ISSN 0120-2383
CIAT Series No. 02ETP1-79
August 1980

1979
Tropical Pastures Program
Annual Report

Centro Internacional de Agricultura Tropical
Apartado Aéreo 67-13
Cali, Colombia

Centro Internacional de Agricultura Tropical, CIAT
Apartado 6713
Cali, Colombia

ISSN 0120-2383
CIAT Series No. 02ETP1-79
August 1980

Correct citation:

Centro Internacional de Agricultura Tropical. Tropical Pastures Program 1979 Annual Report. Cali, Colombia. 1980. 156 p.
Also available in Spanish.

Stylosanthes/ Zornia/ Pueraria/ Centrosema/ Leucaena/ Desmodium/ Brachiaria/ Panicum/ Calopogonium/ Macroptilium/ Legume crops/ Gramineae/ Research/ Ecosystems/ Climatic requirements/Soil requirements/Water requirements/Plant breeding/Selection/Germplasm/ Introductions/Seed Production/Soil fertility/Soil microbiology/*Rhizobium*/Fertilizers/Phosphate rock/Phosphorus/Aluminium/Toxicity/Yield/Establishment/Pasture management/Planting density/Cultivation/Weed control/Cultivation systems/Legume-grass mixtures/Plant nutrition Diseases and pathogens/*Colletotrichum/Sclerotium rolfsii/Camptomeris leucaena*/Injurious/ insects/Insect control/Resistance/Beef production systems/Animal management/Animal health/ Anaplasmosis/Babesiosis/Chronic malnutrition/Parasite incidence/Photosensitization/Disease control/Forage/Nutritive value/Economics/Technology transfer/Technology/

Print order: 900 copies

CONTENTS

INTRODUCTION

The Program's name has been changed from Beef Program to Tropical Pastures Program which reflects more accurately the central strategy of the Program. Within this context, the Program's objective is to remove the main constraints to increased beef (and milk) production in the acid, infertile soils of the tropics by developing low-cost pasture technology for the various ecosystems and associated animal management practices feasible for those regions.

Major Ecosystems and Germplasm

As a result of the Land Resources Evaluation Project for Tropical Latin America, the Program's target area was divided into major ecosystems according to Total Wet Season Potential Evapotranspiration (TWPE) patterns (Figure 1). This parameter has provided a rational quantitative basis to explain existing vegetation coverage patterns on the basis of available energy for seasonal plant growth and to anticipate major differences in pasture growth and performance. The following ecosystems were identified:

1. Tropical savannas (TWPE 910-1060 mm), well drained, hyperthermic (mean temperature during wet season > 23.5°C) which include the Llanos of Colombia, Venezuela, Guyana, and Surinam, and the savannas of Roraima and Macapá in Brazil.
2. Tropical savannas (TWPE 910-1060 mm), well drained, thermic (mean temperature during wet season, 23.5°C) tropical savannas, the major portion represented by the Cerrados of Brazil.
3. Poorly drained (varying TWPE) tropical savannas such as the Beni in Bolivia, Pantanal of Brazil, Casanare of Colombia and the Apure region in Venezuela.
4. Tropical semi-evergreen, seasonal forests (TWPE 1061-1300 mm).
5. Tropical rainforests (TWPE > 1300 mm).

Preliminary results of regional trials (for details see section on Transference of Technology page 130) showed overall distinct performance of the germplasm in the different ecosystems. Therefore, from a single list of promising germplasm for all ecosystems the Program now has separate lists of germplasm by categories for each ecosystem. Presently there are lists of germplasm for the hyperthermic and thermic well-drained tropical savannas as a result of screenings and research carried out at Carimagua in ICA (Instituto Colombiano Agropecuario)/CIAT's co-managed experimental station and at the Centro de Pesquisa Agropecuaria dos Cerrados (CPAC-EMBRAPA) near Brasilia, Brazil, respectively.

Hyperthermic savannas

Within this ecosystem, *Andropogon gayanus* CIAT 621 continued showing outstanding performance as a highly productive forage grass in terms of (1) growth and dry matter production in acid, infertile soils with minimum inputs; (2) tolerance to drought stress, burning, and high levels of Al saturation; (3) low P requirements; (4) insect and disease tolerance; (5) seed production ability; (6) compatibility with legumes; (7) adaptability to low-cost pasture establishment

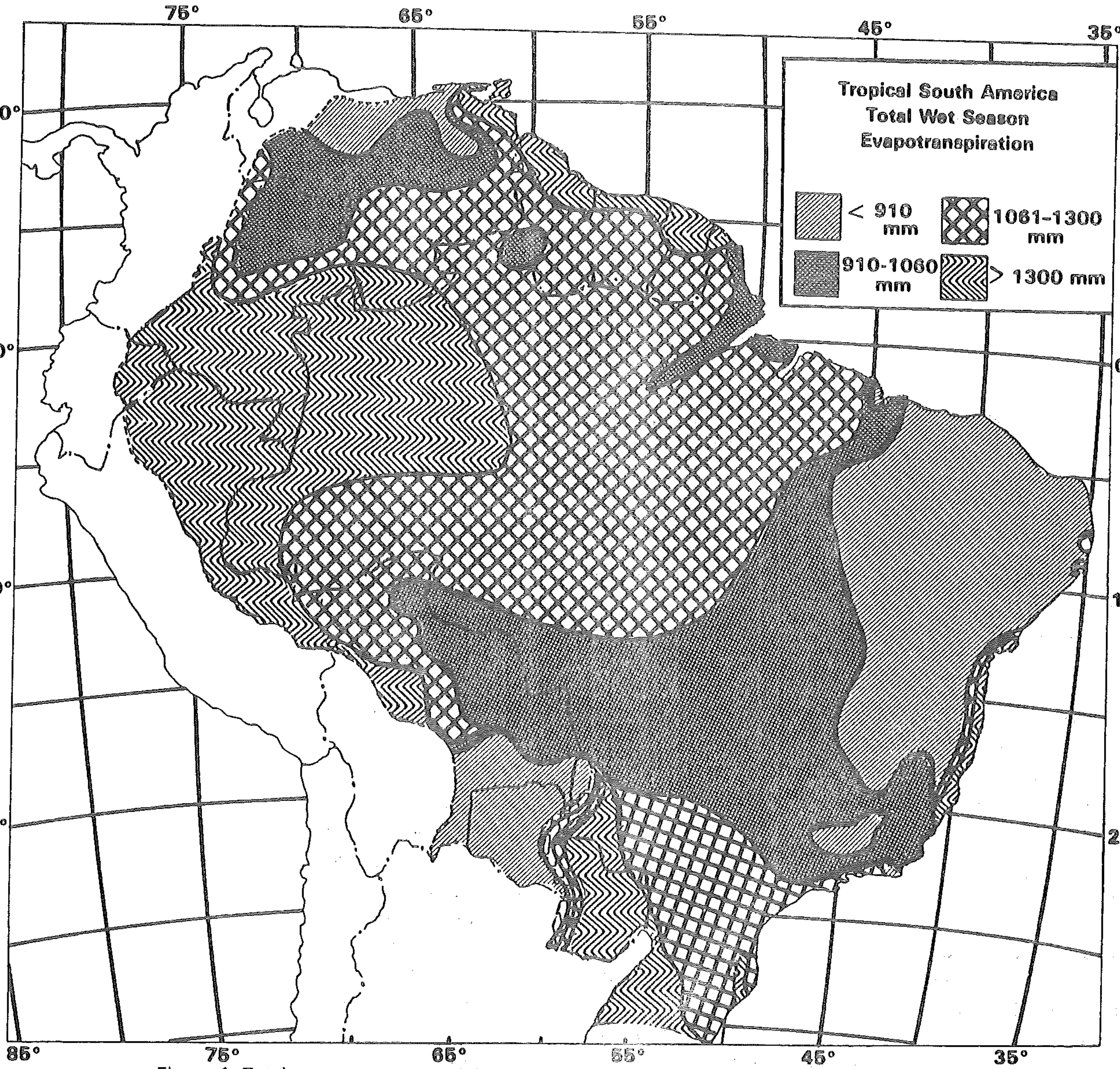

Figure 1. Total wet season potential evapotranspiration in tropical lowland South America.

systems; (8) good acceptability by animals particularly when in association with legumes; and (9) high animal production levels. Under grazing in pure stands *A. gayanus* produced 457 kg/ha/year with stocking rates between 3 and 4 animals/ha. Body weight gains in association with legumes were in the order of up to 670 g/day with nearly 2 head/ha.

Regional trials in Venezuela, Brazil and Peru confirm the excellent agronomic performance of this grass, particularly in areas of well-drained savannas with TWPE below 1061 mm. *A. gayanus* provides an alternative improved grass for such areas in associated pasture systems with legumes. An expanded seed production effort is underway anticipating future needs.

Legumes *Stylosanthes capitata, Zornia latifolia,* and *Pueraria phaseoloides* continued showing a promising performance (persistence, reasonable proportion of sward and high liveweight gains during both the dry and wet seasons) in association with *A. gayanus* at Carimagua. *S. capitata* CIAT 1019, 1315 and 1405 continued showing resistance to anthracnose in this ecosystem. While most accessions of *Z. latifolia* were severely affected by the fungus *Sphaceloma* sp., some other accessions were found to be resistant. Thus efforts are being made to screen the 401 *Zornia* spp.

accessions presently available for resistance to this fungus, and germplasm collection activities will continue to increase variability.

The highly productive, aggressive *Desmodium ovalifolium* with good nitrogen fixing capacity was confirmed as a promising legume for the Carimagua environment as well as for other more humid areas. In addition, *D. ovalifolium* has demonstrated its compatibility with vigorous grasses such as *Brachiaria decumbens* and *B. humidicola.* Animal performance was, however, substantially reduced by low palatability of the legume in a stand with low grass proportion. Thus a highly specific and successful plant collection trip to Thailand for *D. ovalifolium* and *D. heterocarpon* was made in order to increase genetic variability within these species in the Program's forage germplasm collection.

Thermic savannas

The joint program with EMBRAPA at CPAC became fully operational during 1979.

A total of 352 legume accessions were established in 1978 on the two major soil types of the Cerrado — a red-yellow latosol and a dark-red latosol. The most promising genus was *Stylosanthes;* 40 accessions of *S. guianensis, S. capitata, S. scabra,* and *S. viscosa* have been selected for further evaluation. Selected accessions of *S. guianensis* were almost exclusively represented by the tardío* type, which has shown high tolerance to anthracnose over a four-year period. Seed production trials showed high seed yields of *S. capitata* and *S. hamata.*

In experiments to evaluate grass/legume compatibility, *A. gayanus* showed better performance with legumes than *B. decumbens.*

Consolidation of Program Activities

Several sections of the Program are developing technology components to overcome specific constraining and/or methodological barriers. Low density space-planting systems have proved feasible for large scale planting for several species by providing significant savings in seed and machinery and resulting in well-established pastures for grazing within a year.

A quantitative method for screening germplasm for tolerance to high soil aluminum under greenhouse conditions was developed (hematoxilintest). Simultaneous screenhouse and field experiments for aluminum tolerance gave similar rankings for accessions. This method is simple, quick, allows for screening large numbers of materials, and is fairly accurate.

The evaluation of promising germplasm has been continued throughout the Program's target area in a network of regional trials.

In October, a workshop was held at CIAT on the Regional Trial Network for Adaptation of Tropical Forage Species. Eighty-one scientists from 40 research institutions in 14 different countries participated. Emphasis was made on the major differences between ecosystems and standardized evaluation methodologies were defined. A handbook with a standard set of analytical methods and procedures for soil and plant material was developed on the basis of these discussions.

During the year, a broad-scale survey of the incidence of diseases and insects was continued for the target area. In *Andropogon gayanus,* a rapid indirect method for the estimation of seed purity was developed and large scale seed increases and mechanical seed processing was undertaken. Finally, a new thrust was initiated towards genetic improvement within selected legumes and grass genera. Screening of *Stylosanthes guianensis* (particularly tardío type materials) for anthracnose resistance and seed production ability was initiated. A similar project is already underway for *Stylosanthes capitata.* Accessions of *Andropogon gayanus* are being evaluated for plant type, leafiness, flowering time and other characteristics in order to design a recurrent selection program with this cross-pollinating species. A characterization and selection program was initiated for 90 *Panicum maximum* accessions, to identify genotypes adapted to low fertility and drought stress conditions in the acid soils.

* Henceforth in this report the term "tardío" will be used to describe a group of *Stylosanthes guianensis* germplasm characterized by late flowering, fine stems, viscous pubescence, narrow leaves, and particular seed-head structures, originating from Brazil and Venezuela.

PLANT INTRODUCTION

During 1979, the responsibilities of the Germplasm section as related to plant introduction activities were: (1) assembling of germplasm through direct collection and exchange with other institutions; (2) multiplication and maintenance of germplasm; and (3) preliminary evaluation of germplasm and initial seed increase.

Collection and Introduction of Forage Species

The collection trips conducted during 1979 had the purpose of increasing germplasm of specific genera and species that, because of their known potential, are of particular interest to the Tropical Pastures Program overall goal. Thus, a collection expedition from Carimagua to the Orinoco river was aimed particuarly at *Zornia* and *Centrosema* germplasm native to the Colombian Llanos Orientales. Another collection trip concentrated on *Desmodium ovalifolium*/heterocarpon germplasm native to Thailand and covered a 2000 km distance from north to south. The latter expedition was conducted in collaboration with the Thailand Institute of Scientific and Technological Research. During these systematic expeditions and other several collections (including a *Desmodium* collection trip in Queensland Australia), a total of 297 accessions were assembled. Furthermore, 468 accessions were acquired through germplasm exchange with other institutions (Table 1).

With these additions during the year, CIAT's collection of tropical forage germplasm — specializing in materials originating from regions with acid, infertile savanna and jungle soils — increased to a total of 5475

Table 1. Introduction (number of accessions) of forage germplasm through direct collection and exchange with other institutions during 1979.

Genera	Introductions during 1979: Collections: Colombia (Vichada)	Thailand	Occasional collections	Exchange[1]	Total 1979	Total accessions in germplasm bank[2]
Stylosanthes	9		22	62	93	1301
Desmodium	15	32	31	45	123	734
Zornia	12		36	41	89	401
Aeschynomene	7		6	8	21	274
Macroptilium/Vigna	4		5	10	19	426
Centrosema	6	2	13	95	116	437
Galactia	2		3	14	19	189
Miscellaneous legumes[3]	24	10	50	123	207	1357
Grasses	2		6	70	78	356
Total	81	44	172	468	765	5475

1 Major contributions from the Instituto de Pesquisas IRI, Brazil; CSIRO, Australia; EPAMIG, Brazil; EMBRAPA-CENARGEN, Brazil; and Grassland Research Station Marendellas, Zimbabwe.
2 As of November 1, 1979.
3 Arachis, Calopogonium, Pueraria, Teramnus, Glycine, Rhynchosia, Leucaena, Clitoria, Cassia, Crotalaria, Tephrosia, Eriosema, Indigofera and others.

accessions. Of this germplasm, the collection of the priority species *Andropogon gayanus* (48 accessions), *Zornia* spp. (401 accessions), *Stylosanthes capitata* (118 accessions) and *Desmodium heterocarpon/ovalifolium* (45 accessions) is unique in the world.

Multiplication and Maintenance of Germplasm

During 1979, much of the section's work consisted of small-scale germplasm multiplication (1) for the preservation and maintenance of germplasm, including material for distribution outside CIAT (e.g., for germplasm exchange with other institutions); and (2) preliminary evaluation and further germplasm screening activities by other sections within the Program. Within this service function, germplasm of about 2000 accessions was multiplied under screenhouse and field conditions in CIAT-Quilichao and CIAT-Palmira, and more than 4000 germplasm samples were distributed (Table 2).

Table 2. Multiplication and distribution of forage germplasm during 1979.

Genera	Multiplication (No. of accessions)	Distribution (No. of samples)	
		CIAT	Outside CIAT[1]
Stylosanthes	359	1532	369
Desmodium	295	268	145
Zornia	320	546	89
Aeschynomene	135	197	83
Macroptilium/ Vigna	104	214	9
Centrosema	235	278	175
Galactia	117	116	6
Miscellaneous legumes[2]	256	75	52
Grasses	120	188	20
Total	1941	3414	947

1 To institutions in 14 countries in the Americas (Latin America and the United States), Africa, Asia and Europe.

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

Preliminary Evaluation of Germplasm

During this phase observations are made in the space-planted introduction nursery at CIAT-Quilichao for preliminary characterization and multiplication of germplasm (Figure 2).

On the basis of a system of monthly ratings for vigor, productivity and adaptation to the CIAT-Quilichao environment (very acid soil, insects, diseases), the potential of priority species and genera is preliminarily assessed. New germplasm showing promise in CIAT-Quilichao compared to known standard materials, is selected for priority evaluation by the forage agronomy sections in Carimagua and Brasilia, and in Regional Trials A in the other major ecosystems. Furthermore,

Figure 2. Preliminary evaluation plots of *Stylosanthes guianensis* "tardío".

these selected materials undergo an additional evaluation stage in CIAT-Quilichao to confirm their superiority. This is conducted in replicated spaced-plant plots which are also used for initial seed increase (Figure 3).

During 1979, after at least 12 months of observations, a series of new accessions of several species and genera were identified as promising materials suitable for priority evaluation in the other major ecosystems. These included 2 of *S. capitata,* 11 of *Centrosema* spp., 2 of *Aeschynomene* spp., 17 of *Zornia* spp., and 9 of *Desmodium barbatum;* no promising materials were found between accessions of *Macroptilium* spp., *Vigna* spp., and erect browse types of *Desmodium* spp.

Of those species which are presently of major interest to the Program accessions selected during 1978 were established in replicated variety trials. Using the preliminary evaluation methodology, the promise of the selected material in comparison with standard varieties was confirmed. Furthermore, in these experiments the good seed production potential of the selected lines was shown by the considerable amounts of seed harvested.

At present, a total of 817 accessions are under preliminary evaluation in CIAT-Quilichao (Table 3).

Table 3. Preliminary evaluation of new forage germplasm accessions during 1979 in CIAT-Quilichao[1].

Species	No. of accessions
Stylosanthes aff. leiocarpa	16
S. capitata	42
S. bracteata/macrocephala	20
S. guianensis "tardío"	26
Zornia spp. (2 - leaflet spp.)	138
Zornia spp. (4 - leaflet spp.)	24
Desmodium barbatum	21
D. heterocarpon/ovalifolium	44
D. heterophyllum	7
Calopogonium spp.	81
Pueraria phaseoloides	10
Galactia spp.	75
Centrosema spp.	132
Cassia rotundifolia	15
Andropogon gayanus	47
Brachiaria spp.	24
Panicum maximum	95
Total	817

1 Evaluations will be concluded in 1980.

Figure 3. Preliminary evaluation of selected germplasm of *Zornia* spp. in CIAT-Quilichao.

FORAGE AGRONOMY IN THE HYPERTHERMIC SAVANNAS (CARIMAGUA)

Germplasm Evaluation

Plant introduction continues to play an important role in the forage species selection and evaluation work. Some 600 accessions have been established in nursery plots for evlauation in the hyperthermic, well-drained savanna region of Colombia represented by the Carimagua research station.

The objectives are: (1) to evaluate a wide range of tropical legumes and grasses for adaptation to the climatic and edaphic conditions prevailing in this ecosystem and (2) to test compatibility of adapted grasses and legumes mixtures and their persistence in mixtures under grazing.

Stability of yield of sown grass and legume components under actual grazing conditions is the ultimate yardstick in the selection of improved forage cultivars. As a result of these trials, several promising pasture plants are in the final stages of evaluation and domestication. Certain deficiencies still exist and the primary objective of the evaluation work centered at Carimagua is to select superior genotypes of the "key species" which have shown promise in preliminary tests over the past four years.

Stylosanthes capitata, S. bracteata, Desmodium ovalifolium (syn. *D. heterocarpon), heterocarpon, Zornia, Centrosema, Aeschynomene* sp. and accessions of *Andropogon gayanus* constitute the majority of materials currently under trial. Other promising species each with a series of accessions, are *S. guianensis* tardío and *S.* aff. *leiocarpa.*

Anaropogon gayanus

The effect of fire on the rate of recovery of grasses and legumes was studied in another experiment following the burning of grass/legume associations shortly after the first rains in March. The strongly rhizomatous *A. gayanus* showed a significantly faster rate of growth during the eight-week period immediately after burning than *B. decumbens* (Figure 4). Two ecotypes of *Stylosanthes capitata* also recovered faster than three other legumes (Table 4).

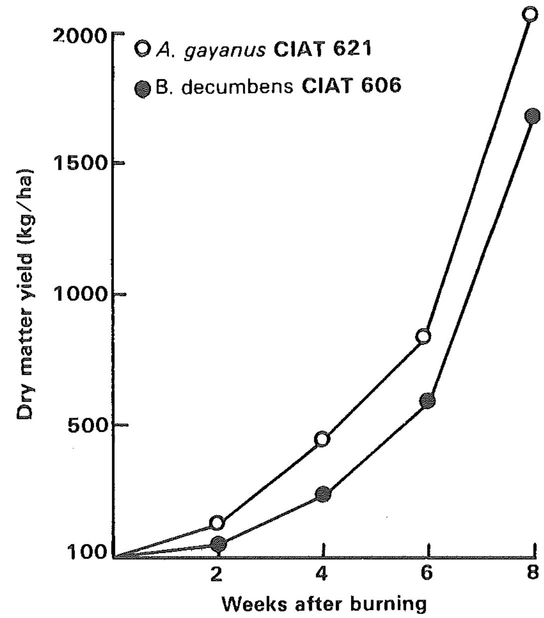

Figure 4. Rate of regrowth of *Andropogon gayanus* CIAT 621 and *Brachiaria decumbens* CIAT 606 after burning (March 12, 1979) at the beginning of the wet season.

Table 4. Rate of regrowth of five legumes in association with Andropogon gayanus CIAT 621 or Brachiaria decumbens cv. Basilisk after burning. Llanos Orientales, Colombia. (Mean dry matter production every two weeks after eight weeks after burning.

Species	Rate of regrowth (kg/ha every 2 weeks)
Legumes	
Stylosanthes capitata CIAT 1019	138.5a[1]
Stylosanthes capitata CIAT 1328	110.1a
Desmodium ovalifolium CIAT 350	30.5b
Macroptilium sp. CIAT 535	22.7b
Desmodium barbatum CIAT 3063	1.4b
Grasses	
Andropogon gayanus CIAT 621	701.7a
Brachiaria decumbens cv. Basilisk	422.2b

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

Open-pollinated progenies of *A. gayanus* CIAT 621, a strongly outcrossing type, show considerable variation in several important forage traits. Variation in flowering date is one of the readily discernible characteristics of this accession. Early and late flowering segregates display a range of over one month for flower initiation. This difference seems to be reduced with shorter day-lengths at the end of the year. Under light grazing, later flowering types are preferentially grazed. In a preliminary study, early and late flowering segregates of *A. gayanus* were compared for N, P, Ca content and *in vitro* digestibility (Table 5). Both N content and digestibility declines in the early flowering segregates; late flowering segregates showed 8.7% higher *in vitro* digestibility than the early flowering ones. P and Ca contents did not vary due to differences in flowering date.

As a follow-up, 100 late-flowering clones have been selected from old grazed pastures of *A. gayanus* 621 at the Carimagua station and were assembled in a polycross nursery to obtain seed and data on productivity and nutritional value.

Stylosanthes spp.

Of a large number of *Stylosanthes* accessions tested in the Carimagua environment, to date only a few *S. capitata* accessions, some varieties of *S. guianensis* tardío and one unidentified, rhizomatous species of *Stylosanthes,* possibly *S. leiocarpa,* are showing long term persistence in small plot studies. The late and mid-season types of *S. capitata* are the most productive in mixtures with *A. gayanus* for the 2000 mm rainfall zone represented by the Carimagua site (Table 6). Persistence was affected by overgrazing the young seedling stands in the second year following establishment. Adequate spelling and a heavy but intermittent system of grazing apparently will prevent this situation.

Table 5. Mineral analysis (N, P and Ca) and in vitro digestibility of early and late flowering segregates of Andropogon gayanus CIAT 621.

	N	P	Ca	in vitro digestibility (%)
Early flowering segregates	0.78	0.08	0.28	38.0
Late flowering segregates	1.19	0.10	0.28	46.7

Table 6. Presentation yields of four ecotypes of Stylosanthes capitata and Andropogon gayanus at Carimagua.

Species	Mean dry matter yield (kg/ha/month)
Stylosanthes capitata	
CIAT accession No.	
1097 - late flowering	1771.1a[1]
1078 - late flowering	1533.9a
1405 - early/mid - season	1128.3b
1019 - early	978.0b
Andropogon gayanus	968.0b

1 Values followed by the same letter are not significantly different at the P = 0.05 level.

The mid-season variety of *S. capitata* CIAT 1328 and *Desmodium ovalifolium* CIAT 350 exhibited similar long seasonal growth patterns and compatibility with *A. gayanus* (Figures 5 and 6). The early flowering *S. capitata* CIAT 1019 showed a reduced growth rate during the wet and post-wet seasons when this accession was fully reproductive. In the same cutting experiment dry matter yields of *D. barbatum* CIAT 3063 and *Macroptilium* sp. CIAT 535 were very low.

Desmodium ovalifolium

This legume of the tropics of the eastern hemisphere formed productive pastures in mixtures with stoloniferous, aggressive grasses such as *Brachiaria decumbens, Cynodon nlemfuensis* and *Digitaria decumbens* as well as with the vigorous tufted species, *A. gayanus* and *P. maximum.*

The seasonal distribution of yield and grass/legume composition of promising associations is being monitored in areas established in 1977. A very satisfactory grass/legume balance of 51:49 was recorded in *B. decumbens/D. ovalifolium* pastures. On

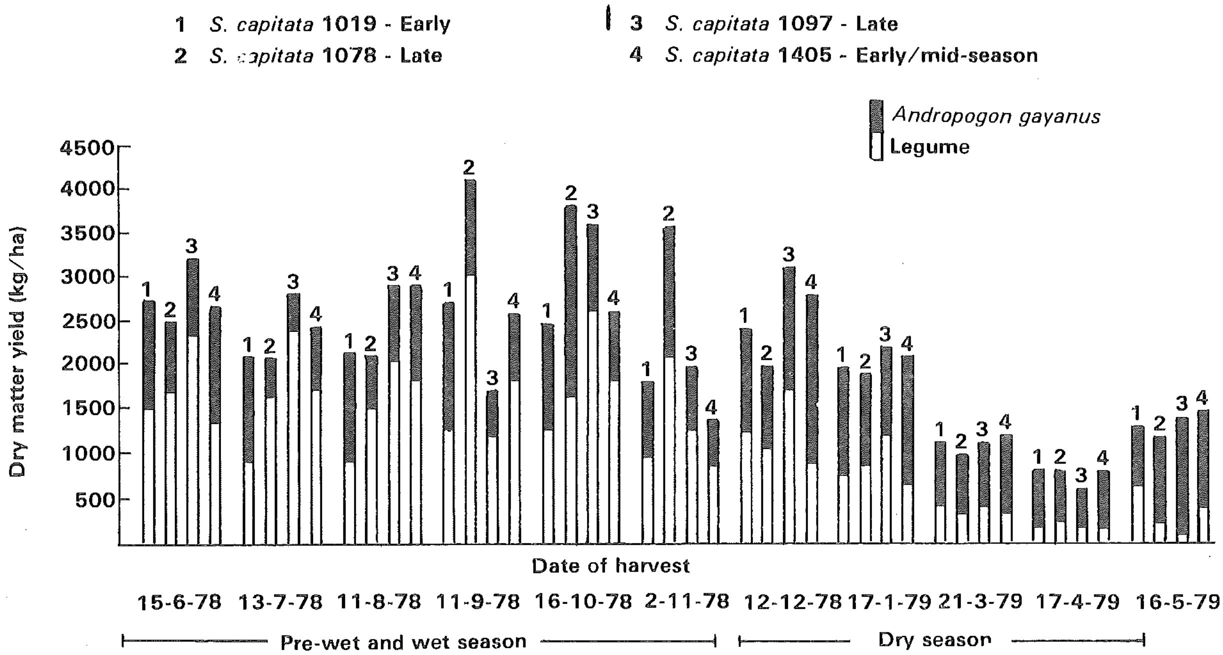

Figure 5. Mean monthly presentation yields of four ecotypes of *Stylosanthes capitata* in association with *Andropogon gayanus* under grazing in Carimagua.

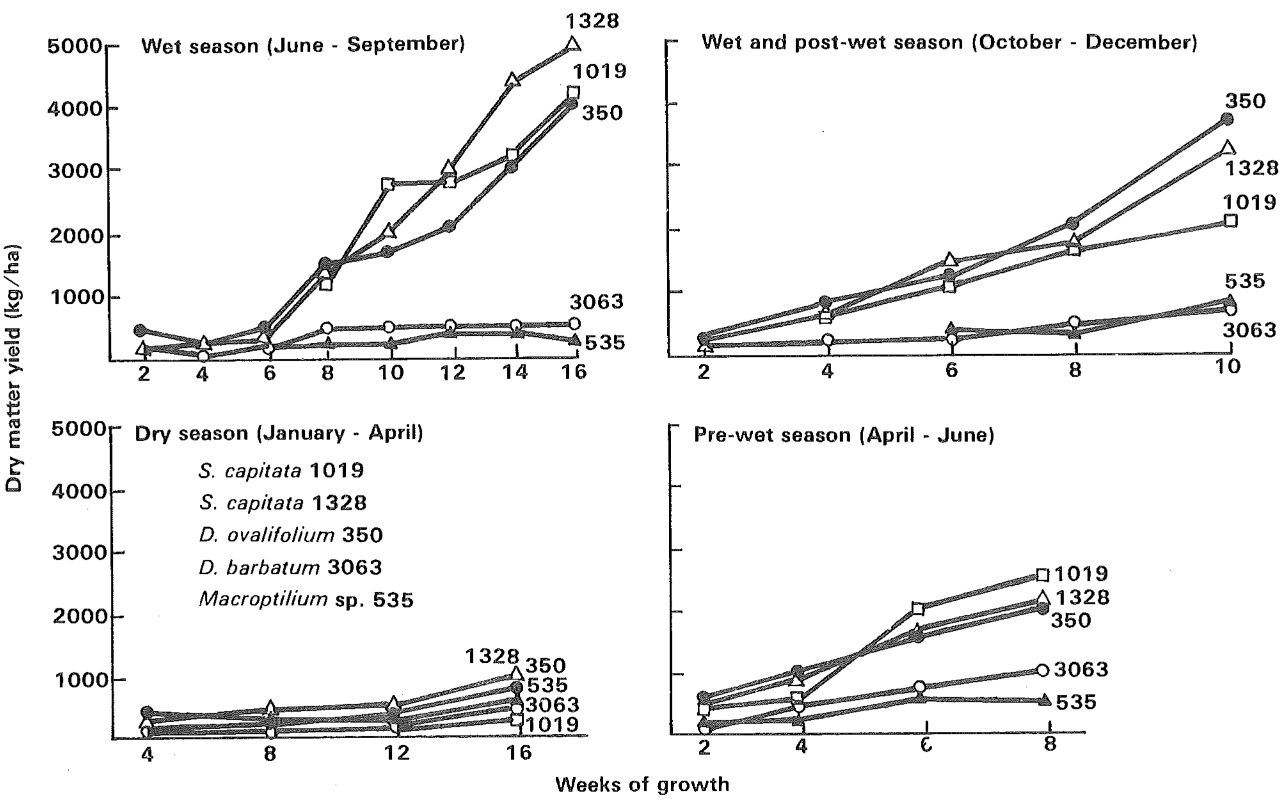

Figure 6. Growth rate and seasonal distribution of yield of early (1019) and mid-season (1328) *Stylosanthes capitata*, *Desmodium ovalifolium* (350), *D. barbatum* (3063), and *Macroptilium* sp. (535) in Carimagua.

the other hand, in the *A. gayanus/D. ovalifolium* plots, a slight legume dominance occurred under a heavy grazing pressure (Figure 7).

D. ovalifolium 350 is apparently a moderately palatable species, well accepted by grazing animals during the dry season. The aim of a current selection program is to identify genotypes with better palatability, voluntary intake and digestibility within the *D. ovalifolium/heterocarpon* complex.

Zornia sp.

Many of the *Zornia* accessions in CIAT's collection are affected by a fungal disease caused by *Sphaceloma zorniae*. Although plants have, in some cases, recovered from severe attacks of this fungus, disease resistance is a major selection objective of a recently established screening project. Disease resistance seems to be more frequent in Brazilian *Zornia* species.

Work with this species includes grazing trials and mixtures with *A. gayanus* of 10 ecotypes.

Emphasis in future work will be on the systematic evaluation of all available introductions in order to select for better dry season performance and resistance to *Sphaceloma* scab.

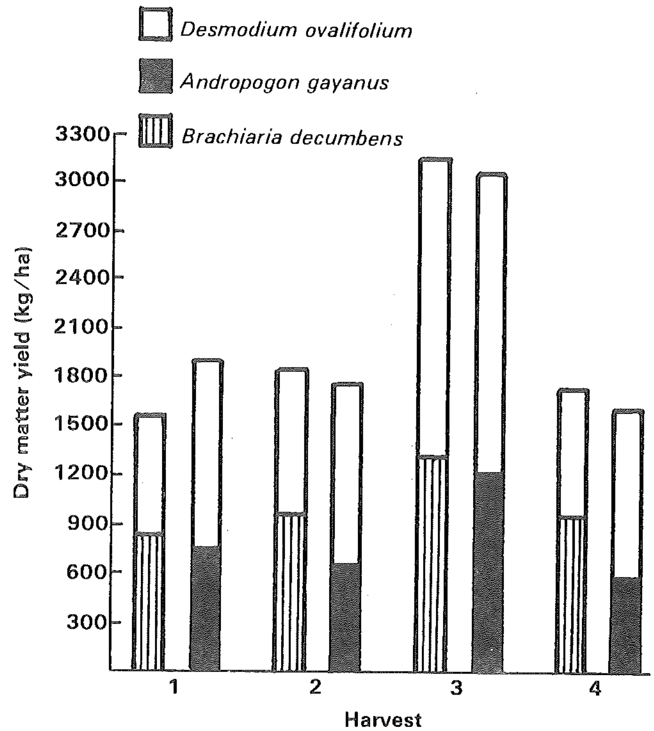

Figure 7. Presentation yields of *Desmodium ovalifolium* in association with *Andropogon gayanus* CIAT 621 and *Brachiaria decumbens* cv. Basilisk established in 1977 in the Llanos Orientales, Colombia. (Monthly harvests during the wet season, 1979.)

FORAGE AGRONOMY IN THE THERMIC SAVANNAS (CERRADO)

The objectives of this section are to: (1) evaluate and select germplasm under Cerrado conditions for adaptation to acid soils, persistence under grazing and resistance or tolerance to pests and diseases; (2) evaluate the potential of the Cerrado for commercial seed production; and (3) produce seed of selected germplasm to supply the evaluation programs at the Cerrado Center (Centro de Pesquisa Agropecuaria dos Cerrados, CPAC).

Pasture Evaluation

Preliminary germplasm evaluation

In November 1978, 352 legume introductions were planted in the two major soil types of the region, i.e., red-yellow latosol (Latosolo Vermelho Amarelo-LVA) and dark-red latosol (Latosolo Vermelho Escuro-LVE). Some physical and chemical characteristics typical of these soils are found in Table 7. The LVA site was 100 m higher than that on the LVE, on a more exposed plateau area. On the LVE, one replicate was sown with *Andropogon gayanus* for grazing, to indicate whether any accessions were rejected by the animals. Genera and number of accessions evaluated are listed in Table 8. Species of *Stylosanthes* accounted for almost 50 percent of the introductions and a total of 159 introductions originated in Brazil. Emphasis has been placed on the genus *Stylosanthes* because previous experience has demonstrated its good adaptation to the acid, infertile soils of the target area.

Dry matter production of most accessions growing on the LVE was higher than that on the LVA.

Table 7. Physical and chemical characteristics of the profile of the Dark-Red Latosol (LVE) and the Red-Yellow Latosol (LVA) at the Cerrado Center.

Soil	Depth (cm)	Texture	pH in water	Exchangeable cations Al (meq/100 g)	Ca+Mg	K (meq/100 g)	Al sat. (%)
LVE	0- 10	Clayey	4.9	1.9	0.4	0.10	79
	10- 35	Clayey	4.8	2.0	0.2	0.05	89
	35- 70	Clayey	4.9	1.6	0.2	0.03	88
	70-150	Clayey	5.0	1.5	0.2	0.01	88
LVA	0- 20	Sandy clay loam	5.0	0.4	0.05	0.06	77
	20- 40	Sandy clay loam	4.9	0.07	0.03	0.03	50
	100-120	Sandy clay loam	5.6	0.01	0.03	0.01	07

Source: CPAC Annual Report, 1976.

Table 8. Legume germplasm under preliminary evaluation at the Cerrado Center.

Legume species	No. of accessions
Stylosanthes guianensis	58
S. guianensis (tardío)	12
S. capitata	27
S. viscosa	14
S. humilis	14
S. bracteata	4
S. hamata	4
S. ingrata	1
Total	134
Other genera	
Zornia	49
Desmodium	30
Leucaena	18
Centrosema	18
Aeschynomene	16
Galactia	14
Calopogonium	13
Macroptilium/Vigna	11
Pueraria	3
Soemmeringia	2
Teramnus	2
Total	176

Differences in dry matter yield between the two sites ranged from 2% for *Zornia* spp. to 65% for accessions of *S. capitata.*

Stylosanthes was again confirmed as the most promising genus. On the basis of dry matter production, regrowth potential, dry season greenness, seed production potential and tolerance to pests and diseases, 40 introductions of this genus have been selected for further evaluation (Table 9). Selected introductions of *S. guianensis* were almost exclusively represented by the "tardío" type; a distinctive fine-stemmed, viscous, late-flowering form which has shown excellent tolerance to anthracnose over a four-year period. Accessions of *S. scabra* have shown good adaptation to both soil types and low anthracnose susceptibility. None of the introductions of *S. bracteata* were better than the control CIAT 1582. Accessions of *S. humilis* and *S. hamata* have shown a high susceptibility to anthracnose.

New introductions of *Calopogonium* and *Galactia* species were no more productive than the Brazilian commercial varieties. In addition, accessions of *Galactia* gave low seed production. *Aeschynomene* species showed high susceptibility to anthracnose while species of *Teramnus, Desmodium, Pueraria, Vigna, Soemmeringia* and *Centrosema* grew relatively poorly.

Table 9. Promising accessions of four Stylosanthes species selected for further evaluation on the two major soil types of the Cerrado.

Species	CIAT accession number	Origin	Adaptation to soil type		Season of flowering[2]		
			LVE	LVA	Early	Mid	Late
S. guianensis	2243[1]	Distrito Federal, Brazil	+	+			+
	2244[1]	Goiás, Brazil	+	-			+
	2203[1]	Goiás, Brazil	+	+			+
	1262[1]	Matto Grosso, Brazil	+	+			+
	2245[1]	Piaui, Brazil	+	-			+
	2247[1]	Bahía, Brazil	+	+		+	
	1059[1]	Bahía, Brazil	+	+			+
	1062[1]	Bahía, Brazil	+	+			+
	1095[1]	Bahía, Brazil	-	+			+
	1175	Colombia	+	+		+	
	1280[1]	Maranhao, Brazil	-	+			+
	1534[1]	Venezuela	-	+			+
	1633[1]	Goiás, Brazil	+	+			+
S. capitata	2246	Piaui, Brazil	+	-			+
	1686	Matto Grosso, Brazil	+	+		+	
	1728	Matto Grosso, Brazil	+	+			+
	1943	Minas Gerais, Brazil	+	+			+
S. scabra	1009	Bahía, Brazil	+	+		+	
	1047	Bahía, Brazil	+	+		+	
	1050	Bahía, Brazil	+	-		+	
	1064	Bahía, Brazil	+	+		+	
	1710	Matto Grosso, Brazil	+	-		+	
	1773	Matto Grosso, Brazil	+	-	+		
	2299	Goiás, Brazil	+	-		+	
	2300	Maranhao, Brazil	+	-			+
	2301	Maranhao, Brazil	-	+			+
	2302	Piaui, Brazil	+	+		+	
	2303	Probably Brazil	+	+		+	
	2304	Probably Brazil	+	-	+		
	2305	Probably Brazil	+	-		+	
	2306	Probably Brazil	+	+		+	
	2307	Pernambuco, Brazil	+	+		+	
	2308	Bahía, Brazil	+	-		+	
	2309	Probably Brazil	+	+		+	
S. viscosa	1094	Bahía, Brazil	+	-		+	
	1132	Belize	-	+		+	
	1547	Venezuela	+	-		+	
	1638	Sao Paulo, Brazil	+	+		+	
	1783	Matto Grosso, Brazil	+	+		+	
	1790	Matto Grosso, Brazil	+	-		+	

1 "Tardío" types.
2 Early = December-January; Mid = February-March; Late = April or later.

Introductions of *Zornia* species, principally *Z. latifolia* from the Colombian Llanos, were more vigorous than the control CIAT 728. However, all accessions showed severe leaf-shedding at the end of the wet season. Furthermore, at the end of the dry season regrowth in almost all introductions was severely damaged by insects and approximately 50 percent of the accessions were suffering from a virus disease. These virus/fungal/insect complex symptoms were also recorded on native *Zornia* species. Therefore, systematic screening of accessions of this species for resistance to this complex is advisable.

Of the browse legumes, *Desmodium (= Codariocalyx) gyroides* CIAT 3001 has shown good adaptation to both LVE and LVA soil types. The plants were readily consumed by cattle and the accession has been selected for further evaluation. Severe leaf virus symptoms have been observed in the other woody *Desmodium* species. Accessions of *Leucaena leucocephala* have been relatively slow to establish.

Anthracnose was the major disease problem. Its incidence in species of *Stylosanthes* and *Aeschynomene*, was, however, lower at the LVA site than at the LVE site. It is not clear whether this difference is a consequence of climatic unsuitability (e.g., lower humidity because of a continuous drying wind) at the LVA site or a presently low level of inoculum resulting from a lack of native legumes and no previous intensive experimentation.

No stemborer (*Caloptilia* sp.) or serious budworm (*Stegasta* sp.) problems have yet been encountered. Severe attacks by leafcutting ants (not specifically a pasture pest) during establishment were controlled by the application of methyl bromide gas to the nests.

Agronomic evaluation

In December 1978, two separate trials were established: one to evaluate legumes and the other, grasses. Germplasm used in these trials included commercial cultivars (controls), accessions from Category II at CPAC and experimental lines from Category IV at CIAT (Table 10).

Table 10. Legumes and grasses under agronomic evaluation at the Cerrado Center, 1978-79.

Legumes[1]	Grasses[2]
Stylosanthes guianensis cv. Cook	Andropogon gayanus CIAT 621
S. guianensis "tardío" CIAT 2243	Brachiaria ruziziensis (commercial)
S. capitata CIAT 1405	B. decumbens cv. Basilisk
S. capitata CIAT 1019	B. humidicola (commercial)
S. capitata CIAT 1315	Panicum maximum cv. Guinezinho
S. capitata CIAT 1097	
S. capitata CIAT 1078	
S. bracteata CIAT 1582	
Zornia latifolia CIAT 728	
Calopogonium mucunoides (commercial)	
Galactia striata CIAT 964	
Desmodium ovalifolium CIAT 350	
Centrosema pubescens (commercial)	
Centrosema pubescens CIAT 438	

1 Sown with Andropogon gayanus CIAT 621 and Brachiaria decumbens cv. Basilisk.
2 Sown with Calopogonium mucunoides (commercial) and Stylosanthes guianensis cv. Cook.

Grazing was withheld this season to allow the plants to establish satisfactorily. In May 1979, at the end of the wet season, the legume plots were sampled. The legume content (Figure 8) of the *A. gayanus* plot was more than twice that of the *Brachiaria decumbens* plots, confirming the greater compatibility of the erect species *A. gayanus*. The two *Centrosema* accessions had almost disappeared from all plots. *Desmodium ovalifolium* was present but below the height of sampling (15 cm). The grass evaluation trial was not sampled this season.

Introductions of *Stylosanthes* were observed for the incidence of anthracnose. All accessions of *S. capitata* and *S. guianensis* showed disease symptoms, but they were not severe. Of special interest was the reaction of *S. guianensis* tardío CIAT 2243. In the seedling stage, plants showed symptoms but then recovered completely. This has been noted previously, and observations made over the subsequent four years showed that after the establishment year plants were no longer attacked by the fungus. This appears to be correlated with the increased viscosity of leaf and stem surfaces of the plants after the seedling stage. Screening was started for selecting resistant ecotypes as well as to understand the nature of the mechanisms of resistance, including the hypothesis about the viscous substances.

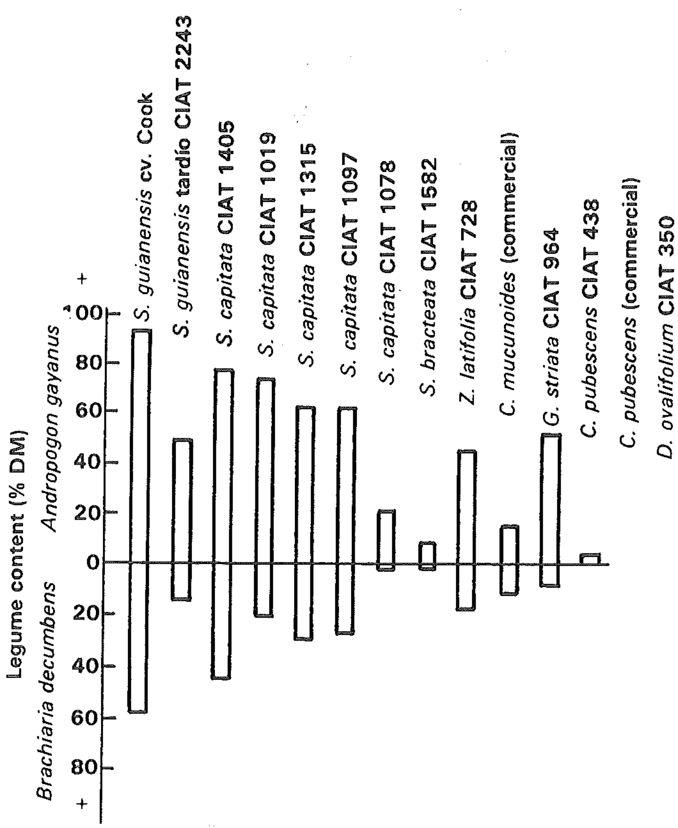

Figure 8. Legume content in Category III plots planted in mixtures with *Andropogon gayanus* or *Brachiaria decumbens at the Cerrado center.* (Late rainy season cutting at 15 cm height.)

Seed Production

Many areas of the Cerrado would appear to be climatically suitable for pasture seed production. To confirm this, an experiment was established in December 1978 with nine promising legume accessions and four promising grass accessions. Results are shown in Table 11. Excellent establishment was noted in all cases with the exception of *Stylosanthes capitata* CIAT 1078 which was slower than the other accessions. No flowers were produced this season by *Desmodium ovalifolium* or *Pueraria phaseoloides;* this may be related to latitude of the site.

Seed yields were particularly low in *S. capitata* CIAT 1078 and *S. bracteata* CIAT 1582. *S. capitata* CIAT 1405 and CIAT 1315 as well as *S. hamata* CIAT 147 gave excellent seed yields.

Production data for the grass accessions are shown in Table 12. *B. humidicola* (commercial) was relatively slow to establish and produced little seed this season. Production of seed in the other three grasses was similar. The pattern of inflorescence production in the four grasses is shown in Figure 9. *B. decumbens* cv. Basilisk and *P. maximum* cv. Petrie Green Panic as occurs with most tropical grasses, produced inflorescences over a long period of time with considerable variation in maturity between and within inflorescences. Furthermore, with successive cycles of inflorescence production, the percentage of fertile tillers declined dramatically. Seed yields in the second and third harvests were correspondingly reduced. On the other hand, more than 83 percent of all inflorescences produced by *A. gayanus* CIAT 621 appeared within a week of initial heading date, with a relatively small increase thereafter.

Severe anthracnose infestation was observed in *S. capitata* CIAT 1405 and large areas of dead plants were noted. High mortality of plants was also found in the plots of *S. capitata* CIAT 1315. Although anthracnose lesions were present on the leaves of the latter, the cause of plant death in *S. capitata* CIAT 1315 is yet to be determined. Grasses were disease-free except for the presence of *Ustilago* sp. on some seeds of *P.*

Table 11. Plant emergence and seed production data for legume accessions at the Cerrado Center.

Legume accession	Plant emergence at 50 days (plants/m²)	Date first flowering	Date harvest	Dry matter production (kg/ha)	Pure seed production (kg/ha)
Zornia latifolia CIAT 728	50	5-3-79	29-5-79	1283	175
Stylosanthes capitata CIAT 1405	74	8-4-79	11-6-79	3200	199
S. capitata CIAT 1315	60	11-4-79	8-6-79	2761	150
S. capitata CIAT 1078	14	28-3-79	6-7-79	566	31
S. bracteata CIAT 1582	30	6-4-79	13-6-79	608	17
S. hamata CIAT 147	38	20-2-79	31-5-79	4036	322
S. guianensis "tardío" CIAT 2243	54	1-6-79	4-9-79	5271	42
Desmodium ovalifolium CIAT 350	94	--[1]	-	-	-
Pueraria phaseoloides CIAT 9900	24	--[1]	-	-	-

1 No flowers produced.

maximum. A caterpillar (*Mocis latipes*) attack in *Panicum* and *Andropogon* was easily controlled by the application of a carbamate insecticide. A mild outbreak of *Stegasta* sp. was controlled with malathion.

In addition to evaluating the potential of the region for commercial seed production, another important function of the Program is to increase seed of promising lines to service successive stages of the evaluation program, to provide seed for other research areas, and, ultimately, the production of foundation seed of new cultivars. Seed of legumes *D. ovalifolium* CIAT 350, *Z. latifolia* CIAT 728, *S. capitata* CIAT 1315, *S. capitata* CIAT 1097, *S. guianensis* CIAT 1262, *S. guianensis* CIAT 2247, *S. scabra* cv. Seca and *A. gayanus* CIAT 621 is presently being increased.

Table 12. Plant emergence and seed production data for grass accessions at the Cerrado Center.

Grass accession	Plant emergence at 50 days (plants/m²)	Date first flowering	Date harvest	Dry matter production (kg/ha)	Pure seed production (kg/ha)
Brachiaria humidicola commercial	16	22-3-79	23-5-79		12
B. decumbens cv. Basilisk	20	20-2-79	2-5-79 4-7-79	6820	147 16
Panicum maximum cv. Petrie green panic	24	13-2-79	12-3-79 27-4-79 22-6-79	6300	93 40 2
Andropogon gayanus CIAT 621	32	27-4-79	7-6-79	8247	128

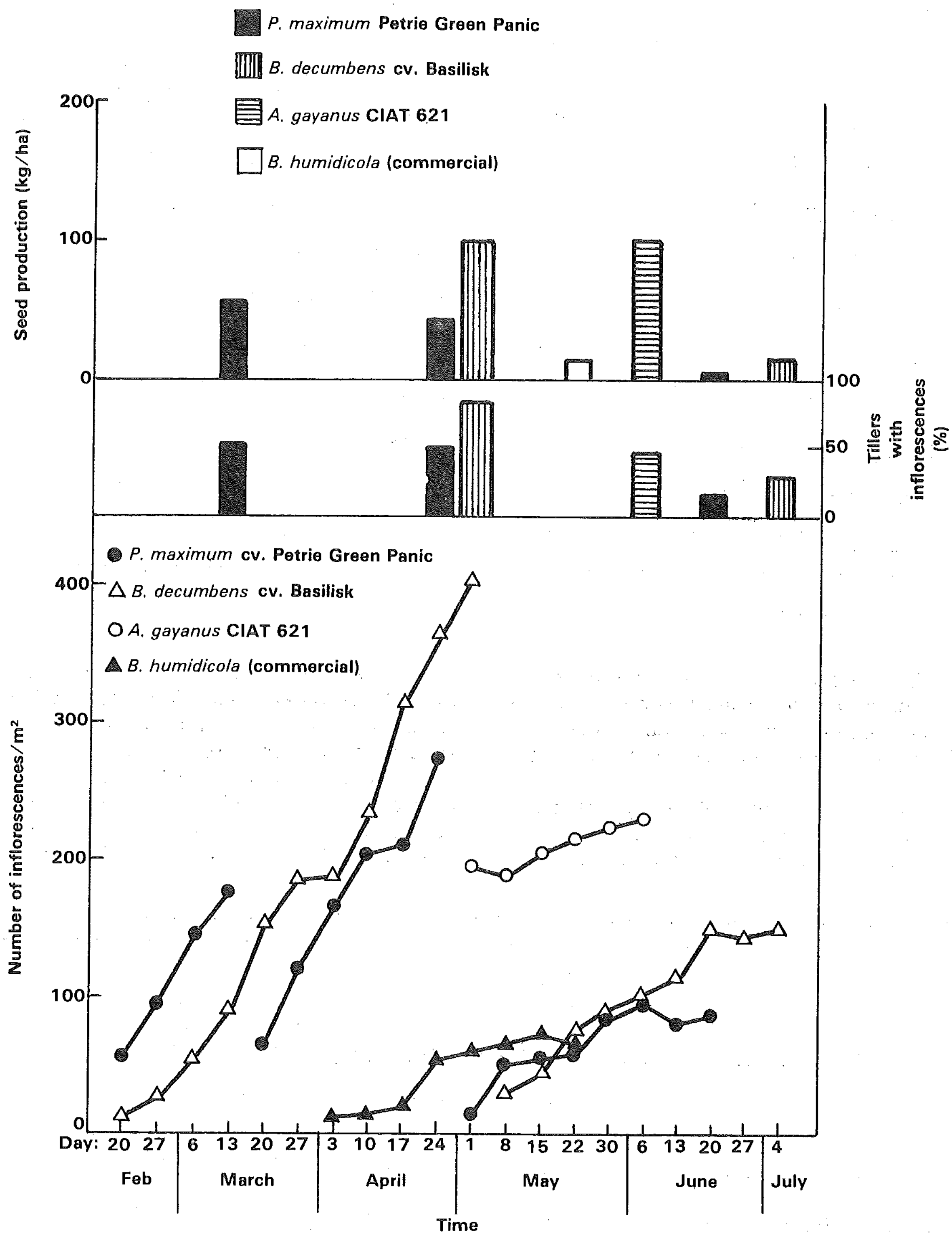

Figure 9. Pattern of inflorescence and seed production in four tropical grasses at the Cerrado Center, 1979.

FORAGE AGRONOMY (CIAT-QUILICHAO)

Within the reorganization of the Tropical Pastures Program, agronomic work in CIAT-Quilichao is mainly confined to basic research in support of other sections of the Program and to testing methodologies with emphasis on the regional trials network as well as to demonstration experiments for training activities.

Germplasm Evaluation

Of the experiments that have been established in previous years, the grazing trial at El Limonar (near CIAT-Quilichao) with five *Centrosema pubescens* accessions (CIAT Nos. 438, 442, 455, 456, and 469) in mixture with *Andropogon gayanus* CIAT 621 was evaluated during its third year under rotational grazing. This area started with an extremely high proportion of legume in the mixture; the botanical composition, however, changed rapidly and stabilized after the second year at a grass/legume ratio of 85:15 (Figure 10).

Despite the decreasing proportion of the legume, it is important to stress the fact that the productivity of the sward increased. The stocking rate was increased from 2.3 head/ha during the first grazing period to 2.7 head/ha during the second year and finally to 4.6 head/ha in the third year. These stocking rates were rotationally applied, with a grazing period of 15 days at

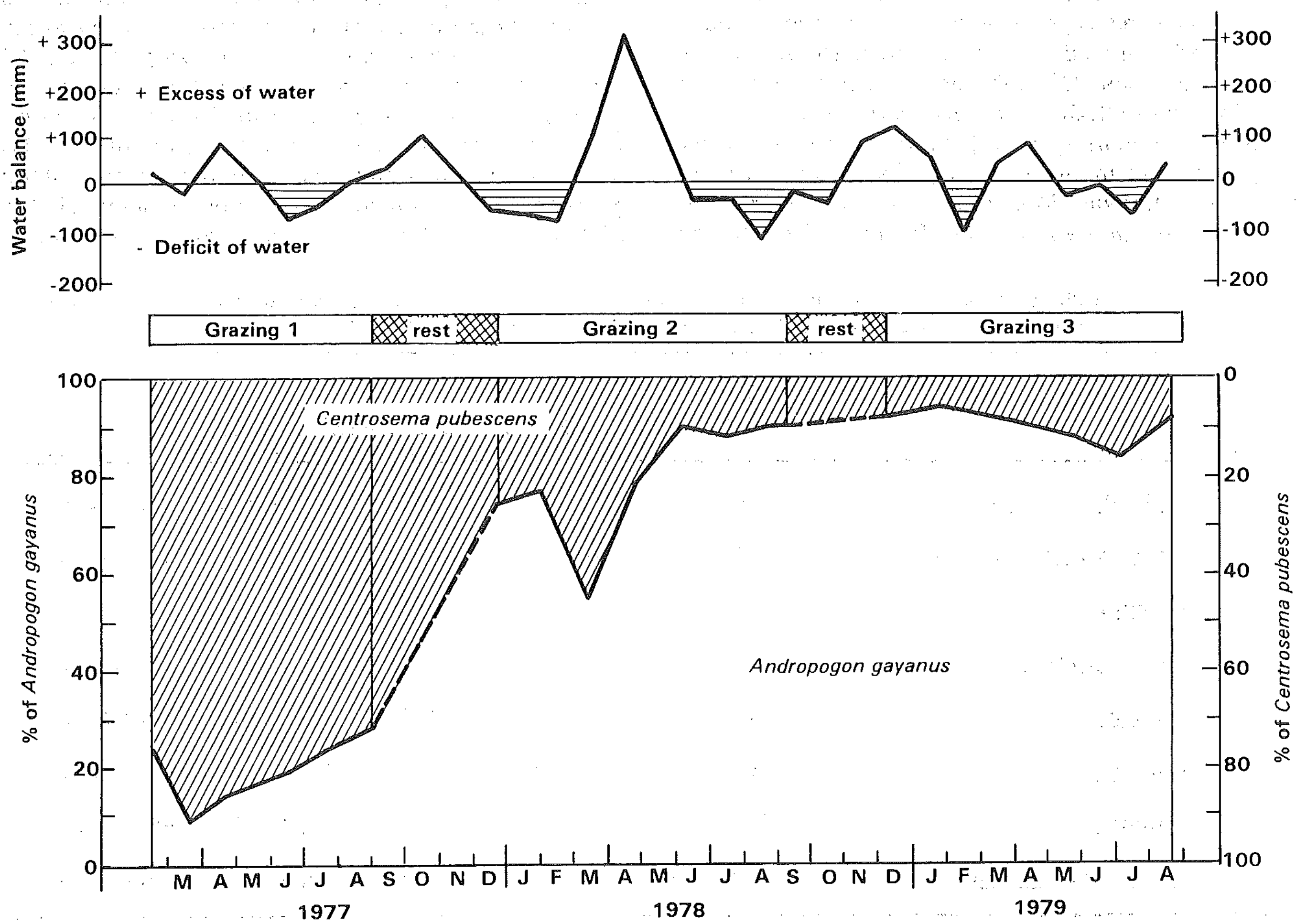

Figure 10. Proportions of *Andropogon gayanus* and *Centrosema pubescens* in mixture, under grazing (1 = 2.3 head/ha, 2 = 2.7 head/ha and 3 = 4.6 head/ha).

30-day intervals during a period of 7-8 months each year.

In this way, the first resting period which coincides with a rainy period after a build up of N in the soil by the legume, strongly favored the growth of *A. gayanus.* The second grazing period with a dry period helped the *C. pubescens* spp. to recover. With the increased precipitation, *A. gayanus* finally covered 85-90% of the population in the sward. This proportion has been held more or less stable throughout the past year with no large effects from grazing treatment nor climatic conditions.

This apparent stability in the mixture and the greater productivity of the sward at this equilibrium state in an interesting finding which will be followed at least for one more year.

The forage potential of *A. gayanus* CIAT 621 was further assessed in grass/legume associations under cutting and in grazed swards, in comparison with other vigorous grasses. Of eight grass species grown in mixed swards with *Desmodium ovalifolium* the highest yielders (in declining order) were: *A. gayanus* CIAT 621, two intermediate growth forms of *Panicum maximum* cultivar Makueni and CIAT 673, and *Brachiaria decumbens* cultivar Basilisk. *Echinochloa polystachya* was the least productive species. In this experiment a highly desirable 60:40 percent grass:legume balance was maintained with the three most productive tufted species under cutting every six weeks. A significantly lower legume content, 30 percent on the dry weight basis, was recorded in the *B. decumbens/D. ovalifolium* association (Table 13).

As indicated in CIAT Annual Report, 1978, an apparently higher protein content of *A. gayanus* was observed when associated with *C. pubescens* spp. than with *S. guianensis* (Figure 11). However, with data made available during this year, it was found that the higher protein content in the samples on offer of *A. gayanus* is due mainly to a confound effect of the amount of dry matter included i.e., samples of *A. gayanus* in most of the cases were smaller when associated with *Centrosema* spp. than with *S. guianensis.* This difference, which is especially clear during the first year is possibly the effect of differences in maturity status which, in the case of *A. gayanus,* may be a result of preferential grazing. Figure 12 shows the relationship between the size of the samples on offer of *A. gayanus* and its protein content. This relationship is expressed by the equation $\hat{Y} = 69.8 X^{-0.32}$ based on averages of the samples on offer of the grass associated with all the legumes considered in the trial. These results seem to confirm the explanation

Table 13. Yields (6-week harvest interval) of eight grass species each grown in association with Desmodium ovalifolium CIAT 350 at CIAT-Quilichao, 1978-1979.

Grass species	CIAT accession No.	Dry matter yield (kg/ha/year) Grass	Legume	Total	Grass: Legume
Brachiaria decumbens	664	7317abc[1]	3229b	10,547abc	69.4:30.6
Panicum maximum cv. Makueni	622	6727abcd	4636a	11,363abc	59.2:40.8
P. maximum	673	7494ab	4828a	12,322ab	60.8:39.2
Andropogon gayanus	621	7580a	5225a	12,805a	59.2:40.8
P. maximum	671	5335bcde	4888a	10,224bc	52.2:47.8
P. maximum	661	4549de	5671a	10,220bc	44.5:55.5
P. maximum	669	5126cde	5289a	10,415abc	49.2:50.8
Echinochloa polystachia	commercial	4305e	4645a	8,950c	48.1:51.9

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

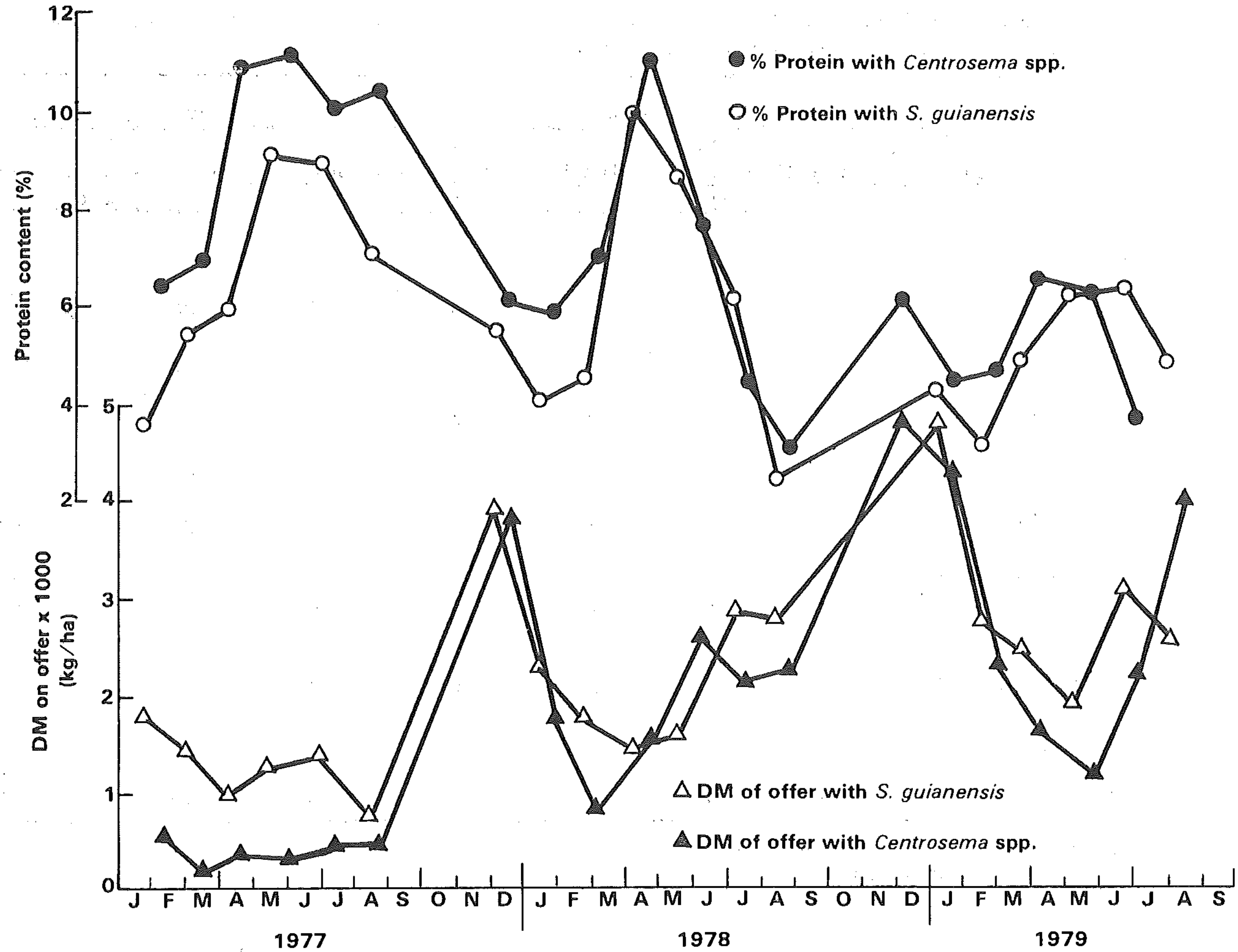

Figure 11. Protein percentage and dry matter on offer of *Andropogon gayanus,* in samples from mixtures with *Centrosema pubescens* and *Stylosanthes guianensis.*

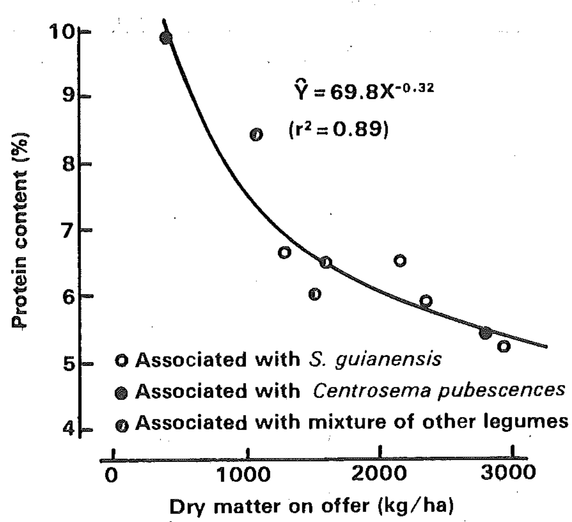

Figure 12. Protein content of samples on offer of *Andropogon gayanus* associated with different legumes.

given above for the differences observed in the protein content of *A. gayanus* when associated with two different legumes.

Herbicide Selectivity and Control

Weeds can become a problem during pasture establishment on acid, infertile soils when the natural fertility is higher in new soils or after P fertilization. To study the selectivity of chemicals on the establishment of promising pasture legumes, 11 pre-emergence and 4 post-emergence herbicides were tested. Table 14 shows the results of the best chemical treatments.

When considering the possibility that *A. gayanus* could become a weed for other crops, seven post-emergence herbicide treatments were applied. The

Table 14. Selectivity and weed control of selected herbicides 60 days after the establishment of forage legume species at CIAT-Quilichao.

Herbicide (kg a.i./ha)	Toxocity index[1]						Weed control (%)		
	S. capitata[2]	*S. guianensis* 136	*S. hamata* 147	*D. ovalifolium* 350	*C. pubescens* 438	*P. phaseoloides* 9900	Grasses	Broad leaf weeds	Total
Pre-emergence									
Alachlor (1.0)	0	0	0	1	0	0	80	13	58
Linuron (1.0)	0	3	0	4	0	3	80	74	97
Fluorodifen (3.0)	2	3	2	0	2	0	96	96	73
Orizalin (1.0)	1	0	1	2	0	1	81	89	80
Chloramben (1.0)	1	0	0	3	0	0	80	79	80
Alachlor + linuron (1.0 + 0.8)	1 1	1	0	1	0	0	95	65	88
Linuron + fluorodifen (1.0+3.0)	0	0	1	5	0	0	88	89	88
Post-emergence									
Bentazone (1.0)	0	0	0	0	0	0	30	90	70

1 Rating 10 = dead and 0 = no damage.
2 S. capitata 1019, 1078, 1405.

Table 15. Effect of post-emergence herbicide treatments on the control of *Andropogon gayanus* 621 at CIAT-Quilichao, 1979.

Treatment[1]	Rate of application (kg a.i./ha)	*A. gayanus* plants controlled (%) at (days after treatment)			
		15	30	45	60
Atrazine + surfactant	1.25 + 0.5	0	0	0	0
Dalapon + surfactant	8.0 + 0.5	30	43	58	-
Dalapon[2]	6.0 + 6.0	0	62	68	71
Atrazine + diesel oil	1.25 + 12	3	0	0	-
Diuron + surfactant	1.0 + 0.5	0	0	0	3
Paraquat + surfactant	1.5 + 0.5	36	0	0	10
Glyphosate	1.5	78	80	75	70
Check	-	0	0	0	0

1 Surfactants were applied at 0.5% and diesel oil at a rate of 12 liters.
2 Two applications, the second 17 days after the first.

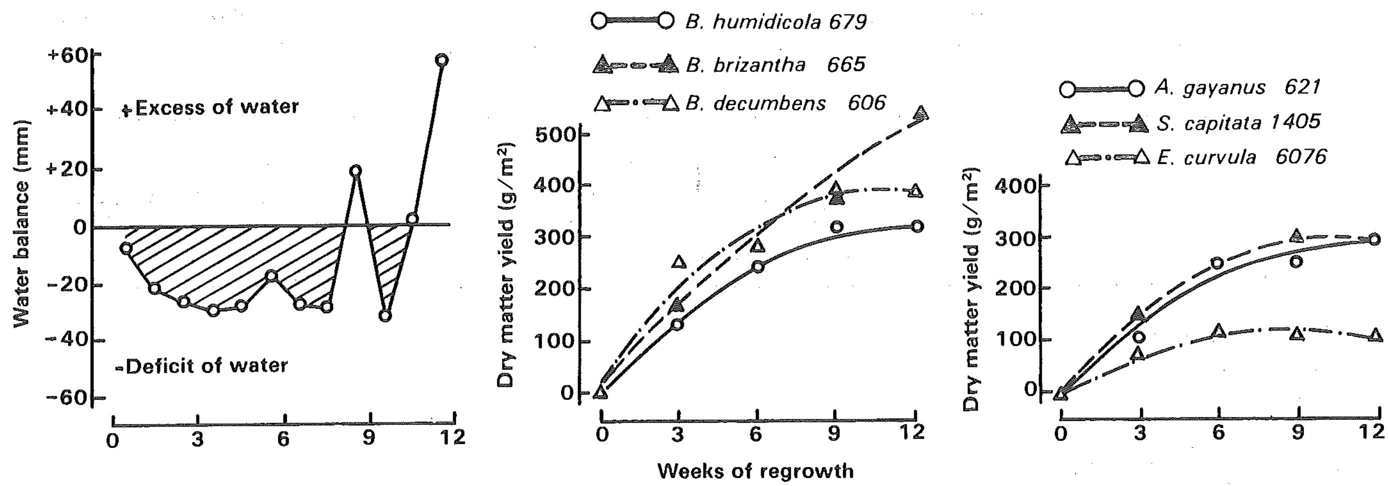

Figure 13. Growth curves of eight grass ecotypes and one legume during a dry period in CIAT-Quilichao (June 4-August 28, 1979).

two more effective treatments were dalapon in two applications and glyphosate (Table 15). This research will continue by applying the two selected herbicides at different rates on different growth stages of *A. gayanus*.

Methodology Studies

Methodological studies were initiated by using germplasm material established in a former grass agronomy experiment (40 grass ecotypes in association with *Stylosanthes capitata* CIAT 1405). The objective of these studies is to establish growth curves during the period of minimum and maximum precipitation for grass and legume germplasm that is being distributed for testing in the Regional Trials Network. Figure 13 shows the growth curves for 5 of the 40 grasses evaluated during a dry period. These studies will be complemented with leaf:stem ratios and tissue analyses. So far it is possible to observe, even under a mostly negative water balance, a faster regrowth of *Brachiaria* spp. Another interesting observation is the similarity of the regrowth rates of *A. gayanus* 621 and *S. capitata* 1405.

PROMISING GERMPLASM FOR THE MAJOR ECOSYSTEMS

For each ecosystem, germplasm under evaluation is classified into previously established categories of promise (CIAT Annual Report, 1977, page A-16) on the basis of results of germplasm evaluation conducted by the Program's agronomists in the major research sites and by collaborators in regional trials.

In the past years, germplasm evaluation was concentrated in Carimagua in the Colombian Llanos Orientales, as a major research site representative for the ecosystem "hyperthermic, well-drained tropical savanna". By late 1978, germplasm evaluation was extended to the thermic, well-drained tropical savannas, where experiments are conducted in collaboration with EMBRAPA at the Cerrado Center (CPAC), Planaltina, Distrito Federal, Brazil. Consequently, to date the classification of germplasm into categories of promise is mainly restricted to the ecosystem represented by Carimagua and only tentatively feasible for the ecosystem represented by the CPAC. For both ecosystems, some preliminary results from the first regional trials can be added.

A comparative classification of germplasm into the three highest categories of promise for the two well-drained savanna ecosystems (Table 16) indicates that: (1) the grasses *Andropogon gayanus* and *Brachiaria decumbens* , and the legumes *Stylosanthes capitata, S. guianensis* tardio and *Desmodium* (syn. *Codariocalyx) gyroides* show the broadest range of

Table 16. Germplasm of forage species in the three highest categories of promise for the tropical well-drained, hyperthermic and thermic savanna ecosystems, as of November 1, 1979.

Species	Hyperthermic savannas (Carimagua-Llanos) No. of accessions in category of promise			Thermic savannas (CPAC-Cerrado) No. of accessions in category of promise		
	III	IV	V	III	IV	V
Andropogon gayanus			1		1	
Brachiaria decumbens		1			1	
B. humidicola		1				
Stylosanthes capitata	4	1		4	1	
S. bracteata				1		
S. guianensis "tardío"	1			1		
S. aff. *leiocarpa*	1					
S. hamata	1					
S. scabra					1	
Zornia spp.	9	1		1[1]		
Desmodium ovalifolium		1		1[1]		
D. gyroides	1			1		
D. heterophyllum	1					
Pueraria phaseoloides		1				
Aeschynomene spp.	4					
Galactia striata				1		
Centrosema spp.				1[1]		
Calopogonium mucunoides					1	

1 Tentative classification.

adaptability to well-drained savanna ecosystems in general. (2) *Zornia* spp., *Desmodium ovalifolium* and *Pueraria phaseoloides* seem to be better adapted to the hyperthermic Llanos ecosystem (longer growing season than in the thermic Cerrado ecosystem), while *Galactia striata, Colopogonium mucunoides* and *S. scabra* seem to perform better under the thermic Cerrado environment, where insect pests and disease stresses are apparently lower.

In addition to this, preliminary information from the first regional trial conducted at a series of sites in humid ecosystems in Bolivia, Brazil, Colombia, Peru and Venezuela, indicates that *B. decumbens, D. ovalifolium* and *P. phaseoloides* are well adapted to tropical forest ecosystems. Also, the performance of *A. gayanus* under humid conditions seems to be considerably lower than under savanna conditions.

FORAGE IMPROVEMENT

Improvement of Legumes

The objective is to develop screening methods, evaluate germplasm accessions, create new and desirable genetic recombinations, and stabilize these desirable characteristics in superior plants suitable for grazed pastures within the target area. Research is centered mainly on species of *Stylosanthes, Centrosema* and *Leucaena.*

Stylosanthes capitata

While most accessions of *S. capitata* have appeared resistant to anthracnose, significant damage has been observed in certain accessions at both Carimagua and the CPAC in Brazil. The wide distribution of the causal agent, *Colletotrichum,* within the target area suggests that a thorough knowledge of the genetic basis of resistance is required.

A greenhouse screening of *S. capitata* collection for seedling resistance to five isolates of anthracnose has been started by the Plant Pathology Section. These results will be used in conjunction with field observations of the anthracnose reactions of the *S. capitata* collection at Carimagua, Brasilia and elsewhere to plan future breeding for resistance. In mid-1979, a space planted nursery was established in Carimagua, containing 9000 F_2 progeny of the crosses *S. capitata* 1078 x 1019 (late x early), 1097 x 1078 (late x late), and 1019 x 1097 (early x late); subsequently it was oversown with *Andropogon gayanus.* This nursery is being used to select superior F_2 plants combining high dry matter yield and prolific seed production with drought resistance. It will also provide an indication of the range of variation which can be expected from crosses between distinct *S. capitata* types.

Stylosanthes guianensis

While common *S. guianensis,* typified by CIAT 136 and 184, is highly susceptible to both anthracnose and stemborer, the tardío types collected in Venezuela and Brazil have appeared resistant to both constraints at several locations. A greenhouse screening of these tardío accessions for reaction to anthracnose is being planned. Results obtained from these experiments in conjunction with field screenings should provide valuable information for future breeding work.

Centrosema pubescens

C. pubescens is widely distributed throughout South America and exhibits an extensive range of variation. Commercial ecotypes of this species are not well adapted to growth in acid, infertile soils, and tend to be susceptible to anthracnose. A preliminary breeding program has been started with the goal of adapting *C. pubescens* for use in the target area. Specific objectives include (1) tolerance to high levels of Al in the soil and low pH; (2) vigorous early growth and nodulation; (3) anthracnose tolerance; and (4) commercially acceptable seed yields.

Eight *C. pubescens* ecotypes selected for vigor in pots of Carimagua soil were intercrossed, and several F_2 populations produced. F_2 seedling populations, as well as new ecotypes are first screened in sand culture (pH 4.2, high Al), and the selections then screened in Carimagua soil, to isolate genotypes with higher acid tolerance. Progeny of selected plants will be evaluated under field conditions at Carimagua.

Leucaena leucocephala

The *L. leucocephala* breeding program is based on hybrids between *L. leucocephala* and *L. pulverulenta* which have been backcrossed several times to *L. leucocephala* cv. Cunningham to produce fertile lines. The aim of this program continues to be the development of productive lines with (1) tolerance to high Al and low soil pH, and (2) lower levels of foliar mimosine. A procedure has been developed to screen progeny of the original lines previously selected for good growth in Carimagua soil. This involves (1) growth of large numbers of seedlings in sand culture (pH 4.2, high Al) and selection of those with best root and top growth; (2) selected seedlings are transferred to 15 cm-diameter pots of Carimagua soil and given a restricted nutrient supply. An acid-tolerant rhizobium culture is used to inoculate the selections.

Various screenings, each involving 5440 plants, have been completed. The average percentage of plants finally selected for seed production and further study varied from 1.8 to 5% in the various lines. Selected hybrid *Leucaena* plants showed at least four times as much top growth in Carimagua soil as the Cunningham controls. Acid-tolerant selections are grown at CIAT-Palmira for mimosine analysis and seed multiplication. Superior lines will be field tested first at Carimagua.

Grasses

Andropogon gayanus

A. gayanus has considerable potential as a pioneer grass for the acid soils of the tropics. While present experience is almost exclusively confined to accession CIAT 621, the species shows a high adaptation capacity as it is able to grow in soils with a low fertility status but responds significantly to applied phosphorus and other minerals.

A range of accessions has been assembled from different sources so that desirable characteristics in these can be sought and compared to A. gayanus CIAT 621. Objectives for the improvement of this cross-pollinating species are being formulated. In addition to the evaluation of new accessions, quantification of genetic variability and selection within CIAT 621 is planned. CIAT 621 is very variable for plant type, leafiness, time of flowering, and other characteristics. A recurrent selection program is being developed with initial selection for later, leafier types which can flower and ser seed during a more restricted period. This should improve both seed production as well as forage quantity and quality.

Panicum maximum

Several cultivars of *P. maximum* are widely grown in South America and have proved to give better animal production than most other tropical grasses. However, commonly grown cultivars are generally observed to have higher nutrient requirements and lower drought tolerance than other forage grass species. The aim of improvement work with this species is to identify or develop lines with lower nutrient requirements and better dry season production than those commonly grown.

A collection of some 90 *P. maximum* accessions is available. Fourteen of these have already been observed at Carimagua and preliminary data on two cuts in the rainy season show significant differences among the accessions for dry matter production. Additional accessions will be evaluated under Carimagua conditions to identify genotypes which show promise under nutrient and drought stress conditions on acid soils.

Most *P. maximum* clones are highly apomictic. A crossing technique has been designed, using an apomictic clone as the male parent and a sexual clone (obtained from the Coastal Plan Research Station, Tifton, Georgia, USA) as the female parent. Preliminary observations of hybrid progenies at CIAT-Palmira show a considerable range of variability for grass plant morphology both between and within progenies. As observations on the accessions under Carimagua conditions accumulate, a breeding program may be develop utilizing the better adapted apomictic clones as parental material.

Brachiaria spp.

B. decumbens and *B. humidicola* are promising forage grass species in the target area. Both species are tetraploid apomictics so that a breeding program is impossible, unless sexual types can be found or produced. An attempt is being made to produce tetraploid material by colchicine treatment of *B. ruziziensis,* a sexual, diploid species. The goal is to produce a sexual tetraploid which might be crossed with the tetraploid *Brachiaria* spp., to overcome the barrier imposed by their obligate apomixis. In the meantime, efforts will be made to expand the germplasm collection of species and ecotypes of this genus.

PLANT PATHOLOGY

In 1979, the Plant Pathology section continued to detect, identify and assess diseases of tropical forages within the target area. Studies were initiated on the most important diseases including anthracnose, blight, root-knot, nematode, Camptomeris leaf spot and Cercospora leaf spot. False-rust, Rhynchosporium leaf spot and Sphaceloma scab were detected as new diseases requiring further study.

Disease Survey

Forage diseases were evaluated at the 20 different sites of the Regional Trials Network. Twenty-two pathogens affecting grasses and legumes were identified (Table 17). The most important finding is the existence of different pathogens at different sites. Surveys will continue at these sites and at new ones within the target area. The accumulating results, however, strongly suggest further decentralization of screening for disease resistance, to expose forage to as many potential pathogens as possible.

Anthracnose

Host range

Surveys on the occurrence of anthracnose continued to show the wide-spread distribution and extensive host range of *Colletotrichum* spp. (CIAT Annual Report, 1978). In CIAT-Quilichao, new hosts identified included accessions of *Aeschynomene, Calopogonium, Desmodium, Galactia, Zornia, Pueraria phaseoloides,* and *Stylosanthes.* In Carimagua, extensive surveys detected other accessions of previously reported legume hosts (CIAT Annual Report, 1978). Other hosts found were native savanna legumes *Aeschynomene, Desmodium, Eriosema* and *Zornia* spp., native savanna non-legumes, and a saprophytic phase of the fungi in *Desmodium ovalifolium* CIAT 350 and many grasses. Although *S. capitata* CIAT 1019, 1315 and 1405 were resistant to anthracnose in Colombia, they were susceptible at CPAC-Brasilia. Similarly, *S. guianensis* accessions destroyed by

Table 17. Frequency of forage diseases in 20 sites of the Regional Trials network.

Diseases	Bolivia		Brazil				Colombia				Ecuador		Perú			Venezuela					
	Santa Cruz	San Ignacio	Brasilia	Sete Lagoas	Goiania	Campo Grande	S. Quilichao	Carimagua	La Libertad	San José del Nus	Pichilingue	Santo Domingo	Pucallpa	Tarapoto	Yurimaguas	Jusepín	Uracoa	El Tigre	Atapirire	Guachi	Total Sites
Anthracnose[1]	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	19
Cercospora leaf spot[1] (in Panicum maximum)	+	+			+	+	+	+	+	+			+	+		+	+	+	+	+	15
Cercospora leaf spot (in Centrosema spp.)	+	+			+	+	+	+	+	+				+		+	+	+		+	13
Root-knot nematode[1]							+														1
Blight[1]								+	+	+											3
Sphaceloma scab[1]			+				+	+	+												4
Smut (Ustilago)[1]		+	+	+	+	+		+	+											+	8
Smut (Urocystis)					+																1
Camptomeris leaf spot[1]							+				+										2
Rust (Uromyces)			+		+	+	+							+				+			6
Rust (Puccinia)							+														1
False rust[1]			+	+	+	+					+										5
Rhizoctonia solani	+							+	+	+		+						+		+	7
Rhynchosporium leaf spot[1]								+	+												2
Drechslera leaf spot	+							+													2
Little leaf virus	+		+		+	+	+	+				+									7
Ergot				+																	1
Giberella inflorescence blight				+																	1
Botrytis inflorescence blight										+											1
Black mold			+		+																2
Powdery mildew	+		+	+	+		+										+				6
Slime mold							+														1

1 Diseases considered as important.

anthracnose in Colombia were only slightly affected at several sites in Brazil. These observations suggest the presence of different races of *Colletotrichum* spp. at different sites.

Severity

At CIAT-Quilichao and Carimagua, anthracnose severely affected accessions of *S. guianensis,* late-flowering *S. capitata, Centrosema* and *Aeschynomene* spp. However, tardio types of *S. guianensis* and *S. capitata* CIAT 1019, 1315 and 1405, were resistant. Although several accessions of *Centrosema* spp. were defoliated, CIAT 5052 5057 and 5066 were resistant. Accessions of *Aeschynomene* spp. were devastated at CIAT-Quilichao; however, the hairy and/or sticky accessions CIAT 7259, 7260, 7262 and 7274 from Venezuela were resistant. Anthracnose spotting was moderate to severe on *Zornia* spp. and on mature leaves of *Desmodium* spp.

Field screening

Due to the extensive indigenous population of anthracnose fungi, glasshouse screening is not feasible, except for specific studies. Field screenings at various sites continued to identify accessions with resistance to local *Colletotrichum* spp. races. At

Carimagua, large plantings of 75 accessions of *S. capitata* and 130 accessions of *S. guianensis* were established for screening purposes, to monitor the expected anthracnose epidemic and to isolate pathogenic races to these species in the Carimagua environment for further studies.

Burning to control anthracnose

Although the use of resistant varieties is the most desirable method to control anthracnose of tropical forage legumes, burning is proving a potentially successful temporary control measure. Ten months after burning affected plots of *S. capitata* at El Limonar, near CIAT-Quilichao, susceptible accessions CIAT 1078 and 1097 had only 29% as much anthracnose as unburnt (Table 18). In Carimagua, three months after burning plots of CIAT 1078, these only showed 50% as much anthracnose as unburnt plots (Table 19).

Host plant resistance studies

Studies are underway to compare anatomical, chemical and developmental characteristics of susceptible 136 type *S. guianensis* and resistant fine-stemmed *S. guianensis* tardío as well as those of susceptible late-flowering *S. capitata* CIAT 1078 and 1097 and the resistant accessions CIAT 1019 and 1315.

Legume germplasm evaluation

Screening of new germplasm of *S. capitata* and *S. guianensis* for resistance to anthracnose was initiated in the glasshouse and in the Carimagua environment, in collaboration with the Legume Breeding section of the Program.

Blight

In Carimagua, *Sclerotium rolfsii* again affected *Stylosanthes* spp. from July to November of this year. Counts of dead plants were made at various sites for *S. capitata* CIAT 1019 (5%), 1097 (7%), 1315 (9%), 1318 (11%), 1325 (7%), 1338 (6%), 1339 (7%), 1342 (11%), 1405 (6%) and *S. bracteata* CIAT 1281 (14%). CIAT 1019 was severely affected (75%) at San Jose del Nus, Colombia, and moderately affected (20%) at La Libertad, Colombia. Soil populations of sclerotia of this pathogenic fungus are being monitored in Carimagua.

In glasshose trials with 70-day old plants, most legumes including the promising *S. capitata* CIAT 1019 and 1315, *D. ovalifolium* CIAT 350 and *Z. latifolia* CIAT 728, were highly susceptible to *S. rolfsii* (Table 20). Studies on changes in the susceptibility of *S. capitata* CIAT 1019 with age showed that plants with 10-24

Table 18. Effect of burning on the incidence of anthracnose in Stylosanthes capitata susceptible accessions CIAT 1097 and 1078, 5 and 10 months after treatment at El Limonar, near CIAT-Quilichao.

CIAT accession No.	Treatment	Months after burning	No. of lesions on stems	Dry weight of sample (g)	No. lesions/ 10 g dry matter
1097	Without burning	5	415.3	45.9	90.5
	Burning		2.7	6.0	4.5
	Without burning	10	338.0	63.4	53.3
	Burning		51.7	33.5	15.4
1078	Without burning	5	445.0	75.1	60.5
	Burning		38.3	36.3	10.6
	Without burning	10	381.7	46.4	82.3
	Burning		74.0	31.2	23.7

Table 19. Effect of burning on the incidence of anthracnose on Stylosanthes capitata CIAT 1078 1, 2, and 3 months after treatment in Carimagua.

Treatment	Months after burning	No. of lesions on stems	Dry weight of sample (g)	No. lesions/ 10 g dry matter
Without burning	1	87.9	17.1	51.4
Burning		15.5	17.9	8.7
Without burning	2	150.0	101.0	14.9
Burning		7.8	41.0	1.9
Without burning	3	199.0	97.9	20.3
Burning		79.4	71.2	11.2

Table 20. Reaction of tropical forage legumes to Sclerotium rolfsii.

Susceptible	No. of accessions	Moderately susceptible	No. of accessions	Resistant	No. of accessions
Calopogonium mucunoides	1	Gentrosema pubescens	1	Leucaena leucocephala	4
Desmodium barbatum	1	Desmodium canum	1		
Desmodium distortum	1	Desmodium heterocarpon	2		
Desmodium heterocarpon	3				
Desmodium heterophyllum	1				
Desmodium ovalifolium	1				
Macroptilium sp.	1				
Pueraria phaseoloides	1				
Stylosanthes capitata	11				
Stylosanthes guianensis	14				
Stylosanthes hamata	4				
Stylosanthes humilis	1				
Stylosanthes scabra	7				
Stylosanthes viscosa	3				
Zornia latifolia	2				
Total	52		4		4

weeks were more susceptible than older and younger plants.

Studies are continuing on the susceptibility of promising legumes under pasture conditions, the susceptibility of progeny of plants surviving inoculation and the effect of soil and organic matter content in it on the pathogenicity of the fungus to *S. capitata* CIAT 1019.

Root-Knot Nematode

Surveys of indigenous legumes and savanna plants at Carimagua have failed to detect *Meloidogyne javanica.* At CIAT-Quilichao, however, various weed hosts were found and plots of *D. ovalifolium* CIAT 350 and *Cordariocaly* x *gyroides* were severely affected. In a screening trial carried out in pots, resistance was found in *Stylosanthes* spp., *Z. latifolia, P. phaseoloides* and *Leucaena leucocephala* (Table 21). Most accessions of *Desmodium* spp. were susceptible, except for *D. distortum* CIAT 335 and *D. heterophyllum* CIAT 349.

As roots of some grasses produce toxins to nematodes, two studies were initiated to determine the effect of root-knot nematode on *D. ovalifolium* CIAT 350 association with various grasses; a pot trial with 54 accessions of 25 grass species was established and also a field trial in a nematode-infested plot at CIAT-Quilichao, with *Andropogon gayanus* CIAT 621, *Brachiaria decumbens* CIAT 606 and *Panicum maximum* CIAT 604.

Table 21. Effect of *Meloidogyne javanica* isolated from *Desmodium ovalifolium* CIAT 350 on other tropical forage legumes.

Legume	No. of accessions	Reaction[1]
Calopogonium mucunoides	1	3
Centrosema pubescens	1	2
Codariocalyx gyroides	1	4
Desmodium barbatum	1	2
Desmodium distortum	1	1
Desmodium heterocarpon	3	3
Desmodium heterocarpon	3	2
Desmodium heterocarpon	1	1
Desmodium heterophyllum	1	1
Desmodium ovalifolium	1	4
Leucaena leucocephala	1	1
Macroptilium sp.	1	2
Pueraria phaseoloides	1	1
Stylosanthes capitata	6	1
Stylosanthes guianensis	2	1
Stylosanthes hamata	1	1
Zornia latifolia	2	1

1 Reaction: 1 = no galling; 5 = severe galling.

Camptomeris Leaf Spot

Camptomeris leucaenae continued to damage *Leucaena leucocephala* CIAT 734 at CIAT-Quilichao. A screening trial to observe reactions of 38 accessions of *Leucaena* spp. to the fungus was established near an infested pasture of *L. leucocephala* 734. After eight months exposure, 21 accessions, including commercial cultivars Cunningham and Peru, were moderately to highly susceptible to *C. leucaenae* (Table 22). Potencial resistance was found in six accessions of *L. leucocephala* and several accessions of five other *Leucaena* spp.

Fertilized plots of *L. leucocephala* 734 located near infected plots were only slightly damaged by Camptomeris leaf spot. Leaf tissue analyses showed higher levels of K, Ca and Mg and considerably higher levels of Zn and B in leaves from fertilized plots in contrast to leaves from non fertilized plots. Two experiments were established to determine the effect of various fertilizer treatments on the susceptibility of CIAT 734 to the fungus. One study will determine the effect of four levels of P_2O_5, K_2O, Mg, Ca Cu, Zn, B and Mo while the other will determine the effect of different combinations of Zn, Cu and B on Camptomeris leaf spot.

Cercospora Leaf Spot

In the target area, Cercospora leaf spot affecting *Panicum maximum* is a widespread disease. Damage to this species is moderate to severe. *P. maximum* cultivars Green Panic, Makueni and Guiniensis are

Table 22. Effect of Camptomeris leucaenae on Leucaena spp. at CIAT-Quilichao.

Species	No. of accessions	Reaction[1]
L. collinsii	2	2
L. diversifolia	3	1
L. esculenta	1	1
L. esculenta	1	4
L. leucocephala	6	2
L. leucocephala	9	3
L. leucocephala	7	4
L. leucocephala	1	5
L. macrophylla	2	3
L. pulverulenta	1	1
L. pulverulenta	1	2
L. pulverulenta	1	3
L. shannoni	1	1
L. shannoni	1	2
L. trichodes	1	1

1 Reaction: 1 = no disease; 5 = severe defoliation.

resistant. Studies on the effect of *Cercospora* leaf spot on yield and quality of *P. maximum* CIAT 604 and Makueni, using various fungicides to assess potential yield, are in progress in Carimagua. The effect of burning and cutting on Cercospora leaf spot development is also being studied.

False-Rust

This disease, caused by *Synchytrium phaseoli*, was observed for the first time on forage legumes in Brazil and Ecuador. The fungus affects leaves, petioles and stems forming orange rust-like pustules. Leaves become distorted and stems and petioles severely galled. *Macroptilium* sp. CIAT 535 was devastated in Santo Domingo, Ecuador, while *Macroptilium* spp. (including Siratro) and *Glycine wightii* were severely affected at several locations in Brazil. At the moment, the disease has not been detected in Colombia.

Rhynchosporium Leaf Spot

Rhynchosporium leaf spot was first observed on *Andropogon gayanus* CIAT 621 at La Libertad near Villavicencio, Colombia in March 1979 and in Carimagua in May the same year. Few orange-brown spots per leaf developed on mature leaves. Although the majority of lesions were marginal or located towards the leaf tips, a small proportion cut the mid-vein causing premature senescence and necrosis.

Although the incidence of Rhynchosporium leaf spot is higher in Villavicencio than Carimagua, only slight damage to *A. gayanus* has been observed in Villavicencio. It is probable that high rainfall (3000 mm/year) and continuous high humidity places *A. gayanus* under stress at Villavicencio and more susceptible to parasites.

Further observations will be made at Villavicencio during the following wet season, especially on *A. gayanus* under grazing. Cross inoculation studies with *Rhynchosporium* sp. from rice will be carried out. Rhynchosporium leaf spot is a major disease of rice at Villavicencio and it is possible that the same fungus finds *A. gayanus* as an alternative host.

Sphaceloma Scab

In 1979, *Zornia* spp. in Carimagua and CIAT-Quilichao were severely affected by *Sphaceloma* sp. This fungus, indigenous to Colombia, produces elliptical-elongated, pale-brown spots with reddish margins on petioles and stems. Lesions coalesce forming raised corky scabs which often destroy large lengths of stem, resulting in defoliation and dieback.

Under CIAT-Quilichao conditions, *Zornia* spp. accessions from Colombia were slightly to moderately affected, while in Carimagua, the same accessions, including CIAT 728, were moderately to severely affected. However, annual species from Brazil were resistant. *Z. guanipensis* from Venezuela and *Z. brasiliensis* from Brazil were resistant in CIAT-Quilichao and the same accessions of *Z. brasiliensis* were resistant in Carimagua. More germplasm of the latter species is necessary to further explore this resistance.

Smut

Smut caused by Ustilago sp. is widespread on *P. maximum* and often severely affects inflorescences.

Sixty-eight percent of inflorescences of *P. maximum* common in San Ignacio, Bolivia and *P. maximum* colonial in Goiania, Brazil were smutted. In a trial established in Carimagua to evaluate Cercospora leaf spot on *P. maximum*, smut destroyed most inflorescences of CIAT 604 while Makueni was completely resistant. It is recommended that seed from infected stands be treated before sowing.

Rust

Although *Uromyces appendiculatus* is widespread on *Macroptilium*, *Phaseolus* and *Vigna* spp. throughout almost the total target area, it affects mature leaves only.

Rhizoctonia solani

Generally, *R. solani* caused slight to moderate damage to *P. phaseoloides* and *Macroptilium* spp. throughout the target area. Plots of *P. phaseoloides* at CIAT-Quilichao (Colombia) and Santa Cruz (Bolivia) were moderately to severely affected.

Black Mold

In 1979, black mold was severe on *Zornia* spp. from Brazil and moderate on *Zornia* spp. from Colombia at CPAC-Brasilia. The disease is apparently associated with insect attacks.

Minor Diseases

Powdery mildew, Drechslera leaf spot, little leaf virus, Botrytis inflorescence blight, slime mold and snow mold were diseases of minor importance detected on legumes at various locations within the target area. Ergot, Giberella inflorescence blight, Urocystis smut and rusts were detected on grasses.

Seed Pathology

Surveys on the microflora of forage seed and the effect of seed treatments on pathogens showed that the best and most practical method for reducing levels of storage fungi associated with grass seed is its treatment with captafol. Studies are continuing on improving the application method and on reducing the bacterial population. Similarly, captafol was the best for reducing levels of stored-seed fungi and eliminating pathogenic *Colletotrichum* spp. associated with legume seed. Studies are in progress on the effect of captafol on *Rhizobium* spp.

Surveys have commenced on changes occurring in the microflora of green and dry seed of *S. capitata* at CIAT-Quilichao and Carimagua during the year. The effect of inoculating seed of *Stylosanthes* spp. with *Colletotrichum* spp. on germination and seedling survival is also being studied.

ENTOMOLOGY

During 1979, the Entomology Section continued basic studies on the taxonomy and biology of the stemborer, *Caloptilia* sp., the most limiting insect pest of the genus *Stylosanthes*. Work was also intensified to understand the resistance and/or tolerance of several *S. capitata* accessions to the stemborer.

After two years of monthly field observations at CIAT-Quilichao and Carimagua, a consistent resistance and/or tolerance reaction to the stemborer damage was observed for several *S. capitata* and *S. guianensis* accessions.

Population dynamics studies were continued providing possible explanations of the observed population fluctuations of insects on legumes and grasses. Also, studies were initiated to evaluate damage caused by spittlebugs (genera *Aeneolamia, Zulia, Deois*, etc.) and aphids to *Andropogon gayanus* accessions.

Stylo Stemborer

Biology and biological control

During 1979, studies were conducted on the biology of the stemborer confirming last year's results (CIAT Annual Report, 1978) and its taxonomic identification as of the genus Caloptilia.

The wasp *Bracon* sp. (Hymenoptera:Braconidae) was again the most frequent parasite of the stemborer larvae found in CIAT-Quilichao.

Host plant resistance

Screening for resistance to stemborer was continued at CIAT-Quilichao and Carimagua under field and laboratory conditions. To date 10 *S. guianensis* and 9 *S. capitata* accessions have been evaluated. At CIAT-Quilichao, three *S. guianensis* accessions (CIAT

No. 1312, 1062, and 1162) showed less than one larvae per plant and seven *s. capitata* accessions (CIAT No. 1356, 1342, 1019, 1298, 1315, and 1405) showed either no damage or less than one larvae per plant which was lower than the initial level. At Carimagua, field evaluations were made in *S. capitata/A. gayanus* mixtures under grazing. Mixtures with both *S. capitata* 1019 and 1300 showed higher levels of stemborer infestation, than *S. capitata* 1405, but these are still considered low. Thus, *S. capitata* 1019 and *S. capitata* 1300 are considered to be resistant to stemborer (Table 23).

Laboratory studies under controlled conditions (26°C and 65% RH) were conducted utilizing *S. guianensis* 136 (considered as susceptible) and *S. capitata* 1019 (considered as resistant), to test for oviposition preferences of females of *Caloptilia*. Results show a high reduction in oviposition (89.5%) for *S. capitata* 1019 compared to *S. guianensis* 136 (153 and 1295 eggs oviposited, respectively).

Artificial diets were developed with ground dry stems of either *S. guianensis* 136 or *S. capitata* 1019 as the main components. Results showed that pupae reared on the *S. capitata* 1019-based diet were smaller (Figure 14). These preliminary results indicate that the possible mechanism of resistance observed in species of *S. capitata*, could be an antibiotic effect. Further studies on the stemborer progenies will be conducted to determine the possible effects of *S. capitata*-based diets on the fecundity, fertility and longevity of stemborer females.

Anatomical studies of stems (Figure 15) as well as chemical analysis of the glandular trichomes found in some *Stylosanthes* spp. accessions are being conducted to detect inter-or intra-specific differences in order to better understand the mechanisms of resistance to the stemborer observed in *S. capitata* spp.

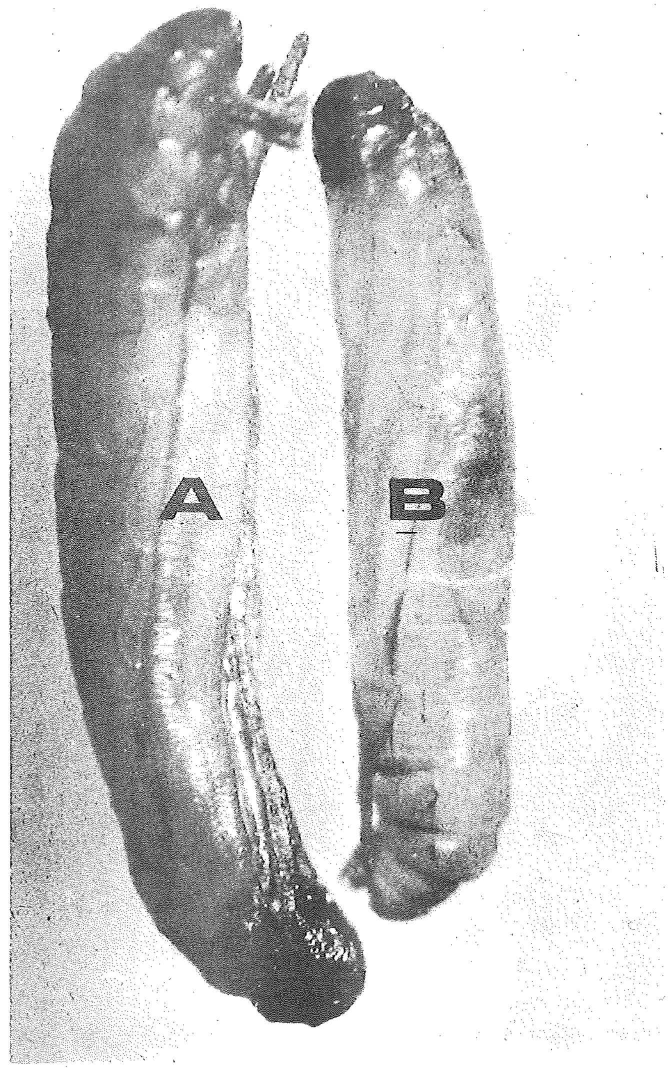

Figure 14. Difference in size of *Caloptilia* sp. pupae reared on (A) a *Stylosanthes guianensis* CIAT 136-based diet or (B) an *S. capitata* 1019-based diet.

Table 23. Resistance to stemborer (Caloptilia sp.) in two populations of Stylosanthes capitata in mixture with Andropogon gayanus under grazing at Carimagua.

S. capitata CIAT No.	Damaged plants (%)	No. of larvae/plant	Tunnel length (cm)
1019 + 1300	16.16 (a)[1]	0.23 (a)	0.71 (a)
1405	0.81 (b)	0.01 (b)	0.03 (b)

1 Means within columns followed by the same letter are not significantly different at a 0.05 level.

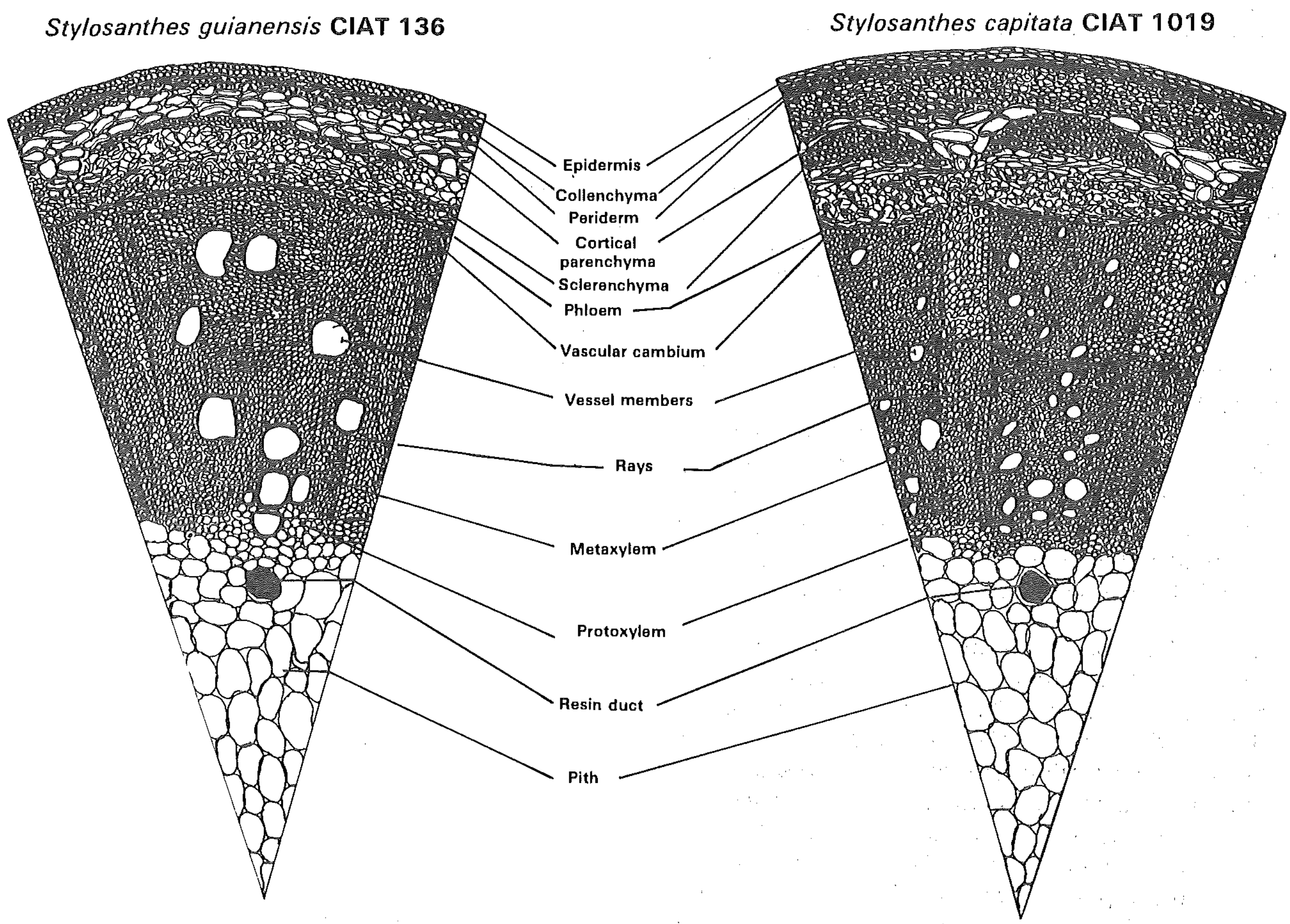

Figure 15. Comparative scheme of the internal structure of stems of *Stylosanthes guianensis* CIAT 136 and *S. capitata* CIAT 1019.

Within *Stylosanthes, S. capitata* continues to be the most resistant or tolerant species to stemborer damage in different ecosystems.

Population dynamics

Insect population fluctuations on 10 legumes and 3 grasses were studied at both Carimagua and CIAT-Quilichao. The objective was to identify and evaluate the most frequent insect populations and analyze insect preferences.

Dry-vacuum samples were taken at weekly intervals during 16 months. Insect orders, families and species were recorded and coded for later observations. Total insect distribution by orders is shown in Figure 16 for CIAT-Quilichao. Results also indicate that the pattern of insect distribution is similar in both the Carimagua and the CIAT-Quilichao ecosystems.

It is worthwhile indicating that the highest proportion of the insect population counts on legumes were homopterous (mainly Cicadellidae), and on grasses (especially *A. gayanus*), specimens of Diptera which include several beneficial species. Hemiptera and Hymenoptera populations were higher on legumes than on grasses, while Coleoptera populations were similar in both types of forages. A special reference to Homoptera population (mainly Cicadellidae) and Coleoptera (Chrysomelidae) is necessary as these two orders, together with Hemiptera, include many species which are known as vectors of viral, bacterial and fungal diseases (Table 24). However, the natural beneficial insect population is considered abundant and heterogenous in both ecosystems. Further studies will be conducted to characterize and establish the possible relationship of insect species and disease transmission.

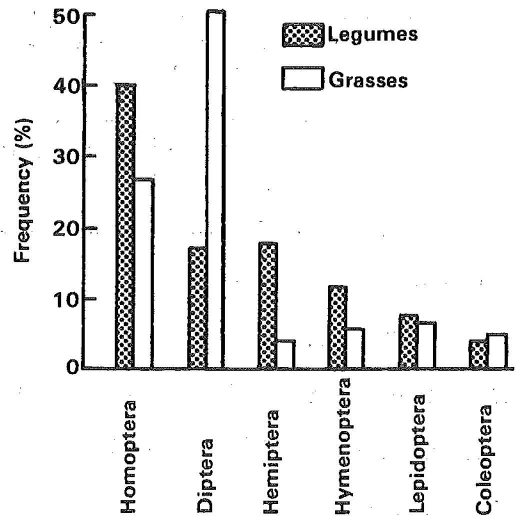

Figure 16. Distribution of insect populations (frequency) observed on legumes and grasses in CIAT-Quilichao experimental station during 1979.

Aphids

Although *A. gayanus* showed tolerance to insects prevailing in the region, an aphid attack was observed in some *A. gayanus* pastures in Carimagua. Thus studies on their possible relationship with the occurrence of red-purple leaves on *A. gayanus* were carried out. When plants of *A. gayanus* were exposed to different population levels of aphids under controlled conditions, there was an increase in the number of aphids and an increase of red-purple leaves.

Tolerance or resistance to damage caused by aphids was also studied under field conditions in four *A. gayanus* accessions. Results showed *A. gayanus* CIAT 6053 as possibly the most tolerant. On the other hand, six morphological type-forms of *A. gayanus* were tested for aphid attack under field conditions. Results showed that some of the morphological type-forms of *A. gayanus* tested could also be sources of tolerance to aphids.

Table 24. Identification and feeding habits of some insect genera involved in disease transmission in some accessions of forage legumes and grasses.

Insect	Feeding habit	Stylosanthes guianensis 136	Stylosanthes guianensis 184	Stylosanthes capitata 1019	Stylosanthes capitata 1978	Stylosanthes capitata 1405	Stylosanthes capitata 1097	Stylosanthes scabra 1047	Zornia 728	Centrosema 1733	Desmodium ovalifolium 350	Brachiaria decumbens 606	Panicum maximum 604	Andropogon gayanus 621	Macroptilium sp. 535
Homoptera:															
Scaphytopius fuliginosus	Sucking on leaves; disease vector										+				+
Empoasca sp.	Sucking on leaves; possible disease vector	+	+		+	+		+		+	+	+	+		
Graminella spp.	Sucking on leaves; vector of the corn stunt in grasses											+	+	+	+
Coleoptera:															
Chaetocnema sp.	Feeding on leaves; vector of the disease of Stewart in grasses			+	+	+	+		+			+	+		
Diabrotica graminae B	Feeding on leaves									+	+			+	
D. melanocephala F.	Disease vector									+	+			+	
D. gratiosa B.	Disease vector									+	+			+	
D. viridula F.	Disease vector									+	+			+	

Spittlebugs

Field evaluations of forty ecotypes of grasses for their resistance to spittlebugs (of the genera *Aeneolamia, Deois, Zulia* and others) were initiated at Carimagua. The first observations showed *Brachiaria ruziziensis* CIAT 654 and 656 and *Brachiaria* sp. CIAT 6058 as the most susceptible ones to the attack of spittlebug nymphs and adults. *A. gayanus* CIAT 6053, 6054, 635 and 621, however, showed low levels of infestation by nymphs and no adults (Table 25).

The effect of grazing on populations of spittlebug nymphs and adults was studied. The preliminary data show a greater reduction in the number of nymphs than of adults. This situation could be explained on the basis of adult activity that may allow them to escape or move from the site where the animal is grazing. These studies will be intensified.

Table 25. Infestation of spittlebug (Aneolamia varia) nymphs and adults on severity grass accessions at Carimagua.

Species	CIAT No.	Spittlebug nymphs/ 10 m^2	Spittlebug adults/ 25 m^2
Brachiaria sp.	6058	9.60	1.54
Brachiaria ruziziensis	656	5.83	1.23
Brachiaria ruziziensis	654	4.61	1.20
Andropogon gayanus	6053	0.07	0.07
Andropogon gayanus	6054	0.10	0.07
Andropogon gayanus	635	0.27	0.03
Andropogon gayanus	621	0.13	0.00

Entomological Evaluation in Regional Trials

Visits to several countries (Bolivia, Brazil, Colombia, Ecuador, Peru, Venezuela) were made in order to evaluate the regional trials established in different ecosystems regarding insect pest problems. Results show species of Homoptera/flea beetle complex, Chrysomelidae and Hemiptera, as common insect pests in most of the ecological regions. Also, the frequency distribution of insect orders is similar to the general pattern of insect pests registered in the population dynamics studies carried out at Carimagua and CIAT-Quilichao. It is important to point out that beneficial insect populations, represented by several orders and species, are abundant in all locations. This suggests a good possibility of using biological control in an integrated pest management scheme for tropical pastures in Latin America. To date, forage legumes are more frequently affected by insect pests than grasses. *S. capitata,* one of our promising legumes has shown consistent resistance or tolerance to the stemborer *Caloptilia* sp., considered as a key pest of the genus *Stylosanthes.* In the case of grasses, *A. gayanus* has not shown any serious insect pest up to the present time.

SEED PRODUCTION

The Seed Production Section continues to meet two basic objectives: (1) seed increase of experimental lines to be used by the Program and its collaborators and (2) development of relevant technology for commercial seed production.

During 1979, major emphasis was placed on expanding grass and legume areas for seed multiplication purposes. The total area harvested increased significantly as well as the total volume of seed produced. The technology development efforts were restricted to the initiation of the field experimental phase of the regional seed production potential project and to the quantification of certain aspects of seed handling of *Andropogon gayanus.*

Seed Increase

Seed increase activities are confined to accessions nominated by the Program's Germplasm Committee. An initial production target is related to the five categories assigned and reflects an estimate of seed required to establish new experiments to fulfill the next evaluation phase by other program sections. In the case of accessions in categories IV or V, an additional production target may be undertaken to fulfill a defined experimental proposal. Actual crop areas established are defined by interrelating the seed production target for the particular accessions with the seed multiplication rate for the species in the particular location where it is to be grown.

In the case of new germplasm very often the supply of planting material (seed or vegetative material) limits the seed multiplication area which can initially be established. This requires the use of single plant transplanting, and vegetative propagation or successive cycles of crop expansion following seed harvesting. The net effect is a general lag phase of one to two years before the production target is attained.

Production areas are located at CIAT-Palmira, CIAT-Quilichao and Carimagua to exploit climatic and edaphic differences and also to distribute risk and effort. All processing, storage and distribution activities are centered at CIAT-Palmira. All three locations experience little day-length variation due to their common low latitude (3-4°N). Rainfall distribution is bimodal at CIAT-Palmira and CIAT-Quilichao (where irrigation is available), while at Carimagua rainfall is unimodal with a prolonged growing season. With the inherent sensitivity of forage species to climatic and edaphic factors, the relationship between actual seed yields and potential seed yield varies with each species.

A summary of the main seed increase activities during 1979 is presented in Table 26. Seed of a total of 39 accessions (37 legumes and 2 grasses) was increased. The legumes were essentially located at

Table 26. Seed increase activities during the year (October 1978-1979).

Description	Location			Average or sum
	CIAT-Palmira	CIAT-Quilichao	Carimagua	
Number of introductions				
Grasses	2	2	1	2
Legumes	4	33	4	37
Crop areas (ha)				
New	12	6	25	43
Total	15	9	27	51
Seed harvesting				
Area (ha)	17[1]	16[1]	7	40
Method (%)				
Manual	90	80	100	90
Mechanical	10	20	0	10
Distribution of seed				
Requests (No.)	-	-	-	
CIAT	-	-	-	143
Outside	-	-	-	57
Total weight (kg)				
CIAT	-	-	-	4002
Outside	-	-	-	137
Seed Produced (kg)				
Grasses	2185	812	388	3385
Legumes	468	1080	426	1974
Total	2653	1892	814	5359

1 Areas of certain accessions were harvested twice.

CIAT-Quilichao to allow concentration of small plot management but four high priority accessions were also planted at Carimagua on a scale appropriate for combine harvesting. Grasses were multiplied over all three locations but with the larger area at CIAT-Palmira. A record total new crop area of 43 ha was successfully established this year. These areas include a significant additional production target relating to *Andropogon gayanus.* The total area established for seed production purposes now reaches 51 ha.

With a trend toward increasing average plot size of the higher category accessions, it was possible to increase harvesting by mechanical means. This trend represents a significant operational development as the section has reached its absolute capacity in terms of manual harvesting. Mechanical harvesting capacity was further improved with the addition of a tractor-mounted suction harvestor. This machine provides both an alternative and supplementary harvest method for some species under experimental increase conditions. It has particular potential for harvesting *Desmodium heterophyllum.* Processing the large volumes of *Andropogon gayanus* has been a slow and dirty operation. While the mechanical deawner has functioned well, it needs to be complemented by mechanical handling and dust control measures in the processing line.

Total volume of seed production was 5359 kg with the largest volumes corresponding to *A. gayanus, Stylosanthes capitata, S. hamata, D. ovalifolium, Zornia latifolia, Codaricolyx* (syn. *Desmodium*) *gyroides* and *D. heterophyllum* (Table 27).

The new storage facilities have allowed basic organization of seed stocks in terms of storage and inventory control. Dry seed is stored in sealed containers. Seed distribution has involved responding to a total of 200 requests and the delivery of 4586 kg of seeds.

Table 27. Summary of forage seed produced by species between October 1978 and October 1979.

Species	Number of accessions	Total weight of seed (kg)
Legumes[1]		
Aeschynomene sp.	1	1
Centrosema spp.	5	8
Codariocalyx gyroides	1	46
Desmodium ovalifolium	1	61
Desmodium heterocarpon	1	10
Desmodium heterophyllum	1	25
Glycine wightii	2	15
Pueraria phaseoloides	1	4
Stylosanthes capitata	10	1190
Stylosanthes hamata	1	550
Stylosanthes humilis	1	1
Stylosanthes guianensis	1	2
Stylosanthes viscosa	1	1
Zornia latifolia	10	60
Total legumes		1974
Grasses[2]		
Andropogon gayanus	1	3382
Panicum maximum	1	3
Total grasses		3385
Total all accessions	39	5359

1 Legumes: seed or seed in pods, > 95% purity.
2 Grasses: seed, > 40% purity.

Seed Production Technology

Andropogon gayanus

Seed purity determination

In chaffy grasses, there are alternative definitions and methodologies to estimate the proportion of a seed lot consisting of pure seed. Purity determinations, however, are always defined on a weight basis. By the standard international definition, purity refers only to those spikelets which contain the confirmed presence of a caryopsis. Awns, empty spikelets, vegetative plant parts, sand and soil are assigned to the inert matter fraction. This is the most precise and desirable definition. However, when separation work of the working sample for purity analysis is conducted manually, spikelet by spikelet, this task is both laborious and time consuming.

Investigations have continued to verify the utility of the definition and methodology referred to as Indirect (International) Purity. This method is based on the relationship between Caryopsis Content (the proportion of spikelets containing a confirmed caryopsis and expressed as percent based on number) and the Actual Purity (estimated by manual separation) of the spikelet fraction. This relationship has been quantified by linear regression using a basic data set of both Caryopsis Content and Actual Purity of the spikelet fraction as measured in 35 seed samples. The regression coefficient was estimated as 1.123 with a $R^2 = 0.9899$ (Figure 17).

The procedure to determine indirect (International) purity in any seed sample is to estimate (1) Spikelet Content (or Irish pure seed) and (2) Caryopsis Content. These observations are then used in the following formula:

$$\text{Indirect (International Purity)} = \underset{\%\ (\text{weight})}{\text{Spikelet Content}} \times \left[\underset{\%\ (\text{no.})}{\text{Caryopsis Content}} \times 1.123 \right] \div 100$$

$$= \left[0.0123 \times \text{Spikelet Content} \times \text{Caryopsis Content} \right] \%\ (\text{weight})$$

where Spikelet Content (or Irish purity) is defined on a 5 g random sample of the seed lot.

Caryopsis Content is determined upon 200 random spikelets (or Irish pure seeds).

1.123 is the regression coefficient expressing the generalized relationship between Caryopsis Content and International Purity of this species.

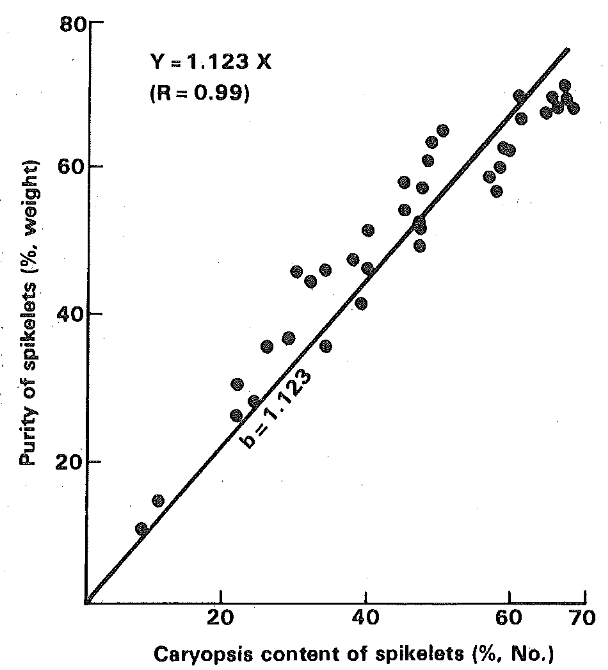

Figure 17. Regression of purity and caryopsis content of spikelets in *Andropogon gayanus* CIAT 621.

The degree of precision or relationship between purity as measured directly by manual separation and by the indirect formula method, was estimated by testing the correlation between values derived from 47 seed samples (Figure 18). A highly significant value of 0.98 was found. It was concluded that the indirect formula method does have sufficient precision to warrant its use.

The advantages of the indirect method are: (a) determinations can be made in 25% of the time required by the hand separation method; and (b) its precision is relatively high. The indirect estimate of purity depends heavily on the representativeness of the 200 spikelets which enter the determination of Caryopsis Content. Obviously, variation will be caused by sampling errors present with masses of light, fluffy seed.

The basic utility of the indirect method lies not in its capacity to measure purity in absolute terms but in the greatly increased capacity it offers to estimate yield of pure seed. In a program with both production and experimental objectives, there is a need to record both seed weight and purity of a large number of samples so as to determine pure seed yield. A purity determination, therefore, must be reasonably rapid and precise while not extreme in either regard.

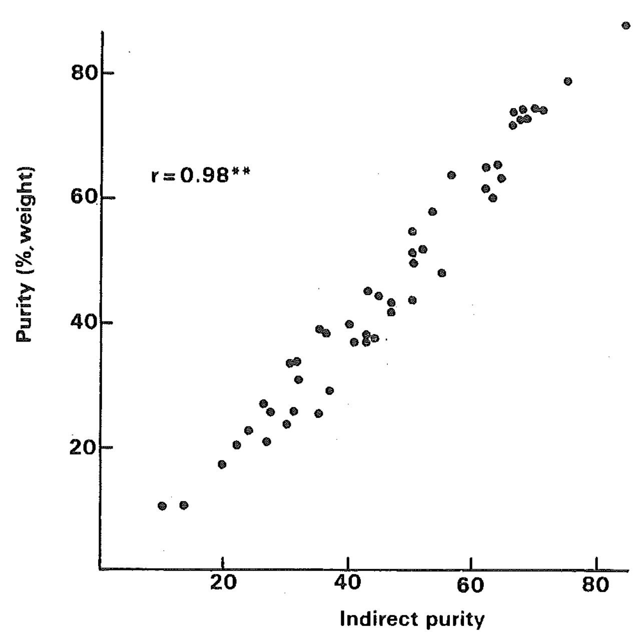

Figure 18. Correlation between direct and indirect estimates of seed purity in lots of clean seed of *Andropogon gayanus*.

Crop maturity patterns

A preliminary study of crop and seed maturity was conducted at CIAT-Palmira based upon replicated spikelet collections made at eight intervals during crop maturation.

Weight of harvested spikelets reached a maximum at 22 days after peak flowering and declined markedly after 36 days. The proportion of spikelets containing caryopsis ranged from 24-68%, indicating temporal variations in the overall efficiency of seed set, but was at a maximum at 43 days after peak flowering.

Weight of pure seed spikelets was at a maximum at 22 days after peak flowering and declined very markedly after 43 days. Unit weight of pure seed spikelets tended to decline constantly from a maximum of 292 mg/100 at 22 days after peak flowering to 250 mg/100 pure seed spikelets after 64 days (Figure 19).

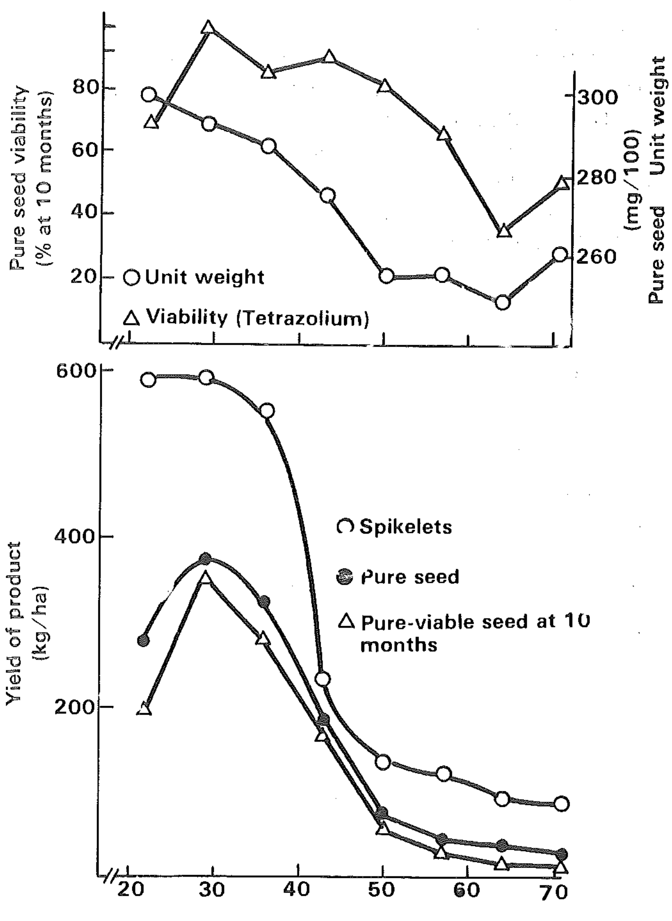

Figure 19. Characteristics of pure seed and yield dynamics during crop maturity of *Andropogon gayanus* CIAT 621, at CIAT-Palmira.

Both viability and germination of pure seed spikelets exhibited maximum values of approximately 90% (at 10 months post-harvest), while showing some tendency to decline from 50 days after peak flowering.

Both yield of pure seed and yield of pure viable seed increased to their maximum values which were recorded at 29 days after peak flowering and then declined rapidly, especially after 36 days when the rate of shedding was at a maximum.

The optimum point of harvest maturity should coincide with maximum yield of pure viable seed. On this basis, harvest maturity occurred approximately 29 days after peak flowering. As maximum yield of spikelets preceeded this point by approximately seven days, shedding of spikelets is initiated before optimum harvest maturity; in fact, spikelets will be shed at least two weeks before harvest maturity.

Seed processing

The seed mass of *A. gayanus* is light and adhesive because of the pilose and awned spikelets. This poses handling problems compared with other grasses. Bridging effects impede mechanical transfer to conventional hoppers or elevators while clumping reduces the rate and efficiency of passage across flat screens.

A mechanical deawner or modified hammer mill (where both hammers and interior cylinder are rubberized) has been used to homogenize particle size, remove awns and thereby allow improved flow rates and separation across an air screen cleaner.

A comparison was made of seed mechanically processed by the deawner and then the air screen cleaner, to seed only subjected to manual scalping after hand threshing. Results are presented in Table 28. The deawning function is obviously very effective provided the crude seed is dry when fed into the deawner. The increases in caryopsis content and purity indicate the ability of the air screen cleaner to eliminate dust, awns, and small particles of vegetative material but also many small or empty spikelets and florets. Bulk density is also increased by approximately 39% (relative basis). Germination is not reduced by the mechanical handling and may even be improved for an initial period. Longer term effects still need to be defined.

The data in Table 28 represents two extremes of alternative processing pathways. The actual crude

Table 28. Characteristics of unprocessed crude seed and mechanically graded seed in three lots of *Andropogon gayanus*.

Description	Crude seed[1]		Graded seed[2]	
	Mean	Range	Mean	Range
Deawned spikelets (%, No.)	28	22-34	94	88-98
Spikelet Content (%, weight)	71	67-75	92	88-95
Caryopsis Content (%, No.)	39	34-46	51	37-64
Purity (%, weight)	30	27-36	51	37-62
Germination (%, No., at 10 months)	21	8-43	39	34-45
Pure Live Seed Content (%, at 10 months)	6	2-15	20	13-28
Bulk density (kg/m^{-3})	47	45-49	65	59-71

1 Seed material after hand threshing, without any mechanical refinement.
2 Seed material after hand threshing, followed by one pass through a mechanical deawner and two passes through an air-screen cleaner.

Table 29. Locations, collaborators, and legume and grass introductions established in the regional seed production potential network.

Location	Latitude	Altitude (m)	Collaborating institution[1]	Date of planting	No. of introductions established	
					Legume	Grasses
Bolivia						
Chapare	16°S	250	COTESU	Dec. 1978	9	3
Santa Cruz	17°S	200	CIAT	Jan. 1979	5	2
Brazil						
Brasilia	15°S	1007	CPAC	Dec. 1978	9	4
Felixlandia	18°S	600	EPAMIG	Jan. 1979	11	3
Sete Lagoas	19°S	700	EPAMIG	Dec. 1978	6	3
Colombia						
CIAT-Quilichao	3°N	1100	-	Oct. 1978	10	3
Valledupar	10°N	340	ICA	May 1979	3	5

1 COTESU, Cooperación Técnica del Gobierno Suizo; CIAT, Centro de Investigación Agrícola Tropical; CPAC, Centro de Pesquisa Agropecuaria dos Cerrados; EPAMIG, Empresa Brasileira de Pesquisa Agropecuaria de Minas Gerais; ICA, Instituto Colombiano Agropecuario.

seed samples in this study had received the benefit of a partial hand scalping of the threshing material, so averages for typical crude lots will be lower. The mechanically processed seed was all passed twice through the cleaner, whereas commercially it is highly probable that only one pass will be made and slightly lower values will result.

The relative demand for crude and graded seed will be influenced by the planting system used and the costs of seed transport. Crude seed will undoubtedly be used where seed is produced on the same farm and where mechanical planters are unavailable or too costly. Graded seed will facilitate more precise and mechanical planting and will reduce storage and transport costs. Where seed is combine-harvested mechanical scalping could be desirable before drying or deawning.

Regional Seed Production Potentials

As part of an overall assessment of regional seed production potentials, a field experimental phase was initiated in six regions during 1979. Actual regional locations and collaborators are shown in Table 29. The initial, emphasis was to initiate the project at locations in higher latitude regions with some seasonality of rainfall distribution and low frost incidence and to collaborate with institutions already active in germplasm evaluation.

The field experiment aims to define phenology, seed yields and the incidence of weeds, pests and diseases, while additional climatic, edaphic, agronomic and economic data are collected from other sources for each region.

The genetic materials included were nominated by both the collaborator and CIAT. Each material was sown in pure stands in 80m² plots with three replications.

Adverse seasonal conditions had negative effects on the number of entries established and within-site variability at Santa Cruz, Sete Lagoas and Valledupar. Weeds were a problem for the legumes at Sete Lagoas reflecting site history. The first year seed harvests of grasses and legumes were made at Chapare, Brasilia, Felixlandia CIAT-Quilichao and Santa Cruz, while only grasses were harvested at Sete Lagoas.

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, with priority given to the legume/*Rhizobium* symbiosis. The research strategy is: (1) to maintain and enlarge 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 Tropical Pastures Program's target area.

Rhizobium Collection

The addition of 55 *Rhizobium* strains in 1979 brought the bank number to 2098. Information about the entire collection is recorded in a retrieval system detailed in the CIAT *Rhizobium* Catalogue.

Nodule collection, especially from *Zornia* spp., was carried out in the Llanos Orientales of Colombia (Meta and Vichada departments). Complete information for each site was collected and soil samples were taken for analysis.

Strain Selection

The five stages of *Rhizobium* strain selection have remained unchanged since 1977 (CIAT Annual Report, 1977).

Stage I (Aseptic tube culture)

Although Stage I testing was delayed due to unavailability of a growth chamber, alternate systems were explored.

In a hemotoxilin study with the Soil Nutrition Section, nodulation occurred in a non-aerated system, indicating the potential for replacement of the currently used agar plates with nutrient solution. Several nutrient solutions were tested and growth pouches were selected for a comparative study with the routine, enclosed-plant, agar tube method. The former system employs plastic bags filled with nutrient solution and a paper wick. One apparent advantage is that six times as many treatments can be placed in the same space in the light room. Plant appearance, days to nodulation, and location and abundance of nodules of several legumes was observed in both systems. Norris and Date as well as Hoagland's nutrient solutions (modified to simulate acid soil stresses, with or without 3 ppm Al) were used in the growth pouches, while Jensen's agar was used in tubes. Preliminary results show more rapid and enhanced plant growth in growth pouches. One hundred and nine strains were proven infective on a member of the host genus from which they were isolated.

Stage II (Sand culture with nutrient solution, pH 7)

The lack of a suitable inert matrix to substitute the previously used river sand limited the number of tests completed in 1979.

Zornia latifolia 728 and *Stylosanthes capitata* 1315 were not able to establish sufficient root growth in the N free quartz sand to permit nodulation initiation. Starter nitrogen at the rate of 5 ppm N will be used.

Stage III (Pot culture in site soil)

Evaluation of nine *Desmodium* isolates on *D. ovalifolium* 350 grown in soil from CIAT-Quilichao was repeated due to anomalous results compared to those obtained in Stages II and IV. The first Stage III test indicated that strains varied significantly in their ability to affect dry matter production, *Rhizobium* sp. CIAT 283 ranking first among inoculating strains (Table 30). However, it was not better than native *Rhizobium* as indicated by its statistical equivalence with the non-inoculated control without applied N. In the second Stage III test, *Rhizobium* sp. CIAT 283 produced more dry matter than the control with applied N, although

Table 30. Comparison of rankings obtained for Rhizobium strains in Stage II and two identical Stage III studies with Desmodium ovalifolium CIAT 350.

Rhizobium strain CIAT No.	Mean dry matter yield: Stage III November 1978 (g/2 shoots)		Stage III July 1979 (g/2 shoots)		Stage II July 1978 (g/2 plants)	
+N control	1[1]	4.98a[3]	2[1]	12.52a	2[1]	0.411a
-N control	2	4.07ab	6	11.46a	37[2]	0.054g
283	3	3.95ab	1	14.14a	11	0.202bcdefg
359	4	3.75b	8	10.91a	3	0.402a
388	5	3.59b	11	10.39a	5	0.338abc
297	6	3.42bc	10	10.66a	9	0.254bcdef
533	7	3.32bc	7	11.42a	8	0.264abcdef
512	8	3.29bc	4	12.09a	4	0.347ab
529	9	3.02bc	5	11.68a	7	0.295abcd
507	10	2.86bc	3	12.09a	1	0.419a
299	11	2.33c	9	10.68a	6	0.334abc

1 Overall rank by means.
2 In the Stage II experiment some of the best out of 39 strains and the nitrogen controls are shown.
3 Mean values within columns followed by the same letter are not significantly different at a 0.05 level.

not significantly. In the Stage II test, CIAT 283 was the least effective.

The lack of correlation between Stage III tests may have been due to seasonal effects on rhizobial performance. This needs to be determined with duplicate experiments established in the field and harvested at time intervals to measure wet and dry season effects on foliage production and inoculation response.

To test the response of *Z. latifolia* 728 and *S. capitata* 1315 to 15 *Rhizobium* strains, a contamination-free system, enabling more plants to be placed in the same space (50/m^2 vs. 9/m^2), was adopted.

Statistical analysis of *Zornia* shoot dry matter production in CIAT-Quilichao and Carimagua soils indicated no significant difference between strains, nor between strains and the plus and minus N controls. The high N content of the CIAT-Quilichao soil may mask inoculation responses. In Carimagua soil, results may indicate the presence of efficient native *Rhizobium* strains. Antisera will be prepared to determine the identity of the nodulating strains.

Although dry matter yields of *S. capitata* CIAT 1315 in Carimagua soil were not analyzed statistically, a visual evaluation of nodulation indicated that strains CIAT 301 and 871 were superior. Mean dry matter production of *S. capitata* 1315 in the CIAT-Quilichao soil (Table 31) shows *Rhizobium* strains CIAT 301 and 1363 to be superior.

Table 31. Stylosanthes capitata CIAT 1315 mean dry matter production under greenhouse conditions in soil from CIAT-Quilichao (Stage III).

Rhizobium strain CIAT No.	Rank[1]	Mean dry matter yield (g/2 shoots)
71	12	1.76ab[2]
79	10	1.78ab
301	1	2.10a
763	5	1.96ab
765	4	1.96ab
870	11	1.78ab
871	7	1.88ab
882	3	2.00ab
887	16	1.53ab
1238	8	1.83ab
1358	6	1.91ab
1359	13	1.72ab
1363	2	2.10a
1460	14	1.71ab
1468	17	1.29b
+N control	15	1.56ab
-N control	9	1.82ab

1 By mean dry matter production.
2 Mean values followed by the same letter are not significantly different at a 0.05 level.

Stage IV (Field trials)

In Stage II and Stage III tests (CIAT Annual Report, 1978), strain-dependent statistical differences were observed for *D. ovalifolium* 350 inoculation response. In Stage IV experiments, although results were statistically significant for the first cutting, this was not so for further cuttings in 1979. The inoculant technology experiment at CIAT-Quilichao utilizing three strains and three pelletization technologies again did not show significant treatment effects after the first cutting, nor for treatment yields accumulated over all harvests.

The purpose of a 31-strain, single replicate experiment with *Leucaena leucocefala* CIAT 871 was to determine if any strain could nodulate this legume in an acid soil. However, by accumulating dry matter over two harvests as replications, a Duncan multiple range test was run on the inoculation response. At Carimagua, no statistically different yield responses to strains were observed (Table 32). The five highest ranking strains for the first harvest were different from those of the second.

After the second harvest, roots of five plants from each treatment were rated for nodulation. The treatment nodulation scores were not significantly correlated with dry matter yield. In treatments with greater than average dry matter production, only half had better than average nodulation. Native *Rhizobium* or contamination from inoculated plants produced nodules on plants in non-inoculated treatments. Some strains found to be initially good nodulators such as CIAT 1967 and 1920 (Carimagua Annual Report, 1978) were poorly infective this year, while other strains improved. At CIAT-Quilichao, statistical yield differences were recorded for accumulated harvests.

The establishment of a study with *S. capitata* 1315 and *Z. latifolia* 728 for strain selection was undertaken at CIAT-Quilichao and Carimagua.

Verification of Stage IV results. Recorded inoculation responses should be verified by determining that

Table 32. Dry matter production accumulated over two harvests by *Leucaena* sp. CIAT 871 inoculated with *Rhizobium* strains in Carimagua.

Rhizobium strain CIAT No.	Mean dry matter yield (kg/ha)	Nodulation[2] score (second harvest)	Rhizobium strain CIAT No.	Mean dry matter yield (kg/ha)	Nodulation score (second harvest)
1920	610	3	42	370	6
1967	540	5	685	362	5
1919	533	10	1921	361	7
1931	524	11	1963	352	8
1939	480	10	1961	345	12
1964	471	9	847	338	5
1966	468	7	1923	337	7
1965	460	10	1959	301	10
1934	449	10	1732	284	5
+N control	433	2	1937	259	8
1944	429	4	1747	251	7
1740	418	5	1742	250	8
1735	415	6	1947	237	8
346	399	4	-N control	234	1
843	394	6	1962	137	2
1942	375	10	1927	121	10
1917	371	13	9	85	1

1 No significant differences were found between strains.

2 Sum of five plants scored by visual inspection (3 = abundant, 2 = moderate, 1 = scarce, 0 = none; average = 6.9).

the nodules formed on the plant correspond to the inoculating strain. This is especially necessary under the septic conditions in the field where competitive native *Rhizobium* may be nodulating the plant. In order to accomplish this, several additions to the laboratory's antisera collection have been made.

Inoculation Response Potential

Due to the high N content in the CIAT-Quilichao soil, the potential for dry matter production responses to inoculation is questionable. A control of ground corn stalk (2 t/ha) was incorporated in the *S. capitata* 1315 experiment established at CIAT-Quilichao. If there is a large difference between this treatment and the minus N control, strain selection at CIAT-Quilichao should be re-evaluated, as high soil N may be limiting inoculation response.

Inoculant Recommendations Extrapolability Study

A host-range study is in progress to determine the infectivity and efficiency of several *Rhizobium* strains on various promising lines of *Stylosanthes*.

As in Stage I, infectivity of strains under defined, acid soil conditions was studied in growth pouches. Information on the range of infectivity will be used in planning Stage II and III experiments to study the efficiency of a strain under defined, aseptic conditions and in septic site soil. This information will help clarify the limitations to strain recommendation.

This type of information is apparently necessary as related *Desmodium* species reacted very differently to *Rhizobium* at the Carimagua field station. *D. ovalifolium* 350 nodulated readily in the non-inoculated plots. None of the three strain x three inoculant-technology treatments significantly increased dry matter production over the plus and minus N controls. Native *Rhizobium* appear to be equally effective as the best strains selected from among 70 *Desmodium* isolates at preliminary screening levels. On the other hand, *D. heterocarpon* 365 (taxonomically the same species as *D. ovalifolium, D. heterocarpon* var. *heterocarpon)* appeared chlorotic and nodulated poorly. An effective inoculant would prove to be of great advantage for this accession. Stage I, II and III experiments to select suitable inoculant strains are in progress.

Comparison of Acid and Rich Media for Rhizobium Culturing

Phenotypic differences between strains isolated from a single nodule have been observed. Isolates grown on routine (rich) laboratory medium may demand special growth factors, and may not be suited for acid soils. Furthermore, strain storage on such media has been considered a cause of loss of competence (survival and infectivity) under field conditions. On the other hand, strains were less efficient when maintained on acid medium. A study is in progress to determine the best isolation medium, and to determine the correlation, between type of isolation-maintenance medium and strain efficiency with time under defined, acid conditions.

Table 33. Growth and stability of *Rhizobium* strains in various acid screening media and changes in the pH of the latter.

Culture medium[1]	*Rhizobium* CIAT No.[2]		Cell density (cells/ml) Initial	Final	pH Initial	Final
1	270	A	$2.2.10^{4}$	$8.28.10^{3}$	4.7	4.75
		B		$1.12.10^{8}$		4.50
	861	A	$1.8.10^{4}$	1.10		4.7
		B		1.10_{3}		4.7
	907	A	$3.5.10^{3}$	$1.49.10^{3}$		4.7
		B		$1.75.10^{3}$		4.7
2	270	A	$2.2.10^{4}$	$4.\ 7.10^{8}$	4.7	6.9
		B		$9.\ 1.10^{7}$		7.3
	861	A	$1.8.10^{4}$	0.10^{1}		4.8
		B		0.10^{1}		6.2
	907	A	$3.5.10^{3}$	$1.\ 2.10^{8}$		4.5
		B		$6.\ 9.10^{8}$		4.5
3	270	A	$2.2.10^{4}$	$1.\ 2.10^{7}$		6.0
		B		-		-
	861	A	$1.8.10^{4}$	$>.10^{1}$		5.1
		B		$>.10^{1}$		5.2
	907	A	$3.5.10^{3}$	1.10^{6}		5.5
		B		8.10^{6}		6.2
4	270	A	$2.2.10^{4}$	$4.\ 4.10^{7}$	4.7	4.9
		B		$3.\ 7.10^{6}$		6.5
	861	A	$1.8.10^{4}$	$1.\ 0.10^{9}$		4.8
		B		-		-
	907	A	$3.5.10^{3}$	$>.10^{1}$		4.3
		B		2.10^{7}		4.9
5	270	A	$2.2.10^{4}$	$2.\ 2.10^{8}$	6.6	6.6
		B		$>.10^{6}$		4.9
	861	A	$1.8.10^{4}$	$>.10^{1}$		4.9
		B		1.10^{3}		4.8
	907	A	$3.5.10^{3}$	$4.\ 6.10^{7}$		6.5
		B		$3.\ 2.10^{7}$		6.6

1 Key to media: 1 = Keyser's with glycerol, no pH indicator; 2 = Keyser's with glycerol, with bromocresol green pH indicator; 3 = Keyser's with arabinose, no pH indicator; 4 = Keyser's with arabinose, with bromocresol green pH indicator; 5 = Yeast mannitol medium, no pH indicator.

2 Replicates A and B.

Table 34. Current inoculation recommendations developed for several promising forage legumes.

Species	Accession CIAT No.	Rhizobium strain CIAT No.	Technology
Category 4			
Desmodium ovalifolium	350	299	Rock phosphate pellet
Zornia latifolia	728	71	Rock phosphate pellet
Stylosanthes capitata	1019, 1315	71 + 1238	Rock phosphate pellet
Pueraria phaseoloides	9900	79	Rock phosphate pellet
Category 3			
Stylosanthes capitata	1318, 1323, 1325, 1342, 1405, 1728, 1943	71 + 1238	Rock phosphate pellet
Zornia spp.	9179, 9220, 9245, 9258, 9260, 9270, 9286, 9295, 9648	71	Rock phosphate pellet
Aeschynomene brasiliana	9681, 9684	71	Rock phosphate pellet
A. histrix		71	Rock phosphate pellet
Desmodium heterophyllum	349	31	Rock phosphate pellet
Stylosanthes hamata	147	71	Rock phosphate pellet
Codariocalyx gyroides	3001	299	Rock phosphate pellet

The acid medium was slightly modified and two carbon sources (arabinose and glycerol) were tested for ability to support rhizobial growth without a change in the pH. Bromocresol green, a pH indicator with an equivalence point in the acid range (pH = 4.5), was also tested for possible adverse effects on rhizobial growth. Preliminary results indicated that both media permitted rhizobial growth, while final reaction was dependent on the strain (Table 33). Glycerol was chosen as a suitable, yet less expensive C-source (US$461.90/kg and $9.55/kg for arabinose and glycerol, respectively).

Strains have been isolated from nodules collected from *Z. latifolia* 728 and *S. capitata* 1315 grown under greenhouse conditions in a non-inoculated Carimagua soil. The cultures were obtained by streaking rich and acidified rhizobial media with the cell suspension from a single nodule. The paired isolates' efficiencies will be compared under defined conditions in Leonard jars. This study will be periodically repeated to determine if there are adverse effects of storage on either media over time.

Inoculant Recommendations

The inoculant recommendations for promising legume accessions are given in Table 34. During 1979, 63 kg of peat-based inoculum were produced, 36 kg were used by CIAT and the Instituto Colombiano Agropecuario (ICA), while 12 and 8 kg were sent to national and international agencies, respectively, and 7 kg to private entities.

SOIL FERTILITY AND PLANT NUTRITION

The overall objective of the Soil Fertility and Plant Nutrition Section is to identify and correct mineral deficiencies and toxicities during the pasture establishment period on the acid soils with low native fertility of the Tropical Pastures Program target area. The research strategy takes into account the soil-plant relationship as an important criteria to define the critical nutrient requirements and tolerance to certain mineral stresses. The specific objectives of this section are: (1) to select germplasm for tolerance to Al and Mn toxicity, and low available P in the soil; (2) to determine the nutrient requirements of promising germplasm during the establishment period; and (3) to identify the nutritional status of soils and forage plants in representative regional trial sites of the Tropical Pastures Program.

Attention was focused this year on: (1) germplasm selection for tolerance to Al toxicity and low available P in the soil; (2) systematic estimation of the nutrient requirements of promising grass and legume accessions; and (3) evaluation of the soil fertility-plant nutrition status in regional trials.

Tolerance to Al Toxicity and Low Available P

There is clear evidence that most of the acid Oxisols and Ultisols of the target area have high Al levels in the soil profile that adversely affect the productivity of forage species. One of the most striking effects of high Al saturation in the soil is a reduction of root penetration inhibiting the use of subsoil nutrients and moisture. In addition, these soils require a certain amount of P fertilizer to counteract their high P fixation capacity and satisfy the plant's needs for adequate yield. Al toxicity and P deficiency frequently occur simultaneously in these soils. It is difficult to separate these two problems because of the tendency of Al to react chemically with P.

When taking into consideration the present high cost of P fertilizers and the strong evidence of differential responses of forage species in tolerating high Al levels and low P levels in the soil, it appears that the selection and use of forage species and/or accessions tolerant to both situations must be considered as an integral part of the solution to the problems challenging the Tropical Pastures Program.

A preliminary selection for tolerance to high soil Al was carried out for the large number of forage germplasm introduced to the Program's collection. The technique used was simple and rapid and is based on a visual estimation of the stainability of the root system of young seedlings and is calibrated with controls of known Al tolerance. This method uses a hematoxilian solution (0.2%) which has a high affinity for Al and permits distinguishing between tolerant and less tolerant plants. All forage accessions were grown in three Al treatments (0, 5, and 10 ppm Al with 0.5 ppm P) in a 1/10 Arnon and Hoagland solution. The differentiation of meristem tissues between tolerant and sensitive accessions to Al toxicity was readily determined as the concentration of Al in the seedling root increased in relation to the reduction in root elongation.

The results showed that genera *Stylosanthes* and *Zornia* had the largest number of accessions tolerant to Al and *Centrosema* and *Macroptilium* the largest number of sensitive accessions (Table 35). Although Al tolerance varied widely at the genera level, it also varied markedly among accessions within genera. Since the grass and legume germplasm has been previously classified in categories based on qualitative field evaluations in Carimagua, the results from the hematoxilin tests were related to field performances. This relationship is presented in Table 36 which includes germplasm in categories II, III and IV. The comparison between the hematoxilin tests and the field results shows a close relationship. Consequently, screening of forage accessions for Al tolerance using the hematoxilin test meets the requirements of simplicity, quickness, high-volume screening, and accuracy.

Morphological and Physiological Effects of Al Toxicity

Due to the close relationship between the hematoxilin test and field data, a better understanding of the morphological and physiological changes that occur in the forage legumes from Al toxicity was necessary. Accordingly, a study was designed to determine the effect of Al on the growth of three *Stylosanthes* species and to identify, through the hematoxilin test, anatomical and morphological changes in roots resulting from Al toxicity. The results of this study are shown in Figure 20. Al damage to tops and roots of these *Stylosanthes* species varied markedly. In general, however, *S. capitata* and *S. guianensis* were less affected than *S. sympodialos,* an Al sensitive species. A 69% reduction in root length was observed for *S. sympodialos,* while only 13 and 19% reductions for *S. capitata* and *S. guianensis,* respectively. Dry matter of tops and roots decreased in a similar manner.

From a nutrient standpoint, increasing Al resulted in a decreased P, Ca and Mg content in the tissues

Table 35. Evaluation of forage legume germplasm for aluminum tolerance by the hematoxilin test.

Genera	No. of accessions evaluated	Tolerant		Sensitive	
		5 ppm Al	10 ppm Al	5 ppm Al	10 ppm Al
Stylosanthes	296	197	182	99	114
Zornia	156	112	93	44	63
Centrosema	151	23	15	128	136
Macroptilium	104	19	19	85	85
Vigna	69	10	10	59	59
Phaseolus	9	1	1	8	8
Aeschynomene	93	42	32	51	61
Calopogonium	55	0	0	55	55
Galactia	81	30	30	51	51
Pueraria	1	1	0	0	1
Leucaena	1	0	0	1	1
Desmodium	2	1	1	1	1
Total	1018	436	383	582	635

(Figures 21 and 22). The P content in *S. sympodialos* decreased significantly in tops as Al concentrations increased. Similar results were obtained with the Ca content in tops and roots as well as Mg in roots. Al levels, however, appeared to have little or no effect on the K contents (Figure 22).

Increasing Al in the nutrient solution appeared to cause the accumulation of P in the roots and restricted its translocation to the tops in all *Stylosanthes* species (Table 37). *S. capitata,* however, was less affected than the other two species. By contrast, the strong reduction of total Ca and Mg uptake by increasing Al did not appear to affect the translocation of these nutrients to the tops. This would indicate that the Ca and Mg transport indices cannot be used to identify Al tolerant species. The practical implication of these results is that Ca and Mg deficiencies in the presence of Al in a forage crop is a result of the reduced uptake of Ca and Mg rather than their translocation to the upper parts.

From a morphological standpoint, the elongation of the primary root axis of *S. sympodialos* was inhibited soon after the plants were transferred to the Al solutions. In addition, the root color changed from white to brown and lateral roots exhibited a disintegration and disorganization of cells. These observations were significantly less evident in the other two species. By longitudinal sectioning of the roots after hematoxilin straining, it was possible to differentiate Al accumulation zones. In the case of an Al tolerant species, such as *S. capitata,* Al accumulation did not cause cell destruction in the outermost cortical region of the primary root. In contrast with *S. sympodialos,* an Al sensitive species, the red staining hematoxilin showed a flow of Al into the central part of the primary root which coincided with disintegration of cells.

In another experiment related to the above-mentioned ones, forage grass and legume accessions were subjected to Al and P stress under field conditions. This experiment was established in 1977 during the rainy

Table 36. Comparative performance of legume germplasm for tolerance to high Al saturation and P stress under field conditions and using the hematoxilin test.

Species	Accession CIAT No.	Category of promise	Relative yield under field conditions 86% Al sat. 2.6 ppm P	Hematoxilin test[1] 5 ppm Al 0.5 ppm P	Hematoxilin test[1] 10 ppm Al 0.5 ppm P
Desmodium ovalifolium	350	IV	79	T	T
Zornia latifolia	728	IV	82	T	T
Stylosanthes capitata	1019	IV	60	T	S
Stylosanthes capitata	1315	IV	80	T	T
Pueraria phaseoloides	9900	IV	70	T	S
Stylosanthes capitata	1318	III	85	T	T
Stylosanthes capitata	1323	III	48	S	S
Stylosanthes capitata	1325	III	22	S	S
Stylosanthes capitata	1342	III	16	S	S
Stylosanthes capitata	1405	III	55	T	T
Stylosanthes capitata	1693	III	-	-	-
Stylosanthes capitata	1728	III	-	T	T
Stylosanthes capitata	1943	III	-	T	T
Zornia latifolia	9179	III	-	T	T
Zornia sp.	9220	III	-	T	T
Zornia sp.	9245	III	-	T	T
Zornia latifolia	9258	III	-	T	T
Zornia sp.	9260	III	-	T	T
Zornia sp.	9270	III	-	T	T
Zornia sp.	9286	III	-	T	T
Zornia sp.	9295	III	-	T	T
Zornia sp.	9648	III	-	T	T
Aeschynomene brasiliana	9681	III	50	T	T
Aeschynomene brasiliana	9684	III	24	S	S
Aeschynomene histrix	9666	III	33	S	S
Aeschynomene histrix	9690	III	66	T	T
Stylosanthes hamata	147	III			
Desmodium heterophyllum	349	III	20	S	S
Desmodium gyroides	3001	III	-	-	-
Zornia sp.	813	II	-	T	T
Zornia sp.	935	II	-	T	T
Zornia sp.	7041	II	-	-	-
Zornia sp.	7214	II	-	T	T
Zornia sp.	7373	II	-	-	-
Zornia sp.	7376	II	-	-	-
Zornia sp.	7377	II	-	-	-
Zornia sp.	7465	II	-	-	-
Zornia sp.	7475	II	-	-	-
Zornia latifolia	9151	II	83	T	T
Zornia latifolia	9199	II	-	T	T
Zornia latifolia	9215	II	-	T	T
Zornia latifolia	9225	II	-	T	T
Zornia latifolia	9226	II	-	T	T
Zornia latifolia	9265	II	48	T	T
Zornia latifolia	9267	II	12	S	S
Zornia latifolia	9282	II	83	T	T
Zornia sp.	9284	II	89	T	T
Zornia sp.	9292	II	17	S	S
Zornia sp.	9472	II	-	-	-
Zornia sp.	9473	II	-	-	-
Zornia sp.	9589	II	-	T	T

Table 36 (cont.)

Species	Accession CIAT No.	Category of promise	Relative yield under field conditions 86% Al sat. 2.6 ppm P	Hematoxilin test[1] 5 ppm Al 0.5 ppm P	10 ppm Al
Zornia sp.	9600	II	15	S	S
Zornia sp.	9616	II	9	S	S
Zornia sp.	9771	II	51	T	S
Zornia sp.	9896	II	8	S	S
Stylosanthes capitata	1007	II	-	S	S
Stylosanthes capitata	1191	II	-	T	T
Stylosanthes capitata	1298	II	-	S	S
Stylosanthes capitata	1319	II	-	T	T
Stylosanthes capitata	1321	II	-	S	S
Stylosanthes capitata	1322	II	-	S	S
Stylosanthes capitata	1324	II	-	S	S
Stylosanthes capitata	1328	II	-	S	S
Stylosanthes capitata	1332	II	-	T	T
Stylosanthes capitata	1333	II	-	S	S
Stylosanthes capitata	1334	II	-	S	S
Stylosanthes capitata	1338	II	-	T	T
Stylosanthes capitata	1339	II	-	S	S
Stylosanthes capitata	1340	II	-	S	S
Stylosanthes capitata	1343	II	-	S	S
Stylosanthes capitata	1414	II	78	T	T
Stylosanthes capitata	1419	II	52	T	T
Stylosanthes capitata	1441	II	69	T	T
Stylosanthes capitata	1495	II	-	T	T
Stylosanthes capitata	1497	II	100	T	T
Stylosanthes capitata	1499	II	-	T	S
Stylosanthes capitata	1504	II	36	S	S
Stylosanthes capitata	1516	II	-	S	S
Stylosanthes capitata	1519	II	-	T	T
Stylosanthes capitata	1520	II	67	T	T
Stylosanthes capitata	1535	II	-	T	T
Stylosanthes capitata	1642	II	-	T	T
Stylosanthes capitata	1686	II	-	T	T
Stylosanthes capitata	1781	II	-	T	T
Stylosanthes capitata	1899	II	65	T	T
Stylosanthes bracteata	1906	II	-	S	S
Stylosanthes bracteata	1281	II	83	T	T
Stylosanthes bracteata	1582	II	57	T	T
Stylosanthes bracteata	1643	II	20	S	S
Stylosanthes humilis	1222	II	37	-	-
Stylosanthes humilis	1303	II	12	S	S
Centrosema spp.	5062	II	-	S	S
Centrosema spp.	5064	II	-	T	T
Centrosema spp.	5065	II	-	T	T
Centrosema spp.	5066	II	-	S	S
Centrosema spp.	5126	II	-	S	S
Centrosema spp.	5127	II	-	T	T
Centrosema spp.	5189	II	-	S	S
Vigna adenantha	4016	II	51	T	T
Stylosanthes guianensis	136	RT	-	T	T
Stylosanthes guianensis	184	RT	90	T	T
Stylosanthes capitata	1078	RT	79	T	T

Table 36 (cont.)

Species	Accession CIAT No.	Category of promise	Relative yield under field conditions: 86% Al sat., 2.6 ppm P	Hematoxilin test[1]: 5 ppm Al, 0.5 ppm P	Hematoxilin test[1]: 10 ppm Al, 0.5 ppm P
Stylosanthes capitata	1097	RT	-	-	-
Macroptilium sp.	535	RT	-	S	S
Centrosema hybrid	438	RT	55	T	S
Leucaena leucocephala	734	Negative control	30	S	S
Medicago sativa	Alfalfa	Negative control	0	S	S

1 T = tolerant; S = susceptible.

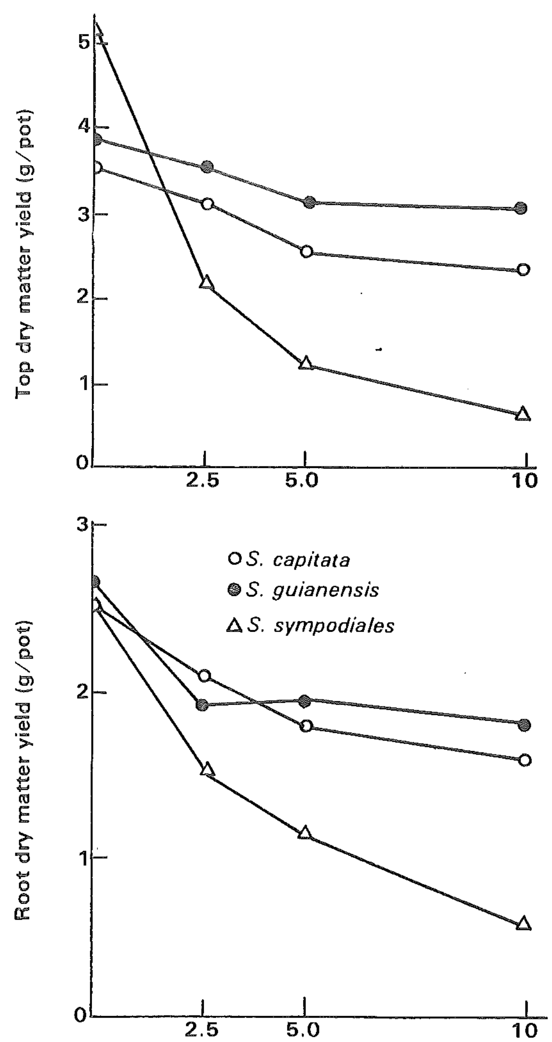

Figure 20. Effect of Al on root and top dry matter production of three *Stylosanthes* species grown in nutrient solutions.

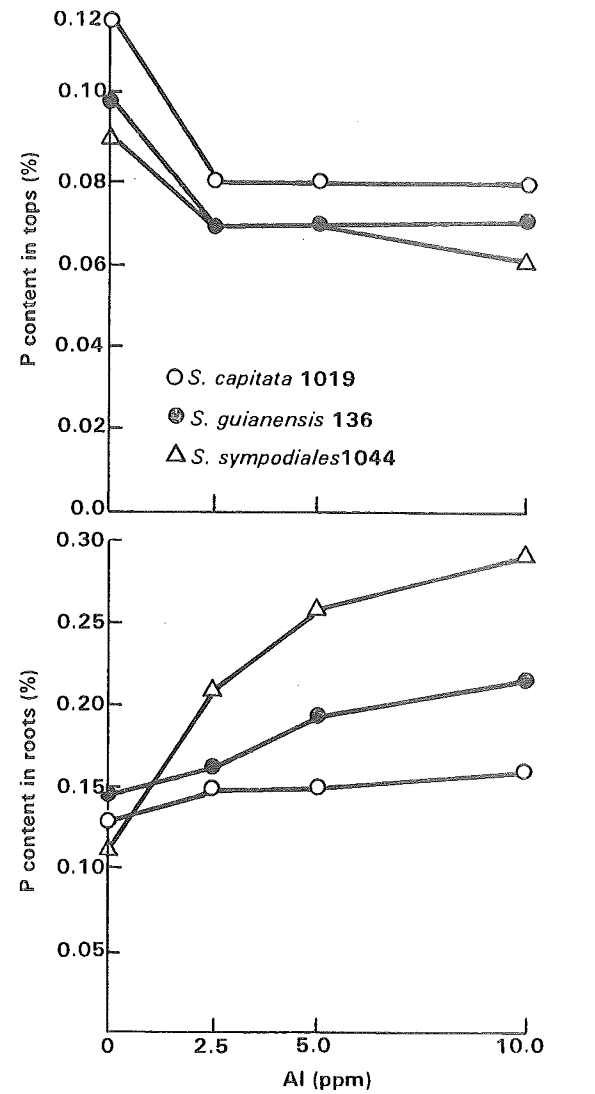

Figure 21. Effect of Al on the P content in tops and roots of three *Stylosanthes* species grown in nutrient solutions.

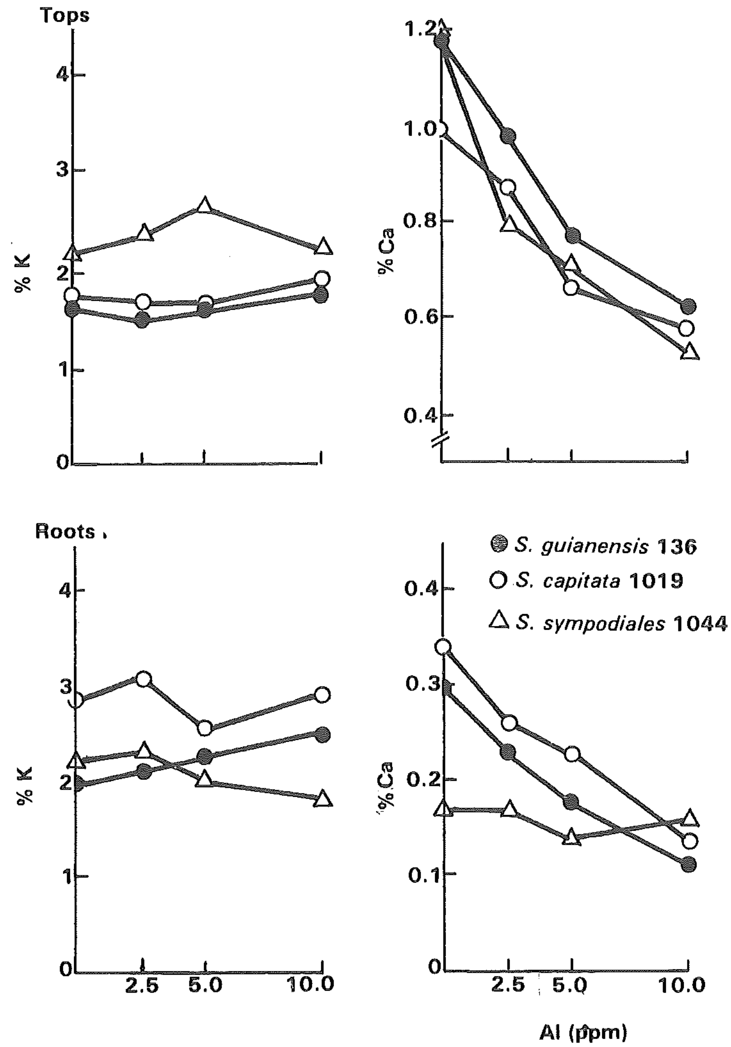

Figure 22. Effect of Al on the content of K, Ca, and Mg in roots and tops of three *Stylosanthes* species grown in nutrient solutions.

season in Carimagua with four lime levels (to provide 90, 85, 75 and less than 20% Al saturation) and four P levels (to provide 1.5, 3, 9 and 30 ppm available in soil P-Bray II). Lime levels applied were 0, 0.5, 1.0 and 5 t/ha and the P rates were 0, 17, 117 and 277 kg P/ha. Both lime and P (as triple superphosphate, TSP) were broadcast and incorporated to a 20 cm depth.

The relative yield seems to be the most useful criterion for comparing the tolerance of different forage species and/or accessions to Al or P stress. Thus, survival of a plant under Al and/or P stress was defined as having a dry matter production level not exceeding 50% of its maximum yield. On the other hand, a producing plant under Al or P stress was defined as having the relative yield between 50 and 80% of its maximum. The upper limit was fixed at 80% due to the inflection point observed in many forage ecotypes. A relative yield of over 80% was considered excellent.

The performance of eight tropical grasses is illustrated in Figure 23. When no lime and no P were applied (93% Al saturation and 1.7 ppm P) all grasses showed marked differences under both P and Al stress. *Brachiaria humidicola* 682 and *Andropogon gayanus* 621 produced more than 50% of their maximum yield while the rest of the grasses had 40% or less of their maximum yields. The 93% Al saturation histogram shows the ranking of the grasses illustrating wide differences to Al and P stresses between them. As the P level was increased, with Al saturation kept constant, all grasses increased their relative yields.

Table 37. Effects of Al on the uptake and translocation of P, Ca, Mg and K by three *Stylosanthes* species grown in nutrient solution.

Al treatment (ppm)	*Stylosanthes capitata* Uptake (mg/g dry wt.) Tops	Roots	Total	Transport index[1] (%)	*Stylosanthes guianensis* Uptake (mg/g dry wt.) Tops	Roots	Total	Transport index (%)	*Stylosanthes sympodiales* Uptake (mg/g dry wt.) Tops	Roots	Total	Transport index (%)
					Phosphorus							
0.0	1.2	1.3	2.5	48	1.0	1.4	2.4	42	0.9	1.2	2.1	43
2.5	0.8	1.5	2.3	35	0.7	1.6	2.3	30	0.7	2.1	2.8	25
5.0	0.8	1.5	2.3	35	0.7	2.0	2.7	26	0.7	2.6	3.3	21
10.0	0.8	1.7	2.5	32	0.7	2.2	2.9	24	0.6	2.9	3.5	17
					Calcium							
0.0	9.9	3.4	13.3	74	11.8	3.0	14.8	80	12.7	1.7	14.4	88
2.5	8.3	2.6	10.9	76	8.9	2.3	11.2	79	7.6	1.6	9.2	83
5.0	6.8	2.3	9.1	75	6.7	1.8	8.5	79	7.0	1.4	8.4	83
10.0	6.0	1.4	7.4	81	5.5	1.2	6.7	82	5.7	1.5	7.2	89
					Magnesium							
0.0	2.3	3.0	5.3	43	2.3	4.2	6.5	35	2.6	3.7	6.3	41
2.5	2.0	2.3	4.3	47	2.2	2.7	4.9	45	2.7	1.3	4.0	68
5.0	2.2	1.7	3.9	56	2.2	1.3	3.5	63	2.7	1.2	3.9	69
10.0	2.2	1.3	3.5	63	2.2	0.9	3.1	71	2.5	0.7	3.2	78
					Potassium							
0.0	18.3	20.2	38.5	48	18.0	29.5	47.5	38	21.8	22.1	43.9	50
2.5	15.9	22.0	37.9	42	15.2	30.8	46.0	33	23.2	22.6	45.8	51
5.0	15.8	22.2	38.0	42	16.4	26.0	42.0	39	25.7	21.0	46.7	55
10.0	16.7	25.0	41.7	40	17.6	28.5	46.1	38	22.5	18.9	41.4	54

1 Transport index = (top mineral uptake/total mineral uptake) x 100.

With the addition of 0.5 and 1.0 t lime/ha most of the species showed an increase in dry matter production. This indicates that the response of grasses tolerant to Al is mainly related to Ca and Mg requirements rather than to the effect of liming. When Al toxicity was eliminated by applying 5 t lime/ha all grasses showed more than 50% of their relative yields at the two lowest P levels. However, when P was increased most of the grasses showed a sharp yield decrease which is probably related to some nutritional imbalance due to the high lime and P applications.

Results with forage legumes are given in Figure 24. Although there were marked variations between species in response to the P and lime applications, in general the results were similar to those obtained for grasses.

Nutritional Requirements of Grass and Legume Forages

The research strategy developed by the Soil/Plant Nutrition Section for determining the mineral requirements of promising forage species has taken into account: (1) the need for standardized analytical methods for acid soils and plant tissues; (2) the description of visual foliar symptoms caused by mineral disorders; and (3) the determination of responses of promising forage species to a given

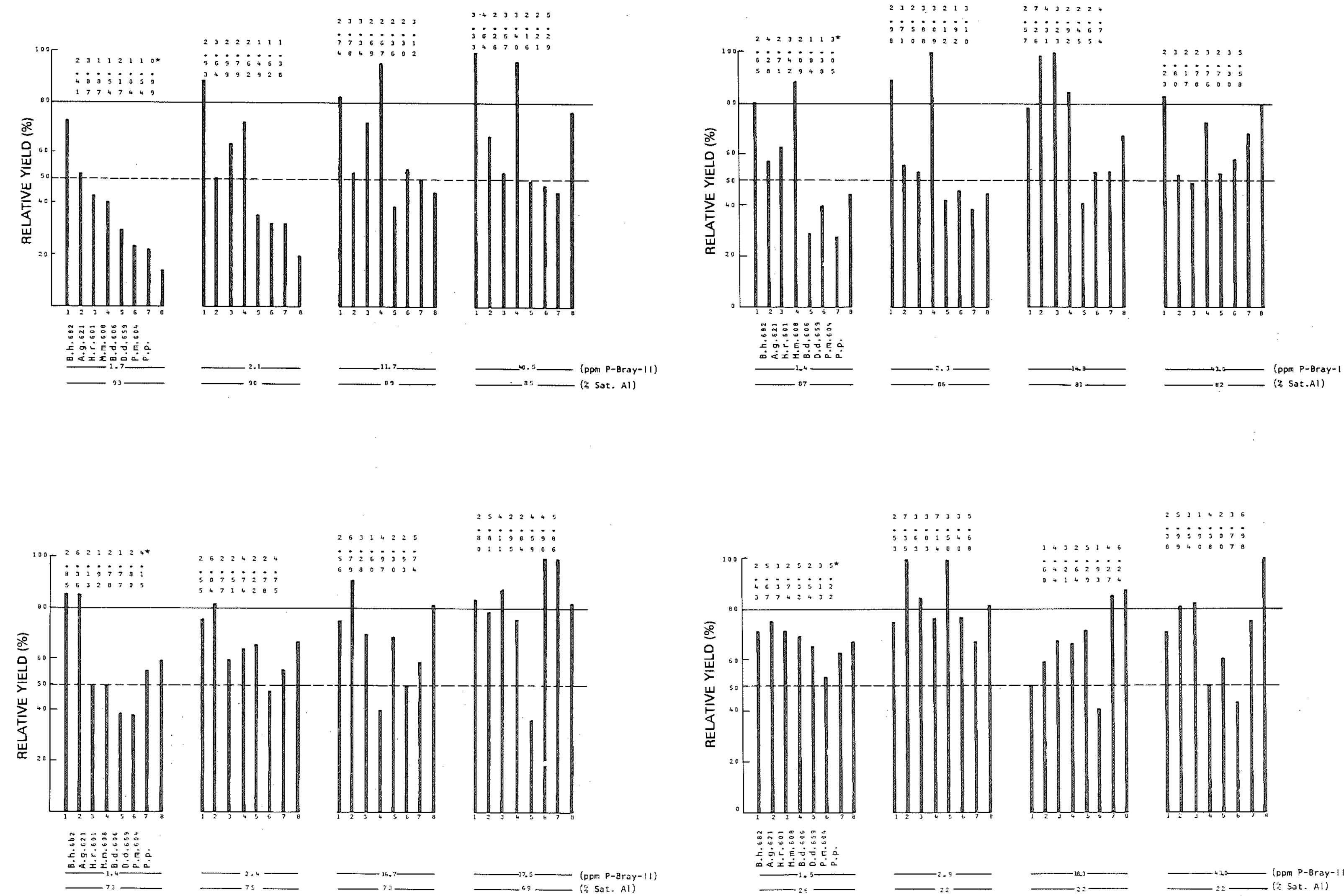

Figure 23. Differential response of eight tropical grasses at different P levels and 92, 86, 77 and 27% Al saturation (0, 0.5, 1, and 5 t lime applied/ha) under field conditions at Carimagua. 1 = *Brachiaria humidicola* 682; 2 = *Andropogon gayanus* 621; 3 = *Hyparrhenia rufa* 601; 4 = *Melinis minutiflora* 608; 5 = *Brachiaria decumbens* 606; 6 = *Digitaria decumbens* 659; 7 = *Panicum maximum* 604; 8 = *Pennisetum purpureum*.
(Figures on bars are dry matter yield beans in t/ha.)

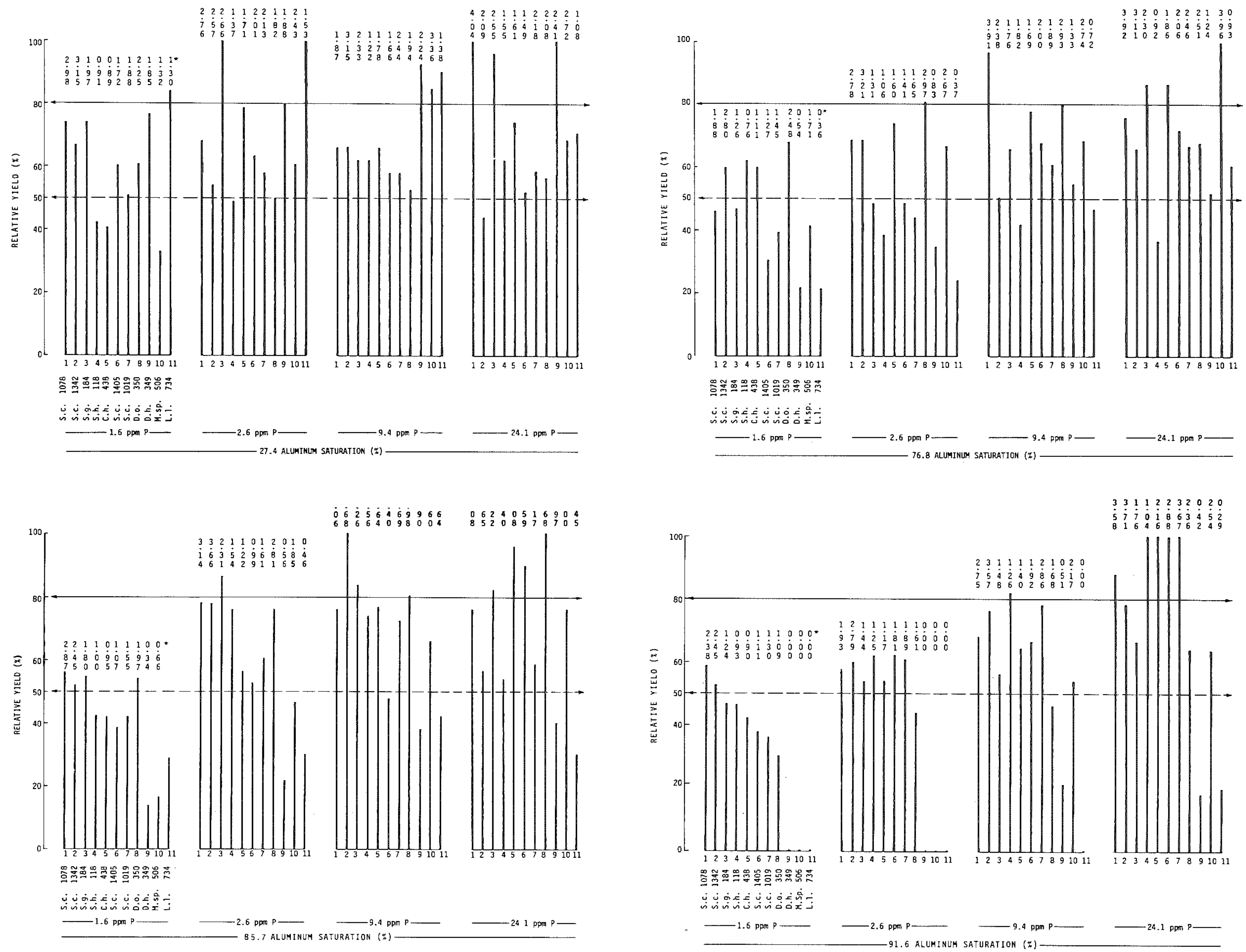

Figure 24. Differential response of 11 forage legumes at different P levels and under 92, 86, 77, and 27% Al saturation (0, 0.5, 1, and 5 t lime applied/ha) under field conditions at Carimagua. 1 = *Stylosanthes capitata* 1078; 2 = *Stylosanthes capitata* 1342; 3 = *Stylosanthes guianensis* 184; 4 = *Stylosanthes humilis* 438; 5 = *Centrosema hybrid* 438; 6 = *Stylosanthes capitata* 1405; 7 = *Stylosanthes capitata* 1019; 8 = *Desmodium ovalifolium* 350; 9 = *Desmodium heterophyllum* 349; 10 = *Macroptilium* sp. 506; 11 = *Leucaena leucocephala* 734. (Figures on bars are dry matter yield means in t/ha.)

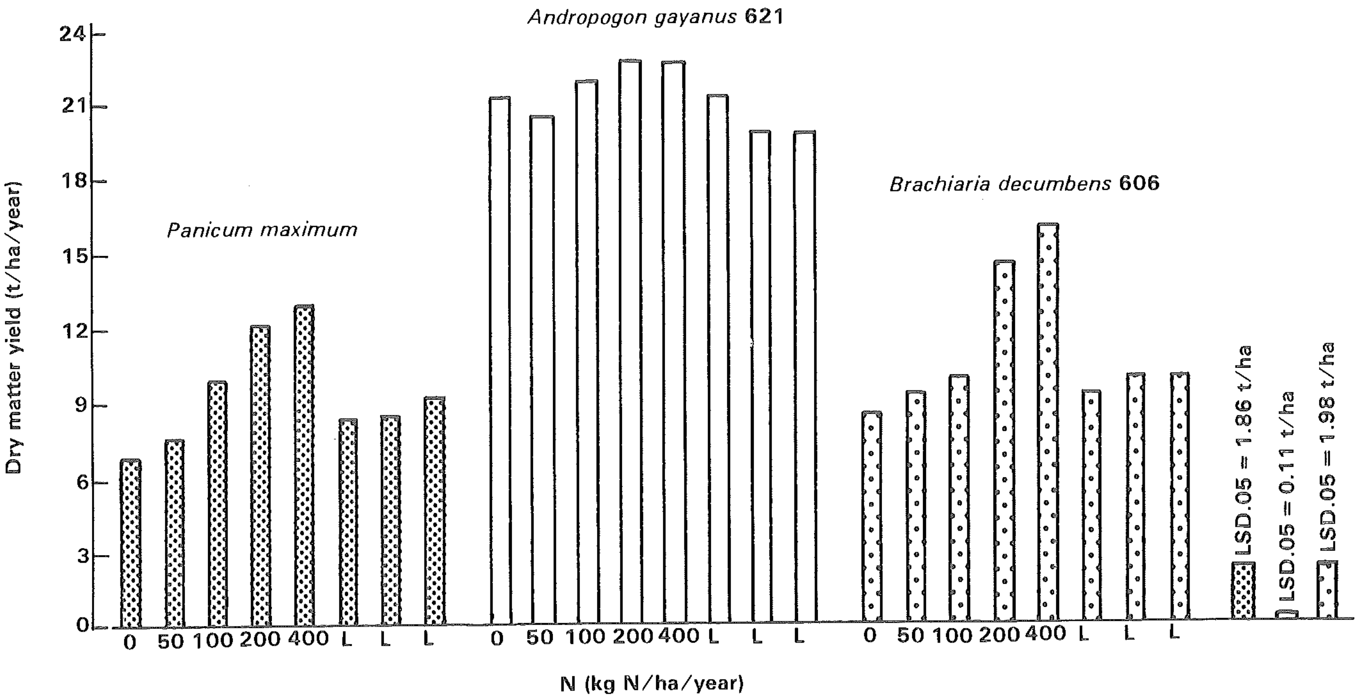

Figure 25. Effect of varying rates of nitrogen (applied as urea) on yield of three forage grasses compared to their mixtures with three legumes (L_1 = *Stylosanthes guianensis* 136, L_2 = *S. guianensis* 184, and L_3 = *Centrosema* hybrid 438) under field conditions at CIAT-Quilichao.

nutrient and its effect on the mineral composition of the plant.

Standardized analytical methods for acid soils and plant tissues

During 1979, a considerable effort was devoted to preparing a handbook describing analytical methods and procedures for running soil and plant analyses in the acid infertile soils of the Tropical Pastures Program target area. Since soils from other countries cannot be brought into Colombia it is essential that standardized methods and Orocedures be used by collaborating laboratories. To date six national laboratories have been identified, located near the regional trials sites. Soil and plant samples have been distributed to these laboratories to verify uniformity of results from the proposed methods and procedures.

Visual foliar symptoms of mineral disorders

A series of greenhouse experiments was conducted to develop mineral deficiency and toxicity symptoms. The study included N, P, K, Ca, Mg and S deficiencies among the micronutrients group, and Al and Mn toxicities. Photographs of these deficiencies and toxicities were taken on the various grass and legume forage accessions; these, along with a detailed description will be incorporated into a handbook for practical use by researchers involved in forage evaluation in regional trials.

Fertilizer requirements during pasture establishment

Attention was focused on estimating fertilizer requirements during the establishment stage of promising forage species. Results reported here are for N, P, K, and S fertilization in soils from CIAT-Quilichao and Carimagua.

N requirements of forage grasses

Although N fertilization of forage grasses is not considered feasible for the target area, it is important to have an understanding of the N demand of promising forage grasses. In any given pasture situation it is assumed that the N will be supplied by the legume in the mixtures. Figure 25 shows the response of three forage grasses *(Panicum maximum, Andropogon gayanus* 621 and *Brachiaria decumbens* 606) to N fertilization at CIAT-Quilichao during the second year of evaluation compared to their mixtures with three forage legumes *(Stylosanthes guianensis* 136 and 184 and *Centrosema pubescens* hybrid 438). All three grasses showed a positive response to N, although *A. gayanus* 621 showed a significant response only up to 200 kg N/ha/year; *P. maximum* and *B. decumbens* 606 showed linear responses up to 400 kg N/ha/year. On the other hand, it was observed that *A. gayanus* 621 also had a much higher yield potential than the other two grasses at all N rates; in this regard, it is interesting to note that the percentage recovery of the applied N was much lower for *A. gayanus* (Table 38). However, because of the higher yield potential, *A. gayanus* still proved to be a more efficient user of the N applied.

In this same study the N:S ratios of the three grasses was also considered. It is generally assumed that a critical S level of 0.1% is required for tropical forage grasses. This apparently is not the case with *A. gayanus,* however, as in almost every instance the S content in the tissue was below the considered minimum (Figure 26). These results suggest that the critical S requirement for *A. gayanus* 621 is less than that required by *P. maximum* and *B. decumbens* 606, however, it must be kept in mind that the S content in the tissue of *A. gayanus* probably does not satisfy the S requirement of the animal.

Positive responses to N fertilization of the grasses were also observed in Carimagua (Figure 27). *A. gayanus* 621, *B. decumbens* 606 and *M. minutiflora* gave significant responses from 75 to 225 kg N/ha during the 1979 rainy season. However, the efficiency of N utilization is expected to be better in *A. gayanus* 621 than in *B. decumbens* 606 based on the percent N recovery observed at CIAT-Quilichao. Further studies are being carried out to confirm this.

P and K requirements of forage grasses

Calibration of soil P tests. To date several different extractants have been used to determine available soil P. It was necessary to compare these tests to see how well they correlated with one another.

Accordingly, four different methods were evaluated for available P in a Carimagua Oxisol. Regression and correlation analysis between percentage yield of *P. maximum* and P extracted by the four methods (Bray I,

Table 38. Plant nitrogen content, protein equivalent, nitrogen uptake, and nitrogen recovery for three forage grasses under a cutting regime at CIAT-Quilichao.

Grass species	N applied (kg N/ha/year)	N (%)	Protein (%)	N uptake (kg N/ha/year)	N recovery[1] (%)
Andropogon gayanus 621	0	1.27	7.94	197	-
	50	1.24	7.75	188	0
	100	1.31	8.19	218	21
	200	1.32	8.25	226	15
	400	1.48	9.25	248	13
Panicum maximum	0	1.29	8.06	84	-
	50	1.30	8.13	94	20
	100	1.38	8.63	132	48
	200	1.53	9.56	178	47
	400	1.90	11.87	234	38
Brachiaria decumbens 606	0	1.06	6.62	83	-
	50	1.12	7.00	94	20
	100	1.16	7.25	113	30
	200	1.38	8.62	193	55
	400	1.78	11.12	269	46

1 $\%\ N\ recovery = \frac{N\ uptake\ at\ applied\ rate\ -\ N\ uptake\ without\ added\ N}{N\ rate} \times 100$

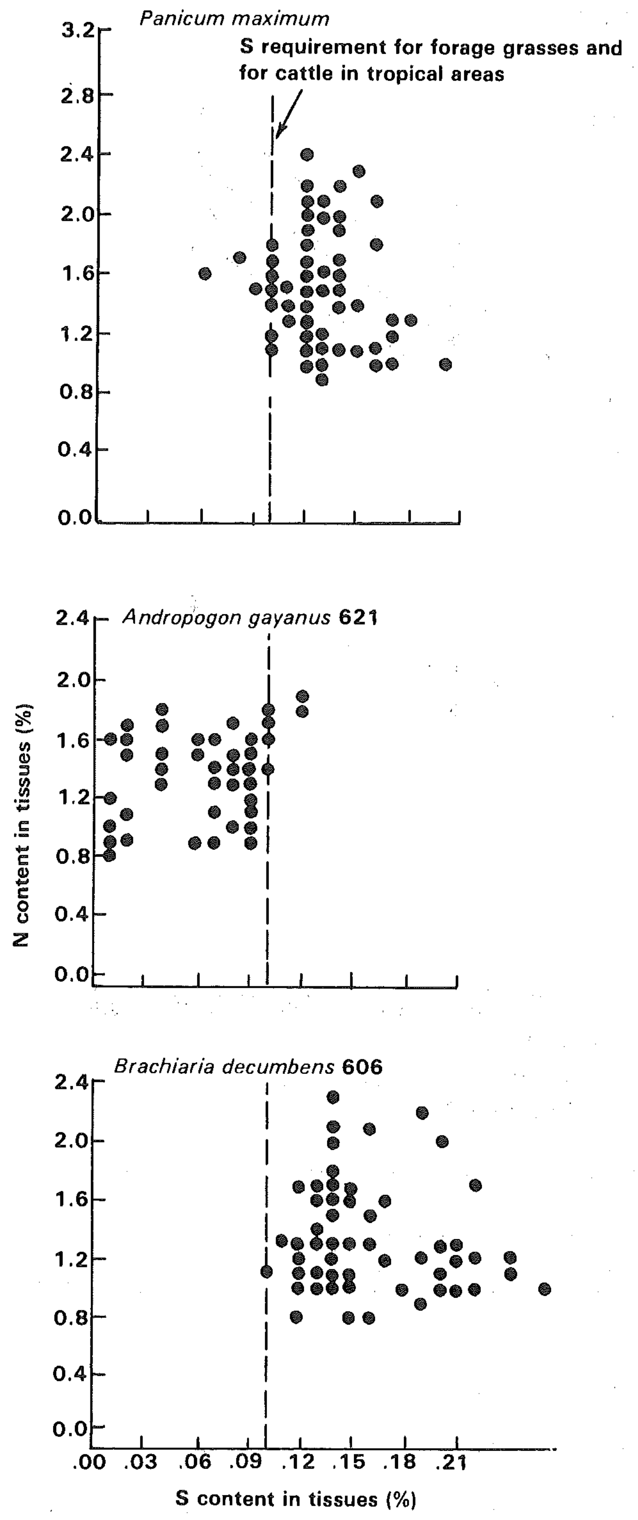

Figure 26. Relationship between S and N content in the tissue of three grass species at CIAT-Quilichao.

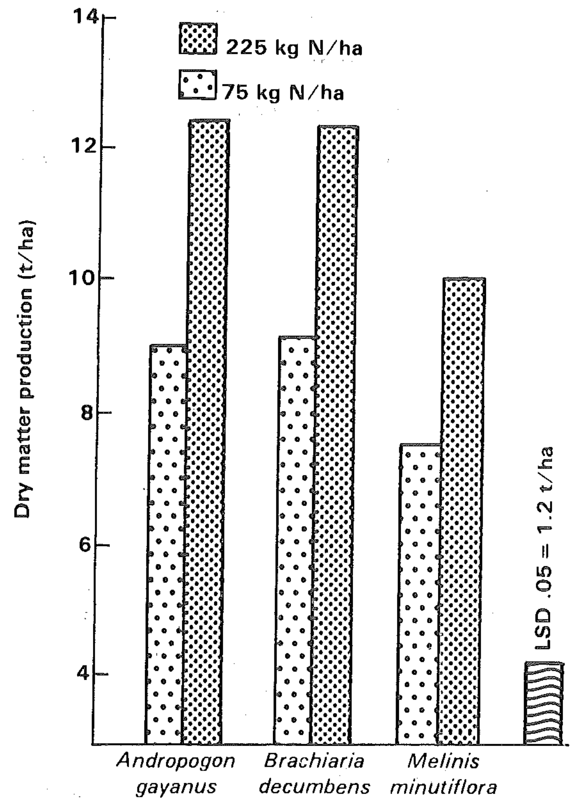

Figure 27. Response of three tropical grasses to nitrogen fertilization under field conditions in the Carimagua Oxisol. (Sum of four cuts during rainy season.)

Bray II, North Carolina 1:4 soil-extractant ratio, and North Carolina 1:10 soil-extractant ratio) showed that the amounts of P extracted were in direct relation to the amount of P fertilizer applied (Figure 28). However, the amount of P extracted by Bray I, Bray II and the modified North Carolina method (1:10 ratio) were much higher and with a wider range in available P than the traditional North Carolina method (1:4 ratio). Correlation coefficients relating P extracted by the four methods to *P. maximum* yields are shown in Table 39. Although the methods are well correlated, the Bray II extractant gave the best correlation with percentage yield (r= 0.90) but with no significant differences compared with Bray I and North Carolina 1:10 methods. A low correlation coefficient (r= 0.66) for North Carolina 1:4 methods vs. percentage yield was found. The results of this study have shown that the Bray II method as well as the Bray I and the modified double acid North Carolina methods provide good indices of P available to plants in the Carimagua Oxisol.

Effects of P sources on forage grasses. A long-term field experiment with *A. gayanus* 621 and *P. maximum*

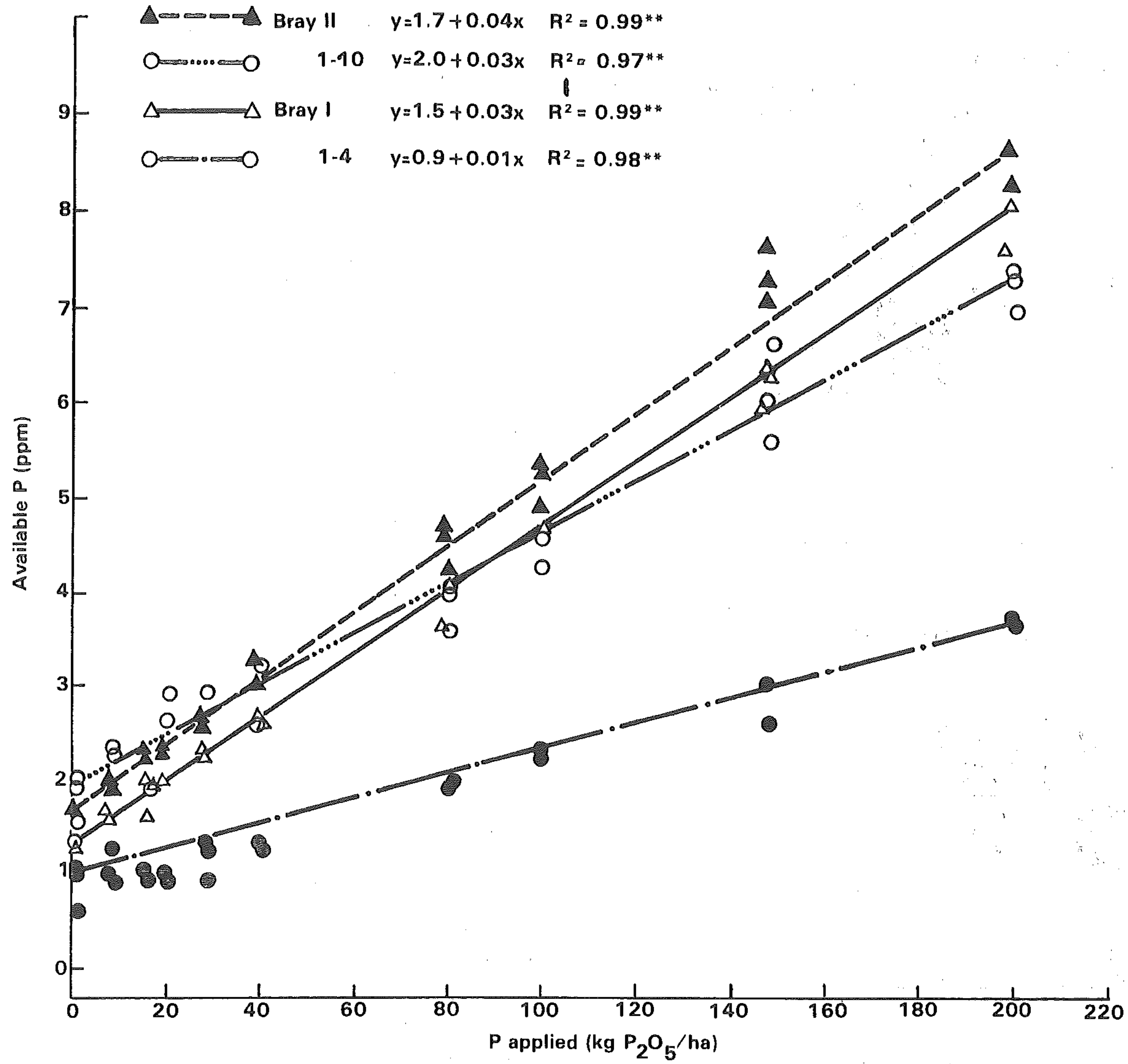

Figure 28. Soil available P in the Carimagua Oxisol, determined by extractant solutions Bray I, Bray II, North Carolina (NC) 1:10 soil extractant ratio, and NC 1:4 soil extractant ratio.

Table 39. Simple correlation coefficients (r) relating four soil tests for available P and yield of Panicum maximum for the Carimagua Oxisol.

Soil test	Extractant	Bray I	Bray II	NC-1:10	NC-1:4	Yield
Bray I	0.03N NH_4F + 0.025N HCl	1.00	-	-	-	0.87**
Bray II	0.03N NH_4F + 0.1N HCl	0.99**	1.00	-	-	0.90**
NC-1:10	0.025N H_2SO_4 + 0.05N HCl	0.98**	0.98**	1.00	-	0.85**
NC-1:4	0.025N H_2SO_4 + 0.05N HCl	0.97**	0.97**	0.96**	1.00	0.66*

* Probability at the 0.05 level.
** Probability at the 0.01 level.

was established early in 1978 at CIAT-Quilichao to evaluate the effects of cheaper P sources and the differential P requirements of forage grasses in order to decrease the cost of fertilizer applications. Three phosphate rocks (Pesca, Gafsa, and Huila) and triple superphosphate (TSP) were broadcast applied at rates from 0 to 1600 kg P_2O_5/ha, incorporated into the topsoil. To date the results have shown no significant differences between P sources so only the TSP results will be given.

Figure 29 shows yields of the two forage grasses. *A. gayanus* 621 showed a significant response only at the 800 kg P_2O_5/ha rate compared with the check plot. It must be kept in mind, however, that control yields were very high. A significant increase in yield of *P. maximum* was obtained with only 60 kg P_2O_5/ha; a linear response continued reaching a peak up to 100 kg

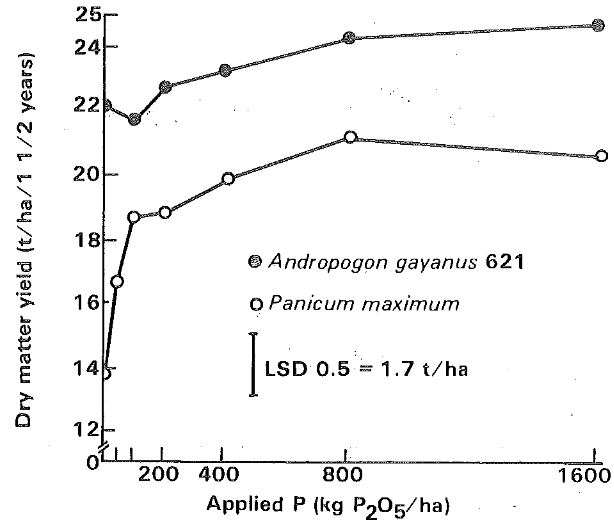

Figure 29. Effect of phosphorus fertilization on the dry matter yield of two tropical grasses grown at CIAT-Quilichao.

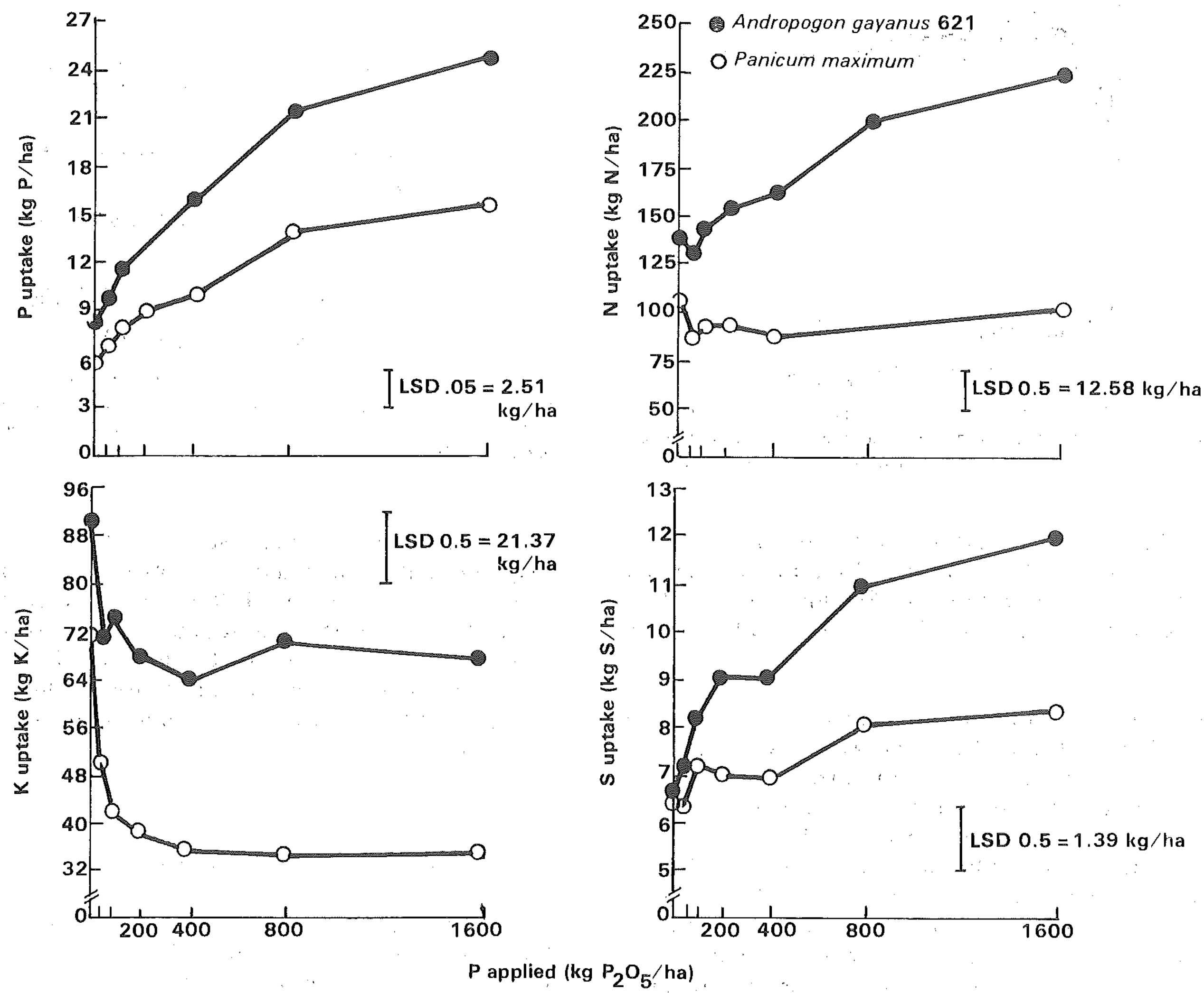

Figure 30. Effects of P fertilization on the P, N, K and S uptake by two tropical grasses.

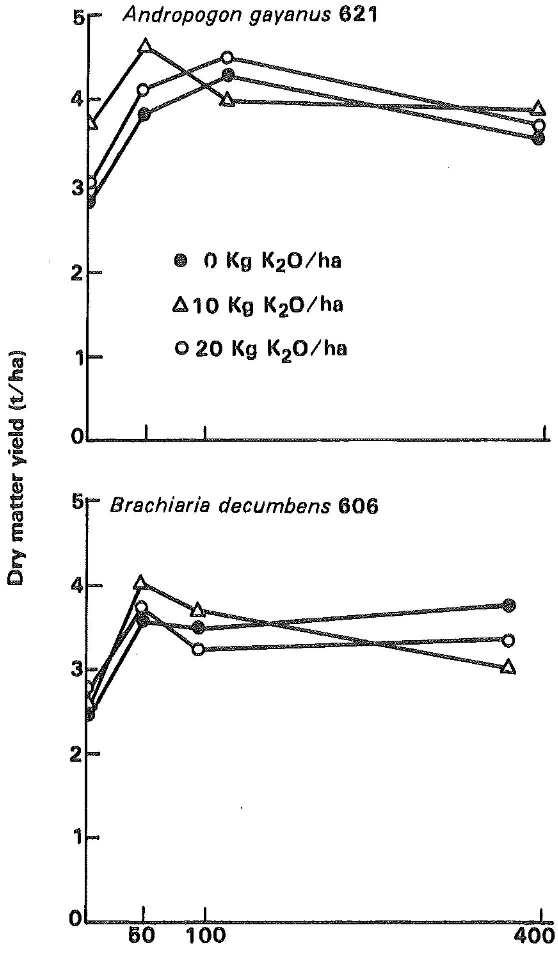

Figure 31. Effects of phosphorus and potassium on dry matter production of *Andropogon gayanus* and *Brachiaria decumbens* grown in an Oxisol from Carimagua. (Sum of the two first cuts, 1979)

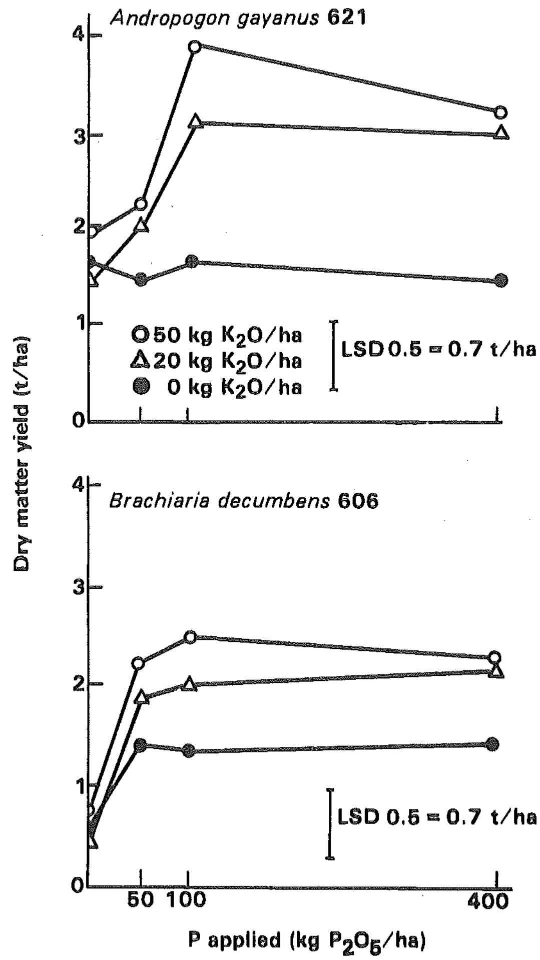

Figure 32. Effects of phosphorus and potassium on dry matter production of *Andropogon gayanus* and *Brachiaria decumbens* grown in an Oxisol from Carimagua. (Third cut during the rainy season, 1979.)

P_2O_5/ha after which it leveled off. The results suggest that *A. gayanus* 621 has a lower P requirement for high yields than *P. maximum*. Figure 30 illustrates the effect of P fertilization on P, N, K and S uptake by the two grasses.

P x K fertilization. *A. gayanus* 621 and *B. decumbens* 606 are also being evaluated for P and K responses in Carimagua. After two cutting periods, both grasses showed a response to P at the 50 kg P_2O_5/ha rate but no response to K (Figure 31). After the second cut, K fertilization was increased to 20 and 50 kg K_2O/ha, respectively. Figure 32 illustrates the results of the third cut showing a significant interaction with K and P. With very low K application rates *A. gayanus* 621 did not respond to P applications; however, when K was applied at the rate of 20 kg K_2O/ha it showed a large response to P up to 100 kg P_2O_5/ha. With the addition of 50 kg K_2O/ha, dry matter yield was increased. *B. decumbens* showed a similar type of response to K application, it was only responsive up to a level of 50 kg P_2O_5/ha. These preliminary results suggest that, in order to determine the critical percentage of a nutrient, other nutrients must not be limiting.

S fertilization of forage legumes

A greenhouse experiment was conducted in CIAT-Quilichao and Carimagua soils to determine the effects of S on the yield of *Zornia latifolia* 728, *Stylosanthes capitata* 1019, and *Desmodium ovalifolium* 350.

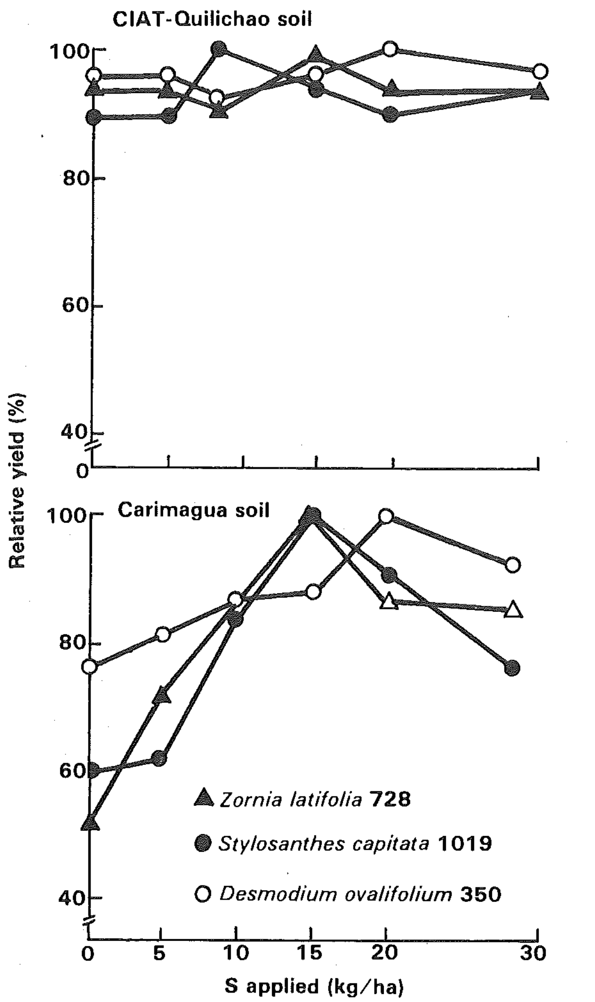

Figure 33. Relative yields of three tropical forage legumes grown under greenhouse conditions in soils from CIAT-Quilichao and Carimagua in response to fertilization with sulphur.

Table 40. Sulphur contents and forms in the top layer (0-20 cm) of soils from CIAT-Quilichao and Carimagua.

S forms	S contents (ppm) CIAT-Quilichao	Carimagua
Total S	1013	420
Organic S	633	231
Inorganic S	380	189
Available S [$Ca(H_2PO_4)$]	29	10

Relative dry matter yields are shown for both soils in Figure 33. There was no response to S application in the CIAT-,quilichao soil, but all three legumes gave significantly higher relative yields in the Carimagua soil. *S. capitata* 1019 and *Z. latifolia* 728 showed a linear response to S applications and then attained maximum yields at the rate of 15 kg S/ha. *D. ovalifolium* 350 also showed a positive response to S with maximum yields at 20 kg S/ha. Dry matter yields were depressed at the highest S treatment which is probably due to a nutritional imbalance between N and S.

The lack of response to S application at CIAT-Quilichao may be explained by the fact that the native S supply is considerably higher due to the high organic matter content in the topsoil. Table 40 shows the S contents and forms in the top layer of both soils.

PASTURE DEVELOPMENT IN THE HYPERTHERMIC SAVANNAS (CARIMAGUA)

The objectives of the Pasture Development section in Carimagua continue to be the development of simplified, low-cost establishment methods and efficient maintenance practices. New trials were initiated during the year and long term trials were continued.

Several new legume/grass associations were established. It is recommended that the grass and legume be seeded simultaneously and in rows spaced 0.50-1.00 m using a 1:1 or 2:2 legume/grass planting pattern. Row planting combined with band fertilization favors the establishment of a vigorous population of seedlings with minimum fertilizer and both species have sufficient time and space to become well established with minimum weed competition. The 1:1 planting pattern may present a problem with bunch type grasses as the grazing animal moves between the grass rows, trampling the legume planted in that space.

The importance of firming the seed bed in the row at the time of planting was reconfirmed in a seed production plot which was plowed and disked shortly before planting to *Stylosanthes capitata* and *Zornia latifolia*. The rows that happened to fall in the wheel tracks of the tractor germinated and developed much better than the non-compacted rows. Seed bed firming appears to be especially important when the land is plowed shortly before planting, due to deep loosening and insufficient time for rains to settle the soil.

As more experience has been gained with low density planting, the importance of mother plants becomes evident, especially for planting in native savanna with only partial vegetation control. The original plants should be adequately protected from competing vegetation and insects and supplied with sufficient fertilizer so that strong plants with deep, vigorous root systems develop before being subjected to competition from other introduced or native species. Once established, well-adapted species are very persistent and some are aggressive displacers of native savanna species. The cost of fertilizer and insect control is so low, due to the reduced number of hills/ha, that optimum conditions for seedlings can be afforded to assure the development of a vigorous population.

Reducing Pasture Establishment Costs

Besides using species tolerant to acid soil conditions, pasture establishment costs can be further reduced with the low density seeding method reported in CIAT Annual Reports of 1977 and 1978. This method requires much less seed for the establishment of strong and prolific seeders such as *Andropogon gayanus* and for stoloniferous or trailing species such as *Brachiaria humidicola, Desmodium ovalifolium* and *Pueraria phaseoloides*. Less labor is required as fewer hills are planted and fertilized. This is especially important for vegetatively propagated species since the tasks of harvesting and transporting seeding material are greatly simplified. Little fertilizer is required initially; optimum rates for a planting density of 1000 hills/ha are 3 and 1 kg/ha of P_2O_5 and K_2O, respectively. The recommended fertilizer rate is applied only after establishment is assured. By associating legumes and grasses, fertilizer costs are further reduced since the legume/rhizobia symbiosis supplies N to the pasture.

By using well-adapted, aggressive species combined with row planting and band fertilization, weed control costs are kept to a minimum. At least one of the species in the association should be a strong competitor, capable of protecting the sward from weed invasion.

Other means of reducing establishment costs include the development of simple, mechanized planting systems. Commercial scale planting is now practiced in Carimagua with a drill-box type fertilizer-lime spreader equipped with a planting attachment. Seeding is done directly on the surface with no additional tillage required if the surface is sufficiently rough and protected from rain drop impact and erosion.

One of the major costs (after fertilizer) in pasture establishment is the tillage required for seed bed preparation. A trial was initiated last year in which four grasses and three legumes were planted in association each at 1000 hills/ha in all possible legume/grass combinations. Planting was done in 60 cm strips 3.16 m apart, prepared with the spring tines of a field cultivator to a depth of 12 cm. The native savanna in the area between strips received four control treaments: (a) burning, (b) chemical control, (c) one pass with the spring tines of the field cultivator, 30 cm apart and 12 cm deep, and (d) disking. Starter fertilizer was applied only in the hills; the intermediate areas were fertilized after stolon coverage was well advanced. There was strong species by vegetation control interaction. *Panicum maximum* was included in the trial, however, ant damage was so severe to the seedlings that no effective coverage was achieved, thus results for this species are not reported.

The two trailing legumes, *D. ovalifolium* and *P. phaseoloides*, were very effective in invading areas not colonized by grasses. Therefore, if a given treatment was not favorable to the spread of the associated grass, both legumes compensated and covered all of the area not covered by the grass. Both *D. ovalifolium* and *P. phaseoloides* covered the area completely. In the chemical control treatment, *B. humidicola* successfully colonized the entire area, thus the development of the legume was much more restricted. *B. decumbens* was less successful but its shortcomings were compensated by the legumes. *S. capitata* is quite persistent but not very aggressive and did not succeed in invading the native savanna. A summary of the observations is presented in Table 41.

This trial has demonstrated the feasibility of pasture establishment using appropriate legume/grass associations even with no tillage in the intermediate area and only low cost tine tillage in the seeded strip.

Table 41. Competitive ability of different forage species to invade and displace fertilized native savanna vegetation receiving four different treatments in Carimagua, 1979.

Treatment of native savanna	Species	Capable of: Invading	Displacing
Burn only	Desmodium ovalifolium	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria radicans	Yes	No
Chemical control	Desmodium ovalifolium	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria humidicola	Yes	Yes
	Brachiaria radicans	Yes	No
Tine tillage to 12 cm	Desmodium ovalifolium	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria humidicola	Yes	Yes
	Brachiaria decumbens	Yes	Yes
	Andropogon gayanus	Yes	Yes
	Brachiaria radicans	Yes	No
Complete seedbed preparation	Desmodium ovalifolium	Yes	Yes
	Pueraria phaseoloides	Yes	Yes
	Brachiaria radicans	Yes	Yes
	Brachiaria decumbens	Yes	Yes
	Andropogon gayanus	Yes	Yes
	Brachiaria radicans	Yes	No

This reduction in tillage requirement reduces the total establishment cost. New trials established this year are exploring the possibility of even wider spacing between seeded strips since *B. humidicola* and *P. phaseoloides* were both capable of extending and invading more than the 3.16 m space between hills used in the current trial. It may be possible to gradually replace the Savanna with wide spacing (5-10 m) between rows of introduced species, while the grazing animal utilizes native savanna to complement the introduced species during the process of establishment which might take several years.

The risk of establishment is considerably reduced with low density seeding methods and also with the gradual replacement of the native savanna. The initial investment is low and the major investment in fertilizer is deferred until establishment is assured.

Additional low density trials were initiated in 1978. *A. gayanus* was planted at four densities ranging from 100 to 800 hills/ha. Table 42 shows that average plant counts obtained with complete seed bed preparation were high even at very low initial plant population. However, complete coverage was only obtained with 400 hills/ha.

Table 42. Effect of the initial plant population of Andropogon gayanus and three treatments to control native savanna on seedling count.

	Seedling counts (plants/m^2) Control method applied		
No. hills/ha	Complete seedbed preparation	Sweeps	Chemical control
100	2.03	0.37	0.4
200	5.38	1.33	0.51
400	10.39	3.93	0.95
800	7.46	3.41	7.94

A. gayanus was planted with *D. ovalifolium*, *S. capitata* and *P. phaseoloides* in an experiment to study the effect of stage of savanna maturity, method of control, and P levels on establishment. The legumes were planted at 1000 hills/ha and the grass at 500 hills/ha in mature savanna and savanna recently burned, with and without stubble mulch sweep tillage to partially control the native vegetation and loosen the surface soil. The two trailing legumes *D. ovalifolium* and *P. phaseoloides* have provided essentially complete cover in all tillage and vegetation treatments at medium to high P levels. In the first year after planting, *A. gayanus* did not provide the expected stand due to late planting and limited seed production.

The low density seeding method has been used successfully for pasture establishment in wet areas along streams and lakes with species that are well adapted to inundation or saturated soil conditions. There is, however, much greater weed potential in these areas and, therefore, a higher seeding density is used (2500 hills/ha) to provide more rapid cover and minimize weed competition.

Spatial Distribution of Associated Species

The strip seeding of aggressive species like *B. decumbens* continues to show promise, both under rotational and continuous grazing. The combination *B. decumbens/P. phaseoloides* planted in alternate 2.5 m strips appears to be relatively stable after three years, but the frequent grazing favors the legume. Figure 34 shows that there was no effect of increasing the maintenance fertilizer beyond 0-15-15 kg/ha (N-P_2O_5-k_2O, respectively) on productivity and legume/grass balance under three grazing regimes. In a new trial in which the two species are planted in alternating triangles and strips as described in the CIAT 1978 Annual Report, *P. phaseoloides* has become strongly dominant under continuous grazing. This is in part due to a severe attack of spittlebug which limited *B. decumbens* production early during the rainy season. The legume has invaded over 50% of the area originally seeded to grass. The grass is not displaced and appears to be responding to improved N fertility in the area invaded by the legume. Each species initially occupied 50% of the total area.

A trial on date of seeding was established to study the effect of planting the legume prior to the grass in

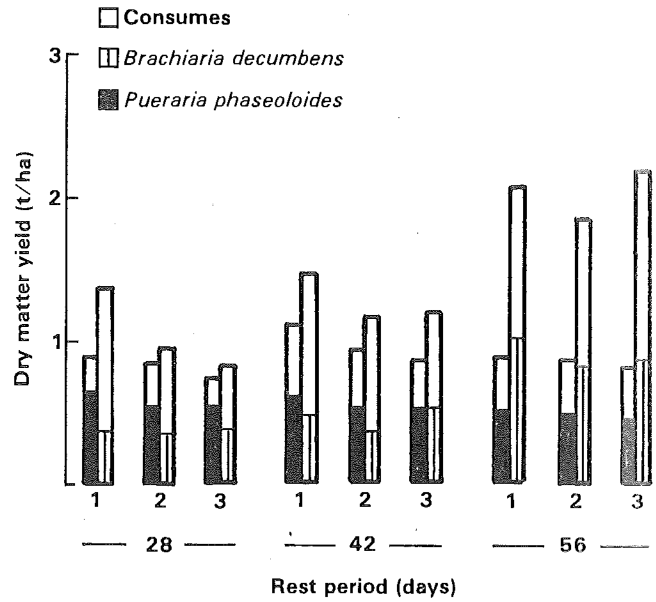

Figure 34. Effect of rest period duration and maintenance fertilizer application (1 = 0-15-15; 2= 0-45-15; 3=0-45-45) on production and consumption of legume/grass associations, 1978.

four different associations and three patterns of planting including broadcast, 1:1 and 2:2 grass/legume patterns in rows spaced 50 cm apart. In Figures 35 and 36, the effect of relative seeding time can be seen in three harvests. In the first harvest the effect is very large and it is surprising that it continues to be large especially in the case of *A. gayanus* and *P. maximum* even in the last harvest, a year after establishment. As shown in Figure 37, row planting was clearly superior to broadcast planting as measured by stand counts.

In another trial on date of planting, eight species were seeded at monthly intervals through the rainy season, with two different types of seed bed preparations. Figures 38 and 39 show the effect of date of seeding and seed bed preparation on stand count after three weeks and six months. Both date of seeding and seed bed preparation appear to have large effects on some species whereas others are little affected by either. Successful seeding in Carimagua can be accomplished with most species during a long planting season in which rainfall is adequate and dependable.

Additional experience is reported on the extraction of moisture from the soil profile during the dry season. The dry season stress has naturally been viewed as moisture stress, but with the large amount of moisture

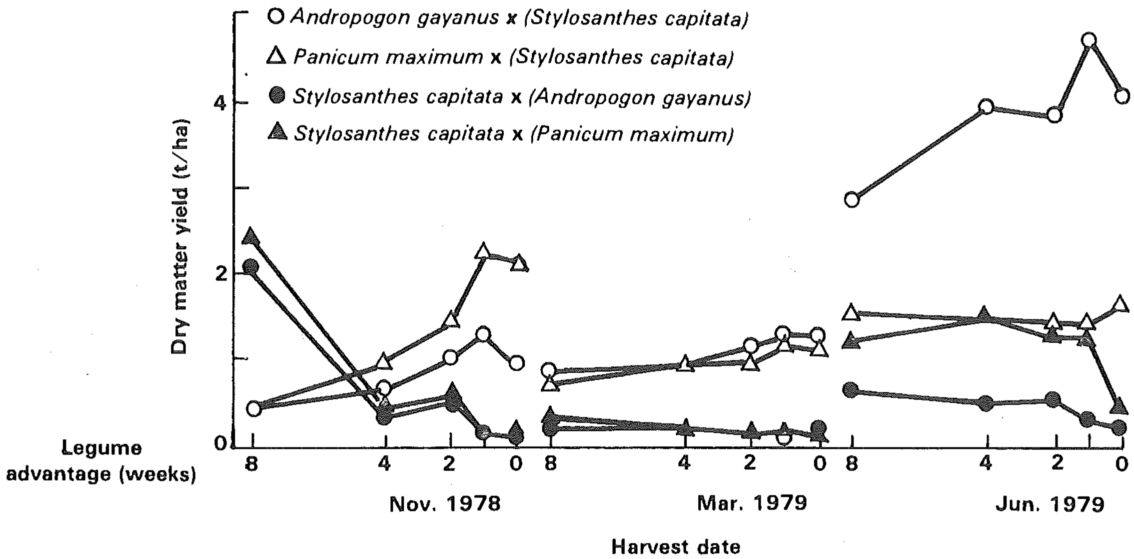

Figure 35. Effect of relative plating date of *Stylosanthes capitata* in mixture with *Andropogon gayanus* or *Panicum maximum* on forage production. Yield data are for first species listed; associated species are shown in parenthesis.

stored in the subsoil at Carimagua, it would appear that the stress is as much nutritional as it is moisture, due to the extremely low fertility of the subsoil. Most pasture species used in Carimagua are sufficiently tolerant to Al that subsoil acidity should not restrict root penetration. However, the lack of nutrients, especially Ca, may restrict penetration or at least reduce root proliferation in the subsoil, and the plant is subjected to a situation wherein there is no water where there is fertility and very little fertility where water is found. Ca would appear to be especially critical since it does not move downward to the growing root tip within the plant. Species like *S. capitata,* which appears to be exceptionally efficient in Ca uptake, may be especially capable of extracting moisture from deep friable soil profiles in Oxisols like those in Carimagua. The patterns of extraction in Figure 40 show the apparent strong effect of stage of maturity on moisture utilization by two *S. capitata* ecotypes (one early flowering and the other late flowering). By the time the

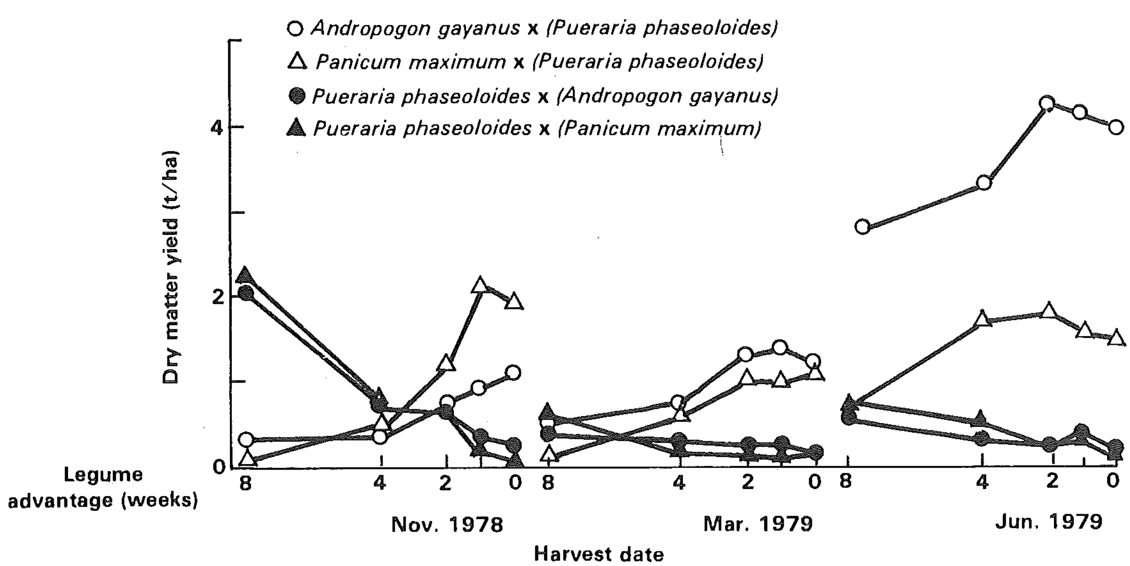

Figure 36. Effect of relative planting date of *Pueraria phaseoloides* in mixture with *Andropogon gayanus* or *Panicum maximum* on forage production. Yield data are for first species listed; associated species are shown in parenthesis.

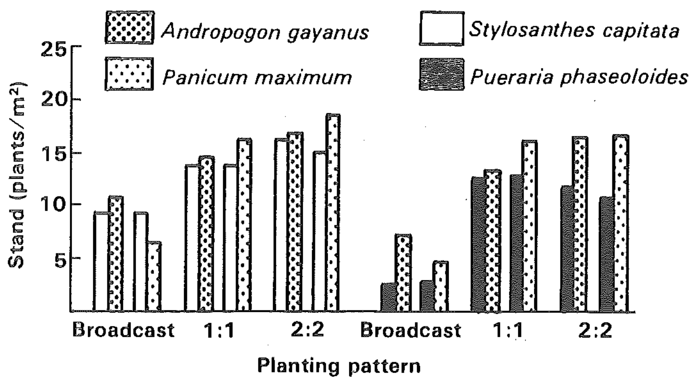

Figure 37. Effect of planting pattern (row spacing: 50 cm) on stand counts of four associations.

dry season began, *S. capitata* 1019 had flowered and was harvested; therefore, it used relatively little moisture from the profile. However, *S. capitata* 1078 flowered in early January and was harvested late in January by which time it had dried the profile to a depth of 1.50 m.

Figure 41 shows the effect of time of application of herbicide after burning the native savanna. It appears that optimum control is obtained with glyphosate and dalapon when applied 15 days after burning, and further delay considerably reduces the effectiveness of both. MSMA and DSMA were slightly more effective after 30 days delay. Figure 42 shows the effect of the application rate of the four herbicides. Little advantage was observed for increasing rates beyond the recommended levels.

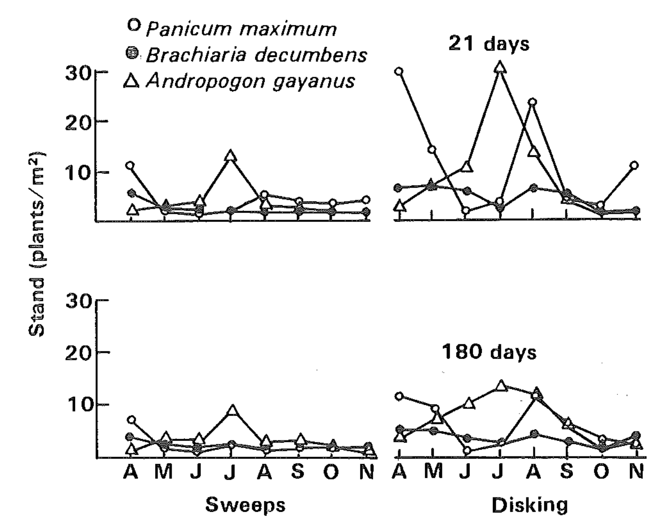

Figure 38. Effect of seed bed preparation and planting date on stand counts of three forage grasses, 21 and 180 days after seeding.

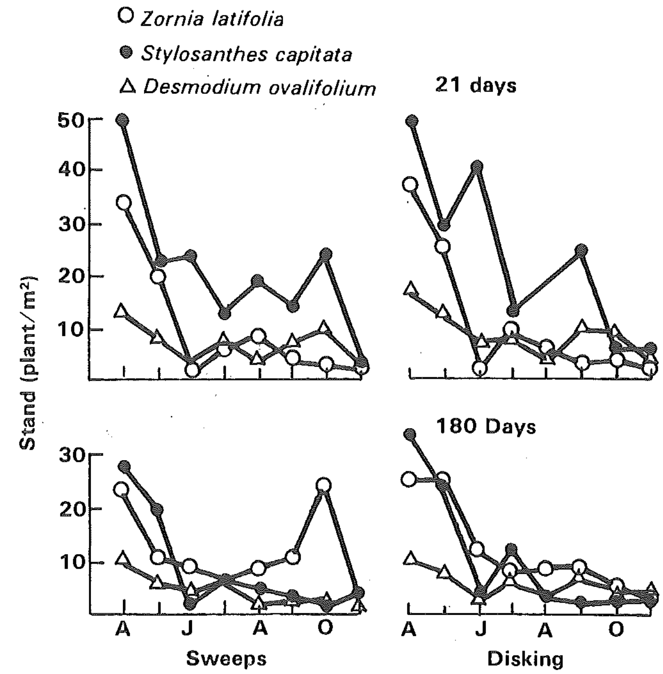

Figure 39. Effect of seed bed preparation and planting date on stand counts of three forage legumes, 21 and 180 days after seeding.

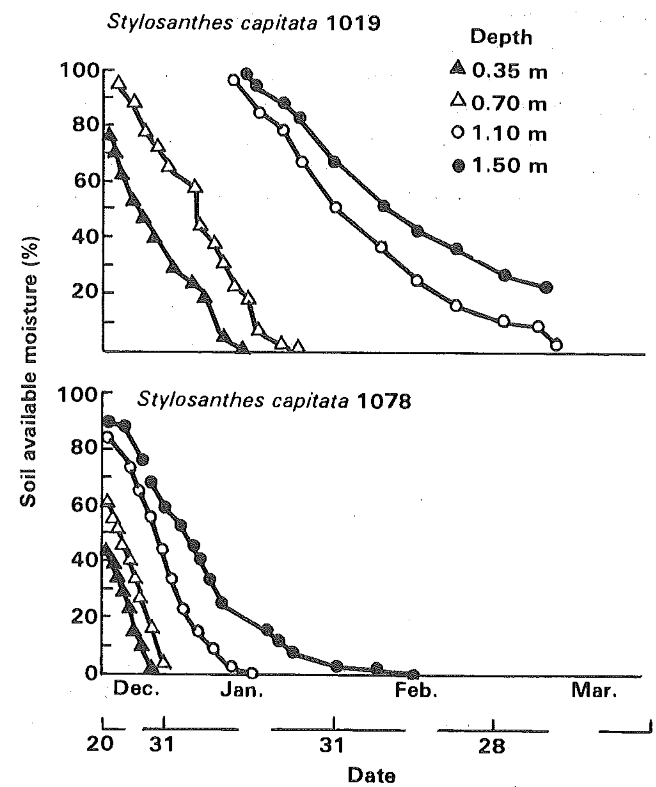

Figure 40. Soil moisture extraction patterns for *Stylosanthes capitata* 1019 (maximum flowering in early November and harvested in early December) and *S. capitata* 1078 (maximum flowering early January and harvested in late January).

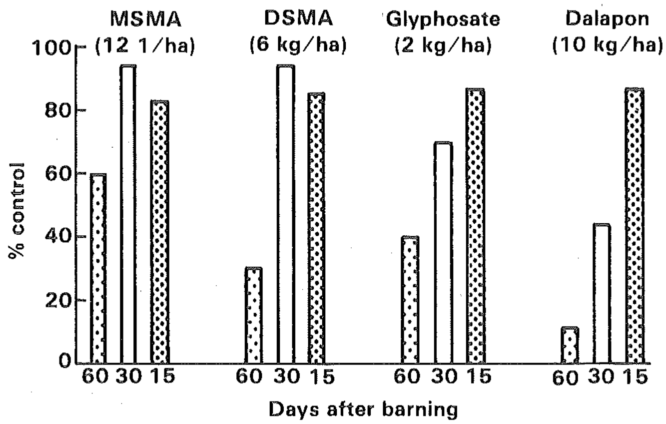

Figure 41. Effect of delaying the application of herbicides after burning on control of native savanna vegetation.

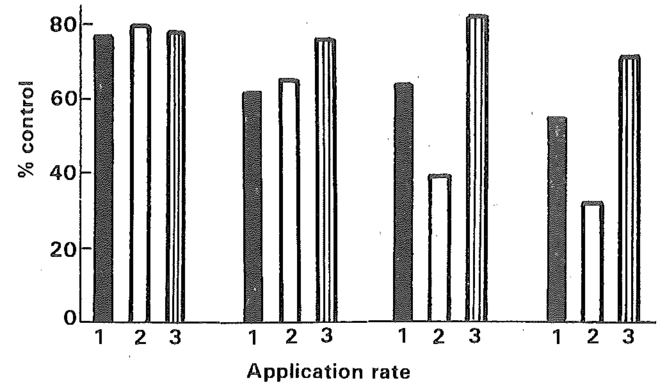

Figure 42. Effect of herbicide application rate on control of native savanna vegetation (1 = recommmended rate; 2 = twice the recommended rate; 3 = three times the recommended rate fitures in parenthesis are the recommended application rates.)

PASTURE DEVELOPMENT IN THE THERMIC SAVANNAS (CERRADO)

The objectives of the Pastura Development section of the Cerrado are: (1) to develop efficient systems of establishing forage legumes and grasses appropriate for representative ecosystems in Cerrado type savannas of South America and (2) to determine establishment and maintenance fertilizer requirements for the most promising grasses and grass/legume associations for the area.

The pasture development strategy adopted at the Cerrado center was presented in the CIAT 1977 Annual Report. The research activities designed to fill the technological gaps for implementation of this strategy include: (a) identifying the most important edaphic factors limiting pasture establishment, with emphasis on legumes; (b) determining establishment and maintenance requirements of selected grass/legume associations for Cerrado soil conditions; (c) developing efficient systems for pasture establishment with emphasis on minimum inputs; (d) developing renovation techniques for degraded pastures.

Identification of Nutrient Deficiencies

The main nutrient deficiency in the Cerrado soils is phosphorus. Other nutrients including K, Mg, Zn and Mo have been identified as limiting for some crops. Pasture species, especially the forage legumes, have specific nutrient needs to assure establishment, productivity and persistence. These requirements vary from soil to soil and among species.

Exploratory fertility experiments were initiated in 1978 on two important Cerrado soils, Yellow Red Latosol (LVA) and Dark Red Latosol (LVE), using *Centrosema pubescens* CIAT 438 and *Calopogonium mucunoides* as test forages. The experiments consisted of 2^8 factorials in a fractional replication design that included Ca, Mg, K, S, Cu, Zn, Mn, Mo and B. All pots received basal application of P equivalent to 100 kg P/ha. The effect of levels of P and $CaCO_3$ were studied in a parallel experiment.

There was a significant response to 30 kg S/ha (CIAT Annual Report, 1978) with *Centrosema* in the LVE soil. *Calopogonium,* which responded to S, also responded to 500 kg $CaCO_3$/ha. Both legumes also responded to K in both soils. Mg was not as important as S, Ca and K, but interactions of Mg with S and Mo were detected. Based on the greenhouse results, a field experiment including similar treatments was established.

A parallel experiment with levels of 50, 100, 200, and 400 kg P/ha and 0, 100, 500, and 1000 kg $CaCO_3$/ha, showed the importance of Ca as a nutrient.

Ca and P content in *Calopogonium* plants varied with $CaCO_3$ and P levels, as shown in Figures 43 and 44. It is interesting to note that when no lime was applied to the LVA soil, *Calopogonium* plants contained less than 1% Ca, unless more than 200 kg of P as monocalcium phosphate were applied. On the other hand, when high levels of P were applied, plants contained more than 1% Ca even without lime. Plants grown in the LVE soil followed the same trend but seemed to require more $CaCO_3$ or phosphate to reach desirable tissue Ca values. This points out the importance of Ca and the possible need for additional Ca when a low Ca P-source, such as triple superphosphate (TSP) is used.

Plant Mg content decreased with increasing levels of $CaCO_3$ in both soils but more in the LVA than in the LVE, reaching extremely low values when 1000 kg $CaCO_3$/ha were applied. It is clear that a balanced supply of both Ca and Mg is required for optimum growth.

Field experiments are now under way to confirm these results and to determine optimum levels of Ca, Mg, K and S.

Phosphate Requirements for Andropogon gayanus Establishment

A field experiment was initiated in 1979 to determine P requirements for establishment and early growth of *A. gayanus* and *S. capitata* and to evaluate different sources of P. Levels of 0, 60, 120 and 240 kg/ha of P_2O_5 were applied as triple superphosphate (TSP), Araxa rock phosphate and thermophosphate (a heat-treated rock phosphate). The basal application

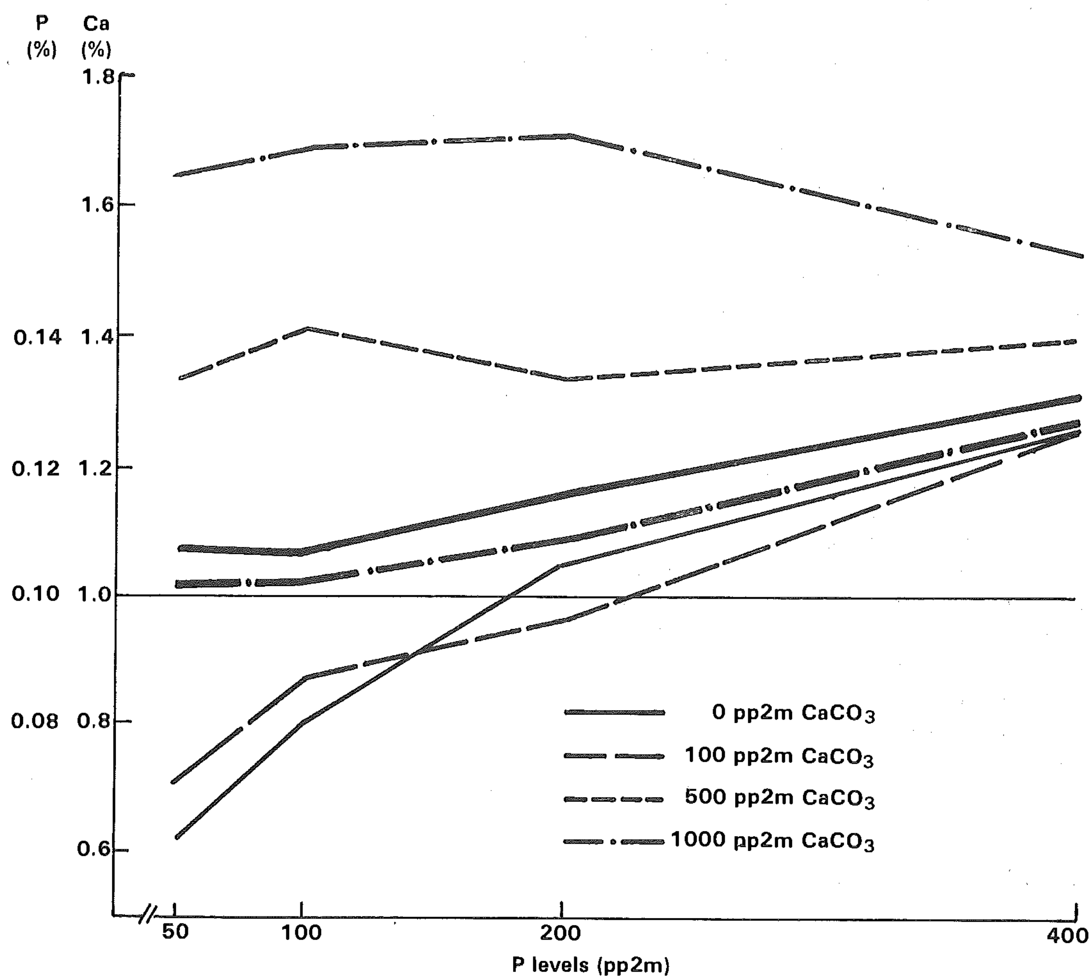

Figure 43. Effect of different levels of applied P and $CaCO_3$ on Ca and P contents in *Calopogonium mucunoides* plants grown on a LVA soil under greenhouse conditions.

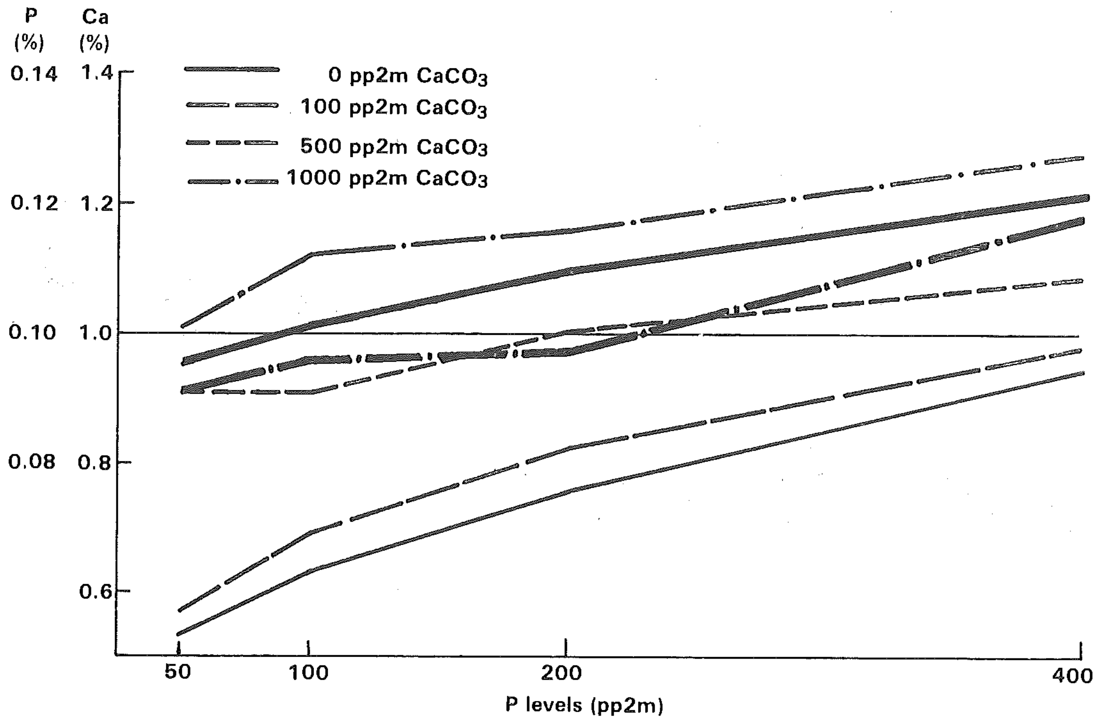

Figure 44. Effect of different levels of applied P and lime on Ca and P contents in *Calopogonium mucunoides* plants grown on a LVE soil under greeenhouse conditions.

consisted of 50 kg S/ha, 100 kg K_2O/ha, 5 kg Zn/ha, and 0.5 kg of ammonium molybdate/ha. A mixture of *A. gayanus* 621 and *S. capitata* 1078 was planted at seeding rates of 6 and 4 kg/ha, respectively, in recently prepared virgin land.

Good establishment was observed for both species as indicated by the number of plants/U.A. in all plots, except the checks. However, initial plant growth was very slow for all treatments. *S. capitata* did not produce high dry matter and by the time the pasture was cut at 15 cm height it was almost pure grass.

Figure 45 shows dry matter production as a function of P levels of three sources. With no added P there was no measurable growth reflecting the extreme P deficiency in this soil. Maximum dry matter production was obtained with 240 kg of P_2O_5/ha as thermophosphate, and the response was linear over the range of P utilized in the experiment. It appears that 240 kg P_2O_5/ha was too low for maximum growth in this soil. The TSP treatment produced less than thermophosphate at all but the lowest level (60 kg P_2O_5/ha) at which production was similar. Maximum production with this source was reached at 120 kg P_2O_5/ha with some decrease at a higher level. Araxa rock phosphate resulted in good response with production similar to TSP at the rate of 240 kg P_2O_5/ha.

The rapid fixation of water soluble P and the initial low availability of P from rock phosphate may explain these differences in plant performance. However, available P was very high at the highest level of applied TSP as shown in Figure 45. Plant analysis showed clearly that the main parameter associated with the higher production observed for thermophosphate was the Mg content in the plant tissues. Mg was considerably higher at all levels of applied thermophosphate (Table 43). Plant content of P was low for all treatments. However, P values were similar to or higher than at all levels of TSP which performed poorly. These results confirm the importance of Mg for pasture species in this soil and coincide with the results of the greenhouse experiment.

The effect of source and level of phosphate on P, exchangeable Ca, and Mg in the soil are shown in Figure 46. High levels of applied phosphate of all sources resulted in increased exchangeable Ca. Exchangeable Mg increased when thermophosphate was used but decreased when TSP or Araxa rock

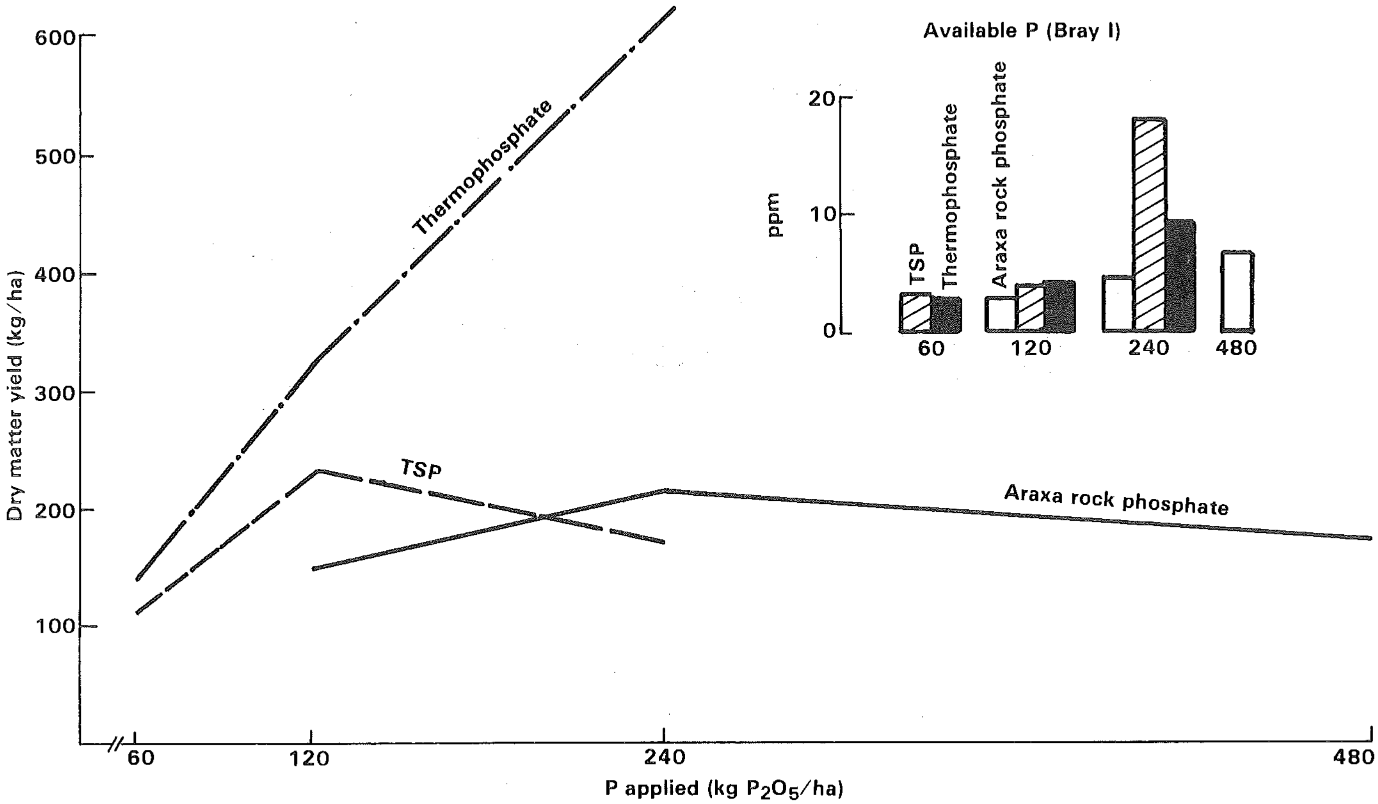

Figure 45. Effect of source and level of P on total dry matter of an *Andropogon gayanus/Stylosanthes capitata* pasture (first cut) and on available P in a LVA soil.

Table 43. Effect of three levels of applied P from three sources on content of P, Ca and Mg in *Andropogon gayanus* and *Stylosanthes capitata* (as percent of dry matter) grown in the field on a LVA soil in the Cerrado of Brazil. (Means of three observations.)

	P applied (kg P_2O_5/ha)								
	60			120			240		
P sources	P	Ca	Mg	P	Ca	Mg	P	Ca	Mg
	Andropogon gayanus								
TSP	0.07	0.21	0.12	0.07	0.21	0.13	0.08	0.24	0.14
Thermophosphate	0.07	0.23	0.15	0.07	0.19	0.17	0.07	0.30	0.23
Araxa rock phosphate				0.07	0.23	0.14	0.07	0.22	0.11
	Stylosanthes capitata								
TSP	0.09	0.74	0.20	0.09	0.78	0.20	0.10	0.87	0.21
Thermophosphate	0.09	0.83	0.24	0.09	0.78	0.25	0.10	0.78	0.31
Araxa rock phosphate				0.09	0.91	0.21	0.10	0.81	0.20

LSD at 0.05 = 0.01 (P); 0.02 (Mg); 0.07 (Ca).

phosphate were used, thus supporting the hypothesis that the response to thermophosphate was due not only to P but to increased Mg availability as well.

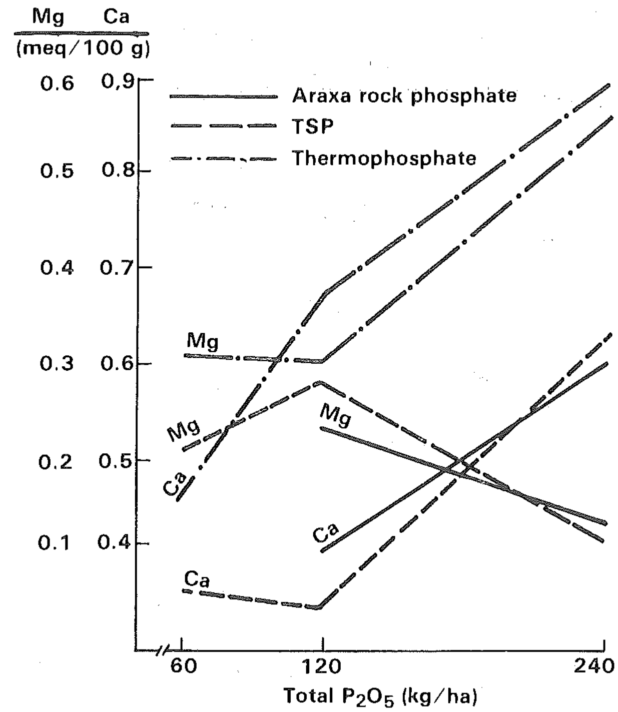

Figure 46. Effect of source and level of phosphate on exchangeable Ca and Mg in a LVA soil.

Adaptability of Two Grasses to Varying Levels of P and pH

Panicum maximum var. Trichoglume is widely used in more fertile Cerrado areas or after high levels of lime and fertilizer have been applied. This high quality grass is known for its high productivity and drought tolerance. *A. gayanus* is less demanding than *P. maximum* and appears to be equally compatible with legumes. With the purpose of defining the optimum range of pH and available P for these two grasses in association with legumes, a trial was initiated on an old experimental site where a wide range of phosphate levels from different sources (0, 86, 345, and 1380 kg P_2O_5/ha) and lime (0, 1.5 and 4.5 t $CaCO_3$/ha) were applied in 1973. In 1978, the soil pH ranged from 4.1 to 5.7 and P levels from 0 to 130 ppm. No additional fertilizer or lime was applied.

The associations *P. maximum* var. *Trichoglume/Macroptilium atropurpureum* and *A. gayanus* 621/*S. capitata* 1078 were planted in a factorial arrangement in a split-block experimental design.

The initial development of both legumes was slow while the grasses generally exhibited vigorous early growth, accounting for most of the dry matter production.

Figure 47 shows the effect of $CaCO_3$ and phosphate levels on dry matter production of the two grasses. *A. gayanus* performed well, especially when lime was also applied. At higher levels of phosphate (345 kg P_2O_5/ha) no effect of lime was observed in *A. gayanus* production. This has been interpreted as a response to Ca rather than to lime *per se,* since phosphate application increased Ca in the soil but did not modify the pH. *P. maximum* responded to lime at all but the highest level of phosphate (1380 kg P_2O_5/ha) probably because of its lack of tolerance to high exchangeable Al levels.

Detailed soil sampling has been done as a basis for determining the optimum available P and pH ranges for growth and grass/legume ratio.

Introduction of Legumes into Native Pastures

Native pastures are an important component of farming systems in the Cerrado. They are very low in both productivity and quality, especially during the dry season. The introduction of legumes into native pastures could increase their productivity due to increased N fixation and improved forage quality and consumption during the dry season.

A field experiment was initiated in 1978 to study establishment methods for three legume species. Establishment was better for those methods which included some soil disturbance like disking or sodseeding, independent of burning.

The methods investigated included oversowing undisturbed pasture, oversowing after light disking, and sodseeding in rows spaced 50 cm apart all with and without previous burning. Burning was done in December. Two controls, one with fertilizers alone and no tillage, and another with planting and disking plus 1 t $CaCO_3$/ha, were included.

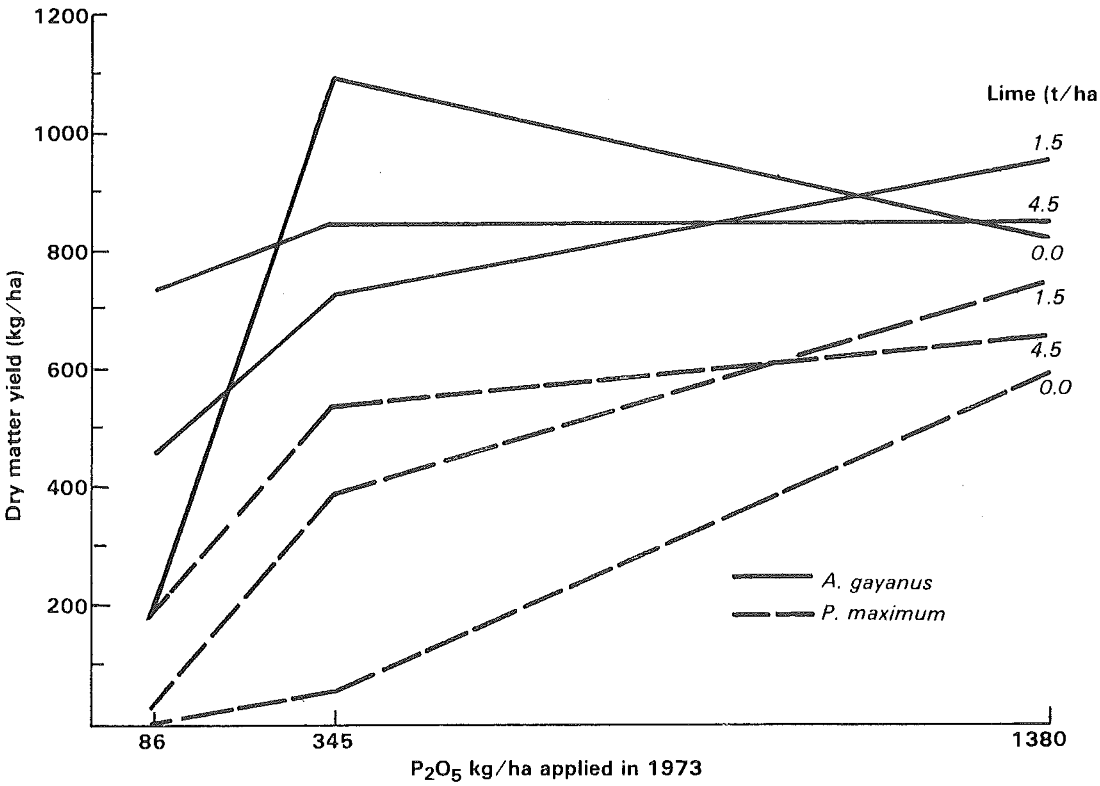

Figure 47. *Andropogon gayanus* 621 and *Panicum maximum* var. Trichoglume dry matter production as a function of levels of P and lime applied in 1973, in a LVE soil of the Cerrado of Brazil, 1979.

Galactia striata, C. mucunoides and *S. capitata* were seeded at 6, 9 and 4 kg/ha, respectively.

The effects of establishment method on stand counts have been reported (CIAT Annual Report, 1978). The effect on the native pastures can be observed in Table 44. Disking reduced dry matter production, especially when combined with burning. Sodseeding was as effective as disking in terms of established legume stand and had less effect on native pasture production. Burning did not improve legume establishment and severely decreased pasture productivity.

Table 44. The effect of tillage and burning and legume introduction on yield of native grasses after one year.

Establishment method		Native grass dry matter yield
Disking	Burning	(kg/ha)
-	-	949
-	+	590
+	-	467
+	+	142
Sodseeding	Burning	
+	-	919
+	+	305

The initial growth of legumes was very slow. However, a reasonable number of plants survived and produced abundant seed during the first year. Growth during the second year was much more aggressive; *C. mucunoides* tended to dominate native vegetation and extend outside the plots. *G. striata* produced more harvestable dry matter due to its erect growth habit. The cutting height was 15 cm which missed most of the *C. mununoides.*

In treatments which resulted in poor growth of native grasses, legumes established well and significantly increased dry matter and protein production. By the end of the rainy season, crude protein of the grasses was as low as 4%; legumes ranged over 14%.

Renovation of a Brachiaria Pasture

Brachiaria decumbens has been extensively planted in the Cerrado and is presently the most important cultivated grass in the area. Once P deficiency has been corrected, productivity of this grass depends mainly on soil N availability. N fertilizers are too expensive for use in beef production under Cerrado conditions.

B. decumbens is initially an aggressive grass which is difficult to associate with legumes. In the absence of legumes, organic soil N mineralization decreases with time and reaches a relatively low rate, severely limiting productivity. In addition, forage quality of grass swards decreases sharply during the dry season. The introduction of legumes into grass pastures could contribute to improved quality and increased availability of forage throughout the year and especially during the dry season.

An experiment was initiated early last rainy season in a 6-year old *B. decumbens* pasture, in which four methods of introducing three legumes were studied. Control plots with no legumes were fertilized with 0, 60 and 120 kg N/ha. The establishment methods tested were (a) oversowing with no seed bed preparation; (b) planting in 1.5 m wide strips with complete seed bed preparation; (c) oversowing after moderate disking; and (d) sodseeding. A basal application of 90 kg P_2O_5/ha, 100 kg K_2O/ha, 0.5 kg of sodium molybdate/ha and 4 kg Zn/ha was used. *C. mucunoides, Desmodium ovalifolium* 350 and *C. pubescens* 438 were planted at 4, 3 and 4 kg/ha, respectively.

Calopogonium establishment was good in all treatments except oversowing and competed strongly with the grass during the first year. *Centrosema* and *Desmodium* established reasonably well but growth was poor during the first year. Forage quality is being monitored throughout the year.

PASTURE UTILIZATION

The Pasture Utilization section conducts its research activities at CIAT-Quilichao and Carimagua. Due to the specific conditions of each site, the more basic less location-specific studies, which require less land but intensive observation and sophisticated methodology, are carried out at CIAT-Quilichao. Large grazing experiments are located at Carimagua.

The section concentrates its efforts in (1) evaluating the nutritional value of new forage material, (2) studies on pasture grazing management, and (3) pasture evaluation measured by animal production potential.

Nutritional Value of Promising Germplasm

The working program of the section includes mainly studies on intake and *in vivo* digestibility of grasses with emphasis on *Andropogon* and legumes, particularly *Desmodium ovalifolium* and *Stylosanthes capitata.*

More attention will be placed on measuring the nutritional value of forage under grazing conditions, since it is recognized that results obtained with confined animals are in certain cases misleading, as in the case of *D. ovalifolium,* which was well accepted by crated wethers (CIAT Annual Report, 1978, p. B-112), but apparently not palatable to the grazing animal.

At Carimagua, experiments with oesophageal fistulated steers were initiated to study selective grazing on different Category 4 legumes in mixtures with *A. gayanus.* Emphasis will be placed on the effect of the season of the year on the qualitative diet composition as compared to botanical composition of the available forage.

Grazing Management of Grass/Legume Mixtures

At CIAT-Quilichao, there are two similar sets of experiments to evaluate *Centrosema pubescens* (hybrid) 438 and *D. ovalifolium* in association with three grasses *(A. gayanus, Brachiaria decumbens,* and *Panicum maximum)* in separate blocks within a grazing unit.

Each set of experiments includes rotational grazing at 4, 6, and 8-week intervals and two grazing pressures (6.5 and 13.0 kg dry matter/animal/day), as well as continuous grazing with fixed stocking rate.

In each experiment, measurements of forage availability, botanical and plant parts composition, plant coverage (estimated by the method of Penfound and Howard) and diet selection, are made.

Experimental grazing of the experiments with *Centrosema* started in March 1978 and ended in October this year. The *D. ovalifolium* mixtures were grazed from March 1979 onwards.

From these as well as from other experiments, it becomes evident that *A. gayanus* is very compatible with most legumes, but is dominated rather easily by less palatable and more aggressive ones, such as *D. ovalifolium*. This is possibly an indication that *A. gayanus* is sensitive to shading of the crown. In contrast, *B. decumbens* competes more aggressively, dominating the companion legumes under the conditions of this experiment. *P. maximum* is intermediate compared to the other two grass species.

The effect of grazing pressure on forage availability and botanical composition of the mixtures with *D. ovalifolium* for the 4-week grazing interval is illustrated in Figure 48. With the other grazing intervals (6 and 8 weeks), a similar effect of grazing pressure was observed. In general, results indicate that low grazing pressure and short resting periods (or continuous grazing) favors the legume, while high grazing pressure and long resting periods tend to favor the grass component in the mixture. This is particularly true for *A. gayanus* which produces a higher amount of leaves under high grazing pressure.

The results also suggest that *D. ovalifolium* is susceptible to intense trampling, as is the case of high grazing pressure. This characteristic can be used as a management practice to prevent this aggressive legume from becoming excessively dominant in the mixture.

Diet selection of oesophageal fistulated steers (Figure 49) indicates that *D. ovalifolium* is only consumed if grass availability is limited.

D. ovalifolium appears to be of low palatability. This has become evident in all grazing trials at CIAT-Quilichao and Carimagua where this species is included. This emphasizes the need to include fistulated steers at an early stage of germplasm evaluation.

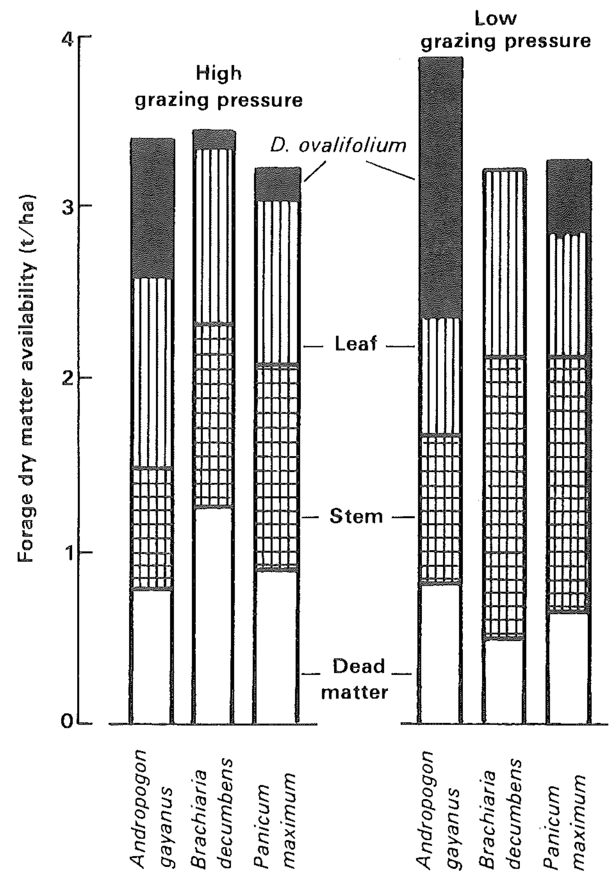

Figure 48. Effect of grazing pressure on forage available and botanical composition of three grass association with *Desmodium ovalifolium* at CIAT-Quilichao, during the dry season.

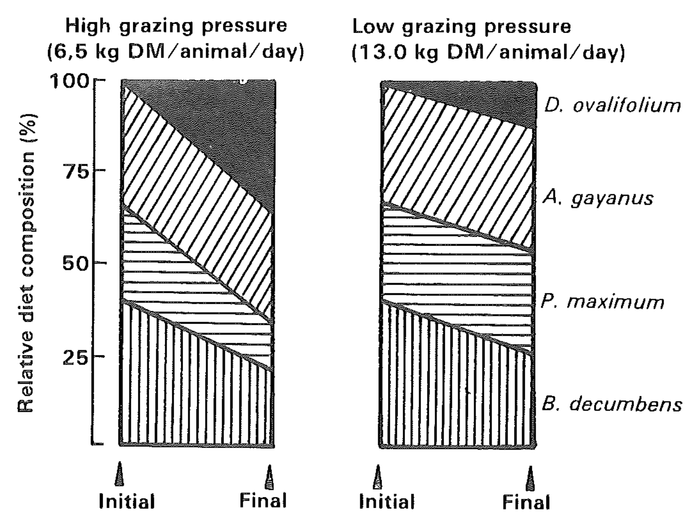

Figure 49. Effect of grazing (4-week grazing period, 9 h/day) on diet composition of oesophageal fistulated steers grazing a *Brachiaria decumbens, Panicum maximum* and *Andropogon gayanus/Desmodium ovalifolium* pasture at CIAT-Quilichao.

It is interesting to note that, in spite of less availability, the proportion of *A. gayanus* in the selected diet is almost constantly high during this period (Figure 49). This might be related to the relative good acceptance of *A. gayanus* stems.

Figure 50 shows the residual forage availability and Figure 51 the diet composition of oesophageal fistulated steers on the continuously grazed *D. ovalifolium/A. gayanus* and *P. maximum,* mixtures at four sampling dates.

On 90% of the 1-ha paddocks, *D. ovalifolium* is mixed with *A. gayanus,* while at the other 10%, this legume is associated with *P. maximum.* As can be observed in Figure 50, residual forage availability of *D. ovalifolium* was higher than *A. gayanus,* with a tendency to increase as grazing increased. Changes in the availability of *A. gayanus* were related to increasing proportion of stem and dead material. The stem proportion of *A. gayanus* was relatively constant in the selected diet (Figure 51), independent of total forage availability. This was not the case for leaves, which were selected according to availability.

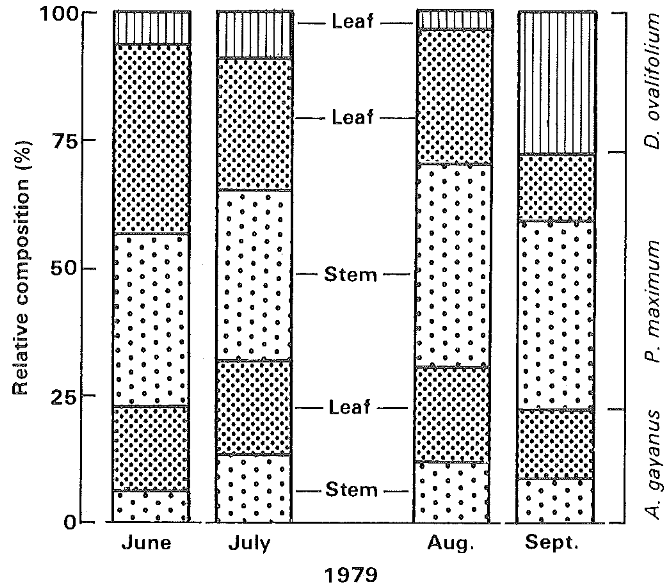

Figure 51. Diet composition of oesophageal-fistulated steers grazing an *Andropogon gayanus/Panicum maximum/Desmodium ovalifolium* pasture at CIAT-Quilichao.

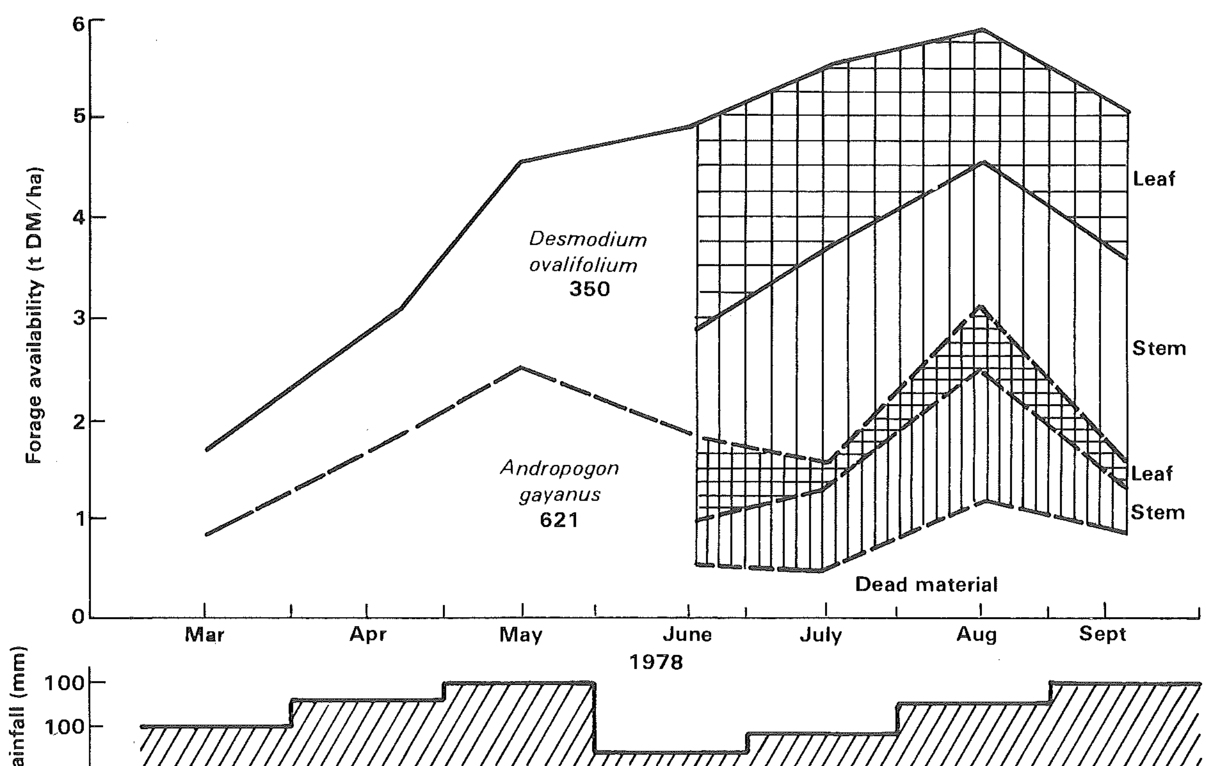

Figure 50. Residual forage availability of an *Andropogon gayanus/Desmodium ovalifolium* pasture, under continous grazing, at CIAT-Quilichao.

Again, voluntary intake of *D. ovalifolium* is determined by the availability of the companion grasses. Since only 10% of the paddocks is covered with the *P. maximum* mixture, intake of this species was limited by availability. It appeared, however, that selectivity for this species was high.

During the experimental continuous grazing period of 196 days (March-September), the three steers/ha gained, on the average, 464 g/day. The results of the monthly weighings suggest that the animal weight gains are directly related to *A. gayanus* availability.

In relation to the rotational and continuous grazing experiments with *C. pubescens* and *S. guianensis* 136 + 184 (only in continuous grazing) in mixtures with *B. decumbens, P. maximum,* and *A. gayanus,* the legumes could only persist with *A. gayanus*. In the rotational scheme, low grazing pressure favored dry matter production of the legume, particularly during the dry season.

In terms of plant coverage, legume coverage tended to decrease as the resting periods increased from 4 to 6 and 8 weeks. There was little difference in grass coverage and availability between the three grazing intervals. In general, and as expected, legume coverage decreased as grass coverage increased.

In rotational grazing systems it would appear more convenient to estimate coverage after grazing by the method of Penfound and Howard, as the bulk of forage before grazing makes it a difficult task. High correlations were found between amount of forage before grazing and coverage after grazing, indicating that this simple method provides very useful information if used after grazing.

Oesophageal fistulated animals were used to estimate chemical and botanical composition of the selected diet. At any season of the year, the steers were able to select a diet with over 9% crude protein, which was 2% higher than the average crude protein content of the available forage. Digestibility of the selected diet was also 5% higher than the digestibility of the forage offered.

The botanical composition of the available forage in two different seasons, and the diet composition of these mixture under continuous grazing, are presented in Figure 52. A seasonal effect on diet composition was evident, confirming that animals select more legume forage during the dry season, while grasses are preferred during the wet season. Thus the presence of the legume would allow cattle to select a good quality diet in the dry season. Protein content of the forage appears to be an important selection criterion.

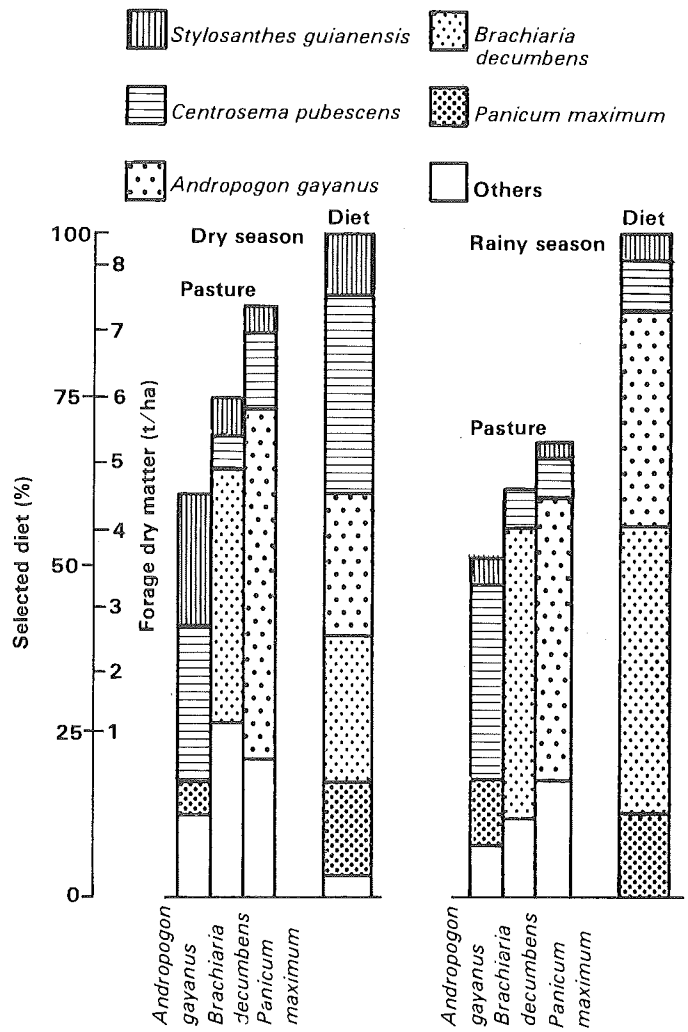

Figure 52. Botanical composition of the pasture and of the selected diet by oesophageal fistulated steers by season (dry season, Aug-Sept. and rainy season Nov-Dec.) under continuous grazing, at CIAT-Quilichao, 1978.

During 1978, the continuously grazed experiment with *Centrosema* had a stocking rate of 2 steers/ha and the average daily gain of the animals was 720 g. Until September 1979, the stocking rate was 3 steers/ha, and the average daily gain 612 g. These figures indicate that in the CIAT-Quilichao ecosystem and under the conditions of the experiment, the *Centrosema* based pasture is able to persist and to produce liveweight gains of 520-680 kg/ha/year.

Animal Production Potential of Pure Grass Pastures

All these experiments are conducted at Carimagua.

Brachiaria decumbens

The weight gains obtained during the fifth year of continuous grazing *Brachiaria decumbens* pastures at fixed stocking rates are presented in Table 45. During 1979, this experiment had a higher stocking rate than in former years, because analyses of forage availability data indicated a sub-utilization of the pasture. Compared to the 1978 results, weight losses were higher during the 1979 dry season in all stocking rates, but compensatory gains during the following rainy season were also higher than in any other year of the experiment, resulting in an overall higher liveweight gain per animal. This is a remarkable result, as during the last two years no maintenance fertilizer had been applied and the rainfall pattern remained similar to that in previous years.

Compared with the other grasses studied, *B. decumbens* appears to have the highest nutritional value, as reflected in animal weight gains. Nevertheless, it is important to acknowledge the increasing risk of pasture losses due to the attack of spittlebug in the region. The *B. decumbens* experiments have not been seriously attacked by this insect yet, but other pastures have been seriously affected. Thus, the availability of an alternative grass is also important for the Colombian Llanos.

Panicum maximum

During the second year of grazing, this species showed severe symptoms of mineral deficiencies. As a consequence, forage availability decreased and, by July, the steers had to be removed from the paddocks. Maintenance fertilization was applied and grazing was initiated again in November. The extreme high fertilizer requirements of *P. maximum* makes it an unattractive species for the Carimagua environment.

Andropogon gayanus

Three experiments with *A. gayanus* are being conducted. Continuous grazing started in late 1977 on the oldest paddocks.

As reported last year (CIAT Annual Report, 1978), grazing management of this species has not been easy. The management of this grass during the first year of establishment would appear to influence its performance in subsequent years. Thus, grazing management during the establishment phase should allow the plants to accumulate some reserves. High grazing pressure during establishment appears to result in small clusters and weak plants. If this occurs within a mixture with an aggressive legume, *A. gayanus* will be dominated. On the other hand, under low initial grazing pressure, *A. gayanus* accumulates excessive, poor-quality dry matter which is difficult to remove without burning or the use of mechanical means. Fortunately, *A. gayanus* is resistant to burning and in fact, it would appear as if the careful use of this practice had a positive effect on regrowth

Table 45. Liveweight gains obtained in Brachiaria decumbens pastures grazed at continued fixed stocking rates at Carimagua during 1979[1].

Stocking rate (animals/ha)	Daily liveweight gains (g/animal)			Yearly liveweight gains (kg/ha)[2]
	Dry season	Rainy season	Total period	
1.3	-73	679	441	209
1.8	-73	657	436	285
2.4	-41	578	308	269

1 Dry season (December-March), 99 days; Rainy season (March-October), 214 days; total period = 313 days.

2 Extrapolated to 365 days.

For this reason, one of the three experiments is used to study the effect of burning on pasture performance.

Another complicating factor is related to the fast rate of regrowth when environmental conditions are favorable. This created problems in one experiment at a low stocking rate, where *A. gayanus* grew so tall that it became difficult to observe the grazing animals. As a consequence, a high tick infestation was detected only when it already had caused weight losses and mortality due to tick-borne diseases. A good alternative management seems to be intermittent grazing, particularly in production systems where the proportion of sown pastures is small.

Liveweight gains were obtained in an experiment with different stocking rates in the dry and in rainy seasons (Table 46). The high carrying capacity and, therefore, the high animal production per unit area of a well established *A. gayanus* pasture is evident. In contrast, the nutritional value is not very high, as evidenced by liveweight gains of 110-150 kg/animal/year, which are not attractive for fattening operations.

In Figure 53, the residual forage availability of the three paddocks, at a given moment of the dry and the rainy season are shown. At any stocking rate, the green leaf proportion was rather low, and dead material high. In September, at the high stocking rate, the proportion of leaves appeared to be critical for the persistance of the pasture.

The main advantage of this grass seems to be the compatibility with less aggressive legumes and the possible resistance to spittlebug. Thus, it appears to be a good alternative for the widespread *B. decumbens* which is highly susceptible to spittlebug and difficult to associate with most legumes.

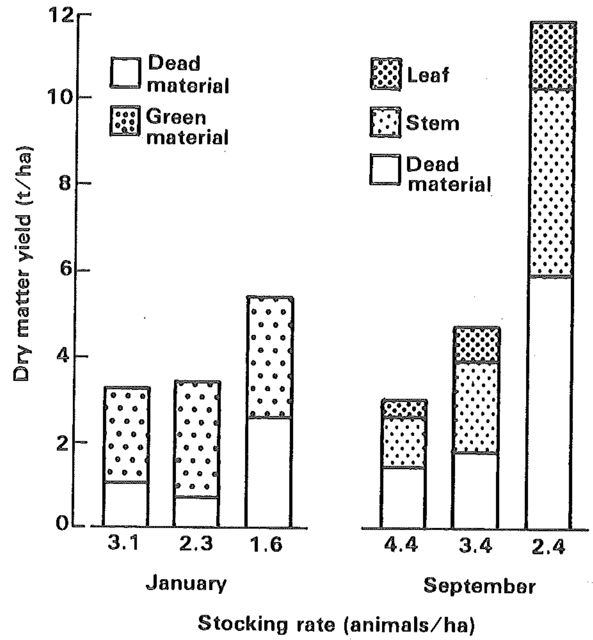

Figure 53. Residual forage availability of an *Andropogon gayanus* pasture at Carimagua during 1979. (First year of continuous grazing.)

Brachiaria humidicola

As with any new species, specific management strategies have to be developed, thus results presented are still preliminary. Grazing of the first experiment with *B. humidicola* started in December 1978.

Table 46. Liveweight gains obtained in Andropogon gayanus 621 pastures at continous fixed stocking rates at Carimagua during 1979[1].

Stocking rate[2] (steers/ha)	Dry season (g/animal/day)	Rainy season (g/animal/day)	Mean for total period (365 days)		
			(g/animal/day)	(kg/animal)	(kg/ha)
2.4	-95	444	300	107	265
3.4	-99	467	316	115	395
4.4	-86	359	240	90	389

1 Dry season (December-March), 98 days; Rainy season (March-December), 270 days; total period = 365 days.

2 13 steers/paddock.

Stocking rates were adjusted at the beginning of the rainy season but had to be increased again in August, due to excess of forage availability. Since August, animal performance was poor at any stocking rate. As it is known from other areas where *B. humidicola* has become important over the last years, its nutritional value is possibly lower than that of *B. decumbens.* This might be related to the coarse texture of the leaves, particularly as they become mature.

Nevertheless, this grass is of interest for the savanna conditions due to its good adaptation and its relative tolerance so far to the spittlebug. On the other hand, because of its extreme aggressiveness and dense cover, associations with less competitive legumes would be difficult.

Management and Production of Grass/Legume Pastures

A large grazing experiment was established in 1978 in Carimagua, to determine the animal production potential of pastures based on Category IV legumes. Replicated 2-ha paddocks with *Zornia latifolia* 728, *Stylosanthes capitata* 1019 plus 1315, *S. capitata* 1405, *Desmodium ovalifolium* 350 and *Pueraria phaseoloides* were seeded in association with *A. gayanus* 621. *D. ovalifolium* was also planted in mixture with *B. decumbens.* Similar paddocks with the two grasses alone were established as controls.

The basal fertilization for establishment of the *Z. latifolia, S. capitata* and grass pastures included 20 kg P, 18 kg K, 22 kg S and 11 kg Mg/ha and for *D. ovalifolium* and *P. phaseoloides,* 46 kg P, 43 kg K, 22 kg S and 11 kg Mg/ha.

Experimental grazing of the paddocks with mixtures of *Z. latifolia, S. capitata* 1019 plus 1315, *D. ovalifolium* and *P. phaseoloides* with *A. gayanus* started in December 1978. Due to later planting, grazing of the other pastures started in April. Results for the legume based pastures which were grazed during the dry season are presented in Table 47.

During the dry season, only the steers on *D. ovalifolium/A. gayanus* pastures lost some weight, while all other pastures produced significant weight gains. These legume/grass mixtures appear to have a productive potential of 360-420 kg/ha/year, if a reasonable voluntary intake of the legume and

Table 47. Liveweight gains obtained from four legume/*Andropogon gayanus* mixtures during 1979 at Carimagua.

Legume/ *A. gayanus*	Dry season: Grazing (animal/ days/ha)	Dry season: Daily liveweight gains (g/animal)	Rainy season: Grazing (animal/ days/ha)	Rainy season: Daily liveweight gains (g/animal)	Total period: Grazing (animal/ days/ha)	Total period: Daily liveweight gains (g/animal)	Total liveweight gains (kg/ha)
Zornia sp.	165[2]	317	429[3]	836	594	672	399
S. capitata 1019 + 1315	165	500	340[4]	673	505	610	308
D. ovalifolium	165	-21	223[5]	606	388	329	128
P. phaseoloides	165	371	438[6]	732	603	618	373

1 Dry season (December-March), 96 days; rainy season (March-October), 208 days; total period = 304 days.
2 December-February: 2 animal/ha x 69 days; February-March: 1 animal/ha x 27 days.
3 March-May: 1 animal/ha x 55 days; May-September: 2.5 animal/ha x 135 days; September-October: 2 animal/ha x 18 days.
4 March-May: 1 animal/ha x 55 days; May-August: 2.5 animal/ha x 114 days, discontinued.
5 March-May: 1 animal/ha x 55 days; May-July: 2.5 animal/ha x 67 days, discontinued.
6 March-May: 1 animal/ha x 55 days; May-October: 2.5 animal/ha x 153 days.

availability of the grass (stability of the association) can be maintained.

Regression coefficients for each of the comparable associations compared with the pure grass are shown in Figure 54. There was no significant difference in average daily gain between *Z. latifolia* and *P. phaseoloides* mixtures, but both were superior to *S. capitata*.

Stocking rates were equal for all pastures during the dry season, starting with 2 steers/ha in December and being decreased to 1 steer/ha in February. This low stocking was maintained until May for all treatments to allow recovery of the pastures. Since May, a fixed stocking rate of 2.5 steers/ha had been planned for all treatments and for the rest of the rainy season. This could not be maintained in the case of *D. ovalifolium* with *A. gayanus* and with *B. decumbens* due to the dominance of the legume, which resulted in low grass availability. Thus, in July these paddocks were left ungrazed in an attempt to recover the balance of the association. In August the same was done for the *S. capitata/A. gayanus* pastures.

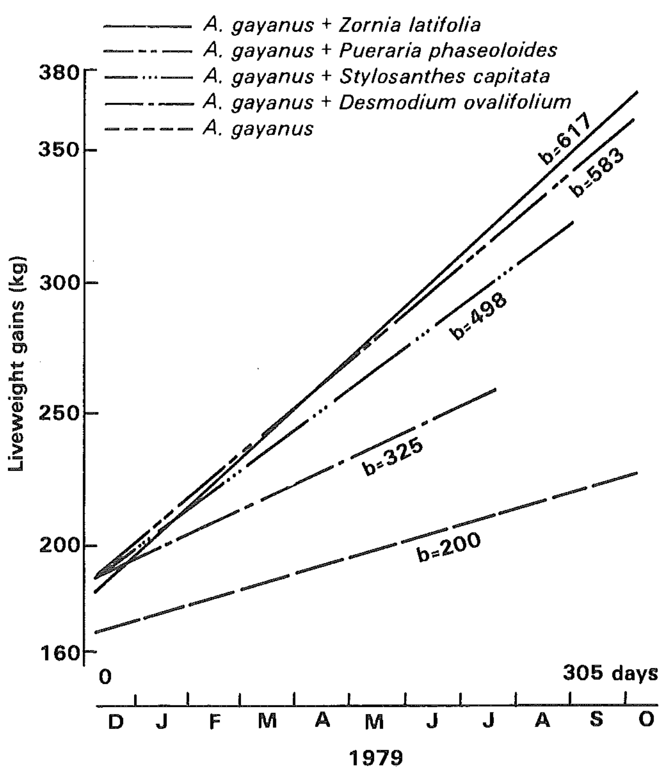

Figure 54. Liveweight gains during an actual grazing period of four legume/*Andropogon gayanus* pastures at Carimagua. (First year of grazing, based on regression.)

To illustrate this situation, the botanical composition of three different grass/legume mixtures in two sampling period is shown in Figure 55. *Z. latifolia/A. gayanus* was a stable mixture, although the legume was defoliated several times by insects and fungi. The high liveweight gains obtained in these pastures suggest that a good quality (high protein) legume may be effective even when present in the mixture in a rather low proportion.

In the *D. ovalifolium/A. gayanus* mixtures, legume coverage increased at the expense of the grass.

P. phaseoloides combined well with *A. gayanus* and produced excellent weight gains, at a relatively high level of fertilizer inputs.

Factors such as differences in palatability, growth habit and aggressiveness, make the combination *D. ovalifolium/A. gayanus* less compatible. In addition, and in agreement with data from CIAT-Quilichao, continuous grazing does not appear to be suitable for this mixture. It is possible that intermittent grazing may be a better strategy of utilization of this mixture.

A similar situation, though less severe, was observed with the *S. capitata* pastures, possibly as a result of high stocking rates, early grazing after establishment or both.

The difficulties encountered in the management of grass/legume mixtures is possibly not only a conse-

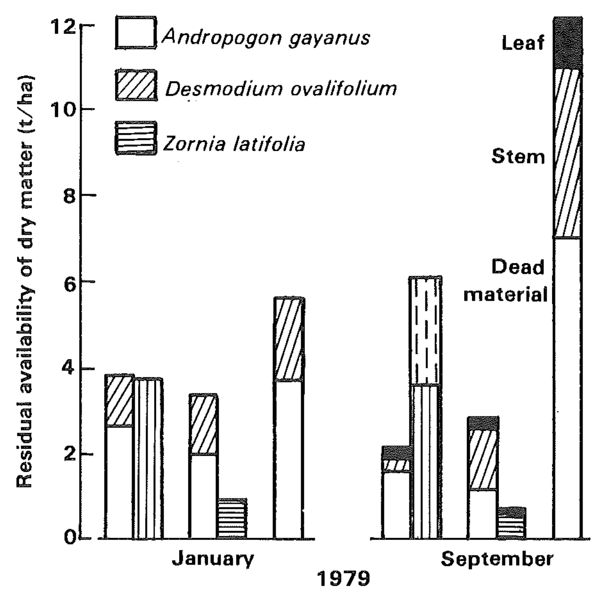

Figure 55. Botanical composition of two legume based pastures and a grass pasture at Carimagua.

quence of the competition between the grass and the legume under grazing and/or differences in palatability which result in selective grazing by the steers, but also to the lack of knowledge about basic management strategies on the first year of establishment. It becomes clear that each combination of species requires a very specific management, i.e., each grass/legume association has to be evaluated as a separate unit.

The two replicated pastures of *S. capitata* 1405/*A. gayanus* produced an average daily gain of 678 g/animal/day with continuous stocking of 2.5 steers/ha from April to October (for 173 days); this mixture has been stable and well balanced.

In another set of replicated experiments the "protein bank" concept is studied, i.e., the use of small areas sown with a legume in pure stand to be used to supplement cattle grazing pure grass pastures. This concept appears to suit some legumes with management problems when used in mixed swards.

P. phaseoloides is used with *B. decumbens* or with native savanna. When the protein banks were not fenced, *P. phaseoloides* was soon overgrazed. In some cases, a long rest period with some fertilization was required for the legume to recover.

The experiment using fenced *P. phaseoloides* protein banks in conjunction with native savanna could be followed through for 11 months of experimental grazing (Table 47). Results so far indicate better animal gains in the low stocking rate compared to the high stocking rate used. At the end of this period (November), plant coverage and vigor continued to be satisfactory in both stocking mates used.

New pastures established during 1979 include 2 ha paddocks with *S. capitata* 1019 and *S. capitata* 1315 in mixtures with *A. gayanus*. Since the *S. capitata* 1019 is early flowering and 1315 intermediate, the effect of the difference in maturity on pasture productivity will be studied.

Table 48. Liveweight gains obtained with native savanna and *Pueraria phaseoloides* protein banks, at two stocking rates at Carimagua during 1979[1].

Stocking rate savanna + *P. phaseoloides* (ha/animal)	Liveweight gains (g/animal/day) Dry season	Rainy season	Total period (kg/animal)	(kg/ha)
1.8 + 0.2	10	486	119	60
3.8 + 0.2	170	551	152	38

1 Dry season, 59 days; rainy season, 245 days; total period = 342 days.

CATTLE PRODUCTION SYSTEMS (CARIMAGUA)

The Cattle Production Systems section (formerly called, Animal Management section) continued (a) the evaluation of existing beef production systems in Colombia, Brazil and Venezuela; (b) the evaluation of the strategic use of improved pastures in Colombia; (c) herd management experiments in Brasilia; and (d) management of test herds.

Evaluation of Beef Production Systems (ETES)

The data collection phase of the Beef Production Systems Evaluation Project (ETES, an interdisciplinary project carried out in conjunction with the Economics and Animal Health sections of the Tropical Pastures Program) has been concluded in the Colombian Llanos, is well advanced in the Brazilian Cerrado and has been reinitiated in the Northeastern Llanos of Venezuela.

Llanos Orientales of Colombia

In the previous year (CIAT Annual Report, 1978), emphasis was given to the inter-farm variation in herd structure and management, including availability of sown pastures. This year, emphasis was somewhat different; however, variation between farms in various items will again be presented, as well as aspects common to all farms.

The physiographic characteristics (Table 49) show that the dry savanna is the principal component of the

Table 49. Physiographic characteristics of 16 farms in the Eastern Plains of Colombia. (ETES Project.)

Farm No.	Total area (ha)	Dry savanna (ha)	Wet savanna (ha)	Hilly savanna (ha)	Forest (ha)
2	1083	839 (78)[1]	140 (13)	7 (0)	97 (9)
4	3052	2385 (78)	410 (13)	85 (3)	172 (6)
5	810	623 (77)	54 (7)	40 (5)	93 (11)
6	1605	1015 (61)	504 (33)	0 (0)	86 (6)
7	4932	4089 (83)	414 (8)	90 (2)	339 (7)
8	375	203 (54)	172 (46)	0 (0)	0 (0)
9	474	55 (12)	155 (32)	234 (50)	30 (6)
11	5252	2243 (43)	2052 (39)	877 (16)	80 (2)
12	4325	2982 (69)	583 (13)	710 (16)	50 (2)
13	1412	306 (22)	406 (29)	700 (49)	0 (0)
14	1701	751 (44)	540 (32)	410 (24)	0 (0)
15	3580	2986 (83)	505 (14)	0 (0)	89 (3)
17	2239	1805 (80)	248 (11)	186 (9)	0 (0)
18	8891	7835 (88)	621 (7)	70 (1)	365 (4)
19	3972	3119 (78)	545 (14)	200 (5)	108 (3)
20	2744	2174 (76)	379 (13)	50 (2)	141 (8)
Mean	2903	64	20	11	4
CV	77.0	35.8	62.5	144.8	83.7

1 Figures in parenthesis are percentages.

farms, followed by the wet savanna, the hilly savanna and forest areas. The proportion of the total area represented by dry savanna is less variable between farms than the proportion of the other physiographic units.

Soil fertility is also less variable between farms in the dry savanna than in the wet savanna (Figure 56, 57 and 58). Available soil P in the dry savanna was above 2 ppm in only four farms. In contrast, more than 2 ppm available soil P was found in the wet savanna portion of 13 farms, and more than 4 ppm in four farms. Al saturation in the dry savanna was above 80% in all but one farm. In the wet savanna it was below 80% in five farms, and below 60% in two farms. Soil pH in the dry savanna was less than 4.7 in all cases, whereas in the wet savanna the pH range was 4.2 to nearly 5.0.

The number of animal units (AU) per farm depended largely on available dry savanna (correlation between area of dry savanna and total AU = 0.85) and was practically independent of the availability of wet savanna (correlation between area of wet savanna and total AU = 0.23).

The overall average stocking rate was 5.9 ha/AU, with 3.9 ha of dry savanna and 1.2 ha of wet savanna available per AU. As expected, the availability of dry savanna/AU varied less between farms than the availability of wet savanna/AU (Table 50).

The herd structure (Table 51) shows that all farms are cowcalf and stocker operations with some minor fattening activity in farms 2, 12, 17 and 20.

Tables 52 and 53 contain information on animal management practices additional to the data presented in the previous report (CIAT Annual Report, 1978).

The main objectives of herd subdivision are to avoid interference of male animals with females, and to

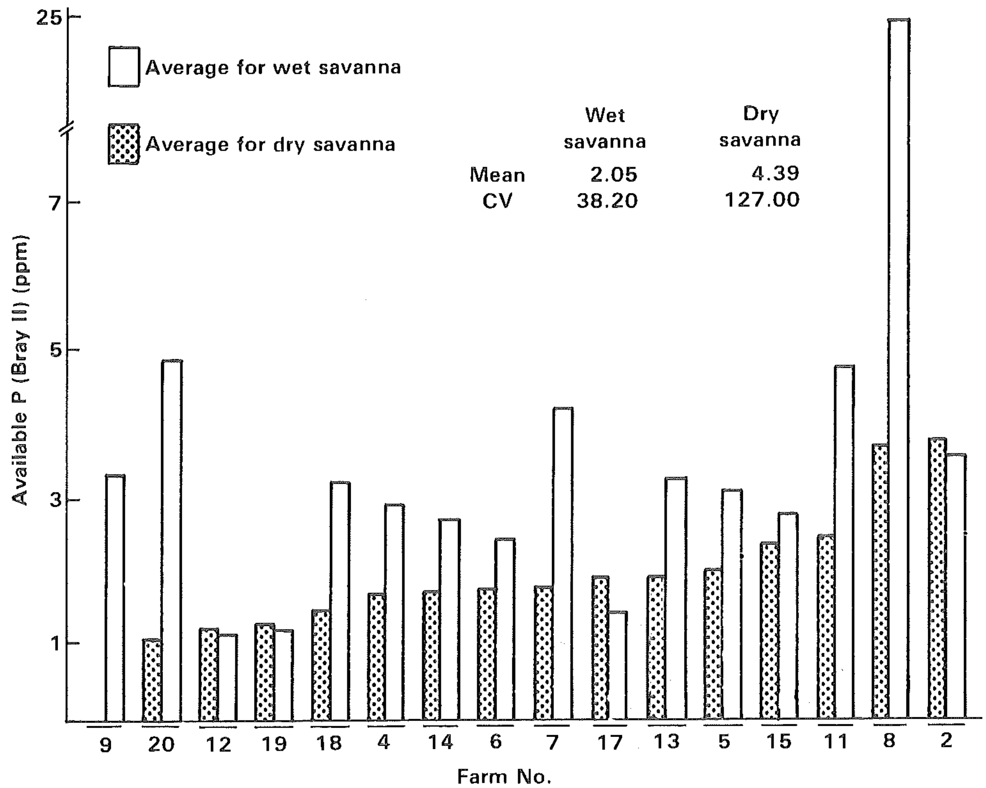

Figure 56. Available soil P in 16 farms of the Eastern Plains of Colombia (ETES Project).

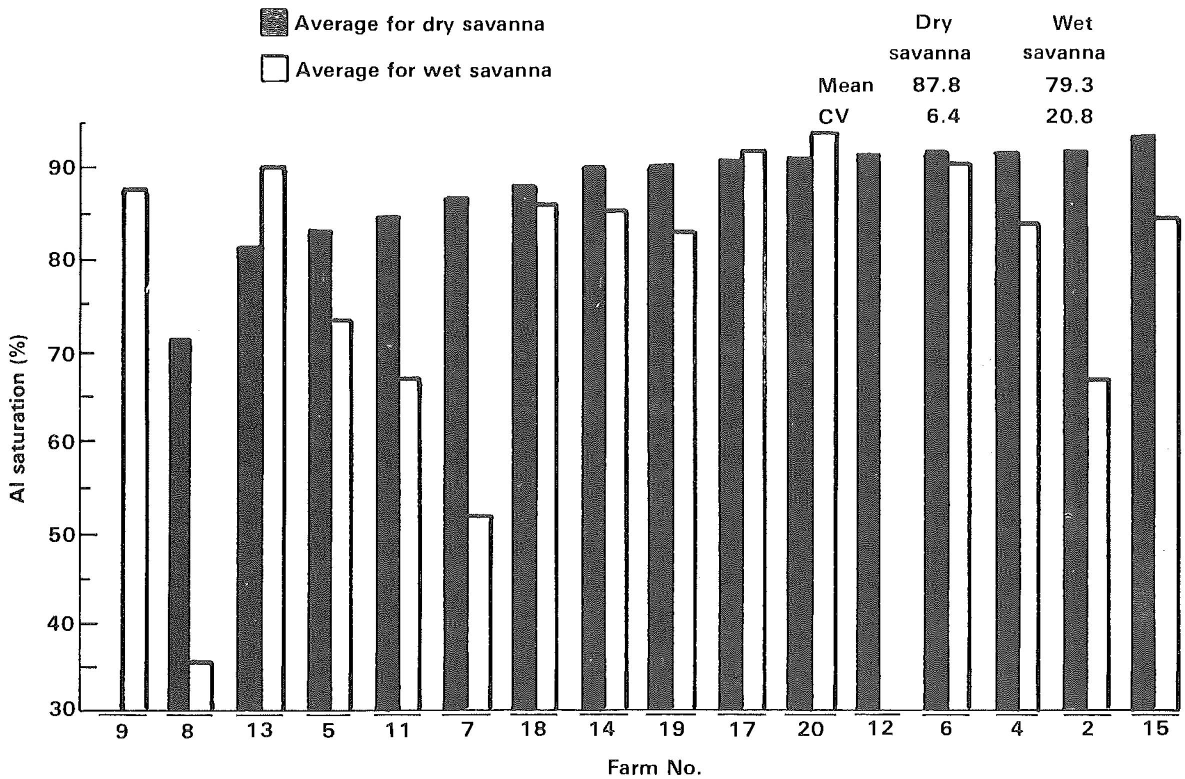

Figure 57. Al saturation in the soil of 16 farms of the Eastern Plains of Colombia (ETES Project).

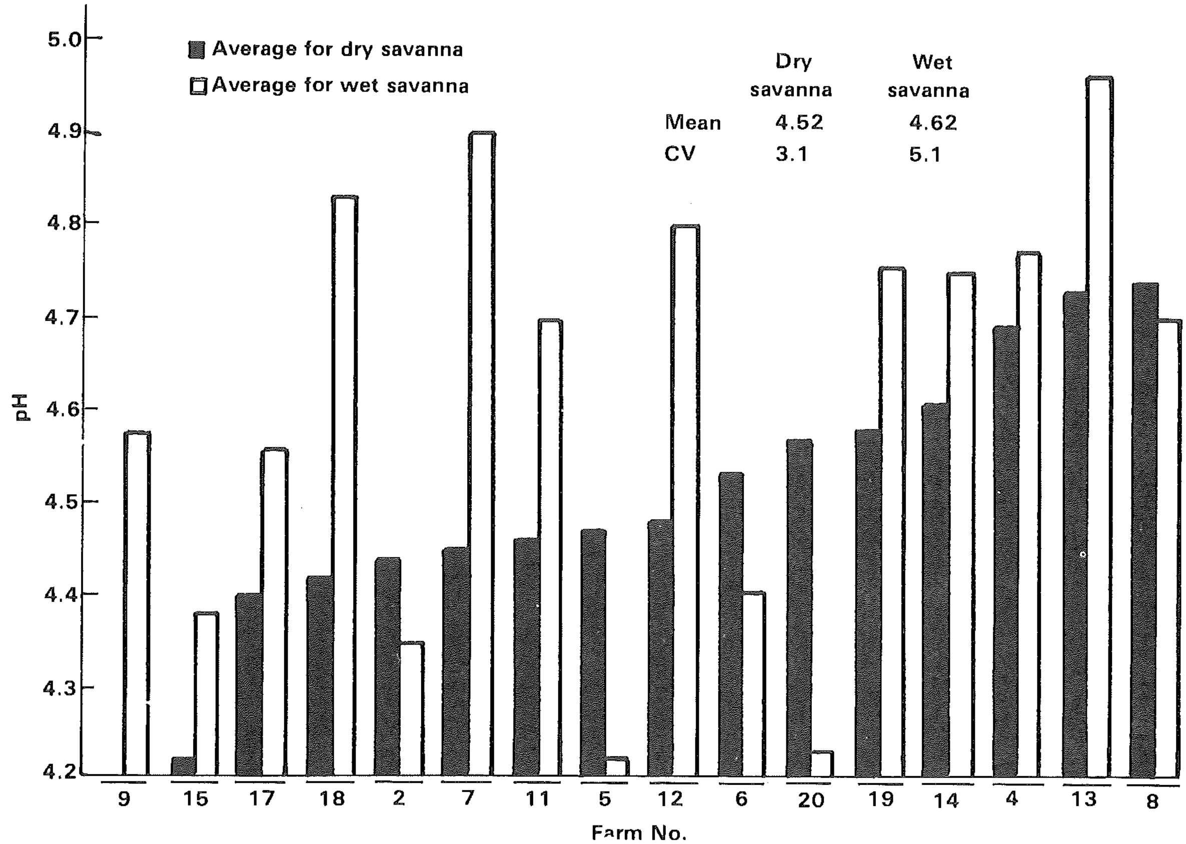

Figure 58. Soil pH in 16 farms of the Eastern Plains of Colombia (ETES Project).

adjust forage offer to the nutritional requirements of the stock. Only three farms practiced separation of animal categories in addition to the separation by sex (Table 52), although paddock availability does not appear to be limiting to more advanced practices of herd subdivision.

Mineral supplementation is difficult to evaluate in farm case studies. It is necessary to know not only the amount of mineral supplement, but also its quality, which animals receive it, and how often. In this study, only the amount of P supplement used by the farms was measured. The information was enough, however, to show that in general the level of supplementation is very low (Table 53). Only an average 46% of the level of supplementation recommended in Carimagua is used, and only three farms utilized 90-100% of the amount of P supplement used in Carimagua.

Disease control on the farms is also difficult to evaluate. No impact of vaccination against foot and mouth disease could be measured because no outbreaks occurred during the monitoring period, despite the large variation between farms in the use of vaccination (Table 53). Few farmers vaccinate against brucellosis but the prevalence of the disease in the Eastern Plains appears to be negligible. Blackleg is the only other infectious disease against which immunization is carried out by the farmers. No information on the incidence of the disease is available for the region and, on the other hand, only early mortality of calves (too early to be due to blackleg) could be recorded. Consequently, no relationship between vaccination against blackleg and productivity could be established.

Routine navel disinfection of calves is practiced on 7 of the 16 farms. The unweighted average of calf mortality in these seven farms was 4.3%, against 9.5% in the other nine farms. However, the high average mortality amongst farms without routine navel disinfection is due mainly to two farms with 20 and 28% calf mortality.

Ticks and gastro-intestinal parasites do not appear as major herd problems in the ETES farms (see Animal

Table 50. Mean stocking rates on 16 farms in the Eastern Plains of Colombia. (ETES Project.)

Farm No.	Stocking rate (ha/AU)	Available savanna (ha/AU) Dry	Wet
2	4.1	3.2	0.5
4	5.3	4.2	0.7
5	3.9	3.0	0.2
6	4.4	2.8	1.4
7	4.9	4.1	0.4
8	3.8	2.0	1.7
9	4.3	0.5	1.4
11	11.6	4.9	4.5
12	9.0	6.2	1.2
13	5.6	1.2	1.6
14	4.0	1.8	1.3
15	4.0	3.3	0.5
17	5.3	4.3	0.6
18	9.1	8.0	0.6
19	9.9	7.8	1.4
20	5.9	4.6	0.8
Mean	5.9	3.9	1.2
CV	42.4	53.8	85.6

Health section on page 107); however, there is still no clear explanation for this situation.

The main animal production parameters are presented in Table 54.

Conception rate was measured as the average annual conception rate of cows monitored during two years (actual monitoring was 18 months but pregnancy diagnoses by rectal palpation covered two complete years). The average for 15 farms was 49.8%, with a 15.5% CV and a range from 39 to 65%. These data confirm the low calving rates found in previous short term work in the Eastern Plains. Precise estimates per farm, however, require evaluation over two consecutive years because large yearly fluctuations can severely bias estimates obtained on particular farms in any single year. This variation must be expected with the low fertility levels that prevail in the region. The poor reliability of figures for a single year is illustrated by the fact that the calving rate estimates presented in the CIAT Annual Report, 1978 had a correlation of only 0.43 with the conception rates averaged over two years.

The cumulative conception rate of heifers up to three years of age also confirms previous observations on the advanced age at first conception. The pregnancy rate of heifers at three years of age is strongly correlated with the average annual conception rate of cows (r = 0.88) suggesting the presence of common causes for the fertility level of cows and heifers on individual farms.

Abortion rate was measured as the percentage of pregnancies detected by rectal palpation that did not lead to a calving or that ended in a recorded abortion. The abortion rate was high on average, but varied widely between farms. The very high abortion rate in about half of the farms indicates the need for further research on the causes of these losses.

Calf mortality was also high, particularly in two farms (Table 54). Calf mortality appears to have little relationship with abortion rate (r = 0.21) suggesting independent causes for the two types of losses, but the two farms with highest calf mortality also had high abortion rates. The low calf mortality found on some farms must be viewed with caution because under extensive grazing early calf deaths may be unnoticed. Besides, so far in Carimagua, it has been impossible to reduce calf losses below 5% despite improved management.

Annual weight gains of stockers were calculated by fitting regressions of weight on age through age categories of one year each, up to four years. With the exception of two farms, the annual weight gain per animal was well below the best results obtained on savanna in Carimagua (52.5 vs. approximately 90 kg/animal/year).

Farm annual liveweight production was estimated as follows:

$$(N \times C \times W) + \sum S \times G$$

where, N = number of cows; C = calving rate calculated from the average annual conception rate over two years, corrected for abortions and calf mortality; W = weight of one year old calves; S = number of stockers in the ith age category (1-2, 2-3, 3-4 years, and >4 years); G = annual weight gains of stockers in the ith age category.

Table 51. Herd estructure in 16 farms in the Eastern Plains of Colombia[1] (ETES Project).

Farm No.	Cows	Bulls	Calves	Heifers (age in years) 1-2	2-3	3-4	Steers (age in years) 1-2	2-3	3-4	4	Culled cows
2	104	6	63	24	15	7	30	63	0	0	0
4	346	23	148	53	17	60	0	5	1	0	0
5	116	7	61	24	19	9	0	10	5	0	0
6	213	22	79	43	30	22	7	0	3	0	0
7	393	26	122	83	113	115	119	80	15	0	0
8	52	4	24	9	15	0	27	0	0	0	0
9	54	5	25	10	14	9	12	4	0	0	0
11	197	24	155	47	27	0	39	18	0	0	0
12	123	14	55	57	64	25	71	93	58	0	4
13	130	8	54	24	27	10	12	15	0	0	0
14	190	12	93	35	28	18	32	15	0	0	0
15	406	20	135	147	65	52	141	45	0	0	10
17	126	10	84	60	30	22	35	40	0	1	15
18	458	40	189	137	59	39	115	88	15	6	0
19	161	9	50	32	45	39	33	20	15	17	0
20	214	11	107	39	30	33	41	10	83	0	0
Total	3283	241	1444	824	598	460	714	506	195	24	29
					1882			1415			

1 The number in each category is the average for the first two farm visits in October-November 1977 and April 1978.

The annual liveweight production/AU on the farm is shown in Figures 59 and 60.

Farm production/AU varied from 34 to 129 kg/year, but when the top farm is excluded, the coefficient of variation in production is only 22%. Four farms produced less than 50 kg/AU/year, 10 farms produced between 50 and 70 kg/AU/year and only two farms produced more than 70 kg/AU/year.

Production/ha and production/AU were closely correlated (Figure 60). This indicates that farmers reached a remarkably close equilibrium between per animal and per ha output, despite the variation in farm production.

Much of the inter-farm variation in production appears to be related to the availability and fertility of wet savanna and, at a lesser extent, to the presence of sown pastures on the lower land. Sown pastures on the dry land do not contribute to explain inter-farm variation in production. This is shown by the following relationship:

$$Y = 29.71 + 3.50\ X_1 + 5.44\ X_2 + 0.03\ X_3 + 0.09\ X_4$$

where, Y = liveweight production/AU/year; X_1 = P (ppm) in wet savanna; X_2 = ha of wet savanna available/AU; X_3 = ha of sown pasture on dry land; X_4 = ha of sown pasture on wet land. The coefficient of determination for this model is 0.91; the partial regression coefficients for X_1, X_2 and X_4 are significant at the 1% level, and the regression coefficient for X_3 is not significant at the 5% level.

The main economic aspects of the ETES farms are the following:

Total investment per farm ranges from US$40,000-450,000; the average for the 16 farms is US$120,000 or $100/ha and $500/AU (Table 55).

The two most important investment items are cattle (43%) and land (39%). These two components make up over 70% of the total investment in all but one farm (farm 8) which has a larger investment in constructions, machinery and equipment than all other farms.

Table 52. Farm subdivision, herd subdivision and phosphorus supplementation in 16 farms, in the Eastern Plains of Colombia (ETES Project).

Farm No.	Farm subdivision (Paddocks/ 100 AU)	Herd subdivision[1]	Phosphorus supplementation[2]
2	3.4	2	24
4	1.7	5	77
5	4.8	2	24
6	2.7	4	3
7	2.1	4	91
8	11.0	3	51
9	0.9	2	5
11	2.4	6	95
12	2.9	2	55
13	0.4	2	25
14	1.4	2	100
15	1.0	1	62
17	1.4	3	50
18	1.4	2	33
19	1.5	2	13
20	1.3	3	33
Mean	2.5		46
CV	99.7		68.4

1 Herd subdivision scale: Males separated from females: At three years of age (1); at two years of age (2); at one year of age (3); heifers separated from cows (4); dry cows from lactating cows (5); cows in early lactation from cows in advanced lactation (6).

2 As percentage of phosphorus supplementation in Carimagua (1683 g/AU/year).

This farm also has the highest investment per animal unit.

Investments in constructions are mainly housing (37%), fences (32%) and corrals (20%). Small-sized equipment and tools, an old tractor and a vehicle constitute investments in machinery and equipment.

Farms are growing on the basis of increasing their cattle stock (Table 56). Some farms have increased their area in sown pastures during the observation period. Investments in constructions were either a building to house workers (farm 8) or chutes (farms 13 and 15). Three farms invested in machinery: farms 8 and 13 bought electric plants and farm 15 bought a used tractor.

A second possibility of growth, i.e., through purchasing land, is also taking place. Farm owners are buying other farms, usually in the Piedmont, with the purpose of fattening stockers from their farms in the savanna. Average new investments were US$9500 per farm, equivalent to a 4.5% annual growth rate.

Average farm income during 1978 was US$18,300 per year (Table 57). The main source of income was cattle sales, although 22% of sales were simply at the expense of reducing cattle inventories.

Income estimates on the basis of production is shown to provide a close average estimate of actual income, but correlation is very low on a per-farm basis with actual income. This fact confirms common knowledge that a one-year income flow should not be used as the basis for economic analysis of cattle farms where the production cycle comprises at least 3-4 years. Instead, production parameters obtained from these farms will be used for the economic analysis, with the aid of budgeting, simulation or programming techniques.

Average annual current expenditures in the ETES farms during 1978 were US$8000 per farm, with large differences between farms (Table 58). These expenditures consisted mainly of labor costs, administration and purchase of mineral supplements (despite the low level of supplementation).

Labor is mainly permanently hired cowboys. The larger survey of cattle farms in this region (see Economics section on page118) showed a somewhat different result in this respect with a large share of occasional laborers in the labor cost. Finally, purchases of other inputs, particularly fertilizer, were virtually nonexistent.

To summarize, cattle farms in the Colombian Llanos are cow-calf-stocker operations; fattening is of minor importance and essentially a speculative activity.

The production level, both per animal unit and per unit area, is low. The main limiting factor to a higher production is the low fertility of the dry savanna. There is little variation between farms in the quality of this main land resource which determines the total

Table 53. Animal health practices in 16 farms in the Eastern Plains of Colombia (ETES Project).

Farm No.	Vaccination against[1] Foot & mouth disease	Blackleg	Brucellosis	Control of[2] Ticks	Endoparasites	Routine navel disinfection
2	2.0	0.5	0.0	1.6	0.7	no
4	0.8	0.3	0.0	3.5	0.8	yes
5	3.2	1.0	0.0	0.0	0.4	yes
6	2.4	1.0	0.0	1.6	0.3	yes
7	0.1	0.5	0.0	1.5	1.0	yes
8	2.2	1.0	1.0	2.6	1.4	yes
9	4.5	1.0	0.0	1.0	0.7	no
11	2.7	0.5	0.0	4.0	1.0	yes
12	0.9	0.0	1.0	1.0	0.0	no
13	1.3	1.0	0.3	0.9	0.9	no
14	0.0	0.0	1.0	0.0	0.0	no
15	1.1	0.0	0.0	2.0	0.0	no
17	1.1	0.2	0.4	3.3	0.2	yes
18	0.9	1.0	0.0	1.0	0.6	no
19	0.0	0.0	0.0	3.5	0.1	no
20	2.0	1.0	0.0	5.5	0.5	no

1 Doses/animal to be vaccinated/year estimated from amount of vaccine consumed during the year.
2 Treatments/animal/year estimated from amount of drugs consumed during the year.

stocking rate of the farms. Differences in production between farms, therefore, originate principally from variation in the minor land component with frequently higher fertility, i.e., the wet savanna. Farms with larger proportions of more fertile low land produce more than farms with little wet savanna; this relative advantage is even further increased if pastures are sown on the better soil (which for this purpose must comply with another restriction: the low lands in the farms should not flood in the rainy season).

As suggested by the close relationship between production per unit area and production/AU, farmers apparently have succeeded in adjusting the stocking rate of their land to its natural production potential. This managerial aspect and the introduction of sown pastures to the more fertile areas, probably are the main management components of the prevailing farming system. Other management practices widely used in more advanced cattle production systems are either not applied at all, or are applied at a level of doubtful impact. Thus seasonal mating and weaning at a defined age are not practiced; herd subdivision is only applied at a low level; mineral supplementation, although clearly necessary, is inadequate; disease control appears to be haphazard and nonproductive animals are not culled systematically.

Improved management would increase production; particularly, adequate mineral supplementation could have an immediate response. The change, however, would probably not be dramatic as the major limitation is poor nutrition (responsible for the poor growth rate of the stock and, in all likelihood, for most of the low fertility of breeding females).

The means to substantially increase animal production, therefore, must be through the improvement of forage production on the dry savanna, along the lines proposed by the Tropical Pastures Program — grass/legume pastures adapted to the infertile savanna soils, to be used strategically and in conjunction with improved management.

A note of caution about improved management must be included: a severe limiting factor to any improve-

Table 54. Animal production parameters in 16 farms in the Eastern Plains of Colombia (ETES Project).

Farm No.	Conception rate of cows[1] (%)	Heifers pregnant at 3 years of age[2] (%)	Abortion rate[3] (%)	Calf mortality[4] (%)	Weight gain of stockers[5] (kg/animal/year)
2	56	53	18	28	53
4	*[6]	NA	NA	NA	*
5	41	29	6	8	41
6	57	74	16	7	47
7	51	NA	18	5	NA
8	65	100	3	0	141
9	50	62	15	20	48
11	56	NA	0	6	68
12	44	57	18	4	33
13	42	58	9	8	68
14	43	44	9	3	110
15	54	NA	4	1	NA
17	48	62	16	0	64
18	39	33	20	8	46
19	43	42	42	7	52
20	58	78	22	7	58
Mean	49.8	57.7	14.4	7.5	53.8
CV	15.5	34.7	71.1	99.6	46.9
				(excluding farm 8)	57.3
					34.4

1 Annual conception rate calculated from conceptions occurred during two years.
2 Cummulative conception rate up to three years of age.
3 Pregnancies ending in abortion x 100/total pregnancies occurred in one year.
4 Calves that died at one month of age or less/calves born in one year.
5 kg/animal/year estimated by regression of weight for age through age categories.
6 * = calving interval 23.5 month (n=116). No stockers present on this farm.
7 NA = information not available.

ment in management and to the adoption of more advanced technology will be the lack of managerial skill of farmers in the Eastern Plains region in general and of their administrators or farm managers in particular.

Cerrado of Central Brazil

Of the 15 farms initially selected, three were excluded from the project, two in Mato Grosso and one in Goiás. On the remaining farms data collection continued normally. Preliminary data analyses will be available in early 1980.

Northeastern Llanos of Venezuela

After inconveniences which delayed progress of the ETES Project in Venezuela, the final selection of 13 farms has been accomplished and the project is now in the early stages of on-farm data collection.

Characteristics of the farms surveyed in the pre-selection phase are presented in Tables 59 and 60 and data on the selected farms are shown in Table 61. Obvious differences with both the Colombian and Brazilian farms are the greater proportion of sown pastures, the higher stocking rate, the presence of

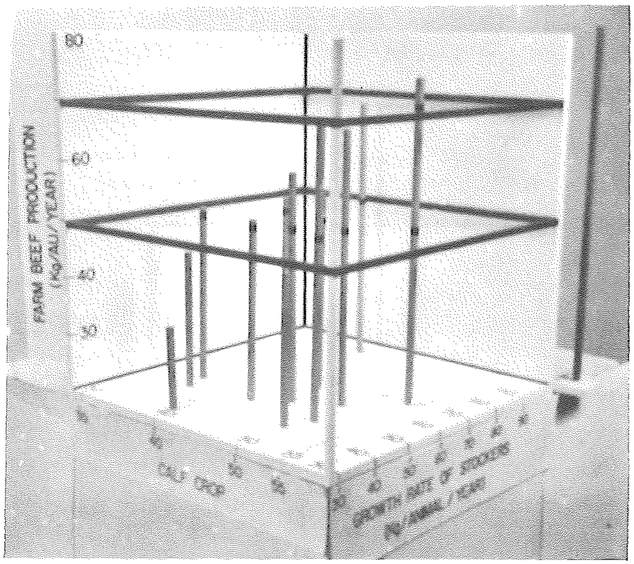

Figure 59. Farm production per animal per year to calving rate and growth rate of stockers.

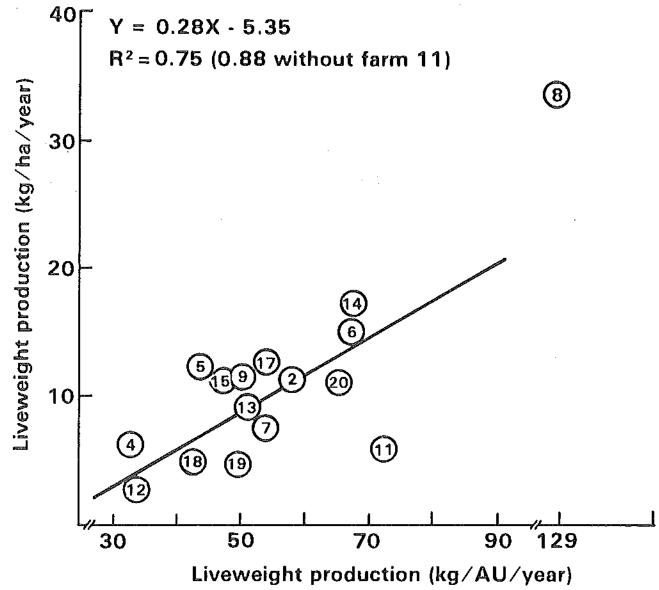

Figure 60. Liveweight production of cattle in 16 farms in the Eastern Plains of Colombia (ETES Project).

Table 55. Size and composition of total investment for 16 farms in the Eastern Plains of Colombia (ETES Project).

Farm No.	Land (%)	Cattle (%)	Sown pastures (%)	Installations and buildings (%)	Machinery and equipment (%)	Total investment (000 US$)[1]	Investment/ha (US$)	Investment/AU (US$)
2	40	34	10	8	8	163	150	620
4	55	35	0	7	3	322	100	560
5	43	35	10	12	0	109	1320	520
6	43	33	8	10	6	257	160	705
7	38	40	8	8	6	448	90	440
8	20	27	11	21	21	80	212	802
9	37	51	0	12	0	39	80	350
11	62	29	1	4	4	327	78	720
12	52	34	5	6	3	252	58	522
13	39	50	0	7	4	100	70	400
14	37	51	1	7	4	156	90	365
15	21	65	2	9	3	244	65	270
17	33	43	11	9	4	212	70	500
18	34	54	3	6	3	356	40	365
19	42	51	0	7	0	134	50	330
20	24	57	10	8	0	166	60	360
Avg.	39	43	5	9	4	210	95	490

1 1978 US$.

Table 56. New investments during 1978 for 16 farms in the Eastern Plains of Colombia (ETES Project).

Farm No.	New investments ('000 US$)[1] Cattle[2]	Sown pastures	Installations and buildings	Machinery and equipment	Total new investment
2	10.1	5.0	0.0	0.0	15.1
4	16.5	0.0	0.0	0.0	16.5
5	7.2	0.0	0.0	0.0	7.2
6	28.7	0.0	0.0	0.0	28.7
7	- 7.1	8.4	0.0	0.0	1.3
8	15.3	7.9	0.4	1.7	25.3
9	6.9	0.0	0.0	0.0	6.9
11	-16.0	0.0	0.0	5.0	-11.0
12	27.9	4.0	0.0	0.0	31.9
13	5.5	0.0	0.0	3.3	8.8
14	-14.3	0.0	0.0	0.0	-14.3
15	30.0	3.6	0.0	3.8	37.4
17	-14.3	0.0	1.1	0.0	-13.2
18	29.7	2.8	1.1	0.0	33.6
19	-27.1	0.0	0.0	0.0	-27.1
20	3.7	0.6	0.0	0.0	4.3
Average					9.5

1 1978 US$.

2 Farms with negative investment in cattle show reduction in cattle inventory during the year due to sales.

fattening and dairy-ranching activities, the use of concentrates and the presence of crops. Thus, ETES Venezuela will be faced with a greater variety of cattle production systems and with more intensive enterprises than the other two ETES Projects.

ETES Project - Phase II

After the study of the prevailing cattle production systems in the first part of the ETES Project, a second phase will be devoted to the introduction of improved technology into some selected farms.

The objectives of the second phase are:

1. To evaluate the impact of grass/legume pastures developed by the Tropical Pastures Program on animal production and on net farm income. These pastures will be used strategically with the breeding herd, as a complement of the native savanna, in conjunction with improved animal management and animal health practices.
2. To study in detail the behavior of the improved grass/legume pastures under farm conditions, in terms of adaptation to the particular soil, disease and insect resistance, and productive persistence.

The second phase has been initiated on farm 4 in the Colombian Llanos.

The changes introduced so far include the sowing (July 1979) of the following improved pastures: (a) 25 ha of *Brachiaria decumbens* 606 in mixture with *Desmodium ovalifolium* 350; (b) 40 ha of *Andropogon gayanus* 621 in mixture with *Stylosanthes capitata* 1019; (c) 55 ha of *A. gayanus* 621 (49 ha in pure stand,

Table 57. Annual gross income for 16 farms in the Eastern Plains of Colombia (ETES Project).

Farm No.	Source of income ('000 US$) Cattle sales	Changes in inventory	Milk sales	Total gross income ('000 US$) Observed in 1978	Estimated according to production[1]
2	7.6	9.3	0.0	16.9	11.6
4	23.6	- 7.1	0.0	16.5	14.6
5	13.8	- 3.0	0.0	10.7	7.0
6	44.0	-26.8	0.0	17.1	18.6
7	58.9	-17.4	0.0	41.6	41.5
8	0.9	4.6	3.1	8.6	9.7
9	0.0	6.3	0.0	6.3	4.2
11	51.5	-16.0	0.0	35.5	25.1
12	27.8	- 5.6	0.0	22.2	12.3
13	2.8	5.5	0.0	8.3	9.8
14	24.0	-14.3	0.0	9.6	21.8
15	0.0	30.0	0.0	30.0	33.8
17	41.3	-21.2	0.0	20.1	17.4
18	28.0	11.9	0.0	47.9	32.3
19	28.0	-27.1	0.0	0.9	15.3
20	26.3	-13.1	0.0	13.1	23.1
Average	23.7	- 5.2	0.2	18.3	18.6

1 1978 US$.
2 Production measured in kg of liveweight/year at US$0.75/kg.

1 ha in mixture with *S. capitata* 1300 and 5 ha in mixture with *Zornia latifolia* 728); (d) 5 ha of *Pueraria phaseoloides* 9900.

The establishment of these pastures was satisfactory and the first grazing is about to begin.

Breeding Herds Management Systems

The effects of the strategic use of improved pastures and of the length of the mating season on the productivity of breeding herds is studied in this experiment at Carimagua.

The objectives and the experimental design were described in detail in previous reports (CIAT Annual Reports 1977 and 1978).

The experiment includes six herds of 54 cows each. Herds 1, 3 and 5 graze only on native savanna. Herds 2, 4 and 6 have access to improved pastures during 3.5 months in the late dry and/or early rainy season. Herds 1 and 2 mate all year round; the mating period for herds 3 and 4 extends from June until September (120 days) whereas herds 5 and 6 have a 90 day mating period between May and July.

The calving rate in 1979 calculated for all cows in each herd is presented in Figure 61. However, as some animals were pregnant during the mating season of 1978 or had calved shortly before the introduction of bulls of the herds, empty cows were classified as "able" if they had calved at least 90 days before the end of the mating season (arbitrarily, end of July for herds 1 and 2). The calving rate and the distribution of calvings in 1979 for these able cows is shown in Figure 62.

Comparing herds 1 with 2 and 5 with 6, it can be seen that the calving rate of able cows with no access to improved pastures in 1978 was higher than the calving rate of their counterparts that grazed only on

Table 58. Annual current expenditures for 16 farms in the Eastern Plains of Colombia (ETES Project).

Farm No.	Labor: Occasional	Labor: Permanent	Administration	Purchase of inputs: Mineral supplements	Purchase of inputs: Drugs	Purchase of inputs: Fertilizer	Others	Total
	Annual expenditures ('000 US$)[1]							
2	0.4	19.2	9.1	6.8	3.0	0.0	4.8	43
4	6.5	23.6	49.1	44.8	8.8	0.0	4.2	137
5	3.7	0.0	11.9	5.7	3.1	0.0	1.8	26
6	13.0	33.2	15.8	4.3	3.6	0.0	2.3	72
7	11.2	56.4	51.9	68.9	8.0	0.0	6.6	203
8	4.4	26.5	39.8	5.7	2.3	0.0	0.0	79
9	0.7	0.0	15.6	1.0	2.6	0.0	0.5	20
11	1.9	17.2	42.1	26.0	23.3	0.0	8.8	119
12	5.5	21.3	11.7	13.4	2.3	0.0	4.1	58
13	0.0	3.9	18.7	6.0	2.3	1.0	4.0	36
14	0.6	0.0	16.0	15.8	1.1	0.0	2.6	36
15	0.0	59.2	17.8	35.2	9.3	1.1	8.9	132
17	11.1	29.1	11.7	11.8	7.7	2.9	1.9	76
18	0.0	34.5	15.2	39.3	13.5	2.6	2.1	107
19	0.6	13.4	3.9	6.5	3.0	0.0	0.0	27
20	0.0	12.1	4.6	10.9	6.5	0.0	2.5	37
Average	3.7	21.9	20.9	18.9	6.2	0.5	3.5	76
Percentage	5	29	27	25	8	1	5	100

1 1978 US$.

Table 59. Characteristics of farms surveyed in the pre-selection phase in the Northeastern Llanos of Venezuela. ETES Project.

Stratum (ha)	n	Area (ha)	Area to sown pastures (ha)	Area to sown pastures (%)	Cattle	Cows (No.)	Cows (%)	Stocking rate: Savanna pastures (ha/animal)	Stocking rate: Sown pastures (ha/animal)	Stocking rate: Savanna (ha/animal)
<500	9	224	78	36	271	126	48	1.1	0.3	0.8
		(33)[1]	(82)	(84)	(51)	(61)	(40)	(68)	(71)	(98)
500-1000	21	699	236	34	487	160	40	2.2	0.6	1.6
		(26)	(95)	(91)	(90)	(84)	(43)	(78)	(103)	(111)
1001-2000	10	1555	690	46	904	259	38	2.7	0.9	1.8
		(21)	(71)	(72)	(77)	(68)	(58)	(84)	(77)	(137)
>2000	5	7000	352	9	1790	603	43	5.7	0.3	5.4
		(63)	(90)	(126)	(83)	(54)	(35)	(71)	(84)	(73)

1 Figures in parenthesis are coefficientes of variation (%).

Table 60. Other characteristics of farms surveyed in the pre-selection phase in the Northeastern Llanos of Venezuela (ETES Project).

Stratum (ha)	Use of mineral supplements (%)	Use of concentrates (%)	Dairy ranching[1] (%)	Fattening[1] (%)	Agricultural crops (ha)
< 500	50	63	56	22	22
500-1000	70	50	52	52[2]	33
1001-2000	90	40	40	40	60
> 2000	40	20	0	80	20

1 Plus cow-calf-stocker operation.
2 Two farms are exclusively fattening enterprises.

savanna. This effect, however, was not apparent in herd 4 which had practically the same calving rate as herd 3.

The shortening of the mating period from four to three months did not reduce the calving rate of cows with access to improved pastures (herd 6 vs. herd 4, Figure 62). In contrast, the shortening of the mating season for cows in savanna decreased the calving rate (herd 5 vs. herd 3). On the other hand, continuous mating should be compared with seasonal mating only at a more advanced stage of the experiment.

With regard to the possibility of maintaining a seasonal mating period, attention should be focused on the reconception rate of cows in early lactation. The reconception rate between 90 and 180 days post-parturition was 80% between 30 cows of herds with access to improved pastures. The reconception rate for 30 cows belonging to herds with access to savanna only was 40%.

Table 61. Characteristics of selected farms in the Northeastern Llanos of Venezuela (ETES Project).

Farm No.	Type of operation[1]	Area (ha)			Cattle		Stocking rate (ha/animal)	
		Savanna	Sown pastures	Crops	Total	Cows	Savanna	Sown pastures
1	C/R/F	165	650	0	855	390	0.2	0.8
2	C/R/D	200	470	0	500	240	0.4	0.9
3	C/R/F	100	600	0	300	60	0.2	2.0
4	C/R/D	180	70	0	350	150	0.5	0.2
5	C/R/F	400	250	0	1125	500	0.4	0.2
6	C/R/F	1600	300	100	1500	600	1.1	0.2
7	C/R/D	1775	125	0	300	200	5.9	0.4
8	C/R/D	600	600	0	1100	400	0.5	0.5
9	R	440	10	60	130	-	3.4	0.1
10	C/R	1180	20	0	300	150	3.9	0.1
11	C/R	890	80	30	500	300	1.8	0.1
12	C/R/D	400	50	50	350	200	1.1	0.1
13	C/R	550	50	0	250	120	2.2	0.2

1 C = cow-calf; R = raising; F = fattening; D = dairy-ranching.

Figure 61. Effect of strategic use of sown pastures on calving rate during 1979 in the Breeding Herds Management Systems Experiment, Carimagua (calvings until September 30).

The reconception rate of cows on improved pastures is the required level for a seasonal mating system with high fertility. The reconception rate obtained on savanna only is too low for this purpose, but much higher than usual in the Llanos where cows normally almost never conceive while they are lactating. This suggests that the application of the management practices of herds 1, 3 and 5 to commercial herds in the Llanos might substantially increase fertility.

Pre-weaning mortality of calves was 8.4% in the herds that grazed on savanna only and 7.3% in those with access to improved pastures. This difference between grazing treatments was not statistically significant ($P<0.05$). The cause of death could not be determined in 53% of the cases; 32% of the losses were due to starvation (poor mothering ability of the dams), 10% to bone fractures and 5% to poliarthritis.

Calves born in 1978 were weaned at nine months of age. Weaning weight (Table 62) was increased due to access of the dams to improved pastures (168.1 vs. 158.8 kg). The period in which the calves were born had no effect on their weight at weaning and male calves were 11.3 kg heavier at weaning than females.

Body weight of cows at the bimonthly weighings is shown in Figure 63. During 1978, cows with access to improved pastures were always heavier than cows on savanna. From early 1979 onwards, however, cows on improved pastures lost weight progressively, particularly those in early lactation. This can be

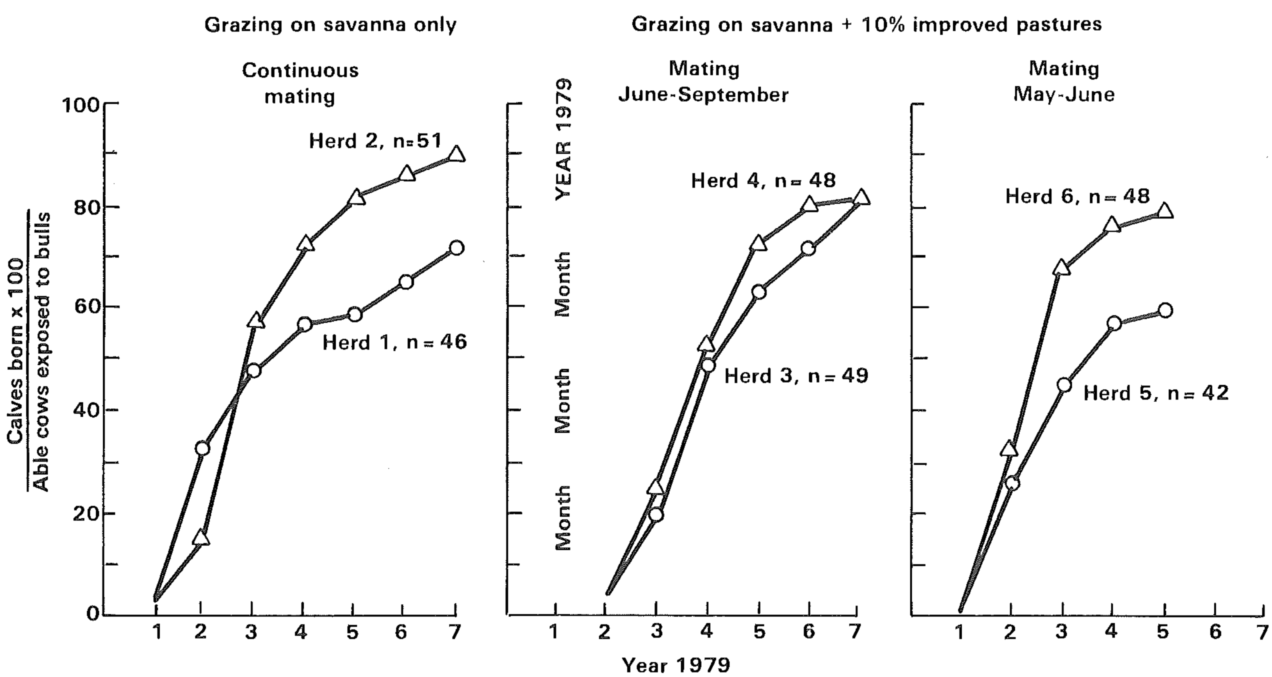

Figure 62. Accumulative calving percentage of cows classified as "able" during the mating periods of 1978.

Table 62. Effect of three variables on weaning weight of calves born in 1978 (ETES Project).

Variable		Weaning weight[1] (kg)
Strategic use of improved pastures ($P < 0.05$)		
Dams on savanna only		158.8 ± 3.0 (84)
Dams with access to improved pastures		168.1 ± 3.1 (77)
Sex		
Male calves		169.3 ± 3.1
Female calves		158.0 ± 2.9
Seasonal effect ($P > 0.05$)		
Born	Weaned	
January-March	October-December	161.6 ± 3.2 (70)
April-June	January-March	164.9 ± 3.6 (56)
July-September	April-June	163.9 ± 4.6 (35)

1 Weaned at nine months of age; mean weight ± standard error; figures in parenthesis are the number of observations.

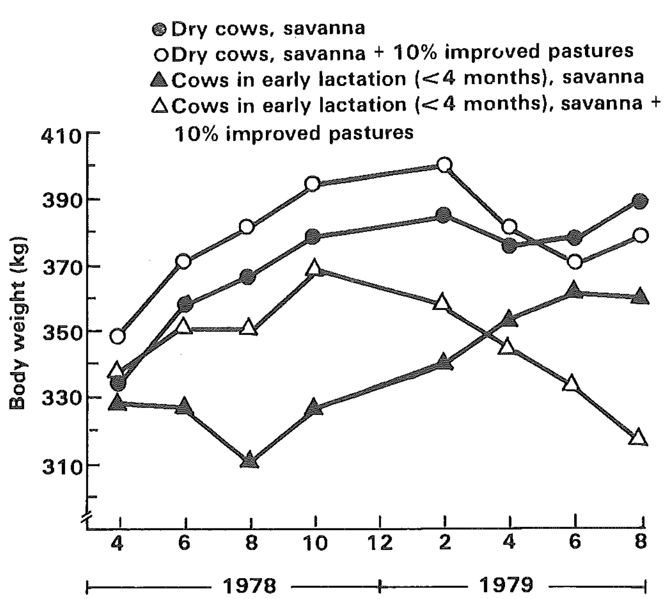

Figure 63. Effect of lactation status on body weight of cows on savanna only or on savanna + 10% improved pastures.

attributed to the facts that *S. guianensis* was severely attacked by anthracnose during the last trimester of 1978 and the *B. decumbens* paddocks were overstocked (as available area was reduced by 25% in order to sow additional legume pastures) and severely affected by a spittlebug (*Aneolamia varia, Zulia pubescens*) attack.

The utilization of improved pastures is shown in Figure 64. In addition to the programmed utilization, a paddock of *Melinis minutiflora* outside the experimental area was grazed (1.4 AU/ha) during July and August by herds 2 and 4. This was an attempt to overcome the emergency caused by the reduction of available *B. decumbens.*

Only preliminary information on the pregnancy rate for 1979 can be given at this stage. Pregnancy diagnoses were carried out in October when conceptions that occurred in late August and in September are still undetectable.

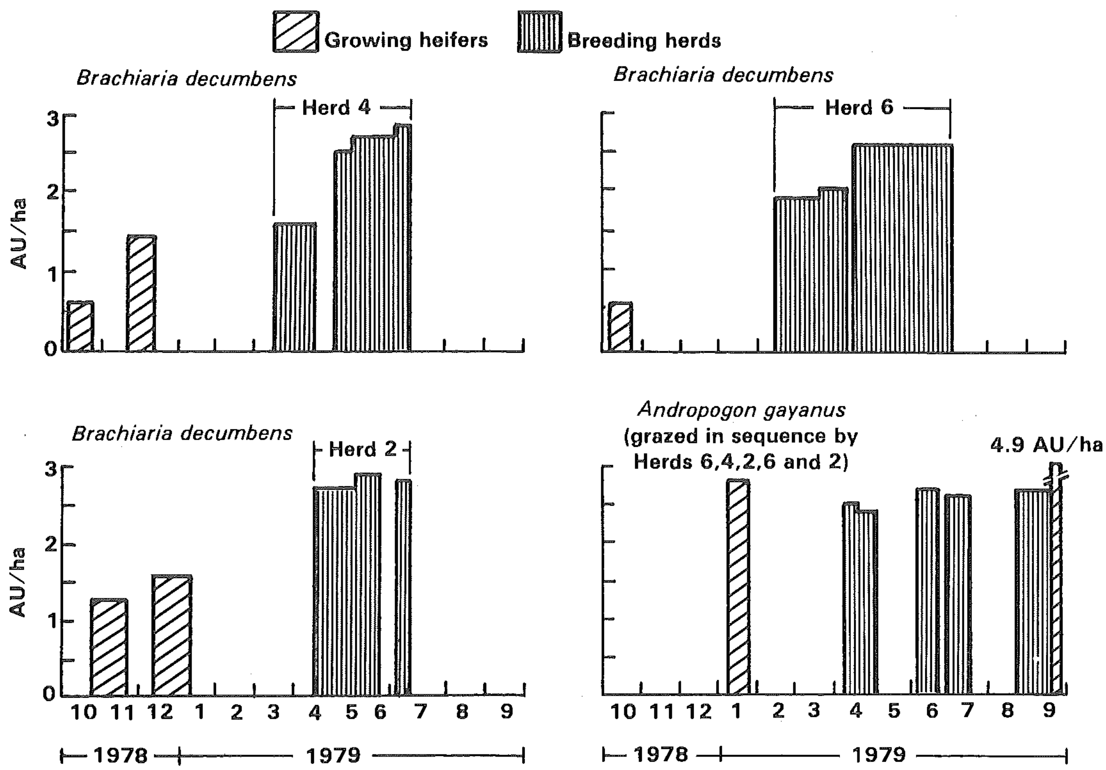

Figure 64. Utilization of improved pastures in the Breeding Herds Management Systems Experiment at Carimagua.

Herds 5 and 6 both had a 75% pregnancy rate. The average pregnancy rate for herds on savanna was only 58%. For herds with access to improved pastures the corresponding figure was 51%.

Compared to last year, fertility of cows on savanna plus improved pastures dropped, most likely as a consequence of the lower nutritional level achieved after the loss of the legume component in the pastures and grazing on *B. decumbens* attacked by spittlebugs.

The pregnancy rate of cows on savanna is only slightly lower than their previous calving rate. This difference, however, is likely to disappear when late conceptions (that were undetectable by rectal palpation in October) are computed.

The reduction in the conception rate of the cows on savanna plus improved pastures, compared to that obtained last year can be attributed mainly to the disappearance of the legume component of the pastures. This stresses the importance of the legume to obtain high pregnancy rates.

Test Herds

Size, management, and production objectives of these ICA-CIAT herds were described in the previous report (CIAT Annual Report, 1978).

The calving rate and the distribution of calving during the year are presented in Table 63. The calving rate in herds 1, 2 and 3 was slightly lower than in the previous year (53.9 vs. 58.2%). This difference is not statistically significant ($P>0.05$) and probably reflects chance fluctuations around a mean annual calving rate of approximately 55%.

In herds 4 and 5 the calving rate between October 1978 and September 1979 was 77.2%, 38.3 percentage points higher than the year before. Last year's calving rate was obtained for a mating period of only two months. This left many non-pregnant cows that conceived readily in the following mating season and consequently increased this year's calving rate.

Table 63. Distribution of calvings and calving rate in the ICA/CIAT Test Herds for the period October 1978-September 1979 at Carimagua.

Herds	Cows	October - December	January -March	April -June	July-September	Calving rate
1, 2 and 3	152	12	47	20	3	53.9
4 and 5	97	4	40	21	5	72.2

Calf mortality this year (5.9%) was practically similar to last year's (5.4%). Of the nine calves lost, two died from snake bite, one due to poliarthritis and another one after a bone fracture; cause of death could not be established for the remaining five calves.

The test herds provided 228 steers, 50 heifers, 9 cows and 9 bulls for other research projects at Carimagua. All these animals were transferred to different sections for other research work.

CATTLE PRODUCTION SYSTEMS (CERRADO)

Animal Management

Previous work at the CPAC, Brazil, has shown that a 3-month mating season is as good as the traditional continuous mating practice in terms of reproductive performance. Since seasonal mating facilitates animal and pasture management, continuous mating has been eliminated from experiments designed to test new management practices based on the strategic use of native and improved pastures at the CPAC.

In November, 1978, three breeding herds were put together from the existing females within the CPAC (Table 64). The females were assigned to herds according to weight, age, and reproductive status such that at the beginning of the mating season each herd

Table 64. Treatments used at the CPAC, Brazil, to study the effects of improved pasture, mating season and weaning age on reproduction in Zebu cows.

Herd	No. of cows	Pasture: Type	Pasture: Grazing period (months)	Mating season (days)	Weaning age (days)
A	50	native	9	90 (Nov/Jan)	90
		improved	3		150
B	50	native	9	45 (Nov/Dec)	90
		improved	3	45 (Apr/May)	150
C	50	native	12	45 (Nov/Dec)	90
				45 (Apr/May)	150

included 15 lactating cows, 21 dry cows and 14 heifers. Mature cows averaged more than 300 kg at the start of the experiment while the 2-year old and 3-year old heifers weighed 243 kg and 289 kg, respectively. The stocking rate to be followed during the experiment will be 5 ha/cow in native pasture and 2 cows/ha in improved pastures. A previously established pasture of *Brachiaria ruziziensis* plus a mixture of legumes *(Glycine wightii, Stylosanthes guianensis* cv. Endeavour and *Macroptilium* sp.) will be used during the mating season. Results presented here are based on the first-year observations.

The average daily gain (Table 65) during the first breeding season (at the befinning of the rainy season) demonstrates that nursing cows gained less than dry cows or heifers suggesting that the lack of quality and/or quality of forage in the native pasture does not provide enough nutrients for the nursing cow to regain sufficient condition to rebreed during the mating season (Herd C). The weights shown for the second breeding season, (at the end of the rainy season) include only those cows in Herds B and C which did not conceive during the first breeding season. Most of these cows were nursing during the first mating season but were subsequently weaned and regained body condition by the time the second mating season began. The weight changes from the beginning of the breeding season to the beginning of the calving season are shown in Figure 65.

The conception rates in Table 66 are closely related to the weight changes observed in Table 65 with the greatest treatment difference occurring among lactating cows. The 90-day mating period for the lactating cows gave better results than the 45-day period due to a longer exposure to the bull and the effect of weaning which occurred approximately 50 days after the breeding season began allowing two additional estrous cycles post-weaning in Herd A. This is further substantiated by the conception rates of the dry cows, 95% of which apparently conceived during the first 45 days. At the begining of the second breeding season all the previously lactating cows had been weaned for at least one month. The effect of improved pasture is noticeable between Herds B and C during the second breeding season.

When conception rates are observed according to physiological status of the cows (Table 67) it is apparent that dry cows and heifers were not the problem breeders. It can also be observed that an unexpectedly high number of 2-year old heifers conceived at weights below that normally considered adequate for heifers. This would indicate that 2-year old heifers with average development are fertile; however, if they are mated before they reach a target weight of approximately 300 kg, their subsequent reproductive performance can be expected to be retarded because of the weight loss during the first lactation and the extended period required to recuperate body condition. Experiments are underway to develop a management program based on various combinations of native and improved pastures which will produce 300 kg heifers at 24-27 months of age. The above experiment will be continued for three more years.

During the same period, a more detailed experiment was initiated to provide more basic information (Table

Table 65. Weights of Zebu females by treatments and physiological status at mating time in the Cerrado, CPAC, Brazil.

	Mean weights (kg)					
	First breeding season			Second breeding season		
Herd	Nursing cows	Dry cows	Heifers	Weaned cows	Dry cows	Heifers
A	303 (.325)[1]	329 (.529)	269 (.617)	-	-	-
B	310 (.289)	325 (.578)	266 (.622)	348	380	324
C	311 (.133)	328 (.544)	267 (.422)	335	373	315

1 Figures in parenthesis are mean daily weight gains during the breeding season.

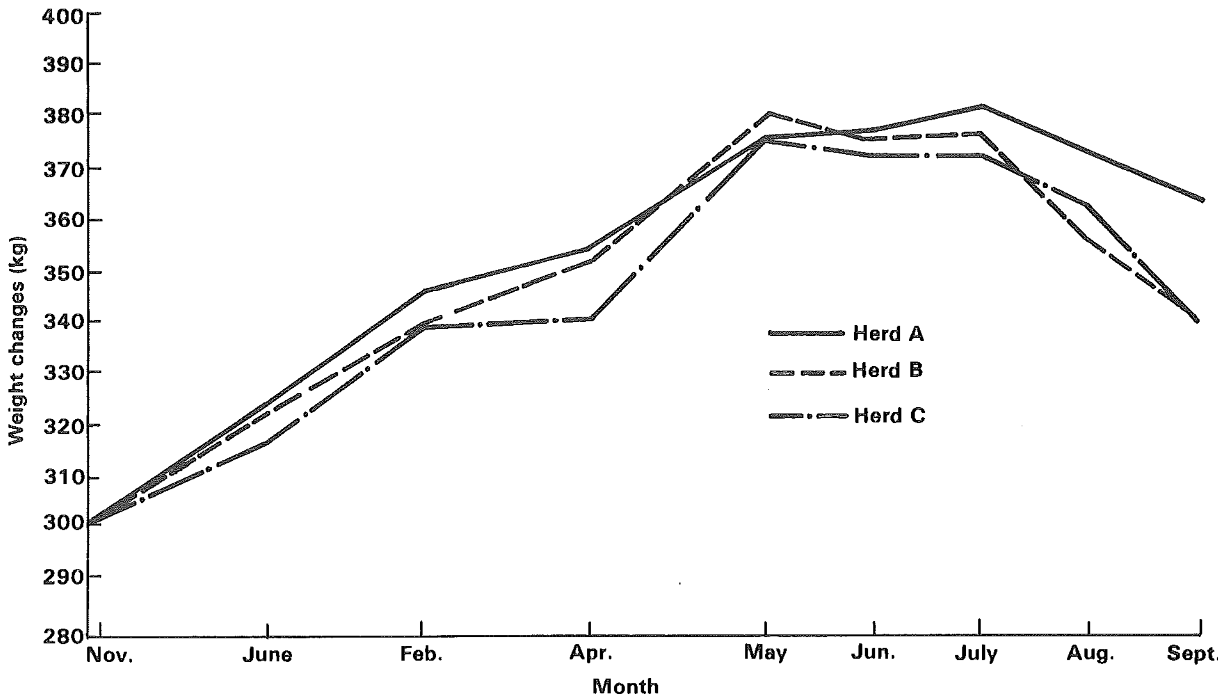

Figure 65. Weight change of Zebu cows during the breeding and lactation periods in the Cerrado, CPAC, Brazil.

68) on the reproductive response of commercial Gir cattle to (a) post-partum energy levels, and (b) different ages at weaning. The cows were confined and trough fed a mixture of grass hay, ground corn and cotton seed meal to provide high (1.3 times NRC requirements) and low (0.7 NRC) energy levels while maintaining the protein level (10%) constant for both herds. The cows were assigned to the two energy levels at calving time according to post-partum weights; weaning age was assigned at random within herds. The cows were removed from the experiment and returned to native pasture as they were found pregnant.

As expected, the low energy herd lost more weight (21%) during the first 150 days after parturition than the high energy cows (Figure 66). However, both herds began to gain weight 150 days after calving which corresponds to weaning at five months and time at which only five lactating cows were left in each herd.

Table 66. Conception rates of Zebu cows by treatments and physiological status at breeding time in the Cerrado, CPAC, Brazil.

	First mating season[1]				Second mating season[2]			
Herd	Lactating cows	Dry cows	Heifers	Subtotal	Weaned cows	Dry cows	Heifers	Total
A	67	95	80	82	-	-	-	82.0
B	20	90	64	62	91	50	60	92.0
C	13	100	57	62	62	0	50	84.0

1 Beginning of rainy season.
2 End of rainy season.

Table 67. Reproductive response of Zebu cows at various physiological stages during the breeding season in the Cerrado, CPAC, Brazil.

Reproductive stage	No. exposed to bull	Weight at initial breeding season (kg)	Conception rate (%)
Nursing during first half of breeding season	45	308	75.6
Dry at onset of breeding season	62	327	96.8
27 month old heifers	28	243	71.4
35 month old heifers	15	289	100.0

The effect of weaning age had a stronger effect on post-partum cow weight change than energy level (Figure 67). When the lactation stress was removed at 30 days post-partum, the daily weight loss decreased but the cows did not reach a gaining condition until 60 days post-weaning. Separating the calves from their dams at 30 days of age and allowing them to nurse twice daily (30 minutes each) reduced the rate of weight loss in these cows and put them in a gaining state sooner than cows weaned later than one month. Weaning the cows at 90 days post-partum stopped their weight loss at that point; however, they did not begin gaining until 60 days after weaning. There were no great differences in weight changes between cows and weaned at five or six months post-partum suggesting that the major affect of lactation stress had ended by five months post-partum.

Table 68. Treatments to study the effect of energy level and weaning age on reproduction in Zebu cows, CPAC, Brazil.

Treatment No.	No. of cows	Age of calf at weaning (months)	Energy level[1]
1	5	1	High
2	5	1	Low
3	5	3	High
4	5	3	Low
5	5	5	High
6	5	5	Low
7	5	6	High
8	5	6	Low
9	5	Controlled nursing[2]	High
10	5	Controlled nursing	Low

1 High energy = 1.3 NRC recommendation; low energy = 0.7 NRC recommendation.

2 Two nursings/day beginning at 30 days post-partum.

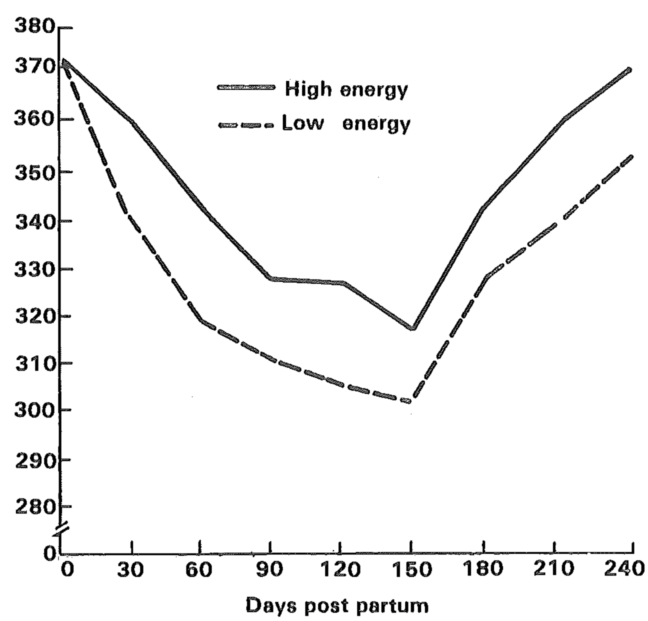

Figure 66. Effect of two energy levels on post-partum weights of cows fed in confinement.

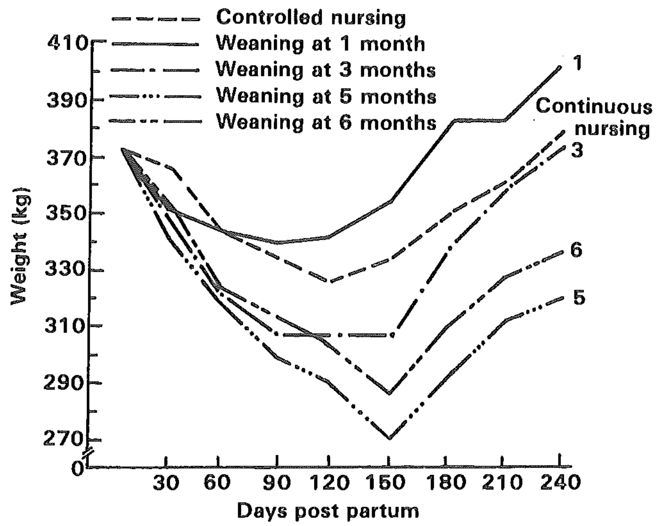

Figure 67. Effect of weaning age on post-partum weights of cows fed in confinement.

The service period (days from parturition to reconception) was estimated from palpation data which appears in Table 69. These data show a positive response to the higher energy level in reducing the service period by 41 days. The trends indicate that better nutrition becomes more important as the weaning time is prolonged. There appears to be little effect of energy level on the service period between weaning at 90 days or controlled nursing. However, in the low energy group, the controlled nursing cows conceived while nursing, while cows weaned at 90 days conceived 16 days post-weaning.

Table 69. Effect of energy and weaning age on the post-partum service period of Zebu cows in the Cerrado, CPAC, Brazil.

Weaning age (months)	Service period[1] (days)		
	Energy level		
	High	Low	Average
1	46	58	52
3	81	106	94
Controlled nursing	85	111	98
5	124	210	167
6	180	236	208
Average	103	144	

1 Days from parturition to reconception.

The difference in service period between weaning at one month and at six months was a reduction fo 156 days. Cows weaned at one month reconceived on an average of 52 days post-partum indicating excellent fertility when physiological and nutritional stress of the calf on the cow is removed early. The above service period would give an annual calf crop greater than 100%. While weaning at one month is not considered practical, the treatment was included to investigate if Gir cattle are physiologically capable of rebreeding as early as other breeds of temperate cattle.

Weaning at 90 days post-partum or controlled nursing during the breeding season are management practices which could be employed under improved ranch conditions. The data indicate that an annual calf crop greater than 90% could be achieved by using either of the two methods recognizing the fact that an improved calf raising program must be included in the management system.

The calves from this experiment were maintained on an average quality *Brachiaria decumbens* pasture without supplementation. At weaning, the 6-month weaned calves were 30 kg heavier than the calves which had been weaned three months earlier; however, at one year of age the difference between the two groups had been reduced by 34%.

The controlled weaned calves were only 9 kg lighter than the 6-month weaned claves at one year. The negative effect of controlled nursing during the breeding season on calf growth is minimal. Although some extra labor and infrastructure are required, controlled nursing offers the possibility of increasing the reconception rate in areas where subnutrition is a problem without delaying the growth of the nursing calf. Experiments were initiated with legume based pasture in search of a high quality pasture suitable for calf rearing which would make early weaning a viable alternative towards increasing reproduction.

Pasture Utilization

Two stocking rates were used to evaluate the productivity of an established *Brachiaria ruziziensis*/legume pasture during the dry season. The pasture had been rested for six weeks before the animals entered at the start of the dry season. Pasture samples taken at the beginning of the dry season showed high dry matter availability which was approximately 80% grass and 20% legume *(Stylosanthes guianensis, Macroptilium* sp. and *Glycine wightii)* (Table 70). As

Table 70. Pasture and animal performance during the 1979 dry season under two stocking rates in a Brachiaria ruziziensis and legume[1] pasture in the Cerrados, CPAC, Brazil.

Stocking rate (AU/ha)	Available dry matter (t/ha)				Liveweight gains (g/head/day)
	Beginning of dry season		End of dry season		
	Grass	Legume	Grass	Legume	
1.25	3.76	0.94	2.24	0.0	7.0 (28.0)[2]
0.65	3.83	0.56	2.63	1.01	44.0 (88.0)

1 Glycine wightii, Stylosanthes guianensis cv. Endeavour, and Macroptilium sp.
2 Figures in parenthesis are liveweight gains in g/ha/day).

expected, the reduction of dry matter from the sward was greater at the higher stocking rate (17.6 versus 12.5 kg/ha/day) assuming no correction for regrowth; however, the dry matter reduction per AU was the contrary (14.1 versus 19.2 kg/animal/day) suggesting that the animals in the lower stocking rate had a higher intake.

While animal liveweight gains were small both groups lost no weight during the dry season. The 28-day weight changes are shown in Figure 68. Weight losses during July and August are more closely associated with the disappearance of the legume component from the sward than the reduction in total available dry matter. By the end of the dry season the legume had practically disappeared from the sward. The positive weight change which occurred in late September was due to an unseasonal rain in late August. The experiment will be continued through the rainy season where both animal and pasture performance will be monitored.

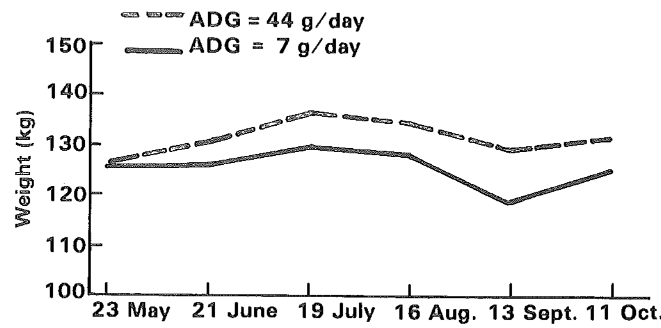

Figure 68. Effect of stocking rate on liveweight change in Zebu calves grazing a *Brachiaria ruziziensis*/legume mixture during the dry season in the Cerrado, CPAC, Brazil.

ANIMAL HEALTH

The objective of the Animal Health section is to develop preventive medicine schemes adjusted to the pasture/animal management systems developed by the Tropical Pastures Program. Work continued at three levels: at the macro-level, an inventory of disease and syndromes conducive to mortality or decreased productivity is being assembled and will be integrated with the target area survey in order to piece together distributions based on ecosystems. Macro-level studies are providing a catalogue of all existing conditions that are influencing productivity in the target area and their relative importance. At the intermediate level, work continued on surveillance in farms of the ETES project and monitoring of the test herds at Carimagua. Intermediate level monitoring provides information from individual animals in specific farms that permits quantification of main disease causes. At the micro-level, studies continued on the profile of gastro-intestinal parasites and hemoparasites at Carimagua, and the development of photosensitization in steers grazing *Brachiaria decumbens.* Micro-level studies provide information on incidence of specific conditions defined as important for the development of a preventive medicine control scheme.

Table 71. Importance of cattle diseases as reported by cattlemen from two sources.

Colombian Llanos Orientales[1]		Cerrado of Brazil[2]	
Condition	No. of farms	Condition	Farms (%)
Vulvovaginitis	28	Pneumoenteritis	21.4
Retained placenta	25	Hemoparasites	18.8
Abortion	23	Foot and mouth disease	18.4
Metritis	19	Black-leg	14.9
Chronic malnutrition	19	Endoparasites	6.2
Hidrosanmi	13	Colibacilosis	4.3
Black-leg	11	Brucellosis	2.8
Brucellosis	9	Salmonellosis	2.4
Anaplasmosis	8	Ectoparasites	1.6
Septicemia	8	Pasteurellosis	1.5
Bone fractures	6	Rabies	1.2
Anthrax	6	Botulism	1.0
Calf diarrhea	4	Anthrax	0.9
Babesiosis	4	Tuberculosis	0.2
Foot and mouth disease	3		

1 From : "Survey of cattle health problems in the eastern plains of Colombia" Corrier, D.E. et al. Br. Vet. J. (1978).

2 From : A survey of cattlemen. States of Mato Grosso, Goias and Minas Gerais. In: "Diagnostico Saude Animal. Ministerio de Agricultura, Brazil, 1977".

Macro-monitoring

Animal disease inventory

Data is being collected and analyzed primarily from Brazil, Colombia, Venezuela and Paraguay. There are three main levels for the information collected. The first is data collected from livestock owners and private professional practitioners either through survey questionnaires or direct visits. The second level corresponds to official figures given by regional laboratories, slaughterhouses and animal health offices at the regional and national level. The third level of information corresponds to data obtained through specific surveys in which samples from individual animals are examined by a laboratory. Information from the first level is subjective and figures need confirmation from the other levels of information. It is especially useful for a description of syndromes that cause deaths or decreased productivity which do not appear on the official morbidity and mortality reports. Table 71 illustrates two sources of information at this level. A condition such as pneumo-enteritis from one source is probably equivalent to diarrhea in calves from the other; hemoparasites appear together in one source but as *Anaplasma* and *Babesia* in the other. The work which is underway has the aim of selecting conditions that are appearing only at this level and classifying them by their relative importance. The information on specific infectious diseases from this level is not considered as reliable unless data from laboratory examinations are presented. The second source corresponding to official figures, is oriented towards specific recognized infectious diseases causing morbidity and mortality. The information from this level is being arranged by geographical sectors within the target area.

The third source corresponds to conditions that can be identified by direct observation of the cattle or by serological diagnostic tests. This level of information is more reliable for entities that can be identified by serological procedures. Work is underway on serological testing of samples from cattle of Brazil (Mato Grosso) and Venezuela (Western Llanos) obtained by collaborators. When the work is completed at all three levels, a complete listing of syndromes and diseases and their relative importance in the target area of the program, will be available.

Intermediate Monitoring

ETES Project

A full description of the ETES project is found in the Cattle Production Systems section (see page 85). Animal Health information was obtained from a survey of cattle ranchers completed in two visits; parasite levels (internal and external) were measured through four samplings, reproductive analysis by rectal examinations were carried out and observations on malnutrition were made. Farm visits were carried out every six months. Ranchers believed that their main cause of calf mortality is "black scours". According to their records it is the cause of a 3.2% mortality of animals up to 12 months of age. In the case of adults, ranchers consider that the main causes of mortality are drowning (2.8% mortality, mostly during February at the end of the dry season), fractures (1.8%) and malnutrition (1.3%), all three are due to management factors. Nine farms reported 28 cases of snake bite deaths.

Four fecal examinations for internal parasites were completed for 10% of adults and 5% of calves that passed through the chute. The level of infestation in adults is negligible. In calves, few farms had herd parasitosis. It was considered a herd problem when more than 20% of the examined calves had over 300 *Trichostrongylidae* eggs/g of feces. There was one farm with that level of infestation in the first visit, two in the second and none in the other visits. For the protozoan *Eimeria* spp., using the same level of infestation and the clinical examination of calves, there was one farm with herd parasitosis in the first visit and five farms in the second. Whether it is economically sound to control this level of parasitosis is to be determined. Although all farms reported to be doing deworming, there is no evidence of a regular schedule followed. The parasite profile reported below studies population fluctuations of the parasites in the area in order to determine the need and the best timing for deworming.

A sampling of adult cattle for trematodes revealed the presence of eggs of *Paramphistomum* sp. in 6 of 14 farms examined. Five samples were analyzed per farm and eggs of the trematode were found in 16.4% of them. This parasite was reported last year in steers of Carimagua and this is the first evidence of its presence in other farms of the Llanos Orientales. However, there is no evidence indicating that it is a cause of losses in productivity.

Observations on tick levels were made on three visits; counts were made on both sides of 10% of the animals that came through the chute. Semi-engorged ticks (5 mm and over) were counted. All farms had low levels of infestation. From 738 observations, 9.6% had less than 5 ticks/animal. All farms had established tick control procedures, mainly tick baths, and 10 our of 17 reported sprays every months.

Counts of *Dermatobia hominis* larvae were made. Low infestation levels were found; from 6789 animals examined, only 3.3% had 1-6 larvae/animal. However, 16 of the farms examined had animals infested indicating a wider distribution than previously observed.

Two other parasites were monitored. Lice *(Haematopinus quadripertusus)* was found in 10.3% of adult cattle examined in 10 of 17 farms. *Estefanofilaria stilesi*, a cutaneous worm, was found in 71% of animals examined, and was present in all farms. There is no evidence of damage in cattle affected by either of these parasites.

Analysis of reproductive tract

The examination of 1305 female cattle of the 16 farms during the four visits in 1978-79, revealed 2.2% of abnormalities of the reproductive organs, a figure within the expected limits. The finding of nine cases of hidrallantois (abnormal collection of fluids in the uterus) confirms previous findings in relation to its frequency. It was found more often in the less productive farms, supporting the hypothesis that this condition would not be found in farms where a complete salt-supplement is fully utilized.

Conception rates varied from 39 to 65% as measured in cows that for two years had no abortions nor dead calves. Abortion rates for the same period were obtained only considering pregnant cows (see Table 54 on page 93). Nine of the 15 farms had high abortion rates from 9 to 42%; the remaining six farms had abortion rates within the expected limits. Abortions are occurring at all times of pregnancy and do not seem to be seasonal. This most likely indicates that there is no specific infectious disease as the main cause of abortions. However, there are two infectious veneral reproductive diseases, Vibriosis and Trichomoniasis, that should be discarded before a final conclusion is drawn. Mortality of calves at birth and up to the first month of age (perinatal mortality) was for 6 of the 15 farms (7 to 28%). Besides nutritional deficiencies which may be the cause of perinatal mortality, Leptospirosis is known to be endemic in the area and could be involved in its etiology.

Chronic malnutrition ("secadera")

The overall condition of the body of adult cows was classified as good, fair, poor (lean animal) and very poor (chronic malnutrition, commonly called secadera or wasting disease), based on physical appearance and weight. An average of 1780 head of cattle was examined four times in 16 farms. Only five farms showed no animals classified as very poor. These are some of the best farms in terms of productivity per AU (see Figure 59 on page 94). However, the highest number of cases of malnutrition was also from one farm with a high productivity index (Table 72). The average age for the 73 cases found was six years. Three deaths due to malnutrition were recorded and three animals were diagnosed with malnutrition in two consecutive examination periods. This contrasts with beliefs that chronic malnutrition usually ends with the death of the animal. There is some tendency to observe more cases of chronic malnutrition by the end of the rainy season, perhaps when most animals are in better body condition, and thus the chronically ill are more noticeable. In the 73 cases observed in these farms no correlation was found between the condition and the lactation status of the animals, as approximately half (43) were dry at the time of examination.

Case study

One farm (Farm 4, ETES Project) which reported a high abortion rate (8.6%) as the main factor affecting productivity was followed in depth to monitor the problem. A rigorous sampling for clinical, bacteriological, virological, hematological, parasitological and reproductive analysis was completed. The general condition of the animals as well as weights and blood parameters showed considerable nutritional deficiencies. The mean stocking rate for the farm is high (3.5 ha/AU) compared to other farms of the ETES Project. Poor animal condition is thereby reflected in low fertility (50% of the cows did not have active ovaries). A comparison of blood parameters from this farm with parameters obtained at Carimagua in a herd without mineral supplementation is shown in Table 73. The ETES farm has lower average figures for hemoglobin and packed cell volume (PCV) for cows in the lactating open conditions as well as in the dry non-pregnant condition. This indicates that the animals in

Table 72. Chronic malnutrition in 16 farms of the ETES Project, Llanos Orientales de Colombia, during four visits from November 1977-May, 1979.

Farm No.	No. of observations	Average number of animals/visit	Total number of animals with chronic malnutrition	Chronic malnutrition cases/ total number of observations (x 100)
2	306	102	1	0.3
4	643	160	6	0.9
5	381	95	10	2.6
6	476	119	0	0
7	444	111	4	0.9
8	438	109	0	0
9	331	82	11	3.3
11	471	157	0	0
12	470	117	4	0.8
13	491	122	1	0.2
14	427	106	18	4.2
15	434	108	6	1.4
17	502	125	0	0
18	626	156	9	1.4
19	293	73	3	1.0
20	379	94	0	0
Total	7112	1778	73	1.0

the farm were in a similar nutritional condition or worse than those in a herd that was kept without mineral supplementation at Carimagua.

Table 73. Comparison of two blood parameters and weights between cows from one ETES farm (Farm 4) and a herd from Carimagua with no mineral supplemtation.

Parameter	Carimagua herd[1] Lactating open	Carimagua herd[1] Dry open	ETES Farm 4[2] Lactating open	ETES Farm 4[2] Dry open
Hemoglobin (g/100 ml)	12.7	13.7	11.5	12.4
Packed cell volume (%)	36.9	40.5	34.2	35.4
Weight (kg)	277.0	302.0	286.0	271.0

1 Number of animals sampled, 35. Source: CIAT Annual Report, 1977, p. A-89.
2 Number of animals sampled, 64.

Hemoparasites were detected in blood smears of cows and calves. Seven (10%) cows showed parasitemia for *Anaplasma marginale, Bemisia argentina* or both. Two cows had counts of eosinophils (24 and 19%) which appear in parasitic infections (Table 74). Serologic evidence is also confirming *Anaplasma* and *Babesia* infections. Seven calves (70%) showed parasitemia for *A. marginale,* one with a high percentage of infection (24%) and a low PCV value (22%); the others had blood values within normal ranges. Serologic tests indicated active infections. Although there were no animals infested with ticks at the time of the sampling visit, infestations were known to be very high in the farm and represent a serious problem. No venereal diseases were found and brucellosis is not a problem. It appears that hemoparasites and ticks together with nutritional deficiencies are contributing to the low productivity in this farm. Although there is still no definite explanation for the high abortion rate reported, the analysis showed the need of rigorous sampling to understand health status.

Table 74. Blood analysis of cattle with parasitemia, Farm 4 of the ETES Project, Llanos Orientales, Colombia.

Identification	Hemoparasites[1] Thick smear	Hemoparasites[1] Thin smear[2]	Packed cell volume (%)	Hemoglobin g/100 ml	Eosinophiles (%)
Cows					
1	Ba	0.01 Ba	35	11.5	14
2	Am	-	38	12.5	13
3	Am	-	40	13.5	8
4	Am	0.01 Am	34	11.5	19
5	Am, Ba	0.005 Ba	27	9.0	24
6	Am, Ba	0.005 Am	33	11.0	10
7	Am	0.010 Am	35	12.0	3
Calves					
1	Am	0.01 Am	36	12.0	-
2	Am	1.40 Am	34	11.0	-
3	Am	0.02 Am	47	15.5	-
4	Am	-	35	12.0	1
5	Am	24.00 Am	22	7.0	-
6	Am	-	43	14.5	1
7	Am	-	43	14.0	2

1 Ba = Babesia argentina; Am = Anaplasma marginale.
2 % of red blood cells affected.

Carimagua surveillance

Chronic malnutrition, sinking in watering holes, bone fractures and septicemia continue to be the main causes of cattle mortality in Carimagua, as shown in Table 75. The first three causes are mostly management-related conditions. Overall mortality rate was a little lower this year (3.0%) compared to the 1978 figure (3.7%). Most of the entities responsible for deaths in Carimagua seem to be endemic. Some conditions like bone fractures and malnutrition decreased while others such as photosensitization occurred more frequently this year.

Micro-monitoring

Gastro-intestinal parasite profile at Carimagua

Work continued on the study of the natural evolution of internal parasites in the savannas of the Colombian Llanos, as a basis to design control methods adapted to the ecological conditions. Two herds of 50 cows with their progeny at a stocking rate of 6.5 ha/AU are being studied. The native pasture is being burned sequentially and management is similar to that used by farmers in the area. Animals received a complete mineral supplement, were treated to control internal parasites, and were subjected to the standard vaccination scheme used for the farm. In Group I the calves were born from March-July 1978 (beginning of rainy season), and in Group II from September 1978-January 1979 (beginning of dry season). Both groups were sampled at monthly intervals for fecal examinations and blood analysis. Weights were recorded and one calf from each group was slaughtered at 1, 2, 4, 6, 8, 12, and 18 months of age. All parasites in abomasum, and in the large and small intestines were collected and identified. The trial will be concluded in mid-1980.

Table 75. Causes of cattle mortality in Carimagua (October 1, 1978-September 30, 1979).

Cause of death	No. of animals
Malnutrition	15
Sinking in mud or watering holes	14
Bone fractures	9
Septicemia	7
Snake bite	6
Photosensitization (*B. decumbens*)	5
Polyarthritis	4
Tick infestation	2
Herniae	1
Meningoencephalitis	1
Accident	1
Peritonitis	1
Unknown	20
Total deaths	86[1]
Total animals in station	2900
Mortality rate	3%

1 Only from calves that had been ear tagged.

Internal parasite loads varied considerably in relation to calf age and season (Table 76). The results of internal parasite examinations assessed by the counts of eggs have to be correlated with the total parasite counts in the slaughtered calves. In the total counts the most important parasite in both groups was *Cooperia* which reached its highest level at eight months of age (Table 77); this corresponds to the highest egg counts of Trichostrongylidae (*Cooperia* sp. is included) at seven months for Group I, and nine months for Group II. Total counts of the more damaging *Haemonchus* sp. follows exactly the same pattern (it is also included in the Trichostrongylidae family in Table 76.

Cooperia parasites account for 89.2% of the total parasites collected in the slaughtered animals of Group I after four months, and 71.5% of Group II; *Haemonchus* accounts for 8.2% and 18.6% of both groups, respectively. The total parasite counts for other species are probably negligible.

The gastro-intestinal worm infestations of beef cattle grazing native savannas in the Colombian Llanos were more noticeable towards the middle and end of the rainy season (Figure 69). It is important to note that the additive effect of two or more species poses a different problem than considering only one species. In this case the sinergism between *Cooperia, Haemonchus* and *Eimeria* affecting productivity in calves 4-8 months of age has to be considered. Further research will be carried out to determine if, with the levels of infection found and high prevalence of *Cooperia* spp. it is economically sound to apply control measures. If control would appear economically feasible, treatments should be done at the end of the rainy season or when calves are 6-8 months of age.

Profile of hemoparasites at Carimagua

The same calves used for the gastro-intestinal parasite profile are being utilized for the description of infections associated with *A. marginale, B. argentina* and *B. bigemina.* It is interesting to note that *Babesia*

Table 76. Average fecal egg counts (egg/g feces) for the most common gastro-intestinal parasites found in calves at Carimagua, 1978-79. (Parasite Profile Trial.)

Sampling date	Group I			Group II		
	No. animals examined	Trichostrongylidae	Eimeria	No. animals examined	Trichostrongylidae	Eimeria
1978						
III-6	8	0	0			
IV-5	18	35.1	0			
V-9	15	540.3	17.4			
VI-6	29	197.6	54.6			
VII-5	31	200.2	514.1			
VIII-2	36	183.5	1860.7			
IX-1	34	27.0	173.7	3	12.0	0
X-2	37	239.0	149.4	7	22.0	288.1
XI-1	40	332.6	441.0	15	128.6	2107.0
XII-2	34	300.0	200.0	27	126.0	674.0
1979						
I-2	36	105.3	111.0	36	124.0	1390.0
II-3	38	169.4	36.2	36	136.0	80.0
III-4	41	219.3	38.0	35	76.7	94.0
IV-2	37	108.3	6.8	41	43.7	3.5
V-3	35	79.3	97.7	35	60.4	70.0
VI-5	34	117.2	279.9	36	155.6	33.2
VII-4	34	93.5	14.5	34	320.5	75.4
VIII-1	37	164.9	44.0	31	285.3	24.1
IX-2	35	105.0	60.4	41	170.3	48.0
X-2	36	98.0	38.9	29	88.4	212.2

infections, as detected by the fluorescent antibody test, vary greatly from one season to another. The infection progresses slowly in calves born at the beginning of the rainy season and the peak coincides with the following rainy season (Figure 70). In the case of calves born at the end of the rainy season (Group II), the peak infections for hemoparasites coincide with an increased rainfall. It is thus possible that, from the standpoint of the development of immunity against hemoparasites, calves will be less affected if they are born at the beginning of the rainy season. This has to be correlated with fluctuations of vector populations, since hemoparasite levels are influenced by tick burdens.

Photosensitization in cattle grazing Brachiaria decumbens

Photosensitization appears to be increasing in recent years in Carimagua and other farms in the Llanos Orientales of Colombia. Table 78 shows the distribution of animals which were grazing *B. decumbens* during 1979 in Carimagua. Six experimental groups of animals were grazing *B. decumbens,* and two of them showed clinical cases of photosensitization. Five hundred fifty-four animals grazed *B. decumbens* and there were nine cases of intoxication (1.6%). One died before the appearance of any sign of skin lesion, but showed severe hepatic damage at necropsy. Clinical cases were observed in two specific pastures in Carimagua, with 8 and 2.7% morbidity and 6.7% mortality in the first group. The pastures held cows, calves, steers and heifers but only young animals (8-24 months of age) were affected. The clinical sign most evident in affected animals was skin necrosis. Two animals also had facial edema, particularly in the neck and ears. Six animals were found in poor body conditions.

Table 77. Total gastro-intestinal parasite counts in calves slaughtered at various age intervals in Carimagua.[1]

Species	Group I (from April/78)					
	Age (months)					
	1	2	4	6	8	12
Cooperia	22	52	4774	6435	16040	2948
Haemonchus	1	0	25	648	2547	78
Oesophagostomum	0	0	35	100	262	50
Strongyloides	69	594	0	65	0	0
Bunostomum	0	0	0	0	0	30
	Group II (from December/78)					
Cooperia	212	290	280	120	5518	
Haemonchus	10	50	30	70	1090	
Oesophagostomum	0	2	5	32	32	
Strongyloides	1908	490	40	0	0	
Bunostomum	0	1	0	1	112	

1 One animal sacrificed in each age group. Includes counts from abomasum and large and small intestines.

Information from the farms studied in the ETES Project was collected during the year to determine the magnitude of the problem in those farms where *B. decumbens* is being utilized. A total of 11 from the 16 farms have animals grazing *B. decumbens*. Three farms reported clinical signs of photosensitization associated with grazing of *B. decumbens* (Table 79). Morbidity was high in Farm 7 (11%); two deaths were reported in this farm. Half of the animals in each of the *B. decumbens* pastures were cows. Cases of photosensitization corresponded only to young animals and were evident by signs of skin necrosis and facial edema.

A laboratory technique was adapted to detect the fungus *Pitomyces chartarum* which has been considered as partially responsible in association with *B. decumbens* (in some areas of Brazil) in causing a severe liver damage and consequently photosensitization. Several fungi were obtained from the *B. decumbens* samples analyzed from the paddocks that had photosensitization cases in Carimagua. The most prevalent fungi were *Fusarium* sp., *F. fusaroides, F. semitectum, F. solani, F. oxysporum, Curvularia* sp., *Penicillium* sp., *Drechslera* sp. and *Leptosphaeruleria* sp. Most of these species are saprophitic but *Fusarium* has been reported as a possible cause of toxicity in cattle. Spores resembling those of *P. chartarum* were observed in three samples. Pasture conditions and factors related to grazing might influence the prevalence of photosensitization. However, there is no relationship between time elapsed from establishment of the paddock and appearance of affected animals (Table 79). In six cases, the pastures were mature and one was at flowering. Previous reports and informations indicated that the majority of cases occur at the beginning of the rainy season, but in the case of observations presented in Table 79 photosensitization occurred at all times of the year. The time the animals remained on the pasture does not seem to have a direct effect on its prevalence.

Research will continue to establish the causal agent(s) of photosensitization.

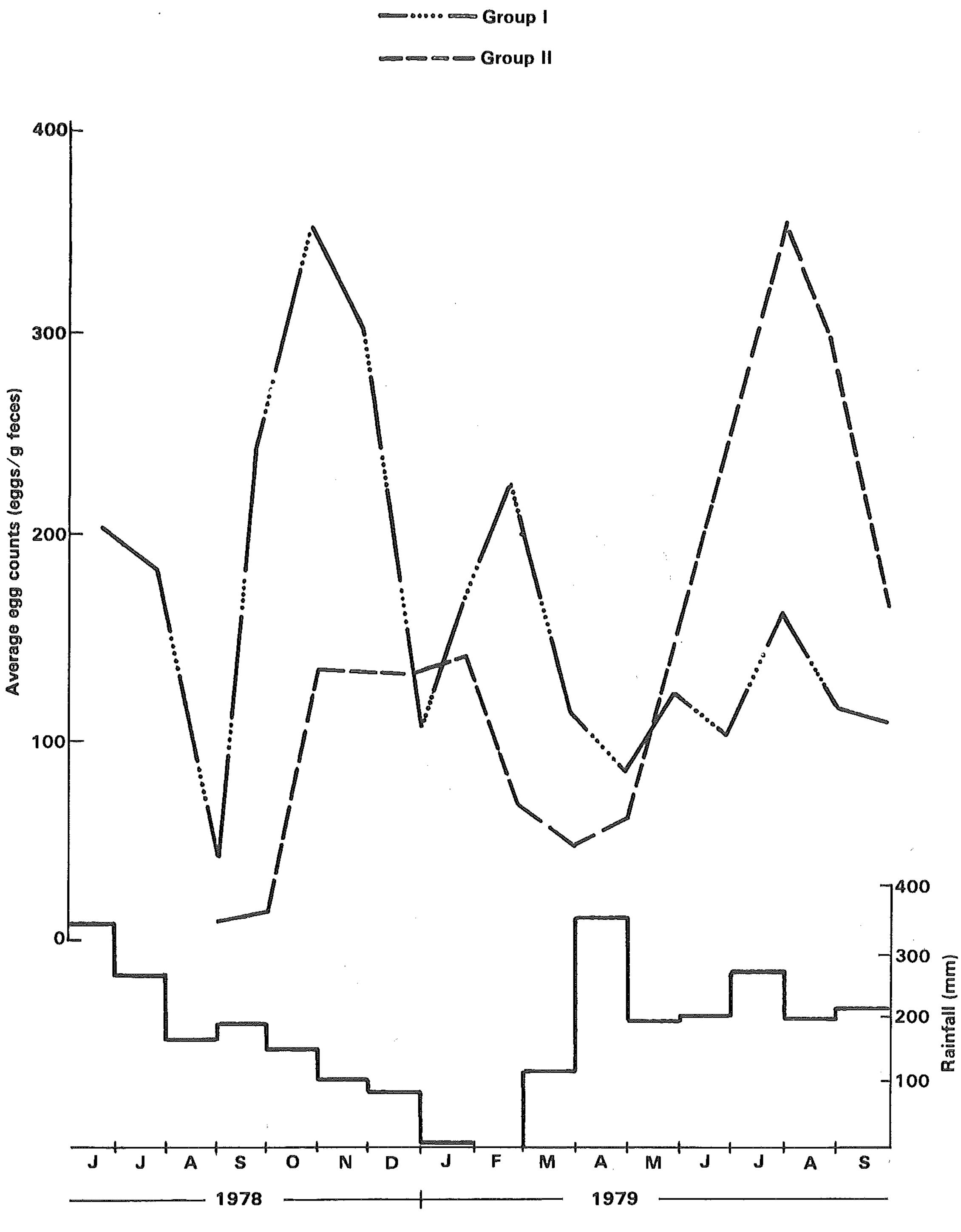

Figure 69. Trichostrongylidae parasite loads in calves from Carimagua on native pasture.

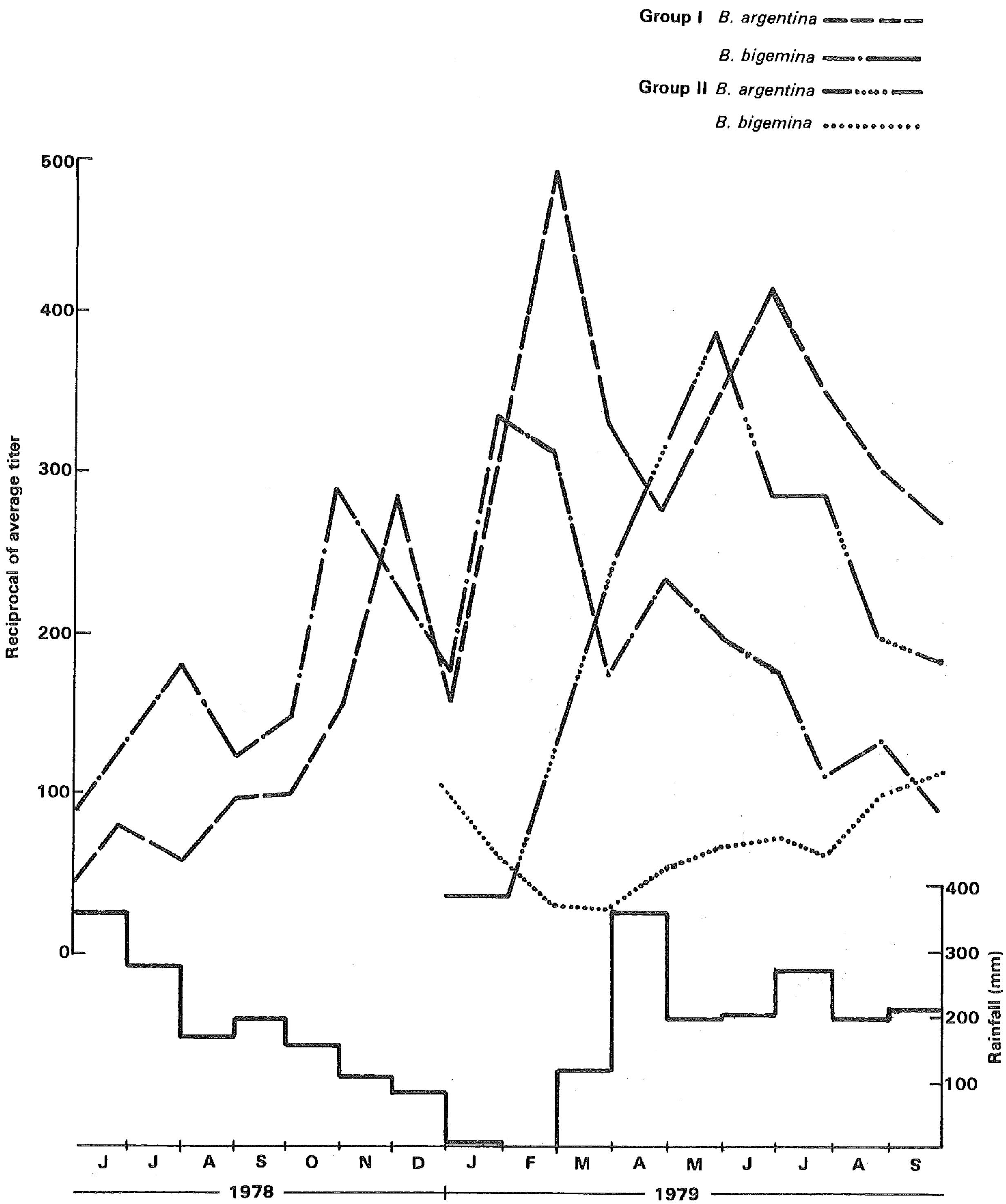

Figure 70. Development of a *Babesia* infection in calves (10 per group) on native pasture at Carimagua.

Table 78. Distribution of animals grazing Brachiaria decumbens and cases of photosensitization in Carimagua during 1979.

Pasture or herd	No. of animals	No. of cases	No. of deaths	Morbidity (%)	Mortality (%)	Group of animals
Breeding herd systems	163	0	0	0	0	Young heifers
La Alegría	47	0	0	0	0	Heifers, cows, calves
La Arepa	110	3	0	2.7	0	Heifers, cows, calves (up to 18 months)
Tomo 5	81	0	0	0	0	Cows, calves
Tomo 3	79	0	0	0	0	Cows, calves
Pasture Utilization	74	6	5	8.0	6.7	Young steers (up to 24 months)
Total	554	9	5	1.6	0.9	

Table 79. Animals grazing Brachiaria decumbens pastures in the Llanos Orientales of Colombia and affected by photosensitization.

Site	Establishment year	Stocking rate (animals/ha)	Condition of pasture	Animals with photosensitization	Date	Observations
Carimagua						
Pasture A	1975	1.2	Abundant, mature flowering	3	IX-X, 1979	Once a month
Pasture B	1973-74-75	0.7-3	Variable	6	XI 1978-	Animals pasturing since 1978
ETES Farms						
Farm 8		1	Mature, scarce	2	XII, 1976	
Farm 7	1978	0.5	Abundant, mature	6	VI, 1978	First grazing. One month after introduction
Pasture B	1975	0.5	Abundant, mature	4	IX, 1978	Several grazings of pasture
Pasture C	1975	0.5	Abundant, mature	1	IX, 1978	Several grazings of pasture
Farm 5	1977	0.28	Scarce, tender	1	XI, 1978	

ECONOMICS

During 1979, the Economics section was engaged in: (a) the ETES Project, conducted jointly with a Cattle Production Systems and Animal Helath sections; (b) a survey of cattle ranches in the Llanos Orientales of Colombia; (c) an *ex-ante* Cost/Benefit analysis of increasing cattle production in the Llanos Orientales of Colombia; (d) the expected distribution of benefits from increased cattle production among consumers of different income levels in 12 cities of Latin America; (e) the study of input/output prices of the livestock industry in the target area of the Program; and (f) seed production costs of tropical pastures.

The results obtained in the ETES Project are reported in the Production Systems section on page

Survey of Cattle Farms in the Colombian Llanos Orientales

As a complement of the detailed case study of farms in the ETES Project during 1979, a general field survey of cattle ranches was carried out in the well drained Colombian Llanos, south of the Meta river. Data obtained from this survey will be used to extrapolate the results obtained from the case studies, as there is no basic census data available for the savanna area of the department of Meta.

The area surveyed was divided into two zones according to distance to the market: Zone I, between Puerto López and Puerto Gaitán. the closest to the market, and Zone II, east of Puerto Gaitán at a greater distance from the market. The location of the farms is shown in Figure 71.

Within both zones, farms were divided into four groups according to size. Characteristics of farms were summarized according to zone and size strata (Table 80). All farms are cow-calf and stocker operations with a few exceptions in Zone I where sporadic additional fattening is carried out. In Zone I, 50% of farms belong to the class of farms of 1000-3000 ha, and average size for this zone is around 3000 ha with very few farms of 7000 or more ha. In Zone II, farms are larger in size; over 60% of farms have more than 3000 ha and the average size is more than 6000 ha. Average herd size is also larger in Zone II than in Zone I (568 vs 352 AU, respectively), increasing with farm size within each

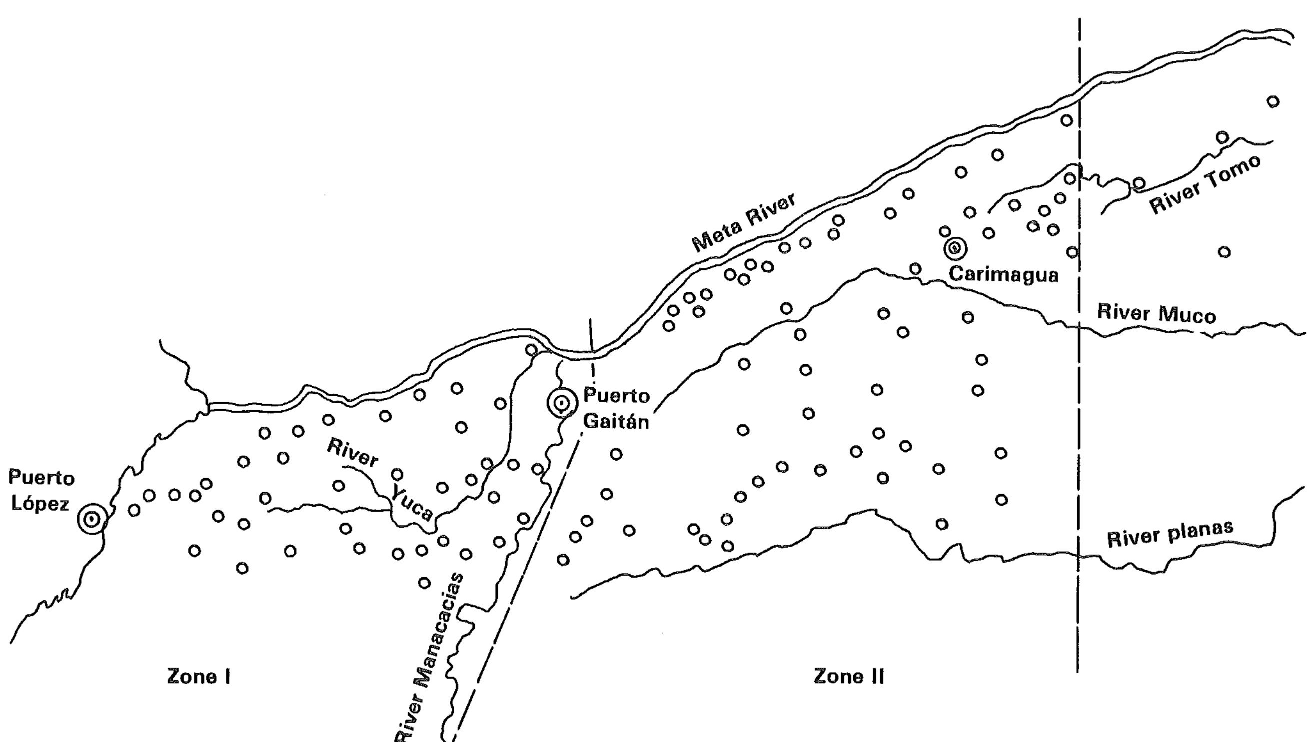

Figure 71. Location of cattle ranches surveyed in the Colombian Llanos.

Table 80. Descriptive characteristics of farms by zone and size of farm. Survey of cattle farms in the Colombian Llanos Orientales, 1979.

Zone and strata (ha)	No. of farms surveyed	Average farm size (ha)	Average proportion of wetland (%)	Average herd size (AU)	Average stocking rate (ha/AU)
Zone I					
1-999	7	699 (0.34)[1]	17 (1.00)	120 (0.74)	7.61 (0.78)
1000-2999	20	1704 (0.33)	18 (0.66)	270 (0.48)	7.94 (0.63)
3000-6999	8	4262 (0.22)	18 (0.50)	489 (0.40)	7.79 (0.26)
7000	5	9800 (0.36)	29 (0.41)	786 (0.39)	13.78 (0.45)
Subtotal	40	3051	20	352	7.90
Zone II					
1-999	5	760 (0.12)	12 (0.50)	92 (0.44)	11.20 (0.85)
1000-2999	21	1793 (0.32)	28 (0.42)	191 (0.60)	12.90 (0.68)
3000-6999	26	4082 (0.02)	37 (0.38)	415 (0.64)	13.20 (0.65)
7000	19	15972 (0.52)	39 (0.33)	1776 (0.94)	14.20 (0.87)
Subtotal	71	6352	34	690	14.00
Total region	111	5162	28	568	11.60

1 Figures in parenthesis are coefficients of variation.

zone, but there is large variation in herd size between farms in any given class group, as shown by the coefficients of variation.

The average stocking rate are 8 ha/AU in Zone I and 14 ha/AU in Zone II. In Zone I, the stocking rate remains rather constant across farm classes, except for those with 7000 ha or more which have a stocking rate of 14 ha/AU, a figure similar to that for the same class in Zone II. In the latter, the stocking rate decreases slowly with increasing farm size.

The total area of wet savanna and availability of this kind of land per animal are important indicators of the current production potential of farms in the Llanos as has been indicated by the ETES case studies. The average proportion of wet savanna reported in the surveyed farms varies from 20% in Zone I to 33% in Zone II, while the average for the ETES farms is 20%.

Table 81 presents information concerning the use of sown pastures in the region; 85% of farms surveyed have reported sown pastures, regardless of location of farm size. Only the small farms in Zone I have a relatively high proportion of sown pastures. In Zone II, only 1% of farm area is in sown pastures. Given that considerably lower land values prevail in this remote area, the sown grass pastures, which basically increase production per unit of land, have low demand. In terms of sown pasture availability per AU, there are 0.5 ha/AU in Zone I, and 0.1 ha/AU in Zone II. The average figure for the whole region is 0.3 ha/AU, which is not different from the average value obtained in the ETES farms.

It is interesting to note that in Zone I almost 80% of sown pastures corresponds to *Brachiaria decumbens*, while in Zone II, only 40% is *B. decumbens*, and *Hyparrhenia rufa* and *Melinis minutiflora* 28% each of total sown pasture area (Table 81).

Data on size and composition of on-farm investments are summarized in Table 82 and Figure 72. Total average investment per farm is in the range of US$200,000-230,000, being slightly higher in Zone I than in Zone II. But investment per unit area and per AU is substantially larger in Zone I as a consequence of smaller farm and herd size. The most important investment item in Zone I is land, followed by cattle. Investment in sown pastures, physical installations, machinery and equipment each represent 3-4% of total investment. The figures for Zone II are very similar except that in this area total investment in cattle is larget than in land due to lower land values and larger

Table 81. Availability of sown pastures according to the survey of cattle farms in the Colombian Llanos, 1979.

Zone and strata (ha)	Total number of farms	Farms with sown pastures	Availability of sown pastures (ha/AU)	Composition of sown pastures (%) Brachiaria decumbens	Hyparrhenia rufa	Melinis minutiflora
Zone I						
1-999	7	6	0.33 (12)[1]	92	5	3
1000-2999	20	18	0.23 (3)	70	12	18
3000-6999	8	6	0.80 (3)	89	6	5
7000	5	5	0.15 (1)	56	13	31
Subtotal	40	35	0.53 (4)	78	10	12
Zone II						
1-999	5	4	0.09 (1)	89	3	8
1000-2999	21	16	0.21 (1)	23	52	25
3000-6999	26	22	0.10 (1)	22	34	43
7000	19	17	0.09 (1)	82	1	18
Subtotal	71	59	0.12 (1)	43	28	28
Total region	111	94	0.27 (2.1)	56	21	23

1 Figures in parenthesis are percentages of total area.

Table 82. Size and composition of investments (US$, 1979) in cattle farms of the Colombian Llanos Orientales. (Exchange rate: Col.$40/US$1.)

Zone and strata (ha)	Land[1]	Cattle[2]	Sown pastures[3]	Installations	Machinery and equipment	Total investment	Investment per ha	per AU
Zone I	144,900	61,800	8700	7900	8400	231,700	75	655
Zone II	79,400	120,800	7700	7700	4900	220,500	35	325
Total region	103,900	99,500	8000	7800	6200	225,400	48	443
Percentage	46	44	4	3	3	100		

1 Average values of land: US$47.5/ha in Zone I and US$12.5/ha in Zone II.
2 Average value: US$175/AU.
3 Average value: US$100/ha of sown pastures.

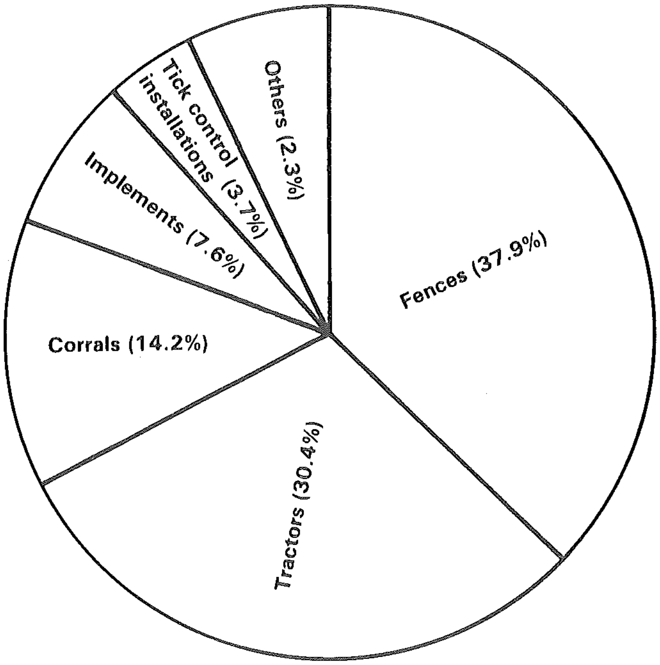

Figure 72. Average composition of on-farm investments in machinery and installations for cattle farms in the Colombian Llanos Orientales.

herd sizes. Investment in installations and machinery consist mainly of fences (38%), old tractors (30.4%), and corrals (14.2%).

Results on farm expenditures in labor and management are summarized in Table 83. Annual average expenditure in labor and management is US$3300 per farm in both zones, and increases slowly with farm size. Expenditures on a unit area or AU basis decrease with farm size as expected, indicating the presence of economies of scale in the use of labor and management. It may be noticed that the importance of occasional labor increases with farm size; in the class of large farms (≥7000 ha) occasional labor accounts for 50% of total expenditures in labor and management. Payments to occasional labor increase while management expenses decrease with farm size. Although no data were obtained for other expenditures, such as purchased inputs, information gathered from the case studies indicate that they correspond to less than 40% of total annual farm expenditures, and half of this figure is spent in mineral supplementation.

Table 83. Annual expenditures in labor and management by zone and farm size for cattle farms in the Colombian Llanos Orientales.

Zone and strata (ha)	Labor expenditures Permanent (%)	Labor expenditures Occasional (%)	Management[1]	Total (US$)[2]	Total (US$) Per ha	Total (US$) Per AU
Zone I						
1-999	21.2	32.4	46.4	2389	3.3	25.0
1000-2999	24.4	40.0	35.6	2906	1.8	10.6
3000-6999	16.1	41.3	42.6	5288	1.3	10.6
7000	25.0	48.2	26.8	2522	0.3	4.2
Subtotal	20.8	41.7	37.5	3326	1.8	12.2
Zone II						
1-999	20.9	18.4	60.7	872	1.1	10.0
1000-2999	35.5	29.0	35.5	2119	1.2	11.0
3000-6999	27.9	35.2	36.9	2933	0.7	7.5
7000	18.8	52.9	28.3	5818	0.4	4.5
Subtotal	23.6	45.0	31.4	3319	0.8	8.0
Total region	22.6	43.8	33.6	3453	1.2	9.5

1 Includes payments to administrators and foremen.
2 1979 US$.

Ex-ante Cost/Benefit Analysis

A study was initiated this year to determine the potential economic benefits expected from increased beef (and milk) production due to improved technology developed by research for pastures adapted to acid, infertile soils of tropical Latin America.

Efforts were concentrated in adapting the HATSIM model[1], which was originally developed for the simulation of herd development and cash flows at the farm level, in order to enable the simulation of regional herd dynamics and beef output. A sector of farms which adopt new technology is compared with a sector of traditional farms. The main additional variables included in the system are: (a) percentage of farms adopting new technology each year, and (b) percentage of farm area to be planted each year with the improved grass/legume pastures.

The variables are altered parametrically in order to estimate the expected impact on beef supply and producer benefits.

The model will be fed with data from the ETES Project in order to obtain a set of estimates for different combinations of values for the additional variables mentioned above.

Distribution of Benefits from Increased Beef Production

This study is a continuation of the project begun in 1978 (CIAT Annual Report, 1978), dealing with the distribution of urban consumer benefits, due to increased production as a result of research in tropical pastures. In 1978, preliminary results were obtained for four Colombian cities as well as for Sao Paulo, Brazil. The results obtained in the following cities are reported: Santiago, Chile; Guayaquil and Quito, Ecuador; Asunción, Paraguay; Lima, Perú; and Caracas and Maracaibo, Venezuela. Table 84 contains some selected descriptive characteristics of the sample of families included in the Family Budget Surveys of these cities. Families are classified into income quartiles, according to average per capita expenditures. Each quartile comprises 25% of the households in the sample of each city. Econometric estimates of the income elasticities of demand for beef along with the main descriptive statistics are presented in Table 85. Elasticities were obtained by fitting double-log regressions between per capita beef expenditures and total per capita expenditures.Most estimates were significant at $P<0.05$ except in a few of the highest income quartiles where there are large differences in beef expenditures between families not explained by income differences. In the lowest income strata, the income elasticity of demand for beef ranges between 0.8 and 1.28, just as in the Colombian and Brazilian cities, reflecting a high preference for beef consumption. The elasticity is lower for higher income strata. This study confirms the importance of beef expenditures in the consumption basket of urban families of all income groups in terms of both the high proportion of the food budget and total income spent in beef, and the high values obtained for the income elasticity of demand.

Data on family expenditures in milk and dairy products from the same surveys were also studied, given that these are important by-products of beef herds in many regions within the target area of the Program.

Table 86 includes average family expenditures in milk products by socioeconomic strata, for the 12 cities included in the study. In general, 7 to 18.6% of the food budget is spent in dairy products, with the highest values observed in Maracaibo, and the lowest in Santiago. Expenditures in dairy products, although smaller than for beef, absorb no less than 3.4% (Santiago) and as much as 12.2% (Maracaibo) of the total family income.

Income elasticities of demand for milk and dairy products were estimated by city and income strata using the same econometric model specified for beef. As shown in Table 87 except for two of the income strata in Asunción, all estimates were significant at $P<0.05$. These figures are high, particularly in the case of the low income strata, reflecting, as in the case of beef, a high preference for dairy products.

On the basis of the estimates obtained in this study, the preliminary conclusions highlighted in 1978 are confirmed for most of the main urban areas in Latin America. It may be stated that new technology which increases beef and milk supply in Latin America will provide large absolute benefits to all income strata, with a larger net impact on protein intake among protein deficient groups. Also, consumer benefits from increasing beef and milk supply will be distributed less regressively than current income distribution.

1 Juri, P., N.F. Gutiérrez and A. Valdés. Modelo de Simulación por Computador para Fincas Ganaderas; CIAT, August, 1977.

Table 84. Selected descriptive characteristics of the sample of families in a survey on beef expenditures among urban consumers in Latin America.

Country	City	Income quartile	Per capita expenditure range (US$/month)	Average per capita total expenditure (US$/month)	Average family size (persons)	No. of persons interviewed
Chile	Santiago	I	3.2- 27.7	18.5	6.3	4504
		II	27.8- 50.7	38.4	4.7	3361
		III	50.8- 103.6	74.0	4.1	2932
		IV	103.7-1428.7	199.8	3.3	2356
Ecuador	Guayaquil	I	5.6- 128.7	91.2	7.5	1778
		II	129.4- 243.6	179.9	6.3	1499
		III	243.7- 450.6	333.0	5.5	1304
		IV	451.0-3953.2	932.4	5.4	1280
	Quito	I	23.0- 145.8	97.8	7.1	1420
		II	147.1- 303.6	212.6	5.8	1160
		III	304.2- 633.9	449.5	5.2	1040
		IV	634.1-6497.0	1264.8	5.0	995
Paraguay	Asunción	I	19.9- 191.3	126.1	6.0	762
		II	192.1- 348.6	269.3	5.3	678
		III	348.7- 619.0	461.4	4.8	610
		IV	619.0-5894.2	1116.7	4.2	433
Peru	Lima	I	3.5- 26.6	17.9	7.6	2265
		II	26.7- 50.4	37.5	6.1	1818
		III	50.5- 92.9	69.7	6.5	1937
		IV	93.6-1263.6	169.8	6.1	1818
Venezuela	Caracas	I	5.8- 41.7	26.7	7.3	1672
		II	41.9- 76.2	57.0	5.4	1242
		III	76.3- 123.5	98.2	4.6	1058
		IV	124.1-1250.8	216.4	4.2	962
	Maracaibo	I	4.8- 21.4	16.1	8.6	1496
		II	21.5- 32.2	26.8	6.9	1208
		III	32.3- 52.4	41.7	5.6	980
		IV	52.8- 401.1	92.9	4.3	748

Study on Input/Output Prices in the Target Area

Given the importance of performing an economic evaluation of improved beef production technology components for some important regions within the target area, during 1979 a survey of on-farm prices for the main inputs was initiated. Different relative input/output prices between regions will imply different profitability of technology adoption and different desirable characteristics for the new technology, even under similar soil condltions. Relative prices are indicators for the farming systems on how to allocate their resources and can help explain differences in production levels, product-mix and use of inputs within the target area. Additional information is needed before an economic analysis can be carried out for other countries or regions.

Table 85. Allocation of family income and expenditures to beef consumption and income elasticity of demand for beef, by city and income strata.

Country	City	Income quartile	Food/total expenditure (%)	Food expenditure	Total expenditure	Total income	Income elasticity of demand (%)
Chile	Santiago	I	48.1	14.1	6.6	7.2	0.90
		II	39.2	15.8	6.1	6.7	1.16
		III	30.7	17.7	5.3	5.9	0.55
		IV	22.5	19.3	4.2	4.0	0.68
		Total					0.74
Ecuador	Guayaquil	I	80.2	17.8	16.6	10.9	1.10
		II	55.2	19.9	11.2	10.4	0.68
		III	46.1	20.5	9.5	9.1	0.32*[1]
		IV	30.6	17.1	5.1	4.6	0.55
		Total					0.56
	Quito	I	56.6	12.9	7.3	7.9	1.28
		II	46.1	15.3	7.2	7.2	0.54**
		III	36.7	16.7	6.1	6.0	0.68
		IV	24.1	15.8	3.7	3.7	0.49
		Total					0.62
Paraguay	Asunción	I	43.3	26.0	11.4	17.4	0.80
		II	37.4	25.1	9.3	14.6	0.99
		III	33.1	22.9	7.5	10.4	0.21*
		IV	24.7	18.9	4.5	6.2	0.11*
							0.41
Peru	Lima	I	53.9	18.6	9.9	11.7	0.92
		II	40.2	19.4	7.7	8.7	0.88
		III	29.4	20.9	5.9	7.8	0.79
		IV	20.0	18.3	3.5	4.4	0.04*
		Total					0.56
Venezuela	Caracas	I	49.8	12.4	6.2	5.7	0.80
		II	37.6	14.3	5.4	5.7	0.54
		III	30.9	14.0	4.3	4.7	0.72
		IV	22.5	14.0	3.0	3.8	0.48
		Total					0.59
	Maracaibo	I	59.1	14.0	8.2	9.2	1.20
		II	58.3	13.8	8.0	9.0	0.88**
		III	54.7	15.0	8.0	8.8	0.97
		IV	41.8	13.7	5.6	6.3	0.78
		Total					

1 * = not significant at a 95% confidence level; ** = significant only at a 95% confidence level.

Table 86. Allocation of family income and expenditures to milk and dairy products and income elasticity of demand for milk, by city and income strata.

			Expenditure in dairy products as percentage of:		
Country	City	Income quartile[1]	Food expenditure	Total expenditure	Total income
Brazil	Sao Paulo	I	10.5	5.5	4.9
		II	10.2	4.6	4.2
		III	9.9	3.7	3.4
		IV	10.4	2.7	2.5
Colombia	Bogotá	I	9.6	5.4	6.1
		II	10.0	5.0	5.3
		III	11.6	4.9	5.3
		IV	10.6	3.0	3.1
	Barranquilla	I	10.4	6.9	8.4
		II	10.0	5.9	7.8
		III	10.7	5.2	6.0
		IV	11.0	3.8	3.8
	Cali	I	7.0	4.5	4.9
		II	9.5	5.2	6.0
		III	13.1	6.1	6.6
		IV	12.5	4.2	4.1
	Medellín	I	8.5	5.0	4.8
		II	11.2	5.9	6.2
		III	13.5	6.2	6.2
		IV	13.1	4.2	3.8
Chile	Santiago	I	6.9	3.2	3.4
		II	9.2	3.4	3.8
		III	10.2	2.9	3.2
		IV	9.5	1.9	2.1
Ecuador	Quito	I	8.7	5.0	5.2
		II	10.8	5.1	5.2
		III	13.7	4.9	4.9
		IV	13.7	3.3	3.2
	Guayaquil	I	8.9	8.3	5.1
		II	11.5	6.2	5.8
		III	12.4	5.5	5.2
		IV	12.5	3.8	3.4
Paraguay	Asunción	I	11.2	4.4	6.0
		II	11.8	4.2	6.3
		III	12.6	4.1	5.5
		IV	13.2	3.1	3.9
Perú	Lima	I	11.7	5.9	6.7
		II	14.1	5.0	5.6
		III	13.6	3.8	5.0
		IV	11.4	2.0	2.6
Venezuela	Caracas	I	13.1	6.4	6.0
		II	14.6	5.4	5.8
		III	13.7	4.1	4.5
		IV	12.7	2.7	3.3
	Maracaibo	I	18.6	10.7	12.2
		II	17.0	9.7	1.8
		III	18.6	10.0	11.9
		IV	17.9	7.4	8.2

1 Families are classified into income quartiles according to average per capita expenditure, each quartile represents 25% of the families.

Source: CIAT, estimated from ECIEL Family Budget Surveys (organized by Brookings Institution and FIPE University of Sao Paulo, 1971-1972).

Table 87. Income-elasticities of demand for milk and diary products, by city and income strata among urban consumers.

Country	City	Income quartile I (low)	II	III	IV
Brazil[1]	Sao Paulo	0.87	0.66	0.42	0.40
Colombia	Bogotá	0.91	0.69*	0.69	0.52
	Barranquilla	0.99	1.19	0.76	0.32
	Cali	1.02	0.91	1.15	0.37
	Medellín	1.55	1.45	1.20	0.56
Chile	Santiago	1.16	0.90	0.52	0.58
Ecuador	Quito	0.87	1.14	0.82	0.51*
	Guayaquil	0.78	1.12	0.51	0.33
Paraguay	Asunción	1.02	0.21**	0.96	0.13**
Perú	Lima	0.94	0.44	0.47	0.28
Venezuela	Caracas	1.06	0.44	0.43*	0.46
	Maracaibo	1.12	1.37	0.92	0.32

1 In Brazil, only milk (liquid, condensed and powdered) is included. In all other countries, expenditure in milk products such as cheese are also included.

2 *=Significant at a 95% confidence level; the remaining values are significant at a 99% confidence level. **=not significant at a 95% confidence level.

Source: CIAT, based on ECIEL Family Budget Surveys, organized by Brookings Institution, and FIPE-University of Sao Paulo.

Figure 73 presents the prices of fertilizers, land, labor, machinery and milk relative to beef prices in four locations: Llanos Orientales of Colombia, Llanos Nororientales of Venezuela, and two states of the Brazilian Cerrado, Goiás and Minas Gerais. The bars indicate the number of units of each input or product which can be bought with 1 kg liveweight of beef. The differences between countries are very large in all cases. The relative prices of fertilizers are substantially lower in Venezuela, land price is lowest in the Colombian Llanos, while machinery, labor and milk are cheaper in the Brazilian Cerrado.

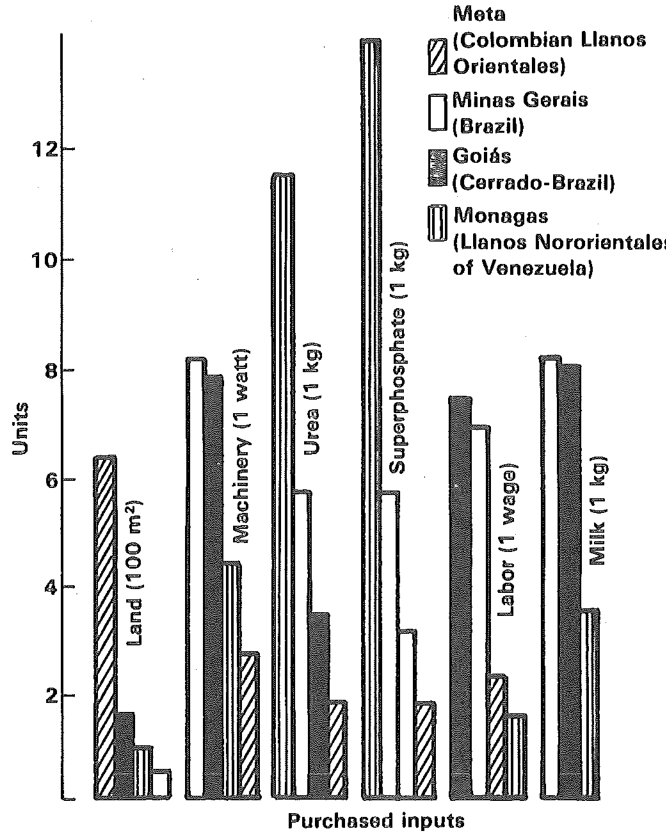

Figure 73. Units of different cattle inputs purchased with 1 kg of liveweight of beef in the target area of the Tropical Pastures Program, 1979.

Data on the relative price of triple superphosphate for a number of other locations are shown in Figure 74. Again, in the Colombian Llanos the relative price of fertilizer is higher than in most other places.

Given the cyclical nature of the livestock industry, price information for a given year has to be complemented with time-series data. Figure 75 and 76 present the evolution of the real prices of beef, milk and several of the cattle inputs in Goiás, Brazil, for the period 1973-78. It is quite clear that the relative prices of these inputs with respect to the beef price have varied over time, and depend on the stage of the cattle cycle. This type of information is being collected for other regions and will serve not only for comparison across countries but also for anticipation of possible adoption patterns.

Seed Production Costs in Colombia

Economic analysis of livestock production systems in the Colombian Llanos through the use of simulation,

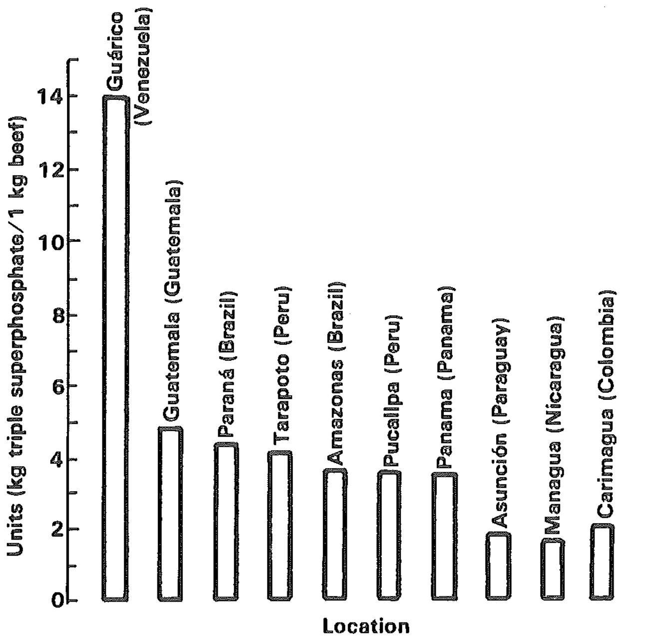

Figure 74. Amount (kg) of triple superphosphate bought with 1 kg of beef (liveweight) in selected location, 1979. (Source: CIAT survey.)

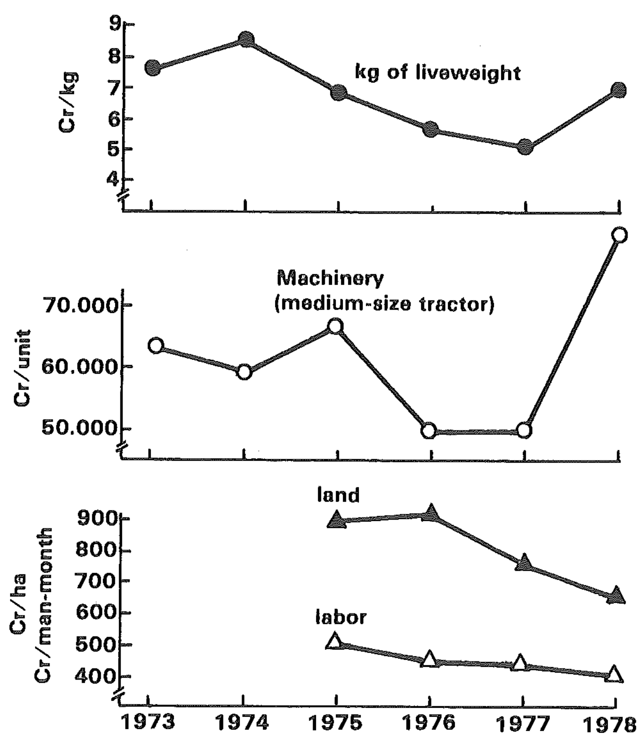

Figure 75. Real prices of beef and cattle inputs in Goiás, Brazil, 1973-1978. (Prices deflated by whoesale price index, 1975-100.)

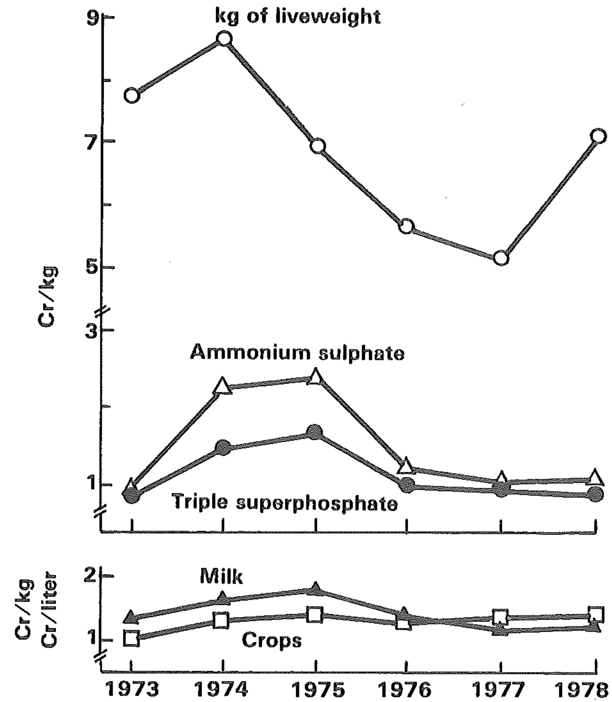

Figure 76. Real prices of beef and cattle inputs in Goiás, Brazil, 1973-1978. (Prices deflated by wholesale price index, 1975-100.)

has shown that reductions in pasture establishment costs can significantly increase the profitability of improved pastures (see for example CIAT's 1978 Annual Report). Seed is an important input in pasture establishment, normally accounting for approximately 20% of the total establishment cost. Thus, it may be expected that price of seed and price elasticity of seed supply will be among the more important factors determining the rate of diffusion of new pasture technology.

Due to the high price of commercial seed observed in Colombia during 1979, seed production costs for tropical grasses and legumes were studied.

Ferguson[1] (1978) has described five basic systems for tropical pasture seed production presently used in lowland tropical Latin America. Under the most intensive and specialized method of seed production (System 5 in Ferguson's classification) not yet widespread or well developed in the area, grasses and legumes are cultivated as crops, with limited emphasis

1 Ferguson, J.E. Systems of pasture eed production in Latin America. *In* Sánchez, P.A. and Tergas, L.E., Eds. Pasture Production in Acid Soils of the Tropics. Cali, Colombia. CIAT Series 03EG-5. 1979. pp. 385-395.

on forage production. Seed production of *B. decumbens* in Brazil, Bolivia and Colombia is one of few examples of this production system in the region. However it is thought that this system offers greater opportunities for viable commercial production, higher yield and quality potentials and more consistent market availability at lower prices than any of the other systems.

The development of a sizeable market for commercial seed will depend not only on supply but also on demand considerations. Demand for commercially produced seed will depend largely on the price of commercial seed versus the cost of seed from alternative sources. On farms which already have some stoloniferous species, vegetative propagation may be a feasible alternative, but it is labor intensive, and requires more logistical support than planting with seed. In ecosystems where a species is well adapted for forage production and has high seed set, on-farm seed production from selected pastures without additional inputs (such as System 4 in Ferguson's classification) may be a profitable alternative. Since the amount of seed required per unit area depends on quality, and this characteristic is influenced by the production method used, the comparison between seed production systems should be made in terms of cost of pure live seed.

Seed production of B. decumbens and A. gayanus as crops

During 1979, costs of commercial seed production of *B. decumbens* and *A. gayanus* were estimated for production System 5 for two harvesting methods. Costs include seed processing but not packaging nor distribution costs. Seed prices were also estimated as a function of seed yields, harvesting method and area cultivated.

Since pastures grown for seed production may be used for several years, all project costs and returns have to be capitalized. In this analysis, the internal rate of return (IRR) is estimated for each of the alternatives considered. Once a target 10% IRR is set, it is possible to estimate the minimum sale price of seed.

Costs of pasture establishment were estimated assuming conventional land preparation of plowing plus two diskings (CIAT Annual Report, 1978, pp. B-157). The coefficients of machinery use/ha, fuel consumption/hour, time employed/ha and labor use/ha were estimated at CIAT experiment stations. All of the cultural practices required to assure optimum seed production are included in the projects; i.e., high fertilizer rates during the establishment phase, annual urea applications, high seeding rates, weed and insect control, and irrigation in the case of *A. gayanus.* Costs of seed drying and land rental costs are also included. Cost estimates obtained for *B. decumbens* seed correspond to prices and yields of the Villavicencio area where commercial seed of this species is currently produced to supply the Colombian Llanos. Data used for *A. gayanus* correspond to the Cauca Valley region, where research on the production of this seed is currently being conducted.

The following additional considerations were taken into account: (a) two seed crops are harvested each year; (b) crop durations of three and five years for *B. decumbens,* and of three years for *A. gayanus* are assumed; (c) prices and costs are those which prevailed in September 1979; (d) yields are expressed in terms of pure seed. (In order to estimate sale prices for commercial seed, purity must be specified); (e) a range of possible seed yields are considered in each case, based on experimental results and observations of Colombian commercial seed production; (f) two harvesting methods are compared (direct combine harvesting and manual cutting, field sweating for three days and manual threshing; the difference in seed

Table 88. Establishment costs for *Brachiaria decumbens* and *Andropogon gayanus*.

	Cost (US$/ha)[1]	
Cost item	Brachiaria decumbens	Andropogon gayanus
Land preparation	67	55
Machinery use	17	18
Labor use	50	37
Inputs	105	196
Fertilizer	32	32
Seed	63	146
Herbicides	10	18
Total	172	251

1 Costs are based on September, 1979 prices at an exchange rate of Col.$42/US$1.00.

Table 89. Annual seed production costs (1979 prices) for Brachiaria decumbens and Andropogon gayanus using two harvest methods (20 ha/year).

Cost item	Cost (US$/ha) Brachiaria decumbens	Andropogon gayanus
Rental cost of land[1]	175	300
Maintenance cost	63	116
Fertilizers	35	26
Irrigation	-	29
Other[2]	28	61
Harvest costs[3]		
Mechanical harvest	200	205
Manual harvest	248	409
Total cost		
Mechanical harvest	438	621
Manual harvest	484	825

1 The rental cost of land for B. decumbens is the price which prevails in the Villavicencio area, while that for A. gayanus is the current price of irrigated land in the Cauca Valley region.
2 These include costs of labor and machinery.
3 Two harvest per year are assumed in both cases. Harvest costs include cost of seed drying and cleaning.

yields due to harvesting method used are described elsewhere, CIAT Annual Report, 1978, pp. B-49); (g) it is assumed that seed is sun dried, with allowance for labor cost; (h) an additional annual income of US$18/ha from the forage by-product is included for *B. decumbens.*

Establishment and maintenance costs

Establishment costs (for both species considered in this study) are shown in Table 88. A cost of US$251/ha is estimated for the establishment of *A. gayanus* as a crop (1.5 times that for *B. decumbens*); although land preparation costs are lower, the costs of both seed and herbicides used are higher. However, the current price of *A. gayanus* seed is artificially high due to scarcity in the market. If *A. gayanus* seed were half the current price, the establishment cost of the pasture would decrease to US$178/ha, very similar to that for *B. decumbens.* It is noteworthy that seed costs represents at least 35% of the total establishment cost, followed by fertilizer and labor costs.

Annual costs of seed production are shown in Table 89. The main cost items are the following: **Rental price of land.** The selection of better soils for seed production entails higher costs. In this case, *A. gayanus* is cultivated in an area where land is rented at US$300/ha/ years. The price of land in the piedmont area is US$175/ha/year. Costs of pasture maintenance include fertilization, weed control, and also irrigation in the case of *A. gayanus.* These costs

Table 90. Effect of harvest method and area planted on minimum prices[1] of pure seed of Andropogon gayanus and Brachiaria decumbens (1979 US$/kg).

Harvesting method	Brachiaria decumbens Yield (kg pure seed/ha)	Area planted (ha) 25	50	100	Andropogon gayanus Yield (kg pure seed/ha)	Area planted (ha) 25	50	100
Mechanical	15	43	40	37	25	47	40	39
	30	21	20	18	50	19	16	15
	50	13	12	11	75	13	11	10
Manual	25	30			75	15		
	50	15			150	8		
	84	9			225	5		

1 These are minimum prices, estimated by assuming a 10% internal rate of returns.
2 Seed production in smaller areas would probably be harvested manually. The opposite is expected for large planted areas, where mechanical harvesting would predominate.

are therefore higher for the latter than for *B. decumbens*. **Harvest costs** depend basically on the method used for harvesting, and are highest in the case of manual harvesting of *A. gayanus* seed which is more labor demanding. Mechanical harvesting is cheaper in both grass species, but 1.7 times higher seed yields are obtained with manual harvesting. Thus, the final comparison between harvesting methods has to be done in terms of the price at which seed can be produced in each instance, and not just on the basis of production costs.

Table 90 shows the minimum price which could be charged for the seed to maintain the target 10% IRR. Prices can be substantially lowered through the use of manual harvesting, but this method can only be used in small areas due to high labor requirements. For a given harvesting method, economies of scale are minimal. The largest reduction in seed price can be achieved by obtaining sustained high seed yields. Using the *B. decumbens* crop for seed production during five instead of three years would have almost no effect on seed price, as shown in Table 91. Moreover, it is likely that seed yields will decrease over time and/or more fertilizer will be required; thus the impact of longer crop duration might be to increase rather than decrease production costs.

Table 91. Effect duration of crop productivity of Brachiaria decumbens on the price of seed[1] (1979 US$/kg pure seed).

Pasture duration	Area planted (ha)				
(years)	25	50	100	200	300
3	21	20	18	18	17
5	22	19	17	17	16

1 Prices shown are estimated by fixing the internal rate of return at 10% assuming an average yield of 30 kg/ha of pure seed of Brachiaria decumbens, and using mechanical harvesting.

If average yields are achieved, the price of pure seed of *B. decumbens* should be between US$15/kg - US$15/kg-20/kg, and US$8/kg-19 kg for *A. gayanus* seed. Assuming a 90% purity of commercial classified seed, price of *B. decumbens* seed should be half the price which currently prevails in the region. It can be concluded that the high prevailing price is due to low seed yields, high risk, high profit margin or a combination of these factors.

TRANSFERENCE OF TECHNOLOGY

This section was reorganized during 1979 with the following objectives: (a) to coordinate the technical aspects of training activities; (b) to propose the strategy and mechanisms for validation of technology on tropical pasture production and utilization; and (c) to coordinate activities related to international collaboration.

Training

A total of 42 professionals received training during 1979 in the various sections of the Program to continue the efforts on developing and strengthening a network of scientists and technicians working on tropical pastures on acid, infertile soil conditions in Latin America (Table 92).

Among these, eight visiting research associates participated in collaborative projects with universities in Canada, Colombia, England, France, United States and West Germany, to fulfill requirements for MS, PhD, or equivalent degrees. In addition, five visiting research associates and nine postgraduate interns for research participated in projects related to specific activities within the Program. The main purpose of these types of training activities is the strengthening of national programs to conduct independent and cooperative research with CIAT at the regional level.

Twenty four professionals from nine countries in the target area of the Program in Latin America, representing research and development institutions participated in the Second Course on Research on Tropical Pasture Production and Utilization conducted during the first semester 1979. A third course with similar objectives has been planned for the first semester in 1980.

Table 92. Countries of origin of professionals trained in Tropical Pastures at CIAT in 1979.

Country	No. of professionals	Country	No. of professionals	Country	No. of professionals
Antigua	1	Colombia	11	Perú	5
Argentina	1	Cuba	4	Venezuela	7
Belize	3	Dominican Republic	1	Australia	1
Bolivia	3	Ecuador	3	Holland	2
Brazil	6	Guatemala	1	United States	5
Chile	1	Nicaragua	3	West Germany	2
				Total	60

1 The disciplines in which training participants specialized include Agronomy, Animal Health, Economics, Enthomology, Germplasm, Production, Seed Production, Soil Microbiology, Soils, Pasture Establishment, and Pasture Utilization.

Experiments for training purposes

Several experiments have been established at CIAT-Quilichao to serve as a basis for training on research methodology on pasture evaluation, and on methodology related to regional trials on adaptation of tropical pasture species to acid infertile soil conditions. In addition to training purposes, experiments on weed control were also conducted.

As part of the training program, two experiments were established in late 1977 to determine the relative adaptation of selected grass and legume ecotypes under grazing and forage species under cutting, to different levels of soil fertility at CIAT-Quilichao. Although little change occurred due to fertilizer treatments, except for a significant increase in available P and exchangeable Ca, selected grass and legume ecotypes responded differently and some showed good dry matter yields indicating remarkable adaptation to these conditions (Figures 77 and 78).

On the basis of first year yields, *Cynodon dactylon* cv Coast-cross 1 could be considered the best adapted improved short-creeping grass according to criteria on plant survival, tolerance, and adaptation to acidity and low soil fertility developed by the Soil Plant Nutrition section, compared to the native grass *Paspalum notatum*, producing a similar dry matter yield at the highest fertility level with 85 and 67% relative yield at the medium and low fertility levels, respectively. *Digiratia decumbens* and *Cynodon nlemfuensis* performed well only at the highest soil fertility level. *Brachiaria humidicola, B. decumbens* and *Melinis minutiflora* performed very well; *B. decumbens* outyielded all other grasses in this group. *Andropogon gayanus* 621, *Panicum maximum* and *Paspalum plicatulum* were the best adapted, tall-fufted grasses; *P. maximum* produced the highest dry matter yields during the first year.

The best adapted and more productive legume ecotypes which also were relatively disease-free were *Desmodium ovalifolium* 350, *Centrosema* sp. 438 and *Pueraria phaseoloides* for the trailing types, and *Stylosanthes hamata* 118 and *S. capitata* 1019 for the bush types. Within this last group, *Macroptilium* sp. 535, *S. guianensis* 136 and 184 performed relatively well at the beginning but showed very little persistence towards the end of the first year due to fungal diseases.

Figure 79 shows the results with the forage species. *Pennisetum purpureum* cv. H-534 was the only species producing high dry matter yield at the higher soil fertility level; however, the relative yield at the medium and low levels were below the limits for good

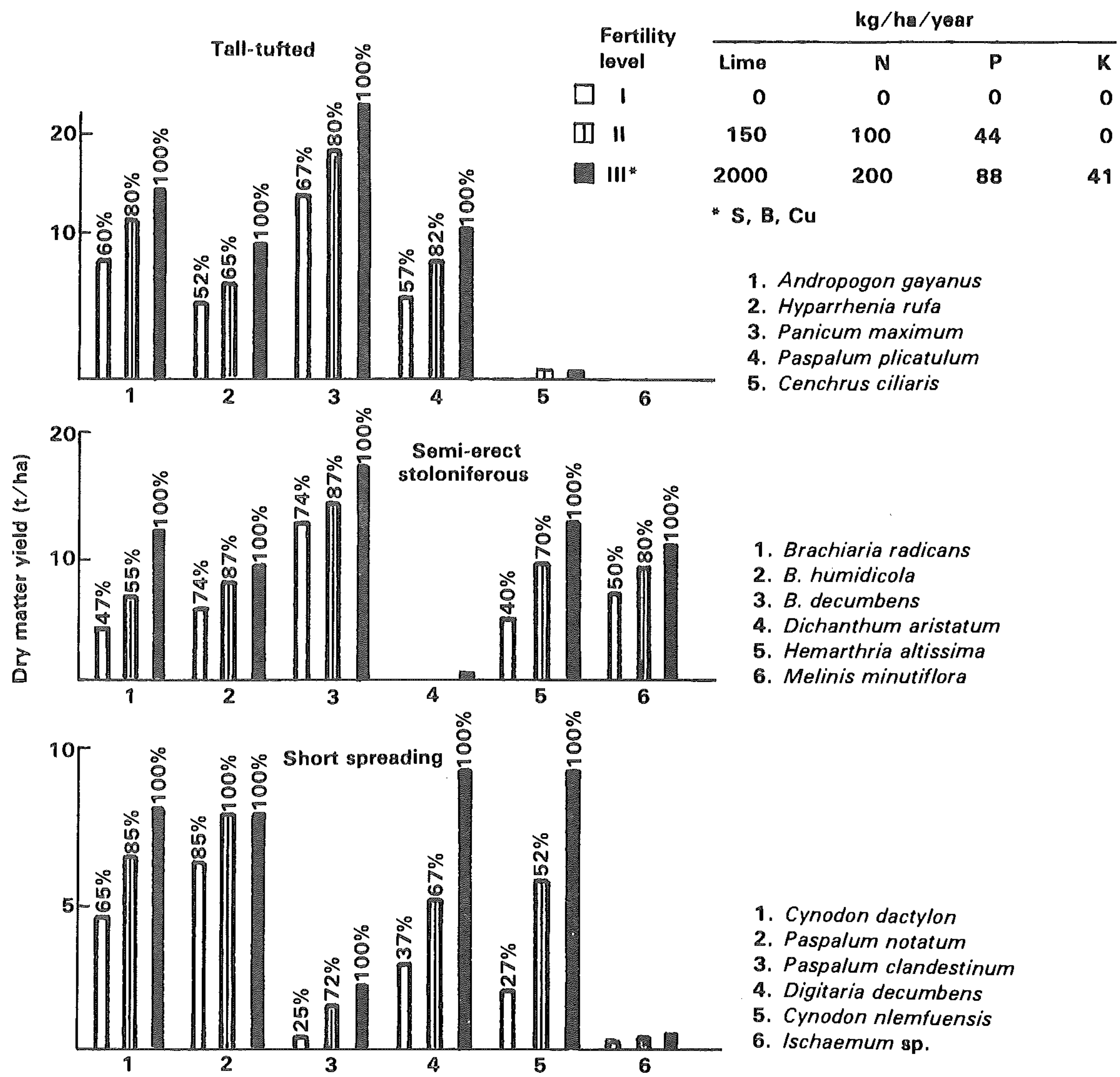

Figure 77. First year dry matter yields and differential responses of three tropical grass groups to three soil fertility levels at CIAT-Quilichao, 1979.

adaptation. *Axonopus scoparius* was better adapted but its productivity during the dry season was only 10% of the annual yield, indicating poor adaptation to drought. All of the other species, including good materials such as *Saccharum officinarum, Manihot sativa,* and *Leucaena leucocephala* performed poorly, showing the limitations in the use of forages for feed supplementation during the dry season under acid, infertile soil conditions.

Table 93 shows the results of the evaluation of selected grass and legume ecotypes for adaptation at CIAT-Quilichao. This experiment was part of the network of regional trials which was established in 24 sites in eight countries in the target area of the Program. After 16 months, the three grasses were performing very well without any significant difference in dry matter yield and growth rates, and *S. capitata* 1019 and 1405 were outyielding all of the other legumes and were observed relatively free of diseases and insect pests.

Validation of Technology

Results of experimental work and of evaluation of improved pasture species in the regional trials network are very encouraging.

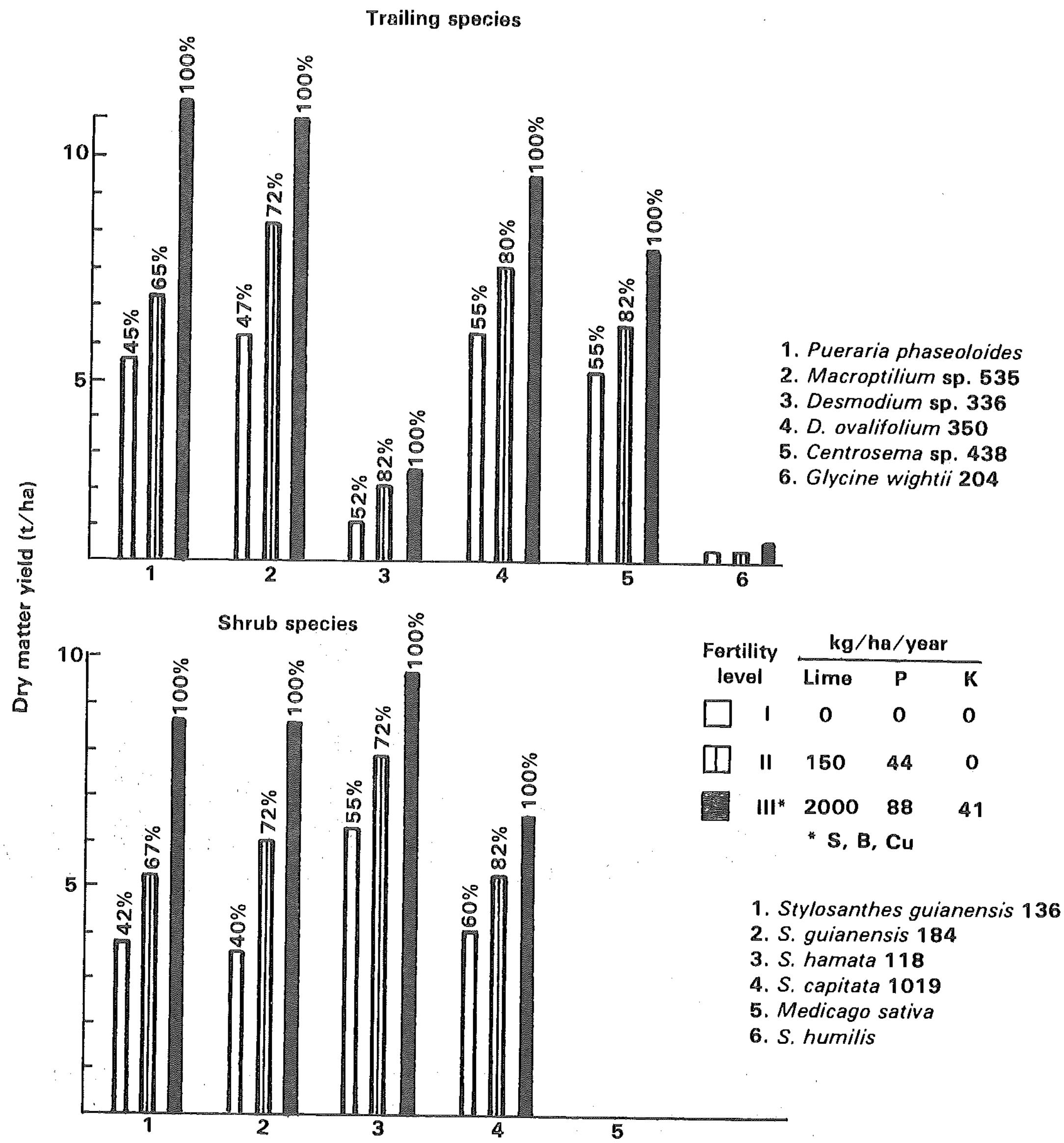

Figure 78. First year dry matter yields and differential responses of two tropical legume groups, to three soil fertility levels at CIAT-Quilichao, 1979.

The strategy that has been considered for the validation of technology in the near future includes: (a) the identification of active development institutions in the target area of the Program; (b) the training of professionals in the validation and transfer of technology; and (c) the participation in all activities related to regional trials to identify germplasm that could be used in validation trials at the farm level.

Regional trials

During 1979, the Tropical Pastures Program focused attention on the organization and execution of the Regional Trials Network. A Regional Trials Committe was formed in order to integrate other sections of the Program in the handling of the Network.

The range of ecosystems included and the technical and economic constraints most common to the participant institutions in the Network were taken into account by the committee in the elaboration of an Organization and Methodology proposal for the evaluation of the Regional Trials Network.

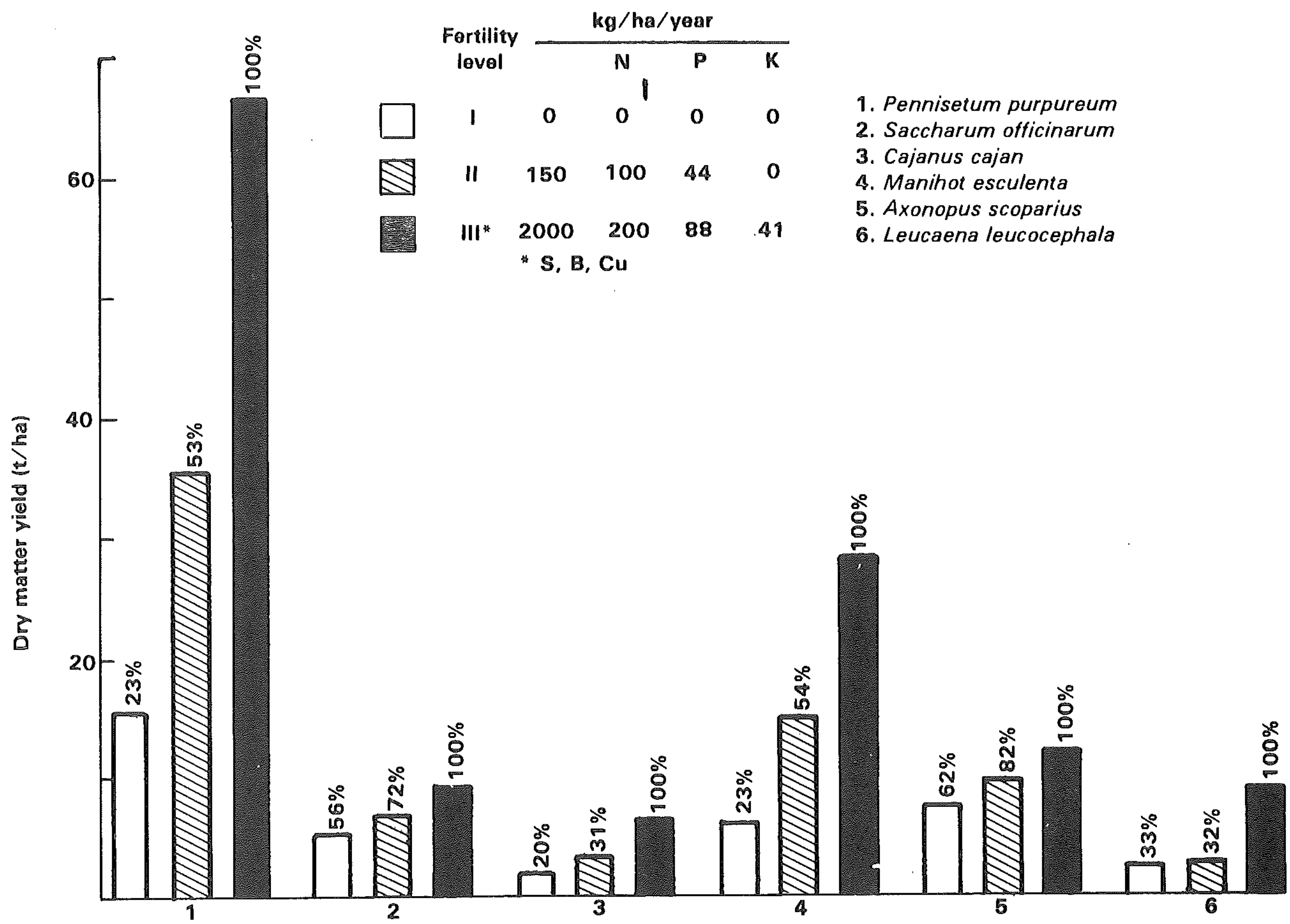

Figure 79. First year dry matter yields and differential responses of forage species to three soil fertility levels at CIAT-Quilichao, 1979.

This proposal was submitted for discussion and approval to the attendants of a workshop on the Regional Trials Network held at CIAT, October 1-4, 1979. Ninety-one scientists and officers of institutions of 14 countries participated (Table 94).

The approved proposal clearly establishes the orientation of the Regional Trials Network towards studying pasture germplasm adaptability to the different major ecosystems rather than considering the network as a medium for technology validation.

An experimental sequence for germplasm evaluation through the network was approved (Figure 80). In Regional Trials A (RTA), the survival to main factors of the ecosystem (climate, soil, diseases and insects) will be studied. This first step included a large number of entries (more than 100) to be tested in few sites representing the major ecosystems.

The Regional Trials B (RTB) should evaluate a reduced number of entries (approximately 25) selected for each major ecosystem from the RTA. This RTB will be carried out in subecosystems within a major ecosystem. At this stage of the evaluation, dry matter yield of individual ecotypes is measured during the periods of maximum and minimum rainfall.

The discussions during the workshop were restricted to the evaluation methodologies of RTA and RTB. It was agreed that a uniform evaluation system should be used to obtain reliable and comparable data throughout the network.

Table 93. Dry matter yields and average growth rates of selected grass and legume ecotypes under grazing 16 months after establishment at CIAT-Quilichao, 1978-79.

Ecotypes	Dry matter[1] yield (kg/ha)	Production (kg/ha/day)
Grasses		
Andropogon gayanus 621	27,132a[2]	56.7a
Brachiaria decumbens 606	25,964a	56.8a
Panicum maximum	33,089a	67.1a
Average	28,728	60.2
Legumes		
Pueraria phaseoloides 9900	9,697c	19.0c
Desmodium heterophyllum 349	6,005d	12.3d
D. ovalifolium 350	9,187c	19.9c
Stylosanthes capitata 1405	17,514a	36.7a
S. capitata 1019	18,170a	37.1a
S. hamata 147	13,055b	26.9b
Centrosema pubescens	7,975c	17.3cd
Centrosema sp. 438	8,869c	17.8c
Macroptilium 535	8,155c	15.8cd
Average	8,033	27.0

1 80°C for 36 h.
2 Numbers within colums followed by the same letters are not significantly different at the 0.05 level.

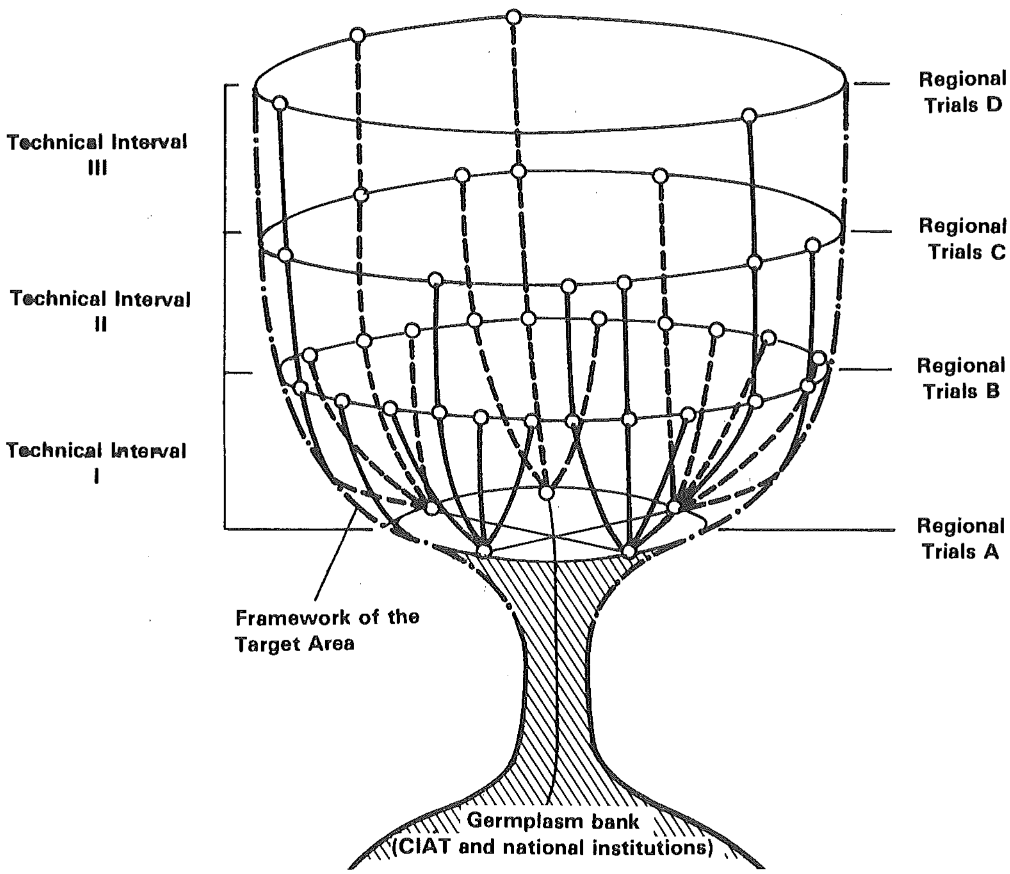

Figure 80. Germplasm flow through the Tropical Pastures Regional Trials Network.

Table 94. Participants in the workshop on the Network of Regional Trials for Adaptation of Tropical Forage Species held at CIAT, October 1-4, 1979.

Country	Institution	Number of participants by Institutions	Number of participants by Countries
Australia	Davis Laboratory	1	1
Bolivia	Centro de Investigación Agrícola Tropical, Santa Cruz	2	2
Brazil	CEPLAC, Bahía	1	
	CIAT-CPAC, Brasilia	3	
	EMAPA, Maranhao	1	
	EMBRAPA, Brasilia	1	
	EMBRAPA/CENARGEN, Brasilia	2	
	EMBRAPA/CNPGC, Mato Grosso	1	
	EMBRAPA/CNPGL, Minas Gerais	3	
	EMBRAPA/CPAC, Brasilia	3	
	EMBRAPA/CPATU, Pará	2	
	EMGOPA, Boiás	1	
	EPAMIG, Minas Gerais	3	
	FAO/UEPAE, Teresina, Piauí	1	
	IAPAR, Paraná	1	23
Colombia	CENICAFE	1	
	CIAT	20	
	Fondo Gandero del Putumayo	1	
	ICA	4	26
Cuba	Instituto de Ciencia Animal	1	
	Ministerio de Agricultura	4	5
Ecuador	Escuela Superior Politécnica de Chimborazo	2	
	INIAP	4	6
Guyana	Livestock Development Co. Ltd.	1	
	Ministry of Agriculture	1	2
Jamaica	Ministry of Agriculture	1	1
Mexico	INIA	1	1
Nicaragua	INTA	1	1
Peru	COPERHOLTA, Tarapoto	1	
	INIA/CIA, Tarapoto	1	
	INIA-NCSU, Yurimaguas	2	
	IVITA, Pucallpa	2	
	Universidad Agraria "La Molina", Tarapoto	1	7
Suriname	Ministry of Agriculture	1	1
Trinidad	Ministry of Agriculture	1	1
Venezuela	Centro Nacional de Investigación Agropecuaria	1	
	FONAIAP	3	
	FUSAGRI	1	
	Universidad Central de Venezuela	5	
	Universidad de Oriente	2	
	Universidad de Zulia	2	14
	Total of participants		91

Table 95. Tropical Pastures publications issued in the established CIAT series during 1979.

Code	Title	Language	Pages	Press run
02E1G-78	Annual Report 1978	English	182	940
02S1G-78	Separata Informe Anual 1978	Spanish	193	1500
05EG-1	Handbook for the Collection, Preservation and Characterization of Tropical Forage Germplasm Resources	English	102	500
05SG-1	Manual para la Colección, Preservación y Caracterización de Recursos Forrageros Tropicales	Spanish	106	500
03EG-5	Pasture Production in Acid Soils of the Tropics	English	488	2917
03SG-5	Producción de Pastos en Suelos Acidos de los Trópicos	Spanish	524	3020
08SG-1	Resúmenes Analíticos sobre Pastos Tropicales, Vol. I	Spanish		1500
01SG-1	Boletín Informativo de Pastos Tropicales No. 1	Spanish		1200

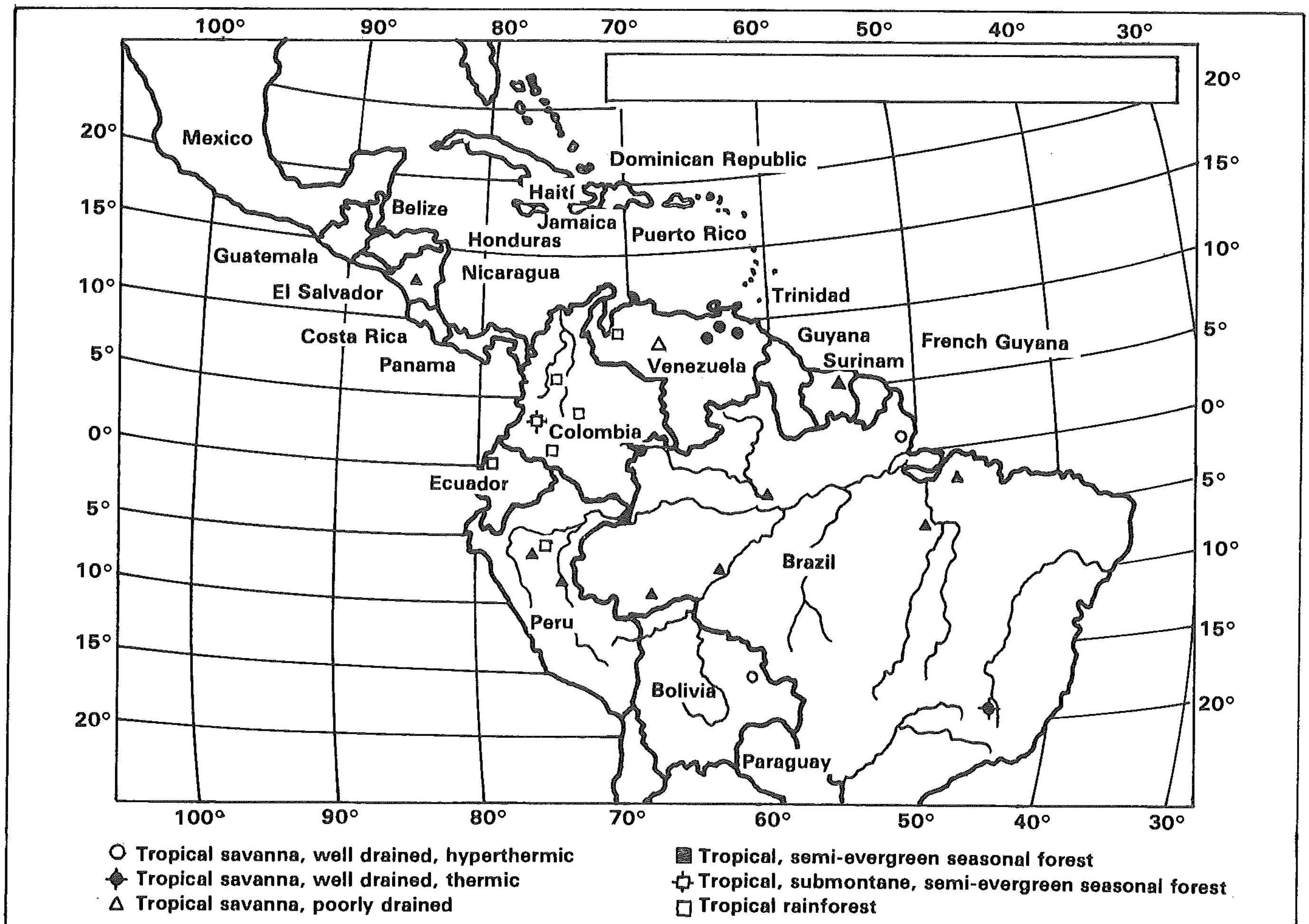

Figure 81. Location of the first Regional Trials for adaptation of tropical forage species in Latin America by ecosystems.

It was also approved that the network should include Regional Trials C and D in which selected germplasm from RTB (5 to 10 entries) should be evaluated in grass/legume mixtures under grazing. The methodologies for these two levels will be discussed in a future workshop planned for 1981.

Reports of the first Regional Trials already established were presented. Figure 81 shows the location of the existing trials in the target area.

Eventually the Regional Trials Network will provide information to the national institutions and to CIAT about the range of adaptability of pasture germplasm to specific ecological conditons. This information should be a solid basis for extrapolating tropical pastures research findings throughout the target area of the Program.

Printed Media

New titles in the area of tropical pastures published by CIAT in 1979 are shown in Table 95. At CIAT's Documentation Center a newsletter on tropical pastures (in Spanish) was initiated to provide relevant network information to researchers, basically in Latin America.

CIAT/IFDC PHOSPHORUS PROJECT

The objective of the CIAT based IFDC Phosphorus Project is to develop a phosphorus management strategy for the various crops and cropping systems now employed on the acid infertile soils of subtropical and tropical Latin America. Since the soils under consideration are low in both available and total P and generally have a high P fixation capacity, the P needs of the soil as well as the plant must be considered. It is not likely that these P needs will be accommodated through the use of triple- or simple-superphosphate (TSP and SSP, respectively) because of their high cost per unit of phosphate. Also, since these forms of P are quite soluble, a large percentage of the P is fixed by the soil and thus, in part, is not available to the plant.

It seems reasonable, therefore, that less available forms of P such as phosphate rock (PR), partially acidulated PR, cogranulated mixtures of S with PR, and cogranulated mixtures of TSP or SSP with PR may be reasonable alternatives to either TSP or SSP. Not only are these forms of P less likely to be fixed by the soil but their residual value should prove to be superior to that of the more available forms of P. It is also logical to take advantage of the soil acidity by using PR or other similar P carriers that will respond favorably under an acid environment.

In addition, the cost per unit of P as PR is about one-third that for TSP or SSP. In this regard, South America is fortunate in that there are some 17 known major PR deposits (CIAT Annual Report, 1978).

A series of greenhouse and field experiments have been established in Colombia, Ecuador, and Peru in which many of these South American PRs and their altered products are being tested for agronomic effectiveness using several different test crops. To date, many of these PR carriers appear to be promising and in some instances have shown to be superior to TSP.

Phosphate Rocks

A greenhouse experiment was conducted on an Oxisol from Las Gaviotas in the Colombian Llanos Orientales, to compare the agronomic effectiveness of 18 different phosphate rocks (PR) with TSP, and *Panicum maximum* as the test crop. Yield results are given in Table 96.

The PRs which are known to be highly reactive such as North Carolina, Fosbayovar, and Gafsa performed nearly as well as TSP. Other PRs such as South Africa, Florida, Huila, Maranhao, Arad, and Pesca also appear promising for direct application. In general, the effectiveness of all the rocks increased with higher rates when compared to simiar rates of TSP.

In a field experiment conducted on a Carimagua Oxisol with *Brachiaria decumbens,* six PRs were compared to TSP. This long-term experiment which was established in 1976 included application rates ranging from 0 to 400 kg P_2O_5/ha, all broadcast and incorporated into the topsoil. To date, the grass has

Table 96. Agronomic effectiveness of phosphate rocks determined by yield of Panicum maximum grown on an Oxisol under greenhouse conditions.

P source	Relative yield (%)			
	P applied (mg/pot)			
	50	100	200	400
TSP[1]	100 (13.3)[2]	100 (19.0)	100 (20.2)	100 (22.2)
Brazil				
Abaeté	11	33	52	55
Araxá	30	33	56	58
Catalao	5	6	22	38
Jacupiranga	12	13	19	51
Maranhao	60	69	86	91
Patos de Minas	27	42	66	72
Tapira	4	7	10	23
Colombia				
Huila	58	59	84	84
Pesca	56	61	80	83
Sardinata	29	44	68	74
Israel				
Arad	62	62	95	92
Peru				
Fosbayovar	99	79	104	91
Tunisia				
Gafsa	63	72	114	105
South Africa	71	68	93	92
United States				
Florida	59	71	86	91
North Carolina	70	78	107	108
Tennessee	42	51	78	95
Venezuela				
Lobatera	56	56	65	76
Control (0.6)				

1 TSP considered 100% within each level of applied P.
2 Figures in parenthesis are yields in g/pot as the sum of three cuttings.

been cut 11 times and the comparative yield results are given in Table 97. In all cases, the yields obtained with the PRs compared favorably with those for TSP at all levels of applied P. Althought the initial yields were higher for TSP, the residual value of the PRs appears superior to that of the more soluble form. Based on this experiment it would appear that an initial application of 50 kg P_2O_5/ha is sufficient for grass forage production.

In a similar field experiment conducted in collaboration with the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), in Peru, on a Pucallpa Ultisol, *B. decumbens* yielded slightly better with Fosbayovar PR than with SSP (Table 98). These data are consistent with those from Carimagua (Table 99).

Agronomic Effectiveness of P Placement

A field experiment was set up in CIAT-Quilichao to determine which would be the best method of P application as TSP, in conjunction with different levels of broadcast and incorporated Pesca PR, for a forage production scheme. *B. decumbens* was used as the test crop and to date five cuts have been taken. The results are quite surprising as the application of Pesca PR is comparing very favorably with TSP and combinations of TSP with PR (Table 99). It should also be noted that the topdressed PR also performed similarly to all other treatments. This would indicate that at least some PRs could be used as P sources on established pastures.

Table 97. Relative agronomic effectiveness of phosphate rocks from several sources as determined by yield of Brachiaria decumbens grown in the field at Carimagua (sum of 11 cuts taken over a 40-month period), 1976-1979.

P source	Relative yield (%) P$_2$O$_5$ applied (kg/ha)			
	25	50	100	400
Annual TSP	(28.6)	(31.6)	(32.3)	(39.2)
Residual TSP[1]	100 (19.4)[2]	100 (27.0)	100 (28.0)	100 (33.7)
Florida (USA)	124	92	101	105
Fosbayovar (Peru)	121	79	105	106
Gafsa (Tunisia)	106	107	107	101
Huila (Colombia)	93	112	100	109
Pesca (Colombia)	109	81	112	113
Tennessee (USA)	104	76	96	107
Control (12.4)				

1 Assumed at 100% for each level of application.
2 Dry matter yields in t/ha.

When this experiment was established, the control plots were so P-deficient that it was difficult to obtain a good stand of grass. However, with time it is apparent that considerable mineralization of P occurs. As a result, after five cuts of the grass, the control plots were yielding about 50% of the high P treatments. This has also been noted in other experiments at CIAT-Quilichao and is quite atypical for a soil classified as an Ultisol.

Agronomic Effectiveness of Granule Size of PR

A greenhouse experiment with maize was set up on a Carimagua Oxisol to determine the effect of granule size on P availability of several P carriers. The results of two harvests are given in Table 100. In the case of the more reactive PRs, the yields were approximately the same for the ground and minigranulated materials which compared very favorably with those for TSP and SSP. With the lesser reactive PRs, P availability decreased with increasing granule size and yields did not compare favorably with the soluble P carriers at any given mesh size.

Table 98. Effect of two rates and sources of phosphorus on yield of Brachiaria decumbens grown in the field on a Pucallpa Ultisol (sum of 3 cuts), 1978-1979.

P source	Yield (t/ha) P applied (kg/ha)	
	40	160
SSP	9.7	11.2
Fosbayovar (Sechura)	10.9	11.9
Control (4.7)		

The relative yields decreased markedly for all PRs when the -6 + 14 mesh granules were employed.

Agronomic Effectiveness of PR:TSP Ratios

A field experiment was set up to study the agronomic effectiveness of three Colombian PRs, alone and in combination with TSP, on yield of rice and peanuts grown in rotation at CIAT-Quilichao. Results for two harvests of rice and one of peanuts are given in Table 101.

In general, with the first rice harvest, yields increased with each additional increment of P as PR, except in the case of Huila PR where near maximum yields were obtained with 50 kg P_2O_5/ha. With the lesser reactive Pesca and Sardinata PRs, the 1:1 ratios of PR:TSP generally gave higher yields at the lower P application rates. This illustrates the initial need for a soluble form of P when low rates are used.

Table 99. Management of phosphorus in establishing and maintaining *Brachiaria decumbens* grown in the field at CIAT-Quilichao (sum of 5 cuts), 1978-1979.

P source ($kg\ P_2O_5/ha$)	Method of application	Relative yield (%) Pesca phosphate rock ($kg\ P_2O_5/ha$)			
		0	100	200	400
TSP					
0		53	87	98	100
50	Topdress	103	96	95	103
100	Topdress	88	98	106	-
50	Banded	58	85	95	100[1] (17.1)[2]
100	Banded	84	75	102	-
50	Broadcast & incorporated	82	98	102	98
100	Broadcast & incorporated	104	103	102	-
50	Strips	-	-	-	84
Pesca[3]	Topdress	-	75	103	89

1 Treatment regarded as 100%.
2 Dry matter yield in t/ha.
3 Included as topdress treatment of PR only.

Peanut yields did not reflect the levels and combination of applied P with the exception of Huila PR which yielded comparably to TSP at the high rate of application. Many of the PR treatments at the lower levels of applied P were only slightly better than the P-free control.

The second rice harvest showed large yield increases at all levels and combinations of applied P. It appears that significant amounts of P are being released from all of the PRs and the yields of rice were comparable to similar P applications of TSP.

In a similar experiment with *B. decumbens,* the yields after six cuts were comparable to those just described for rice (Table 102). Although the initial two cuts of grass were considerably higher for those treatments with higher ratios of TSP, the total yields are about the same within a given rate of P due to the residual value of the PRs. At the lower rate of applied P, the yields obtained with Sardinata PR, however, are somewhat lower due to its apparent low reactivity.

Agronomic Effectiveness of Cogranulated Mixtures of PRs with TSP and SSP

When monocalcium phosphate is applied to the soil it forms dicalcium phosphate and phosphoric acid. In order to take advantage of this acid, it seems logical that if SSP or TSP were cogranulated with PR, the acid might react with the PR rather than being dissipated in the soil.

A greenhouse experiment was conducted to study the effect of the ratio of PR to SSP and TSP on yield of maize grown on a Carimagua Oxisol. Table 103 shows quite clearly that as the ratio of soluble P is increased, yields increase correspondingly. When the ratios of PR:TSP or SSP in powder are compared to

Table 100. Effect of granule size of five phosphate rocks applied to maize (200 kg P_2O_5/ha) grown in the greenhouse on a Carimagua Oxisol (sum of two harvests).

P source	Relative yield (%)		
	Powder (200 mesh)	Minigranule (-48 + 150 mesh)	Regular granule (-6 + 14 mesh)
TSP	91	95	100[1] (17.7)[2]
SSP	114	98	97
Arad (Israel)	116	84	18
Araxa (Brazil)	63	44	15
Florida (USA)	84	95	26
North Carolina (USA)	95	97	55
Pesca (Colombia)	45	32	20
Control (2.4)			

1 TSP is regular granule size assumed to be 100%.
2 Figure in parenthesis is tissue yield in g/pot.

Table 101. Agronomic effectiveness of three Colombian phosphate rocks, alone and in combination with TSP, as measured by relative yields of upland rice and peanuts grown in rotation at CIAT-Quilichao, 1978-1979.

P source	PR:TSP[1]	Relative yield (%)											
		Rice 1978B				Peanuts 1979A				Rice 1979B			
		50	100	200		50	100	200		50	100	200	
		(kg P_2O_5/ha)				(kg P_2O_5/ha)				(kg P_2O_5/ha)			
TSP banded	1:0	91	101	100[2]	(5.5)[3]	79	94	100[2]	(3.8)[3]	85	93	100[2]	(7.2)[3]
Huila PR	1:0	103	99	109		82	77	95		97	83	104	
Huila PR + TSP	1:0	99	108	111		72	80	86		76	84	104	
Pesca PR	1:0	73	95	93		72	68	77		83	91	97	
Pesca PR + TSP	1:1	79	94	103		69	73	74		86	91	96	
Sardinata PR	1:0	71	73	94		68	73	76		83	79	04	
Sardinata PR + TSP	1:0	85	96	94		75	74	84		83	86	97	
Check		(2.9)[3]				(2.5)[3]				(4.9)[3]			

1 Based on total P_2O_5 content of P source.
2 200 kg P_2O_5/ha as TSP assumed to be 100%.
3 Yield in t/ha.

Table 102. Effect of varying ratio of TSP and each of three Colombian phosphate rocks on the relative yield of Brachiaria decumbens grown in the field at CIAT-Quilichao (sum of 6 cuts), 1978-1979.

P source	PR:TSP[1]	Relative yield (%) (kg P_2O_5/ha) 100	200
TSP	0:1	94	100[2] (21.2)[3]
Huila PR	1:0	88	99
Huila PR + TSP	3:1	84	103
Huila PR + TSP	1:1	87	97
Huila PR + TSP	1:3	84	94
Pesca	1:0	81	95
Pesca PR + TSP	3:1	95	93
Pesca PR + TSP	1:1	90	95
Pesca PR + TSP	1:3	102	118
Sardinata	1:0	71	84
Sardinata + TSP	3:1	80	93
Sardinata + TSP	1:1	72	91
Sardinata + TSP	1:3	82	90
Check 63%			

1 Based on total P_2O_5 content of P sources.
2 200 kg P_2O_5/ha as TSP assumed to be 100%.
3 Dry matter yield in t/ha.

Table 103. Effect of ratio of phosphate rock to SSP and TSP on yield of maize grown in the greenhouse on a Carimagua Oxisol (sum of 2 harvests).

P source	Relative yield (%)[1] PR:SSP or TSP 1:0	3:1	1:1	1:3	0:1
SSP	-	-	-	-	100[2] (18.9)[3]
TSP	-	-	-	-	91
Florida RP + SSP	71	70	91	99	-
Florida RP + TSP	71	72	92	98	-
Pesca RP + SSP	27	53	75	99	-
Pesca RP + TSP	27	64	70	89	-
Check (16%)					

1 All P rates were averaged. Granule size used: Minigranule (-48 + 150).
2 SSP assumed to be 100%.
3 Tissue yield in g/pot.

minigranules (Table 104), it appears that the latter are more effective sources of P when a more reactive PR such as Florida is used. In the case of the lesser reactive PR from Pesca, the results vary depending on whether the PR was mixed with SSP or TSP. In general, when Pesca is mixed with SSP, the ground PR appears superior to the minigranulated material. The reverse is true when the Pesca PR is mixed with TSP. The reason for this is being studied.

Agronomic Effectiveness of Partially Acidulated PR

A field experiment is being conducted to determine the agronomic effectiveness of partially acidulated PR (20% with H_2SO_4) on yield of upland rice at Carimagua. To date only one harvest has been taken (Table 105). At the lower rate of application (100 kg P_2O_5/ha) there was an increase in yield with the partially acidulated Florida PR over the nonacidulated one. Minigranulation further enhances this effect. In the case of North Carolina PR, there appears to be a slight yield decrease with acidulation. At the higher rate of applied P, all treatments compared favorably with TSP.

In another field experiment at Carimagua with partially acidulated Florida PR (20% with H_3PO_4) and *Panicum maximum* as the test crop, similar results to those just described for Florida PR were obtained (Table 106). The partially acidulated minigranule was better than powdered PR. It is also interesting to note how well the partially acidulated regular size granule (-6 + 14 mesh) performed at the higher rates of application. The residual value of these larger particles could be quite significant agronomically.

It is apparent that if partially acidulated PR is to have an agronomic impact, lesser reactive rocks should be used. Since many of the PRs in South America have

Table 104. Effect of ratio of phosphate rock to SSP and TSP, and granulation on yield of maize grown in the greenhouse on a Carimagua Oxisol (sum of 2 harvests).

P source	Ratio PR:SSP or TSP	Relative yield (%)[1] Powder	Minigranule (-48 + 150 mesh)
SSP	0:1	105	100[2] (18.9)[3]
TSP	0:1	88	91
Florida PR	1:0	65	71
Florida RP + SSP	3:1	59	70
Florida PR + SSP	1:1	51	91
Florida PR + SSP	1:3	89	99
Florida PR + TSP	3:1	66	72
Florida PR + TSP	1:1	56	92
Florida PR + TSP	1:3	73	98
Pesca PR	1:0	40	27
Pesca PR + SSP	3:1	61	53
Pesca PR + SSP	1:1	83	75
Pesca PR + SSP	1:3	101	99
Pesca PR + TSP	3:1	55	64
Pesca PR + TSP	1:1	57	70
Pesca PR + TSP	1:3	79	89
Control (16%)			

1 All P rates were averaged.
2 SSP minigranulated treatment assumed to be 100%.
3 Tissue yield in g/pot.

relatively low reactivities, perhaps partial acidulation will be beneficial. Greenhouse screening trials are currently underway to evalute this.

Phosphorus Fixation Mechanisms

In an attempt to gain a better understanding of the P fixation mechanisms in the tropical soils of Latin America, several different analyses were carried out to determine if certain parameters could be correlated. These analyses were run on 23 different Colombian soils; a summary is given in Table 107.

In general it was found that active Al (extracted with NH_4OAc buffered at pH 4.8), reactive Al (extracted with $MgCl_2$ at pH 8.2 to 8.5), and organic matter content appeared to be directly correlated with P fixation. There appears to be no consistent relationship between P fixation and other soil parameters such as soil pH, exchangeable Al, and free Fe oxides.

Table 105. Effect of partial acidulation, P rates, and granulation of two phosphate rocks on yield of upland rice grown in the field at Carimagua, 1978.

P source[1]	Granule size	Acidulation with H_2SO_4 (%)	Relative yield (%) (kg P_2O_5/ha) 100	200
TSP	Regular	100	81	100[2] (4.3)[3]
North Carolina PR	Powder	0	79	93
North Carolina PR	Powder	20	74	98
North Carolina PR	Minigranule	0	93	112
North Carolina PR	Minigranule	20	84	109
Florida PR	Powder	0	70	107
Florida PR	Powder	20	81	109
Florida PR	Minigranule	0	74	107
Florida PR	Minigranule	20	95	100
Control (42%)				

1 TSP was band applied and all phosphate rocks broadcasted.
2 TSP 200 kg P_2O_5/ha as TSP assumed to be 100%.
3 Yield in t/ha.

Table 106. Effect of partial acidulation, P rates, and granulation of Florida phosphate rock on yield of Panicum maximum grown in the field at Carimagua (1 cut), 1979.

P source	Granule size	Acidulation with H_3PO_4 (%)	Relative yield (%) (kg P_2O_5/ha) 50	100	200
TSP	Regular	100	50	73	100[1] (6.0)[2]
Florida PR	Powder	0	28	53	73
Florida PR	Minigranule	20	53	63	82
Florida PR	Regular	20	37	68	102
Control (1.7%)					

1 200 kg P_2O_5/ha as TSP assumed to be 100%.
2 Dry matter yield in t/ha.

Table 107. Summary of average soil chemical parameters grouped into relative P fixation categories (soils from 23 Colombian sites).

Category	Soil classification	Relative P fixation	% P fixed (10 ppm P added)	pH	Organic matter (%)	Exchangeable Al (meq/100 g)	% Al saturation	Active Al (meq/100 g)	Reactive Al (meq/100 g)
1	Andept	Very high	80%	5.3	20.4	1.3	39.2	12.3	29.8
2	Andept-Oxisol-Ultisol	High	60-80%	5.0	7.8	2.3	40.9	3.8	8.9
3	Oxisol-Inceptisol	Medium	40-60%	4.8	4.2	2.5	56.7	3.1	7.3
4	Mollisol	Low	40%	6.3	4.3	0.2	0.8	0.7	3.4

Category	Free Fe oxide (% Fe_2O_3)	P-Al ppm	% P-Al of total P	P-Fe ppm	% P-Fe of total P	Organic P (ppm)	% organic P of total P	Number of sites
1	2.9	16.2	2.1	6.3	1.1	603.0	72.0	4
2	4.6	4.1	0.8	46.4	6.7	267.1	54.8	6
3	4.7	1.2	0.6	8.7	5.7	126.8	40.2	8
4	2.9	4.5	0.9	6.5	1.4	106.9	21.2	5

LAND RESOURCE EVALUATION OF TROPICAL AMERICA

In order to create a foundation for the effective development and transfer of germplasm based technology, and to facilitate the development and revision of research priorities compatible with geographic realities and economic trends, CIAT, in conjunction with national agencies including the Centro de Pesquisa Agropecuaria dos Cerrados, Empresa Brasileira de Pesquisa Agropecuaria (CPAC-EMBRAPA) in Brazil and the Ministries of Agriculture of other countries, is currently evaluating land resource information in tropical America. The work started in mid-1977 as a specific study of the Oxisol and Ultisol regions to help establish technical priorities for forage improvement. Land information is reduced to a common base in terms of climate, landscape, vegetation, and soils. The study now covers over 850 million ha (Figure 82). The 1977 and 1978 CIAT Annual Reports contain progress reports and some preliminary findings.

With the virtual completion of the study as originally envisaged by mid-1979, its scope was extended to cover regions of interest for CIAT's other commodity programs including cassava, beans, rice and maize (Andean region only), and to provide useful information for crop, forage, and agro-forestry production throughout tropical Latin America in general.

In order to accelerate the analysis of the land resources information, a computerized data storage, retrieval and analytical system, map and data printout facility has been set up. This is readily expandable and permits the analysis of the land resource data in the light of additional information from other sources, particularly economic studies. The information recorded in the data bank has already been made available to agricultural institutions as a series of computer tapes.

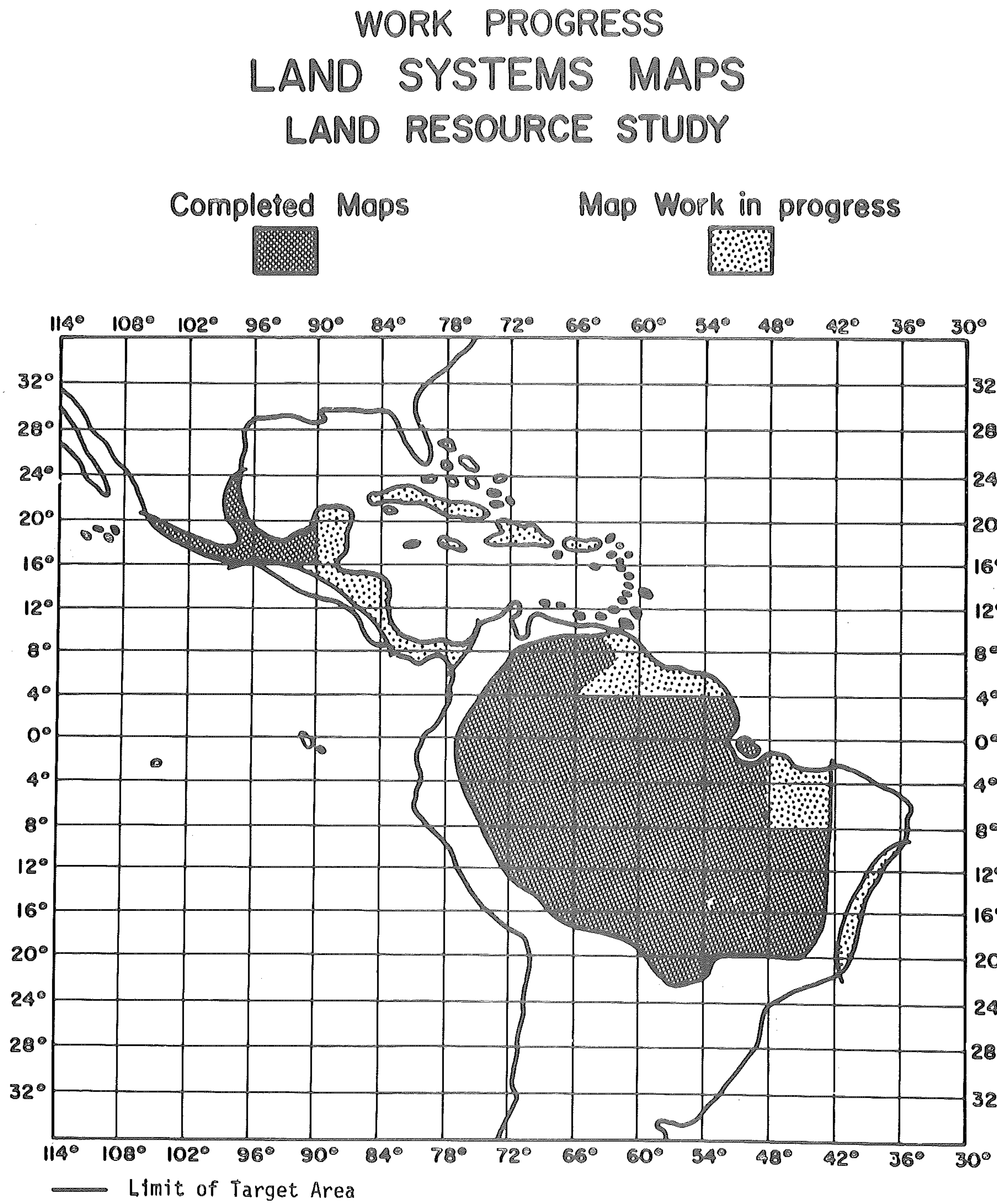

Figure 82. The geographical extent of the study.

Methodology

Land classification

In order to provide a geographical summary of the land resources, it was decided to modify the land systems approach developed by Christian and Stewart in 1953 in their study of the land resources of the Katherine-Darwin region of Northern Australia. For this study, a land system was defined as "an area or group of areas throughout which there is a recurring pattern of climate, landscape and soils". The environmental parameters were arranged in categorical order to form a true land classification:

- Climate
  - Radiant energy received
  - Temperature
  - Potential evapotranspiration
  - Water balance
  - Other climatic factors
- Landscape
  - Land-form
  - Hydrology
  - Vegetation
- Soil
  - Soil physical characteristics
  - Soil chemical characteristics

These were the principal parameters used to delineate a land system. Paradoxically, the delineation of land systems was effectively used not only to describe the land resources of regions where little or no information was available, but also to condense and summarize the great amount of printed information occasionally available for some regions of lesser geographical extent, where detailed studies including soil surveys, climatological studies and in-field experimentation had been recorded. Where information was not available a limited amount of field work was carried out. The land systems maps were made at a scale of 1:1,000,000, and numbered according to the International Chart of the World Index.

Satellite and radar imagery were used to provide an accurate geographical base for the delineation of land systems. Radar imagery was available for the Amazonian region of Brazil. By using satellite and radar imagery, the topographical inaccuracies of many existing maps were avoided.

Climate

Data from 1144 meterological stations throughout Central and South America were initially analyzed for the study, and the analyses for selected representative stations incorporated as an integral part of the land resource data bank. This work is available either as a printout with an explanatory text[1] or as a computer tape.

The methodology used for calculating potential evapotranspiration (ETP) followed that described by Hargreaves. This method was selected because it used available climatic data to give a proven estimate of ETP. It was of fundamental importance that ETP be calculated as realistically as possible to assess the water balance and growing season, and provide a guide as to the total amount of energy available for plant growth. Solar radiation and temperature are the most important factors in determining ETP, the two basic parameters of Hargreaves' equation.

Figure 83 shows a straight printout of the climatic analysis of Luziana, Brazil, used for describing the climate of land system No. 1 of the study.

The precipitation deficit in mm is the difference between the precipitation and the potential evapotranspiration.

Dependable precipitation (PD) is the 75% probability of precipitation occurrence, which can be described as the amount of precipitation that will be equaled or exceeded in three out of four years.

The Moisture Availability Index (MAI) is a moisture adequacy index at the 75% probability level of precipitation occurrence. It is defined as PD divided by the ETP. A MAI value of 1.00 means taht PD equals ETP.

1 Hancock, J.K., Hill, R.W., and Hargreaves, G.H., comp. Potential evapotranspiration and precipitation deficits for tropical America. Cali, Colombia. CIAT. 1979. 398 p.

TARGET AREA SURVEY

POTENTIAL EVAPOTRANSPIRATION AND PRECIPITATION DEFECIT FOR BRAZIL

2070 LUZIANIA LAT 16 15 LON 47 56 958. METERS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN TEMP	21.9	22.0	21.7	21.1	19.4	18.3	18.1	20.0	22.1	22.3	21.9	21.6	20.9
REL HUM	72	78	79	61	52	41	38	43	63	75	79	87	64
PCT SUN	59	52	51	69	76	84	87	83	67	55	50	40	64
MEAN RAD.	574	523	481	495	452	440	461	512	526	529	527	475	500
PRECIP.	228	201	229	96	16	7	4	5	27	130	215	317	1475
POT ET	164	135	136	134	120	110	118	139	146	152	145	134	1632
DEF PREC	-65	-66	-93	38	104	103	114	133	119	22	-70	-183	157
DEP PREC	141	123	142	53	0	0	0	0	7	76	132	200	
MAI	0.86	0.91	1.04	0.40	0.00	0.00	0.00	0.00	0.05	0.50	0.91	1.49	

MEAN TEMP .... Mean Temperature in Degrees Celcius
REL HUM .... Relative Humidity
PCT .... Percent Possible Sunshine
MEAN RAD .... Mean Solar Radiation in Langleys/Dary
PRECIP .... Mean Precipitation in mm
POT ET .... Potential Evapotranspiration in mm
DEF PREC .... Precipitation Deficit in mm
DEP PREC .... Dependable Precipitation in mm
MAI .... Moisture Availability Index

Figure 83. A computer printout of the the climatic analysis for Luziania, Brazil.

Apart from the climatic work leading to the estimation of the water balance, separate note was taken of other climatic hazards such as hurricane risks along the Gulf coast of Mexico and Caribbean countries.

A system of direct access information storage and retrieval files is being developed in CIAT to manage the meterological data from this study and from other sources. These files (SAMM DATA) will allow easy programmer access to the data and can be updated to incorporate the best estimates of climatic parameters as they become available. A manual describing the program structure and use will be available in late 1980. The operation of this additional system, and the on-going active accumulation of climatic data, should provide for a more comprehensive analysis of climate in the future.

A defined pattern of climate was used as the first criterion for setting the boundaries of the land systems. The second criterion was landscape.

Landscape

Farming is carried out on units of land. The landscape, especially topographical and hydrological aspects, is often critical in determining the type of farming systems adopted. For this reason, in considering practical agricultural production and evaluating land as a resource for farming, it is necessary to have a clear appraisal of landscape characteristics.

Most of the delineation of land systems was carried out using satellite imagery, using black and white photographic prints of the spectral bands 5 and 7. Band 5 (lower red) gave a useful image of vegetation and topography, and band 7, the near infrared band of the spectrum, gave better haze penetration and land-water discrimination.

Satellite imagery has one major drawback. For the more humid areas of tropical America it is still difficult to obtain cloud-free imagery. The largest area affected by this problem is the Amazon region. Fortunately, side-looking radar imagery has now become available for most of the Brazilian Amazon and this was used as a geographic base for the delineation of land systems throughout that region. Side-looking radar produces an excellent topographical picture of the landscape, but is not so effective as satellite imagery in helping to interpret land resource characteristics such as vegetative cover and hydrological characteristics.

For some other areas, including the wet eastern piedmont of Bolivia, aerial photography was used for interpreting the landscape patterns.

Wherever possible, and especially when little or no information was available in the published literature about land characteristics, field work was carried out to check the photo-interpretation. A small plane (STOL) was used to cover remote areas, and every effort was made within the close time schedule to examine the principal soil sequences that followed the landscape patterns.

With the delineation of land systems, the landscape within individual systems was described in such a way as to enable the computerization of its principal characteristics.

The landscape facets. The subdivision of landscape into facets is used to bridge the gap between land systems and soil units, as facets are often relatively uniform in so far as soil characteristics are concerned. Obviously, in some cases the landscape facets will contain soils with differing properties, but some level of generalization must be accepted in making an inventory of land resources. The objective of the study was not to replace soil survey work *per se;* the smallest map unit is the Land System. However, it is axiomatic that the study should provide an inventory of the land characteristics including soil physical and chemical properties of land facets within the land systems.

Figure 84 illustrates a typical landscape identified as one land system; it is clear that the landscape can be subdivided into facets 1 and 2 to represent the flat plain surface and the minor valley regions. For convenience of computation, land systems were described in terms of a maximum of three land facets.

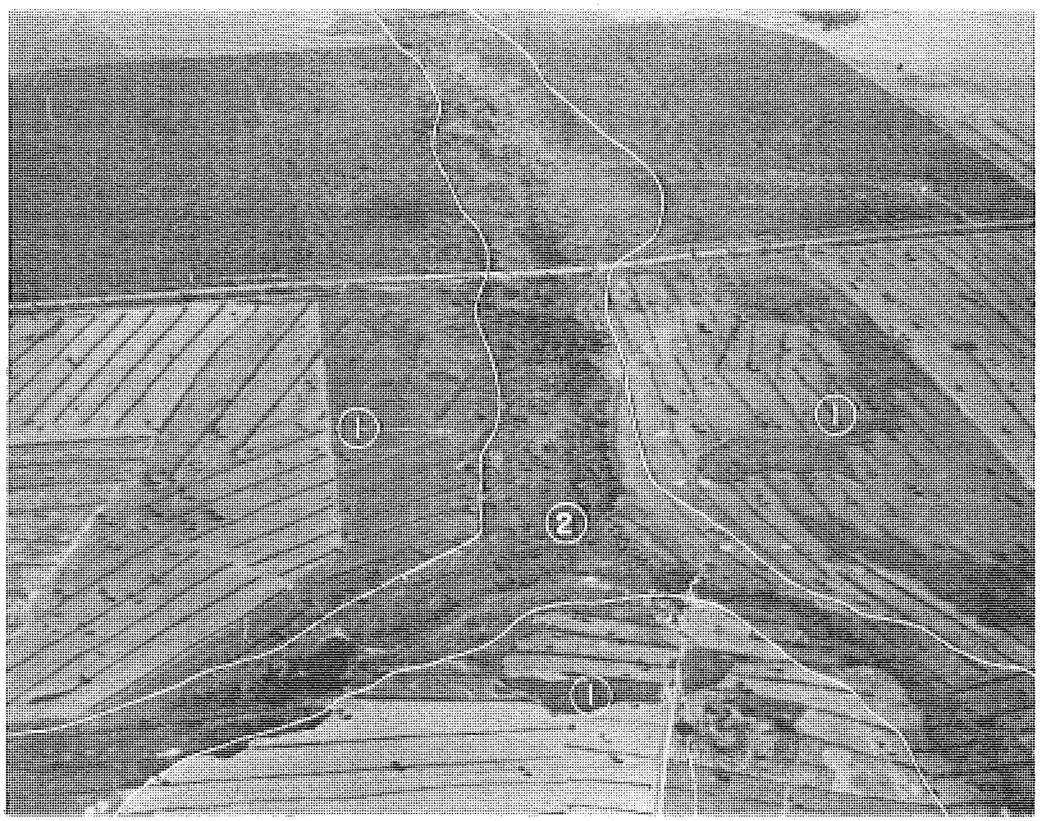

Figure 84. Land system No. 49 subdivided into land facets 1 and 2.

Soil

In order to describe the soils of the land facets, they were classified to the Great Group category of the Soil Taxonomy system used by the USDA, and then categorized in terms of their physical and chemical properties.

In the USDA Soil Taxonomy system, soils are not grouped according to those soils "having similar physical and chemical properties that reflect their response to management and manipulation for use", until the soil Family category is reached. This follows a subdivision of the Great Groups into Sub-groups. However, the separation according to Sub-groups does not add very much to knowledge concerning the characteristics of the soils. Therefore, it was decided to classify soils only as far as the Great Group category, then describe them in terms of their physical and chemical characteristcs in such a way as to facilitate the computer grouping and comparison of properties.

Soil physical properties. Soil physical properties have been classified and coded in terms of slope, texture, presence of coarse material, depth, initial infiltration rate, hydraulic conductivity, drainage, moisture holding capacity, temperature regime, moisture regime, and presence of expanding clays. The categorization is designed to evalute the suitability of soils for crop production from a physical standpoint. It contains the elements necessary to apply the technique developed by Mansfield for assessing land capability for arable crops based on soil physical limitations, and those necessary to use the Soil Fertility Capability Classification, developed by Buol *et al.*

Soil chemical properties. The following are the main soil chemical properties classified and coded for both topsoils (0-20 cm depth) and subsoils (21-50 cm depth): pH, percent Al saturation, exchangeable Al^{3+}, Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}, total exchangeable bases, cation exchange capacity, organic matter, P, Mn, S, and trace elements, the presence of free carbonates salinity and cat clays, and elements of importance to animal nutrition.

A classification system was used to describe soil nutritional levels as a first attempt to equate crop needs in the following sense: A = adequate for most crops, B = inadequate for crops requiring high nutrient levels, and C = inadequate for all crops, except those tolerant to very low nutrient levels.

In classifying soil pH, the level less than 5.3 was chosen to identify those soils with the probability of sufficient free Al in the soil solution to indicate the need for liming. For such soils, the formula developed at CIAT[1] for estimating the liming requirement of acid mineral soils for a given crop might profitably be applied.

It should be emphasized that each landscape facet within a land system is described and collated separately. The limit of describing a maximum of three major landscape facets within a land system was set for the convenience of managing the data. This limit can be extended to handle more detailed studies in the future.

With the completion of the collection and collation work the land resource information was recorded in a data bank.

Data management system

The computerized system of data management was created to facilitate and accelerate the diverse analyses contingent to the study. It had to be sufficiently comprehensive to cope with large amounts of data, and flexible enough to permit the analyses of the land resource data with other information from economic and agricultural studies.

The methodology adopted for the system was largely developed by the SAS (Statistical Analysis System, Institute Inc. of North Carolina). The work was carried out using an IBM 370/145 computer with a terminal link-up IBM-3780 at CIAT's administration center, Palmira.

Data input

The input achieved from:

- Land information formats summarizing the landscape, vegetation and soil data in a coded form.

- Map code formats; each 5' x 5' area of the land system maps were coded to permit their reproduction.

- Climatic tapes; the climatic information and analyses of the Hancock, Hill and Hargreaves study was recorded on magnetic tape, which permits direct

1 Cochrane, T.T., J.G. Salinas, and P.A. Sámchez. An equation for liming acid mineral soils to compensate Al tolerance. *In* Tropical Agriculture. Trinidad. Vol. 57, No. 2, April 1980. pp. 133-140.

entry of climatic data to the system. Additional climatic information will eventually be available by input from the SAMM data files.

Data output

It is possible to generate different information according to the varying needs of the users of the land resource evaluation study. Basic information output includes:

- Printouts of the land resources information for individual land systems in terms of the collated climatic, landscape, vegetation, and soil data.

- List of comparative data for selected properties of any predetermined group of land systems or geographical areas.

- Areal totals for any recorded characteristic in terms of the values assigned to those characteristics, either descriptive or numerical, over any predefined geographical area.

- Map printouts of the land systems for any given area.

- Thematic map printouts of any of the parameters evaluated according to their classification, for any geographical area.

Additionally, the system has the capacity to:

- Identify possible correlations between any of the characteristics described.

- Permit the analysis of the land resource data in terms of information obtained from other types of study, particularly economic studies.

The methodology already developed by SAS which integrates the management of data according to their Relational Data Base Concept with procedures for statistical analyses and those that facilitate reporting, was chosen to implement the major part of the storage, analysis and retrieval system. The study has been detailed in a publication available to interested institutions[1].

Application

The value of the study may be illustrated by two examples related to climatic and soil factors, respectively.

An analysis was carried out to check if climatic parameters were related to differences in the natural vegetation throughout Central west Brazil (some 243 million ha). The natural vegetation was compared with a number of variables. Figure 85 shows the result of comparing the vegetation classes with the total wet season potential evapotranspiration (TWPE). TWPE was generated from the climatic data by totalling the ETP figures for those months with a MAI greater than 0.33. As can be seen, the area within the box in Figure 85 indicates that there is a much greater frequency of occurrence of "cerrado" type (savanna) vegetation between the 900 to 1050 mm range of potential ETP.

This observation led to the finding that TWPE is an effective yardstick for classifying lowland tropical climates in tropical America for perennial crop production. It has provided a quantitative basis for the subdivision of the region into climatic sub-regions for CIAT's work in evaluating forage germplasm

The areal totals and distribution of the percent Al saturation in the soils of Central-west Brazil were needed to define preliminary guidelines for establishing criteria for selecting forage germplasm tolerant to soils with varying levels of Al throughout that region. With the appropriate computer program, the areal extent of both the topsoil and subsoil percent Al saturation values were quickly obtained as a printout (Figure 86). The term frequency used on the printout multiplied by 10,000 will give the areas in ha. Thematic maps of the several levels of percent Al saturation coded as part of the soil description of the system were made (Figure 87).

1 Cochrane. T.T. *et al.* An Explanatory Manual for CIAT's Computerized Land Resource Study of Tropical America. Cali, Colombia. CIAT. 1979. 130 p.

TABLE OF GTWSPE BY COD

TWSPE COD

FREQUENCY
PERCENT
ROW PCT
COL PCT

	SEAS.IN.P.	CL+CS	CC	C	CD	TRF	SESF	SDSF	CAAT	OTHER	TOTAL
DE 650 A 699	0	0	0	0	0	0	0	0	2	1	3
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.28	0.84
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	66.67	33.33	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.38	4.17	
DE 700 A 749	2	0	0	0	1	0	3	7	3	2	18
	0.56	0.00	0.00	0.00	0.28	0.00	0.84	1.97	0.84	0.56	5.06
	11.11	0.00	0.00	0.00	5.56	0.00	16.67	38.89	16.67	11.11	
	5.41	0.00	0.00	0.00	2.04	0.00	15.00	16.28	23.08	8.33	
DE 800 A 849	1	0	0	0	0	0	0	1	3	0	5
	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.84	0.00	1.40
	20.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	60.00	0.00	
	2.70	0.00	0.00	0.00	0.00	0.00	0.00	2.33	23.08	0.00	
DE 850 A 899	3	2	3	3	4	0	0	4	0	1	20
	0.84	0.56	0.84	0.84	1.12	0.00	0.00	1.12	0.00	0.28	5.62
	15.00	10.00	15.00	15.00	20.00	0.00	0.00	20.00	0.00	5.00	
	8.11	5.00	5.26	4.17	8.16	0.00	0.00	9.30	0.00	4.17	
DE 900 A 949	8	13	17	20	10	1	6	5	0	3	83
	2.25	3.65	4.78	5.62	2.81	0.28	1.69	1.40	0.00	0.84	23.31
	9.64	15.66	20.48	24.10	12.05	1.20	7.23	6.02	0.00	3.61	
	21.62	32.50	29.82	27.78	20.41	100.00	30.00	11.63	0.00	12.50	
DE 950 A 999	5	5	13	21	17	0	4	9	0	1	75
	1.40	1.40	3.65	5.90	4.78	0.00	1.12	2.53	0.00	0.28	21.07
	6.67	6.67	17.33	28.00	22.67	0.00	5.33	12.00	0.00	1.33	
	13.51	12.50	22.81	29.17	34.69	0.00	20.00	20.93	0.00	4.17	
DE 1000 A 1049	6	6	11	14	9	0	3	5	1	1	56
	1.69	1.69	3.09	3.93	2.53	0.00	0.84	1.40	0.28	0.28	15.73
	10.71	10.71	19.64	25.00	16.07	0.00	5.36	8.93	1.79	1.79	
	16.22	15.00	19.30	19.44	18.37	0.00	15.00	11.63	7.69	4.17	
DE 1050 A 1099	2	8	5	3	1	0	3	0	0	2	24
	0.56	2.25	1.40	0.84	0.28	0.00	0.84	0.00	0.00	0.56	6.74
	8.33	33.33	20.83	12.50	4.17	0.00	12.50	0.00	0.00	8.33	
	5.41	20.00	8.77	4.17	2.04	0.00	15.00	0.00	0.00	8.33	
DE 1100 A 1149	9	4	8	10	7	0	1	7	3	9	58
	2.53	1.12	2.25	2.81	1.97	0.00	0.28	1.97	0.84	2.53	16.29
	15.52	6.90	13.79	17.24	12.07	0.00	1.72	12.07	5.17	15.52	
	24.32	10.00	14.04	13.89	14.29	0.00	5.00	16.28	23.08	37.50	
DE 1200 A 1249	0	0	0	1	0	0	0	1	1	1	4
	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.28	0.28	0.28	1.12
	0.00	0.00	0.00	25.00	0.00	0.00	0.00	25.00	25.00	25.00	
	0.00	0.00	0.00	1.39	0.00	0.00	0.00	2.33	7.69	4.17	
MAYOR DE 1250	1	2	0	0	0	0	0	4	0	3	10
	0.28	0.56	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.84	2.81
	10.00	20.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	30.00	
	2.70	5.00	0.00	0.00	0.00	0.00	0.00	9.30	0.00	12.50	
TOTAL	37	40	57	72	49	1	20	43	13	24	356
	10.39	11.24	16.01	20.22	13.76	0.28	5.62	12.08	3.65	6.74	100.00

Natural vegetation classes code:

TWSP........................ Total Wet Season Potential Evapotranspiration
SEAS. IN. P .... Seasonally Inundated Pampas or Savannas
CL + CS .... Campo Limpo + Campo Sujo (Grasslands)
CC............................ Campo Cerrado (Open Savannas)
C .... Cerrado (Savanna)
CD............................. Campo Cerrado (Closed Savanna)
TRF............................ Tropical Rainforest
SESF .... Semi-Evergreen Seasonal Forests
SDSF......................... Semi-Deciduous Seasonal Forests
CAAT......................... Caatinga (Dry Forest)

Figure 85. Comparison of the frequency of occurrence of the native vegetation classes with total wet season potential evapotranspiration levels

LAND RESOURCE STUDY OF TROPICAL AMERICA
PERCENT AL SATURATION

TOPSOIL'S AL SATURATION %

F19	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
1) □ 10%	9506	9506	39.160	39.160
2) 10-40 %	2362	11868	9.730	48.890
3) 40-70 %	4385	16253	18.064	66.954
4) 70%	8022	24275	33.046	100.000

SUBSOIL'S AL SATURATION % MEQ/100 GM

F20	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
1) □ 10%	11780	11780	48.527	48.527
2) 10-40 %	3836	15616	15.802	64.330
3) 40-70 %	2088	17704	8.601	72.931
4) 70%	6571	24275	27.069	100.000

Figure 86. A computer printout of topsoil and subsoil percent Al saturation levels for Central-west Brazil.

A COMPUTER PRINTOUT OF PERCENT Al SATURATION LEVELS IN TOPSOIL, MAP SC-22 TOCANTINS

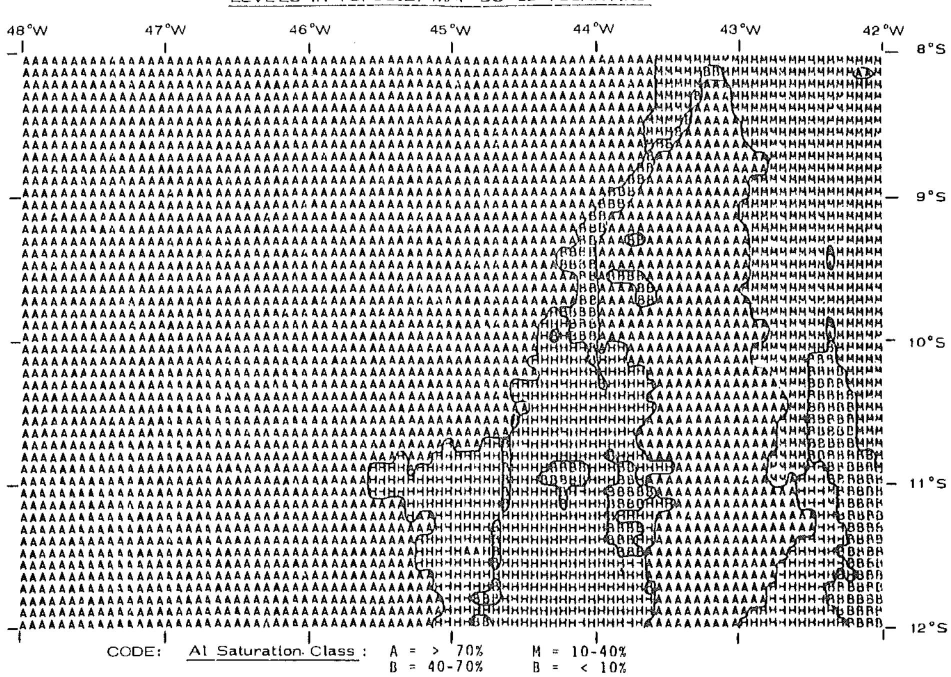

Figure 87. A thematic map printout of percent Al saturation levels. (Map SC-22, Tocantins, Brazil.)

PERSONNEL

(as of December 31, 1979)

Senior staff

Gustavo A. Nores, PhD, Economist (Acting Coordinator)
* Pedro A. Sánchez, PhD, Soil Scientist (Coordinator)
Eduardo Aycardi, PhD, Animal Health Specialist
Mario Calderón, PhD, Entomologist
Walter Couto, PhD, Soil Scientist, Pasture Development (stationed in Brasilia, Brazil)
John E. Ferguson, PhD, Agronomist, Seed Production
Bela Grof, PhD, Forage Agronomist, (stationed in Carimagua, Colombia)
* Jake Halliday, PhD, Soil Microbiologist
* C. Allan Jones, PhD, Grass Agronomist
Ingo Kleinheisterkamp, DAgr, Animal Scientist, Pasture Utilization
Jillian M. Lenné, PhD, Plant Pathologist
C. Patrick Moore, PhD, Animal Scientist, Cattle Production Systems (stationed in Brasilia, Brazil)
* Osvaldo Paladines, PhD, Animal Scientist, Pasture Utilization
José G. Salinas, PhD, Soil/Plant Nutritionist
Rainer Schultze-Kraft, DAgr, Legume Agronomist, Germplasm Evaluation
James M. Spain, PhD, Soil Scientist, Pasture Development (stationed in Carimagua, Colombia)
Luis E. Tergas, PhD, Agronomist, Technology Transfer/Training
José M. Toledo, PhD, Soil/Plant Nutritionist, Forage Agronomy/Regional Trials
Derrick Thomas, PhD, Forage Agronomist (stationed in Brasilia, Brazil)

Visiting scientists

E. Mark Hutton, D.Sc. Legume Breeder
Nobuyoshi Maeno, PhD, Legume Agronomist Forage Agronomy

Postdoctoral fellows

Antonio Carrillo, PhD, ETES Project
Carlos Lascano, PhD, Pasture Utilization
John W. Miles, PhD, Grass Improvement
Eugenia de Rubinstein, PhD, Economics
James E. Sumberg, PhD, Legume Improvement

Visiting specialists

* Peter Kammer, MS, ETES Project (stationed in Maturín, Venezuela)
Rolf Minhorst, MS, ETES Project (stationed in Brasilia, Brazil)
Cristoph Plessow, MS, ETES Project (stationed in Maturín, Venezuela)

Research associates

Edgar Burbano, MS, Seed Production
Carlos Castilla, MS, Pasture Development (stationed in Carimagua, Colombia)
Rubén Darío Estrada, MS, Economics
Clemencia Gómez, MS, Training/Technology Transfer
Alberto Ramírez, MS, Forage Agronomy/Regional Trials
Libardo Rivas, MS, Economics
Fabio Nelson Zuluaga, MS, Animal Health

Visiting research associates

Elke Bohnert, MS, Pasture Utilization
* Fabio Calvo, Ing. Agr., Pasture Development
* Guido Delgadillo, MS, Soil/Plant Nutrition
Jorge Luis Díaz, MS, Pasture Utilization
* William F. Gómez, DVM, Pasture Utilization
Hendrick Jansen, MS, Legume Agronomy
* Joel Levine, MS, Economics

---

* Left during 1979.

* Frank Müller, MS, Legume Agronomy (stationed in Carimagua, Colombia)
Karen Speidel, MS, Soil Microbiology

Research assistants

Amparo de Alvarez, Ing. Agr., Plant Pathology
* Edgard Belalcázar, Ing. Agr., Soil Microbiology
Javier Belálcazar, Ing. Agr., Plant Introduction
* Francisco Bonilla, Ing. Agr., Seed Production
Gerfried Carlos Buch, Ing. Agr., Forage Agronomy (stationed in Carimagua, Colombia)
Raúl Botero, DVM, Cattle Production Systems (stationed in Carimagua, Colombia)
Arnulfo Carabaly, Ing. Agr., Forage Agronomy
Manuel Coronado, Ing. Agr., Plant Improvement
* Misael Cortés, DVM, Animal Health
Patricia Chacón, Biologist, Entomology
Martha Lucía Escandón, Ing., Agr., Plant Improvement
* Luis E. Forero, Biologist, Plant Introduction
Luis H. Franco, Ing. Agr., Pasture Development (stationed in Carimagua, Colombia)
Duván García, Ing. Agr., Seed Production
Obed García, DVM, Animal Health (stationed in Carimagua, Colombia)
Hernán Giraldo, Ing. Agr., Germplasm Evaluation
Ramón Gualdrón, Ing. Agr., Soil/Plant Nutrition (stationed in Carimagua, Colombia)
* Fabio Gutiérrez, Ing. Agr., Soil Microbiology
Silvio Guzmán, DVM, Technology Transfer/Training
Phanor Hoyos, Zoot., Pasture Utilization (stationed in Carimagua, Colombia)
Carlos Humberto Molano, Ing. Agr., Plant Improvement (stationed in Carimagua, Colombia)
Rodrigo F. Mutis, Zoot., Cattle Production Systems (stationed in Carimagua, Colombia)
Bernardo Rivera, DVM, Animal Health
Manuel Sánchez, Ing. Agr., Seed Production
Roberto Sánchez, Ing. Agr., Biometrics
José Ignacio Sanz, Ing. Agr., Soil/Plant Nutrition
Celina Torres, Ing. Agr., Plant Pathology
Luis Miguel Uribe, Zoot., Pasture Utilization
Gustavo Adolfo Urrea, Ing. Agr., Technology Transfer/Regional Trials
Fernán Alberto Varela, Ing. Agr., Entomology (stationed in Carimagua, Colombia)
Bernardo Velosa, Ing. Agr., Plant Improvement

* Left during 1979.