisol	5.1	5	75
Itacoatiara	CPATU	A. Canto	"	2101	III	Oxisol	4.6	5	27
Boa Vista	CPATU	A. Canto	"	1941	II	Oxisol	(5.3)	(5)	(20)
Porto Velho	CPATU	A. Serrão	"	2232	III	Ultisol	(5.1)	(3)	(75)
Guiomar Santos	CPATU	A. Serrão	"	(2200)	III	Ultisol	6.5	3	0

1 Based on potential evapotranspiration during the rainy season: I<910; II=910-1060; III=1060-1300; IV > 1300
2 Numbers in parentheses are estimated. Data for P are variable extracts.
3 Projected

Table 88.

Species and ecotypes of forage legumes and recommended *Rhizobium* strains under evaluation in regional trials of adaptation for forage species selected by CIAT.

Species	CIAT No.	*Rhizobium* strain (CIAT No.)	No. of locations
Stylosanthes guianensis	184	71	4
Stylosanthes guianensis	136	71	25
Stylosanthes capitata	1019	71	25
Stylosanthes capitata	1405	71	25
Stylosanthes capitata	1078	71	17
Stylosanthes capitata	1097	71	17
Stylosanthes hamata	147	71	25
Desmodium heterophyllum	349	80	6
Desmodium ovalifolium	350	46	25
Macroptilium sp.	535	313	25
Centrosema sp.	438	590	25
Zornia latifolia	728	103	15
Pueraria phaseoloides	Check	79	25
Centrosema pubescens	Check	590	7
Macroptilium atropurpureum	Check	79	5
Macroptyloma axilare	Check	79	1
Zornia sp. (native)	Check	103	1
Stylosanthes guianensis cv. Schofield	Check	71	2

189 participants from 69 institutions in 23 countries.

Principal objectives of this seminar were to review the state of knowledge on production, management and utilization of forages under conditions of acid, infertile soils (Oxisols and Ultisols) of the Latin American tropics and similar areas. Thirty papers were presented in seven groups, including a series on experiences in transfer of technology to beef producers. Proceedings of the seminar are being produced in Spanish, Portuguese and English, for distribution in the first part of 1979.

Both conferences included meetings to discuss mechanisms of collaboration between national, regional and international institutions and the CIAT Beef Program in order to enhance the development and transfer of technology on pasture production to beef producers. Participants also visited the experimental stations at Quilichao and Carimagua.

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