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

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Contents

Introduction

Beef and milk are staple foods in tropical Latin America. Regardless of income levels, urban consumers spend large portions of their food budgets on both commodities. Beef represents between 10 and 24% of total food expenditures; milk represents between 7 and 15% (Trop. Past. Prog., 1979 Ann. Rept.). Only in the temperate countries of Latin America and in Mexico has the production growth rate kept ahead of the growing demand for beef. The annual growth rates of demand and production of beef in Latin America between 1970 and 1978 are illustrated in Table 1. The imbalance between the two causes prices to increase continually, affecting both diets and the general standard of living of the low income strata of the population. High income elasticities of demand for beef prevail within these income levels.

Table 1. Annual growth rates of demand and production of beef in Latin America, 1970-1978.

Region and Country	Growth rate of	
	Demand (%)	Production (%)
Tropical Latin America	5.9	3.3
Bolivia	6.1	5.9
Brazil	7.2	3.5
Colombia	7.2	3.5
Dominican Republic	7.5	1.2
Ecuador	8.3	2.6
Mexico	4.5	9.3
Paraguay	3.5	3.2
Peru	5.4	-3.2
Venezuela	4.6	4.1
Central America	4.6	3.3
Caribbean	4.0	1.7
Temperate Latin America	1.7	2.7
Latin America	5.4	4.5

Source: Latin America: Trend Highlights for CIAT Commodities. CIAT 1980.

Productivity in the Latin American cattle industry is low compared to that in many other countries. For example, cattle stocks in Latin America are twice those of the United States, but herd productivity (production per head of stock in 1974-77) is less than 70% that of the U.S. One primary reason is the prevailing production systems: intensive systems in the U.S. and extensive systems in Latin America. Even so, herd productivity is very different between tropical and temperate Latin America. While animal production in the U.S. is twice that of temperate Latin America (88 *vs.* 43 kg/year), production in tropical areas of the region is less than one-third that of the U.S. (about 26 kg/year). This lower productivity is due to the combined effects of management, nutrition, animal health and breeds. Undoubtedly, nutrition plays a key role and essentially determines the levels of the other three factors.

Latin America is a region of vast areas of acid infertile soils (the Oxisols and Ultisols). These soils comprise 849 million ha (51% of the land resource) of tropical Latin America. The current average stocking rate in the Oxisol savannas can be potentially increased more than tenfold from the present 0.12 animal/ha. In addition, beef production per head could be more than doubled. Increased productivity on acid infertile soils could also contribute significantly to expanded milk supplies, especially where ranches are close to markets.

These areas have a large potential for agricultural production since they have abundant solar radiation and, in general, good soil physical properties and extended growing seasons. However, acidity, high levels of Al in the soils and a general lack of fertility constitute a serious limitation to animal and crop production. Consequently, most agriculture and cattle production systems today are on more fertile soils. The Oxisols and Ultisols of Latin America are the underutilized agricultural frontier land of the continent.

Low quality and quantity of available forage for the animals is the prevailing constraint for beef and milk production on these acid infertile soils. Another constraint is the lack of infrastructure; its importance varies among countries and according to the farm-to-market distance.

Program Objectives

In response to the above problems and considering the importance of beef and milk in the diets of the Latin American populations, as well as the potential of the vast areas of acid infertile soils for the production of both commodities, CIAT's Tropical Pastures Program adopted the following overall objectives: to increase beef and milk production by developing appropriate pasture production technology which allows expansion of the agricultural frontier in the acid infertile soils of tropical Latin America, releasing, at the same time, fertile lands currently devoted to cattle for expansion of crop production.

From its original emphasis on identification of problems and solutions in the areas of animal health, animal management, and cattle production systems, which showed malnutrition and nutrition-related problems as the main constraint to production, the Program narrowed its focus on pasture research, and concentrated specifically on the acid infertile soils in the lowlands of tropical America.

Area of Interest

A survey of the acid infertile soil regions of tropical Latin America was begun in 1978 in order to classify the land resources in terms of climate, landscape and soils. The survey provides an ecosystem perspective that serves as the basis for the Program's research design and strategy.

An analysis of the survey data led, in 1979, to a subdivision of the area of interest into five major ecosystems: (a) the Llanos (tropical well-drained savannas); (b) the Cerrados (also tropical well-drained savannas); (c) tropical poorly drained savannas; (d) tropical semievergreen seasonal forests; and, (e) tropical rain forests. The above ecosystems are clearly divided by the total wet season potential evapotranspiration (TWPE). TWPE between 910 and 1060 mm defines the "Llanos" and "Cerrados" as the savanna ecosystem and include the poorly drained savanna ecosystem. TWPE between 1060-1300 mm differentiates the semievergreen seasonal forest, and the TWPE above 1300 mm differentiates the rainforest. The tropical well drained savannas were in turn divided into two types: isohyperthermic and isothermic savannas using as a parameter the mean temperature during the rainy season. "Llanos" are predominantely isohyperthermic, and in the "Cerrados" both types occur according to latitude and elevation. Figure 1 shows the distribution of these five ecosystems throughout tropical South America.

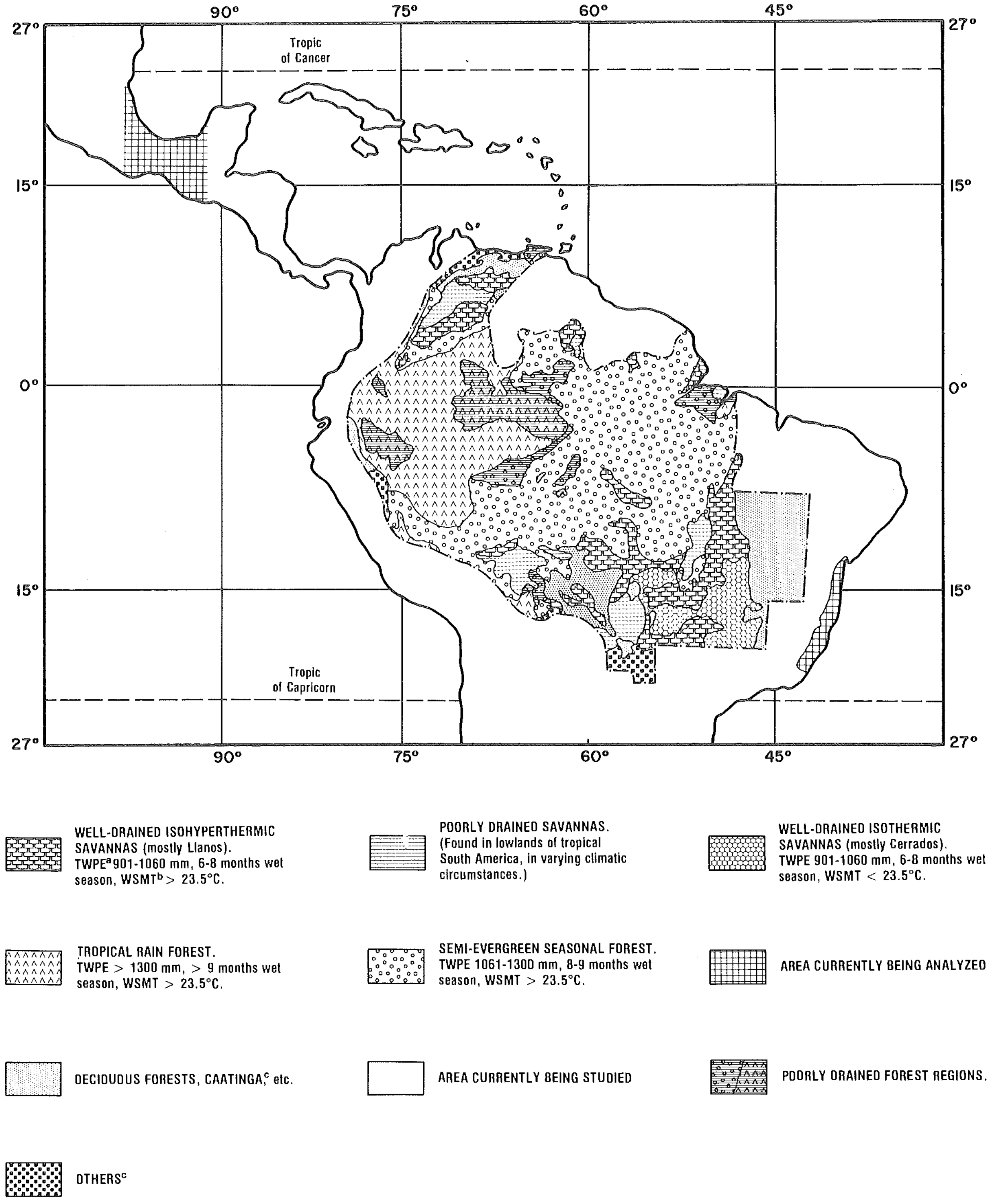
Program Strategies and Organization

The Program's approach toward its main objective is to develop, in cooperation with national programs, low-cost, low-input technology to increase beef and milk production in acid infertile soils of the lowlands of tropical America. This is pursued through the following research strategies: a) selection of pasture germplasm adapted to the environmental constraints of climate and soils as well as prevalent pests and diseases; b) development of persistent and productive pastures and their management techniques; c) study of the role of improved pastures in the production systems, and development of the complementary system components of animal management and animal health.

A specialized germplasm bank comprising more than 7000 entries of pasture grasses and legumes constitutes the basis of the Program's research strategies. The various steps are shown in Figure 2. Germplasm flows downward on a single plane for each major ecosystem. It is important to note the participation of CIAT and cooperating national institutions in the diagram at the right. CIAT's participation is greatest in initial stages (top) of germplasm and information development, with that of national institutions becoming greater as one moves downward, i.e., as new technology becomes more refined.

Three major decision points are evident in the illustration of technology development. These points also define three groups (units) of scientists in the Tropical Pastures Program.

The first group may be considered a germplasm evaluation group which centers its attention on characterizing germplasm with emphasis on the so-called "key species". Results of this group's work provide the rationale for the first decision — the promotion of germplasm, assembled in promising pasture systems, for evaluation under grazing.



[a] TWPE: Total Wet Season Potential Evapotranspiration.

[b] WSMT: Wet Season Mean Temperature.

[c] Not included in the activity area of the Tropical Pasture Program.

Figure 1. *Main ecosystems of tropical South America.*

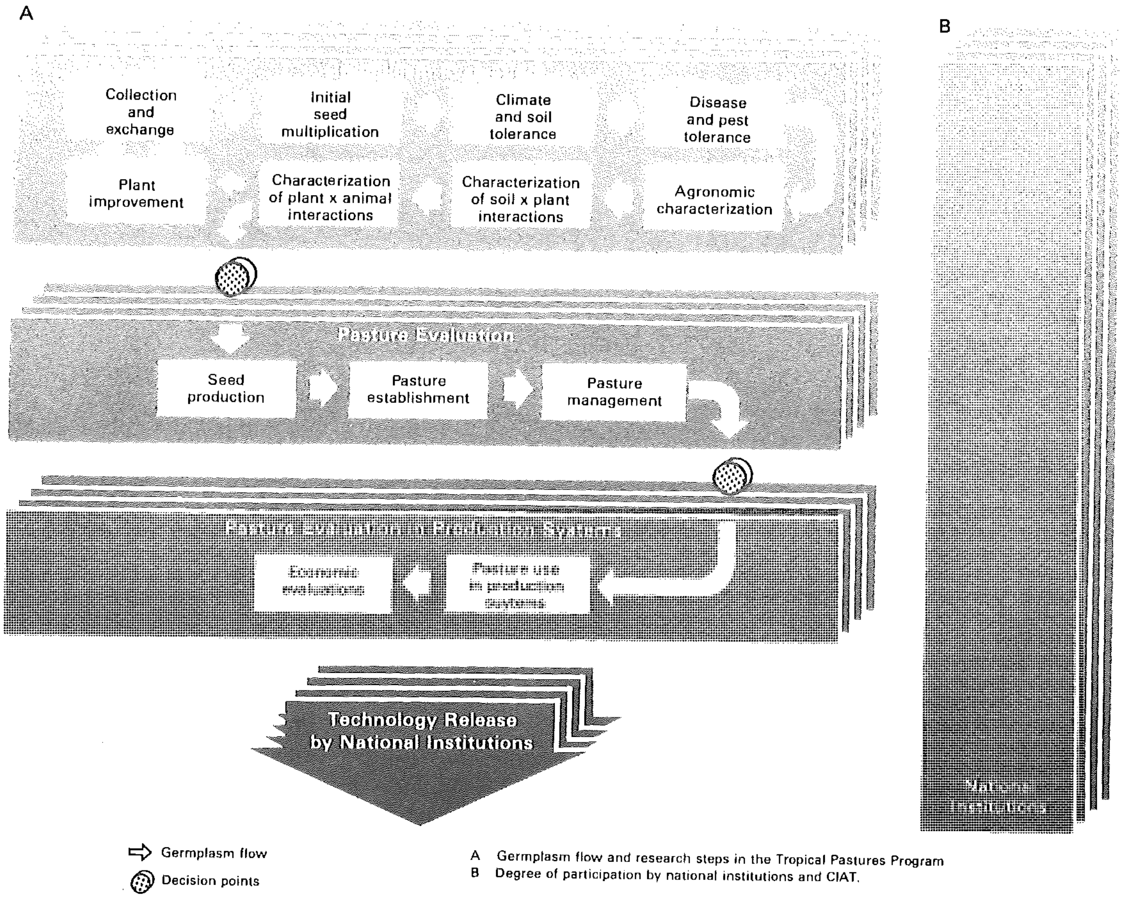


Figure 2. *Organizational structure and germplasm flow (arrows) of the Tropical Pastures Program. Activities within the respective ecosystems are represented in the various planes and the degree of collaboration with national programs is illustrated in the figure at the right.*

The pasture management evaluation unit concentrates on developing pastures and evaluating pasture management requirements and animal productivity potential. From their research comes the necessary information for the second decision — movement of pasture technology with possibilities of making positive contributions into the various farm systems.

The unit working with pastures in farm systems analyzes the production systems prevalent in the specific ecosystem, within the socioeconomic framework of the respective country or region. It defines for the Program the pasture components required to solve the main productivity constraints in the farm system. Scientists in this unit also evaluate the expected impact of alternative improved pasture technology in the various production systems.

The final decision point occurs after the farm system evaluations, when national institutions decide to release the package of new technological components to farmers.

Simultaneously, the International Pasture Evaluation Network, working throughout the five major ecosystems with its four different levels of Regional Trials (A, B, C and D) — mostly the responsibility of national programs — provides a solid base for extrapolating the research findings of the cooperating programs and CIAT.

Data banks for germplasm, pastures and production systems, together with the information coming out of the Regional Trials Network, are being assembled to facilitate the storage, retrieval and exchange of information.

Plant Introduction

Plant introduction activities of the Germplasm Section during 1980 continued along three lines: a) assembling of germplasm through direct collection and exchange of materials with other institutions; b) multiplication and maintenance of germplasm of priority species; and, c) preliminary evaluation of germplasm and initial seed increase.

Collection and Introduction of Germplasm

Collection. Three major collection trips were conducted during the year to areas with acid infertile soils. Their purpose was to increase the collection of particular genera and species, which due to their already known potential, are of specific interest to the Tropical Pastures Program.

A collection expedition in the Colombian Llanos Orientales, particularly through the Intendencias of Casanare and Arauca, sought native germplasm of *Zornia latifolia* and *Centrosema (C. pubescens, C. macrocarpum, C. brasilianum* and other species).

A considerable portion of the area covered during this trip was poorly drained savanna (mainly along the routes Tame-Puerto Rondón (Arauca), Puerto Rondón-Hato Corozal (Casanare) and Pore-Trinidad (Orocué). Some important collections of legume species adapted to flooded conditions were made (Fig. 1).

During the first of two collection trips in Brazil as joint projects with EMBRAPA's Centro Nacional de Recursos Genéticos-CENARGEN, a major portion of the humid coastal strip of the northeastern states Bahia, Sergipe, Alagoas, Pernambuco, Paraiba and Rio Grande do Norte was covered. (Fig. 2).

Collecting was directed toward legume species that normally originate in drier savanna areas. These materials, if they evolved under more humid conditions, would possibly have superior disease tolerance; materials collected included: *Stylosanthes (S. capitata, S. macrocephala, S. guianensis* "tardío" and *S. leiocarpa), Zornia* spp., *Aeschynomene* spp. and *C. brasilianum.*

The second Brazilian trip covered principally the area along the Goiania-Belem route (Fig. 3). Occurring at the end of a five-month dry season, it was aimed particularly at drought-resistant legume germplasm of *Stylosanthes (S. capitata, S. macrocephala, S. guianensis* "tardío"), *Zornia* spp. and *Centrosema* spp. native to the Cerrado areas of the state of Goias.

Introduction. Efforts to introduce germplasm through exchange with other institutions during 1980 concentrated on grasses.

An important collection of approximately 350 accessions of *Panicum maximum* and *Brachiaria* spp. of African origin was added to the germplasm bank of CIAT's Tropical Pastures Program. With regard to legumes, an important collection was received from EMBRAPA-CENARGEN.

With the additions during the year — 1243 accessions of directly collected germplasm and 475 accessions introduced through exchange with other institutions — the Program's collection increased to more than 7100 accessions (Table 1). The majority of these originate from regions with acid infertile savanna and jungle soils, thus constituting a unique working collection.

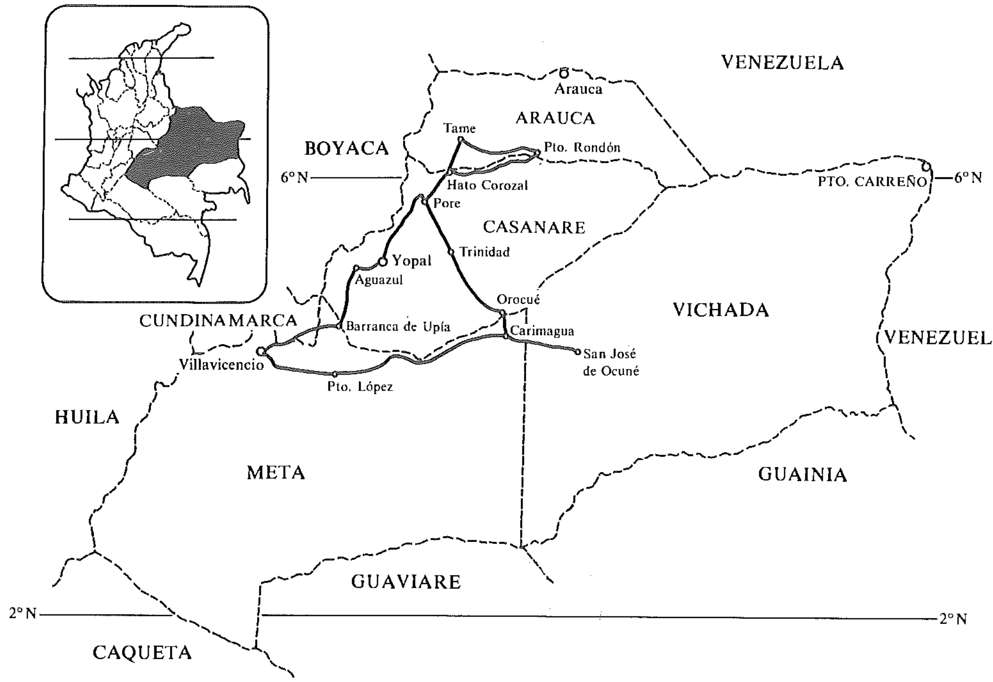


Figure 1. *Routes of systematic collection of germplasm of tropical pasture species in the Llanos Orientales, Colombia, in February, 1980.*

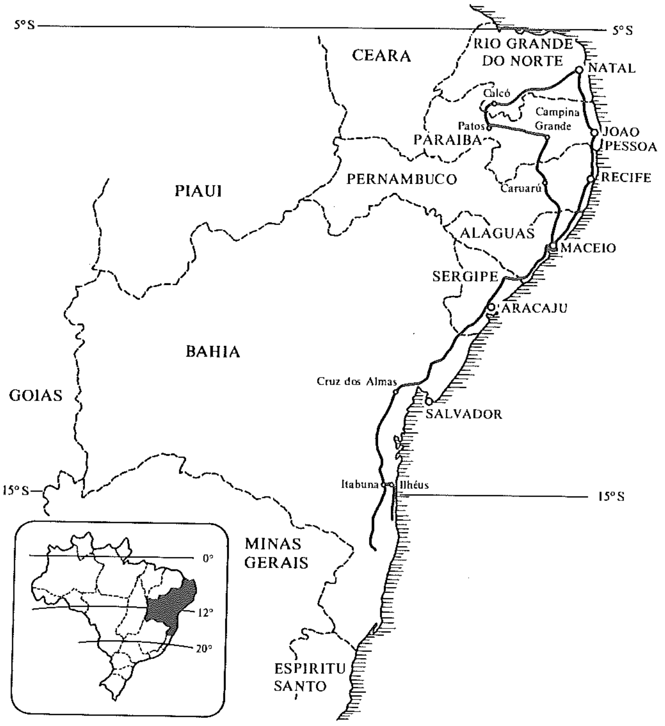


Figure 2. *Routes of systematic collection of germplasm of tropical pasture species in Brazil, in July 1980.*

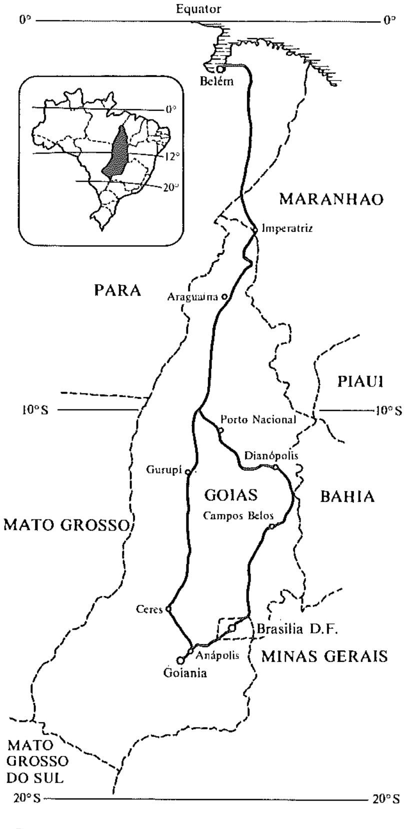


Figure 3. *Routes of systematic collection of germplasm of tropical pasture species in Brazil in October 1980.*

Table 1. Introduction (number of accessions) of germplasm of tropical pasture species through direct collection and through exchange with other institutions during 1980.

Genera	Collections in				Exchange	Total 1980	Total accessions in germplasm bank
	Colombia	Brazil		Occasional collections			
	(Casanare/Arauca)	Northeast	Goias				
Stylosanthes	22	168	176	31	38	435	1723
Desmodium	13	50	32	32	4	131	865
Zornia	15	79	48	9	16	167	561
Aeschynomene	18	47	21	14	3	103	377
Centrosema	63	64	18	17	31	193	605
Macroptilium/ Vigna	18	21	7	10	4	60	486
Calopogonium	22	6	13	3	-	44	143
Galactia	14	7	8	10	-	39	226
Miscellaneous legumes[1]	40	49	35	33	11	168	1421
Grasses	1	2	2	5	368	378	728
Total	226	493	360	164	475	1718	7135

[1] *Arachis, Cassia, Clitoria, Crotalaria, Dioclea, Eriosema, Indigofera, Leucaena, Pueraria, Rhynchosia, Tephrosia, Teramnus* and others.

Multiplication and Maintenance of Germplasm

The responsibility for general maintenance and distribution of forage germplasm was assumed by CIAT's Genetic Resources Unit early in 1980. Multiplication and distribution of priority materials to other sections within the Program and to special collaborators outside CIAT continued as one of the Germplasm Section's most important activities during the year. Initial seed stocks were increased from plants of approximately 1000 accessions established for characterization and preliminary evaluation in the field in CIAT-Quilichao. In addition, seed is being multiplied from approximately 500 accessions of legume germplasm growing as potted plants in the CIAT-Palmira greenhouse. About 2000 samples of priority materials were provided to Program staff and to special collaborators outside CIAT.

Characterization and Preliminary Evaluation of Germplasm

During the characterization and preliminary evaluation phase, new legume germplasm accessions, particularly priority species but also new, agronomically unknown genera and species, are established in unreplicated, space-planted plots in CIAT-Quilichao. Seed is increased and observations are made on the most important plant descriptors (life form, growth habit, flowering time, etc.). Based on monthly ratings over 12-24 months of preliminary evaluation, the adaptation of germplasm to the Quilichao environment is assessed in terms of: (a) yield potential on a very acid, infertile ultisol; (b) disease tolerance; (c) seed production potential. Outstanding accessions as well as any new material with especially interesting plant characters are then given priority for entering the germplasm flows to the Tropical Pastures Program's primary testing sites in Carimagua and Brasilia.

A series of new accessions of several species and genera was identified as promising during preliminary evaluations concluded in 1980 (Table 2). More than 1000 accessions are currently being studied in experiments established in late 1979 or during 1980. Some of the most important preliminary observations indicate:

(a) A considerable variation mainly regarding morphological plant characters exists within the collection of *S. guianensis* "tardío"; many of the accessions show excellent vigor and anthracnose resistance.

(b) Some *S. capitata* accessions originating from the dry Brazilian Northeast show outstanding vigor.

(c) The potential of some *Centrosema* species such as *C. macrocarpum, C. arenarium* and *C. brasilianum* becomes increasingly evident. Up to now, these have been practically unknown agronomically.

(d) Some of perennial four-leaflet *Zornia* species (mainly *Z. brasiliensis*, but also *Z. marajoara* and *Z. myriadena)* seem to have an interesting potential as pasture plants.

Table 2. Characterization and preliminary evaluation of germplasm of tropical pasture species during 1980 in CIAT-Quilichao.

Species	No. of accessions		Observations
	Evaluated	Identified as promising	
Arachis spp.	45	0	Lack of adaptation (soil); problems with seed production.
Calopogonium spp.	82	11	*C. caeruleum* identified as a species with excellent adaptation to the Quilichao ultisol; selected materials include some perenniating *C. mucunoides* accessions.
Desmodium barbatum	21	2	Selected accessions seem to perenniate.
Desmodium heterophyllum	8	0	Lack of adaptation (soil).
Galactia spp.	77	14	Selected accessions seem to perenniate.
Pueraria phaseoloides	11	0	Lack of adaptation (soil, Mn toxicity).
Stylosanthes capitata	40	7	Anthracnose problems only in late-flowering accessions; however, one resistant ecotype selected. Other ecotypes identified as promising are mid-season flowering.
Stylosanthes guianensis "tardio"	26	25	With one exception all material tested is very well adapted, vigorous and anthracnose-resistant. Some of them have satisfactory seed production potential.
Stylosanthes macrocephala	21	6	One late-flowering ecotype from the humid coastal strip of Bahia, Brazil, outstanding. No disease problems in any of the materials tested.
Zornia spp.	165	18	Only perennial *Zornia latifolia* accessions from the Colombian Llanos Orientales sufficiently productive; some of them apparently *Sphaceloma*-tolerant. Good adaptation and disease resistance of *Z. brasiliensis* material from Brazil and Venezuela. All other accessions are *Sphaceloma*-susceptible and short-living annuals.

Follow-up of Germplasm Evaluation

Follow-up activities to germplasm evaluation during 1980 essentially consisted of monitoring the classification of germplasm into the Program's five established categories of promise.

In order to more clearly illustrate the meaning of the various categories and their implications in terms of research to be done with the respective germplasm, the categories were renamed:

I - Identification of germplasm with potential
II - Agronomic small plot evaluation
III - Agronomic pasture evaluation
IV - Pasture evaluation and management
V - Pasture evaluation in farm systems.

Germplasm is classified into these categories for each of the five ecosystems of the Tropical Pastures Program's target area. So far, this has been done only for the two well-drained savanna ecosystems, on the basis of germplasm evaluations at the two primary research sites Carimagua (Llanos-hyperthermic savanna) and Brasilia (Cerrado-thermic savanna). Preliminary classifications for the poorly drained savannas and the two tropical forest ecosystems are expected next year, based on results from the first set of Regional Trials "A"

The list of species in Table 3 summarizes the results of past germplasm evaluations. Results refer to species, rather than individual accessions, that have proved well-adapted to the respective ecosystems and of which either the total or a great majority of accessions so far are considered promising. Whereas the lack of adaptation of *Desmodium ovalifolium* and *Pueraria phaseoloides* to the thermic Cerrado ecosystem can be explained by their need for a longer growing season, the *Centrosema* species and *S. leiocarpa* have not yet been evaluated long enough. In spite of intraspecific differential responses of accessions to disease and insect stresses, all other species as such are showing good adaptation to soil, climate, disease and insect conditions of either savanna ecosystem.

The germplasm accession that had reached the most advanced category of evaluation, *Andropogon gayanus* CIAT 621, was released by the respective national institutions as an officially recommended grass cultivar for both types of savanna. As preliminary results from regional trials indicate, this grass also shows excellent adaptation to the tropical forest ecosystems.

Table 3. Identification of promising tropical forage species for the well-drained savanna ecosystems.

Species	Promising for	
	Llanos (hyperthermic)	Cerrado (thermic)
Stylosanthes capitata	yes	yes
Stylosanthes guianensis "tardío"	yes	yes
Stylosanthes macrocephala	yes	yes
Stylosanthes leiocarpa	yes	unk[1]
Centrosema brasilianum	yes	unk
Centrosema macrocarpum	yes	unk
Zornia brasiliensis	yes	yes
Desmodium ovalifolium	yes	no
Pueraria phaseoloides	yes	no
Andropogon gayanus	yes	yes
Brachiaria humidicola	yes	yes

[1] Unk = Unknown.

In cooperation with CIAT's Data Services Unit, first steps were taken towards the development of an information system to assist in follow-up of germplasm evaluation. The objective is to form a centralized data bank with easily retrievable information on germplasm performance in the various evaluation levels.

Forage Agronomy in the Iso-hyperthermic Savannas (Carimagua)

The research strategy of forage agronomy is based on evaluating native and introduced tropical forage species with the main objective of selecting superior genotypes adapted to oxisol savanna environments, for grazing utilization.

The need to broaden the restricted genetic diversity of forage species available in collections in tropical America has been recognized for some time. A major project was initiated in the mid-1970's to collect, introduce and evaluate forage species adapted to acid, low-base-status savanna soils. The agronomic assessment of this initial collection of germplasm has recently been concluded and data accumulated on the performance of species of major importance are summarized this year.

Germplasm Evaluation

Evaluation and improvement of forage germplasm continue as major activities at the Carimagua research station. Adapted grasses and legumes have already been identified and the aim of current research is to select improved genotypes within these key species which have performed well under grazing in tests initiated in 1977.

Some 680 forage accessions belonging to six leguminous and three gramineous genera were established during the year for agronomic assessment. Of these, 53 legumes (mostly *Centrosema* spp., *Desmodium* spp. and *Stylosanthes* spp.) and three grasses *(Brachiaria* spp.) are included in grazing tests.

Forage species that have shown desirable agronomic characteristics and good potential as forage cultivars over a four-year period are described here.

Stylosanthes spp.

The widespread and diverse genus *Stylosanthes* has provided a range of useful variation. Species displaying the best performance are: *S. capitata, S. macrocephala,* a fine-stemmed form of *S. guianensis,* and *S. leiocarpa.*

Stylosanthes capitata. This is a hardy perennial species adapted to low-fertility soils. Several varieties were found resistant to anthracnose and stemborer attacks. It is a prolific seeder and regenerates from self-sown seed. The first accession of *S. capitata* (CIAT 1019) was introduced in mid-1974.

Ecotypes differ morphologically, and in addition, accessions vary in flowering date. Late-flowering accessions have a distinct advantage of a longer active growing period and higher yields. On the other hand, early-flowering ecotypes recover faster at the onset of the wet season and produce more seed; this compensates for reduced forage yields during the next season. Early-flowering ecotypes, e.g., CIAT 1019, behave like self-regenerating annuals, producing an abundance of seed for dry season feed and regeneration.

Stylosanthes macrocephala. This species spreads into the dry sub-tropics and it is also native to the southern fringes of the Campo Cerrado and drier regions of Paraguay. Some accessions in CIAT's germplasm bank originate from lower latitudes in Brazil, e.g., Bahia, Goias and Mato Grosso, where it is found in plant communities with *S. scabra* and *S. capitata.*

Eighty-one accessions in the *S. capitata* and *S. macrocephala* groups were tested in a small sward plot experiment established in 1979. In general, much variation was recorded in yield and accessions with distinctive forage traits, and a range of flowering/ maturity dates was observed. Four accessions of *S. macrocephala* showed average yields of 1100 g/m^2 and were among the 14 highest-yielding entries.

S. macrocephala accessions examined at Carimagua show a high degree of tolerance to stylo anthracnose and stemborer attacks. There are differences in flowering time between some accessions with seed setting in early-flowering types starting at the end of August.

Stylosanthes guianensis. Early selections of the fine-stemmed forms (CIAT 1020, 1059 and 1062) showed long-term persistence coupled with stemborer and anthracnose resistance; however, they produce only modest yields of seed. The search for improved genotypes which combine the desired agronomic characters continues. The next step is to evaluate selected lines under regular grazing.

Stylosanthes leiocarpa. This species is characterized by good persistence and low DM yields. It resists fire and drought due to its strong underground rootstock. The accessions CIAT 1093, 1087 and 2115 are promising and all three originate from Bahia, Brazil. Evaluation under regular grazing, to test compatibility with standard grass species, is proposed for the coming season.

Desmodium spp.

Desmodium ovalifolium. The chief difficulty in developing legume-grass pastures in tropical areas has been to find suitable legumes which are not only well-adapted to environmental conditions but are compatible with aggressive grass species and are able to withstand heavy grazing.

In experiments conducted in the Llanos Orientales, *Desmodium ovalifolium* was the most persistent legume to grow with aggressive stoloniferous grasses such as *Brachiaria decumbens* and *B. humidicola.*

Not only are commercial species of *Brachiaria (B. decumbens, B. humidicola, B. radicans* and *B. dictyoneura)* very aggressive, but experiences in Colombia and other tropical countries indicate that over the long-term, the mat-forming growth of these grasses suppresses most associated legumes.

A sampling program was begun to follow changes in the botanical composition of *Andropogon gayanus, B. decumbens* and *B. humidicola,* each in association with *D. ovalifolium. D. ovalifolium* established well and formed productive pastures with both *Brachiaria* species and with the tufted *A. gayanus.* Legume percentages increased steadily in each mixture. This increase of legume content in the sward was aided by the fact that the grasses were preferentially grazed during the wet season. At the end of the second wet season following establishment, the three mixtures of *B. decumbens, B. humidicola* and *A. gayanus,* each with *D. ovalifolium,* showed 48.5, 35.9 and 48.3% legume contents, respectively.

A similar trend of increasing legume content was recorded in grazed plots of *B. humidicola* and *D. ovalifolium* in which grazing started during the dry season.

Desmodium canum. Apart from *D. ovalifolium,* this scarcely known legume proved to be the most persistent under regular grazing in areas established in 1977. Establishment and initial growth of *D. canum* were slow but, once established, it has spread rapidly and formed compatible associations with *A. gayanus* and *B. decumbens* under grazing. Some 124 accessions of *D. canum* are included in a recently established row-plot experiment.

Centrosema spp.

Forty accessions, including *C. brasilianum, C. pubescens, C. macrocarpum, C. acutifolium* and *C. pascuorum,* were compared in small sward plots for forage yield and resistance to pests and diseases. Several accessions of *C. brasilianum* and *C. macrocarpum* showed high-yielding ability. However, only a few accessions displayed resistance to diseases affecting the foliage; *C. macrocarpum* was particularly susceptible to attacks of leaf-eating insects during the wet season. Dry matter yields obtained in the first year averaged about 1100 g/m^2 and varied widely. A field scale grazing test containing 26 accessions of *Centrosema* spp. was established in mid-1980.

Zornia spp.

Agronomic assessment of *Zornia* spp. was seriously handicapped due to the fungal disease *Sphaceloma* scab. Most accessions were severely affected by the disease and this legume is only a short-lived component of grazed pastures. In view of the promise shown by *Z. latifolia* CIAT 728 in grazing tests over a short period, it was considered worthwhile to initiate a new evaluation program and in-depth study of *Zornia* spp. At present, 214 accessions are under evaluation in row-plots. Six months after establishment, only a few of these remained disease-free. This group included a number of annuals of prostrate growth habit. At this stage, these accessions show sufficient promise to include them in sward trials.

Evaluation under Grazing

Sets of grass-legume mixtures were established for evaluation under regular grazing at the Category III germplasm level. These experiments have recently been concluded and the results for the period November 1977-September 1980 are summarized.

D. ovalifolium-A. gayanus and *D. ovalifolium-B. decumbens*

The seasonal distribution of DM yield and pasture composition has been monitored in these pasture plots established in 1977. Dry matter "on offer" was measured in the two pasture mixtures on 25 harvest/grazing dates.

A significant difference in presentation yields was found between the two grasses in the trial. *B. decumbens* produced significantly more dry matter on offer than *A. gayanus* at the first ($P<0.05$), second ($P<0.01$) and sixth ($P<0.05$) grazing period. However, there were no significant differences between the two pasture treatments in total yield. In total DM on offer grass content (57%) was higher in the *B. decumbens-D. ovalifolium* pastures while legume dominance (59%) was displayed in the *A. gayanus-D. ovalifolium* pasture in the year of establishment, but it diminished with time, and a legume:grass balance was maintained after the tenth grazing period. *D. ovalifolium* suppressed *A. gayanus* in the early establishment phase of the pasture and this mixture was legume-dominant for almost the entire evaluation period under actual grazing conditions. Total DM on offer and grass-legume contents are summarized for both mixtures in Figure 1.

The potential of *D. ovalifolium* as forage legume for savanna regions has not been recognized before and there are no commercial pastures based on this legume. As was mentioned in the discussion on germplasm, the data obtained at Carimagua indicate that *D. ovalifolium* is one of the few legumes compatible with the aggressive, mat-forming *B. decumbens* and *B. humidicola* under actual grazing conditions. In view of the large areas of monospecific swards of these *Brachiaria* spp. established in the interior of tropical America, particularly in the Brazilian Campo Cerrado and the cleared forest regions of the Amazon Valley, the compatibility of *D. ovalifolium* is of special significance. The utilization and wider testing of *D. ovalifolium*, especially with stoloniferous species such as *Brachiaria* spp., in lowland tropical regions with an annual rainfall of 2000 mm or more is recommended.

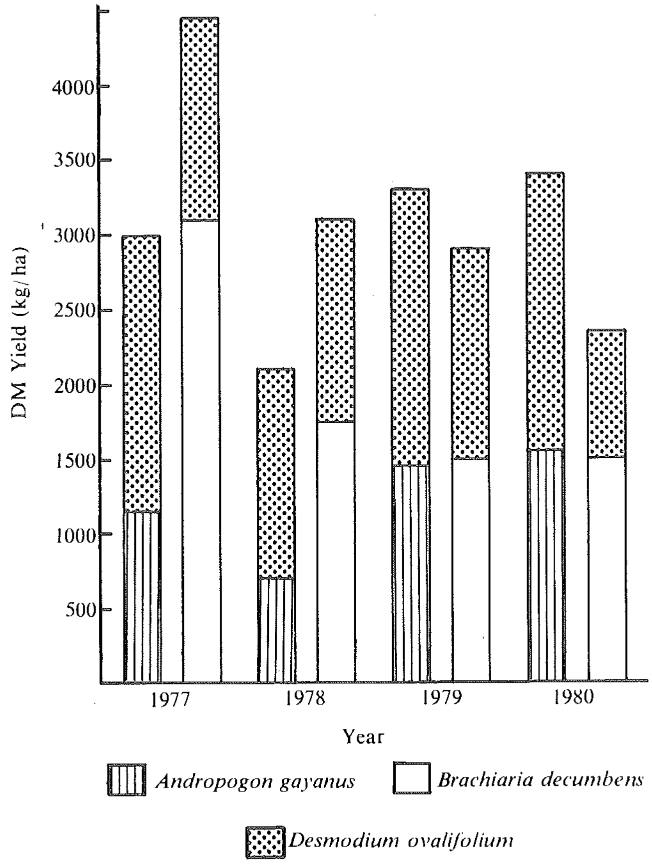


Figure 1. *Presentation yields of grazed* **Andropogon gayanus-Desmodium ovalifolium** *and* **Brachiaria decumbens-D. ovalifolium** pastures, at Carimagua.

The objective of a recently established grazing experiment is to identify *D. ovalifolium* ecotypes with lower tannin content and higher palatability and digestibility. For this purpose nine accessions were planted in association with *B. humidicola*. In another experiment, the ecotypes x cutting interval x fertilizer interactions and their effect on yield and tannin content of *D. ovalifolium* will be studied.

S. capitata, S. macrocephala-A. gayanus, B. decumbens

Ten accessions of *S. capitata* and one *S. macrocephala* were tested in association with *A. gayanus* and *B. decumbens* under regular grazing. Both mixtures were productive and the legumes persisted well with both grass species. At the end of the experiment, in the fourth year following establishment, legume contents in the *S. capitata-B. decumbens* mixture ranged from 16.4% at the beginning of the wet season to 35.9% at the end of the wet season (Table 1).

Table 1. Seasonal distribution of dry matter "on offer" in a *Brachiaria decumbens-Stylosanthes capitata* pasture from May 1978 to September 1980, at Carimagua.

Harvest/Grazing period	DM Yield (kg/ha)		
	S. capitata	*B. decumbens*	Total
1 May-June	1071	347	1419
2 **Pre-wet**	868	476	1344
3 July-August	1097	234	1331
4 September-October	1186	425	1611
5 November	1611	612	2223
6 **Wet**	968	776	1744
7 January-february	367	522	889
8 **Dry**	325	512	836
9 March-April	321	809	1126
10 **Pre-wet**	876	975	1851
11 May-June	799	4078	4877
12 July-August	1131	2023	3154
13 September	1080	2617	3697
14 **Wet**	1428	3310	4738
15	681	2223	2904

In this experiment, the late-and mid-season flowering accessions of *S. capitata* (CIAT 1078, 1315) produced more DM on offer than did the early flowering accessions (CIAT 1007 and 1019). *S. macrocephala*, also an early flowering type, was in the low-yielding group. Dry matter on offer in these two pastures is shown in Figure 2.

Evaluation of Introduced Grasses

The range of forage grasses available for experimentation and pasture improvement in the Llanos Orientales has been increased recently with *Brachiaria dictyoneura* CIAT 6133. This grass is closely related to *B. humidicola* and most morphological characters of the two species intergrade. In a preliminary study, *B. dictyoneura* produced about five times more caryopsis per unit weight of florets than either *B humidicola* or *B decumbens.*

B. dictyoneura 6133 was established in a small-plot grazing experiment with *B. decumbens, B. humidicola* in mixtures with *D. ovalifolium* and *D. canum* in four randomized blocks for evaluation.

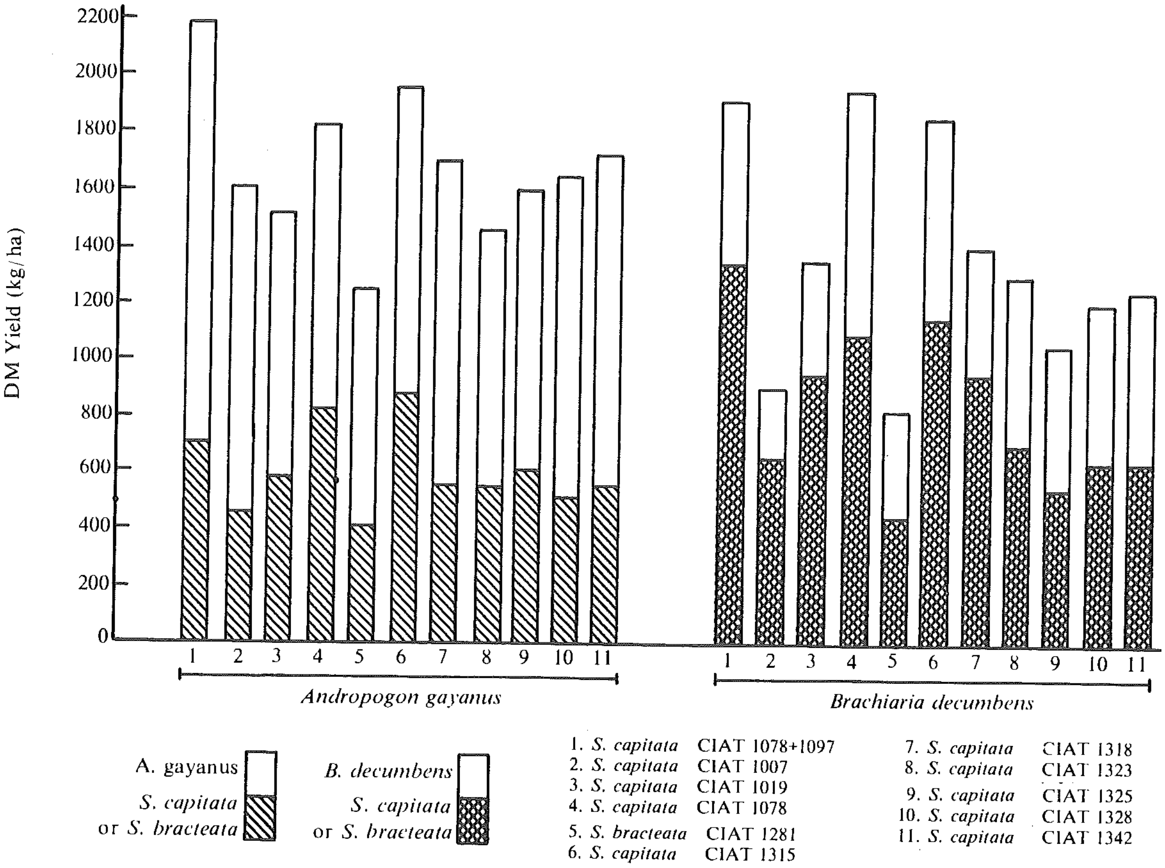


Figure 2. *Dry matter "on offer" in* **Andropogon gayanus** *CIAT621 or* **Brachiaria decumbens** *cv. Basilisk pastures, in association with each of 11* **Stylosanthes** *spp. accessions, at Carimagua. (Yields are means of 10 harvests.)*

Table 2. Mean dry matter production of 34 introductions and 16 selections of *Andropogon gayanus*.

	DM (g/plant)	S.E.
34 introductions	142.12	10.77
16 selections	162.72	18.39

Thirty-four new accessions of *A. gayanus* were compared in row-plots with 16 selections representing late-flowering, vigorous genotypes selected from old pastures at Carimagua. The introductions originated from Northern Nigeria and the Ivory Coast. It is noteworthy that the average yield/plant for the selections was higher than the average yield of the introductions (Table 2).

Forage Agronomy in the Iso-Thermic Savannas (Cerrado)

The objective of forage agronomy research is the selection of germplasm that is: a) adapted to the acid soils and Al stress found in the thermic savannas; b) persistent under grazing; and (c) tolerant of pests and diseases. Activities for the thermic savanna conditions are conducted mostly at the Cerrado Center (Centro de Pesquisa Agropecuária dos Cerrados, CPAC), near Brasilia, Brazil.

Preliminary Evaluation of Germplasm

Legumes

The 541 legume accessions being evaluated in Categories I and II in the two major soil types of the region are from 13 genera. Sixty percent are species of *Stylosanthes* with *Zornia* spp., *Desmodium* spp., *Calopogonium* spp. and *Galactia* spp. also represented by several accessions each. Accessions are established as spaced plants and observations made on phenology, DM yield, regrowth potential, nutritive value, seed production, and tolerance to pests and diseases.

***Stylosanthes* spp.** The genus *Stylosanthes* continues to show the greatest potential for Cerrado conditions. Seventeen accessions from germplasm planted in 1978-79 and 17 of those planted in 1979-80 have been selected for further evaluation. These accessions have better productivity and/or tolerance to anthracnose than the commercial control lines. Species composition of the selections is: *S. capitata* (14), *S. guianensis* (6), *S. macrocephala* (5), and *S. viscosa* (1). Most of the selections flower in mid-or late-season and all retained green leaves in the dry season, regrew well after cutting and were readily consumed by cattle.

Representative edaphic data for the two soil types at CPAC were detailed last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). There were differences between species and accessions in their adaptation to soil type. Accessions of *S. guianensis* and *S. macrocephala* produced more DM on the dark-red latosol (latossolo vermelho escuro - LVE) than on the red-yellow latosol (latossolo vermelho amarelo -LVA). *S. viscosa* CIAT 1094 grew satisfactorily on both soils while accessions of *S. scabra* and *S. capitata* varied in their adaptation. *S. guianensis* accessions belong to a distinctive group widely distributed in Brazil and Venezuela. This group is currently referred to as the "tardío" group to distinguish the ecotypes from the "common" types such as the commercial cultivars Schofield, Endeavour and IRI 1022. In contrast to the common types, "tardío" accessions are predominantly late-flowering, fine-stemmed and very viscid with narrow leaflets. Their outstanding attribute is good tolerance to anthracnose, a trait deficient in the common types.

Anthracnose continues to be the most important disease and primary limiting factor to the genus in the Cerrados. Observations during 1980 indicated that the incidence of the disease has increased markedly at the LVA site. No stemborer *(Caloptilia* sp.) or serious budworm *(Stegasta bosqueella)* problems have been encountered.

The evaluation is continuing and during 1980-81, another 29 ecotypes of *S. capitata* were introduced, so that all accessions of the species are now under evaluation in Brasilia and Colombia. In addition, a further 20 accessions of *S. macrocephala* and 57 accessions of the "tardío" ecotypes of *S. guianensis* have been introduced.

Other genera. None of the other genera has shown the same promise as has *Stylosanthes*. Accessions of *Calopogonium* and *Galactia* species showed good adaptation to the acid soils, but proved no more productive than the Brazilian commercial control cultivars *Calopogonium mucunoides* and *Galactia striata*. *Pueraria, Teramnus, Vigna* and *Soemmeringia* grew poorly at both sites. Only *Centrosema macrocarpum* CIAT 5062 warrants continued observation among the accessions of *Centrosema*. Accessions of *Zornia* were very vigorous with excellent regrowth potential, but the control *Z. latifolia* CIAT 728 remained the most productive ecotype. With the exception of the browse species *Codariocalyx gyroides* CIAT 3001, accessions of this genus had poor vigor and leaf shed was severe in the dry season.

A number of diseases were prevalent. *Zornia* accessions were attacked by an insect-virus-fungus complex, common on native species, and several plants were killed. The four-leaf ecotypes of *Zornia brasiliensis* CIAT 9472 and 9473, planted in 1979-80, have not been affected by the disease complex. "Little leaf mycoplasma" was a problem in *Desmodium* species. *C. gyroides* CIAT 3001, despite showing good adaptation to the acid soils, was severely affected by the disease this season. Nematode problems were found in *D. ovalifolium* CIAT 350. This evaluation is continuing and during 1980-81, four new ecotypes of *Z. brasiliensis* were introduced and 17 ecotypes of *Centrosema*. Of particular interest were accessions of *C. macrocarpum* and *C. brasilianum*, a species showing promise on the acid soils of the Colombian Llanos.

The potential of promising accessions of the key species for other areas of the Cerrado will be investigated through the Regional Trials Network. In the 1980-81 season a Regional Trial (type A) will be established in the state of Goias in cooperation with the state organization EMGOPA. Preliminary observations in the field indicate variation in anthracnose tolerance of *Stylosanthes* accessions at different sites.

Grasses

At the beginning of the 1979-80 wet season, 101 grass accessions from the genera *Panicum*(75), *Brachiaria*(13), *Melinis* (11), and *Setaria* (2) were sown in the two local soils. Observations are the same as those made on legumes.

Panicum maximum. Four commercial cultivars — Hamil, Common, Gatton and Petrie Green Panic — were included as controls. The 54 new accessions that established successfully in the field were classified morphologically as follows:

a) Hamil-type: Giant, robust-type with large leaves and rather thick stems. A cut-and-carry type of high production potential. Six accessions.

b) Common-type: Medium-sized type with predominantly basal leaves, usually stemmy. Twenty-nine accessions.

c) Gatton/Green Panic type: Numerous leaves and fine stems. A grazing type. Sixteen accessions.

d) Embu-type: Semi-erect, fine-leaved type. Three accessions.

Data could not be collected from the accessions at the LVA site because of poor growth. At the LVE site, the control cultivar Hamil was markedly more productive than the six new Hamil-type accessions. Sixteen accessions of the Common type yielded more than the control, with the top five (CIAT 6093, 6141, 6145, 6146, 6162) averaging, at 6579 kg DM/ha, twice the production of Common. From 16 new Green Panic/Gatton types, only two accessions (CIAT 6125 and 6176) yielded more DM than the controls. Yields of the three Embu-type accessions were very low, ranging from 1146 to 2834 kg DM/ha.

Establishment problems were encountered. Seventeen accessions failed to establish at both sites, probably because of poor seed quality. However, a further 25 ecotypes failed to establish at the LVA site. Differences between the two sites in soil physical properties are thought to be responsible.

Melinis minutiflora **and** *Brachiaria* **spp.** Four accessions (CIAT 6371, 6372, 6373 and 6374) of *M. minutiflora* produced three times more DM than the commercial control. However, the digestible DM *(in vitro)*, crude protein and Ca contents were lower. Three new accessions of *Brachiaria* species are also showing promise. Growth of all accessions was poor on the LVA and no data on DM were collected.

In 1980-81 accessions of *Paspalum* species will be introduced to the LVA site. This genus is native to Latin America and should be better adapted to this soil type than genera originating from the more fertile areas of Africa. Evaluation of the other genera will continue.

Evaluation under Grazing

Promising accessions from Category II are evaluated in Category III for four years in small, individually-grazed plots. Each legume is sown separately with two grasses of contrasting growth habit, namely *Andropogon gayanus* CIAT 621, of tufted habit, and the mat-forming *Brachiaria decumbens* (cv. Basilisk). Grasses are sown with *Stylosanthes guianensis* (cv. Cook). Observations are made on species compatibility, persistence, production of DM and crude protein, and fixation and transfer of symbiotic N. In this system, pasture mixtures are exposed not only to defoliation but also to the physical effects of grazing such as trampling and to nutrient cycling via feces and urine.

Legume Germplasm. Currently, 14 legumes are being evaluated in this category. Total DM production and legume content for the first two years of the evaluation are shown in Figure 1. With the exception of the *D. ovalifolium* CIAT 350 association, the legume contents of the *Andropogon* plots were approximately twice those of the *Brachiaria* plots. Accessions of *S. capitata* are showing good persistence, but *S. capitata* CIAT 1405 and 1315 have been attacked by anthracnose. Productivity of *S. macrocephala* CIAT 1582 improved markedly in the second year. The most promising legumes at present are *S. guianensis* (cv. Cook), *S. guianensis* CIAT 2243 (a "tardío" type), *S. capitata* CIAT 1097 and *Z. latifolia* CIAT 728. The two *Centrosema pubescens* accessions and *Calopogonium mucunoides* have disappeared from the plots.

In every grass-legume association the N and Ca contents were higher than in the pure grass controls. However, any increases in P content were small. The ranges for these nutrients in the grass-legume plots and values for the pure grass controls are found in Table 1. Estimated annual net N fixation in the mixtures ranged from 9 to 80 kg/ha.

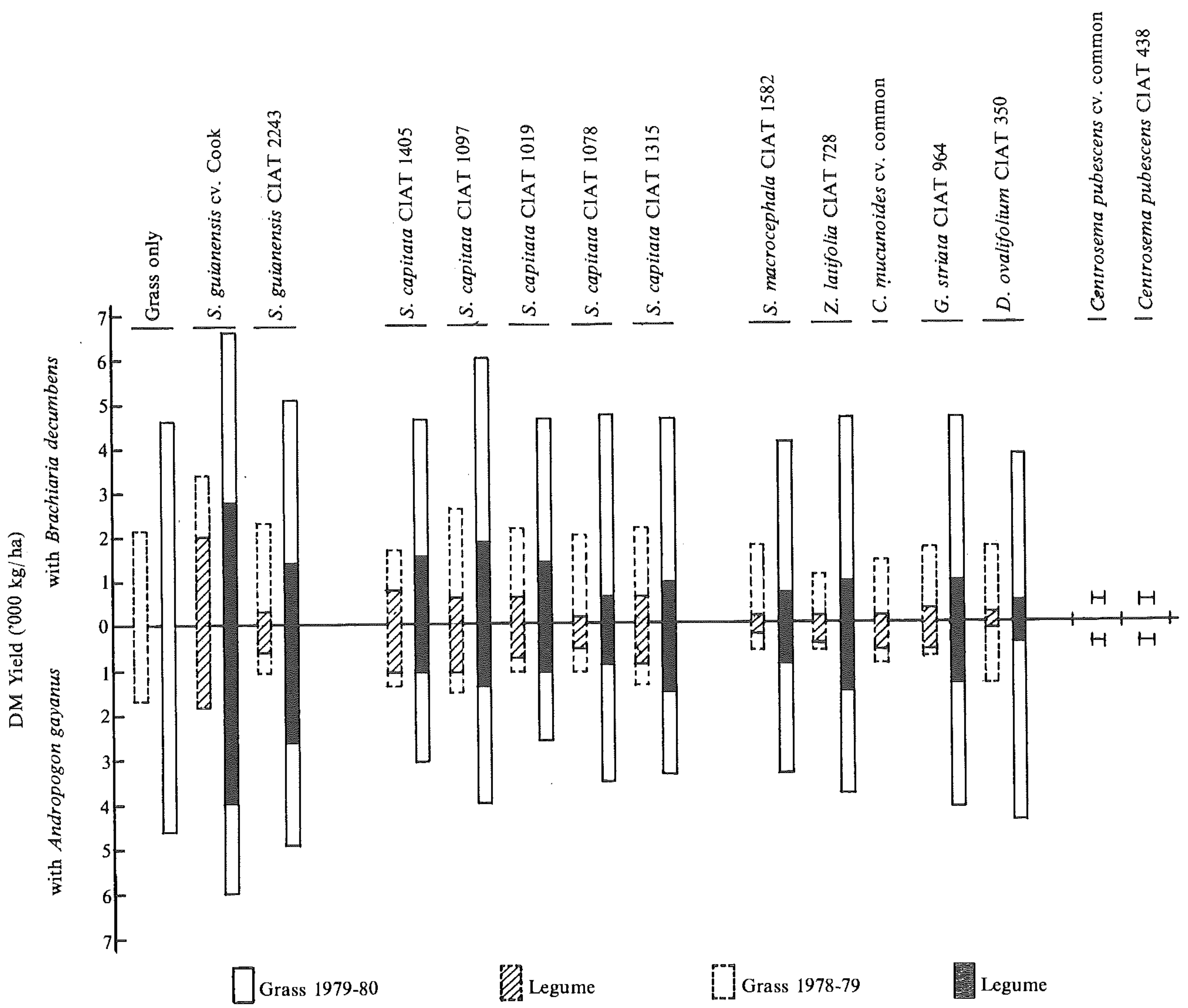


Figure 1. *Performance of Category III legume accessions in association with* **Andropogon gayanus** *or* **Brachiaria decumbens,** *at CPAC, Brasilia, Brazil.*

Table 1. Chemical composition of grass and grass-legume combinations under grazing (Category III) at CPAC, Brasilia, Brazil.

Element	Range of animal requirements		Content (%)	
	% Ca	% P	Grass alone	Grass-Legume association
Brachiaria				
N			0.73	0.78 - 1.44
Ca			0.21	0.31 - 0.61
P			0.11	0.10 - 0.13
Andropogon				
N			0.92	1.12 - 2.11
Ca			0.25	0.29 - 0.79
P			0.10	0.10 - 0.14
	0.18-0.60	0.18-0.43		

Grass Germplasm. The five grasses under evaluation are *A. gayanus* CIAT 621, *B. decumbens* (cv. Basilisk), *B. ruziziensis* (common), *B. humidicola* (common) and *P. maximum* (cv. Guinezinho). The *Brachiaria* and *Panicum* species are already commercially available in Brazil, and of particular interest is the comparison of their productivity with the newly released *A. gayanus* CIAT 621 (cv. *Planaltina).*

Table 2 shows the marked differences in productivity between the grasses with *B. humidicola* being the least productive. In all treatments, *S. guianensis* increased DM yield of the mixtures relative to the pure grass stands. The proportion of legume in the mixtures was excellent, but the value for *B. humidicola* reflects the low yield of the grass.

Table 2. Dry matter production of five grasses under grazing in Category III alone and in association with *Stylosanthes guianensis* cv. Cook at CPAC, Brasilia, Brazil.

Grass	Total DM production (kg/ha/yr)		Legume content
	without legume	with legume	(% DM)
Andropogon gayanus	3463	5219	38
Brachiaria decumbens	4435	5820	39
Brachiaria humidicola	2935	4323	81
Brachiaria ruziziensis	3616	6552	58
Panicum maximum	4139	5425	73

Dry matter digestibility values were highest for *B. ruziziensis* and lowest for *A. gayanus.* Legume inclusion increased digestibility, N and Ca contents but had little effect on P content. Estimated net annual N fixation ranged from 29 to 67 kg/ha.

Seed Production

This part of the program at CPAC is to: a) investigate the potential of the Cerrados for commercial seed production; and b) multiply seed of promising germplasm to service the pasture evaluations and other programs at CPAC. The former work is being achieved by cooperation in a Regional Trial program involving other areas of Brazil, Bolivia and Colombia.

Regional Trial. Nine grasses and four legumes are included in this trial. Seed production parameters for the grasses are presented in Table 3. Seed yields of *B. decumbens, B. humidicola* and *P. maximum* were appreciably increased in the second year; this increase was dramatic in the case of *B. humidicola.* Severe lodging in *A. gayanus* in the second year reduced seed yield by one-third.

The relationship between inflorescence development and seed yield is shown in Figures 2 and 3. In *A. gayanus,* 89% of all inflorescences appeared within one week of "initial-heading-date" (4 inflorescences/m^2). The percentage of fertile tillers was increased in the second year, but lodging minimized this potential. *P. maximum* and *B. decumbens* flowered over a long period with variation between and within inflorescences in maturity. A decrease in flower numbers and fertile tillers in the third cycle was reflected in low seed yields. The most striking contrast between years was in *B. humidicola,* with production of inflorescences in the first cycle in the second year almost reaching 2000/m^2. No major diseases or pests were noted.

Figure 4 shows the flowering characteristics of the legumes. *D. ovalifolium* CIAT 350 and *P. phaseoloides* CIAT 9900 flowered in the second season. Seed production data are presented in Table 4. Anthracnose destroyed *S. capitata* CIAT 1405 in the second year, and *S. capitata* CIAT 1315 was severely attacked by the disease. Anthracnose also reduced seed yield in *S. hamata* CIAT 147 in the second year.

Table 3. Seed production parameters for four tropical grasses at CPAC, Brasilia, Brazil.

Parameter	*Brachiaria humidicola*		*Brachiaria decumbens*		*Andropogon gayanus*		*Panicum maximum*	
	1978-79	1979-80	1978-80	1979-80	1978-80	1979-80	1978-79	1979-80
No. of harvests	1	2	2	3	1	1	3	3
Total pure seed yield (kg/ha/yr)	12	501	163	443	128	45	132	382
100 seed wt. (mg)	294	424 376	315 178	428 416 346	333	278	58 57 --	93 90 99

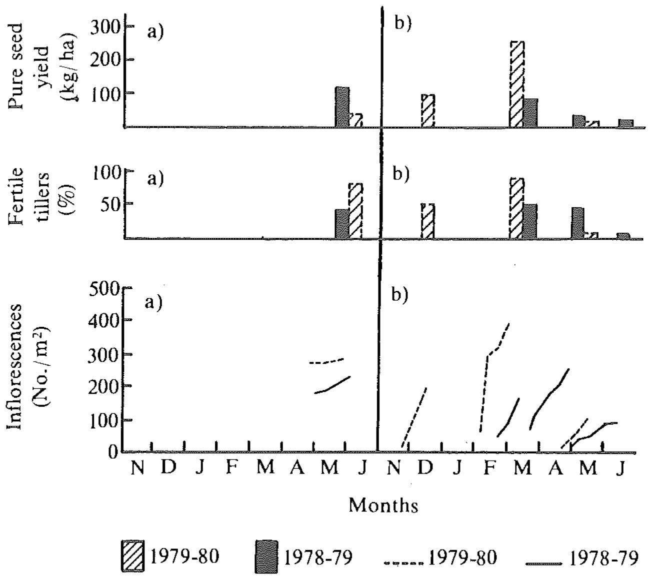


Figure 2. *Inflorescences and seed production patterns in* **Andropogon gayanus,** at CPAC, Brasilia, Brazil. a) **A. gayanus;** *b)* **P. maximum.**

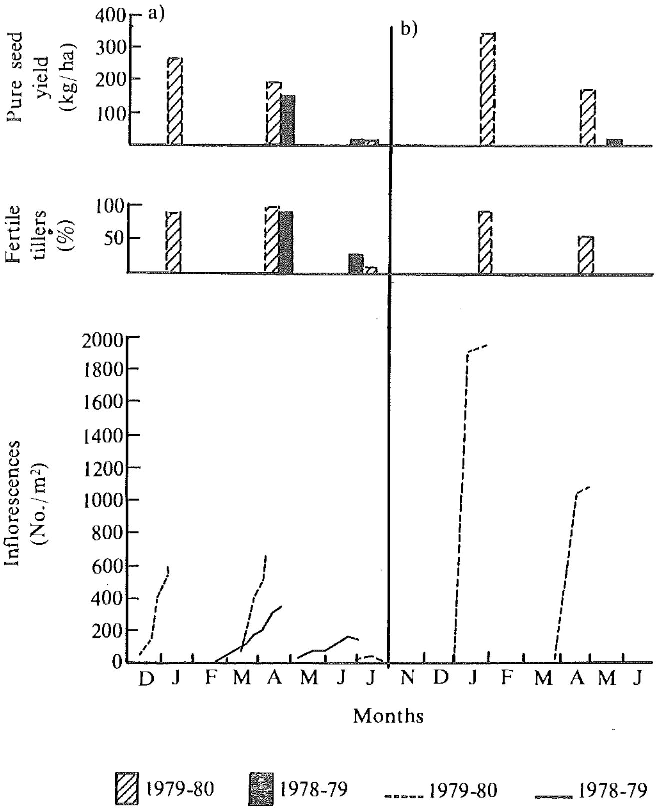


Figure 3. *Inflorescences and seed production patterns in two* **Brachiaria** *species, at CPAC, Brasilia, Brazil. a)* **B. decumbens**;*. b)* **B. humidicola.**

After slow establishment, *S. macrocephala* CIAT 1582 produced significantly higher yields in the second year. Despite attacks of a virus-fungus complex and Sphaceloma scab, seed yields of *Z. latifolia* CIAT 728 increased four-fold in the second year. *D. ovalifolium* CIAT 350 gave poor yields of seed in the second year and was attacked by nematodes. Yields of the late-flowering, "tardio"-type *S. guianensis* CIAT 2243 were relatively low in both years. This trial will continue and work will be initiated to investigate ways of reducing lodging in *A. gayanus* by early grazing.

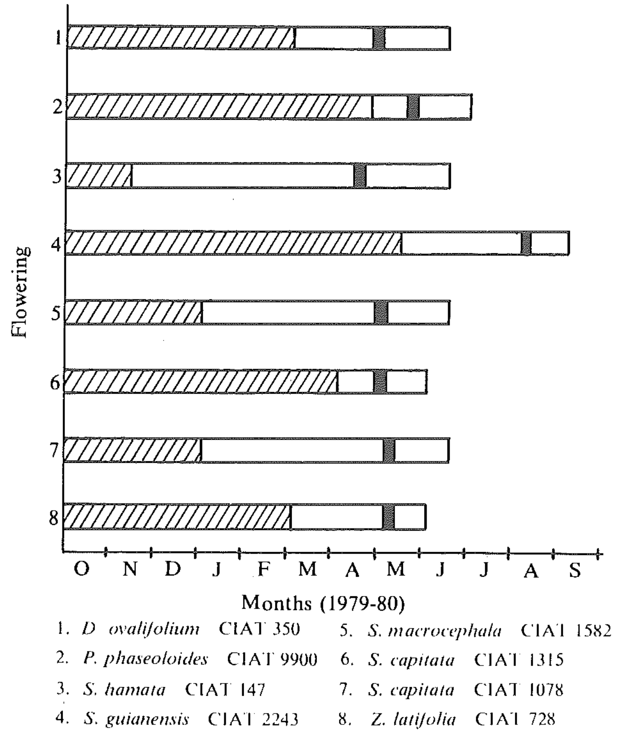


Figure 4. *Flowering characteristics of eight legumes grown at CPAC, Brasilia, Brazil.*

Table 4. Seed production of nine tropical pasture legumes at CPAC, Brasilia, Brazil.

Accessions and CIAT No.	Production of pure seed (kg/ha)		100 seed wt. (mg)	
	1978-79	1979-80	1978-79	1979-80
Zornia latifolia 728	175	687	153	148
Stylosanthes capitata 1405	199	D[1]	235	---
Stylosanthes capitata 1315	150	25	314	204
Stylosanthes capitata 1078	31	40	191	192
Stylosanthes macrocephala 1582	17	207	208	208
Stylosanthes guianensis 2243	42	61	185	240
Stylosanthes hamata 147	322	208	385	327
Desmodium ovalifolium 350	NF[2]	18	---	158
Pueraria phaseoloides 9900	NF	186	---	1038

[1] D died from anthracnose

[2] NF no flowers produced.

Seed Multiplication. Forty-four accessions selected from Category II (1978-79) were multiplied for seed. The number of accessions has now been reduced to 17, and multiplication will continue with these accessions. The 17 new selections from Category II (1979-80) will be multiplied this coming season. A 0.5-ha area of *S. guianensis* CIAT 2243 was planted this year, and seed multiplication of this accession continues. The 0.2-ha area of the promising accession *S. capitata* CIAT 1097 will be increased to 5 ha. Seed multiplication of *D. ovalifolium* CIAT 350 (0.2 ha) and *Z. latifolia* CIAT 728 (0.1 ha) will continue while the 8-ha area of *A. gayanus* CIAT 621 will be increased to 29 ha.

Forage Agronomy Evaluations in Regional Trials

The Agronomy/Regional Trials Section has three primary objectives: a) To evaluate germplasm adaptation within various ecosystems through the Regional Trials Network; b) to conduct supportive agronomic evaluations of promising germplasm being sent into and coming out of the Network; and c) to develop and test methodologies to be implemented in the Network.

Regional Trials Network

The International Tropical Pasture Evaluation Network is a key research strategy for identifying and evaluating improved forage germplasm adapted to the pasture ecosystems of Latin America. Detailed information on the operation, including chracteristics of the different levels of testing, and objectives of the regional trials was reported last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). Table 1 lists the types of agronomic information that will be obtained from the four levels of trials within the Network.

Table 1. Specific information obtained at the various levels in the Regional Trials Network and additional information required that should be obtained from parallel trials.

Regional Trial levels	Main factors affecting establishment, persistence and productivity of pastures
Regional Trials A	1) Climate and soil adaptation
	2) Pest and disease tolerance
	3) Nutrient requirements
	a) for establishment
	b) for maintenance
Regional Trials B	4) Seasonal growth and productivity
	5) Seasonal quality
	6) Grass-legume compatibility
Regional Trials C	7) Grazing and trampling effect
	8) Differential preference under grazing
	9) Seed productivity
Regional Trials D	10) Pasture animal yields

Note: Reg. Trials A, B, C, and D only evaluate factors 1, 2, 4, 7 and 10. The others are evaluated by independent research activities of the participants in the International Network.

Regional Trials A. Twelve locations were selected in 1980 as sites for germplasm testing at the (A) level (Fig. 1). Regional trials in Boa Vista, Brazil (in cooperation with PROPASTO/EMBRAPA) and at El Tigre, Venezuela (FONAIAP) are alternative sites for Carimagua (CIAT/ICA), the major screening site in the well-drained, isohyperthermic savannas. Similarly, Jatai, Brazil (EMGOPA) is an alternative site for Brasilia, Brazil (CPAC/CIAT), the major screening site for the well-drained, isothermic savannas.

Three sites were selected for evaluations in the poorly drained savannas. These are located in Orocue, Colombia (HIMAT/CIAT), Mantecal, Venezuela (FONAIAP) and Corumba, Brazil (EMBRAPA). Three sites were also selected for the tropical rain forest ecosystem: Macagual (ICA) and Leticia (CIAT), both in Colombia, and Tabuleiro, Brazil (CEPLAC).

Two sites in the semi-evergreen seasonal forest ecosystem are at Pucallpa, Peru (IVITA) and Paragominas, Brazil (PROPASTO/EMBRAPA). A Regional Trial A will also be conducted at Nueva Guinea, Nicaragua (INTA).

All of these trials were established during 1980 except for Boa Vista. The latter is expected to be established early in 1981.

Regional Trials B. The Program's Germplasm Committee developed two lists of materials to be tested in Level B Regional Trials. One list, for the well-drained, isohyperthermic savannas, is comprised of germplasm selected as promising at Carimagua. The other group, for tropical forests, is based on selections from earlier regional trials and from previous testing information from national institutions such as PROPASTO, in Brazil, and IVITA, Peru. Tables 2 and 3 show the locations, collaborators and establishment dates for the Level B trials, for the well-drained, isohyperthermic savannas and the tropical forests, respectively.

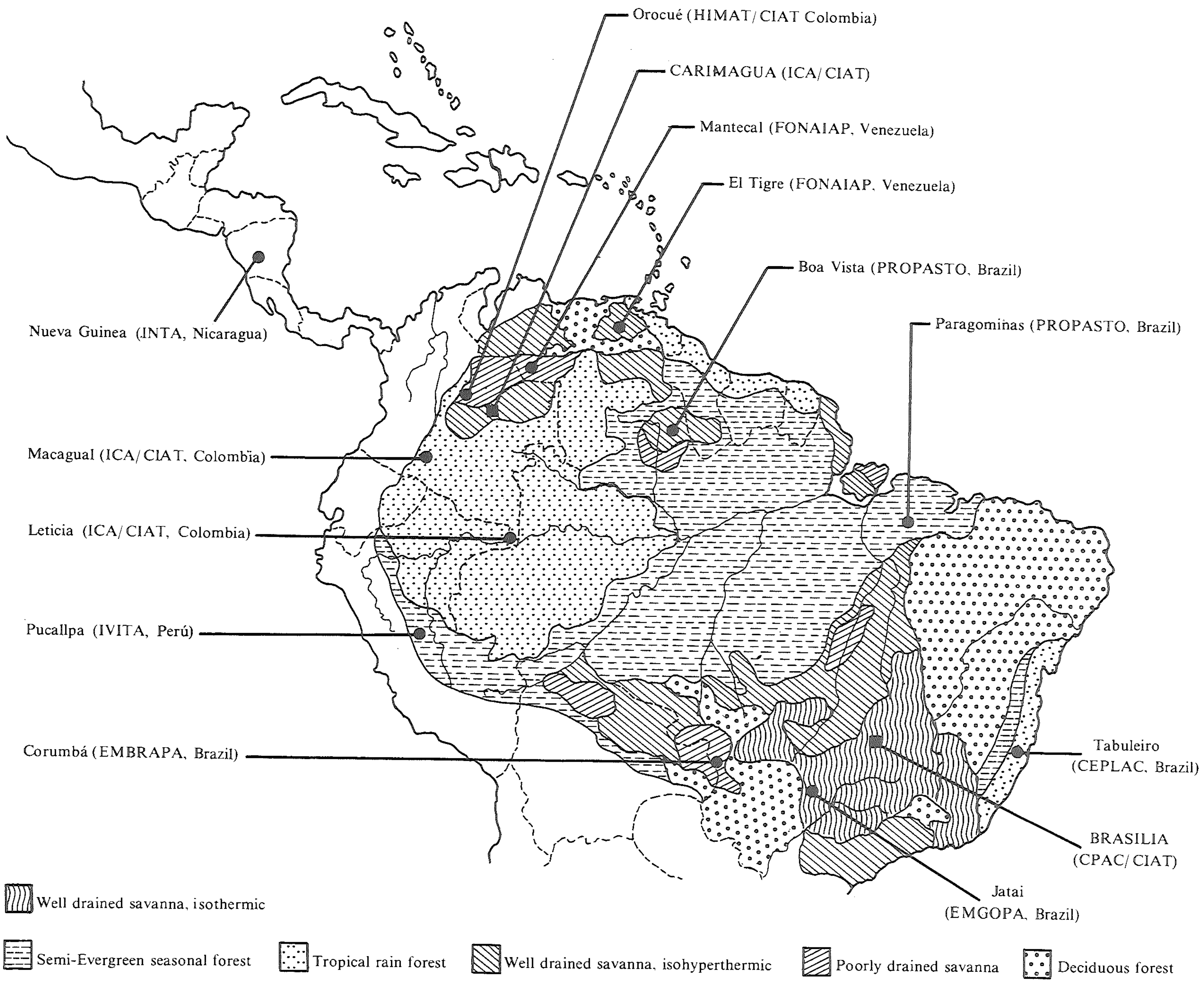


Figure 1. *Location of A level Regional Trials and major screening sites, within ecosystems.*

Table 2. B-level Regional Trials established during 1980 in the well-drained, isohyperthermic savanna ecosystems.

Country	Locality	Collaborator/Responsible	Date of establishment
Colombia	Carimagua	Soils and Plant Nutrition Section, CIAT	May 1980
	"Paraiso", Puerto Gaitán	ETES Project, CIAT	May 1980
	"Guayabal", Puerto Gaitán	ETES Project, CIAT	May 1980
	"EL Viento", Puerto López	ETES Project, CIAT	May 1980
Guyana	Lethem (Rupununi)	J.W. Smith and Clive Devers, CARDI	
Honduras	Olancho	M.R. Alvarado, Min. de Recursos Naturales (DARCO)	Sept.-Oct. 1980
Panama	Calabacito, Veraguas	M.A. Avila, IDIAP	Sept.-Oct. 1980
	Los Santos	J. Quintero, Fac. de Agronmía, Univ. de Panamá	Sept.-Oct. 1980
	El Chepo	J. Quintero, Fac. de Agronomía, Univ. de Panamá	Sept.-Oct. 1980
Venezuela	Mantecal (Banco), Apure	R. Torres, FONAIAP	October 1980
	"Las Marías", Calabozo	C. Sánchez, Min. Agricultura y Cría (MAC)	May 1980
	"Gran Sabana"	J. Rodríguez, CVG, and Z. Flórez, MAC	
	"San José", El Palmar	Z. Flórez, MAC, and J. Rodríguez, CVG	
	"Monserrate", Ciudad Bolívar	V. Gamboa and Z. Flórez, MAC	
	Atapirire, Anzoátegui	D. Sanabria, FONAIAP	May-June 1980
	Jusepín, Monagas	C. Alcalá and M. Corado, UDO	
	La Esperanza	I. Urdaneta and R. Paredes, Univ. del Zulia	May 1980

Table 3. B-level Regional Trials established during 1980 in the tropical forest ecosystems.

Country	Location	Collaborator/Responsible	Date of establishment
Bolivia	Valle del Sacta	J. Espinoza, Universidad San Simón	Sept.-Oct. 1980
Brazil	Barrolandia	J. Marques Pereira, CEPLAC	October 1980
Colombia	Caucasia	L.F. Ramírez, Fac. Med. Vet. y Zoot., Univ. de Antioquia	July 1980
	Puerto Asís	D. Orozco, Fondo Ganadero del Putumayo	January 1980
Costa Rica	Buenos Aires	V. M. Prado, Min. de Agricultura y Ganadería	Sept.-Oct. 1980
Ecuador	Estación "Napo"	K. Muñoz, INIAP	September 1980
	Estación "Pastaza" El Puyo	M. Freire, ESPOCH	May 1980
Guyana	Moblissa	J. W. Smith, Livestock Development Co. Ltd.	September 1980
Honduras	La Ceiba	H. Nolasco, Secretaría de Recursos Naturales	Sept.-Oct. 1980
Nicaragua	El Recreo	A. Cruz Mallona, INTA	Sept.-Oct. 1980
Perú	Tarapoto	J.C. Rodríguez, E. Delgado and W. López, INIA/COPERHOLTA	October 1980
	Yurimaguas	M. Ara and D. Bandy, INIA/NCSU	September 1980
Trinidad	Centeno	N. Persad, Ministry of Agriculture	October 1980
Venezuela	Casigua	I. Urdaneta and R. Paredes, Univ. del Zulia	May 1980
	Gauchi	I. Urdaneta and R. Paredes, Univ. del Zulia	May 1980

Data analysis. Computer programs and data-reporting formats have been developed in cooperation with CIAT's Data Services Unit. Data processing is being done first with information coming from the B level trials established with the new design and methodologies that will yield comparable data for the overall testing program. Processing of one site data is completed within about 20 days, after which collaborators receive the statistical analyses of results from their respective locations. As more data from more locations become available, across-location analyses will be accomplished to analyze the range of adaptability of ecotypes.

In general, the Regional Trials Network constitutes a pioneer "minor screening" of germplasm for those ecosystems in which the Tropical Pastures Program is not yet directly involved. In the two ecosystems where the Program is conducting major screening efforts —at Carimagua and Brasilia— the Network is providing scientists from various disciplines the opportunity to evaluate selected germplasm in many locations. This will in turn provide a better understanding of adaptation and the possibility of extrapolating information within and among ecosystems.

Supportive Agronomic Evaluations

To accomplish its second objective, the Section has initiated trials at CIAT-Quilichao to evaluate some promising germplasm in terms of important agronomic characteristics. Experiments include studies of grass-legume compatibility and seasonal growth and quality of various species.

Six grass species were planted with *Desmodium ovalifolium* CIAT 350 and *Stylosanthes capitata* CIAT 1315, to determine the effects of the legumes on relative yields of the grasses. Preliminary results eight months after planting indicated that all the grasses yield more in association than in monoculture, either with or without added N (Fig. 2). These results can be explained at this early stage as the effect of competition among plants (grass *vs* grass or grass *vs* legume). Clearly grasses are more aggressive than legumes.

This result was reversed when nine legumes were planted with *Andropogon gayanus* CIAT 621 and *Brachiaria decumbens* CIAT 606 (Fig. 3). In almost every case, the legume alone yielded more DM than when each was associated with either of the grasses.

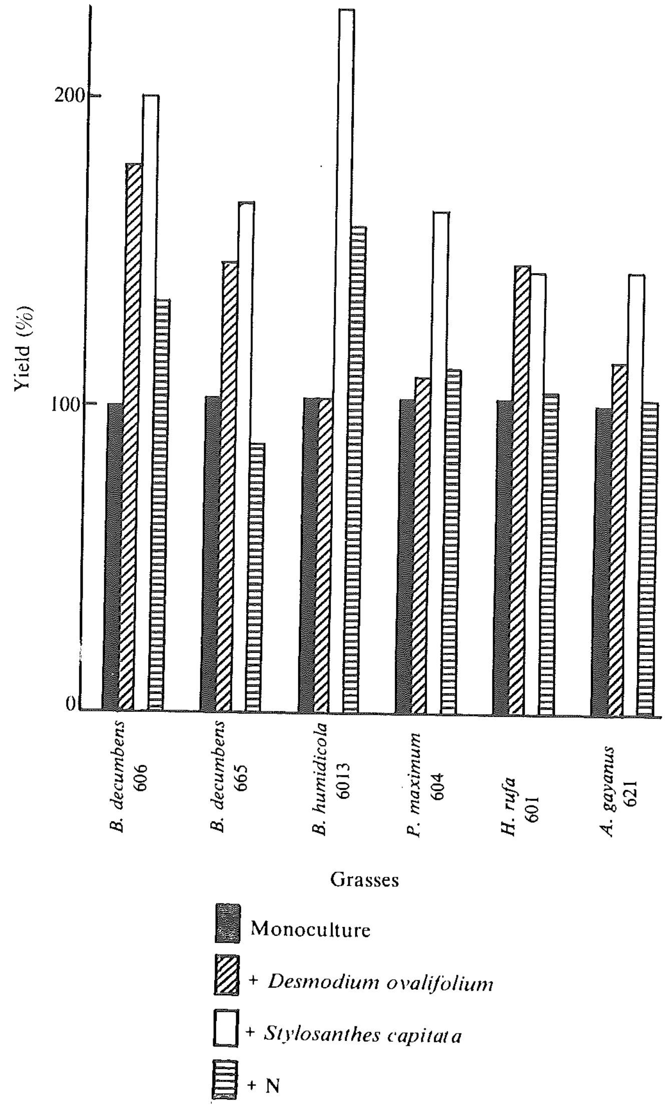


Figure 2. *Effects of two associated legumes and added N on the DM yields of six grasses at the fourth cutting after planting. (Planted Nov. 25, 1979; fourth cut on July 28, 1980.)*

In another trial, a clone of *A. gayanus* was selected for its leafiness and leaf width and planted in strips to provide various degrees of shading on six legume species growing in row associations with the grass. Figure 4 shows the range of reactions observed — from positive responses (*Centrosema pubescens* CIAT 438 and *Pueraria phaseoloides* CIAT 9900) through neutral (*C. pubescens* CIAT 438) to negative (*S. capitata* CIAT 1314 and *S. guianensis* CIAT 184). While these results are preliminary, experiments of this type will provide important information for managing various mixtures of species in pastures.

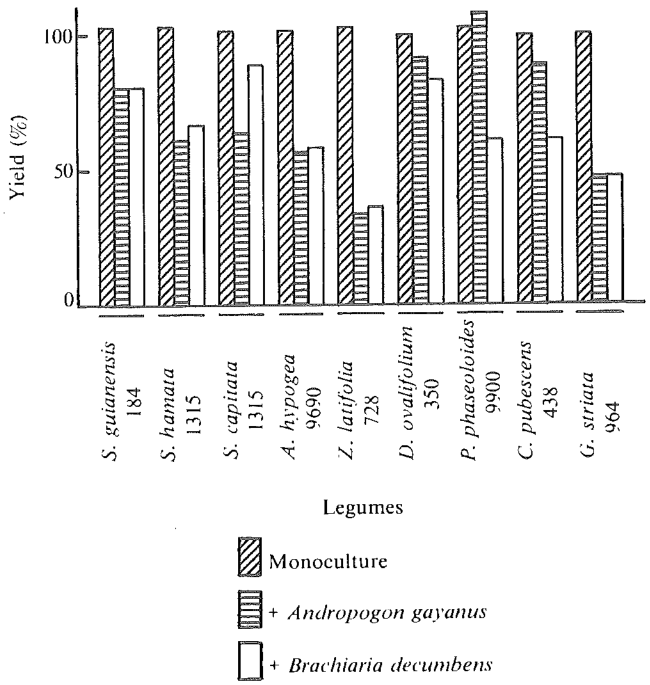
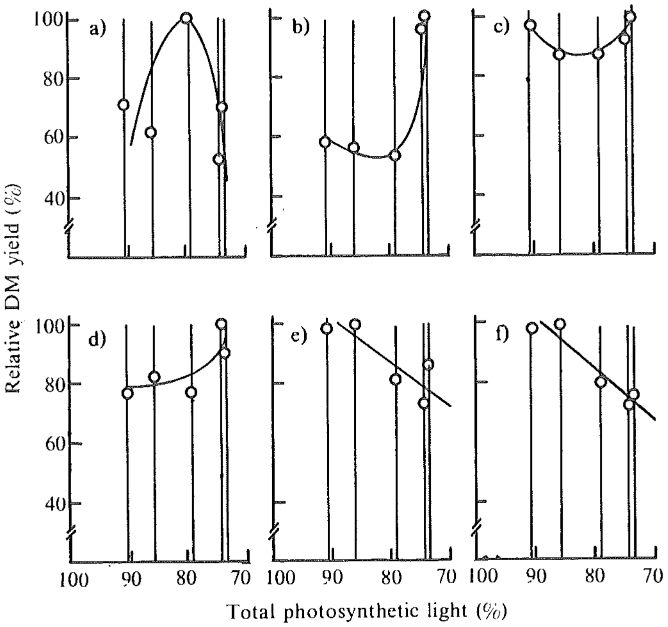


Figure 3. *Effects of two associated grasses on the DM yields of nine legumes at the fourth cutting after planting. (Planted Dec. 5, 1979; fourth cut on Aug. 18, 1980.)*



a) *Zornia latifolia* 728
b) *Centrosema pubescens* 438
c) *Desmodium ovalifolium* 350
d) *Pueraria phaseoloides* 9900
e) *Stylosanthes guianensis* 184
f) *Stylosanthes capitata* 1315

Figure 4. *Effect of received photosynthetic light on the DM yields of six legumes associated with* **Andropogon gayanus,** *in CIAT-Quilichao.*

Other trials were established to study growth and quality changes through ages of regrowth and seasons for 12 legumes and nine grasses. Leaf and stem fractions are also being determined, as well as contents of protein, Ca and P, cell wall constituents and *in vitro* digestibility for each fraction.

All of the agronomic and chemical data is being introduced to the data bank of the Tropical Pastures Program. It will serve as reference information for collaborators in the Regional Trials Network.

Methodology Testing

Testing of new methodologies to meet the Section's third objective is being directed to the C and D levels of the Regional Trials. The experimental forms of these two trials are still being defined.

The main objective of the C level trial will be to select under grazing the most productive and easy-to-manage mixture of species (Table 1). A trial to study selected germplasm in compatible associations under the grazing effect is being established and animals should be grazing these plots early in 1981.

An old grazing trial near CIAT-Quilichao established six years ago on three plots with different grass-legume mixtures is being used to test a methodology as a Regional Trial D prototype. The 1-ha pastures are being evaluated under flexible, continuous grazing. The number of animals in each plot is adjusted every six weeks, depending upon the expected DM regrowth in the next six-week period. Basically, the grazing pressure (based on expected forage regrowth) is held constant over the seasons. Pasture cages are used to measure actual regrowth *versus* the expected regrowth. Green and dead dry matter availability as well as animal gains are being recorded.

The objectives of the Plant Pathology Section have been: a) to screen all new germplasm for resistance to diseases in major evaluation sites; b) to detect, identify and assess diseases of germplasm under forage evaluation; and c) to evaluate and develop control measures for damaging diseases of promising forage species.

Screening of germplasm for resistance has been the major activity at Carimagua and CIAT-Quilichao, Colombia, and at the Cerrado Center in Brazil. Forages have been evaluated for diseases at 36 different sites within the Tropical Pasture Program's target area, with seven sites being visited more than once. These evaluations have given valuable information on disease distribution within ecosystems. This year studies continued on anthracnose and blight of *Stylosanthes* spp., root-knot nematode of *Desmodium* spp., and *Camptomeris* leaf spot of *Leucaena* spp. Studies were initiated on *Sphaceloma* scab of *Zornia* spp. and *Rhynchosporium* leaf spot of *Andropogon gayanus*. Several new diseases were detected this year; one, *Centrosema* bacterial blight, is regarded as a potentially important disease.

Target Area Disease Survey

Results from Regional Trial surveys continue to show that different diseases and different races of some pathogens exist in different locations and in different ecosystems. (Table 1). These results highlight the need for decentralization of screening for disease resistance, to expose forages to as many potential pathogens as possible.

Diseases of *Stylosanthes* spp.

Anthracnose

During 1978-79 surveys of the incidence of anthracnose showed extensive indigenous populations of *Colletotrichum* spp. existing in major legume evaluation sites. Glasshouse screening of germplasm was therefore not recommended except for specific studies. Over the past year major emphasis has been placed on field screening to identify ecotypes with resistance.

Field screening. Evaluation of ecotypes of *S. macrocephala, S. capitata* and *S. guianensis* ("tardío" types) at CIAT-Quilichao and *S. macrocephala* and *S. capitata* at Carimagua continued to show that most germplasm is resistant to anthracnose in Colombia.

At the Cerrado Center, Brazil, however, although *S. macrocephala* is resistant, many accessions of *S. capitata* are susceptible to anthracnose. Field screening of the same 78 ecotypes of *S. capitata* rated 68 as resistant in Colombia and only eight as resistant in the Cerrado Center. Clearly, the specialized races of *Colletotrichum* spp. which attack *S. capitata* exist in Brazil, because Brazil is the natural habitat and probable center of diversity of this legume.

The majority of legumes under evaluation in the Program may be screened in their natural habitats where the legume's specialized pathogens and pests also live. In this way, it should be possible to select germplasm with multiple field resistance to each one's specialized pathogens and pests. This approach will be made first with the valuable legume *S. capitata*.

This legume is native to Eastern Brazil and Venezuela and is not native to Colombia. On the basis of frequency of collection, the states of Minas Gerais, Goias, Maranhao and Piaui, in Brazil, and Anzoategui, in Venezuela, are most suitable for locating screening trials. Screening for anthracnose resistance in Colombia, where *S. capitata* is exotic, will select susceptible ecotypes. This approach may also be made with potentially valuable *S. guianensis* "tardío" ecotypes, also native to Eastern Brazil and Venezuela.

Table 1. Distribution of forage diseases in different ecosystems and locations of the target area.

Number of locations		6	1	4	1	7	1	10
		Ecosystem or location						
Forage disease		Tropical Savanna, Hyperthermic	Carimagua, Colombia	Tropical Savanna, Thermic	Brasilia, Brazil	Tropical Semi-evergreen Seasonal Forest	Tropical Sub-montane Seasonal Forest (CIAT-Quilichao)	Tropical Rainforest
1.	Anthracnose	+	+	+	+	+	+	+
2.	*Cercospora* leaf spot (A), grasses	+	+	+		+	+	+
3.	*Cercospora* leaf spot (B), legumes	+	+	+	+	+	+	+
4.	Root-knot nematode			+*			+	
5.	Blight		+	+				+
6.	*Sphaceloma* scab		+	+	+	+	+	+*
7.	Smut-*Ustilago*		+	+	+		+	+
8.	Smut-*Urocystis*			+*				
9.	*Camptomeris* leaf spot		+				+	+
10.	Rust-*Uromyces*	+		+	+	+	+	+
11.	Rust-*Puccinia*					+*		+
12.	False rust			+	+	+*		+
13.	*Rhizoctonia solani*	+	+	+*	+	+	+	+
14.	*Rhynchosporium* leaf spot		+				+	+*
15.	*Drechslera* leaf spot	+*	+	+	+		+	+
16.	Little leaf phyllody		+	+	+		+	+
17.	Ergot		+	+*			+	+*
18.	*Giberella* inflorescence blight			+*		+		+*
19.	*Botrytis* inflorescence blight							+*
20.	Black mold			+*	+			
21.	Powdery mildew		+		+		+	+*
22.	Slime mold						+	
23.	Bacterial blight		+				+	+*
24.	Bacterial pod blight						+	+
25.	*Botryosphaeria* canker		+					+
26.	*Macrophomina phaseolina*		+					
27.	Crazy top							+*
28.	*Cerebella* inflorescence blight		+			+		+*
29.	Viruses	+*	+	+	+	+	+	+
30.	*Rhizopus* inflorescence blight		+					

* Present at only one site

Burning. Although resistance is the most desirable control for anthracnose, experiments in 1979 showed the value of burning as a temporary control measure of anthracnose in *S. capitata* (CIAT Trop. Past. Prog. 1979 Ann. Rept.). Burned plots of susceptible accessions of *S. capitata* in Carimagua had only 50% as much anthracnose as unburned plots.

In 1980, further treatments were applied to these plots at the end of the dry season. In Carimagua, seven months after burning, burned treatments had only 24% as much anthracnose as other treatments (Table 2). The loss of N to the atmosphere by burning *S. capitata* at the end of the dry season was slight.

Host-plant resistance studies. Studies were initiated to compare physical and chemical characters of *S. guianensis* 136 and *S. guianensis* "tardío" ecotypes, susceptible and resistant, respectively, to anthracnose.

The effect of age on resistance or susceptibility of *S. guianensis* 136 and *S. guianensis* "tardío" CIAT 1283 was studied with plants from 3-24 weeks old. No effect of age was observed in the reaction of plants to anthracnose.

Table 2. Effect of burning on anthracnose incidence on *Stylosanthes capitata* 1078 in Carimagua.

Treatment	Evaluation (lesions/ 10 g DM)		
	Months after burning		
	one	four	seven
Control	5.3 a [1]	48.9 a (144) [2]	35.3 a (920)
Cut 1980	2.2 b	23.6 a (140)	29.5 a (708)
Burned 1979, cut 1980	2.4 b	6.3 b (204)	8.4 b (660)
Burned 1979, burned 1980	--	5.5 b (112)	7.3 b (580)

[1] Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

[2] Values in parentheses are g DM/m².

Treatment of the glandular trichomes of *S. guianensis* CIAT 1283 in various ways showed that neither removing the secretions nor removing the trichomes had any effect on the legume's reaction to anthracnose. This suggests that the resistance of "tardío" types to anthracnose in Colombia is not based on their character of glandular trichomes.

"Tardío" types CIAT 1283 and 1959 were analyzed for the presence of chemical substances known to be toxic to fungi, including: flavanoids, mono- and dihydric phenols, phenolic glucosides, anthocyanins and tannins. Both ecotypes contained mono- and dihydric phenols and phenolic glucosides.

This positive finding could be the basis of resistance to anthracnose in this group of *S. guianensis*. Analysis for phenolics of all "tardíos" and common *S. guianensis* will be made to see how widely distributed are the phenolics.

Specific screening studies. After the decision to reevaluate the *S. guianensis* collection, 154 ecotypes, including 62 "tardíos", were planted in 1979 in Carimagua. Another 180 common ecotypes, together with common x "tardío" crosses from the Legume Breeding Section were planted this year; the rest of the collection will be planted in April 1981.

Evaluations of anthracnose reaction began in May 1980 and continued each month. Reaction of the common types followed the expected progression and by October most were dead (Fig. 1). Ecotypes CIAT 1122, 1873 and 1875 are still only slightly affected and worthy of further study. Although the majority of "tardío" types remained resistant, there was a reaction distribution among them (Fig. 1). Continuing evaluations of the common types and "tardíos" and crosses between them should give interesting results in 1981.

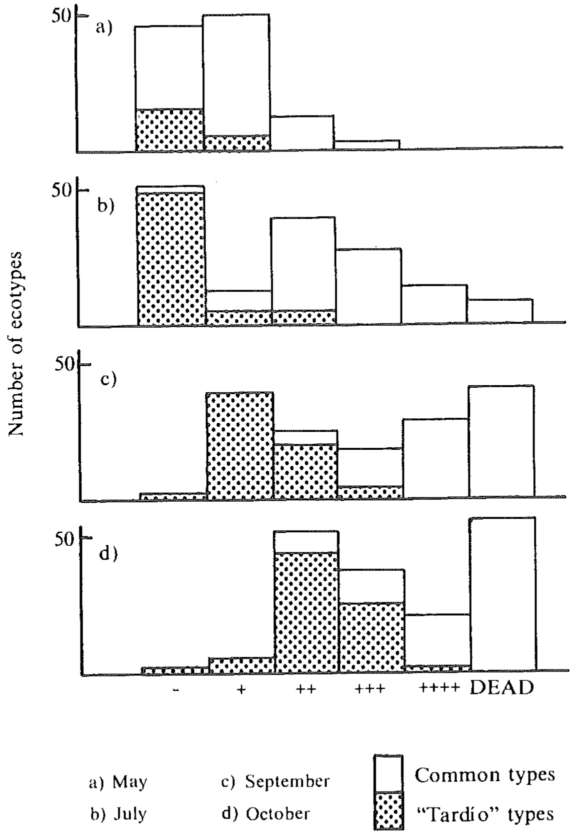


Figure 1. *Reactions of ecotypes of* **Stylosanthes guianensis** *to anthracnose, in Carimagua, 1980.*

The susceptible reaction of many *S. capitata* ecotypes to anthracnose at the Cerrado Center led to seedling screening there of the entire *S. capitata* collection using fungus isolates from CIAT 1019, 1315 and 1405. Results to date from 90 ecotypes show that isolates from CIAT 1019 and 1405 are more pathogenic than those from 1315 and that ecotypes from Venezuela are resistant, while most Brazilian ecotypes are susceptible.

Blight

Surveys. During 1978 and 1979, blight caused by *Sclerotium rolfsii* was detected only in Colombia. In 1980 it was also found in Brazil. Although glasshouse tests showed that most forage legumes are susceptible to *S. rolfsii* (CIAT Trop. Past. Prog. 1979 Ann. Rept.), only *Stylosanthes* spp. are affected in the field. At Carimagua this year, numbers of *S. capitata* plants killed by *S. rolfsii* were generally lower than in 1979 for important ecotypes CIAT 1019, 1315 and 1405.

Viable sclerotia in the soil were again monitored at different sites in Carimagua. There were considerably fewer viable sclerotia this year than in 1979.

Other Studies

Studies were initiated on the effect of soil type and form of organic matter on the pathogenicity of *S. rolfsii* to *S. capitata* CIAT 1019. Soil type had a considerable effect. Only 27% of the inoculated plants were killed in soil from CIAT-Quilichao, whereas 75% of inoculated plants were killed in Carimagua soil. Although adding organic matter in the form of ground leaf material, small pieces of leaves and whole leaves did not have a significant effect, *S. rolfsii* was slightly more pathogenic in soil containing ground material than in soil containing whole leaves.

Amending Quilichao soil with different sources of ground leaf material had a considerable effect. Material from grasses and *Zornia latifolia* CIAT 728 had only a slight or no inhibitory effect on pathogenicity (Table 3). Material from *Pueraria phaseoloides, Centrosema, S. capitata* and its mixture with *Andropogon gayanus,* and especially *Leucaena,* had a stimulatory effect, while material from *Desmodium ovalifolium* CIAT 350 inhibited the pathogenicity of *S. rolfsii.* This is probably due to the presence of tannins, which are broad spectrum toxins to fungi. Therefore, the most important factors affecting pathogenicity of *S. rolfsii* are soil type and type of organic matter.

Table 3. Pathogenicity of *Sclerotium rolfsii* to *Stylosanthes capitata* 1019 in a CIAT-Quilichao soil containing different sources of organic matter.

Source of organic matter	Dead plants (%)
Soil only (control)	17.0
Desmodium ovalifolium 350	6.3
Zornia latifolia 728	14.0
Panicum maximum 604	12.5
Andropogon gayanus 621	15.6
Brachiaria decumbens 606	17.0
Pueraria phaseoloides 9900	34.4
A. gayanus/S. capitata mixture	46.9
Centrosema 438	64.1
Stylosanthes capitata 1019	68.8
Leucaena leucocephala	79.7

Diseases of *Desmodium* spp.

Root-Knot Nematode

Surveys. Over the past two years surveys have shown the root-knot nematode to be indigenous at CIAT-Quilichao and introduced to Carimagua. Failure to find the nematode at Carimagua during 1980 suggests that control measures have been successful and present quarantine restrictions are preventing its reintroduction. This year the nematode was found also on *D. ovalifolium* 350 at the Cerrado Center and Sete Lagoas, Brazil.

At CIAT-Quilichao, several new ecotypes of *Desmodium* spp. were susceptible to the root-knot nematode. CIAT-Quilichao is therefore a useful site for screening for resistance to the nematode if replicates are widely distributed to account for natural variation. Glasshouse screening trials showed that generally only *Desmodium* spp. and related *Codariocalyx gyroides* are susceptible to root-knot nematodes (CIAT Trop. Past. Prog. 1979 Ann. Rept.); field screening has confirmed this. The root-knot nematode is widely distributed on crop plants throughout tropical Latin America and futher problems with susceptible *Desmodium* spp. may occur in the future. Studies were initiated, therefore, to find possible control measures.

Various plants are antagonistic to nematodes. Some include marigold *(Tagetes* sp.), asparagus, crucifers, and various grasses — *Eragrostis curvula* var. Ermelo, *Chloris gayana* var. Katambora (Rhodes grass), *Panicum maximum* var. Sabi, *Pennisetum glaucum* and *Digitaria decumbens* (Pangola grass).

Two studies were made to determine the effect of root-knot nematode on *D. ovalifolium* 350 in association with various grasses. A pot trial with 54 ecotypes of 25 grass species showed many grasses had no effect on the nematode (Table 4). These included ecotypes of *B. decumbens* and *P. maximum.* While several others, including *A. gayanus* 621 and *B. decumbens* 606, appeared to stimulate the nematode, several important grasses appeared to reduce nematode attacks on *D. ovalifolium.* These grasses, including ecotypes of *A. gayanus, B. humidicola* and *P. maximum,* may produce toxins to this nematode. This will be studied further, especially with *B. humidicola.* This grass associates well with *D. ovalifolium* and results suggest that *D. ovalifolium* could be grown successfully in nematode-infested soil in association with *B. humidicola.*

Table 4. Effects of various grasses on the reaction of *Desmodium ovalifolium* CIAT 350 to root-knot nematode, *Meloidogyne javanica.*

No galling	Slight galling	Moderate galling	Severe galling
*Brachiaria ruziziensis**[1]	*Andropogon gayanus* 6053*	*Axonopus micay* 6050*	*Andropogon gayanus* 621*
Eragrostis curvula 6073	*Brachiaria humidicola* 679*	*Brachiaria decumbens* 6009*	*Brachiaria brizantha* 6016*
Hemarthria altissima 663*	*Brachiaria humidicola* 682*	*Brachiaria decumbens* 6012*	*Brachiaria decumbens* 606*
Ischaemum ciliari 6062	*Brachiaria humidicola* 6013*	*Chloris gayana* 6042	*Digitaria decumbens* 659
Panicum maximum 604*	*Brachiaria mutica* Pará*	*Dichanthium aristatum* Angleton	*Echinochloa pyramidalis* 657
Tripsacum andersonii 6051	*Brachiaria radicans*	*Echinochloa polystachya* 6018	*Eragrostis curvula* 6074
Tagetes spp. (marigold)	*Eragrostis curvula* 6066	*Eragrostis curvula* 6064	*Eragrostis curvula* 6078
	Eragrostis curvula 6067	*Eragrostis curvula* 6065	*Eragrostis curvula* 6079
	Eragrostis curvula 6068	*Eragrostis curvula* 6069	*Eragrostis curvula* 6081
	Eragrostis curvula 6075	*Eragrostis curvula* 6076	*Hyparrhenia rufa**
	Paspalum dilatatum 6049	*Eragrostis curvula* 6082	*Panicum maximum* 695*
	Setaria sphacelata 6043	*Panicum maximum* 662*	*Panicum coloratum* 683
	Dichanthium aristatum	*Pennisetum purpureum**	*Pennisetum purpureum* 672*
	Digitaria sp. 6014	*Digitaria* sp. 651*	
	Panicum maximum 6002*	*Desmodium ovalifolium* 350 alone	
	Urochloa mosambicensis 614		

[1] Species followed by an asterisk are considered more important for the Target Area.

Diseases of *Leucaena* spp.

***Camptomeris* leaf spot.** During 1980 results from the screening trial of *Leucaena* spp. for reactions to *Camptomeris* leaf spot (CLS) remained the same as reported last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). Ecotypes of *L. diversifolia, L. esculenta, L. pulverulenta, L. shannoni* and *L. trichodes* have remained resistant to the disease and may be of value in future breeding programs.

Two studies were initiated in 1979 to determine the effects of fertilizers on the severity of CLS on *L. leucocephala.* First, the effect of four levels of a fertilizer containing $P_2 0_5$, $K_2 0$, Mg, Ca, Cu, Zn, B and Mo on CLS of *L. leucocephala* showed that CLS was severe in the control and decreased to slight as the amount of fertilizer applied increased (Table 5). Although yields of leaves, stems and pods in the control were significantly less than in fertilizer treatments, there were no significant differences between fertilizer treatments. Secondly, different combinations of microelements (Zn, Cu and B) did not significantly affect incidence of CLS on *L. leucocephala.*

This year the fungus *Hansfordia pulvinata* was found to rapidly colonize lesions of *Camptomeris leucaenae,* especially under moist conditions. This fungus has previously been reported as a mycoparasite of several other fungi. By rapidly colonizing lesions caused by *C. leucaenae, H. pulvinata* prevents dispersal of most spores, and therefore considerably reduces dissemination of the pathogen. It may prove a useful biological control agent.

Table 5. Effects of different levels of fertilizers on *Camptomeris* leaf spot of *Leucaena leucocephala.*

Treatment	Lesion rating	Yields		
		Leaves (g)	Stems (g)	Pods (No.)
Control	+++	101.2 b[1]	56.5 b	0 b
Recommended level x o.5	++	325.6 a	234.0 a	28 a
Recommended level	+/++	320.5 a	213.1 a	29 a
Recommended level x 1.5	+	283.1 a	247.7 a	46 a

[1] Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Diseases of *Zornia* spp.

***Sphaceloma* scab.** It was first recorded on *Zornia* spp. in 1979. Although this disease is widespread in Colombia and Brazil on two-leafed *Zornia* spp., including *Z. latifolia,* four-leafed *Zornia* spp., including *Z. brasiliensis,* are presently resistant. In Carimagua, *Sphaceloma* scab is the most important disease of *Zornia* spp. and most ecotypes are susceptible (Table 6). Among resistant ecotypes are some from Venezuela and Brazil, mostly four-leafed types. Two Colombian ecotypes of *Z. latifolia* have remained resistant in Carimagua. More Colombian material should be evaluated as ecotypes resistant to Colombian races of *Sphaceloma zorniae* are more likely to be found among Colombian material. New germplasm of *Z latifolia* will be collected in the Colombian Llanos in the next dry season. Screening of all new germplasm will continue in Carimagua to find resistance to *Sphaceloma* scab.

Table 6. Evaluation of diseases of *Zornia* spp. in Carimagua.

Disease	Reaction (No.)			
	Resistant	Moderately resistant	Moderately susceptible	Susceptible
Sphaceloma scab	20	0	18	62
Anthracnose leaf spot	58	35	7	0
Drechslera leaf spot	78	17	5	0

Quality and loss studies. An analysis of foliage of diseased and healthy *Z. latifolia* CIAT 728 showed *Sphaceloma* scab does not significantly affect the digestibility or N content of legume. Studies were begun on the effect of *Sphaceloma* scab on yield of *Z. latifolia* 728 in Carimagua, both with and without grazing. After six-months of rain, plots treated with fungicide had significantly less *Sphaceloma* scab than controls and more lesions were present without grazing (Table 7). *Sphaceloma* scab caused more than 50% loss of DM in comparison to the fungicide treatments, both with and without grazing.

Laboratory studies. Because *S. zorniae* is so difficult to work with in artificial culture, studies were made to improve isolation, culturing and inoculating techniques. Cross-inoculation studies with other hosts of *Sphaceloma* spp. will be made during 1981.

The fungus was found to be seed-borne and all seed to be imported is carefully treated with fungicides. Also recently, the sexual stage of the fungus *Elsinoe* was found; this increases the likelihood that races of the fungus will be found.

Estrogen assay. Recent findings in Australia, Europe, New Zealand and the U.S.A. have shown that a number of common temperate legume foliage pathogens cause considerable increases in the concentrations of estrogenic compounds in the foliage. These compounds may affect the fertility of female animals.

The possibility that *Zornia* affected by *Sphaceloma* may contain estrogenic compounds was considered when steers continued to grow well on a *Z. latifolia* 728 pasture severely infected by *Sphaceloma* scab. Estrogens act as growth stimulants causing improved gain rates and feed efficiency in steers.

Table 7. Effect of *Sphaceloma* scab on DM production of *Zornia latifolia* 728 with and without grazing and fungicide treatments, in Carimagua.

Treatment	May			June			September		
	Lesions 10g DM	DM yield (g)	DM loss (%)	Lesions 10g DM	DM yield (g)	DM loss (%)	Lesions 10g DM	DM yield (g)	DM loss (%)
With grazing; with fungicide	48.3 b[1]	60.0		57.3 b	37.5		47.2 c	30.5	
With grazing; without fungicide	72.8 a	40.5	32.5	196.4 a	30.0	20.0	138.6 b	13.8	54.8
Without grazing; with fungicide	19.7 c	59.8		48.6 b	36.0		63.9 c	30.3	
Without grazing; without fungicide	85.3 a	47.1	21.2	256.3 a	29.5	18.1	265.9 a	13.7	54.8

[1] Means within columms followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Sphaceloma-affected *Zornia* was tested for estrogens by mouse bioassay, with presence of estrogens indicated by increased uterine weight in immature female mice. Four diets similar in form except for crude fiber were used (Table 8). Uterine weights of mice on the strogen-ammended (DES) diet and diseased *Zornia* diet were significantly greater than those of mice on the commercial and healthy *Zornia* diets (Table 9). This most probably indicates that *Zornia* with *Sphaceloma* scab contains estrogenic substances and may adversely affect reproduction of female animals. Studies on the identity of the estrogenic substances and their direct effect on ruminants are planned.

Table 8. Analysis of diets fed to immature female mice in estrogen evaluation trials.

Diet	Crude fiber (%)	Nitrogen (%)	Protein (%)	M.C.
Commercial ration	12.6	3.75	23.4	3.3
Commercial ration + DES	11.9	3.67	22.9	5.3
Commercial ration + healthy *Zornia*	21.8	3.14	19.6	5.3
Commercial + diseased *Zornia*[1]	29.7	3.14	19.6	4.7

[1] With *Sphaceloma* scab

Table 9. Response of immature female mice to diets containing healthy and *Sphaceloma* scab-infected *Zornia latifolia* CIAT 728.

Diet	Diet consumed in 24 hours (g)	Mouse weight at death (g)	Uterus weight (mg)
Commercial ration	2.8	16.3	22 b[1]
Commercial ration + DES	2.4	17.1	64 a
Commercial ration + healthy 728	4.2	14.0	19 b
Commercial ration + diseased 728	4.3	14.9	53 a

[1] Means followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Virus-black mold complex. In 1979 this disease complex, manifest as leaf rolling, distortion and stunted growth, was observed on most *Zornia* spp. at the Cerrado Center in Brazil. It also affects most native *Zornia* spp. in the Brasilia area. Within one year most affected ecotypes died. It is possible that associated aphids and thrips are transmitting the virus and that the fungus *Meliola* sp. is a secondary invader. This disease requires further study in Brazil.

Diseases of *Andropogon gayanus*

***Rhynchosporium* leaf spot (RLS).** It was first observed on *A. gayanus* CIAT 621 in 1979. It caused slight damage at Villavicencio, Colombia, but almost no damage at Carimagua. Generally, lesions were restricted to mature leaves as orange or brown spots. Ten to 20% of the lesions developed further, causing necrosis and death of leaves. Under ideal environmental conditions, typical zonate lesions developed. It was difficult to find RLS on young leaves.

Although RLS caused only slight damage to *A. gayanus* at Villavicencio, a further evaluation was planned because of the great potential of this grass. Studies were initiated this year at Villavicencio on the effect of RLS on yield of *A. gayanus* with and without grazing. Although results are preliminary, it appears that a fungicide is controlling lesion development both with and without grazing; most lesions, however, are small and cause little damage. Apart from the yield of one ungrazed, fungicide-treated plot, yields within each of two stocking rates were similar and as yet there is no evidence that RLS affects yield. Analysis of the quality of healthy, diseased and red leaves showed that RLS lowers both digestibility and N content (Table 10). Interestingly, red leaves contained only half as much N as green leaves.

Table 10. Nutritional analysis of healthy and diseased leaves of *Andropogon gayanus* CIAT 621.

Leaf type	Digestibility (%)	Nitrogen (%)	Protein (%)
Healthy leaves	53.9	1.71	10.69
Red leaves	55.7	0.84	5.25
Diseased leaves	44.7	1.32	8.25

[1] Leaf area 20-50% affected by *Rhynchosporium* sp.

The importance of determining whether *Rhynchosporium* sp. from *A. gayanus* is the same as *Rhynchosporium oryzae*, an important pathogen of rice in the Villavicencio area, was recently stressed. These fungi have identical cultural characters and similar spore measurements, closer to those of *R. oryzae* than those of other *Rhynchosporium* spp. given (Table 11). Isolates of *Rhynchosporium* from rice and *A. gayanus* from both Villavicencio and Carimagua were collected and cross-inoculation studies made. Preliminary observations suggest that isolates from rice and *A. gayanus* are different, while isolates collected from the two crops at Carimagua are the same. Further tests are being made to confirm these observations.

Table 11. Measurements of *Rhynchosporium* spp. spores collected from various sources.

Species or source	Length (µm)	Width (µm)
Rhynchosporium secalis[1]	19.0	4.0
Rhynchosporium orthosporium[1]	16.9	3.8
Rhynchosporium oryzae[1]	11.0	3.7
Rhynchosporium sp. on rice at Villavicencio	10.5	3.2
Rhynchosporium sp. on *Andropogon* at Villavicencio	11.8	3.6
Rhynchosporium sp. on rice at Carimagua	13.1	3.8
Rhynchosporium sp. on *Andropogon* at Carimagua	10.5	3.7

[1] From the literature (various sources)

Diseases of *Panicum maximum*

Cercospora **leaf spot** (CLS), caused by *Cercospora fusimaculans*, is widespread on common types of *P. maximum* throughout the Program's target area. Cultivars such as Makueni and Green Panic are resistant. A trial was established in 1979 to study the effect of CLS on yield and quality of *P. maximum* in Carimagua. Although CLS does not appear to affect DM production, it does reduce quality by reducing both digestibility and N content.

New Diseases

Stylosanthes **spp.** *Botryosphaeria ribis* was identified in Carimagua causing bark splitting and canker of 1- to 2 year-old woody *S. capitata* and *S. scabra*. *Macrophomina phaseolina* was found causing wilting and death of young *S. capitata* CIAT 1315 plants. And recently, after a period of cool, wet weather, *Rhizopus* inflorescence blight was moderate to severe on various accessions of *S. capitata*.

Centrosema **spp.** Bacterial blight caused by a species of *Pseudomonas* was found in Carimagua, CIAT-Quilichao and CIAT-Palmira. It is regarded as the most important disease of this genus and pathogen identification and screening are in progress.

Leucaena **sp.** Bacterial pod blight caused by *Pseudomonas fluorescens* Biotype 2 has been recorded in Colombia, Brazil and in Belize and Southern Mexico in Central America. It appears to be insect-borne. As yet it has been recorded only on *L. leucocephala*. Screening trials with six other species are planned.

Zornia **sp.** The rust *Puccinia offuscata* was recorded as severe on *Zornia* sp. in Peru.

Andropogon gayanus **621.** Crazy top, a downy mildew probably caused by *Sclerophthora* sp., was recorded affecting a few plants in each plot in Brazil and Colombia.

Viruses

Over the past two years various viruses have been observed on forages. They are widespread, occurring in each ecosystem. The level of losses is presently unknown. An analysis of healthy and virus-affected leaves of *A. gayanus* showed digestibility of only 31% in virus-affected leaves compared to 43.2% for healthy leaves.

Phyllody

Phyllody, or little leaf, is widespread throughout the target area, especially on *Desmodium* spp. but also on *Centrosema* spp.

Phyllody causes a progressive loss of plant vigor and yield and eventually death. It has also been shown that phyllody reduces the number, size and effectiveness of nodules involved in N fixation. Normally effective *Rhizobium* strains become less effective in phyllody-affected plants.

These bacteria remain good competitors with other soil *Rhizobia* for sites on healthy roots but nodulate healthy roots less effectively. Phyllody may, therefore, be more of a problem than previously thought.

Seed Pathology

Various studies have been made on the microflora of forage legume and grass seed over the past two years. The most interesting results are presently being obtained from surveys of changes occurring in the microflora of *S. capitata* seed in Carimagua and CIAT-Quilichao during the year. This study is concentrating on changes in populations of *Aspergillus* and *Penicillium* spp., commonly associated with seed. *Aspergillus* spp., in particular, are noted for aflatoxin production, both before harvest and in storage. Because cattle eat seed of *S. capitata* in the dry season, a knowledge of *Aspergillus* and *Penicillium* spp. associated with seed was considered of value.

Since May 1979 in Carimagua, 10 *Aspergillus* species have been isolated. Four of them — *A. ochraceus, A. flavus, A. fumigatus* and *A. nidulans* — are known aflatoxin producers. The most commonly isolated is *A. flavus.* Five species of *Penicillium* including one toxin producer, *P. oxalicum,* have been isolated. These fungi will be tested for production of toxins.

The survey in Carimagua showed that the number of *Aspergillus* spp. associated with both green and dry seed increases at the end of the wet season, reaches a peak in the dry season and declines as the wet season progresses (Fig. 2). It appears that more *Aspergillus* spp. are associated with seed of *S. capitata* at the time when animals eat more seed. If the tests on the fungi prove positive for aflatoxins, there may be problems for animals. This study will continue in 1981.

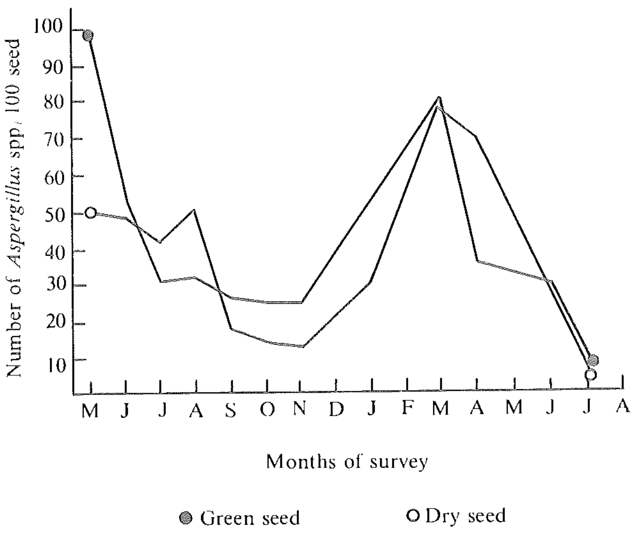


Figure 2. *Numbers of* **Aspergillus** *spp. associated with dry and green seed of* **Stylosanthes capitata,** *in Carimagua.*

Entomogenous Fungi

This year a project in collaboration with the Entomology Section was begun on biological control of the spittlebug (various genera) with entomogenous fungi. *Metarhizium anisopliae* is the most important fungus. Indigenous entomogenous fungi from spittlebugs are being collected from as many sites in Colombia as possible and also from many other countries. Studies will be made on the morphology, cultural characters and biology of the fungi collected. Studies also have begun on the pathogenicity of these fungi to both nymphs and adults and on conditions necessary for effective control of the insect with the fungi.

Plant Entomology

Research work in the Entomology Section is directed to accomplishing the following objectives: a) to screen systematically the germplasm bank of the Tropical Pastures Program for plant materials tolerant or resistant to insect pests; b) to study taxonomy, biology and population dynamics of the main pests; and c) to screen germplasm included in Regional Trials for insect damage in various ecosystems.

Studies continued during 1980 on key pests, especially the stemborer which is considered the most important pest of *Stylosanthes,* and the spittlebug which is important on various grasses.

New germplasm introductions were evaluated for insect tolerance, and pest survey monitoring was continued in locations where Regional Trials were planted.

Preliminary studies were also done on the false army worm, a locally important pest on grasses.

Pests of Legumes

Stemborer

Because of the high priority given to evaluations of *Stylosanthes* as a forage, the Section is directing considerable efforts to studies on the stemborer, *Caloptilia* sp. Hubner. Information on the pest's biology and population dynamics and results of some host-plant resistance work have been reported earlier (CIAT Ann. Rept. 1978 and CIAT Trop. Past. Prog. 1979 Ann. Rept.).

As a continuation of anatomical studies of *S. capitata,* of which most ecotypes have been shown to be resistant to the stemborer, stem structures of several ecotypes were analyzed. These analyses have shown that sclerenchyma distribution in groups or packs of fibers surrounding the stem is variable and their shapes are polyhedral. Although these groups of sclerenchymatous cells vary in number, shape and size between species, materials considered susceptible to the stemborer (*S. guianensis* CIAT 136) have thinner layers of sclerenchyma while cell layers in resistant *S. capitata* are thicker. This characteristic appears consistent for each species.

Another experiment was designed to investigate the association of thicker layers of cells with stem hardness and thinner layers of cells with softness of stems. Results clearly showed that ecotypes having thicker layers of cells are harder than those with thinner layers of cells (Fig. 1).

In addition to stem physical structures, the presence of glandular trichomes that secrete substances that may attract females to oviposit on these preferred plants also is being studied. The presence of one or both characteristics in a given species or ecotype may affect preference or non-preference for oviposition and, consequently, penetration of the recently hatched larvae into the stem.

These differences have been found within ecotypes of the same species, e.g., *S. guianensis* common types and some *S. guianensis* "tardío" types, and between late- and early-flowering *S. capitata.* It is possible that ecotypes with "field resistance" to stemborer could be used as a control measure against this pest. However, it is very important to remember that the disease anthracnose is, in many locations, a limiting factor in *Stylosanthes* persistence.

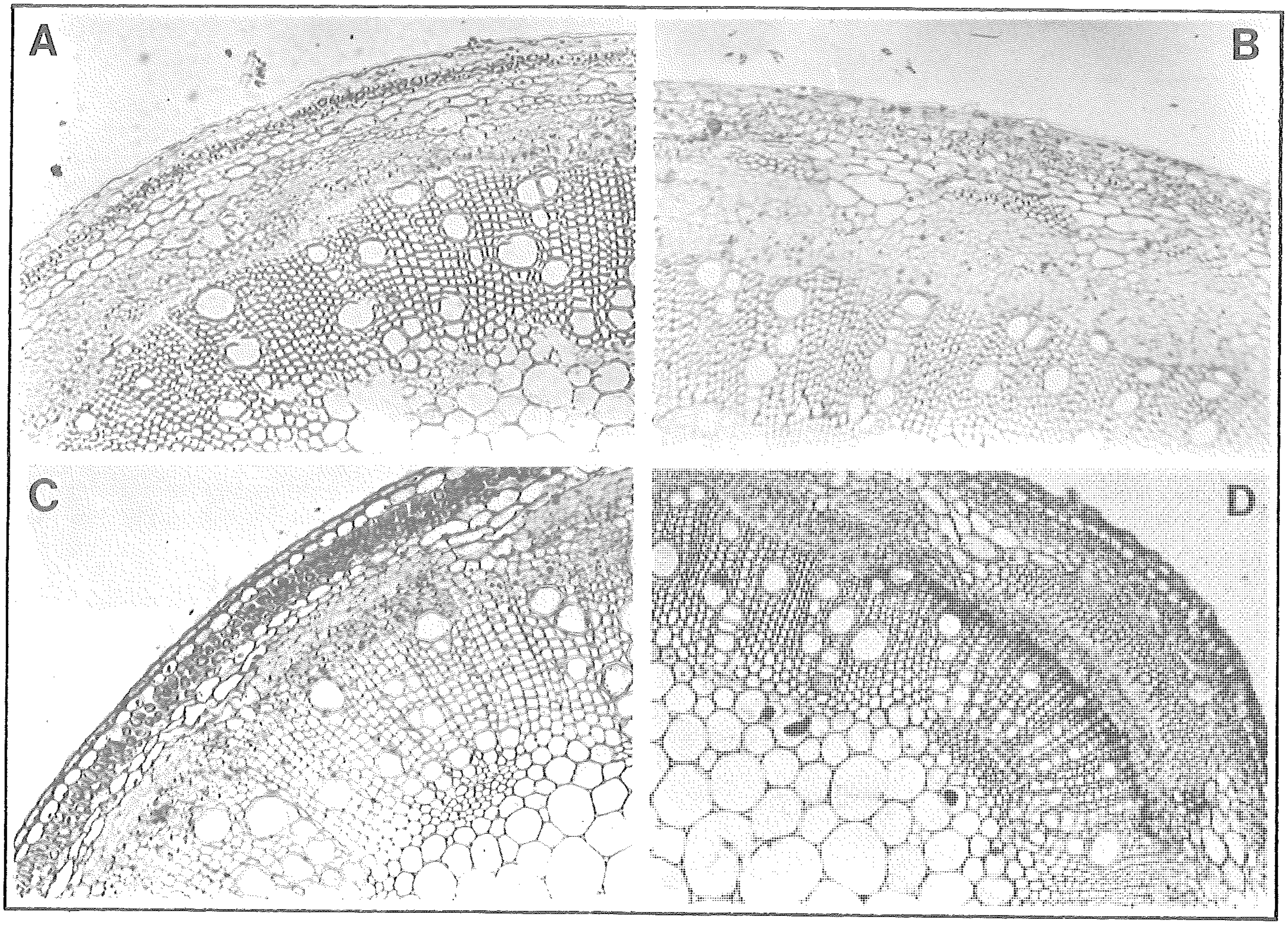


Figure 1. *Anatomical study of ecotypes susceptible (top) and resistant (bottom) to the stemborer:* (a) **S. guianensis** 136; b) **S. capitata** 1078; c) **S. guianensis** 1062; d) **S. capitata** 1315.

Grazing management presents another possibility of population regulation when used wisely (CIAT Trop. Past. Prog. 1979 Ann. Rept.). For example, an increase in the normal stocking rate established at Carimagua during April, May and August, could reduce the stemborer population. Burning is not recommended yet because it kills many plants and the slow recovery of surviving plants allows weeds to compete with the legume.

The association of *S. capitata* with an erect grass such as *Andropogon gayanus* improves the heterogeneity of the agroecosystem and, in theory, is unfavorable for insect population increase. Management of biological control agents would also provide another alternative for regulating stemborer populations in the field in the future.

Budworm

Critical damage levels. In determining the critical level of damage caused by the budworm *(Stegasta bosqueella* Chambers) in flowers of *Stylosanthes,* it is very important to consider the seed production capacity of the forage species. For example, *S. guianensis* produces less seed and has smaller inflorescences than *S. capitata.* Therefore, while *Stegasta* larvae could damage several flowers of *S. guianensis,* larval damage might not be so severe in *S. capitata* because of the large inflorescences and amount of seed produced.

The effect of stemborer larvae on seed production was studied with *S. capitata* CIAT 1315 at Carimagua. Three levels of infestation were used: 0-9, 10-19 and 20-29. Larvae numbers were kept constant by spraying malathion (1.5 liters c.p./ha).

Preliminary results showed seed production was not significantly reduced at any level of infestation and that infestation up to 30% did not reduce seed production in *S. capitata* 1315.

Pests of Grasses

Spittlebug

Spittlebug *(Aeneolamia* sp., *Zulia* sp.) populations increase at the start of the wet season. In April 1980, an experiment was initiated at Carimagua to compare infestation in *Brachiaria decumbens* plots under three establishment systems: pure stand, in association with *Pueraria phaseoloides* in strips, and in association with *P. phaseoloides* in blocks under continuous grazing with two different stocking rates; 1 animal/ha during the dry season and 2 animal/ha during the wet season.

Results were obtained when populations were highest (April to July); however, infestation generally was very low. The differences among establishment systems could be due to the effect of N from the legume in the treatment with legume strips and better management of the grass in the treatment with legume blocks when compared with grass in pure stand (Table 1).

Table 1. Infestation levels of nymphs and adults of the spittlebug *(Aeneolamia reducta)* in *Brachiaria decumbens* paddocks under three management systems at Carimagua, 1980.

Treatment	Spittlebug masses (No./m²)	Adults (No./m²)
B. decumbens + *Pueraria phaseoloides*, as strips	1.03 a[1]	0.60 a
B. decumbens + *Pueraria phaseoloides*, as protein banks	0.94 a	0.38 a
B. decumbens, pure stand	0.15 b	0.15 b

[1] Means followed by the same letter do not present significant difference at 0.05 level (Duncan's Multiple Range Test).

A new concept within the Entomology Section is to analyze and quantify the losses caused by different groups of insect pests attacking legumes and grasses. An experiment was designed utilizing *B. decumbens* and *A. gayanus* to measure the effect of spittlebug damage on the quality of forage produced by these grasses at two sites in Carimagua. A similar experiment was done on a farm located in the Cauca Valley of Colombia utilizing a different grass, *Pennisetum clandestinum,* and a different genus of spittlebug, *Zulia* sp.

Preliminary observations showed that spittlebug drastically affected the quality of both *B. decumbens* and *P. clandestinum*. In forage damaged by spittlebug, percentages of N and S were significantly lower than in undamaged forage in both locations under different conditions of soil fertility (Table 2).

No spittlebug damage was detected on *A. gayanus.* This is in accord with previous observations that while the insect is sometimes found on this species, no damage occurs.

It is thought that the growth habit of dense, compact clumps offers a strong barrier to young nymphs attempting to reach the soft plant parts and growing points. Whenever nymphs have been found, they are only on the external stems of the clumps.

Other plant characteristics such as stem hardness, presence of hairs and the chemical composition of the plant might be other factors that apparently make *A. gayanus* an unsuitable host for the spittlebug. Host-plant resistance studies were initiated at several locations in 1980 to investigate further the basis of resistance.

Table 2. Effects of two species of spittlebug *(Aeneolamia reducta* and *Zulia* sp.) on forage quality of *Brachiaria decumbens* and *Pennisetum clandestinum*, at two locations, 1980.

Host species	Spittlebug species	Location	Type of Sample[1]	Plant tissue contents (%)	
				N	S
Brachiaria decumbens	*Aeneolamia reducta*	Carimagua (Site 1)	A	1.18	0.13
			B	0.48	0.07
Brachiaria decumbens	*Aeneolamia reducta*	Carimagua (Site 2)	A	1.48	0.15
			B	0.36	0.10
Pennisetum clandestinum	possibly *Zulia* sp.	Coconuco (Cauca)	A	3.46	0.17
			B	1.96	0.16

[1] A = Normal leaves; B = Leaves heavily damaged by spittlebug

Yellow Aphid

A preliminary analysis of the effect of the yellow aphid (*Sipha flava* Forbes) on forage quality of *A. gayanus* was begun this year in Carimagua. Data were obtained from collections of red leaves with aphids, red leaves without aphids but free from any disease or mechanical damage, and healthy green leaves. The quality of *A. gayanus* was severely affected by aphids, especially percentages of N and S, which are significantly lower in aphid-affected leaves (Table 3). Because of this significant reduction in forage quality of *A. gayanus,* aphids could become an important pest of this grass if attacks are persistent.

Table 3. Preliminary analyses of the possible effect of the yellow aphid *(Sipha flava* Forbes) on forage quality of *Andropogon gayanus* at Carimagua, 1980.

Treatment	No. of samples	Plant tissue contents (%)	
		N	S
Normal leaves	18	1.505 a[1]	0.137 a
Red leaves with aphids	10	1.224 b	0.116 b
Red leaves without aphids	10	0.918 c	0.085 c

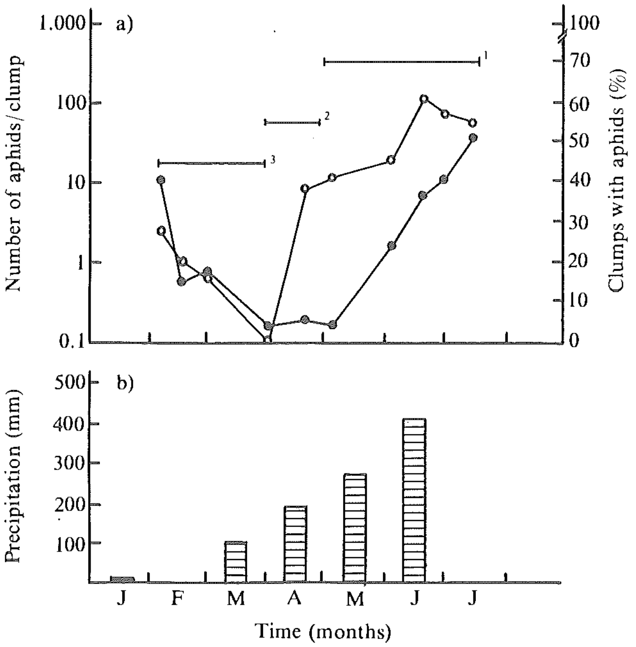
[1] Means followed by the same letter do not present significant difference at 0.05 level (Duncan's Multiple Range test).

Population dynamics. Population dynamics studies of the yellow aphid were initiated this year. Mean numbers of aphids per clump of *A. gayanus* and the percentage of clumps with aphid infestation recorded in six paddocks in Carimagua are shown in Figure 2.

Three behavioral phases of the aphid population were recognized in relation to rainfall, the main effect of the environmet.

The survival phase occurs from the middle of the dry season to the beginning of the wet season (January-April). During this period, initially a large percentage of clumps were infested with very few aphids. At the end of this phase, a small percentage of clumps were infested with few aphids.

During the multiplication phase, a rapid and progressive increase in the aphid population was observed in a few clumps, those that remained infested from the survival phase. This period commences at the start of the wet season (April) and is characterized by localized infestation in patches, easily observed because of the reddish-purple leaves which contrast with the natural green color of the paddock.



[1] Dispersion in the paddock

[2] Multiplication

[3] Survival

Figure 2. *a) Population fluctuations of the yellow aphid,* **Sipha flava,** *and percentage of infestation of clumps of* **Andropogon gayanus;** *and b) first semester precipitation, at Carimagua, 1980.*

The dispersion phase (invasion of the paddock) occurs during the period of highest rainfall (May-July). Aphid populations increase progressively and it is easy to observe a high percentage of affected clumps, hosting a very high aphid population. During this phase, the heaviest damage occurs. It is very important to mention that the initiation of the phases may change from year to year due to environmental changes.

Control. Burning may be a good method of control. The end of the dry season in Carimagua may be the best time to burn because the grass is dry. If burning is not done at the end of the dry season, localized burning of infested patches in April, may also be effective. A systemic insecticide could be used to prevent or reduce effects of the dispersion phase.

During the third phase, heavy grazing (high stocking rate) could also be recommended to reduce foliage and minimize the aphid population. Systematic and permanent monitoring of the paddocks to understand and record what is happening with the grass and with the insect population in the field is required.

False Army Worm

Preliminary observations. The false army worm *(Mocis latipes* Guenne) has been reported in Carimagua since 1975. Infestations were very high during 1977 on the native grass *Paspalum plicatulum* and on *A. gayanus.*

Some observations of populations were made in 1980. In early May adults (probably second generation) were seen and oviposition noted. Later that month first-instar larvae were observed. Last-instar larvae were seen during the first half of June and later that month, pupae and first adults were present. By the first half of July more adults and oviposition were again recorded.

When rainfall records at Carimagua are compared with sudden heavy outbreaks that cause heavy defoliation of *A. gayanus,* most damage occurs after a severe dry season (December-March). Outbreaks are also more serious when the rainy season begins slowly with less than average rainfall, usually as isolated showers.

While little is known about *M. latipes* in the Carimagua environment, some preliminary and general recommendations would be the following: a) new paddocks must be monitored, especially from March to May, to detect the presence of the insect; b) native grasses, such as *Setaria* spp., must be checked for oviposition of *Mocis* and that grass should be controlled; and c) the fungus *Bacillus thurigiensis,* which is effective against first-instar larvae of *Mocis,* could be applied.

During 1981, more extensive studies will be initiated to better understand this insect pest. It can presently be considered a secondary pest of *A. gayanus.*

Regional Trial Surveys

During the past two years, evaluations of Regional Trials and forage introductions have been made at 36 sites within eight countries. Systematic evaluations, using the ranking system developed for pests and diseases, have given an idea of insect and disease incidence, abundance and insect preference in each ecosystem. In general, the different groups of insects found are more or less evenly distributed throughout the ecosystem. Groups of insects such as Homoptera, Heteroptera, Coleoptera, Hymenoptera, Diptera and Lepidoptera are present in all ecosystems under study; however, the genera and species found change from one ecosystem to another and from one season to another. These changes are also reflected in the type and severity of damage recorded in each ecosystem and each season.

Germplasm Bank Evaluations

Evaluation of the introductions in Carimagua and CIAT-Quilichao continued throughout 1980. To evaluate the germplasm, insect damage was divided into two groups:

Chewing insects. This group includes Coleoptera, Lepidoptera, Orthoptera and Hymenoptera (ants), with Coleoptera being the most important. The family Chrysomelidae, including several genera and species, is especially critical. Other orders are considered secondary or potential pests.

Sucking Insects. This group is considered the most important because their damage is "systemic" and many species are vectors of diseases. They affect plants' vascular systems and when their infestation is heavy, the forage deteriorates greatly. Homoptera and Heteroptera, including several genera and species, comprise this group.

Insect damage ratings have been integrated into the forage production and persistence system by measuring forage losses due to chewing insects and by measuring losses in forage production and quality caused by sucking insects. This year studies were initiated to develop techniques to measure and quantify the effect of insect damage on forage production and quality.

Forage Improvement

The two Forage Improvement sections undertake in-depth evaluations of certain legume and grass species in order either to select materials which meet the requirements of the Tropical Pastures Program or to improve species through breeding to combine desired characteristics.

Improvement of Legumes

Stylosanthes capitata

Primary aims of the *Stylosanthes capitata* breeding program are to gain high DM production and seed yield. Drought resistance and the ability to produce leaves and seed in the dry season are also sought. Resistance to anthracnose and the stemborer are other important objectives.

In July 1979 about 2000 F_2 seedlings of each of the crosses CIAT 1019 x 1097 (early x late), CIAT 1078 x 1019 (late x early) and CIAT 1097 x 1078 (late x late), together with parental controls were established at Carimagua. Seedlings were fertilized with minimum quantities of all essential nutrients. The area was later oversown with *Andropogon gayanus.*

The early x late crosses combined most of the characters required. At the end of the dry season (March 1980) populations were evaluated for four important characters.

Data in Table 1 show that the vigor and high DM production of the late parents, 1078 and 1097, had been transferred to a high proportion of the progeny of the early x late crosses. The late-flowering habit of 1078 and 1097 was also transferred to a significant percentage of the progeny of the early x late crosses. More importantly, progenies of these crosses, especially 1019 x 1097, had a significant proportion of high seed yielders (the high seed yield of the early 1019 was not evident as much of its seed had dropped by the time of the evaluation).

After the March 1980 dry season evaluation, a number of vigorous, green, drought-resistant plants with seed production were selected — 87 in 1019 x 1097 and 61 in 1078 x 1019. In May 1980, after the wet season had started in Carimagua, all the selections were examined for amount and vigor of regrowth; about one-half showed excellent regrowth.

In early August 1980, the second Carimagua breeding trial was established with F_3 populations from 69 F_2 selections which had been most vigorous and persistent in the 1979 trials. Also planted were 11 F_2 populations incorporating mainly crosses with one of the basic parents CIAT 1019, 1078 or 1097, and several Venezuelan ecotypes. The Venezuelan ecotypes could possibly contribute anthracnose resistance and greater adaptability to less acid soils.

Results at the end of November 1980 indicated that about one-half of the F_3 lines are more vigorous than the late parents. Flowering appeared to be late but was also profuse. Evaluations for all important characters will be repeated at the end of the dry season in March 1981.

Seed from the best F_3 selections will be used for F_4 single plant populations. However, some of the F_3 lines already appeared fairly uniform, so bulked F_4 seed from the best selections could be used for small preliminary plot trials in several areas.

It is apparent that some of the main objectives of the breeding program could be achieved, especially the needed combination of late vigor and high seed production. The CIAT 1078 x 1019 lines should also have a good level of anthracnose resistance.

Table 1. Evaluation of plants for various rating classes of four agronomic characters in three F_2 populations of *Stylosanthes capitata* and the parents.

Character and rating class	Mean percentages of plants for cross or accession[1]						
	1019 x 1097	1078 x 1019	1097 x 1078	1019	1078	1097	CV
Vigor[2]							
1	31.1 b[3]	20.2 c	12.6 c	81.9 a	15.0 c	11.3 c	19.909
2	45.3 b	54.3 a	57.8 a	13.4 c	56.1 a	56.6 a	12.410
3	23.6 a	25.5 a	29.7 a	4.7 b	28.9 a	32.1 a	32.692
Stemborer resistance[4]							
1	49.7 a	25.9 b	25.8 b	58.1 a	23.8 b	24.4 b	21.179
2	39.4 cd	51.1 ab	46.5 bc	35.1 d	59.3 a	52.4 ab	13.692
3	9.4 bc	17.1 a	20.9 a	5.7 c	14.9 ab	19.4 a	25.527
4	1.4 c	5.9 a	6.6 a	1.0 c	2.0 bc	3.7 b	33.527
Flowering							
Early	56.0 a	35.6 b	12.6 c	67.0 a	13.9 c	26.6 bc	35.556
Late	44.0 c	64.4 b	87.3 a	33.0 c	86.0 a	73.3 ab	19.399
Seed production[5]							
1	13.0 b	24.3 ab	38.1 a	23.1 ab	35.6 a	27.0 ab	43.348
2	39.1 a	48.6 a	48.8 a	52.5 a	48.4 a	54.9 a	25.749
3	33.3 a	20.7 bc	12.7 c	24.4 ab	13.4 c	16.6 bc	31.752
4	14.6 a	6.3 b	0.3 c	0.0 c	2.2 c	1.4 c	50.476

[1] Total plants: 1019 x 1097=2354; 1078 x 1019=1899; 1097 x 1078=1999; 1019=580; 1078=581; 1097=566.

[2] Vigor: 1=30-60 cm width; 2=60-90 cm; 3=90-120.

[3] Mean percentages with different letters are significantly different by Duncan's Multiple Range Test.

[4] Stemborer resistance: 1=no attack; 2=insignificant attack; 3=moderate attack; 4=severe attack.

[5] Seed production/plant: 1=none, but flowering; 2=10-100 g; 3=100-200 g; 4=200-300 g.

Stylosanthes guianensis

Anthracnose has proved to be devastating on most *S. guianensis* ecotypes. Breeding and genetic work is directed primarily to clarifying the genetic basis of resistance to anthracnose and developing enhanced levels of stable resistance. Additional studies of breeding methodology provide information which will facilitate the handling and evaluation of breeding materials.

Genetic studies. A group of *S. guianensis* ecotypes typified by their late flowering habit and viscid stems (the so-called "tardíos") are generally considered resistant to anthracnose. In an effort to understand the genetic basis of the resistance shown by these "tardíos", six different F_2 populations from "common" (susceptible) x "tardío" (resistant) crosses were established at Carimagua in September 1980. For each cross, both parents, the F_1, and 30 F_2 seedlings were vegetatively propagated to establish a trial of replicated genotypes which allows separation of genetic and environmental variation in reaction to anthracnose.

Breeding. A field screening of over 100 *S. guianensis* ecotypes planted in 1979 in Carimagua by the Plant Pathology Section showed several to have some level of anthracnose resistance in that environment. The majority of resistant ecotypes are "tardíos", although a few common ecotypes also appear to have some resistance after one year in the field. Differences in symptom severity have been noted among "tardío" ecotypes.

Both common and "tardío" ecotypes selected from this screening trial will be the basis of a project to develop a genetically diverse *S. guianensis* population with enhanced and stable anthracnose resistance. Intermating resistant ecotypes of diverse type and origin followed by cyclic selection and genetic recombination should allow the accumulation of genes for resistance and ultimately provide a source of enhanced resistance for future cultivar development. As subsequent field screenings of ecotypes identify additional sources of resistance, these will be incorporated into the population.

Other studies. To determine the degree of cross-compatibility between the "tardío" type and the common type of *S. guianensis* (var. *guianensis*) and between those two types and *S. guianensis* var. *intermedia*, a complete five-parent diallel [including two "tardíos", two commons and one var. *intermedia* (cv. Oxley)] was formed. Fertility of F_1 hybrids, as measured by percentage stained pollen (acetocarmine stain), showed no fertility barrier between the common and the "tardío" types. Both types produced fewer fertile hybrids with the var. *intermedia* line. The high pollen fertility of common x "tardío" F_1 plants is reflected in the normal seed set of these hybrids. Hybrids with Oxley have produced almost no seed.

In this same experiment, significant heterosis for shoot length was detected for common x "tardío" F_1's while within-group F_1's (common x common and "tardío" x "tardío") did not differ from the mid-parent.

These results show that the genetic difference between the common and the "tardío" types (indicated by between-type heterosis) is not so extreme as to cause fertility barriers between the two types. Both the common and the "tardíos" are so distinct from Oxley (a fine-stemmed stylo) that serious fertility barriers exist.

Table 2. Effects of photoperiod on days to flower of nine *Stylosanthes guianensis* "tardío" ecotypes.

Ecotype	Days to flower	
	Short days[1]	Normal days[1]
1283	33.5 a[2]	41.0 b
1021	35.0 a	86.0 g
2160	37.5 ab	60.5 e
1959	42.0 bc	86.0 g
104	42.5 bcd	77.0 f
1280	43.5 bcd	86.0 g
2028	45.0 cd	86.0 g
2180	45.0 cd	86.0 g
1020	48.0 d	64.0 e

[1] Short days = 9 hours light/15 hours darkness; normal days ± 12 hours light/12 hours darkness

[2] Means followed by the same letter do not differ by the t-test at the 0.05 probability level.

Both long-and short-day flowering induction responses are reported for *S. guianensis*. Short-day (nine-hour) treatment of nine "tardío" accessions showed a clear response of these types to short days with a significant reduction in days to flower compared with plants grown under normal daylengths (+ 12 hr) (Table 2). Significant differences among ecotypes in days to flower were found. These data on short-day flowering response have direct, practical implications since they indicate a simple, effective method of decreasing generation time in a breeding program.

Centrosema spp.

Objectives of *Centrosema* breeding are to obtain tolerance to high soil acidity and Al levels, to low soil fertility and also to have high seed production. *Centrosema pubescens* is an important pasture legume in South America; seed has been sold for a decade or more and will likely continue to be marketed. Current cultivars, however, are not well adapted to the oxisols and ultisols of South America.

In an early 1978 glasshouse trial, selected *C. pubescens* lines and several other species were grown in Carimagua soil with limited applications of a complete nutrient solution. Plants were inoculated with the CIAT 590 strain of *Rhizobium*. Several *C. pubescens* lines with medium to good acid tolerance, and the lines *C. macrocarpum* 5062 and *C. schiedeanum* 5066, both highly tolerant, were selected for a half-diallel crossing program.

Not all crosses were achieved, including those with *C. schiedeanum* 5066. However, a cross was successful between *C. pubescens* 5052 and *C. macrocarpum* 5062, both of which had been collected in the savannas of the Meta area of Colombia. Both accessions, and especially 5062, have persisted and performed well in the Carimagua introduction trials. At the end of the second dry season in March 1980, *C. pubescens* 5052 produced moderately and *C. macrocarpum* 5062 gave excellent production, while many other *Centrosemas* in this trial had died.

The F_1 plants from the *C. pubescens* crosses and the *C. pubescens* 5052 x *C. macrocarpum* 5062 cross were grown in the field at CIAT-Palmira. Plants were selected in the F_2 for high acid tolerance, first by screening large populations in sand culture for 4-6 weeks and then by growing the tolerant plants in Carimagua soil for 6-8 weeks.

None of the F_2 populations from the *C. pubescens* crosses showed high acid tolerance in sand culture. Selections grew slowly in Carimagua soil and were usually yellow-green in color. Consequently it was decided to concentrate on screening populations from the *C. pubescens x C. macrocarpum* cross.

In the first screening the high Al level (8 ppm) in sand culture prevented nodulation. In the second experiment with 6 ppm Al, nodulation was good (more than 80%) in CIAT 5052 and the cross, but relatively poor in *C. macrocarpum*. This species may require a different type of *Rhizobium* from *C. pubescens*. These results do show it is possible to transfer the high acid tolerance of *C. macrocarpum* to about 20% of the F_2 progeny.

The acid-tolerant F_2 selections from the *C. macrocarpum* cross, with controls and parents, have been grown in the field at CIAT- Palmira. About one-third had good seed production and half of these were heavy seeders. The best F_3 selections will be grown in Carimagua in 1981. Results at Carimagua with the unselected F_2 generation are promising, with about 20% of the plants showing vigorous spreading growth.

In view of the possibility of markedly increasing the acid tolerance and adaptability of *C. pubescens*, more crosses between some *C. pubescens* types and *C. macrocarpum* introductions have been made. Their F_2 populations will be evaluated for acid soil tolerance early in 1981 and the most promising lines established at Carimagua.

Leucaena spp.

The leguminous tree *Leucaena leucocephala* can produce high-protein forage throughout the year as a supplement or in association with grasses. Because it roots deeply and resists drought, it could be valuable during the dry season in many areas.

No *L. leucocephala* ecotypes have been found highly tolerant to acid soil conditions, either among commercial cultivars or available introductions. Fertile hybrid lines *(L. leucocephala* cv. Cunningham x *L. pulverulenta)* from F_1 backcrossed twice to Cunningham provided a new source of variability even though the parents have only moderate acid tolerance.

The hybrid interspecific selections are evaluated in the same manner as *Centrosema*, first in sand culture and later in Carimagua soil. Ten separate screenings involving more than 45,000 seedlings from the original fertile backcross selections have been completed. Fewer than 3% (1231) of the seedlings have been selected for acid tolerance; these are growing in the field at CIAT-Palmira for observation and production of third generation, open pollinated seed.

Foliar analyses of the acid-tolerant and intolerant plants in Carimagua soil showed that Al contents of the leaves of intolerant plants were two to three times greater than in the tolerant plants. It seems that tolerant selections have a mechanism for restricting the uptake and transport of Al in the plant. Only tolerant plants nodulate freely, so it could be that the reduced Al uptake creates in the roots a mineral balance, especially of P and Ca, favorable to nodulation.

Results of the 1980 Carimagua trials with second generation, open-pollinated seed are similar to those obtained in the CIAT glasshouse. Small but significant numbers of plants in each hybrid line at Carimagua nodulated well and appear to have deep root penetration. This latter very important character will be measured in March 1981 at the end of the dry season.

It is essential to know whether the high acid tolerance in selections from second generation, open-pollinated seed will be transmitted to a high percentage of their seedling progeny in the next generation. Current glasshouse results show that among the lines, a high proportion of their seedlings from the third generation, open-pollinated seed are either tolerant or intolerant, indicating stabilization of acid tolerance in the best lines.

Improvement of Grasses

Andropogon gayanus

A detailed quantitative study of *A. gayanus* CIAT 621 was initiated in 1979. Analysis of data recorded on vegetative replicates of 1000 clones established in Carimagua and CIAT-Quilichao will allow estimation of broad-sense heritabilities, genetic correlations and genotype-environment interactions for a series of quantitative traits such as forage yield, leaf:stem ratio, nutritional quality, plant height, flowering date, and seed production.

This information will identify traits for which significant genetic variability exists and will provide a sound basis for designing future selection schemes.

Preliminary analyses, over locations, indicate that significant genetic variation exists for several traits (Table 3). The moderately large heritability estimates suggest that selection should be effective in changing the population means for these traits.

Table 3. Means and heritability estimates for five traits in *Andropogon gayanus* 621.

Traits[1]	Mean	±	s.e.	Heritability
Number of flower stems[2]	13.70	±	0.24	0.40 **
Total dry weight yields[2] (g)	130.60	±	1.75	0.47 **
Percent leaves[2]	45.90	±	0.41	0.67 **
Eight-day regrowth length[3] (cm)	36.40	±	0.13	0.44 **
Leaf width[3] (cm)	1.66	±	0.006	0.69 **

[1] Traits measured on single-plant experimental units with two replications at each of two locations.

[2] At nine weeks from cut made on June 17, 1980.

[3] Three leaves per plant.

As data accumulate on CIAT 621 and other *A. gayanus* introductions, selection of clones will be initiated to develop a later, leafier synthetic with more uniform flowering response. Other traits of interest in improved cultivars may include reduced plant height and improved seed production and nutritional quality. Several cycles of selection and recombination will be needed to develop materials improved for a number of traits.

Agronomic Evaluations

During the past year, 25 *Brachiaria* spp. and 36 *Panicum maximum* ecotypes were established in small, unreplicated plots at Carimagua for initial observation. This represents essentially the complete *Brachiaria* collection and a sample of the *P. maximum* collection selected at CIAT-Quilichao for vigor and high leaf:stem ratio.

A small-plot, two-replicate trial of 20 new *A. gayanus* ecotypes was established at Carimagua to compare these introductions with the original CIAT 621. Preliminary observations indicate a considerable range of variation among accessions for flowering date, growth habit and leaf:stem ratio.

Soil Fertility and Plant Nutrition

The Soil Fertility and Plant Nutrition Section continued to work this year in three areas: (a) germplasm screening for tolerance to Al toxicity and low available P in the soil, (b) estimating the nutrient requirements of promising germplasm during the establishment period; and (c) evaluating the soil fertility-plant nutrition status in representative sites of the regional trials network.

Tolerance to Al Toxicity and Low Available P

The hematoxylin test (CIAT Trop. Past. Prog. 1979 Ann. Rept.) was used during preliminary mass screening for tolerance to Al toxicity. All forage accessions are grown in three Al treatments (0,5 and 10 ppm Al) in a nutrient solution with low P supply (0.5 ppm). The 5 ppm Al level was chosen according to the amount of Al in the soil solution of the Carimagua Oxisol and is closely related to percent Al saturation under natural conditions.

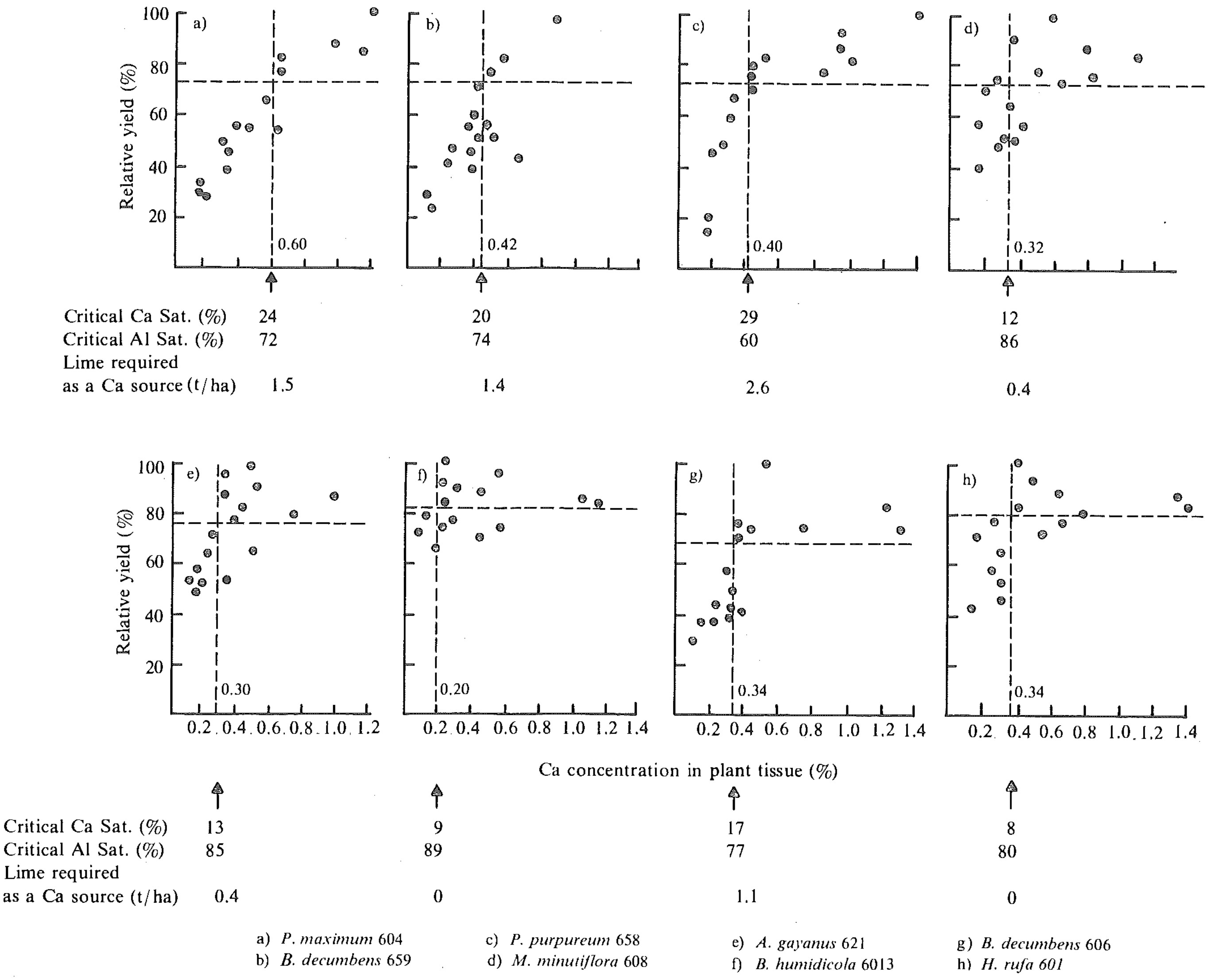
Work during 1980 included preliminary screening of additional *Desmodium* species (200 accessions) and *Stylosanthes* species (50 accessions). In general, tolerance and sensitivity to high Al content were closely related to original collection sites. For example, most of the *Desmodium canum, tortosum, intortum, uncinatum,* and other species introduced from Mexico (Campeche, Yucatan) and Colombia (Antioquia, Valle del Cauca) were Al-sensitive, probably due to the relatively calcareous soils of these regions. Of the 343 *Stylosanthes* spp. accessions screened, 237 were tolerant to Al toxicity, while 81 of 180 *Desmodium* spp. accessions were tolerant. Results for other pasture legumes were reported last year (CIAT Trop. Past. Progr. 1979 Ann. Rept.).

In another experiment eight pasture grasses and four legumes were evaluated under different Al (95-75% sat.) and P (1.5-34.1 ppm Bray II) stresses in the field at Carimagua. This experiment was established in 1979 on plots having residual effects from lime and P applied two years earlier. The differential responses of the pasture accessions were measured as DM production over three harvest periods covering both dry and rainy seasons.

Under high Al and P stress conditions (95% Al sat. and available soil P less than 2 ppm) *Brachiaria humidicola* 679, *B. brizantha* 665 and *B. decumbens* 664 and 6012 yielded significantly more DM than *Panicum maximum* 604, *B. ruziziensis* 664, *B. radicans* 6020 and *B. mutica* 6047. Among the legumes, *Stylosanthes capitata* 1315 and *Desmodium ovalifolium* 350 performed well under high Al and P stress conditions although their DM yields were less than the grasses. *Zornia latifolia* 728 and *S. hamata* 147 initially (first cut) performed well, but their yields decreased sharply due to disease problems. As the soil P level was increased under Al stress, DM yields of most grasses and legumes increased. Under slightly lighter conditions of Al stress (less than 90% but over 75% Al sat.), most of the grasses and legumes again increased their DM production. *Brachiaria decumbens* 6012, for example, achieved 90% of its maximum yield and *B. brizantha* 665 and *Desmodium ovalifolium* produced 64% of their maximum yields still under Al and P stress (89% Al sat. and available P less than 2 ppm).

Among the grasses, *B. humidicola* 679 was the most tolerant of Al stress (95% Al sat.). Yield of *B. brizantha* 665 was affected at 86% Al saturation and yields of *B. decumbens* 664 and *P. maximum* 604 decreased at 82% Al saturation.

The response of the Al-tolerant grasses was mainly related to Ca requirements rather than to the effect of liming on Al saturation. Critical Ca concentrations in plant tissue were determined in eight tropical grasses grown in another field experiment at Carimagua. Figure 1 shows the critical Ca concentration in the tissue as well as the critical Ca and Al saturation levels for the grasses. Based on these critical levels the lime required as a Ca source was determined using an equation developed at CIAT for liming acid mineral soils to compensate crop Al tolerance. The results show differential lime requirements as a Ca source among the pasture grasses.



Critical Ca Sat. (%)	24	20	29	12
Critical Al Sat. (%)	72	74	60	86
Lime required as a Ca source (t/ha)	1.5	1.4	2.6	0.4

Critical Ca Sat. (%)	13	9	17	8
Critical Al Sat. (%)	85	89	77	80
Lime required as a Ca source (t/ha)	0.4	0	1.1	0

Figure 1. *Critical Ca concentrations in the tissues of eight tropical grasses grown on a Carimagua Oxisol under field conditions.*

In another field experiment at Carimagua, a new group of *Stylosanthes* and *Zornia* accessions were grown under different Al and P stress conditions. Most of the *S. capitata* accessions were more Al-tolerant than were the *Zornia* spp. accessions (Fig. 2).

Among the *S. capitata* accessions, CIAT 1691, 1943, 1441 and 1414, followed by 1318, 1323, 1642 and 1504, were the most Al-tolerant. The first four had yield reductions of 20% or less under high Al saturation (95%); and yields of the others were reduced only 20% under Al stress (more than 86% Al saturation). The *Zornia* spp. accessions 9292, 9286, 9284, 9600, 9267, 9258 and 9648 were the most Al-tolerant (50% yield reduction under 95% Al saturation and only 20% yield reduction at 86% Al saturation).

Many *S. capitata* accessions produced 80% or more of their maximum yields under low concentrations of P (less than 2 ppm). A few of them (*S. capitata* 1899 and 1325) required higher external P levels to produce 80% of maximum yields (Fig. 3).

None of the *Zornia* spp. accessions appear to be responsive under low P. In general most of the Al-tolerant *S. capitata* accessions were also tolerant to P stress.

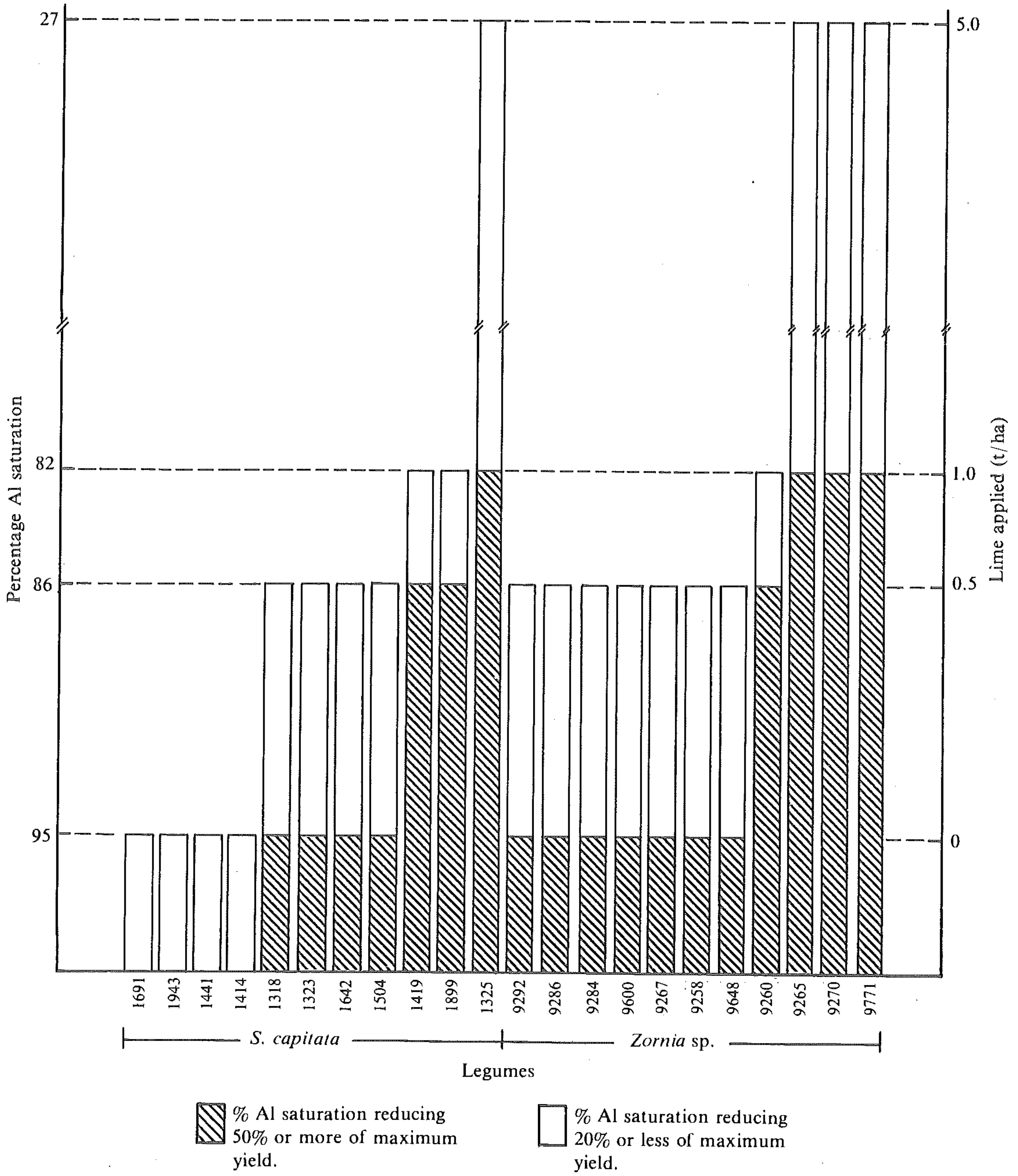


Figure 2. *Differential responses of 22 tropical pasture legume accessions under different Al stress conditions in the field at Carimagua.*

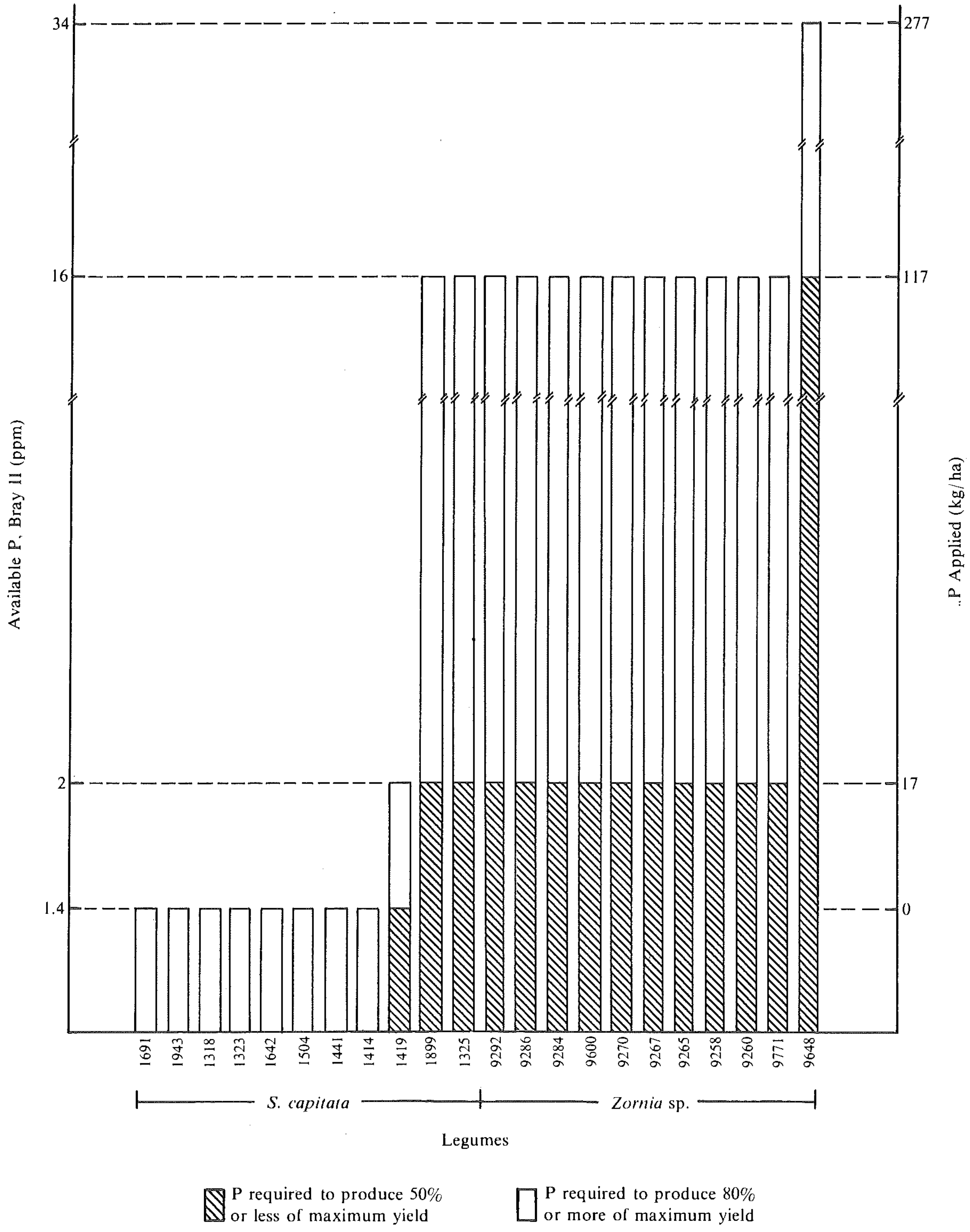


Figure 3. *Differential responses of 22 tropical pasture legume accessions under different P stress conditions in the field at Carimagua.*

Nutritional Requirements of Promising Grasses and Legumes

As part of an overall assessment of the nutritional requirements for establishment of promising pasture species, several greenhouse and field experiments were set up covering initially the most limiting nutrients in the acid infertile soils.

N Demand of Grasses

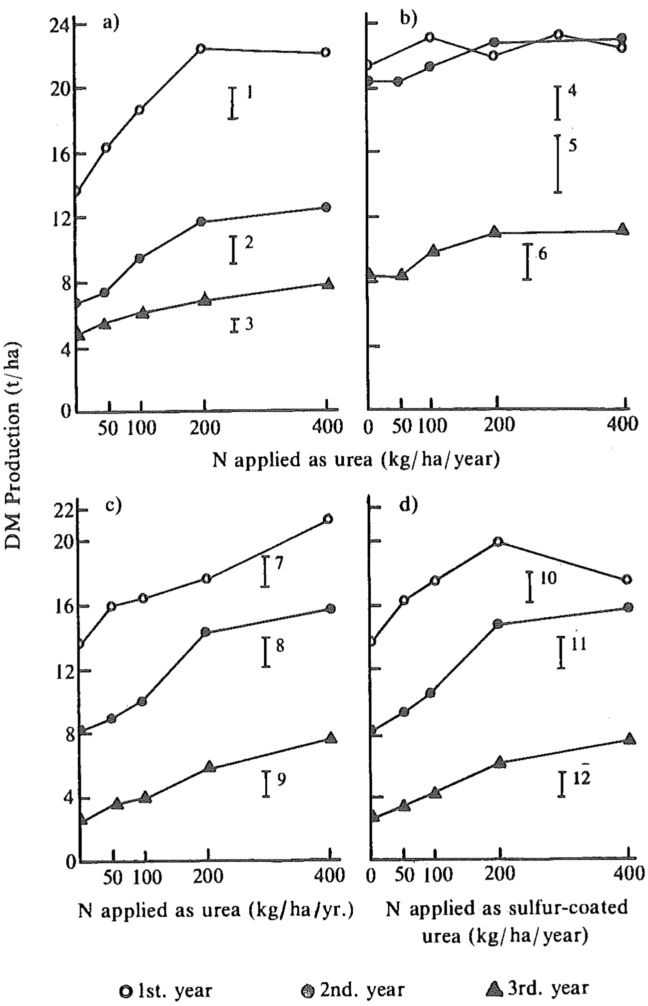
Nitrogen fertilization of pasture grasses is not considered feasible for the Program's target area since it is assumed the N will be supplied by the legume in the mixtures. However, in order to compare the legume's N contribution, the response of grasses to N must be understood.

A field experiment established in 1978 at CIAT-Quilichao with three tropical pasture grasses was evaluated in its third year. Two main objectives were considered in this evaluation: (a) to study the lack of N response by *A. gayanus* 621, compared to *P. maximum* 604 and *B. decumbens* 606 (CIAT Trop. Past. Prog. 1979 Ann. Rept.), and (b) to determine the N contribution by the legumes in the mixtures during three years.

Figure 4 shows the response of the three grasses to N fertilization over three years. *Panicum maximum* 604 and *B. decumbens* 606 responded significantly to N fertilization during the three years in contrast to *A. gayanus* 621. On the other hand, *A. gayanus* also had a much higher yield potential than the other two grasses at all N rates during the first two years.

Yields of *P. maximum* and *B. decumbens* decreased significantly the second year and yields of all the grasses decreased the third year. These yield reductions were attributed to a sharp decrease in K content in grass tissues the last two years (Fig. 5). Although the grasses had received a basal application of 60 kg K_2O/ha and regular maintenance applications of 50 kg K_2O/ha, large amounts of K were extracted under a cutting regime.

The use of sulphur-coated urea (SCU) as an alternative N source with *B. decumbens* 606 gave DM production levels similar to plots fertilized with urea in applications after each cut. Hence, the advantages of SCU over urea might be only the single application each year and the S contributed.



[1] LSD(0.05)=2
[2] LSD(0.05)=1.8
[3] LSD(0.05)=0.6
[4] LSD(0.05)=2
[5] LSD(0.05)=3.5
[6] LSD(0.05)=2.3
[7] LSD(0.05)=2
[8] LSD(0.05)=2
[9] LSD(0.05)=1.5
[10] LSD(0.05)=2
[11] LSD(0.05)=2
[12] LSD(0.05)=1.5

Figure 4. *Dry matter production of three tropical pasture grasses as a function of N rates and N sources, during three years at CIAT-Quilichao. a) Panicum maximum 604; b)* **Andropogon gayanus** *621; c), d)* **Brachiaria decumbens** *606.*

Table 1 shows the N content and N recovery of the three pasture grasses during three years. In addition to the lack of N response by *A. gayanus* 621, the percentage recovery of the applied N was much lower than in the other two grasses during the first two years but similar the third year at rates over 100 kg N/ha/yr. However, due to its lack of N response and higher yield potential, *A. gayanus* 621 still proved to be a more efficient user of the native soil N (Table 2).

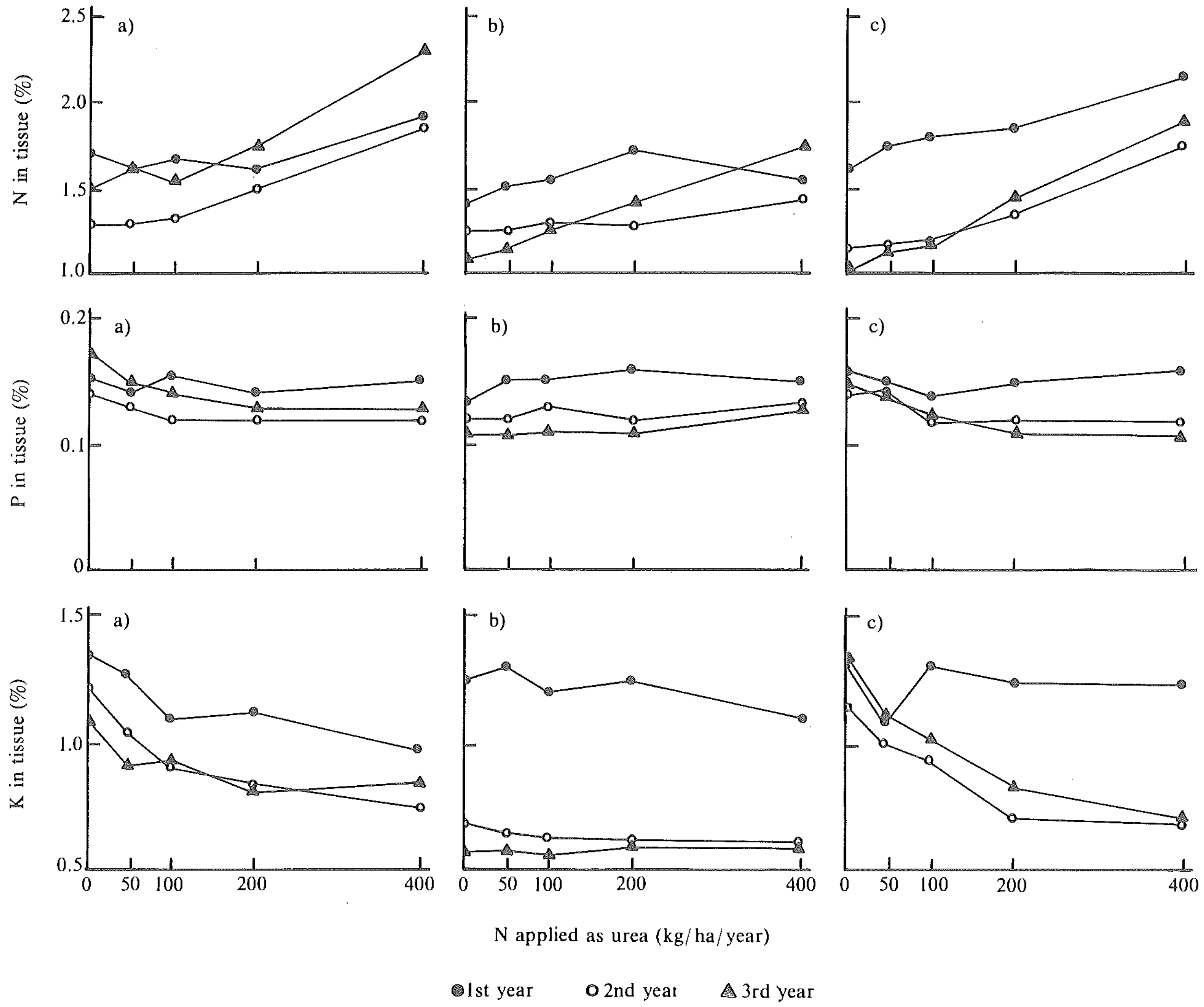


Figure 5. *Changes in plant nutrients in three tropical forage grasses as a function of N treatments, during three years in a cutting regime at CIAT-Quilichao. a)* **Panicum maximum** *604; b)* **Andropogon gayanus** *621; c)* **Brachiaria decumbens** *606.*

Table 2 also shows the N contribution of three legumes (*S. guianensis* 136 and 184, and *C. pubescens* 438) measured as effective N uptake by the three grasses. Effective N uptake with legumes the first year was negative. Legumes probably not only contributed any N but also competed with grasses for soil N. The second year the legumes contributed N to *P. maximum* 604 and *B. decumbens* 606. The N supplied by the legumes in these mixtures was between 50 and 200 kg N/ha/yr. In the case of *A. gayanus* 621, no N contribution was measured from the legumes; this may be attributed to a continuous competition for the native soil N without using the N supplied by the legumes.

A field experiment was conducted at Carimagua over 26 months on *B. decumbens* pastures with one, two and three years of grazing and under different levels of N fertilization. The annual N application rates were 0, 50, 100, 200 and 400 kg/ha plus a basal annual application of P, K, S, and Mg. During the first year, yields in the check plots with basic fertilization had significant yield reductions which were also related to pasture age; the yield differences were only eliminated by N fertilization (CIAT Ann. Rept., 1978). During the two dry seasons of the experiment, no N response was observed and significant responses to N fertilization were obtained only at the beginning of the experiment and at the early and late months of the rainy season. Both the high, concentrated rainfall in the area and the low water retention capacity of the Carimagua Oxisol are favorable conditions for nitrogen lixiviation and other nutrients.

Table 1. Dry matter yield, N content in plant tissue and N recovery of three pasture grasses under a cutting regime at CIAT-Quilichao, during three years.

Grasses	N applied	DM yield (t/ha)			N content in tissue (%)			N recovery (%)[1]		
	(kg/ha)	1st yr.	2nd yr.	3rd yr.	1st yr.	2nd yr.	3rd yr.	1st yr.	2nd yr.	3rd yr.
Panicum maximum 604 [2]	0	14	7	5	1.7	1.3	1.5	–	--	--
	50	16	7	6	1.6	1.3	1.6	55	20	36
	100	19	10	6	1.7	1.4	1.6	79	48	25
	200	20	12	7	1.9	1.5	1.8	74	47	25
	400	22	12	8	1.9	1.9	2.3	49	38	27
Andropogon gayanus 621 [2]	0	21	21	8	1.5	1.3	1.1	--	--	--
	50	23	20	8	1.5	1.2	1.1	76	0	0
	100	22	21	10	1.5	1.3	1.3	25	21	34
	200	23	23	11	1.5	1.3	1.4	14	15	30
	400	22	23	11	1.5	1.5	1.7	8	13	23
Brachiaria decumbens 606 [2]	0	13	8	3	1.6	1.1	1.0	--	--	--
	50	15	9	4	1.7	1.1	1.1	82	20	27
	100	16	10	4	1.8	1.2	1.1	74	30	18
	200	18	14	6	1.8	1.4	1.4	55	55	30
	400	21	16	7	2.1	1.8	1.9	57	46	28
Brachiaria decumbens 606 [3]	0	13	8	3	1.6	1.1	1.0	–	--	--
	50	16	10	4	1.7	1.2	1.1	78	60	26
	100	17	10	4	1.8	1.3	1.2	92	54	26
	200	19	14	6	2.0	1.6	1.4	87	71	32
	400	17	16	7	2.3	2.1	2.3	44	65	36

[1] Nitrogen recovery based on each cutting period.

[2] Common urea (46% N).

[3] Sulphur coated urea (33% N and 40% S).

Table 2. Effects of N source (urea and legumes) and urea rates on the total N uptake and effective N uptake by three tropical forage grasses under a cutting regime at CIAT-Quilichao.

Grasses	N source and rates	Total N uptake (kg/ha/yr)			Effective N uptake (kg/ha/yr)[1]		
		1st yr.	2nd yr.	3rd yr.[2]	1st yr.	2nd yr.	3rd yr.[2]
Panicum maximum 604	**Urea**						
	0 kg N/ha/year	231	86	72	0	0	0
	50 "	259	97	90	28	11	18
	100 "	310	134	96	79	48	24
	200 "	434	181	122	203	95	50
	400 "	425	238	181	194	152	109
	Legume N source						
	S. guianensis 136	192	98	--	-39	12	--
	S. guianensis 184	187	97	--	-44	11	--
	C. pubescens 438	208	105	--	-23	19	--
Andropogon gayanus 621	**Urea**						
	0 kg N/ha/year	312	197	92			
	50 "	350	188	92	38	9	0
	100 "	337	218	126	25	21	34
	200 "	341	226	152	29	29	60
	400 "	343	248	185	31	51	93

Table 2. Continued.

Grasses	N source and rates	Total N uptake (kg/ha/yr)			Effective N uptake (kg/ha/yr)[1]		
		1st yr.	2nd yr.	3rd yr.[2]	1st yr.	2nd yr.	3rd yr.[2]
Andropogon gayanus 621	**Legume N source**						
	S. guianensis 136	253	191	--	-59	-6	--
	S. guianensis 184	192	166	--	-120	-31	--
	C. pubescens 438	223	170	--	-89	-27	--
Brachiaria decumbens 606	**Urea**						
	0 kg/ N/ha/year	222	83	26	0	0	0
	50 "	284	94	40	62	11	14
	100 "	292	113	44	70	30	18
	200 "	322	193	86	100	110	60
	400 "	454	269	140	232	186	114
	Legume N source						
	S. guianensis 136	179	100	--	-43	17	--
	S. guianensis 184	231	104	--	9	21	--
	C. pubescens 438	184	103	--	-38	20	--

[1] Effective N uptake = Total N uptake at applied rate and N source minus N uptake without N applied.

[2] Diseases destroyed all legumes in the 3rd year.

Consequently, in that location and other similar ecosystems, the strategic application of soluble fertilizers during April, May, September and October would permit a more efficient use of fertilizer inputs.

P and K Requirements

Calibration of soil P tests. Results of several studies have shown that the extractant solutions of Bray I, Bray II and Mehlich-2 methods provide good indices of available soil P in the Carimagua Oxisol during the establishment period (CIAT Trop. Past. Prog. 1979 Ann. Rept.). However, over time the common tests do not reflect additions of P, especially at low rates of application. This makes it difficult to recommend P applications based only on soil tests. Tissue analysis and P extraction by pasture plants appear to be more practical parameters under the minimum input strategy.

Some studies were done to improve the sensitivity of the existing soil tests. Figure 6 shows how increasing NH_4F concentrations in the Bray II extractant increased the so-called "available soil P" reflecting the absorbed P available to the plants. Since NH_4F is able to extract some of the P-Al and P-Fe in addition to the existing P-Ca, all these P fractions might be playing important roles in P uptake by plants, probably through root excretions or microorganism activity.

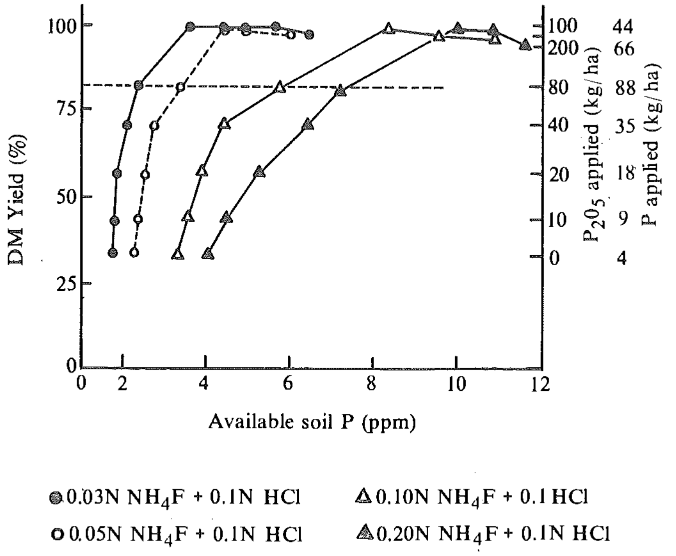


Figure 6. *Available soil P levels obtained by four extractan solutions in relation to P fertilizer rates and DM yield of* **Brachiaria decumbens** *grown in a Carimagua Oxisol.*

Table 3 shows the P fractions for the Carimagua Oxisol as a function of P rates. All P fractions contribute to P availability, but plants growing under low rates of applied P appear to extract this nutrient from some P fractions that the common soil tests are not able to detect.

Table 3. Phosphorus fractions in a Carimagua Oxisol as a function of P rates.

P applied		P contents of fractions (ppm)						
P_2O_5 (kg/ha)	P (kg/ha)	Available Bray-II	P/Ca	P/Al	P/Fe	Inorganic P	Organic P	Total P
0	0	1.8	0.9	0.5	26	29.2	101	130.2
10	4.4	1.8	0.8	0.6	29	32.2	97	129.2
20	8.7	1.9	1.0	0.6	32	35.5	97	132.5
40	17.5	2.1	1.1	0.6	35	38.8	108	146.8
80	34.9	2.2	1.7	0.9	40	44.8	102	146.8
100	43.7	3.5	1.7	1.0	42	48.2	92	140.2
150	65.5	5.5	1.9	1.3	43	51.7	101	152.7
200	87.3	6.6	2.2	1.5	45	55.3	101	156.3

External critical P levels. A greenhouse experiment was done on a Carimagua Oxisol with five promising forage legumes to determine their critical external P levels. The equivalent P rates used were 0, 4, 9, 18, 35, 44, 66 and 87 kg P/ha. The critical soil P level (Bray II method) was used as an indicator of the external P requirements. These P requirements are shown in Figure 7 which presents the data according to the Cate-Nelson method for determining critical P levels in the soil.

Although the critical P levels range between 2.8 and 3.5 ppm P (Bray II), the equivalent P fertilizer rate for the five legumes is about 22 kg P/ha (50 kg P_2O_5/ha).

Based on these results the critical levels should be considered a range of values rather than unique ones, which in turn, will require calibration for different pasture species as well as for certain soils.

Effects of P and K on grasses. A field experiment was conducted in Carimagua to determine the effects of P and K rates on the DM production of three tropical forage grasses.

Plots with *A. gayanus* 621 and *B. decumbens* 606 already established with four P rates (0, 22, 44 and 176 kg P/ha broadcast) were utilized and a third grass, *B. humidicola* 679, was planted. Potassium was applied at rates of 0, 30 and 80 kg K/ha/yr in two split applications and all grasses received 25 kg N/ha after each cut.

Figure 8 illustrates the significant interaction between K and P for all three grasses. Despite the positive response to K, the best efficiency in DM production of the three grasses per kilogram of applied K occurred with 30 kg K/ha at the three broadcast P rates (Fig. 9).

Andropogon gayanus 621 was most efficient in using K in terms of DM produced per kilogram of K.

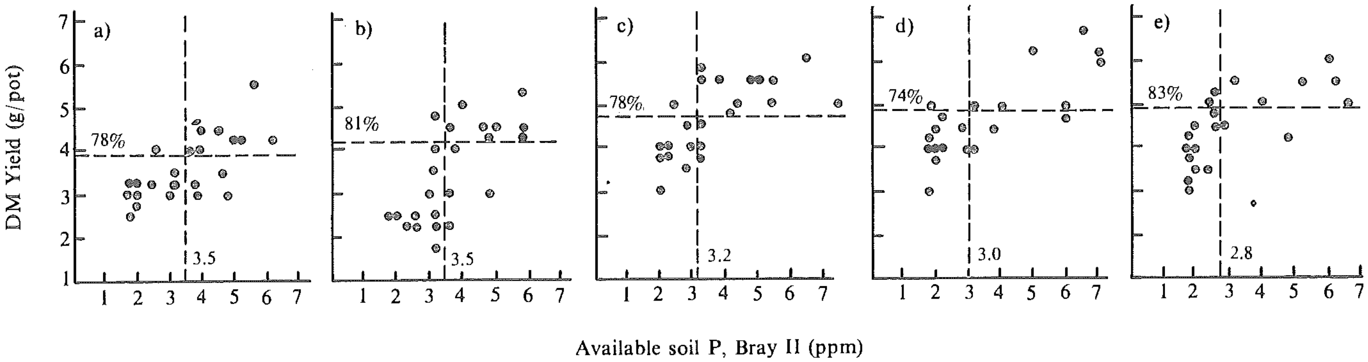


Figure 7. *Critical levels of available soil P for five promising tropical legumes grown on a Carimagua Oxisol. a)* **Pueraria phaseoloides** *9900; b)* **Stylosanthes capitata** *1019; c)* **Stylosanthes capitata** *1315; d)* **Desmodium ovalifolium** *350; e)* **Zornia latifolia** *728.*

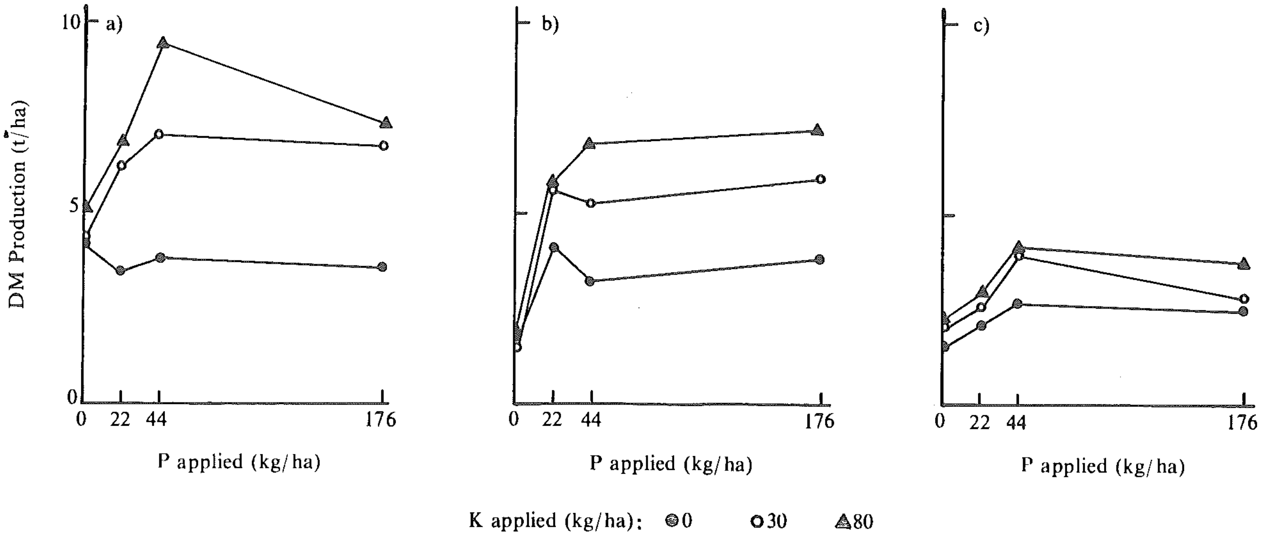


Figure 8. *Effects of P and K rates on DM production of three tropical forage grasses grown in the field at Carimagua. a)* **Andropogon gayanus** *621; b)* **Brachiaria decumbens** *606; c)* **Brachiaria humidicola** *679.*

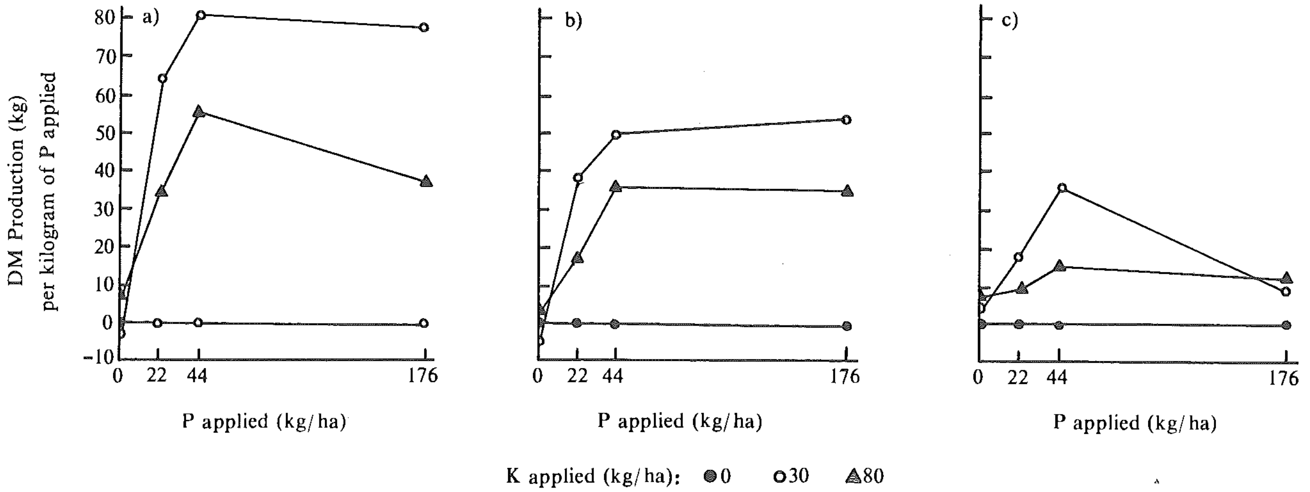


Figure 9. *Efficiency of DM production of three tropical forage grasses per kilogram of K applied at different broadcast P rates,on an Oxisol at Carimagua. a)* **Andropogon gayanus** *621;* **Brachiaria decumbens** *606;* **Brachiaria humidicola** *679.*

Critical S Requirements

A series of greenhouse experiments was established on a Carimagua Oxisol to determine external and internal critical S requirements of several promising grasses and legumes. The equivalent S rates used were 0, 5, 10, 15, 20 and 30 kg S/ha. Dry matter yields of the grasses and legumes are shown in Figure 10.

Based on DM yields, internal and external critical S levels were determined using the Cate-Nelson method (Figs. 11 and 12). According to these results, the critical levels and especially the external critical levels should be considered a range of values rather than unique values. Critical values will have to be determined for different pasture species and soils due to a differential nutrient extraction under the same external conditions.

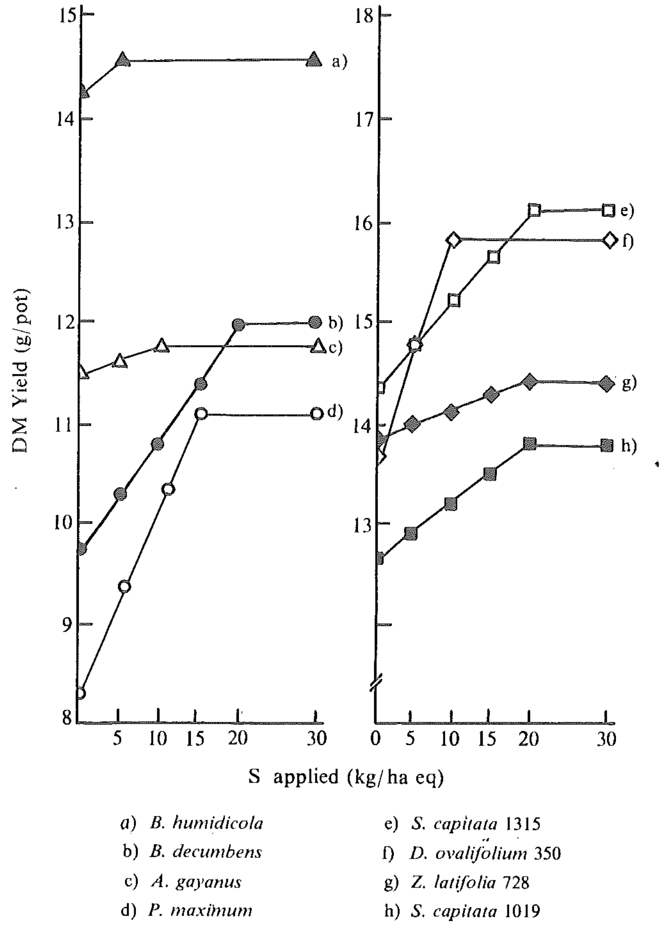


Figure 10. *Effect of applied S rates on yields of four tropical forage grasses and four tropical forage legumes grown on a Carimagua Oxisol in the greenhouse (Avg. of three cuttings).*

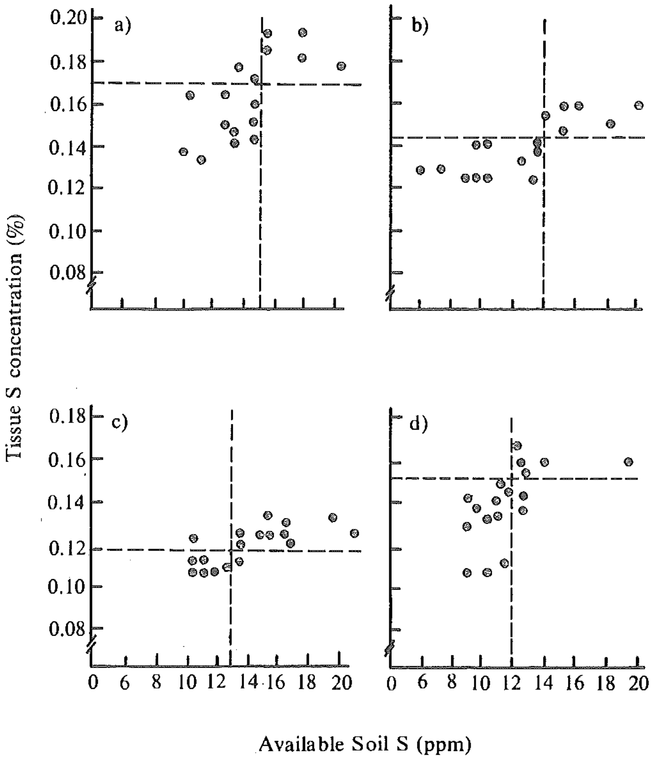


Figure 11. *Critical available S levels in the soil and critical S concentrations in tissues of four tropical forage legumes grown on a Carimagua Oxisol in the greenhouse. a)* **Stylosanthes capitata** *1019; b)* **Zornia latifolia** *728; c)* **Desmodium ovalifolium** *350; d)* **Stylosanthes capitata** *1315.*

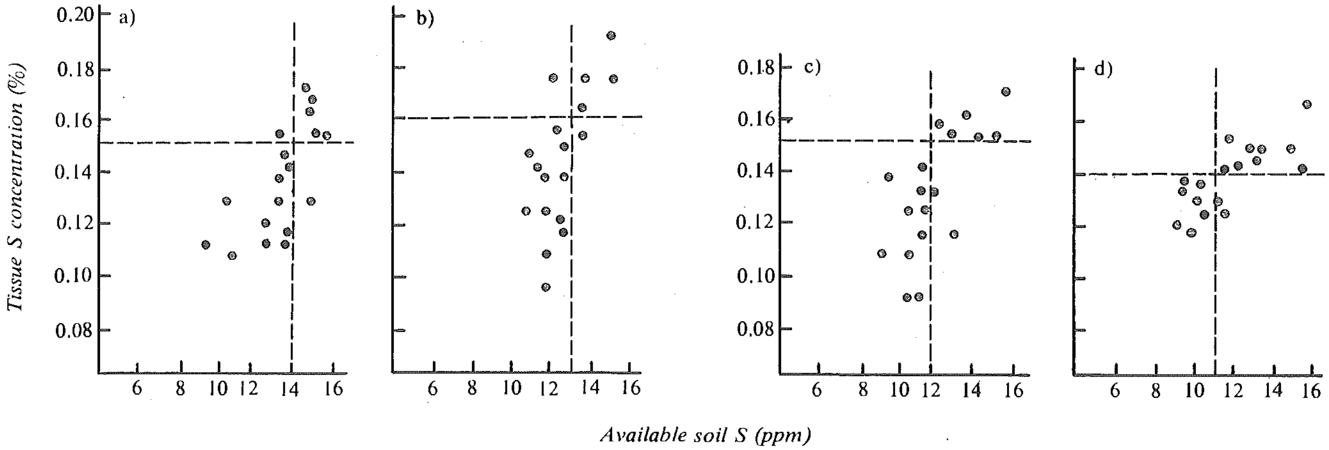


Figure 12. *Critical available S in the soil and critical S concentrations in tissues of four tropical forage grasses grown on a Carimagua Oxisol in the greenhouse. a)* **Panicum maximum** *604; b)* **Brachiaria decumbens** *606; c)* **Andropogon gayanus** *621;* **Brachiaria humidicola** *679.*

Soil Fertility-Plant Nutrition Status in the Regional Trials Network

Because soils and some plant materials from other countries cannot be brought into Colombia for testing in CIAT laboratories, it was essential to develop as a part of the Regional Trials Network, a Regional Laboratories Network located near the trial sites. Six national laboratories were selected initially in Bolivia, Brazil, Colombia, Ecuador, Peru and Venezuela. During 1980 four additional laboratories in Bolivia, Costa Rica, Cuba and Panama were incorporated into this network.

A handbook[1] with a standard set of analytical methods and procedures for acid soils and plant material has been prepared and distributed, together with soil and plant samples, to these laboratories to be used as controls. Another handbook[2] describing visual mineral deficiency and toxicity symptoms on several forage grasses and legumes will be distributed during 1981 to the researchers involved in germplasm evaluation in the regional trials network.

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[1] Salinas, J.G. and García R. 1979. *Métodos analíticos para suelos ácidos y plantas.* CIAT, Cali, Colombia.

[2] Salinas, J.G., Sánz, J.K. and García, R. 1980. *Síntomas foliares de deficiencia y toxicidad mineral en forrajes tropicales.* CIAT, Cali, Colombia.

Soil Microbiology

The current objectives of the Soil Microbiology Section are to ensure that pasture legumes selected by the Program posses an N-fixing system which can supply the N needs of the legume, the associated grass and the cattle grazing on them. This obviates the need for applying inorganic N fertilizer to maintain worthwhile production levels. Estimates indicate that good tropical grass-legume pastures may fix up to 300 kg/ha/yr of N.

Preliminary ***Rhizobium*** **strain screening.** A preliminary screening method featuring an acid medium has been used at CIAT to evaluate the ability of *Rhizobium* strains to grow under acid soil conditions (CIAT Ann. Rept. 1978, and CIAT Trop. Past. Prog. 1979 Ann. Rept.). This growth ability may be related to the strains' ability to persist in acid soils. The medium may also be useful for isolating rhizobia which grow only under acid conditions and therefore cannot be isolated on conventional luxurious nutrient media.

Further work in which one hundred and fifty CIAT *Rhizobium* strains were screened for their ability to grow on acidified (pH 4.5) or neutral (pH 6.8) yeast mannitol medium showed that some strains which had been isolated from acid soils on acidified medium were not able to grow on neutral medium although in fact the majority of strains grew equally well on the two media. Some strains (including all strains from *Leucaena leucocephala)* were unable to grow on the acidified medium.

In the acidified yeast mannitol medium the strains produce alkaline metabolic by-products which cause the pH of the medium to increase (blue color in media containing bromocresol green indicator). A new acid medium has been developed in which a large number of strains can be screened rapidly and in which alkaline by-products of growth are not produced (Table 1). New *Rhizobium* isolates are being tested for their ability to grow on this medium in order to evaluate its usefulness as an indicator of the strains' ability to persist in acid soils, and for isolation of new acid-tolerant *Rhizobium* strains.

Table 1. Suggested acid medium[1] for screening growth of *Rhizobium* strains.

Ingredient	Amount			
	mg/liter	g/liter	µg/liter	ml/liter
KH_2P0_4	68.0			
K_2HPO_4	87.0			
$CaCl_2.H_20$	7.35			
EDTA	29.2			
$FeCl_3.\ 6H_20$	27.0			
$MgS0_4\ .7H_20$	73.9			
Biotin (filter sterilized)	0.1			
NH_4CI		1.2		
Agar		20.0		
$MnCl_2.4H_20$			252.0	
$ZnSO_4.\ 7H_20$			114.0	
$CuCl_2\ .2H_20$			17.0	
$NaMo0_4.2H_20$			4.1	
Glycerol				5
Bromocresol green (0.4% aqueous solution)				4

[1] Final pH 4.5 corrected with HCl after autoclaving and plates poured immediately.

Responses to inoculation and nitrogen fertilization in the field. A field trial at Carimagua (Figure 1) with three *Centrosema* spp. showed that all three species responded to 33 kg N/ha after three months, but only *C. pubescens* had responded to inoculation with the most promising selected strain (CIAT 590). After five months the production of the inoculated *C. pubescens* was equal to that of the nitrogen fertilized treatment, and *C. macrocarpum* had begun to respond to inoculation, although production had not reached that of the nitrogen fertilized treatment. *C. brasilianum* did not respond to inoculation with CIAT 590, and after 5 months both the uninoculated and inoculated treatments had reached the level of the nitrogen fertilized control, which indicates that efficient nodulation by soil *Rhizobium* and not the inoculant strain was occurring. These results imply that although some *Centrosema* spp. respond to inoculation with CIAT 590, this response is slow and considerable improvement could be achieved by selecting strains which nodulate more rapidly.

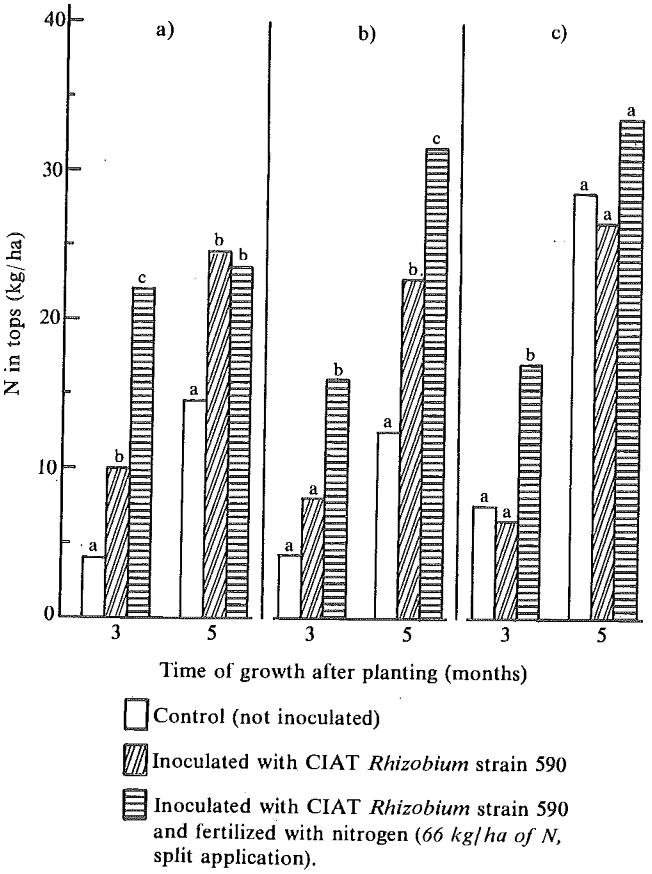


Figure 1. *Nitrogen produced in the tops in two sequential cuts of three* **Centrosema** *accessions planted in June 1980, with three treatments. Significant differences shown by different letters on top of bars. a)* **C. pubescens** *5050; b)* **C. macrocarpum** *5065; c)* **C. brasilianum** *5234.*

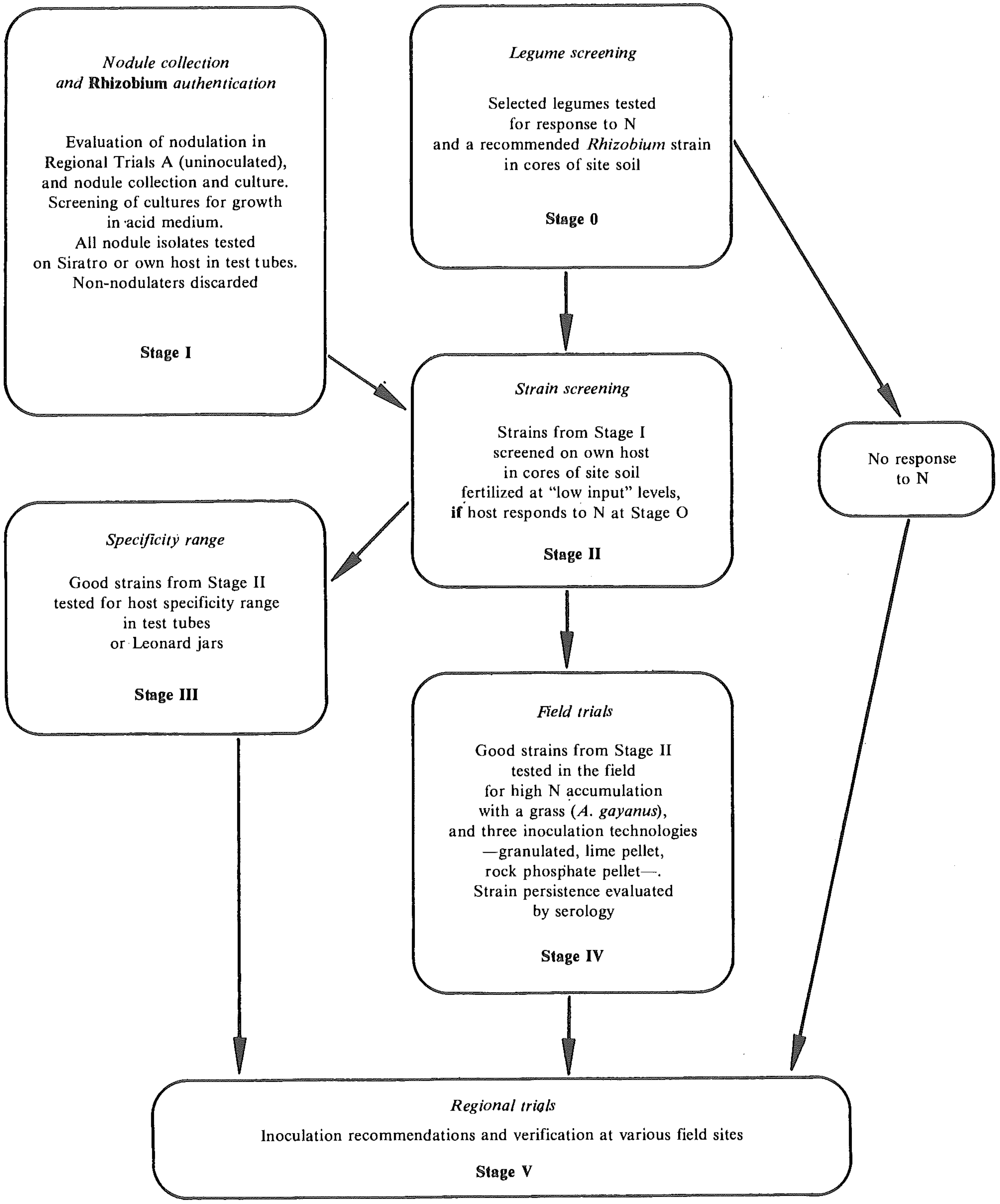
Five-stage screening of Rhizobium. Although considerable progress has been made with the five-stage screening method utilized in previous years, certain difficulties have occurred. For example, a lack of correlation between Stage II and Stage III results has been observed. Strains appearing good in Stage II may be bad at Stage III and vice versa.

Also, significant differences between inoculated and uninoculated forage legumes have been observed in the field (Stage IV) during the establishment year, but these differences disappeared in the second year, and in many cases very soon after establishment. Thirdly, this screening procedure does not provide a basis for choosing which legumes will be screened, and only a small number of legumes can be included in the rather laborious screening process. This means that little information is available concerning the N-fixing potential of most legumes in Categories I - III

Until the present time Category I - III legumes being screened in the agronomic evaluation trials have been inoculated with the strain most likely to nodulate them. However, there are known cases of specificity of legumes for *Rhizobium* strains even within species. If the wrong strain of *Rhizobium* is inoculated it may form ineffective nodules and consequently parasitize the plant, causing N deficiency symptoms. This might cause an otherwise well-adapted plant to be discarded in the agronomic selection procedure.

Figure 2 illustrates a proposed program which, although fundamentally the same as that used previously, does include two important modifications. One of these is a new preliminary screening stage (Stage 0) where a wider range of legumes will be tested for their responses to N and inoculation in cores of site soil. Only those legumes responding to N will be screened further. Nonresponsive legumes will be tested again in soil from different sites to determine whether a recommendation not to inoculate them can safely be made. This procedure should increase the capacity for screening legumes that do need inoculation.

The second major modification is that Leonard jar tests ("N-fixing potential") will no longer be part of the major screening sequence. The major proposed screening sequence can be considered to be Stages 0, II IV and V. Thus all selections for legume and strain N-fixing efficiency will be based on experiments carried out either in cores of soil or in the field.



Nodule collection
and **Rhizobium** *authentication*

Evaluation of nodulation in
Regional Trials A (uninoculated),
and nodule collection and culture.
Screening of cultures for growth
in acid medium.
All nodule isolates tested
on Siratro or own host in test tubes.
Non-nodulaters discarded

Stage I

Legume screening

Selected legumes tested
for response to N
and a recommended *Rhizobium* strain
in cores of site soil

Stage 0

Strain screening

Strains from Stage I
screened on own host
in cores of site soil
fertilized at "low input" levels,
if host responds to N at Stage O

Stage II

No response
to N

Specificity range

Good strains from Stage II
tested for host specificity range
in test tubes
or Leonard jars

Stage III

Field trials

Good strains from Stage II
tested in the field
for high N accumulation
with a grass (*A. gayanus*),
and three inoculation technologies
—granulated, lime pellet,
rock phosphate pellet—.
Strain persistence evaluated
by serology

Stage IV

Regional trials

Inoculation recommendations and verification at various field sites

Stage V

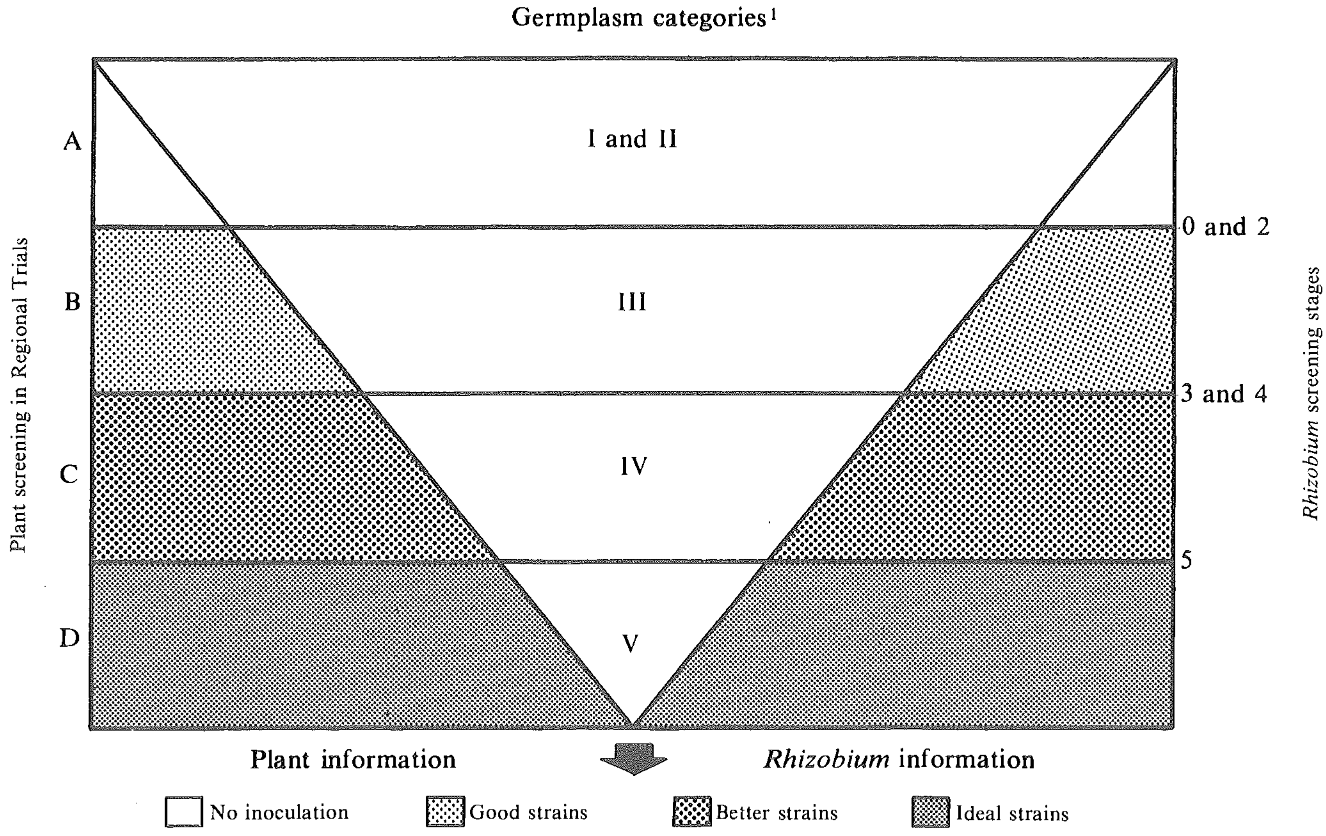
Figure 2. *Summary of proposed legume-***Rhizobium** *screening methods.*

The other changes shown in Figure 2 are mainly technical details (use of Siratro instead of the host plant at Stage I; use of soil cores instead of pots of dried and sieved soil; inclusion of a grass, *Andropogon gayanus,* in the field trials; and use of granulated inoculant as one of the inoculation technologies). This procedure may be modified later when more information is available.

Initially, work will be carried out using soil from Carimagua and Brasilia, but as more legumes are selected in the other ecosystems, representative soils will be used for their evaluation. Economically acceptable fertilizer rates for pasture establishment at the chosen site will be used.

Figure 3 illustrates the way in which the screening program shown in Figure 2 is expected to fit into the legume plant agronomic screening program. It is recommended that the initial plant screening stages (A) should not be inoculated unless there is a particular reason to do so. If the plants appear to be nitrogen deficient they may be fertilized with nitrogen. Native *Rhizobium* strains may be collected from these non-inoculated plants. Legumes will be selected from the initial agronomic evaluations (A) for Stage 0 tests (nitrogen and inoculation response). Those responding to nitrogen will be screened at Stage 2. The results of Stages 0 and 2 will be used to make preliminary inoculant recommendations for plant screening stages B. Results of Stages 3 and 4 will be used to improve these preliminary recommendations.

The diagram shows that as the numbers of plants being screened at each stage decrease, the amount of information about each plant, including its nitrogen-fixing potential, increases. The final results should be a legume with good agronomic characteristics which fixes up to 300 kg N/ha per year.



[1] Number of plant accessions decreases as category number increases.

Figure 3. *Relationship between legume plant screening in Regional Trials (A-D) and* **Rhizobium** *screening stages (0-5).*

The Seed Production Section has the basic objectives of: (a) producing seed of experimental lines and basic seed, and (b) developing relevant technology for commercial seed production.

Seed Increase

Species and accessions for seed increase are defined by the Program's Germplasm Committee, from the lists of promising accessions for the various ecosystems. An initial seed production target is then defined for each accession according to the planting density for each species and a standard area required for the next phase of pasture evaluation. An additional production target may be undertaken upon request, to provide seed for other evaluation projects or for basic seed production.

Production areas are located at CIAT-Palmira, CIAT-Quilichao and/or Carimagua, depending upon climatic or edaphic suitability plus land and labor requirements. Generally, legume small-plot work is at CIAT-Quilichao, with larger areas at Carimagua. Grass seed may be produced in each of the three locations.

During 1980, the manual harvesting and processing of 5 t of clean seed of *Andropogon gayanus* seed was the dominant production effort. Legume seed production involved over 30 different accessions of various genera but was concentrated upon *Stylosanthes capitata, Zornia latifolia* and *Desmodium ovalifolium.* A summary of seed produced is presented in Table 1.

The Section also provides a service function of seed storage and distribution to the the Program and collaborators. During 1980, 210 multiple seed requests were made and a total of 10 t of seed was distributed.

The Instituto Colombiano Agropecuario, ICA, in Colombia, and the Centro de Pesquisa Agropecuária dos Cerrados, CPAC, of EMBRAPA, in Brazil, officially released during the year a cultivar of *A. gayanus* based upon the CIAT 621 population. Two tons of basic seed were delivered to each institution to contribute towards the rapid buildup of commercial seed supplies within each country.

Table 1. Summary of seed produced by species between October 1979 and October 1980.

Species	Number of accessions	Seed weight[1] (kg)
Legumes		
Aeschynomene spp.	2	42
Centrosema spp.	4	4
Codariocalyx gyroides	1	12
Desmodium ovalifolium	1	585
Desmodium heterophyllum	1	30
Stylosanthes capitata	11	3306
Stylosanthes leiocarpa	1	1
Zornia spp.	10	404
Total legumes	31	4384
Grasses		
Andropogon gayanus	1	5560
Panicum maximum	1	10
Total grasses	2	5570
Total, all accessions	33	9954

[1] Legumes: seed or seed in pod, 95% purity; grasses: clean seed, 35% purity

Production Technology

Regional Seed Production Potentials

Regional and species seed production potentials are being investigated in a medium-term, collaborative experiment at various locations. Data for flowering, maturity and pure seed yield are available from five sites for two consecutive years. The establishment year was 1979, and 1980 represents year 2. In general terms, 1979 tended to be above average in precipitation, while 1980 conformed more to long-term averages.

The legume accessions and *A. gayanus* exhibited a single flowering peak and one subsequent harvest at all locations except CIAT-Quilichao (3°N). The multiple flowering peaks at Quilichao result from the bimodal rainfall distribution combined with prevailing short photoperiods at this low altitude, in contrast to the longer unimodal rainfall distribution at the other high (15-19° S) latitude locations.

The grasses *Brachiaria decumbens, B. humidicola* and *Panicum maximum* produced multiple flowering peaks and harvests in both 1979 and 1980. These species commence flowering earlier in the season than the majority of legumes and *A. gayanus.*

The value of flowering and maturity data in 1979 was confounded with effects of establishment, so more emphasis is placed on data from 1980.

Andropogon gayanus flowered at all locations during 1979, with flowering commencing from mid-April onwards. The range of seed yields in 1979 was 5-159 kg/ha; the highest yields were recorded at Sete Lagoas, Brazil (19° S) and Brasilia, Brazil (15° S), with 159 and 128 kg/ha, respectively. In 1980, commencement of flowering occurred fairly consistently in late April with seed maturing from late May to June. Seed yields in 1980 were reduced by sub-optimum plot management in that appropriate pre-cuts were not applied, so that excessive height and lodging complicated harvesting and reduced yields. Yields ranged from 8-45 kg/ha, with the highest yield recorded at Brasilia. A pre-cut in approximately mid-February followed by maintenance fertilizer will be applied in future years.

Desmodium ovalifolium did not flower at either Brasilia or Felixlandia, Brazil (18° S) during 1979, but did flower at CIAT-Quilichao and Chapare, Bolivia (16° S). In 1980 it flowered at all four locations but onset of flowering was erratic between locations from March onwards, with seed maturity occurring from mid-June to late July. Maximum yield during 1979 was 123 kg/ha at Quilichao, while in 1980, maximum yield was 220 kg/ha in the Chapare. Nematodes were reported at Brasilia, where yield was only 12 kg/ha in 1980. It appears that this species requires a long establishment season and adequate moisture until early phases of seed maturity. Seed production appears feasible only in locations with extended rainfall patterns. The highest recorded yield occurred at a high latitude location, but the influence of photoperiod remains to be clearly established as commencement of flowering was erratic between such locations.

Stylosanthes capitata 1315 and 1405 both flowered and set seed at all locations during the establishment year. Flowering commenced in mid-April with seed maturing from approximately mid-June, depending upon location. The range of seed yields in 1979 was 97-546 kg/ha/harvest, with an average of 175 kg/ha over four locations. The maximum was recorded at CIAT-Quilichao where average annual yield of the two accessions was 500 kg/ha, from two harvests. This relatively consistent high yielding pattern was not maintained in year 2. In 1980 yields ranged from zero to 1057 kg/ha/harvest. Maximum yields of both accessions were recorded at Felixlandia. At Brasilia, CIAT 1405 was destroyed and CIAT 1315 severely affected by anthracnose. Excluding Brasilia, average yield was 260 kg/ha over four locations. These *S. capitata* accessions exhibit high yield potential over a wide range of locations, except where particular races or inoculum potential of anthracnose are prevalent (e.g. Brasilia).

Zornia latifolia 728 flowered at all sites during the establishment year but was erratic between locations. Maximum seed yield in 1979 was 175 kg/ha at Brasilia, with maturity at the end of May. At other locations yields ranged from 5-79 kg/ha. In 1980, flowering commenced during February, with seed maturity in late May and early June, except in the wetter Chapare region where maturity was delayed until late July. Seed was harvested at all locations with a range of 16-691 kg/ha. High seed yields, approximately 600 kg/ha, were recorded at both Brasilia and Felixlandia. A complex of insect-virus symptoms was recorded at these same sites; *Sphaceloma* scab was serious at CIAT-Quilichao, and an unidentified fungus was observed at Chapare. Natural *Zornia* spp. were numerous at Brasilia and Felixlandia. *Zornia* 728, however, appears to yield well over a wide range of locations.

Andropogon gayanus

The overall seed increase effort with species, involving different locations, years and seed lots, also generated data relating to basic profiles of seed yield, multiplication rate and seed quality.

Pure seed yield. Pure seed yields vary greatly and for this reason both ranges and averages are presented in Table 2. All seed was harvested manually. Maximum average yields per harvest and per year were 161 and 234 kg/ha, respectively, both recorded at CIAT-Palmira. Differences between locations relate principally to (a) two harvests per year at both CIAT-Palmira and CIAT-Quilichao but only one at Carimagua, (b) differences in inherent soil fertility, (c) occurrence of strong winds during seed maturity at Carimagua, and (d) differences in mature crop height. At Palmira and Quilichao, with short growing seasons, average heights were 2.2 m, while under the longer growing season in Carimagua uncut crops reached 3.0-3.5 m, lodging occurred and harvesting was more difficult and less efficient. To facilitate mechanical harvesting, a timed precut or grazing is necessary to promote an even crop and restrict mature height to 2.0-2.2 m.

Table 2. Yields of pure seed and multiplication rates of *Andropogon gayanus* at three locations.

		Yield of pure seed[1] (kg/ha) at					
Year	Semester	CIAT-Palmira Average	CIAT-Palmira Range	CIAT-Quilichao Average	CIAT-Quilichao Range	Carimagua Average	Carimagua Range
First (1977)	A	36	20- 43	10			
	B	99	58-144	39	27- 78	54	41-64
Total		135	95-188	49	38- 88	54	41-64
Second (1978)	A	59	29- 92	108	105-121		
	B	136	119-197	124	88-260	33	28-45
Total		195	150-243	232	193-380	33	28-45
Third (1979)	A	72	68- 74	53	39-103		
	B	78	50- 87	56	52- 58		
Total		151	118-161	109	97-154		
Average multiplication rate[2] (ha/year)		48		39		13	

[1] Yields of pure seed, by the International Definition, from various unreplicated plots harvested during 1977 and 1979 with areas> 1 ha.

[2] Over full year, assuming a planting density of 3.3 kg/ha of pure seed.

Multiplication rate. Seed yield data is not always fully meaningful for a relatively new species. An alternative concept of seed yield potential is the multiplication rate which relates annual productivity and planting density on a hectare basis. While it can be defined in terms of any class of seed, it is best defined in terms of either pure seed or pure-germinable seed. This parameter is comparable between species, and can be used within a species to compare locations, years and management systems.

Based upon the average annual pure seed yields at CIAT-Palmira, CIAT-Quilichao and Carimagua and assuming a high planting density of 4 kg/ha pure seed, multiplication rates of 51, 34 and 10 are derived for these respective locations (Table 2). These figures suggest that, with appropriate location and management, an average multiplication rate for seed production planning is about 25 ha/yr. This could be increased by higher yield or by lower planting density.

Seed quality. Because of the relative difficulty in processing seed of chaffy grasses, commercial seed will include both crude (unprocessed) and cleaned (processed) seed classes. The characteristics of these classes are presented in Table 3. Following mechanical de-awning and one pass over an air screen cleaner, physical changes include an increase in de-awned spikelets, bulk density, caryopses content and purity (both Irish and International definitions). If equal germination of pure seed is assumed, pure germinating seed values are 6.0% and 10.5% for crude and cleaned seed, respectively. In a study of seven different seed lots, germination was halved by mechanical processing, indicating that negative effects can occur. The same experiment, however, showed similar or greater differences in germination due to lot origin and/or changes in storage. While mechanical de-awning allows conventional machinery to increase the purity of seedlots, apparently some seed lots can be damaged. De-awned seed should be used immediately as any damage would be magnified by subsequent storage. The relative utility of crude and cleaned seed will depend upon the relative costs and benefits in seed storage and transport, seed quality level and stability, and especially in the means of planting commercial pastures with either standard or modified equipment.

Table 3. Summary of the characteristics of crude and machine-cleaned seed of *Andropogon gayanus*.

Characteristic	Crude seed[1]		Machine-cleaned seed[2]	
	Range	Average	Range	Average
Awned spikelets (%)	70-90	80	5-30	20
Bulk density (kg/m³)	35-45	40	50-70	55
Cariopsis content (%)	10-40	25	30-60	35
Purity (Irish, % wt)	60-80	70	80-95	90
Purity (International)	5-36	20	25-60	35
Germination (% at 5 months)		30[3]		30
Pure germinating seed (% at 5 months)		6.0		10.5

[1] Seed material after manual threshing and partial manual scalping.

[2] Seed material after mechanical de-awning and one pass through an air screen cleaner.

[3] Measured on a pure (International Definition) seed basis.

Pasture Development in the Iso-hyperthermic Savannas (Carimagua)

The objectives of the Pasture Development Section in Carimagua are to develop: (a) simple low-cost establishment methods and (b) efficient maintenance practices. To attain these objectives, several long-term trials are being conducted and new trials have been established during 1980. Considerable progress has been made over the past three years in developing a number of low-cost establishment methods and maintenance practices that show promise of providing persistent, productive and stable legume-grass associations.

Results to 1980

Pasture development work in Carimagua began almost a decade ago with field experiments in soil fertility and management. Results from these early experiments with both food crops and pasture species, and from the work of other sections of the Tropical Pastures Program, and the experiences of farmers and ranchers in the area have all contributed to the sequential development of activities by the Section, in the areas of seedbed preparation, vegetation control, planting systems and spatial distribution of associated species.

Table 1 summarizes the principal advantages and disadvantages of the different systems of seedbed preparation and vegetation control. The major goal has been to reduce both costs and erosion hazards. The major trade-off has been the reduction in the number of species which are suitable for use in the reduced and zero tillage systems.

Advantages and disadvantages of the different planting methods are shown in Table 2. Fertilizer efficiency is of special importance in most savanna ecosystems because of the low native fertility of Oxisols and Ultisols and the high on-farm cost of fertilizer.

Table 1. Principal advantages and disadvantages of tillage and vegetation control systems used in pasture establishment in Carimagua.

System	Advantages	Disadvantages
Conventional tillage (plowing and/or disking)	• Good vegetation control • Suitable for all especies, if not overdone • It is a traditional method	• High cost • Heavy machinery requirement • May result in unfavorable seedling environment if overdone • Erosion hazard high during establishment
Minimum tillage (stubble mulch sweeps, chisel tines)	• Lower cost • Less erosion hazard • Favorable seedling environment	• Requires "heavy" machinery • Does not control all native vegetation
Zero inter-row tillage	• Low cost • Little erosion hazard • Suitable for rolling landscapes	• Still requires machinery for row tillage • Not suitable for all species • Limited control of native vegetation • Not tested at commercial scale
Chemical control + **manual tillage**	• Low cost • No erosion hazard • Suitable for steep sites • Simple, inexpensive equipment • Takes technology to small farms	• Suitable for only a few species • Limited vegetation control • Not thoroughly proven.

Table 2. Principal advantages and disadvantages of planting methods and spatial distribution systems used in pasture development in Carimagua.

Systems	Advantages	Disadvantages
Conventional seeding (broadcast seeding)	⊚ Can be done manually or with spinner type seeders ⊚ It is a traditional method	⊚ Higher seed requirement ⊚ More weed problems ⊚ Low fertilizer efficiency
Row seeding	⊚ Less seed required ⊚ Higher fertilizer efficiency ⊚ Allows better initial establishment of each component ⊚ Reduces early competition ⊚ Reduces shading	⊚ Requires more complex machinery ⊚ Slower than broadcast seeding
Spatial distribution (species planted in separate strips)	⊚ Results in more stable and persistent associations of some species than if intimately mixed ⊚ Permits association between species otherwise not compatible ⊚ Does not lose advantage of association; avoids some problems of "protein banks"	⊚ More complex than traditional planting ⊚ Wide strips may not favor efficient nitrogen use by associated grass
Low density methods	⊚ Low labor, seed and initial fertilizer requirements ⊚ Well suited to small farms ⊚ Results in very strong, persistent mother plants ⊚ Reduces the risk of failure inherent in pasture establishment	⊚ May require more time for establishment ⊚ Not suitable for all species ⊚ May not work where weed potential is high

Weeds are not so important in many native savanna regions when planting after virgin savanna. However, weed problems increase with time, especially when reseeding old pasture sites or other previously cultivated areas.

Association x Fertility Interactions

The P x association trial established in 1978 is completing the second full year under grazing. *Panicum maximum* essentially disappeared from the association with *Pueraria phaseoloides* in 1979. Animal performance was so poor on this treatment that grazing was suspended during 1980. The two associations with *Andropogon gayanus* have proven to be stable and productive in terms of both forage and animal live weight gain. *P. maximum* is persisting well in the association with *Stylosanthes capitata.*

Spatial Distribution Trial

In a trial established in 1978 *Brachiaria decumbens* and *P. phaseoloides* are associated in a systematic "triangle" design which has been described previously (CIAT Ann. Rept., 1978). This experiment has been managed under continuous grazing for two years with stocking rates of 2.5 A.U./ha during the rainy season and 1.25 A.U./ha during the dry season. Continuous grazing appears to favor this particular association and so far it has been more stable than were the same two species managed under rotational grazing in a previous trial. Although there is aggressive invasion of both species, legume-grass balance and animal performance are excellent. Strip widths of 4 to 5 m for each of the two species would appear to provide for adequate persistence, stability and production.

Tillage System and Depth

A trial was established in 1979 to determine the effect of tillage system and depth of soil disturbance. A zero tillage treatment was included in which the native vegetation was controlled chemically. Figures 1 and 2 show the effects of three systems and two depths of tillage on the forage production of eight species. The 20-cm depth in the offset disc treatment was achieved by tilling with a spring tine cultivator after disking. It appears there is little advantage to plowing over offset disking and little advantage to increased depth of tillage. Plowing, however, is especially useful in renovating old pastures or preparing other cultivated areas. Weed seeds and seeds of other pasture species are buried deeply and weed competition is reduced during the pasture establishment phase. *Brachiaria humidicola, B. decumbens* and *D. ovalifolium* appear to be best suited to the zero tillage systems. It is not clear why *P. phaseoloides* did not perform well in that treatment.

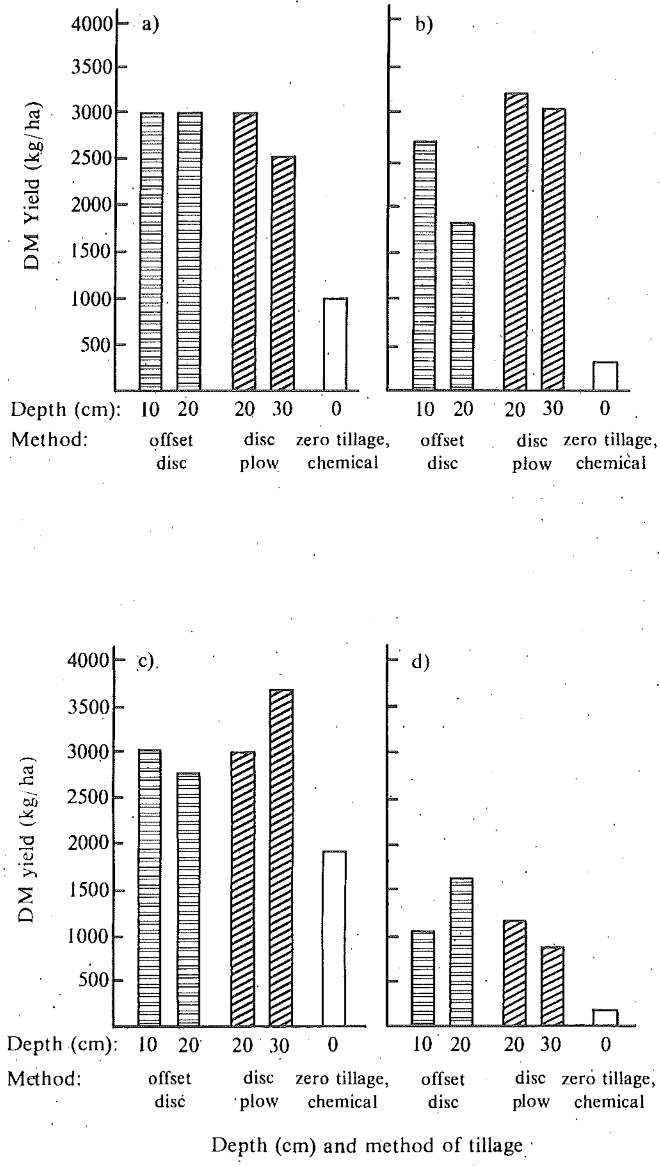


Figure 1. *Effects of tillage system and depth on DM production of four grasses, at the first harvest 10 months after establishment, at Carimagua. a)* **B. decumbens**; *b)* **A. gayanus**; *c)* **B. humidicola**; *c)* **P. maximum**.

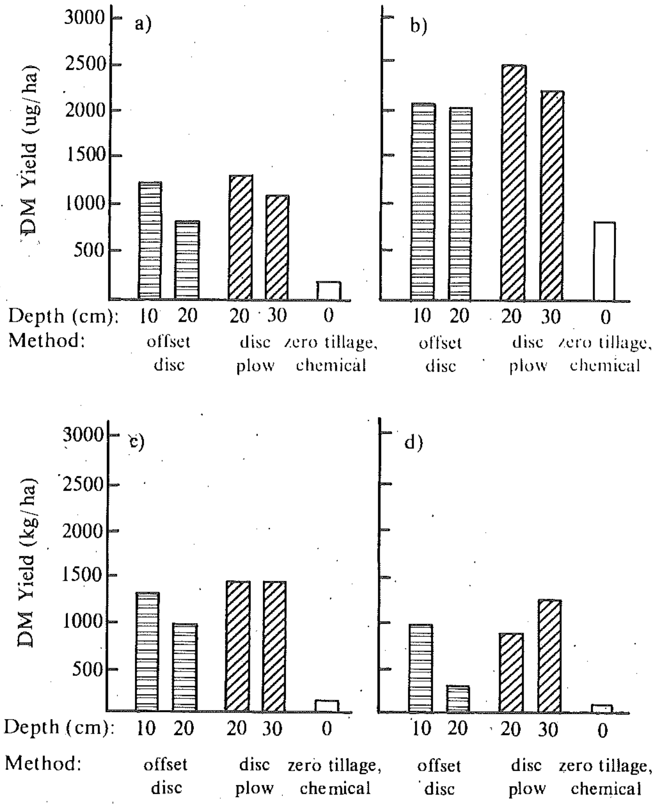


Figure 2. *Effects of tillage system and depth on DM production of four legumes, at the first harvest 10 months after establishment, at Carimagua, a)* **P. phaseoloides**; *b)* **D. ovalifolium**; *c)* **Z. latifolia**; *d)* **S. capitata**.

Minimum and Zero Tillage for Low Density Pasture Seeding

Three legumes were established in a low density pattern of 1000 hills/ha, with manual tillage of the planting site, to study the effect of inter-row tillage and fertility on invasion and establishment. *Desmodium ovalifolium* and *P. phaseoloides* successfully colonized both disturbed and undisturbed savanna when adequate P was applied; *P. phaseoloides* was the more aggressive of the two. Unfortunately, this trial was not designed for management under grazing. More recent work has shown establishment is generaly enhanced by light grazing, especially with trailing legumes like *P. phaseoloides* and *D. ovalifolium. Stylosanthes capitata* did not provide effective cover in this trial. It too would undoubtedly benefit from grazing, since cattle effectively distribute the seed. All species performed as well or better when the savanna was burned, compared to unburned, mature savanna. Inter-row tillage was beneficial for both *S. capitata* and *D. ovalifolium.*

Low Density Seeding

A trial was established to determine the effect of seed material, date of planting and fertilizer on seed production. There was little effect of fertilizer on amount of seed produced. The use of vegetative material permits later planting than does sexual seed. It appears that vegetative material can safely be used for seeding until about one month before the end of the rainy season. Sexual seed should probably not be used after August in Carimagua in order to assure adequate seed production during the dry season.

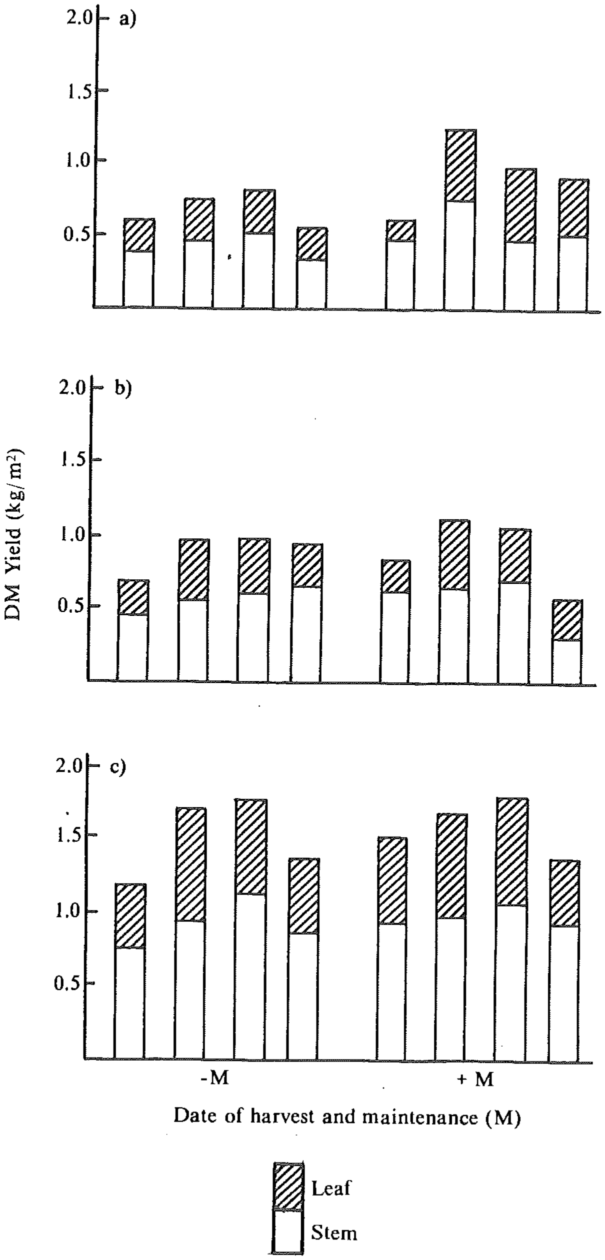
In another low density seeding trial, different planting rates were used in row seeding with rows spaced from 1 to 10 m. The effect of planting rate in the row was largely obscured by uncontrolled factors including heavy rains and severe insect damage in the post-seeding period, but results confirmed that the currently recommended 5-m row spacing is adequate. The 1-m row spacing yielded no new seedlings due to competition from the original stand.

Management of *Andropogon gayanus* for Maximum Dry Season Production

A harvested seed production lot was utilized to study the effect of stubble management on *A. gayanus* forage production and quality during the dry season. Treatments imposed in early December 1979 included cutting, burning and a control plot in which no forage was removed. Maintenance fertilizer treatments were applied in a split-plot design. Separate plots were harvested monthly to measure regrowth through the dry season. The effects of fertilizer and stubble management are shown in Figure 3.

The control plot yielded more total leaf and DM than cutting and burning treatments, however, much of the leaf and stem was dead material present when the trial began. The burn treatment appeared to respond more to fertilizer than the other two treatments, especially in the last three harvests. The last harvest data are questionable because of an accidental fire which burned parts of two replications, thus requiring the generation of "missing data".

Moisture extraction patterns for this experiment showed that the profile was dried almost completely to a depth of 1.8 m during the dry season. The cutting treatment resulted in earlier use of moisture in the 0-1.2 m depth compared to the burn treatment, perhaps reflecting the more rapid recovery observed after cutting than after burning for both leaves and total DM.



Dates of harvest: 1 Jan, 1 Feb, 1 Mar, 1 Apr.

Figure 3. *Effects of stubble management and maintenance fertilizer on dry season forage availability of* **Andropogon gayanus,** *at Carimagua. (Plot harvested for seed just prior to establishing the trial.). a)* **Burned;** *b)* **clipped to 15 cm;** *c)* **control.**

Commercial Scale Pasture Establishment Experience

During 1979-80, a number of large scale plantings were made in Carimagua using low density seeding systems. A 23-ha pasture was renovated by planting a low-density stand of *A. gayanus* and *P. phaseoloides*. Establishment of both species was satisfactory despite severe competition from *Paspalum plicatulum*, the dominant species in the old pasture. The *P. plicatulum* responded strongly to tillage and fertilizer, produced large quantities of seed during the late rainy and early dry seasons, and produced a very dense stand of seedlings at the beginning of the 1980 rainy season. Grazing began in August and at present there are good stands of *A. gayanus*, *P. phaseoloides*, *P. plicatulum* and, surprisingly, *Stylosanthes humilis*, which had appeared to be a very minor component of the old pasture but also responded strongly to tillage and fertilization. It may be that Mg and/or S, not previously applied, were limiting factors for that legume.

Another pasture of 30 ha was renovated with a low density of *A. gayanus* and *P. phaseoloides*. Excellent stands of both species were obtained but the pasture is now legume-dominant and may require special management to favor the grass. Low density planting was also used to establish 15 ha of *A. gayanus* with *D. ovalifolium* and *S. capitata* in a nearby site. The grass was planted at 1000 hills/ha; the legumes were row-planted with conventional seedings rates.

Pasture Development in the Iso-thermic Savannas (Cerrado)

Research activities of the Pasture Development Section for the thermic savannas are conducted at the Centro de Pesquisa Agropecuária dos Cerrados in a cooperative program with EMBRAPA. The main aims of the Section are: a) to develop efficient systems of establishing pasture legumes and grasses for the thermic savannas of South America, and b) to determine establishment and maintenance requirements for the most promising grass-legume pastures for the area.

Soil Nutrient Deficiencies and Plant Requirements

Previous work has focused on identifying soil nutrient deficiencies in a Dark Red Latosol (LVE) and a Red Yellow Latosol (LVA), the two most important Cerrado soils. Results show that once P deficiency has been corrected, S, K, Zn and Mo become the most limiting nutrients for plant growth. Calcium is also deficient in LVA soil. This work was conducted in the greenhouse with two test species, *Centrosema pubescens* CIAT 438 and *Calopogonium mucunoides* cv. common. A similar study was initiated this year with *Stylosanthes guianensis* 2243, a "tardío" type, and *Andropogon gayanus* 621; both have passed through the forage evaluation scheme at the CPAC and look extremely well adapted to low fertility soils. *Stylosanthes guianensis* responds to initial P application but response then levels off. Response to lime was significant only in the LVA soil with 250 ppm $CaCO_3$

By contrast, *A. gayanus* responded sharply to P up to 50 ppm and even to 100 ppm P, showing that although adapted to low fertility conditions, it will respond to higher fertility levels.

Figure 1 shows the response of *A. gayanus* and *S. guianensis* to P and lime in both soils. Note that $CaCO_3$ at rates of 250 and 500 ppm increased the DM yield of *A. gayanus* as well as its response to initial P levels, especially in the LVA soil. Lime applied to the LVA soil did not increase DM yield in *S. guianensis* but enhanced plant response to lower levels of P. This was interpreted as a plant response to Ca at low levels of applied P. The P source was Ca (H_2 PO_4) H_2O, and it appears that more of this compound was required when no other source of Ca was added.

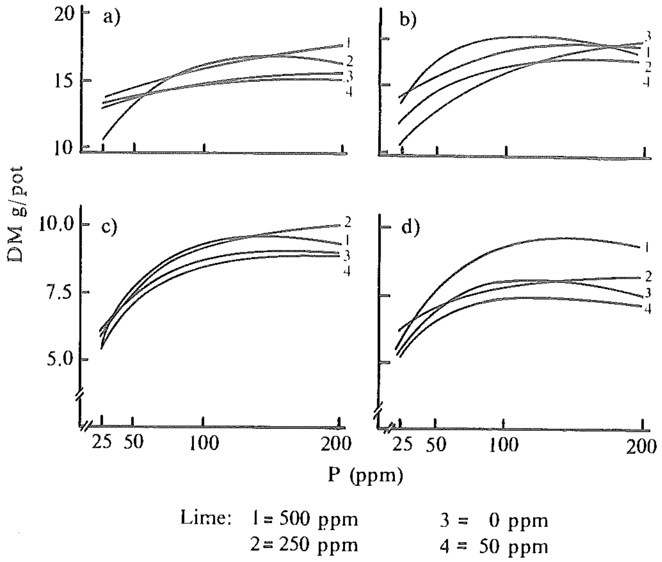


Figure 1. *The effect of P and lime on DM production of* **Andropogon gayanus** *and* **Stylosanthes guianensis** *on LVE and LVA soils, at CPAC, Brazil. a)* **S. guianensis** *(LVE soil); b)* **S. guianensis** *(LVA soil); c)* **A. gayanus** *(LVE soil, 2 cuts average); d)* **A. gayanus** *(LVA soil, two cuts average).*

S. guianensis 2243 was better adapted to low levels of other nutrients than the *Centrosema* and *Calopogonium* used as test plants in earlier experiments. However, late in the growing period, responses to S were apparent in both soils. Final DM yields were increased significantly by S, K and Mo applications in the LVE soil and S, Ca and Zn in the LVA soil.

Andropogon gayanus responded to S, Ca and Mg in the LVA soil and to K and S in the LVE soil. Response to Mg was higher when S was applied. Dry matter production tended to be slightly higher when Cu was applied but the increase was not statistically significant.

Based on the results of the exploratory experiments described above, field experiments were established in both soils. The purpose was to confirm the greenhouse findings and to estimate the fertilizer required to overcome deficiencies of S and K.

Andropogon gayanus 621 and *Stylosanthes capitata* 1405 were sown together on a recently cleared area of a heavy textured LVA soil in a high plateau area. The experiment consisted of varying levels of K, Ca, Mg and S with a basic application of P at the rate of 105 kg/ha. Additional treatments included those nutrients which had significant effects in the greenhouse expriments. As observed previously, initial growth and total DM production were low, but important responses to K, Ca and Mg were obtained. This confirmed deficiencies of those elements and the importance of S deficiency in this soil, even though organic matter was initially high in the top soil. Mineral S status in these soils is still unknown and will be investigated throughout the soil profile in future experiments.

Potassium response was not detected in the first cut but Ca and Mg increased DM production. A Cu tratment (2 kg Cu/ha) doubled DM production.

P requirements in an LVE soil. Cerrado soils are very low in available P and because of their physical and mineralogical characteristics they are expected to fix large amounts of P when fertilizers are applied to a virgin soil. To determine the amount of P fertilizer that should be applied to a new pasture being established in a recently cleared, unfertilized area, a field experiment was established in the LVE. Triple superphosphate at rates of 0, 26, 53, 106 and 211 kg P/ha was applied with and without lime. The lime rate was equivalent to 1 t/ha of $CaCO_3$. Zinc sulfate and sodium molybdate were applied at rates of 20 and 0.5 kg/ha, respectively; K, S and Mg were applied at rates of 74, 90 and 46 kg/ha, respectively. *Andropogon gayanus* 621 was sown after full seedbed preparation.

Figure 2 shows the first harvest DM production as a function of P and lime levels. The rate of DM increase per unit of applied P was higher up to 106 kg P/ha, and within the range of levels used in the experiment, DM production was always higher in the limed treatments. Given the low price of lime and the high cost of P fertilizers in most of the Cerrados region, it is apparent that 1 t/ha of lime could reduce the amount of P required for good pasture establishment in a newly opened area. Since *A. gayanus* is known for its tolerance to soil Al and because 1 t/ha of lime does not reduce the percentage of Al saturation significantly, better performance of the grass with lime might be due to Ca availability or some indirect effect on other plant nutrients. The experiment will be continued to see if the effect of lime persists during following years.

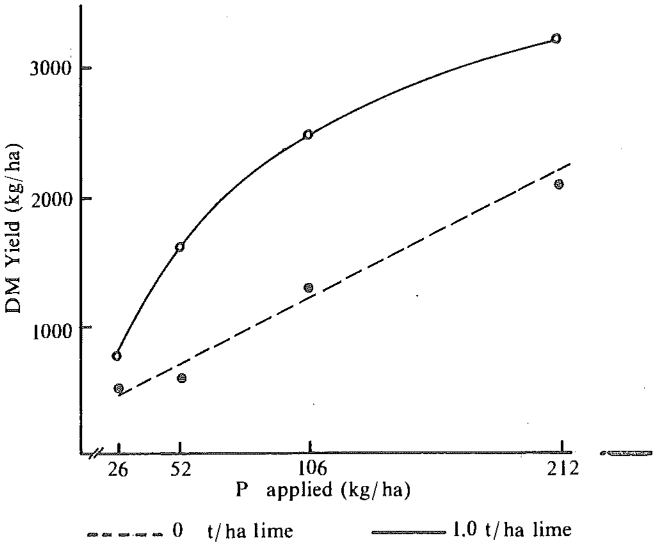


Figure 2. *The effect of P and lime on DM yield of* **Andropogon gayanus** *at the first cut, on an LVE soil at CPAC, Brazil.*

Sources and levels of P in an LVA soil. A similar experiment was established in an LVA soil in 1978. First year results were presented in 1980 (CIAT Trop. Past. Prog. 1979 Annual Report). Three sources of P were included. First year results showed a low rate of growth and productivity. Plant analyses indicated a possible Mg deficiency which was accentuated when triple superphosphate or rock phosphate was used as a P source. Dolomitic lime was surface applied as a source of Mg and Ca to half of each plot in the second year and DM production increased in all treatments. However, Yoorin thermophosphate, which contains Mg, was still superior to other sources.

This year's results are presented in Figure 3. The favorable effect of lime is not due entirely to Mg; yields were further increased by lime over those obtained with the P source that contained a high level of Mg. A greenhouse experiment is being conducted to further explore the reasons for the low productivity of this soil and the effects of lime on soil properties and plant nutrition.

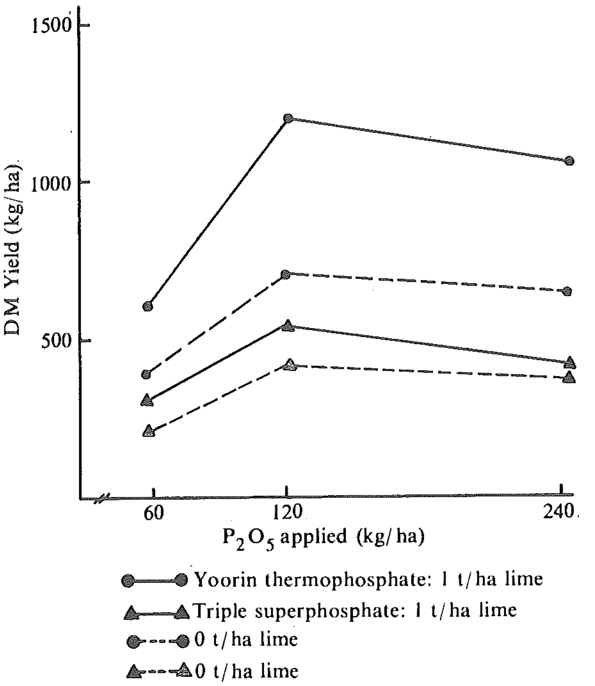


Figure 3. *The effect of three levels and two sources of P on yields of an* **Andropogon gayanus-Stylosanthes guianensis** *mixture in the second year, on an LVA soil at CPAC, Brazil.*

Residual effects of fertilizer. Research has shown that rather large amounts of fertilizer must be applied to virgin Cerrado soils to assure reasonable forage production during the first wet season after establishment. Pastures are commonly established in the Cerrado after clearing the land and planting two or more annual crops. Fertilizer and lime are usually applied for soybean and rice leaving residual fertility for the following pasture, thus reducing or eliminating the need for fertilizer for pastures.

In an attempt to estimate the levels of P, Ca and Mg required for adequate pasture establishment and production, plots of *A. gayanus* and *Panicum maximum* var. *trichoglume* cv. Petrie were established in an old experimental site where a wide range of P and lime levels were applied six years earlier. No fertilizer was applied when planting. Available soil P, pH and exchangeable Ca, Mg, K and Al were determined before planting. Dry matter production was measured during two years. The average yield from four cuts was correlated with soil variables and a production function on those variables was developed which correlated better with DM yield.

Available P and soil pH (or % Al saturation) accounted for more than 66% of the variation between treatments. Figure 4 shows *A. gayanus* and *P. maximum* yield estimates using the model $\hat{Y} = \alpha + \beta_1 Al + \beta_2 P + \beta_3 P^2$, where $\hat{Y}$ is DM yield in kg/ha, Al is percent Al saturation in soil, P is ppm available P in soil by the method of Bray I and β_1, β_2 and β_3 are constants.

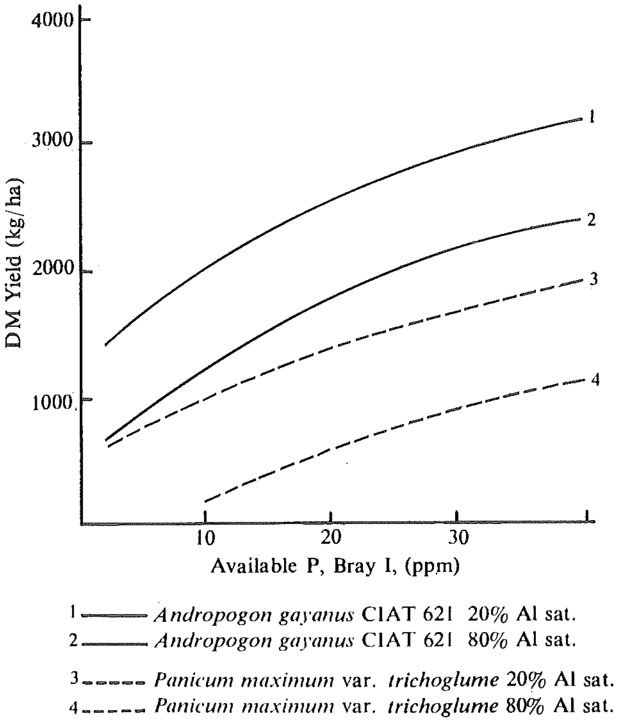


Figure 4. *The effect of available P levels and % Al saturation resulting from previous soil treatments on dry matter production of two forage grasses.*

A. gayanus produces rather high levels of DM with about 6 ppm of available P and high Al saturation, but it also takes advantage of higher levels of available P as well as lower Al saturation. It is important to note that Al saturation is not in itself harmful for *A. gayanus* but it is highly correlated with exchangeable Ca and Mg which have been shown to be essential for a productive *A. gayanus* pasture. In contrast, *P. maximum* production is very poor at levels of Al saturation > 20%. It is interesting to note that, throughout the experimental range, *A. gayanus* produced a larger DM increase per unit of available P than did *P. maximum*.

Pasture Renovation

Large areas of the Cerrados now planted with *Brachiaria* sp. are declining in productivity, and pastures are degrading rapidly due to N deficiency. The introduction of legumes into these degraded pastures should improve forage quality and productivity by increasing protein content and yield of the pasture. Priority is given to the identification of legumes able to establish and compete with *Brachiaria* and the development of appropriate seeding techniques. Preliminary results of research in this area were reported last year (CIAT, Tropical Pastures Program, 1979. Annual Report). *Calopogonium mucunoides* was best able to compete with *B. decumbens* and contributed 32% of the total DM yield. *Centrosema pubescens* was also able to establish but produced <5% of the total DM yield when associated with *B. decumbens.*

Of four seeding methods, oversowing after a light disc harrowing and sod-seeding, were the most promising, both in terms of number of established plants per unit area and in percent legume in the total forage.

While forage quality increased as a result of legume incorporation, especially for the *C. mucunoides-B. decumbens* association, total DM production obtained with the best combination of planting methods and species was no better than *Brachiaria* alone without N. Most of the N is expected to return to the soil under grazing conditions, gradually increasing soil fertility and productivity of the pasture.

Native Pasture Improvement

Observations in an experiment started in 1978 (CIAT Tropical Pastures Program, 1979 Annual Report) on a heavy textured LVA showed an increasing proportion of introduced legumes in the total forage harvested. *Stylosanthes capitata* 1405 was a slow starter but has improved substantially in the second year. Figure 5 shows DM production of native grass and legumes for all methods of establishment. Forage quality has also markedly improved as observed with cultivated pastures on this soil; DM production is still low for both native and introduced species.

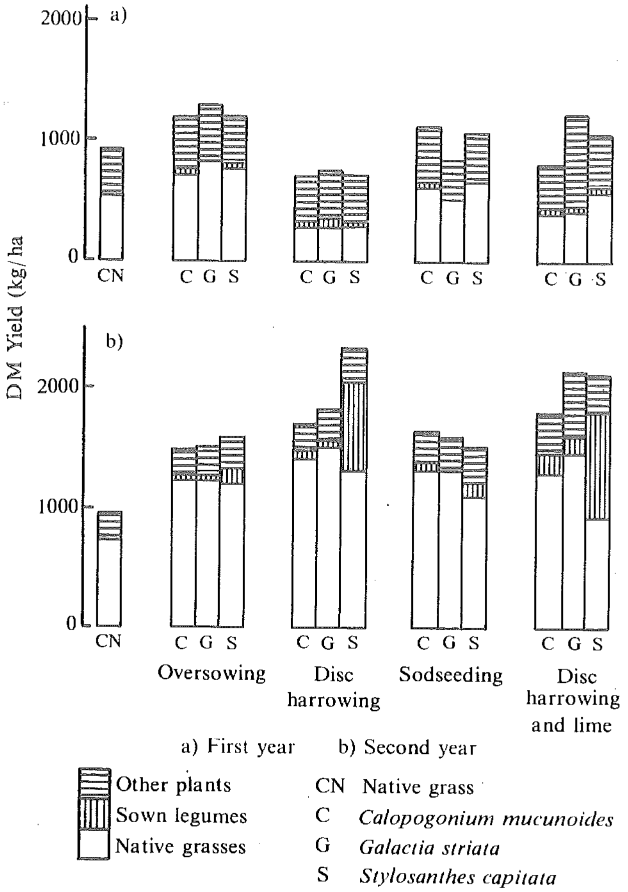


Figure 5. *The effect of pasture treatment on total DM yield and contribution of each forage component to total yield in an improved native pasture on an LVA soil, CPAC, Brazil.*

Pasture Utilization

The overall objective of the Pasture Utilization Section is to characterize and evaluate promising germplasm for its feeding value and animal productivity potential, and to determine proper pasture management to insure persistence.

Forage Quality

Studies with crated wethers were conducted in CIAT-Quilichao to determine intake and digestibility of promising legume species and ecotypes fed alone or with grasses. In addition, the nutritive value of germplasm from cutting and grazing experiments was estimated by chemical and *in vitro* digestibility analyses.

Stylosanthes capitata. The quality of *S. capitata* in the flowering stage was determined for three ecotypes (1019, 1315, and 1405) of similar maturity and plant part composition by feeding fresh, unchopped material to crated wethers. At similar feeding levels intake and digestibility of the three ecotypes were similar and they provided almost twice the digestible nutrients required for maintenance (Table 1). Of the total DM consumed, the inflorescence was the greatest proportion (69%), followed by the leaf (21%) and stem (10%). These results suggest that the inflorescence of *S. capitata* has a high nutritive value; this is of particular relevance during the dry season when the legume defoliates.

The effect on intake and digestibility of different legume proportions in the forage on offer was investigated with immature *Andropogon gayanus* (six weeks regrowth) and *S. capitata* (12 weeks regrowth), both of which are characterized in Table 2. Wethers were offered fresh, unchopped forage at three levels (50, 100, 150 g $DM/kg^{0.75}/day$), each of which included four legume proportions by weight (0, 10, 20, 30%). Intake increased linearly with level of offer at any legume combination, and the slopes of the regression lines were very similar for the four legume combinations (Fig. 1). It is clear that substitution of grass by legume occurred at all feeding levels and that the legume had no effect on total forage intake or digestibility when the quality of grass was not limiting. However, the substitutions of grass by legume in the consumed forage may have resulted in an increased retention of N.

Table 2. Plant part and chemical composition of *Andropogon gayanus* 621 and *Stylosanthes capitata* 1019 fed fresh and unchopped to crated wethers in different combinations, at CIAT-Quilichao.

Species	Component	DM offered (%)	Plant part (%)		
			Leaf	Stem	Flowers
A. gayanus[1]	Proportion	-	61.20	38.80	-
	Protein	7.2	8.90	4.10	-
	P	-	0.12	0.07	-
	Ca	-	0.33	0.21	-
	IVDMD[3]	60.8	62.70	56.10	-
S. capitata[2]	Proportion	-	29.40	34.60	36.00
	Protein	13.2	17.20	9.20	16.50
	P	-	0.16	0.09	0.18
	Ca	-	0.95	0.58	0.84
	IVDMD[3]	58.4	60.30	49.80	64.30

[1] 6-week regrowth [2] 12-week regrowth [3] *In vitro* dry matter digestibility.

Table 1. Intake and digestibility of three *S. capitata* ecotypes in the flowering stage[1] fed to crated wethers, at CIAT-Quilichao.

Legume	Level of offer	Protein on offer	DM intake	MS digestibility
	(g $DM/kg^{0.75}/day$)	(%)	(g $DM/kg^{0.75}/day$)	(%)
S. capitata 1019	128	10.4 ± 1.2	75.7 ± 5.5	59.4 ± 3.3
S. capitata 1315	117	8.9 ± 2.8	71.6 ± 5.5	56.8 ± 3.0
S. capitata 1405	122	9.1 ± 1.8	71.9 ± 7.2	59.2 ± 1.2

[1] Average proportion of plant parts on dry matter offered: 15% leaf, 34% stem and 51% inflorescence.

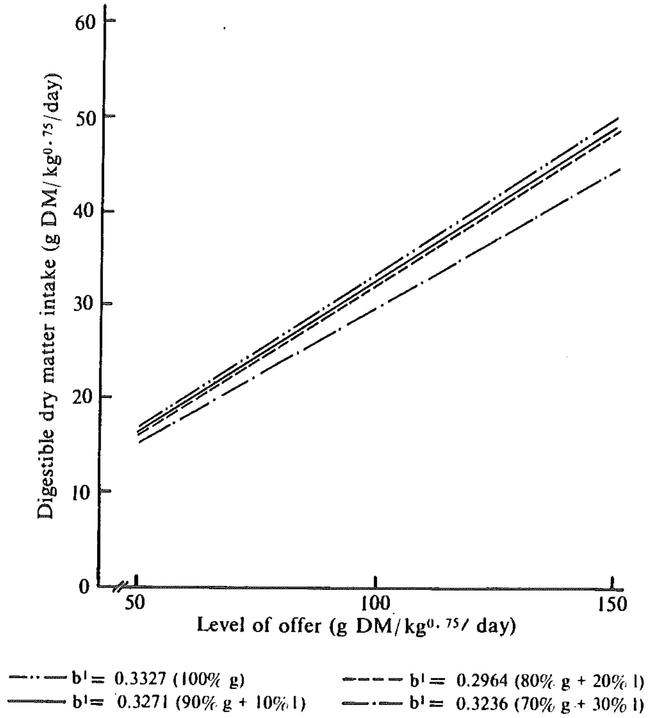
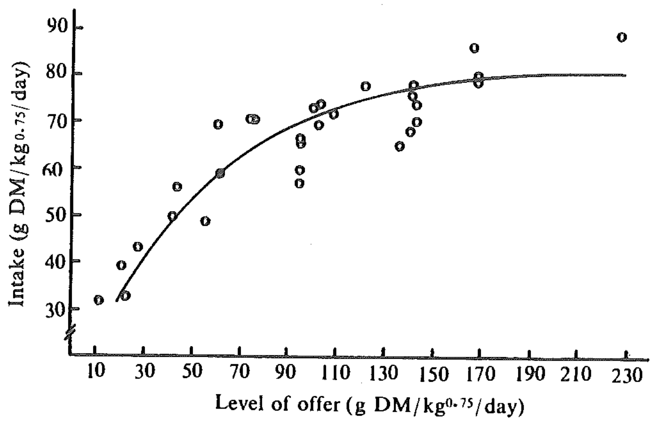


Figure 1. *Digestible dry matter intake of* **A. gayanus + S. capitata** *mixtures with crated wethers* **vs.** *level of dry matter offered at CIAT-Quilichao. Interaction = % legume x level of offer* $(P< 0.99)$*. Maturity stages: grass, 6 weeks regrowth; legume, 12 weeks regrowth. Grass = g; legume = l.*
[1] $y = ax+b$.

***Desmodium ovalifolium*.** Studies continued with *D. ovalifolium* 350 in an attempt to identify factors affecting palatability of this promising legume. Most of the previously observed variation on intake of *D. ovalifolium* with crated wethers in CIAT-Quilichao could be accounted for by the level of DM offered, through a relationship that was clearly asymptotic (Fig. 2). It was thought that crated wethers would select against *D. ovalifolium* when a grass was available, as has been the case with grazing animals.

Two experiments were conducted at Quilichao to study effects on selection and intake due to substitution in the forage offered of 20% *Brachiaria humidicola* and *Brachiaria decumbens* with *D. ovalifolium*. Results with *B. humidicola* (Table 3) indicate that crated wethers replaced part of the grass by legume, with no effect on total DM intake or digestibility compared to the grass alone. In contrast, substitution of grass by legume in the consumed forage was less with *B. decumbens* and resulted in higher $(P<.05)$ DM intake relative to the grass (Table 3), probably due to a marginal protein deficiency in the grass (4.7% protein in leaf). The variation between trials in voluntary intake of *D. ovalifolium* was probably related to different levels of DM offered. These results indicate that the low palatability of *D. ovalifolium* relative to companion grasses that was observed under grazing at Carimagua could not be reproduced with crated wethers fed the legume harvested at CIAT-Quilichao.



$$y = 82.6\ (1 - e^{-0.015})$$
$$r^2 = 0.99\ (P< 0.01)$$

Figure 2. *Dry matter intake of* **D. ovalifolium** *350 with crated wethers* **vs.** *level of dry matter offered at CIAT-Quilichao.*

Table 3. Intake and digestibility of *Desmodium ovalifolium* 350, *Brachiaria humidicola*, *B. decumbens* and mixtures of the grasses and legume fed fresh and unchopped to crated wethers, at CIAT-Quilichao.

Forage offered	Level of offer	DM intake (g DM/kg$^{0.75}$/day)	DM digestibility (%)
Trial I			
D. ovalifolium	159	71.6^{a} ± 5.1[1]	56.7^{a} ± 3.2
B. humidicola	144	82.8^{b} ± 3.4	59.1^{b} ± 1.2
Mixture			
B. humidicola	109 (78)[2]	70.1 (81)	
D. ovalifolium	31 (22)	17.8 (20)	
Total	140	87.0^{b} ± 7.2	60.9^{b} ± 2.1
Trial II			
D. ovalifolium	114	61.3^{c} ± 4.7	57.0^{c} ± 0.7
B. decumbens	125	59.9^{c} ± 5.8	60.2^{d} ± 2.8
Mixture			
B. decumbens	100 (81)	55.5 (79)	
D. ovalifolium	23 (19)	15.0 (21)	
Total	123	70.5^{d} ± 1.5	61.9^{d} ± 1.5

---

[1] For each trial means in the same column and followed by different letters are significantly different at $P<.05$.

[2] Figures in parenthesis are percentages.

Four steers were allowed to graze a pure stand (2 ha) of *D. ovalifolium* in Carimagua to determine if the legume would be refused. The animals not only consumed the legume but gained weight (average of 429 g/animal/day during 178 days). After three months on the pasture it was apparent that animals were grazing very selectively.

Soil and leaf samples were taken from the grazed and ungrazed areas for chemical analyses. Results in Table 4 indicate that soil from the grazed areas had higher levels ($P<0.5$) of P, S and Ca than soil from ungrazed areas. Foliar tissue from areas being grazed had less tannin (catequin equivalent) but higher levels ($P<0.5$) of N, P, K and S than leaves from the ungrazed spots. Higher *in vitro* digestibility was also associated with leaves from grazed areas relative to ungrazed areas. The observed differences in tannin and mineral content in leaves of *D. ovalifolium* from the two areas could be due to not only soil fertility but also a dilution effect from the stage of maturity.

Table 4. Chemical analysis of soil and leaf of *Desmodium ovalifolium* 350 from grazed and ungrazed areas, at Carimagua.

Component	Grazed	Ungrazed
Soil		
pH	3.7	3.7
Al (meq/100 g)	3.0	3.2
P, Bray II (ppm)	1.4^{c1}	0.7^{d}
S (ppm)	16.0^{c}	11.7^{d}
Ca (meq/100 g)	0.28^{c}	0.10^{d}
Mg (meq/100 g)	0.06	0.04
K (meq/100 g)	0.09	0.06
Foliar tissue[2]		
Tannins[3] (%)	20.2^{c}	31.3^{d}
P (%)	0.20^{c}	0.11^{d}
K (%)	0.89^{c}	0.52^{d}
Ca (%)	0.91	0.92
Mg (%)	0.20	0.26
S (%)	0.17^{c}	0.09^{d}
Protein (%)	16.4^{c}	10.2^{d}
IVDMD (%)	51.6^{c}	45.4^{d}

[1] Means within rows and followed by different letters are significantly different at $P<0.5$.

[2] Average of samples from two periods (three and five months after initial grazing).

[3] Catequim equivalent (Vanillin-HCl method).

The tannin content of *D. ovalifolium* leaves fed to crated wethers in CIAT-Quilichao has consistently been about 14%, considerably lower than that in leaf samples from Carimagua (20-30%). This could be related to the higher soil fertility of the field from which material has been cut for intake and digestion trials. Experiments are underway to determine the exact role of soil fertility on tannin content and palatability of *D. ovalifolium.*

Other studies related to nutritive value of *D. ovalifolium* have been done in collaboration with the Agronomy Section in CIAT-Quilichao. Protein and tannin content were determined in *Desmodium gyroides* 3001 and *D. ovalifolium* 350 cut at five stages (3, 6, 9, 12 and 15 weeks) of regrowth during the rainy season. The protein content was higher in the leaves of *D. gyroides* than in *D. ovalifolium* at any stage of maturity, and the opposite was true for tannin levels. It was also apparent that tannins in both *Desmodium* species increased up to 9 weeks of regrowth and remained relatively stable thereafter. The increase in tannin content was accompanied by a decline in crude protein in the leaves of both species.

The tannin content in the leaves also appeared to be related to N solubility (Wohlt Method) (Fig. 3). In general, of the legumes studied in another experiment, *D. ovalifolium* 350 had the lowest protein content and solubility (Fig. 4). The low solubility and possibly low degradation rate could result in bypass protein, which is advantageous for animal production if the enzymes in the lower digestive tract are able to degrade the protein reaching that site. Methods for estimating rates of protein degradation and passage are being investigated for future research on nutritive value of *Desmodium* species.

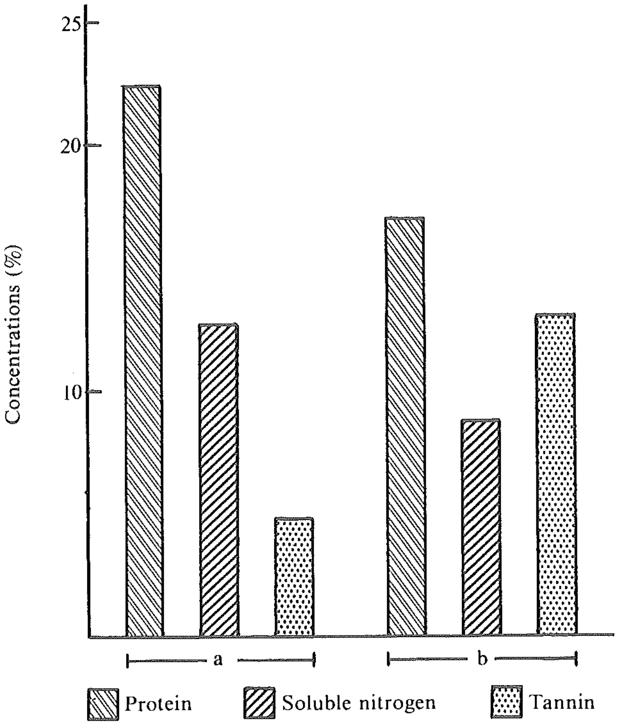


Figure 3. *Mean protein content, soluble nitrogen and tannins in two* **Desmodium** *species cut at 3-6 weeks of age, at CIAT-Quilichao. a)* **D. gyroides** *3001; b)* **D. ovalifolium** *350.*

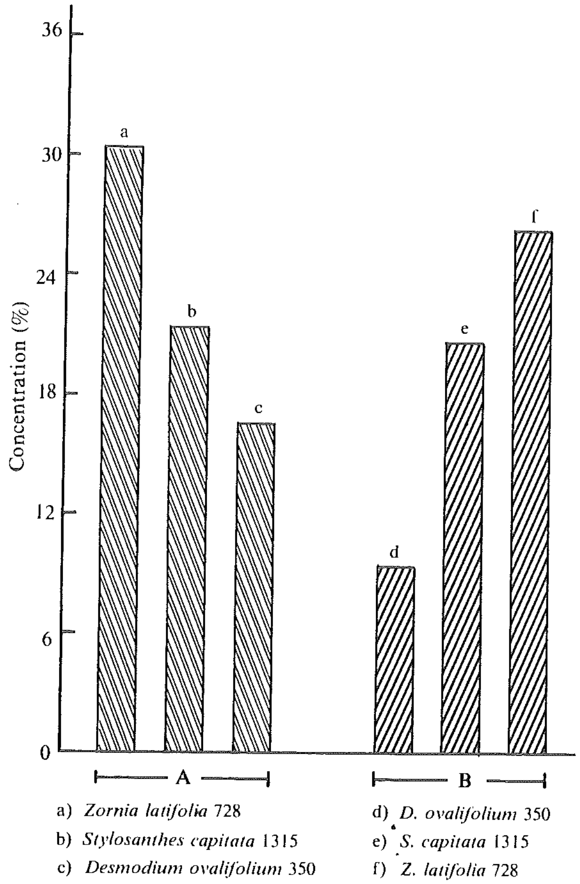


Figure 4. *Mean protein content and N solubility of three legumes sampled at three to six weeks of regrowth, at CIAT-Quilichao.* A. *Protein;* B. *Soluble nitrogen.*

Grasses. Pastures under experimental grazing in Carimagua are being systematically evaluated by season to determine *in vitro* digestibility of plant components in the available forage.

Digestibility estimates for *B. decumbens, B. humidicola, A. gayanus* and *Panicum maximum* in three periods of the year are presented in Table 5. As expected, digestibility of leaf and stem was strongly influenced by season. However, the rate of decline in leaf digestibility was less in *B. decumbens* and *A. gayanus,* compared to *B. humidicola.*

The faster decline in digestibility of the leaf of *B. humidicola* could be contributing to the lower live weight gains obtained so far with this grass, compared with *B. decumbens.*

Table 5. *In vitro* digestibility (IVDMD) of four grasses under continuous grazing in three periods of the year, at Carimagua.

Grass		IVDMD (%)		
	Plant part	Initial[1] rains	Late[2] rains	Initial[3] dry
Brachiaria decumbens	Leaf	71.0 ± 4.9	69.0 ± 3.1	60.9 ± 4.6
	Stem	60.0 ± 6.4	54.0 ± 3.9	49.3 ± 3.3
Brachiaria humidicola	Leaf	76.5 ± 1.9	63.9 ± 2.1	54.6 ± 3.7
	Stem	60.0 ± 2.0	56.9 ± 1.8	47.2 ± 1.2
Andropogon gayanus	Leaf	57.3 ± 3.6	53.2 ± 3.9	44.2 ± 2.8
	Stem	62.2 ± 3.4	48.8 ± 4.6	33.8 ± 3.8
Panicum maximum	Leaf	—	51.7 ± 4.3	40.4 ± 0.7
	Stem	—	43.9 ± 3.3	25.2 ± 2.0

[1] May, 1980
[2] October, 1979
[3] January, 1980

Selective Grazing in Grass-Legume Pastures

The relationship between botanical and chemical composition of forage on offer and selected by the grazing animal is being studied in legume-based pastures in Carimagua and CIAT-Quilichao.

Carimagua. Esophageal fistulated steers were used to obtain representative samples of ingested forage in pastures of *A. gayanus* in association with *Pueraria phaseoloides, S. capitata* and *Zornia latifolia.* The botanical composition of the forage available and selected during the dry and early rainy seasons is presented in Figure 5. It is evident that more legume was selected in the dry season than in the early season. This was particularly true for the *S. capitata* ecotypes and *P. phaseoloides* which were not limiting in the pasture as was *Z. latifolia.* Legume selection in the *S. capitata* associations during the dry season appeared to depend on the botanical composition of the pasture, at least on the range studied.

The inflorescence of *S. capitata* was a major component of the legume available and selected by the animal in the dry season. The high nutritive value of the inflorescence relative to other plant parts on the available forage is evident from the *in vitro* digestibility values in Table 6.

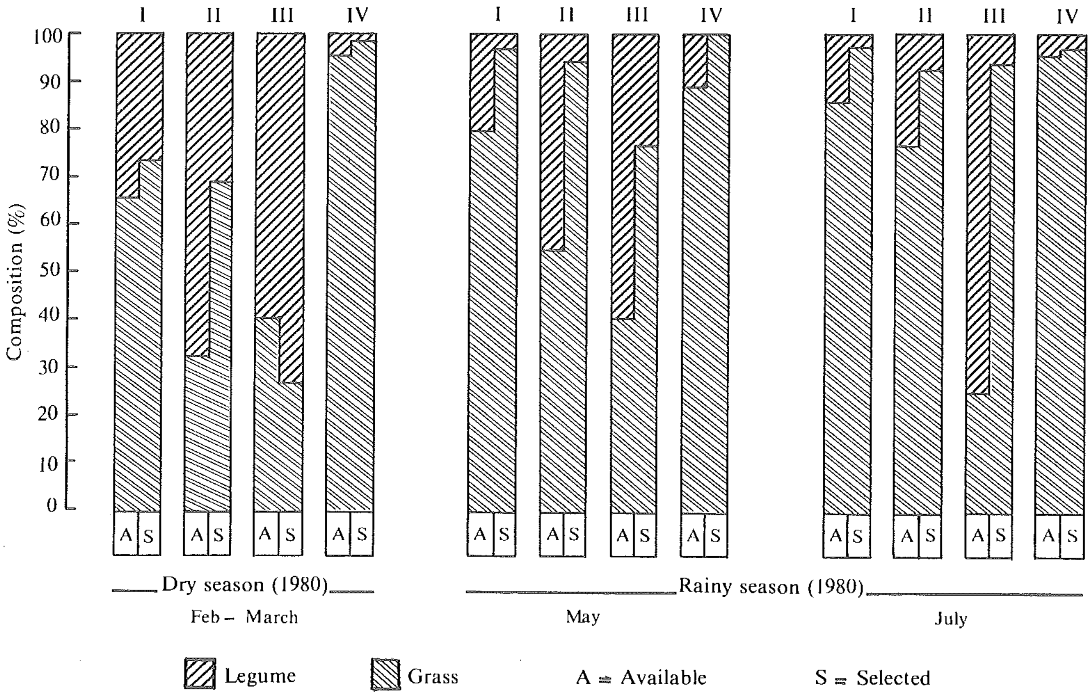


Figure 5. *Botanical composition by season of the forage available (by weight) and selected (presence) by esophageal fistulated steers in four grass-legume associations under grazing, at Carimagua. Mixtures: I =* **A. gayanus + S. capitata** *1405; II =* **A. gayanus + S. capitata** *1019+1315; III =* **A. gayanus + P. phaseoloides**; *IV =* **A. gayanus + Z. latifolia.**

Table 6. *In vitro* digestibility (IVDMD) of plant parts in the forage available in various grass-legume associations in the dry season[1] in Carimagua.

Pasture	Component	IVDMD (%)			
		Leaf	Stem	Dead matter	Flowers
Andropogon gayanus	Grass	51.7	43.4	35.1	-
Andropogon gayanus	Grass	47.8	38.9	32.4	-
+ *Stylosanthes capitata*	Legume	65.2	37.2	30.4	65.2
Andropogon gayanus	Grass	54.9	41.8	33.2	-
+ *Stylosanthes capitata* 1019	Legume	63.3	41.0	36.0	64.8
+ *Stylosanthes capitata* 1315	Grass	48.0	41.7	33.4	-
Andropogon gayanus	Legume	56.7	50.0	41.2	59.9
+ *Pueraria phaseoloides*	Grass	53.4	51.8	39.0	-
Andropogon gayanus	Legume	-	48.4	43.5	-
+ *Zornia latifolia*	Legume	-	-	-	-
Average	Grasses	51.2	43.5	35.8	-
	Legumes	61.7	44.1	37.8	63.3

[1] Sampling February 1980

A major objective of studies on selective grazing has been to relate attributes of the available and consumed forage with observed animal performance. Changes in liveweight during the dry season in grass-legume associations are presented in Table 7, together with botanical and chemical composition of the forage available and selected by esophageal fistulated steers. Protein was obviously a limiting factor in the pure *A. gayanus* and *Z. latifolia* pasture with very little legume present. Animals in these two pastures selected a diet higher in protein than what was available, but still marginally deficient to the extent of animals maintaining or losing weight. In contrast, in the *S. capitata* and *P. phaseoloides* pastures, with higher legume proportions in the available forage, animals gained weight, most likely due to the correction of protein deficiency through legume consumption.

Of interest was that the high legume proportion in the *P. phaseoloides* (58%) and *S. capitata* 1019 + 1315 (67%) pastures did not produce higher liveweight gains than the *S. capitata* 1405 mixtures with less legume (34%). This suggests that if legume availability is not limiting in the pasture, a balance that favors *A. gayanus* over *S. capitata* or *P. phaseoloides* during the dry season would be desirable for improved animal gains.

CIAT-Quilichao. The effect of grazing intensity (days of grazing) on selectivity was studied in two grass-legume associations in Quilichao.

Small pastures (550 m^2) with *Centrosema pubescens* in mixture with *A. gayanus, P. maximum* and *B. decumbens* were grazed during six days in sequence, first by A grazers (2 days), then by B grazers (2 days) and finally by C grazers (2 days). Samples of available and consumed forage were taken before each of the grazers (A, B, C) entered the pasture. By reducing the number and/or weight of animals as grazing progressed from A to C, the resulting grazing pressure was less with the C grazers (4 days of grazing-51.2 kg DM/100 kg BW), compared to the A grazers (initial grazing-25.3 kg DM/100 kg BW).

Legume presence in the diet increased with grazing intensity. However, more legumes were present in esophageal forage samples from the second day of grazing compared to the fourth day, where legume availability in the pasture appeared to be limiting. The increased presence of legume in the consumed forage was accompanied by more stem (Fig. 6) and lower *in vitro* digestibility of the available and esophageal forage (Fig. 7). It is clear that selection for *C. pubescens* resulted when the quality of forage on offer was low.

Table 7. Botanical and chemical composition of forage on offer and selected by esophageal fistulated steers and changes in liveweight in grass-legume associations during the dry season[1]/ in Carimagua.

Pasture	On offer (%)		Selected (%)			Changes in weight (g/animal/ day)
	Legume	Protein	Legume[2]	IVDMD	Protein	
Andropogon gayanus		2.4		49.1	4.2	-21
Andropogon gayanus + *Stylosantes capitata* 1405	34	5.1	26	47.2	6.3	+224
Andropogon gayanus + *Stylosanthes capitata* 1019 + *Stylosanthes capitata* 1315	67	6.5	31	41.7	6.6	167
Andropogon gayanus + *Pueraria phaseoloides*	58	6.7	73	45.9	9.8	208
Andropogon gayanus + *Zornia latifolia* 728	4	2.7	1	43.2	4.6	21

[1] Period December 12 to April 8 (117 days grazing with 1 A.U./ha).

[2] Legume present.

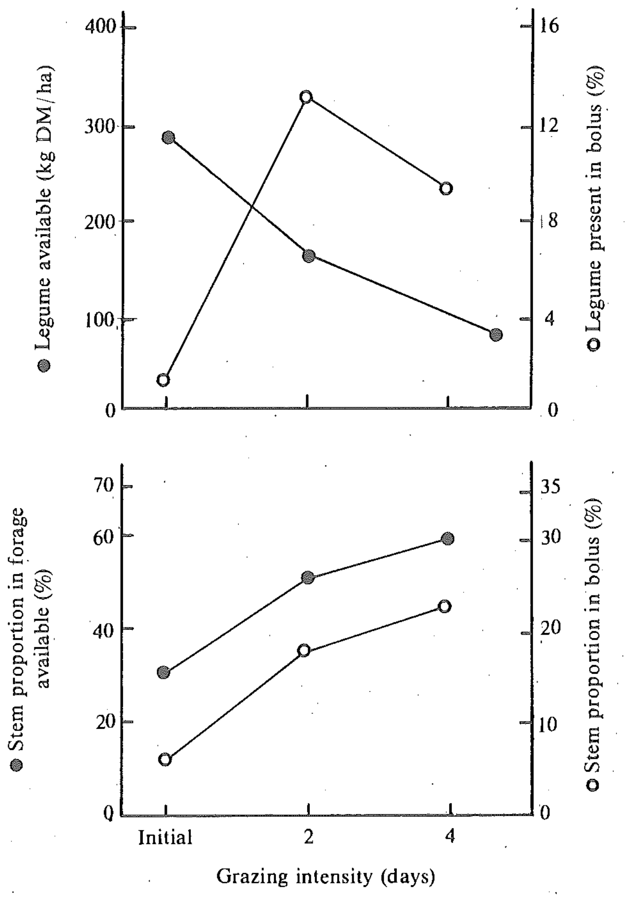


Figure 6. *Changes in the proportion of legume and stem in forage available and selected (bolus) by esophageal fistulated steers in* **C. pubescens, B. decumbens** *and* **A. decumbens** *associated with* **P. maximum** *under different grazing intensities (0 = initial) at CIAT-Quilichao.*

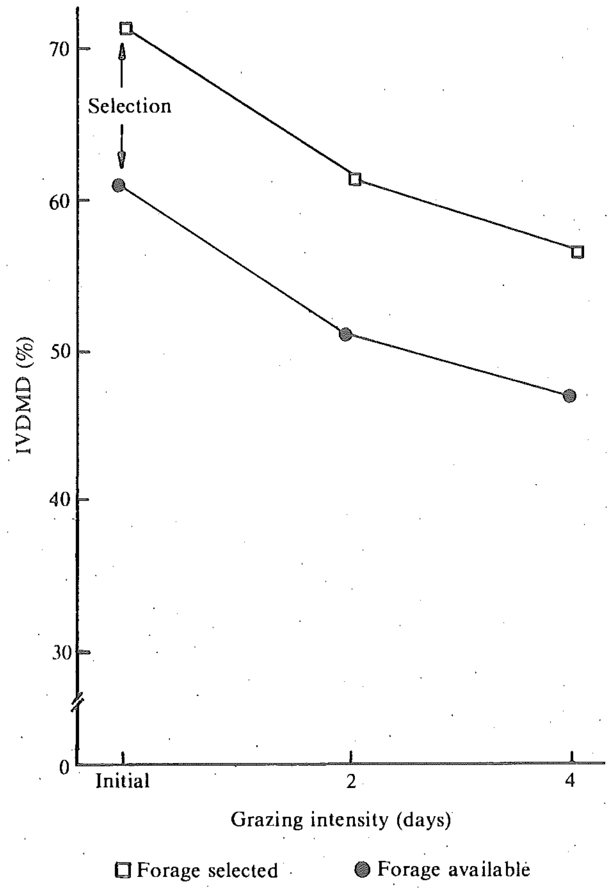


Figure 7. *Changes in the* **in vitro** *digestibility (IVDMD) of forage available and selected by esophageal fistulated steers in an association of* **Andropogon gayanus + Panicum maximum + Centrosema pubescens,** *under different grazing intensities (0 = initial) at CIAT-Quilichao.*

Another experiment was conducted at CIAT-Quilichao to study selective grazing of an *A. gayanus-D. ovalifolium* association at two stages of maturity. Small plots (360 m² immature and 180 m² mature) were grazed for 4 days, first by A grazers (2 days) followed by B grazers (2 days). As in the experiment above, samples of available and esophageal forage were taken before each grazer entered the experimental plot.

After two days of grazing the grass was more scarce than the legume in the forage available at both maturities (Fig. 8). This dominance of *D. ovalifolium* over the associated grass had been observed in larger grazing trials under continuous grazing, and is due to the greater preference of the animal for the companion grass. Only when the grass component was limiting did animals select *D. ovalifolium*. It was evident, however, that legume selection was influenced by the maturity stage of the companion grass.

These results point out the great effect of differences in relative palatability of species on stability of some grass-legume associations. It would seem desirable to determine relative preference of species in promising grass-legume associations before large grazing trials are planned.

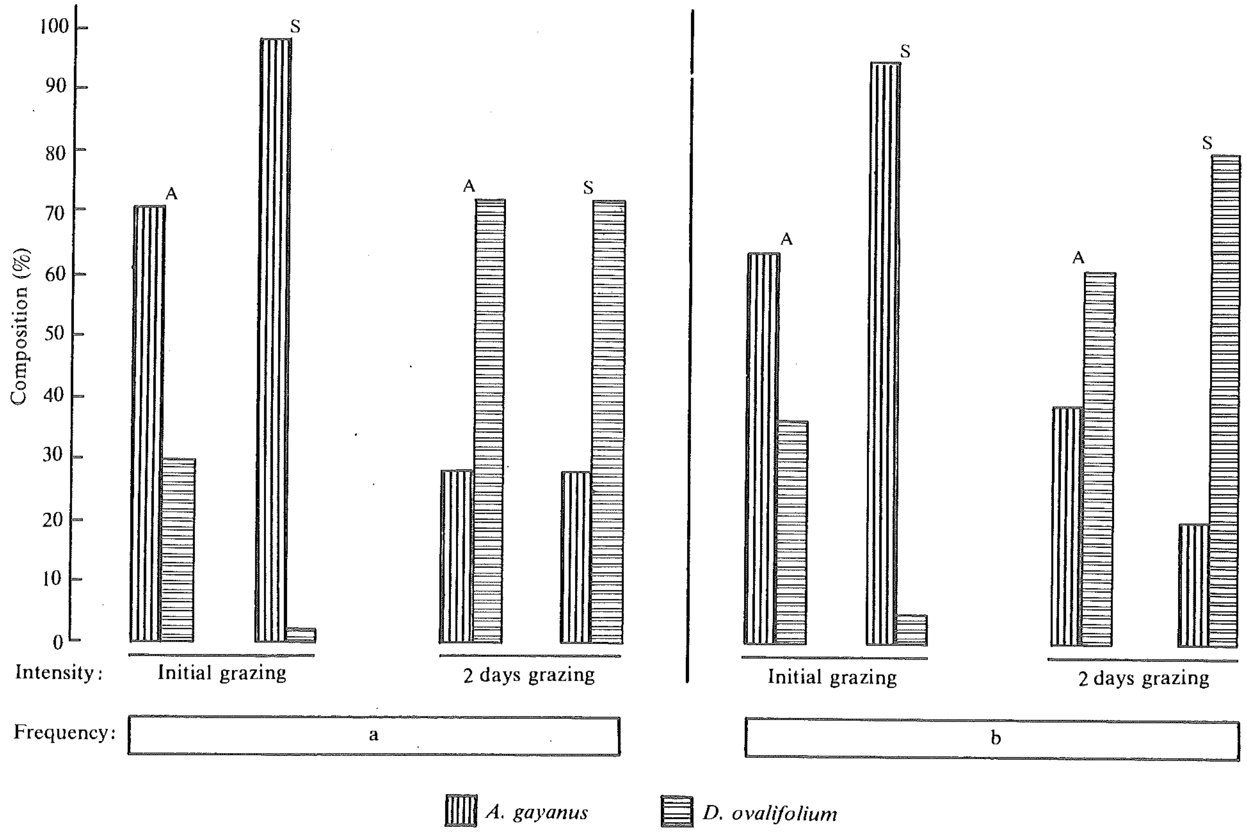


Figure 8. *Changes in the botanical composition of forage available (by weight) and selected (presence) by esophageal fistulated steers in an* **A. gayanus-D. ovalifolium** *association under different grazing frequencies and intensities, at CIAT-Quilichao. Frequency: a) Inmature; b) Mature. A=available; S= selected.*

Productivity and Management of Grass Pastures

Brachiaria decumbens. This grass has been under investigation since 1973 and partial results for most parts of 1980 are consistent with previous years. Evaluation of this species could now be considered almost finished except for long-term evaluation under the best management treatments.

Results of animal performance studies on well-managed *B. decumbens* indicate that it tolerates a rather wide range of stocking rates under continuous grazing. Steers have been able to maintain or gain some weight during the dry season and gain weight (average of 450 g/day) during the rainy season. The best management seems to be continuous grazing with seasonal stocking rates of 1 and 2 animal/ha for the dry and rainy season, respectively. Productivity tends to decrease after the fourth year as previously reported, but with minimum maintenance fertilizer, increases in both annual weight gains per steer and per hectare were observed. Average liveweight gains in four years are presented in Table 8.

Brachiaria decumbens could presently be considered the best grass for the Colombian well-drained savannas on the basis of its production potential and easy management, although susceptibility to the spittlebug is a major risk factor associated with the species. Spittlebugs (*Aneolamia* sp. and *Zulia* sp.) have not caused the same devastation in the Colombian Llanos as reported in Brazil; however, the incidence may possibly increase as larger areas of this grass are planted.

Andropogon gayanus. The first experimental pastures of *A. gayanus* were sown in Carimagua in 1976. However, only in 1979 did animal production data become available, due to problems in finding an adequate management system for this grass. Animal weight gains for the continuous grazing treatment during 1979 and until August 1980 are presented in Table 9. So far, liveweight gains during 1980 are consistent with those reported for 1979. During 1980 the experiment was modified to compare continuous grazing with a two-paddock intermittent grazing system at the same stocking rates (2.4, 3.4, and 4.4 animal/ha). Three paddocks (2.94, 3.85 and 5.50 ha) of the 3-year-old *A. gayanus* were subdivided and grazed intermittently based on forage availability of the medium stocking rate (3.4 animal/ha) treatment. Preliminary results with this two-paddock system indicate that liveweight gains during the rainy season are less than those with the continuous grazing system at any stocking rate.

Brachiaria humidicola. This is another promising grass species under evaluation since 1978. Animal performance data (Table 10) are, however, somewhat contradictory and a strong and still unclear paddock effect is apparent. In addition, overall animal weight gains in both seasons are much less than what has been recorded for *B. decumbens;* this could be partially explained by available nutritional data (see Table 1) and or improper grazing management.

Pure grass pastures in Carimagua were sampled at different times of the year to evaluate the effect of season and stocking rate on forage availability and plant part composition as a possible explanation for differences in weight gains.

Table 8. Average liveweight gains (1976-1979) by season of the year on the best treatments of *Brachiaria decumbens* under continuous grazing in Carimagua.

Experiment	Treatment	Dry season	Rainy season	Year average		
		(g/A.U./day)		Stocking rate (A.U./ha)	Gain per animal (kg/A.U.)	Gain per hectare (kg/ha)
B1	Fixed stocking rate	45	419	1.7	116	176
B2	Variable stocking rate (rainy season)	106	439	0.73/3.0[1]	127	235
B3	Variable stocking rate (dry season)	154	439	1.0/2.0	146	266
Average		102	450		130	

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[1] Dry season/rainy season, respectively

Table 9. Liveweight gains with *Andropogon gayanus* under continuous grazing in Carimagua.

Treatment	1979 Season						1980 Season					
	Dry (98 days)		Rainy (270 days)		Total (368 days)		Dry (147 days)		Rainy (242 days)		Total (362 days)	
	Stocking rate	Liveweight gains/day	Stocking rate	Liveweight gains/day	Liveweight gains		Stocking rate	Liveweight gains/day	Stocking rate	Liveweight gains/day	Liveweight gains	
	(animal/ha)	per animal (g)	(animal/ha)	per animal (g)	per animal (kg)	per ha (kg)	(animal/ha)	per animal (g)	(animal/ha)	per animal (g)	per animal (kg)	per ha (kg)
High	4.4	-86	4.4	365	90	396	1.0	47	4.4	318	77	248
Medium	3.4	-99	3.4	460	115	391	1.5	83	3.4	518	126	451
Low	2.4	-84	2.4	472	119	285	2.0	-49	2.4	629	153	359

Table 10. Liveweight gains with *Brachiaria humidicola* in two experiments under continuous grazing in Carimagua.

Treatment	1979 Season						1980 Season					
	Dry (97 days)		Rainy (271 days)		Total (368 days)		Dry (120 days)		Rainy (243 days)		Total (363 days)	
	Stocking rate	Liveweight gains/day	Stocking rate[1]	Liveweight gains/day	Liveweight gains/day		Stocking rate	Liveweight gains/day	Stocking rate[2]	Liveweight gains/day	Liveweight gains	
	(animal/ha)	per animal (g)	animal/ha)	per animal (g)	per animal (kg)	per ha (kg)	(animal/ha)	per animal (g)	(animal/ha)	per animal (g)	per animal (kg)	per ha (kg)
Low	1.3	181	1.8/2.5	447	139	207	1.8	-74	1.8/2.4	116	42	88
Medium	1.8	-28	2.6/3.6	329	86	196	2.6	-138	2.6/3.4	107	38	116
High	2.4	255	3.4/4.8	279	100	280	3.4	-47	3.4/4.4	82	30	116

[1] First rate was during July-August, second during August-December.

[2] First rate was during December-May, second during May-December.

As expected, stocking rate significantly affected forage DM availability, as illustrated for *B. decumbens* in Figure 9. Stocking rate had little effect on plant part composition during the dry season in *A. gayanus, B. humidicola* and *B. decumbens* (Fig. 10). During the rainy season, however, the higher stocking rates resulted in an increased proportion of dead material in *A. gayanus* and *B. humidicola,* but not in *B. decumbens.* This difference appears to be associated with the higher stocking rate (4.4 animal/ha) in *A. gayanus* and *B. humidicola* as compared to *B. decumbens* (2.4 animal/ha). The lower forage availability and reduced leaf proportion in the forage on offer largely account for the lower liveweight gains recorded in the rainy season with the high stocking rate treatment in *A. gayanus* and *B. humidicola* reported in Tables 9 and 10.

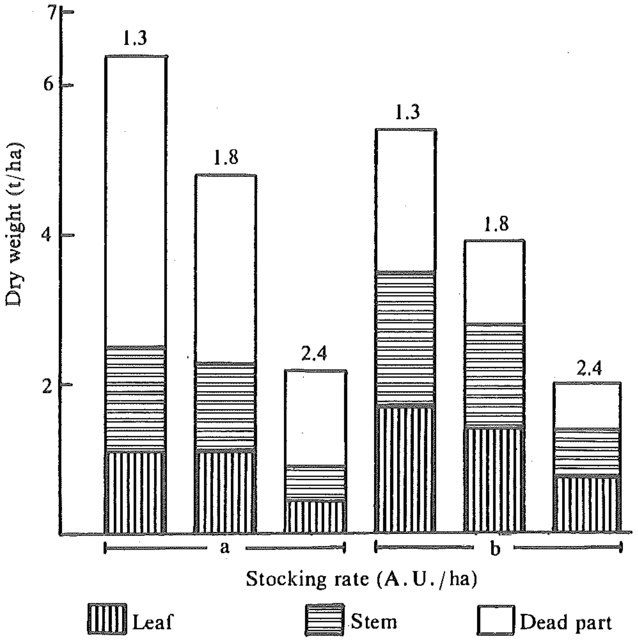


Figure 9. *Forage availability and plant part composition of* **Brachiaria decumbens** *under different stocking rates in a continuous grazing system, at Carimagua. a) February; b) June.*

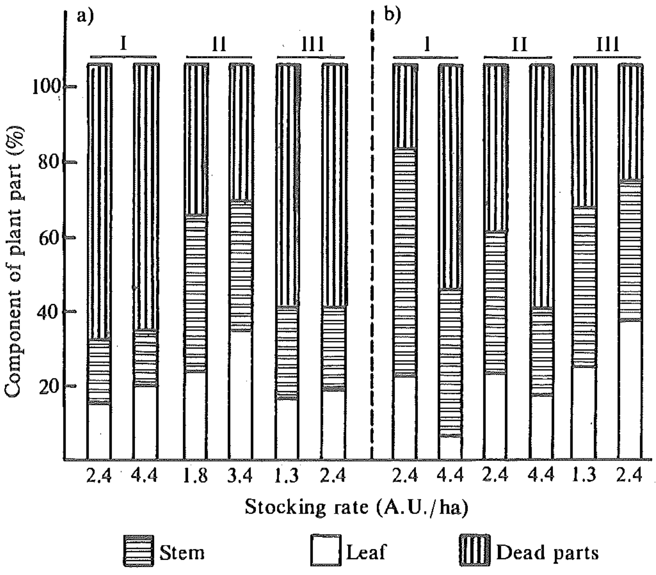


Figure 10. *Effects of stocking rate on plant part composition of three forage grasses under continuous grazing, at Carimagua. I:* **Andropogon gayanus**; *II:* **Brachiaria humidicola**; *III:* **Brachiaria decumbens**. *a) Dry season; b) Rainy season.*

Productivity and Management of Legume-Grass Pastures

Several legumes [*S. capitata* 1019 + 1315 (mixture), *S. capitata* 1405, *P. phaseoloides* and *Z. latifolia* 728] in association with *A. gayanus* have been under evaluation in Carimagua during the past two years. Each mixture was established in two paddocks of 2 ha each. In the same experimental block, pastures of *D. ovalifolium* associated with *A. gayanus* and *B. decumbens* failed under grazing due to the aggressiveness of the legume and inadequate grazing management.

Grazing management applied to the existing grass-legume associations is shown in Figure 11. Figures in horizontal bars refer to stocking rates (steers/ha) which were established at the end of 1979, when it became evident that each paddock would have to be managed independently due to the dynamics of the various associations.

One of the two pastures of each mixture was burned at the end of the 1980 dry season, except for the *P. phaseoloides* association which was rested during the dry season to evaluate the effect on animal productivity. After burning, pastures were also rested. In addition, in some paddocks high grazing pressure (i.e., 34 steers for 10 days) was exerted for a few days and sometimes repeatedly, to control the fast growth of *A. gayanus* and provide better light penetration for the legumes.

Animal weight gains from the unburned paddocks are listed in Table 11. The mixtures of *A. gayanus* with *S. capitata, P. phaseoloides* and *Z. latifolia* produced somewhat lower animal weight gains the second year of grazing. This was mainly due to relatively low gains obtained during the dry season, particularly in the *Zornia* association where legume availability was extremely low.

When experimental grazing started (dry season 1978-79) total forage availability was higher than in the following dry season. Thus, animal performance during the first year will not represent the potential animal productivity of these pastures.

The *S. capitata* and the *P. phaseoloides* associations still produced reasonable weight gains during the 1980 dry season, particularly when compared to pure grass pastures, which at best were only able to maintain weight.

At the beginning of the rainy season, the *Z. latifolia* recovered well in the mixtures with *A. gayanus* mainly due to a high population of new seedlings. The non-burned *Zornia* paddock has so far produced high animal weight gain, with a lower stocking rate (1.4 animal/ha), compared to the rate used in other mixtures (1.8 animal/ha).

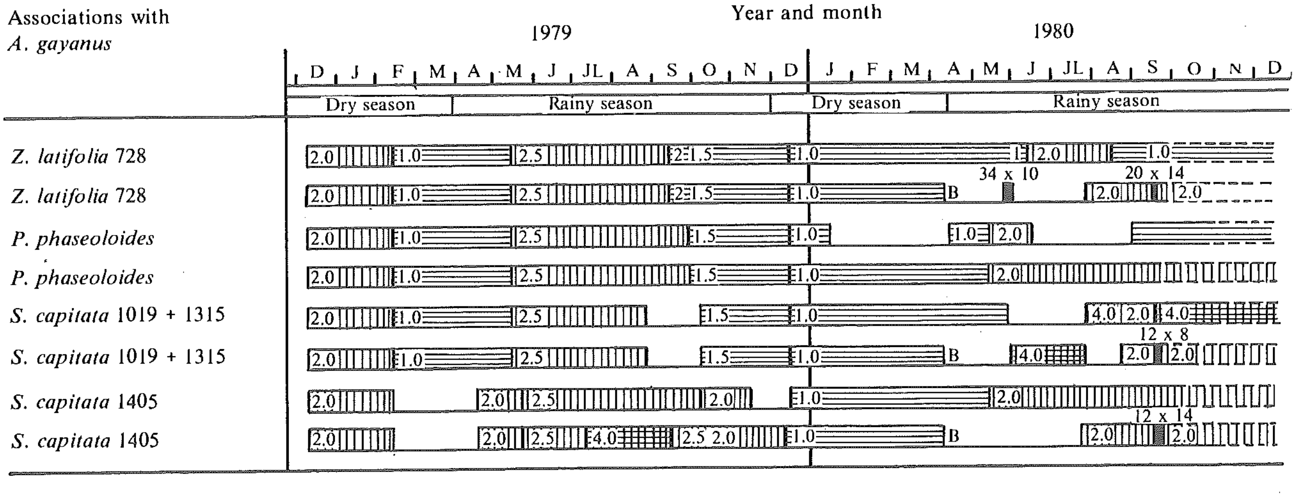


Figure 11. *Management of legume-based pastures during 1979 and 1980, at Carimagua. Figures within horizontal bars are steers/ha; figures over bars are A.U. x No. of grazing days. B = burning.*

Table 11. Liveweight gains in associations of *Andropogon gayanus* with four legumes in Carimagua.

Legume associated with *A. gayanus*	1979 Season						1980 Season					
	Dry (96 days)[1]		Rainy (272 days)[1]		Total (368 days)		Dry (118 days)[1]		Rainy (248 days)[2]		Total (366 days)	
	Stocking rate (animal/ ha)	Liveweight gains/day per animal (g)	Stocking rate[1] (animal/ ha)	Liveweight gains/day per animal (g)	Liveweight gains per animal (kg)	per ha (kg)	Stocking rate (animal/ ha)	Liveweight gains/day per animal (g)	Stocking rate[2] (animal/ ha)	Liveweight gains/day per animal/ (g)	Liveweight gains per animal (kg)	per ha (kg)
S. capitata 1019 + *S. capitata* 1315	1.7	500	1.5	679	233	367	1.0	167	1.8	609	170	238
S. capitata 1405	-	-	1.9	667	196	(372)	1.0	224	1.8	625	192	324
Z. latifolia	1.7	317	1.9	776	242	453	1.0	21	1.4	744	184	223
P. phaseoloides	1.7	371	2.0	681	221	419	1.0	208	1.8	667	190	322

[1] Mean at two pastures of 2 ha each

[2] Mean at one pasture of 2 ha

One of the *A. gayanus-P. phaseoloides* pastures was rested during the dry season in order to prevent disappearance of the legume, since it is known to be susceptible to drought conditions. Apparently this decision was wrong and resulted in legume dominance the next rainy season.

In view of the high preference observed for the legume during the dry season, it seems that the *A. gayanus-P. phaseoloides* association should be grazed during the dry season when it is needed and also to maintain a balance within the association. Alternatively, because of the apparently low palatability of the legume relative to the grass during the rainy season, it would seem desirable to vary the grazing pressure or to graze intermittently, to obtain a better grass-legume balance towards the end of the rainy season.

Although animal productivity data are unavailable from the paddocks of *A. gayanus* with *S. capitata* 1019 and 1405 that were burned at the very end of the 1980 dry season, forage availability, plant part distribution and botanical composition of the pasture were evaluated. As expected, *A. gayanus* in the burned pastures had a higher proportion of leaf, compared to the unburned grass, at least during part of the rainy season.

The availability of *S. capitata* ecotypes decreased after burning (Fig. 12), although *S. capitata* 1019 recovered sooner than 1405 with the initial rains. In general, burning grass-legume pastures seems to involve a risk factor that probably is not worth taking.

Grazing management experiments are in progress in Carimagua and CIAT-Quilichao to help explain the dynamics of grass associations with *D. ovalifolium.* As explained earlier, this legume has failed under grazing at Carimagua due to its lower relative palatability and aggressiveness.

The effect of grazing frequency and pressure on the legume proportion seems to be specific for each mixture as it relates to growth habit, light competition and relative palatability of associated species. In mixtures with the grasses *A. gayanus, P. maximum,* and *B. decumbens* at CIAT-Quilichao, frequent grazing (4-week intervals) provided greater legume coverage, particularly with the first two grasses (Fig. 13). With bunch-type grasses, such as *A. gayanus* and *P. maximum,* less frequent grazing has favored grass growth which adversely affects the legume's competition for light.

In another experiment, low grazing pressure favored *C. pubescens* associated with *A. gayanus,* but this was not the case in a *D. ovalifolium-B. decumbens* mixture, probably due to differences in relative palatability.

The effect of continuous grazing, rotational grazing and cutting on botanical composition of a *B. decumbens-D. ovalifolium* association is also being studied in CIAT-Quilichao. After 11 months of continuous or rotational grazing, the legume component in the pasture has tended to increase, but has decreased under cutting (Fig. 14).

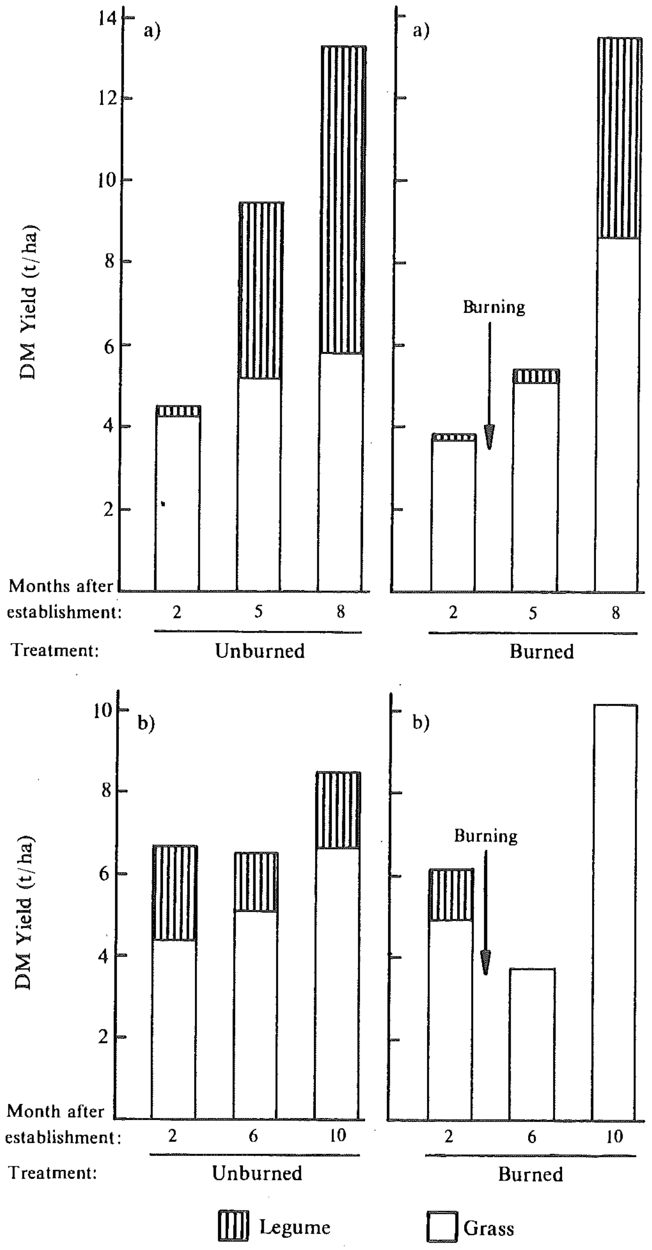


Figure 12. *Forage availability and botanical composition of burned and unburned* **Andropogon gayanus** *in association with* **Stylosanthes capitata** *1019 and 1405, in Carimagua. a)* **S. capitata** *1019; b)* **S. capitata** *1405.*

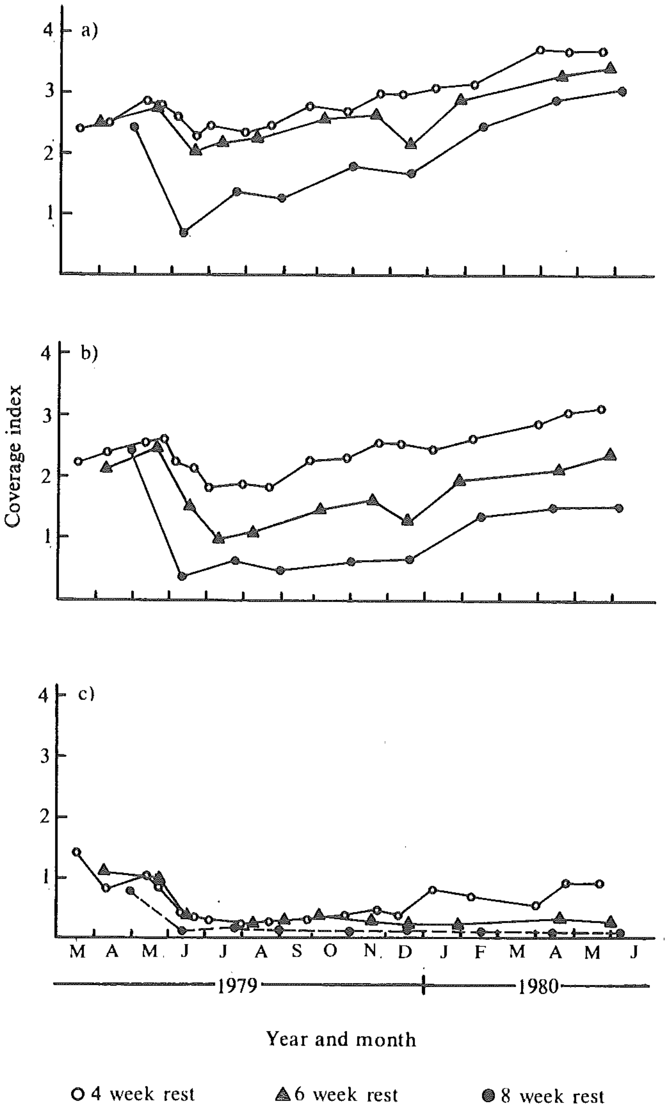


Figure 13. *Effects of grazing frequency on coverage of* **Desmodium ovalifolium** *in association with three grasses, at CIAT-Quilichao. High grazing pressure: a) with* **Andropogon gayanus**; *b) with* **Panicum maximum**; *c) with* **Brachiaria decumbens.**

This could be because animals prefer *B. decumbens,* particularly during the rainy season. Obviously, under cutting forage is uniformly removed from the paddock. The *B. decumbens-D. ovalifolium* mixture appears to have great potential, provided that proper establishment and management are accomplished.

Additional grass-legume associations with *A. gayanus* were established in 1979 to study possible differences in animal productivity between the early *S. capitata* 1019 and the intermediate flowering *S. capitata* 1315. The grazing management plan is shown in Figure 15.

During the 1980 rainy season it was evident that the two *S. capitata* ecotypes were very different in plant vigor. Whether the differences in flowering stages between ecotypes will influence animal production is unknown.

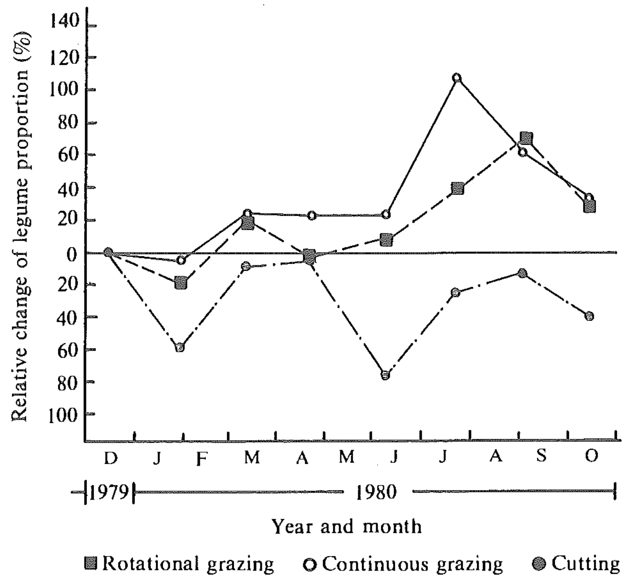


Figure 14. *Relative change in legume proportion in a* **Brachiaria decumbens + Desmodium ovalifolium** *mixture under three management systems, at CIAT-Quilichao.*

Another alternative for utilizing legumes — particularly those difficult to manage — is as "protein banks" in strips or blocks within a grass paddock. This concept was tested with *P. phaseoloides* in combination with *B. decumbens* and with native savanna.

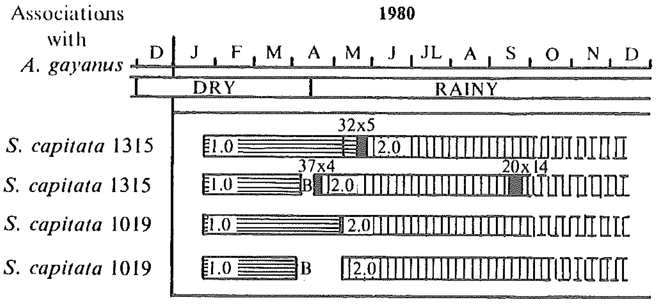


Figure 15. *Management of legume-based pastures established in 1979, at Carimagua. Figures within horizontal bars are steers/ha; figures over bars are A.U. x No. grazing days. B = burning.*

Results suggest that the *P. phaseoloides* protein bank with *B. decumbens* may produce as much animal weight gain as the association (Table 12).

The same legume with native savanna provided increased carrying capacity and higher liveweight gains for the savanna. At the higher continuous stocking rate of 0.5 steers/ha, production per animal was similar or even higher, compared to the lower stocking rate (0.24 steers/ha).

Table 12. Liveweight gains in *Brachiaria decumbens* and native savanna supplemented with blocks, strips and banks of *Pueraria phaseoloides* in Carimagua.

Treatment	1979 Season[1]						1980 Season					
	Dry (97 days)		Rainy (190 days)		Total (287 days)		Dry (118 days)		Rainy (248 days)		Total (366 days)	
	Stocking rate[2] (animal/ ha)	Liveweight gains/day per animal (g)	Stocking rate[2] (animal/ ha)	Liveweight gains/day per animal (g)	Liveweight gains per animal (kg)	per ha (kg)	Stocking rate[2] (animal/ ha)	Liveweight gains/day per animal (g)	Stocking rate[2] (animal/ ha)	Liveweight gains/day per animal (g)	Liveweight gains per animal (kg)	per ha (kg)
B. decumbens with												
P. phaseoloides blocks	2.0	311	2.0/2.5	478	121	278	1.0	313	1.8	460	134	262
P. phaseoloides strips	2.0	272	1.0/2.5	624	145	333	1.0	417	1.8	591	174	314
Savanna with												
P. phaseoloides banks[3]	0.25	172	0.25	475	146	36	0.25	126	0.25	395	113	28
P. phaseoloides banks[3]	0.50	10	·0.50	443	122	61	0.50	52	0.50	460	120	60

[1] Grazing was stopped in September because of low legume availability

[2] 3.8 ha/animal on native savanna and 0.2 ha/animal on bank.

[3] 1.8 ha/animal on native savanna and 0.2 ha/animal on bank.

Estimation of Forage "On offer"

The double sampling method for estimating forage "on offer" is a simple, non-destructive technique, particularly useful to measure forage quantity in very heterogeneous pure grass pastures. However, this method presents some difficulty for estimating forage yield in legume-based pastures.

A modification to the double-sampling method was attempted on the basis that forage volume consists of two components: plant height and plant basal area. Instead of visually estimating forage volume, measurements of plant height and coverage were made on the grass and legume components. A highly significant ($P < .01$) positive correlation was found between the **height** x **coverage** and **dry weight** of the grass and legume. This high correlation existed not only for bunching grasses (*A. gayanus* + *S. capitata* mixture) but also for prostrate grasses *(B. decumbens* + *D. ovalifolium* mixture).

The advantages of the **height** x **coverage method** for estimating dry matter yield can be summarized as follows: (a) Measurements of height and coverage are more objective than usual estimates of forage volume (double-sampling); (b) measurements can be done on the grass and legume and the dry weight of each component estimated independently; and, (c) additional information can be obtained on botanical composition and pasture structure. More data are being collected in a wide array of pastures to validate the proposed procedure and to reduce bias on the estimations by different research workers.

Pasture Utilization (Cerrado)

The Pasture Utilization and Animal Production Section of the forage group at the Cerrado Center is responsible for testing new germplasm in large scale grazing trials after it has been screened in other sections of the Program. Simultaneously, animal management experiments are conducted to determine the priority classes of animals to receive the improved pasture and in what seasons of the year for maximum pasture utilization and animal productivity.

Because of the time lag required for germplasm to flow through the systematic screening and seed multiplication stages, new material is just becoming available at CPAC for large-scale testing under grazing. Under the standardized testing scheme, these materials will be subjected to three fixed stocking rates throughout the year, during which the plant will be evaluated in the sward and for animal production.

Pasture Evaluation

Given that large areas of the Cerrados are being sown with grasses and legumes relatively new to the area and because little is known about their long-term management, grazing experiments are underway which will provide more information about managing these species.

Previous results at CPAC have shown that excellent animal gains can be obtained with stocking rates up to 2 animal/ha during the first rainy season following establishment. However, weight losses are severe the following dry season because overgrazing during the rainy season leaves relatively little DM.

Table 1 gives the results of two stocking rates in *Brachiaria ruziziensis* with *Glycine wightii* and *Macroptilium* sp. Animals on the low stocking rate of 0.80 A.U./ha were 48% heavier after one year than the animals at a stocking rate of 1.43 A.U./ha; however, annual gains per hectare were 35% greater with the higher stocking rate. Going into the second dry season it became obvious that due to low available DM, the higher stocking rate could not be continued without the risk of losing animals from starvation and destroying the pasture, so the annual stocking rate was reduced further. The percent legume in the pasture appeared to be directly related to the stocking rate, especially during the rainy season. The seasonal change of the legume in total DM composition would also indicate that the grazing animal eats very little legume during the rainy season but turns to it when the quality of the grass declines in the dry season. This is especially true at the lower stocking rate where the animal can be more selective.

In a similar experiment, *B. ruziziensis* in association with *Calopogonium mucunoides* was compared to *B. ruziziensis* plus 40 kg N/ha/yr in the form of urea (Table 2). The higher stocking rates in this trial than in the experiment above were reflected in reduced individual animal gains.

Table 1. The effect of annual stocking rate on the performance of Zebu calves on a legume-based *(Glycine wightii* and *Macroptilium* sp.) *Brachiaria ruziziensis* pasture, at CPAC, Brazil.

Number of animals	Stocking rate (A.U./ha)	Animal weights (kg)		Total gain (kg)		
		Initial	Final	Per day	Per day	Per ha
10	0.80	114	243	0.353	129	258
20	1.43	114	201	0.239	87	348

Table 2. The performance of Zebu calves in N-fertilized *Brachiaria ruziziensis* and *B. ruziziensis-Calopogonium mucunoides* pastures, at CPAC, Brazil.

Pasture	Season						Total gain	
	Dry			Rainy			Per animal	Per ha
	Animals	(A.U.)	Gain/animal (kg)	Animals	(A.U.)	Gain/animal (kg)	(kg)	(kg)
B. ruziziensis + N	2.0	(0.75)	54	5.0	(2.1)	102	156	611
B. ruziziensis + *C. mucunoides*	2.0	(0.75)	54	5.0	(2.0)	79	133	492

The gains per hectare were exceptionally high during the first year, largely due to the abundance of forage present when the experiment was started at the end of the rainy season. There was a definite improvement in animal performance where N was applied (Table 2) in the first year. It is expected that this difference will diminish with time as the legume begins to play its role in providing N to the grass.

The legume *C. mucunoides* appears well-adapted to the Cerrados region; however, its contribution to animal production in a mixed sward is still in question under local conditions. The legume comprised only 10% of the sward at the beginning of the rainy season but had increased to about 65% of the total composition when the rains ceased in May. The grass was overgrazed and the *C. mucunoides* was virtually untouched because of low acceptability by the animal. During the second dry season (not completed) it appears the animals are eating some of the legume. Although it does have a problem of leafdrop during the dry season, the animals are able to harvest the dried leaves. The first year's data also suggest that a reduced annual stocking rate would permit the *B. ruziziensis* to compete more vigorously with the legume so that a more nutritious grass-legume mixture is available for the dry season.

The first germplasm to reach Category IV at CPAC was planted during the year. Eight ha of *Andropogon gayanus* and *Stylosanthes scabra* cv. Seca will be grazed at three stocking rates as the final phase of the evaluation process.

Pasture Utilization and Animal Production

Work in pasture utilization for the predominant cow-calf operations of the Cerrados is focused on increasing animal productivity by increasing reproduction in the cow herd and rapidly developing the young animal. In order to increase reproduction in the local cattle, they must have the potential for high fertility.

Weaning period. A short-term experiment was conducted to measure the effects of energy fed after parturition and age at weaning on the service period (time from parturition to reconception). As expected, a high energy level shortened the service period from more than five months to less than four. Shortening the weaning period, however, had a much more pronounced effect. By weaning the calf at one month of age, the service period was shortened from more than 200 days with weaning at five or six months to 56 days, which is acceptable for any breed in any environment. While weaning at one month is not practical, it proved that the cows are fertile if given the proper conditions. Weaning at three months also produced a shorter service period (100 days or less) than did feeding extra energy. Weaning at three months is feasible where good management is practiced and offers an alternative system for increasing reproduction where intensifying the growing phase of calves may be more attractive than improving large areas of native pasture for the cow herd.

Herd experiment. The long-term herd systems experiment described last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.) is showing very little treatment effect on cows' weights during the mating season; however, there is a definite trend towards heavier cows in the second year. This may be a general effect of early weaning and improved management or may be only a year effect.

Age at weaning appeared not to affect cow weights during the November-February mating season; during the April-May mating season, however, cows weaned at three months were about 16 kg heavier than cows weaned at five months (Table 3). The large effect of early weaning on conception rate was evident in the herd with 90-day mating season where 92% of the three-month weaned cows conceived *vs* 65% of the five-month weaned cows. Many of the three-month weaned cows were weaned midway through the mating season, which allowed them to have one or two estrous cycles without the calf during the mating season.

Table 3. Effects of calf weaning age on Gir cow weights and conception rates during the mating season in the Brazilian Cerrado.

Treatments	Mating season November-February		Mating season April-May		Annual conception
	Weaning age		Weaning age		
	3 months	5 months	3 months	5 months	(%)
One 90-day mating on improved pasture					
Average weight (kg)	333	339	---	---	
Conception (%)	92 (25)[1]	65 (26)	---	---	78 (51)
Two 45-day matings on improved pasture					
Average weight (kg)	338	339	374	358	
Conception (%)	42 (19)	42 (19)	59 (17)	50 (18)	69 (51)
Two 45-day matings on native pasture					
Average weight (kg)	330	332	367	350	
Conception (%)	47 (19)	32 (19)	60 (15)	79 (19)	78 (50)

[1] Values in parentheses are numbers of cows.

Since very few three-month weaned cows are actually weaned before the end of the 45-day mating season inmediately following parturition, there is little chance for the effect of weaning to be realized in that mating period. However, all cows in the two 45-day mating treatments will have weaned their calves at least one month when they enter the second mating season following parturition; this should eliminate most of the effect of early calf removal in this type of mating system.

This is very clear in results showing 51% of the cows calving in September from the 90-day mating (herd A) reconceiving in two consecutive years, compared to cow herds B and C which had only 29 and 12% reconception, respectively, during the first 45-day mating. However, during the second 45-day mating and after all the cows were weaned, 53 and 85%, respectively, reconceived. Of the 24 cows that calved in February, only three conceived in the April-May mating season; the rest should conceive in the following November mating season. After two years there are no differences in reproductive rates among the three herds, all of which have greater than 75% calving rate. The most unexpected result is that the herd on native pasture is maintaining the highest fertility rate.

Calf development. Probably the greatest bottleneck to improving reproduction through early weaning is the postweaning care of the calf. The herd systems cows produced more than 100 calves in 1979 which were born in September or February and weaned at either three or five months. At weaning, all the calves were placed on improved pasture consisting of either *A. gayanus* or *B. ruziziensis* plus a legume. The six-month weight of calves born at the end of the dry season (September) was 18 kg higher than the corresponding weight of calves born in the middle of the rainy season (February). The differences are due to seasonal pasture availability.

During the dry season two different pastures *(B. ruziziensis* + *G. wightii* + *Macroptilium* sp. or *A. gayanus* + *Stylosanthes guianensis* cv. Cook) were tested under grazing for their potential to support weaned calves during this critical period. Both groups gained weight but the *A. gayanus*/ *S. guianensis* pasture produced gains three times better than the *B. ruziziensis*/ mixed legume pasture. *Andropogon gayanus* is definitely more resistant to drought than *B. ruziziensis,* which produces no green material during the dry season and appears to be inferior to *A. gayanus* as a companion grass for most legumes.

Probably the most exciting results obtained during the past year have been the successful rearing of early weaned calves. The three-month weaned calves suffered an expected decline in weight gain at weaning. However, they continued to gain weight and were growing steadily when the five-month weaned calves suffered a similar weaning stress, giving the earlier weaned calves a chance to partially catch up. The results after one year show that the three-month weaned calves were only 12 kg lighter than those weaned at five months. This was accomplished by weaning the calves directly onto a high quality grass-legume pasture of *A. gayanus* + *S. guianensis* cv. Cook without the need for concentrates.

Animal Health

The objective of the Animal Health Section is to study and develop animal health preventive medicine schemes adjusted to the pasture and animal management production systems developed by the Tropical Pastures Program. Strategies for attaining this objective were explained in detail last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.).

Animal Disease Inventory

The major purpose of gathering and analyzing data from animal disease incidence and prevalence is to quantify and evaluate the relative importance of the disease conditions occurring in cattle throughout the Program's target area. The listing is important in understanding the evolution of current infections, comparing findings for different areas and ecosystems, and deciding which problems need more study. The disease inventory contains information gathered from official statistics, professional technical reports, surveys of commercial livestock operators, slaughterhouse findings, information from visits to specific farms and laboratory analyses of samples taken from individual animals.

Considerable information has been gathered and analyzed. A first attempt to classify diseases and other health problems according to their current impact on productivity and for priority assignment in the Tropical Pastures Program is presented in Table 1. It is important to note that for the conditions listed, their current expected impact on productivity is not the only criterion for defining a research priority within the Program. Other considerations, such as availability of a specific preventive medicine scheme or vaccine for controlling the disease, work in progress by national or international organizations, and lack of complete knowledge of the factors involved in the decrease of productivity, are also taken into account.

Table 1. Animal disease inventory of the Tropical Pastures Program's target area.

Disease	Ranking effect on productivity	Priority for CIAT Tropical Pastures Program
Ticks *(B. microplus)*	Medium	1
Anaplasmosis	Medium	1
Babesiosis	Medium	1
Photosensitivity syndrome	Medium	1
Intestinal roundworms	High	2
Calf mortality syndrome	High	2
Dermatobia hominis (nuche)	Low	2
Leptospirosis and IBR	Medium	2
Mineral deficiencies (microelements)	Low	3
Toxic plants	Low	3
Black-leg (clostridia)	Medium	3
Trypanosoma vivax	Low	3
Foot-and-mouth disease	High	4
Brucellosis	High	4
Tuberculosis	Low	4
Cisticercosis	Low	4

Based on all these considerations, it appears that the tick, *Boophilus microplus,* which is widespread throughout the target area, is gaining in importance as a production-limiting factor in many regions of the target area. There is evidence that it may become the major animal health constraint on increased cattle productivity with the intensification of animal production systems arising from better pastures. The hemoparasitic infections from *Babesia* sp. and *Anaplasma* sp. are linked to ticks since the first has been proven to be readily transmitted by them and ticks are suspected of transmitting the second. The prevalence of ticks in the target area varies considerably depending on environment and intensity of control.

Checks of animals on farms of the Beef Production Systems Evaluation Project (ETES) revealed that the Colombian Llanos farms had 10% of the animals infested, versus 8% in the Mato Grosso and 14% in the north of Goias, Brazil. Although Goias had a higher percentage of infested animals, there is also less tick control on the farms. This contrasts with the Colombian Llanos where there is more control at present, with most farms using some type of dipping or spraying.

At the Carimagua research farm, experimental and test herds under more intensive management have to be treated more frequently (as often as monthly) to keep ticks at levels that will not affect productivity. This evidence points to the need for economically sound schemes to control ticks for the newer production systems under development.

Research work in national institutions throughout the target area suggests intestinal roundworms will increase with the intensification of animal production systems. However, much more is known about the control methods and strategic ways of worming cattle economically to keep parasites at low levels.

Work by EMBRAPA in the Campo Grande area of Brazil suggests that four applications of an antihelmintic are necessary to economically control gastrointestinal worms where the animal density is 0.5 A.U./ha; only two applications are recommended in the Colombian Llanos in a system with an animal density of 0.16 A.U./ha — in Carimagua, one in July for calves and adults and a second in December for calves only.

For other external parasites such as *Dermatobia hominis* ("nuche"), evidence shows it has increased in recent years in the Mato Grosso of Brazil and in the Colombian Llanos. There are reports now of a need to control infestations of this fly larva in both areas, something that was not needed five years ago. According to data from the ETES project, in the Mato Grosso area, 40% of the animals were infested with *D. hominis,* whereas in northern Brazil (Goias) and in the Colombian Llanos, only 2 and 3.7%, respectively, were infested. Although the larvae do not kill affected animals, they cause weight reductions and also produce hide damage. The increase in animals infected with this larva is probably a result of several factors: the intensification of production systems, more favorable micro-environments for the persistence of the fly, and introducing infected animals to areas free of larvae.

Other conditions such as toxic plants and specific mineral deficiencies are decreasing as a consequence of introducing sown pastures and a better feed supply. Syndromes like "hidroallantois" and "secadera" in Colombia and "peste de rachar" and "peste de secar" in Brazil also are diminishing, probably as a consequence of better feeding.

ETES Project

A complete description of the ETES project is found in the Cattle Production Systems Section. Animal health information is being obtained from surveys of cattle ranches and examination of samples taken from individual animals from each farm.

Analyses of the data collected on Colombian farms in the ETES project were presented last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). Most of this information will also be included in the animal disease inventory project already described.

For the ETES-Brazil farms, a full reproductive analysis (lactation and pregnancy) was completed this year and the third palpation cycle is underway. Ten percent of the animals on each farm were chosen for fecal examinations, blood serum analyses and external parasite counts. Interpretation of findings is being entered in the animal disease inventory.

Farms chosen for the continuation of the second phase of the project are being examined periodically to eliminate reactors to brucellosis and to establish a basic preventive medicine scheme. This scheme consists of vaccination for foot-and-mouth disease, brucellosis vaccine for heifers, vaccination for black-leg (on farms that have had outbreaks), and use of antihelmintics to control roundworms once a year in calves, preferably at weaning. Dipping or spraying with acaricides will be done every four months.

Surveillance of Carimagua Herds

Malnutrition, sinking into watering holes and bone fractures have caused about 40 to 55% of cattle deaths in Carimagua during the past three years. Causes of about one-quarter of the deaths each year cannot be fully determined. Overall mortality is approaching acceptable figures, reflecting better nutrition in the herds, as well as closer and more effective animal management. Total mortality has decreased from 4.4% in 1978 to 2.5% in 1980.

The decrease in mortality was probably a consequence of the decreased mortality of nursing calves. Although births increased by 22%, calf mortality decreased from 7.7 to 6.3% between 1979 and 1980. Herds with closer supervision do not necessarily have lower death figures; the closely observed milking herd has a high calf death rate (10.8%), probably due to poor nutrition from underfeeding.

Surveillance of tick levels was intensified during 1980 with each herd being examined sequentially. Information obtained has been used to assign the control interval for dipping the respective herds. Some herds still maintain a standard six-month interval, while others have moved to a one-month span. Treatment intensities have been determined mostly by total tick counts, but also by special micro-environmental conditions favoring tick persistence in some areas of the farm. Yet another factor is the cattle breed involved since the *Bos taurus* cattle (San Martinero) are more susceptible to high tick levels.

Profile Studies in Carimagua

Gastrointestinal parasites. Work was completed in 1980 on population dynamics studies of internal parasites at the Carimagua station, as a basis for designing control methods adapted to ecological conditions. As reported last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.), two herds of 50 cows with their progeny at a stocking rate of 0.16 A.U./ha were studied. Animals were not treated against internal parasites but received the standard vaccination scheme used for the farm. Animals received a complete mineral supplement and the native pasture was burned sequentially. Overall management was similar to that used by farmers in the area.

Calves in group I were born from March to July 1978 (beginning of rainy season), and in group II, from September 1978 to January 1979 (beginning of dry season). Both groups were sampled monthly by fecal examinations and blood analyses. One calf from each group was slaughered at 1, 2, 4, 6, 8, 12 and 18 months of age. All parasites in abomasum, large and small intestines were collected and identified. The investigation ended in June 1980.

The gastrointestinal roundworm load varied considerably according to calf age and season. The moderately pathogenic *Strongyloides* was noticeable only up to six months of age. The *Eimeria* protozoans reached high counts in the feces between three and nine months of age. The immunity that the calves developed against these two parasites prevented any further infestation for both groups. Protozoans are, however, of potential importance when abundant soil moisture in the rainy season favors their proliferation and exposes calves to a high level of challenge. A syndrome of bloody feces, caused by these protozoans, is often seen in calves from the Colombian Llanos.

Fecal counts were more significant in the Trichostronglidae family which includes two pathogenic species — *Cooperia* and *Haemonchus*. For group I calves, levels above 500 eggs/g of feces were recorded at three months of age (Fig. 1), followed by another peak at nine months. In group II a peak of 300 eggs/g was counted at 10 months of age, with low levels up to that stage. Rainy periods seemed to favor the presence of larger worm loads. August of 1978 had a peculiar low rainfall (100 mm) which apparently produced a rather low average of roundworms (30 eggs/g). On the other hand, levels of infestation also seemed to increase as a consequence of stress factors, the most likely being weaning, which occurred between seven and eight months of age.

Total parasite counts from slaughtered calves followed the same general trend of the fecal egg counts. Results from most of the slaughter periods were reported last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). For group I calves the genus *Cooperia* reached highest levels in the 18-month-old calf, same as the genus *Haemonchus*. For group II, the highest *Cooperia* counts were in the 12-month-old calf, whereas most *Haemonchus* were found in the 18-month-old calf; both levels were in the order of 80% lower than counts in group I.

Cooperia levels of about 12,000 parasites are said to affect animal productivity, whereas *Haemonchus* levels around 3000 can be detrimental. Based on this assumption, calves in group II were less affected than calves in group I. The calf slaughtered at 18 months was especially under stress, since it had parasite levels that could seriously affect its performance (30,000 *Cooperia* and 6,000 *Haemonchus).*

The overall picture of the gastrointestinal roundworms in cattle grazing native savanna showed more prominent infestations toward the middle and end of the rainy season and also when the calves were between 8 and 10 months old.

Results of this trial generally indicate that one standard antihelmintic treatment at 6-8 months of age for calves pasturing native savanna would prevent any effects on animal productivity in animals up to 18 months of age.

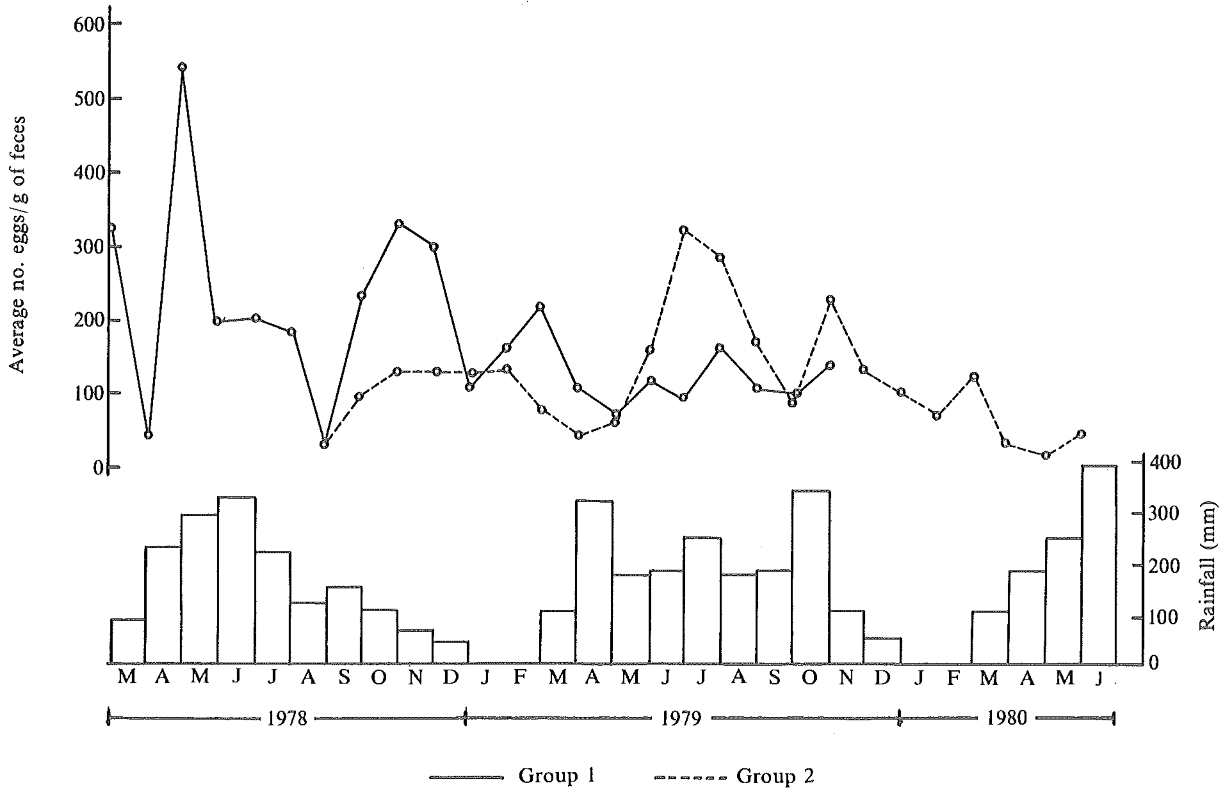


Figure 1. **Trichostrongylidae** *roundworm levels in calves on native pasture, in relation to season (rainfall), at. Carimagua. (Calves in Group I born March-July 1978; calves in Group II born September 1978- January 1979.)*

From the standpoint of worm levels, calves born at the end of the rainy season developed more stable infestations, which they could control, than animals born at the beginning of the rainy season.

Hemoparasites. Development of natural defenses against Anaplasma, *Babesia argentina* and Bigemina was studied to help define the best management of ticks and other vectors. The same calves used for the gastrointestinal parasite profile described above were utilized for the measurements.

Few differences were observed between reactions of the two calf groups to *Anaplasma marginale.* Peak antibody levels for Anaplasma in both groups almost coincided in Abril 1979, at the beginning of the rainy season, independent of calf age (Fig. 2). It appeared that infection determined by the antibody levels dropped considerably at the middle of the rainy season, in August. During this last period there were 45% reacting animals, compared to 95% reactors in June of the same year and only 6% a year earlier. This indicates changes not only in the degree of response (average titers), but also in the numbers of calves with detectable infection.

Greatest infections occurred in both groups at the onset of the dry season, possibly as a result of an increase of the main vectors. Calves from group I did not have large active infections during their first seven months (March-October 1978), whereas calves from group II had low infections only during their first four months (September 1978-January 1979). During these periods 90-95% of the calf population was at risk in both groups, meaning that if a high challenge occurred, they could have clinical disease.

From the standpoint of the development of an immune population, group II calves born toward the end of the rainy season (September) were much better off than calves of group I. After four months of age a high proportion of them (70%) had defenses against future infections.

Reactions to *Babesia argentina* infections depended more on calf age than on season (Fig. 3). Considerable increases in antibody titers occurred in both groups only after 12 months of age. However, the first increase in group I was during the dry period of 1979, and in group II, the second titer rise occurred just toward the end of the dry period a year later (March 1980).

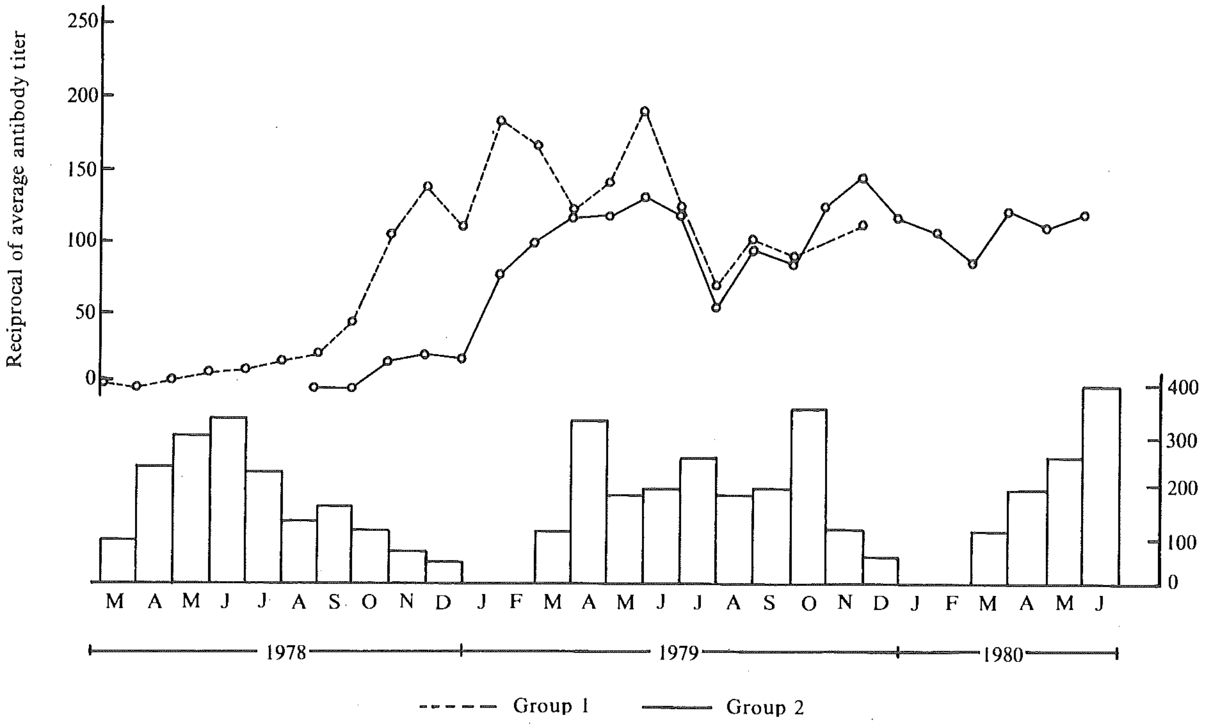


Figure 2. *Assessment of* **Anaplasma marginale** *infection for calves on native pasture, in relation to season (rainfall), at Carimagua. (Calves in Group I born March-July 1978; calves in Group II born September 1978-January 1979.)*

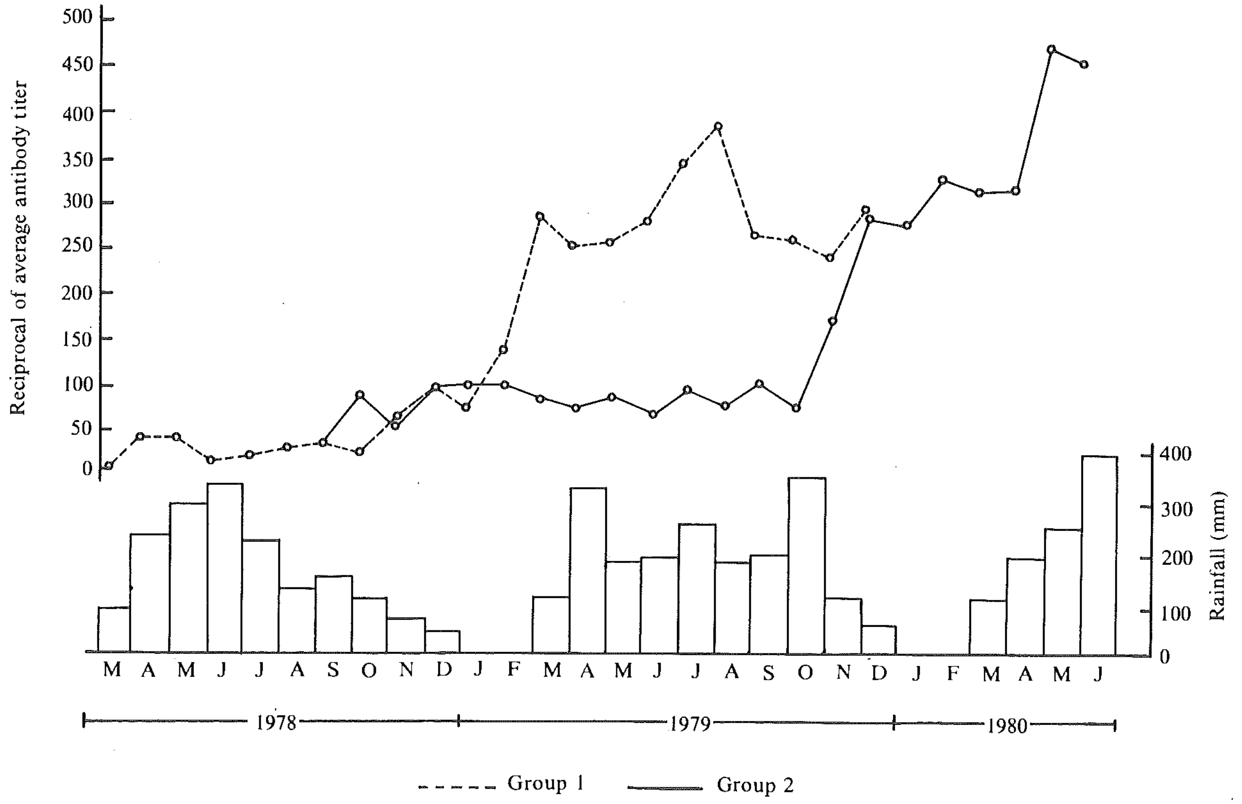


Figure 3. *Assessment of* **Babesia argentina** *infection for calves on native pasture, in relation to season (rainfall), at Carimagua. (Calves in Group I born March-July 1978; calves in Group II born September 1978-January 1979.)*

These reactions could be the result of two different factors. First is age susceptibility which is probably determined by the main *Babesia* vector, the *B. microplus* tick. Calves up to a year old generally have fewer ticks. Counts made during monitoring of various herds at Carimagua showed very low numbers for calves (0-3 average). A second factor could be increases in vector numbers that are thought to happen during the dry season, although this has not been proven. A bio-ecological study of *B. microplus* (described below) should provide more information about this vector.

Photosensitization in Cattle

Work continued to determine possible causes of this syndrome affecting cattle grazing *Brachiaria decumbens*. Clinical symptoms have been described previously (CIAT Trop. Past. Prog. 1979 Ann. Rept.).

This year for the first time, new cases appeared with steers at the CIAT-Quilichao station and on a private ranch near that station. Animals in four of the five cases on the experimental station had grazed *B. decumbens* at some time. No relationship has been found between the presence of affected animals and time after initial grazing of the paddock or months after pasture establishment. In the five outbreaks that occurred, 8 of 99 steers were affected (8.1%) and there were no deaths.

Although many more animals grazed *B. decumbens* in Carimagua, the proportion of affected cattle (2.8%) was much less than in CIAT-Quilichao. Of 560 animals that grazed this species intermittently, 16 were affected from 1979 through 1980. Once again no relation was evident between time elapsed after pasture establishment or after initial grazing of the paddock, and the development of lesions in cattle. With one exception, affected animals on both stations were always less than 18 months of age.

There is a strong indication that this syndrome is produced by the toxin of *Pithomyces chartarum*, a fungus that grows saprophytically in the pastures, as described in New Zealand. *Pithomyces chartarum* spores have been detected in pasture samples taken from the paddocks that had affected animals but weekly samples showed low spore numbers (Table 2). The technique for isolating the fungus was improved, and for the first time, numerous isolations were obtained from pastures at CIAT-Quilichao. A representative culture was confirmed as *P. chartarum* by the Commonwealth Mycological Institute. A preliminary trial to study the toxigenic ability of the isolates was conducted using rabbits. Spore suspensions of one isolate applied in the conjunctiva produced opacity of the cornea, an indication of toxin presence. Other trials are underway to determine toxin production and the ability to reproduce the syndrome in sheep and calves. There is no explanation at present for the clinical cases in paddocks with low *P. chartarum* spore counts.

Table 2. Spore counts and *Pithomyces chartarum* isolations from pastures in relation to photosensitization cases in CIAT-Quilichao.

Clinical cases	Pasture	No. of. samples	Average spores/g	Isolations of *P. chartarum*
1	*A. gayanus* and	10	19.2	3
	B. decumbens	7	93.7	0
0	*B. decumbens*	9	16.8	3
1	*A. gayanus* and	21	13.3	1
	B. decumbens	16	48.0	1
1	*B. decumbens* and	3	5.3	0
	Panicum maximum	5	3.2	1

Bio-ecology of *Boophilus microplus* in Carimagua

Boophilus microplus is the most important tick in the target area of the program. A project was designed to study the population dynamics of the tick for the conditions of the Colombian Llanos. The main objective is to understand the effect of the environments offered by four pastures on tick population fluctuations in two dry and rainy seasons. Paddocks were established with *Andropogon gayanus, B. decumbens, Melinis minutiflora,* and native savanna. After artificial infestation and establishment, tick larvae will be counted weekly on the pastures and rate of infection of engorged females infecting the animals determined. Levels of infection with homoparasites will also be evaluated.

Cattle Production Systems

Objectives of the Cattle Production Systems Section are (a) to identify the main limiting factors that exist in beef production systems in the area of interest, and (b) to integrate new technological components developed by the Tropical Pastures Program into relevant production systems.

The overall product of the Program is improved pastures. It is the function of this Section to conduct final evaluations of these pastures in commercial or other large-scale grazing systems. Currently, the legume-based improved pastures are utilized to strategically supplement native savanna pastures. This concept is consistent with both the low-input philosophy of CIAT and with the principle of concentrated resources.

Evaluation of Beef Production Systems (ETES) - I

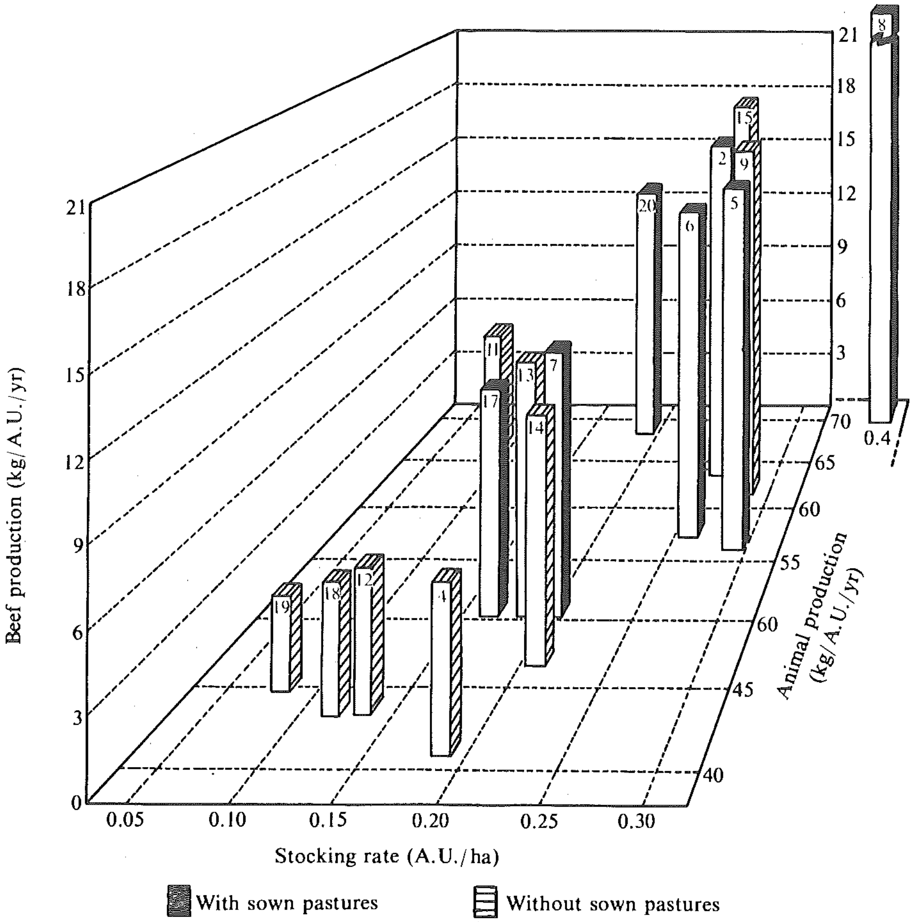


Figure 1. *Relationship between stocking rate and productivity on 16 farms in the ETES-I project, in Colombia.*

The ETES project is designed to evaluate, in technological and economic terms, prevailing beef production systems of the Colombian and Venezuelan Llanos and the Cerrados of Brazil. The project is a joint venture between the Program and the Institute for Animal Production, University of Berlin and the Goverment of the Federal Republic of Germany (GTZ); EMBRAPA's Cerrado Center (CPAC), in Brazil; and the Northeastern Plains Center (CIARNO) of the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP), in Venezuela.

ETES - Colombia. Results of data analyses from 16 farms of the Colombian Llanos were discussed in detail last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). These results indicated all farms belong basically to a low-input/low-output production system. Between-farm variation is due mainly to minor differences in the availability of better quality, low-lying savanna pasture. The presence of sown pastures (mainly the grasses *Brachiaria decumbens* and *Melinis minutiflora)* has no measurable effect on herd productivities.

Farms in the Colombian sample generally produce a 40-55% calf crop, 40-85 kg/animal/yr of growth by young animals and 45-65 kg/A.U./yr overall. The stocking rate (A.U./ha) and animal production (kg/A.U./yr) were significantly correlated ($r^2=0.84$). This suggests that as land utilization intensifies (indicated by the use of improved pastures), herd output tends to increase (Fig. 1). The economic effects of some of these results are presented in the following section (Economics) of this Report.

ETES - Brazil. Collection of field data started in mid-1978 and six working visits have been completed. Problems have occurred in obtaining complete cattle inventories, due to the land physiography and vegetation of the Cerrado area. The recovery rate of animals between visits was, therefore, rather low, compared to that obtained on open savannas. Additional farm visits have been necessary and samples of animals in each category are being evaluated as an alternative methodology.

Characteristics of the 12 farms in the project are shown in Table 1. Overall stocking rates range from 2.2 to 8.4 ha/animal; the average rate of about 4.5 ha/animal is similar in the two subregions. Cropping (in a shifting type of system where crops are followed by sown pastures) is an important component on most of the farms. Thus, overall stocking rates is not a strict indicator of forage availability, but rather indicates intensity of land use.

Table 1. Land areas and cattle numbers for 12 farms in the Beef Production Systems (ETES-I) project in Brazil.

Farm No.	Total area (ha)	Land area (ha) in:			No. of cattle	
		Cerrado	Sown pastures	Crops	Herd	Cows
Mato Grosso						
1	5452	3752	1200	500	1256	520
2	986	606	240	80	442	205
3	4400	3070	800	500	800	460
5	2000	1410	550	-	503	200
8	1023	936	25	12	200	85
Goias						
1	1628	900	288	440	592	370
2	813	280	378	-	239	90
3	735	518	217	-	256	188
4	3365	1870	402	95	540	300
5	3556	3390	136	30	791	408
6	3569	2547	502	20	661	150
8	700	300	250	-	255	120
$\bar{x}$	2352	1632	416	140	544	258
C.V.(%)	70	77	77	149	56	58

Soil studies on the farms show pH readings somewhat higher in Goias (5.6) than in Mato Grosso (5.1). Phosphorus availability in the soil is quite variable within and between farms. Average available P on five farms was less than 1 ppm.

Weights of animals within the various categories must still be adjusted for seasonal age an sex effects and reproductive status of the cows. However, cow body weights (reflecting nutrition) do not appear very different between subregions. Differences are evident due to seasons.

Calving rates, estimated from the April-May 1980 reproductive status diagnosis, appear to be a bit higher (56%) than rates on Colombian ETES ranches. This value can fluctuate between years so it should be regarded as very preliminary.

ETES - Venezuela. Field data collection began on the 14 farms in this sample in January 1980 and has continued throughout the year. Some characteristics of the farms in this project were given last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.).

Evaluation of Beef Production Systems (ETES) - II

The objective of the ETES-I project is to evaluate prevailing cattle production systems within certain ecosystems in the area. The second phase of the project, on the other hand, has the objective of evaluating a system which includes a newly adopted technology package designed to overcome previously identified constraints.

This phase of the overall ETES project was initiated on a farm of rather low productivity. The farm has about 3000 ha with no previous sown pastures. It is a cow-calf operation only, with about 350 breeding cows, an average stocking rate of 5.2 ha/A.U., mean calving rate of 50% and an overall production index of about 42 kg/A.U./yr.

Components of the technology package are: *ad libidum* mineral supplementation, 170 ha (5% of total area) in an improved, legume-based pasture for strategic use, restricted mating to 7-8 months to avoid calving near the end of the rainy season, systematic weaning at 8-10 months, close supervision of parturition by using the improved paddocks as maternity pastures, and the strict application of a very basic animal health scheme.

Low pressure grazing of *Brachiaria decumbens* + *Desmodium ovalifolium* paddocks (25 ha) began in November 1979. Grazing of *Andropogon gayanus* + *Stylosanthes capitata* pastures (76 ha) started after 1600 kg of legume seed were harvested in December. All calving cows have had access to these paddocks since February 1980.

The body weight of cows obtained at the first two weighing dates in 1980 are shown in Table 2.

During 1980, the ETES project was expanded to another three farms formerly in the first phase (farms 7, 13 and 17 in previous reports). The technological package is basically the same as on the farm above.

Table 2. Body weight changes and percentage of pregnant cows according to physiological status after one year of strategic use of improved pasture on a farm in the Colombian Llanos (ETES-II project).

Physiological status	Evaluation period								
	November, 1979			April, 1980			November, 1980		
	No. of cows	Body weight (kg)	Percent of total	No. of cows	Body weight (kg)	Percent of total	No. of cows	Body weight (kg)	Percent of total
Lactating									
Pregnant	0	-	-	0	-	-	4	355	1
Open	82	252	25	157	293	45	65	306	21
Dry									
Pregnant	137	268	41	36	321	11	171	329	56
Open	111	233	34	150	290	43	58	297	19
Milking									
Pregnant	0	-	-	4	391	1	5	406	1.5
Open	0	-	-	0	-	-	5	398	1.5
$\bar{X}$									
Pregnant	137	275.3	41	40	328	12	180	332	59
Open	193	241.1	59	307	291.5	88	128	306	41

Breeding Herds Management Systems

The objective of this project at Carimagua is to study the strategic use of improved pastures in combination with restricted mating seasons, as components of an improved cow-calf production system.

Six savanna pastures of about 380 ha each are grazed by six herds of 50 cows. Herds 1, 3 and 5 remain on savanna year around, while herds 2, 4 and 6 have access to improved pasture paddocks (150 ha) during calving and early lactation (3-4 months). Herds 1 and 2 are mated continuously, herds 3 and 4 for four months, from June until September, and herds 5 and 6 are mated three months from May until July. Other management details have been discussed in previous annual reports.

Problems encountered from the loss of sown pastures were described last year (CIAT Trop. Past. Prog. 1979 Ann. Rept.). These pastures recovered during the latter part of 1979 and produced well during 1980.

Figure 2, with cow weight data adjusted for physiological status, shows clearly the positive effect improved pasture supplementation had on herds 2, 4 and 6 during 1978 and again in 1980, as sown pastures recovered. Due to the failure of the sown pastures in early 1979, cows in those herds had a somewhat lower calving rate (64%) in 1980, compared to herds on savanna (69%).

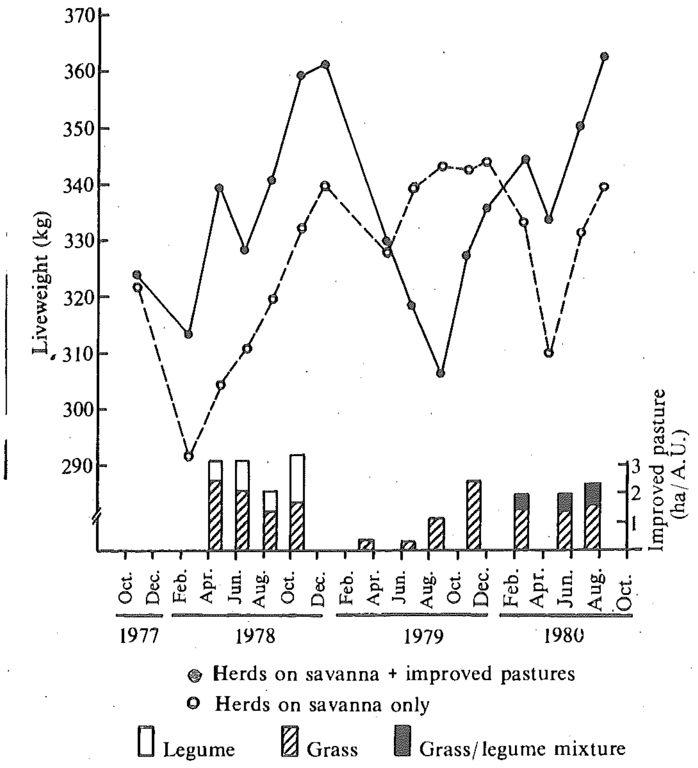


Figure 2. *Changes in body weight of cows (adjusted to "open-lactating" status) in the Breeding Herds Management Systems project, at Carimagua.*

Results in Table 3 indicate that lactating cows with access to sown pastures had, as an average of 1978 and 1979 performance, a substantially higher likelihood of conceiving than those that remained on savanna. It is obvious that, in order to increase reproductive efficiency (i.e., decrease the calving interval), more cows have to reconceive during lactation. During 1979, the calving rate in herds 2, 4 and 6 was substantially higher than in herds 1, 3 and 5 (84% *vs.* 65%). Thus, to achieve a similar conception rate during the same year, a higher proportion of lactating cows in herds 2, 4 and 6 had to reconceive. The mean calving rates in 1979 and 1980 are shown in Table 4.

Table 3. Percentage of cows within various physiological status categories, during the late rainy season (mean 1978-1979), in the Breeding Herds Management Systems project at Carimagua.

Physiological status	Cows grazing:	
	Savanna only (%)	Savanna + sown pasture (%)
Dry, open	6.8	6.5
Early lactating, open	16.6	14.6
Late lactating, open	21.7	20.1
Dry, early pregnant	24.2	20.2
Dry, late pregnant	20.0	15.6
Lactating, pregnant	10.7	22.9

Table 4. Reproductive performance during 1979 and 1980 of cows in the Breeding Herds Management Systems project at Carimagua.

Herds	Pasture treatment	No. of cows (mean)	No. of births (total)	Mean calving rate (%)
1	Savanna only	51	76	75
3		62	68	65
5		51	62	61
2	Savanna plus sown pastures	50	81	81
4		51	69	68
6		50.5	76	75

The preliminary conclusion regarding adoption of restricted mating periods is that it seems advisable in a savanna-only grazing system. However, if improved pastures are available during early lactation, a three-month mating period early in the rainy season could be sufficient.

Specific objectives of the Economics Section are: (a) to assess technical and economic constraints to livestock production at both the farm and regional levels over the Tropical Pasture Program's target area; (b) to identify the main livestock production systems and their potential demand for improved pastures according to the relevant environmental and socioeconomic characteristics; and, (c) to evaluate the potential impact of technology adoption on beef and milk production and prices, and the expected benefits for consumers and producers by income strata.

Research during 1980 was concentrated in three sectors. Relative input-output prices in Brazil, Colombia and Venezuela were studied to assess the differences in the type of technology demanded by each country. The expected return on investment was estimated for improved pastures used strategically in cow-calf farm operations in the Colombian Llanos. Finally, selected case studies on farms in Colombia and Brazil (ETES study) were analyzed to characterize the existing farm systems in the region.

Relative Prices for Inputs in Brazil, Colombia and Venezuela

According to information from Phase I of the ETES Project in Brazil, Colombia and Venezuela, substantial differences were detected between cattle production systems in these regions. These differences involve not only technical and physical factors but also the socioeconomic framework supporting production activities.

Due to agricultural credit policies, big differences exist in the availability of certain key inputs. The main policy instruments are direct subsidies to producers and low interest credit (see reports on ETES-Brazil and Colombia later in this chapter).

Differences between countries may be summarized by relating the main product of the subsector to the most used inputs in the form of relative prices (input prices relative to the price of beef) (Table 1).

Regarding fertilizers, Venezuela has a noticeable price advantage over Brazil and Colombia; between these two countries there is no significant difference on these items. Venezuela and Brazil have better relative prices for fuel than Colombia. Transportation in Brazil and Colombia costs three times more than in Venezuela. Wire fence and machinery have almost the same relative prices in all countries.

The amount of labor purchased by the same quantity of beef is approximately 60% less in Venezuela than in Brazil and Colombia. The lack of workers in the Venezuela region is a problem not only for cattle raising, but also for cropping activities which are not entirely adapted to mechanization.

The relative land prices are more than four times lower in the Colombian Llanos than in Brazil and Venezuela. The establishment costs of cultivated pastures are not easily comparable, because not all countries have the same pasture types on the project farms. For *Brachiaria decumbens,* found on the Brazilian and Colombian ETES farms, Brazil can establish about twice as much pasture for the same amount of beef as can Colombia.

Table 1. Relative prices of products and inputs in Brazil, Colombia and Venezuela, November 1980.

Beef price relative to[1]	Brazil		Venezuela	Colombia	
	Mato Grosso	Goias	Maturin	Villavicencio	Llanos
Fertilizers (t/t)					
Triple superphosphate	1.86	2.02	17.24	2.17	1.79
Urea	2.12	2.12	14.13	2.43	1.99
Lime (t/t)	26.00	30.40	34.39	26.90	12.48
Fuel (t/1000 gallons)	2.37	2.32	11.68	0.96	0.78
Wire fence (t/km)	1.49	1.27	1.70	1.26	1.05
Machinery					
Tractor (10 t/tractor)	0.66	0.69	0.65	0.58	0.52
Plow (t/plow)	0.58	0.60	0.69	0.47	0.41
Rake (t/rake)	0.29	0.37	0.34	0.31	0.27
Labor (t/man-day)					
Permanent worker	0.34	0.27	0.18	0.30	0.27
Land (t/ha)					
Natural savanna	10.50	7.20	6.20	2.30[2]	40.70
Transport (t/head/km)	8.56	10.70	29.50	8.87	7.90
Pasture establishment cost (t/ha)					
Brachiaria decumbens	11.60	9.80	-	-	5.20
Panicum maximum	8.80	8.00	-	-	5.00
Hyparrhenia rufa	6.80	6.70	-	-	-
Digitaria decumbens	-	-	5.20	-	-
Digitaria swazilandensis	-	-	3.40	-	-
Andropogon gayanus	-	-	-	-	3.20

[1] Amount of each input that can be purchased with the revenue of the sale of one ton beef liveweight.

[2] Piedmont land price, not savanna.

Subsidies and Support Policies

Although Venezuela has a relative price advantage for most items over the other countries and Brazil is favored over Colombia, these relationships may change if credit and subsidy policies are considered (Table 2).

Indirect subsidies through low interest favor Brazil and Venezuela over Colombia. The market price conditions on which relative prices were estimated are altered if producers have cheap capital available to purchase inputs. In Venezuela, direct price subsidies exist in addition to indirect subsidies through credit. Thus, for the principal inputs the direct price subsidy to the producer ranges from 25 to 55%, depending on the item. The relationship of the three countries with regard to producer support policies remains the same as stated due to relative prices, but is accentuated through subsidy effects.

Table 2. Agricultural credit interest and inflation rates (official) in three countries, 1979.

Country	Average credit interest (%)	Inflation rate (%)
Brazil	15	56[1]
Colombia	20	24
Venezuela	6	15

[1] For the first half of 1980, the inflation rate of Brazil had already reached 80%.

Source: **International Financial Statistics**, September 1980.

Changes in Relative on-Farm Prices between 1979 and 1980

Fertilizer prices in Colombia and Brazil became more expensive in terms of beef for 1980. Venezuela showed an opposite tendency (Table 3). Thus, Venezuela's advantage on this item has increased after one year.

During the same period, price increases for machinery were higher than price increases for beef in Venezuela and Brazil, while in Colombia the relative price increases for the two items were the same. Nevertheless, farmers in Venezuela and in Brazil should have a clear advantage due to credit at negative real interest rates.

A devaluation of cattle in relation to land prices was noted in Venezuela and Brazil. In Colombia the cattle/land price relation did not change. Relative prices of triple phosphate and urea were similar in Brazil and Colombia during the two-year period, while farmers in Venezuela got much more of these items for the same amount of beef in 1980.

Table 3. Relative prices of inputs for beef among areas of interest in Brazil, Colombia and Venezuela, 1979-80.

Inputs	Brazil		Venezuela		Colombia			
	Goias		Maturin		Villavicencio		Llanos [1]	
	1979	1980	1979	1980	1979	1980	1979	1980
Fertilizers (txt)								
Triple Superphosphate	3.91	2.02	14.37	17.24	2.58	2.17	2.13	1.79
Urea	4.07	2.12	11.50	14.13	2.62	2.43	2.15	1.99
Machinery								
Tractor (10 t/tractor)	1.13	0.69	0.80	0.65	0.57	0.58	0.52	0.52
Labor (10 kg/man-day)								
Permanent worker	2.60	2.70	1.50	1.80	3.40	3.00	3.00	2.70
Land (100 kg/ha)								
Natural savanna	1.53	0.72	1.00	0.62	0.24	0.23	4.08	4.07

[1] Llanos: 200 km from Villavicencio.

The Low-input Strategy

The use of inputs to establish cultivated pastures is high in Venezuela and Brazil and relatively low in Colombia. This is due to lower input prices, the interaction between crops and pastures and more subsidized credit availability in the first two countries. Although changes are occurring in Brazil as credit is suspended for direct pasture establishment, credit availability for crops and investments is still increasing and can be used to establish pastures after upland rice.

For pasture maintenance and persistence, the outlook is different. The residual effects of crop fertilization do not last very long and there is no credit line for "pasture maintenance" at present.

A longer observation period would reveal whether relative prices for fertilizer tend to equalize between Brazil and Colombia. The energy and import problems of Brazil could accentuate this process. Hence, the development of persistent pastures with low-input intensity is important for the three countries in the long-run.

Return on Investment in Improved Pastures (Colombia)

Results of a simulation exercise on strategically used legume-based pastures in cow-calf farms were reported in the 1978 Annual Report. The objective at that time was to answer the questions: Would the legume-based pasture be profitable at the farm level? How many years should the pasture persist in order to be profitable? How is this profitability affected by establishment and maintenance costs?

Since fertilizer costs, as well as cattle prices, have increased substantially during the last 2-3 years, the question was whether the results obtained at 1976 prices were still applicable in 1980, or whether the expected profitability of the improved pastures had indeed changed. In order to perform a sensitivity analysis, costs for three levels of fertilizer application required for establishment and maintenance were considered (Table 4). The "medium" level is the current fertilizer recommendation (by the Program) for a legume-based pasture composed of adapted species for the Carimagua region.

Table 4. Fertilizer cost estimates for establishment and maintenance of an improved pasture in the Colombian Llanos (at 1976 and 1980 prices).

Input level	Costs (US$/ha) for:				
	Establishment			Maintenanee	
	1976 (A)	1980 (A)	1980 (B)	1980 (A)	1980 (B)
High	94	164	209	63	110
Medium	64	109	155	34	58
Low	41	60	78	17	29

[1] Cost differences in 1980 reflect the use of (A) basic slag or Huila rock phosphate as the P source, while (B) is for P from triple superphosphate.

It is evident that on-farm fertilizer costs have increased (although part of the increase since 1976 is due to upward adjustments in the recommended fertilizer mixtures). More important, however, is the price differential between the two phosphorus sources. This is particularly relevant for Colombia, since basic slag is produced in limited quantities and is becoming relatively unavailable on the market. This suggests that rock phosphate and other cheap P sources should continue to be evaluated and explored in research and with regard to commercial availability. The relative agronomic effectiveness of rock phosphate in the first year should be taken into account, although it is usually high in very acid soils (see CIAT Trop. Past. Prog. 1979 Ann. Rept.).

Table 5 summarizes total pasture establishment costs by major components under three levels of fertilization and using two seed cost estimates (low and high). At the current fertilizer recommendation (medium), total costs have increased about 60% since 1976, and nearly doubled when TSP is used as a source of P.

Comparison of the rates of return on incremental capital and management obtained in 1978 (at 1976 prices) with those obtained in 1980 (Table 6), and with the average return obtained in the native system (between 6 and 9%) are rather encouraging. Even though fertilizer prices have increased substantially since 1976, prices of cattle have also increased, roughly compensating the effect of the former. However, if pastures are established with TSP as a source of P and/or prices of other nutrients increase relative to the price of cattle, the rate of return on capital decreases markedly.

Return on investment in pastures is even more sensitive to pasture maintenance costs; Table 7 illustrates this point. Three alternative pastures with different maintenance requirements (high, medium and low) but with similar animal outputs were simulated.

Table 5. Pasture establishment cost estimates for the Colombian Llanos, 1976 and 1980.

Input level	Costs (US$/ha) for:[1]							Total cost		
	Fertilizer			Tilling		Seed				
	1976 (A)	1980 (A)	1980 (B)	1976	1980	1976	1980	1976 (A)	1980 (A)	1980 (B)
High	94	164	209	30	41	34	53	158	258	303
Medium	64	109	155	30	41	34	53	128	203	249
Low	41	60	78	30	41	26	26	97	127	145

[1] Cost differences in 1980 reflect the use of (A) basic slag or Huila rock phosphate as the P source, while (B) is for P from triple superphosphate.

The results demonstrated that returns on pasture investment are highly sensitive to pasture maintenance costs. Therefore, research on maintenance requirements of legume-based pastures under grazing should be expanded in order to assess the **minimum requirement** needed for persistent and productive pastures. This high sensitivity of the return on investment to the costs of maintenance fertilizers may well explain why pastures in beef production systems are seldom, if ever, fertilized in tropical Latin America.

Table 6. Return to incremental capital and management, for improved pastures established in the Colombian Llanos, at 1976 and 1980 input costs[1].

Establishment input level	Incremental rate of return[2] for pasture persistence of:					
	Six years			Twelve years		
	1976 (A)	1980 (A)	1980 (B)	1976 (A)	1980 (A)	1980 (B)
High	15.3	14.3	7.9	17.8	18.5	12.7
Medium	17.3	18.2	11.2	19.5	21.6	14.3
Low	20.9	22.4	15.2	22.2	24.4	17.7

[1] See Table 4 for establishment costs.

[2] Percentage differences in 1980 reflect the use of (A) basic slag or Huila rock phosphate as the P source, while (B) is for P from triple superphosphate.

Table 7. Return on incremental capital and management for improved pastures established at a medium cost in the Colombian Llanos and maintained at 1976 and 1980 fertilizer costs[1].

Management input level	Incremental rate of return[2] for pasture persistence of:					
	Six years			Twelve years		
	1976 (A)	1980 (A)	1980 (B)	1976 (A)	1980 (A)	1980 (B)
High	12.8	13.7	3.9	14.2	14.6	7.3
medium	17.3	18.2	11.2	19.5	21.6	14.3
Low	20.5	22.8	16.7	23.7	25.4	19.8

[1] See Table 4 for maitenance costs.

[2] Percentage differences in 1980 reflect the use of (A) basic slag or Huila rock phosphate as the P source, while (B) is for P from triple superphosphate.

Beef Production Systems Evaluation Project (ETES)

Colombia

The data collection phase of the project was concluded during the early part of 1980. After evaluating the principal production and reproductive parameters in the systems, an economic analysis of these components was done. Last year the economic structures of the 16 farms were analyzed (CIAT Trop. Past. Prog. 1979 Ann. Rept.). Now, results of the on-going analysis of the profitability of current management practices are available.

In contrast to preliminary results from ETES-Brazil, the internal rate of return (IRR) in Colombia decreases with increasing investments per animal (IRR=12.1 - 0.17 Inv. Head, $r^2 = 0.54$) (Fig. 1). This tendency indicates that intensification of capital is not profitable under prevailing farm conditions. The rate of subsidy is less important in Colombia than in Brazil and Venezuela, but in this analysis, IRR statistics were computed without considering the effects of subsidized credit.

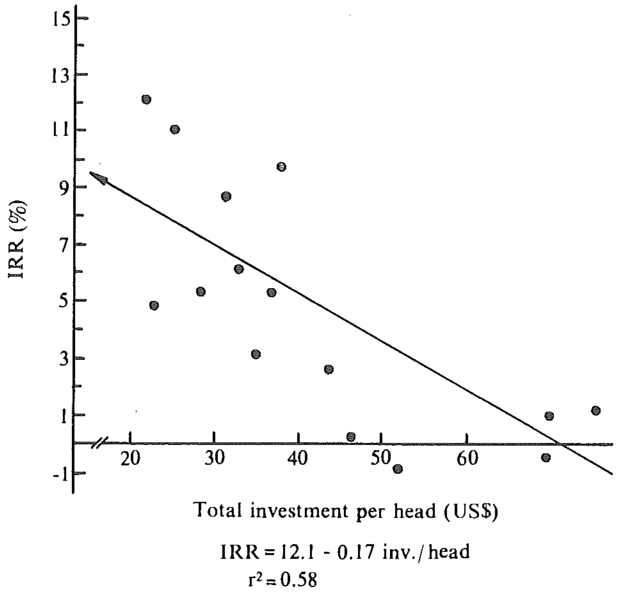


Figure 1. *Total investment per head of stock and internal rate of return (IRR), for ETES Project farms in Colombia.*

The results of the productivity analysis for each farm in terms of beef (kg/A.U./yr) showed no strong correlation with the IRR (IRR = -3.27 + 0.15 kg/A.U., $r^2 = 0.11$). Nevertheless, farms with less than 10% of their area in cultivated pastures have a higher IRR with increasing productivity per A.U. (Fig. 2). On the other hand, farms with more than 10% area in cultivated pastures form a clearly different group; their IRR also tends to increase with greater productivity per animal, but at a lower rate of return than the first group (Fig. 2).

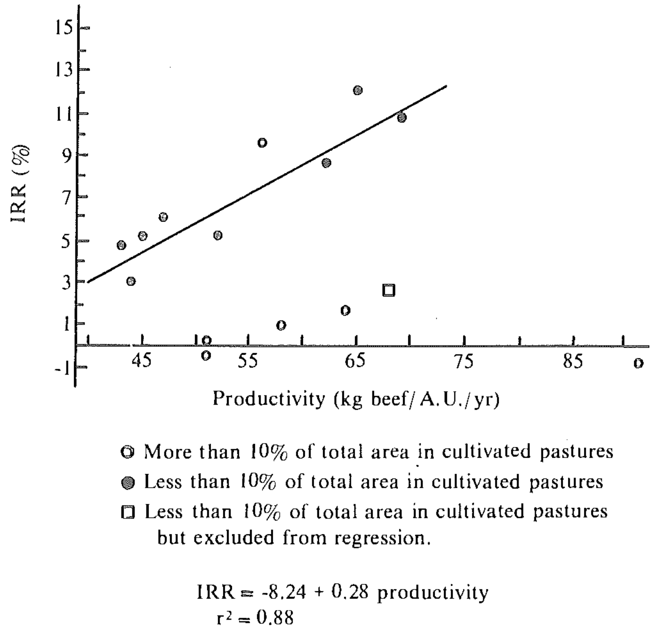


Figure 2. *Animal productivity and internal rate of return (IRR) for farms with less than 10% of total area in cultivated pastures (one farm excluded due to very high current expenditure per A.U.), for ETES Project farms in Colombia.*

Two factors suggest there is a lack of proper technology and resource allocation on the Colombian farms: (a) the negative relation between investment per head and the IRR; and, (b) the lower rate of return on farms with more than 10% of the total area in cultivated pastures compared to other farms. The role of pastures in farms of the former group probably tends to be more one of speculation rather than one of technology improvement, since a farm with some cultivated pastures has a higher value. However, this does not necessarily imply better management nor increased productivity.

In the Colombian case studies, therefore, the use of cultivated grass pastures can hardly be considered an appropriate technology. The effect of cultivated (grasses) and improved (grass-legume) pastures as an integral part of a technological package (including management, mineral supplementation and other components) will be simulated using the results of the ETES-I phase, experimental results from the Carimagua Station and the first data from the on-farm validation of technologies (ETES-II).

Brazil

The ETES research work in Brazil is based on 12 case studies (see previous chapter). Final farm evaluations and analyses will be possible when raw data collection is completed at the end of 1980. Nevertheless, data from two production years allow a description of the most important economic and structural farm aspects, especially those contrasting with the structure of the Colombian project farms (interaction between annual crops and pastures and agricultural credit), which seem important for adoption of new technologies.

Land use. The average proportion of cultivated pastures in the total farm area is 25% for Mato Grosso and 36% in Goias. The average area under annual crops is 5% and 6% respectively (Fig. 3). This relatively high proportion of land under cultivation is of recent origin and has a very dynamic character.

Data from four years show an increase of 2.2% in the total area of all the project farms, suggesting a restricted possibility of land purchase around the farms.

The amount of Cerrado pasture decreased due to expansions in annual crops and cultivated pastures. The highest increase rates belong to different *Brachiaria* species (*B. decumbens, B. ruziziensis* and *B. humidicola*) (Table 8).

The cultivated pastures area had a lineal increase from about 6500 ha in 1978 to 11,000 in 1981. The main annual crop is upland rice, which has the function of an introductory culture for cultivated pastures (mainly *Brachiaria)* due to its high contribution to the financing of mechanized clearance of the Cerrado.

The Cerrado utilization patterns take one of three forms: (a) direct utilization for cattle raising, (b) light clearance and sowing to *Hyparrhenia rufa;* and, (c) mechanized Cerrado clearance for annual crops or cultivated pastures. Variants of these patterns occur according to the consecutive years of cropping or to the persistence of the sown pasture.

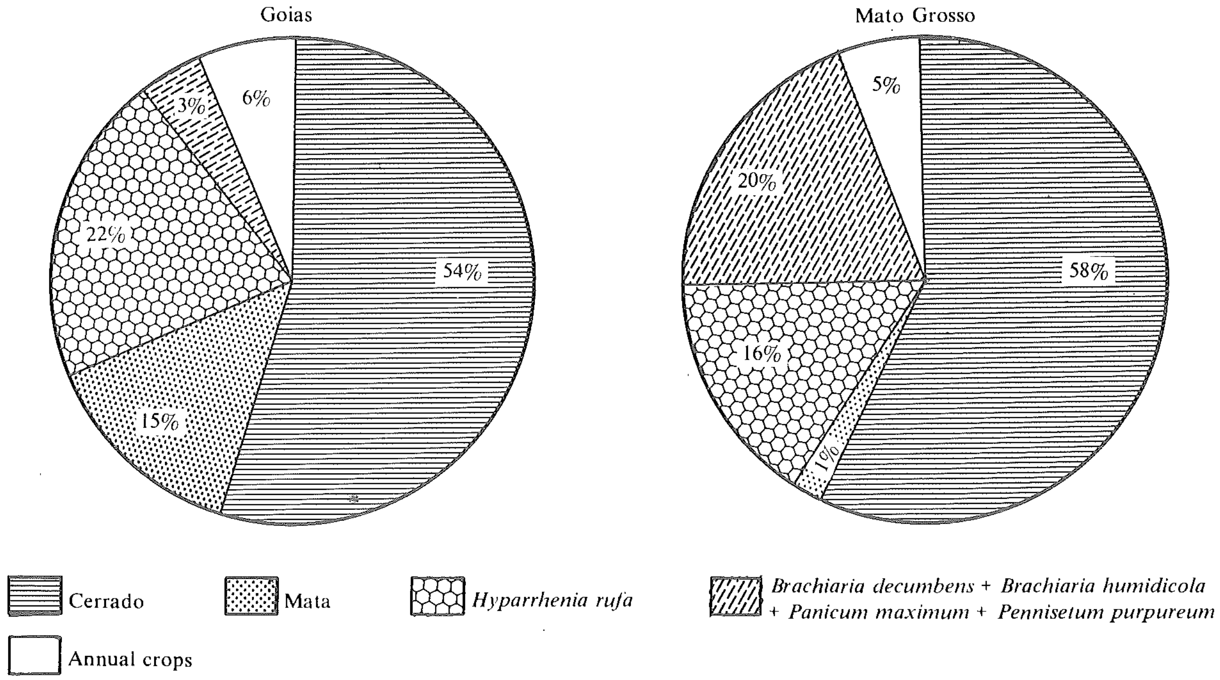


Figure 3. *Land use patterns on ETES Project farms in Brazil, 1980.*

Table 8. Changes in area for different types of land use in ETES Project farms in Brazil, 1978-1979.

Land use	Growth rate (%)
Cerrado	-3.9
Mata	-5.0
Hyparrhenia rufa (total)	1.4
Brachiaria decumbens	38.5
Brachiaria ruziziensis	52.0
Brachiaria humidicola	89.3
Panicum maximum	-20.3
Upland rice	-0.9
Maize	3.9
Banana	22.6
Cassava	0.0
Total area	2.2

Sown pastures can be established directly after Cerrado clearance or after annual crops, mainly upland rice. With an appropriate technology and rice yields around 1500 kg/ha, this production activity can be economically feasible for some years, before decreases in productivity lead to unprofitable input intensity. In any case, the culture rotation system ends with pastures, e.g., cattle raising. The establishment costs of sown pastures change considerably depending on whether it is made directly or follows annual crops. When charging the costs of Cerrado clearance and tree stump removal to upland rice, the average cost reduction for establishing *Brachiaria* was 73% for the ETES farms. Another aspect of this interaction that should be evaluated is the availability of rice straw and ratoon, with a low estimated carrying capacity of 0.1 to 0.3 A.U./ha/yr, but actually being available during the peak of the dry season.

Structure of investments. The main investment items on the farms are land, cultivated pastures, cattle, machinery and infrastructure. The predominant investment item was land — 71% in Goias and 59% in Mato Grosso and showing little variability between farms (Table 9). Although farms in Goias are smaller (average of 2277 ha) than in Mato Grosso (3003 ha), land investment is higher for Goias, partly due to the higher land prices. In contrast with this situation, the most important investment item for the Colombian farms is cattle (43%), followed by land (39%). Expressed in terms of cattle, land is a cheaper 'factor in Colombia.

Table 9 Total investments by categories on ETES Project farms in Brazil, 1980.

State and farm	Machinery and infrastructure		Cattle		Cultivated pastures		Land		Total investment	
	Invest-ment (1000 US$)	Proportion of total (%)	Invest-ment (1000 US$)	Proportion of total (%)	Invest-ment (1000 US$)	Proportion of total (%)	Invest-ment (1000 US$)	Proportion of total (%)	(1000 US$)	(US$/ ha)
Goias										
01	56.1	9	80.2	13	93.7	16	391.2	62	621.2	293
02	10.5	6	32.2	17	7.7	4	135.5	73	185.8	218
03	10.0	6	30.8	19	16.0	10	107.8	65	164.6	224
04	40.9	6	93.0	14	17.2	3	519.4	77	670.5	187
05	45.1	6	84.6	13	24.0	3	553.4	78	707.2	175
06	50.9	9	57.1	9	15.4	3	477.1	79	600.6	161
08	11.9	7	52.3	28	3.3	2	116.3	63	183.8	214
$\bar{x}$	32.2	7	61.5	16	25.3	6	328.7	71	447.7	210
C.V. (%)	64	20	41	38	122	89	61	11	57	21
Mato Grosso										
10	111.9	13	173.5	20	109.5	12	480.0	55	875.1	133
20	17.0	8	62.4	31	9.3	5	114.5	56	203.2	207
30	32.3	5	112.5	18	41.6	6	464.0	71	650.4	148
50	48.5	12	73.0	19	59.6	15	210.0	54	391.0	196
80	21.0	13	33.4	19	19.8	11	97.8	57	172.0	168
$\bar{x}$	46.1	10	91.0	21	48.0	10	273.2	59	458.3	170
C.V. (%)	84	36	60	26	82	42	68	12	66	18

Investments in sown pastures, machinery and infrastructure have similar proportions in both countries (15 *vs.* 18%). Nevertheless, the average total investment in Brazil (US $452,103) is almost twice as much as in Colombia (US $233,667). The same relation was found for total investment per hectare (US$190/ha *vs* US$105/ha). This is partly due to a better access to capital, thus a more intensive capital use in Brazil than in Colombia.

The distribution of the marginal investments can be used to indicate expanding production activities. The establishment of cultivated pastures (32%) is the most important item, followed by Cerrado clearance for annual crops or for direct pasture establishment (31%). The amount of Cerrado clearance was greater in the first observation years than in 1980, due to regional administrative delays in credit availability. Farmers claimed they made no investments in cattle in 1980. Another widespread investment item was the purchase of other farms in more distant regions, which was not possible to quantify. The investments in pastures are influenced by the profitability of the previous crop and the access to subsidized credit.

Cost structure for pasture establishment. The cost structure for pasture establishment was analyzed on the farms with *B. decumbens* (Table 10).

For all types of pasture establishment the main source of cost reduction was to plant pastures following upland rice since rice partly carries the cost of Cerrado clearance. This is the most common way to establish pastures (except *H. rufa).* In the case of intensive fertilizer and lime use (Table 10), these items account for 61% of the establishment costs. In five cases with less intensive fertilizer use and without pH correction, this item accounts for only 32% of total costs. For one observation with no use of fertilizer, the costs are equally distributed between land preparation and seeding.

There is a direct relationship between input use intensity and access to credit. Obviously, the farm with higher input intensity produces more (year-round carrying capacity of 2 A.U./ha/yr compared to 1.0-0.5 A.U./ha/yr for the other farms). The effect of good pasture management cannot be measured separately. The sensitivity to increases of input prices and to changes in the subsidized credit policy is higher, the higher the intensity of fertilizer and lime use.

Table 10. Cost structure for establishment of *Brachiaria decumbens* on ETES farms in Brazil.

Cost	Distribution (%)					
	B. decumbens with $CaCO_3$[1]		*B. decumbens* without $CaCO_3$[2]		*B. decumbens*[3]	
	Alone	Rotation	Alone	Rotation	Alone	Rotation
Land preparation	49	25	77	41	92	46
Fertilizers	27	42	14	32	-	-
Seed	7	14	7	27	8	54
Lime ($CaCO_3$)	17	19	-	-	-	-

[1] One farm [2] Five farms [3] One case, without fertilizer

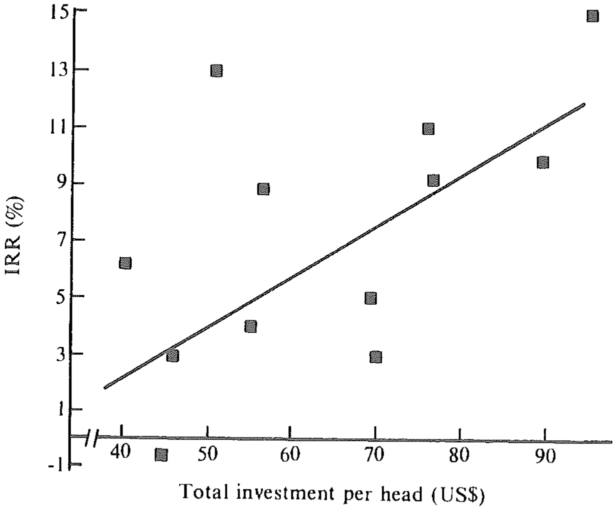
Bank credit. In contrast with the Colombian Llanos, the agricultural and cattle sector in Brazil has various regional credit programs (POLOCENTRO, PROTERRA, PROAGRO, etc.). Credit programs are specific for subsectors (crop or livestock production) and for activities (operating capital, credit, investment, marketing). Of all the project farms only one currently uses no bank credit. The amount of credit for Mato Grosso averages 46.4% of the farm in terms of equity as valued by the bank debt incurred during the course of the next five years. In Goias the average debt ratio was 40.7% of the farm property.

The most important aspect of this rural credit is the subsidy through low nominal interest rates (15% for 1980). Using average data and an inflation rate at 80%, the proportion of subsidy for one-year credits was calculated at 40.29% of the total credit amount. This 80% inflation rate is probably an underestimate. For investment credit with an eight-year term (Cerrado clearance + pasture establishment), the real discounted subsidy reaches 81.36%. Calculations for one farm indicated that subsidized credit effectively reduced annual costs for establishing sown pastures of *B. decumbens* or *B. humidicola* by 65% per hectare or per A.U.

Use of subsidized credit for the agrarian sector has expanded both in terms of the amount and number of clients in Brazil during recent years. Thus, for the ETES case studies it can be assumed that subsidized credit will continue to be important.

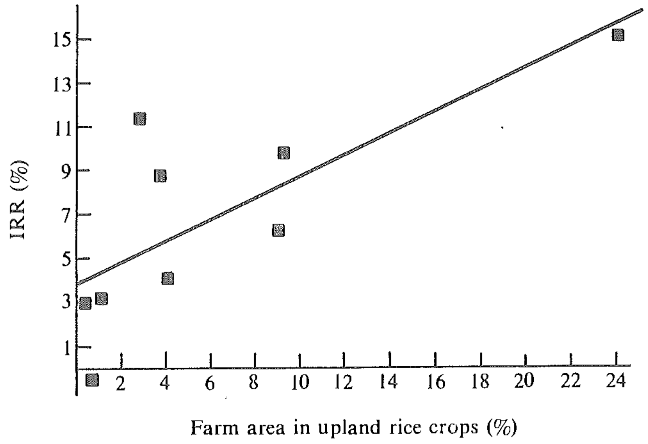
Profitability of the ETES farms. Using available technical coefficients and economic data for 1980, projections of herd development, prices and cash flow were made for each farm assuming constant technical coefficients (computerized HATSIM Model). The results on herd development, cash flow and internal rate of return (IRR) might change slightly due to new data from the last working visit on animal production by the ETES years (November 1980). Nevertheless, the tendencies of five previous visits will not change significantly.

In contrast to the Colombian cases, increasing investments in Brazil lead to increases in the IRR (Figure 4). Including all farms, the IRR as a function of total investments per animal head (without cattle and land), shows a positive tendency (IRR = 5.05 + 0.18 Inv., $r^2 = 0.58$). Among the 12 case studies, two have a noticeably different relationship between the two variables. With very few investments and high production parameters, farm 03 has one of the highest IRR's (13.49%). This can be explained partly by the quality of its soils (Al saturation of 2.2.% compared to 13.4% over all ETES farms). Farm 03 has no crops and, therefore, was not included in the function. Since cropping was expected to influence profitability, the relationship between the percentage of area in upland rice and the IRR was checked. Including only those farms planted with rice, there is a positive correlation between the two variables (IRR = 3.86 + 0.49 cult., $r^2 = 0.56$) (Figure 5). Therefore, the positive relationship between higher investments and IRR is not solely due to the livestock enterprise.



IRR = 5.05 + 0.18 inv.
$r^2 = 0.58$

Figure 4. *Total investment per head of stock and internal rate of return (IRR) for ETES Project farms in Brazil.*



IRR = 3.86 + 0.49 cult.
$r^2 = 0.56$

Figure 5. *Percentage of total farm area in upland rice and internal rate of return (IRR) for ETES Project farms in Brazil.*

Adoption of new technologies. There are two main possibilities of expanding the cattle raising activity on the ETES farms: (a) by purchasing additional land (Cerrado) and/or (b) by intensifying use of available land use (sown pastures).

A total farm area increase of only 2.2% during three observation years and its stagnation during the last year point out the limited possibility of expanding cattle raising activity through Cerrado use in these regions. Furthermore, according to calculations for each farm the use of Cerrado happens to have higher annual costs per A.U. than cultivated pastures under proper management.

The intensification of land use in the farms has been done through the interaction between annual crops (upland rice) and cultivated pastures. The type of pastures used includes only grasses. This kind of land use intensification can be limited by the Cerrado area available for clearance. Furthermore, increases in the input-output price ratio will demand not only increases in productivity per unit area, but essential increases in the production parameters per A.U.

The use of cultivated pastures is a widespread technology among the ETES farms and in the project regions, although no grass-legume mixtures are sown. Since establishment of cultivated pastures is a dynamic, on-going process among the ETES farms and the credit support for such activities seems likely to continue in the coming years, the introduction of new technologies related to legume-grass mixtures and their management could be readily integrated into this process.

Transference of Technology

In 1980 this Section continued to assist the Program to set conditions for transferring technology to national institutions. This was accomplished mainly by coordinating technical aspects of training activities and participating in regional trials in Central America and the Caribbean region to evaluate the adaptability of pasture germplasm selected for the ecosystems of the target area.

Training

Sixty-five professionals received training during 1980 in the various sections of the Program (Table 1). The main objective continued to be the development and strengthening of a network of scientists and technicians working on tropical pastures in the target area.

Table 1. Countries of origin of professionals trained in the Tropical Pastures Program in 1980.[1]

Country	No. of professionals	Country	No. of professionals
Argentina	4	Honduras	2
Bolivia	2	Mexico	1
Brazil	6	Netherlands	2
Colombia	10	Nicaragua	5
Costa Rica	2	Panama	4
Cuba	8	Peru	5
Dominican Republic	2	United States	1
Ecuador	3	Venezuela	4
Germany, Federal Republic of	4	Total	65

[1] Includes those who entered training prior to 1980.

Twenty-eight professionals from 12 countries in Latin America participated in the Third Course on Research on Tropical Pastures Production and Utilization, conducted during the second semester of 1980. This third course was modified to allow greater participation of trainees on individual research projects in various sections of the Program but with emphasis in agronomy, soil fertility and animal nutrition. The other 37 trainees participated as visiting research associates and postgraduate interns in activities related to projects in collaboration with universities to fulfill requirements for M.S., Ph.D. or equivalent degrees or specific research projects.

Experiments for research purposes. Several experiments have been established at CIAT-Quilichao to serve for training on research methodology on pasture evaluation and to offer trainees the opportunities to conduct research and to evaluate data relevant to the problems of pasture production and utilization under acid infertile soil conditions. The results of these experiments were presented and discussed with trainees throughout their training programs.

Last year results were reported on first-year DM yields of several forage grasses under three levels of soil fertility (CIAT Trop. Past. Prog. 1979 Ann. Rept.). After the second year all species except *Digitaria decumbens* still showed good adaptation under these conditions. Among the short spreading grasses, *Paspalum notatum* had highest yields this year at all fertility levels. *Brachiaria decumbens* 606 was outstanding in the semierect stoloniferous group and *Andropogon gayanus* 621 performed best at all levels among the tall tufted grasses.

The *in vitro* DM digestibility of selected pasture species was shown to increase in response to soil fertility (Table 2). There were, however, no significant changes in the composition of structural carbohydrates which might explain changes in digestibility.

Two ecotypes of *Pennisetum purpureum,* King Grass and Merker, showed remarkable adaptation to acid soil conditions in CIAT-Quilichao during their first year. With DM yields generally above 40 t/ha, these ecotypes were highly productive. They could be used as supplemental feed during the dry season, especially by small landholders.

Grazing trials on improved pastures have been established on four farms near CIAT-Quilichao. Their soil characteristics indicate acid infertile conditions similar to the research station where species were selected for adaptation. The summary of results of these trials in Table 3 shows the potential productivity of improved pastures, especially grass-legume associations, under the conditions in which these experiments were established.

Table 2. Average composition of structural carbohydrates and lignin for selected tropical pasture species in relation to three fertility levels, at CIAT-Quilichao, 1979-80.

Forage group[1]	Soil fertility levels [2]	IVDM[3] (%)	CC[4] (%)	CWC[4] (%) Total	Cellulose	Hemicellulose	Lignin
Grasses	I	37.8	24.4	76.0	38.5	30.1	7.0
	II	41.7	21.7	78.2	44.0	34.1	7.9
	III	46.8	22.9	77.0	34.2	35.7	7.0
	Average	42.1	23.0	77.0	38.9	33.3	7.3
Legumes	I	35.6	32.4	67.5	33.7	20.2	13.5
	II	39.4	33.9	66.0	31.5	18.6	15.9
	III	50.6	32.4	67.5	30.5	22.8	14.2
	Average	41.8	32.9	67.2	31.9	20.5	14.5

[1] Grasses: *Digitaria decumbens, Brachiaria decumbens, Andropogon gayanus, Panicum maximum.*
Legumes: *Pueraria phaseoloides, Stylosanthes capitata, Desmodium ovalifolium, Zornia latifolia.*

[2] Fertility levels: I = control; II = 150, 100, 44 kg/ha, respectively, of lime N and P; III = 2000, 200, 88, 42 kg/ha, respectively, of lime, N, P, and K plus S, B and Cu.

[3] IVDMD = *In vitro* dry matter digestibility.

[4] CC = cell content; CWC = cell wall constituents.

Table 3. Cattle liveweight gains on improved tropical pastures in grazing trials established for training purposes, 1979-80.

Location and treatments	Duration (days)	Stocking rate (animal/ha)	Daily gain (g/animal/day)	Total gain (kg/animal)	Average gain (kg/ha/day)
CIAT-Quilichao					
Hemarthria altissima	186	6.00	535	99.5	3.20
Andropogon gayanus	188	4.00	622	116.9	2.49
Andropogon gayanus + mixed legumes	160	3.50[1]	400	64.0	1.40
El Limonar farm					
Cynodon nlemfuensis	212	1.25	557	118.0	0.69
Brachiaria decumbens	212	2.40	595	126.0	1.42
Brachiaria humidicola	417	2.40[2]	516	215.0	1.44
Andropogon gayanus + *Centrosema*	167	2.90[3]	652	109.0	2.15
Andropogon gayanus + mixed legumes	417	2.87[4]	652	272.0	2.12
El Congo farm					
Andropogon gayanus	182	4.00	498	91.0	2.00
Andropogon gayanus + *Pueraria phaseoloides*	181	4.00	506	84.0	1.85
Andropogon gayanus + *Stylosanthes capitata*	182	4.00	471	58.0	1.27
La Real farm					
Andropogon gayanus + *Pueraria phaseoloides*	112	4.00	544	61.0	2.17

[1] Average: 2.7 animal/ha for 73 days, then 4.3 animal/ha

[2] Average: 2.0 animal/ha for 187 days, then 2.8 animal/ha

[3] Average: 2.5 animal/ha for 33 days, then 3.3 animal/ha

[4] Average: 2.5 animal/ha for 187 days, then 3.25 animal/ha

Program and Staff Publications

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* Until October 14, 1980
** Starting October 15, 1980; previously in charge of Agronomy/Regional Trials
*** Left during 1980
**** Senior scientist starting Sep. 1980
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