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# Tropical Pastures Program
# Annual Report 1981

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

# Contents

# Introduction

It has been well documented in previous annual reports that beef and milk are staple food commodities in tropical America. It has also been shown that low income urban families spend a large proportion of their income on beef and milk, and that they prefer those products over other food commodities.

The growth rates of demand and production of beef in Latin America are shown in Table 1. With the exception of temperate Latin America, the fast growing demand for beef is not being met by production in all other countries and sub-regions. The same applies to dairy products. This inbalance between demand and production growth rates causes a continuous increase in real prices affecting both the diet and the standard of living of the low income strata of the population. Figure 1 shows real changes in beef prices in Brazil, Colombia and Venezuela for the last 15 years. Table 2 shows that the total import value of dairy products spent by tropical American countries exceeds 600 million US dollars per year.

Tropical America is a region with vast areas of acid infertile soils totalling 850 million ha. Table 3 shows the distribution and proportion of Oxisols and Ultisols in Latin America.

Stocking rates, as well as animal productivity, in these acid infertile soil regions have always been low. The current average stocking rate in Oxisol savannas of 0.12 animal/ha can potentially be increased more than ten fold. In addition, beef production per head could be more than doubled. These acid infertile soils could also contribute significantly to increased milk production through dual-purpose production systems, especially in regions close to markets.

## Area of Interest

Ecosystems Classification. This vast frontier land of tropical America has nearly one billion hectares of savannas and tropical forests. A survey of its lowland acid infertile soil regions was initiated in 1978 in order to classify land resources in terms of climate, land slope and soils, and to provide an ecosystem perspective of the program's area of interest, which would serve as a basis for the design of its research strategy.

An analysis of the survey data led in 1979 to a sub-division of the area into five major ecosystems: (i) "Llanos" (tropical well-drained savannas, isohyperthermic), (ii) "Cerrados" (tropical well-drained savannas, isothermic), (iii) tropical poorly drained savannas, (iv) tropical semi-evergreen seasonal forest, (v) tropical rain forest.

The distribution of these five major ecosystems is shown in Figure 2. Up to the present, the Program has focused its research only on the well-drained savannas of the "Llanos" and "Cerrados" type. However, regional trials have been established in the other three ecosystems.

Table 1. Beef: Annual growth rates of demand and production by countries of Latin America, periods 1960/74 and 1971/79.

| Region and country | Demand[a] 1960/74 (%) | Demand[a] 1971/79 (%) | Production 1960/74 (%) | Production 1971/79 (%) |
|---|---|---|---|---|
| Tropical Latin America | 5.6[b] | 5.9[b] | 3.6 | 2.5 |
| Brazil | 6.0 | 7.2 | 3.9 | 1.7 |
| Mexico | 5.3 | 4.5 | 5.2 | 8.1 |
| Colombia | 5.2 | 5.1 | 2.0 | 4.4 |
| Venezuela | 6.9 | 4.6 | 5.1 | 3.9 |
| Peru | 4.7 | 5.4 | 1.4 | -2.5 |
| Ecuador | 7.5 | 8.3 | 4.2 | 5.0 |
| Paraguay | 3.1 | 3.5 | -1.1 | -2.0 |
| Bolivia | 4.9 | 6.1 | 0.0 | 6.1 |
| Dominican Republic | 5.8 | 7.5 | 3.7 | 1.3 |
| Central America | 5.2[b] | 4.6[b] | 5.8 | 3.7 |
| Nicaragua | 5.2 | 5.0 | 6.7 | 3.4 |
| Costa Rica | 5.2 | 4.6 | 7.1 | 5.7 |
| Guatemala | 5.6 | 5.3 | 4.6 | 2.9 |
| El Salvador | 4.8 | 4.8 | 1.8 | 4.9 |
| Honduras | 4.6 | 3.1 | 8.3 | 2.1 |
| Panama | 5.9 | 4.0 | 5.3 | 4.0 |
| Caribbean | 4.5[b] | 4.0[b] | 2.3 | 2.2 |
| Guayana | - | 4.0 | - | 2.9 |
| Other Caribbean countries[c] | - | 4.0 | - | 2.9 |
| Temperate Latin America | 2.0[b] | 1.7[b] | 0.3 | 5.5 |
| Argentina | 1.7 | 1.5 | 0.5 | 6.1 |
| Uruguay | 1.3 | 0.7 | -1.2 | 1.7 |
| Chile | 3.0 | 2.5 | 0.2 | 3.3 |
| Latin America | 5.1[b] | 5.4[b] | 2.2 | 3.7 |

[a] Estimated as: d = P +  y Y +  y PY, where P and Y are average annual rates of population growth and the respective entry and Ey are the beef income elasticity of demand.
[b] Pondered average by population.
[c] Includes: Trinidad and Tobago, Haiti, Jamaica and Barbados.

Source: Population: World Bank 1979. 1978 World Bank Atlas, Washington, D.C. Production and elasticity entry of demand. FAO 1980. Production Yearbook 1970-79, and Projection of Agricultural Commodities, Rome.

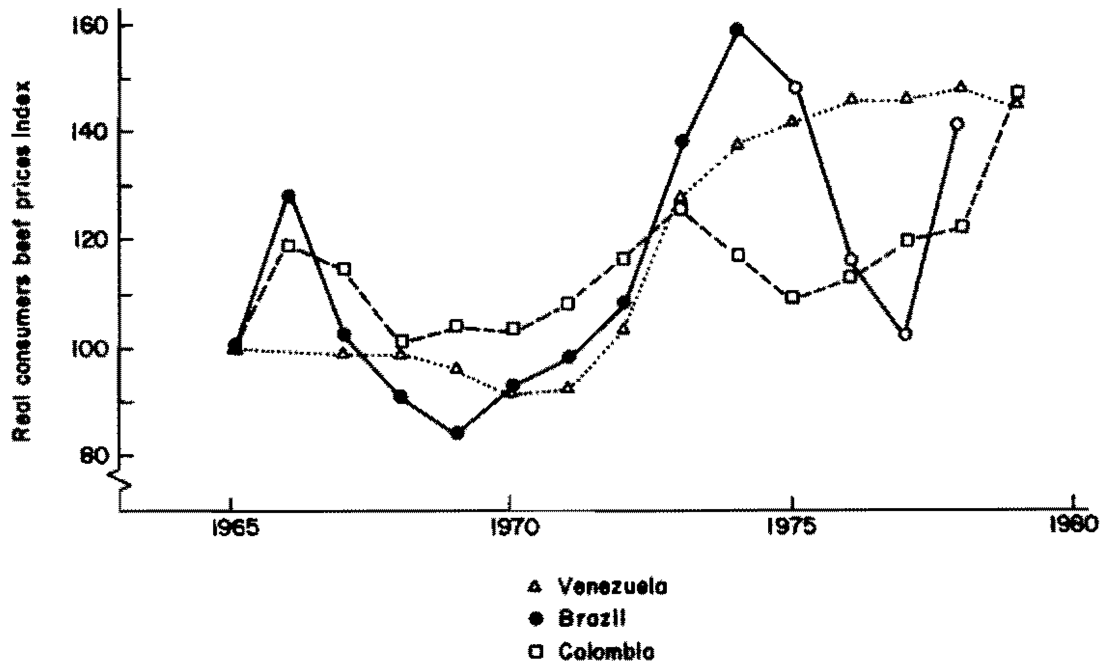


Figure 1. Changes in real consumer beef prices index, Brazil, Colombia and Venezuela, 1965-1979 (1965=100).

Sources: FGV, Anuario do Brasil; DANE, Boletín mensual de estadística, World Bank, International Financial Statistics; MAC, Anuario Estadístico Agropecuario. Ministerio de Agricultura y Cria (various issues).

Table 2. Dairy products: value of imports in Latin America during 1979.

| Products | Tropical America | Latin America |
|---|---|---|
| | US$ x 10[b] | |
| Milk | 404 | 462 |
| Butter | 133 | 153 |
| Cheese | 71 | 82 |
| Total | 608 | 697 |

Source: FAO. 1979 Yearbook.

Table 3. Distribution and proportion of Oxisols and Ultisols in Latin America.

| Regions | Oxisol and Ultisol areas (million ha) | Percentage of region (%) |
|---|---|---|
| Tropical Latin America | 848.5 | 51 |
| Tropical South America | 828.2 | 59 |
| Tropical Central America and Caribbean | 15.8 | 23 |
| Total Latin America | 851.1 | 42 |

Source: CIAT, 1980. Latin America: Trend Highlights for CIAT Commodities, Cali, Colombia.

The ecosystems classification by climatic and soil conditions made by the Agrometeorology Studies Unit is used for designing germplasm collection strategies and for selection of major screening sites and locations for regional trials.

## Objectives

Pasture-based animal production on acid infertile soils constitutes a real challenge--a challenge which CIAT accepted in consideration of the existence of vast areas of acid infertile soils, their potentiality for cattle production, and the pioneer nature of animal production in the frontier.

CIAT's Tropical Pastures Program has the following overall objective: "To develop low-cost low-input pasture technology for acid infertile soils of tropical America".

With development of this technology, the Program expects to increase beef and milk production in tropical America, and to release fertile cattle land for expansion of crop production.

The strategic approach to the problem involves:

a) Selecting pasture germplasm adapted to the environmental constraints (climate and soils), as well as prevailing pests and diseases;

b) developing persistent and productive pastures;

c) integrating improved pasture technology into biologically and economically efficient animal production systems.

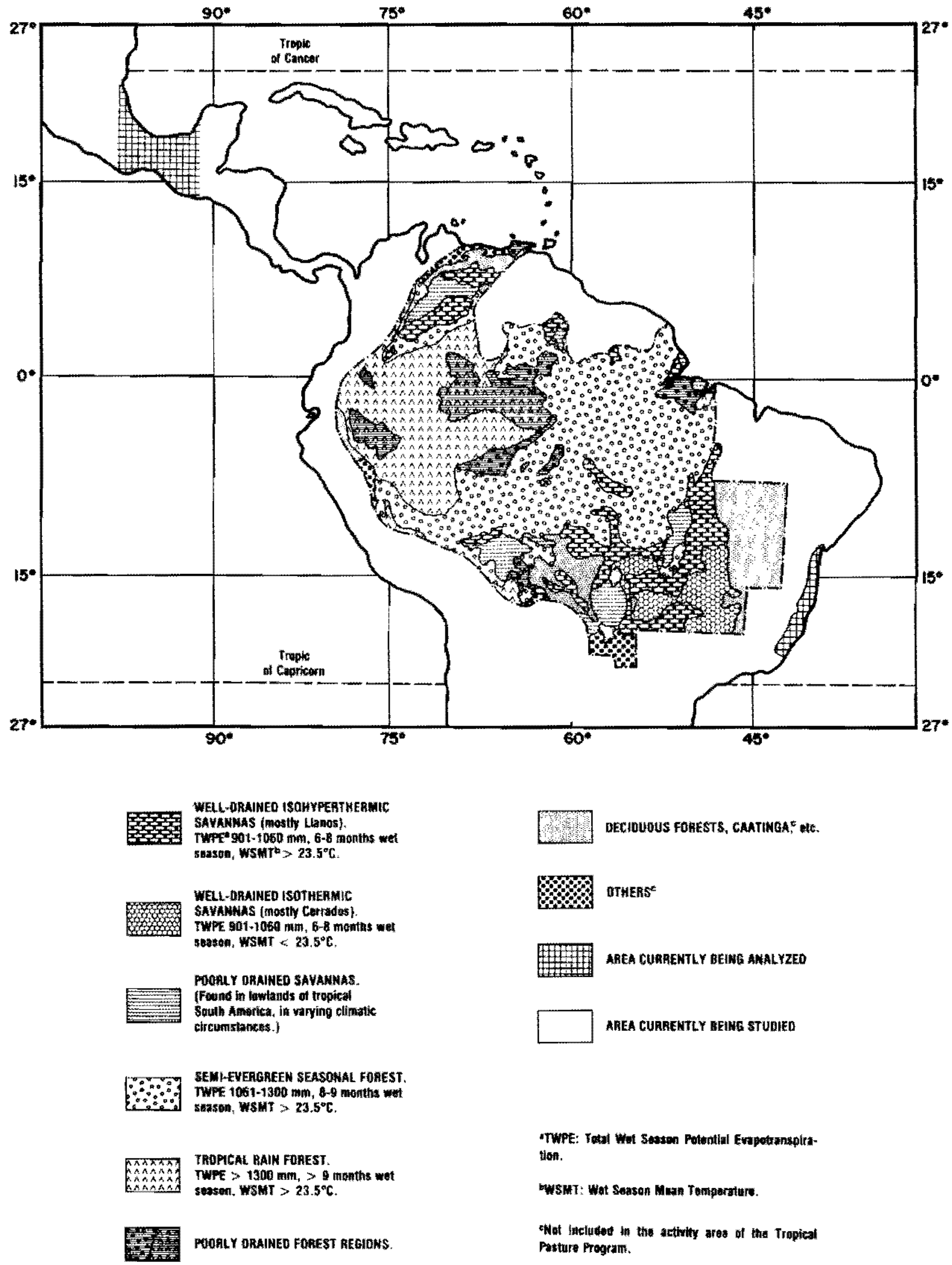


Figure 2. Main ecosystems of tropical South America.

Organization

In accordance with the three strategies above, the structure of the Tropical Pastures Program comprises the following three inter-disciplinary units or groups of researchers:

- Germplasm Evaluation
- Pasture Management Evaluation
- Pasture Evaluation in Farm Systems.

The Germplasm Unit centers its attention on selection, characterization and development of legumes and grasses adapted to acid infertile soils and tolerant to pests and diseases. The Farm Systems Unit analyzes production systems prevailing in specific areas, socioeconomic conditions in which the systems operate and their implications for pasture technology. This group defines improved pasture components needed to strategically solve and correct the critical constraints in the farm system. It also evaluates the expected impact of alternative improved pasture technologies in the production system.

The Pasture Management Evaluation Unit serves as a bridge between the other two units. Starting with characterized germplasm provided by the Germplasm Evaluation Unit, it assembles pastures in response to the requirements set by the Farm Systems Unit and concentrates its efforts on the development and evaluation of pastures under different management schemes, measuring animal productivity potential.

After collection of germplasm, initial evaluation and seed multiplication follow, as shown in Figure 3. Thereafter, all accessions are distributed to different ecosystems for screening for climate and soil adaptation as well as for initial disease and pest tolerance tests. Agronomic characteristics facilitating persistence and productivity are assessed in each ecosystem, as well as soil-plant and plant-animal interactions.

At this level promising germplasm is intensively characterized to provide sufficient information to answer the question (first decision point): What is the alternative use of each promising germplasm entry in a pasture system? After the decision is taken by the first two units, a large seed multiplication effort is required to supply medium-scale pasture establishment and pasture management grazing trials. At this point the number of accessions under evaluation is greatly reduced. A second decision is made by the second and third evaluation units in answer to the question: What is the alternative use of the pastures in the farm systems?

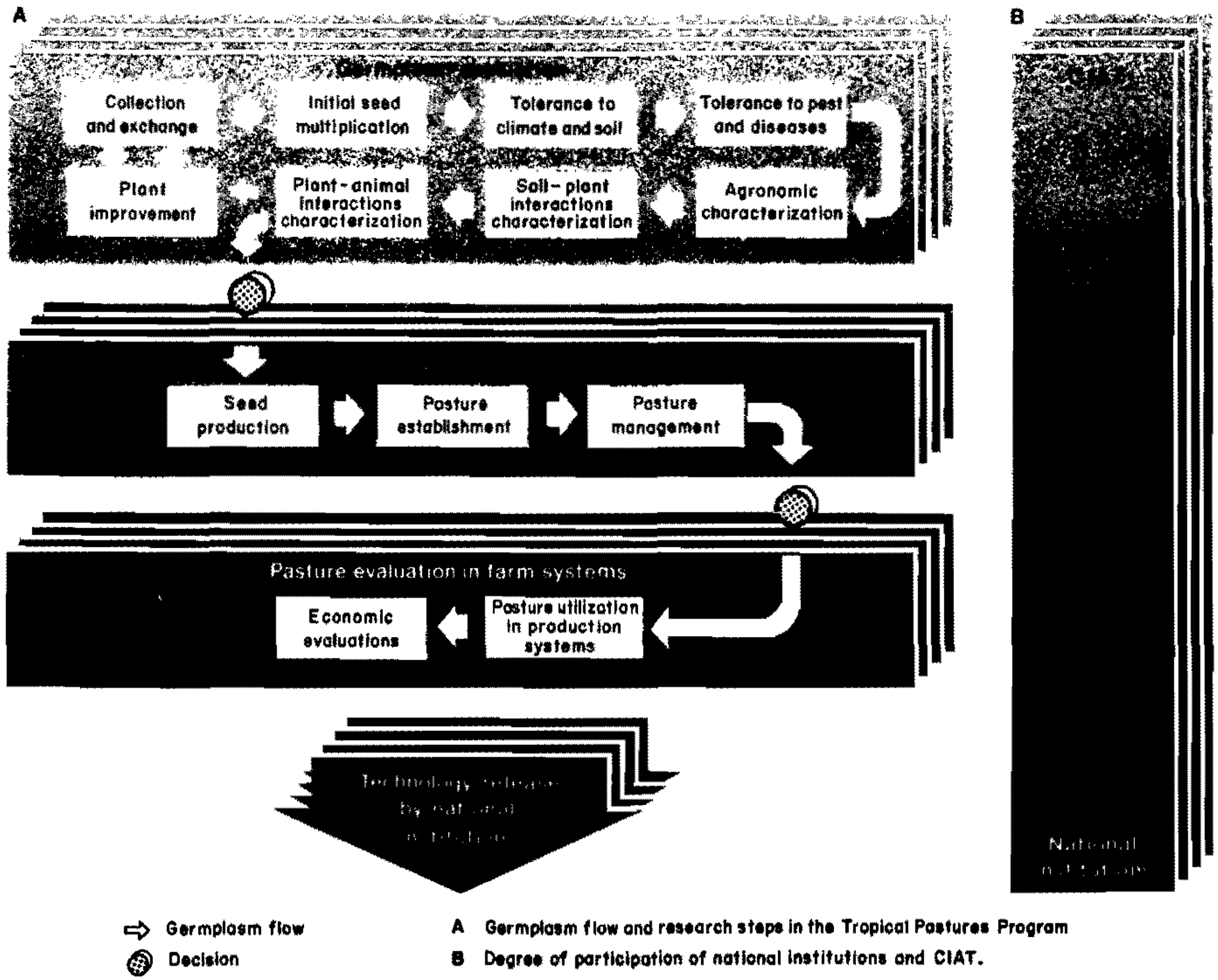


Figure 3. Organizational structure and germplasm flow (arrows) of the Tropical Pastures Program.

As germplasm flows through the evaluation sequence, the number of accessions passing the different tests is reduced. Figure 3 graphically illustrates the reduction that takes place as they go from category to category, namely, Category I, "Identification of germplasm with potential"; Category II, "Agronomic evaluation in small plots"; Category III, Agronomic "Pasture Evaluation", Category IV, "Pasture evaluation and management"; and finally, Category V, where pastures are evaluated in production systems. The final step of cultivar and technology release is an exclusive responsibility of national institutions.

The major screening sites of the Program are Carimagua (in the Llanos Orientales of Colombia) in collaboration with ICA, for the Llanos ecosystem, and CPAC (Centro de Pesquisa Agropecuãria dos Cerrados) in Brazil, in collaboration with EMBRAPA, for the Cerrados ecosystem.

In addition, initial stages of evaluation and seed multiplication take place at the FES-CIAT Quilichao station. Due to its proximity to headquarters, this station is used also for specific studies such as nutrition and methodology research. Another important use for this station is training.

A key activity of the Program is the International Tropical Pastures Evaluation Network, a multi-institutional activity in which national programs evaluate tropical pasture germplasm (from national institutions and CIAT germplasm banks.)

The Network follows sequential steps for evaluation of adaptability and productivity of promising materials. This screening procedure is complementary to the major screening work done in Carimagua and Brasilia.

The International Evaluation Network operates in the five major ecosystems providing a solid basis for extrapolation of results. Information from each Regional Trial site is channeled to and processed in the supporting network data bank and made available to the Program as well as to the participant institutions. In this way, use of available information is maximized, unnecessary duplication of efforts is avoided, and horizontal transfer of technology is achieved.

# Germplasm

During 1981, the activities of the Germplasm section continued focused on:

a) Assembling of germplasm through direct collection and through exchange of materials with other institutions.

b) multiplication and maintenance of germplasm of priority species;

c) preliminary evaluation of germplasm and initial seed increase.

## Collection and Introduction of Germplasm

Collection: During 1981, three major collection trips were conducted, mainly to areas with acid, infertile soils and with the purpose of increasing the collection of particular genera and species, which due to their already known potential, are of specific interest to the Tropical Pastures Program:

1. A collection expedition through the Venezuelan states of Aragua, Carabobo, Yaracuy, Lara, Trujillo, Portuguesa, Cojedes, Guárico, Anzoátegui, Sucre, Monagas, and Nueva Esparta (Fig. 1) aimed at native germplasm particularly of the species *Stylosanthes capitata*, *S. guianensis* "tardío", *Centrosema macrocarpum*, *C. brasilianum*, and *Zornia* spp. This trip was conducted in collaboration with the Venezuelan Fondo Nacional de Investigaciones Agropecuarias, FONAIAP.

2. A trip to the area of the Sierra Nevada de Santa Marta (Fig. 2) to collect mainly *Centrosema* germplasm, particularly of *C. macrocarpum*.

3. The collection trip through the Brazilian states of Goiás, Bahía, Espirito Santo and Minas Gerais (Fig. 3) sought to increase the collection of germplasm of *Stylosanthes* (mainly *S. capitata*, *S. macrocephala* and *S. guianensis* "tardío"), *Zornia* (mainly four-leaflet species such as *Z. brasiliensis*, *Z. myriadena* and *Z. flemmingioides*) and *Centrosema* (mainly *C. brasilianum* and *C. macrocarpum*). This trip was conducted as a collaborative project with EMBRAPA's Centro Nacional de Recursos Genéticos, CENARGEN, to areas with very low rainfall (e.g. caatinga in Bahía) as well as to very humid regions (e.g. tropical rain-forest in the coastal strip of Espirito Santo and Bahía). The specific aim was to broaden the genetic base of priority species with regard to probable drought resistance of material evolved under dry conditions, as well as better disease tolerance of germplasm evolved under rather humid conditions.

Introduction: The efforts to introduce germplasm through exchange with other institutions during 1981 continued concentrated on African grasses and added to the Program's germplasm bank an important collection from CSIRO, Australia, of approximately 100 accessions of Brachiaria spp. and Andropogon gayanus. In terms of legumes, the most important contributions were received from EMBRAPA-CENARGEN.

With the additions during the year -- 1175 accessions of directly collected germplasm and 325 accessions introduced through exchange with other institutions -- the Program collection reached more than 8600 accessions (Table 1), the majority originating from regions with acid, infertile savannas and forest soils. Table 2 shows that the collection increased considerably in terms of germplasm of "key species" for well-drained savanna ecosystems, the Llanos and the Cerrado.

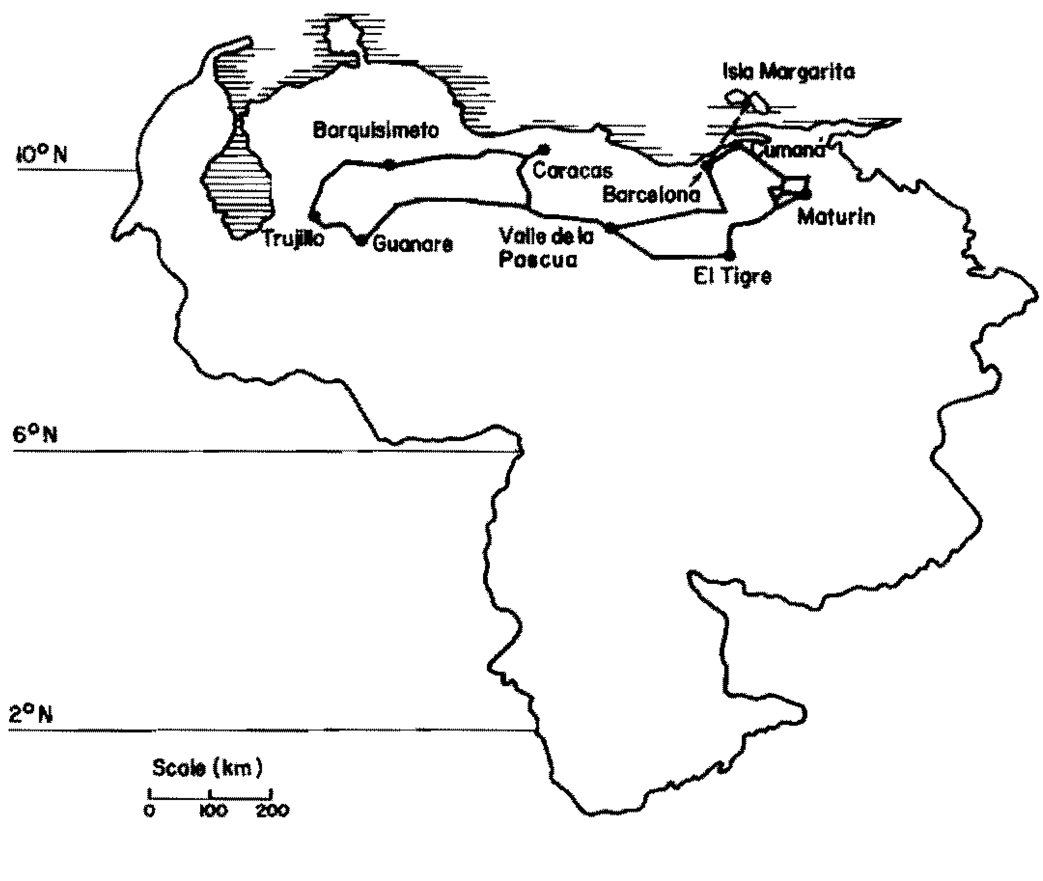


Figure 1. Routes of systematic collection of germplasm of tropical pasture species in Venezuela, January/February, 1981.

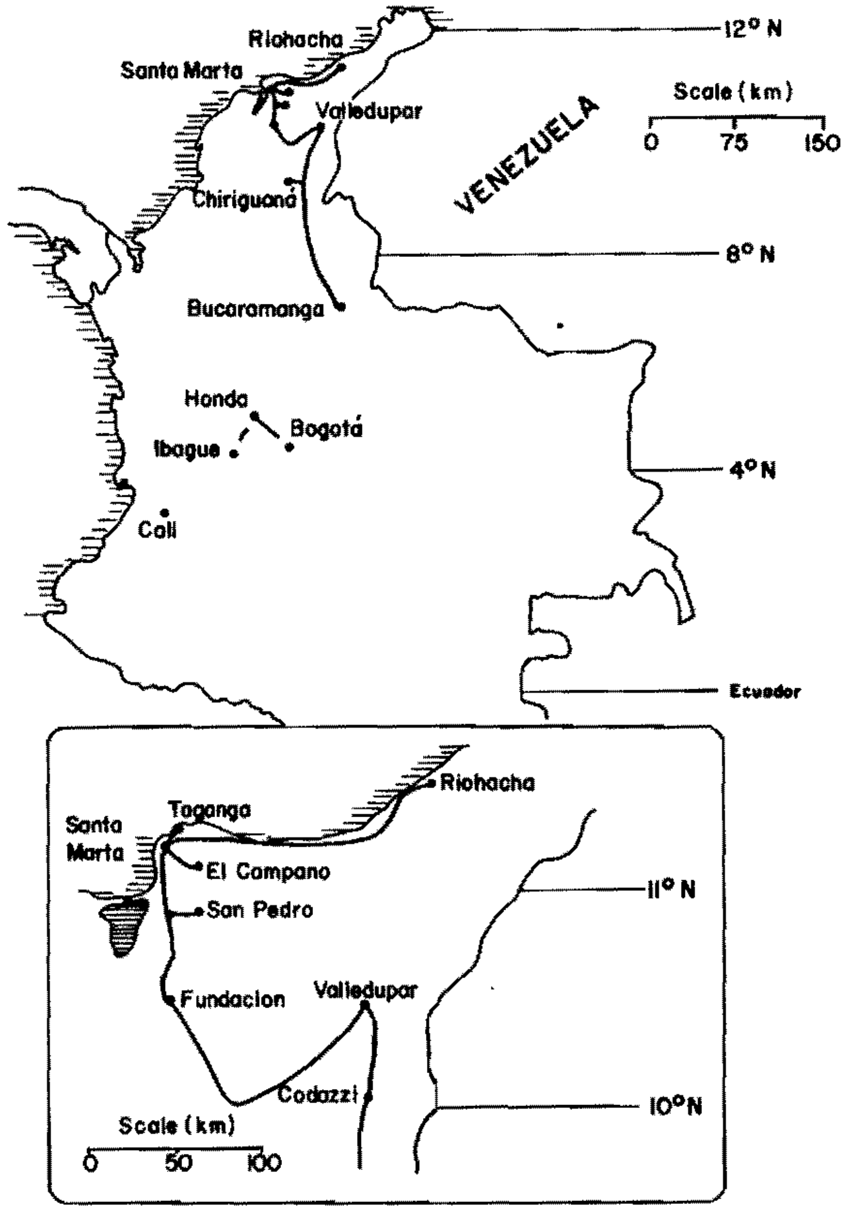


Figure 2. Routes of systematic collection of germplasm of tropical pasture species in Colombia, March/April, 1981.

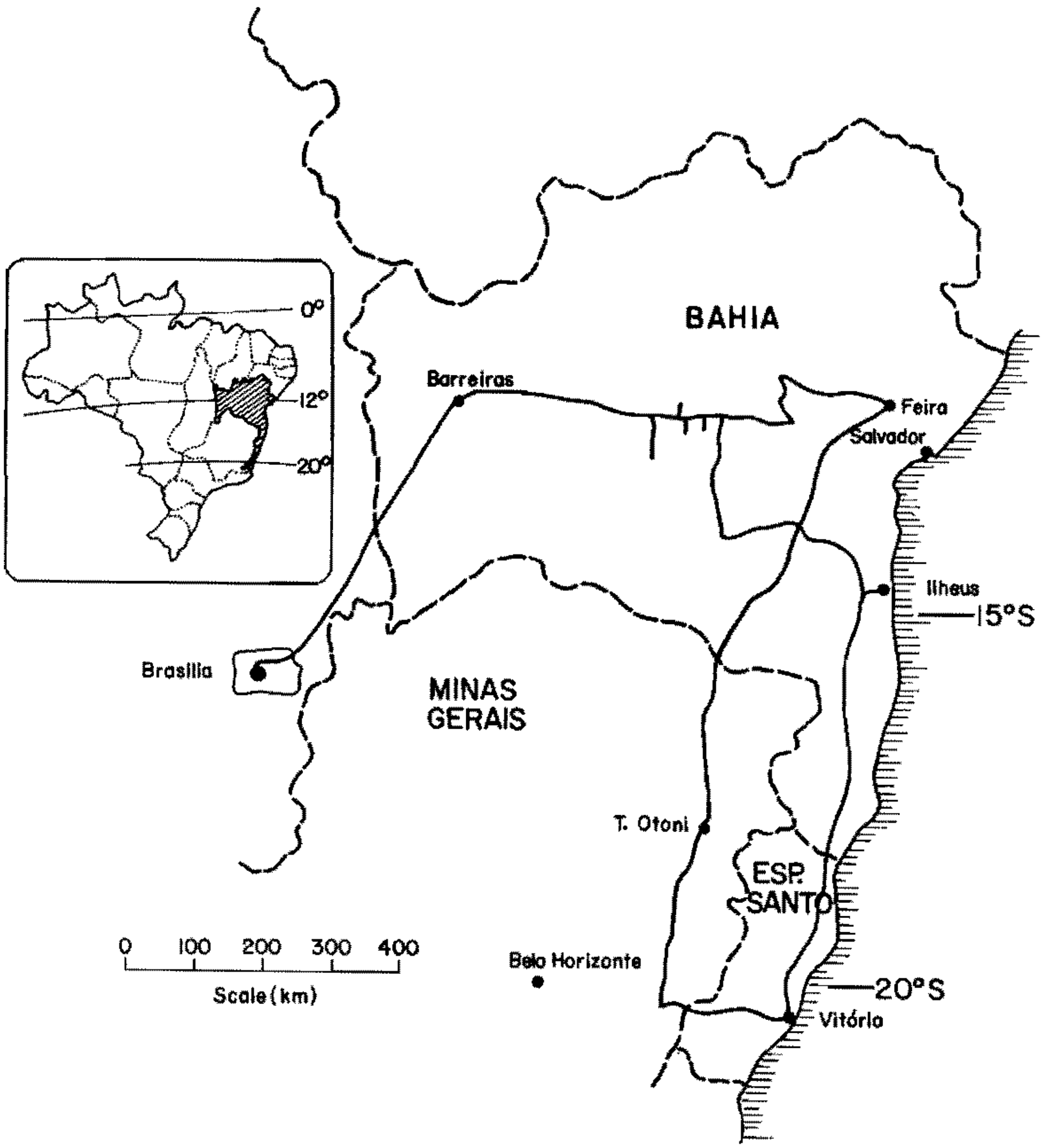


Figure 3. Routes of systematic collection of germplasm of tropical pasture species in Brazil, August/September, 1981.

Table 1. Introduction (number of accessions) of germplasm of tropical pasture species through direct collection and through exchange with other institutions during 1981.

| Genera | Collections: Major collection trips in: Venezuela | Colombia | Brazil | Occasional collections | Exchange | Total 1981 | Total accessions in germplasm bank |
|---|---|---|---|---|---|---|---|
| *Stylosanthes* | 66 | 10 | 210 | 22 | 99 | 407 | 2130 |
| *Desmodium* | 23 | 19 | 37 | 20 | 5 | 104 | 969 |
| *Zornia* | 36 | 1 | 80 | 15 | 52 | 184 | 745 |
| *Aeschynomene* | 12 | 8 | 54 | 4 | - | 78 | 455 |
| *Centrosema* | 102 | 66 | 47 | 15 | 58 | 288 | 893 |
| *Macroptilium/Vigna* | 9 | 18 | 26 | 4 | 3 | 60 | 546 |
| *Calopogonium* | 10 | 10 | 10 | 3 | - | 33 | 176 |
| *Galactia* | 37 | 16 | 20 | 2 | 1 | 76 | 302 |
| Miscellaneous legumues* | 40 | 58 | 57 | 8 | 2 | 165 | 1586 |
| Grasses | - | - | - | - | 105 | 105 | 833 |
| Total | 335 | 206 | 541 | 93 | 325 | 1500 | 8635 |

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

Table 2. Introduction (No. of accessions) of germplasm of key species for both well-drained savanna ecosystems through direct collection and exchange with other institutions during 1981.

| Species | Collections in: Venezuela | Colombia | Brazil | Occasional collections | Exchange | Total 1981 | Total accessions in germplasm bank |
|---|---|---|---|---|---|---|---|
| *Andropogon gayanus* | - | - | - | - | 14 | 14 | 65 |
| *Brachiaria* spp. | - | - | - | - | 79 | 79 | 191 |
| *Stylosanthes capitata* | 7 | - | 12 | | 43 | 62 | 241 |
| *Stylosanthes macrocephala* | | | 27 | | 9 | 36 | 83 |
| *Stylosanthes guianensis* "tardío" | 13 | | 26 | 5 | 1 | 45 | 187 |
| *Zornia brasiliensis* | | | 2 | | 1 | 3 | 11 |
| *Centrosema brasilianum* | 25 | 1 | 11 | 4 | 8 | 49 | 132 |
| *Centrosema macrocarpum* | 14 | 15 | 4 | 1 | | 34 | 63 |

## Multiplication and Maintenance of Germplasm

Multiplication of priority materials and their distribution to other sections within the Program as well as to special collaborators outside CIAT, continued being one of the Germplasm Section's most important activities. In addition to seed harvesting from all germplasm materials established for characterization and preliminary evaluation in CIAT-Quilichao (approximately 1100 accessions), some 700 legume germplasm accessions were under seed multiplication as potted plants in the CIAT-Palmira greenhouse. Approximately 1500 seed samples of priority materials were given to members of the Program and to special collaborators.

## Characterization and Preliminary Evaluation of Germplasm

During this phase, new legume germplasm, particularly of priority or "key" species, as well as new, agronomically unknown genera and species, are established in unreplicated, space-planted plots in CIAT-Quilichao for seed increase and for observations on the most important plant descriptors (life form, growth habit, flowering time, perenniality, etc.). Furthermore, the adaptation of germplasm to the Quilichao environment is assessed in terms of: (a) yield potential on a very acid, infertile Ultisol, (b) disease and insect tolerance and (c) seed production potential. Accessions with outstanding performance as well as any new material with especially interesting plant characters are then given priority at entering the flow of germplasm to the Program's principal testing sites in Carimagua and Brasilia as well as for Regional Trials A. In 1981 a series of new accessions were identified as promising (Table 3). Approximately 1100 accessions are currently being studied (Table 4). Some of the most important preliminary observations indicate:

- An increasing variation in the *Stylosanthes guianensis* "tardío" collection with regard to morphological and physiological plant characters, including resistance to anthracnose and seed production potential.

- Resistance to anthracnose of the whole collection of *S. macrocephala*.

- Lack of productivity as well as of anthracnose resistance of the *S. leiocarpa* collection.

- Considerable variability in the *S. viscosa* collection with respect to morphological and physiological plant characters.

- Continuing *Sphaceloma* resistance of *Zornia brasiliensis* and a few two-leaflet *Zornia* sp. accessions from high rainfall areas in Bahía, Brazil.

- Increasing variability in the *Centrosema macrocarpum* collection due to new Venezuelan and Colombian germplasm.

Table 3. Characterization and preliminary evaluation of germplasm of tropical pasture legume species during 1981 in CIAT-Quilichao. Evaluations concluded.

| Species | No. of accessions evaluated | Observations |
|---|---|---|
| Stylosanthes capitata | 73 | With exception of late-flowering ecotypes from Brazil, all ecotypes anthracnose-resistant. Outstanding vigor of material from the dry Brazilian Northeast. Potential of Mato Grosso material confirmed. Venezuelan material very healthy but lack vigor. |
| Centrosema spp. | 160 | High potential for acid infertile soils identified for C. macrocarpum, C. brasilianum, C. arenarium, C. schiedeanum, some C. pubescens ecotypes as well as two not-yet-described new species. |
| Centrosema brasilianum | 49 | Rhizoctonia blight limiting factor; some moderately resistant accessions identified. |
| Centrosema macrocarpum | 10 | Outstanding vigor of germplasm native to Colombian Llanos, lack of adaptation of material from Belize and Mexico. |
| Centrosema pubescens | 144 | Only few ecotypes identified with adaptation to acid, infertile soil. |
| Centrosema plumieri/C. schottii | 24 | Very poor growth of C. schotti; one C. plumieri accession with good vigor. |
| Centrosema virginianum | 35 | Lack of adaptation (soil). |
| Zornia spp. (2-leaflet) | 100 | With very few exceptions all material Sphaceloma-susceptible and/or short-living annuals. |
| Zornia spp. (4-leaflet) | 24 | All tested material Sphaceloma-resistant and with good adaptation to acid, infertile soil; Z. brasiliensis and Z. myriadena particularly productive. |
| Desmodium spp. (erect browse types) | 27 | D. gyroides (syn. Codariocalyx gyroides) the only species with potential. |
| Desmodium heterocarpon | 29 | Lack of adaptation (in contrast with D. ovalifolium). |
| Mimosa spp. (spineless) | 11 | With one exception, lack of adaptation and unfavorable growth habit. |
| Cassia rotundifolia | 15 | Good adaptation; two selected ecotypes seem to be perennials. |

Remarkable Rhizoctonia tolerance of some Centrosema brasilianum ecotypes from high rainfall areas in Bahia, Brazil.

Excellent adaptation and productivity of the subshrub Rhynchosia schomburgkii and the twining Rh. reticulata var. kuntzei.

Table 4. Characterization and preliminary evaluation of germplasm of tropical pasture legume species during 1981 in CIAT-Quilichao. Evaluations not yet concluded.

| Species | No. of accessions |
|---|---|
| *Stylosanthes guianensis* "tardío" | 142 |
| *Stylosanthes macrocephala* | 54 |
| *Stylosanthes capitata* | 124 |
| *Stylosanthes leiocarpa* | 26 |
| *Stylosanthes viscosa* | 156 |
| *Zornia* spp. (2-leaflet) | 237 |
| *Zornia brasiliensis* | 7 |
| *Centrosema* spp. | 25 |
| *Centrosema macrocarpum* | 58 |
| *Centrosema brasilianum* | 77 |
| *Desmodium ovalifolium* | 18 |
| *Dioclea guyanensis* | 45 |
| *Calopogonium caeruleum* | 43 |
| *Rhynchosia* spp. | 58 |
| *Cassia rotundifolia* | 23 |
| Total | 1093 |

# Agronomy in the Isohyperthermic Savannas (Carimagua)

## Germplasm evaluation and selection

The aim of this work is to provide forage species adapted to the soils of low nutrient status, and select species which are resistant to pests and diseases and can withstand heavy grazing. A number of grasses and legumes have been identified which meet these criteria.

A current and more specific objective is to identify species and ecotypes of grasses and legumes which are more compatible under sward conditions, form stable associations, and persist longer under grazing.

Over one thousand accessions representing nine legume genera and seven grass genera are under evaluation in nursery plots or in grazed swards. Their inventory is presented in Table 1.

## Preliminary evaluation of grass germplasm

The range of promising grass species with good adaptation to savanna conditions was further expanded. Main emphasis is on *Brachiaria* spp. and *Andropogon gayanus*.

Experience over the last four years indicates that *Desmodium ovalifolium* can withstand competition from aggressive mat-forming grasses. Consequently, *Brachiaria* species and ecotypes assumed greater importance in the testing program. Several accessions are currently being evaluated in association with *Desmodium ovalifolium* ecotypes.

*Brachiaria dictyoneura* CIAT 6133 continued to show good performance. It combined well with *Desmodium canum* and *Desmodium ovalifolium*. It was grazed in preference to *Brachiaria humidicola* when animals had free access to both species.

*Brachiaria dictyoneura* is a strongly rhizomatous grass with a rather tufted growth habit. Morphologically it resembles *Brachiaria humidicola*. One of the important attributes of *Brachiaria dictyoneura* is a high caryopsis content of the florets coupled with high seed yield. At Carimagua this species produced 405 kg/ha of cleaned seed in the year of establishment with an average caryopsis content of 44%. Both yield and caryposis content were significantly (P=0.01) higher than those of *Brachiaria humidicola* (Table 2). Apparently, freshly harvested seed of *Brachiaria dictyoneura* has a strong dormancy. Sulfuric acid treatment for 25 and 20 minutes gave 6% and 3% germination one month after harvesting. Shorter periods of acid treatment as well as heat treatments were ineffective in increasing germination. When the lemma and palea were removed, 15% of the naked caryopses germinated within one week and without acid treatments. This phenomenon would suggest the presence of germination inhibiting substances within the glumes and/or caryopses (Table 3).

Table 1. Forage species introductions under evaluation at Carimagua, 1980-81.

| | Legumes | | | | Grasses | | |
|---|---|---|---|---|---|---|---|
| | Genus | No. of species | No. of accessions | | Genus | No. of species | No. of accessions |
| | Aeschynomene | 18 | 193 | | Andropogon | 1 | 46 |
| | Arachis | 2 | 2 | | Brachiaria | 8 | 18 |
| | Cassia | 2 | 21 | | Echinocloa | 1 | 1 |
| | Calopogonium | 1 | 1 | | Hemarthria | 1 | 1 |
| | Centrosema | 18 | 172 | | Melinis | 1 | 1 |
| | Desmodium | 12 | 196 | | Panicum | 2 | 2 |
| | Stylosanthes | 11 | 242 | | Setaria | 1 | 1 |
| | Tephrosia | 1 | 1 | | | | |
| | Zornia | 8 | 281 | | | | |
| Total legumes | 9 | 73 | 1109 | Total grasses | 7 | 15 | 70 |
| Total No. of accessions | | | | | | | 1181 |

Table 2. Seed production potential of two species of Brachiaria, Carimagua, Llanos Orientales.

| Species | Yield (kg/ha) | Caryopsis content (%) | No. of seeds per kg |
|---|---|---|---|
| B. dictyoneura CIAT 6133 | 405.20** | 44** | 200,000 |
| B. humidicola CIAT 619 | 286.40 | 18 | 250,000 |

** P = 0.01

Table 3. Effect of treatment on the germination of Brachiaria dictyoneura CIAT 6133 seed.

| Treatment | Means of four replications (%) |
|---|---|
| $H_2SO_4$ 25' + Tiourea | 6 |
| $H_2SO_4$ 20' + Tiourea | 3 |
| $H_2SO_4$ 15' + Tiourea | 0 |
| Control | 0 |
| Naked caryopsis | 15 |

Brachiaria brizantha CIAT 664. This ecotype of signal grass was introduced from Puerto Rico where it was rated as one of the top yielders. An important attribute of this Brachiaria species is its rapid spread by stolons. Currently, its productivity is being tested in association with eight ecotypes of Desmodium ovalifolium. Another accession, CIAT 6298, has a similar prostrate, creeping habit, but it is somewhat less vigorous.

Andropogon gayanus. In populations of Andropogon gayanus, the percentage of early flowering, stemmy types is showing an increase with advancing generations. The aim of the Andropogon gayanus improvement project is to produce a vigorous and fairly uniform, late-flowering cultivar.

*Andropogon gayanus* is a strongly out-crossing, practically self-incompatible grass. The polycross technique was considered most appropriate with this grass. It is based on the vegetative propagation of clones with the desired characters and selection of those with progenies exhibiting the highest percentage of these characters. The principle is to arrange the provisionally selected plants in such a way that they pollinate each other uniformly. A time table and schematic plan of the project is shown in Table 4.

Table 4. Time table and schematic plan of the *Andropogon gayanus* improvement project.

| | |
|---|---|
| 1979 | Selection of late flowering, vigorous segregates of *A. gayanus*, establishment of clonal propagates in space-planted field plots, 16 clones x 5 plants x 3 replications, seed harvested from "seed islands" containing the best late flowering plants. |
| 1980 | To ensure maximum intercrossing, 12 clonal selections were intercrossed in the plant house to form synthetic I. |
| 1981 | Twelve clones and their polycrossed seeds were established in replicated field plots. Parent offspring relationship was determined on the basis of yield and flowering/maturity date. Final selection of genotypes with high combining ability for vigor and late flowering habit, seed production of synthetic II. |

## Preliminary evaluation of legume germplasm

*Arachis pintoi*. Most wild species of *Arachis* examined to date suffer from a range of fungal and virus diseases, which normally affect the cultivated species as well. This new accession, originally from Bahía, has shown good tolerance to pests and diseases over the past two years. *Arachis pintoi* spreads by stolons; an important attribute of this legume is its compatibility with the stoloniferous *Brachiaria humidicola*. In general, perennial species of peanut provide high quality fodder.

Seed production is feasible and it may be tried on sandy soils; like other peanuts, it sets pods underground. They are rather small, and it is hard to recover the seeds.

*Aeschynomene*. Preliminary agronomic evaluation of 193 accessions representing 18 species was started 12 months ago. A very small number of accessions exhibited tolerance to disease and insects. Included in this group were eight accessions of *Aeschynomene americana* out of a total of 64 accessions of this species. By the end of August several of these showed symptoms of one or more fungal diseases, anthracnose being of very common occurrence. Aeschynomene villosa CIAT 7008 was one of the accessions that was still disease-free after one year; this prostrate, fine-leaved species appears to have the morpho-agronomic attributes to withstand intense grazing.

Cassia. A few disease-resistant accessions of Cassia rotundifolia show useful forage traits, e.g. early vigor, disease tolerance, late flowering and good seed production. The seed pods do not shatter very easily, and at this stage CIAT Nos. 8389, 8390 show some promise.

Centrosema. All species under observation including C. macrocarpum and C. brasilianum were severly attacked by leaf diseases. Less damage occurred in the plots under grazing. Nevertheless, it will be necessary to examine other species and ecotypes of Centrosema for disease resistance. Annual yields of dry matter of six Centrosema accessions are shown in Table 5.

Desmodium ovalifolium. Of the 12 species under observation, ecotypes of Desmodium ovalifolium and Desmodium canum continued to show good promise. An "in depth" study of D. ovalifolium ecotypes was commenced. Marked variation was observed among the nine ecotypes included. Dry matter "on offer" was recorded during the first semester in grazed pastures of these nine ecotypes, each established in association with Brachiaria humidicola.

The top yielder was CIAT accession 3652. The standard CIAT 350 and the other ecotypes gave presentation yields ranging from 8 to 10.6 t/ha. Legume percentages of five mixtures containing high yielding ecotypes ranged from 62 to 77%. The remaining four ecotypes produced 6.2 to 7.9 t/ha DM, and legume percentages in these associations ranged from 50 to 59% (Table 6).

## Seed yield, variation in flowering/maturity dates

Variation was observed among the accessions of D. ovalifolium in flowering/maturity dates. CIAT 3784 was the earliest. It began flowering shortly after the end of the wet season. By the last week of December it had reached the "full seedhead" stage. Hand harvesting of mature seed in 2 x 1 $m^2$ quadrats in each of the four replications was carried out on 27 December.

Two other accessions, CIAT 3666 and 3793, were the next to ripen the seed and were harvested on 27 January. Although these ecotypes showed prolific flowering, seed yields were much reduced due to severe moisture stress. Both December and January were rainless in Carimagua.

A second flowering was observed immediately after the early opening rains in February, and seed was harvested in all plots on 24 April. On this occasion seed yields were low in all accessions.

Table 5. Dry matter "on offer" in grazed pastures of six accessions of *Centrosema* spp. in association with *Andropogon gayanus*.

| Mixture | Dry matter "on offer" (kg/ha/season): Dry season Grass | Dry season Legume | Wet season Grass | Wet season Legume | Total (kg/ha/year) | Legume (%) |
|---|---|---|---|---|---|---|
| *A. gayanus* + *C. brasilianum* 5234 | 4219 | 5482 | 9733 | 7706 | 27140 | 48.6 |
| *A. gayanus* + *C. brasilianum* 5184 | 3634 | 5281 | 9553 | 3752 | 22220 | 40.7 |
| *A. gayanus* + *C. brasilianum* 5181 | 6945 | 5240 | 11312 | 3172 | 26669 | 31.5 |
| *A. gayanus* + *C. macrocarpum* 5062 | 4450 | 4973 | 10290 | 3935 | 23648 | 37.7 |
| *A. gayanus* + *C. macrocarpum* 5276 | 4188 | 4670 | 11077 | 3423 | 23358 | 34.7 |
| *A. gayanus* + *Centrosema* sp. 5278 | 4561 | 4451 | 13686 | 6418 | 29116 | 37.3 |

Table 6. Dry matter "on offer" in grazed pastures of nine ecotypes of D. ovalifolium in association with B. humidicola for the period 30 Jan. 1981 to 14 July 1981.

| Ecotypes | Grass | Legume (t/ha) | Total | Legume (%) |
|---|---|---|---|---|
| 3652 | 4.0 | 13.4 | 17.4 | 77 |
| 350 | 4.4 | 10.6 | 15.0 | 71 |
| 3794 | 5.5 | 9.2 | 14.7 | 63 |
| 3793 | 5.1 | 8.2 | 13.3 | 62 |
| 3666 | 4.8 | 9.0 | 13.8 | 65 |
| 3776 | 6.4 | 7.9 | 14.3 | 56 |
| 3780 | 5.0 | 7.2 | 12.2 | 59 |
| 3784 | 5.4 | 7.8 | 13.2 | 59 |
| 3788 | 6.3 | 6.2 | 12.5 | 50 |

There was an inverse relationship between seed yield and dry matter (DM) yield. To date, the late flowering CIAT 3652 produced the highest DM yields and the lowest seed yields. The early flowering 3784 produced the highest seed yield but it had lower DM yields than five other accessions. CIAT 3784 and four other accessions also yielded more seed than the control variety CIAT 350.

Seedling counts carried out in July also showed variation among the ecotypes in self-propagation. The highest number of volunteer seedlings was found in CIAT 3784. It is recommended to test 3784 in regions with shorter growing season. Yields of clean seed obtained during the first semester and results of seedling counts are summarized in Table 7.

In a normal season much higher seed yields are expected from the late flowering ecotypes including CIAT 350. However, the very late flowering accession CIAT 3652 may be a poor seed producer in most circumstances.

Observations on the palatability of Desmodium ovalifolium ecotypes carried out during the wet season showed the following trends:

- In some ecotypes presentation yields under grazing declined more rapidly than in others; in one case this was associated with a higher CP content in the herbage.

- Tannin levels in the leaves were high in all cases and showed an increase from 5.9% in May to 39% in July. In comparison, Desmodium canum (range 7-12.8%) and D. gyroides (range 2.2-6.5%) showed considerably lower levels of tannin content. The latter two legumes had a higher palatability rating than any D. ovalifolium.

Figure 1. *Desmodium ovalifolium* CIAT 3784, a free-seeding ecotype, regenerates by auto-propagation.

Table 7. Yields of clean seed* and number of volunteer seedlings in grazed pastures of nine accessions of *Desmodium ovalifolium*, Carimagua, Llanos Orientales.

| CIAT Accession No. | Seed (kg/ha) | Mean number of seedlings per $m^2$ |
|---|---|---|
| 3784 | 152.57 | 53.31 |
| 3666 | 109.10 | 9.81 |
| 3793 | 48.94 | 40.06 |
| 3780 | 15.15 | 18.50 |
| 3788 | 4.50 | 21.25 |
| 3794 | 2.75 | 2.75 |
| 3776 | 1.75 | 2.56 |
| 3652 | 0.82 | 0.19 |
| 350 (control) | 0.75 | 2.88 |
| L.S.D. P = 0.05 | 54.84 | 15.82 |
| P = 0.01 | 74.32 | 21.43 |

Correlation coefficient for all comparisons: 0.54 (P = 0.01)

*Mechanically scarified seed.

At least during the wet season, there were no marked differences in palatability between the ecotypes of D. ovalifolium currently under trial at Carimagua.

Desmodium canum. The original selection from old pastures, established over four years ago, CIAT 3005A, a rather robust growth form, is continuing to show the best promise. So far, no major insect or disease problems occurred in this species. The ecotype 3005A was included in various mixtures with molasses grass, several Brachiaria species and Andropogon gayanus. These companion grasses were selected to include a range of species from the least competitive molasses grass to the most aggressive species such as Brachiaria spp. and Andropogon gayanus.

Stylosanthes guianensis, "fine-stemmed" stylo. Some 42 accessions were established of this species form in legume-only sward plots in late 1980. Five accessions showed satisfactory performance, yield and disease tolerance in the second season under a seasonal cutting regime (Table 8).

Table 8. Dry matter yields of five ecotypes of S. guianensis "tardío" type.

| CIAT No. | Seasonal yield Wet | Seasonal yield Dry | Total year |
|---|---|---|---|
| | (t/DM/ha) | | |
| 10136 | 6.6 | 1.6 | 8.2 |
| 1062 | 5.9 | 1.4 | 7.3 |
| 1317 | 4.8 | 1.0 | 5.8 |
| 1808 | 4.0 | 0.9 | 4.9 |
| 2034 | 5.8 | 1.2 | 7.0 |

Accession CIAT 10136 was the top yielder in this experiment, and at this point in time CIAT 1808 is highly resistant to anthracnose. However, none of these accessions produce adequate amounts of seed for self-regeneration, and certainly none of them produce sufficient seed to make commercial seed production an economically feasible proposition. A few ecotypes of S. guianensis, however, are showing promise, being resistant to anthracnose and stemborer; they are free-seeding types as well.

Zornia. The two species, Z. brasiliensis and Z. myriadena are the best species and their resistance to fungal diseases is still holding. Nutrient contents of both are exceptionally high. Both species were included in sward plot studies. Again, grass species of greatly different growth habit and vigor were used in order to test their compatibility with these distint growth forms of Zornia.

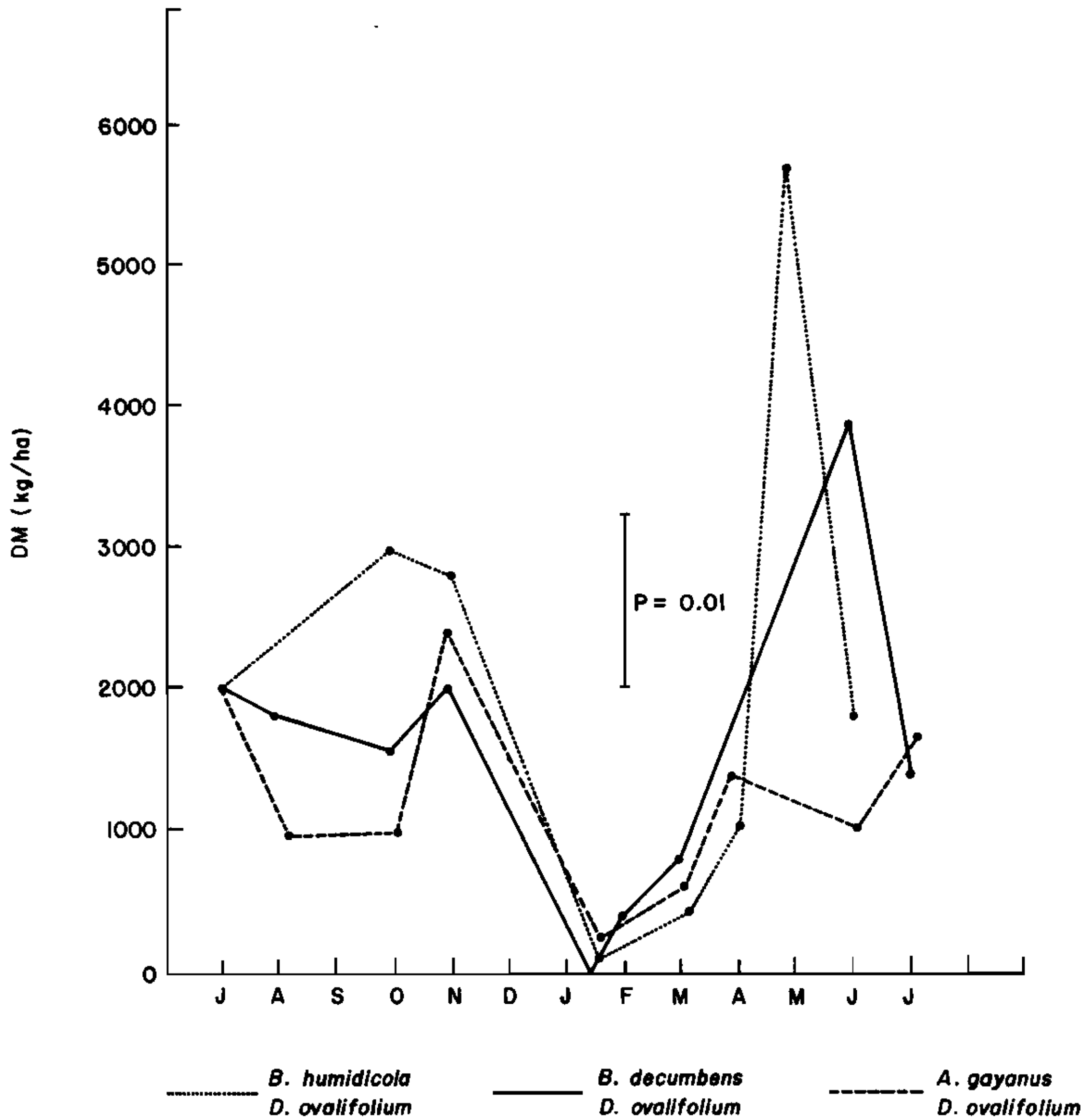


Figure 2. Growth rates of Brachiaria humidicola - Desmodium ovalifolium, B. decumbens - D. ovalifolium and Andropogon gayanus - D. ovalifolium pastures harvested by cutting at six-week intervals.

## Grass-Legume Associations Under Grazing

B. decumbens - D. ovalifolium vs. B. humidicola - D. ovalifolium. These mixtures were grazed by 2.5 animals/ha all year-round.

B. humidicola showed significantly higher growth rate in grazed pastures than B. decumbens, and this resulted in a significantly ($P = 0.01$) higher total yield of the B. humidicola - D. ovalifolium mixture (Figure 2). No significant difference occurred in these two associations between legume yields. Also the Brachiaria humidicola - Desmodium ovalifolium association produced the highest presentation yields. The legume percentage in this pasture showed a marked build-up during the wet season (Table 9), (Fig. 3).

Andropogon gayanus - D. ovalifolium. Growth rates and presentation yields of the component of this mixture were remarkably uniform throughout the year indicating grass-legume compatibility under a suitable grazing pressure. In general, this mixture was less productive than D. ovalifolium with the two Brachiaria spp.

Stylosanthes capitata. Two experiments are in progress with 10 and 16 accessions of S. capitata, respectively, each in mixture with A. gayanus. The former pasture is two years old and the latter one was established in 1980. This second experiment also includes seven S. macrocephala ecotypes. A marked reduction in the yields of these legumes occurred in the second year following establishment. Again, the S. macrocephala accessions were in the low-yielding group, an obvious competition effect from the tall A. gayanus (Tables 10 and 11).

Table 9. Dry matter "on-offer" in a Brachiaria humidicola - Desmodium ovalifolium pasture - Carimagua, Llanos Orientales.

| Harvest date | B. humidicola | D. ovalifolium | Grass + legume | Legume (%) |
|---|---|---|---|---|
| | ------------------ t/ha ------------------ | | | |
| 15- II-80 | 6.11 | 0.95 | 7.06 | 13.46 |
| 1- IV-80 | 5.43 | 0.73 | 6.16 | 11.85 |
| 13- V-80 | 4.51 | 0.70 | 5.21 | 13.44 |
| 23- VI-80 | 5.25 | 0.85 | 6.10 | 13.93 |
| 5-VIII-80 | 3.49 | 0.98 | 4.47 | 21.92 |
| 16- IX-80 | 2.96 | 0.94 | 3.90 | 24.10 |
| 29- X-80 | 2.82 | 1.73 | 4.55 | 21.98 |
| 10- XII-80 | 2.65 | 2.73 | 5.38 | 18.59 |
| 23- I-81 | 2.02 | 1.36 | 3.38 | 40.23 |
| Total | 35.24 | 10.97 | 46.21 | $\bar{X}$: 23.74 |
| S.E. | 0.64 | 0.37 | 0.79 | |

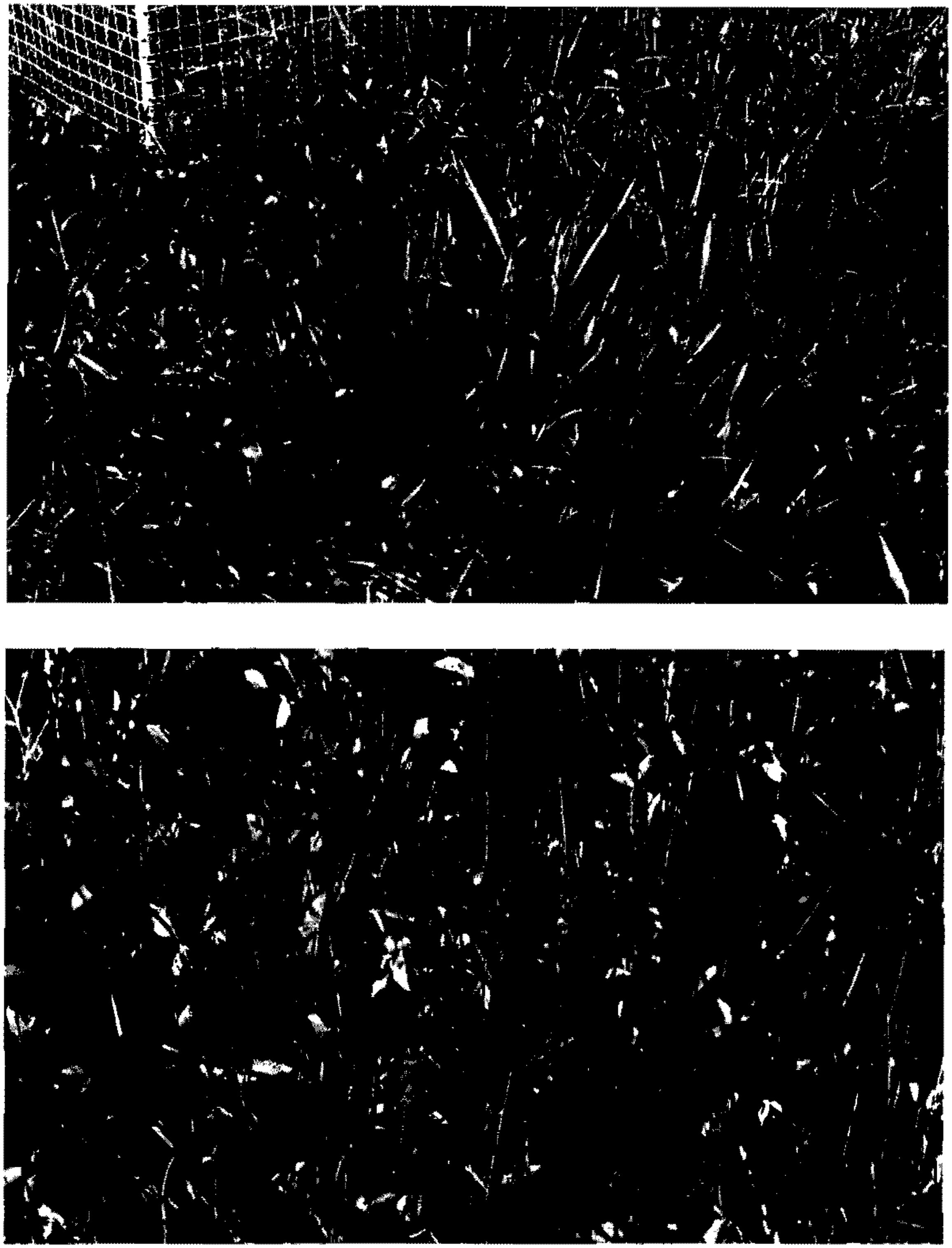

Figure 3. Desmodium ovalifolium formed productive and stable associations with Brachiaria decumbens (photo above) and B. humidicola (below) at Carimagua in the Llanos Orientales.

Table 10. Mean monthly presentation yields of 10 ecotypes of *Stylosanthes capitata* in association with *A. gayanus* in the first and second year.

| CIAT Accession No. | Year 1 | Year 2 |
|---|---|---|
| 1315 | 978 | 236 |
| 1318 | 951 | 144 |
| 1323 | 786 | 180 |
| 1342 | 681 | 108 |
| 1405 | 741 | 418 |
| 1325 | 668 | 134 |
| 1693 | 760 | 335 |
| 1728 | 1222 | 351 |
| 1943 | 413 | 144 |
| 1019 | 787 | 298 |

Table 11. Mean monthly presentation yields of 16 ecotypes of *Stylosanthes capitata* and 7 *S. macrocephala* in association with *Andropogon gayanus* under grazing (2 Dec. 1980-7 Sept. 1981).

| CIAT Accession No. | DM (kg/ha) |
|---|---|
| *S. capitata* | |
| 1686 | 2744 |
| 1441 | 2139 |
| 2013 | 1792 |
| 1414 | 1710 |
| 1019 | 1475 |
| 2044 | 1274 |
| 1318 | 952 |
| 1315 | 946 |
| 2041 | 912 |
| 2055 | 826 |
| 1943 | 651 |
| 2201 | 570 |
| 2092 | 482 |
| 1642 | 466 |
| 1781 | 411 |
| 55840 (CSIRO) | |
| *S. macrocephala* | |
| 1643 | 739 |
| 2039 | 668 |
| 1582 | 552 |
| 2061 | 471 |
| 2066 | 421 |
| 2093 | 301 |
| 2082 | 290 |

*Desmodium gyroides* (= *Codariocalyx g.*) - *D. ovalifolium* - *Andropogon gayanus*. The mixture containing both legumes produced the highest total yield. *D. gyroides* was preferentially grazed in the two-legume mixture, and the role of *D. ovalifolium* as a ground cover legume seems to function well (Table 12).

Table 12. Dry matter "on offer" in *Andropogon gayanus*, *Desmodium ovalifolium* and *Codariocalyx gyroides* associations.

| Mixture | Grass[1] (kg/ha) | Legume[1] A (kg/ha) | Legume[1] B (kg/ha) | Legume (%) |
|---|---|---|---|---|
| *A. gayanus* - *D. ovalifolium* | 15310 | 13041** | | 46 |
| *A. gayanus* - *C. gyroides* | 19033** | | 12569** | 40 |
| *A. gayanus* - *D. ovalifolium* - *C. gyroides* | 13202 | 7841 | 9235 | 56 |
| * P = 0.05 | 3606 | 2174 | 2420 | |
| L.D.S.** P = 0.01 | 5463 | 3189 | 4443 | |
| c.v. | 13.15% | 9.25% | 9.87% | |

[1] $\bar{X}$ of ten cuts.

## Plans for the Future

### Grasses

1. Evaluation of a wider range of accessions of *Brachiaria* spp., e.g., *B. humidicola*, *B. dictyoneura*, *B. brizantha* is of particular importance, with the aim to find productive companion grasses for various types of *D. ovalifolium*, and resistance to spittlebug.

2. *Andropogon gayanus*: seed multiplication and testing of the synthetic variety in mixtures under grazing.

### Legumes

1. *S. guianensis*, "fine-stemmed" stylo. It is proposed to continue the search for seeding types and accessions resistant to anthracnose and stemborer in cooperation with the Plant Pathology and Entomology sections, followed by agronomic evaluation of free-seeding ecotypes in grass-legume associations.

2. *S. capitata*. Multilocational testing of 5 to 10 promising ecotypes in the Regional Trials Network in the Llanos of Colombia, Venezuela and in Roraima, Brazil. Preference to be given to accessions resistant to anthracnose and stemborer at all three sites. This should be an opportunity to test bred-lines of *S. capitata* produced by the Legume Breeding section.

3. *Desmodium ovalifolium*. Continue evaluation of existing collection and new accessions to be obtained. Include selected material in the Regional Trials Network and test different flowering/maturity types and adaptation of early flowering accessions to lower rainfall conditions.

4. *D. canum*. Evaluate promising lines under grazing. CIAT 3005A to be included in regional trials and grazing productivity experiments.

5. *Centrosema* spp. In collaboration with the Plant Pathology section, study performance of new accessions with the objective of selecting disease resistant material of *C. macrocarpum*, *C. brasilianum*, *C. pubescens*. Test accessions of other species (*C. arenarium*, *C. rotundifolium*) in grass-legume mixtures under grazing.

6. *Zornia* spp. Test new accessions of *Z. brasiliensis* and study seed production potential of existing and new ecotypes of *Z. myriadena*.

# Agronomy in the Isothermic Savannas (Cerrado)

## Pasture Evaluation

Its objective is to select, under Cerrados conditions, legumes and grasses that will (i) grow and produce seed on acid soils under aluminum and water stress, (ii) persist under grazing, and (iii) tolerate pest and diseases.

### Preliminary evaluation of legume germplasm (Category II)

Legume accessions presently under evaluation in Category II are listed in Table 1. The 900 accessions represent 13 genera, and 69 per cent of them are species of Stylosanthes. Accessions are established as spaced plants on the two most important soil types of the region, i.e., the dark-red latosol (LVE) and red-yellow latosol (LVA). Observations are made on phenology, dry matter yield, regrowth potential, nutritive value, seed production and tolerance of pests and diseases.

Stylosanthes species. Observations over a four-year period indicate that the key Stylosanthes spp. for the region are Stylosanthes guianensis (specifically the "tardío" types), Stylosanthes capitata and Stylosanthes macrocephala. The early promise shown by accessions of Stylosanthes scabra has not been maintained.

Eight accessions from germplasm planted in 1978-79 and 1979-80 have been selected for further evaluation in Category III under grazing when sufficient seed is available. These accessions appear in Table 2. All Stylosanthes guianensis accessions are of the "tardío" type, and all eight accessions are of Brazilian origin. These are more productive than control accessions and, in general, were of higher nutritive value. In addition, the accessions have shown good tolerance to anthracnose, which continues to be the major disease problem. It was responsible for another 15 accessions being eliminated from the 24 selected last season.

Eight more accessions were selected as promising from new germplasm planted in 1980-81 (Table 3). The three Stylosanthes guianensis accessions were substantially more productive on the LVE than the control CIAT 2243, now in Category IV. The two new Stylosanthes capitata accessions CIAT 2253 and CIAT 2254 performed similarly. The new Stylosanthes macrocephala accessions appear to be better adapted to the LVA than the control CIAT 1582, which is also in Category IV. All selected accessions showed good tolerance to anthracnose.

In 1981-82, more accessions will be introduced particularly those of Stylosanthes viscosa.

Other genera. The two key non-Stylosanthes genera showing potential for the region are Zornia and Centrosema.

Table 1. Legume germplasm under preliminary evaluation in Category II at CPAC, Brazil.

| | 1978-79 | 1979-80 | 1980-81 | Total |
|---|---|---|---|---|
| *Stylosanthes* spp. | | | | |
| *S. guianensis* | 70 | 0 | 101 | 171 |
| *S. scabra* | 42 | 70 | 59 | 171 |
| *S. capitata* | 27 | 61 | 68 | 156 |
| *S. macrocephala* | 4 | 17 | 31 | 52 |
| *S. viscosa* | 14 | 0 | 19 | 33 |
| *S. humilis* | 14 | 0 | 7 | 21 |
| *S. species* | 0 | 2 | 6 | 8 |
| *S. hamata* | 4 | 0 | 0 | 4 |
| *S. leiocarpa* | 0 | 2 | 0 | 2 |
| *S. tomentosa* | 0 | 0 | 2 | 2 |
| *S. ingrata* | 1 | 0 | 0 | 1 |
| *S. campestris* | 0 | 0 | 1 | 1 |
| *S. ruellioides* | 0 | 0 | 1 | 1 |
| *S. angustifolia* | 0 | 0 | 2 | 2 |
| Totals | 176 | 152 | 297 | 625 |
| Other spp. | | | | |
| *Zornia* | 49 | 28 | 25 | 102 |
| *Centrosema* | 18 | 5 | 23 | 46 |
| *Desmodium* | 30 | 0 | 0 | 30 |
| *Calopogonium* | 13 | 10 | 0 | 23 |
| *Galactia* | 14 | 6 | 0 | 20 |
| *Leucaena* | 18 | 0 | 0 | 18 |
| *Aeschynomene* | 16 | 0 | 0 | 16 |
| *Macroptilium/Vigna* | 11 | 0 | 0 | 11 |
| *Pueraria* | 3 | 0 | 0 | 3 |
| *Soemmeringia* | 2 | 0 | 0 | 2 |
| *Teramnus* | 2 | 0 | 0 | 2 |
| *Cratylia* | 0 | 2 | 0 | 2 |
| Totals | 176 | 51 | 48 | 275 |

Five *Zornia* accessions, predominantly *Zornia brasiliensis*, have been selected as being more productive on the LVE than the control *Zornia latifolia* CIAT 728 (Table 4). However, there were indications that the species are better adapted to the LVE soil. No symptoms of the insect-virus fungus complex or *Sphaceloma* scab which attack accessions of *Zornia latifolia* (including CIAT 728) have been observed on *Zornia* spp., CIAT 7847 or on the selected *Zornia brasiliensis* accessions.

Table 2. Performance of selected *Stylosanthes* accessions planted in Category II (1978-79 and 1979-80) at CPAC, Brazil (samples collected in June 1981).

| CIAT accession No. | Origin | Season of flowering | Anthracnose score | DM production (g/plant) | *In vitro* DDM[1] (%) | CP content[1] (%) | Ca content[1] (%) | P content[1] (%) |
|---|---|---|---|---|---|---|---|---|
| *S. guianensis* | | | | | | | | |
| cv. Endeavour[2] | Guatemala | Late | 4.0 | 39 | 40.6 | 11.1 | 0.55 | 0.12 |
| 1095 | Bahía | Late | 1.5 | 149 | 43.8 | 11.8 | 0.67 | 0.12 |
| 2191 | Bahía | Mid | 1.5 | 105 | 45.6 | 12.4 | 0.61 | 0.11 |
| 2203 | Goias | Late | 1.5 | 340 | 43.2 | 11.6 | 0.68 | 0.12 |
| 2244 | Goias | Late | 1.0 | 198 | 41.2 | 11.8 | 0.60 | 0.12 |
| 2245 | Piaui | Late | 1.5 | 160 | 42.0 | 12.0 | 0.58 | 0.12 |
| *S. capitata* | | | | | | | | |
| 1405[2] | Mato Grosso | Mid | 3.0 | 45 | 41.0 | 6.9 | 0.66 | 0.10 |
| 1318 | Maranhão | Mid | 1.5 | 266 | 49.3 | 9.6 | 0.69 | 0.11 |
| *S. macrocephala* | | | | | | | | |
| 1582[2] | "Distrito Federal" | Early | 1.0 | 139 | 35.4 | 7.6 | 0.65 | 0.09 |
| 2039 | Bahía | Mid | 1.0 | 240 | 30.1 | 5.1 | 0.63 | 0.08 |
| 2053 | Bahía | Mid | 1.0 | 206 | 43.5 | 5.9 | 0.66 | 0.09 |

+ Early (December, January), Mid (February, March), Late (April or later).
++ 1.0 (no anthracnose) to 5.0 (plant death).

1 DM = dry matter, DDM = digestible dry matter, CP = crude protein, Ca = calcium, P = phosphorus.
2 Control accessions.

Table 3. Performance of selected *Stylosanthes* accessions planted in Category II (1980-81) at CPAC, Brazil.

| CIAT accession No. | Origin | Anthracnose score[+] LVE | Anthracnose score[+] LVA[++] | DM production[+++] (g/plant) LVE | DM production[+++] (g/plant) LVA |
|---|---|---|---|---|---|
| *S. guianensis* | | | | | |
| 2243* | "Distrito Federal" | 1.0 | 1.5 | 44 | 56 |
| 2950 | Minas Gerais | 1.0 | 1.0 | 265 | 22 |
| 2951 | Minas Gerais | 1.0 | 1.0 | 123 | 39 |
| 2953 | Minas Gerais | 1.0 | 1.0 | 122 | 17 |
| *S. capitata* | | | | | |
| 1405* | Mato Grosso | 2.5 | 2.0 | 59 | 31 |
| 2253 | Ceará | 2.0 | 2.0 | 144 | 26 |
| 2254 | Ceará | 2.0 | 2.0 | 135 | 15 |
| *S. macrocephala* | | | | | |
| 1582* | "Distrito Federal" | 1.0 | 1.0 | 85 | 15 |
| 2133 | Bahía | 2.0 | 1.0 | 71 | 40 |
| 2280 | Minas Gerais | 2.0 | 1.0 | 60 | 37 |
| 2732 | "Distrito Federal" | 1.5 | 1.0 | 84 | 29 |

[+] 1.0 (no anthracnose) to 5.0 (plant death).
[++] LVE (dark-red latosol), LVA (red-yellow latosol).
[+++] DM = dry matter.

* Control accessions.

Three new *Centrosema macrocarpum* accessions, *Centrosema* spp., CIAT 5118 and *Centrosema brasilianum*, CIAT 5234 have been selected as showing promise on the LVE (Table 4). No pest or disease problems have been hitherto noted.

Preliminary evaluation of grass germplasm (Category II)

The grass accessions presently under evaluation in Category II are found in Table 5. They had been established in 1979-80 on both soil types. Observations are made on phenology, dry matter yield, regrowth potential, nutritive value, seed production and pest and disease tolerance.

Table 4. Performance of selected *Zornia* and *Centrosema* accessions planted in Category II (1980-81) at CPAC, Brazil.

| CIAT accession No. | Origin | Season of flowering+ | DM production[1] (g/plant) LVE | LVA++ |
|---|---|---|---|---|
| *Z. latifolia* | | | | |
| 728* | Colombia | Mid | 45 | 41 |
| *Zornia* spp. | | | | |
| 7847 | Bahía | Mid | 96 | 17 |
| *Z. brasiliensis* | | | | |
| 9472 | Bahía | Mid | 109 | 45 |
| 9473 | Bahía | Mid | 103 | 21 |
| 7485 | Goiás | Mid | 90 | 16 |
| 8023 | Pernambuco | Mid | 93 | 9 |
| *C. macrocarpum* | | | | |
| 5062* | Colombia | Late | 50 | - |
| 5274 | Colombia | Late | 102 | - |
| 5275 | Colombia | Late | 107 | 10 |
| 5276 | Colombia | Late | 95 | - |
| *Centrosema* spp. | | | | |
| 5118 | Mato Grosso | Late | 145 | 14 |
| *C. brasilianum* | | | | |
| 5234 | Bahía | Late | 119 | 22 |

\+ Mid (February, March), late (April or later).
++ LVE (dark-red latosol), LVA (red-yellow latosol).

1 DM = dry matter.
* Control accessions.

*Panicum maximum*. Performance of selected accessions on the LVE is shown in Table 6. The situation has changed appreciably since the first season (1979-80). Of the selections made last season only the common-type CIAT 6141 has continued to show promise. Two new green panic/Gatton-types, CIAT 6116 and CIAT 6124, are currently showing significantly better production than the controls. No disease problems have been recorded.

cv. Basilisk. Grasses are sown with Stylosanthes guianensis cv. Cook. Observations are made on persistence, species compatibility, productivity, fixation and transfer of symbolic nitrogen. In this system pasture mixtures are exposed not only to defoliation but also to the effects of grazing such as trampling and to nutrient cycling via faeces and urine.

Legume germplasm. Originally, 14 legumes were sown in Category III in 1978-79. Total DM production and legume contents for the first three years of evaluation are shown in Figure 1.

The most persistent and productive legumes are Stylosanthes capitata CIAT 1097, Stylosanthes capitata 1019, and Stylosanthes macrocephala CIAT 1582. The DM production of these associations is now appreciably higher than that of the pure grass controls. In 1980-81 the legume contents of the three species with both Andropogon and Brachiaria ranged from 27 to 38 percent on a DM basis. No serious anthracnose problems have been recorded except with Stylosanthes capitata CIAT 1405 and CIAT 1315.

Across legume associations the DM yield of Andropogon in its third year was markedly higher than that of Brachiaria. A sharp decline in third year yield of Brachiaria is a common occurrence on commercial ranches in the region.

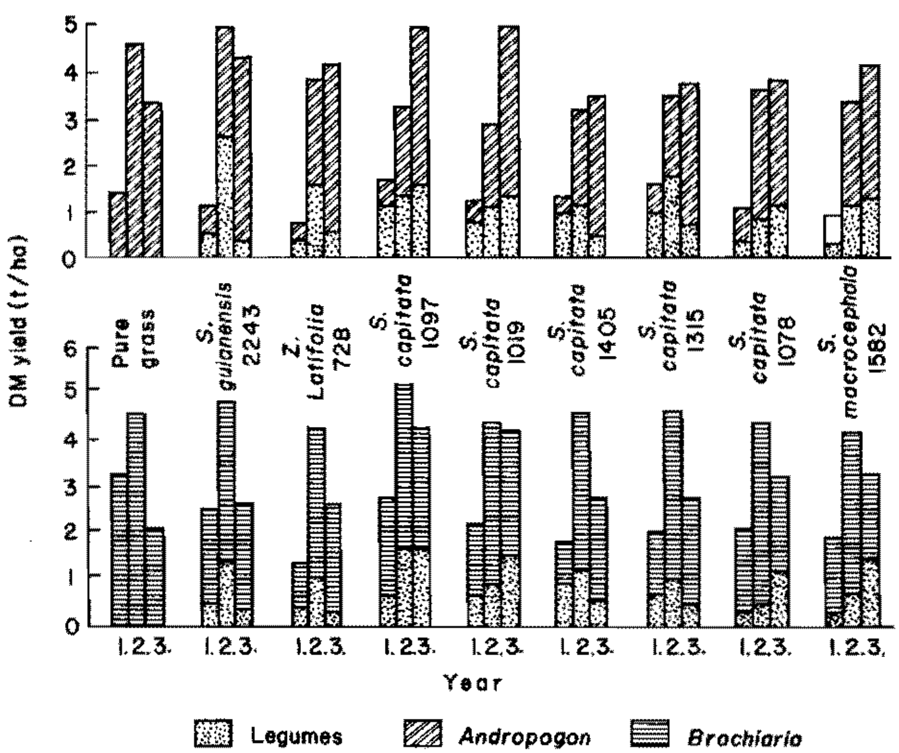


Figure 1. Performance of legume accessions under grazing in Category III.

The content of Stylosanthes guianensis "tardío", CIAT 2243, has declined significantly under high grazing pressure. However, this accession is anthracnose-tolerant and has persisted longer than the commercial cultivar Cook which disappeared in the second year due to disease. The content of Zornia latifolia CIAT 728 has also declined in the third year. Plants were seriously attacked by the insect-virus-fungus complex. Other legumes that have disappeared during the course of the evaluation are Desmodium ovalifolium CIAT 350, Galactia striata CIAT 964, Centrosema pubescens CIAT 438 and the commercial cultivars of Centrosema pubescens and Calopogonium mucunoides.

Grass germplasm. The five grasses under evaluation are Andropogon gayanus cv. Planaltina (CIAT 621), Brachiaria decumbens cv. Basilisk, Brachiaria ruziziensis cv. common, Brachiaria humidicola cv. common, and Panicum maximum cv. guinezinho.

The associated legume Stylosanthes guianensis cv. Cook disappeared during the second dry season because of anthracnose. However, Figure 2 shows that there was a strong residual effect from the high legume contents in earlier years. For each grass species, DM production of the former associations was substantially higher than that of the pure grass controls.

Andropogon gayanus was the highest yielding grass while Brachiaria humidicola continued to be the least productive. The superior performance of Andropogon gayanus in the third season is in agreement with the observations made in Category III (legume evaluation).

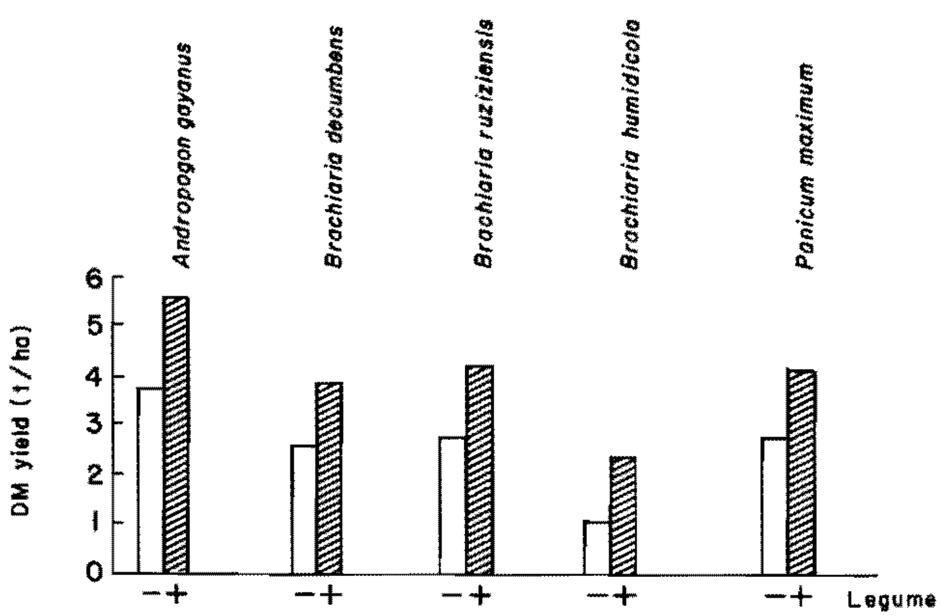


Figure 2. Performance of accessions under grazing in Category III (grasses).

## Seed Production

This part of the program aims at (i) investigating the potential of the Cerrados for commercial seed production of adapted species and to define their limitations; (ii) conducting research on seed production problems in adapted species; (iii) multiplying seed of promising germplasm to service pasture evaluation and other programs at CPAC. This activity is being conducted in cooperation with a regional trial involving other areas of Brazil, Colombia and Bolivia.

### Regional trial

Nine legumes and four grasses were originally sown in 1978-79 (Table 7). Seed yields for the nine legumes over the three years are shown in Table 8. Anthracnose destroyed the Stylosanthes capitata CIAT 1405 plots the second year, and those of Stylosanthes capitata CIAT 1315 in the 1980-81 season. A heavy weed infestation prevented seed and production of Stylosanthes capitata CIAT 1078 in 1980-81. Stylosanthes macrocephala CIAT 1582, after slow establishment, produced very good seed yields the second year. Stylosanthes guianensis "tardío" CIAT 2243 did not persist into the third season because the post-harvest cut (5 cm) was too low. Stylosanthes hamata CIAT 147, Pueraria phaseoloides CIAT 9900 and Zornia latifolia CIAT 728 gave significantly lower seed yields in the third year because of dry conditions during flowering. D. ovalifolium CIAT 350 disappeared during the second dry season, because of severe nematode attack.

Seed yields for the three-year period are presented in Table 9. Andropogon gayanus seed yield was significantly improved in the third year. A pre-flowering cut in January reduced plant height and susceptibility to lodging. It should be recalled that low seed yields in the second season resulted from heavy lodging. Peak seed yields for the other grasses were observed in the second season.

Table 7. Species and accessions originally sown in 1978-79 in the regional seed production trial.

| Legumes | Grasses |
|---|---|
| Stylosanthes guianensis CIAT 2243 | Panicum maximum var. Trichoglume cv. Petrie |
| S. capitata CIAT 1405 | Brachiaria decumbens cv. Basilisk |
| S. capitata CIAT 1315 | B. humidicola cv. common |
| S. capitata CIAT 1078 | Andropogon gayanus CIAT 621 (cv. Planaltina) |
| S. macrocephala CIAT 1582 | |
| S. hamata CIAT 147 | |
| Zornia latifolia CIAT 728 | |
| Desmodium ovalifolium CIAT 350 | |
| Pueraria phaseoloides CIAT 9900 | |

Table 8. Seed production in nine tropical pasture legumes at CPAC, Brazil.

| Species | CIAT accessions No. | Pure seed yield (kg/ha) | | |
|---|---|---|---|---|
| | | 1978-79 | 1979-80 | 1980-81 |
| *Stylosanthes capitata* | 1405 | 199 | - | - |
| *Stylosanthes capitata* | 1315 | 150 | 25 | - |
| *Stylosanthes capitata* | 1078 | 31 | 40 | - |
| *Stylosanthes macrocephala* | 1582 | 17 | 207 | 40 |
| *Stylosanthes guianensis* | 2243 | 42 | 61 | - |
| *Stylosanthes hamata* | 147 | 322 | 208 | 60 |
| *Zornia latifolia* | 728 | 175 | 687 | 210 |
| *Desmodium ovalifolium* | 350 | NF* | 18 | - |
| *Pueraria phaseoloides* | 9900 | NF | 186 | 111 |

* NF = no flowers produced.

Table 9. Seed production of four tropical grasses at CPAC, Brazil.

| Species | Pure seed yield (kg/ha) | | |
|---|---|---|---|
| | 1978-79 | 1979-80 | 1980-81 |
| *Brachiaria decumbens* cv. Basilisk | 163 | 443 | 373 |
| *Brachiaria humidicola* cv. common | 12 | 501 | 84 |
| *Andropogon gayanus* CIAT 621 cv. Planaltina | 128 | 45 | 330 |
| *Panicum maximum* cv. Petrie green panic | 132 | 382 | 70 |

The relationship between inflorescence development and seed yield grasses is presented in Figures 3 and 4. In *Andropogon gayanus* the majority of tillers appeared within one week of "initial-heading-date" (4 inflorescences per $m^2$). A preflowering cut in January 1981 did not significantly reduce the percentage of fertile tillers, and the absence of lodging problems resulted in a high seed yield. In the other grasses, which produce inflorescences cyclically during the wet season, a reduction in fertile tillers in 1980-81 resulted in lower seed yields. No major pest or disease problems were noted.

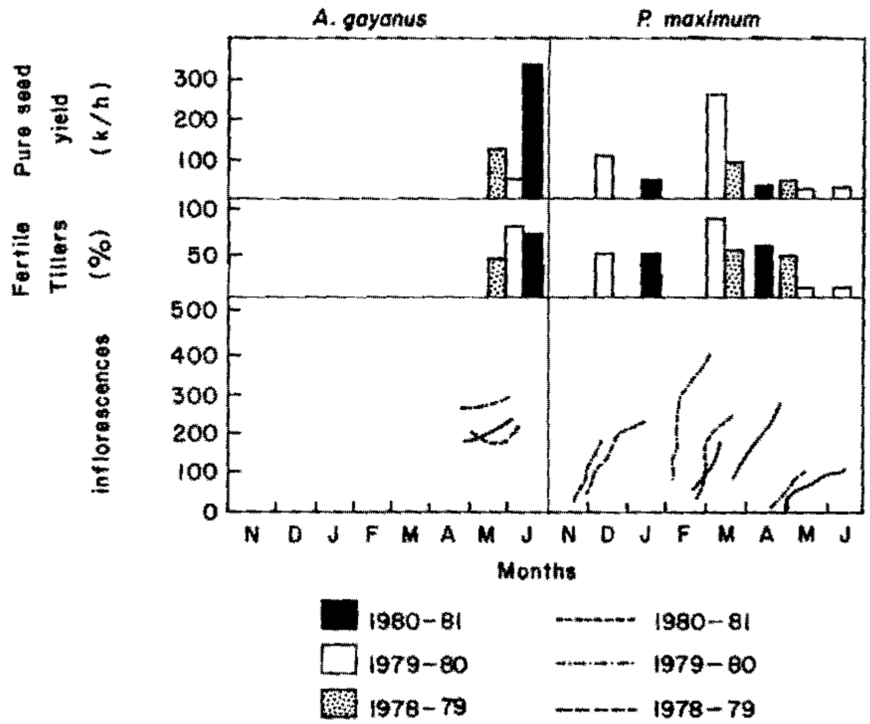


Figure 3. Pattern of inflorescence and seed production in *A. gayanus* and *P. maximum*.

## Effects of cutting or deferred grazing on Andropogon seed production

In the 1979-80 wet season *Andropogon gayanus* CIAT 621 (cv. Planaltina) suffered from severe lodging, and seed yields were well below the species potential. Plant height in the second part of the wet season may reach 3 m or more which makes the crop very vulnerable to lodging under conditions of relatively high fertility. Defoliating the crop early in the wet season would seem to be a suitable management strategy.

To determine the optimum time to defoliate the crop without prejudicing seed yield, two trials were established in 1980-81 in an existing *Andropogon* area. In one trial, plots were cut to 20 cm on either 20 January, 20 February or 20 March. An uncut control treatment was included. In another trial, treatments were grazed until either 12 January, 12 February, 12 March or 12 April. Animal numbers were adjusted to maintain the treatments to a height of approximately 40 cm. At the point of deferment of grazing for each treatment, the plots were cut 20 cm to obtain uniformity. An ungrazed control treatment was also included.

Table 4. Performance of selected *Zornia* and *Centrosema* accessions planted in Category II (1980-81) at CPAC, Brazil.

| CIAT accession No. | Origin | Season of flowering[+] | DM production[1] (g/plant) LVE | LVA[++] |
|---|---|---|---|---|
| *Z. latifolia* | | | | |
| 728* | Colombia | Mid | 45 | 41 |
| *Zornia* spp. | | | | |
| 7847 | Bahía | Mid | 96 | 17 |
| *Z. brasiliensis* | | | | |
| 9472 | Bahía | Mid | 109 | 45 |
| 9473 | Bahía | Mid | 103 | 21 |
| 7485 | Goiás | Mid | 90 | 16 |
| 8023 | Pernambuco | Mid | 93 | 9 |
| *C. macrocarpum* | | | | |
| 5062* | Colombia | Late | 50 | - |
| 5274 | Colombia | Late | 102 | - |
| 5275 | Colombia | Late | 107 | 10 |
| 5276 | Colombia | Late | 95 | - |
| *Centrosema* spp. | | | | |
| 5118 | Mato Grosso | Late | 145 | 14 |
| *C. brasilianum* | | | | |
| 5234 | Bahía | Late | 119 | 22 |

[+] Mid (February, March), late (April or later).
[++] LVE (dark-red latosol), LVA (red-yellow latosol).

[1] DM = dry matter.
* Control accessions.

*Panicum maximum*. Performance of selected accessions on the LVE is shown in Table 6. The situation has changed appreciably since the first season (1979-80). Of the selections made last season only the common-type CIAT 6141 has continued to show promise. Two new green panic/Gatton-types, CIAT 6116 and CIAT 6124, are currently showing significantly better production than the controls. No disease problems have been recorded.

Table 5. Grass germplasm under preliminary evaluation in Category II (as per October 31, 1981) at CPAC, Brazil.

| Genus | Species | | No. accessions |
|---|---|---|---|
| Panicum | P. maximum | (75) | 75 |
| Brachiaria | B. decumbens | ( 4) | |
| | B. humidicola | ( 2) | |
| | B. ruziziensis | ( 2) | |
| | B. brizantha | ( 5) | 13 |
| Melinis | M. minutiflora | (11) | 11 |
| Setaria | S. anceps | ( 2) | 2 |
| Andropogon | A. gayanus | (22) | 22 |
| | Total | | 123 |

For the second successive year data could not be collected from the accessions at the LVA site because of poor growth.

Other genera. The three most promising non-Panicum spp. are Brachiaria brizantha CIAT 6016 and 6021, and Brachiaria spp. CIAT 6058 (Table 6). All three accessions have produced markedly more DM than the commercial control cultivar Basilisk.

Melinis minutiflora accessions have shown a decline in productivity with cutting. This is consistent with observations elsewhere that the species does not withstand frequent defoliation or heavy grazing.

None of the new accessions of Andropogon gayanus are superior to the control cultivar CIAT 621 which was released as cv. Planaltina in Brazil in October 1980.

As with Panicum maximum accessions, no data were collected at the LVA site because of poor growth. No disease problems have been noted in the genera Brachiaria, Melinis or Andropogon.

Agronomic evaluation of legume and grass germplasm under grazing (Category III)

Promising accessions from Category II are evaluated in this category in small, individually-grazed plots. Each legume is sown separately with two grasses of contrasting growth habit, namely Andropogon gayanus CIAT 621 (cv. Planaltina) and Brachiaria decumbens

Table 6. Performance of selected grass accessions planted in Category II (1979-80) on the dark-red latosol at CPAC, Brazil.

| CIAT accessions No. | Time of flowering[+] | DM production[1] (kg/ha) Year 1 | DM production[1] (kg/ha) Year 2 | *In vitro* DDM[1] (%) | CP content[1] (%) | Ca content[1] (%) | P content[1] (%) |
|---|---|---|---|---|---|---|---|
| *Panicum maximum* | | | | | | | |
| (common type) | | | | | | | |
| cv. Common* | Mid | 3395 | 2670 | 72.7 | 14.0 | 0.28 | 0.19 |
| 6141 | Mid | 6825 | 8130 | 61.9 | 13.4 | 0.23 | 0.17 |
| (Green-Panic/Gatton Type) | | | | | | | |
| cv. Petrie* | Early | 4405 | 5900 | 55.6 | 10.6 | 0.27 | 0.18 |
| cv. Gatton* | Early | 4010 | 3480 | 72.8 | 12.5 | 0.32 | 0.19 |
| 6116 | Early | 3515 | 8630 | 60.6 | 13.9 | 0.23 | 0.18 |
| 6124 | Early | 2948 | 7400 | 54.5 | 12.6 | 0.35 | 0.23 |
| *Brachiaria decumbens* | | | | | | | |
| cv. Basilisk | Early | 3262 | 3510 | 61.5 | 11.9 | 0.18 | 0.23 |
| *Brachiaria brizantha* | | | | | | | |
| 6016 | Early | 4896 | 7320 | 58.4 | 12.7 | 0.17 | 0.23 |
| 6021 | Early | 2695 | 5840 | 64.3 | 13.2 | 0.14 | 0.24 |
| *Brachiaria* spp. | | | | | | | |
| 6058 | Early | 5120 | 8470 | 65.6 | 13.2 | 0.17 | 0.22 |

[+] Early (January, February), mid (March, April).

[1] DM = dry matter production (two harvests), DDM = digestible dry matter, CP = crude protein, Ca = calcium, P = phosphorus, (sample for chemical analysis taken December 1980).

* Control accession.

cv. Basilisk. Grasses are sown with Stylosanthes guianensis cv. Cook. Observations are made on persistence, species compatibility, productivity, fixation and transfer of symbolic nitrogen. In this system pasture mixtures are exposed not only to defoliation but also to the effects of grazing such as trampling and to nutrient cycling via faeces and urine.

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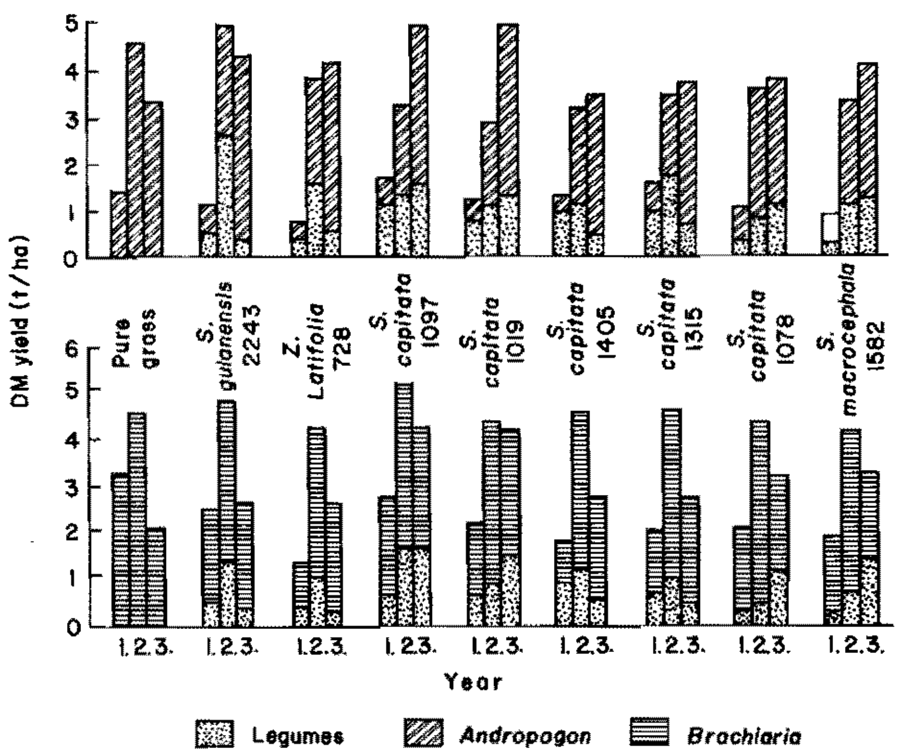


Figure 1. Performance of legume accessions under grazing in Category III.

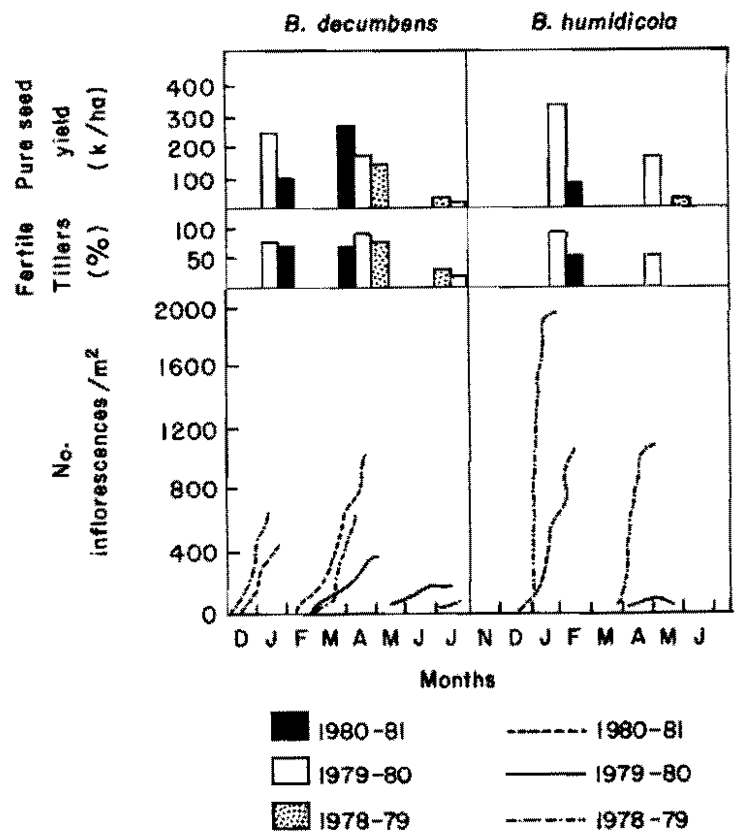


Figure 4. Pattern of inflorescence and seed production in B. decumbens and B. humidicola.

The results for both trials for the first season are presented in Figure 5. The highest seed yields were recorded when the crop was cut or grazing deferred in late January. Defoliating later than the first week of February reduced seed production.

Evidence from the regional trial in 1980-81 and these data indicate that defoliation early in the wet season can prevent lodging and the ensuing reduction in seed yield.

## Seed Multiplication

Seed multiplication of promising material is continuing. It is anticipated that there will be sufficient seed of many promising Category II accessions to commence a new Category III evaluation in 1981-82 with both legumes and grasses.

Almost 3000 kg of clean seed of Andropogon gayanus CIAT 621 (cv. Planaltina) have been collected on 15 ha. Sufficient seed has been collected of Stylosanthes capitata CIAT 1097, Stylosanthes macrocephala CIAT 1582 and Stylosanthes guianensis CIAT 2243 to initiate new Category IV grazing trials.

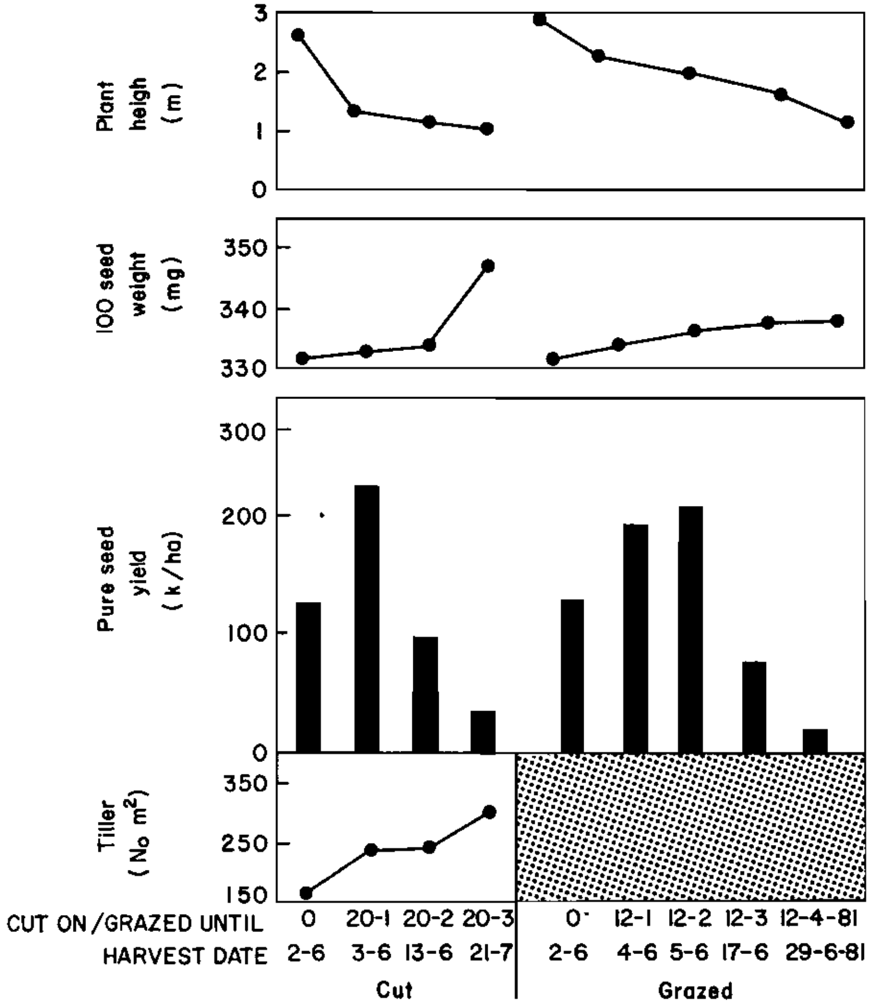


Figure 5. Effects of cutting time and deferred grazing on seed yield in *Andropogon gayanus*.

# Agronomy Evaluations in Regional Trials

The objectives of this section are:

a) To evaluate germplasm adaptation to different ecosystems through the International Network of Regional Trials.

b) To conduct agronomic evaluations of promising germplasm going to and coming out of the Network.

c) To test and develop methodology to be implemented in the Network through the different levels of evaluation in the Regional Trials.

## The International Network of Regional Trials

The Network has now assembled 13 Regional Trials A for first evaluation of a large (100-120) number of accessions in the five main ecosystems of tropical America (Llanos, Cerrados, poorly drained savannas, tropical rain forest and semi-evergreen seasonal forest). Table 1 shows the location of participant institutions responsible for the trials, the represented ecosystems, and the planting date of each trial. Eleven of the 13 trials have to this date been established, and 10 of them have reported data. The information being gathered from this first level of Network evaluations is under statistical analysis in order to select the best materials in terms of survival under the prevalent conditions of each site. Table 2 lists the grass and legume accessions classified as excellent or good in Regional Trials A in the savanna ecosystems. Legume and grasses classified as excellent or good in the tropical forest ecosystems are listed in Tables 3 and 4.

The previous two tables for the tropical forest ecosystems depict the outstanding behavior of Stylosanthes guianensis common type (136 and 184) as well as some "tardío types" and the good performance of Desmodium ovalifolium 350. In general, a large number of legume accessions are regarded as potentially good in the humid tropics. In the case of grasses, the good performance of Andropogon gayanus 621 is quite apparent and the even better performance of the other two Andropogon gayanus (6053 and 6054) entries. The excellent performance of some Brachiarias should be pointed out also, particularly Brachiaria humidicola 6013 which is spreading out rapidly into the Amazon ecosystems, especially in Brazil, where it is known as "Quicuio da Amazônia".

Progress has been made also in terms of Regional Trials B. These trials are designed to evaluate seasonal productivity of the promising material coming out from the two major screening sites of the Tropical Pastures Program (Carimagua and CPAC) as well as from Regional Trials A. Location, participant institutions and persons responsible for the trials, ecosystem, and planting date of each Trial are presented in Table 5. Thirty six Regional Trials B were established out of 54 seed

Table 1. Network of Regional Trials (type A) in tropical America.

| Country | Location | Institution/person responsible | Ecosystem* | Planting date |
|---|---|---|---|---|
| Colombia | Macagual | ICA/A. Acosta | TRF | VI-80 |
| | Leticia | CIAT-ICA/G. Sierra | TRF | III-80 |
| | Orocué | HIMAT-CIAT/P. Argel | PDS | VI-80 |
| Brazil | Boa Vista | PROPASTO-CPATU/E.A. Serrão | WDHS | VI-80 |
| | Corumbá | EMBRAPA/A. Pott, J.A. Comastri | PDS | XI-80 |
| | Jataí | EMGOPA/E. Barbosa | WDTS | XII-80 |
| | Paragominas | PROPASTO-CPATU/E.A. Serrão | SESF | IV-81 |
| | Tabuleiro | CEPLAC/J. Marques Pereira | TRF | XI-80 |
| Peru | Pucallpa | IVITA/L. Pinedo, C. Reyes | SESF | III-80 |
| Venezuela | El Tigre | FONAIAP/D. Sanabria | WDHS | VII-80 |
| | Apure | FONAIAP/R. Torres | PDS | X-81 |
| Nicaragua | Nueva Guinea | MIDINRA/A. Cruz, C. Avalos | SESF | VII-80 |

* TRF = Tropical rain forest; PDS = poorly drained savannas; WDHS = well drained isohypterthermic savannas (Llanos); WDTS = well drained thermic savannas (Cerrados); SESF = semi-evergreen seasonal forest.

Table 2. Legumes and grasses classified as excellent or good in the Regional Trials in tropical savannas.

| Well drained savannas | Poorly drained savannas | |
|---|---|---|
| Isohyperthermic (Llanos) RTA "El Tigre" Venezuela | RTA "Orocué" Colombia | RTA "Corumba"* Brazil |
| **Legumes:** | | |
| Excellent | | |
| Aeschynomene brasiliana 9684 | Desmodium gyroides 3001 | Aeschynomene americana 7562 |
| Centrosema brasilianum 5180 | Desmodium ovalifolium 350 | Calopogonium mucunoides 7367 |
| Centrosema macrocarpum 5274 | | Vigna adenantha 4016 |
| Stylosanthes guianensis 1280** | | |
| Stylosanthes guianensis 1283** | | |
| Stylosanthes guianensis 1523** | | |
| Good | | |
| Centrosema pubescens 5053 | Aeschynomene sp. 8057 | Aeschynomene americana 9881 |
| Stylosanthes macrocephala 1582 | Cassia rotundifolia 7792 | Aeschynomene histrix 9690 |
| Stylosanthes macrocephala 2133 | Desmodium heterophyllum 349 | Aeschynomene sp. 8057 |
| Stylosanthes capitata 1097 | Pueraria phaseoloides 9900 | Calopogonium mucunoides 9161 |
| Stylosanthes capitata 1315 | | Vigna lasiocarpa 4044 |
| Stylosanthes capitata 1342 | | Vigna sp. 9143 |
| Stylosanthes capitata 1693 | | Vigna vexillata 9546 |
| Stylosanthes capitata 1728 | | |
| Stylosanthes capitata 1943 | | |
| Stylosanthes guianensis 1493** | | |
| Stylosanthes sp. 2115 | | |
| Zornia brasiliensis 7485 | | |
| Zornia sp. 7485 | | |
| **Grasses:** | | |
| Excellent | | |
| | Brachiaria humidicola 679 | |
| Good | | |
| Andropogon gayanus 621 | Brachiaria brizantha 665 | |
| Brachiaria decumbens 606 | | |

* Only one repetition
** "tardío"

Table 3. Legumes classified as *excellent* or *good* in the Regional Trials A in tropical forest ecosystems.

| Tropical rain forest | | Semi-evergreen seasonal forest | |
|---|---|---|---|
| RTA "Leticia" Colombia | RTA "Macagual" Colombia | RTA "Pucallpa" Peru | RTA "Nueva Guinea" Nicaragua |
| Legumes: | | | |
| Excellent | | | |
| *C. macrocarpum* 5065 | *A. histrix* 9666 | *Centrosema* sp. 5112 | |
| *D. ovalifolium* 350 | *A. histrix* 9690 | *S. guianensis* 136 | |
| *S. guianensis* 184 | *C. macrocarpum* 5065 | *S. guianensis* 184 | |
| *S. guianensis* 1175 | *D. gyroides* 3001 | | |
| *Z. latifolia* 728 | *D. ovalifolium* 350 | | |
| | *Desmodium* sp. 3019 | | |
| | *G. striata* 964 | | |
| | *P. phaseoloides* 9900 | | |
| | *S. guianensis* 136 | | |
| | *S. guianensis* 184 | | |
| | *S. guianensis* 1175 | | |
| | *S. guianensis* 1283* | | |
| Good | | | |
| *A. histrix* 9666 | *C. brasilianum* 494 | *A. histrix* 9666 | *A. histrix* 9666 |
| *A. histrix* 9690 | *C. brasilianum* 5234 | *C. brasilianum* 5180 | *C. pubescens* 438 |
| *C. pubescens* 438 | *C. pubescens* 438 | *C. macrocarpum* 5065 | *C. pubescens* (common) |
| *Centrosema* sp. 5112 | *Centrosema* sp. 5112 | *C. mucunoides* 9161 | *D. gyroides* 3001 |
| *C. pubescens* 5118 | *C. pubescens* 5118 | *C. mucunoides* 9892 | *L. leucocephala* (native) |
| *D. gyroides* 3001 | *C. pubescens* 5126 | *C. pubescens* 438 | *M. atropurpureum* 4048 |
| *D. heterophyllum* 349 | *D. ovalifolium* 3673 | *C. pubescens* 5126 | *S. guianensis* 136 |
| *D. heterophyllum* 3782 | *S. macrocephala* 1281 | *C. schiedeanum* 5066 | *S. guianensis* 184 |
| *D. ovalifolium* 3673 | *S. capitata* 1019 | *D. heterocarpon* 365 | *S. guianensis* 1175 |
| *P. phaseoloides* 9900 | *S. capitata* 1097 | *D. heterophyllum* 349 | *S. hamata* 147 |
| *S. capitata* 1019 | *S. capitata* 1315 | *D. ovalifolium* 9179 | *Z. latifolia* 9179 |
| *S. capitata* 1078 | *S. hamata* 147 | *G. striata* 964 | |
| *S. capitata* 1097 | *S. viscosa* 1132 | *G. striata* 9339 | |
| *S. capitata* 1405 | *S. viscosa* 1790 | *P. phaseoloides* 7182 | |
| *S. guianensis* 136 | *Z. latifolia* 728 | *S. capitata* 1315 | |
| *S. guianensis* 1283* | *Zornia* sp. 935 | *S. hamata* 147 | |
| *Z. latifolia* 9179 | *Zornia* sp. (native) | *V. adenantha* 4016 | |
| *Z. latifolia* 9199 | | *Zornia* sp. 7475 | |
| *Zornia* sp. (cv. Tarapoto) | | | |
| *Zornia* sp. 7475 | | | |

* "tardío"

Table 4. Grasses classified as excellent or good in the Regional Trials A in tropical forest ecosystems.

| Tropical rain forest | | Semi-evergreen seasonal forest | |
|---|---|---|---|
| RTA "Leticia" Colombia | RTA "Macagual" Colombia | RTA "Pucallpa" Peru | ERA "Nueva Guinea" Nicaragua |
| Grasses: | | | |
| Excellent | | | |
| *B. decumbens* 606<br>*B. humidicola* 6013 | *A. gayanus* 621<br>*A. gayanus* 6053<br>*A. gayanus* 6054<br>*B. brizantha* 667<br>*B. humidicola* 6013 | *A. gayanus* 6053 | *P. maximum* (cv. Colonial) |
| Good | | | |
| *A. gayanus* 6053<br>*B. brizantha* 665<br>*B. brizantha* 667<br>*B. ruziziensis* 655<br>*B. ruziziensis* 656<br>*P. maximum* 673<br>*P. plicatulum* 6046<br>*T. andersonii* 6051 | *A. micay* 6050<br>*B. decumbens* 606<br>*B. ruziziensis* 654<br>*B. ruziziensis* 656<br>*P. maximum* 604<br>*P. plicatulum* 600<br>*P. purpureum* 672<br>*S. sinensis* 6263<br>*T. andersonii* 6051 | *A. gayanus* 621<br>*A. gayanus* 6054<br>*P. maximum* 604<br>*P. maximum* 697 | *A. gayanus* 6054<br>*P. maximum* (common) |

Table 5. Network of established Regional Trials B in tropical America.

| Country | Location | Institution/person responsible | Ecosystem* | Planting date |
|---|---|---|---|---|
| Bolivia | Valle del Sacta | Univ. M. San Simon/J. Espinoza | WDHS | X-80 |
| Brazil | Barrolandia | CEPLAC/J. Marques Pereira | TRF | XII-80 |
| | Maraba | PROPASTO-CPATU/E.A. Serrão-A. Camarao | WDHS | V-81 |
| | Paragominas | PROPASTO-CPATU/E.A. Serrão, M. Diaz Filho | TRF | IV-81 |
| | Porto Velho | PROPASTO-CPATU/E.A. Serrão, C.A. Goncalves | TRF | II-81 |
| Colombia | Carimagua | CIAT/R. Gualdrón | WDHS | V-80 |
| | Guayabal, Pto. Gaitán | CIAT/C. Castilla, A. Carabaly-Gómez | WDHS | V-80 |
| | El Paraiso, Pto Gaitán | CIAT/C. Castilla, A. Carabaly-Gómez | WDHS | V-80 |
| | El Viento, Pto. Gaitán | CIAT/C. Castilla, A. Carabaly-Gómez | WDHS | V-80 |
| | Caucasia | Univ. Antioqua/L.F. Ramírez | TRF | VII-80 |
| | Puerto Asís | Fondo Ganad. Putumayo/D. Orozco | TRF | I-80 |
| | Quilichao | CIAT/H. Giraldo, A. Ramírez | SESF | XI-79 |
| | Orocué | HIMAT-CIAT/A. Carabaly-Gómez, C. Castilla | PDS | VI-81 |
| Costa Rica | Buenos Aires | Min. Agric. y Ganad./V.M. Prado | TRF | VIII-80 |
| Ecuador | El Napo | INIAP/K. Muñoz | TRF | IX-80 |
| | El Puyo | ESPOCH/M. Freire | TRF | V-80 |
| Guyana | Moblissa, Ebini | Livestock Dev. Co./J.M. Wilson | TRF | IX-80 |
| | Lethem, Rupununi | Livestock Dev. Co./J.M. Wilson | WDHS | X-80 |
| Mexico | Arriaga, Chiapas | INIA/F. de León Espinosa, A. Ramos | WDHS | VII-81 |
| Nicaragua | El Recreo | MIDINRA/A. Cruz, C. Avalos | TRF | VIII-80 |
| Panama | Calabacito | INIAP/M. A. Avila | WDHS | X-80 |
| | Los Santos, Chiriquí | Univ. Panama/J. Quintero | WDHS | VII-80 |
| | El Chepo | Univ. Panama/J. Quintero | WDHS | VI-81 |
| Peru | Yurimaguas | INIPA-NCSU/D. Bandy, M. Ara | TRF | XI-80 |
| | Tarapoto | INIPA-COPERHOLTA/W. López | TRF | II-81 |
| | C. Educativo, Tarapoto | INIPA-COPERHOLTA/W. López | TRF | II-81 |
| | Alto Mayo | INIPA/E. Palacios, W. López | TRF | XI-81 |
| Surinam | Coebiti | Fac. of Nat. Resources/R.F. Druiventak, F.W. van Amson | SESF | |
| Trinidad | Centeno | CARDI/N. Persad | TRF | X-80 |
| USA | Hawaii | Univ. of Hawaii/A.S. Whitney | TRF | VI-80 |
| Venezuela | Guachi | Univ. de Zulia/I. Urdaneta, J. Landaeta | TRF | V-80 |
| | Mantecal | FONAIAP/R. Torres | WDHS | V-80 |
| | Calabozo | MAC/C. Sánchez | WDHS | VIII-80 |
| | Atapirire | FONAIAP/D. Sanabria | WDHS | VII-80 |
| | Jusepín | UDO/C. Alcalá, M. Corado | WDHS | VI-80 |
| | La Esperanza | Univ. de Zulia/I. Urdaneta, R. Paredes | WDHS | X-80 |

* WDHS = well-drained isohyperthermic savannas; TRF = tropical rain forest; SESF = semi-evergreen seasonal forest; PDS = poorly drained savannas.

packages sent accounting for 67% initial success. Out of the 36 established trials 23, or 64% of the total, are being evaluated already.

Data received from Network participants are being processed by means of a statistical analysis package developed by the Biometrics Section of the Data Services Unit, using the SAS package as a base. The computer output for each location includes an ANOVA test and DUNCAN mean separation for the different harvesting ages (3, 6, 9, and 12 weeks of regrowth) in two seasons of the year (maximum and minimum precipitation). The data is also fitted with a linear and quadratic model in order to estimate seasonal rates of growth for each accession under test. Information on changes in number of plants, coverage, and diseases and pest effects, are also analyzed statistically. Processed data is sent back to the participants within the next month after it is received.

The first multilocational data analysis from Regional Trials B has been done using a modification of the Environmental Index developed by Eberhart, S.A. and Russell, W.A. (1966)*. The Environmental Index (EI) was computed with the following formula: $EI = P_1 - P$, where: $P_1$ is the local overall yield mean and P is the overall yield mean including all the locations in the analysis. This modified formula eliminates the dependence of the X and Y axis by excluding, in the calculation of the two means, the values of the entry under consideration. In this manner the X axis of the regression, corresponding to dry matter production is independent of the Y axis which corresponds to the Environmental Index. EI gives an indication of how superior or inferior a location is relative to mean productivity in all locations, expressed as mean dry matter production of all entries at each location, excluding the one being tested. This method assumes that the best integrating sensor of the attributes of the location's environment (soil, climate, pests, etc.) is the mean performance of the germplasm in the trial. Obviously, legumes have to be treated separately from grasses because their productivity is different.

An example is presented in Figure 1 of regression analysis (dry matter production vs. EI) with four ecotypes of *Stylosanthes capitata* for the Llanos of Colombia, using six points representing locations. Four of the points correspond to Regional Trials B with the same level of fertility (22 kg of P + 41.50 kg K), while the other two points correspond to a trial in Carimagua which was run with a low (11 kg of P + 20.75 kg K) and a high (33 kg P + 62.25 kg K) level of fertilization. The intercept is an estimate of the mean productivity of an ecotype throughout different trials in the ecosystem and the slope represents changes in performance of that ecotype with changes in EI. The chosen *Stylosanthes capitata* accessions have a narrow range of intercepts which means that all produce similarly throughout the Llanos ecosystem of Colombia. However, a large difference is apparent in slopes, indicating degrees in which the four *S. capitata* ecotypes perform with changes in the locations' general quality of the environment. More specifically,

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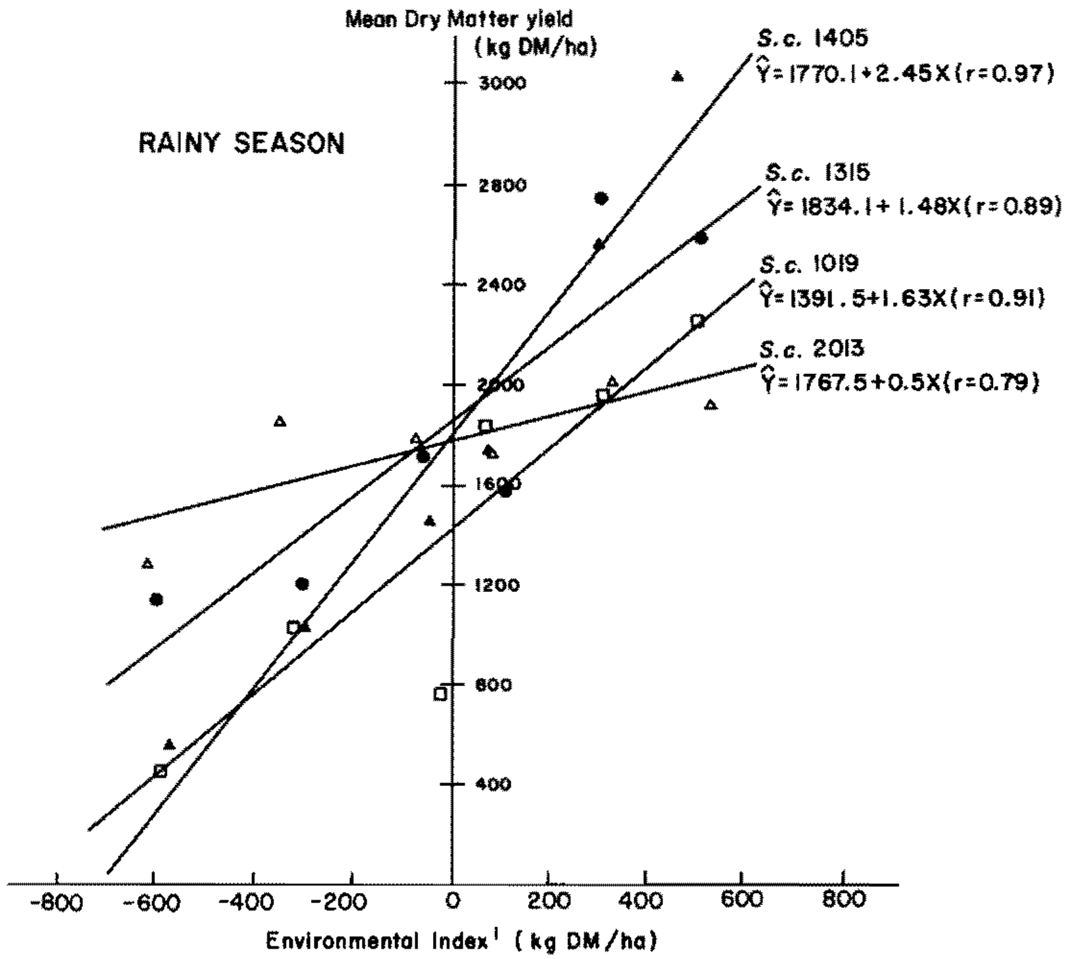
*Eberhardt, S.A.; Russell, W.A. 1966. Stability parameters for comparing varieties. Crop Science. 36-40.




[1] EI = Environmental Index = Mean by locality minus general mean of the different trials
Note: each entry has different IA due to the exclusion of its production in the means.

Figure 1. Adaptability of four accessions of S. capitata throughout the Colombian Llanos. Mean of six points included.

while Stylosanthes capitata 1405 has a very high response to general quality of the location environment, S. capitata 2013 responds less to these changes in environment and Stylosanthes capitata 1315 and 1019 respond similarly and intermediately relative to 1405 and 2013.

This study of the species and entries of promising material's adaptability across locations has clear implications for the success of adoption by producers. It follows that the Program should emphasize the selection of accessions with the highest production throughout the ecosystem (intercept) and least changes in performance throughout the different locations (slope). However, there is no clear definition yet of the magnitude of the slope for selection of germplasm; tentatively, germplasm with slopes in the order of 1.5 or less could be taken as having wide range adaptability.

A multilocational analysis including six locations in the Llanos of Colombia and all grasses and legumes commonly tested in Regional Trials B has been done using growth rates rather than dry matter production. The analysis has been done with information for the rainy season (maximum precipitation period) and dry season (minimum precipitation period), and results are presented in Tables 6 and 7 for location and entries, respectively. Locations included in the Llanos of Colombia were significantly different for both grasses and legumes in terms of mean-growth rates of all entries tested (Table 6). The superiority of Stylosanthes capitata accessions in terms of wide adaptability to the Colombian Llanos ecosystem for both the rainy and dry periods is quite evident (Table 7). This high degree of adaptability of S. capitata as a group is particularly remarkable when one considers the low level of fertilizer used in their evaluation (22 kg of P + 41.50 kg of K). It should be noticed that Desmodium ovalifolium 350 follows S. capitata in terms of growth rate during the rainy season, but outperforms all legumes during the dry season. Among the grasses Brachiaria decumbens and Andropogon gayanus perform very similarly as indicated by the non-significant differences in growth rate in both seasons.

Table 6. Seasonal mean growth rate[1] of legumes and grasses by location (3 RTB + 1 RTB with 3 levels of fertilization) of the Colombian Llanos.

| Regional Trials B | Growth rate by season | |
|---|---|---|
| | Rainy | Dry |
| | --------kg DM/ha/day-------- | |
| Legumes | | |
| Carimagua (level A)[2] | 25.4 b | 4.3 ab |
| Carimagua (level B)[2] | 30.6 a | 4.8 a |
| Carimagua (level C)[2] | 34.1 a | 4.6 a |
| Finca "El Paraiso" | 24.0 b | 2.5 b |
| Finca "Guayabal" | 20.7 b | 1.7 b |
| Finca "El Viento" | 12.7 c | 2.7 b |
| Grasses | | |
| Carimagua (level A)[2] | 26.3 ab | 15.9 a |
| Carimagua (level B)[2] | 29.9 ab | 15.0 a |
| Carimagua (level C)[2] | 41.4 a | 19.6 a |
| Finca "El Paraiso" | 28.4 ab | 3.6 b |
| Finca "Guayabal" | 10.4 b | 3.0 b |
| Finca "El Viento" | 18.7 b | 4.5 b |

[1] Mean of growth rates of 4 regrowth periods (0-3, 3-6, 6-9 and 9-12 weeks)

[2] Fertility levels: A = 11 of P + 20.75 of K; B = 22 of P + 41.50 of K = all other RTB; and C = 33 of P + 62.25 of K.

Table 7. Mean growth rate[1] of legumes and grasses tested in four Regional Trials B in the Colombian Llanos.

| Entries | Mean growth rate/season | |
|---|---|---|
| | Rainy | Dry |
| | -------- kg DM/ha/day------- | |
| Legumes[2] | | |
| S. capitata 1019 | 26.45 cdef | 2.78 d |
| S. capitata 1315 | 35.85 ab | 4.64 bc |
| S. capitata 1318 | 37.25 abc | 3.75 bcd |
| S. capitata 1342 | 33.95 abcd | 4.37 bcd |
| S. capitata 1405 | 34.94 ab | 3.02 cde |
| S. capitata 1693 | 39.22 a | 4.32 bcd |
| S. capitata 1728 | 35.92 ab | 4.10 bcd |
| S. capitata 1943 | 27.52 bcde | 2.98 de |
| S. capitata 2013 | 33.70 abcd | 3.71 bcd |
| C. pubescens 5053 | 2.91 h | 1.38 e |
| C. pubescens 5126 | 7.95 gh | 2.80 de |
| C. macrocarpum 5065 | 11.72 gh | 2.85 de |
| P. phaseoloides 9900 | 19.32 efg | 5.17 b |
| D. ovalifolium 350 | 25.12 def | 7.70 a |
| C. gyroides 3001 | 18.10 efg | 3.48 bcde |
| A. histrix 9690 | 13.78 gh | 4.31 bcd |
| Z. latifolia 728 | 17.18 fg | 2.72 de |
| Z. latifolia 9199 | 17.51 fg | 2.74 de |
| Zornia sp. 9286 | 15.05 g | 2.78 de |
| Grasses[2] | | |
| B. decumbens | 25.9 a | 9.6 a |
| A. gayanus 621 | 25.8 a | 10.9 a |

[1] Mean of growth rates of four regrowth periods (0-3, 3-6, 6-9 and 9-12 weeks).

[2] ANOVA and Duncan calculated separately for grasses and legumes.

The EI analysis was much more sensitive with the mean absolute yield that with growth rate. Mean yields correspond to the accumulated DM yield at 3, 6, 9 and 12 weeks of regrowth. Tables 8 and 9 show the linear regression parameters for dry matter production vs. EI on commonly tested legumes in the Regional Trials B of the Llanos of Colombia for the rainy and dry season, respectively.

As mentioned above, Stylosanthes capitata as a group outyields all other legumes; this is indicated by the intercept followed by Desmodium ovalifolium 350. In general, a relatively wide range of slopes is evident not only with S. capitata but with all other species.

Table 8. Rainy season mean yield (intercept) and degree of adaptability (slope) of legumes and grasses in the Llanos of Colombia. Linear regression of dry matter production[1] vs. environmental index (EI)[2] with six points.

| Entries | Intercept (kg DM/ha) | Slope | r |
|---|---|---|---|
| Legumes | | | |
| *S. capitata* 1019 | 1391.5** | 1.63** | 0.91 |
| *S. capitata* 1315 | 1834.1** | 1.48** | 0.89 |
| *S. capitata* 1342 | 1781.4** | 1.83** | 0.97 |
| *S. capitata* 1943 | 1441.5** | 0.97** | 0.94 |
| *S. capitata* 1405 | 1770.1** | 2.45** | 0.97 |
| *S. capitata* 1728 | 1841.7** | 1.37** | 0.96 |
| *S. capitata* 1693 | 2009.1** | 1.79** | 0.96 |
| *S. capitata* 1318 | 1969.1** | 2.08* | 0.91 |
| *S. capitata* 2013 | 1767.5** | 0.50* | 0.79 |
| *Z. latifolia* 728 | 857.0** | 0.47 NS | 0.69 |
| *Z. latifolia* 9286 | 787.2** | 0.63 NS | 0.79 |
| *Z. latifolia* 9199 | 964.0** | 0.97* | 0.85 |
| *C. gyroides* 3001 | 890.3** | 0.54 NS | 0.70 |
| *D. ovalifolium* 350 | 1167.3* | 1.11** | 0.96 |
| *C. macrocarpum* 5065 | 392.7* | 0.56* | 0.89 |
| *C. pubescens* 5126 | 342.1** | 0.39* | 0.85 |
| *C. pubescens* 5053 | 140.0* | 0.07 NS | 0.42 |
| *P. phaseoloides* 9900 | 899.5** | 0.93** | 0.94 |
| *A. histrix* 9690 | 713.4** | -0.41 NS | 0.61 |
| Grasses | | | |
| *A. gayanus* 621 | 1313.4** | 0.61 NS | 0.65 |
| *B. decumbens* 606 | 1376.4** | 0.69 NS | 0.65 |

[1] Dry matter mean by location from the yields at four different regrowth ages (3, 6, 9 and 12 weeks)

[2] EI = Environmental Index, explained in the text.

* Significant (P = 0.05)

** Significant (P = 0.01)

NS = Not significant

The same statistical analysis procedure was applied to data obtained by the Regional Network Trials in the tropical forest ecosystems. A comparison of locations in terms of growth rate for the maximum and minimum periods of precipitation (Table 10) indicates the best sites for both grasses and legumes. This could be rated to better fertility and humidity conditions in those locations. The seasonal mean growth rate of some legumes and grasses commonly tested in the 11 Regional B Trials in the tropical forest ecosystem are presented in Table 11.

Table 9. Dry season mean yield (intercept) and degree of adaptability (slope) of legumes and grasses in the Llanos of Colombia. Linear regression of dry matter production[1] vs. environmental index (EI)[2] with six points.

| Entries | Intercept (kg DM/ha) | Slope | r |
|---|---|---|---|
| **Legumes** | | | |
| S. capitata 1019 | 123.6** | 0.88** | 0.96 |
| S. capitata 1315 | 232.2** | 1.39** | 0.98 |
| S. capitata 1342 | 219.9** | 1.90** | 0.98 |
| S. capitata 1943 | 138.5** | 0.41 NS | 0.74 |
| S. capitata 1405 | 151.9** | 0.71** | 0.95 |
| S. capitata 1728 | 212.7** | 1.49** | 0.96 |
| S. capitata 1693 | 227.6** | 1.43** | 0.98 |
| S. capitata 1318 | 199.9** | 1.17** | 0.98 |
| S. capitata 2013 | 182.0** | 0.57* | 0.81 |
| Z. latifolia 728 | 132.7** | 0.33 NS | 0.62 |
| Z. latifolia 9286 | 137.8* | -0.08 NS | 0.10 |
| Z. latifolia 9199 | 101.8** | 0.40* | 0.78 |
| C. gyroides 3001 | 133.5** | 1.09* | 0.96 |
| D. ovalifolium 350 | 212.7** | 2.64** | 0.97 |
| C. macrocarpum 5065 | 118.0** | 1.19** | 0.96 |
| C. pubescens 5126 | 78.8** | 0.78* | 0.90 |
| C. pubescens 5053 | 41.1* | 0.34* | 0.84 |
| P. phaseoloides 9900 | 153.5** | 1.49** | 0.95 |
| A. histrix 9690 | 214.8** | 1.18* | 0.88 |
| **Grasses** | | | |
| A. gayanus 621 | 595.3** | 1.55** | 0.97 |
| B. decumbens 606 | 504.0** | 0.60** | 0.97 |

[1] Dry matter mean by location from the yields at four different regrowth ages (3, 6, 9 and 12 weeks)

[2] EI = Environmental Index explained in the text

* Significant (P = 0.05)

** Significant (P = 0.01)

NS = Not significant

Table 10. Seasonal mean growth rate[1] of legumes and grasses by locations (11 Regional Trials B) in the tropical forest.

| Regional trials B | Growth rate/period of | |
|---|---|---|
| | Maximum ppt. | Minimum ppt. |
| | ---------- kg DM/ha/day ---------- | |
| Grasses | | |
| "EL Napo", Ecuador | | 107.0 a |
| "El Puyo", Ecuador | | 76.0 a |
| "Quilichao", Colombia | 100.7 a | 82.2 a |
| "Caucasia", Colombia | | 25.4 b |
| "Puerto Asís", Colombia | | 10.5 b |
| "Pucallpa", Perú | | 13.3 b |
| "Yurimaguas", Perú | 58.7 b | |
| "Tarapoto", Perú | 21.0 c | |
| "El Recreo", Nicaragua | 116.9 a | 11.1 b |
| "Guachi", Venezuela | 91.2 a | |
| "Valle del Sacta", Bolivia | 93.0 a | |
| Legumes | | |
| "El Napo", Ecuador | | 54.2 a |
| "El Puyo", Ecuador | | 45.4 a |
| "Quilichao", Colombia | 20.8 c | 24.5 b |
| "Caucasia", Colombia | | 14.1 bc |
| "Puerto Asís", Colombia | | 18.9 bc |
| "Pucallpa", Perú | | 9.9 c |
| "Yurimaguas", Perú | 38.6 b | |
| "Tarapoto", Perú | 17.9 c | |
| "El Recreo", Nicaragua | 20.3 c | 9.1 c |
| "Guachi", Venezuela | 57.9 a | |
| "Valle del Sacta", Bolivia | 29.8 bc | |

[1] Mean of growth rates of four regrowth periods (0-3, 3-6, 6-9 and 9-12 weeks).

Table 11. Mean growth rate[1] of some legumes and grasses tested in 11 Regional Trials B in tropical forest ecosystems.

| Entries | Mean growth rate | |
|---|---|---|
| | Maximum ppt. | Minimum ppt. |
| | ---------- kg DM/ha/day --------- | |
| Legumes* | | |
| S. capitata 1405 | 28.4 b | 23.6 bcd |
| S. guianesis 136 | 50.5 a | 29.1 abc |
| S. guianensis 184 | 47.5 a | 37.9 a |
| D. heterophyllum 349 | 16.9 b | 12.5 d |
| D. ovalifolium 350 | 34.1 ab | 30.6 ab |
| C. pubescens 438 | 18.4 b | 16.6 cd |
| P. phaseoloides 9900 | 25.4 b | 21.9 bcd |
| Grasses* | | |
| P. maximum | 68.3 b | - |
| B. decumbens | 73.8 ab | 59.8 a |
| A. gayanus 621 | 91.4 a | 48.6 a |

[1] Mean growth rate of four growth periods (0-3, 3-6, 6-9 and 9-12 weeks)

*ANOVA and Duncan separate for legumes and grasses.

As in the case of the multilocational analysis for the Llanos, the interaction location x entry is analyzed by the regression between seasonal dry matter mean yield of each entry vs. the EI. Results of this analysis (Table 12) for the 11 locations of the humid tropic forest ecosystem show Stylosanthes guianensis 136, 184 and Desmodium ovalifolium 350 as the legumes with highest productivity for the maximum period of precipitation. In terms of changes in performance with changes in quality of the environment in each location, Desmodium ovalifolium showed the less steep slope eventhough not significant. In contrast, Stylosanthes guianensis 136 shows the steepest slope, probably due to differences across locations in anthracnose resistance. During the minimum period of precipitation, the slope of Stylosanthes guianensis 136 is reduced in magnitude, but it increases in the case of Desmodium ovalifolium 350. This could be the result of reduced effect of anthracnose in some of the locations in the case of S. guianensis 136, and of different water holding capacity of the soils and length of the dry period in the different locations in the case of Desmodium ovalifolium 350.

Andropogon gayanus is the more productive grass during the maximum and minimum periods of precipitation and shows the greatest range of adaptation as indicated by a non-significant slope during the maximum period of precipitation; like Brachiaria decumbens, it shows a moderate slope during the minimum period of precipitation.

Table 12. Seasonal mean yield (intercept) and degree of adaptability (slope) of some legumes and grasses in 11 locations of the tropical forest ecosystems. Linear regression of dry matter production[1] vs. environmental index (EI)[2].

| Entries | Maximum ppt. Intercept (kg DM/ha) | Maximum ppt. Slope | Maximum ppt. r | Minimum ppt. Intercept (kg DM/ha) | Minimum ppt. Slope | Minimum ppt. r |
|---|---|---|---|---|---|---|
| Legumes | | | | | | |
| *S. capitata* 1405 | 1336.1* | 1.02 NS | 0.75 | 1015.3** | 1.32** | 0.99 |
| *S. guianensis* 136 | 1980.7** | 2.62* | 0.91 | 1523.2** | 1.45** | 0.94 |
| *S. guianensis* 184 | 2001.8** | 1.17 NS | 0.77 | - | - | - |
| *D. heterophyllum* 349 | 1046.9* | 0.45 NS | 0.59 | 649.3** | 0.71** | 0.91 |
| *D. ovalifolium* 350 | 1961.5** | 0.64 NS | 0.70 | 1598.9** | 1.12** | 0.93 |
| *C. pubescens* 438 | 938.8** | 0.53 NS | 0.77 | 866.3** | 0.26 NS | 0.72 |
| *P. phaseoloides* 9900 | 1186.9* | 0.46 NS | 0.59 | 1127.8** | 0.57* | 0.85 |
| Grasses | | | | | | |
| *P. maximum* 604 | 2809.2** | 1.30* | 0.93 | 1317.0* | 0.62* | 0.98 |
| *B. decumbens* 606 | 2557.5* | -0.01 NS | 0.05 | 2602.4** | 1.35** | 0.98 |
| *A. gayanus* 621 | 3929.5* | -0.02 NS | 0.08 | 2896.9** | 0.98* | 0.91 |

[1] Dry matter mean by location from yields at four regrowth ages (3, 6, 9 and 12 weeks)
[2] EI = Environmental Index explained in the text.

* Significant (P = 0.05)
** Significant (P = 0.01)
NS = Not significant

The use of the Environmental Index (EI) technique is very useful to show germplasm performance in different locations. However, it is recognized that the methodology for analysis of the interaction location x entry should be based on physical and biological information from each location. In other words, the analysis should separate the effects of weather, soils, pests and diseases in order to explain behavior of the germplasm under test. Consistent with this, the International Regional Trials Network is recording, in addition to entry performance by season and location, soil chemical analysis of the site, weather parameters from the closet meteorological station, and diseases and pests observed during the trial.

The information being recorded through Regional Trials A and B is very valuable to assess not only the adaptability of the materials throughout ecosystems, but also to set solid bases for extrapolation and exchange of information among institutions participating in the International Regional Trials Network.

## Supportive Agronomic Research

Various factors and characteristics of pasture plants determine productivity and persistence under grazing, among them, seasonal productivity which is measured by Regional Trials B throughout the Network. Selected legume and grass species being tested in RTB are simultaneously evaluated at the Quilichao Station to study their growth pattern and changes in forage quality during periods of positive and negative water balance. Two trials are conducted, one for grasses and one for legumes. This section reports on the growth curves for two different periods of extreme water balance. The Pasture Quality and Nutrition section is reporting data pertaining to the same trial on quality analysis and relative acceptability of these materials to the grazing animals. The growth curves of nine grasses are presented in Figure 2. The X axis scale used in the dryer period is four times larger than the Y axis scale used in the rainy period. The growth rates of the five Brachiaria species are presented in the bottom part of Figure 2. It should be noticed that Brachiaria decumbens 606 is the only Brachiaria that performs similarly to Andropogon gayanus 621 and Panicum maximum 604 in terms of drought tolerance and response to the first rains.

Figure 3 shows the growth curves of 12 legumes in two different water balance periods. During the rainy period Desmodium ovalifolium 350 (bottom of Figure 3) had a linear growth rate. However, during the dry period it did not grow and responded only moderately to the first rains.

Looking at the Stylosanthes species (center of Figure 3), Stylosanthes guianensis 184 and Stylosanthes hamata 147 had similar growth rates during the rains and during the negative water balance periods, with a strong reaction to first rains. Stylosanthes capitata 1315, had the slowest growth rate during the rainy period, and was the only Stylosanthes that did not grow during periods of negative water balance, but it strongly reacted to the first rains.

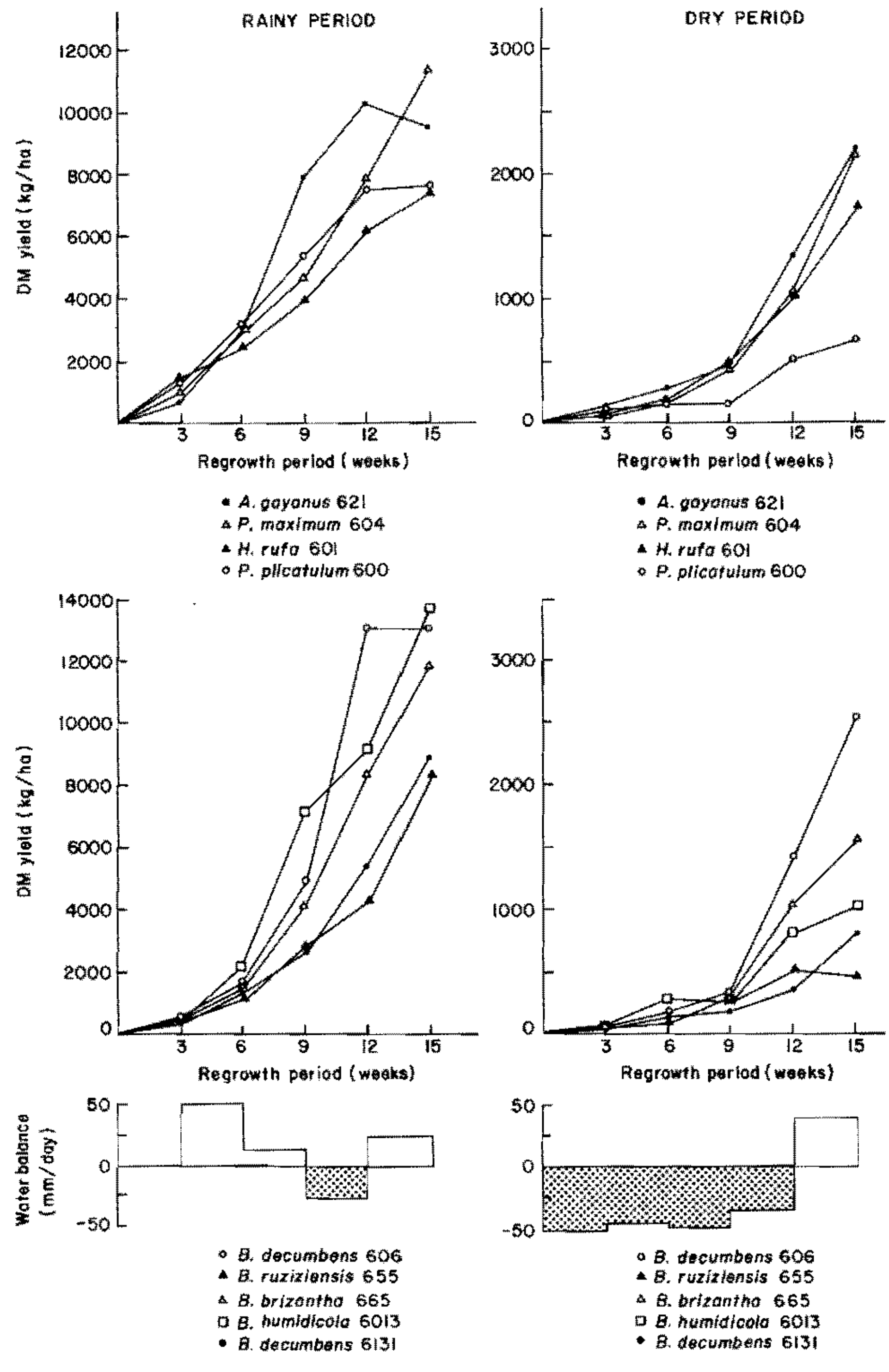



Figure 2. Growth curves of nine grasses affected by two different water balance periods (rainy and mostly dry). Notice that the X scale is four times bigger in the curves for the drier period.

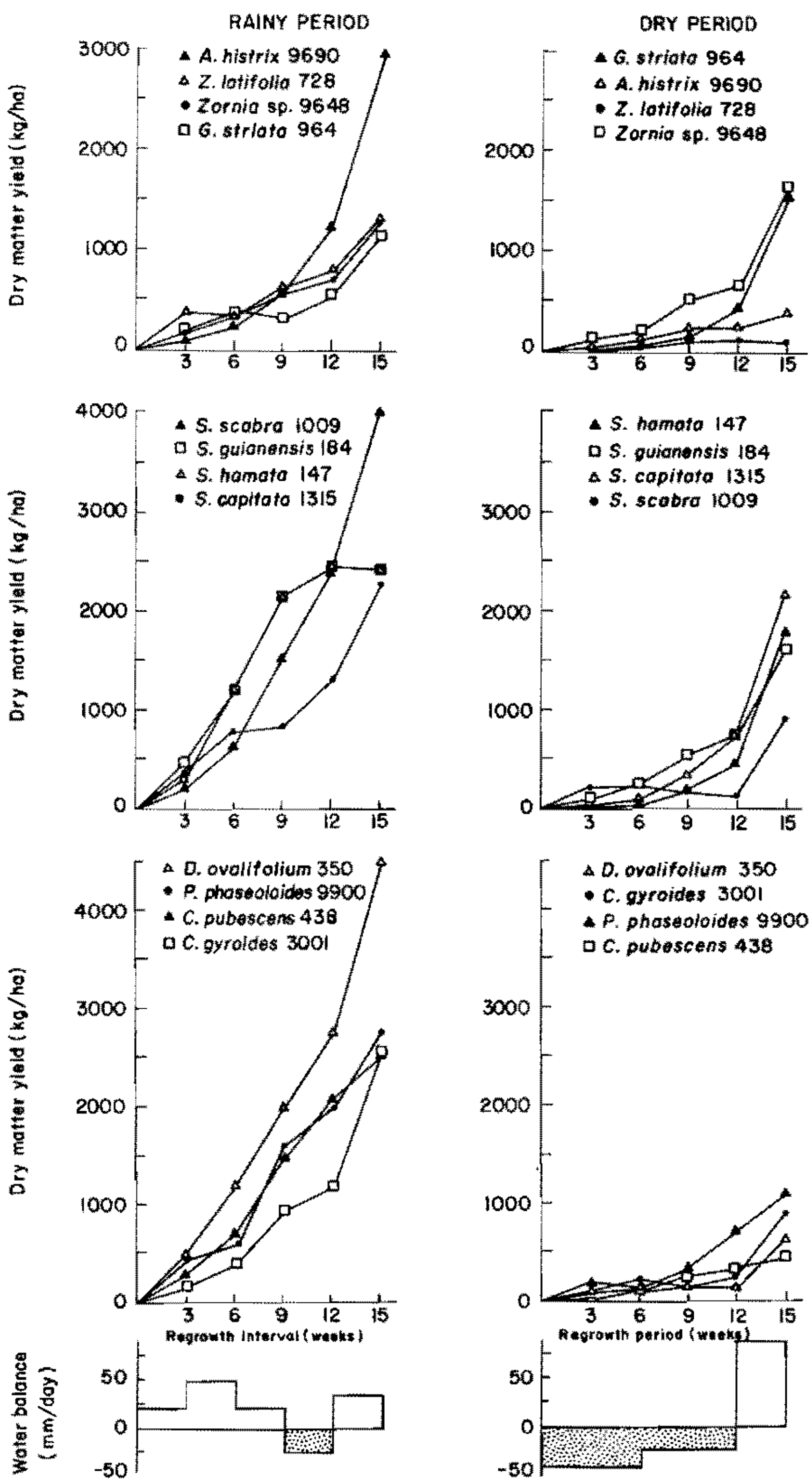



Figure 3. Growth curves of 12 legumes affected by two different water balance periods (mostly rainy and dry).

The legume Galactia striata 964 (top of Figure 3) is a well known drought-tolerant species, and this is confirmed by this study which shows that it grew during the dry period even at a faster rate than in the rainy period.

In order to study the potential compatibility of grass-legume mixtures, two trials were conducted, one to test nine legumes associated with two grasses, in monoculture, and the other to test six grasses associated with two legumes, in monoculture, with and without nitrogen fertilization.

Relative dry matter yield of the components in each plot are shown in Figures 4 and 5 for the associations of the six grasses with Desmodium ovalifolium 350 and Stylosanthes capitata 1315. In Figure 4 the three Brachiaria species show different degrees of aggressiveness as indicated by the growth of Desmodium ovalifolium and Stylosanthes capitata in different proportions in the mixture. It would seem that Brachiaria humidicola is a grass that requires time to show its aggressiveness in full potential, as indicated by the high proportion of legumes at the first cuttings.

In the case of bunch type grasses (Andropogon gayanus 621, Hyparrhenia rufa 601 and Panicum maximum 604), the proportions of Stylosanthes capitata in the association was similar. However, when the associated legume was Desmodium ovalifolium, Hyparrhenia rufa seemed to be the weakest grass, as indicated by greater proportion of Desmodium ovalifolium through the eight cuts.

To complement the information on relative competition between grasses and legumes, root studies are carried out by sampling the interphase between the lines of grasses and legumes in each plot. This attempts to study root interaction, as indicated by occupation and utilization of the soil. As a summary, Table 13 shows values for the eighth cut of a Root Efficiency Index (REI) calculated by dividing the root dry matter present in the 40 cm top soil by the top dry matter production. This index is interpreted as an indication of the amount of roots required for the plant to produce certain amount of aerial dry matter, and consequently it is an important indicator of aggressiveness or ability of the plant to occupy and use the soil. In this context, Brachiaria humidicola 6013 is the grass with the greatest REI, in other words, with the ability to locate more roots in the soil as compared to other grasses. A comparison of means across grasses for the different competition treatments with legumes, indicates little differences, possibly with the exception of Desmodium ovalifolium, with the lowest REI (2.73).

In order to evaluate the nitrogen contribution of legumes to the grasses, chemical analyses of the sward components in the different plots were done on each of the cuttings. Table 14 shows the seasonal nitrogen yields of six grasses when associated with Desmodium ovalifolium 350, Stylosanthes capitata 1315 and in monoculture with an without nitrogen fertilization (100 kg per hectare).

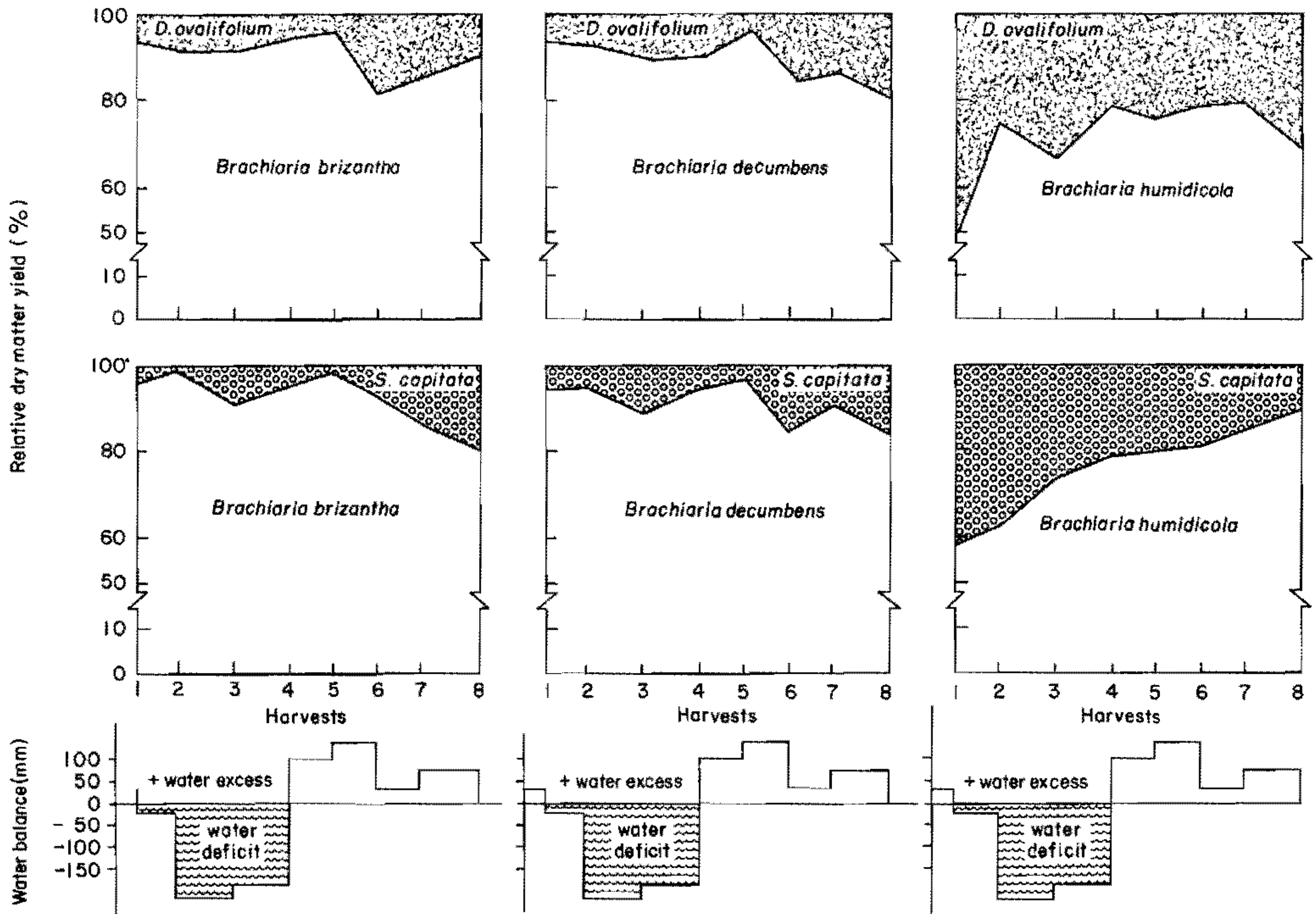



Figure 4. Relative dry matter production of prostrate grass species and companion legumes.

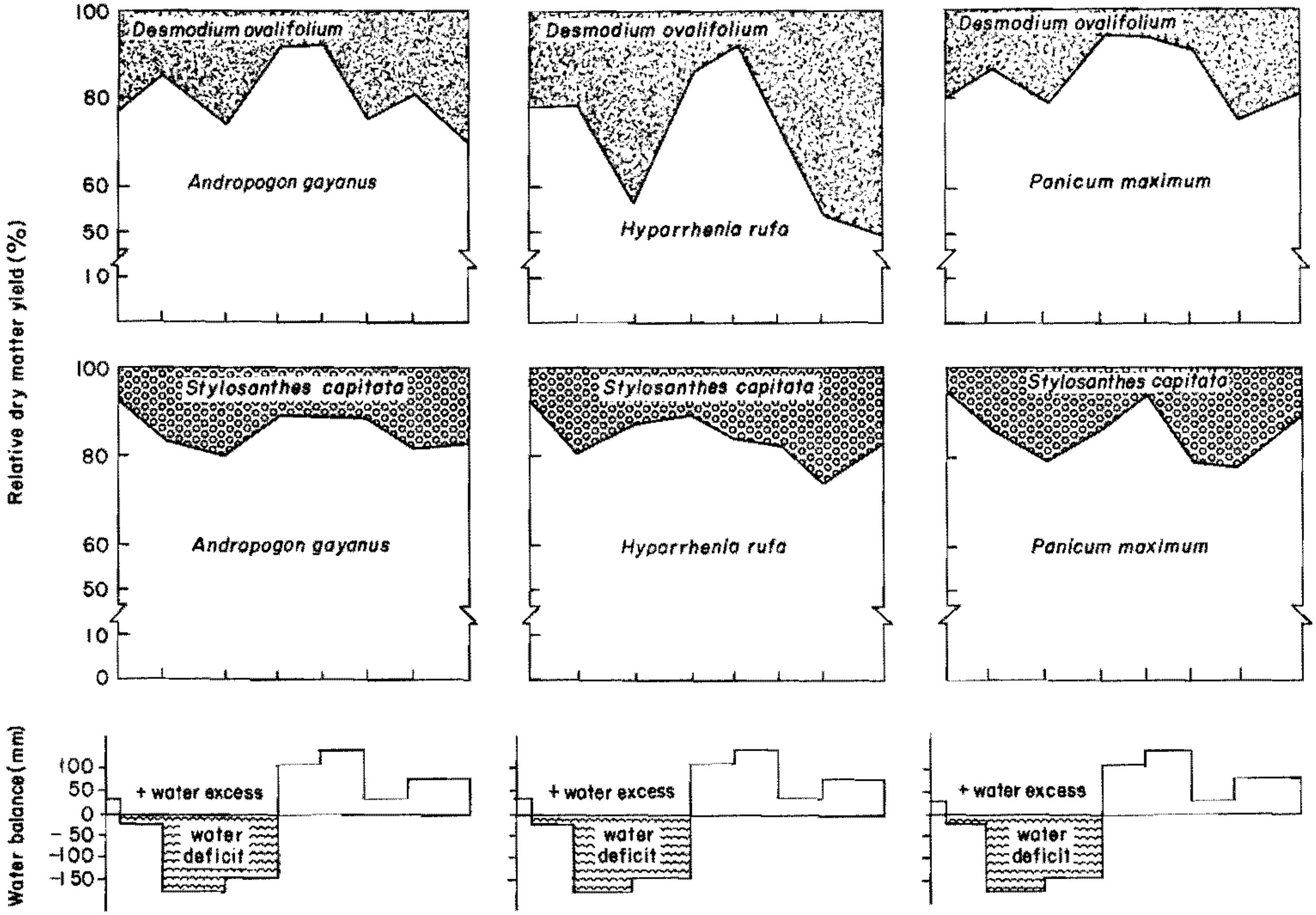



Figure 5. Relative dry matter production of bunch type grasses and companion legumes.

Table 13. Root efficiency index (REI) of six grasses when associated with *Desmodium ovalifolium* 350, *Stylosanthes capitata* 1315 or in monoculture, with and without fertilization with 100 kg of N/ha. Measure at eighth cut (15 months after planting).

| Treatment of competition | *Andropogon gayanus* | *Hyparrhenia rufa* | *Panicum maximum* | *Brachiaria brizantha* | *Brachiaria decumbens* | *Brachiaria humidicola* | Mean |
|---|---|---|---|---|---|---|---|
| | REI = (kg root DM/kg top DM) | | | | | | |
| *Desmodium ovalifolium* | 1.23 | 1.40 | 2.47 | 2.46 | 2.55 | 6.27 | 2.73 |
| *Stylosanthes capitata* | 1.26 | 1.44 | 2.56 | 3.12 | 3.22 | 8.60 | 3.36 |
| Grass + nitrogen | 1.28 | 0.99 | 2.37 | 3.47 | 2.77 | 7.60 | 3.08 |
| Grass without nitrogen | 1.53 | 1.30 | 3.16 | 3.12 | 2.89 | 7.67 | 3.28 |
| Mean | 1.32 | 1.28 | 2.64 | 3.04 | 2.85 | 7.53 | |

Table 14. Seasonal N yields (kg N/ha) of six grasses when associated with *Desmodium ovalifolium* 350, *Stylosanthes capitata* 1315 or in monoculture with and without fertilization with 100 kg of N/ha.

| Treatment of competition | Grasses | | | | | | Mean |
|---|---|---|---|---|---|---|---|
| | *P. maximum* 604 | *A. gayanus* 621 | *H. rufa* 601 | *B. decumbens* 606 | *B. brizantha* 665 | *B. humidicola* 6013 | |
| | kg N/ha | | | | | | |
| **Rainy season** | | | | | | | |
| *D. ovalifolium* | 23.4 | 34.0 | 20.4 | 28.6 | 27.0 | 21.4 | 25.8a |
| *S. capitata* | 26.6 | 30.6 | 41.7 | 27.4 | 23.1 | 20.8 | 28.4a |
| Grass + N | 29.8 | 31.9 | 30.1 | 26.5 | 22.1 | 30.3 | 28.5a |
| Grass | 13.1 | 19.2 | 17.3 | 14.3 | 12.8 | 15.6 | 15.4b |
| Mean | 23.2b | 22.0b | 29.0 | 27.4a | 24.2ab | 21.3b | |
| **Dry season** | | | | | | | |
| *D. ovalifolium* | 12.1 | 10.2 | 15.2 | 8.4 | 16.2 | 15.9 | 13.0a |
| *S. capitata* | 15.0 | 7.3 | 13.1 | 11.8 | 17.2 | 16.1 | 13.4a |
| Grass + N | 12.3 | 7.5 | 12.1 | 12.1 | 10.0 | 13.4 | 11.2b |
| Grass | 7.7 | 5.5 | 9.6 | 7.6 | 10.4 | 7.5 | 8.1c |
| Mean | 11.8bb | 7.6c | 12.5ab | 10.1bc | 13.4a | 13.2ab | |

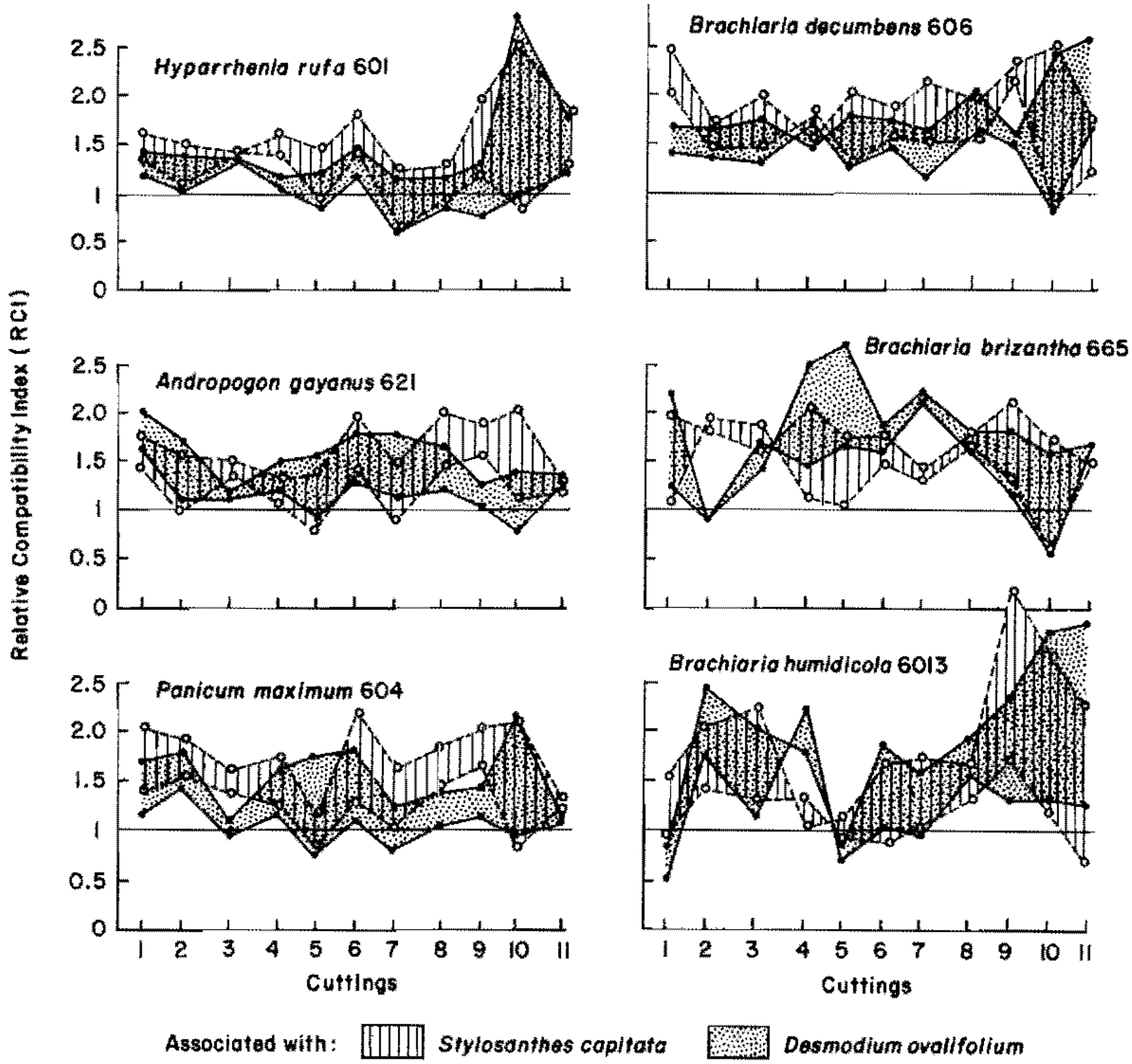



Figure 6. Changes with time of Relative Compatibility Index (RCI) of six grasses when associated with Desmodium ovalifolium 350 and Stylosanthes capitata 1315 in Quilichao.

A Relative Compatibility Index (RCI) was calculated to indicate the degree of yield of such species in association vs. the productivity of the same species in monoculture. The RCI was calculated by dividing DM yield of the species associated vs. DM yield of the species in monoculture. In the case of grasses, two controls were used with and without nitrogen fertilization. Consequently, two RCI are calculated for each grass under competition by two companion legumes. An RCI of 1 represents a situation of equilibrium in which the species is not affected by the companion species. An RCI above 1 indicates that the species is benefited by the companion species in the association, whereas an RIC of less than 1 indicates that the species is negatively affected by the companion species. In general, the productivity of grass was in most cases favored by the association with a legume (Figure 6). The two extreme situations were Hyparrhenia rufa 601 (the less aggressive grass) and Brachiaria decumbens 606, always benefited by the companion legume. Andropogon gayanus 621 seemed in most cases to benefit by the companion legumes except with Desmodium ovalifolium. In Figure 6, the difference between the two RCI's calculated using the two nitrogen levels of the monoculture as the denominator, shows the range of benefit due to the nitrogen contribution. The difference from RCI=1 explains the reduced competitive ability of the associated legumes.

The same RCI calculations have been done with data recorded from the experiment in which nine legumes are associated with Andropogon gayanus 621 and Brachiaria decumbens 606. Figure 7 shows RCI changes with time for the nine legumes under the influence of associated species. It is clear that all legumes have a high tendency to be negatively affected by the companion grass (RCI $<$ 1). This is an important difference with grasses which normally benefit from the companion legume.

Desmodium ovalifolium 350 is the legume with highest RCI throughout the period of evaluation; in other words, it is the most aggressive legume in the study. It also shows the largest difference in RCI between the two companion grasses as it was only slightly affected by Andropogon gayanus as compared with Brachiaria decumbens, in which case it reached a somewhat stable level after the fourth cut.

The information obtained in this clipping trial has to be interpreted with caution, since it is only meant to indicate the potential aggressiveness or compatibility among grasses and legumes eliminating factors such as trampling, preferential grazing and perenniality of species which strongly affect the compatibility and productivity of a mixture under grazing.

## Methodological Studies

The section is currently testing alternative methodologies and sampling techniques that could be used in Regional Trials C and D, in which animals are introduced in the evaluations.

A prototype of a Regional Trial C which attempts to evaluate the effect of three grazing pressures on five grass-legume mixtures (Andropogon gayanus 621 with Centrosema pubescens 438 and Stylosanthes capitata 1405; Panicum maximum 604 with Centrosema pubescens 438 and Stylosanthes capitata 1405; and Brachiaria decumbens 606 with Desmodium ovalifolium 350) has completed six months under grazing. This trial is conducted simulating rotational grazing with a three-to-four-days grazing period followed by six weeks (rainy) or eight weeks (dry) resting periods. Figure 8 shows the changes in dry matter availability in two mixtures of Centrosema pubescens with Andropogon gayanus and Panicum maximum. As a consequence of the three grazing pressure treatments applied (2.4 and 6 kg of DM on offer per 100 kg of liveweight), botanical composition of the pasture changed with time. Starting from similar DM availabilities, after the first six months of grazing, DM on offer has changed drastically as shown in the last August evaluation.

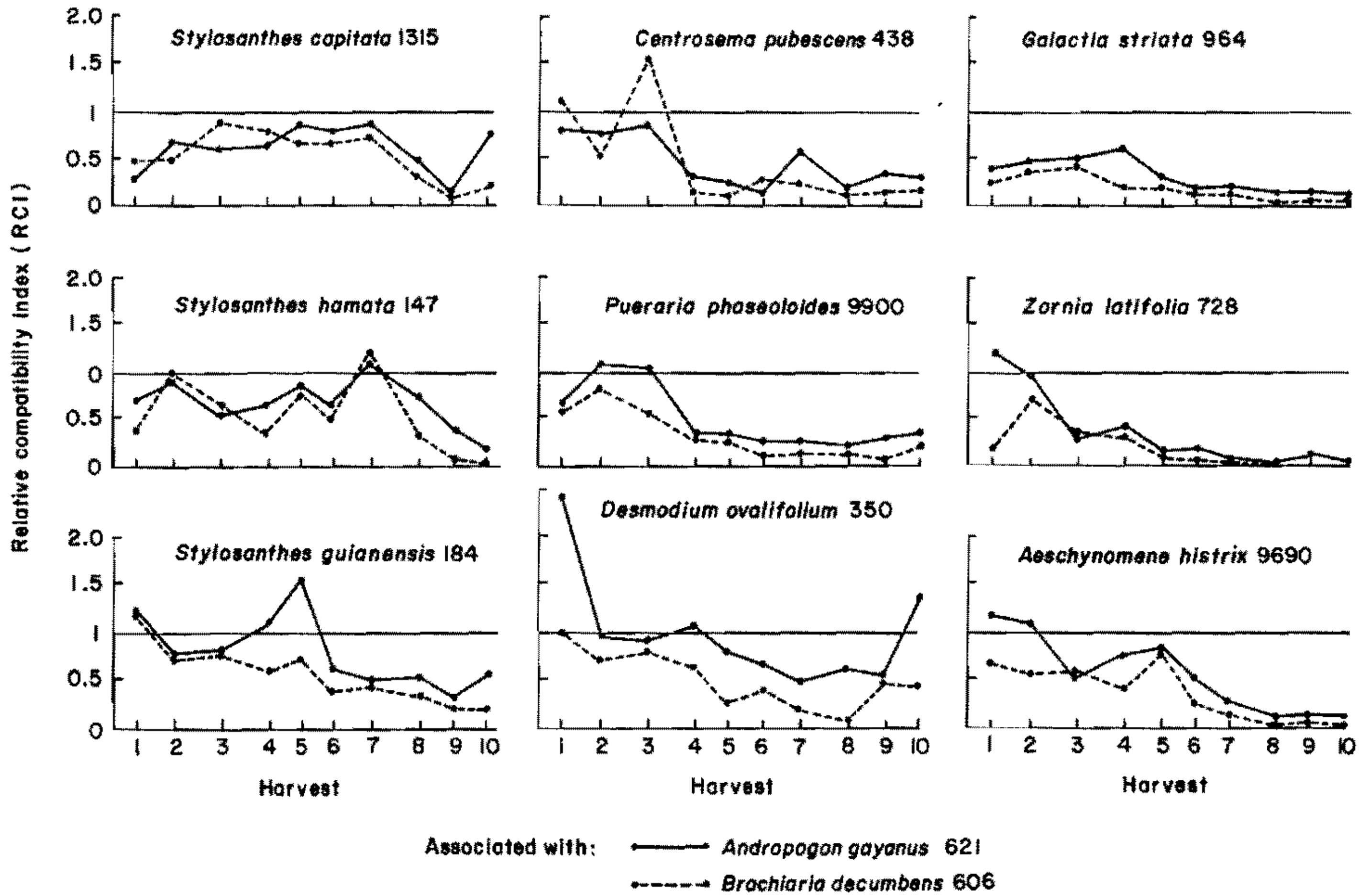



Figure 7. Changes with time of Relative Compatibility Index (RCI) of nine legumes when associated with Brachiaria decumbens 606 and Andropogon gayanus 621 in Quilichao.

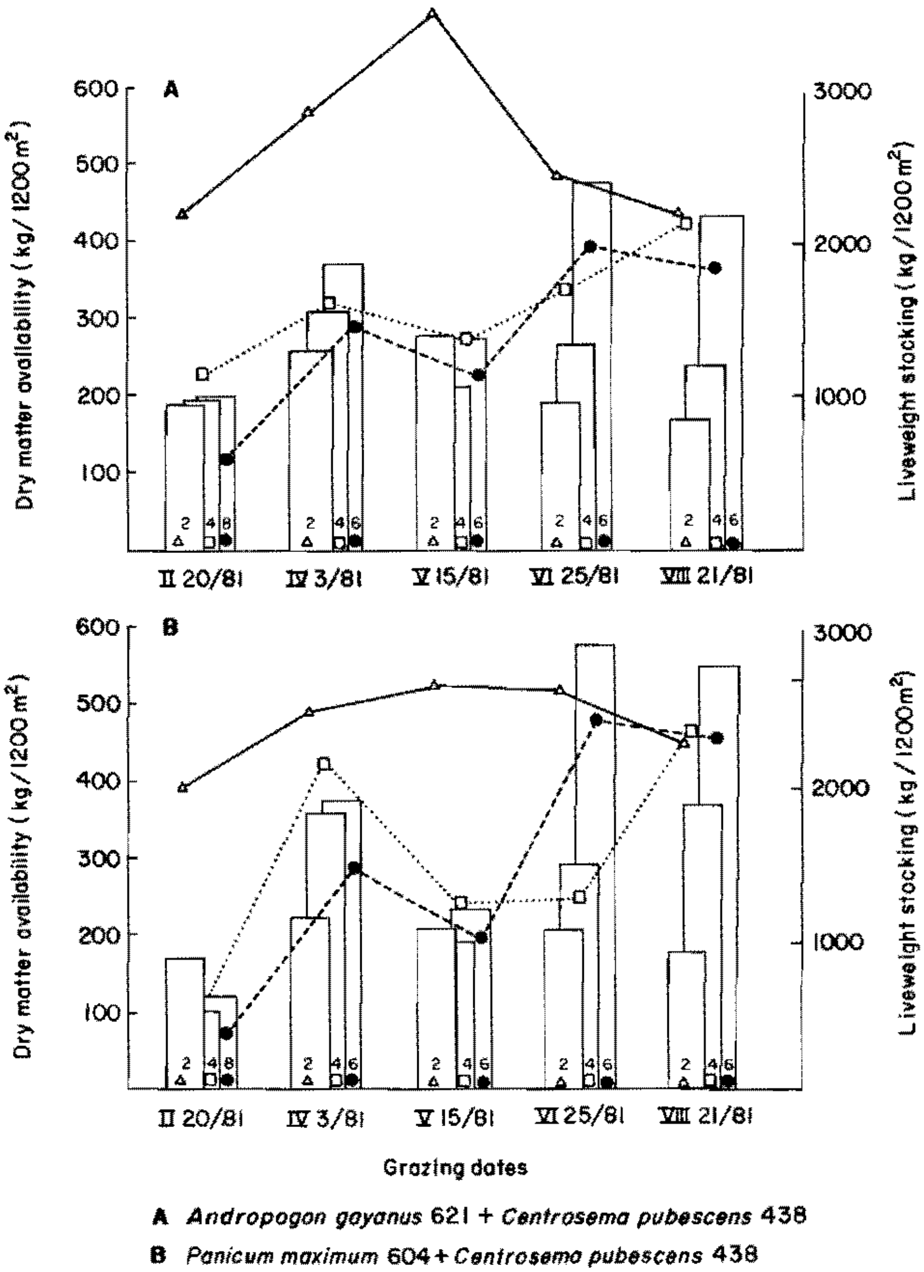



Figure 8. Dry matter (grass-legume) availability changes in two mixtures under three different grazing pressures (2,4 and 6 kg MS/100 kg liveweight) applied rotationally.

Measurements of the botanical components in the mixture are done during the grazing period to monitor changes with time of botanical composition of the different mixtures under the different grazing pressures. At this point, it is too early for a definite picture of the treatment effects on botanical composition. However, this information should prove very valuable after one or more years to get information on the range of productivity (carrying capacity) and persistence of the mixtures under different defoliation regimes. Obviously, this type of information for a few selected associations will allow the Network researcher in charge to chose for a Regional Trial D, not only the best pasture mixture in terms of total productivity but that having the widest range of tolerance to under- or overgrazing.

In designing a Regional Trial D, there are basically two options: 1) using fixed grazing pressures and, 2) using fixed stocking rates. The choice of either one technique to evaluate the productivity of pasture in terms of animal gains, should not be, by any means, a dogmatic decision. The advantages and disadvantages of either approach are related to the potential productivity of the ecosystems (soil fertility, dry season length, carrying capacity level of native species, etc.) and the prevalent animal production system (intensity of management, level of stocking rate required, other sources of feed availability, type of animal, etc.). Methodologies should be assembled in each case to respond to specific ecosystems and production systems.

In order to try one of the alternatives an old trial was used. This included three pastures: 1) Andropogon gayanus 621 + Panicum maximum 604 + Hyparrhenia rufa 601 + Brachiaria decumbens 606 in blocks, with five repetitions in the same paddock; 2) Andropogon gayanus 621 + five Centrosema pubescens ectoypes sown in separate mixtures also with five repetitions within the same paddock; 3) the four grasses indicated above in mixture with Stylosanthes guianensis, Centrosema pubescens, Pueraria phaseoloides and Galactia striata. Starting in December 1980, a pure stand of Andropogon gayanus 621 was added to this trial. These four pastures are grazed using a "put and take" or constant grazing pressure management, adjusting the stocking rate to the availability of forage plus an estimate of the growth rates obtained with enclosed areas.

The changes in botanical composition of one of the four paddocks (Andropogon gayanus 621 + Centrosema pubescens) is shown in Figure 9. Since the beginning of 1980 the proportion of grass and legume has been stable in terms of green dry matter, varying from 15 to 20% of legume on offer. These results show a high degree of compatibility of the two species when properly managed. Figure 10 shows the accumulated gains per head and per hectare on the four pastures. Gains per head have increased linearly in all paddocks as expected, with small inflections between July and September 1980, when a long and drastic dry period occurred. This drought effect is more clearly shown in terms of animal gains per hectare where number of animals per paddock was drastically reduced during that period. The mean animal gains are around 550 g/an/day and 1700 g/ha/day.

An important aspect of this trial is to make measurements in the paddocks that could be used to predict animal performance. A first analysis of the data shows some interesting results. The relationship between animal gains per hectare and per head with total dry matter on offer (TDMO) for the paddock of Andropogon gayanus 621 with the five Centrosema pubsecens is presented in Figure 11. The TDMO, usually measured in grazing trials, had no relationship with animal gains and even shows less gains with more DMO. When "present green dry matter on offer" (PGDMO) is correlated to animal gains (Figure 12), the situation

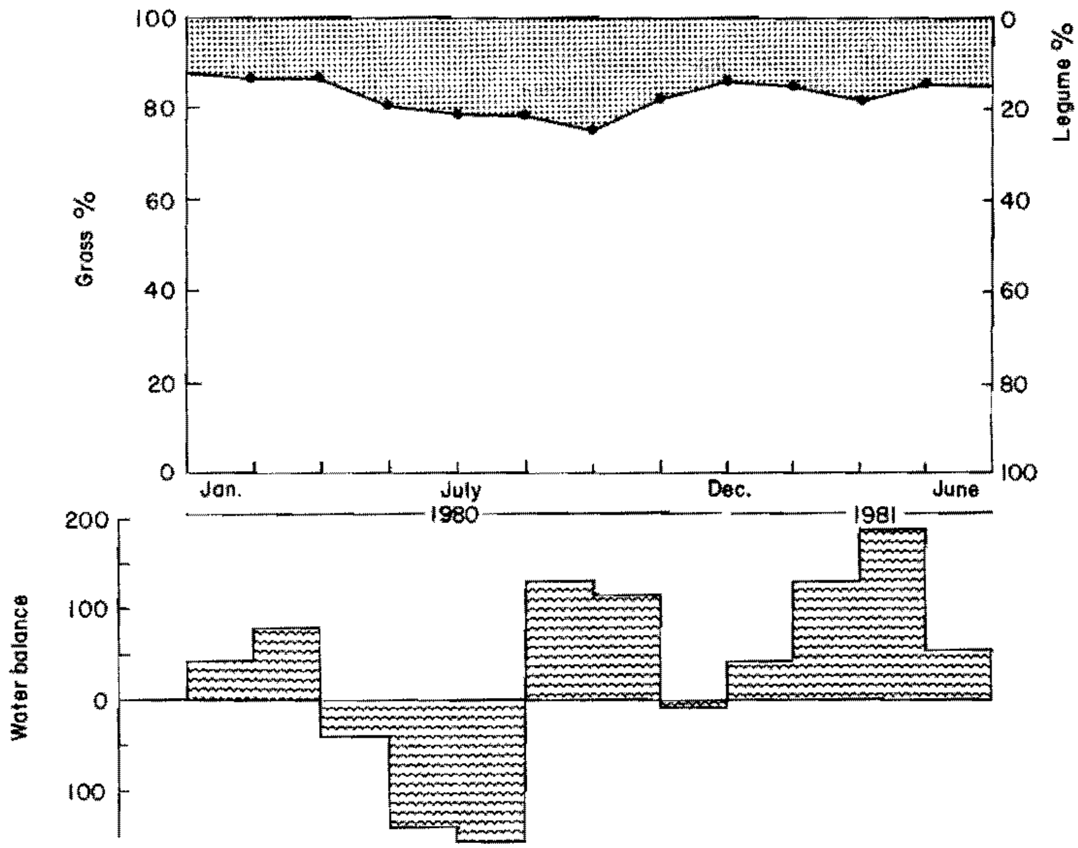
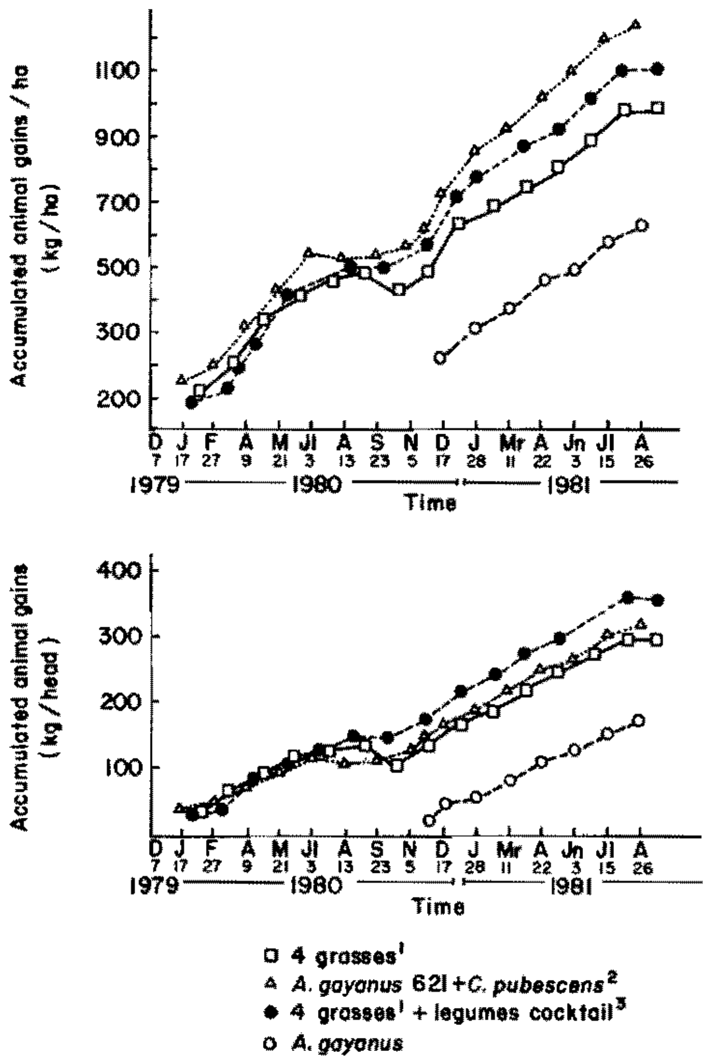



Figure 9. Changes in botanical composition of an Andropogon gayanus + Centrosema pubescens paddock based on green DM on offer.

improves drastically as indicated by the r , and the relationship becomes logical. This PGDMO is obtained by discarding dead material from the samples taken in the pasture. Furthermore, when daily average regrowth is added to the PGDMO, or "true green dry matter on offer" (TGDMO), variation in animal weight grains is better explained (Figure 13).

Several other botanical separations are being done as well as chemical analyses on resulting materials. It is expected to have enough information in the future to be able to select those measurements on pastures that provide the highest prevailing value of animal performance, so that they can be used by the Network participants.

As a closing statement, it is important to mention that one of the most critical constraints to research on pasture evaluation in tropical America is the lack of a reliable methodology, compatible with the national institution resources, with the productivity potential of different ecosystems, and with the feed resources of the prevailing production systems. It is then important for the Tropical Pastures Program to emphasize research in the methodology field.




[1] *A. gayanus* 621; *P. maximum* 604; *H. rufa* 601; and *B. decumbens* 606 in blocks of each in the paddock

[2] *C. pubescens* 438, 442, 469, 455 and 456 sown in 5 replicated blocks in mixture with *A. gayanus* 621

[3] Legume cocktail made of: *S. guianensis*, *C. pubescens*, *P. phaseoloides* and *G. striata*

[4] Gains/head = mean weight gains from "testers"

[5] Gains/ha = (gains/head) (No. of grazing animals)

Figure 10. Accumulated gains per head[4] and per ha[5].

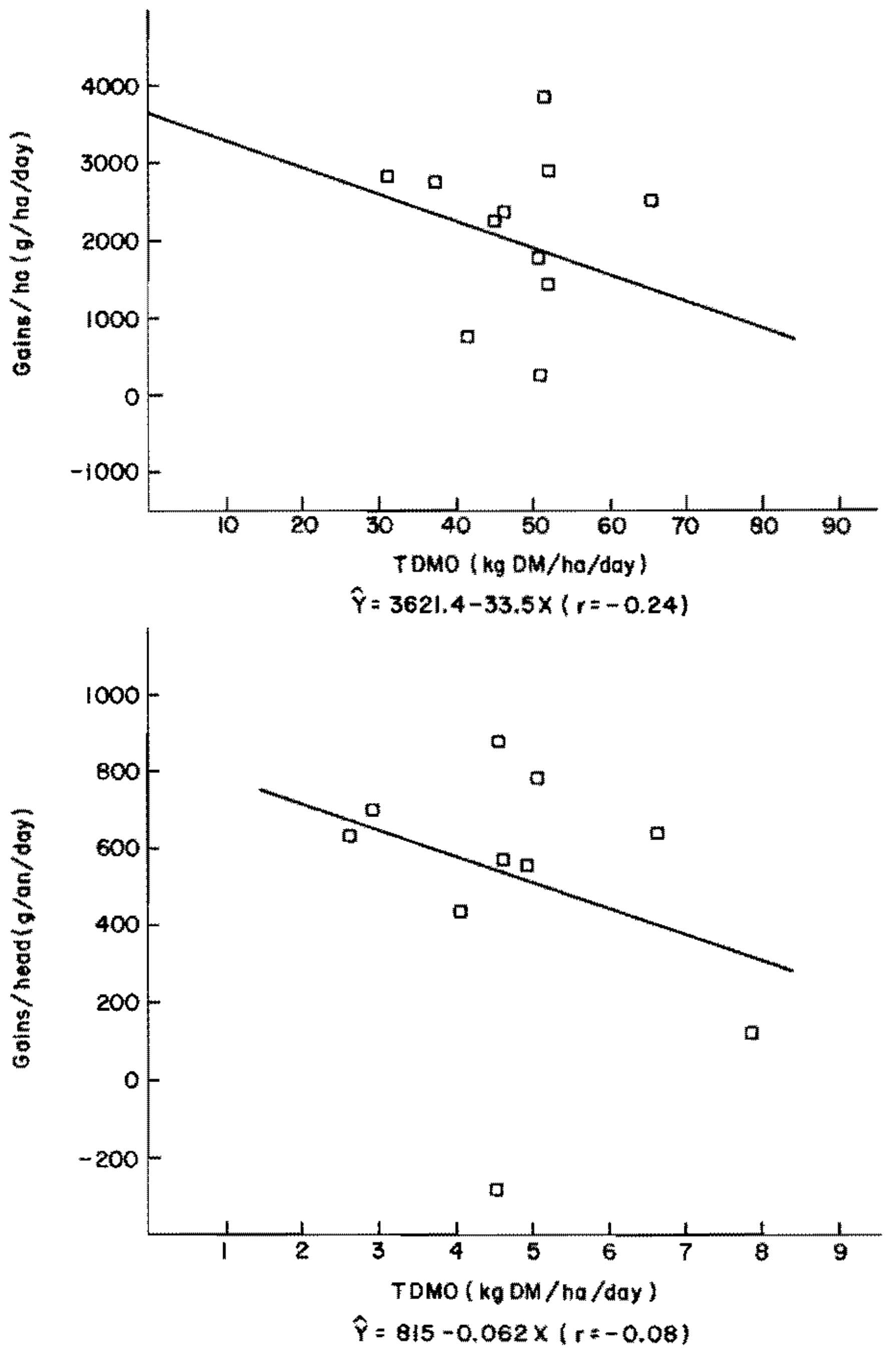



Figure 11. Relationship between animal gains per ha and per head with total DM on offer (TDMO) in a continuously grazed *Andropogon gayanus* 621 + *Centrosema pubescens* paddock.

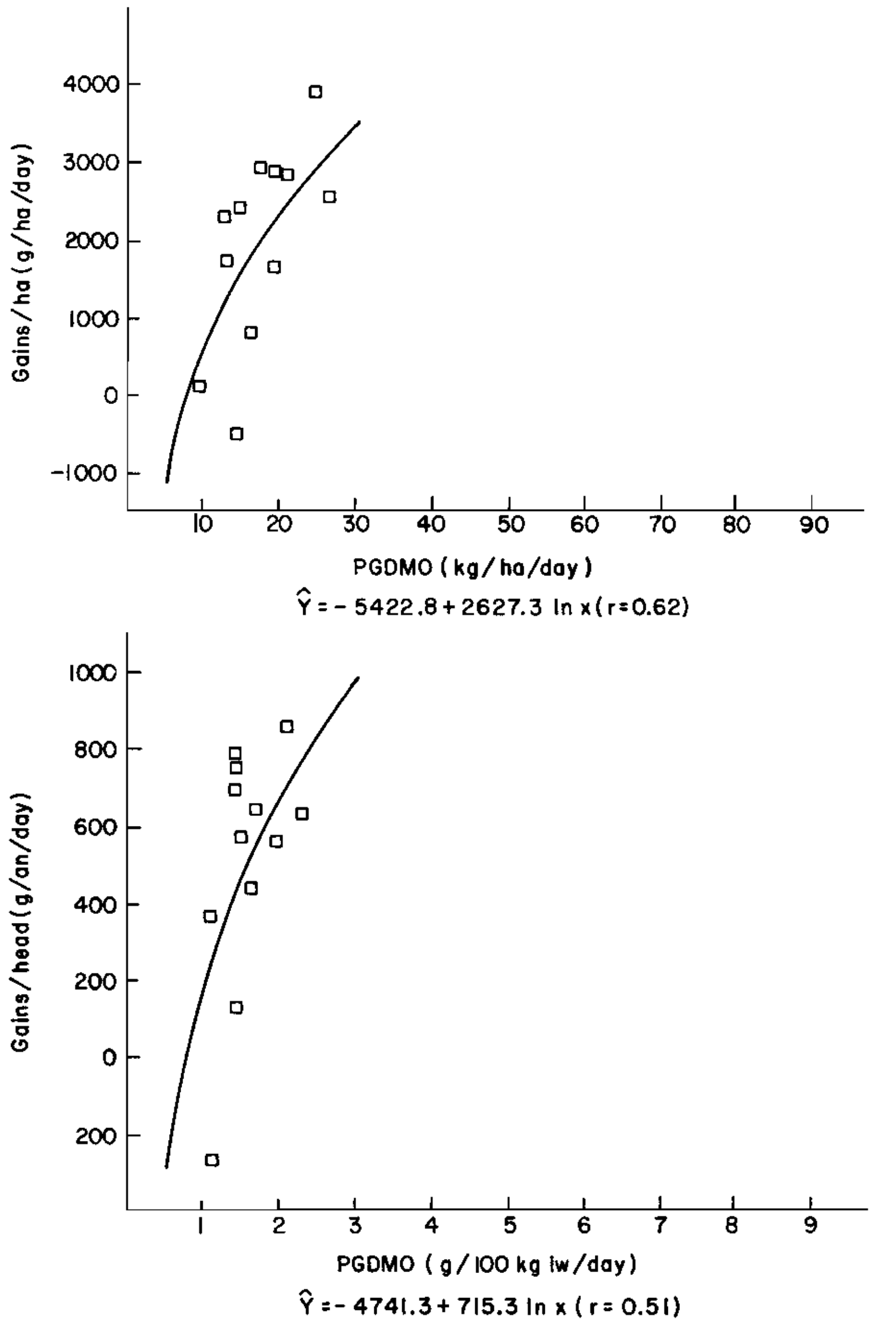



Figure 12. Relationship between animal gains per ha and per head with present green dry matter on offer (PGDMO) in a continuously grazed Andropogon gayanus 621 + Centrosema pubescens paddock.

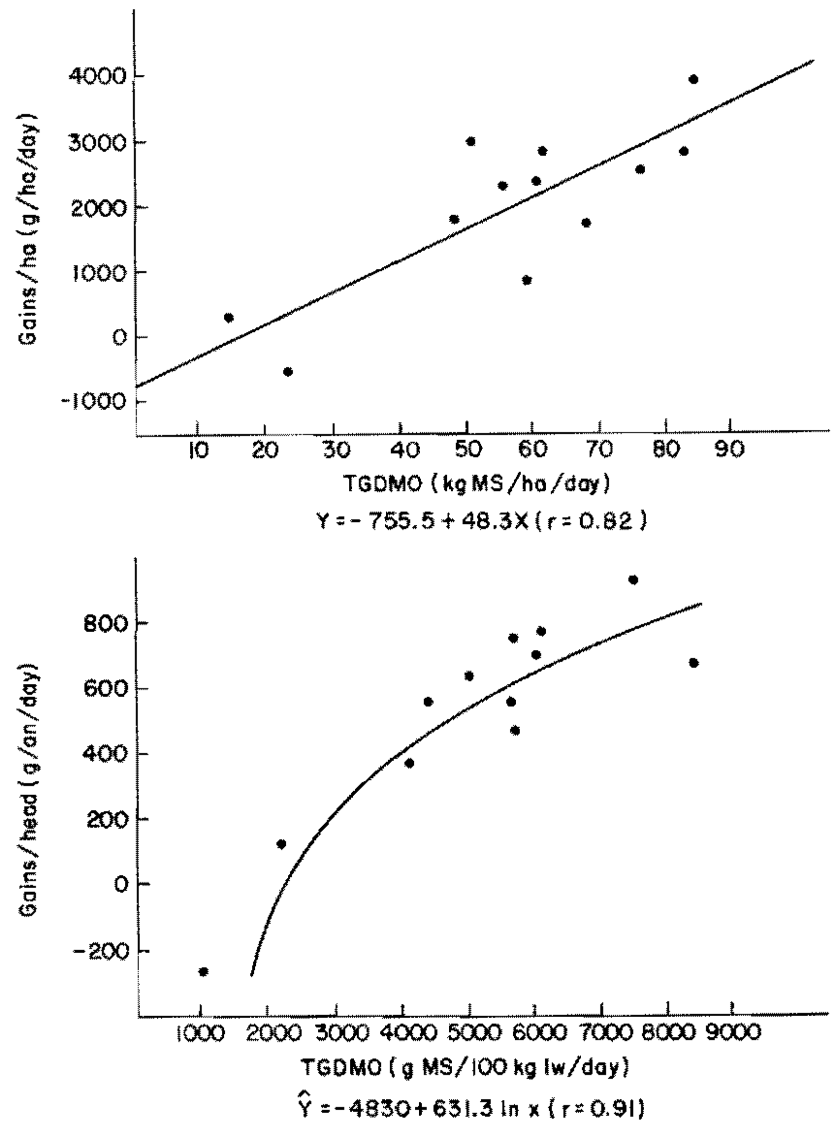



Figure 13. Relationship between animal gains per ha and per head with true green DM on offer (TGDMO) (present DM on offer + regrowth) in a continuously grazed Andropogon gayanus 621 + Centrosema pubescens paddock.

# Plant Pathology

## Introduction

The major aims of the Plant Pathology Section continued to be: 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; c) to evaluate and develop control measures for damaging diseases of promising forage species.

Evaluation of germplasm continued as a major activity at Carimagua and Quilichao, Colombia, and CPAC, Brazil. Further information was collected on disease distribution. Studies continued on anthracnose and blight of Stylosanthes spp., Rhynchosporium leaf spot of Andropogon gayanus, biological control of spittlebug with fungus Metarrhizium in close collaboration with Entomology, and on seed pathology. Studies were initiated on several bacterial diseases and Rhizoctonia foliar blight of Centrosema brasilianum. Several new diseases were detected.

## Disease Survey

The following additions were made to the table of distribution with respect to ecosystem of forage diseases (Table 1).

1. Sooty blotch (Polythrincium sp.), affecting some of the more prostrate Aeschynomene sp., was detected only at Carimagua;

2. Bacterial wilt (Corynebacterium flaccumfaciens) affecting Zornia 7847, and Zornia brasiliensis, was found both at Quilichao and Carimagua;

3. Alternaria leaf spot, another disease of Centrosema spp., was detected at Carimagua and in regional trials of the Llanos.

During the three years of disease survey, 25 diseases have been detected in the Tropical Iso-hyperthermic Savanna Ecosystem, 18 in the Tropical Isothermic Savanna Ecosystem, 11 in the Tropical Semi-Evergreen Seasonal Forest Ecosystem and 24 in the Tropical Rainforest Ecosystem (Table 1). It should be noted that the table does not include genus host range. Some diseases, e.g., anthracnose, affect 10 or more genera.

## Diseases of Stylosanthes spp.

Field screening continued as a major activity. New and old germplasm was evaluated at 4-6 week intervals in Carimagua and Quilichao and once at CPAC, Brazil. Results are presented in Table 2.

a) Stylosanthes capitata. As for the last three years, most accessions were susceptible at CPAC, Brazil, and resistant in Carimagua.

b) Stylosanthes guianensis "common". Although less accessions have been evaluated at CPAC, Brazil, the Carimagua environment appears to have greater anthracnose pressure than the CPAC environment (Table 2).

c) Stylosanthes guianensis "tardío". Although few have been screened in the two major evaluation sites, CPAC-Brazil and Carimagua, these two sites have greater anthracnose pressure than Quilichao. The total collection should be evaluated next year at both sites.

A comparison among accessions of S. guianensis "tardío" in reaction to anthracnose at Quilichao, Carimagua and CPAC was made. The similarity between CPAC and Carimagua was considerably higher than between Quilichao and those two sites, again stressing the importance of screening the whole collection in the major screening sites. It was interesting to note that in both, the Venezuelan "tardíos" are more susceptible to anthracnose than the Brazilian "tardíos". In Quilichao recuperation of anthracnosed accessions of S. guianensis "tardío" was common in the dry seasons.

d) S. macrocephala. It remained resistant to anthracnose in both major screening sites. Also, the large CIAT-EPAMIG trial in Sete Lagoas, Minas Gerais, Brazil, was free of anthracnose. This species is worthy of further collection and study.

e) S. leiocarpa. In Carimagua most accessions were susceptible to anthracnose.

f) S. scabra. In CPAC many accessions are susceptible to anthracnose. In addition, plants are stressed by another problem, tentatively described as an insect-virus complex, which probably increases their susceptibility to anthracnose. This will be studied in Brazil.

g) S. viscosa. The planting in Quilichao had two levels of anthracnose during 1981.

Specific screening studies

Anthracnose of S. guianensis in the forest (e.g., Pucallpa, Perú). During the past ten years, S. guianensis cultivars Cook, Endeavour, Schofied and CIAT 136 and 184 have persisted in Pucallpa, Peru, and for several years in other forest environments in Bahía, Brazil and Leticia, Colombia, with only slight levels of anthracnose. At the same time, these ecotypes are severely affected by anthracnose in savanna ecosystems. Studies were therefore initiated to investigate why S. guianensis is only slightly affected by anthracnose in Pucallpa, Peru.

Table 1. Distribution of forage diseases in different ecosystems. Summary.

| | Forage disease | Ecosystems | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 9* | 1 | 4 | 1 | 9 | | 11 |
| | | Tropical savanna, Isohyperthermic ("Llanos") | Tropical savanna, isohyperthermic ("Llanos") Carimagua, Colombia | Tropical savanna, Isothermic ("Cerrado") | Tropical savanna, isothermic ("Cerrado") Brasilia, Brasil | Tropical semi-evergreen seasonal forest | Tropical sub-montane seasonal forest, Quilichao | Tropical rainforest |
| Grasses | 1. Anthracnose | + | + | + | + | + | + | + |
| Legumes | 2. Cercospora leaf spot (A) | + | + | + | | + | + | + |
| | 3. Cercospora leaf spot (B) | + | + | + | + | + | + | + |
| | 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. Pokkah Boeng | + | + | | | | | +** |
| | 28. Cerebella inflorescence blight | | + | | | + | | +** |
| | 29. Viruses | +* | + | + | + | + | + | + |
| | 30. Rhizopus inflorescence blight | + | + | | | | | |
| | 31. Sooty blotch | | + | | | | | |
| | 32. Bacterial wilt | | + | | | | + | |
| | 33. Alternaria leaf spot | + | + | | | | | |

* Number of sites surveyed
** Only at one site

Table 2. Disease, evaluation, anthracnose, at CPAC, Carimagua, and Quilichao. 1979-1981.

| Sp./site | Evaluation[1] R | MR | MS | S | Total accessions |
|---|---|---|---|---|---|
| *Stylosanthes capitata* | | | | | |
| CPAC-LVE[2] | 6.3[3] | 11.8 | 35.4 | 46.5 | 119 |
| Carimagua | 83.3 | 10.6 | 6.1 | 0 | 132 |
| *Stylosanthes guianensis* "common" | | | | | |
| CPAC-LVE | 0 | 4.8 | 64.6 | 30.6 | 62 |
| Carimagua[4] | 1.6 | 6.8 | 20.4 | 71.2 | 545 |
| *Stylosanthes guianensis* "tardío" | | | | | |
| CPAC-LVE | 15.7 | 19.3 | 25.3 | 39.7 | 51 |
| CPAC-LVA[6] | 25.3 | 18.4 | 24.1 | 32.2 | 55 |
| Quilichao | 77.9 | 16.8 | 5.3 | 0 | 131 |
| Carimagua | 27.3 | 33.3 | 27.2 | 12.1 | 33 |
| *Stylosanthes macrocephala*[7] | | | | | |
| CPAC-LVE | 92.6 | 7.4 | 0 | 0 | 41 |
| Carimagua | 87.1 | 12.9 | 0 | 0 | 31 |
| *Stylosanthes leiocarpa*[8] | | | | | |
| Carimagua | 0 | 15.3 | 61.5 | 23.1 | 13 |
| Quilichao | 23.3 | 36.7 | 20.0 | 20.0 | 30 |
| *Stylosanthes scabra*[9] | | | | | |
| CPAC | 1.5 | 24.5 | 46.4 | 24.6 | 102 |
| *Stylosanthes viscosa*[10] | 72.6 | 17.9 | 5.1 | 4.4 | 117 |

1 R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible.
2 LVE = dark red latosol soil site.
3 Percentage of accessions.
4 Evaluation till September 1981.
5 7 8 9 Evaluation in 1980-1981.
6 LVA = red-yellow latosol soil.
10 Evaluation in 1981.

Various hypotheses were set up: 1) less pathogenic isolates in the Pucallpa environment; 2) lack of inoculum in the forest environment; 3) reduced inoculum spread; 4) favorable environmental conditions; 5) biological control agents.

The first hypothesis was tested by seedling inoculation studies in the greenhouse with isolates of *C. gloesporioides* from *Stylosanthes* spp. collected in Pucallpa, Peru, Colombia and Brazil. Isolates from *S. guianensis* CIAT 17 and 184 from Pucallpa were just as pathogenic to *S. guianensis* as isolates from CIAT 136, 184 and 13 in Colombia (Table 3).

At the same time, it was found that four isolates from *S. guianensis* "common" (CIAT 13, 17 and 184) were pathogenic to *S. guianensis* "tardío" 1283. Previously it had been found that isolates from "common" types do not attack "tardíos". It was also found for the first time that isolates from *S. capitata* affected *S. guianensis* (Table 3).

Table 3. Reaction of 10 *Stylosanthes* spp. accessions to eight isolates of *Colletotrichum gloeosporioides* from Brazil, Colombia and Perú.

| *Stylosanthes* spp. CIAT No. | Species | Anthracnose reaction 1019[1] B[2] | 2310 C | 1097 P | 136 C | 17 P | 13 C | 184 P | 184 C |
|---|---|---|---|---|---|---|---|---|---|
| 147 | *S. hamata* | ++ | - | + | - | - | - | - | - |
| 1283 | *S. guianensis* | + | + | - | + | + | + | + | ++ |
| 136 | *S. guianensis* | + | + | +++ | +++ | +++ | +++ | ++ | +++ |
| 184 | *S. guianensis* | + | + | ++ | +++ | +++ | +++ | +++ | +++ |
| 1019 | *S. capitata* | ++ | - | - | - | - | - | - | - |
| 1405 | *S. capitata* | ++ | - | - | - | - | - | - | - |
| 1315 | *S. capitata* | ++ | - | - | - | - | - | - | - |
| 1078 | *S. capitata* | + | - | - | - | - | - | - | - |
| 1074 | *S. viscosa* | - | - | - | - | - | - | - | - |
| 1047 | *S. scabra* | + | - | - | - | - | - | - | - |

1 CIAT accession numbers
2 B = Brazil, C = Colombia, P = Peru

Other hypotheses are presently being tested in Pucallpa particularly to determine whether biological control agents of C. gloeosporioides exist on leaves and stems of S. guianensis.

Studies on S. guianensis in Colombia. During the past two years, 545 accessions of S. guianensis "common" (all accessions of which seed was available) have been evaluated in Carimagua (Table 2). Almost all accessions were susceptible to anthracnose and died within one wet season. One moderately resistant accession, CIAT 1875 from Panama, is under further evaluation in a larger planting.

Isolates are being collected from all anthracnosed accessions in Carimagua. Pathogenic variation studies are in progress, and isolates are being grouped according to their reactions. To date, many isolates were found not pathogenic. Of the pathogenic ones, eight groups have so far been identified (Table 4). One group affected all accessions tested of S. guianensis common, others affected certain accessions, while Group 8 affected both S. guianensis common and S. guianensis tardío. Isolate collection and screening is continuing.

Table 4. Reactions of Colletotrichum gloeosporioides isolates from Stylosanthes guianensis, Carimagua, to seedlings of Stylosanthes spp.

| Stylosanthes spp. | Reactions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| S. capitata 1019 | | | | | | | | | |
| S. capitata 1405 | | | | | | | | | |
| S. capitata 1315 | | | | | | | | | |
| S. guianensis 136 | + | + | | + | + | + | | | |
| S. guianensis 184 | + | | | + | | + | + | + | |
| S. guianensis 77 | + | + | + | + | | + | | | |
| S. guianensis 1003 | + | | | | | + | + | + | |
| S. scabra 1047 | | | | | | | | | |
| S. viscosa 1074 A | | | | | | | | | |
| S. hamata 147 | | | | | | + | | | |
| S. macrocephala 1281 | | | | | | | | | |
| S. guianensis T 1283 | | | | | | | | + | |
| No. of isolates | 15 | 1 | 2 | 2 | 1 | 3 | 2 | 2 | 40 |

Screening studies with S. capitata. Seedling screening of the whole S. capitata collection of which seed was available was completed with isolates from S. capitata CIAT 1019, 1405 and 1315 from CPAC. Isolates from CIAT 1019 and 1405 were more pathogenic than those from 1315 (Table 5). It appears more likely that differences in reaction among isolates are due to strain differences, rather than pathogenic variation or race differences. All Venezuelan accessions were resistant to all isolates. The data is being analyzed for pathogenic variation. In addition, studies are in progress with isolates collected from *S. capitata* in Minas Gerais. Results show that isolates from Minas Gerais are generally less pathogenic than those from CPAC.

To date, studies of pathogenic variation among isolates of *C. gloeosporioides* from *Stylosanthes* spp. have recognized seven groups of isolates:

Group 1 - *Stylosanthes guianensis* "common"

Group 2 - *Stylosanthes guianensis* "tardío"

Group 3 - *Stylosanthes guianensis* "common" and "tardío"

Group 4 - *Stylosanthes capitata* and *Stylosanthes scabra*

Group 5 - *Stylosanthes capitata* and *Stylosanthes hamata*

Group 6 - *Stylosanthes capitata* late flowering accessions

Group 7 - *Stylosanthes capitata* and *Stylosanthes guianensis* "common"

Groups 1, 2, 3 and 6 have been found in Colombia, while Groups 4, 5 and 7 have been found only in Brazil; Groups 1 and 2 are present in both countries; Groups 1 and 6 appear to be closely related.

These studies are showing that *C. gloeosporioides* is an extremely variable pathogen, and considerable work will be needed to fully classify its variation.

Table 5. Reaction of *Stylosanthes capitata* seedlings to isolates of *Colletotrichum gloeosporioides* from *S. capitata* at CPAC.

| Isolate | Reaction | | |
|---|---|---|---|
| | Resistant (%) | | Susceptible (%) |
| 1019 I[1] | 40 | (40)[2] | 60 |
| 1019 II | 25 | (64) | 75 |
| 1315 | 59 | (27) | 41 |
| 1405 I | 34 | (47) | 66 |
| 1405 II | 37 | (43) | 63 |

1 Roman numerals indicate different isolates from the same host

2 16 accessions of Venezuelan *S. capitata*

## Multilocational screening trials

The first multilocational *S. capitata* screening trial was planted in El Tigre, Venezuela in August. This comprised 86 accessions of *S. capitata*, including 14 from Venezuela. The first evaluation will be made in October. The second trial will be planted in Acaua in northern Minas Gerais in November. This comprises 100 accessions of *S. capitata*, 24 accessions from Minas Gerais, 29 accessions from Bahía, 13 from Venezuela, and the remainder from various sites in Brazil. Several of the Minas Gerais accessions were collected at the trial site. The third trial is planned for Bahía in collaboration with EMBRAPA; however, alternative sites will be considered in Maranhão and Pernambuco.

## Host plant resistance studies

Studies were continued on the physical and chemical characters of anthracnose-susceptible and-resistant accessions of *S. guianensis*.

*Physical studies*. During the past year they showed that neither removing the trichome secretions nor removing the trichomes of *S. guianensis* "tardío" 1283 had any effect on the reaction of this legume to slightly pathogenic isolates of *C. gloeosporioides*. Further work was planned with isolates of higher pathogenicity.

Recent tests with pathogenic isolates have shown that seedlings of several accessions of *S. guianensis* "tardío" were susceptible to anthracnose while adult plants were resistant. Trichomes may form a physical barrier to penetration by *Colletotrichum gloeosporioides*.

The effect of age on trichome density was therefore evaluated in stems of *S. guianensis* "common" CIAT 136, and *S. guianensis* "tardío" CIAT 1283 (Figure 1). Trichome density reached a maximum in CIAT 136 at 17 weeks of age at 160 trichomes/$cm^2$. In CIAT 1283, however, trichome density increased rapidly when plants reached 18-19 weeks of age. Counts are continuing on older plants, and further work is planned to study trichome density on susceptible and resistant accessions of *S. guianensis* "tardío".

*Determination of phenols in Stylosanthes guianensis*. In the past, various plant phenols have been noted as toxins to fungi. These include tannins, polyphenols and glucosides. Plants possessing phenols have been shown to be resistant to plant pathogenic fungi. In particular, it has been shown in many tropical fruits that the phenomenon of anthracnose latent infection caused by *Colletotrichum* spp. is due to immature fruit containing high levels of phenolic compounds which prevent development of anthracnose. As fruit ripens, levels of tannins decreased markedly, and anthracnose ripe rot occurs. Also, it has been shown that onions resistant to rot by *Colletotrichum dematium* possess phenolic compounds in their skins. Preliminary analyses of two *S. guianensis* "tardíos" showed glucosides and dihydro-monophenols, both members of the phenol group.

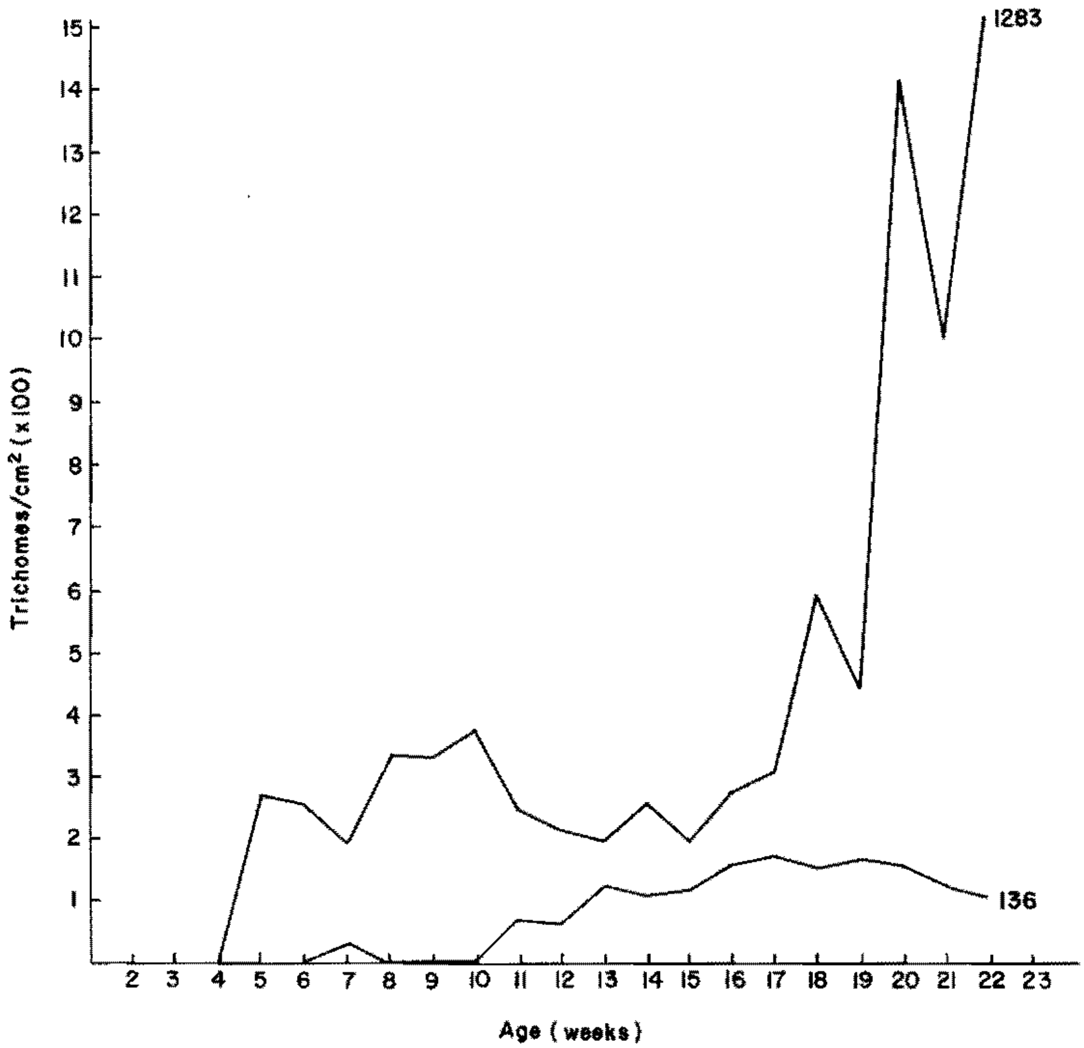



Figure 1. Changes in time in the density of trichomes on stems of *S. guianensis* CIAT 136 and CIAT 1283.

A project in collaboration with the Animal Nutrition Section was therefore initiated to survey *S. guianensis* for phenols using the Folin-Dennis method to determine if there is any correlation between possession of phenols and resistance to anthracnose.

Small samples of adult plants of *S. guianensis* "tardío" were taken from field plots and greenhouse at the same time. Percentage tannic acid was determined. Results were classified according to adult plant reaction to anthracnose at Carimagua (Table 6). For greenhouse samples, there was a decrease in percent tannic acid from 2.98 to 1.15 as the level of anthracnose increased from 1 to 5. For field samples, although percent tannic acid decreased from 2.25 to 1.37 as the level of anthracnose increased from 1 to 3, the mean percent tannic acid in accessions rating 4 and 5 was, however, higher than the level in accessions rating 3. Preliminary results suggest that a relationship may exist between plants possessing higher levels of phenols and resistance to anthracnose. Further studies are planned to identify phenols in resistant and susceptible accessions of *S. guianensis* "tardío".

Table 6. Analysis of tannins in accessions of *Stylosanthes guianensis* "tardío".

| Sample | No. of samples | Reactions to anthracnose in Carimagua | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Greenhouse | 23 | 2.50[1] | 2.98 | 1.81 | 1.74 | 1.15 |
| Field | 51 | 2.25 | 1.72 | 1.37 | 1.58 | 1.70 |

[1] % Tannic acid

Cross-protection. It has been shown that plants inoculated by non-pathogenic isolates of pathogens are protected against disease caused by subsequent infections of pathogenic isolates. Also, that primary infection by pathogenic isolates, followed by recuperation and subsequent infection by the same isolates results in less damage. Activation of chemical defense mechanisms appears to be part of the plants' resistance to some diseases, including anthracnose.

Various preliminary studies were therefore made to investigate cross-protection against anthracnose in *Stylosanthes* spp. The effect of different concentrations of inoculum on the reaction of *S. guianensis* CIAT 136 and *S. capitata* 1019 to anthracnose was studied. In each treatment the first inoculation was made with a non-pathogenic isolate and subsequent inoculations with a pathogenic isolate. In CIAT 136, no protection by the non-pathogenic isolate was found; in CIAT 1019, protection was found for the first inoculation with the pathogenic isolate; however, all other inoculations cause infection.

The effect of different concentrations of inoculum and time of recuperation on the reaction of *S. guianensis* CIAT 136 and *S. capitata* CIAT 1019 to anthracnose was also studied. In CIAT 136, no protection by either the non-pathogenic or pathogenic isolates was observed. In CIAT 1019, although no protection by the non-pathogenic isolate was observed, protection by the pathogenic isolate occurred for four weeks and six weeks after the inoculation. By 12 weeks after inoculation with the pathogenic isolate, however, plants were susceptible to the subsequent inoculation with the pathogenic isolate. Possibly there is activation of chemical defense mechanisms to anthracnose in *S. capitata* 1019, but the effect appears to be short-term and thus of little value for anthracnose resistance in *S. capitata*.

Effect of anthracnose on yield and quality of S. guianensis[1]. Although it has been known since the early 70's that *S. guianensis* is severely affected by anthracnose, no attempts have been made to quantify losses in yield and quality. A study was made during the past year of the effect of anthracnose on yield and quality of *S. guianensis* CIAT 136 and CIAT 184.

Level of disease followed the rainfall pattern closely (Figure 2). Yield reduction in dry matter over one year was 62.8% in CIAT 136 and 64.4% in CIAT 184 in relation to the fungicide protected control (Figure 3). Losses in crude protein (Figure 4), phosphorus, potassium and digestibility were of the same level.

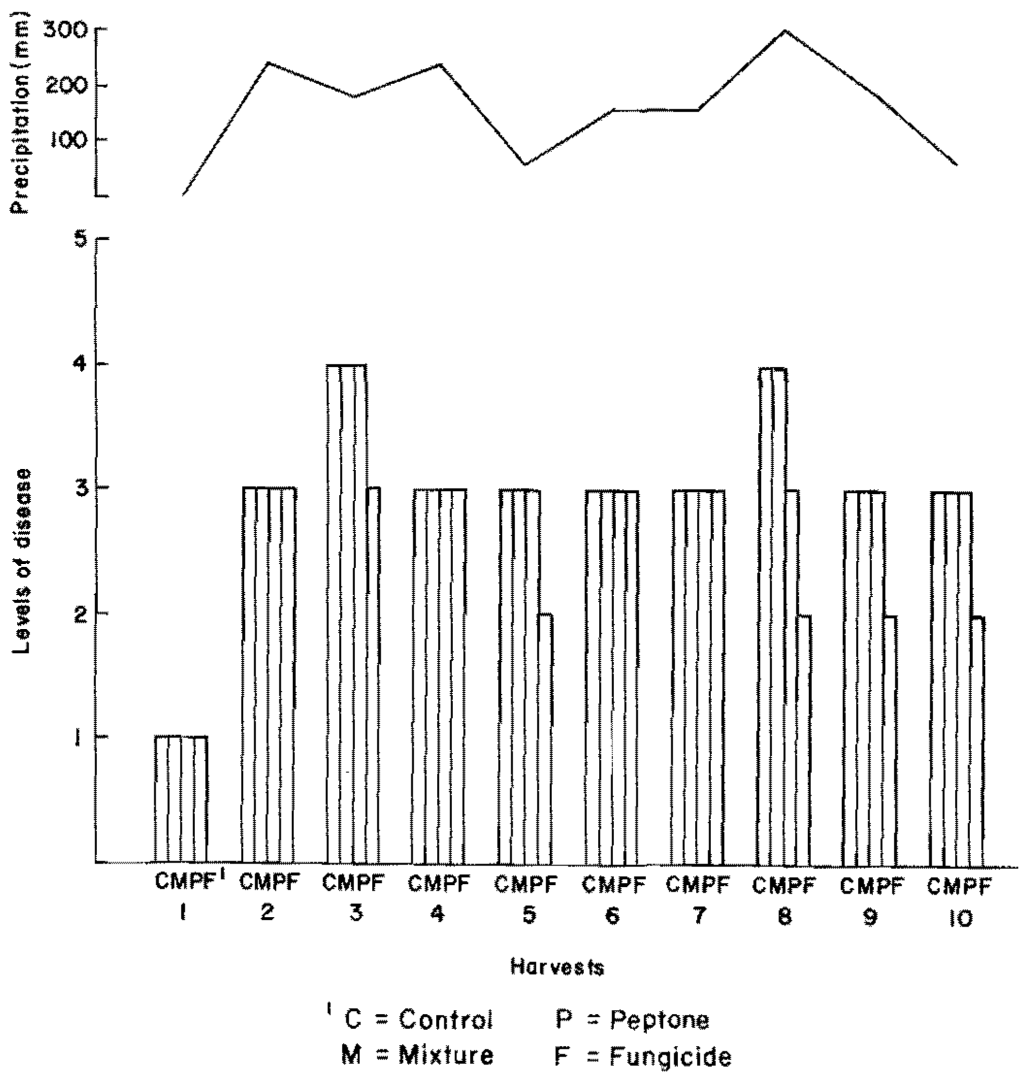



Figure 2. Levels of disease during the trial.

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[1] Student thesis project by Jorge Gutiérrez and Carlos Cardozo.

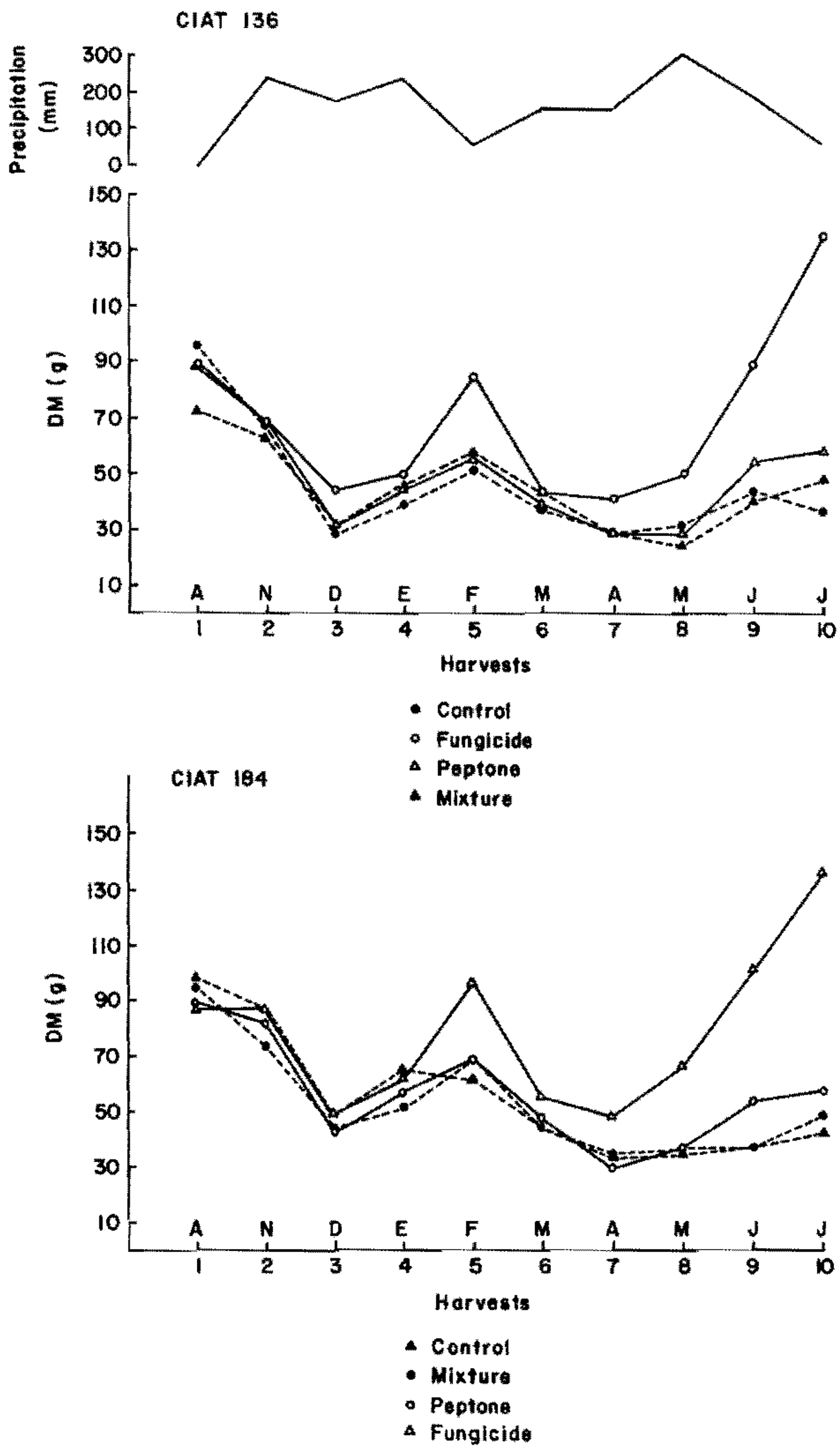



Figure 3. Yield of _S. guianensis_ by treatment and harvest.

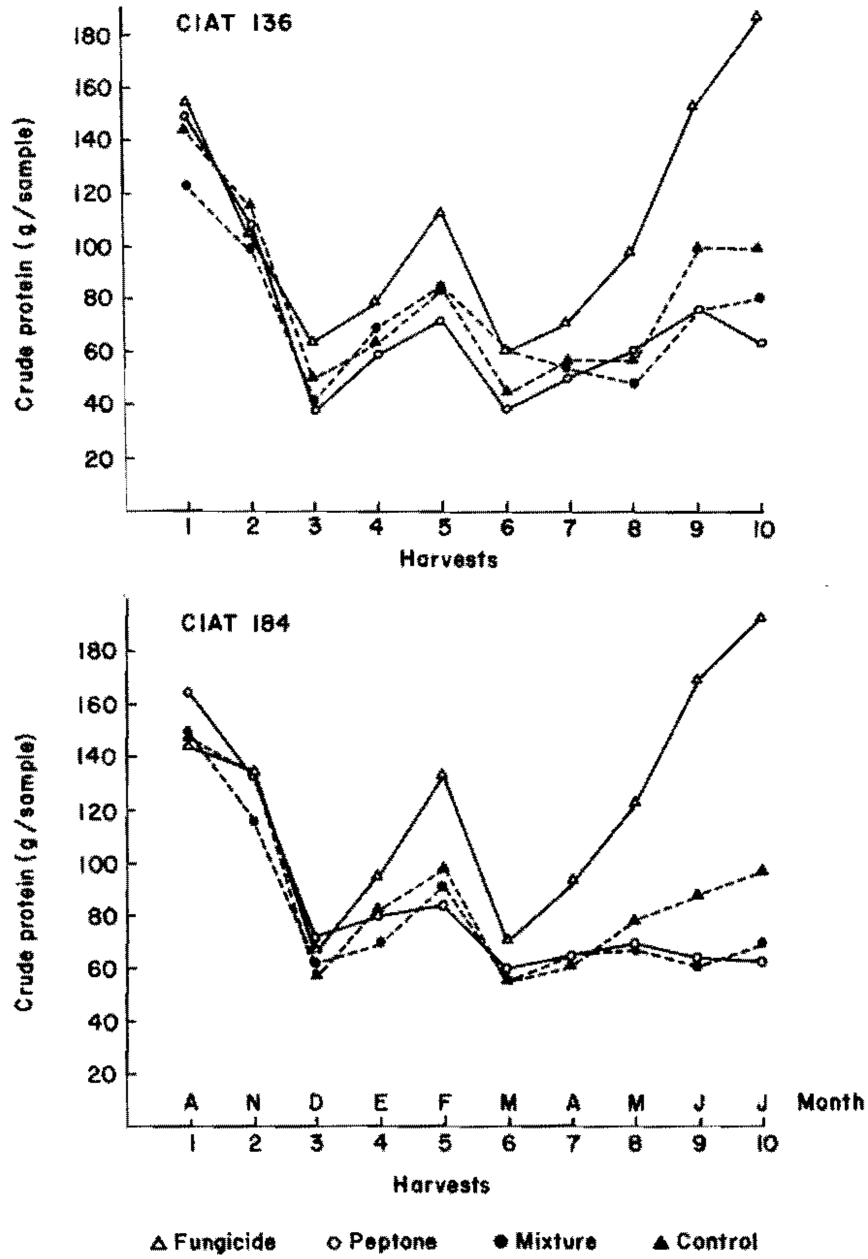



Figure 4. Production of crude protein of S. guianensis by treatment and harvest.

## Blight

Counts of S. capitata plants killed by S. rolfsii continued in Carimagua this year. Only 2-4% of plants were killed (Table 7). Viable sclerotia were again monitored at different sites in Carimagua. Levels have been considerably lower during the past two years than in 1979 (Table 8). Blight has now been classed as a minor disease of S. capitata, and no further studies of this disease are planned.

Table 7. Counts of S. capitata plants killed by Sclerotium rolfsii in Carimagua (mean of various sites).

| CIAT No. | Dead plants (%) | | |
|---|---|---|---|
| | 1979 | 1980 | 1981 |
| 1019 | 5 | 5 | 4 |
| 1315 | 9 | 6 | 2 |
| 1405 | 6 | 3 | 2 |

Table 8. Viable sclerotia of Sclerotium rolfsii in the soil at different sites in Carimagua.

| Sites[1] | Sclerotia/100 g soil (No.) | | |
|---|---|---|---|
| | 1979 | 1980[2] | 1981[3] |
| 1 | 9.8 | 2.3 | 0.3 |
| 2 | 6.8 | 1.0 | 0.8 |
| 3 | 2.7 | 0.9 | 0.4 |

[1] Sites: 1 = 3 years; 2 = 2 years; 3 = 1 year
[2] Mean of May and December samplings
[3] May sample only

### Rhizopus head blight

This disease was first detected in Carimagua in 1980 causing severe damage to several accessions of S. capitata. It was detected again in July, August and September at low levels in S. capitata in Carimagua and also in the regional trials in the Llanos. It is very similar to Rhizopus head rot of sunflower, an important disease in Asia and the Americas. Three species of Rhizopus are thought to be involved: R. arrhizus, R. oryzae and R. stolonifer. Surveys of the occurrence of this disease will continue.

## Diseases of Desmodium spp.

Germplasm surveys. Germplasm surveys of Desmodium spp. continued in Quilichao and Carimagua (Table 9). Of the more important species, D. heterocarpon has most disease problems, including anthracnose, Cercospora leaf spot, little leaf mycoplasm and root knot nematodes sporadically at Quilichao. Desmodium ovalifolium and D. heterophyllum have few disease problems.

Root knot nematode. No further studies were made on this disease due to low populations of nematodes in Quilichao.

Table 9. Disease evaluations of Desmodium spp., 1980-1981.

| Disease | D. ovalifolium[2] C | D. ovalifolium Q | D. heterocarpon C | D. heterocarpon Q | D. heterophyllum C | Others[1] C |
|---|---|---|---|---|---|---|
| Anthracnose | - | - | + | ++ | - | + |
| Cercospora leaf spot | -/+ | -/+ | + | + | + | + |
| Little leaf mycoplasma | - | - | ++ | ++ | - | ++ |
| False Rust -Synchytrium | -/++ | - | - | - | - | - |
| Root knot nematode | - | ++ | - | ++ | - | - |

[1] Others include: D. barbatum, D. tortuosum, D. scorpiurus, D. adscendens
[2] C = Carimagua; Q = Quilichao

False rust. A new disease of Desmodium ovalifolium was detected in El Tomo, Carimagua, in July. It caused distortion of young leaves, shortening of internodes and, subsequently, stunting of plants. Fruiting bodies or sori of the fungus filled with orange sporangia were produced in large quantities on the undersurface of leaves, on petioles and young stems. Galls were formed on old stems. The seed for this planting was a mixture made up of lots imported from Sri Lanka and India via Singapore. The disease was identified as Synchytrium desmodii, first described on D. ovalifolium in Sri Lanka in 1955. Because of the importance of D. ovalifolium, the El Tomo planting was destroyed and resown with Brachiaria dictyoneura. All plantings of D. ovalifolium will be surveyed periodically over the next year for false rust.

## Diseases of Leucaena sp.

Bacterial pod rot. In February 1980, pod rot was observed for the first time on Leucaena leucocephala in southern Mexico and at forage evaluation sites in Belize and Panama. In 1981, the same disease was observed in Colombia, Brazil, and Perú on cultivars of L. leucocephala Cunningham. A bacterium was consistently isolated from rotted pods and seeds, and on the basis of morphology, cultural characters, biochemical and physiological properties, it was identified as Pseudomonas flourescens Biotype 2.

Symptoms were manifest firstly as water-soaked lesions surrounding insect feeding holes. Lesions expanded and became necrotic as seeds began to rot. Under humid conditions, there was general pod rotting and bacteria oozed from insect feeding holes. Pods often fell prematurely, and few seeds were recovered from affected pods.

The bacterium caused pod rot of L. leucocephala when inoculated by injection, and bacteria were readily reisolated from affected pods. Cross-inoculation studies with four other species of Leucaena showed that all were susceptible to pod rot; however, L. diversifolia and L. shannoni were more resistant than L. esculenta and L. pulverulenta.

The development and association of lesions with insect-feeding holes under natural conditions indicated that the bacterium may be insect-borne by a Heteroptera of the family Pentatomidae (Mario Calderõn, personal communication). However, a survey of seed harvested from healthy pods of 14 accessions of L. leucocephala and one each of L. macrocephala and L. pulverulenta found 48-95% of seed infected with the bacteria (Table 10). It is possible that Pseudomonas flourescens Biotype 2 is a natural component of the microflora of Leucaena pods and seed and usually does not cause disease. However, when insects feed on pods, the wounds caused enable the bacteria to enter and cause rotting of seeds. This will be further investigated.

Table 10. Survey of Leucaena leucocephala seed for Pseudomonas flourescens Biotype 2.

| Accession of L. leucocephala | Seeds with bacteria (%) |
|---|---|
| 78-36 | 60 |
| K 4 | 66 |
| K 8 | 88 |
| K 9 | 76 |
| K 29 | 76 |
| CIAT 734 | 80 |
| K 72 | 80 |
| 78-165 | 95 |
| 78-19 | 68 |
| K 132 | 76 |
| 78-50 | 58 |
| 78-85 | 78 |
| K 341 | 48 |
| 78-24 C | 86 |
| K 340* | 50 |
| 78-65** | 64 |

* L. pulverulenta
** L. macrocephala

## Diseases of Zornia spp.

Sphaceloma scab. Evaluations of germplasm continued in major screening sites (Table 11). Most accessions in Carimagua were susceptible. Resistant accessions included Z. brasiliensis, Z. myriadena and other four-leafed types. Although Sphaceloma scab pressure was not as great in CPAC, the virus-fungus complex affected many accessions. Evaluations of regional trials in the Llanos of Colombia also showed that Sphaceloma scab is the most important disease of Z. latifolia. CIAT 9199, however, was resistant at all sites.

Table 11. Disease evaluations of Zornia spp. 1980-1981.

| Site | Sphaceloma scab evaluation | | | | Total |
|---|---|---|---|---|---|
| | R | MR | MS | S | accessions |
| Carimagua[1] | 17.0 | 6.6 | 43.9 | 32.5 | 212 |
| CPAC-LVE[1] | 25.0 | 19.3 | 52.7 | 3.0 | 72 |
| Quilichao | 44.4 | 28.9 | 0 | 16.7 | 54 |
| | **Virus-fungus complex evaluation** | | | | **Total** |
| | R | MR | MS | S | accessions |
| CPAC-LVE[1] | 31.9 | 19.4 | 33.3 | 15.4 | 72 |

[1] Collections contain a high percentage of Z. latifolia and related spp.

Bacterial wilt. Over the past year, young plants and mature plants after cutting of accessions of Z. brasiliensis and Zornia sp. CIAT 7847 wilted and often died at Quilichao and Carimagua. Of 73 accessions of Zornia sp. at Quilichao, 13 were found affected in the field. At Carimagua, however, only CIAT 7847 was affected. Cross-sections of lower stems and taproots showed brown coloration of the outer vascular tissue. The bacterium consistently isolated from affected tissues was identified as Corynebacterium flaccumfaciens on the basis of its morphological, cultural, biochemical and physiological characters.

All isolates of the bacterium caused chlorosis, wilting, dieback, and death of young plants of CIAT 7847. In addition, it caused chlorosis and severe wilting of young plants of Phaseolus vulgaris P 635. Cornyebacterium flaccumfaciens is an important pathogen of beans in the U.S.

The bacterium was readily isolated from seed of CIAT 7847 at levels ranging from 75-100% of seed infected. One hundred percent of seed from diseased plants carried the bacterium while 75% of seed from apparently healthy plants in the same plot were affected. The bacterium is able to colonize plants in a symptomless manner. It is also present in the Quilichao soil.

Further studies are in progress to determine the host range of the pathogen, especially among tropical forage legumes, to determine the survival of the bacterium in soil, and to produce clean seed. Survival was studied by locating nylon discs impregnated with bacterial suspensions in nylon bags of soil on the soil surface and at 10 cm depth. Disc samples were taken each week to determine survival by the dilution plate method. Preliminary results suggest that *C. flaccumfaciens* does not survive for long in soil without the presence of plant roots. After three weeks in the field, percent survival at the soil surface was as low as 13.8% and at 10 cm depth was 10.8%. After five weeks in the field, no colonies of *C. flaccumfaciens* were found associated with the nylon discs. Sampling is continuing; however, it appears that this bacterium can survive only in association with plants.

## Diseases of Centrosema spp.

*Germplasm surveys*. Due to increased planting of *Centrosema* spp. in Carimagua and Quilichao during the past year, detailed disease evaluations were made. Diseases detected were Cercospora leaf spot, Anthracnose, Rhizoctonia foliar blight, bacterial blight and Alternaria leaf spot. However, the importance of disease in *Centrosema* depends on the species.

In Carimagua it was found that Cercospora leaf spot has a wide host range affecting all species especially *C. pubescens* (Table 12). Rhizoctonia foliar blight affects *C. brasilianum* severely and *C. pubescéns* slightly while bacterial blight affects *Centrosema* sp. CIAT 5112, 5118 and 5278 moderately (Table 12). Anthracnose and Alternaria leaf spot are presently regarded as minor diseases. *Centrosema macrocarpum* has less disease problems than other species. A similar species-disease pattern was found in Quilichao; however, Bacterial blight was severe on CIAT 5112, 5118 and 5278 and also affected *C. virginianum* and *C. brasilianum*. Due to their severity on particular species of *Centrosema*, the two diseases are being studied further.

Table 12. Diseases commonly associated with species of *Centrosema* in Carimagua.

| Species | CLS[1] | A | RFB | BB | ALS |
|---|---|---|---|---|---|
| *C. brasilianum* | + | + | +++ | | + |
| *C. macrocarpum* | + | | | | |
| *C. plumieri* | ++ | + | | | + |
| *C. pubescens* | +++ | + | + | + | ++ |
| *Centrosema* sp.[2] | ++ | | | ++ | |

[1] CLS = Cercospora leaf spot; A = anthracnose; RFB = Rhizoctonia foliar blight; BB = bacterial blight; ALS = Alternaria leaf spot.

[2] CIAT 5112, 5118, 5278

Bacterial leaf spot and dieback of Centrosema spp. In 1980 and 1981, a previously unreported leaf spot and dieback of young growth was detected on accessions of *C. brasilianum*, *C. plumieri*, *C. pubescens*, *C. virginianum* and *Centrosema* spp. at Quilichao and Cariamgua. At Quilichao, leaf spotting and dieback appeared to greatly reduce yield of promising accessions of *Centrosema* sp. CIAT 5112, 5118 and 5278. This disease, however, was less severe in Carimagua. A bacterium was consistently isolated from affected plants and was identified as a species of *Pseudomonas*.

The first symptoms expressed were wilting of young leaves and terminals and chlorotic spotting of mature leaves. Young leaves and terminals became partially or completely necrotic and dieback developed. On mature leaves, chlorotic spots became necrotic and were of varying size and shape. Leaves were often crinkled or distorted.

All isolates of the bacterium caused wilting, dieback and necrotic spotting of four-week old plants of *Centrosema* spp. in pathogenicity tests. The bacterium was also found associated with seed of CIAT 5112 and 5118 at levels of infection ranging from 8 to 32%.

High susceptibility to bacterial leaf spot and dieback appears to be restricted to accessions of *Centrosema* sp. CIAT 5112, 5118, 5277 and 5278 which are similar morphologically. Although it has been isolated from accessions of five other *Centrosema* spp., few accessions are more than slightly affected.

Rhizoctonia foliar blight. In the past, Rhizoctonia foliar blight (RFB) was considered a minor disease in Carimagua occasionally attacking *Pueraria* and *Macroptilium*. Since 1980, however, RFB has been observed as an important disease of *Centrosema brasilianum* in Carimagua.

Observations and rating of RFB in two *Centrosema brasilianum* plantings were made each month during 1981. Levels were found generally high early in the wet season but declined as the wet season progressed, with lowest levels of damage being recorded to date in September. Exceptions were 5173 where damage increased and 5367 where damage remained at a low level. Because rainfall and, probably, relative humidity increased, as disease level decreased, and because RFB is favored by high humidity, climatic conditions failed to explain the decrease in RFB.

One possible explanation is an increase in the population of antagonists of *R. solani* in soil and on foliage which reduced the population of the fungus. A study of natural antagonists of *Rhizoctonia* has been initiated. High populations of *Trichoderma* spp., known antagonists of *R. solani*, have been found associated with soil and on leaves from plots of *C. brasilianum* with reduced RFB. In addition, various fungi, bacteria and actinomycetes have been isolated. Antagonism tests with these micro-organisms and *R. solani* are planned.

Studies are also being made on the pathogenicity of various isolates of *R. solani* from *C. brasilianum*, *Desmodium ovalifolium* and from Phaseolus vulgaris to Centrosema spp. All four isolates of R. solani from C. brasilianum were pathogenic to 4-week-old seedlings of C. brasilianum, C. pubescens 438 and C. macrocarpum 5065 (Table 13). They were also pathogenic to five cultivars of Phaseolus vulgaris. Isolates from D. ovalifolium were slightly pathogenic to Centrosema spp. and Phaseolus vulgaris. Four isolates from Phaseolus vulgaris, however, were variable in pathogenicity.

Table 13. Reaction of Centrosema spp. to isolates of Rhizoctonia solani from Centrosema brasilianum, Desmodium ovalifolium and Phaseolus vulgaris.

| Centrosema spp. Accession No. | Reaction to Rhizoctonia solani: Isolates from C. brasilianum[1] | Isolates from D. ovalifolium | Isolates from P. vulgaris[2] |
|---|---|---|---|
| 438 | +++ | +++ | + → +++ |
| 5055 | +++ | ++ | + → +++ |
| 5062 | +++ | ++ | + → +++ |
| 5065 | ++ | ++ | + → +++ |
| 5173 | ++++ | ++ | - → +++ |
| 5178 | ++++ | ++ | + → ++++ |
| 5184 | ++++ | ++ | - → +++ |
| 5234 | ++++ | ++ | - → +++ |
| 5247 | +++ | ++ | - → ++ |
| 5369 | ++++ | ++ | - → +++ |
| 5372 | +++ | ++ | + → +++ |

[1] Isolates from Centrosema brasilianum CIAT 5178, 5211, 5369, 5372, Carimagua

[2] Isolates from foliage of P. vulgaris Restrepo 1981, Huila 486, 1980. Isolates from roots of P. vulgaris I, II

## Diseases of Andropogon gayanus

Rhynchosporium leaf spot. Studies on the effect of Rhynchosporium leaf spot (RLS) on yield of A. gayanus both with and without grazing continued this year at La Libertad, Villavicencio. Results from the 1980 harvest showed no effect of RLS on yield of A. gayanus (Annual Report, 1980). The second harvest was taken in August this year (Table 14). In the medium stocking rate plot, no significant differences were found among the four treatments. Although the highest level of RLS lesions was found in the treatment without grazing and fungicide, it was as low as 8.3 lesions per 100 leaves. As RLS was present as foci of infection, further evaluations during the year may show higher levels of infection. In the high stocking rate plot, the ungrazed treatments significantly outyielded the grazed treatments; however, there were no differences between treatments with and without fungicide. The RLS level in this plot was extremely low.

Table 14. Effect of Rhynchosporium leaf spot on *Andropogon gayanus*. Harvest August 4, 1981.

| Treatment | Dry weight ($g/m^2$) | Moisture content (%) | Lesion No. |
|---|---|---|---|
| Medium stocking rate | | | |
| A. Without anim. & fung. | 361 a | 46.9 | 8.3 |
| C. Without anim. & with fung. | 425 a | 53.8 | 2.0 |
| B. With anim. without fung. | 432 a | 43.9 | 3.0 |
| D. With anim. & fung. | 379 a | 38.9 | 2.0 |
| High stocking rate | | | |
| G. Without anim. & fung. | 238 b | 53.3 | 1.3 |
| E. Without anim. with fung. | 273 ab | 58.4 | 0 |
| H. With anim. without fung. | 135 c | 55.0 | 0 |
| F. With anim. & fung. | 88 c | 52.7 | 0 |

Harvests will continue every two months. Samples are also being taken to determine forage quality. At present, it appears that RLS is a minor disease of *A. gayanus*. It has been detected on *A. gayanus* at other sites including Carimagua, Quilichao and regional trials in various countries. In all cases, only a few spots have been found. In addition, studies are continuing on the identity of the *Rhynchosporium* which attacks *A. gayanus* and its relation to *Rhynchosporium oryzae* which attacks rice. Isolates of the fungi are being collected from both. Cross-inoculation studies will be made later this year.

## Effect of Different Levels of Various Fertilizers on the Reaction of Tropical Forages to Insect Pests and Diseases

The effects of fertility on disease development and resistance in crops has received much attention in the past. Diseases caused by bacteria, fungi, nematodes and viruses have been shown to be affected by fertilization. For various pathogens, evidence has accumulated that increasing levels of potassium reduced disease levels, while increasing levels of nitrogen increased them.

An experiment was set up in Carimagua in May to determine the effect of different levels of various fertilizers on the reaction of tropical forages to diseases and insect pests, in collaboration with the Entomology Section. With the exception of *Centrosema pubescens* 438, disease levels are low, and trends in the reaction of diseases to different fertilizers are not yet obvious. For *C. pubescens* 438, the highest levels of Cercospora leaf spot were found in zero Mg and high Ca treatments while the highest levels of Rhizoctonia foliar blight were observed in the zero S treatment. It is also planned to assess the most important problem, either disease or pest, in each forage at each fertilizer treatment in collaboration with the Entomology Section.

## Surveys of Diseases and Pests of Native and Naturalized Legumes and Grasses

Periodic surveys of diseases of native and naturalized legumes and grasses are being made in various sites in Colombia and other countries to gain more information about the range and types of pathogens that may affect tropical forages. In Central and South America collections are being made for pathogenicity tests of isolates of *Colletotrichum* spp. mainly from *Stylosanthes* spp. in Colombia.

## Classification of Diseases of Tropical Forage Plants According to Host and Country

During the past year information was collected and collated on diseases of tropical forage plants. The major sources of information were the Commonwealth Mycological Institute, Mycological and Phytopathological Papers, Host-Disease lists from as many tropical countries as possible, including Asia, Africa, Australia, Caribbean, Central America and South America, and miscellaneous papers on the microflora of various countries. This information is being developed into a manual that should provide useful information to plant pathologists and agronomists working with tropical forages.

## Seed Pathology

Surveys of changes occurring in the microflora of *S. capitata* seed in Carimagua and CIAT-Quilichao continued during 1981. Surveys concentrated on *Aspergillus* spp. which are noted for aflatoxin production in seed. After a two-year survey in Carimagua it was found that the percentage of both green and dry seed infected with *Aspergillus* spp. increased toward the end of the wet season and reached a maximum in the dry season before declining as the wet season progressed (Figure 5). Cattle are therefore eating more seed at the time when most seed is infected with *Aspergillus* spp.

Ten different species of *Aspergillus*, including four potential toxin producers, have been isolated from seed since May 1979 (Table 15). *Aspergillus favus* and *A. ochraceous*, both potential toxin producers, were most commonly associated with seed in Carimagua (Table 15). Analysis of toxin production by isolates of both *A. flavus* and *A. ochraceous* associated with *S. capitata* seed is in progress in collaboration with Universidad del Valle.

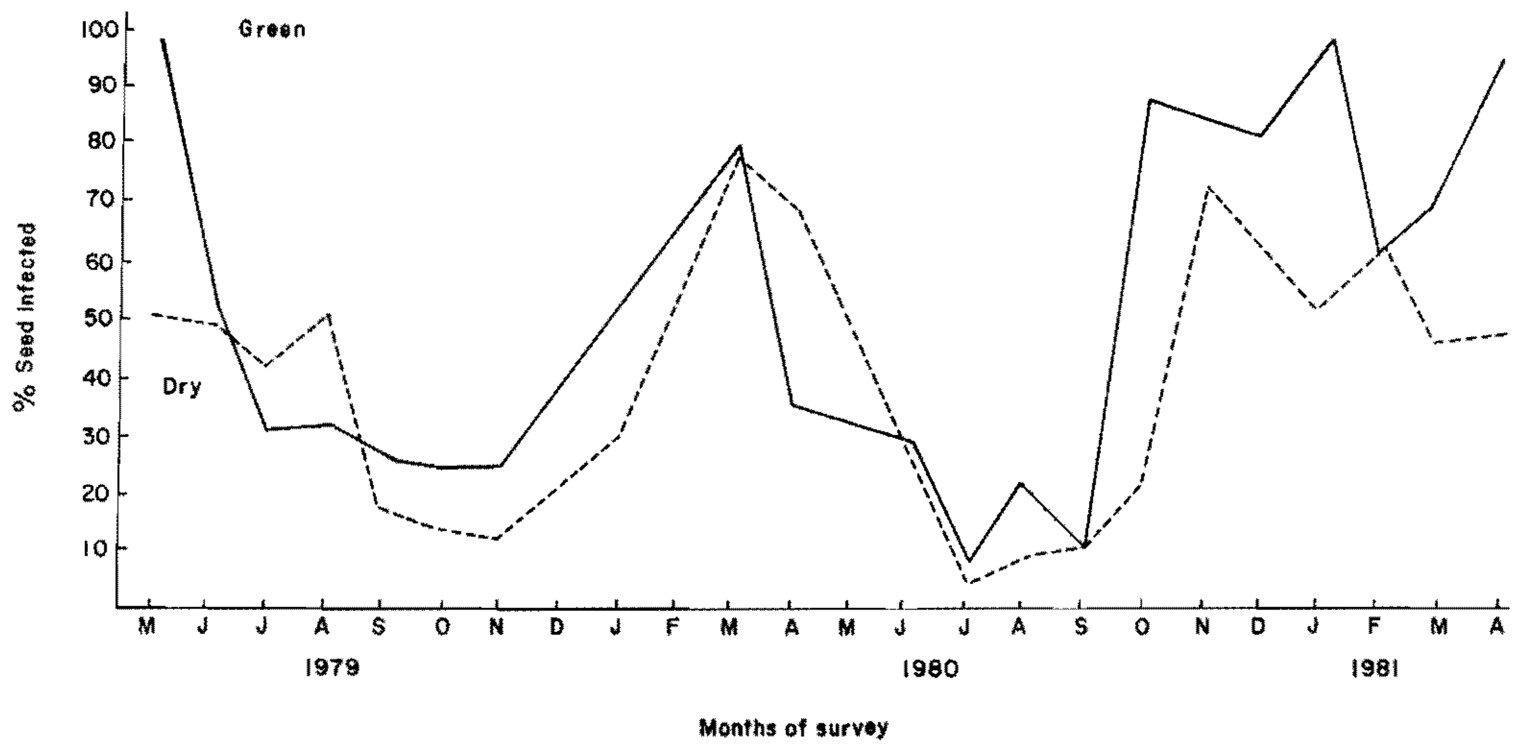



Figure 5. Percentage of dry and green seed of S. capitata infected with Aspergillus spp. in Carimagua.

Table 15. Species of *Aspergillus* associated with seed of *S. capitata* in Carimagua.

| Species | Frequency of isolation (%) | Potential toxin producers |
|---|---|---|
| *A. flavus* | 74 | T |
| *A. ochraceous* | 17 | T |
| *A. niger* | 4 | |
| *A. fumigatus* | 3 | T |
| *A. terreus* | 1 | |
| *A. versicolor* | 0.5 | |
| *A. sydowii* | 0.2 | |
| *A. nidulans* | 0.1 | T |
| *A. chevalieri* | 0.1 | |
| *A. tamarii* | 0.1 | |

## Biological Control of Spittlebug with Entomogenous Fungi

In 1980, a project in collaboration with the Entomology Section was begun on biological control of spittlebug with entomogenous fungi, in particular, *Metarrhizium anisopliae*. Indigenous entomogenous fungi were collected from various pasture evaluation sites in Colombia, including Carimagua, Quilichao, Popayán, Espinal, from infected nymphs and adults of spittlebug and from soil (Table 16). A selective medium was developed to readily isolate *M. anisopliae* from soil. In addition, 35 isolates were obtained from various countries either by collection or request (Table 15). These isolates are being evaluated in pathogenicity and soil survival studies.

Pathogenicity studies were made with 45 isolates of *Metarrhizium* spp. on nymphs and adults of the spittlebug *Zulia colombiana* Lallemand on *Brachiaria decumbens* in pots placed in cages in the greenhouse. Data was taken on death of nymphs and adults, reisolation of fungi and development of adults from inoculated nymphs. Among isolates there was a wide range in percent pathogenicity (Table 15). Of 45 isolates, 25 were rated as pathogenic. Two isolates CAR 7 from Carimagua, Colombia, and FL 11 from Australia, were 100% pathogenic on both nymphs and adults (Table 16).

Studies were also begun on the effect of soil infested with the most pathogenic isolates of *Metarrhizium* spp. on nymphs emerging from soil. Plants of *B. decumbens* were established in trays of fungus-infested soil with four isolates of *M. anisopliae* - CAR 1, CAR 7, FL 11 and FL 12 (Table 17). Emergence of nymphs was irregular and low. This may be due to the methods of placing eggs in the soil and will be further investigated. Pathogenicity to emerging nymphs of infested soil was high for CAR 1 and FL 11.

Table 16. Pathogenicity of isolates of Metarrhizium spp. to nymphs and adults of the spittlebug Zulia colombiana.

| Isolate | Origin | Host | Pathogenicity[1] | |
|---|---|---|---|---|
| | | | Nymphs | Adults |
| BE 1 | Belize | Spittlebug - Adult | 50 | 100* |
| ES 9 | Brazil | Spittlebug - Adult | 50 | 83* |
| MET 1 | Japan | Bombyx mori | 25 | 16 |
| MET 4 | Japan | | - | 50 |
| MET 5 | Japan | Ornebius kanetataki | 75 | 83* |
| MET 6 | Japan | Popillia japonica | 25 | 16 |
| EU 1 | USA | Nemocestus incomputus | - | 50 |
| MET 3258 | New Zealand | Porina sp. | - | - |
| MET 3259 | New Zealand | Black beetle | - | 33 |
| MET 3095 | New Zealand | Costrelytra | 25 | 83 |
| MET 4560 | New Zealand | Rhinoceros beetle | - | 67 |
| CBS 130-22 | Holland | | 25 | 83 |
| CBS 285-59 | Holland | | 25 | 50 |
| CBS 431-64 | Holland | | 50 | 67 |
| CBS 248-64 | Holland | | 50 | 67 |
| CBS 218-56 | Holland | | 25 | 83 |
| CAR 1 | Colombia | Aeneolamia reducta - Adult | - | 100* |
| CAR 2 | Colombia | Soil | 16 | - |
| CAR 3 | Colombia | Aeneolamia reducta - Nymph | 33 | 83 |
| CAR 4 | Colombia | Aeneolamia reducta - Nymph | 83 | 33 |
| CAR 5 | Colombia | Aeneolamia reducta - Nymph | 33 | 50 |
| CAR 6 | Colombia | Mocis sp. - Larva | 16 | 67 |
| CAR 7 | Colombia | Mocis sp. - Larva | 100 | 100* |
| QUIL 1 | Colombia | Zulia colombiana - Adult | 33 | 16 |
| POP 1 | Colombia | Soil | 33 | 16 |
| ESP 1 | Colombia | Soil | 67 | 33 |
| FL 5 | Australia | Telegrillus commodus | 67 | 50 |
| FL 6 | Australia | Rhopaea verreauxi | 100 | 67 |
| FL 7 | Australia | Rhopaea verreauxi | - | 67 |
| FL 8 | Australia | Rhopaea verreauxi | 100 | 83 |
| FL 11 | Australia | Anoplognathus porosus | 100 | 100* |
| FL 12 | Australia | Rhopaea magnicornis | 100 | 83 |
| FL 13 | Australia | Sevicesthis geminata | 67 | - |
| FL 14 | Australia | Sevicesthis nigrolineata | 100 | 33 |
| FL 19 | Australia | Rhopaea verreauxi | 33 | 50 |
| RS 324 | Australia | Austraeris sp. | 83 | 83 |
| RS 435 | Australia | Cricket | - | 50 |
| RS 440 | Australia | Cricket | 16 | 16 |
| RS 445 | Australia | Cricket | 100 | 33 |
| RS 473 | Australia | Soil | 100 | 33 |
| RS 297 | West Samoa | Rhinoceros beetle | 100 | 50 |
| RS 455 | Philippines | Brown plant hopper | - | 16 |
| RS 457 | Philippines | Brown plant hopper | - | 16 |
| RS 485 | Philippines | Brown plant hopper | 100 | 67* |
| RS 487 | Philippines | Brown plant hopper | 50 | 50 |

1 Pathogenicity determined with three replications of six nymphs and six adults
* Selected isolates for soil survival studies

Due to a lack of suitable sites with high populations of spittlebug during the past year, there was a delay in setting up pathogenicity tests in the field. However, an experiment was set up in Carimagua in September in an infested pasture of B. decumbens and P. phaseoloides. Seven isolates of M. anisopliae selected on the basis of greenhouse pathogenicity tests have been applied to determine their pathogenicity to spittlebug nymphs (Table 18).

Table 17. Pathogenicity to nymphs of spittlebug Zulia colombiana of soil infested with Metarrhizium anisopliae.

| Isolate | Country of origin | Emergence of nymphs (%) | Pathogenicity (%) |
|---|---|---|---|
| CAR 1 | Colombia | 22.5 | 67 |
| CAR 7 | Colombia | 22.5 | 0 |
| FL 11 | Australia | 30.0 | 75 |
| FL 12 | Australia | 27.5 | 36 |
| Control | | 10.0 | 0 |

Table 18. Survival of isolates of Metarrhizium sp. in wet* and dry soil from Quilichao under laboratory conditions.

| Isolate | Origin | Host | Survival after 3 months | |
|---|---|---|---|---|
| | | | Wet soil | Dry |
| soil | | | | |
| BE 1 | Belize | Spittlebug - Adult | + | + |
| ES 9 | Brazil | Spittlebug - Adult | + | + |
| MET 1 | Japan | Bombyx mori | + | + |
| MET 4 | Japan | | + | - |
| MET 5 | Japan | Ornebius kanetataki | + | + |
| MET 6 | Japan | Popillia japonica | - | - |
| EU 1 | USA | Nemocestus incomputos | + | - |
| MET 3258 | New Zealand | Porina sp. | + | + |
| MET 3259 | New Zealand | Black beetle | + | + |
| MET 3095 | New Zealand | Costrelytra | - | - |
| MET 4560 | New Zealand | Rhinoceros beetle | + | + |
| CBS 130-22 | Holland | | + | + |
| CBS 285-59 | Holland | | - | - |
| CBS 431-64 | Holland | | - | - |
| CBS 248-64 | Holland | | - | - |
| CBS 218-56 | Holland | | - | + |
| CAR 1 | Colombia | Aeneolamia reducta - Adult | + | + |
| CAR 2 | Colombia | Soil | - | - |
| CAR 3 | Colombia | Aeneolamia reducta - Nymph | - | + |
| CAR 4 | Colombia | Aeneolamia reducta - Nymph | - | - |
| CAR 5 | Colombia | Aeneolamia reducta - Nymph | + | + |
| CAR 6 | Colombia | Mocis sp. - Larva | + | + |
| CAR 7 | Colombia | Mocis sp. - Larva | + | + |
| QUIL 1 | Colombia | Zulia colombiana - Adult | + | + |
| POP 1 | Colombia | Soil | - | - |
| ESP 1 | Colombia | Soil | + | + |
| FL 5 | Australia | Telegrillus commodus | - | - |
| FL 6 | Australia | Rhopaea verreauxi | - | + |
| FL 7 | Australia | Rhopaea verreauxi | - | + |
| FL 8 | Australia | Rhopaea verreauxi | - | + |
| FL 11 | Australia | Anoplognathus porosus | + | + |
| FL 12 | Australia | Rhopaea magnicornis | + | + |
| FL 13 | Australia | Sevicesthis geminata | + | + |
| FL 14 | Australia | Sevicesthis nigrolineata | - | - |
| FL 19 | Australia | Rhopaea verreauxi | - | - |
| RS 324 | Australia | Austraeris sp. | + | + |
| RS 435 | Australia | Cricket | + | + |
| RS 440 | Australia | Cricket | - | - |
| RS 445 | Australia | Cricket | - | + |
| RS 473 | Australia | Soil | - | - |
| RS 297 | West Samoa | Rhinoceros beetle | + | + |
| RS 455 | Philippines | Brown plant hopper | + | + |
| RS 457 | Philippines | Brown plant hopper | - | - |
| RS 485 | Philippines | Brown plant hopper | - | + |
| RS 487 | Philippines | Brown plant hopper | + | - |

*Soil was wet at the time of inoculation with fungi

The value of any fungus as a biological control agent depends not only on its pathogenicity but also on its survival and persistence in the environment. Studies were therefore begun on survival on *M. anisopliae* in soil. Firstly, survival of isolates in wet and dry soil from Quilichao was studied under laboratory conditions in petri plates. After three months (Table 19) 28 isolates were readily reisolated from dry soil while 24 isolates could be reisolated from wet soil. Fourteen isolates did not survive in either soil including three isolates from Holland and five from Australia. Of the four isolates originally obtained from soil, three did not survive in Quilichao soil. It is becoming apparent that the ability of *M. anisopliae* to survive in the soil environment is just as important as its pathogenicity to spittlebug. Of those pathogenic isolates selected for field studies, BE 1, ES 9, MET 5, CAR 1, CAR 7, FL 11 and RS 485, all survived in both soils with the exception of RS 485 in wet soil. Studies are continuing on survival in different soil types.

Secondly, studies were begun on survival of pathogenic isolates in the field in Quilichao and Carimagua. Seven pathogenic isolates (Table 16) were used in both sites, and in Quilichao the isolate Quil 1 was used as a control. Plots of *B. decumbens* were selected and treatments included four pasture cuttings at heights of 2, 10, 20 and 40 cm, and application of the fungi as powder or in suspension with water. Rate of application was 100 kg/ha of rice/fungus mixture with a spore concentration averaging $10^7$ spores/g of mixture. Soil samples will be taken each month to assess survival of these fungi.

# Entomology

Entomology research during 1981 continued to pursue the following main objectives:

a) To systematically evaluate the germplasm bank for plant materials tolerant or resistant to insect pests;

b) to study insect taxonomy, biology and population dynamics of the most important pests, and

c) to evaluate germplasm included in regional trials for insect damage in various ecosystems.

Basically, the Section continued studies on the stemborer, still considered the most important pest of the genus Stylosanthes; on spittlebug, the most important pest of several grasses; it completed studies on population fluctuations of the false army worm and yellow aphid on grasses. It also initiated studies on the components of natural biological control of spittlebug and false army worm, especially in the Carimagua environment.

## Pests of Legumes

### Stemborer

Field evaluations have shown that most accessions of Stylosanthes guianensis, and some of Stylosanthes capitata, are badly affected by the stemborer Caloptilia sp. This pest causes yield reductions and makes the stems breakable under grazing, greatly affecting persistance of the legumes.

The legume Stylosanthes is still considered promisory by the Tropical Pastures Program. Thus, studies on the stemborer were continued to better understand resistance or tolerance observed in this genus to the stemborer attack. On the basis of previous studies, research was conducted this year to understand field resistance observed and to complete information concerning antibiosis reported in S. capitata species. Results have shown clearly that the antibiosis effect of S. capitata is affecting more the biology of the progeny coming from females reared on S. capitata substrate than progeny coming from males reared on S. guianensis substrate (Tables 1 and 1A).

Stem hardness, a characteristic of several Stylosanthes species, is considered an important resistance factor, which restricts the ability of the larvae to penetrate and bore the stem. A penetrometer was used to measure the degree of stem hardness, and this was correlated to percentage of stemborer infestation. Considering different ecotypes of S. guianensis and S. capitata, it could be shown that harder ones - those with more sclerenchyma -- present less stemborer damage. In

Table 1. Effect of food substrate on the biology of the stemborer *Caloptilia* sp.

| Female from accessions | Male from accessions | Substrate | No. eggs | No. larvae | No. pupae | No. adults | Longevity (mean days) |
|---|---|---|---|---|---|---|---|
| *S. guianensis* CIAT 136 | *S. capitata* CIAT 1019 | *S. guianensis* CIAT 136 | 41 | 29 | 28 | 26 | 6.3 |
| *S. capitata* CIAT 1019 | *S. guianensis* CIAT 136 | *S. guianensis* CIAT 136 | 25 | 18 | 17 | 16 | 5.0 |



Table 1A. Effect of food substrate on the biology of the stemborer *Caloptilia* sp.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *S. guianensis* CIAT 136 | *S. guianensis* CIAT 136 | *S. guianensis* CIAT 136 | 53 | 52 | 49 | 48 | 6.9 |
| *S. capitata* CIAT 1019 | *S. capitata* CIAT 1019 | *S. capitata* CIAT 1019 | 16 | 8 | 7 | 2 | 4.3 |

contrast, softer ones -- those with less sclerenchyma layers -- suffer more stemborer damage, with a $r^2 = .83$ (Figure 1). These results are consistent with last year's results. This year, two-year data were completed from a series of experiments on the effect of management on stemborer incidence. Records have shown that the association A. gayanus-S. capitata is superior to B. decumbens-S. capitata. The parameters considered showed higher reduction in number of larvae per plant, percentage of infestation and length of tunnels (Table 2). Grazing reduced incidence of stemborer damage, suggesting good reduction in stemborer populations under field conditions in Carimagua (Table 3).

Budworm

Special emphasis was given to studies on oviposition preference of the budworm Stegasta bosquella (Chambers), considering Stylosanthes spp. and Zornia spp., the two genera most affected by this insect. These studies showed that the females oviposit according to the number of inflorescences available. Consequently, higher oviposition occurs in the outer parts of the branches which is where inflorescences are mainly found. Another study to determine the larval damage of S. bosquella in S. capitata showed that the estimated damage caused by an infestation of one larva/inflorescence was related to the seed production capability of the ecotype. In Z. latifolia this relation was not so evident probably because the seed production capability of the ecotypes under study is similar (Figures 2 and 3).

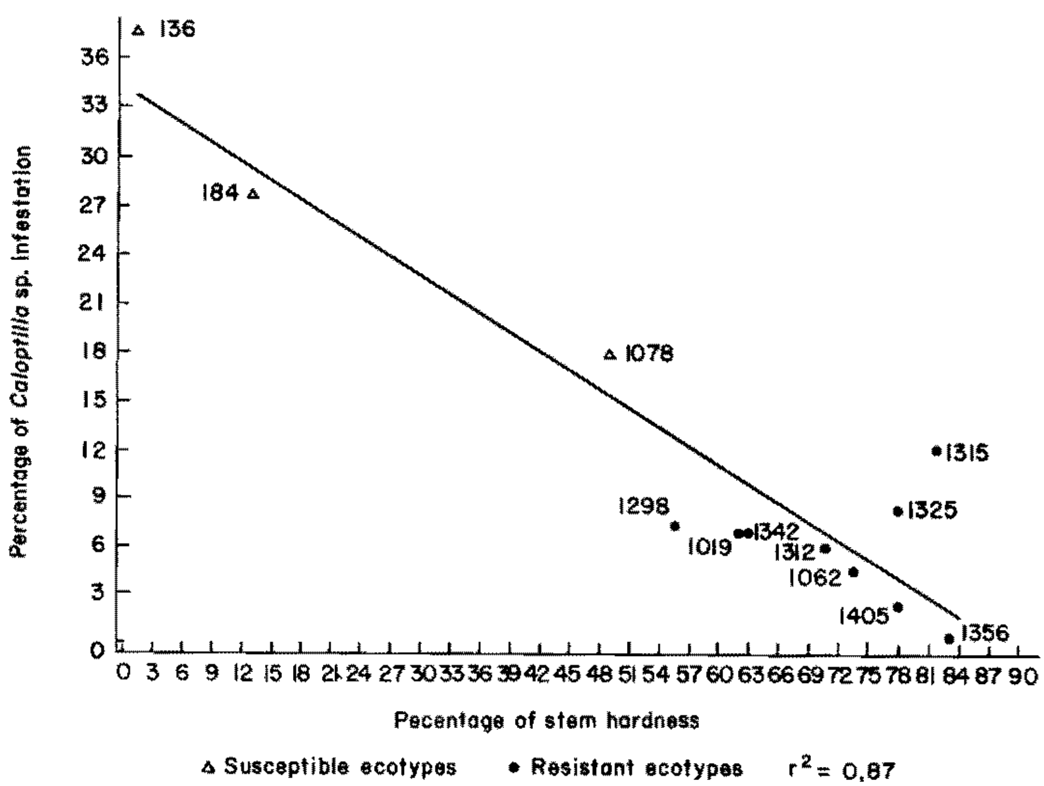



Figure 1. Relationship between percentage of stem hardness and percentage of stemborer infestation in Stylosanthes spp.

Table 2. Effect of associated grass on the incidence of stemborer *Caloptilia* sp. on *Stylosanthes capitata*.

| Parameters | *S. capitata* pure stand (1) | *S. capitata* + *B. decumbens* (2) | *S. capitata* + *A. gayanus* (3) | % reduction 1-2 | % reduction 1-3 |
|---|---|---|---|---|---|
| No. larvae/plant | 0.20 a[1] | 0.17 ab | 0.14 b | 15.0 | 30.0 |
| % plant infested | 28.68 a | 22.51 b | 21.57 b | 21.3 | 24.8 |
| Tunnel length (cm)/plant | 0.32 a | 0.29 ab | 0.27 b | 9.4 | 15.6 |

[1] Means followed by the same letter in the rows do not differ significantly at P = 0.05 level (Duncan).

Table 3. Effect of grazing on the incidence of stemborer Caloptilia sp. on Stylosanthes capitata.

| Parameters | Ungrazed | Grazed | % reduction |
|---|---|---|---|
| No. larvae/plant | 0.20 a[1] | 0.14 b | 30.0 |
| % of infestation | 25.64 a | 22.87 b | 10.8 |
| Tunnel length (cm)/plant | 0.33 a | 0.25 b | 24.2 |

[1] Means of the row followed by the same letter do not different significantly at P = 0.05 level (Duncan)

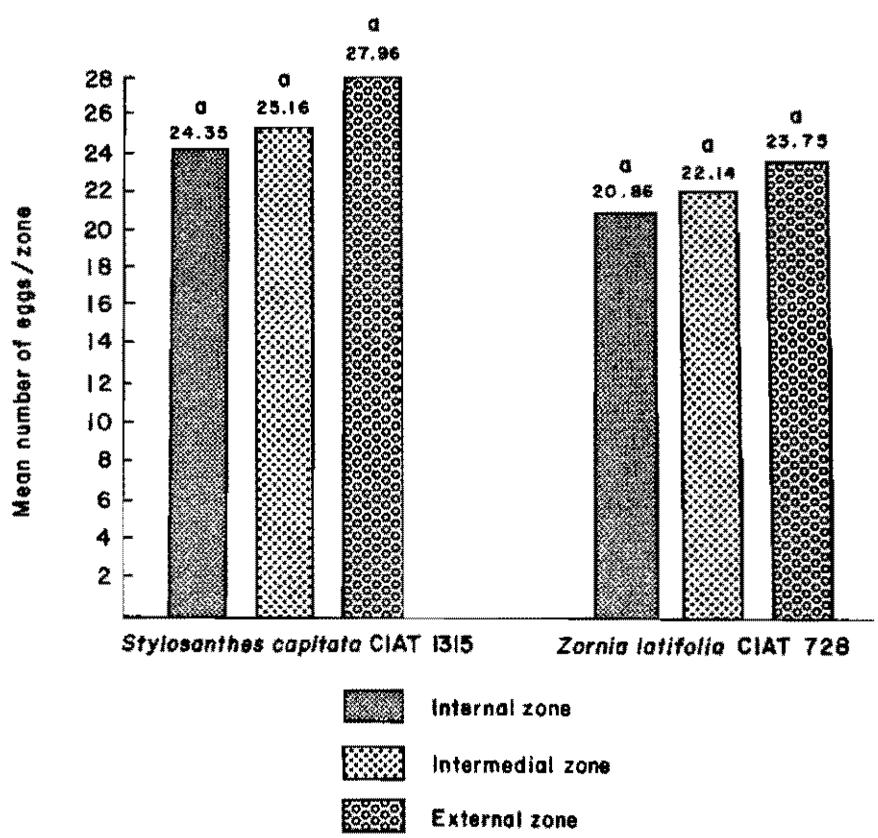



Figure 2. Oviposition preference of Stegasta bosquella (Chambers) on different conventional zones of branches of Stylosanthes capitata and Zornia latifolia plants.

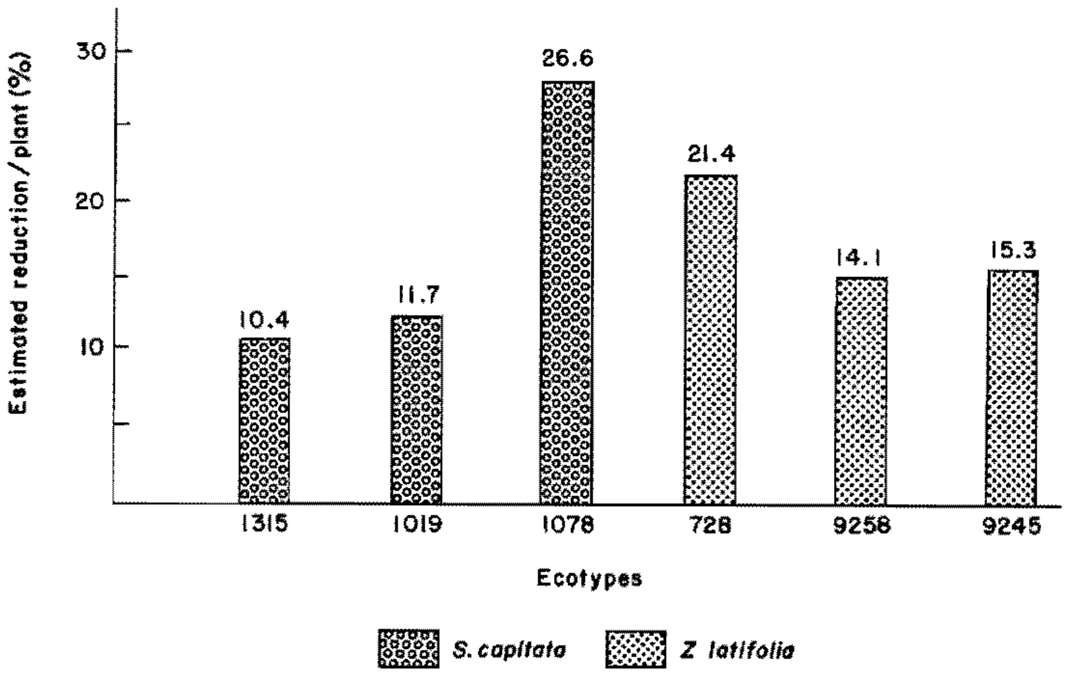



Figure 3. Estimated reduction in seed production of different ecotypes of S. capitata and Z. latifolia, with an infestation level of 1 larva/inflorescence.

In order to determine the critical level of damage of this insect in a given ecosystem, it is necessary to consider the species, seed production capacity, inflorescence size, and flowering time. On such basis it is possible that the losses in seed production caused by S. bosquella may be slight in early flowering plants with good seed production capacity and big seed heads (e.g., some ecotypes of S. capitata).

Desmodium ovalifolium

Preliminary experiments to study possible effect of fertilization on pest incidence were initiated this year in Carimagua. The experiment was set up utilizing D. ovalifolium and four different fertilization levels (Table 4). Results showed that high N content (complete fertilization) and high P content in the tissue had higher Crisomelidae damage. On the basis of these preliminary results, another experiment with promising plant material was set up in order to better understand the relationship between fertilization and disease and pest incidence.

Table 4. Differences in N and P content in foliage of D. ovalifolium with four fertilization levels and different degrees of Crisomelidae damage.

Nitrogen

| Fertilization level | No damage | Damage Slight | Moderate | Severe |
|---|---|---|---|---|
| 1 | 1.79 a[1] | 1.74 a | 1.75 a | 1.80 a |
| 2 | 1.74 a | 1.71 a | 1.67 a | 1.77 a |
| 3 | 1.71 b | 1.74 b | 1.71 b | 1.82 a |
| 4 | 2.18 b | 2.13 b | 2.05 b | 2.28 a |

Phosphorus

| Fertilization level | No damage | Slight | Moderate | Severe |
|---|---|---|---|---|
| 1 | 0.125 a | 0.121 a | 0.125 a | 0.127 a |
| 2 | 0.149 a | 0.146 b | 0.147 b | 0.156 a |
| 3 | 0.141 b | 0.145 b | 0.144 b | 0.157 a |
| 4 | 0.149 b | 0.144 b | 0.142 b | 0.152 a |

[1] Means followed by the same letter in the rows do not differ significantly (DMS; P = 0.05)

## Pests of Grasses

### Spittlebug (Zulia colombiana - Aeneolamia reducta)

During 1981, the attempt to characterize the damage of spittlebug at different stages of its life cycle was intensified. Research was conducted in Carimagua and Quilichao under controlled conditions. The experiments attempted to study the feeding preference of spittlebug nymphs in four grasses, and to characterize the damage of nymphs, adults and adults plus nymphs in three grasses: B. humidicola, B. decumbens and A. gayanus.

Results showed that adult damage is always more severe than nymph damage even when its mean adult population is less than the nymph population (Figure 4). B. decumbens showed the highest yield losses as well as numbers of dead plants. B. humidicola and A. gayanus presented lower yield losses. Recuperation (regrowth) in B. decumbens was slow (more than 90 days) while in B. humidicola it was fast due to its natural condition. In reference to A. gayanus, yield was affected although the spittlebug population was not high under this controlled situation (Figure 4). A general conclusion of this study is that B. decumbens is the most affected grass, being considered highly susceptible to spittlebug. B. humidicola is tolerant, being able to support high insect populations during long periods. Because of its ability to produce new shoots rapidly, this grass is able to recover from spittlebug attack.

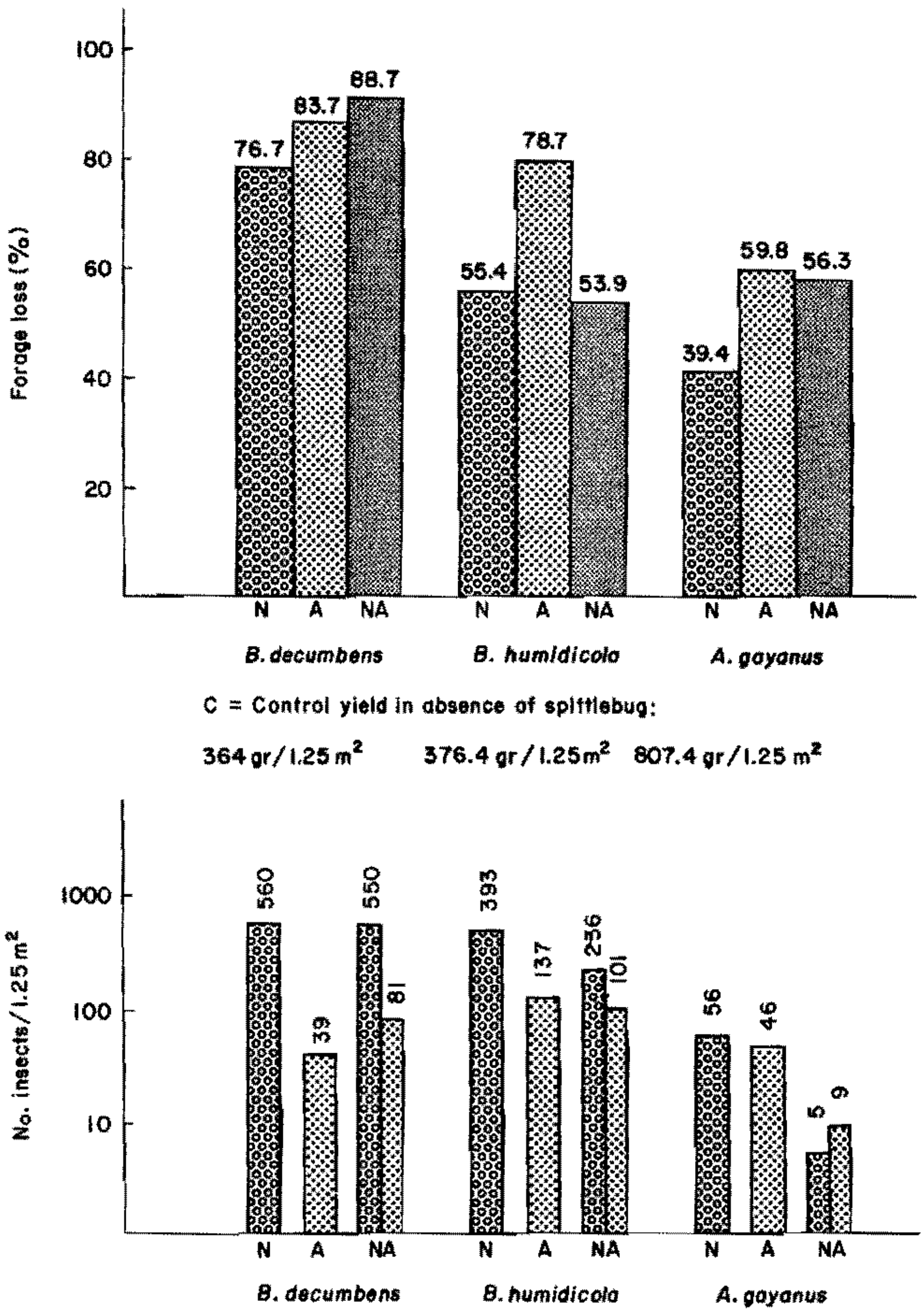



Figure 4. Forage losses of three grasses (above) caused by high infestation levels of Nymphs (N), Adults (A) and Nymphs and Adults (NA) of spittlebug Zulia colombiana, under controlled conditions. Mean number of insects found per treatment (below).

In contrast, A. gayanus is presently considered a bad host to the spittlebug. This is possibly due to its growth habit which is defined as erect, forming compact clumps with its many stems, and/or the hairy condition of the stems, especially in their lower part. As a result of these characteristics and others, the resistance mechanism in A. gayanus is defined as antixenosis.

Feeding preference studies of spittlebug nymphs have shown B. humidicola as the most preferred and A. gayanus the least preferred (Figure 5). These results are in agreement with results of field evaluations (insect infestation) of several grasses from the germplasm bank. During this year preliminary studies were carried out with four grasses, B. decumbens, B. humidicola, B. ruziziensis and A. gayanus. The internal structure of stems and their degree of hardness was studied in an attempt to find an explanation for the degree of susceptibility, resistance and/or tolerance to spittlebug damage.

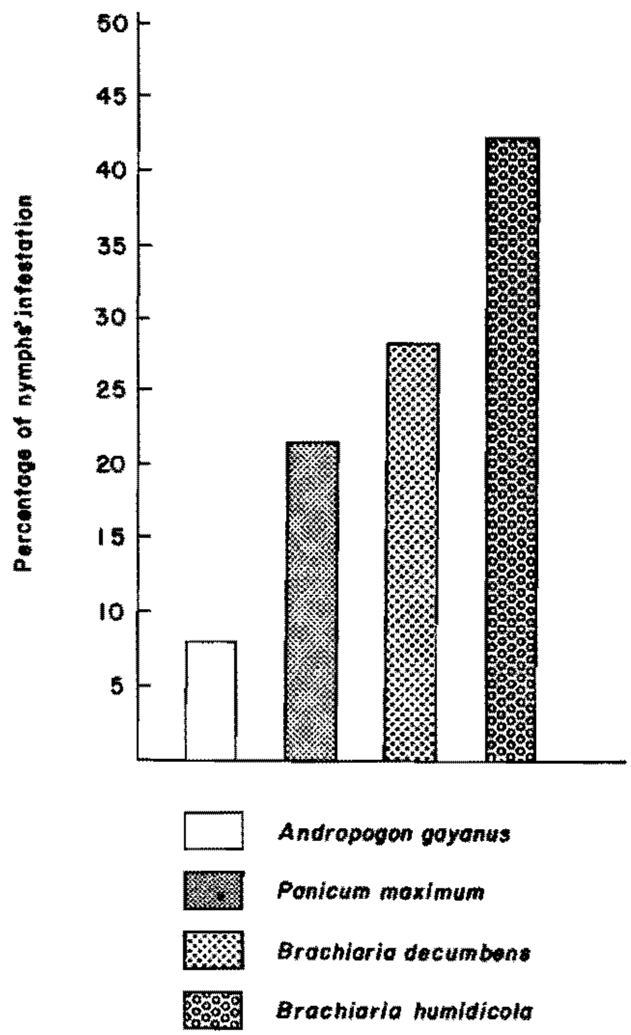



Figure 5. Feeding preference of nymphs of spittlebug Zulia colombiana in four different grasses.

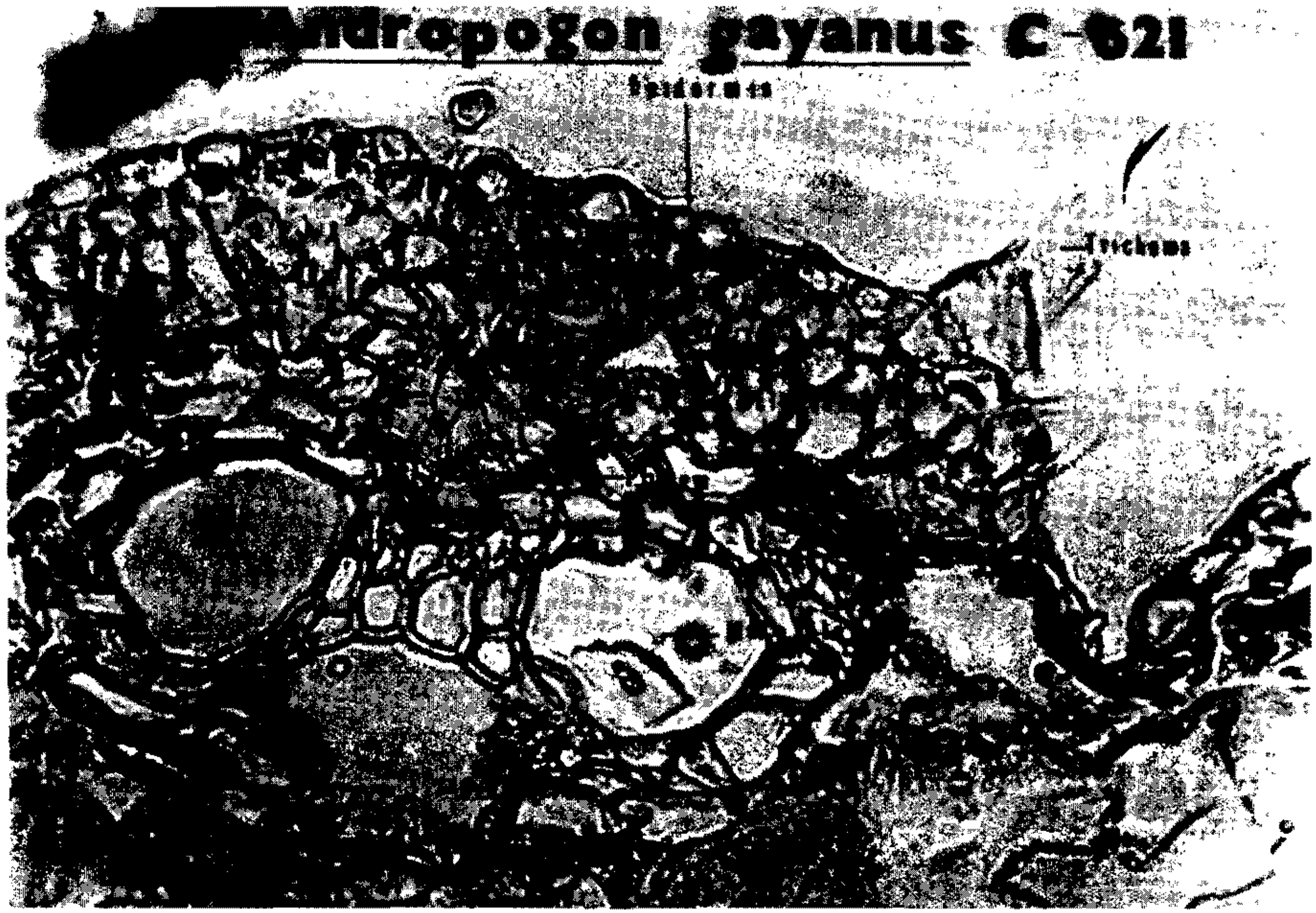



Figure 6. Transverse section of the stem of A. gayanus at 10 weeks of age.

The thickness of the sclerenchymatous tissue was measured. It is composed by lignified cells which make the stems harder and also give good protection to the vascular bundle. Results showed (Figure 6) that A. gayanus has those characteristics in contrast to the Brachiaria species studied. In addition, A. gayanus presents several leaf sheaths around its erect stems that make it difficult for young nymphs to feed on them.

Field surveying of grasses across Colombia has continued in order to understand one of the most important natural biocontrol agents of the spittlebug (Table 5). In collaboration with the Plant Pathology Section, pathogenicity of eight native strains of Metarhizium spp. have been tested using nymphs and adults of Zulia colombiana. Preliminary results indicate that under controlled conditions it is possible to obtain 100% control of nymphs and adults. The importance of this finding is that it may be possible to help natural environment by spraying useful entomogenous fungi to reduce spittlebug populations.

Table 5. Pathogenicity of different isolates of Metar hizium spp. on nymphs and adults of Zulia colombiana.

| Isolate | Origin | Host | Pathogenicity | |
|---|---|---|---|---|
| | | | Nymphs | Adults |
| B 1 | Belize | Aeneolamia spp. - adult | 50 | 100 |
| E 59 | Brazil | Deois spp. - adult | 50 | 83 |
| CAR 1 | Colombia | Aeneolamia reducta - adult | - | 100 |
| CAR 2 | Colombia | Soil - Carimagua | 16 | - |
| CAR 3 | Colombia | Aeneolamia reducta - nymph | 33 | 83 |
| CAR 4 | Colombia | Aeneolamia reducta - nymph | 83 | 33 |
| CAR 5 | Colombia | Aeneolamia reducta - nymph | 33 | 50 |
| CAR 7 | Colombia | Mocis latipes - larva | 100* | 100* |
| QUIL 8 | Colombia | Zulia colombiana - adult | 33 | 16 |

* Native strain highly pathogenic to different stages of spittlebug

Life cycle studies of the spittlebug Zulia colombiana have been completed (Figure 7), and studies continue of a nematode which affects nymphs and adults.

Yellow aphid

Studies on population dynamics of this insect continued. Figure 8 shows population fluctuations in A. gayanus in Carimagua. Aphid population increases rapidly with the first showers, reaching peak numbers when the heaviest rainfall occurs (May, June, July). At the end of the wet season, the population begins to decrease reaching the lowest numbers during the dry season. It was found that a high stocking rate

(4.4 animals/ha) during June, July and August gave good control of aphids in comparison with the lower stocking rate (2.2 animals/ha) (Figure 9).

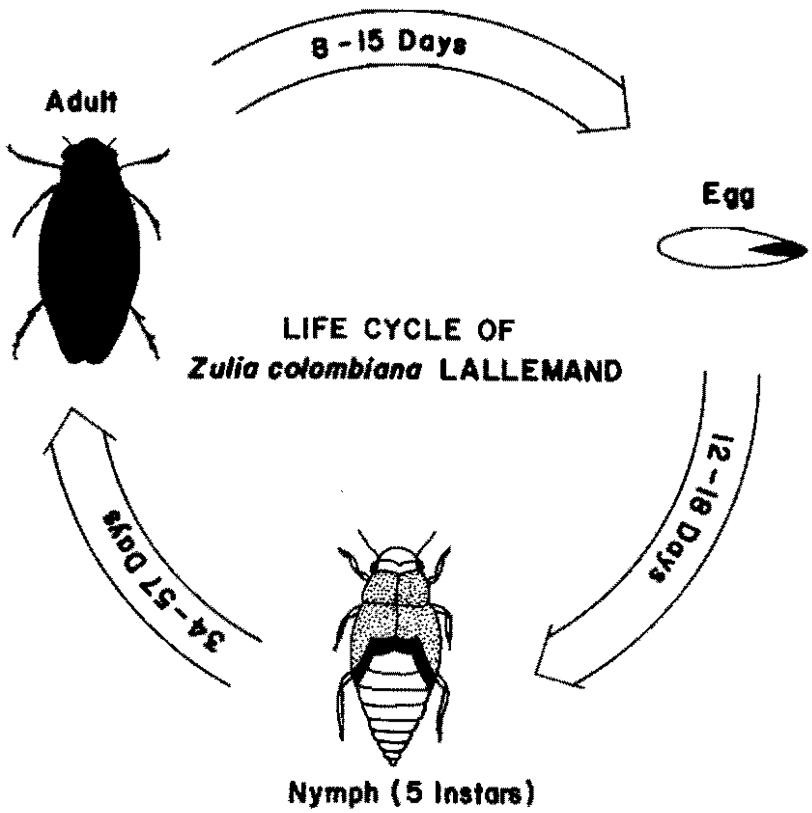



Figure 7. Life cycle of Zulia colombiana Lallemand.

Also the effect of burning of A. gayanus during the dry season (January) on aphid population was studied. This practice kept the A. gayanus paddock practically free of aphid infestation during the year, in comparison with other practices studied (Figure 10). However, burning should be considered carefully when the grass is associated with a legume.

Germplasm Evaluation

Evaluation of entries in Categories I, II and III, as well as in regional trials, continued during the year. As in the past, emphasis was placed on the most important insect groups already defined as a) chewing and b) sucking insects. As a result of the systematic evaluation of germplasm, the most important groups affecting plant material in different ecosystems have been defined (Table 6). Based on insect-plant interaction during the wet season, and in order to better approach the evaluation system, different evaluation schedules of legume

Table 6. Importance of different groups of insects* in relation to damage caused on legumes and grasses in various ecosystems.

| Ecosystem | *Stylosanthes* spp. | *Zornia* spp. | *Centrosema* spp. | *Desmodium* spp. | *Pueraria* spp. | *Andropogon* spp. | *Brachiaria* spp. |
|---|---|---|---|---|---|---|---|
| Brazil (CPAC)<br>Well-drained isothermic<br>savanna-Cerrado | SI +++<br>CI +++<br>SB +<br>BW + | SI +<br>CI +++<br>BW + | SI +<br>CI ++ | CI ++ | CI +++ | | SI +++ |
| Carimagua<br>Well-drained<br>isohyperthermic<br>savanna-Llanos | SI +++<br>CI +<br>SB +<br>BW + | SI +++<br>CI +<br>LM +<br>BW + | SI +++<br>CI ++ | CI ++ | CI +++ | CI +<br>A + | SI +++<br>FBC ++ |
| Venezuela<br>(El Tigre)<br>Well-drained<br>isohyperthermic<br>savanna-Llanos | SI +++<br>CI ++<br>SB +<br>BW + | SI +++<br>CI ++<br>SM +++ | CI +++ | | | | SI +++ |
| Peru (Pucallpa)<br>Seasonal semi-evergreen forest | SI +++<br>CI +++ | SI +++ | CI +++ | CI +++ | CI +++ | | SI +++<br>FBC + |

* SI = sucking insects; CI = chewing insects; SB = stemborer; BW = budworm; FBC - flea bettle (Rasper); LM = leaf miner; A = aphids; SM = spider mites

germplasm were defined: An intensive one at the end of the wet season; two during the dry season, one when the soil is still moist, and the other in the middle of the dry season. This is based on the necessity to have a better understanding of plant performance when plants go into the dry period stress, during which, according to the strategy of the Program, the animal is supposed to utilize the legume as the main source of protein. In this way the Section expects to be able to better appreciate in the future the losses caused by insect damage during this critical period of the year.

Preliminary estimations were done of losses caused by chewing insects (Crisomelidae) in five forage legumes, S. capitata, Z. latifolia, Centrosema pubescens, Desmodium ovalifolium and Pueraria phaseoloides (Table 7). Results showed that the estimated losses for each level of damage in the different legumes under evaluation were very variable among plant species and with respect to leaf-stem ratio and the time when the estimation was made. Further studies will be done to improve this new methodology.

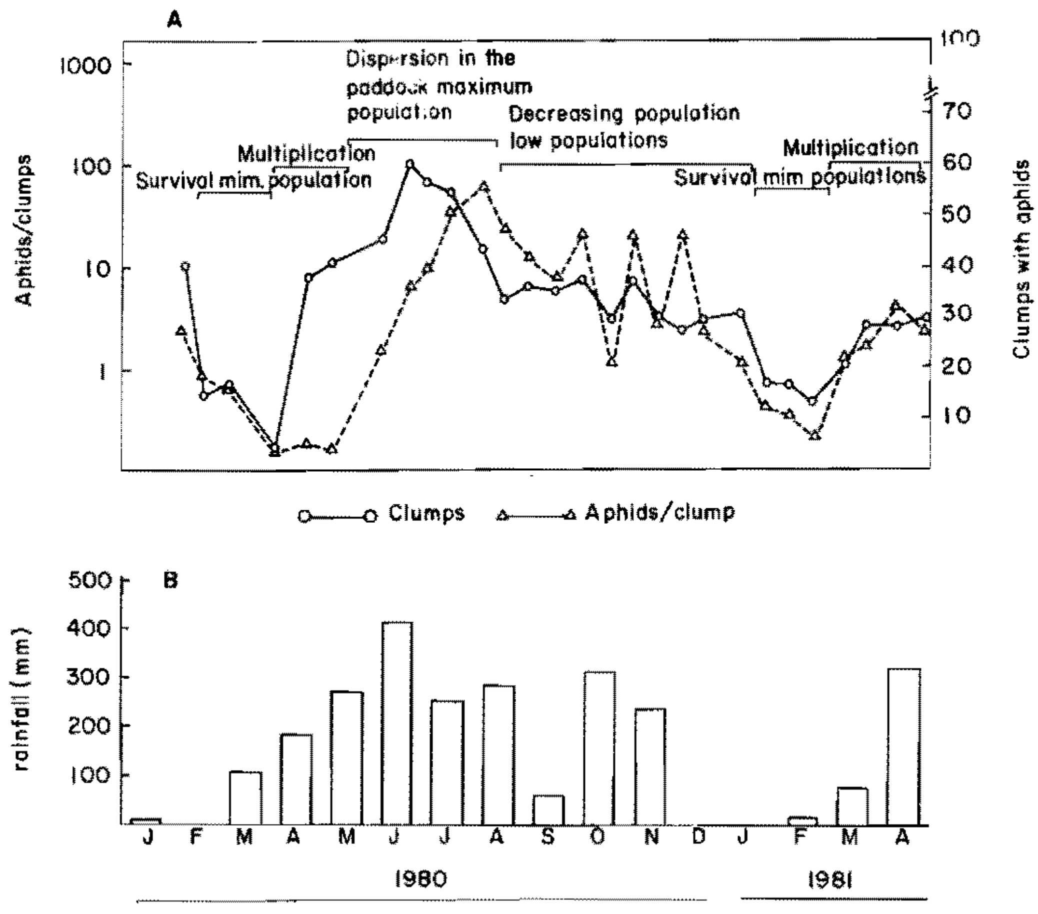



Figure 8. A) Population fluctuations of the sugar cane yellow aphid Sipha flava and percentage of infested clumps of Andropogon gayanus, Carimagua 1980-1981.
B) Rainfall (mm) during the same period.

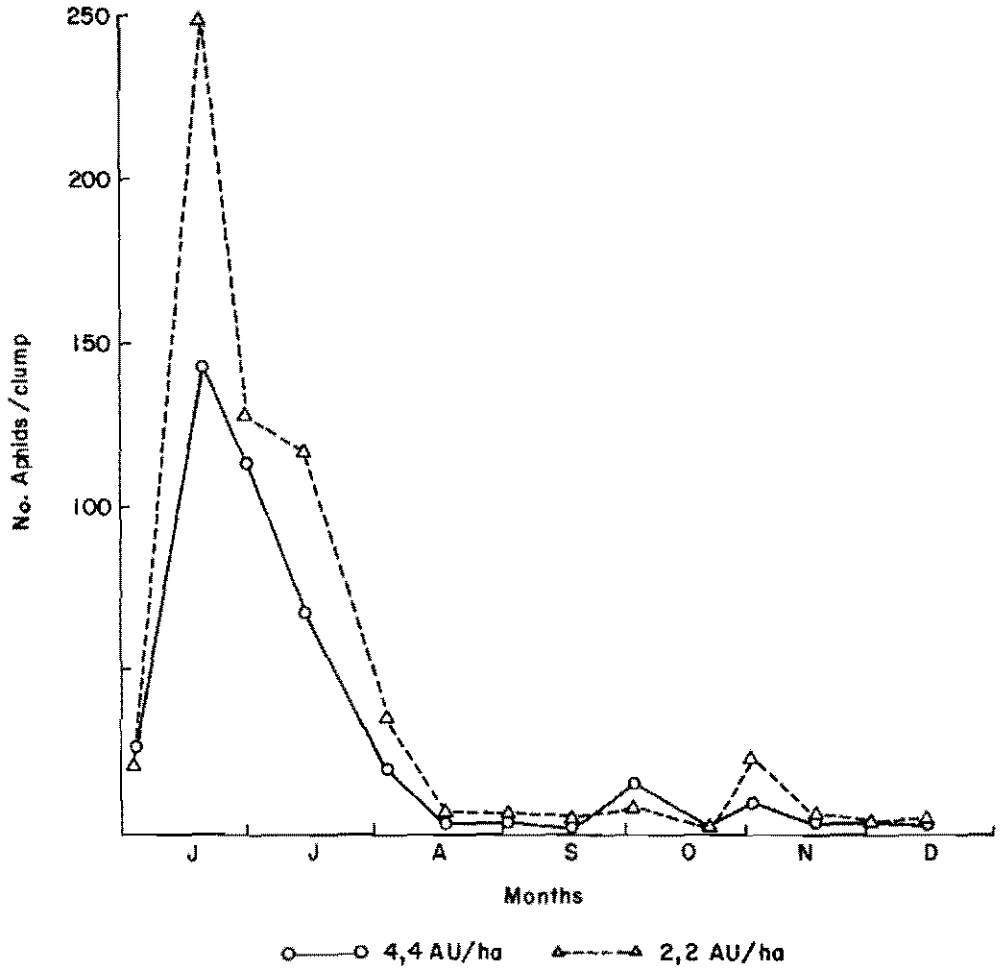



Figure 9. Population fluctuations of yellow aphid *Sipha flava* (Forbes) in two *A. gayanus* paddocks, submitted to two different stocking rates.

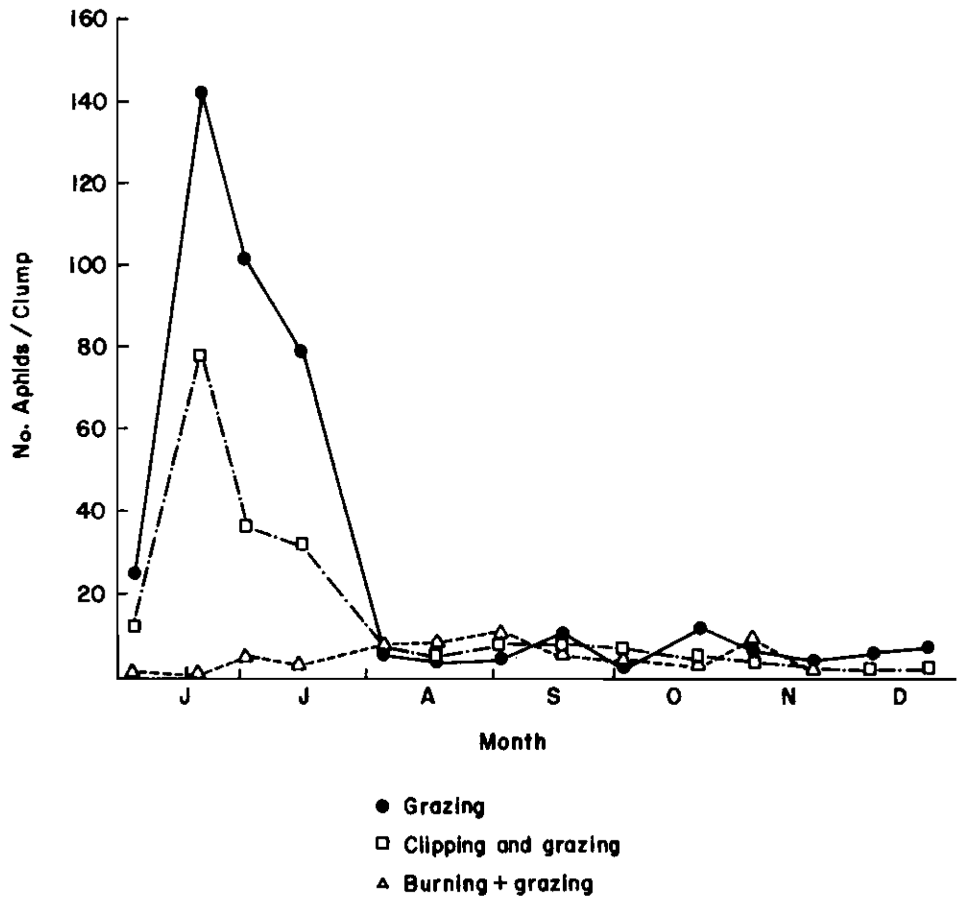



Figure 10. Population fluctuations of yellow aphid Sipha flava (Forbes) in three Andropogon gayanus paddocks under different managements.

Table 7. Damage categories used in evaluating chewing insect damage (Crisomelidae) and estimating final yield reduction of five forage legumes.

| Degree of damage / % foliar area damaged / final yield reduction | 1 - No damage 0.0 (kg DM/ha) | (%) | 2 - Slight >0-10 (kg DM/ha) | (%) | 3 - Moderate >10-20 (kg DM/ha) | (%) | 4 - Severe >20 (kg DM/ha) | (%) |
|---|---|---|---|---|---|---|---|---|
| *S. capitata* | 0.0 | 0.0 | >0- 85.4 | >0-3.3 | > 85.4-170.9 | >3.3- 6.6 | >170.9 | > 6.6 |
| *Z. latifolia* | 0.0 | 0.0 | >0- 51.1 | >0-3.1 | > 51.1-102.2 | >3.1- 6.2 | >102.2 | > 6.2 |
| *D. ovalifolium* | 0.0 | 0.0 | >0-159.8 | >0-5.3 | >159.8-319.7 | >5.3-10.6 | >319.7 | >10.6 |
| *C. pubescens* | 0.0 | 0.0 | >0-135.4 | >0-6.4 | >135.4-270.9 | >6.4-12.8 | >270.9 | >12.8 |
| *P. phaseoloides* | 0.0 | 0.0 | >0-199.8 | >0-7.9 | >199.8-399.7 | >7.9-15.8 | >399.7 | >15.8 |

# Forrage Breeding Agronomy

This Section has responsibility for initial agronomic characterization of new introductions of Andropogon gayanus, Brachiaria spp., and Panicum maximum and for breeding and genetic studies with A. gayanus and Stylosanthes guianensis.

## Grass Introductions

During 1981, continuing observations were made on Brachiaria spp. and P. maximum accessions established at Carimagua in early 1980 (Annual Report, 1980). Periodic ratings of general plant health of P. maximum accessions (freedom from disease and insect damage), vigor, and leafiness show several accessions with sufficient promise to warrant more detailed agronomic evaluation (Tables 1 and 2).

Two ratings of earliness to flower and leafiness were made in later 1980 on 20 A. gayanus accessions in a small plot, replicated trial planted at Carimagua in early 1980 (Annual Report, 1980). The accessions exhibit a considerable range of variation in both traits (Table 3). However, they did not differ in total fresh weight yield over six harvests between January and July, 1981. It has not been determined yet if this collection of A. gayanus germplasm contains useful variation not to be found within accession 621.

With the recent arrival of important new collections of grass germplasm, the Section will be dedicating increasing effort to initial characterization and seed multiplication of these materials. This work will be conducted primarily at the level of small-plot, introduction garden at Quilichao and Carimagua.

Table 1. Promising Brachiaria spp. accessions.

| CIAT No. | Brachiaria sp. | Mean plant health rating* | Mean vigor rating* |
|---|---|---|---|
| 664 | B. brizantha | 4.4 | 4.2 |
| 665 | B. brizantha | 4.2 | 4.0 |
| 667 | B. brizantha | 3.4 | 3.6 |
| 6016 | B. brizantha | 3.6 | 3.2 |
| 6021 | B. brizantha | 2.4 | 4.2 |
| 6297 | B. brizantha | 3.8 | 2.0 |
| 6298 | B. "hibrida" | 3.8 | 1.8 |
| 606 (CK) | B. decumbens | 2.6 | 4.0 |
| Range for 25 Brachiaria accessions** | | 1.8-5.0 | 1.8-5.0 |

* Mean of five ratings from September, 1980 to August, 1981.
** Trial included four B. humidicola accessions.

Table 2. Promising *Panicum maximum* accessions.

| CIAT No. | Mean plant health rating* | Mean vigor rating** | Mean leafiness rating** |
|---|---|---|---|
| 673 | 4.2 | 4.7 | 3.3 |
| 689 | 3.0 | 4.7 | 5.0 |
| 6000 | 3.0 | 3.3 | 4.0 |
| 6168 | 4.2 | 3.7 | 4.3 |
| 6179 | 3.8 | 3.0 | 4.3 |
| 604 (Common) | 2.0 | 1.7 | 1.3 |
| 622 (Makueni) | 2.8 | 3.0 | 4.3 |
| Range of 36 accessions | 1.6-4.2 | 1.0-5.0 | 1.3-5.0 |

* Mean of five ratings from September, 1980 to August, 1981.
** Mean of three ratings from September, 1980 to August, 1981.

Table 3. Earliness and leafiness of *A. gayanus* accessions, Carimagua.

| CIAT No. | Mean earliness rating* | Leafiness ratings** | | |
|---|---|---|---|---|
| | | Sept. 1980 | Nov. 1980 | Mean |
| 621 | 1.6 | 2.5 | 3.5 | 3.0 |
| 635 | 2.4 | 3.8 | 3.3 | 3.5 |
| 6053 | 2.3 | 4.0 | 2.5 | 3.3 |
| 6054 | 1.9 | 2.5 | 2.8 | 2.6 |
| 6201 | 3.0 | 5.0 | 3.0 | 4.0 |
| 6202 | 2.9 | 5.0 | 4.5 | 4.8 |
| 6203 | 3.0 | 5.0 | 4.0 | 4.5 |
| 6204 | 1.3 | 1.0 | 3.8 | 2.4 |
| 6205 | 3.0 | 3.0 | 3.8 | 3.4 |
| 6206 | 2.1 | 3.5 | 4.0 | 3.8 |
| 6207 | 2.8 | 4.3 | 3.5 | 3.9 |
| 6208 | 2.9 | 3.8 | 3.0 | 3.4 |
| 6209 | 3.0 | 4.3 | 3.0 | 3.6 |
| 6210 | 3.0 | 4.8 | 3.8 | 4.3 |
| 6211 | 2.8 | 4.5 | 3.5 | 4.0 |
| 6212 | 2.8 | 5.0 | 3.5 | 4.3 |
| 6213 | 1.4 | 2.3 | 3.0 | 2.6 |
| 6214 | 2.3 | 2.0 | 2.5 | 2.3 |
| 6243 | 1.0 | 1.5 | 5.0 | 3.3 |
| Composit | 1.8 | 2.0 | 3.0 | 2.5 |

* Mean over two reps on two dates on a 1 to 3 (earliest) (latest) scale.
** Leafiness on a 1 to 5 (stemmy) (leafy) scale.

## Breeding and Genetics

### *Andropogon gayanus*

During late 1980 and in 1981 additional data were obtained from a quantitative genetic study of replicated clonal families from accession CIAT 621 planted at Quilichao and Carimagua in early 1980 (Annual Report, 1980).

Analyses of variance for the traits: 1) whole plant dry matter yield, 2) stem number, 3) percent leaf, and 4) leaf dry matter yield show that significant genetic variation exists for all traits with moderately high estimates of broad sense heritability (Table 4). The genotype-location interaction variance components were statistically significant for all traits but were only about one-half as large as the variance components for genotypes.

Table 4. Estimates of means, heritabilities, and variance components for four traits in *Andropogon gayanus*, CIAT 621*.

| Trait | Mean ± S.E | $H^2$ | Var. comp.** Gen. | Var. comp.** Gen.-Loc. |
|---|---|---|---|---|
| Stem No. | 22.1 ± 0.31 | 0.59 | 94.1 | 55.9 |
| Dry wt. (gm/pl) | 197.9 ± 2.12 | 0.59 | 4333.6 | 2555.7 |
| % leaf | 41.1 ± 0.26 | 0.69 | 114.8 | 50.6 |
| Leaf D.W. (gm) | 75.5 ± 0.80 | 0.63 | 961.4 | 599.2 |

* Estimates based on two harvests of 200 clones with two single-plant replications at Carimagua and Quilichao.
** All variance component estimates significantly different from zero at the 0.0001 probability level.

A high genetic correlation between total yield and leaf yield was found, while the genetic correlation between total yield and percent leaf was essentially zero (Table 5). Thus, selection on percent leaf should result in no change in total yield while selection of leaf yield should produce a correlated increase in total yield.

Heritability estimates for fresh weight yield for each of five harvests between 31 March and 27 July, 1981, at Carimagua, were moderately high (Table 6). Due to a negligible genotype-harvest interaction, the heritability estimate for total (or mean) yield over harvests was quite high.

Table 5. Estimates of genetic correlations in Andropogon gayanus CIAT 621*.

| | Leaf D.W. | % Leaf | Stem No. |
|---|---|---|---|
| Dry wt. (gm) | 0.88 | 0.07 | 0.55 |
| Leaf D.W. (gm) | | 0.58 | 0.24 |
| % leaf | | | -0.43 |

* Estimates based on two harvests of 200 clones with two single-plant replications at Carimagua and Quilichao.

Table 6. Estimates of fresh weight yield and heritability for Andropogon gayanus CIAT 621, at five harvests at Carimagua*.

| Harvest date (1981) | Yield ± S.E** | Heritability*** |
|---|---|---|
| 31 March | 34.1 ± 0.75 | 0.58 |
| 24 April | 111.9 ± 2.02 | 0.69 |
| 15 May | 110.8 ± 2.07 | 0.69 |
| 8 June | 157.5 ± 2.79 | 0.72 |
| 27 July | 137.7 ± 2.18 | 0.77 |
| Over harvests | 110.4 ± 0.93 | 0.93 |

* Estimates based on 200 clones with two single-plant replications.
** Grams per plant.
*** All genetic variance component estimates significantly different from zero at the 0.0001 probability level.

Percent protein and in vitro digestibility were measured on hand-separated leaf and stem fractions on two harvest dates at Quilichao. Significant genetic variation was found for all traits on both dates except for percent leaf digestibility on one date (Table 7). However, estimates of genetic correlations between dates were erratic ranging from 0.62 to -0.34, suggesting that the relative values of genotypes for these quality characters are not necessarily stable over seasons. Thus, evaluation in one season may not identify those genotypes with high mean values over an entire year.

At Quilichao, plant height was measured on two dates and internode length on one date in 1981. Both traits showed moderate to high heritability, suggesting that selection should be effective in modifying plant height (Table 8). The data indicate that selection on internode length should be as effective in modifying plant height as selection on plant height itself. Selection for decreased internode length should result in a decrease in plant height without affecting node number or leaf number.

The data to date indicate that phenotypic variation for a number of traits in A. gayanus 621 is predominantly genetic. Thus, selection to modify these traits should be highly effective unless genetic variation is largely non-additive or unless a large genotype-year interaction exists.

A more efficient method of leaf and stem separation was investigated in 1981. Whole plants were passed through a forage chopper, and leaf and stem fractions separated by passing a sample of the choppped material through an air seed cleaner. Heritability values for percent leaf based on the air separation were not as high as when based on hand separation of whole plants. However, the decreased costs of mechanical separations makes it an attractive technique for routine determinations of leaf:stem ratios.

Table 7. *In vitro* percent protein and digestibility of leaf and stem fraction of *Andropogon gayanus* CIAT 621*.

| | Percent protein | | | | | |
|---|---|---|---|---|---|---|
| | Leaf | | | Stem | | |
| Date | Mean ± S.E | $H^2$ | Gen. corr. bet. dates | Mean ± S.E | $H^2$ | Gen. corr. bet. dates |
| XI-80 | 10.2 ± 0.11 | 0.59** | 0.62 | 5.3 ± 0.10 | 0.70*** | 0.05 |
| II-80 | 6.5 ± 0.08 | 0.73*** | | 2.5 ± 0.04 | 0.66** | |

| | Percent digestibility | | | | | |
|---|---|---|---|---|---|---|
| | Leaf | | | Stem | | |
| Date | Mean ± S.E | $H^2$ | Gen. corr. bet. dates | Mean ± S.E | $H^2$ | Gen. corr. bet. dates |
| XI-80 | 49.5 ± 0.26 | 0.79*** | -0.34 | 47.4 ± 0.46 | 0.82*** | 0.30 |
| 11-81 | 38.9 ± 0.36 | -- | | 34.4 ± 0.35 | 0.73*** | |

* Estimates based on 20 clones with two single-plant replicates at Quilichao.

**, *** Genetic variance component differs from zero at the 0.05 or 0.01 probability level, respectively.

Table 8. Estimates of means and heritabilities for plant height or internode length for *Andropogon gayanus* CIAT 621 at Quilichao.

| Date | Mean $\pm$ S.E | $H^2$ (2 reps) | $H^2$ (1 rep) (mass select.) |
|---|---|---|---|
| | | Plant height (cm) | |
| II -81 | 184.2 $\pm$ 0.58 | 0.84 | 0.72 |
| VIII-81 | 201.5 $\pm$ 1.00 | 0.66 | 0.49 |
| Genetic correlation between dates = | | 0.59 | |
| | Internode length (3 measurements per plant) | | |
| VIII-81 | 25.6 $\pm$ 0.11 | 0.66 | 0.50 |
| | Internode length (1 measurement per plant) | | |
| VIII-81 | 25.6 $\pm$ 0.11 | 0.53 | 0.36 |

## *Stylosanthes guianensis*

Anthracnose (*Colletotrichum* spp.) has proved to be devastating on most *S. guianensis* accessions. Breeding and genetic work is directed primarily at 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

An experiment to study genetic segregation for anthracnose reaction in $F_2$ progenies of six "tardío" x common crosses (Annual Report, 1980) was never satisfactorily established. Thus, data are only fragmentary. However, the data obtained do suggest two important points (Table 9): first, that evaluation of disease reaction on the basis of single plants (e.g., in an $F_2$ population) is not entirely reliable, and disease evaluation in segregating progenies should probably be delayed until at least the $F_3$ generation, when family plots could be established. Second, it appears that segregates with greater resistance than that of either parent can be found within the $F_2$ population.

### Breeding

A 10-parent, half-diallel series of crosses was completed during 1981. Parents were chosen for superior survival in the field at Carimagua (primarily anthracnose and stemborer resistance). The objective of this crossing program is to develop lines with improved anthracnose and stemborer resistance combined with high seed yield. It is anticipated that $F_3$ families from these 45 crosses will be under field evaluation at Carimagua by the 1983 season.

Table 9. Anthracnose ratings* on vegetative replicates of "tardío" and common S. guianensis parent and $F_1$ and $F_2$ genotypes**.

| Genotype | Replicate | | | | Mean |
|---|---|---|---|---|---|
| | I | II | III | IV | |
| Parents: | | | | | |
| 184 (Common) | 5.0, --- | ---, --- | 5.0, 4.5 | ---, --- | 4.8 |
| 2160 (Tardío) | 4.5, --- | ---, --- | ---, --- | ---, --- | 4.5 |
| $F_1$ (184 x 2160) | 4.0, 5.0 | 2.5, 4.5 | 1.0, --- | 4.5, --- | 3.6 |
| $F_2$ genotype No. | | | | | |
| 1 | 5.0 | 3.5 | 3.0 | 2.0 | 3.4 |
| 2 | 4.0 | 4.0 | - | 4.5 | 4.2 |
| 4 | 1.5 | 1.0 | 2.0 | 2.5 | 1.8 |
| 5 | 1.5 | 1.0 | 1.0 | 2.0 | 1.4 |
| 7 | 4.5 | 4.5 | - | 5.0 | 4.7 |
| 9 | 0.0 | - | 0.0 | 0.0 | 0.0 |
| 12 | 2.0 | 3.5 | 1.0 | - | 2.8 |
| 13 | 5.0 | 1.0 | 4.5 | 5.0 | 3.9 |
| 16 | 4.0 | 3.0 | 2.5 | 2.5 | 3.0 |
| 17 | 4.5 | 3.5 | 3.5 | - | 3.8 |
| 18 | 2.5 | 3.5 | 3.0 | - | 3.0 |
| 19 | 5.0 | 5.0 | 3.0 | 5.0 | 4.5 |
| 23 | 2.5 | 3.0 | 5.0 | 4.5 | 3.5 |
| 28 | 5.0 | 5.0 | 3.5 | - | 4.5 |

* Rating on a 0 to 5 (no anthracnose) (dead plant) scale.
** Ratings made August. 1981, 11 months after transplanting at Carimagua. Data presented for $F_2$ genotypes with three or more replicates established.
--- Missing plant.

## Other studies

Photoperiod. In the 1980 Annual Report the positive effect of short-day treatment in hastening flowering in nine S. guianensis "tardío" accessions was reported, with the practical implication of providing a simple, effective method of reducing generation time in the breeding program. A subsequent experiment was conducted to determine the plant age at initiation of the short-day treatment which would result in a minimum delay from planting to flowering. Three "tardío" accessions were subjected to short-day (9-hr) photoperiod from day of planting or from 4, 8, 12, or 16 weeks after planting and flowering date was recorded. As in the previous study, differences in earliness among accessions were found (Table 10). Also detected was a non-receptive, juvenile period during which seedlings were not responsive to the short-day treatment. Passage of the juvenile period was delayed under short photoperiod. The plant age at initiation of the short-day treatment resulting in minimum delay to flowering differed with accession, ranging from 4 to 12 weeks. It is apparent that no uniform treatment will give maximum earliness across genotypes. Initiation of short-day treatment at approximately eight weeks after planting should give a significant reduction in time to flower over continuous short-day treatment from planting or over no short-day treatment at all.

Method of establishment. An experiment was planted in 1981 at Quilichao and Carimagua to investigate the effect of three establishment methods (direct seeding, transplanted seedlings, and transplanted rooted cuttings) on growth habit, yield, and persistence of 12 *S. guianensis* accessions. Since transplanting is known to modify the natural root morphology, transplanted or direct seeded plants could differ in drought resistance, nutrient extraction or other important root-related characters. It will be of particular interest to determine if an accession-establishment method interaction exists. This finding, if significant, would imply the avoidance of transplanting in evaluation trials since the results of transplanted trials would not reflect the true relative accession performance of direct-seeded plants.

Table 10. Mean number of days to flower from planting or from initiation of short-day (9-hr) treatment for three *S. guianensis* "tardío" accessions.

| Treatment* | Days from planting | | | Days from initiation of short-day treatment | | |
|---|---|---|---|---|---|---|
| | Accession number | | | Accession number | | |
| | 1280 | 1283 | 1959 | 1280 | 1283 | 1959 |
| Control** | 253.0$^{d}$*** | 180.0$^{d}$ | 194.0$^{d}$ | - | - | - |
| 0 | 202.5$^{c}$ | 163.5$^{d}$ | 175.5$^{cd}$ | 202.5$^{c}$ | 163.5$^{d}$ | 175.5$^{c}$ |
| 4 | 220.0$^{c}$ | 86.5$^{a}$ | 187.0$^{d}$ | 192.0$^{c}$ | 58.5$^{a}$ | 159.0$^{c}$ |
| 8 | 208.0$^{c}$ | 115.0$^{b}$ | 141.0$^{a}$ | 152.0$^{b}$ | 59.0$^{a}$ | 85.0$^{b}$ |
| 12 | 155.5$^{a}$ | 135.5$^{c}$ | 155.5$^{ab}$ | 71.5$^{a}$ | 51.5$^{a}$ | 71.5$^{ab}$ |
| 16 | 183.0$^{b}$ | 163.0$^{d}$ | 165.5$^{bc}$ | 71.0$^{a}$ | 51.0$^{a}$ | 53.5$^{a}$ |

$LSD_{.05}$ = 19.04

* Age in weeks at commencement of short-day treatment.
** Plants grown continuously under natural (± 12 hr) photoperiod.
*** Treatment means within columns followed by the same letter do not differ by t-test at the 0.05 probability level.

## Legume Improvement

Stylosanthes capitata

Selection was continued in $F_3$ lines established at Carimagua early August, 1980, from vigorous $F_2$ selections of the two crosses 1078 x 1019 (late x early) and 1019 x 1097 (early x late). The $F_2$ selections combined high yields of dry matter and seed with resistance to anthracnose, stemborer and drought. All $F_3$ lines were grown in rows, and each line was replicated twice. Preplanting fertilizer broadcasted over the area was 50 kg/ha triple superphosphate, 100 kg/ha calcium carbonate, 100 kg/ha sulfomag and the minor elements Mo, Zn, Cu, B. The aim was to select under low but adequate fertilizer applications, those types most efficient in the use of nutrients.

The extent of flowering was determined in all lines in November 1980, and in February 1981 the most vigorous plants were selected in each $F_3$. Final ratings for vigor of all plants was done in March 1981. In both crosses, comparisons between the $F_3$ lines and parents were made in vigor, flowering and seed production, and these are presented in Tables 1 and 2, respectively.

Table 1 shows that in 1078 x 1019, about half the plants in most $F_3$ lines and the higher yielding parent 1078 had a vigor rating of 3. However, in vigor rating 4, 67% of the $F_3$ lines had 16-37% of plants with significantly greater yields than 9% of the plants of 1078.

Table 2 shows that in 1019 x 1097, and in vigor rating 3, half the $F_3$ lines had over 50% of plants with significantly greater yields than 42% of plants of the higher yielding parent 1097. In vigor rating 4, there were no plants of 1097, but 10.5-27.5% of plants of all $F_3$ lines. 1019 was earlier flowering than all $F_3$ lines in both crosses. However, with regard to seed production, 83% of selected lines of 1078 x 1019, and 46% of 1019 x 1097, had significantly higher seed production than 1019, some lines giving more than twice the seed of 1019. All $F_3$ selections showed high stemborer resistance, inherited mainly from 1019. Anthracnose was not a problem in the $F_3$ lines.

$F_3$ selections comprised single plants combining high yields of dry matter and seed with resistance to stemborer and drought. There were 35 $F_3$ selections of 1078 x 1019 and 106 of 1019 x 1097. This latter cross gave markedly higher numbers of promising lines than 1078 x 1019. The $F_4$ populations from the $F_3$ selections were established at Carimagua in June 1981.

Anthracnose resistance was evaluated in $F_4$ populations at CIAT, Palmira, after inoculation with six strongly pathogenic strains. Half the lines had a mean of 80% plants with a systemic reaction, but the rest had a mean of only 20% plants with a systemic reaction. In all lines, vigorous plants with a localized leaf reaction were easily selected.

Table 1. Evaluations at Carimagua for vigor and seed production in $F_3$ selections of S. capitata 1078 x 1019, March, 1981. (Flowering observed November, 1980.)

| No. plants evaluated | Line | No. plants evaluated (%)* | Vigor 3 80 g/plant (%)* | Vigor 4 140 g/plant (%)* | Early flowering November (%)* | Seed production of 10 plants/line g pure seed |
|---|---|---|---|---|---|---|
| 160 | 1 | 80.0 | 47.0 a | 31.0 a | 45.0 b | 2.42 abc |
| 182 | 2 | 91.0 | 50.0 a | 37.0 a | 47.0 b | 2.36 abcd |
| 182 | 3 | 91.0 | 53.0 a | 6.0 ef+- | 20.5 c | 2.31 abcd |
| 168 | 5 | 84.0 | 29.0 ab+ | 17.5 bc | 26.5 c | 2.64 ab |
| 172 | 9 | 86.0 | 53.5 a | 23.5 b | 27.0 c | 1.79 cde |
| 180 | 10 | 90.0 | 54.0 a | 15.5 cd- | 22.5 c | 3.02 a |
| 166 | 11 | 83.0 | 41.0 a | 9.0 de- | 21.5 c | 2.11 bcde |
| 175 | 12 | 87.5 | 38.5 ab+ | 36.0 a | 24.5 c | 2.40 abc |
| 188 | 14 | 94.0 | 58.0 a | 24.0 b | 40.0 b | 3.01 a |
| 183 | 15 | 91.5 | 47.0 a | 16.5 c | 21.0 c | 1.71 cde |
| 144 | 16 | 72.0 | 28.5 ab+ | 16.0 c | 26.0 c | 1.67 def+ |
| 165 | 19 | 82.5 | 41.0 a | 11.5 cde- | 26.0 c | 1.46 ef+ |
| 166 | 1078 | 83.0 | 56.0 a | 9.0 de | 1.5 d | 0.61 g |
| 159 | 1019 | 79.5 | 2.5 b | 0.0 f | 79.5 a | 0.99 fg- |
| DMS | 5% | | 36.8 | 12.5 | 8.2 | 0.71 |
| CV | | | 39.87 | 32.31 | 12.42 | 16.32 |

1078 x 1019

+ = No difference from 1019; - = No difference from 1078.
Mean percentages followed by the same letter do not differ at the 5% probability level according to Duncan's Multiple Range Test.
* % of plants on the basis of the number of original plants.

Table 2. Evaluations at Carimagua for vigor and seed production in $F_3$ selections of S. capitata 1019 x 1097, March, 1981. (Flowering observed November, 1980.)

| No. plants evaluated | Line | No. plants evaluated (%)* | Vigor 3 80 g/plant (%)* | Vigor 4 140 g/plant (%)* | Early floweing November (%)* | Seed production of 10 plants/line g pure seed |
|---|---|---|---|---|---|---|
| 183 | 25 | 91.5 | 62.5 a | 14.5 b | 37.5 def | 1.90 abcdef |
| 169 | 30 | 84.5 | 43.5 bcde- | 12.0 b | 40.5 def | 2.31 ab |
| 175 | 31 | 87.5 | 50.0 abc- | 15.0 b | 44.5 cd | 1.68 bcdef |
| 178 | 33 | 89.0 | 56.0 abc- | 18.5 ab | 52.0 bc | 2.24 abc |
| 166 | 34 | 83.0 | 49.0 abcd- | 27.5 a | 45.0 cd | 2.06 abcd |
| 137 | 35 | 68.5 | 25.0 f | 18.5 a | 33.0 fg | 2.49 a |
| 170 | 36 | 85.0 | 29.5 ef- | 12.5 b | 49.5 bc | 1.34 fg+ |
| 143 | 37 | 71.5 | 34.0 def- | 12.5 b | 49.5 bc | 1.38 efg+ |
| 158 | 41 | 79.0 | 54.0 abc- | 16.0 b | 56.0 b | 2.05 abcde |
| 149 | 43 | 74.5 | 32.5 ef- | 16.0 b | 43.5 cde | 1.48 defg+ |
| 139 | 45 | 69.5 | 19.5 fg+ | 10.5 b | 35.0 ef | 1.37 fg+ |
| 180 | 46 | 90.0 | 58.0 ab- | 14.5 b | 25.5 g | 1.58 cdefg+ |
| 188 | 47 | 94.0 | 53.5 abc- | 12.5 b | 40.0 def | 1.49 defg+ |
| 168 | 1019 | 84.0 | 6.0 g | 0.0 c | 84.0 a | 0.99 gh- |
| 148 | 1097 | 74.0 | 42.0 de | 0.0 c | 4.0 h | 0.39 h |
| DMS | 5% | | 15.5 | 9.6 | 8.8 | 0.67 |
| CV | | | 17.63 | 33.36 | 9.65 | 19.07 |

1019 x 1097

+ = No difference from 1019; - = No difference from 1097.
Mean percentages followed by the same letter do not differ at the 5% probability level according to Duncan's Multiple Range Test.
* % of plants on the basis of the number of original plants.

Centrosema pubescens

Previously, *C. macrocarpum* 5062 provided a source of high acid tolerance in the cross *C. pubescens* 5052 x *C. macrocarpum* 5062. Additional sources of acid tolerance were sought by growing 135 *Centrosema* introductions in pots of Carimagua oxisol for four months. The pots received rhizobium and the equivalent of a total 18 kg/ha of all essential nutrients. At harvest, acid tolerance was evaluated on the basis of growth and degree of leaf yellowing.

The results presented in Table 3 show that there was a negative correlation between degree of acid tolerance and Al uptake. There were 10 highly acid tolerant introductions, mainly *C. macrocarpum*.

Evaluation of acid and Al tolerance within populations from six *C. pubescens* crosses, and the cross *C. pubescens* 5052 x *C. macrocarpum* 5062, was continued in sand culture and Carimagua oxisol. The sand culture solution contained all essential nutrients, with P at 0.5 ppm, Ca 1 ppm and Mg 1 ppm; pH was at 4.2 and Al 5 ppm in the final experiments. In five sand culture experiments, 3000 $F_2$ plants of the *C. pubescens* - *C. macrocarpum* cross were evaluated. In three of these experiments, 2500 $F_2$ plants of four *C. pubescens* crosses were also evaluated.

Table 3. 135 *Centrosema* introductions classified for acid tolerance after growth in Carimagua oxisol and a relation between acid tolerance and Al content of tops.

| Acid tolerance rating+ and (No. introds.) | Species++ and (No. introds.) | Four random introds. mean dry wt g/pot* (mean Al ppm+++) |
|---|---|---|
| Dead (16) | *C. schottii* (10)<br>*C. pascuorum* ( 3) | ---- |
| 1 (30) | *C. virginianum* (10)<br>*C. pubescens* ( 5)<br>*C. acutifolium* ( 3) | 1.04 (764) |
| 2 (79) | *C. pubescens* (49)<br>*C. plumieri* ( 4) | 2.03 (198) |
| 3 (10) | *C. macrocarpum* ( 6)<br>*C. schiedeanum* ( 1)<br>*Centrosema* sp. ( 3) | 2.74 ( 53) |

\+ 1, 2, 3, low, medium, high acid tolerance, respectively.
++ Only main species listed.
+++ Al from each replicate.
* Least significant difference 0.45 ($P < 0.001$) calculated from analysis of variance. Correlation coefficient between Al and dry weight -0.96.

Table 4 gives the results of the last sand culture evaluation using 4.5 ppm Al. Among the *Centrosema* parents, only *C. macrocarpum* 5062 showed high acid and Al tolerance. This character was transferred to 20% of the $F_2$'s of the cross *C. pubescens* 5052 x *C. macrocarpum* 5062. None of the $F_2$'s of the *C. pubescens* 5052 x 5210 were highly tolerant.

Growth of Al tolerant selections from the various sand culture experiments, including the above experiment F in Carimagua oxisol gave variable results. Up to 20% of the plants had poor growth and yellowing, 60% moderate growth with some yellowing, and about 20% had vigorous green growth. The discrepancy between the results from sand culture and Carimagua soil is explained by the following results from relatively uniform $F_3$ populations grown and evaluated in trays of Carimagua oxisol. The $F_3$ seed was produced from acid tolerant $F_2$ selections grown in the CIAT field.

In the trays of Carimagua oxisol there were 100 plants of each $F_3$ line per tray. Rhizobium was added, and restricted weekly applications of essential nutrients given. Table 5 gives the results for acid tolerance and foliar levels of N, Al, Ca, Mg in 96 $F_3$ lines of *C. pubescens* - *C. macrocarpum* cross and parents. All lines had relatively low Al levels, showing that sand culture selection had been effective. However, only 10% of the lines had high tolerance, due apparently to efficient Ca absorption, as indicated by the high Ca level. This character was inherited from *C. macrocarpum* 5062, and should give the roots the ability to extract the small amounts of Ca in acid subsoils, and so penetrate them deeply. Efficient Ca absorption was present to a lesser degree in the 75% of lines with medium tolerance. The *C. pubescens* parent 5052 and 15% of the hybrid lines had low tolerance in the Carimagua oxisol, and a similar low Ca absorption, but all had Al tolerance.

Table 4. Acid tolerance of $F_2$'s and parents of *Centrosema* crosses in sand culture.

| Experiment f+ | No. plants in ratings++ | | | % population highly acid tolerant |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 5052 (C.p)* | 0 | 97 | 0 | 0 |
| 5062 (C.m)* | 0 | 36 | 67 | 65 |
| 5210 (C.p) | 0 | 98 | 0 | 0 |
| $F_2$ 5052 x 5062 | 250 | 265 | 132 | 20 |
| $F_2$ 5052 x 5210 | 410 | 201 | 0 | 0 |

$$x^{2\ (8)} = 730.24;\ P < 0.01$$

+ Sand culture Al level 4.5 ppm.

++ 1, 2, 3, low, medium, high acid tolerances, respectively.

* C.p = *Centrosema pubescens*; C.m = *Centrosema macrocarpum*.

Table 5. Acid tolerance ratings and foliar levels of N, Al, Ca, Mg of 96 $F_3$ lines and parents of the *C. pubescens* - *C. macrocarpum* cross 5052 x 5062.

| Acid tolerance rating | Symptoms | No. $F_3$'s/96 and parents | Means | | | |
|---|---|---|---|---|---|---|
| | | | % N | Al ppm | % Ca | % Mg |
| 3 | Vigorous, green leafy without symptoms 12-16 cm high | 10 | 4.4[1] | 158[1] | 0.96[1] | 0.30[1] |
| | | 5062 | 4.5 | 240 | 1.79 | 0.43 |
| 2 | Green with yellow mottling 8-12 cm high | 72 | 4.1[2] | 136[2] | 0.70[2] | 0.28[2] |
| 1 | Yellow-green 6-8 cm high | 14 | 4.6[3] | 130[3] | 0.51[3] | 0.32[3] |
| | | 5052 | 3.3 | 280 | 0.55 | 0.22 |

1, 2, 3 Means of 8, 16, 5 lines, respectively.

Most $F_3$ lines shown in Table 5 are growing in the current 1981-82 season at Carimagua. They have been given the same low but adequate fertilizer applications as outlined in S. capitata, so that the most mineral-efficient lines will be selected. There is a good correspondence between glasshouse evaluations and field performance. However, susceptibility to diseases and insects reduced the vigor of a proportion of the highly tolerant lines. Selection for disease and insect resistance are now major aims. Bacterial blight affected all lines moderately to severely, except C. macrocarpum controls. Chrysomelid and Homoptera attack also varied between lines. About 10% of $F_3$ lines showed a high level of resistance to both diseases and insects.

## Leucaena

Selection for acid tolerance was continued in populations from second and third generation seed of the $F_1$ (L. leucocephala cv. Cunningham x L. pulverulenta) backcrossed twice to Cunningham. The sand culture conditions were the same as outlined for Centrosema. As stated in 1980, among 45,000 seedlings evaluated in 10 sand culture experiments, 12.5% were selected for Al tolerance. However, when these were grown in Carimagua oxisol, only 2.7% of the original number proved to be tolerant. This reduction was due, like in Centrosema, to an additional screening for efficiency of Ca absorption, as shown in the following results with populations from third generation open-pollinated seed of selections.

Populations from third generation seed of 100 selected Leucaena lines and the controls were grown in trays of Carimagua oxisol with 100 plants of each line or control per tray. Rhizobium was added, and restricted weekly applications of essential nutrients given. After 10 weeks' growth, foliar samples were taken, and all plants evaluated for acid tolerance. Table 6 gives the results from all highly tolerant lines in which a majority of plants had high acid soil tolerance. It also gives the results from a proportion of the lines with medium and low tolerances, and these also had highly tolerant plants, but in lower numbers. Thus, uniformity for acid soil tolerance had been achieved in only a small percentage of the lines. Among the hybrid Leucaena lines, the most tolerant had the lowest Al and highest Ca contents. In the L. leucocephala controls, all had a low Ca content, but variety 11, a "giant" wood type, had no Al in this experiment. Nodulation was poor in all lines and varieties and accounted for their poor N content.

It appears from Table 6 results that lines with more efficient Ca absorption can be selected in these crossbred populations. Whether their capacity to absorb Ca will be high enough for good growth and deep root penetration in the Llanos at Carimagua, and in other acid soil areas, remains to be fully tested. Observations of the Carimagua trials, planted from seed in May 1981, indicate that lines selected for high acid soil tolerance in the glasshouse have better growth after six months than lines with medium or low tolerance.

Table 6. Foliar levels of Al, N, Ca, Mg in Leucaena lines (from third generation seed) growing in Carimagua oxisol.

| No. lines* | Acid soil tolerance | Al ppm | % N | % Ca | % Mg |
|---|---|---|---|---|---|
| 15 | High | 54 | 2.32 | 0.40 | 0.20 |
| 4 | Medium | 73 | 2.68 | 0.24 | 0.16 |
| 11 | Low | 98 | 2.46 | 0.23 | 0.15 |
| Controls* | | | | | |
| L. leucocephala 11 | Medium | 0 | 2.30 | 0.14 | 0.11 |
| Cunningham | Medium | 120 | 2.44 | 0.19 | 0.17 |
| L. leucocephala 1 | Low | 180 | 2.35 | 0.14 | 0.09 |

* Each line and control variety, 100 plants.

It was necessary to find new sources of acid tolerance in Leucaena to supplement the selection work being done in the above crossbred populations. Seed of eight Leucaena species, produced in the field at CIAT, was planted in pots of Carimagua oxisol in the glasshouse, and also at Carimagua. Table 7 shows that high acid tolerance is present in some varieties of L. diversifolia, L. macrophylla and L. Shannoni. Significant natural outcrossing had occurred in all the 52 chromosome species, except L. trichodes. Planned crosses have been achieved between these species and L. leucocephala cv. Cunningham, so it appears that other sources of acid tolerance could be transferred to L. leucocephala.

At Carimagua, in August 1981, 15 months after seeding as shown in Table 7, there was vigorous growth in the two L. diversifolia varieties, and in trees of L. macrophylla and L. Shannoni and their hybrids, some of which were 3 m high. By contrast at this stage, L. leucocephala 11 (78-15; Table 7) previously with no foliar Al (Table 6), had retarded growth and yellow leaves. Yet in 1980, L. leucocephala 11 was one of the most vigorous accessions at Carimagua.

Leaf samples were collected in August and October 1981, from a number of the species in the Carimagua trial. Table 8 shows that the Al level was lowest in the first sampling of L. leucocephala 11, and in L. macrophylla. The Ca content was lowest in L. leucocephala 11, intermediate in L. diversifolia, and highest in L. macrophylla and L. Shannoni. The low Ca absorption of L. leucocephala 11 was reflected in its retarded second season's growth. However, Ca absorption was apparently high enough in L. diversifolia to sustain active growth in the second season. The most spectacular growth was obtained in L. macrophylla and L. Shannoni, the species with the most efficient Ca absorption.

Table 7. Glasshouse and field evaluations of *Leucaena* species and varieties for variability and acid tolerance at CIAT, 1980-81.

| *Leucaena* species and varieties | 1980 glasshouse evaluation after 5 months' growth: % plants dead | Plants surviving: No. | Plants surviving: % differ. from parent | Acid tolerance* | 1981 Carimagua field evaluation after 15 months' growth: No. plants (mean) | % differ. from parent (mean) | Height (mean m) | Chromosome Nos. 2x |
|---|---|---|---|---|---|---|---|---|
| *L. leucocephala* cv. Cunningham | 0 | 30 | 0 | 1 | 210 | 0 | 1.0 | 104 |
| *L. leucocephala* K8 | 0 | 20 | 0 | 1 | 274 | 0 | 1.0 | 104 |
| *L. leucocephala* 78-15 | 0 | 19 | 0 | 2 | 317 | 0 | 1.5 | 104 |
| *L. Collinsii* 78-57 | 50 | 16 | 0 | 0 | 159 | 0 | 0.2 | 102** |
| *L. diversifolia* 78-3 | 0 | 48 | 10 | 3 | 107 | 1.5 | 2.1 | 52 |
| *L. diversifolia* 78-49 | 0 | 40 | 35 | 3 | 105 | 9 | 2.0 | 52 |
| *L. esculenta* 78-53c | 56 | 7 | 86 | 0 | - | - | - | - |
| *L. esculenta* 78-55 | 53 | 9 | 100 | 0 | - | - | - | 52 |
| *L. macrophylla* 78-65 | - | - | - | 3 | 28 | 17 | 2.3 | - |
| *L. pulverulenta* K 340 | 38 | 24 | 0 | 0-1 | 157 | 6 | 0.2 | 56 |
| *L. pulverulenta* AJO 3279 | 28 | 47 | 57 | 0-2 | 156 | 13 | 0.5 | 56 |
| *L. Shannoni* 78-70 | 0 | 31 | 65 | 3 | 56 | 92 | 2.4 | 52 |
| *L. trichodes* 78-86c | 60 | 8 | 0 | 0 | - | - | - | 52 |

* Acid tolerance 0: 1 (low); 2 (medium); 3 (high) on basis glasshouse and Carimagua results.

** Further investigation required for definite number.

It seems that breeding *Leucaena* lines for the Llanos and Cerrado soils can now be achieved with the knowledge, techniques and acid tolerant lines available. If the interspecific crosses made are able to be manipulated without fertility problems, it will be possible to concentrate a high level of acid soil tolerance in a variety of new forms.

Table 8. Foliar analyses of trees of some *Leucaena* species planted from seed at Carimagua Research Station, June 1980.

| Species and line No. | Sampling date | Means for foliar analyses of dry matter | | | | |
|---|---|---|---|---|---|---|
| | | % N | Al ppm | % P | % Ca | % Mg |
| *L. leucocephala* 11 | Aug. 24/81 | 3.12 | 70 | 0.11 | 0.40 | 0.22 |
| *L. leucocephala* 11 | Oct. 7/81 | 2.91 | 130 | 0.10 | 0.46 | 0.29 |
| *L. diversifolia* 26 | Aug. 24/81 | 3.46 | 150 | 0.11 | 0.54 | 0.16 |
| *L. diversifolia* 26 | Oct. 7/81 | 2.79 | 140 | 0.12 | 0.60 | 0.20 |
| *L. macrophylla* 18 | Aug. 24/81 | 3.86 | 70 | 0.12 | 0.72 | 0.21 |
| *L. Shannoni* 16 | Oct. 7/81 | 3.50 | 170 | 0.10 | 0.74 | 0.39 |

* Means from two replicates; replicates were in close agreement.

# Soil Microbiology

## Objectives

The objectives of the Soil Microbiology section were specified in 1980 as: a) to select promising legumes which do not need inoculating, b) to select *Rhizobium* strains for those which do need inoculating, and c) to evaluate the effect of inoculation techniques and pasture management practices on nodulation and nitrogen fixation in the field.

## Need to inoculate tests in cores of undisturbed soil

A series of experiments was carried out to detect responses to inoculation and nitrogen fertilizer of twenty legumes in Categories III, and IV and V in cores of undisturbed Carimagua soil. It was found that all the legumes tested produced more nitrogen in the tops when fertilized with nitrogen, and none produced more when inoculated than when not inoculated (Figures 1, 2 and 3). The strains used for inoculation were: CIAT 79 for *Pueraria phaseoloides* and *Aeschynomene histrix*; CIAT 71 + 1238 for *Stylosanthes capitata*; CIAT 71 for *S. macrocephala*, *S. leiocarpa*, *S. guianensis* and Zornia *brasiliensis*; and CIAT 299 for *Desmodium ovalifolium* and *D. canum*.

The response to inoculation was sometimes negative (*Z. brasiliensis*, *S. macrocephala*), although this was not statistically significant.

Some legumes nodulated more in the uninoculated treatments than others. For example, *C. brasilianum* ecotypes nodulated more with native strains than *C. pubescens* and *C. macrocarpum*, and produced correspondingly more nitrogen in the tops (Figure 3). Nitrogen fertilization inhibited nodulation in some legumes whereas in others it did not.

## Comparison of disturbed and undisturbed soil, and mineralization studies

Four legumes were tested for their response to inoculation and nitrogen fertilization in cores of undisturbed soil and in pots of the same soil which had been dried and broken into small pieces. Figure 4 shows that the difference between the treatments with and without nitrogen was much greater in the undisturbed than in the disturbed soil. This is partly due to greater production of N in the tops in the disturbed soil than in the undisturbed soil without nitrogen fertilizer. This indicates that disturbing the soil stimulates mineralization of organic matter to produce $NO_3^-$-N which is taken up by the plant.

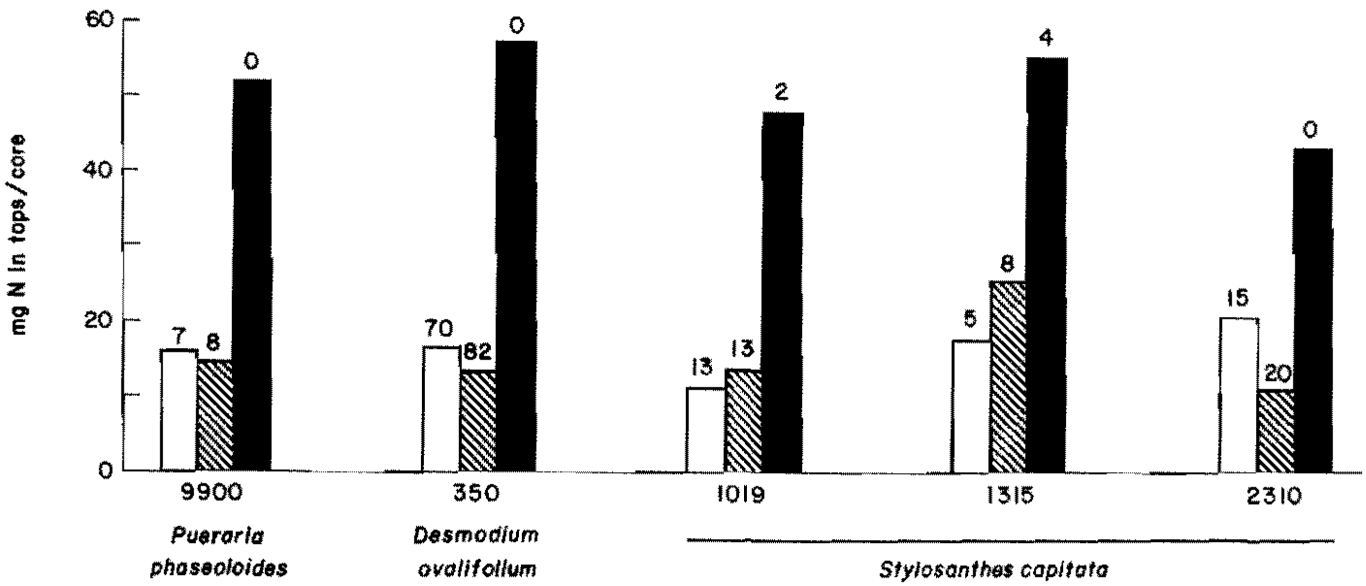



Figure 1. Response of forage legumes to inoculation ( ▧ ) and 150 kg N/ha ( ■ ) in cores of undisturbed Carimagua soil, and number of nodules per core.

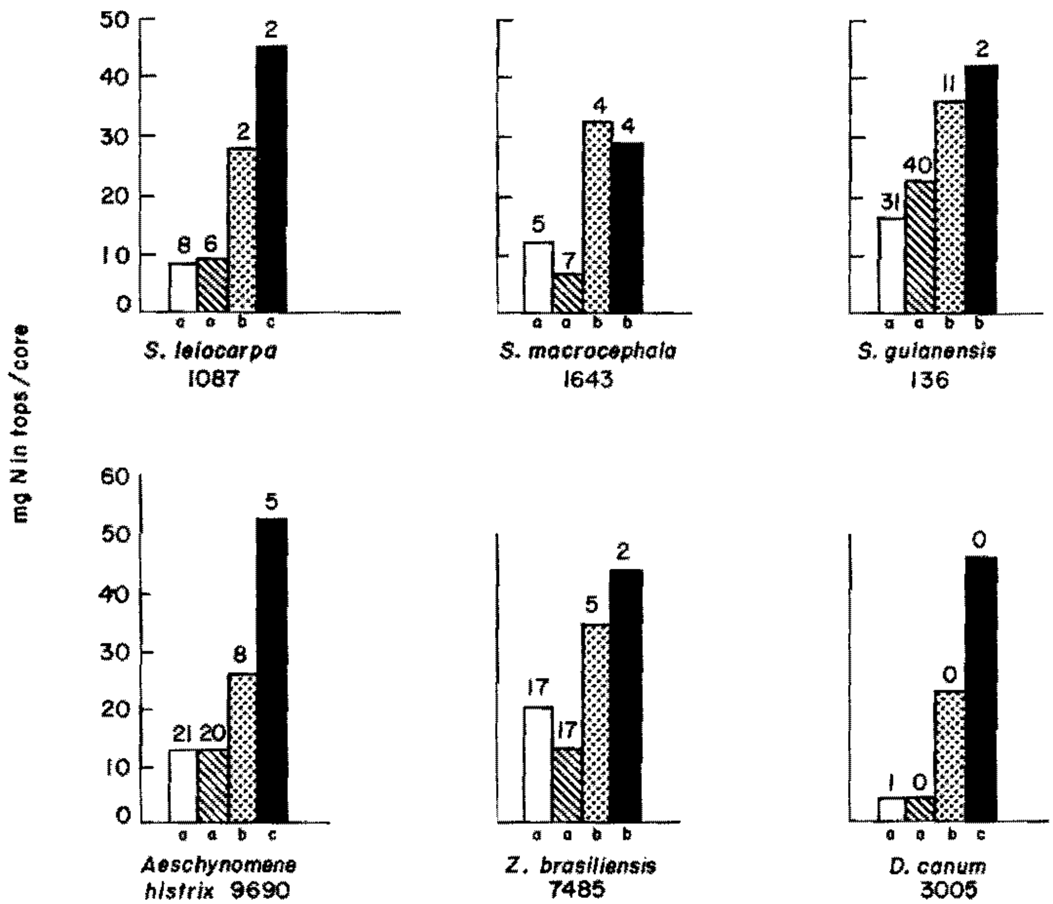



Figure 2. Response of forage legumes to inoculation (▧) and 75 (░) or 150 (■) kg N/ha in cores of undisturbed Carimagua soil, and number of nodules per core. Different letters represent significant differences in nitrogen in the tops.

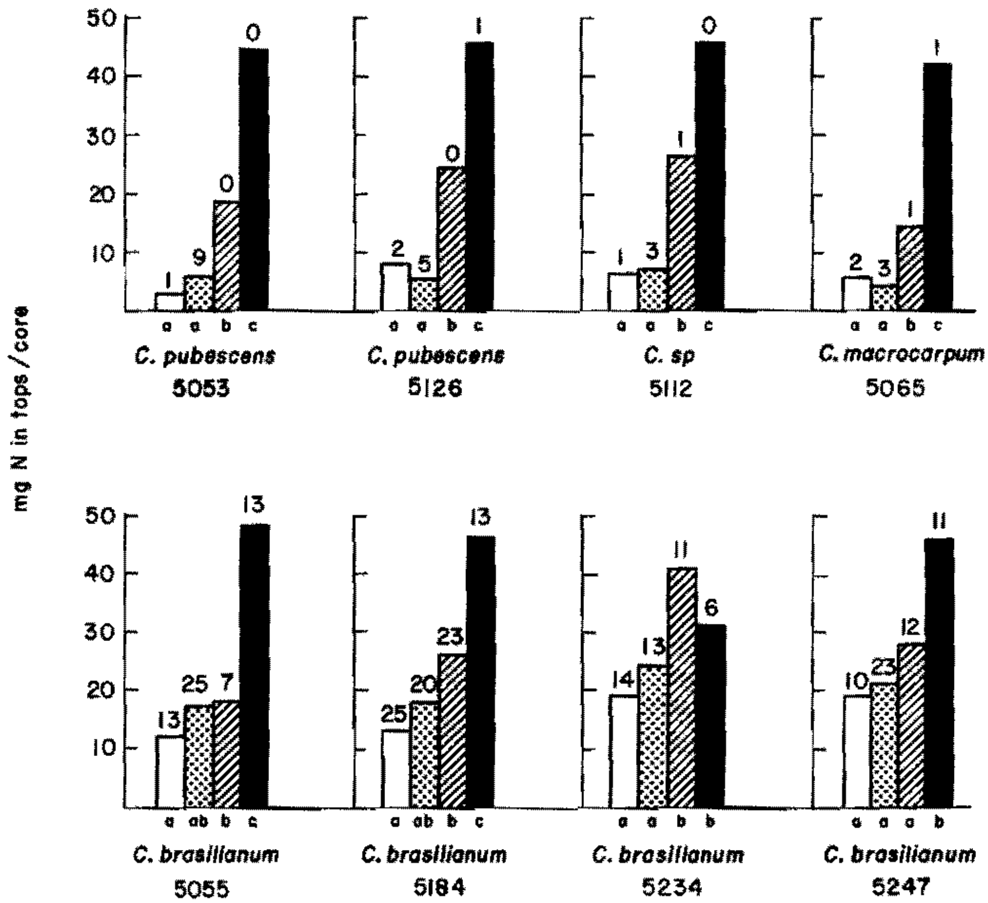



Figure 3. Response of eight Centrosema accessions to inoculation with CIAT strain 590 ( ) and 75 ( ) or 150 ( ) kg N/ha in cores of undisturbed Carimagua soil, and number of nodules per core. Different letters represent significant differences in nitrogen in the tops.

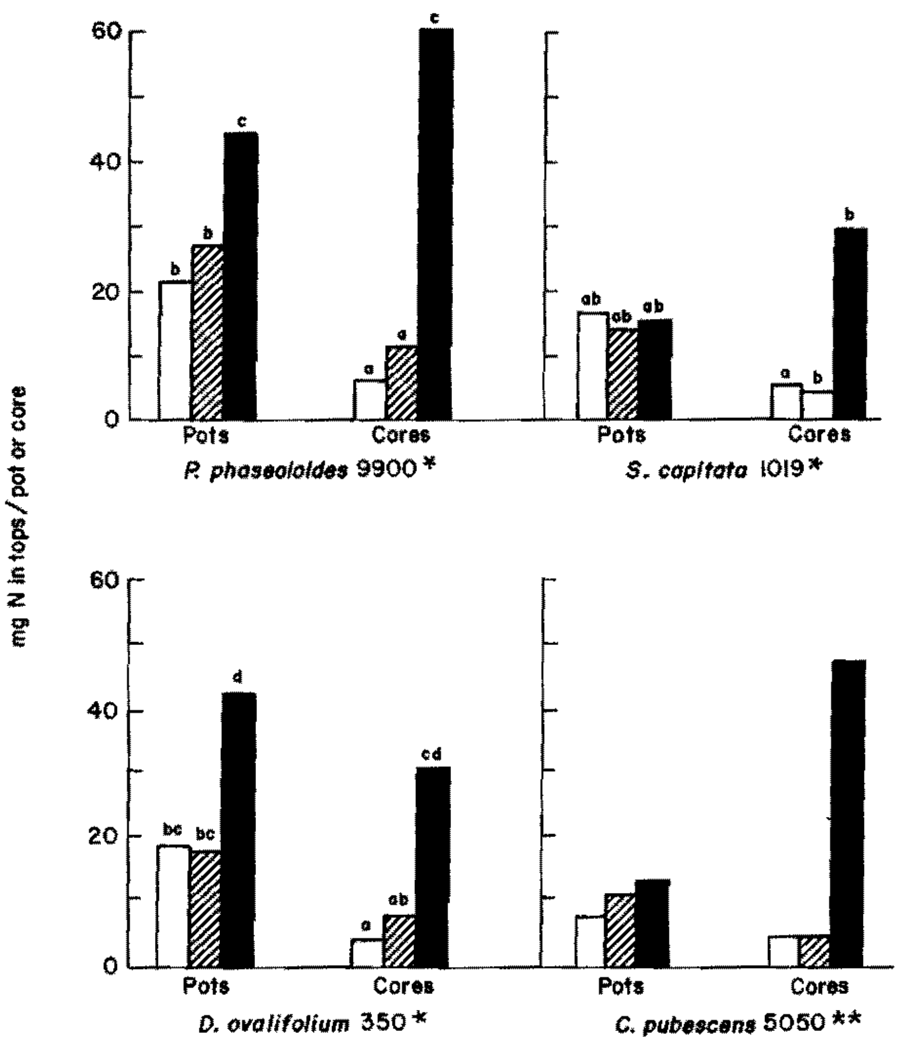



Figure 4. Response to inoculation (▨) and 210* or 120** kg N/ha (■) of four forage legumes in disturbed (pots) or undisturbed (cores) of unsterilized Carimagua soil after 12 weeks growth. Different letters represent significant differences in nitrogen in tops.

Table 1 shows that the soil under undisturbed savanna contains very low concentrations of $NO_3^-$-N. However in soil which had been ploughed but not planted the levels were higher, and at 1 m depth there were 18 ppm $NO_3^-$-N. The $NH_4^+$-N levels in the surface soil were correspondingly lower. In soil from different sites at Carimagua which had been ploughed and planted with S. capitata, the $NO_3^-$-N levels varied between 1 and 3 ppm depending on the site (Table 2). These results indicate that preparation of the land by ploughing can release considerable amounts of $NO_3^-$-N which may diminish the effect of inoculation during establishment. However, the $NO_3^-$-N produced may not remain long in the soil due to leaching and uptake by plant roots, and the amount produced may vary with soil conditions.

Table 1. Nitrogen concentrations in disturbed and undisturbed Carimagua soil, September 1981.

| Depth in soil (cm) | Undisturbed savanna | | | Unplanted ploughed and disked savanna | | |
|---|---|---|---|---|---|---|
| | ppm $NO_3^-$-N | ppm $NH_4^+$-N | ppm N total (Kjeldahl) | ppm $NO_3^-$-N | ppm $NH_4^+$-N | ppm N total (Kjeldahl) |
| 0 - 5 | 0.97 | 18.75 | 1288 | 3.94 | 7.53 | 1064 |
| 20 - 25 | 0.90 | 3.82 | 672 | 7.77 | 3.34 | 672 |
| 40 - 45 | 1.11 | 2.83 | 336 | 6.51 | 2.49 | 392 |
| 60 - 65 | 1.09 | 2.17 | 280 | 3.30 | 1.96 | 336 |
| 89 - 85 | 1.38 | 1.82 | 280 | 9.60 | 2.23 | 336 |
| 95 -100 | 1.18 | 2.50 | 280 | 18.23 | 3.01 | 280 |

## Rhizobium strain selection in cores of undisturbed Carimagua soil

Over 1000 new strains of Rhizobium isolated from legumes for which previously few strains were available have been added to the collection this year. The strains are tested for their ability to nodulate "Siratro" if their cultural characteristics are not those typical of Rhizobium. Some of the strains are fast-growing or produce acid in neutral yeast mannitol agar or both, which is unusual for Rhizobium isolated from tropical pasture legumes. A small proportion of the strains grows better on acid than on neutral medium.

Preliminary experiments have been carried out to test the response of different legume hosts to inoculation with a range of Rhizobium strains (usually isolated from the same species) in cores of undisturbed Carimagua soil in order to determine which strains are most effective.

Table 2. Nitrogen concentrations in ploughed and disked soil planted with Stylosanthes capitata at Carimagua in June-August and sampled in September 1981.

| Depth in soil (cm) | Hato 1 Yopare | | | Hato 6 Yopare | | | Hato 8 Alegría | | |
|---|---|---|---|---|---|---|---|---|---|
| | ppm $NO_3^-$-N | ppm $NH_4^+$-N | ppm N total (Kjeldahl) | ppm $NO_3^-$-N | ppm $NH_4^+$-N | ppm N total (Kjeldahl) | ppm $NO_3^-$-N | ppm $NH_4^+$-N | ppm N total (Kjeldahl) |
| 0 - 5 | 2.17 | 14.78 | 1176 | 1.07 | 11.40 | 784 | 1.05 | 11.73 | 616 |
| 20 - 25 | 2.55 | 5.06 | 560 | 1.53 | 4.43 | 448 | 1.50 | 3.08 | 280 |
| 40 - 45 | 3.00 | 3.98 | 392 | 1.56 | 3.19 | 280 | 1.07 | 1.71 | 168 |
| 60 - 65 | 2.57 | 3.15 | 392 | 1.30 | 2.57 | 224 | 1.06 | 2.11 | 168 |
| 80 - 85 | 2.34 | 3.16 | 280 | 1.32 | 2.52 | 168 | 1.73 | 1.97 | 112 |
| 95 -100 | 2.12 | 4.75 | 280 | 1.60 | 3.87 | 168 | 1.27 | 1.74 | 112 |

Figure 5 shows the results obtained with Desmodium ovalifolium. The best strain increased N in tops of the uninoculated control by 18% (1.81 fold). However N in tops of the N fertilized control was much greater than any of the inoculated treatments, and the best strain was not significantly better than a group of 10 other strains, although it was significantly better than the uninoculated control. Possibly this was due to the limitation of nitrogen fixation by the low nutrient levels in the cores.

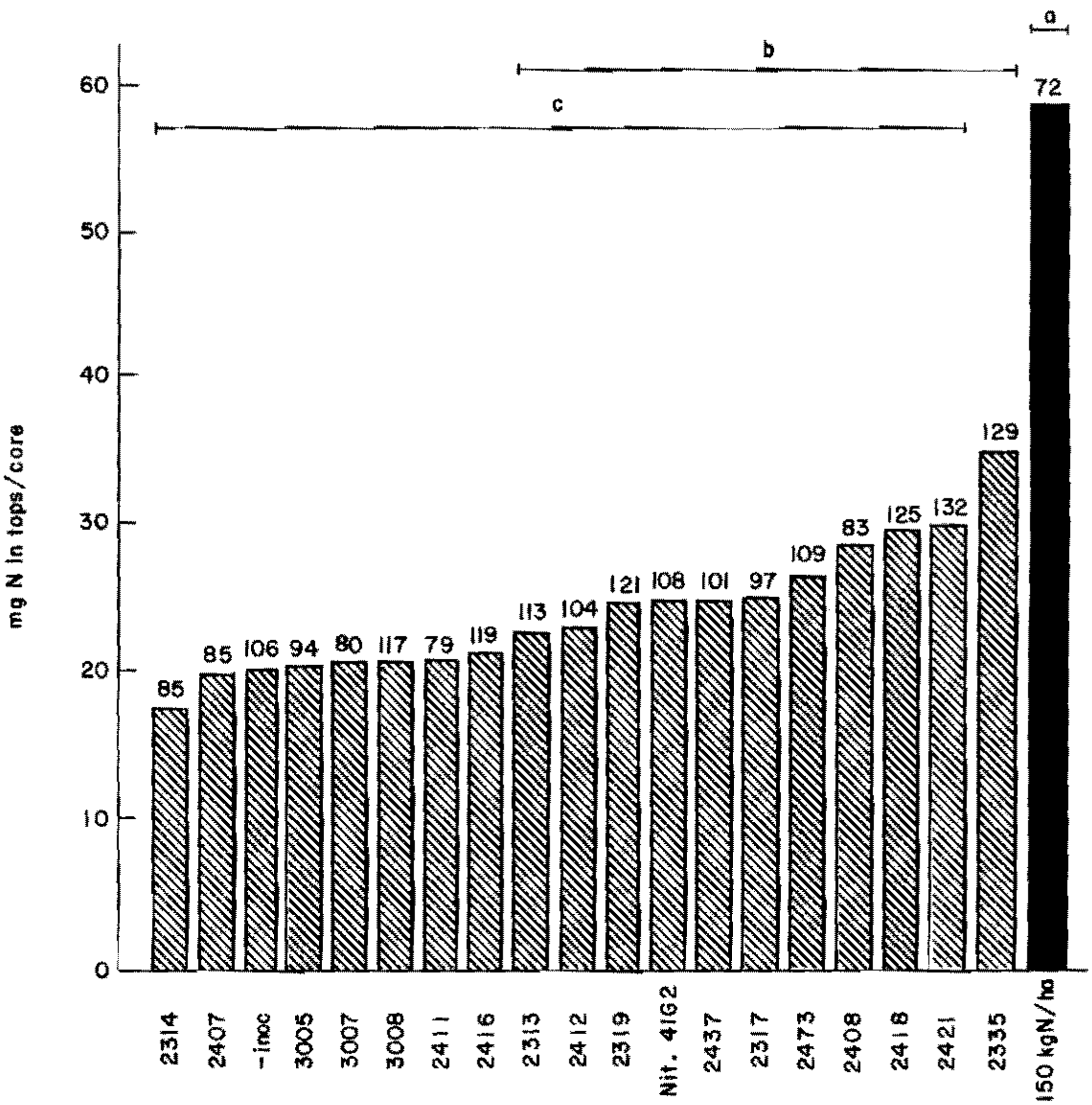



Figure 5. Response of Desmodium ovalifolium 350 to inoculation with different Rhizobium strains (▨) and nitrogen (■) in cores of undisturbed Carimagua soil, and number of nodules per core.

Figure 6 shows that S. capitata responded to nitrogen, but the control without nitrogen or inoculation contained high nitrogen levels even though it had few nodules. The best strain increased N in tops of the uninoculated control by only 39% (1.39 fold) although the total N in these plants was much higher than in the equivalent D. ovalifolium plants.

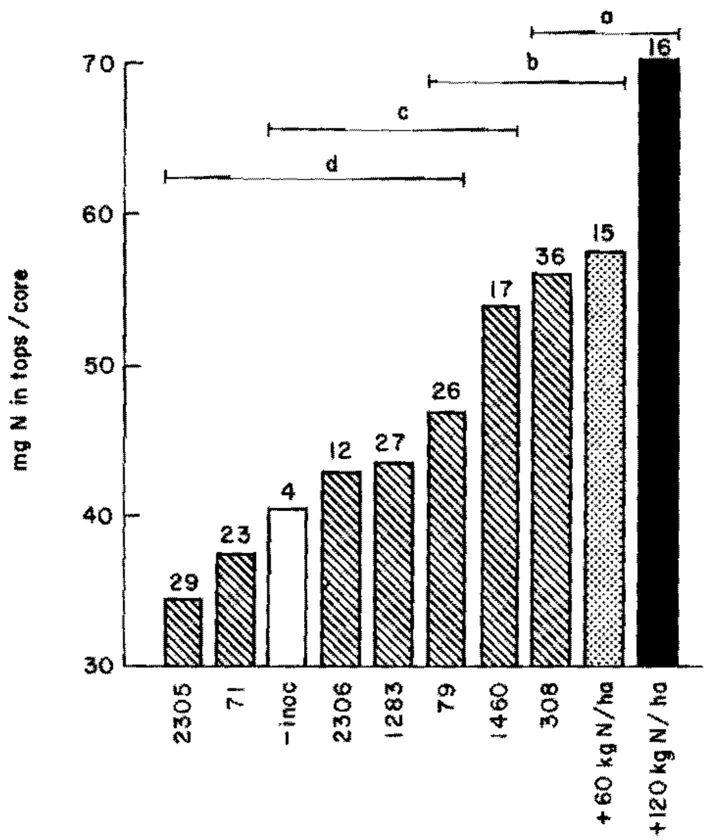



Figure 6. Response of Stylosanthes capitata 1019 to inoculation with different Rhizobium strains (▨) and two levels of N (░ ■) in cores of undisturbed Carimagua soil, and number of nodules per core.

This indicates that nodulation by S. capitata is very sensitive to low levels of soil nitrogen, which are used very efficiently by the plant. In sand and acid (pH 4.5) nutrient solution the difference between the controls with and without nitrogen was much greater, and CIAT strain 1460 was found to be very effective on three ecotypes of S. capitata (Table 3). Strain 308, which was effective in the cores of soil, was not effective in the sand and acid nutrient solution.

Table 3. Effect of inoculation of *Rhizobium* strains on nodulation and growth of three ecotypes of *S. capitata* in sand and acid (pH 4.5) nutrient solution.

| Treatment | Stylosanthes capitata ecotypes | | | | | |
|---|---|---|---|---|---|---|
| | 1019 | | 1315 | | 2310 | |
| | No. nodules/ 2 plants | mg dry weight/2 plants | No. nodules/ 2 plants | mg dry weight/2 plants | No. nodules/ 2 plants | mg dry weight/2 plants |
| Not inoculated | 0 | 15.4 | 0 | 19.4 | 0 | 17.0 |
| Strain 308 | 11 | 23.0 | 31 | 36.6 | 35 | 28.8 |
| Strains 71 + 1238 | 0.2 | 14.5 | 0.6 | 15.2 | 1.6 | 16.4 |
| Strain 1460 | 28 | 456.4 | 24 | 502.8 | 31 | 606.6 |
| 10 ppm N | 0 | 158.4 | 0 | 366.4 | 0 | 227.4 |

Centrosema macrocarpum 5065 and Centrosema sp. 5112 were inoculated with the same 11 strains of Rhizobium. For both legumes strain 1780 was effective increasing N in tops by 260% (3.6 fold) and 150% (2.6 fold), respectively (Figures 7 and 8). However, the three most effective strains of Centrosema sp. 5112 were among the four least effective for C. macrocarpum. Strain 2389 was completely ineffective for both legumes, even though it increased the number of nodules per plant. The two figures show that Centrosema sp. 5112 nodulated more effectively with a wider range of strains than C. macrocarpum.

In other similar experiments with Pueraria phaseoloides and Desmodium canum, strains 2434 and 1502 respectively, produced most nitrogen in the tops.

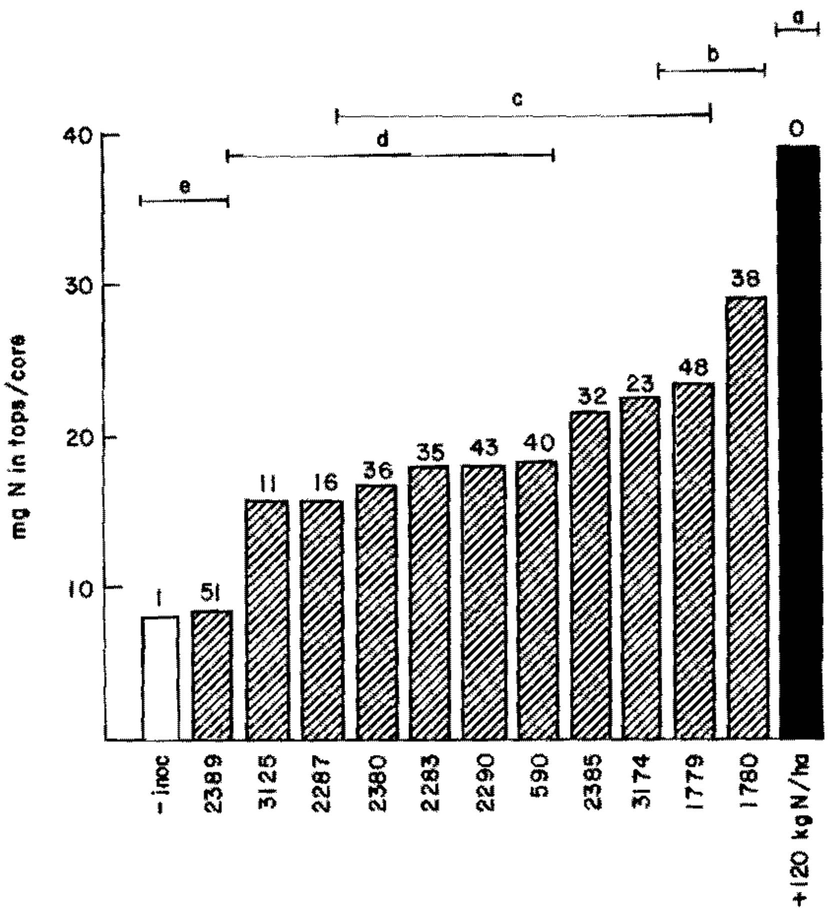



Figure 7. Response of Centrosema macrocarpum 5065 to inoculation with different Rhizobium strains (▆) and nitrogen (▨) in cores of undisturbed Carimagua soil, and number of nodules per core.

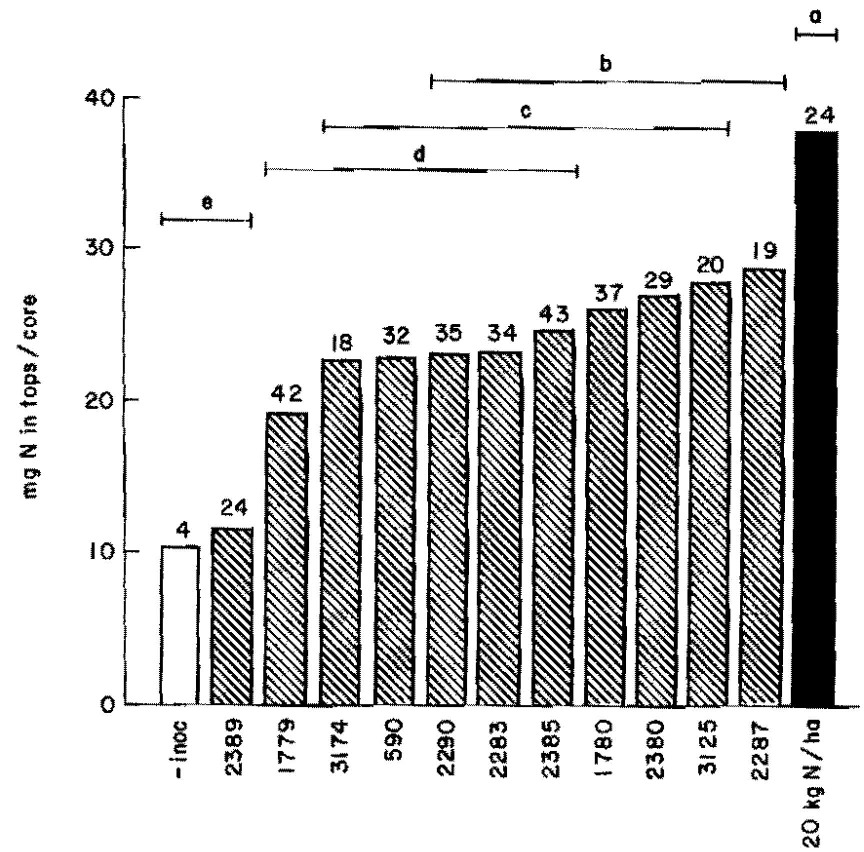



Figure 8. Response of Centrosema sp. 5112 to inoculation with different Rhizobium strains (▧) and nitrogen (■) in cores of undisturbed Carimagua soil and number of nodules per core.

Further experiments are being carried out with different fertility levels and different soil in the undisturbed cores to determine whether the performance of the good strains is consistent under different conditions.

## Response to nitrogen of uninoculated legumes in the field

Figure 9 shows responses to N of uninoculated legumes in the field. Thus, a response of these legumes to inoculation with an effective strain can be expected. However, the differences between the treatments with and without nitrogen are not as great as those observed in the disturbed soil cores. This is probably due to mineralization of soil nitrogen during preparation of the land for planting. These legumes were planted in pure stands. It is possible that if they were planted with a grass, nitrogen uptake by the grass would increase nitrogen deficiency in the uninoculated legumes. Further studies to detect responses of legumes to inoculation in the field will be carried out in soils expected to be deficient in nitrogen such as sandy soils, humid soils, soils prepared with minimum tillage, and in mixed swards with grasses.

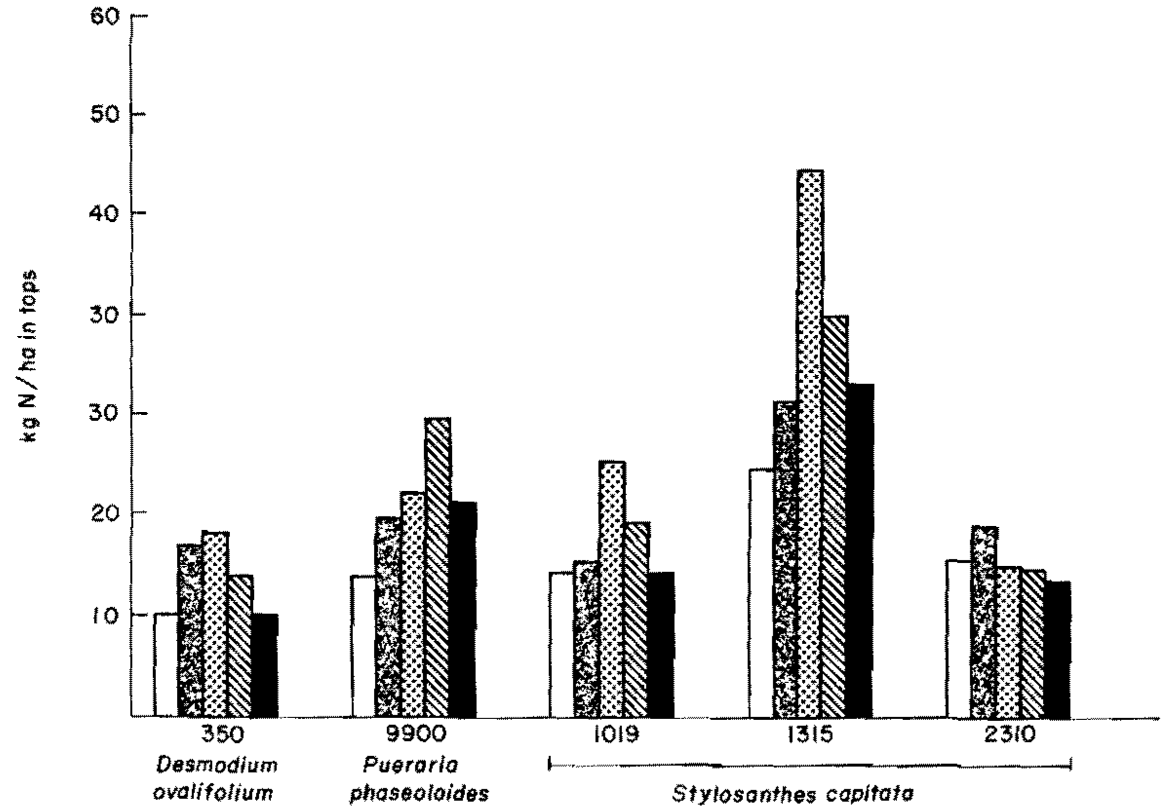



Figure 9. Effect of N (urea) 0 ( ) 25 ( ) 50 ( ) 100 ( ) and 200 ( ) kg N/ha on production of nitrogen in the tops of forage legumes at Carimagua, three months after planting.

# Seed Production

The Section has continued with its basic objectives of: a) production and distribution of seed of experimental lines and of basic seed, and b) the study of limiting factors to production technology of important species.

## Seed Production

Seed production areas are mainly located in Quilichao (Cauca) and Carimagua (Llanos Orientales), and facilitates for cleaning, quality assessment and storage of seed are located at Palmira. Species and accessions for seed increase are defined by a Program Committee and depend on the potential demand for seed in the next phases of pasture evaluation.

Seed of a large number of species is produced in small plots in Quilichao, while larger seed production areas are concentrated in Carimagua. Quantities of seed produced during 1981 are shown in Table 1. Emphasis was on the genera *Stylosanthes*, *Centrosema*, and *Desmodium*.

Table 1. Summary of seed produced, October 1980-October 1981.

| Genus | Accessions (No.) | Seed weight (kg)* |
|---|---|---|
| Legumes | | |
| *Stylosanthes* | 34 | 3,030.5 |
| *Centrosema* | 14 | 70.5 |
| *Desmodium* | 7 | 57.0 |
| *Zornia* | 6 | 67.0 |
| *Aeschynomene* | 2 | 88.0 |
| *Pueraria* | 1 | 2.0 |
| Total legumes | 64 | 3,314.5 |
| Grasses | | |
| *Andropogon* | 3 | 4,949.0 |
| *Brachiaria* | 5 | 43.0 |
| *Panicum* | 1 | 8.0 |
| Total grasses | 9 | 5,000.0 |
| Total all accessions | 73 | 8,314.5 |

* Legumes, seed or seed in pod, $>$ 95% purity.
Grasses, clean seed, $>$ 35% purity.

*D. ovalifolium* 350 failed to produce seed in Carimagua during 1980 due to an early dry season which coincided with the onset of flowering. Observations suggest that this species requires good moisture availability extending through the flowering period for high seed production.

The quantities of seeds distributed by the Section to the Program and to collaborators are shown in Table 2. During 1981, 242 requests were handled and a total of 7370 kg of seed was distributed.

Table 2. Seed processed and distributed during 1980-1981.

| Distribution* | Grasses (kg) | Legumes (kg) | Total (kg) |
|---|---|---|---|
| Pastures Program | 3,327.3 | 2,708.8 | 6,036.1 |
| Regional trials | 138.6 | 30.7 | 169.3 |
| Basic seed | 1,015.0 | 62.0 | 1,077.0 |
| Other | 53.1 | 35.0 | 88.1 |
| Grand total | 4,534.0 | 2,836.5 | 7,370.5 |

*From a total of 242 composite requests.

## Production Technology and *Andropogon gayanus*

In the Quilichao region, the two growing seasons offer two potential harvests annually, provided appropriate management is applied. An experiment is in progress comparing three defoliation treatments and two nitrogen levels. Burning stimulated higher seed yields and later maturity at 2 of 5 consecutive harvests. Otherwise burning, cutting, and cutting with removal of aftermath resulted in similar seed yields. Nitrogen (zero versus 100 kg/ha as urea) increased pure seed yields at 3 of 4 harvests, with increases averaging 40%. Overall, seed yields tended to decrease with age of stand.

The commercial management of established stands destined for seed production requires defoliation so as to restrict mature plant height and allow an efficient harvest. The simplest on-farm defoliation method is via grazing. It will be necessary to determine, within each geographic region, the optimum period and timing of regrowth following grazing to promote maximum seed yield. As a prelude to such a grazing experiment, the effects of different times of cutting and concurrent fertilizer application were compared at Carimagua during 1980. The cutting treatments were, uncut, cut July 30, cut August 29, cut September 30, and cut October 29, using a slasher at 30 cm height.

Nitrogen treatments 0, 50, 100 kg/ha, were applied to subplots as urea, following a common maintenance fertilizer dressing at the time of cutting. The uncut plots grew to 3 m at maturity, while the cut in July, August, September, and October treatments grew to 2.5, 2.1, 1.7, and 1.5 m, respectively. The maximum pure seed yield was recorded in the cut August 29 plus 100 kg N/ha treatment, with a period of 15 weeks between cutting and harvest maturity. Cutting after August 29 resulted in reduced seed yield in 1980. A response to nitrogen was only observed at the August cutting. These results used to plan a follow-up experiment involving different periods of continuous grazing until the same months of the year, to determine how to best manage areas for seed production under grazing.

On several occasions seed harvests have been made in comparable circumstances by both manual harvesting and direct combining. Results are summarized in Table 3 and indicate an average of 50% more pure seed by the manual method whereby inflorescences are hand cut, sweated in heaps for 3-4 days then lightly threshed. On the basis of 25 versus 4 mandays/ha for the manual and combine methods, respectively, a combine harvesting rate of 4 hr/ha and prevailing costs of labor and combine rental at Palmira, the cost of harvesting a kg of pure seed is comparable for the two methods.

Table 3. Pure seed yields from two methods of harvesting *Andropogon gayanus* at Palmira.

| Harvest | Pure seed yield* (kg/ha) | |
|---|---|---|
| | Combine | Manual |
| 1. January, 1978 | 32 | 69 |
| 2. August, 1980 | 19 | 32 |
| 3. September, 1980 | 29 | 49 |
| 4. July, 1981 | 23 | 51 |
| Average | 26 | 50 |

*Pure seed, as defined by presence of a caryopsis.

# Soil Fertility and Plant Nutrition

The research strategy on soil fertility and plant nutrition of the Tropical Pastures Program is based on a low-input soil management technology. Its general objective is to make the most efficient use of scarce fertilizer inputs by establishing pasture species and ecotypes that are most tolerant to existing soil constraints, thus decreasing the rates of fertilizer applications while attaining reasonable, but not necessarily maximum quality and yield. The specific objectives of this strategy are the management of soil acidity (Al and Mn toxicities, Ca and Mg deficiencies) and management of low native soil fertility (macro and micro-nutrient deficiencies, except nitrogen) for the establishment and maintenance of tropical pastures.

## Management of Soil Acidity

The main soil acidity constraints are identified as aluminum and/or manganese toxicities, calcium and magnesium deficiencies, which need to be alleviated in order to obtain successful pasture establishment. Selection of productive pasture species and ecotypes that are tolerant to Al and/or Mn toxicities is the main component in soil acidity management. In addition, the aluminum-tolerant species and ecotypes of tropical pastures do not need a decreased aluminum saturation level of the soil by liming, but in most cases the plants require fertilization with calcium and magnesium.

### Tolerance to aluminum toxicity

Although the hematoxylin test is a very useful technique to separate the germplasm into two broad groups according to tolerance to Al toxicity, it was found that the evaluation in many cases was very qualitative. In order to avoid this situation and in addition to the visual estimation of the stainability of the root system by the hematoxylin, the relative root length was introduced as a quantitative measurement. Figure 1 shows the relationship between regression coefficients of the relative root length and the relative dry matter yields of 47 ecotypes of *Stylosanthes macrocephala* grown under three levels of Al stress. This figure shows the distribution of the ecotypes according to their Al tolerance. Comparing with the hematoxylin test and the Al-susceptible control (*Stylosanthes sympodialis* 1044), the Al-susceptible ecotypes of *S. macrocephala* fall within the group defined as susceptible by the hematoxylin test. There are several ecotypes that were grouped as Al-tolerant by the hematoxylin test but that were identified as susceptible by their low regression coefficients of relative root length. These results may be explained in the sense that the ecotypes identified as Al-tolerant by the visual-hematoxylin test were healthy plants although their root growth was reduced under Al stress. In fact, the relative dry matter yields of most of the ecotypes were over 50% of maximum yield obtained with no Al stress. It appears that not only the reduction in root growth but also the top growth has to be considered in this screening process. However, for practical use the selection of the most Al tolerant ecotypes by any of the two tests is enough considering the high number of ecotypes.

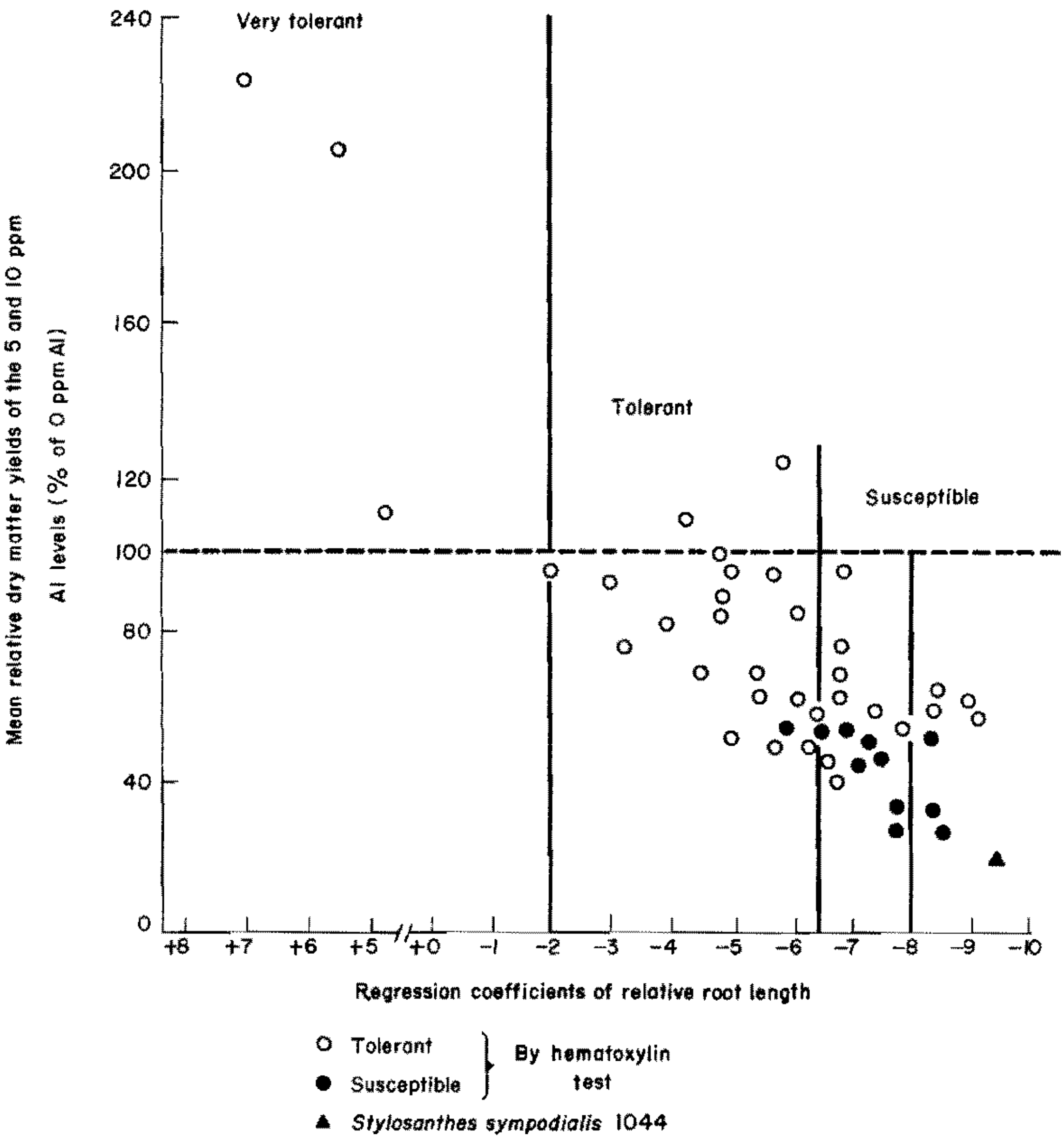



Figure 1. Relationship between regression coefficients of the relative root length and the mean relative dry matter yields of 5 and 10 ppm Al of 47 ecotypes of Stylosanthes macrocephala and their comparisons with the hematoxylin test.

## Tolerance to manganese toxicity

Managenese toxicity is another constraint in certain acid soils but its geographical extent is not known. During the soil characterizations for the pasture regional trials, however, several soils were identified with available soil manganese above the toxic level for tropical pastures ( >50 ppm Mn). Using the natural distribution of the soil manganese from low (0-20 ppm Mn) to high ( > 50 ppm Mn) at Quilichao, a field experiment was established to study the differential tolerance of several species and ecotypes of tropical pasture grasses and legumes.

The results are shown in Tables 1 and 2. The idea that legumes are more susceptible to manganese toxicity than the grasses appears not to be true since among pasture species and ecotypes within species in both grasses and legumes there is a differential tolerance to Mn toxicity. Among the pasture grasses the differential tolerance is better appreciated among ecotypes than at species level. On the other hand, the most tolerant ecotypes had higher dry matter production at high Mn stress than at low Mn stress which would indicate a beneficial rather than a detrimental effect. Some ecotypes within a species judged on the basis of the relative index as Mn-susceptible (Relative Index less than 0.5) had a dry matter production similar to the most Mn-tolerant ecotypes. This fact can be related to the high inherent potential of these ecotypes for biomass production which in many cases may be enough for animal feeding. This is the case of Brachiaria humidicola 679, Brachiaria eminii 6241 and Andropogon gayanus 6200.

Table 2 shows the dry matter yield and differential tolerance of several tropical legume species and ecotypes to Mn toxicity in the soil. The performance of these pasture legumes follows a similar trend to that of grasses. In general, the manganese toxicity symptoms included marginal chlorosis, induced iron deficiency, distortion of young leaves, and localized spots where manganese accumulates.

## Calcium requirements by tropical pastures

The diagnosis of aluminum toxicity in acid soils of tropical America has been based on exchangeable aluminum extracted by 1N KCl. Liming recommendations are commonly derived from the level at which this exchangeable aluminum is almost neutralized and the soil pH is raised to the range 5.2-5.5. However, liming requirements based only on exchangeable aluminum may overestimate the lime rates because of varying degrees of plant tolerance to aluminum toxicity. In addition, initial results (Tropical Pastures Program, Annual Report, 1980) provided the information that the response of the Al-tolerant pasture grasses and legumes was mainly related to calcium requirements rather than to liming. Thus a field experiment was established on an Oxisol of Carimagua to determine the calcium requirements of several tropical pasture grasses and legumes. Four calcium rates (50, 100, 200 and 400 kg Ca/ha) plus a control (no Ca applied) were used and calcitic lime was the calcium source. Table 3 shows the external and internal critical calcium requirements associated with about 80% of maximum yield during the rainy season and dry seasons of several tropical pastures species and ecotypes.

Table 1. Dry matter production and differential tolerance of several species and ecotypes of tropical pasture grasses to manganese toxicity under field conditions.

| Species | Ecotype | Dry matter yield | | |
|---|---|---|---|---|
| | | Low Mn (10 ppm Mn) | High Mn (86 ppm Mn) | Relative Index (High Mn/Low Mn) |
| | | -----t $ha^{-1}$ | $year^{-1}$------ | |
| Brachiaria ruziziensis | 654 | 2.88 | 3.00 | 1.04 |
| | 655 | 4.86 | 3.10 | 0.64 |
| | 660 | 3.53 | 1.83 | 0.52 |
| | 656 | 3.30 | 1.48 | 0.45 |
| Brachiaria decumbens | 606 | 5.52 | 6.69 | 1.21 |
| | 6130 | 3.37 | 3.19 | 0.95 |
| | 6131 | 2.82 | 1.93 | 0.68 |
| | 6132 | 3.14 | 1.28 | 0.40 |
| Brachiaria humidicola | 675 | 2.66 | 2.63 | 0.98 |
| | 6013 | 3.76 | 3.00 | 0.80 |
| | 679 | 5.73 | 2.78 | 0.48 |
| Brachiaria brizantha | 665 | 5.74 | 6.05 | 1.05 |
| | 667 | 5.44 | 3.29 | 0.60 |
| | 6016 | 1.47 | 0.86 | 0.58 |
| Brachiaria radicans | 6020 | 1.30 | 1.87 | 1.43 |
| Brachairia dictyoneura | 6133 | 2.42 | 1.86 | 0.77 |
| Brachiaria eminii | 6241 | 4.70 | 2.20 | 0.47 |
| Andropogon gayanus | 6054 | 3.40 | 4.06 | 1.19 |
| | 621 | 3.70 | 4.01 | 1.08 |
| | 6053 | 6.81 | 6.78 | 0.99 |
| | 6200 | 6.07 | 4.39 | 0.72 |
| Panicum maximum | 661 | 3.14 | 4.45 | 1.42 |
| | 673 | 4.30 | 4.54 | 1.05 |
| | 697 | 4.78 | 4.85 | 1.01 |
| | 684 | 2.28 | 1.95 | 0.85 |
| Pennisetum purpureum | 658 | 10.0 | 8.73 | 0.87 |
| | 672 | 13.1 | 10.39 | 0.79 |
| Setaria anceps | 6187 | 6.25 | 7.13 | 1.14 |
| | 6188 | 3.13 | 1.16 | 0.37 |

Among the grasses, Brachiaria humidicola 679 had the least external calcium requirement (50 kg Ca/ha equivalent to only 125 kg calcitic lime/ha) and also the least internal calcium requirement (0.22% Ca) as compared with the other grasses which required twice the amount of external calcium to have more or less the same dry matter production. However, all these grasses have a low Ca requirement since the small amount of calcium applied to the soil practically did not change the soil pH or the Al saturation percentage at all.

Table 2. Dry matter yield and differential tolerance of several species and ecotypes of tropical pasture legumes to manganese toxicity under field conditions.

| Species | Ecotype | Dry matter yield | | |
|---|---|---|---|---|
| | | Low Mn (10 ppm Mn) | High Mn (86 ppm Mn) | Relative index (High Mn/Low Mn) |
| | | -----t/ha$^{-1}$ | year$^{-1}$------ | |
| Stylosanthes capitata | 1405 | 1.93 | 2.59 | 1.34 |
| | 1315 | 2.14 | 2.31 | 1.07 |
| | 1019 | 1.95 | 2.01 | 1.03 |
| | 1097 | 3.23 | 3.32 | 1.02 |
| Stylosanthes guianensis | 136 | 4.82 | 6.21 | 1.29 |
| | 184 | 5.39 | 5.80 | 1.07 |
| Stylosanthes hamata | 147 | 4.78 | 5.05 | 1.05 |
| Centrosema macrocarpum | 5065 | 3.11 | 2.72 | 0.87 |
| | 5462 | 2.95 | 2.36 | 0.80 |
| Centrosema brasilianum | 5237 | 2.10 | 2.52 | 1.20 |
| | 5180 | 1.61 | 1.44 | 0.89 |
| Centrosema pubescens | 5118 | 1.26 | 1.95 | 1.54 |
| | 5053 | 1.88 | 2.20 | 1.17 |
| | 5112 | 3.03 | 3.23 | 1.06 |
| | 5189 | 2.27 | 2.27 | 1.00 |
| | 5126 | 3.23 | 2.80 | 0.87 |
| | 438 | 3.16 | 2.55 | 0.80 |
| | Common | 2.47 | 1.89 | 0.76 |
| Desmodium ovalifolium | 350 | 3.95 | 4.52 | 1.14 |
| Desmodium heterophyllum | 349 | 2.80 | 2.36 | 0.84 |
| Desmodium heterocarpon | 365 | 2.34 | 1.15 | 0.49 |
| Codariocalyx gyroides | 3001 | 3.37 | 2.20 | 0.65 |
| Calopogonium mucunoides | 7367 | 2.27 | 2.41 | 1.06 |
| | Common | 4.09 | 3.72 | 0.90 |
| | 9161 | 2.79 | 1.68 | 0.60 |
| Pueraria phaseoloides | 9900 | 4.79 | 5.79 | 1.20 |
| Zornia latifolia | 9286 | 1.93 | 1.65 | 0.85 |
| | 728 | 1.54 | 1.27 | 0.82 |

Results with pasture legumes also show marked variations in their calcium requirements not only among species but also among ecotypes within species. Although the external calcium requirements were in many cases the same as with the grasses, the internal calcium requirements for legumes were higher than those of the grasses at both rainy and dry seasons. These observations have implications for competitive effects with respect to calcium in grass-legume mixtures and especially for those with the same external Ca requirement. Under these conditions pasture legumes may compete with grasses since when the immediate supply of calcium falls below the combined demands of the plants, competition begins.

The equivalent amount of calcium to that applied with the calcitic lime would be also applied with the basic slag (Calfos) or rock phosphates to meet the external calcium requirements avoiding in this way the use of lime.

Table 3. External and internal critical calcium requirements* and critical dry matter yields for the rainy and dry seasons of various tropical pasture species for the establishment period.

| Species | Ecotype | External critical Ca level ($kg/ha^{-1}$) | Dry matter yield ($t/ha^{-1}$) Rainy (3 cuts) | Dry matter yield ($t/ha^{-1}$) Dry (2 cuts) | Internal critical Ca level (%) Rainy | Internal critical Ca level (%) Dry |
|---|---|---|---|---|---|---|
| Grasses | | | | | | |
| Brachiaria humidicola | CIAT-679 | 50 | 6.7 | 2.0 | 0.22 | 0.25 |
| Andropogon gayanus | CIAT-621 | 100 | 6.7 | 2.6 | 0.23 | 0.21 |
| B. decumbens | CIAT-606 | 100 | 7.6 | 2.1 | 0.37 | 0.30 |
| B. brizantha | CIAT-665 | 100 | 7.3 | 1.8 | 0.37 | 0.32 |
| Legumes | | | | | | |
| Stylosanthes capitata | CIAT-1315 | 50 | 6.0 | 1.1 | 0.73 | 0.53 |
| S. capitata | CIAT-1693 | 50 | 5.5 | 1.4 | 0.82 | 0.56 |
| S. capitata | CIAT-1691 | 50 | 5.6 | 1.2 | 0.70 | 0.54 |
| S. capitata | CIAT-1318 | 100 | 6.5 | 1.1 | 1.16 | 0.71 |
| S. capitata | CIAT-1019 | 100 | 5.6 | 0.7 | 0.93 | 0.74 |
| S. capitata | CIAT-1441 | 200 | 5.5 | 1.0 | 1.15 | 0.88 |
| S. capitata | CIAT-1405 | 200 | 5.1 | 1.0 | 0.96 | 0.72 |
| S. capitata | CIAT-1342 | 200 | 5.1 | 0.9 | 1.30 | 0.89 |
| S. macrocephala | CIAT-1643 | 50 | 5.5 | 1.4 | 0.78 | 0.49 |
| Desmodium ovalifolium | CIAT-350 | 100 | 4.9 | 1.3 | 0.74 | 0.64 |
| Pueraria phaseoloides | CIAT-9900 | 100 | 4.4 | 0.9 | 1.04 | 0.57 |
| Centrosema macrocarpum | CIAT-5065 | 100 | 2.5 | 0.7 | 0.72 | 0.57 |
| Desmodium gyroides | CIAT-3001 | 100 | 3.0 | 0.5 | 0.66 | 0.48 |
| Zornia sp. | CIAT-9600 | 100 | 2.9 | 0.3 | 0.53 | 0.50 |
| Z. latifolia | CIAT-728 | 200 | 3.5 | 0.8 | 0.82 | 0.66 |
| Z. latifolia | CIAT-9286 | 400 | 2.7 | 0.9 | 0.95 | 0.76 |
| C. pubescens | CIAT-5053 | 400 | 2.0 | 0.6 | 0.98 | 0.74 |

*Critical requirements associated with about 80% of maximum yield.

## Management of Low Native Soil Fertility

The main low-input technology required to manage low native soil fertility centers on increasing the efficiency of fertilization. This may be possible through the identification and correction of soil nutrient deficiencies and use of pasture species and ecotypes that are more efficient users of low fertilizer inputs. In addition, the promotion of nutrient recycling in pasture production systems needs substantial investigation.

## Phosphorus and potassium requirements of tropical pastures

Following the methodology for regional trials but with three fertilization levels of P and K, a field experiment was established with the germplasm identified for the isohyperthermic well-drained savannas such as Carimagua. The results are presented in Tables 4 and 5 in relation to the external and internal requirements for P and K during the establishment period of the pasture species and ecotypes. With few exceptions, most of the pasture species and ecotypes required 20 kg P/ha and 20 kg K/ha.

All the pasture grasses present quite low internal phosphorus requirements in both rainy and dry seasons. On the contrary, the pasture legumes in many cases present twice the tissue P concentrations. These differential internal P requirements imply that pure stands of pasture grasses may not satisfy the animal P requirements (0.2% P). Consequently, a mineral P supplementation would be necessary since these tropical grasses even with high P fertilizer inputs did not increase their tissue P concentration beyond 0.15% P. However, grass-legume mixtures may provide enough phosphorus to fulfill the animal P requirements, and this suggests that research is needed with and without mineral P supplementation to the animal grazing grass-legume mixtures. Results indicating that mineral P supplementation could be reduced or eliminated would imply less input costs.

The differences in internal potassium requirements are less marked between legumes and grasses. In general, there are no major inter or intraspecific differences in terms of tolerance to low available soil potassium. The results presented in Tables 4 and 5 only indicate a temporary low K requirement since sooner or later an external source of K will be needed. The main reason for this is that potassium is similar to nitrogen in that potassium deficiencies increase with time due to the fast consumption by the plants and high susceptibility to leaching in most of the acid soils. All this suggests that the main avenues for increasing the efficiency of the K inputs for the establishment and maintenance of tropical pastures in highly weathered acid soils are: 1) the use of the sources of potassium with slow K release and long residual effects; cement plant kiln flue dust rich in potassium might be evaluated as an alternative for the highly soluble K sources, and 2) the recycling of potassium to the soil from the pasture litter and excreta depositions.

Table 4. External and internal critical levels of P and K of various species and ecotypes of tropical pasture legumes at the establishment period of the isohyperthermic well-drained savanna.

| Species | Ecotype | External critical level* | | Internal critical level* | | | |
|---|---|---|---|---|---|---|---|
| | | | | Rainy season | | Dry season | |
| | | P | K | P | K | P | K |
| | | (kg/ha$^{-1}$) | | (%) | | | |
| Category V | | | | | | | |
| *Desmodium ovalifolium* | 350 | 20 | 20 | 0.10 | 1.03 | 0.08 | 0.43 |
| *Pueraria phaseoloides* | 9900 | 20 | 20 | 0.22 | 1.22 | 0.10 | 0.66 |
| Category IV | | | | | | | |
| *Stylosanthes capitata* | 1019 | 20 | 20 | 0.11 | 1.15 | 0.08 | 0.67 |
| *S. capitata* | 1315 | 20 | 20 | 0.18 | 1.18 | 0.08 | 0.60 |
| *S. capitata* | 1318 | 20 | 20 | 0.11 | 0.98 | 0.09 | 0.64 |
| *S. capitata* | 1342 | 20 | 20 | 0.12 | 1.16 | 0.10 | 0.62 |
| *S. capitata* | 1405 | 20 | 20 | 0.11 | 0.98 | 0.09 | 0.58 |
| *S. capitata* | 1441 | 20 | 20 | 0.12 | 1.18 | 0.09 | 0.61 |
| *S. capitata* | 1693 | 20 | 20 | 0.14 | 1.21 | 0.09 | 0.56 |
| *S. capitata* | 1728 | 20 | 20 | 0.12 | 1.22 | 0.09 | 0.64 |
| Category III | | | | | | | |
| *Centrosema macrocarpum* | 5065 | 11 | 10 | 0.16 | 1.24 | 0.09 | 0.72 |
| *C. pubescens* | 5053 | 20 | 20 | 0.18 | 1.50 | 0.09 | 0.76 |
| *C. pubescens* | 5126 | 20 | 20 | 0.18 | 1.40 | 0.11 | 0.75 |
| *Codariocalyx gyroides* | 3001 | 35 | 30 | 0.17 | 1.15 | 0.11 | 0.57 |
| Other categories | | | | | | | |
| *S. capitata* | 2013 | 20 | 20 | 0.13 | 1.28 | 0.10 | 0.68 |
| *S. capitata* | 1943 | 35 | 30 | 0.15 | 1.19 | 0.13 | 0.86 |
| *S. macrocephala* | 1582 | 20 | 20 | 0.10 | 0.93 | 0.08 | 0.50 |
| *Zornia* sp. | 728 | 11 | 10 | 0.12 | 1.16 | 0.08 | 0.43 |
| *Zornia* sp. | 9199 | 20 | 20 | 0.15 | 1.11 | 0.09 | 0.72 |
| *Zornia* sp. | 9286 | 20 | 20 | 0.18 | 1.28 | 0.09 | 0.60 |
| *Zornia* sp. | 9600 | 20 | 20 | 0.14 | 1.00 | 0.09 | 0.68 |
| *C. brasilianum* | 5055 | 20 | 20 | 0.14 | 0.12 | 0.09 | 0.57 |
| *Aeschynomene histrix* | 9690 | 11 | 10 | 0.19 | 1.25 | 0.07 | 0.47 |

*Critical levels associated with about 80% of maximum yields obtained at eight weeks of plant growth.

Table 5. External and internal critical levels of P and K of four tropical pasture grasses at the establishment period for the isohyperthermic well-drained savanna.

| Species | Ecotype | External critical level* | | Internal critical level* | | | |
|---|---|---|---|---|---|---|---|
| | | | | Rainy season | | Dry season | |
| | | P | K | P | K | P | K |
| | | (kg/ha$^{-1}$) | | (%) | | | |
| *Andropogon gayanus* | 621 | 20 | 20 | 0.10 | 0.95 | 0.04 | 0.53 |
| *Brachiaria humidicola* | 679 | 10 | 10 | 0.08 | 0.74 | 0.05 | 0.39 |
| *Brachiaria decumbens* | 606 | 20 | 20 | 0.08 | 0.83 | 0.05 | 0.38 |
| *Brachiaria brizantha* | 665 | 20 | 20 | 0.09 | 0.82 | 0.05 | 0.44 |

*Critical levels associated with about 80% of maximum yield obtained at eight weeks of plant growth.

Effects of micronutrient applications on pasture establishment

A field experiment was set up in Carimagua to determine the external and internal micronutrient requirements for promising pasture grasses and legumes as well as to determine the residual effects of micronurient applications. Zinc, cooper, boron, manganese and molybdenum (only in legumes) were the micronutrients studied. The grasses tested were Andropogon gayanus 621, Brachiaria decumbens 606, Brachiaria humidicola 679 and, Brachiaria brizantha 665 and the legumes were Stylosanthes capitata 1019, Pueraria phaseoloides 9900, Desmodium ovalifolium 350 and Zornia latifolia 728.

The results for the establishment period are presented in Tables 6 (legumes) and 7 (grasses). After a year of establishment none of the pasture grasses or legumes showed significant responses to the micronutrient applications. Under native savanna conditions, soil analyses of the upper 20 cm provided the information that the levels of available soil zinc and cooper were higher than those considered as deficient for acid soils (0.5 ppm Zn, 0.2 ppm Cu). After a year, the availability of these two micronutrients was even higher with an increment of fertilizer levels.

In the plant tissue, marked differences in zinc concentrations among species as well as between grasses and legumes were observed. During the rainy season and without zinc applications, the pasture grasses with exception of Brachiaria humidicola 697, showed zinc tissue concentrations near or below the level required for the animal. Similar results were obtained with copper. These results indicate that although the dry matter production was not affected when zinc and copper were not applied, the concentrations of these micronutrients in the plant tissue would not fulfill the animal's requirements. Therefore, it would be important to determine whether mineral supplementation provides a more economic source of these micronutrients of whether direct application to the soil is more efficient, since both zinc and copper fertilization produce long residual effects.

Pasture legumes without zinc and copper applications to the soil all fulfilled the minimal requirements for the animal. The plant tissue concentrations showed a differential increment by species, especially Stylosanthes capitata 1019 with zinc and Pueraria phaseoloides 9900 with copper.

In the case of boron the tendency was to increase only with the first level of application (0.5 kg B/ha). In both grasses and legumes the boron concentrations in the plant tissue were higher than that considered as a deficiency level (20 ppm B for legumes and 4 ppm B for grasses). Manganese applications had no effects either on grasses or on legumes. Similar results were found with molybdenum in the case of legumes.

Table 6. Effects of micronutrient applications on the dry matter production and micronutrient contents in plant tissue[1] and soil[1] during the establishment period of four tropical pasture legumes in an Oxisol of Carimagua, Colombia.

| Micronutrient | | D. ovalifolium 350 | | | P. phaseoloides 9900 | | | S. capitata 1019 | | | Z. latifolia | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Applied | Soil available | DM[2] | Tissue content | | DM | Tissue content | | DM | Tissue content | | DM | Tissue content | |
| | | | Rainy | Dry | | Rainy | Dry | | Rainy | Dry | | Rainy | Dry |
| $kg/ha^{-1}$ | ppm | $ton/ha^{-1}/yr^{-1}$ | ---- ppm ----- | | $ton/ha^{-1}/yr^{-1}$ | ----- ppm ---- | | $ton/ha^{-1}/yr^{-1}$ | ----- ppm ----- | | $ton/ha^{-1}/yr^{-1}$ | ----- ppm ---- | |
| Zinc | | | | | | | | | | | | | |
| 0 | 1.7 | 6.0 | 20 | 37 | 4.8 | 71 | 41 | 4.4 | 82 | 91 | 3.6 | 70 | 64 |
| 2 | 1.5 | 5.1 | 23 | 30 | 5.0 | 45 | 35 | 5.6 | 77 | 66 | 3.0 | 71 | 81 |
| 4 | 2.0 | 6.4 | 22 | 33 | 5.2 | 60 | 39 | 4.9 | 102 | 111 | 2.9 | 73 | 96 |
| 8 | 2.2 | 5.2 | 32 | 38 | 5.0 | 73 | 45 | 4.4 | 109 | 72 | 3.2 | 72 | 83 |
| Copper | | | | | | | | | | | | | |
| 0 | 0.7 | 6.1 | 9 | 12 | 5.1 | 17 | 16 | 5.2 | 8 | 10 | 3.0 | 10 | 13 |
| 1 | 0.7 | 5.9 | 9 | 10 | 4.7 | 19 | 15 | 5.3 | 9 | 10 | 3.0 | 10 | 13 |
| 2 | 0.9 | 5.7 | 9 | 10 | 5.0 | 17 | 16 | 4.8 | 8 | 10 | 3.0 | 9 | 12 |
| 4 | 0.9 | 6.0 | 9 | 11 | 5.1 | 16 | 16 | 5.3 | 8 | 11 | 3.3 | 9 | 12 |
| Boron | | | | | | | | | | | | | |
| 0 | 0.3 | 5.4 | 30 | 22 | 4.9 | 38 | 27 | 5.1 | 24 | 23 | 3.5 | 34 | 31 |
| 0.5 | 0.4 | 5.7 | 28 | 22 | 4.9 | 39 | 34 | 5.4 | 21 | 23 | 3.5 | 25 | 29 |
| 1.0 | 0.4 | 5.9 | 28 | 25 | 5.4 | 41 | 39 | 5.3 | 22 | 21 | 3.2 | 33 | 32 |
| 2.0 | 0.5 | 6.1 | 30 | 26 | 5.0 | 37 | 36 | 5.7 | 26 | 23 | 3.3 | 28 | 28 |
| Manganese | | | | | | | | | | | | | |
| 0 | 1.9 | 5.6 | 353 | 184 | 5.0 | 247 | 168 | 5.4 | 209 | 160 | 3.1 | 121 | 173 |
| 0.25 | 1.9 | 5.8 | 312 | 206 | 4.9 | 202 | 218 | 5.1 | 169 | 209 | 3.6 | 102 | 165 |
| 0.50 | 1.7 | 5.2 | 288 | 220 | 4.9 | 247 | 338 | 5.6 | 176 | 288 | 2.7 | 93 | 209 |
| 1.00 | 2.0 | 6.2 | 397 | 187 | 5.2 | 230 | 184 | 5.1 | 183 | 142 | 3.0 | 128 | 193 |
| Molybdenum | | | -----% N----- | | | -----% N----- | | | -----% N----- | | | -----% N----- | |
| 0 | | 6.1 | 1.7 | 1.7 | 5.2 | 2.8 | 2.9 | 5.4 | 2.4 | 2.4 | 3.4 | 2.6 | 2.8 |
| 0.05 | | 5.2 | 1.7 | 1.7 | 5.4 | 2.7 | 3.0 | 5.5 | 2.5 | 2.4 | 2.9 | 2.6 | 2.8 |
| 0.10 | | 6.0 | 1.7 | 1.5 | 5.1 | 2.7 | 2.9 | 5.1 | 2.3 | 2.5 | 3.3 | 2.7 | 2.8 |
| 0.20 | | 6.0 | 1.7 | 1.8 | 5.1 | 2.7 | 3.1 | 5.0 | 2.4 | 2.4 | 3.0 | 2.6 | 3.0 |

[1] Deficiency level:

| | Legume plant tissue | Acid soil |
|---|---|---|
| Zn | 20 ppm (Jones and Clay, 1976) | 0.5 ppm (Cox and Kamprath, 1972) |
| Cu | 4 ppm (Andrew and Thorne, 1962) | 0.2 ppm " " |
| B | 20 ppm (Jones, 1972) | 0.3 ppm " " |
| Mn | 20 ppm (Jones, 1972) | 1.0 ppm " " |
| Mo | - - | - - - |

[2] DM = Dry matter production

Table 7. Effects of micronutrient applications on the dry matter production and micronutrient contents in plant tissue[1] and soil[1] during the establishment period of four tropical pasture grasses in an Oxisol of Carimagua, Colombia.

| Micronutrient | | *A. gayanus* 621 | | | *B. humidicola* 679 | | | *B. decumbens* 606 | | | *B. brizantha* 679 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Applied | Soil available | DM[2] | Tissue content | | DM | Tissue content | | DM | Tissue content | | DM | Tissue content | |
| | | | Rainy | Dry | | Rainy | Dry | | Rainy | Dry | | Rainy | Dry |
| kg/ha$^{-1}$ | ppm | ton/ha$^{-1}$/yr$^{-1}$ | ppm | | ton/ha$^{-1}$/yr$^{-1}$ | ppm | | ton/ha$^{-1}$/yr$^{-1}$ | ppm | | ton ha$^{-1}$/yr$^{-1}$ | ppm | |
| Zinc | | | | | | | | | | | | | |
| 0 | 0.7 | 8.8 | 14 | 17 | 6.9 | 19 | 18 | 7.3 | 13 | 13 | 6.9 | 15 | 28 |
| 2 | 2.7 | 10.1 | 18 | 17 | 8.2 | 32 | 27 | 8.9 | 17 | 25 | 8.7 | 17 | 26 |
| 4 | 2.0 | 8.0 | 28 | 37 | 6.9 | 24 | 34 | 7.8 | 20 | 29 | 7.1 | 18 | 33 |
| 8 | 2.2 | 8.1 | 40 | 52 | 8.1 | 37 | 47 | 7.8 | 19 | 35 | 8.6 | 24 | 44 |
| Copper | | | | | | | | | | | | | |
| 0 | 0.4 | 8.6 | 5 | 9 | 8.2 | 4 | 6 | 8.4 | 4 | 5 | 8.1 | 4 | 6 |
| 1 | 0.5 | 8.4 | 5 | 8 | 7.6 | 4 | 6 | 6.5 | 4 | 5 | 7.7 | 5 | 6 |
| 2 | 0.9 | 8.9 | 4 | 8 | 8.3 | 4 | 6 | 7.7 | 4 | 6 | 7.0 | 4 | 6 |
| 4 | 1.0 | 9.3 | 5 | 8 | 6.8 | 4 | 6 | 7.6 | 4 | 6 | 7.2 | 4 | 7 |
| Boron | | | | | | | | | | | | | |
| 0 | 0.3 | 8.0 | 7 | 6 | 7.3 | 4 | 6 | 7.8 | 5 | 5 | 8.4 | 6 | 10 |
| 0.5 | 0.3 | 7.4 | 10 | 7 | 7.7 | 6 | 5 | 8.4 | 7 | 7 | 8.0 | 7 | 6 |
| 1.0 | 0.4 | 8.4 | 8 | 7 | 7.1 | 5 | 6 | 8.1 | 6 | 5 | 8.3 | 6 | 5 |
| 2.0 | 0.4 | 8.1 | 8 | 7 | 7.3 | 6 | 6 | 8.5 | 7 | 6 | 7.5 | 7 | 6 |
| Manganese | | | | | | | | | | | | | |
| 0 | 3.5 | 9.6 | 109 | 146 | 8.3 | 126 | 118 | 8.9 | 70 | 80 | 8.7 | 80 | 109 |
| 0.25 | 3.3 | 8.9 | 151 | 130 | 8.5 | 183 | 91 | 8.5 | 104 | 115 | 7.9 | 103 | 88 |
| 0.50 | 3.1 | 9.3 | 83 | 120 | 7.9 | 99 | 71 | 8.0 | 86 | 76 | 7.1 | 74 | 89 |
| 1.00 | 4.7 | 7.2 | 151 | 128 | 7.3 | 222 | 101 | 7.7 | 94 | 85 | 7.3 | 86 | 111 |

[1] Deficiency level:

| | Grass plant tissue | Acid soil |
|---|---|---|
| | Zn 20 ppm (Jones, 1972) | 0.5 ppm (Cox and Kamprath, 1972) |
| | Cu 5 ppm " " | 0.2 ppm " " " |
| | B 4 ppm " " | 0.3 ppm " " " |
| | Mn 20 ppm " " | 1.0 ppm " " " |

[2] DM = dry matter production

From the results obtained, the recommendation for the establishment of tropical pasture grasses and legumes in Carimagua is that there is no positive effect of micronutrient applications on the forage availability. The available amount of B and Mn under native savanna is adequate for pasture establishment. Zinc and copper applications to this soil improve the zinc and copper contents in grasses, which is important since without them the levels are below those required by the animal. Hence, maintenance fertilization with zinc and copper is important in pure stands of grasses. The presence and consumption of tropical legumes in the pasture, in addition to the quantity and quality of the protein, may supplement to a great extent the zinc and copper deficiencies in the grasses. This implies that reduction if not elimination of mineral supplementation of copper and zinc may be possible. However, this figure may change completely for tropical pastures growing in sandy soils.

Effects of sulfur fertilization on tropical pastures

Under native savanna conditions with well-drained acid soils, the available soil sulfur is often deficient, and as the soil texture becomes sandier and the organic matter decreases this deficiency is accentuated. Under Carimagua conditions the available sulfur (calcium phosphate extraction) was about 4 ppm S, a value considered as inadequate for pasture establishment.

Tables 8 and 9 show the data from a field experiment established in Carimagua to study the effect of sulfur fertilization on the response of several tropical pasture grasses and legumes. The dry matter production of both shows no significant response at any S rate. In addition, the tissue S concentrations without S application were similar to the critical concentrations determined under greenhouse conditions (Tropical Pastures Program, Annual Report, 1980). The lack of response to S fertilization by the pasture legumes and grasses was attributed to the considerable increment in availability of the native soil sulfur after conventional land preparation. This increment was about five times the initial S value found under native savanna, which was enough to support 90% of the maximum dry matter yields in both grasses and legumes. An explanation for this appears to be that the Carimagua Oxisol has a relatively high organic matter content (about 4%). With the conventional land preparation for pasture establishment, organic sulfur becomes available for the plants during the establishment period. Table 10 shows the sulfur contents and forms in the top layer of the Carimagua Oxisol under native savanna and under pasture one year after establishment. Total sulfur and mainly organic sulfur were less under the established pasture than under the native savanna. As a consequence of this, the available sulfur increased almost four times when no sulfur was applied. This has an important implication for pasture establishment on this type of soil since one can avoid S fertilization when using conventional land preparation and therefore reduce input costs.

Table 8. Effects of sulfur fertilization on the dry matter production and sulfur contents in the plant tissue and soil during the establishment period of four tropical pasture legumes in an Oxisol of Carimagua, Colombia.

| S treatment | | D. ovalifolium 350 | | | P. phaseoloides 9900 | | | S. capitata 1315 | | | Z. latifolia 728 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Applied | Available soil sulfur | DM | S in the tissue Rainy | S in the tissue Dry | DM | S in the tissue Rainy | S in the tissue Dry | DM | S in the tissue Rainy | S in the tissue Dry | DM | S in the tissue Rainy | S in the tissue Dry |
| $kg/ha^{-1}$ | ppm | $ton/ha^{-1}/yr^{-1}$ | (%) | | $ton/ha^{-1}/yr^{-1}$ | (%) | | $ton/ha^{-1}/yr^{-1}$ | (%) | | $ton/ha^{-1}/yr^{-1}$ | (%) | |
| 0 | 22* | 5.3 | 0.12 | 0.14 | 4.7 | 0.17 | 0.19 | 7.8 | 0.12 | 0.15 | 3.2 | 0.17 | 0.17 |
| 5 | 24 | 5.9 | 0.13 | 0.12 | 4.9 | 0.18 | 0.17 | 8.4 | 0.13 | 0.13 | 2.9 | 0.18 | 0.17 |
| 10 | 24 | 5.6 | 0.13 | 0.14 | 5.0 | 0.20 | 0.17 | 8.6 | 0.13 | 0.16 | 3.2 | 0.20 | 0.15 |
| 15 | 29 | 5.3 | 0.13 | 0.13 | 4.6 | 0.20 | 0.19 | 7.3 | 0.14 | 0.16 | 2.7 | 0.22 | 0.16 |
| 20 | 27 | 5.5 | 0.14 | 0.15 | 4.7 | 0.19 | 0.22 | 7.1 | 0.16 | 0.18 | 2.8 | 0.21 | 0.17 |
| 30 | 27 | 5.7 | 0.15 | 0.15 | 4.7 | 0.20 | 0.19 | 7.8 | 0.16 | 0.18 | 3.1 | 0.20 | 0.18 |

*Before conventional land preparation: 4 ppm-available soil sulfur.

Table 9. Effects of sulfur fertilization on the dry matter production and sulfur contents in the plant tissue and soil during the establishment period of four tropical pasture grasses in an Oxisol of Carimagua, Colombia.

| S treatment | | *A. gayanus* 621 | | | *B. decumbens* 606 | | | *B. humidicola* 679 | | | *B. brizantha* 665 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Applied | Available soil sulfur | DM | S in the tissue Rainy | S in the tissue Dry | DM | S in the tissue Rainy | S in the tissue Dry | DM | S in the tissue Rainy | S in the tissue Dry | DM | S in the tissue Rainy | S in the tissue Dry |
| $kg/ha^{-1}$ | ppm | $ton/ha^{-1}/yr^{-1}$ | (%) | | $ton/ha^{-1}/yr^{-1}$ | (%) | | $ton/ha^{-1}/yr^{-1}$ | (%) | | $ton/ha^{-1}/yr^{-1}$ | (%) | |
| 0 | 25* | 8.9 | 0.12 | 0.10 | 8.5 | 0.12 | 0.13 | 7.2 | 0.11 | 0.12 | 8.5 | 0.12 | 0.12 |
| 5 | 24 | 9.0 | 0.13 | 0.08 | 9.3 | 0.14 | 0.13 | 7.1 | 0.12 | 0.12 | 8.4 | 0.15 | 0.13 |
| 10 | 24 | 10.0 | 0.12 | 0.09 | 9.1 | 0.15 | 0.15 | 7.7 | 0.14 | 0.13 | 8.1 | 0.16 | 0.15 |
| 15 | 24 | 8.6 | 0.13 | 0.09 | 7.8 | 0.15 | 0.13 | 7.5 | 0.14 | 0.13 | 8.1 | 0.20 | 0.17 |
| 20 | 24 | 7.6 | 0.14 | 0.08 | 9.2 | 0.16 | 0.14 | 6.7 | 0.16 | 0.15 | 7.7 | 0.17 | 0.15 |
| 30 | 27 | 8.3 | 0.13 | 0.09 | 8.7 | 0.18 | 0.16 | 7.4 | 0.14 | 0.15 | 7.7 | 0.20 | 0.16 |

*Before conventional land preparation: 4 ppm available soil sulfur.

Table 10. Sulfur fractions in the Carimagua Oxisol under native savanna vegetation and under tropical pastures after one-year established with three sulfur treatments.

| Sulfur fraction | Native savanna | One-year pasture established | | |
|---|---|---|---|---|
| | | 0 kg S/ha | 15 kg S/ha | 30 kg S/ha |
| | | ppm | | |
| Total-S | 420 | 280 | 300 | 295 |
| Organic-S | 231 | 101 | 113 | 105 |
| Inorganic-S | 189 | 179 | 187 | 190 |
| Available-S* | 6 | 23 | 26 | 27 |

*Calcium phosphate extraction.

However, the sulfur requirements for maintenance fertilization of pastures under grazing may be completely different. It appears that after a certain time the organic matter returns to a stable state, and there is a net sulfur immobilization. Since a pasture does not receive an annual land preparation, the available soil sulfur seems to return to the status under native savanna. This was the case of a Desmodium ovalifolium pasture established in 1978, which received in addition to a basal fertilization about 20 kg S/ha during establishment. In August 1980 it received four maintenance fertilization treatments including sulfur. The soil nutrient dynamics as a function of these four treatments is shown in Figure 2. Results regarding forage availability, protein quality, tannin content and preferential intake by the animal are presented and discussed in the Tropical Pastures Quality Section.

The available P, with exception of Treatment 4, increased five months after phosphorus was applied, which may be an effect of the end of the rainy season. A similar response was observed with the exchangeable calcium, but the increase occurred at the beginning of the rainy season and in all the treatments, except the control which did not receive any maintenance fertilizer. Treatment 4 received Mg and S in addition to P and Ca. The available P, S, and Mg but not exchangeable Ca became available in the soil as soon as the fertilizers were applied. The sulfur and magnesium levels can be acredited to the fertilizer applied, but the higher availability of P as compared with treatments 2 and 3 may be due to a better nutritional balance in the soil caused by an almost complete fertilization which might have stimulated chemical and biological activity of the soil.

The main conclusion from these results is that the only significant response of this pasture was obtained with the maintenance fertilization applied in Treatment 4. Later on this experiment was modified to test the hypothesis that sulfur is the key element in modifying the soil fertility dynamics as well as the changes in forage availability, protein quality, tannin content and intake of Desmodium ovalifolium by the animal. Preliminary evaluations are confirming the hypothesis.

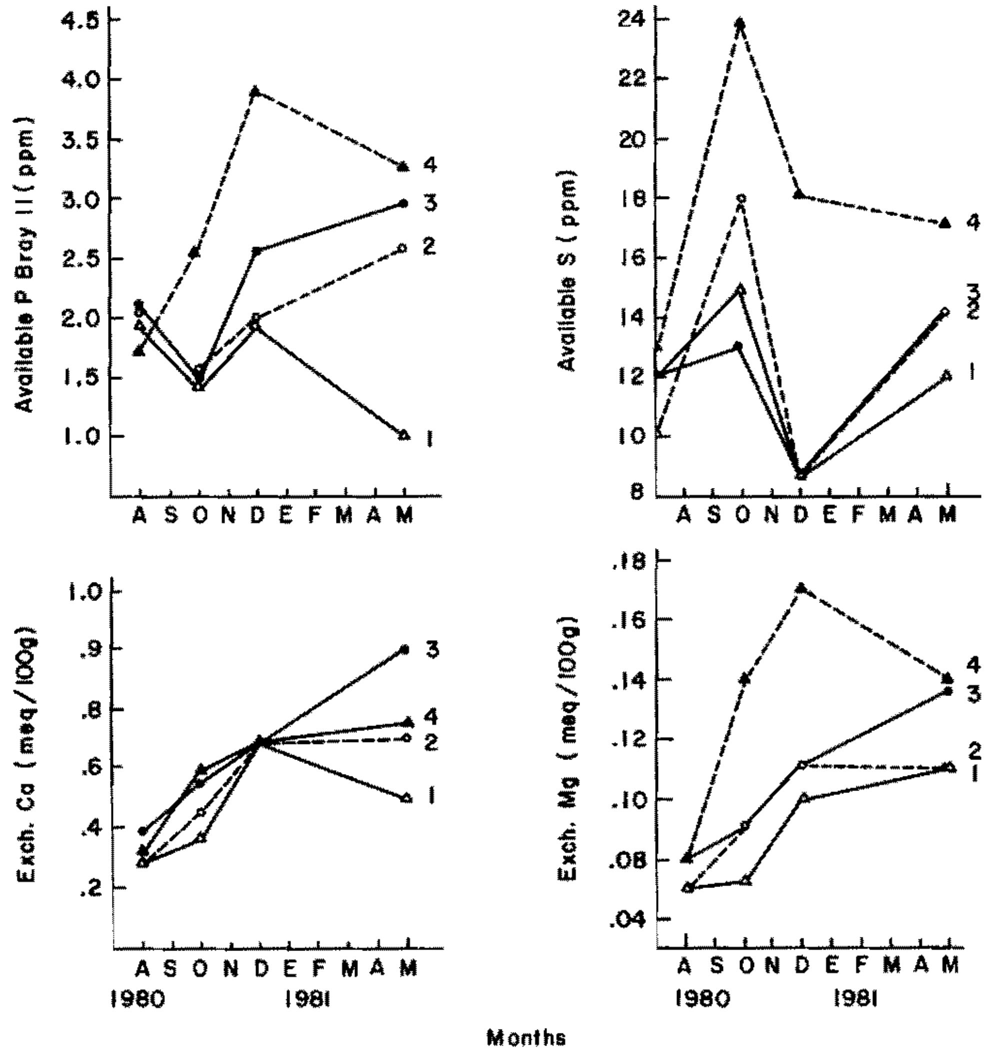



Figure 2. Soil nutrient dynamics as a function of four fertilizer treatments applied to a Desmodium ovalifolium 350 pasture under grazing at Carimagua (August 1980-May 1981). Treatments: 1 = control; 2 = P + Ca; 3 = P + Ca + K; 4 = P + Ca + K + Mg + S.

## Nutrient Recycling in Pastures

In pasture production systems, there is a natural recycling mechanism in which the three main components, the soil, plant, and animal, represent the nutrient pools and determine to a great extent the pasture productivity and the yield of animal product. Thus the magnitude of nutrient recycling in pastures needs quantification in order to define maintenance fertilizer recommendations.

Legume residues as a nitrogen pool

The contribution of a legume to tropical pastures is both as high-protein feed and as plant residues which are sources of nutrients for recycling to the grass-legume components. A major pathway of nitrogen cycling is through legume leaf litter. Thus two experiments were established to evaluate the contribution of this litter to tropical pastures.

For the first experiment, legume leaf materials from two pasture legumes (*Pueraria phaseoloides* 9900 and *Desmodium ovalifolium* 350) were incubated in the presence of a growing grass (*Brachiaria humidicola* 679). The grass was harvested at 11, 18, and 24 weeks and N recovery was calculated. Two soils plus one lime treatment were employed: Soil from a *Desmodium ovalifolium* 350 pasture and the same soil plus lime (Al saturation below 40%); and a soil from an *Andropogon gayanus* 621 pasture. The results are shown in Figure 3. At the first harvest the N in the grass leaves apparently represented the easily mineralizable-N (soluble N). The soil from the *Andropogon gayanus* pasture had a lower Al saturation percentage (74% Al Sat.) than the soil from the *D. ovalifolium* pasture (82% Al Sat.) and this was reflected in higher net nitrogen uptake by *B. humidicola*. The second harvest probably represented mineralization of some of the tannin-bound protein. Apparently the soil from the *A. gayanus* pasture did not have a high population of the micro-organisms that could mineralize this type of protein as there was net immobilization of N, especially with the *D. ovalifolium* dead leaf material (moderately low in both N and tannin). Cumulative net nitrogen recovery data show that the soil from the *A. gayanus* pasture was able to mineralize more of the nitrogen from the dead *P. phaseoloides* leaf material than the other soils and this may be related to its lower Al saturation percentage. Liming the soil from the *D. ovalifolium* pasture apparently stimulated the microbial population responsible for mineralizing tannin-bound protein.

All the soils mineralized N in a similar way and in high quantities from the green leaf material of *P. phaseoloides* (high N, low tannin). However, only limed soil from the *D. ovalifolium* pasture was able to mineralize substantial quantities of nitrogen from the high tannin material, but for some reason this soil was much less able to mineralize the low-tannin dead *P. phaseoloides* leaf material than the other soils at 18 and 24 weeks, respectively.

For the second experiment, four pastures under grazing were sampled to determine the amounts and nitrogen concentrations of the litter; the soils were also sampled at different depths in order to observe the variations in nitrate and ammonia levels in the four pastures.

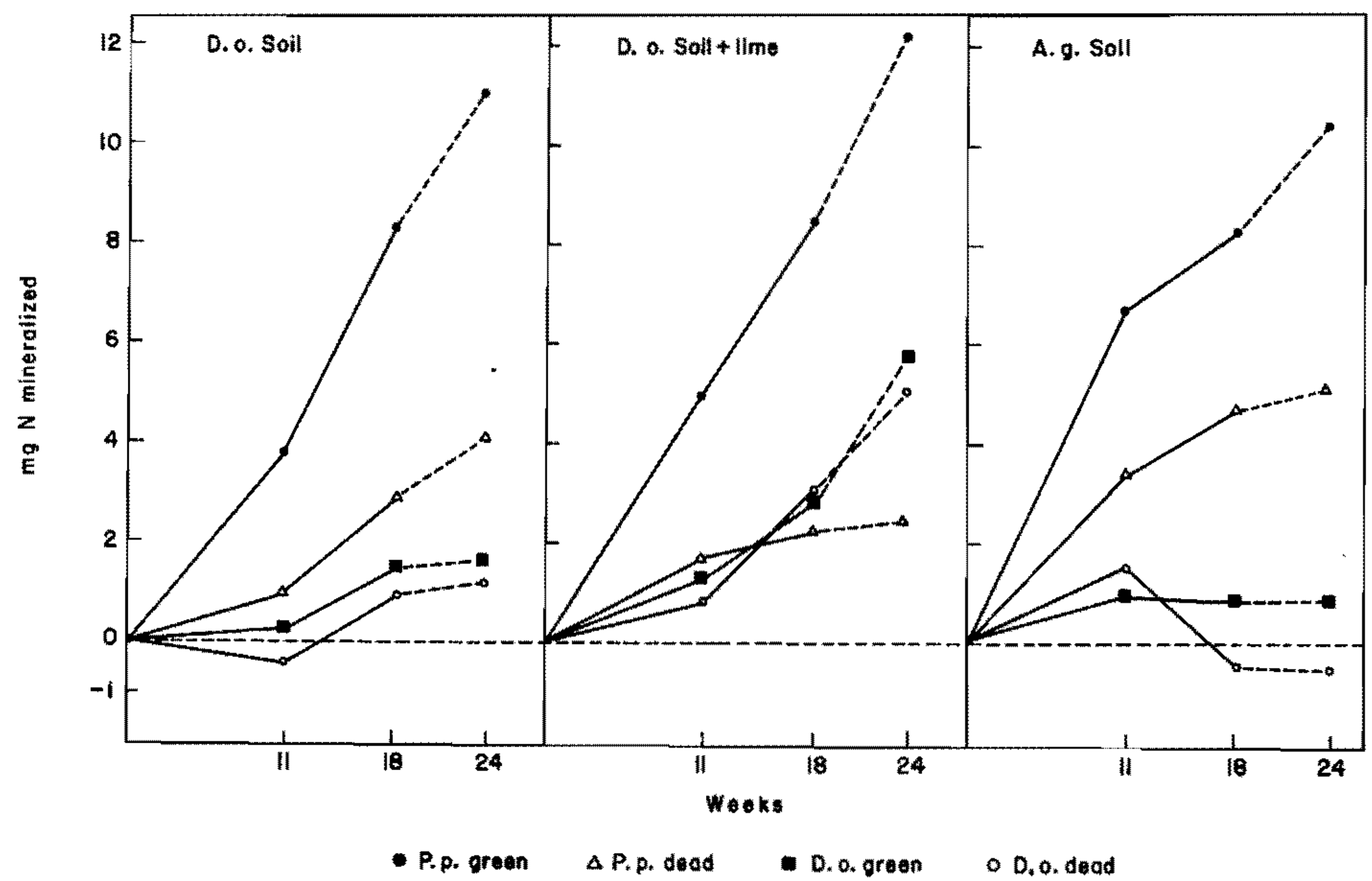



Figure 3. Nitrogen mineralized from green and dead foliar material of two forage legumes (Pp = *Pueraria phaseoloides* 9900, Do = *Desmodium ovalifolium* 350) as a function of time in the Carimagua Oxisol with three different backgrounds.

Figure 4 shows the amount of N from the litter of the four pastures as a function of time (March-August, 1981). In general, the tendency was a decrease in the amount of N as the rains increased. This reduction of N was mainly related to reduced amount of litter and not to a decrease in the N content in the litter due to the growing season in which there is a higher amount of green biomass and lesser defoliation than in the dry season. The litter present at the end of the dry season was high and correlated with the concentration of N-$NO_3^-$ in the soil. The pasture Andropogon gayanus 621/ Pueraria phaseoloides 9900 (A.g/P.p) had high litter production (4.5 t/ha) and was the litter with the highest N content (1.8% N). The litter from the Brachiaria decumbens 606/Pueraria phaseoloides 9900 (B.d/P.p) pasture also had a relatively high N content (1.65 % N), but the amount of litter was less (2.2 t/ha). The pasture Andropogon gayanus 621/ Desmodium ovalifolium 350 (A.g/D.o) had the higher litter production (5.9 t/ha) but the N content was only 0.91%. Finally the pasture Brachiaria humidicola 679/ Desmodium ovalifolium 350 (B.h./D.o) had the least amount both of litter and N content (2.6 t/ha and 0.68% N). Continuation of the sampling for a full year will be essential to characterize the N contribution of the litter material fully.

Figures 5 and 6 show the changes in the nitrate and ammonia levels with soil depth at two sampling dates (May 5 and August 4). At the first soil sampling date the nitrate levels tended to increase with the soil depth with exception for the A.g/P.p pasture soil which had higher levels of nitrate at all depths. For the second set sampling date, nitrate levels tended to decrease and mainly for the A.g/P.p soil but only on the 20 cm topsoil. Ammonium levels decreased sharply with soil depth in the four pastures at the two sampling dates. Apparently the improved grasses are not fully exploiting the 100 cm depth. However, the improved grasses are utilizing this nitrate much more than the native savanna, where there is sometimes abundant "fossil" nitrate (up to 16 ppm $NO_3^-$-N at 100 cm depth and up to 6.5 ppm $NO_3^-$-N at 180-190 cm depth). This has implications for the establishment of legumes associated with improved grasses, because legumes would not be able to compete with these grasses as long as they had access to the "fossil" nitrate. Once the nitrate is depleted the legumes would be more able to compete with the grass.

Animal excreta as nutrient pools

Return of nutrients to the soil via excreta in pasture production systems is an important natural recycling mechanism but depends considerably on stocking rate, grazing management, and other factors. Preliminary data are presented in Figure 7 which shows the changes in the top 20 cm of an Ultisol from Quilichao, Colombia, caused by dung deposition in a Brachiaria decumbens pasture under rotational grazing every 15 days.

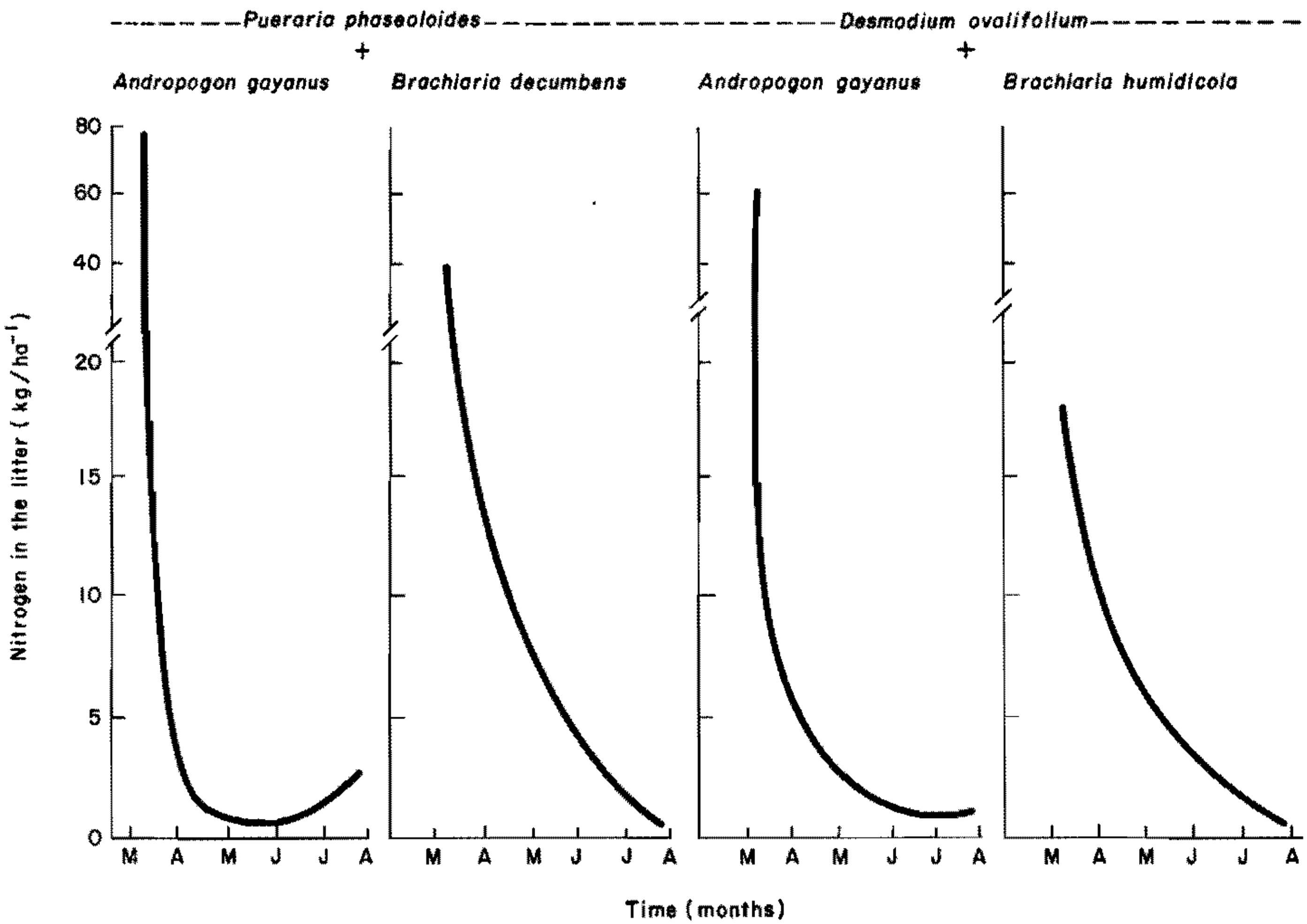



Figure 4. Total nitrogen in the litter as function of time in four pasture mixtures under grazing at Carimagua.

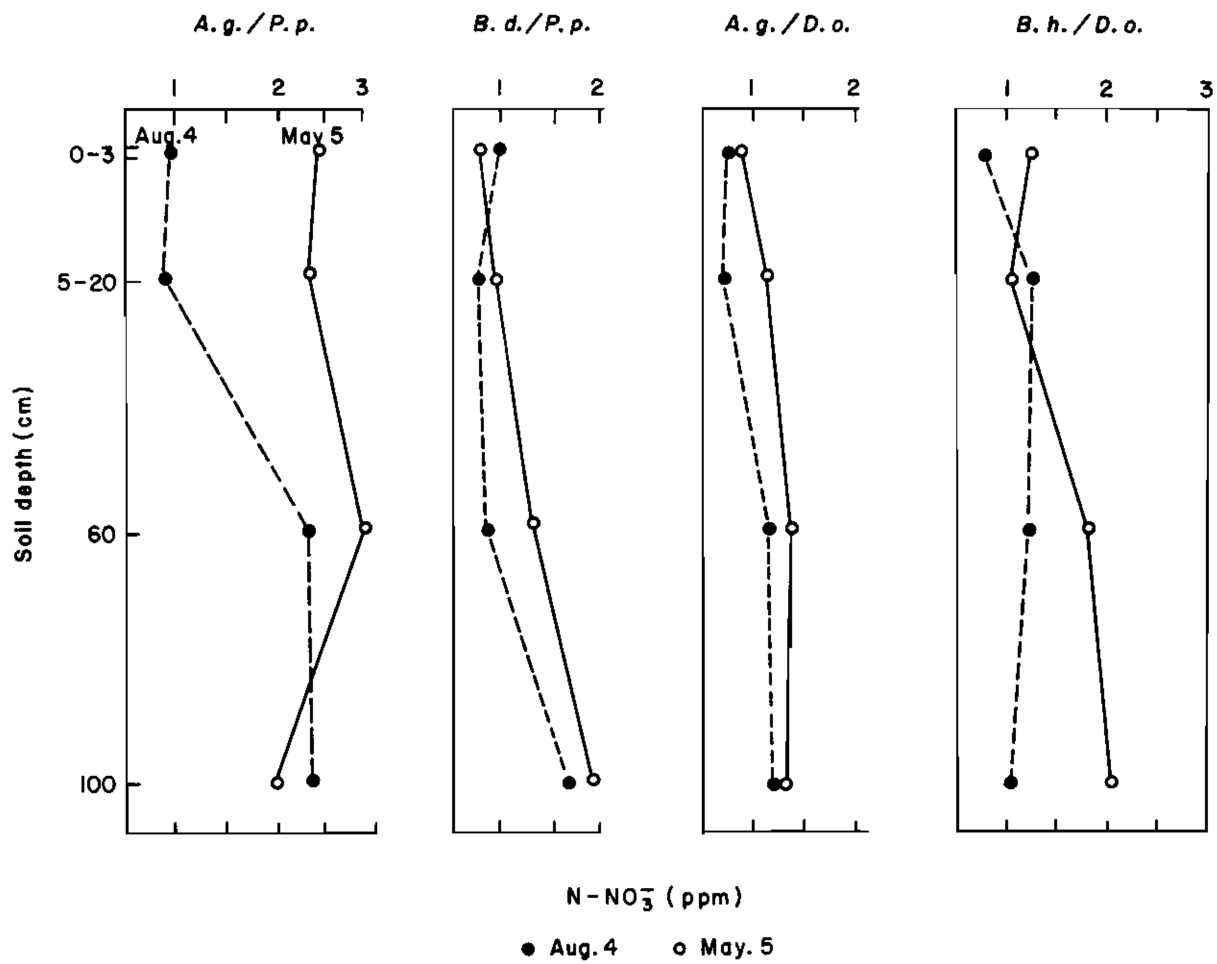



Figure 5. Nitrate distribution with the soil depth in four mixture pastures under grazing at Carimagua.

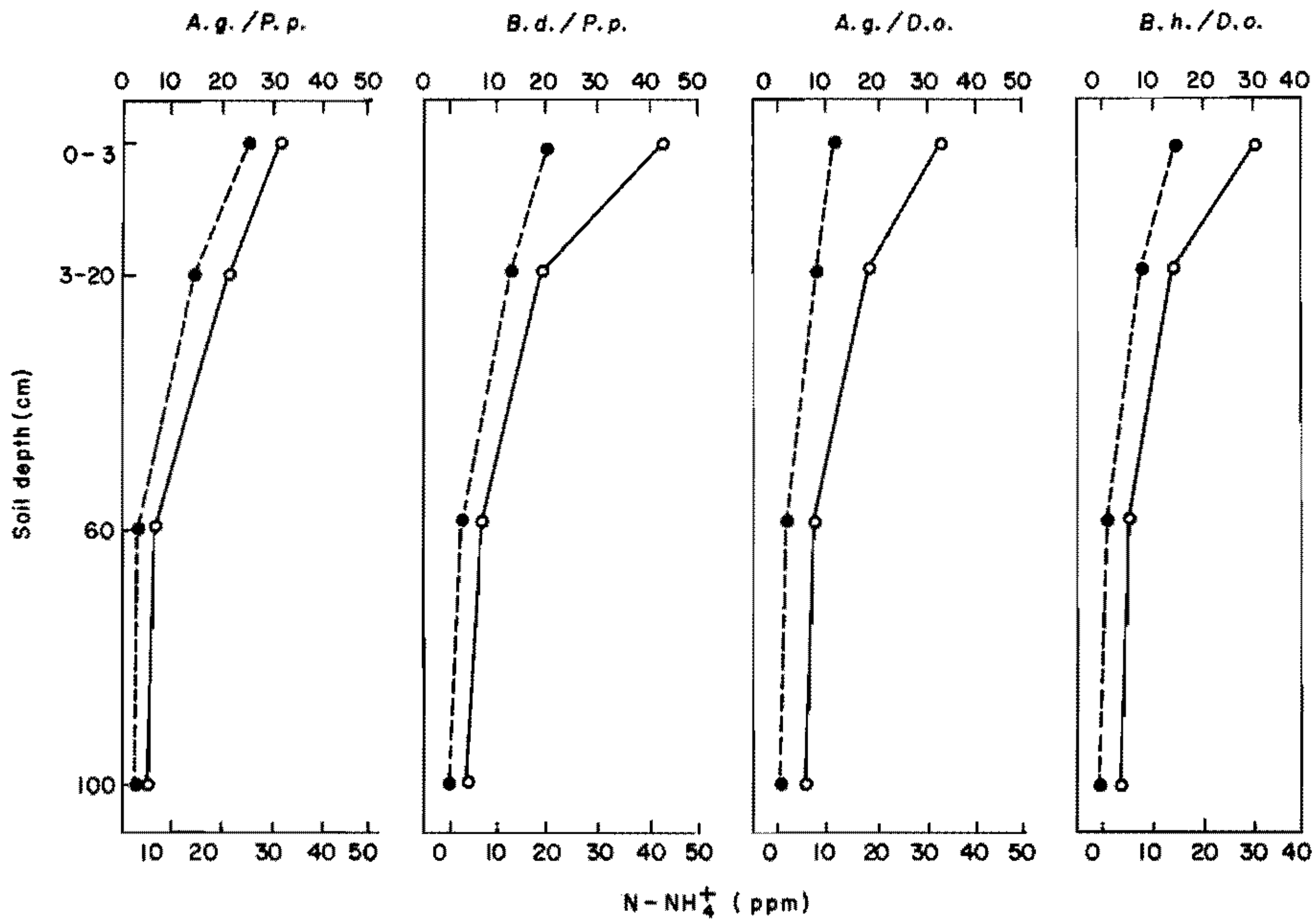



Figure 6. Ammonia distribution with the soil depth in four mixture pastures under grazing at Carimagua.

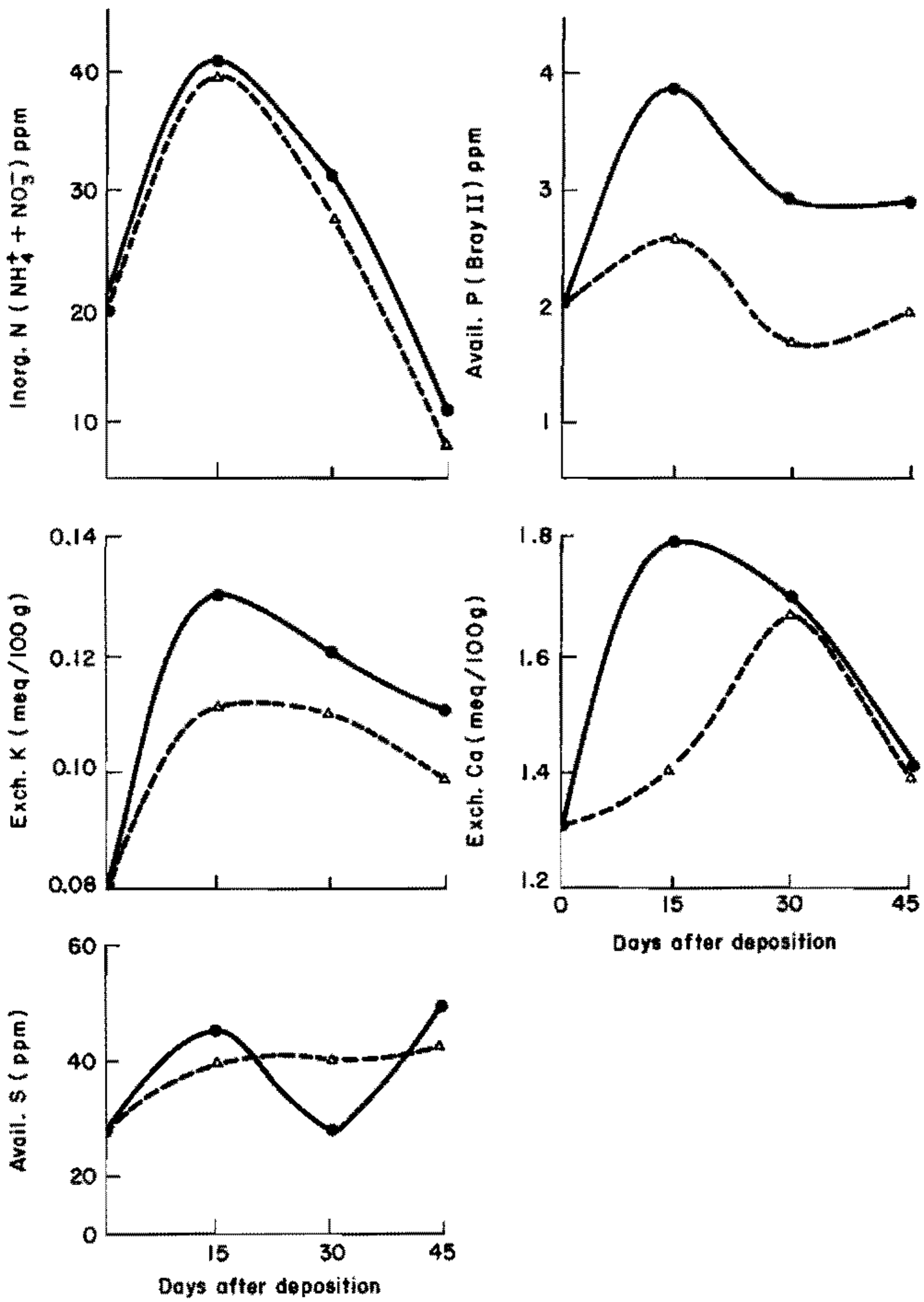



Figure 7. Nutrient recycling on the top cm of an Ultisol from Quilichao, Colombia, as a result of dung deposition by cattle grazing a <u>Brachiaria decumbens</u> pasture. Distance from dung (cm): ● 20; △ 100.

The results show that the topsoil inorganic nitrogen content doubled at the first 15 days within a 1 m radius from the excreta and declined sharply afterward. Available phosphorus, potassium, calcium and sulfur also showed a similar increase but with less effects at 1 m distance, except for sulfur, and followed by a more gradual decrease with time than nitrogen. The effects of the urine depositions (Table 11) indicate a sharper increase in potassium and sulfur than with feces, but a smaller increase in the availability of nitrogen, phosphorus and calcium. The overall effects of these additions were favorably reflected in increases of all five elements in plant tissue concentrations within the first 30 days after excreta deposition.

Table 11. Nutrient recycling on the top cm of an Ultisol from Quilichao, Colombia, as a result of urine deposition by cattle grazing a *Brachiaria decumbens* pasture.

| Time after urine deposition (days) | Distance from urine deposition (cm) | Inorganic-N ($NH_4^+ + NO_3^-$) ppm | Available P (Bray II) ppm | Available S ppm | Exch. K meq/100g | Exch. Ca meq/100g |
|---|---|---|---|---|---|---|
| 0 | 20 | 20 | 2.5 | 25 | 0.09 | 1.20 |
| | 100 | 21 | 3.0 | 26 | 0.10 | 1.24 |
| 15 | 20 | 65 | 2.0 | 36 | 0.19 | 1.39 |
| | 100 | 35 | 2.3 | 33 | 0.11 | 1.17 |
| 30 | 20 | 28 | 1.8 | 37 | 0.20 | 1.61 |
| | 100 | 27 | 1.8 | 38 | 0.11 | 1.61 |
| 45 | 20 | 13 | 2.1 | 42 | 0.22 | 1.59 |
| | 100 | 9 | 2.2 | 40 | 0.11 | 1.56 |

# Pasture Development in the Isohyperthermic Savannas-Carimagua

## Introduction

The period 1980-81 has been one of consolidation for the pasture development section in Carimagua. The role of the section is primarily the development and/or integration of practical establishment and management systems for advanced category species, making use of the basic knowledge derived from activities of other sections and its own previous experience. In this way, the section serves as a bridge between germplasm collection and early evaluation, and later activities. These concentrate on advanced category materials being tested for persistence and productivity under grazing management, and on their utilization in cattle production systems.

## Results for 1980-81

### Establishment

Spatial distribution trials. The association of *B. decumbens* and *P. phaseoloides* in a systematic triangle design (Annual Reports 1978, 79, 80) has been managed under continuous grazing since 1979 with 2.5 and 1.25 animals/ha, respectively, during the rainy and dry seasons. The development of this trial has been somewhat hampered by very heavy spittlebug infestation. In spite of (or because of?) this limitation, the balance of species continues to be satisfactory, and animal performance has been good. During the current rainy season, gains have ranged from 545 to 685 g/animal per day. The pasture is becoming more legume dominant than in previous years, due in large measure to the increasing severity of spittle bug.

As an outgrowth of this trial, another spatial distribution trial was established in May, 1980, and was stocked at the beginning of the current rainy season. The trial is designed to study the effects of initial proportions of legume and grass and strip width. Three proportions and three strip widths, as shown in Table 1, are used for two associations: *B. humidicola*, associated with *D. ovalifolium* and with *P. phaseoloides*. Difficulties were encountered in adjusting grazing pressure to forage availability with the result that excessive amounts of over mature grass accumulated in a number of treatments, thus necessitating clipping. Early observations indicate a strong interaction between proportion and optimum strip width and between both those factors and association. The combination of *B. humidicola* x *P. phaseoloides* is much more sensitive to both factors than the other association, and at the end of the first rainy season under grazing, the legume has almost disappeared in all but the widest strip widths of the 2/3 legume-1/3 grass treatment.

Table 1. Proportions and strip widths used for a trial in which *Brachiaria humidicola* is associated with *P. phaseoloides* and *D. ovalifolium*.

| Proportions Legume | : grass | Strip widths (m) |
|---|---|---|
| 1 | 2 | 1:2, 2:4, 4:8 |
| 1 | 2 | 1:1, 2:2, 4:4 |
| 2 | 1 | 2:1, 4:2, 8:4 |

### Low density seeding

Minimum and zero tillage for low density pasture seeding. Based on experience reported in 1980, a trial was initiated to test the feasibility of entirely substituting chemical control of native vegetation for mechanical control and planting in a low density pattern with manual preparation of the seeding site. The location of the trial adjacent to a large block of savanna, which continues to the Muco river with its flood plains and gallery forests, has resulted in heavy predation by deer and rabbits, making it impossible to obtain a valid test of the treatment variables. It may well be that wild animals would be of relatively minor importance on small farms where this type of establishment would be most relevant.

Mechanized seeding with vegetative material. Some of the most promising grasses produce very little viable seed in the Colombian Llanos, but are readily propagated by vegetative material. Others offer the alternative of planting with vegetative material or seed. In general, farmers readily accept vegetative propagation as an efficient means of establishing pastures and often express a preference for vegetative material over sexual seed because of reduced risk of establishment failure. Nonetheless, the logistics for conventional planting with vegetative material are formidable. Two trainees were interested in developing a simple method of partially mechanizing the planting operation for *B. humidicola*. Two 55 gallon drums were used as a hopper for planting material which was mounted on the front of a small, 25 H.P. field plot tractor. A plank was also mounted on the front of the tractor as a seat for a man on each side to drop stolons into previously opened furrows 1.8 m apart. The stolons were partially covered by modified sweeps mounted on the tool carrier in front of the rear wheels of the tractor, and the soil was firmed over the seed by the rear wheel, thus eliminating exposure of the planting material to sun and wind as is normal with traditional manual seeding. Stands were good and grazing was initiated only three months after planting. Using this system, the three men were able to plant one hectare in 45 minutes using 200 kg (fresh weight) of vegetative material. This resulted in a ratio of seed plot to planted area of over 1:100. The relatively small amount of material required greatly simplifies the logistics of the planting operation.

Commercial scale experience with low density seeding. A number of large scale legume-grass pastures have been established using low density seeding as reported in 1980. These pastures primarily based on A. gayanus and P. phaseoloides, have developed well under grazing management and appear stable and persistent.

Factors influencing establishment using vegetative material. With the cooperation of trainees, the section also investigated the effect of several factors on the establishment of B. decumbens and B. humidicola with stolons. The effects of partial (at least one node exposed) and complete covering of stolons and of compaction after planting are shown in Figure 1. It can be seen that complete coverage of the stolons was very detrimental in both species. Compaction after covering had a large positive effect in the case of B. humidicola, but had little effect on B. decumbens. In another trial, it was observed that field storage of planting material after cutting had relatively little effect on viability under conditions which prevailed during the experiment. Rains were frequent and the days were cool and overcast. Planting material was stored in 50 cm stacks and covered with burlap bags.

## Maintenance

Association x phosphorus levels. This trial is completing three full years of grazing. As previously reported, the P. maximum - P. phaseoloides treatments became strongly legume dominant after the first grazing season. Grazing of this treatment was discontinued in the second year and the plots have been renovated with the same two species and are now under grazing. Other problems which have occurred during the year include severe ant damage to two plots of Andropogon. These plots have also been replanted but are not yet fully established. This trial has proven hard to manage primarily because of difficulty in adjusting stocking rate to achieve uniform grazing pressures for the different treatment combinations. The associations of A. gayanus with P. phaseoloides and S. capitata continue to be the most stable and weed free. The greater persistence of S. capitata with A. gayanus under rotational grazing in this trial contrasts with the same association under continuous grazing in pasture utilization trials in which the persistence of S. capitata has been poor. Likewise, the balance of P. phaseoloides and A. gayanus under rotational grazing contrasts sharply with the seasonal imbalance of the same association, which results from continuous grazing in adjacent pasture utilization plots. The interaction of phosphorus by association has been observed primarily in the P. maximum - S. capitata association in which increasing P levels are reflected in species balance and forage production.

Seedling vigor in S. capitata. The lack of persistence of S. capitata in association with A. gayanus appears to be a serious limitation for that species. Studies conducted by a graduate student are as yet inconclusive but all indications are that one of the major adverse factors is competition by the grass for nutrients, leaving the new seedlings inadequately supplied for normal development. Work

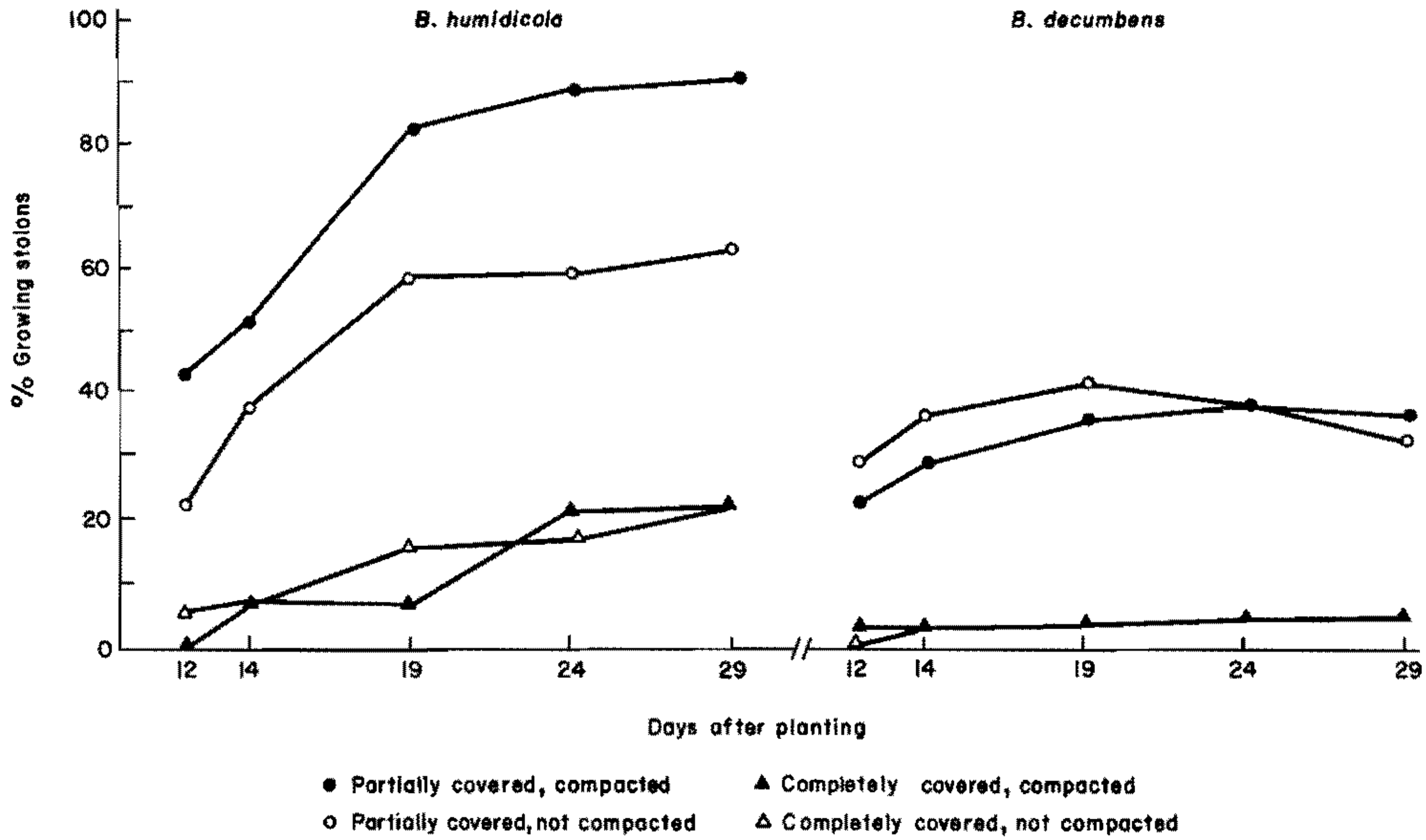



Figure 1. Effect of partial vs. complete coverage and of compaction after planting on stolon growth of B. humidicola and B. decumbens.

initiated by ICA colleagues in 1978 indicates that S. capitata may be quite compatible with M. minutiflora. The trial has been grazed at approximately six week intervals since establishment and stands are excellent after three years.

It is clear that M. minutiflora is less aggressive and competitive than A. gayanus and, therefore, should impose much less stress on seedlings. A similar experience has been observed in which S. capitata was planted with native savanna. Under similar grazing management, the native savanna has largely disappeared from the trial.

Savanna replacement. This experiment involves both establishment and maintenance concepts derived from research in spatial distribution, low density seeding, tillage methods, establishment and maintenance fertilizer requirements. The strategy being pursued is reported in the 1980 Annual Report. Establishment of the initial strips (20% of total area) was successful and the pastures were grazed lightly during the first dry season and stocked beginning early in the present rainy season. The stocking rate is 1 animal/ha total area, or 5 animals/ha seeded area. Animals entered weighing ± 200 kg in May. Both D. ovalifolium and P. phaseoloides have rapidly spread into native savanna strips under grazing and have covered at least an additional 20% of the area with the exception of the 5 m strips of both species where a 2.5 m spread on each side is required to cover the 20% additional area fertilized at the end of the second rainy season (Table 2).

There is a strong species interaction as reflected by markedly different growth of B. humidicola in the two associations. D. ovalifolium has formed a dense and formidable barrier for the spread of B. humidicola from the center third of the strip where it was originally planted. It has spread some in spite of the heavy cover of D. ovalifolium. However, in the other association, the open, rambling growth of P. phaseoloides and improved nitrogen fertility have stimulated the grass to colonize the entire planted strip to the detriment of the legume. Much more planted grass is available than with the other association, and the grass is beginning to spread into the native savanna. Both legumes have covered 2/3 or more of the total area when planted in 50 cm strips with 2 m intervening strips of native savanna as shown in Table 2.

The grazing animals consume the planted grasses preferentially, with A. gayanus receiving the highest grazing pressure in both D. ovalifolium and P. phaseoloides associations. B. humidicola is grazed more heavily in association with D. ovalifolium than in the P. phaseoloides treatments. Consumption of native species is on the increase with animals aggressively consuming savanna which has not been burned for 18 months. This is undoubtedly due to the presence of legume in the diet. A greater volume of D. ovalifolium than P. phaseoloides has accumulated. Animal performance varies with association, with gains ranging from 200 to over 400 g/animal per day from April 22 to September 17 in the following order: B. h. x P. p. > B. h. x D. o. A. g. x P. p. > A. g. x D. o.

Table 2. Effect of associated species and strip width on the invasion of native savanna by two legumes in a savanna replacement trial. Planted May 1980; measurements taken Nov. 1981; grazing initiated April 1981.

| Association | Planted[1] strip width (m) | Average advance[2] from original strip (m) | Additional[3] coverage of total area (%) |
|---|---|---|---|
| B. humidicola x D. ovalifolium | 5 | 1.7 | 14 |
| | 2.5 | 2.75 | 44 |
| | 0.5 | 1.0 | 53 |
| B. humidicola x P. phaseoloides | 5 | 1.65 | 13 |
| | 2.5 | 2.6 | 42 |
| | 0.5 | >2.0 | 80 |
| A. gayanus x D. ovalifolium | 5 | 1.4 | 11 |
| | 2.5 | 1.75 | 28 |
| | 0.5 | 1.0 | 53 |
| A. gayanus x P. phaseoloides | 5 | 2.85 | 23 |
| | 2.5 | 2.8 | 44 |
| | 0.5 | >2.0 | 80 |

[1] Center 1/3 of 5 and 2.5 m strips planted to associated grass. For 0.5 m planted strip width, every third strip planted to grass.

[2] The average advance of legume on each side of planted strip. Advance measured only when coverage was complete; many stolons extend much further into the savanna.

[3] $$\% \text{ additional coverage} = \frac{2 \times \text{average advance}}{\text{center to center distance between strips}} \times 100$$

## Future Plans

### Establishment phase

Priority should be given to the development of alternative systems for seed bed preparation and planting of sloping and/or sandy soils where the erosion hazard is high and soil structure is often very weak. Emphasis will be given to minimum tillage with the possibility of combining chemical control with chisel or stubble mulch sweep cultivation. Some species are capable of establishing after minimum tillage without need of further control.

There is need for a simple system for firming the soil over the row at planting time. This factor is continually shown to be extremely important in Carimagua.

There is need for the development or testing of alternative means of planting _A. gayanus_. It is a difficult seed to handle, and we have thus far only been able to plant it successfully when mixing it with a fertilizer material like rock phosphate or basic slag.

There is need to further develop methods of mechanized planting of vegetative material. It is thought that the basic field cultivator could serve as a carrier for a number of planting systems including mechanized vegetative planting, and planting of legumes into degraded grass pastures, as well as for conventional planting of legumes and grasses in prepared seed beds and minimum tillage planting in native savanna.

There is need for expanding research on pasture establishment in low, wet areas including low density planting in areas of "zurrales".

Maintenance phase

There is need for continued effort in the area of pasture renovation, especially as related to the introduction of legumes in degraded grass pastures.

The problem of low seedling vigor of _S. capitata_ under grazing should be pursued. One possibility is to test associations with less competitive grasses which might be more compatible than _A. gayanus_.

# Pasture Development in the Hyperthermic Savannas-Cerrado

The objectives of this section are to develop efficient systems of pasture establishment for the Cerrado ecosystem and to determine establishment and maintenance fertilizer requirements for the most promising grass-legume associations. There is a range of alternatives available for pasture establishment within multiple production systems in the Cerrado. Planting techniques for legume introduction into native pastures or into declining pure grass pastures have been tested and results were reported in the 1980 Annual Report. This year, more work on conventional planting methods for pasture establishment has been initiated, and preliminary results as well as information on fertilizer requirements are presented.

## Soil Nutrient Deficiencies during Pasture Establishment

Exploratory greenhouse and field experiments have shown that once P deficiency has been corrected, S, Ca, and sometimes Mg and K are limiting in most Cerrado soils. Mo and Zn have been found limiting under some conditions. These findings apply to the dark-red latosol (LVE) and the red-yellow latosol (LVA). There are other soils in the Cerrado which are less important in terms of area but could be of strategic importance if used for planted pastures during the dry season. With this in mind, exploratory work was extended to humic gley (glei humico) and low humic gley (glei pouco humico) soils. According to results, in the low humic gley, limitations are similar to those of the LVE soil, resulting from extremely low levels of P and low levels of S, Ca and K. However, the humic gley is severely deficient in B, and application of this element would be essential for successful pasture establishment. In addition, S, Ca, Mg, K and Mo were found to be limiting as measured by plant response.

## Pasture Response to Phosphorus in a Red-yellow Latosol

A grass-legume pasture was established in a red-yellow latosol three years ago to study pasture response to initial P levels and annual applications of 0, 13 and 26 kg P/ha. Three different sources of P were tested. Lime rates of 0 and 1 t/ha were introduced as treatments in the second year to study pasture response to Mg and Ca.

Plant growth and pasture productivity were much better this year than those observed during the first two years of the experiment. Dry matter production increased three fold. The increase was observed with all sources of P but was more dramatic with Araxa phosphate rock and triple superphosphate, the least effective sources in previous years. This improvement is probably due to a wet season characterized by low rainfall and a 35 day drought which resulted in greater depth to the water table than in normal years. Field observations have shown that the experimental site and other similar high plateau areas are characterized by a high water table during the peak of normal rainy seasons. Greenhouse trials showed that these conditions severely limit plant growth in these soils.

A summary of last year s results is presented in Figure 1. Yoorin thermophosphate continues to be better at 26 and 52 kg P/ha initial rates. Dry matter production at 105 kg P/ha level was similar to that of triple superphosphate, when lime was applied. The beneficial effect of lime was particularly clear at the lower levels of P with triple superphosphate and Yoorin thermophosphate but, as expected, did not improve Araxa phosphate rock performance.

Annual application of 13 and 26 kg of P/ha had little effect on dry matter production during the second and third years of the experiment. The effect was similar for all initial rates; the only significant increase was observed when 26 kg P/ha was applied to triple superphosphate and thermophosphate treatments, to which no lime was applied. Table 1 summarizes these results.

## Response of A. gayanus to Phosphorus on a LVE Soil

A field experiment established in 1980 in a dark-red latosol (LVE) showed lineal response of *A. gayanus* to P levels. Lime applied at 1 t/ha increased yield at low levels of P. The effect of fertilizers applied in 1980 carried over to this year and was very similar to the first year effect. Lime continued to enhance P fertilizer efficiency at the 1 t/ha rate (Figure 2). Results suggest that lime should be applied unless very high rates of P are employed. In the second year, P was applied at rates of 0, 13 and 26 kg P/ha to subplots within each initial P treatment. No benefit was realized from these additional fertilizer applications (Table 2). This experiment and related research will be continued to develop practical fertilizer recommendations for pasture establishment in recently cleared soils. An attempt is being made to correlate response to P with soil test and plant analysis data in those areas in which fertilizers have been applied previously.

## Pasture Response to Other Nutrients

In previous research, nutrients other than P have been shown to be limiting in Cerrado soils. In greenhouse trials, responses to S, Ca, Mg and K have been observed. The importance of S, Ca and Mg fertilization for pasture establishment in LVA soils was confirmed in a field trial as shown in Figure 3. Results show that Ca and Mg can be supplied by small application of dolomitic lime, while sulfur requirements can be satisfied by using ordinary superphosphate as a P source.

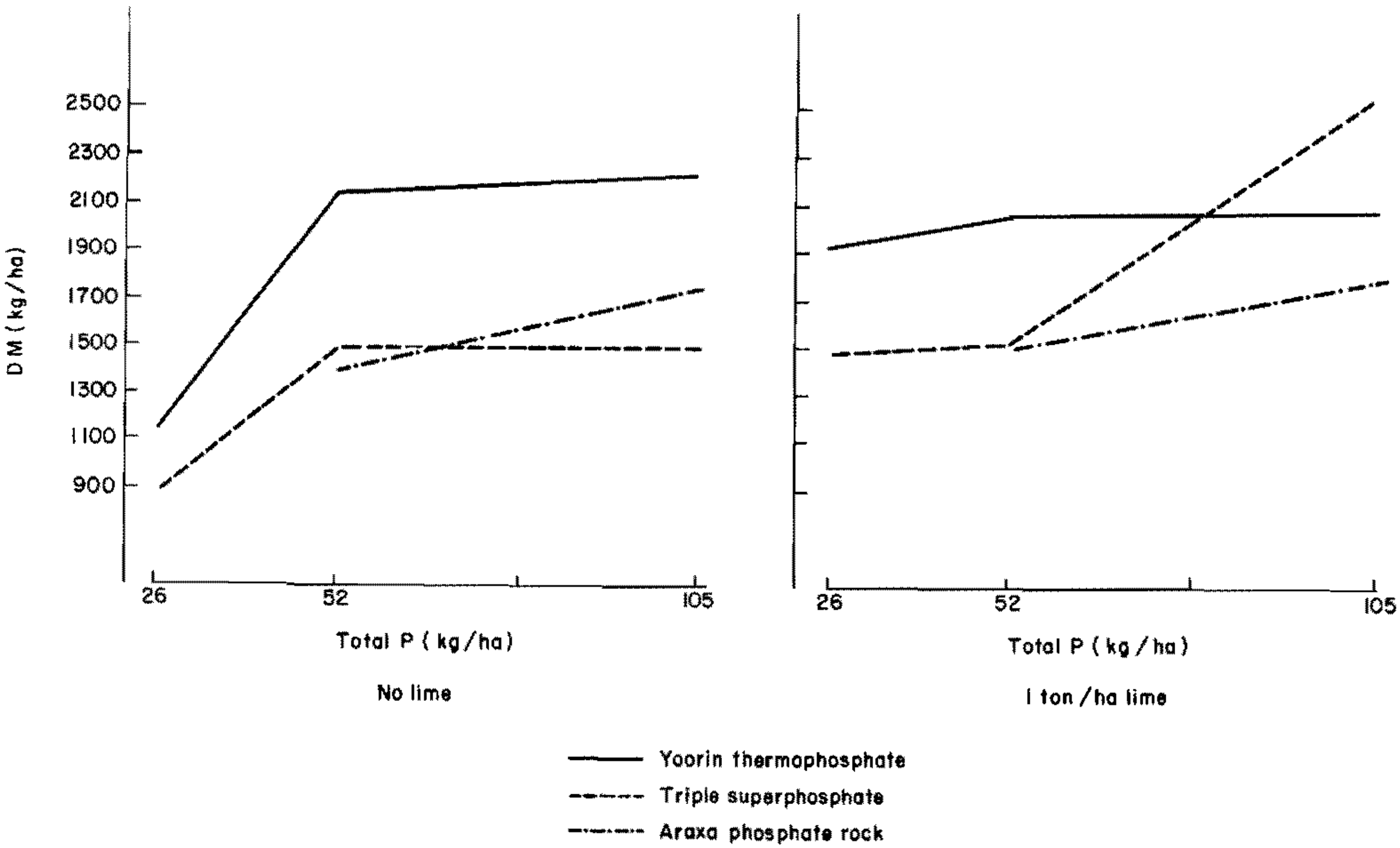



Figure 1. Pasture response to initial levels of P in the third year on a LVE soil.

Table 1. Pasture response in the second and third years to annual dressings of P for two levels of lime and three sources of P on an LVA soil.

| P Sources | Lime t/ha | Year | Annual P rates (P kg/ha) 0 | 13 | 26 | |
|---|---|---|---|---|---|---|
| | | | DM kg/ha per year | | | |
| Araxa | 0 | 2nd | 401 | 459 | 339 | N.S* |
| | | 3rd | 1608 | 1659 | 1547 | N.S. |
| | 1 | 2nd | 347 | 454 | 338 | N.S. |
| | | 3rd | 1742 | 2010 | 1560 | N.S. |
| Super | 0 | 2nd | 275 | 383 | 347 | N.S. |
| | | 3rd | 1301 | 1551 | 1890** | |
| | 1 | 2nd | 418 | 369 | 501 | N.S. |
| | | 3rd | 1878 | 1950 | 2011 | N.S. |
| Yoorin | 0 | 2nd | 385 | 649 | 740** | |
| | | 3rd | 1837 | 2192 | 2049 | N.S. |
| | 1 | 2nd | 743 | 1187 | 990 | N.S. |
| | | 3rd | 2058 | 2140 | 2455 | N.S. |

* N.S.: No significant differences.
**Significantly different from 0 lime level mean.

LSD = 200 (2nd year); LSD = 428 (3rd year).

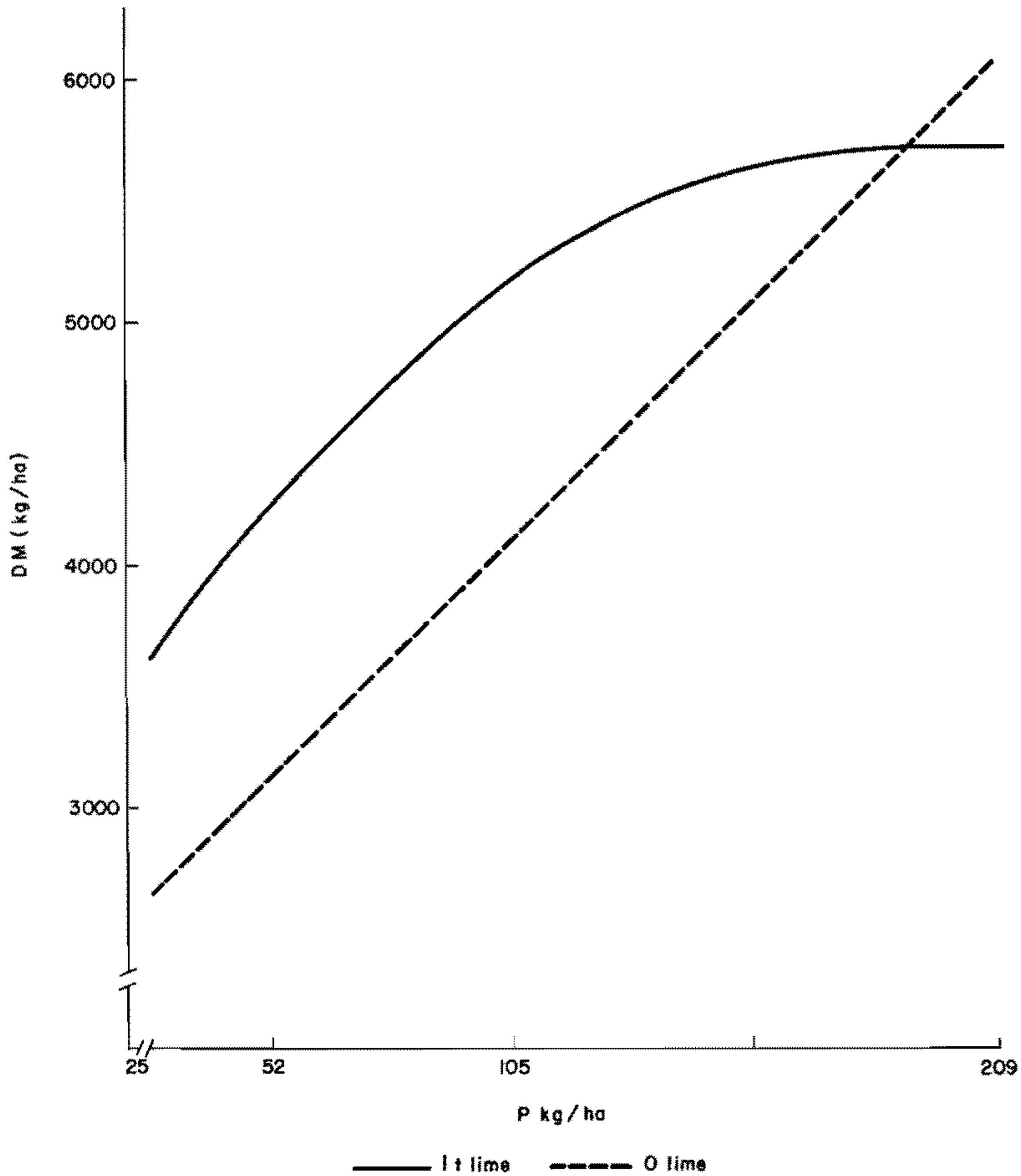



Figure 2. Response of A. gayanus to initial P levels in the 2nd year on a LVE soil.

Table 2. Second year Andropogon response to P application on an LVE soil (means of all initial P levels).

| Lime (t/ha) | Annual P rates (P kg/ha) 0 | 13 | 26 |
|---|---|---|---|
| | ---------------DM yield, kg/ha--------------- | | |
| 0 | 3974 | 4336 | 4094 |
| 1 | 4683 | 5041 | 5801* |

*Significantly different from 0 lime level mean ($P \lesssim 0.05$).

## Planting Methods for Pasture Establishment after Crops

It is common in the Cerrados to establish pastures in areas that have been cropped for some years. In this way establishment costs are reduced as a result of spreading land clearing, tillage and fertilizer costs over several crops. Cerrado vegetation regrowth is also better controlled. However, annual weeds multiply over the years and may become a serious problem for pasture establishment. It has been observed that *A. gayanus* sown on lands previously cropped sometimes fails to establish evenly because of poor germination or loss of seedlings due to unfavorable soil moisture conditions. Weeds make establishment more difficult. A trial was designed to test planting techniques that might improve pasture establishment in weedy areas or under suboptimal weather conditions. An association was planted in a site dominated by annual weeds and *M. minutiflora*. Both row and broadcast planting were used with and without post planting soil compaction. In row planting compaction was done only over the seeded row. Compaction in the broadcast treatment was performed previously and post planting by a pass of a corrugated steel roller. *A. gayanus* CIAT 621 and *S. capitata* CIAT 1405 were planted in association.

Weather conditions after planting were extremely favorable for germination, with daily rains and cloudy skies for a month. Under these conditions, uniform germination of both species was obtained with all planting methods. Weeds also established and grew very aggressively, and dominated the plots during the first year. However, after two mowings, the pasture gained advantage and was completely dominant during the second year. All planting methods were satisfactory under the conditions which prevailed following planting. When weather conditions are less favorable, planting techniques could have an important effect on establishment. Results showed that once established, *Andropogon* and *Stylosanthes* are able to compete with annual weeds and dominate them after two slashings.

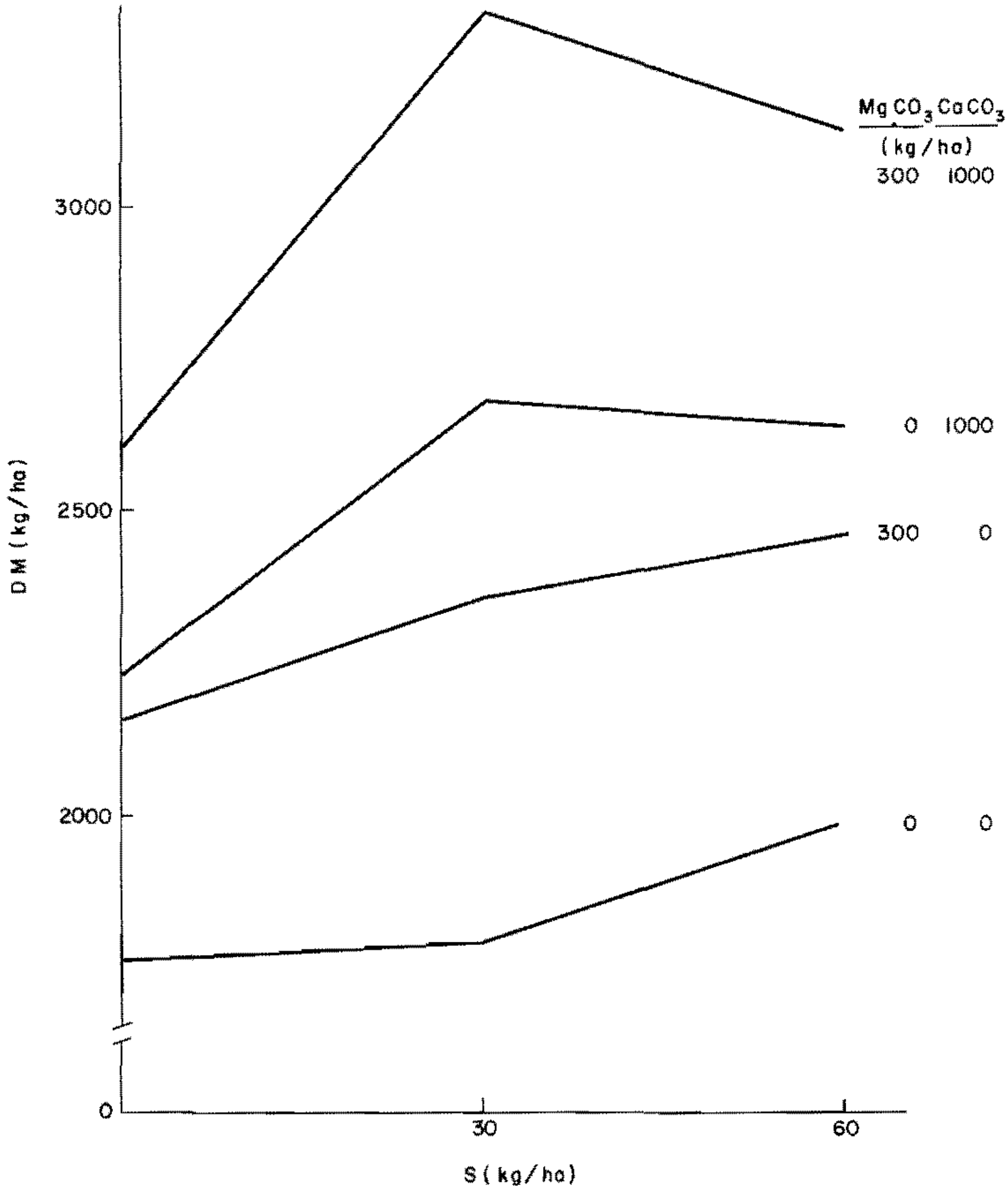



Figure 3. The effect of S, $MgCO_3$ and $CaCO_3$ on DM yield of <u>Andropogon gayanus</u> in a LVA soil, second year data, sum of two harvests.

# Pasture Quality and Nutrition

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

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

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

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

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

## Characterization of Quality Factors in Germplasm

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[a] Values reported are the mean of 157 observations made from 8 am to 12 noon at intervals of 5 minutes on the fourth day of grazing.
[b] Values reported are the mean of 147 observations made from 12 noon to 4 pm at intervals of 5 minutes, after the third day of adjustment.

## Quality Factors in Germplasm in Pasture Systems

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

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

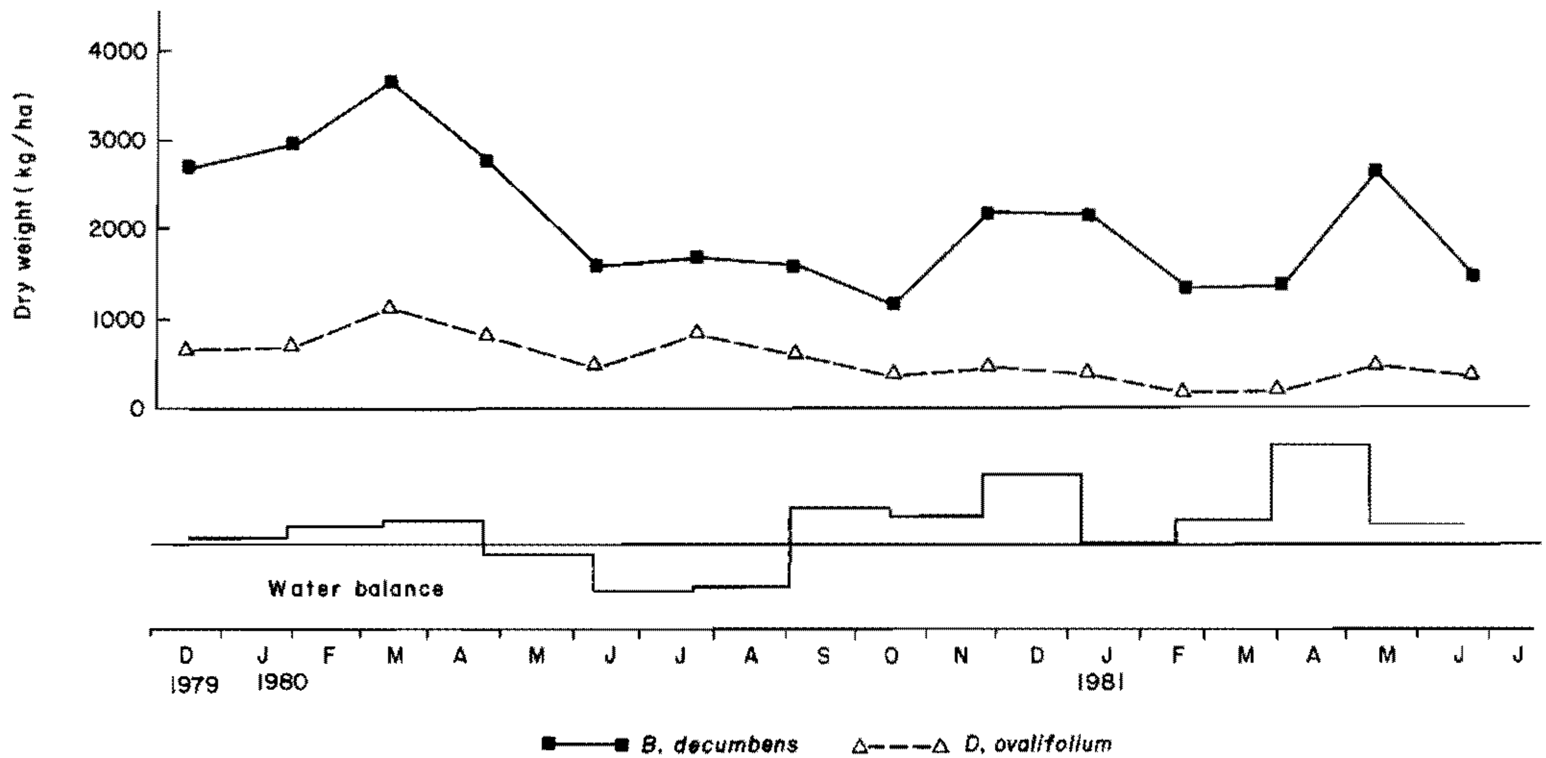



Figure 1.  Forage availability of B. decumbens and D. ovalifolium in a mixture under continuous grazing (Quilichao).

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

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

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

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

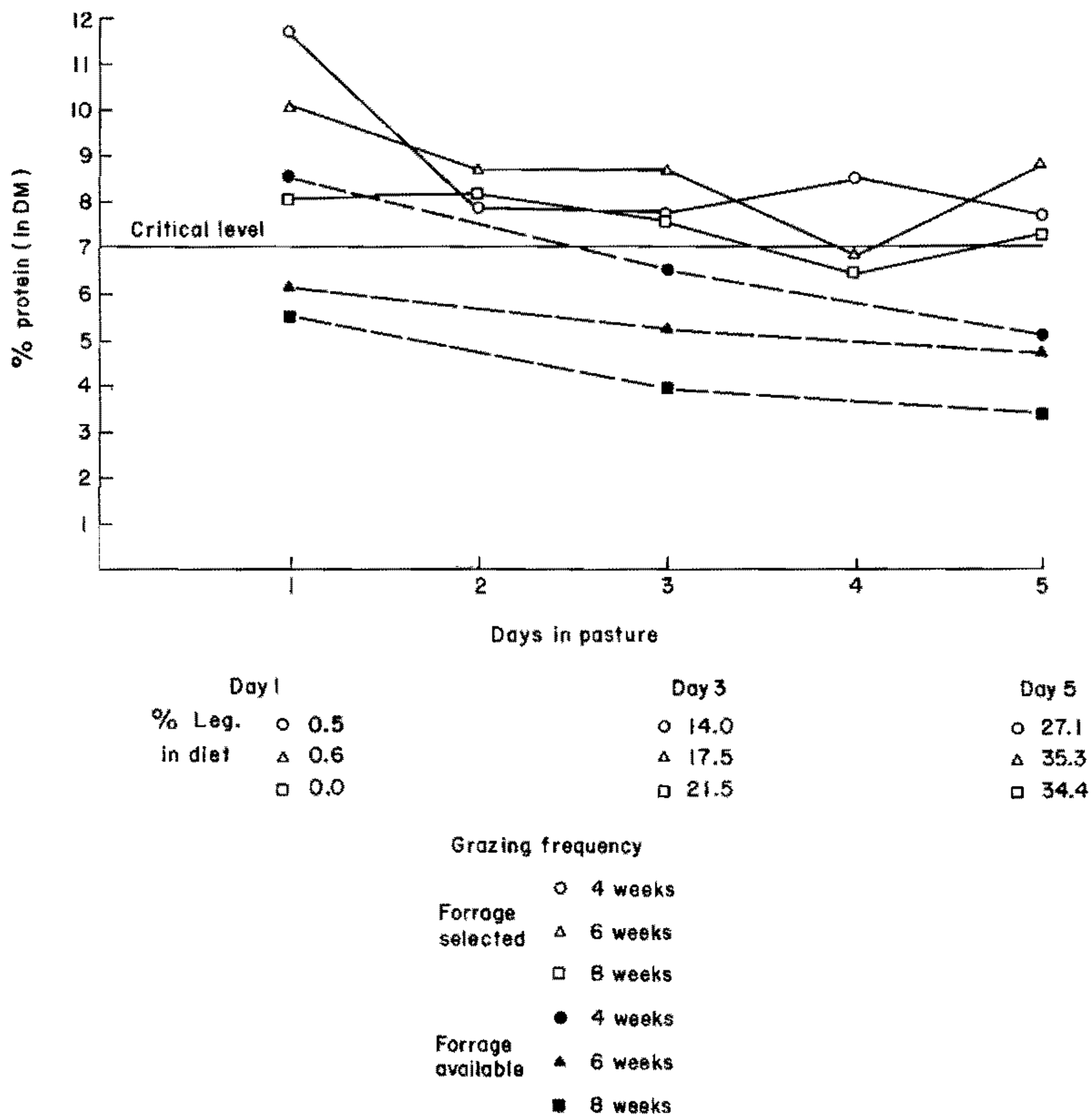



Figure 2. Legume selected and protein content in grass available and selected by esophageal fistulated steers in an association of *D. ovalifolium* with *A. gayanus* + *B. decumbens* + *P. maximum* under different grazing frequencies (Quilichao).

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

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

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

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

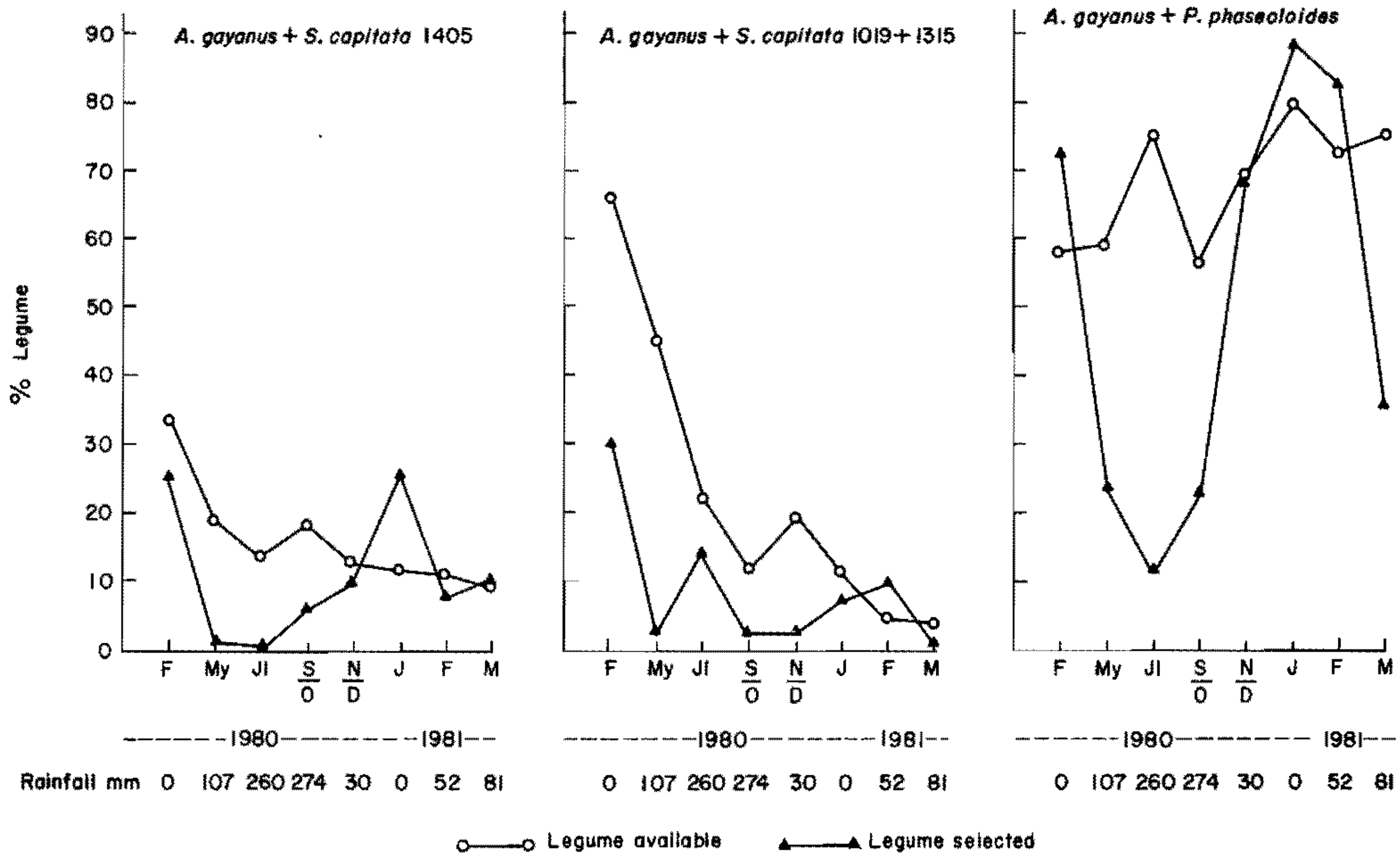



Figure 3. Dynamics of legume available and selected by esophageal fistulated steers grazing mixtures of A. gayanus with ecotypes of S. capitata and P. phaseoloides (Carimagua).

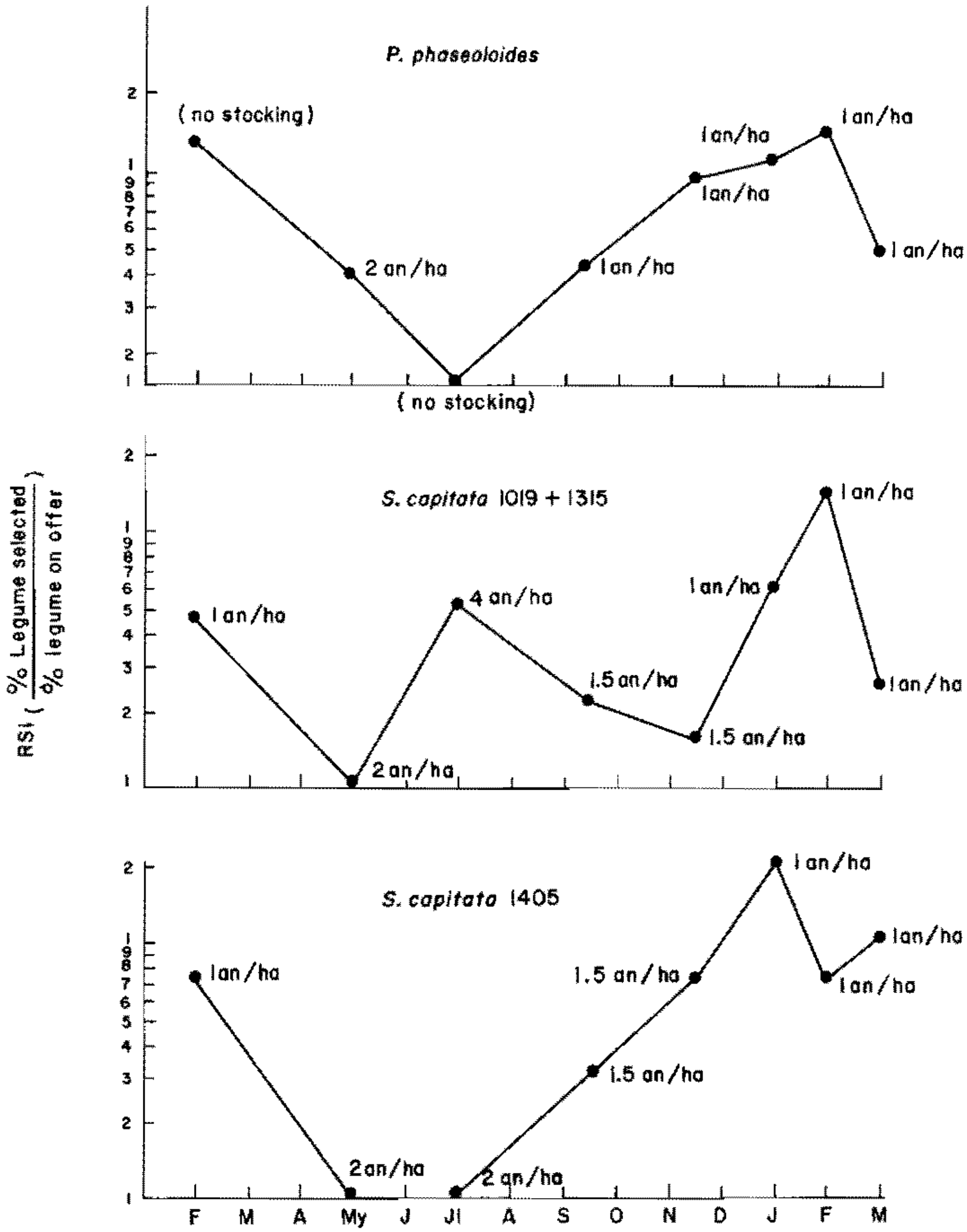



Figure 4. Relative selection index (RSI) for the legume component in associations of A. gayanus with ecotypes of S. capitata and P. phaseoloides under grazing (Carimagua).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

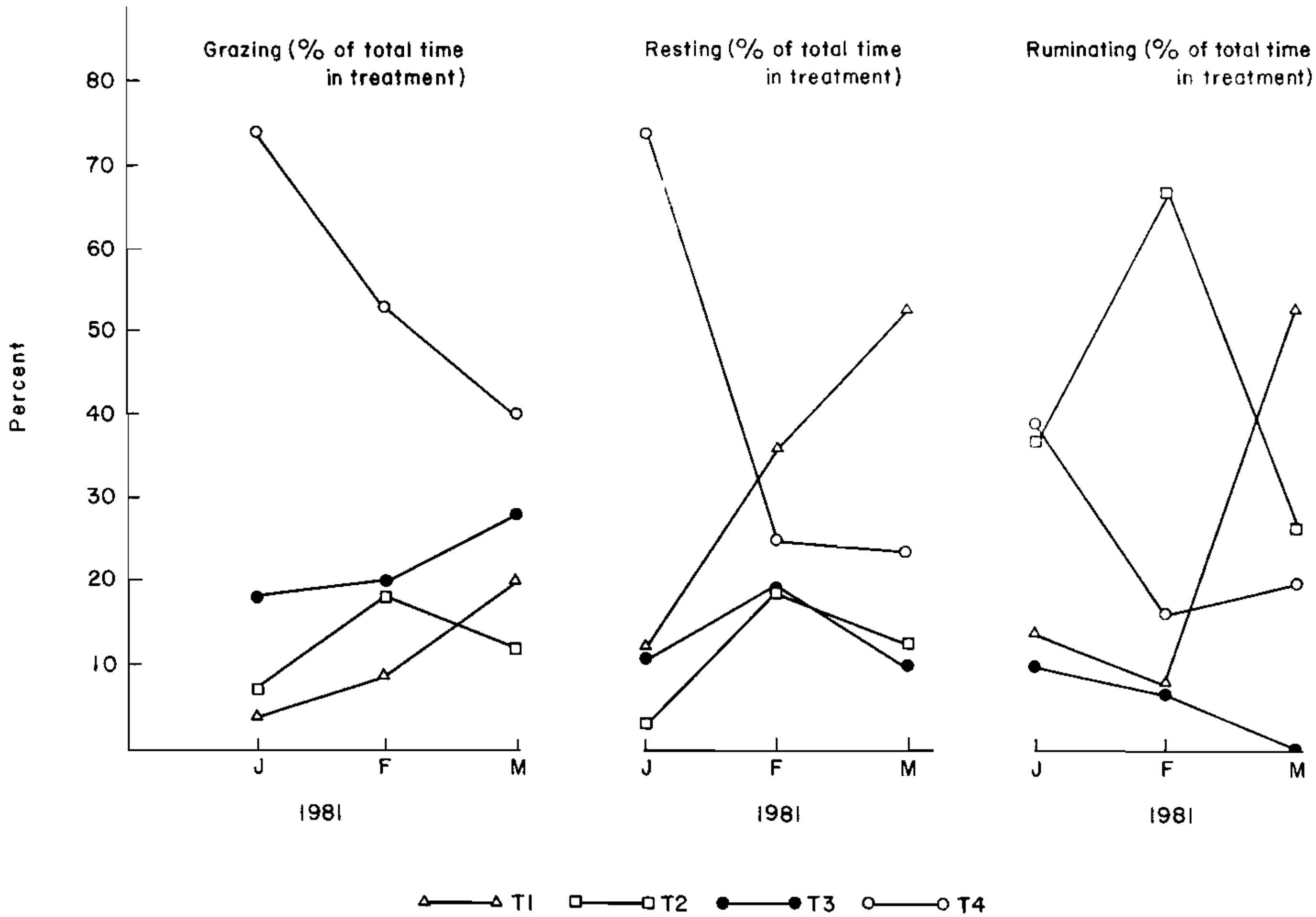



Figure 5. Distribution of activities of animals grazing D. ovalifolium 350 under different fertilizer treatments (T1: control, T2: + P + Ca, T3: + P + Ca + K, T4: + P + Ca + K + Mg + S) (Carimagua).

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

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

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

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

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

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

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

## Alternate Uses of Germplasm

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# Pasture Productivity and Management

This section was separated from the former Pasture Utilization Section in 1981 to concentrate on the study of effects of grazing management on pasture components. Its research is closely related to work conducted in the Pasture Quality and Nutrition Section in order to closely understand the processes of animal selectivity interacting with pasture management. Its main objectives are to determine the potential of promising germplasm for animal productivity in grazing trials, and to determine proper management for persistence and stability for pasture components.

## Grass Pastures

Brachiaria humidicola. Results during this year's rainy season (Table 1) are below those of last year, even though pastures were rested during the dry season and mowed at the beginning of the wet season to get rid of dead material accumulated from previous treatments. During the second part of the rainy season there was significant improvement in animal performance after maintenance fertilization with 18.26, 11, and 22 kg/ha K, Mg and S, respectively, which resulted in greater leaf production at all stocking rates (Figure 1) but was not sufficient to sustain animal productivity.

The productivity of this grass under Carimagua conditions is below that of the other two promising grasses B. decumbens and A. gayanus, and it is related to the lower proportion of leaf compared to total dry matter yields under different stocking rates (Figure 1). At the lower stocking rate the grass seems to mature too rapidly, affecting dry matter intake which, in turn, is related to leaf production, and also to a significant decrease in digestibility compared to B. decumbens, as indicated in Table 1 in the Pasture Quality and Nutrition Section.

Table 1. Liveweight gains of steers feeding on B. humidicola under continuous grazing during the rainy season* at different stocking rates in Carimagua, 1981.

| Stocking rate (an/ha) | Wet season (202 days) (g/an per day) | (kg/an) | (kg/an) |
|---|---|---|---|
| 2.4 | 194 | 39 | 94 |
| 3.4 | 215 | 43 | 147 |
| 4.4 | 138 | 28 | 123 |

* After mowed and rested for 15 days.

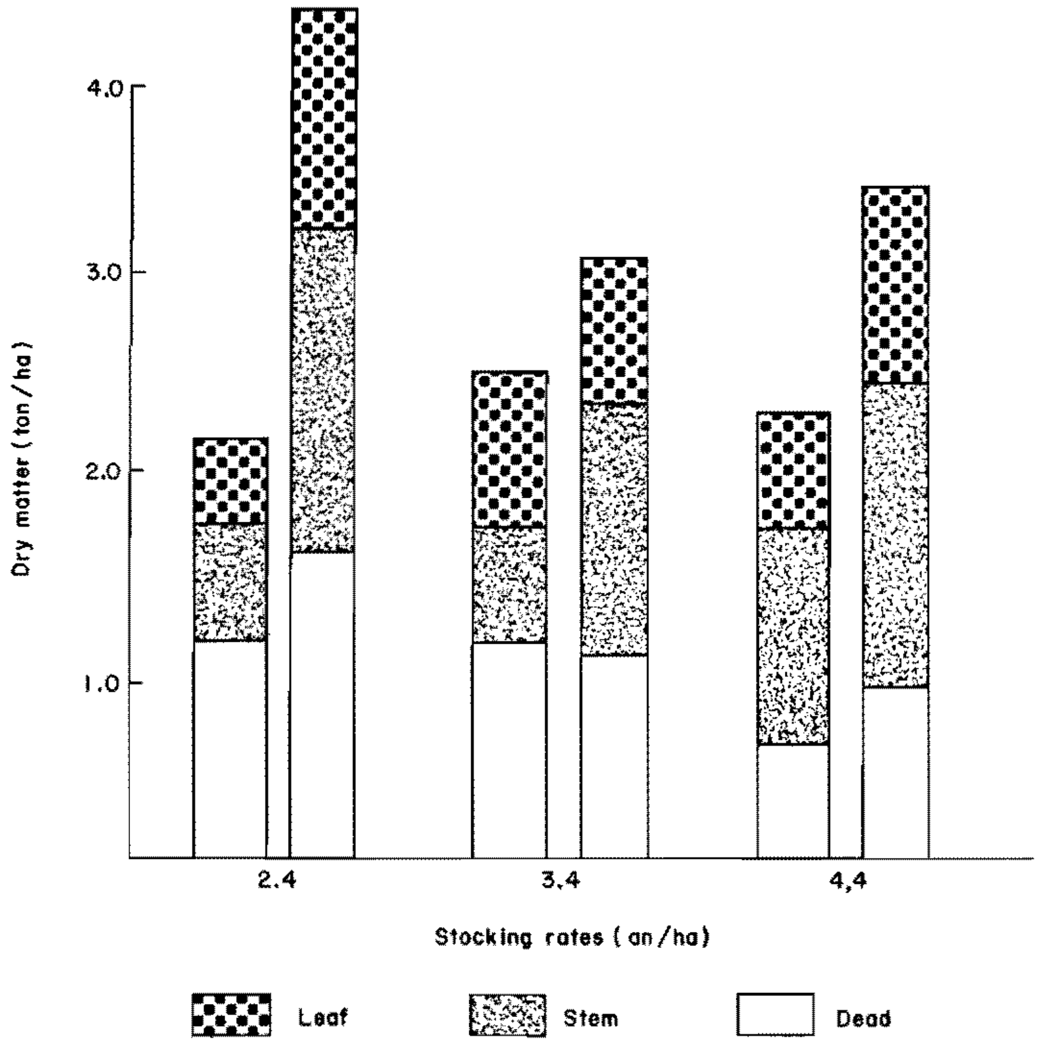



Figure 1. Effects of stocking rates on forage availability and plant part composition of B. humidicola in the wet season in Carimagua, before and after maintenance fertilization with 18.26, 11, 22 kg/ha K, Mg and S, respectively.

## Legume Pastures

Legume protein bank. One alternative to utilize legumes, particularly those species which are aggressive and tolerant to heavy seasonal grazing, is to establish pure stand strips or blocks within a grass pasture to provide high protein forage for supplementation during the dry season or during the growing season. At those times the protein content of the grass may be limiting voluntary intake of dry matter and thus, energy intake and animal productivity. This concept has been tested for the last three years with Pueraria phaseoloides (kudzu) in blocks with savanna, including seasonal burning, and with the improved grass B. decumbens in strips and blocks.

Table 2 shows third year results with savanna. Animal productivity at the low stocking rate was higher than last year's and similar to the first year of evaluation. At the high stocking rate productivity was somehow lower due to the fact that access to the bank was more limited this year. This was done to allow the legume to recover after heavy grazing during the dry season and after application of maintenance fertilization with 22, 11 and 22 kg/ha K, Mg and S, respectively, during the rainy season. Only 1/3 of the total savanna area was burned once at the end of the dry season and another third at the end of the rainy season. This may also have had some effects on animal performance associated with stocking rates as indicated in Figure 2. It shows that at the lower stocking rate access of animals to the legume bank was still higher at the beginning of the rainy season, after burning, compared to the high stocking rate. The results also indicate a strong interaction during most of the rainy season when access to the bank was limited and the selectivity for forage quality on the unburned area was more restricted at the high stocking rate. After three years, there is no apparent effect of stocking rates on pasture structure as indicated by a preliminary study on vegetation succession conducted this year.

Table 2. Liveweight gains of steers grazing on savanna supplemented with *P. phaseoloides* in blocks (0.2 ha/an)[1] in Carimagua, 1981.

| Stocking rate (an/ha) | Dry season (111 days) (g/an per day) | (kg/an) | Wet season (255 days) (g/an per day) | (kg/an) | Total (366 days) (kg/an) | (kg/an) |
|---|---|---|---|---|---|---|
| 0.25 | 117 | 14 | 423 | 108 | 122 | 31 |
| 0.50 | 96 | 10 | 215 | 55 | 65 | 32 |

[1] Access to bank was restricted for 186 days in the rainy season to allow recovery of the legume after maintenance fertilization.

Table 3 shows results in 1981 with *B. decumbens*. After three years animal performance on the bank (established in strips) treatments was significantly different from the grass alone treatment only during the first part of the dry season. Animal productivity on grass alone was much higher than expected, due to early rainfall during the last part of the dry season. During the rainy season leaf production of grass increases very rapidly as shown in Figure 3, and since this grass does not present serious limitation on voluntary intake due to forage quality during the growing season, animals select against kudzu as the season progresses (Figure 4). Animal performance is more related to grass yields. After three years of grazing, the strips of kudzu have invaded the grass area and the pasture has evolved into a grass-legume association explaining perhaps the better animal performance as compared to the block treatment.

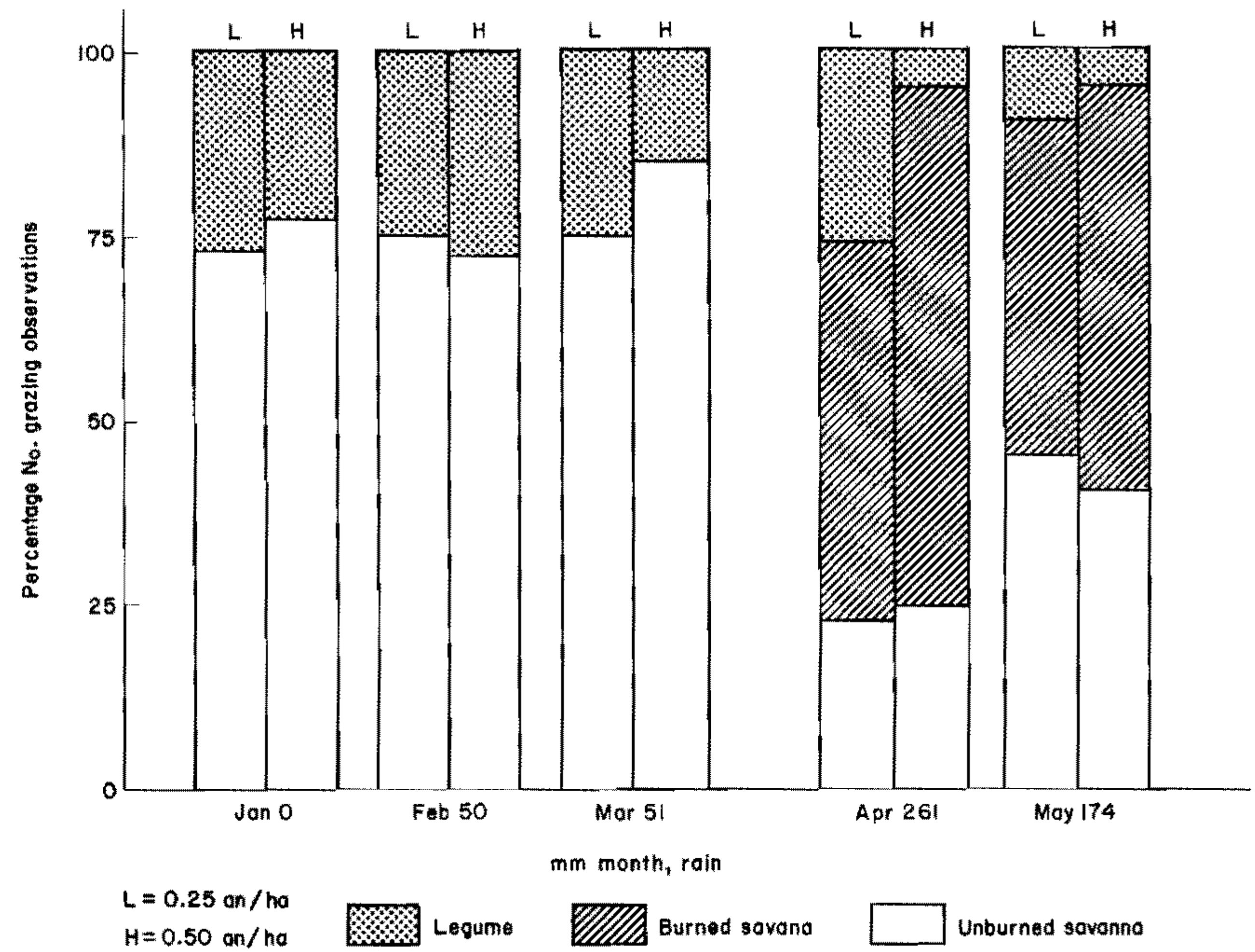



Figure 2. Effects of stocking rates before and after burning at end of dry season on the grazing behavior of steers grazing savanna supplemented with P. phaseoloides in blocks, Carimagua, 1981.

Table 3. Liveweight gains of steers feeding on <u>B. decumbens</u> supplemented with <u>P. phaseoloides</u> in strips[1] and blocks[1] in Carimagua, 1981.

| Treatment | Stocking rate[2] (an/ha) | Dry season: 49 days[3] | | Dry season: 63 days[3] | | Wet season: 254 days | | Total: 366 days | |
|---|---|---|---|---|---|---|---|---|---|
| | | (g/an per day) | (kg/an) | (g/an per day) | (kg/an) | (g/an per day) | (kg/an) | (kg/an) | (kg/ha) |
| Grass | 1.0/1.8 | 265 | 13 | 619 | 39 | 512 | 130 | 182 | 291 |
| Grass + legume strips | 1.0/1.8 | 551 | 27 | 526 | 33 | 567 | 144 | 204 | 335 |
| Grass + legume blocks | 1.0/1.8 | 439 | 21 | 333 | 21 | 500 | 127 | 169 | 294 |

1 0.30 and 0.15 ha/an for dry/wet seasons, respectively
2 Dry/wet seasons, respectively
3 0 and 100 mm rain, respectively.

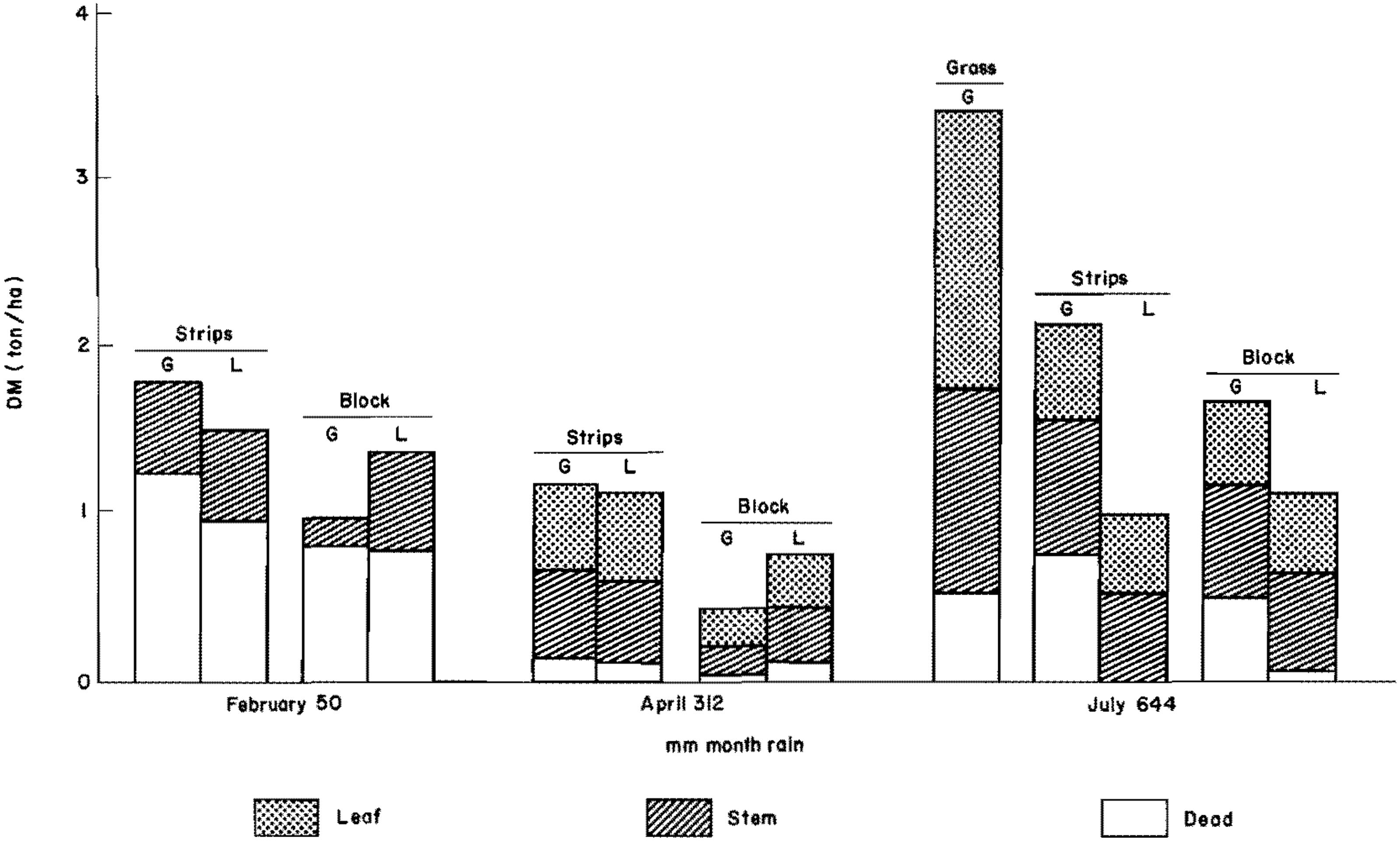



Figure 3. Forage availability and plant part composition in B. decumbens supplemented with P. phaseoloides in strips and blocks during the dry and wet seasons in Carimagua, 1981.

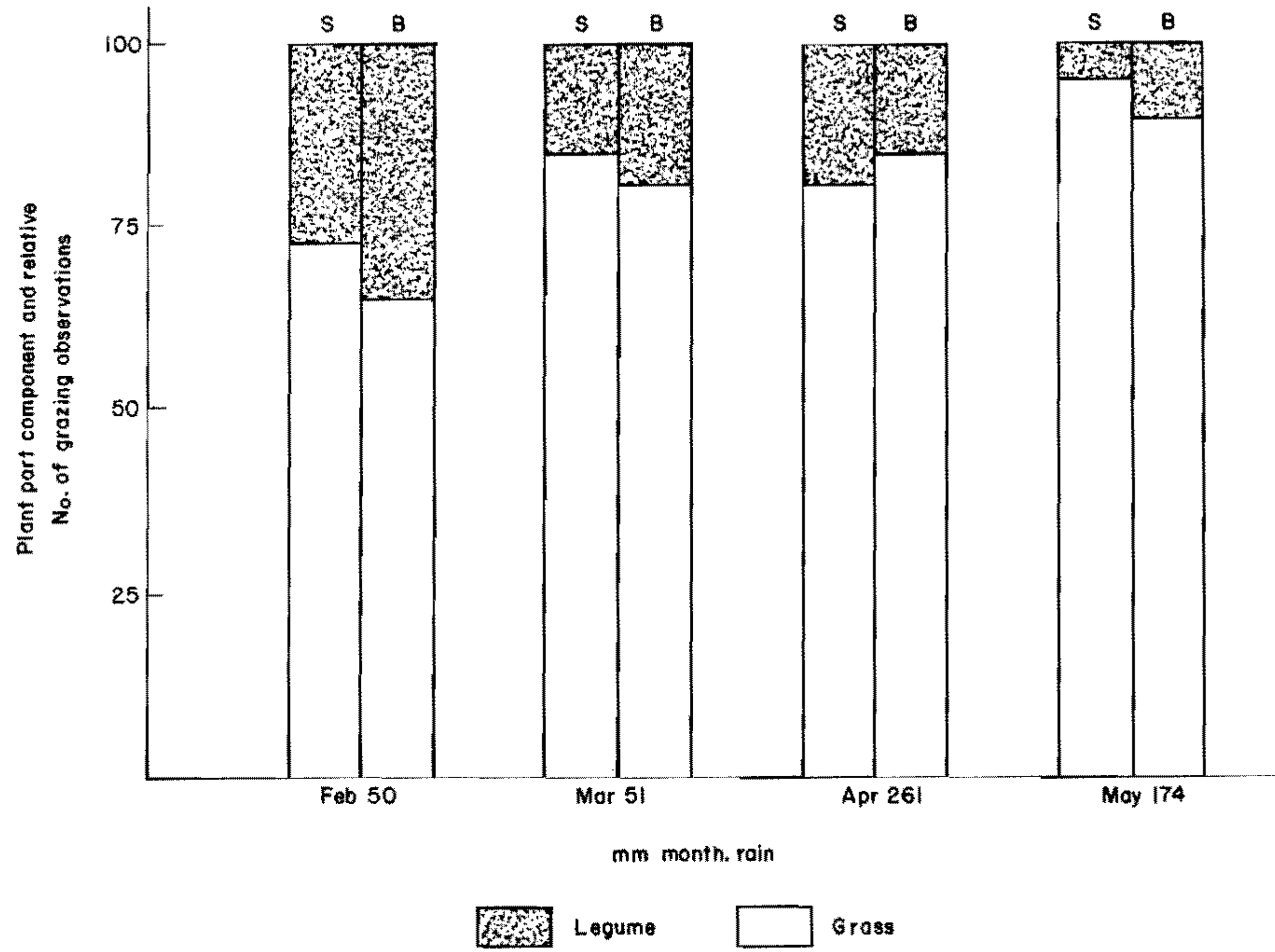



Figure 4. Percentage of plant part components in the diet and percentage number of grazing observations in B. decumbens supplemented with P. phaseoloides in strips (S) and blocks (B), respectively, in Carimagua, 1981.

The beneficial effects of legume banks during the dry season in improving dry matter intake and animal performance have been documented with these studies. However, we still need to learn more about the proportion of legume bank to stocking rates required to offer protein supplementation to the grass quality in order to improve voluntary intake. This in order not to substitute for dry matter intake and intake of energy from the grass, especially with improved species such as B. decumbens which offers no serious quality limitation during the rainy season. The way the banks are established need also to be further evaluated with other legume species, especially the most aggressive ones with the ability to invade adjacent native or cultivated grasslands to facilitate establishment with minimum tillage and land preparation cost.

## Grass-Legume Associations

Andropogon gayanus - legume associations. The evaluation of A. gayanus - Stylosanthes capitata, Zornia latifolia - Pueraria phaseolodies kudzu associations under continuous grazing was continued for the third year with management similar to the previous year. This year animal performance (Table 4) was similar or better than last year for both dry and wet seasons, even though yield and botanical composition of the legumes, except for the kudzu treatment, declined significantly, especially in the dry season (Table 5). According to data presented in Figure 3, Pasture Quality and Nutrition, animals are capable of selecting legumes in their diet even at very low levels of offer, which may explain performance this year. Furthermore, grass productivity in the associations with S. capitata, as shown in Table 5, was as high as the grass alone, and protein content was higher, especially during the rainy season (Table 11 in Pasture Quality and Nutrition). In the kudzu treatment, the legume became dominant, and the presentation yield of A. gayanus was lower compared to grass alone; protein content was much higher for both wet and dry seasons. Lower animal production during the wet season may be explained by the lower amount of grass present in the diet of the grazing animals.

Results of animal productivity on A. gayanus - S. capitata pastures burned in 1980 are compared with unburned treatments in Table 6. There was no significant effect of burning on animal production. In both treatments productivity of the legume associations declined significantly from previous years due to lack of persistence under these conditions. Performance of S. capitata 1315 seems to be better than that of S. capitata 1019, especially in the unburned treatments. However, animal production was lower this year compared to an association with both ecotypes of A. gayanus and similar to S. capitata 1405 (Table 4). Burning does not seem to improve animal performance on this association and may have contributed to decreased persistence of the legume; thus, it is not recommended.

Table 4. Liveweight gains of steers grazing *A. gayanus*-legume associations in Carimagua, 1981.

| Treatment | Stocking rate[1] (an/ha) | Dry season (96 days) | | Wet season (269) days | | Total (365 days) | |
|---|---|---|---|---|---|---|---|
| | | (g/an per day) | (kg/an) | (g/an per day) | (kg/an) | (kg/an) | (kg/an) |
| *S. capitata* 1405 | 1.0/1.8 | 125 | 12 | 598 | 161 | 173 | 291 |
| *S. capitata* (1019 + 1315) | 1.0/1.8 | 166 | 16 | 684 | 184 | 200 | 349 |
| *Z. latifolia* | 1.0/1.0 | 135 | 13 | 420 | 113 | 126 | 126 |
| *P. phaseoloides*[2] | 1.0/1.8 | 531 | 51 | 520 | 140 | 191 | 310 |

1 Dry/wet seasons, respectively
2 Rested for 71 days in 1980.

Table 5. Forage on offer in A. gayanus pastures in pure stand and associated with legumes under continuous grazing in the wet and dry seasons in Carimagua, 1980-1981.

| A. gayanus pasture | Season | Forage on offer grass (t/ha) | legume (t/ha) |
|---|---|---|---|
| | Rainy[1] | | |
| Pure stand | | 10.00 | - |
| + S. capitata 1405 | | 6.95 | 1.33 |
| + S. capitata (1019 + 1315) | | 7.26 | 1.83 |
| + P. phaseoloides | | 2.86 | 4.66 |
| | Dry[2] | | |
| Pure stand | | 6.96 | - |
| + S. capitata 1405 | | 5.35 | 1.17 |
| + S. capitata (1019 + 1315) | | 5.45 | 1.56 |
| + P. phaseoloides | | 1.89 | 4.58 |

1 Sampling on: May, July, Sept.-Oct. 1980, and March 1981
2 Sampling on: Feb., Nov.-Dec. 1980, and Jan.-Feb. 1981

Brachiaria humidicola - Desmodium ovalifolium association. Evaluation started this year on two pastures established in 1980. Previous experience with D. ovalifolium in Carimagua indicated that selection of the companion grass and grazing management of the association to encourage legume consumption are very important to maintain the balance of pasture components for better animal performance. The main objective of the evaluation the first year, with the support of the Pasture Quality and Nutrition Section, has been to study the dynamics of the association components with a vigorous B. humidicola grass, as affected by the grazing animal, and to learn how changes in pasture management may contribute to better utilization of the legume, preventing dominance during initial grazing.

Figure 5 shows the dynamics of the components in the two pastures since the beginning of the evaluation during the dry season. A combination of different stocking rates, adjusted according to dry matter on offer, and changes in grazing method at the beginning of the rainy season, have resulted in a better balanced association at this critical state of evaluation. This balance may be explained by preliminary results on Table 14, Pasture Quality and Nutrition Section, showing a significant increase in legume consumption at the beginning of the rainy season which may be associated with changes in grazing management. Animal performance so far--average of 450 g/ an per day at the end of first year grazing--is very promising considering stocking rates of 3.5 an/ha on alternate grazing.

Table 6. Liveweight gains of steers grazing unburned and burned *A. gayanus* + *S. capitata* associations in Carimagua, 1981.

| Treatment | Stocking rate[1] (an/ha) | Dry season (110 days) | | Wet season (254 days) | | Total (364 days) | |
|---|---|---|---|---|---|---|---|
| | | (g/an per day) | (kg/an) | (g/an per day) | (kg/an) | (kg/an) | (kg/an) |
| **Unburned** | | | | | | | |
| Grass | 1.0/1.8 | 118 | 13 | 527 | 134 | 147 | 248 |
| Grass - *S. capitata* 1019 | 1.0/1.8 | 145 | 16 | 456 | 116 | 132 | 229 |
| Grass - *S. capitata* 1315 | 1.0/1.8 | 445 | 49 | 492 | 125 | 174 | 301 |
| Average | 1.0/1.8 | 236 | 26 | 492 | 125 | 151 | 259 |
| **Burned** | | | | | | | |
| Grass | 1.0/1.8 | 127 | 14 | 504 | 128 | 142 | 237 |
| Grass - *S. capitata* 1019 | 1.0/1.8 | 236 | 26 | 480 | 122 | 148 | 248 |
| Grass - *S. capitata* 1315 | 1.0/1.8 | 436 | 48 | 464 | 118 | 166 | 273 |
| Average | 1.0/1.8 | 266 | 29 | 483 | 123 | 152 | 252 |

[1] Dry/wet seasons, respectively

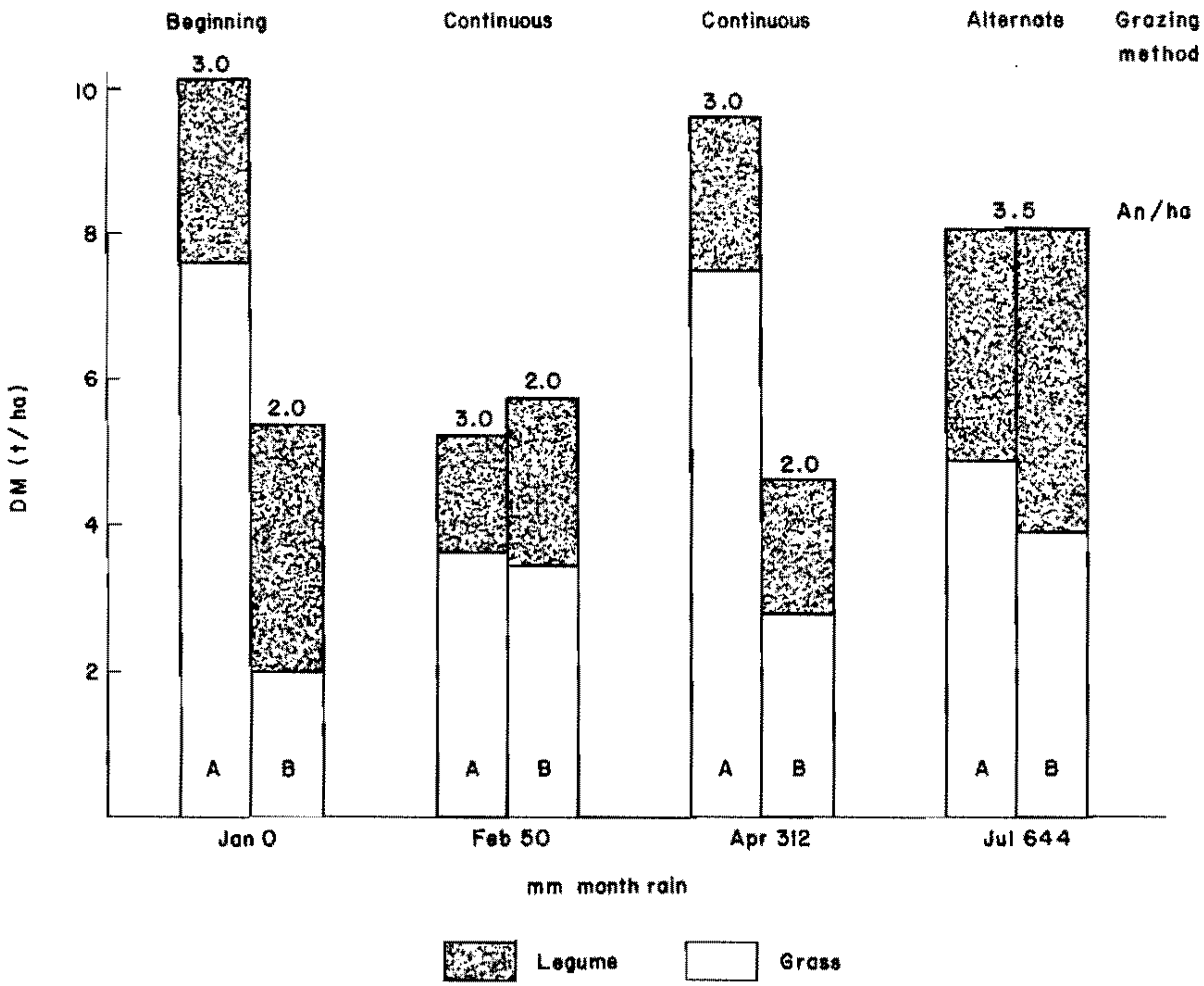



Figure 5. Effects of grazing management on availability of pasture components on two (A,B) B. humidicola - D. ovalifolium pastures in Carimagua, 1981.

# Cattle Production Systems

The objectives of the Section are: a) Identification and quantification of the main limiting factors affecting existing systems of cattle production in the target area; b) integration of new technology into economical systems of production; c) evaluation of the impact of improved pastures and technologies on cattle production, in the context of real and/or feasible systems. To achieve these objectives, several lines of research are pursued in close cooperation with the Economy and other sections of the Tropical Pastures Program. A significant effort is addressed to the problem of identifying and quantitatively describing the existing systems of cattle production in the areas of acid, low-fertility soils of tropical America. This activity has been concentrated in two major ecosystems: the Cerrado of Brazil and the savannas (Llanos) of Colombia and Venezuela (ETES Project).

Another major line of research consists of evaluating the seasonal, strategic use of small areas of sown pastures for the supplementation of savanna-based breeding herds, under the extensive conditions prevailing in the Llanos of Colombia (Breeding Herd Management Systems Experiment).

Lastly, a validation of improved technology, based mainly on grass/legume or legume alone sown pastures, is being attempted at the farm level in ranches previously surveyed by the ETES Project (this activity is called ETES II Project).

## Evaluation of Cattle Production Systems (ETES)

This international description scheme of prevailing cattle production systems involves several national institutions, namely, the Institute for Animal Production of the University of Berlin, the German Agency for Technical Cooperation (GTZ), the Cerrados Research Center (CPAC) of EMBRAPA at Planaltina, Brazil; the North Eastern Plains Research Center (CIARNO) of FONAIAP, at Maturín, Venezuela. It is being coordinated by Economy, Animal Health, and Cattle Production Systems Sections of CIAT. The current status by countries is described below.

ETES Colombia. Comprehensive descriptions and discussion of the results were presented in previous annual reports, and a final report is being prepared.

ETES Brazil. Field collection data was completed in November 1980, and since then the information obtained was codified and analyzed. Technical and economic information was collected on a total of 12 farms, seven of which are located in the State of Goias (districts of Gurupi and Porto Nacional), and five in Mato Grosso (districts of Tesouro and Cuiratinga). Although both regions belong to the Cerrados ecosystem, major differences exist. Average annual rainfall is about 1800 mm, but the wet season extends from October to April in Goias and from September to May in Mato Grosso (Table 1). There is an important difference in terms of physiographic characteristics that affect land use. In effect, the larger proportion of "sierra" in Mato Grosso (Table 2) imposes restrictions on mechanized agriculture.

Table 1. Climatic parameters in two regions of ETES Brazil.

| Parameter | Goias | Mato Grosso |
|---|---|---|
| Elevation, m | 237 | 720 |
| Rainfall, mm | 1813 | 1798 |
| Average temperature, °C | 25.6 | 21.3 |
| Average temperature, °C in | | |
| coldest month (July) | 24.3 | 16.9 |
| warmest month (September) | 35.0 | 24.0 |

Table 2. Physiographic characteristics of farms surveyed in Brazil.

| Means | Goias | Mato Grosso |
|---|---|---|
| Total, ha | 2212 | 3002 |
| Cerrado, % | 65 | 51 |
| Sierra, % | 20 | 48 |
| Mata*, % | 15 | 1 |

* Mata or "Cerradão": closed savanna with dense, tall trees.

Since the area of available rice, together with that on Brachiaria pastures (Table 3) had a significant correlation with liveweight per hectare, it is likely that differences in physiography are associated with differences in productivity. In 1980 sown grasses represented almost one-third of the average farm area. Dramatic increases were noted in the areas sown with Brachiarias (*B. decumbens*, *B. humidicola* and *B. ruziziensis*) during the period 1978-1981, while the areas sown to *Hyparrhenia rufa* tended to remain stable or grew slightly.

The existing systems of animal production are centered on breeding; only one of the farms studied fattens steers, while the rest either sell calves at weaning (four farms) or raise the calves up until about 24 months of age (seven farms). Some indices of animal productivity are shown in Table 4. These are characterized by relatively short calving intervals, when compared to data from ETES Colombia, but low postweaning weight gains. Therefore, it is not surprising that fully 37% of the animal inventory consists of non-bred females (calves and heifers up to $4^+$ years of age). Similarly to what was reported for Colombia (Annual Report 1980), the correlation between the calving rates of successive years was negative (r = -0.08) indicating the inadequacy of data based on a single year; this is a natural consequence of long ( $>$ 12 mo) calving intervals. Breeding cows begin their reproductive phase at an old age; mean age at first conception was 41 months, and liveweight (adjusted for physiological condition) continued to rise until nine years of age.

Table 3. Forage resources of farms surveyed in ETES, Brazil, as percent of total area, 1980.

| Area | Goias (%) | Mato Grosso (%) |
|---|---|---|
| Cerrado | 34 | 10 |
| Sierra | 19 | 48 |
| Rice | 6 | 5 |
| Sown grasses | 26 | 36 |
| Mata | 15 | 1 |

Table 4. Indices of animal productivity in the Cerrado of Brazil.

| | Mean | | SE |
|---|---|---|---|
| Weaning rate, % | 61.1 | ± | 2.9 |
| Calving interval, months | 19.6 | ± | 0.8 |
| Weight gain*, kg | 75.4 | ± | 4.8 |
| Weight gain, kg/ha$^{-1}$ year$^{-1}$ | 16.7 | ± | 2.6 |

* Gain of female calves from weaning to 24 months of age.

ETES Venezuela. Collection of field data continued during 1981, and the fourth and last visit to the farms surveyed was scheduled for October 1981. Thirteen farms are being surveyed, of which eight are located in the state of Monagas and the rest in Anzoâtegui. A preliminary description of the farms was given in the Annual Report 1980; it was noted that, contrary to what was observed in the Cerrado of Brazil and the Llanos of Colombia, extensive dairy ranching is practiced in the Llanos of Venezuela. In effect, 32% of the females recorded during the third visit to the farms (July 1981) were being milked and only two of the farms did not milk cows. Actual numbers of milking cows in this visit varied greatly from 0 to 96 (0 to 71%). Of the total number of cows, only 5% were both pregnant and lactating, while 57% were empty and lactating and the remaining 38% were dry.

Among the 2 to $4^{+}$ year old heifers, 58% were pregnant. Their mean weight was 304 $\pm$ 4 kg and mean age was 45 $\pm$ 1 month, while the nonpregnant heifers were 40 kg lighter and 4 months younger. Compared to the above weights, mature 8-10 year-old cows are only slightly heavier and tend to stabilize around 320 kg. This trend is similar to that observed for Brazil.

## Breeding Herd Management Systems Experiment

This experiment started in 1977 and is scheduled to end in December 1981; therefore, a complete analysis is not yet available. The experiment attempted to determine the effect of the strategic use of sown pastures on the productive efficiency of beef breeding herds raised under extensive conditions in the eastern Llanos of Colombia. Seasonal mating was also compared to continuous mating. Sown pastures were based mostly, though not exclusively, on *Brachiaria decumbens* (Table 5).

Table 5. Availability of sown pastures in the breeding herd experiment.

| Species | Availability (ha/cow) during | | | |
|---|---|---|---|---|
| | 1978 | 1979 | 1980 | 1981 |
| *B. decumbens* | 0.8 | 0.8 | 0.6 | 0.6 |
| *A. gayanus* | - | 0.2 | 0.2 | 0.2 |
| *B. decumbens* + legumes* | - | - | 0.2 | 0.2 |
| *S. guianensis* | 0.2 | - | - | - |

* *P. phaseoloides*, *D. ovalifolium* and *S. capitata*.

Legume persistency was a major problem during the first half of the experiment, which may explain the relatively small differences observed in reproductive performance between the savanna alone and the savanna + pastures treatment (Table 6). This trend is reinforced by the data presented in Table 7, which shows the rate of conception of lactating cows in both treatments, as related to legume availability. Nevertheless, over the same three-year period (1978-80) the average weight of lactating cows at conception was the same (345 kg). As a consequence of similar calving percentages (Table 6) and rate of growth of the calves, the production level of weaners was also similar between treatments (Table 8). However, both in terms of reproductive efficiency and meat production at weaning (Tables 6 and 8), there has been a consistent trend for better performance on herds with access to pastures when the mating season is short (90 days) and occurs at the beginning of the rainy season. Nevertheless, it should be noted that calving percentages and liveweight production in the savanna-alone treatment of this experiment has been consistently larger than the average found for the Llanos in the ETES study (Annual Report 1979). This overall better performance is probably the consequence of a combination of factors such as a consistent policy of mineral supplementation, well defined though not strict, culling criteria, sequential burning of the savanna and better and continuous close supervision of the herds. A more realistic "control" will probably be obtained from the confrontation of results observed in ETES-Colombia versus those to be derived from ETES II.

Table 6. Calving percentage in the breeding herd experiment (calves born/100 bred cows) 1979-1981.

| Mating season | Savanna alone | Savanna + pastures | Mean |
|---|---|---|---|
| Continuous mating | 73 | 78 | 75.5 |
| June/September (120 days) | 61 | 61 | 61.0 |
| May/July (90 days) | 59 | 69 | 64.0 |
| Mean | 64.3 | 69.3 | 66.8 |

Table 7. Proportion of lactating cows conceiving, 1978-1980.

| Treatment | 1978 | 1979 | 1980 | Mean |
|---|---|---|---|---|
| Savanna alone | 23.5 | 22.0 | 28.0 | 24.5 |
| Savanna + pastures | 64.4 | 25.4 | 41.7 | 43.8 |
| Legume availability, $m^2$/cow | 2000 | - | 700 | - |

Table 8. Calf weight weaned per cow in the breeding herd experiment (kg weaned cow/year) 1978-80.

| Mating season | Savanna alone | Savanna + pastures | Mean |
|---|---|---|---|
| Continuous | 107.5 | 117.8 | 112.7 |
| June/September | 90.3 | 91.1 | 90.7 |
| May/July | 90.8 | 105.9 | 98.4 |
| Mean | 96.2 | 104.9 | 100.6 |

ETES II Colombia

This follow-up study is located in seven farms which were included in ETES I. Its objective is to study the effect of introducing a package of improved technology based on sown grass-legume pastures, including mineral supplementation, restricted mating, systematic weaning and a basic sanitary scheme (Annual Report 1980). Sown pastures are mostly Brachiaria decumbens/Desmodium ovalifolium and Andropogon gayanus/Stylosanthes capitata associations, although smaller paddocks of protein banks (Pueraria phaseoloides and Stylosanthes capitata) and of Brachiaria humidicola/Desmodium ovalifolium have also been included. Most pastures were established in 1980-1981 (summarized in Table 9). Complete records are being taken in these farms of both pasture utilization and animal performance.

Table 9. Sown pastures established in farms participating in ETES II.

| Farm* | Area sown | |
|---|---|---|
| | ha | % of total |
| 04 | 170 | 6 |
| 07 | 45 | 1 |
| 08 | 8 | 2 |
| 13 | 98 | 7 |
| 15 | 160 | 5 |
| 17 | 145 | 6 |
| + | 80 | 3 |
| Total | 706 | - |

* Numbers are the same used in ETES-Colombia.

+ Farm not included in initial phase of ETES.

The reproductive condition of cows is recorded twice a year through rectal palpation. Liveweights are also recorded.

A second, complementary aspect of this project consists of a series of farm-level experiments conducted in four farms to evaluate sown pastures--as opposed to native savanna--as forage resources for raising replacement heifers. As noted previously, heifers reach breeding conditions at very advanced ages under the extensive conditions prevailing in the Llanos. Furthermore, once calved, these animals wait a long time before rebred. The objectives of this line of research are, therefore, to evaluate age at first calving and the subsequent interval of raising heifers on improved pastures.

# Cattle Production - Cerrado

This section is responsible for the evaluation of Category IV material in large scale grazing trials. This is the final stage of evaluation for pasture persistence and animal performance before the material moves into Category V, where the section has the responsibility of designing and carrying out experiments to determine where the new material can best be utilized to increase beef productivity at the ranch level in the Cerrados region of Brazil.

## Evaluation under Grazing

Two experiments with Category IV material are currently under grazing at the Cerrados Center. The comparison of Brachiaria ruziziensis fertilized with 40 kg/ha of nitrogen vs. B. ruziziensis in association with Calopogonium mucunoides has completed two years under grazing. Liveweight gains in the second year were not as good as in the initial grazing year due to the greater amount of dry matter present at the beginning of the dry season in the first year. In both years, the animals on the nitrogen-fertilized Brachiaria pasture gained at a faster rate than those on the Brachiaria/Calopogonium pasture both in the dry and wet seasons at the low stocking rate (Table 1). At the high stocking rate the individual animal gains were less than those at the low stocking rate, and differences were less between the nitrogen-fertilized pasture and the legume-based pasture. The nitrogen-fertilized pasture produced about 50 kg/ha per yr more liveweight gain than the legume based pasture at the low stocking rate and approximately 100 kg/ha more at the high stocking rate.

Table 1. Weight gain of animals grazing Brachiaria ruziziensis fertilized with nitrogen or a mixed sward with Calopogonium mucunoides (Exp. 391).

| Season | AU/ha | Brachiaria + $N_2$ | | Brachiaria + Calopogonium | |
|---|---|---|---|---|---|
| | | ha | Animal (kg) | ha | Animal (kg) |
| Dry | .8 | 97 | 48 | 50 | 25 |
| Wet | 1.1 | 186 | 93 | 140 | 70 |
| | 1.8 | 224 | 56 | 222 | 56 |
| Year | 1.0 | 254 | 141 | 204 | 95 |
| | 1.4 | 350 | 104 | 258 | 81 |

As mentioned in the previous Annual Report, the initial stocking rates were too high and were reduced at the end of the first year. The higher stocking rates in the first year resulted in a severe reduction of available dry matter in the grass component of the sward accompanied by a marked increase in the amount of available legume. The effect of adjusting the stocking rate downward can be seen in Figure 1, where during the second rainy season Brachiaria returned to dominate the sward while Calopogonium was held down to 30 percent of the available dry matter at the end of the rainy season.

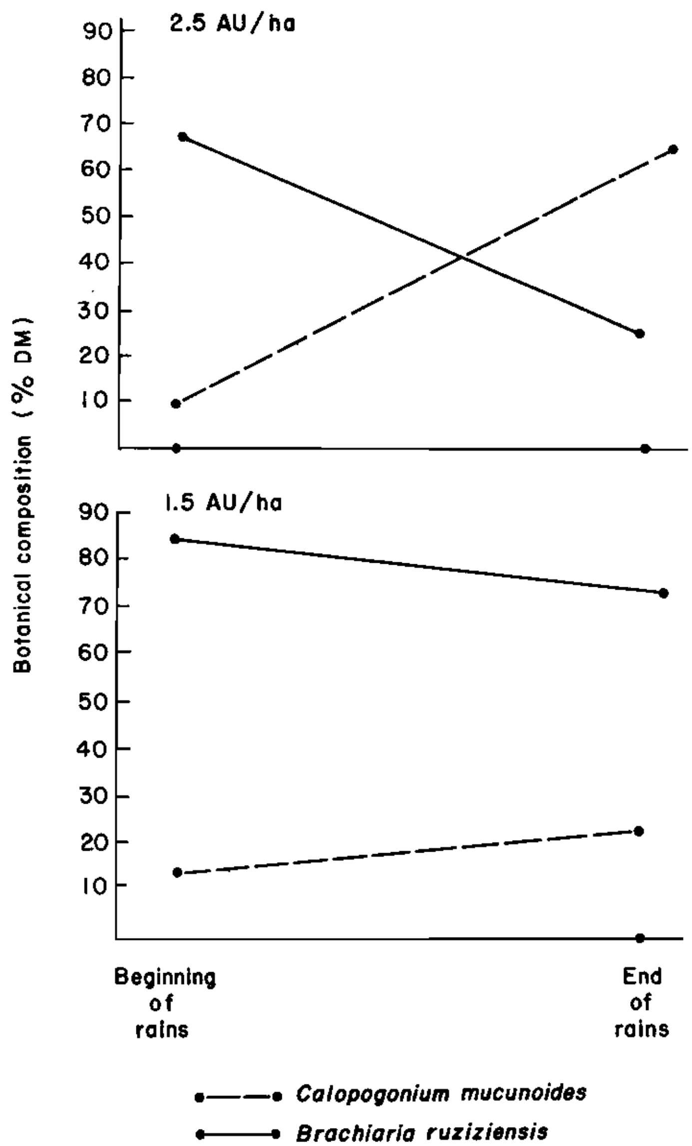



Figure 1. Results of reducing the stocking rate after the first year on changing the botanical composition of a Brachiaria ruziziensis + Calopogonium mucunoides pasture during the rainy season.

While Calopogonium is not readily consumed by the grazing animal, it appears to be making a contribution through nitrogen fixation and greater utilization of the grass by the grazing animal. The protein content of the Brachiaria was higher in the second year, both at the start and at the end of the rains, in association with Calopogonium or fertilized with 40 kg/ha per yr of nitrogen (Table 2). Nitrogen was applied in the middle of the rainy season which explains the lower protein value in the pure grass stand at the start of the rains. The higher protein levels in the grass associated with Calopogonium is probably the combined effect of slow and continuous mineralization of the nitrogen from the residue produced by the legume during the previous growing season and to a greater proportion of young grass regrowth due to heavier defoliation. While the protein content of the grass in the legume-based pasture was superior to that of the nitrogen-fertilized pasture, the dry matter available to the animal was less in the legume-based pasture. The fertilized pasture provided more available dry matter from grass alone at both stocking rates (with one exception in March) than Brachiaria and Calopogonium combined (Figure 2). The superior gains on the pure grass pasture are largely explained by the greater amount of dry matter availability in those paddocks and by the poor direct acceptability of the legume by the animals in the legume-based pasture. However, it is expected that the full effect of nitrogen contribution from the legume will not be realized until the third year thus producing animal gains similar to those from fertilized grass pastures.

Table 2. Percent protein of Brachiaria ruzizinesis when fertilized with nitrogen or in a mixed sward with Calopogonium mucunoides (Exp. 391).

| | B. ruziziensis + $N_2$ | B. ruziziensis + C. mucunoides | C. mucunoides |
|---|---|---|---|
| Beginning of rains (1/12/80) | 8.2 | 13.9 | 21.5 |
| End of rains (30/03/81) | 5.5 | 7.7 | 13.4 |

During the past year the first large scale grazing trial with Andropogon gayanus in association with a legume (Stylosanthes scabra, cv. Seca) was initiated. The data presented (Table 3) pertain to the results obtained from the first rainy season. Since there was an abundance of forage in all paddocks at the start of the experiment, no difference was observed in individual animal performance during the rainy season. However, the high stocking rate produced nearly three times more liveweight gain per ha than the low stocking rate. Figures 3, 4, and 5 give a graphic relationship of the effect of the various stocking rates on changes in botanical composition of the pastures and animal performance during the rainy season. In general, the grass component of the sward declined as the stocking rate increased which also favored an increase in the percent of weeds in the sward. Andropogon comprised 50 percent or more of the available dry matter throughout the rainy season, with the exception of two months toward the end of the rainy season in the high stocking rate. The Stylosanthes component varied between 20 and 30 percent of the sward in the medium and high stocking rate but was less than 20 percent at the low stocking rate.

Table 3. Effect of stocking rate on growing animals grazing Andropogon gayanus plus Stylosanthes scabra cv. Seca during the rainy season (153 days).

| Stocking rate* AU/ha | Paddock size (ha) | Weight gain (kg) Daily | Total | ha |
|---|---|---|---|---|
| 0.7 | 2.14 | .451 | 69 | 97 |
| 1.4 | 1.07 | .425 | 70 | 196 |
| 2.1 | .71 | .425 | 65 | 273 |

* 400 kg liveweight = 1 AU.

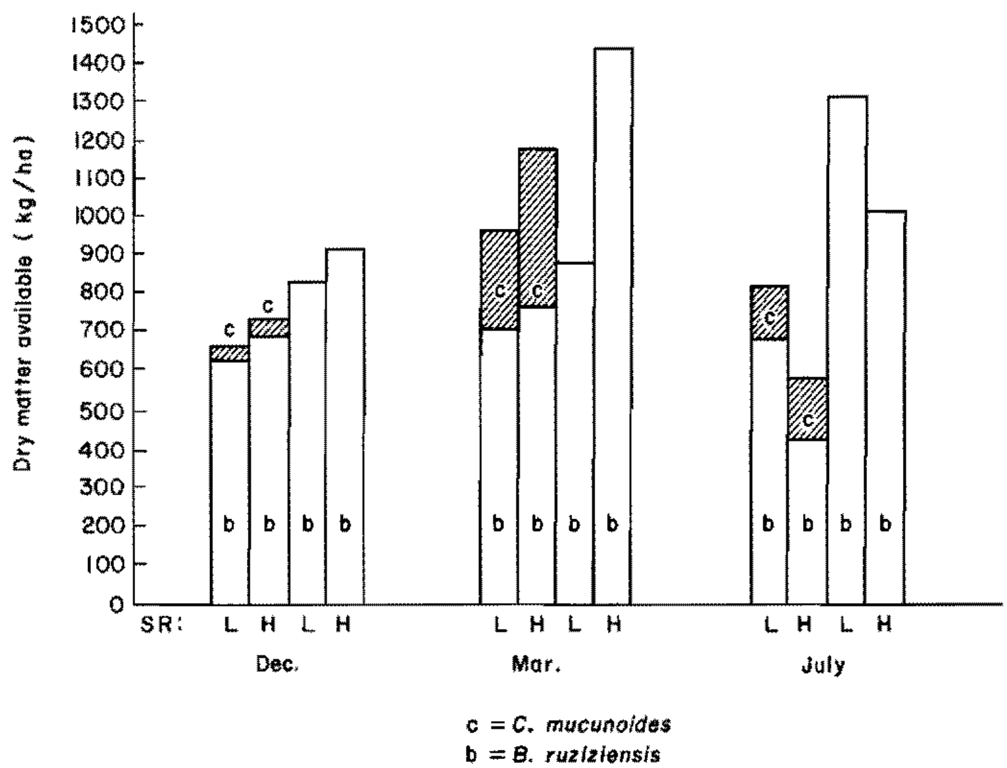



Figure 2. Seasonal availability of dry matter from nitrogen-fertilized Brachiaria ruziziensis grass pasture vs. Brachiaria ruziziensis plus Calopogonium mucunoides mixture.

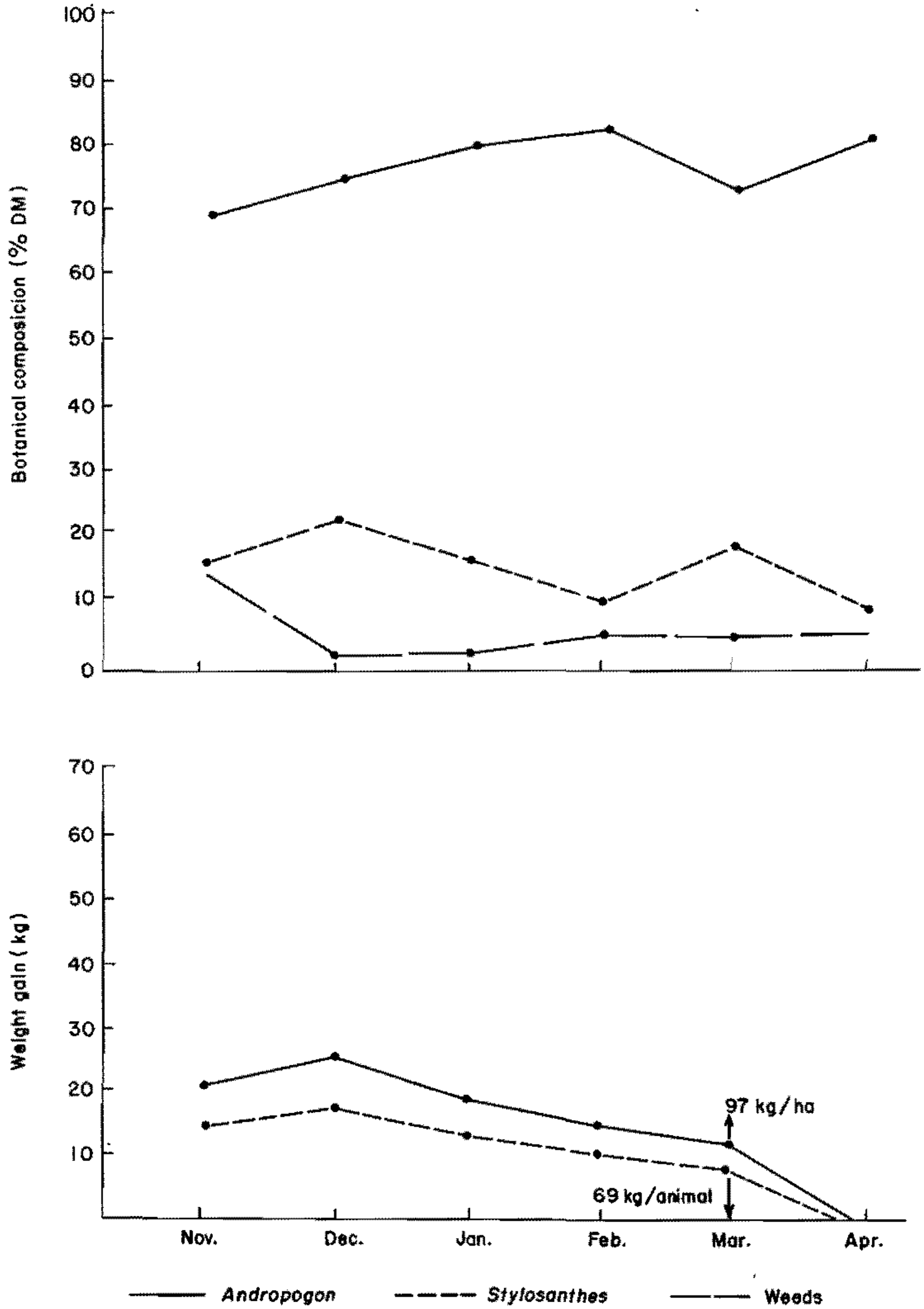



Figure 3. Botanical composition and animal weight gain during the rainy season using a low stocking rate (0.7 AU/ha).

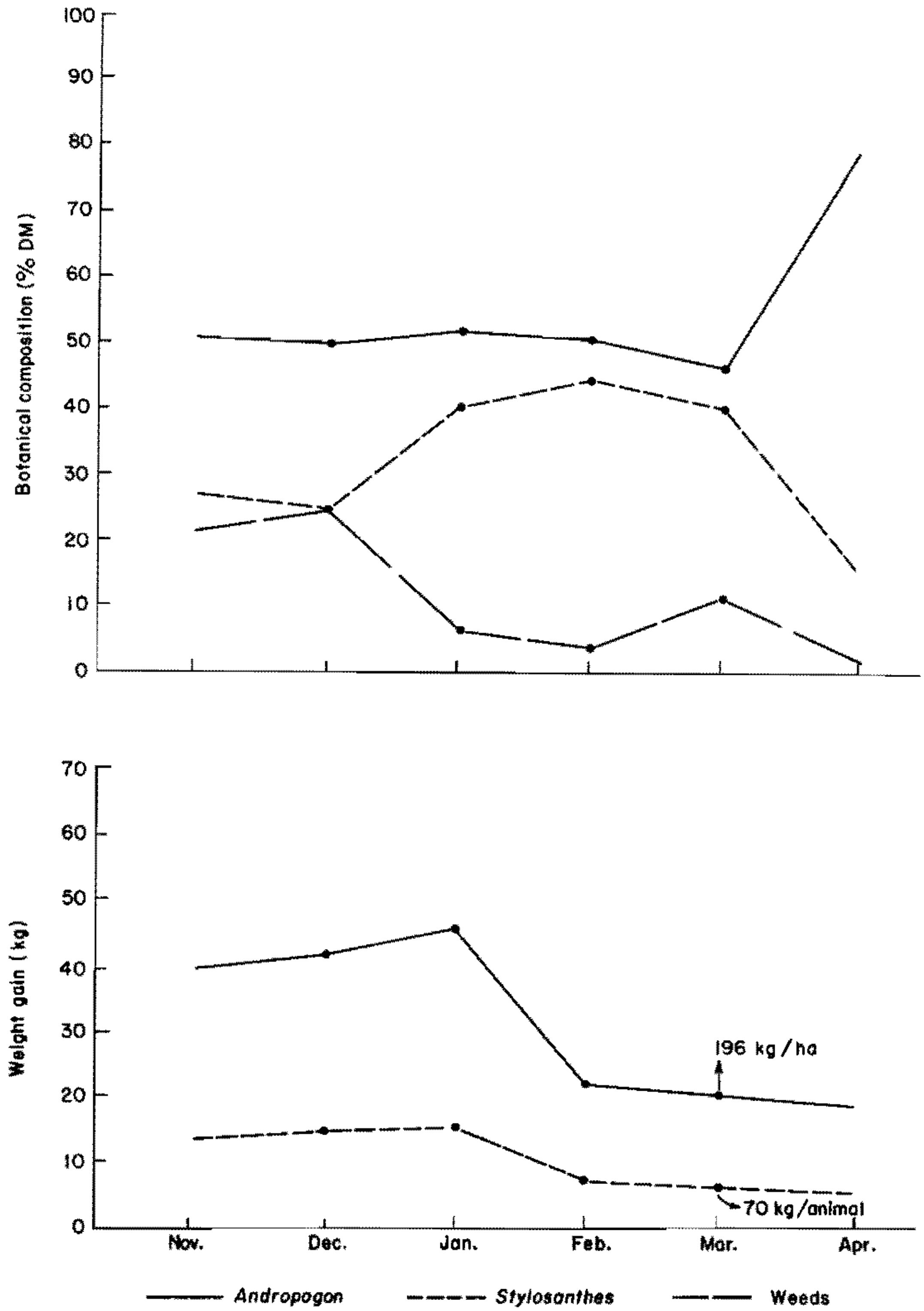



Figure 4. Botanical composition and animal weight gain during the rainy season using a medium stocking rate (1.4 AU/ha).

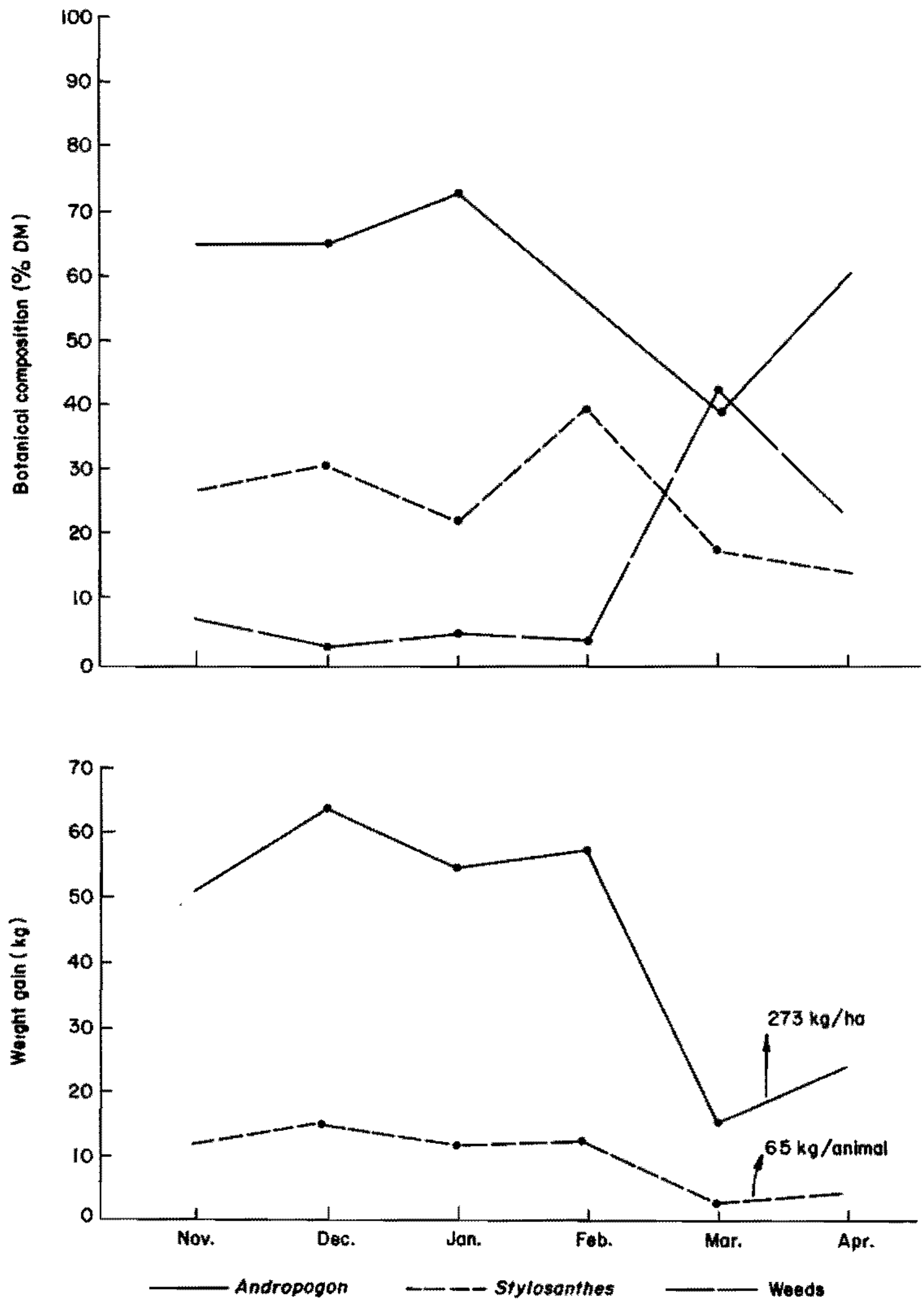



Figure 5. Botanical composition and animal weight gain during the rainy season using a high stocking rate (2.1 AU/ha).

It can be observed (Figure 6) that an excessive amount of grass was produced which was not utilized by the animal and resulted in a reduction in the amount of legume in the sward. Because of undergrazing, Andropogon grew very tall which forced the Stylosanthes plants to grow tall instead of forming a bush type plant with more leaves which could have resulted in more dry matter production. After one grazing season, it would appear that the medium stocking rate of 1.4 AU/ha will be close to that required to keep Andropogon under control and in a stable association with selected legumes in the Cerrado.

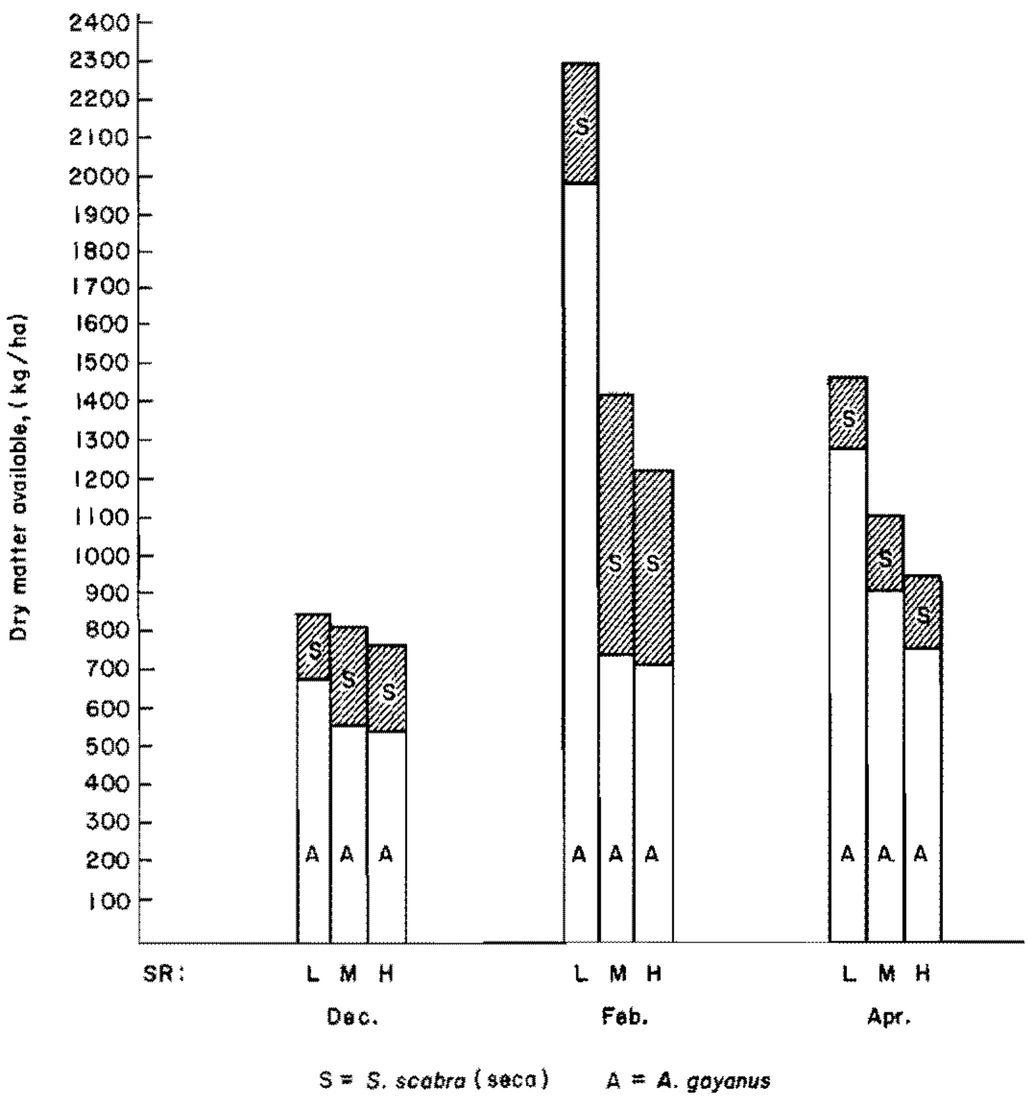



Figure 6. Effect of stocking rate on available dry matter at the start, middle, and end of the rainy season in the Cerrados.

## Pasture Utilization and Herd Management

The ultimate objective in developing new germplasm for pasture improvement is to increase beef productivity. Simultaneously with the development of new pasture species, it is necessary to determine where the new material might best be utilized within the overall beef production system in the region. The Cerrados region is predominantly a cow/calf operation where only about 5 percent of the animals produced are pasture fattened in the Cerrados. Therefore, the most important problem facing the producer is that of increasing the number of young animals available for sale each year. The Cerrados Center is responding to this need by investigating ways in which both native and improved pastures can be best utilized to increase beef reproduction.

A long-term herd management experiment was started in 1977 (see 1980 report) to study the effects on reproduction of using sown pastures during the mating season, two versus one mating season each year, and weaning the calf at either three or five months of age. Results to date are summarized in Table 4.

The stocking rate during the 90-day mating season was 2 cows/ha in the sown pasture vs 5 ha/cow in the native pasture. The three-year average shows that cows on sown pasture during the mating season had a 7 percent higher calving rate than cows permanently on native pasture. This suggests that the native pasture, if properly stocked, is only slightly inferior to sown pasture during the rainy season for cows which have their calves weaned at an early age. A 10 percent advantage in reproduction was observed when the calves were not weaned until they were five months old.

Since groups A and B were both mated on improved pasture, they can be compared for the effect of one vs two matings per year and early weaning which to date appear to be interrelated. When a 90-day mating season is used during the first part of the rainy season, there is a 25 percent increase (84 vs 67%) in calving rate when the calves are weaned at three months vs five months of age, respectively. If a 45-day mating is used at the start of the rains and repeated towards the end of the rainy season, there is only a 7 percent advantage to weaning at three months vs five months. The response to three- vs five-month weaning on native pasture using two 45-day mating seasons (group C) is approximately twice that observed on sown pasture (group B) which was greatly influenced by the unusually large response to early weaning in the third year. Because of year effects the experiment will be continued for at least two more years. However, the results to date suggest that by using a combination of sown pastures and early weaning with one or two matings per year a 75 percent calving rate could be maintained year after year.

Since mature size is highly variable in most tropical zebu cattle populations, the practice of relating liveweight to the reproductive status of the cow does not appear to be a reliable tool for predicting reproductive performance on a herd bases. An additional observation on body condition was started a year ago on each cow in the above experiment. At the beginning of the mating season and again at parturition a body condition score is recorded which is a subjective estimate of the thinness or fatness of the cow on a scale of 1 to 10.

Table 4. Effect of pasture utilization during the mating season and early weaning on calving rate (%) in zebu cows (Exp. 394).

| Treatment | 1978/79 | | 1979/80 | | 1980/81 | | Average | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Weaning age (mo) | 3 | 5 | 3 | 5 | 3 | 5 | 3 | 5 | (3 years) |
| | % | | | | | | | | |
| A<br>90-day mating season in cultivated pasture | 92 | 65 | 80 | 61 | 81 | 76 | 84 | 67 | 75 |
| B<br>45 + 45-day mating season in cultivated pasture | 88 | 84 | 73 | 58 | 77 | 80 | 79 | 74 | 76 |
| C<br>45 + 45-day mating season in native pasture | 76 | 84 | 65 | 76 | 88 | 42 | 76 | 67 | 71 |

Table 5 gives the average condition scores and cow weights at various reproductive stages. The cows are grouped according to the age of the calf at weaning and calving season (dry season Sept./Oct. or in the rainy season, Jan./Feb.). An increase in reproduction due to early weaning was clearly shown in the previous table; however, early weaning made no real differences in body condition or liveweight of the cows. The season of the year in which the cows calved did have an effect on body condition and weight. Cows which calve in the rainy season were in better condition and heavier at calving time and are heavier when they conceive than cows which calved in the dry season. At conception, parturition and weaning, those cows calving in Jan./Feb. were consistently heavier, i.e., 22, 21, and 15 kg, respectively, indicating that cows calving towards the middle of the rainy season tend to be heavier and lose less weight during lactation. The obvious explanation for the difference in cow condition and weight for two distinct calving seasons is the availability of higher quality forage during the rainy season which coincides with the reproductive stages most nutrient demanding in the cow (late gestation and early lactation).

The performance of the calves born in the above experiments was followed from birth onward. Table 6 gives a three-year summary of the birth and weaning weights grouped according to the main experimental treatments. The age at which the cow's calf is weaned had no influence on the birth weight of the calf. The calf weights at weaning were affected by treatment. As expected the calves weaned at five months of age were heavier than the three-month weaned calves (113 vs 81 kg).

Calves whose dams were on sown pasture during the mating season were 10 percent heavier at three months of age. The difference between weaning weights is related to the amount of time the dam spent on sown pasture prior to weaning. Calves with no improved pasture weighed an average of 105 kg at weaning; the calves which spent 45 days on improved pasture averaged 115 kg at weaning and the calves which spent 90 days with their dams on improved pasture weighed 121 kg at weaning.

The two calving seasons each year also permitted the study of seasonal effects on the development of the calf (Table 7). Season of birth was found to influence calf weights both at birth and at weaning. Calves in group B which were born in the rainy season (Jan./Feb.) were 34 percent heavier (7.2 kg) than calves of the same group born in the dry season (Sept./Oct.). This 7-kg advantage was maintained throughout the nursing phase and was still present at weaning time. In group C with cows permanently on native pasture the weight advantage was not as great at birth but the calves born in the rainy season were still 20 percent heavier (4.1 kg) than calves born in the dry season and this weight advantage was still present at weaning time.

The calves which were weaned at three months of age were lighter at one year of age than those weaned at five months. In 1979 there was 12 kg difference between the two groups at one year of age; however, by 18 months of age this difference had virtually disappeared (Figure 7).

Table 5. Effect of season of parturition on weight and body condition of zebu cows (Exp. 394, 1978/79/80).

| Treatment | Body condition* postpartum | | Body condition during mating season | | Conception weight | | Postpartum weight | | Weaning weight | |
|---|---|---|---|---|---|---|---|---|---|---|
| Weaning age (mo) | 3 | 5 | 3 | 5 | 3 | 5 | 3 | 5 | 3 | 5 |
| Cows calving in Sept./Oct. (dry season) | 3.8 | 3.7 | 4.3 | 4.8 | 330 | 325 | 332 | 334 | 324 | 327 |
| Cows calving in Jan./Feb. (rainy season) | 5.2 | 5.1 | 3.3 | 2.8 | 357 | 342 | 352 | 356 | 343 | 339 |

* Larger number indicates better condition.

Table 6. Effect of three herd management systems on calf weights at birth and weaning (Exp. 394).

| Treatment | Birth weights (kg) | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| Weaning age (mo) | 3 | 5 | 3 | 5 | 3 | 5 |
| 1978 | 21.3 | 22.8 | 23.0 | 24.0 | 21.8 | 23.6 |
| 1979 | 21.3 | 22.6 | 23.7 | 23.0 | 22.1 | 22.8 |
| 1980 | 21.5 | 22.6 | 24.0 | 23.0 | 22.0 | 22.4 |
| | Weaning weights (kg) | | | | | |
| 1978 | 83 | 122 | 84 | 112 | 77 | 109 |
| 1979 | 83 | 120 | 82 | 115 | 75 | 101 |
| 1980 | 86 | 120 | 86 | 118 | 76 | 105 |

Table 7. Effect of season on calf weights at birth and weaning (Exp. 394, 1980/81).

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | A | | B | | C | |
| Weaning age (mo) | 3 | 5 | 3 | 5 | 3 | 5 |
| Birth weights (kg) | 21.5 | 22.6 | 24.0 | 23.3 | 22.0 | 22.4 |
| Born in: Sept./Oct. | 21.5 | 22.6 | 22.5 | 19.8 | 20.9 | 20.0 |
| Jan./Feb. | | | 29.9 | 27.0 | 24.9 | 24.2 |
| Weaning weight (kg) | 85.6 | 119.8 | 86.5 | 117.7 | 76.2 | 105 |
| Weaned in: Dec./Jan. | 85.6 | 119.8 | 82.1 | 115.7 | 74.7 | 100.6 |
| May/Jun. | | | 92.0 | 121.6 | 80.0 | 108.1 |

In 1980 there was a greater difference in yearling weights between the two weaning groups which was a result of slower postweaning growth in the three-month weaned calves. These results draw attention to the great importance of nutrition, management and health of early weaned calves, and the need for more research in these areas to obtain better growth rates in the weaned calf.

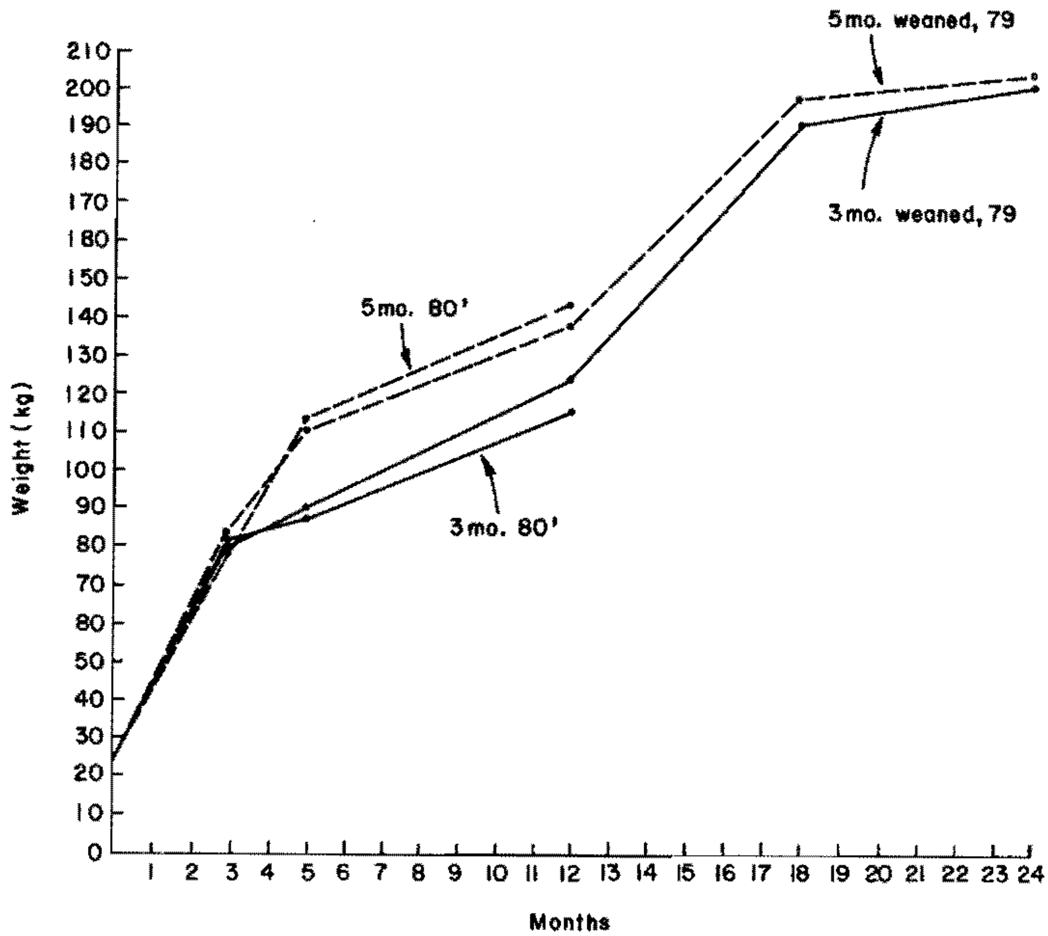



Figure 7. Effect of weaning age on the growth of Gir calves born in 1979 and 1980 (Exp. 394, 1981).

Comments*

The same fertilizer applications have been used for establishment in all Category IV type evaluation on virgin soils. It is difficult to make comparisons among experiments (Tables 8 and 9) since they are of different stages of development. It was surprising to observe that the stocking rate had no real effect on animal performance in the Andropogon/Stylosanthes experiment neither in the rainy nor dry seasons even though the amount of dry matter (especially Andropogon) available was greatly different. Presently, after three weeks of rain all these pastures are growing rapidly with an abundance of seedlings of both species. Seca now has three plant generations: two-year-old plants "mother plant", one-year-old plants which did not mature last year but are now growing, and seedlings now germinating from seeds which fell during the past dry season. Without doing counts, it appears that the high stocking rate has most of the new seedlings and should be the best pasture within one month since no standing dry matter of poor quality was left at the end of the dry season.

Table 8. Annual weight gains on different sown pastures.

| Pasture | Stocking rate (AU/ha) | Weight gain (kg) Animal | Ha |
|---|---|---|---|
| *B. ruziziensis* + | 1.0 | 141 | 254 |
| $N_2$ | 1.4 | 104 | 350 |
| *B. ruziziensis* + | 1.0 | 95 | 204 |
| *Calopogonium mucunoides* | 1.4 | 81 | 258 |
| *Andropogon gayanus* + | 0.7 | 69 | 97 |
| *Stylosanthes scabra* | 1.4 | 70 | 196 |
| (Seca) | 2.1 | 65 | 273 |

Table 9. Animal performance on sown pastures during the 1981 dry season (May 27 to October 4, 1981).

| Pasture | Stocking rate (AU/ha) | | Weight change (kg) | Years under grazing |
|---|---|---|---|---|
| | Prior wet season | Dry season | | |
| *B. ruziziensis* + | 1.1 | .77 | − 2 | 3 |
| $N_2$ | 1.8 | .77 | 3 | 3 |
| *B. ruziziensis* + | 1.1 | .77 | −17 | 3 |
| *C. mucunoides* | 1.8 | .77 | −11 | 3 |
| *Andropogon gayanus* + | 0.8 | .47 | −16.1 | 1 |
| *Stylosanthes scabra* | 1.4 | .91 | −23.8 | 1 |
| (Seca) | 2.0 | 1.30 | −19.6 | 1 |
| *Andropogon gayanus* + *Zornia latifolia* | 1.5 | 0.7 | 9.6 | 0.6 |

Fertilizer applied in all experiments:
Lime: 2.0 t; Supersimple: 35.20 kg P/ha; KCl: 49.80 kg K/ha; Zinc sulfate: 20 kg/ha; Ammonium molibdate: 0.5 kg/ha.

The information reported on Andropogon + Zornia was a 3 ha area sown besides Category IV (Andropogon + seca) for observation, taking advantage of surplus seed and area. The fact that the same class of animals did better during the dry season in the Andropogon/Zornia is suspected to be due to the higher quality of the legume. Zornia seed production was very high, and the ground is presently covered by seedlings. Since Category III Zornia disappeared because of a disease complex and the fact that it was not allowed to produce seed because of the grazing/cutting pressure, this observation under continuous grazing will provide more information as to the severity of the Zornia disease under large scale grazing.

* The following two paragraphs are not part of the annual report.

# Animal Health

The objective of the Section is to study and develop preventive medicine schemes adapted to the pasture and management production systems developed by the Tropical Pastures Program. Strategies for attaining this objective were explained in detail before (CIAT 1979, Tropical Pastures Program Annual Report).

## Animal Disease Inventory

This inventory is important to understand the evolution of current infections, comparing findings for different areas and ecosystems, and deciding on entities or conditions that need more study throughout the target area. The listing described in last year's Annual Report, with rankings by priority for the Tropical Pastures Program has been confirmed by findings from Brazil and Venezuela.

ETES Brazil. Herds surveyed in the vicinity of Brasilia revealed that the farms milking cows in more intensive production systems have considerable more control measures for ticks, hemoparasite and gastrointestinal parasites, than beef herds. Several farms have installed preventive schemes with dippings every 15 days for tick control. This is in concurrence with the need to keep ticks at a level which will not affect productivity, maintaining at the same time a high degree of protection against hemoparasites. In contrast, at the moment there is no widespread control against ticks in pure beef herds in the area. It appears that most of the beef animals are zebu types which are somewhat more resistant to ticks. On the other hand, animal density is much lower in beef than in the mixed dairy herds, an average of 0.5 AU/ha vs. 1 AU/ha, respectively.

As far as vaccination is concerned, 10 of 12 farms in the ETES Brazil Project vaccinate against foot and mouth disease; all of the farms vaccinate against black-leg, and only one vaccinates against brucelosis. This lack of vaccination against brucelosis is probably one of the reasons for the high prevalence of Brucela abortus infection in beef cattle herds under extensive range conditions in the north of Mato Grosso.

Most technical assistants are recommending vaccination of adult animals agains botulism. Even though this could be useful in herds where cases of botulism have appeared, it is not economical for all herds in the area, since reports of botulism cases are localized.

In relation to nematode infestation most farms deworm once a year; however, they treat adults more often than young animals. This practice does not agree with most recommendations, since field studies revealed that young animals are more susceptible to round-worms than adults, and it is more important to remove parasites from growing animals.

In relation to photosensitization, three of seven farms reported cases in animals between 10 and 12 months of age. Ranchers associate the problem with the first grazing of the pasture and believe that it appears more often when the pasture is high.

ETES Venezuela. Some of the farms in the ETES Venezuela Project reported similar problems. Several include ticks as an increasing problem in recent years. Farmers feel they have more tick problems toward the beginning of the dry season. They also feel that *Dermatobia hominis*, "nuche", is rapidly increasing. One possible reason is the forest invasion of the open savannas. This new cover provides an adequate environment for the fly and the vectors. The forest cover is expanding because savannas are not burned, a practice which is banned in Venezuela.

It is also of interest that small farmers who have credit for milk operations have experienced calf mortality problems, probably due to internal parasites and hemoprotozoos, and also are being forced to spray against ticks every 21 days to prevent losses and to maintain milk production. Some farmers at low technical input levels do not treat animals against internal parasites until they experience losses from high infestation and anemia.

In Venezuelan farms two other conditions are reported. One is "sequita" which is probably similar to "secadera" from the Llanos of Colombia and "peste de secar" in the Cerrado of Brazil. Farmers believe that "sequita" occurs at any age including that of young animals. Antibiotic treatments and body stimulants have been tried with limited success. If this conditions is similar to the "secadera" cases in Colombia, mineral deficiencies could be involved. Ranchers also report cases of botulism, especially in areas of "Valle de la Pascua" and "El Tigre". Even though there are no confirmed laboratory cases, farmers are beginning to vaccinate. The main problem could be a mineral deficiency that induces animals to consume carcases, thereby picking up the botulism toxin.

## ETES Project

This project is carried out in full cooperation among the Cattle Production Systems, Economics and Animal Health Sections. A complete description of the project appears in the Cattle Production Systems Section. Animal health information was obtained from surveys as reported above, of cattle ranches and examination of individual samples in each farm. Data analysis from farms in the Colombia and Brazil Projects was presented in CIAT 1980 Annual Report. Collection of data for ETES Venezuela has been completed and will be analyzed shortly.

## Carimagua Surveillance

Overall cattle mortality in Carimagua decreased over the last four years. Present mortality (2.0%) is at a reasonable low level (Table 1). As stated in last year's CIAT Annual Report, this is a reflection of better nutrition of the herds as well as of closer and more effective animal management. Calf mortality stabilized this year at 6.2% of 550 registered births (Table 2). The main factors that contribute to calf mortality in Carimagua are sequelae of navel infections that induce poliartritis and abcesses. This is secondary to difficulties in management when calves are not treated soon after birth.

Table 1. Surveillance of cattle mortality in Carimagua[1].

| Cause | 1980[2] | 1981[2] |
|---|---|---|
| Sinking in watering holes | 17 | 8 |
| Malnutrition | 19 | 20 |
| Bone fractures | 8 | 10 |
| Hepatogenous photosensitivity | 1 | 7 |
| Snake bite | 2 | 1 |
| Miscellaneous | 14 | 17 |
| Undiagnosed | 25 | 18 |
| Total | 87 | 81 |

[1] Cattle population in 1980, 3500, in 1981, 4000; mortality rates (%), 1980, 2.5, in 1981, 2.0.

[2] Through September 31.

Table 2. Surveillance of calf mortality in Carimagua.

| | 1980 | | 1981 | |
|---|---|---|---|---|
| | No. births | Mortality (%) | No. births | Mortality (%) |
| Management systems herd | 190 | 6.3 | 263 | 6.1 |
| Breeding test herds | 202 | 4.4 | 182 | 4.9 |
| Other | 261 | 7.6 | 105 | 5.7 |
| Total | 653 | 6.3 | 550 | 6.2 |

Nutrition-disease relationships. Monitoring of various herds in Carimagua showed the usefulness of two tests to study nutrition-disease relationships. A comparison is made in Table 3 of blood parameters from a group of animals with clinical malnutrition, with apparently normal cattle, and a group with external photosensitivity lesions. The animals with clinical malnutrition have total blood serum protein levels significantly lower than the steers on grass/legume associations ($P < 0.10$). In the photosensitivity animals blood protein is at normal levels and G.G.T. enzyme is significantly higher than in the other two groups ($P < 0.10$), indicating a liver lesion from some toxic effect. Animals with no apparent disease (steers on grass/legume associations) have both total protein and G.G.T. enzyme at normal levels.

Table 3. Comparison of clinical malnutrition and photosensitivity at Carimagua.

| Herd | No. animals | Total serum protein[1] | | G.G.T. enzyme | |
|---|---|---|---|---|---|
| | | Range | Average | Range | Average |
| Steers on native savanna with clinical malnutrition | 5 | 4.2- 8.0 | 5.9[a2] | 5.4- 17.4 | 10.0[a] |
| Steers on grass/legume associations | 12 | 6.8- 8.0 | 7.5[b] | 6.4- 19.3 | 11.1[a] |
| Steers on B. decumbens with clinical photosensitization | 16 | 4.0-10.0 | 7.6[b] | 10.3-122.0 | 59.0[b] |

[1] $LSD_{serum\ protein}$ 1.39, $LSD_{GGT}$ 24.78

[2] Different letters denote differences significant at the 0.1 level.

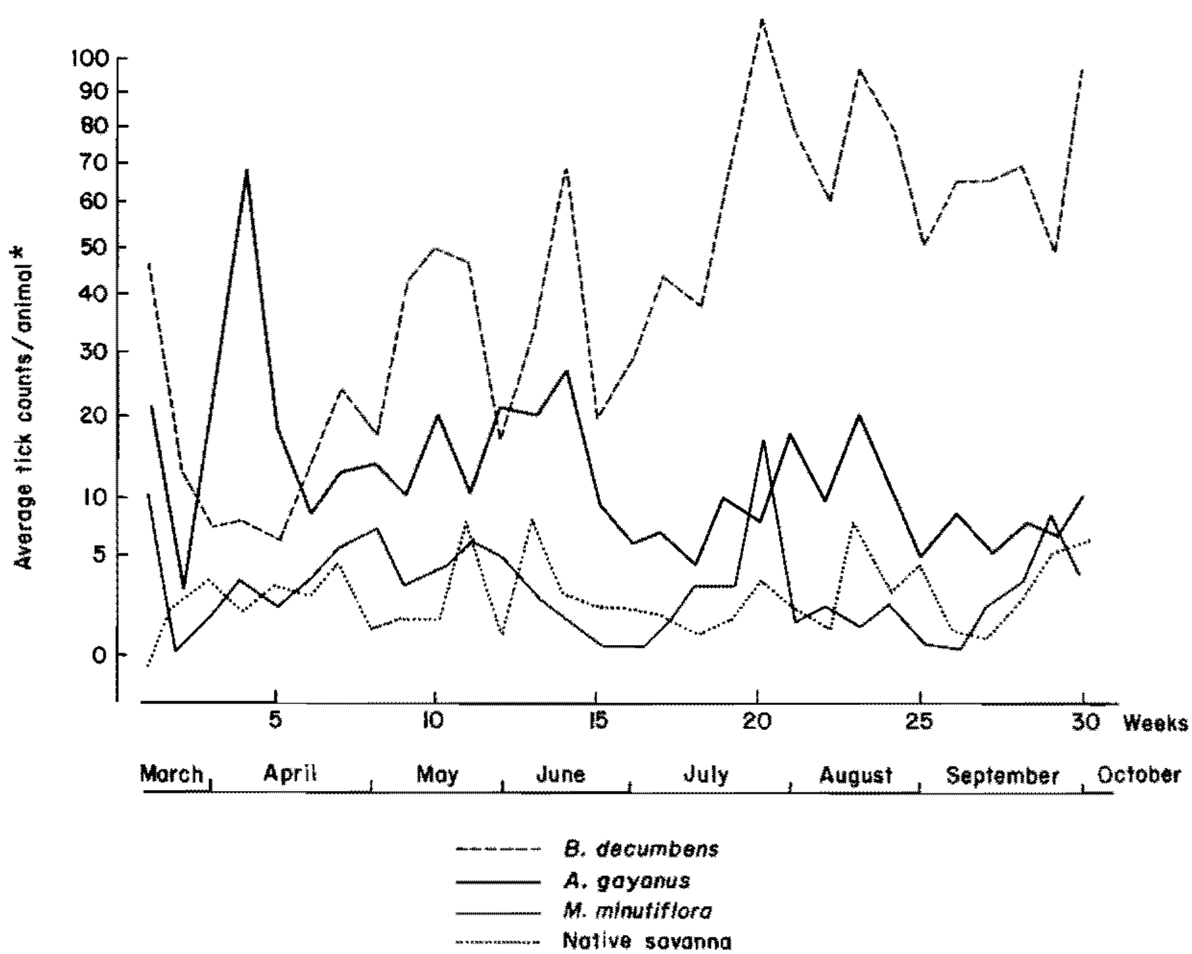
Bioecology of Boophilus microplus. This is the most important external parasite in the Topical Pastures Program target area. It has become one of the priorities for in-depth studies and is one of the factors being modified by changes in animal management resulting from introduction of sown pastures. A project was designed to study population dynamics of the tick in the Colombian Llanos. Its main objective is to study the effects of ecological factors in the infestation levels in animals with adult ticks. It is especially important to know seasonal variations of tick levels in the pastures and in the animals in this area.

The ecological conditions provided by Andropogon gayanus, Brachiaria decumbens, Melinis minutiflora and native savanna in pure stands for tick populations are evaluated during two full rainy and dry seasons. Animals are under continuous grazing and optimum stocking rates for each grass in each season, as described in CIAT's 1980 Annual Report.

Each paddock is infested with 500 evenly distributed engorged female ticks per animal. No acaricides are applied to the animals at any time. Evaluations (height and coverage) of grass in each paddock are made to define the conditions under which the larvae and adult populations are present. Tick larvae are evaluated on the pastures every two weeks and adult ticks on the animals every week.

Tick larvae populations are in the process of stabilization. After the first 13 samplings, Melinis grass had the lowest counts, followed by native savanna, Brachiaria decumbens and A. gayanus; however, the counts on B. decumbens increased toward the end of the rainy season.

Levels of adult ticks on the animals are probably a better reflection of the environment influence on the tick population. Heifers in B. decumbens and A. gayanus paddocks have the highest infestation levels during the first six months of the rainy season (Figure 1).




* Counts transformed by statistical expression $\sqrt{X+1/2}$, where X is the No. of ticks/head.

Figure 1. Boophilus microplus tick counts on heifers grazing four pastures in Carimagua.

Levels of infestation in Brachiaria have increased gradually from low levels of 20 adult ticks/head per day, to levels above 100 ticks/head, which are considered high. Levels in animals on Andropogon gayanus are of medium intensity, averaging between 20 and 30 adult ticks. For animals on M. minutiflora and native savanna the levels of adult ticks are similar and low (5-10 ticks average). In the first rainy season Brachiaria and Andropogon provided better environment for the persistence of larvae that end up as adult ticks in the animals. Pasture coverage could be one of the factors explaining differences in tick levels. At the August sampling (Table 4), Andropogon gayanus had roughly half the coverage of Brachiaria, and the average tick counts on the animals were much lower in the Andropogon group (20-30 ticks/head) as compared to the Brachiaria group (100-120 ticks/head) (Figure 1).

The findings of adult tick counts on the animals parallel observations of potted pastures. Larvae of B. microplus are seen readily in the leaves of B. decumbens, A. gayanus and even native savanna. However, they do not crawl on the leaves of M. minutiflora. Larvae in the pots only crawl dry and dead leaves of Melinis, and this is probably one reason why animals pasturing Melinis have low tick levels. This confirms previous observations that Melinis pastures have some repellent effect on the ticks.

The level of hemoparasites in the heifers is being measured. It is becoming evident (Figure 2) that animals grazing B. decumbens and A. gayanus have increased reactions compared with animals grazing M. minutiflora and native savanna.

The reaction to hemoparasites coincided with the tick adult counts, except for the heifers on A. gayanus. Even though these are results of only one rainy season, there is a tendency for M. minutiflora and native savanna to have lower larvae tick counts on the pasture, lower adult ticks on the animals, and less reaction against hemoparasites.

An apparently stable population of ticks in the pasture has been obtained and variations seen in larvae and adult tick counts are beginning to reflect differences in the environment offered by the pastures for tick multiplication and persistence. Information obtained from the next dry and rainy seasons will be useful for best knowledge of tick ecology that can be used in the design of control measures.

Photosensitization in cattle grazing Brachiaria decumbens. Photosensitization in young animals grazing B. decumbens is a limiting factor for the use of this pasture in the Program's target area. Work continued to determine the main epidemiological factors involved in presentation of the syndrome as well as possible control measures. This syndrome resembles the photosensitization seen in sheep and cattle in New Zealand.

No evidence has been found of the seasonality of the condition. However, clinical cases in the past four years show a tendency for cases to appear in the middle and at the end of the rainy season (Figure 3). Age is an important determinant; most cases occurred in cattle between 9 and 24 months of age.

Table 4. Pasture coverage in paddocks under evaluation for tick ecology and population dynamics.

| Pasture | December 80 | | February 81 | | April 81 | | August 81 | |
|---|---|---|---|---|---|---|---|---|
| | Coverage (%) | Height (cm) | Coverage (%) | Height (cm) | Coverage (%) | Height (cm) | Coverage (%) | Height (cm) |
| *Andropogon gayanus* | 47 | 60 | 34 | 68 | 35 | 44 | 33 | 51 |
| *Brachiaria decumbens* | 40 | 30 | 33 | 27 | 36 | 26 | 58 | 30 |
| *Melinis minutiflora* | 66 | 27 | 51 | 32 | 50 | 31 | 64 | 24 |
| Native savanna | 43 | 24 | 55 | 29 | 54 | 44 | 65 | 51 |

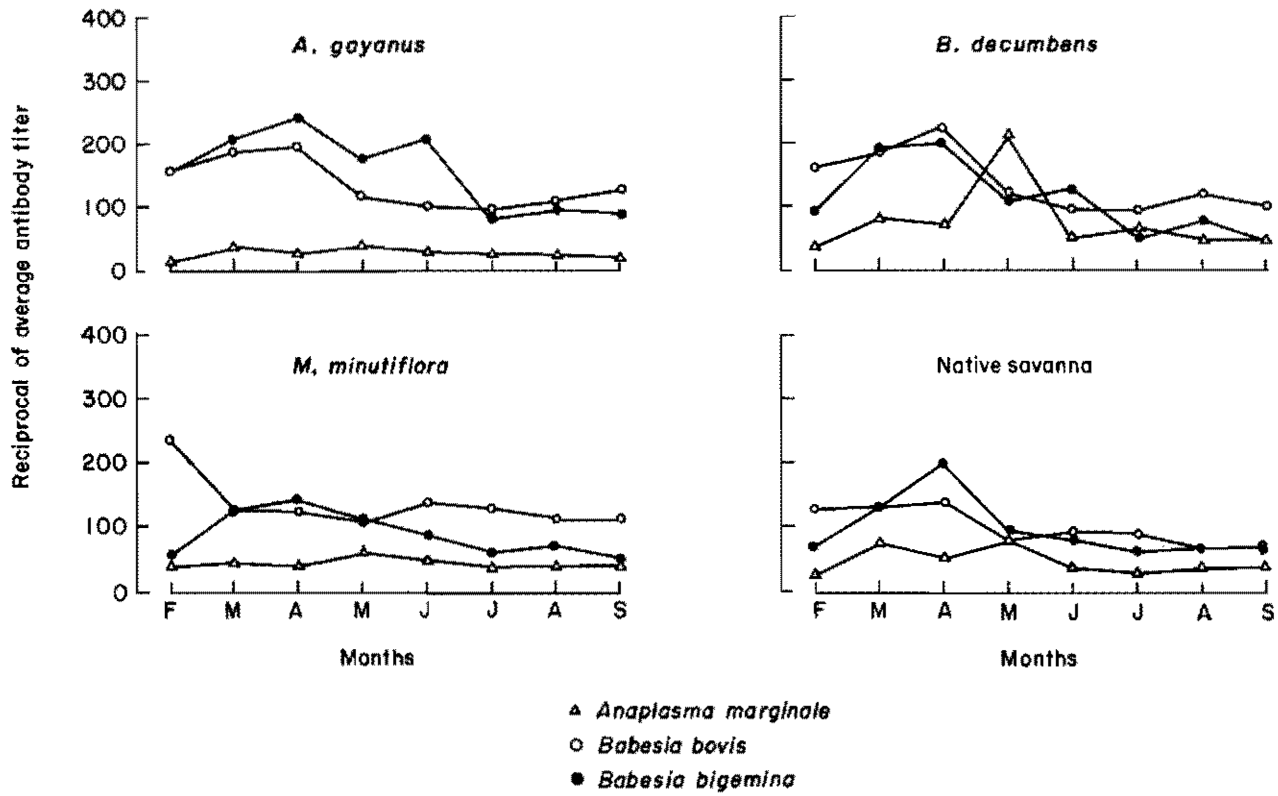



Figure 2. Bioecology of Boophilus microplus tick in Carimagua. Serological reaction to hemoparasites in heifers grazing four pastures.

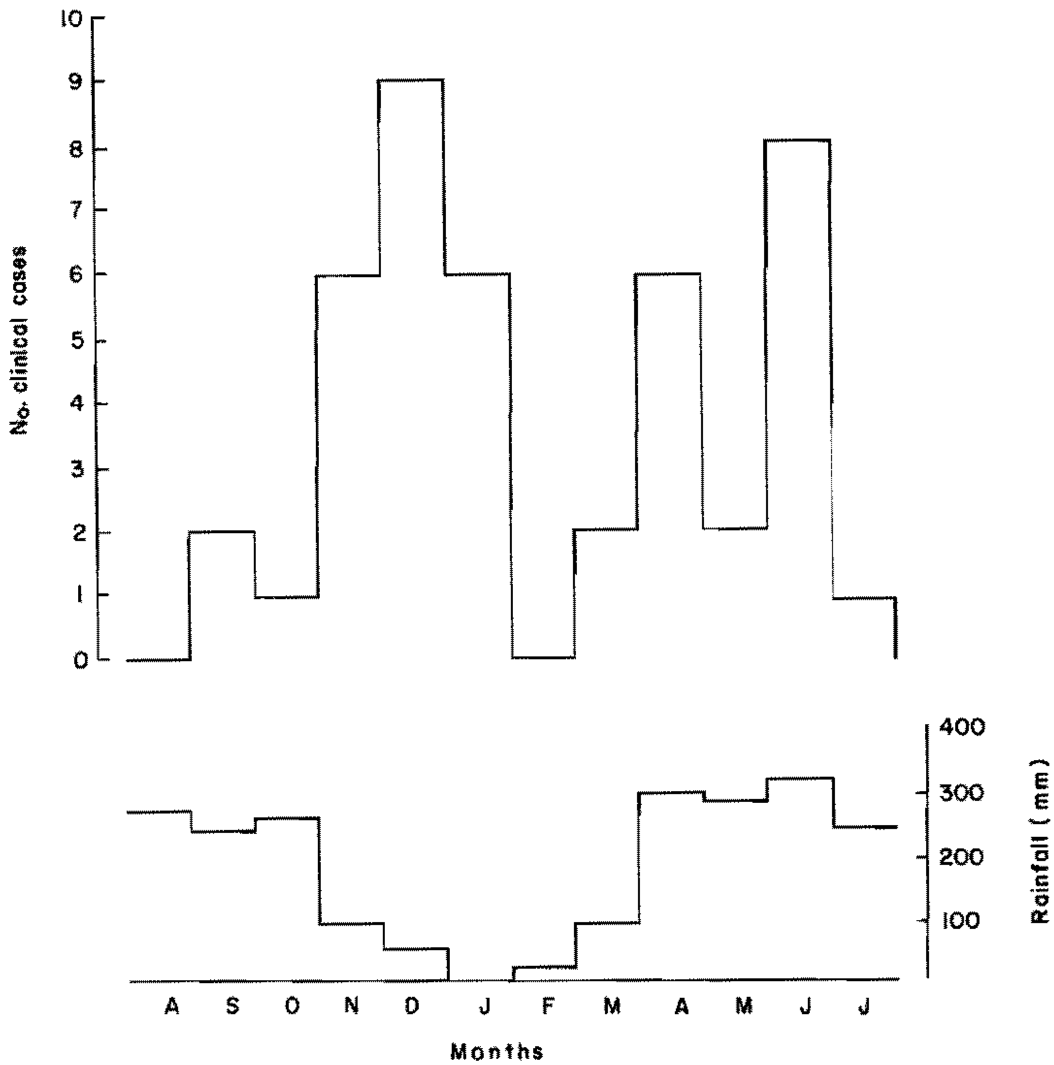



Figure 3. Hepatogenous photosensitivity in animals grazing B. decumbens. Accumulated four-year incidence by month in relation to average rainfall.

Cases in 1981 had two, commonly seen, clinical manifestations (Table 5). The animals developed edemas in the lower neck, dewlap and ears. This edematous form is apparently more acute and usually terminates in death of affected animals (7/6 animals in 1981). There was an obvious liver involvement detected by gross lesions and high levels of G.G.T. and S.G.O.T. enzymes. In the skin necrosis form, the animals developed severe necrosis in several areas of the skin, but most frequently in the perineal region, abdomen and lower part of the neck. Animals thus infected generally recover. The levels of G.G.T. and S.G.O.T. are also elevated as a reflect of liver lesions; animals developed generalized icterous and elarged liver. The clinical and pathological changes were manifestations of the hepatic damage.

Table 5. Characterization of clinical photosensitivity cases from Carimagua in 1981.

| Clinical picture | No. animals | No. deaths | Enzyme G.G.T. | Enzyme S.G.O.T. | Total protein |
|---|---|---|---|---|---|
| | | | ------------ | Range | ------------ |
| Edematous | 7 | 7 | 10.3- 82.3 | 178-330 | 7.0-10.0 |
| Skin necrosis | 9 | 0 | 12.9-122.0 | 42-380 | 4.0-10.0 |
| Total averages | 16 | 7 | (59.0) | (183) | (7.6) |

Forty-one steers grazing Brachiaria decumbens were monitored through weighings and liver functions tests from the end of the dry season through the middle of the rainy season. Monitoring was conducted in cooperation with the Pasture Productivity and Management Section. Weight losses were valued, assuming gains of 100 gm/head per day for the dry season (December-March), 300 gm for March through May, and 500 gm for May through July, as a minimum for B. decumbens.

A comparison of liver damage and weight changes in animals revealed a significant relationship at the March sampling ($P < 0.10$). For the second sampling in May the relationship was highly significant ($P < 0.01$), and for the July sampling there was no relationship (Table 6). It appears that at the initial stages of liver damage, corresponding weight alterations are not significant. However, as liver damage becomes more pronounced weight is significantly altered. This second stage coincided with appearance of animals with external photosensitivity lesions. Toward the end of the observation period, most animals had recovered from liver damage; however, convalescent animals were not gaining weight as expected. It is evident that when hepatic damage is induced in animals grazing B. decumbens a significant proportion loses weight before developing external photosensitization lesions.

Evaluation was made of the relation of enzyme G.G.T. levels and liver lesions in animals with clinical disease. High average levels are seen at the onset of clinical disease (Figure 4). They begin to drop and reach normal levels 30 days after the first appearance of clinical signs.

A hypothesis for the etiology of photosensitivity is that the Pithomyces chartarum fungus is involved in its appearance. However, a system must be found to reproduce clinical signs to better study the syndrome. A strain of P. chartarum was isolated from a Carimagua paddock; the fungus was cultured in the laboratory, multiplied extensively, and returned to the same paddock in greater concentration.

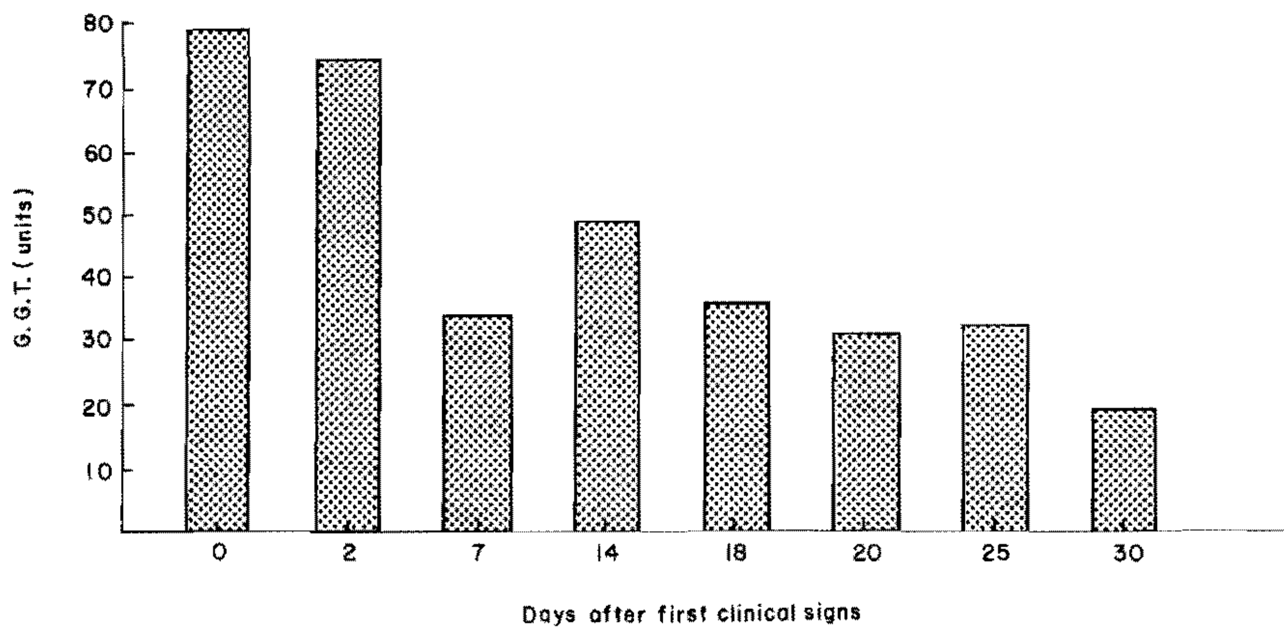



Figure 4. Average enzyme G.G.T. levels from 16 steers with clinical photosensitization grazing B. decumbens.

A suspension of 2.7 x $10^{11}$ spores was sprayed over four ha of the B. decumbens pasture. Fifteen 18-months old heifers were allowed to graze the inoculated pasture. One month after seeding the spores, one animal showed clinical symptoms of photosensitivity and four more were found with subclinical affection (hepatic damage).

Table 6. Analysis of weight changes and liver damage on steers grazing B. decumbens paddocks where clinical photosensitization appeared.

| Sampling (date) | No. animals | Affected weight | | Liver damaged measured by G.G.T. enzyme | |
|---|---|---|---|---|---|
| | | No. animals | Range | No. animals | Range |
| I (March 10) | 41 | 34 | -41.2, +12[a] | 20 | 3.2, +145[b] |
| II (May 9) | 40 | 8 | -1, +53[c] | 13 | 3.8, 60[d] |
| III (July 1) | 28 | 28 | -9, +19[e] | 2 | 4.8, 32.3[f] |

Significant correlation between (a) and (b) $P < 0.01$, (c) and (d) $P < 0.05$, (d) and (e) $P < 0.05$.

Levels of fungus on the grass are low (CIAT 1980 Annual Report). B. decumbens isolates from the Colombian Llanos and Santander de Quilichao area were sent to Ruakura Animal Health Laboratory in New Zealand and to the National Research Council labs in Canada for detection of Pithomyces toxin (sporidesmin). From 15 cultures so far tested only three have shown to produce toxin. However, toxin concentration lower than one was obtained from cultures isolated in New Zealand. Hence, it appears that other factors might be involved in the etiology of the syndrome. The next step will be to evaluate the role of zinc in conjunction with the fungus in the etiology and/or as a control mechanism.

Test herds. This section is in charge of the ICA/CIAT herds. Production objectives were described in the 1978 CIAT Annual Report. Main emphasis is to produce experimental animals of high quality and uniformity. There are 300 breeding cows divided in seven herds, with one bull for every 25 cows in a system of seasonal mating from May through September. Calving rate through September of this year was 61.7%, very similar to the previous two years. Calf mortality up to weaning was 5% this year, considerably below that of 1979 and 1980. Calves were weaned at nine months of age.

During the year the test herds provided 318 animals for research projects at Carimagua.

# Economics

During 1981 the Economics Section concentrated its efforts on:

- Economics of the use of alternative fertilizer sources for improved pastures in the Llanos Orientales of Colombia.
- Comparative advantages of alternative forms and uses of improved pastures in the Llanos Orientales.
- Continuation of the economic analysis of cattle farms, particularly in Brazil and Colombia (ETES Project).
- Initiation of a monitoring study of six dual-purpose (beef and milk) farms in the Central Provinces of Panama.

## Economics of Alternative Fertilizer Sources Use for Improved Pastures in the Llanos Orientales of Colombia

Fertilization is a major cost factor in CIAT's pasture technology, involving 42% (Col$2580) of the pasture establishment costs per hectare and 75% (Col$1260) of the annual maintenance costs. A number of alternative sources of mineral nutrients are presently available on the Colombian market (Table 1). Additional sources could be developed from locally available raw materials.

A linear programming model was developed to minimize per-hectare costs of complying with nutrient requirements determined by the Soils and Plant Nutrition Section (Table 2). All nutrient sources used (Table 1) were assumed to have the same agronomic efficiency. Activities considered in the model include the purchase of different nutrient sources at Bogota and transportation to the Carimagua location in the Llanos Orientales. Cost of on-farm storage and distribution are not considered due to very small differences among possible alternatives.

In this analysis, average fertilizer requirements per-hectare for establishment are used (22 kg P, 33.20 kg K, 100 kg Ca, 20 kg Mg and 20 kg S). Main results indicate that:

1. A combination of basic slag and rock phosphate provides the most economic phosphorus supply (Table 3).

2. At present prices, magnesium subcarbonate is the most efficient magnesium source, followed very closely by Sulpomag and both forms of magnesium oxide.

3. Rising transportation costs do not have a substantial impact on the optimal combination of fertilizer sources. At levels 100% above the present ones, basic slag use is reduced to 1/3 of the original level and rock phosphate use is expanded accordingly. Magnesium subcarbonate is then substituted by a more concentrated source, magnesium oxide.

Table 1. Fertilizer nutrient content and price[1] CIF Bogotá[2] (July 1981).

| Fertilizer | Nutrient content | | | | | Price/ton | |
|---|---|---|---|---|---|---|---|
| | P | K | Ca | Mg | S | Col$ | US$[3] |
| | % | | | | | | |
| Basic slag | 6.60 | 0 | 37 | 1 | 0 | 2,400 | 44.02 |
| Simple superphoshate | 8.80 | 0 | 20 | 0 | 12 | 22,000 | 403.52 |
| Triple superphoshate | 19.80 | 0 | 14 | 0 | 0 | 23,230 | 426.08 |
| Potassium chloride | 0 | 49.80 | 0 | 0 | 0 | 16,560 | 303.74 |
| Potassium sulphate | 0 | 41.50 | 0 | 0 | 18 | 22,000 | 403.52 |
| Sulfur flower | 0 | 0 | 0 | 0 | 85 | 18,000 | 330.15 |
| Gypsum | 0 | 0 | 29 | 0 | 20 | 3,600 | 66.03 |
| Calcitic lime | 0 | 0 | 30 | 0 | 0 | 2,500 | 45.85 |
| Dolomitic lime | 0 | 0 | 37 | 8 | 0 | 3,600 | 66.03 |
| Huila rock phosphate | 9.68 | 0 | 40 | 0.5 | 0 | 4,600 | 84.37 |
| Pesca rock phosphate | 8.80 | 0 | 21 | 0 | 0 | 3,000 | 55.02 |
| Magnesium sulphate[4] | 0 | 0 | 0 | 10 | 13 | 28,800 | 528.24 |
| Magnesium carbonate[4] | 0 | 0 | 0 | 24 | 0 | 11,550 | 211.84 |
| Magnesium oxide 70[4] | 0 | 0 | 0 | 42 | 0 | 22,000 | 403.52 |
| Magnesium oxide 60[4] | 0 | 0 | 0 | 36 | 0 | 18.800 | 344.82 |
| Magnesium subcarbonate[4] | 0 | 0 | 0 | 16 | 0 | 6,100 | 111.88 |
| Sulpomag | 0 | 18.26 | 0 | 11 | 22 | 16,000 | 293.47 |

[1] Bagged
[2] Transport Bogotá-Carimagua: Col$2500/ton
[3] Exchange rate July 15, US$1 = Col$54.52
[4] Prices quoted by Magnesios Bolivalle Ltda., July 1981 plus freight Medellín-Bogotá: Col$1600/ton

Table 2. Recommended fertilization levels for establishment and maintenance of promising species (kg/ha).

| Species | Establishment (kg/ha) | | | | | Maintenance (kg/ha/year) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | K | Mg | S | Ca | P | K | Mg | S | Ca |
| *Andropogon gayanus* | 22 | 33.20 | 20 | 15 | 100 | 6.60 | 33.20 | 5 | 7.5 | 50 |
| *Stylosanthes capitata* | 22 | 33.20 | 20 | 20 | 100 | 6.60 | 33.20 | 5 | 10 | 50 |
| *Pueraria phaseoloides* | 22 | 33.20 | 20 | 20 | 100 | 8.80 | 33.20 | 10 | 10 | 50 |

Sources: Spain, J. "Actualización de Recomendaciones Generales, Establecimiento y Mantenimiento de Pastos", internal document, CIAT, August 1980.
Salinas, J.G. Personal communication, July 27, 1981.

Table 3. Optimal fertilization strategy for pasture establishment in Carimagua (base solution).

| Nutrient | Required level (kg/ha) | Shadow price[1] of the restriction (Col$/kg) |
|---|---|---|
| Phosphorus | 50 | 26.3 |
| Potassium | 40 | 31.8 |
| Calcium | 100 | 1.1 |
| Magnesium | 20 | 53.8 |
| Sulfur | 20 | 24.1 |

| Fertilizers | Required level | Marginal cost of introducing fertilizers not included in the optimal strategy |
|---|---|---|
| Basic slag | 223.5 | - |
| Simple superphosphate | 0 | 16.10 |
| Triple superphosphate | 0 | 13.70 |
| Magnesium carbonate | 0 | 1.20 |
| Potassium chloride | 66.7 | - |
| Potassium sulphate | 0 | 4.20 |
| Magnesium sulphate | 0 | 22.80 |
| Sulfur flower | 23.5 | - |
| Gypsum | 0 | 0.95 |
| Calcitic lime | 0 | 4.66 |
| Dolomitic lime | 0 | 1.39 |
| Huila rock phosphate | 0 | 0.59 |
| Pesca rock phosphate | 82.4 | - |
| Magnesium oxide 70 | 0 | 1.90 |
| Magnesium oxide 60 | 0 | 2.00 |
| Magnesium subcarbonate | 111.0 | - |
| Sulpomag | 0 | 0.28 |
| Cost (Col$/ha) $4.259 | | |
| Total weight (kg/ha) 507.1 | | |

[1] Amount by which total cost per hectare would decrease if 1 kg less of the nutrient were required per hectare.

4. Given the acidity of the soils in the area, the use of more expensive soluble phosphorus sources such as triple superphosphate is not economic. If short-term solubility of rock phosphates were considered too low for a given crop or pasture, the use of basic slag would be expanded.

5. Basic slag is expected to be scarce in Colombia in coming years. Rock phosphates will then substitute for basic slag causing only a minor cost increase. Rock phosphates will substitute basic slag completely if its price rises by 31% or more.

6. Partial acidulation increases the water and citrate solubility of rock phosphates. On very acid soils partial rock acidulation is not economically worthwhile for the establishment of pastures. If certain levels of short-term phosphate solubility are required, they could be achieved more economically by increasing the use of basic slag. The attractiveness of partial rock acidulation is probably higher for crops requiring higher levels of solubility, particularly on less acid soils and if the price of basic slag increases substantially.

7. The potential value of cement dust (a presently unused by-product of the cement industry) as a source of potassium and calcium was evaluated. Available data suggested a content of 6.4% potassium oxide and 31% of calcium. Under these conditions cement dust would only be competitive if basic slag is unavailable and if supplied CIF Bogotá at a price below Col$0.90 per kg. Cement dust supplying calcium and potassium displaces potassium chloride and basic slag in the formula due to the calcium content of the latter. The required phosphorus is in this case supplied by rock phosphates. Due to the low potassium concentration of cement dust, its competitiveness is very sensitive to transport cost changes. Availability of cement dust with a higher potassium oxide concentration (24%) is reported in the literature. This cement dust would be competitive at prices up to Col$5.32 per kg. If basic slag were unavailable, this type of cement dust would be included in optimal fertilizer mixtures up to a price of Col$5.84 per kg CIF Bogotá.

8. The high shadow price of the magnesium and potassium restrictions (Table 3) indicates that the fertilizer cost per hectare is very sensitive to the required level of these nutrients. Therefore, better knowledge of the response surface to magnesium and potassium would be very valuable to assess profitable usage levels.

These conclusions suggest the need to evaluate fertilizer response functions. Classical response surface studies for perennial pastures are very expensive and difficult to undertake. Nevertheless, some more points of the surface, selected as "best bets", particularly with lower levels of these expensive nutrients should be evaluated in the near future.

Fertilizers being such a crucial element of the technological package involving improved pastures, further research is needed on the supply-demand situation on Latin American markets. FAO data (Table 4) show a substantial regional deficit, particularly for potash fertilizers.

Table 4. Fertilizer production and consumption, Brazil, Colombia and Mexico 1979/80[1]. (Thousand metric tons: N-P-K.)

| Country | N | | P | | K | |
|---|---|---|---|---|---|---|
| | Production | Consumption | Production | Consumption | Production | Consumption |
| Brazil | 288 | 783 | 574.66 | 737.44 | 0 | 900.55 |
| Colombia | 57 | 151 | 20.24 | 32.12 | 0 | 58.10 |
| Mexico | 642 | 826 | 99.88 | 112.20 | 0 | 50.63 |

[1] Preliminary data, fertilizer year July 1-June 30.

Source: FAO: Current Fertilizer Situation and Outlook, Rome, June 1981.

The limited number of domestic fertilizer suppliers in most Latin American countries suggests that research on market structure and pricing policy may be rewarding as market prices probably differ from those maximizing national welfare. Research in this area is being planned in collaboration with the International Fertilizer Development Center (IFDC).

## Comparative Advantages of Alternative Forms and Uses of Improved Pastures in the Llanos Orientales

As the program is promoting materials to Categories IV and V of the germplasm selection strategy, a number of these become candidates for eventual release by the national institutions (ICA in Colombia). This release has to be accompanied by information to potential adopters of the merits and drawbacks of each material. Among other information, the appropriate use of specific material in production systems must be assessed. Economics play a major role in this context.

Using the linear programming technique, a first attempt was made at comparing broad groups of improved pasture alternatives of varying degrees of intensity, as well as alternative uses of forage under the conditions of the Llanos Orientales of Colombia.

Table 5 presents the pasture establishment costs and Table 6 gives the technical parameters assumed to be achieved. Data are based on CIAT experimental results, information obtained through the ETES Project and educated guesses. Results therefore have to be considered preliminary and subject to substantial changes as additional information is generated by the program and the model is further disaggregated.

Table 5. Pasture establishment costs[1] (one hectare).

| Cost item | Type of improved pasture | | | | | |
|---|---|---|---|---|---|---|
| | Grass | | Legume | | Legume/grass association | |
| | Units | Col$ | Units | Col$ | Units | Col$ |
| Seed: (kg) | | | | | | |
| *Brachiaria decumbens* | 1.2 | 1560 | | | | |
| *Andropogon gayanus* | | | | | 2.5 | 1000 |
| *Stylosanthes capitata* | | | 5 | 3250 | 2.5 | 1625 |
| Fertilizer: (kg) | | | | | | |
| Basic slag | 300 | 1080 | 330 | 1188 | 330 | 1188 |
| Sulpomag | 100 | 1500 | 100 | 1500 | 100 | 1500 |
| Land preparation: (frequency) | | | | | | |
| Harrowing | 2 | 1700 | 2 | 1700 | 2 | 1700 |
| Seeding | 1 | 300 | 1 | 300 | 1 | 300 |
| Total cost (Col$) | - | 6140 | - | 7938 | - | 7313 |

[1] Maintenance costs: for all types of improved pastures an annual fertilization with 100 kg of Basic slag and 60 kg of Sulpomag at a cost of Col$1600 per hectare per year (including application cost) is assumed.

Table 7a presents the beef production levels achieved, 7b the gross margins per hectare, animal unit, and kg of beef produced for the cow-calf + fattening alternative. Table 8 shows the investment and profitability of alternative systems. The most outstanding features of this comparison are:

- the differences in ranking of forage alternatives when compared on the basis of hectares or animal units indicate that optimal strategies will depend on the relative scarcity of these factors;

- the similarity of per-animal unit investment of all alternatives;

- the rather low profitability of production alternatives based on the exclusive use of improved pastures under the conditions prevailing in the Llanos Orientales[1];

[1] Specialized fattening oeprations were not included as the model was expected to reflect the potential of the region, which cannot be thought of as net importer of feeders, due to the higher fattening potential of the other regions.

Table 6. Technical coefficients assumed for each production system.

| Coefficient | Fodder base: Native pasture | Native pasture plus mineral supplementation | Grass pasture | Native pasture plus protein bank | Legume/grass association |
|---|---|---|---|---|---|
| Stocking rate (AU/ha) | 0.2 | 0.2 | 2.0 | 0.25 | 1.3 |
| Adult mortality rate (%) | 4 | 4 | 4 | 4 | 4 |
| Weaning rate (%) | 45 | 55 | 65 | 70 | 75 |
| Age at first mating (%) | | | | | |
| 24-35 months | - | 10 | 72 | 82 | 92 |
| 36-48 months | 64 | 54 | 100 | 100 | 100 |
| >48 months | 100 | 100 | - | - | - |
| Liveweight (kg) | | | | | |
| At mating | 260 | 270 | 290 | 290 | 290 |
| At weaning | 150 | 160 | 170 | 180 | 190 |
| Weight gains steers (kg/head per year) | 70 | 80 | 110 | 120 | 200 |
| Milk production[1] (litres/cow/ per year) | - | - | 400 | 400 | 400 |

[1] Lactating cows only.

Table 7a. Beef output by forage production system (kg/year)[1].

| Forage system | Production per ha | | | Production per AU | | |
|---|---|---|---|---|---|---|
| | Cow-calf operation | Fattening operation | Cow-calf + fattening operation | Cow-calf operation | Fattening operation | Cow-calf + fattening operation |
| Native pasture | 9 | 14 | 10 | 45 | 70 | 48 |
| Native pasture + minerals | 10 | 16 | 12 | 51 | 80 | 57 |
| Improved grass pasture, exclusive use[2] | 141 | 220 | 164 | 70 | 110 | 82 |
| Grass/legume pasture, exclusive use[3] | 109 | 256 | 150 | 85 | 200 | 117 |
| Protein bank, strategic use[3] | 18 | 29 | 21 | 77 | 120 | 89 |
| Grass/legume pasture, strategic use | 12 | - | 14 | 60 | - | 68 |

Table 7b. Gross margin by forage production system (cow-calf + fattening operation) (Col$)

| Forage system | ha | AU | kg |
|---|---|---|---|
| Native pasture | 236 | 1178 | 25.54 |
| Native pasture + minerals | 243 | 1215 | 21.31 |
| Improved grass pasture, exclusive use[2] | 1494 | 747 | 9.10 |
| Grass/legume pasture, exclusive use[3] | 937 | 732 | 6.25 |
| Protein bank, strategic use[3] | 366 | 1522 | 17.10 |
| Grass/legume pasture, strategic use | 293 | 1467 | 21.57 |

1 Fattening refers only to the production of 3-year-old steers, presently fattened outside the impact region, for the alternatives with native pastures only and for the option with mineral supplementation.

2 Productive life of pasture: 10 years; stocking rate: 2.0 AU/ha.

3 Productive life of pasture: 6 years; stocking rate: 1.28 AU/ha.

Table 8a. Marginal investment per hectare, animal unit and kg of beef per annum produced by production systems[1] (Col$).

| System | ha | AU | kg | Land investment[2] (%) |
|---|---|---|---|---|
| Native pasture | 2,754 | 13,770 | 286 | 36 |
| Native pasture + minerals | 3,034 | 15,170 | 266 | 33 |
| Improved grass pasture, exclusive use[3] | 27,000 | 13,500 | 164 | 4 |
| Grass/legume pasture, exclusive use[4] | 21,284 | 16,846 | 140 | 5 |
| Protein bank, strategic use[4] | 4,001 | 16,644 | 187 | 25 |
| Grass/legume pasture, strategic use[5] | 2,837 | 14,185 | 208 | 35 |

Table 8b. Marginal profitability of alternative production systems[1] (% return).

| System | Improved pastures (% total area) | Cow-calf operation | Cow-calf + fattening operation | Cow-calf + milking |
|---|---|---|---|---|
| Native pasture | 0 | 8.4 | 8.6 | - |
| Native pasture + minerals | 0 | 6.4 | 8.0 | - |
| Improved grass pasture, exclusive use[3] | 100.0 | 3.6 | 5.5 | 13.3 |
| Grass/legume pasture, exclusive use[4] | 100.0 | -0.8 | 4.5 | 8.5 |
| Protein bank, strategic use[4] | 5.0 | 7.4 | 9.1 | 15.8 |
| Grass/legume pasture, strategic use[5] | 1.8 | 9.5 | 10.4 | - |

1 In this context marginal refers to the investment and profitability of buying an additional hectare and using it in one of the systems described, given an already existing farm with its fixed costs. A land price of Col$1000/ha is assumed.
2 As share of total investment.
3 Productive life of pasture: 10 years; Stocking rate: 2.0 AU/ha.
4 Productive life of pasture: 6 years; Stocking rate: 1.28 AU/ha.
5 Used for early weaning of calves and fattening of cull-cows and steers.

- in spite of the adverse economic frame, the strategic use of improved pastures to supplement rather than replace low-cost native pastures to solve specific bottlenecks such as weaning of calves, fattening of cull-cows or steers is an economic proposition;

- feeding improved pastures to milking cows of local breeds is an attractive option even though very low production levels are assumed.

Table 9 presents the linear programming solution for a farm with Col$20 million-own capital. Traditionally used native pastures are the most efficient way to produce calves. Only as land becomes more scarce (more than Col$2000/ha) does fattening of on-farm produced store cattle on improved pastures become profitable. This preliminary analysis neglects the changes in relative prices and technical coefficients generally concommitant with the rise in land prices, but it does point towards the tendency to be expected.

Pasture persistence has a substantial influence on the profitability of improved pastures (Figure 1), particularly when investment is higher (legume and grass/legume mixtures). Furthermore, Figure 1 depicts the changes in competitiveness of alternative pasture improvement techniques due to changing land prices (all other coefficients constant).

A similar analysis was performed to evaluate the potential of producing milk with cows fed improved pastures within dual-purpose systems (Figure 2). Milking leads to a substantial increase in profitability of all types of improved pastures.

<u>It is concluded that:</u>

- Total substitution of native pasture with improved pasture is not economic at the present price structure. Strategic use of improved pastures to solve specific bottlenecks may be very worthwhile, but further research is necessary to improve the efficiency of its use, if adoption in extensive cow-calf operations of the Llanos Orientales is aimed at.

- On the short run the use of larger areas of improved pastures will mainly occur at locations closer to the market, and this forage will in most cases be fed to fattening steers.

- Dual-purpose (beef and milk) systems seem to be another promising option, particularly for smaller farms. Similar production systems operate under commercial conditions at a great distance from the market in the Paraguayan and Bolivian Chaco. More in-depth research is needed to evaluate their potential in the Llanos Orientales of Colombia.

Table 9. Optimal organization of a beef ranch with a total equity of Col$20 million[1].

| | Land price (Col$/ha) | | |
|---|---|---|---|
| | 0 | 1000 | 2000 |
| Land use (ha): | | | |
| Native pasture | 11,523 | 9,831 | 4,966 |
| Grass/legume pasture | - | - | 76 |
| Stock numbers: | | | |
| Cows | 1,047 | 893 | 451 |
| Calves | 494 | 421 | 213 |
| Heifers: 1-3 years | 460 | 392 | 197 |
| 3-4 years | 216 | 184 | 93 |
| >4 years | 78 | 66 | 33 |
| Steers: 1-2 years | 235 | 200 | 101 |
| 2-3 years[2] | - | - | 97 |
| Sales (head): | | | |
| Cows | 178 | 151 | 76 |
| Heifers | 6 | 5 | 3 |
| Steers 2 years old | 226 | 192 | - |
| Fat steers[2] | - | - | 93 |
| Own capital (4% interest opportunity cost) | 20.000,000 | 20.000,000 | 20.000,000 |
| Borrowed capital (7% interest) | - | 6.888,994 | - |
| Total gross margin (Col$) | 1.839,861 | 968,809 | 443,434 |

[1] Technical coefficients of Tables 5 and 6.
[2] Steers reared on native pastures till the age of 2 years, finished on grass/legume pastures.

## Further Activities

- An economic assessment of the marginal profitability of feeding mineral supplements in traditional beef production systems in the Llanos Orientales region was undertaken. The main results were: 4-8 years of negative marginal cashflow and internal rates of return between 8% and 20% p.a. to the phosphorus source used.

- The field phase of the monitoring project (ETES) in Brazil has been completed. In Venezuela the last surveys are being undertaken. The comparative study of all three ETES sites (Colombia, Brazil, and Venezuela) is expected to be completed in 1982.

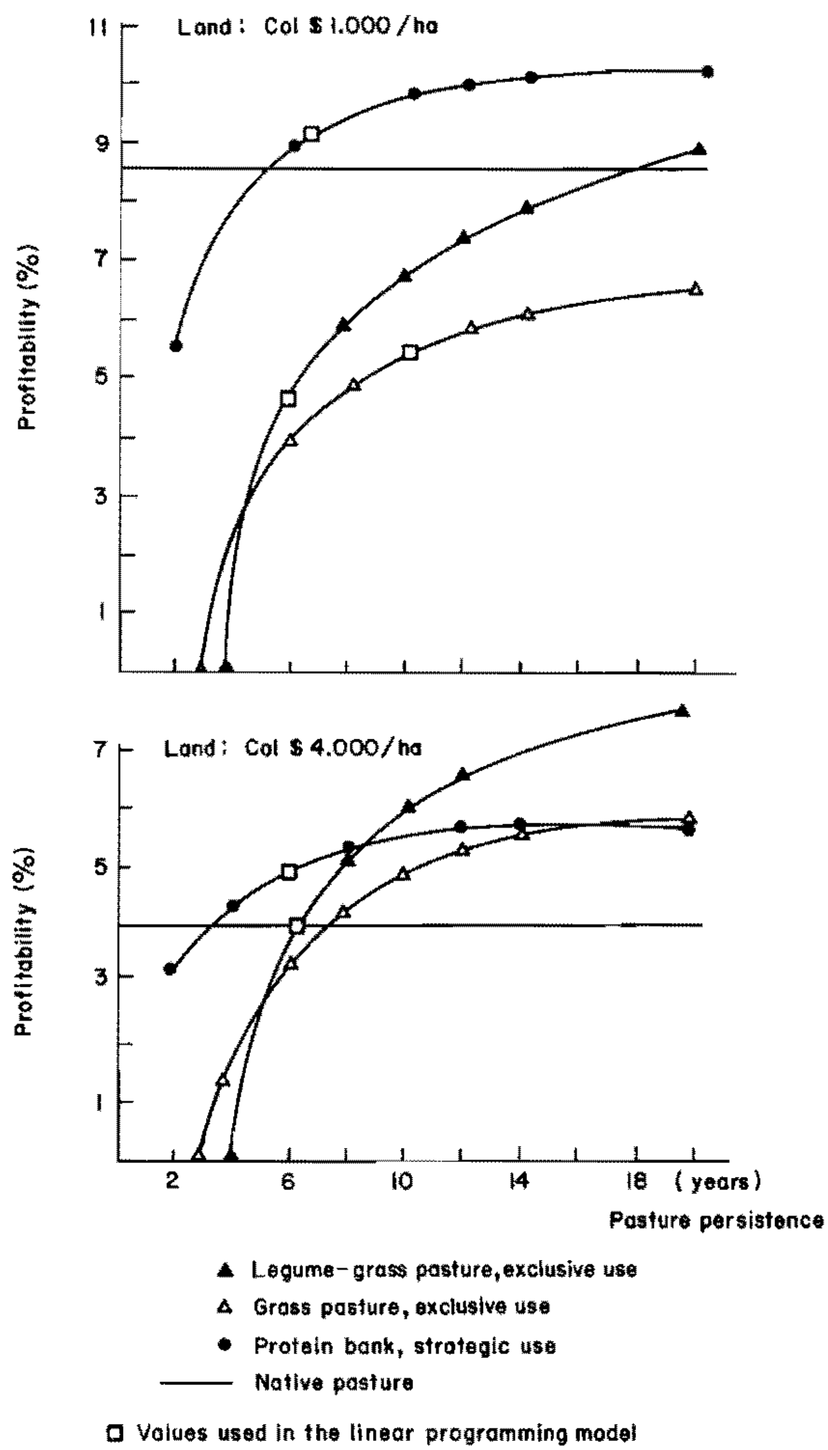



Figure 1. Effect of pasture persistence on the profitability of beef production (cow-calf + fattening operation) at two land price levels. (No mixed strategies, such as running a cow-calf operation on natural pastures and fattening on improved pastures are included here for the sake of simplicity.)

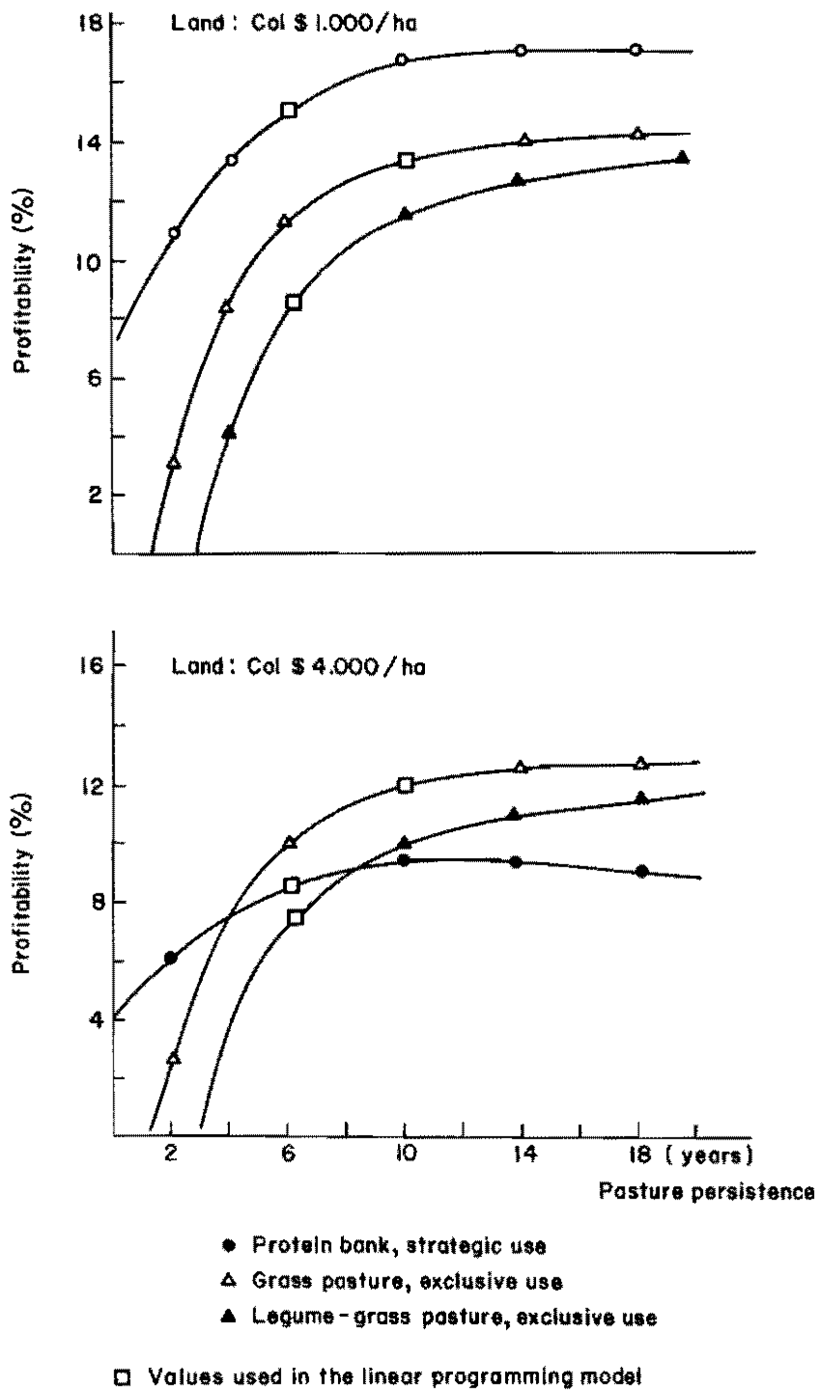



Figure 2. Effect of pasture persistence on profitability of dual-purpose systems (cow-calf operation + milking) at two land price levels.

- A similar monitoring project of dual purpose (beef and milk) farms was started in cooperation with the Banco Nacional de Panama in the Central Provinces of Panama in 1981. This special project undertaken in collaboration with the Technical University of Berlin and funded by the German government through GTZ, includes the posting of a post-doctoral fellow in Panama. The foreseen one-year continuous recording of biotechnical and economic data will be completed in May 1982. A report is expected to be completed by October 1982.

- In cooperation with FAO, a study on the potential to increase beef production in Latin America and its constraints, with particular emphasis on pasture improvement technology for the tropical lowlands, is well under way.

It can be concluded that, due to the increasing availability of detailed biotechnical research and monitoring information, the research approach of the Economics Section is gradually shifting from an emphasis on ex-ante simulation of the potential impact of pastures based on assumed values for these parameters, to an increasingly ex-post analysis of actual performance of grasses and legumes and whole production systems. At the same time research is expanding into production systems of different levels of intensity of resource use to help the program exploit the whole potential of the germplasm being developed.

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