Annual Report 1987

Tropical Pastures Program

Working Document No. 44, 1988

Centro Internacional de Agricultura Tropical

INDEX

INTRODUCTION

Background

Land endowment and cattle in tropical America

Tropical America has some 800 million hectares of significantly under-utilized savannas and forests, two-thirds of which have acid, low-fertility soils (Oxisols and Ultisols). The tropical savanna areas (some 250 million ha) have great agricultural potential because of their abundant solar radiation, adequate rainfall and favorable temperature regimes for extended growing seasons. In most of the area, topography and soil physical properties are also generally favorable. Parts of the forest areas (100-150 million ha) also have high agricultural potential; however, they are at high environmental risk, given current practices and available technology.

The cattle industry in tropical America is by far more important than in any other tropical region of Africa and Southeast Asia. The total herd in tropical America today is estimated at over 250 million head of cattle, roughly 20 percent of the world's cattle population.

Consumption of beef and milk in this continent is clearly higher than in other tropical regions of the world. The average yearly consumption of 16 kg beef per capita (range 7-38 kg) in this region is significantly higher than in Africa and Asia, and about two-thirds that of Europe. The overriding importance of beef and milk in food expenditures and their growing demands in tropical American urban and rural populations have also been documented. Beef and milk are the main components of food expenditure for all income levels, but especially among the lower income strata of the population.

The urbanization process

Urbanization has increased at an average rate of 20% throughout tropical America during the past 25 years. In tropical South America and Mexico, urbanization increased on the average from 46% in 1960 to 67% in 1985; in Central American countries, the increase was from 39.5% to almost 59%.

The previously unnoted poverty of rural areas is being transferred to the cities, becoming more and more evident as the slums grow at the edges and in the centers of most cities. These economically marginal or informal societies are, in fact, poorer in absolute terms than the rural ones. At the same time, they are now and will be, even more so in the future, in a stronger position to bring pressure to bear on politicians and society for a drastic change in wealth distribution. A change towards more balanced societies would benefit both the poor urban and rural sectors with higher incomes and better options to improve their nutrition. This would in turn further increase the demand for beef, milk and other sources of animal protein.

Colonization

Parallel to urbanization, another phenomenon is occurring--population migration. The landless, mostly rural population is moving actively into marginal frontier areas. It is only natural that the majority of these settlers are attracted to the more favorable, and less costly frontiers: areas with abundant water, such as the tropical savannas and rainforests.

The savannas are initially occupied by well-to-do ranchers. Spontaneous colonization by the poor is very difficult in this ecosystem due to the poverty of soils and original vegetation. The rainforest, after infrastructure is developed to integrate territories or to open access to timber and oil exploitation, becomes highly attractive to settlers because of the apparent higher soil fertility occurring after clearing and burning of the original biomass. Logging, shifting cultivation and cattle are the main production systems in these areas.

Population growth rates are currently much higher in humid tropical regions than in the rest of Latin American countries. Settlers are actively migrating to these areas, as in the case of Rondonia in Brazil (8.6% growth rate) and Ucayali in Peru (7.9% growth rate); i.e., about threefold the respective national figure of 2.7%.

Despite the fragility of the environment and unsustainability of existing farming systems with available technology, it must be recognized that this accelerating colonization of the humid tropics is a socioeconomic phenomenon that cannot be ignored and is difficult to stop. It is partially a technical problem that needs to be solved.

Redistribution of land use

Population growth and redistribution in tropical American societies have led to pressures on land distribution and agricultural production systems. Intensification of land use and expansion of crop production on prime lands are pushing cattle production systems into marginal and frontier areas, where land has a lower opportunity cost. For example, cattle populations in the developed southern Brazilian states of Rio Grande do Sul and Santa Catarina comprised 23.8% of the national herd in 1940; whereas in 1985 this contribution was reduced to only 12.7%. On the other hand, cattle in the Cerrados states of Goiás and Mato Grosso (with predominantly acid and poorer soils) increased from a small proportion of 15.3% of the national herd in 1940, to nearly one-third of the Brazilian cattle population in 1985 (Figure 1a). Similarly the Valle del Cauca, where CIAT headquarters is located, accounted for 7.4% of the Colombian herd in 1950; in the predominantly poor acid soils of Meta (Llanos), the cattle population has increased significantly from 0.6% to 6.1%. In Caquetá, a humid tropics region, the cattle population increased from 1.4% to 5.5% of the national herd during the same period (Figure 1b).

It is clear that marginal and frontier regions with poor acid soils are increasingly being incorporated into the countries' agricultural production base. The resulting lower productivity of the cattle industry on these lands, as well as the lack of sustainability of existing production systems and environmental fragility, is a major concern.

Constraints to productivity and sustainability

The main constraint for the expansion of sustainable cattle production systems on these marginal lands is animal nutrition. The most efficient and common way to produce beef and milk on these lands is through grazing; however, the natural productivity of these lands is predominantly poor in forage quantity and quality. The need for new pasture technologies is obvious; however, farmers have only limited resources to invest in new technologies even when the fluctuating relationship between the price of outputs (beef and milk) and inputs (fertilizers, seeds, mineral salts, machinery) is in their favor. Prices are greatly influenced by political decisions that often fluctuate between benefiting farmers or industry and/or consumers. Given the shift of the cattle industry to marginal and frontier areas with deficient infrastructure, the farmers' economic situation is further aggravated by higher transportation costs.

Consequently, if new, appropriate technology to increase productivity of land and animals in a sustainable manner is to be adopted, it must be based on limited use of purchased inputs. The technology available in the past, based on traditional commercial pasture species and introduced cultivars selected elsewhere, failed under the soil and biotic constraints of the savannas and humid tropic regions of this continent.

National institutions participation

Given the importance of the cattle industry in tropical America, as well as the limitations it faces in the increased utilization of marginal and frontier lands with predominantly poor acid soils, the countries in the region are spending important levels of resources (i.e., personnel, infrastructure and operational funds) to resolve constraints associated with the cattle industry in these areas.

After recognition of the need for in situ pasture technology development in 1979, the National Institutions, together with CIAT, jointly developed the International Tropical Pasture Evaluation Network (RIEPT) to consolidate a major cooperative research effort for development of new pasture technology options based on adapted grass and legume germplasm. The RIEPT is a mechanism of cooperation with and among the National Institutions which allows the use of comparative advantages among the participating institutions, as well as capturing large economies of scale, in order to facilitate an efficient and effective pasture research and development process for the poor acid soils of the marginal lands of in tropical America.

General Program Goals

Based on the foregoing analysis of constraints, the goals of the Tropical Pastures Program (TPP), are:

1. To increase productivity and sustainability of pasture-based production systems in marginal acid soils of the subhumid and humid tropics.
2. To improve nutrition of rural and urban populations by increasing their accessibility to beef and milk.
3. To contribute to the overall economic growth and social welfare of both rural and urban populations in the tropics.

Specific Objectives

To maximize complementarity with the National Institutions, the TPP's objectives are further defined as:

1. To develop a low-input, low-risk pasture technology for increasing beef and milk production, thereby contributing to sustainability of production systems on poor acid soils.
2. To strengthen pasture R&D capabilities of the National Institutions and to promote their horizontal cooperation.
3. To backstop national agricultural R&D institutions through the development of a better understanding of cause-effect relationships in the soil/pasture/animal/management interfaces in

in the grazed pasture environments; and the adjustment of appropriate research methodologies.

4. To contribute to the development of sustainable pasture-based production systems in the savanna and rainforest ecosystems, thereby preventing further degradation of these areas and releasing fertile lands for intensive annual crop production.

Program Strategies

To accomplish these objectives, the TPP's strategies are as follows:

1. Broaden the genetic variability base of forage grasses and herbaceous, shrubs and tree legumes in order to generate new technology based on germplasm adapted to environmental constraints. Direct collection of grasses and legumes in their center of diversity (characterized by acid soils) has resulted in high pay-off in obtaining new plants for pasture production on acid soils with low inputs.

   Today CIAT possesses the world's largest collection of tropical forages (grasses and legumes) for low-fertility, acid soils. In the future, collection will be more focused on key grass and legume species; and on aluminum- and acid-soil tolerant leguminous shrubs and trees for the development of silvo-pastoral systems.

   This germplasm development strategy also includes the TPP's plant breeding efforts to recombine positive characteristics of accessions in highly promising species.

2. Screen germplasm for its adaptation to climatic, edaphic and biotic constraints of subhumid and humid ecosystems with acid soils, a key strategy for developing a low-input pasture technology with reduced requirements for soil amendments, fertilizers and other agrochemicals. It includes characterization and evaluation of a wide range of species and accessions in major screening sites representative of the major ecosystems and regions of the TPP's mandate. Preselection of germplasm options for different environments of tropical America is currently done in cooperation with (a) the Instituto Colombiano Agropecuario (ICA) in Carimagua, Colombia, which represents the isohyperthermic savannas; (b) the Centro de Pesquisa Agropecuária dos Cerrados (CPAC-EMBRAPA) in Planaltina, Brazil, representing the isothermic savannas; (c) the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), and the Instituto Nacional de Investigaciones Agrícolas y Agroindustriales (INIAA) in Pucallpa, Peru, which represents the humid tropics; and (d) the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the Ministerio de Agricultura y Ganadería (MAG), in three sites of Costa Rica, representing the major climatic zones of Central America with moderately acid soils.

   The preselections coming out of these major screening activities are finally selected for their adaptation to subecosystem environments and assembled in pastures relevant to predominant farming systems by the National Institutions participating in the RIEPT.

3. Develop technologies with a low-input approach so that farmers with limited access to capital can afford to adopt them in marginal, infertile, acid soil areas. The Program's research approach is designed to reduce production costs through:

a. Adapted grass-legume associations

The legumes in these associations are expected to contribute directly to the animal's diet in terms of protein and energy (particularly during the dry season), and to increase productivity and persistence of grasses due to enhanced N availability in the pasture system. Nitrogen-fixing pastures are an essential low-input strategy to obtain highly productive and sustainable pasture-based production systems.

b. Low-cost, low-risk pasture establishment techniques. This is a particularly important component as the risk and cost of establishment is an important determinant of adoption by farmers. Crop-pasture interactions open the possibility of further reducing the costs of pasture establishment as grasses and legumes could utilize the residual effect of fertilizers and amendments applied to the crops.

c. Appropriate management. Developing strategies to utilize the pastures and to maximize the stability of the components (grass and legumes) and nutrient recycling is also critical. This technology (e.g. maintenance fertilization, intensity and frequency of grazing) must be relevant to farmers' possibilities and needs. Consequently, in assembling new grass-legume pasture, special care is being given to the selection of pastures that tolerate a range of management strategies and that require minimum maintenance fertilization.

d. Farmers' perspective. The role of pastures is extremely variable, depending on the land use potential and their utilization at the farm level. Some pasture-based farming systems may require only a high soil cover, with a high carrying-capacity pasture for cow-calf production on highly erodable slopes or as a seasonal supplement for poor native grasslands. In others the system may require a pasture with year-round high production of good-quality forage to feed milking cows. It is obvious that these pastures must be different or at least managed differently; therefore, incorporating the farmer's perspective at an early stage in the design of alternative systems is es- sential.

4. Promote and consolidate the RIEPT in order to evaluate pasture options systematically within the Program's ecosystem approach. Since 1979 the RIEPT has been the mechanism for cooperation within and among the National Institutions, catalyzing pasture-applied research, and promoting the development of relevant pasture research approaches and methodologies. This strategy includes the training of a critical mass of pasture specialists (researchers and developers) at the national level; the catalysis and consolidation of national networks to maximize the horizontal cooperation within the country, the coordination of regional subnetworks with the RIEPT, the participation of the RIEPT's Advisory Committee in the analysis of the network's development

and the discussion of research techniques and methodologies, as well as in the consideration of R&D approaches. Given the network's network's continued growth, the Advisory Committee decided to decentralize activities, creating four subnetworks, namely the Humid Tropics, Llanos, Cerrados and Central America, coordinated by the TPP's pasture agronomists in Pucallpa, Palmira, Brasilia and San José, respectively (Figure 2).

5. Conduct research on the understanding of environment/germplasm, plant/plant, plant/animal/management interphases and pasture/crop/tree interactions, which is essential to understand the large "black boxes" involved in the adaptation, production and utilization of pastures under a wide range of management and natural resource environments and to allow extrapolation of results for assembling technological recommendations.

6. Develop and adjust methodologies for efficient screening of germplasm, evaluation of new pasture options, and their utilization on relevant land types within farming systems. The backstopping of the RIEPT requires continuous step-by-step analysis of the methodologies utilized elsewhere to conduct the screening, pasture assembly, productivity evaluation and on-farm research. These methodologies are reviewed and analyzed yearly by the RIEPT Advisory Committee. The Tropical Pastures Program, together with other major national centers of pasture research, assumes the responsibility for developing, testing and adjusting the research techniques and methodologies to fit better the resources of different-sized National pasture programs, thereby facilitating a reliable, cost-efficient research process. This includes the capture of important economies of scale among advanced and smaller research groups. In the past, emphasis has been given to methodologies on germplasm screening and pasture evaluation under grazing. With the advance of the activities in the RIEPT toward on-farm research and transfer of the new technological options, better and more reliable methodologies are needed to study the role of pastures and to incorporate the farmers' perspective into the research process. On-farm pasture evaluation studies were initiated recently in contrasting ecosystem/ farming system environments in order to gain experience and to develop methodological approaches to this complex subject for the benefit of the National Institutions.

7. Establish pilot pasture-based farming system studies--i.e., methodological studies in selected environments to validate the new available technologies (pastures/tree/crops)--in integrated sustainable farming systems. The availability of a first set of new pasture options for specific ecosystems such as the isohyperthermic savannas and the humid tropics is expected to make an important contribution toward the sustainability of pasture-based integrated farming systems in marginal and frontier lands with poor acid soils.

   Given the time span required for sustainability studies on integrated farming systems, especially when perennial plants such as pastures and trees are involved, the Tropical Pastures Program, in cooperation with IITA and the International Council for Research in Agroforestry (ICRAF), will seek resources in the near future to evaluate the integration of pastures/crops/trees in two contrasting ecosystems. This research strategy will provide a sound basis for the development of agrosilvopastoral systems of high productivity and sustainability.

Expected Benefits

The aims of the Tropical Pastures Program are, by nature, long term; nevertheless, early pay-off is already evident. Large areas (300,000 ha) have been sown with *A. gayanus* pastures in several countries. *S. capitata* is now rapidly being adopted in the Colombian Llanos. Several new grasses and legumes being selected by national R&D institutions have reached the initial release stage.

The Tropical Pastures Program is gradually moving strategically into regions with smaller farmers and higher adoption potential, as well as evaluating the integration of pastures in mixed farming systems in areas of active colonization. This will ensure rapid adoption in more favorable areas, which will, in turn, trigger adoption in less favorable environments. The immediate challenge, in cooperation with the national institutions, is to demonstrate further and promote the beneficial role of improved legume-based pastures in terms of animal outputs and conservation of resources in relevant farming systems. Over the long term, it is expected that such integrated production systems in marginal acid soil lands will contribute to the economic growth and sustainability in these regions.

The pasture technology generated by the Program is expected to contribute to a relative reduction in the prices of meat and milk for both urban and rural consumers. Better nutrition of both rural and urban populations will result from greater accessibility to beef and milk products. This technology will have a significant impact in the conservation of natural resources in fragile environments, also contributing to the sustainability of production systems. There is no doubt that this strong ongoing national and international commitment to the development of a revolutionary pasture technology can achieve impact in the rural development of presently marginal acid soil lands, and the overall nutrition and social welfare of the continent.

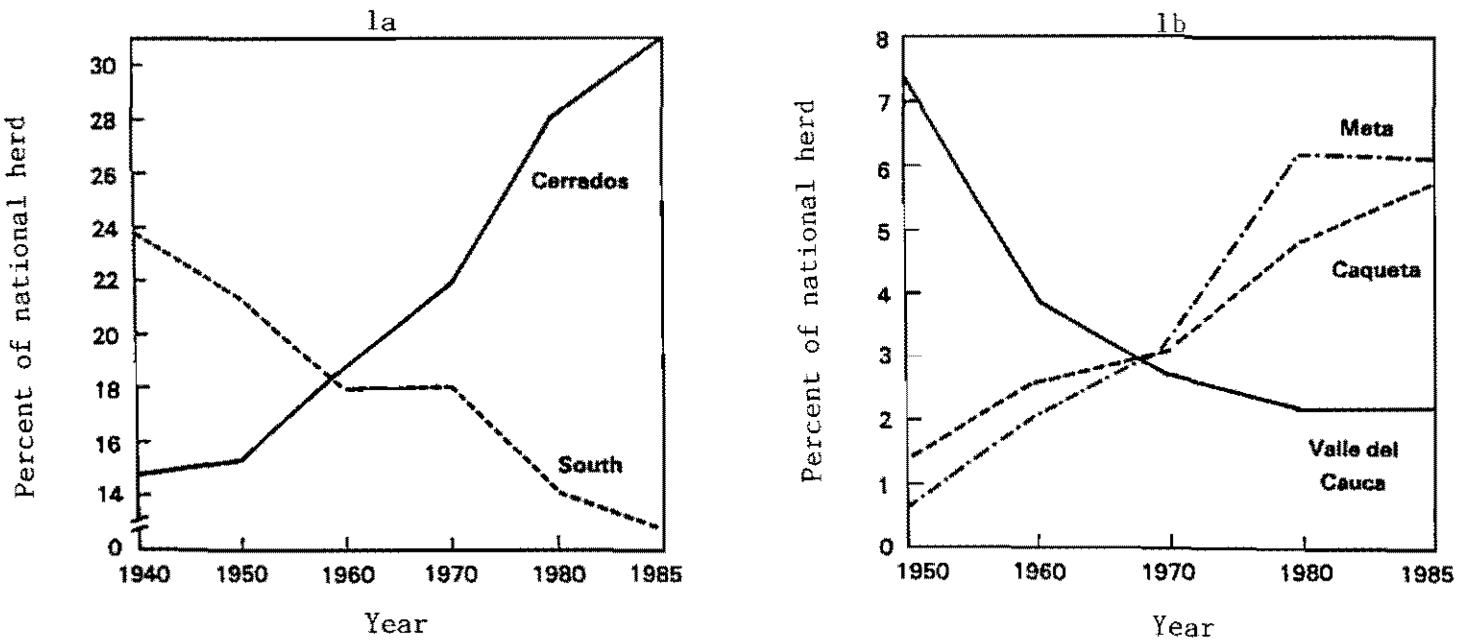


Figure 1. Changes in the location of the national cattle herd for Brazil (1a) y Colombia (1b) respectivelly.

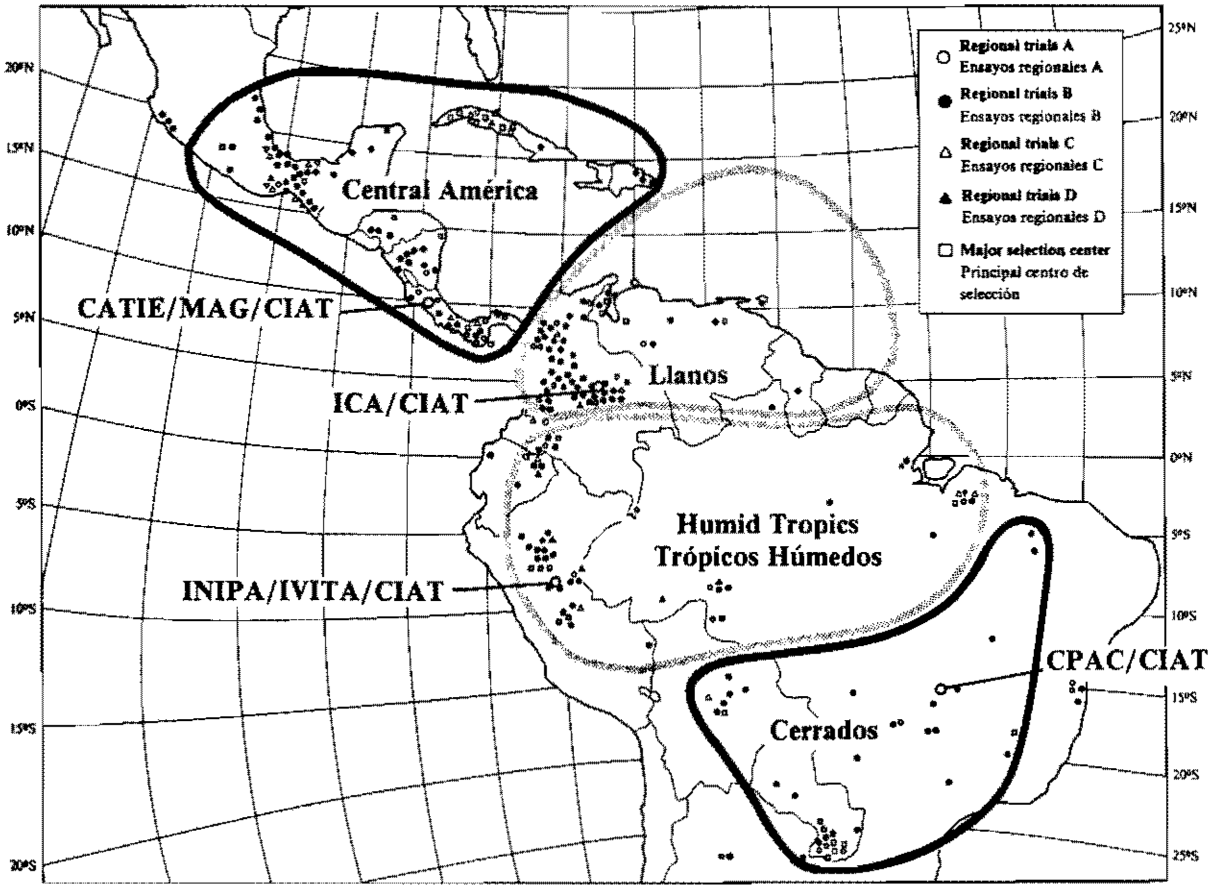


Figure 2. The four subnetworks of RIEPT and the location of regional trials and major screening sites.

1. GERMPLASM

The germplasm section has the responsibility of: assembling germplasm through direct collection in the field and through exchange of materials with other institutions; multiplication and maintenance of germplasm of particular interest to the Tropical Pastures Program; and characterization and preliminary evaluation of new introductions.

During 1987, considerable emphasis was placed on the latter two responsibilities.

COLLECTION AND INTRODUCTION OF GERMPLASM

Germplasm collection

During 1987 germplasm collection took place in Brazil and Colombia.

a) Brazil: In collaboration with the Centro Nacional de Recursos Genéticos (CENARGEN) of the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), and the Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG), a major portion of the southeast region of Brazil was sampled for native legume germplasm, with emphasis on *Centrosema* and *Stylosanthes*. The collecting mission covered parts of the states of Goiás, Minas Gerais, Sao Paulo, Rio de Janeiro, and Espirito Santo (Figure 1). Altogether 328 samples were collected (Table 1). Whereas *Stylosanthes* was the most common genus (129 collected samples = 39%), the frequency of *Centrosema* was disappointingly low. Only 36 samples (= 11%) were collected, and this is obviously the result of considerable genetic erosion in the region.

b) Colombia: In collaboration with the CIAT Genetic Resources Unit (GRU), several collection trips and excursions were carried out, some of them as part of training programs organized for visiting researchers. The details of these collection trips are given in the Annual Report 1987 of the CIAT Genetic Resources Unit. Table 2 summarizes the results. Altogether 356 samples were collected, 24% being *Centrosema* species.

Germplasm introduction

Germplasm introduced during 1987 included principally Brazilian *Centrosema* and *Stylosanthes* material received mainly from EMBRAPA-CENARGEN. Altogether 300 samples were introduced (Table 3).

With the additions made during the year (approx. 1000 accessions), the collection of the CIAT Tropical Pastures Program has now increased to approximately 19,500 accessions. The particular value of this collection lies in the fact that the majority of accessions originate from regions with acid, low-fertility soils.

MULTIPLICATION AND MAINTENANCE

As in previous years, the multiplication of legume and grass germplasm continued as an important service function of the Germplasm section.

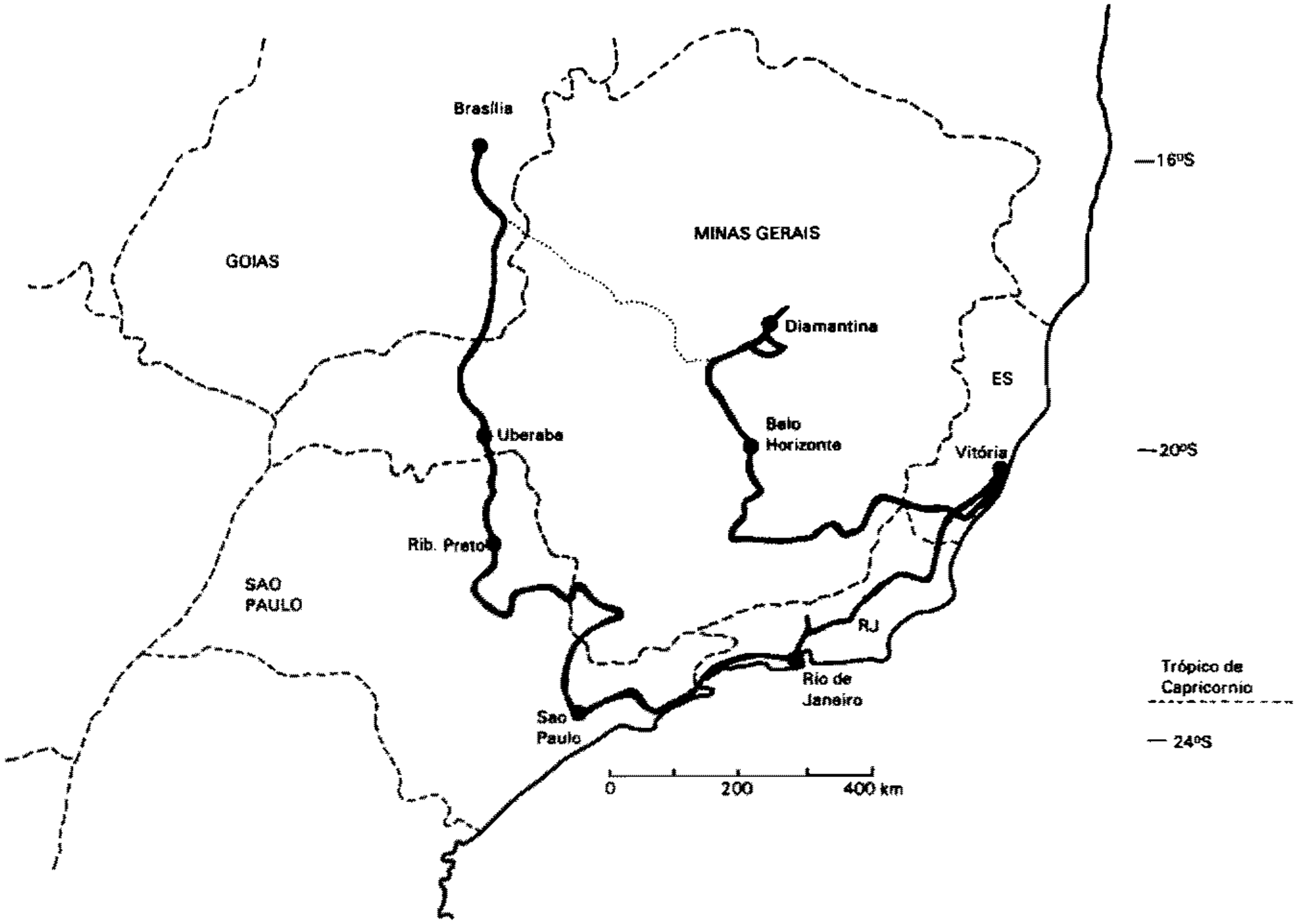


Figure 1. Routes of systematic collection of tropical forage legume germplasm in SE Brazil, 1987 (EMBRAPA/CENARGEN-EPAMIG-CIAT).

During 1987, the seed multiplication activities consisted of:

- Germplasm multiplied from potted plants in the Palmira greenhouse and/or from single plants or small, space-planted plots in specific germplasm multiplication areas of CIAT-Palmira or at CIAT-Quilichao: approximately 2200 accessions.

- Initial seed increase of all germplasm material under preliminary evaluation at CIAT-Quilichao: approximately 2100 accessions, including the *Brachiaria* spp. and *Panicum maximum* collections.

Following multiplication, seed was handed over to the CIAT GRU which is responsible for maintaining germplasm stocks under appropriate cold-storage conditions and distribution of germplasm.

CHARACTERIZATION AND PRELIMINARY EVALUATION

Germplasm of priority or "key" species and of new, agronomically unknown or

Table 1. Summary of tropical forage germplasm collected in Brazil, 1987.

Genera and species		No. of samples	Genera and species		No. of samples
Aeschynomene		18	Stylosanthes		129
Arachis spp.		2	bracteata	1	
Calopogonium spp.		8	capitata	3	
Centrosema		36	gracilis	10	
acutifolium	2		grandifolia	1	
angustifolium	1		guianensis		
arenarium	1		var. canescens	12	
brasilianum	1		var. microcephala	4	
grandiflorum	2		var. pauciflora	15	
jaraguaense	1		var. vulgaris	25	
plumieri	1		linearifolia	1	
pubescens	16		macrocephala	2	
venosum	1		ruellioides	1	
vetulum	1		scabra	38	
virginianum	9		viscosa	16	
Desmodium spp.		32			
Galactia spp.		7	Miscellaneous legumes*)		45
Macroptilium spp.		4			
Vigna spp.		2	Paspalum spp.		13
Zornia spp.		28	Miscellaneous grasses		4
Total: 328					

*) Alysicarpus, Cajanus, Camptosema, Canavalia, Chaetocalyx, Clitoria, Cratylia, Crotalaria, Desmanthus, Indigofera, Medicago, Mimosa, Mucuna, Periandra, Phaseolus, Pueraria, Rhynchosia, Teramnus.

only little known genera and species, is established in CIAT-Quilichao for seed increase and for observations on the most important plant descriptors (plant form, growth habit, flowering time, perenniality, etc.). On the basis of monthly ratings during a total of 12-24 months, germplasm adaptation to the Quilichao environment is assessed in terms of: yield potential on a very acid, infertile Ultisol, including regrowth after cutting and performance during the dry seasons that prevail in Quilichao; disease and pest resistance; and seed production potential. Establishment and evaluation methodology is that of Category I used also at other TPP germplasm evaluation sites.

This initial evaluation assists in defining which materials should be given priority in the flow of germplasm to the Program's principal testing sites in the savanna ecosystems (Carimagua and Brasilia), the humid tropics (Pucallpa) and Central America (Costa Rica).

The following are highlights of preliminary evaluation trials during 1987:

1. Centrosema macrocarpum
   Eighty-nine accessions were classified by cluster analysis into five distinct groups on the basis of: dry matter production; seed production; and capacity to root at the nodes of trailing stems (Table 4). Clusters 1 and 2 comprise 34 particularly interesting accessions with high DM and seed yields and a good

Table 2. Summary of tropical forage legume germplasm collected in Colombia, 1987.

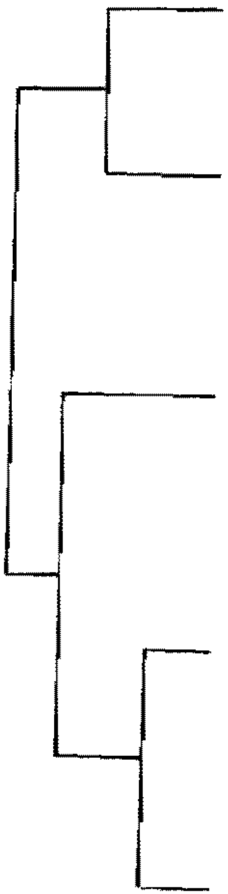
Genera and species		No. of samples	Genera and species		No. of samples
Aeschynomene		22	Macroptilium		20
Calopogonium		12	Stylosanthes		42
Centrosema		87	gracilis	1	
angustifolium	3		guianensis	24	
latidens	1		scabra	16	
macrocarpum	42		viscosa	1	
plumieri	6		Vigna		17
pubescens	27		Zornia		10
virginianum	8		Miscellaneous legumes*)		70
Desmodium		60			
Galactia		15	Grasses		1
		Total: 356			

*) Acacia, Cajanus, Canavalia, Cassia, Chamaecrista, Clitoria, Crotalaria, Desmanthus, Dioclea, Flemingia, Eriosema, Indigofera, Lablab, Phaseolus, Rhynchosia, Sesbania, Stizolobium, Tephrosia, Teramnus.

Table 3. Summary of tropical forage germplasm introduced through exchange with other institutions, 1987.

Species		No. of samples	Species		No. of samples
Hyparrhenia spp.		16	Paspalum spp.		10
Centrosema spp.		123	Stylosanthes spp.		149
acutifolium	1		angustifolia	4	
angustifolium	1		capitata	33	
arenarium	2		gracilis	4	
brachypodum	1		guianensis		
capitatum	2		var. canescens	5	
coriaceum	1		var. microcephala	4	
brasilianum	33		var. pauciflora	15	
grandiflorum	2		var. vulgaris	4	
pascuorum	13		hamata	3	
platycarpum	5		humilis	18	
plumieri	4		leiocarpa	1	
pubescens	16		macrocephala	12	
rotundifolium	2		pilosa	5	
sagittatum	2		scabra	30	
schottii	6		viscosa	11	
venosum	1				
virginianum	31		Arachis pintoi		2
		Total: 300			

Table 4. Classification of a *Centrosema macrocarpum* collection (89 accessions) into five cluster groups, based on DM production, seed yield and number of rooted stolon nodes.

Dendrogram	Cluster No.	Accessions No.	%	Mean DM yield (kg/plot)	Mean Seed yield (g/plot)	Mean No. rooted nodes/m^2	Observations
	1	7	8	7.0	655	129	CIAT 5957, 15103, 15105, 15108, 15367, 15806,15844
	2	27	30	5.2	426	80	Includes CIAT 5713, 15030, 15061,15085, 15106, 15109
	3	13	15	1.1	28	5	All var. *andinum*
	4	23	26	3.9	227	36	
	5	19	21	2.7	277	15	

capacity to root at nodes of trailing stems. They include the control accession CIAT 5713. All accessions in the low-yielding (in terms of DM as well as seed) and non-stoloniferous cluster group 3 belong to var. andinum.

2. Centrosema brasilianum
A collection of 54 accessions was classified according to cumulative DM yields over 12 months. Figure 2 shows the respective frequency distribution where two particularly productive groups stand out. They are composed of 1 accession each, namely CIAT 15387 and CIAT 5657. The group with the third highest DM production (range of 0.4-0.6 kg DM/m^2) includes the control CIAT 5234 and some new introductions from Marajó island, Brazil.

3. Centrosema tetragonolobum
The small 12-accession collection of this new species, which is

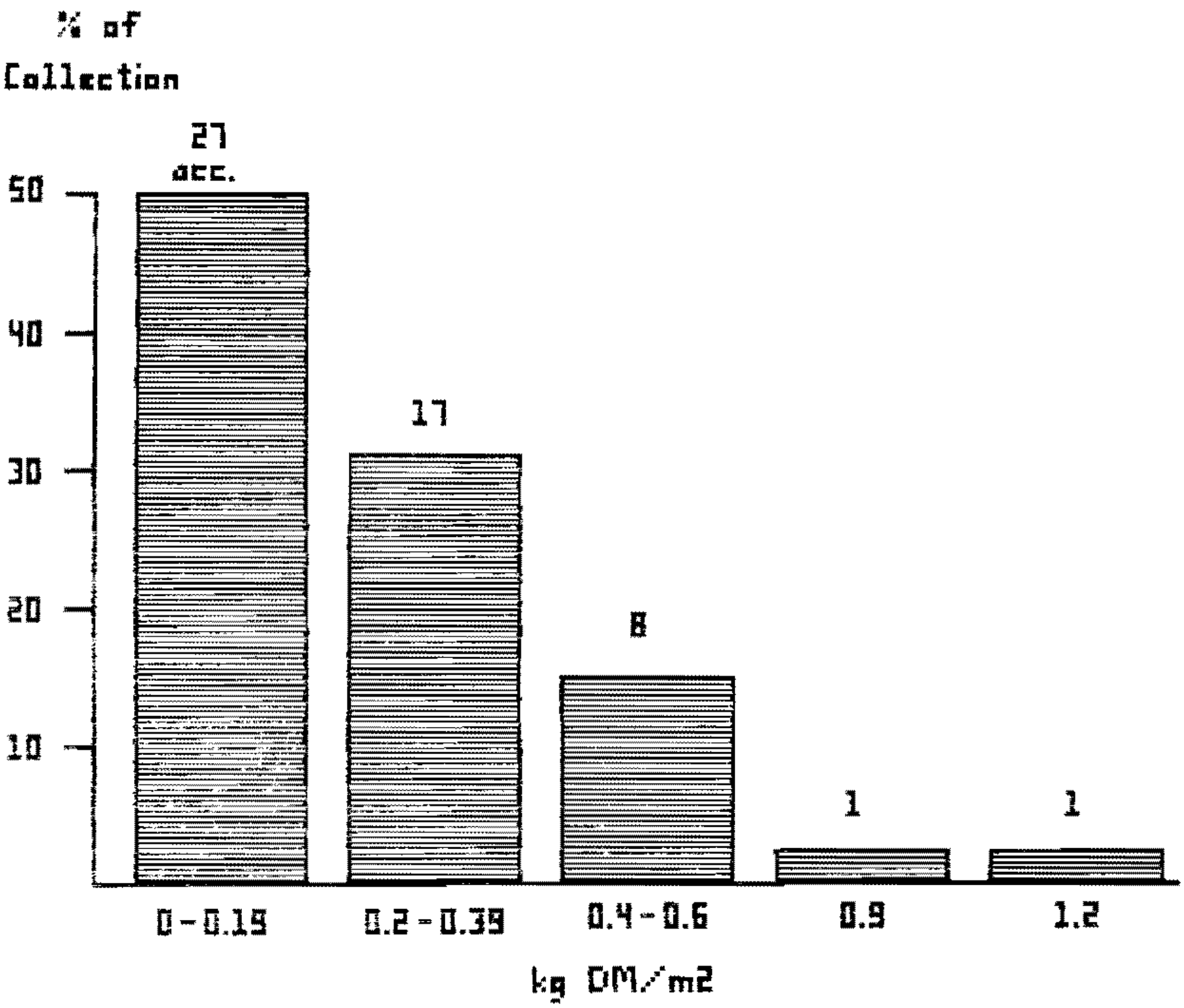


Figure 2. Classification of a 54-accessions of C. brasilianum: Frequency distribution of DM yields.

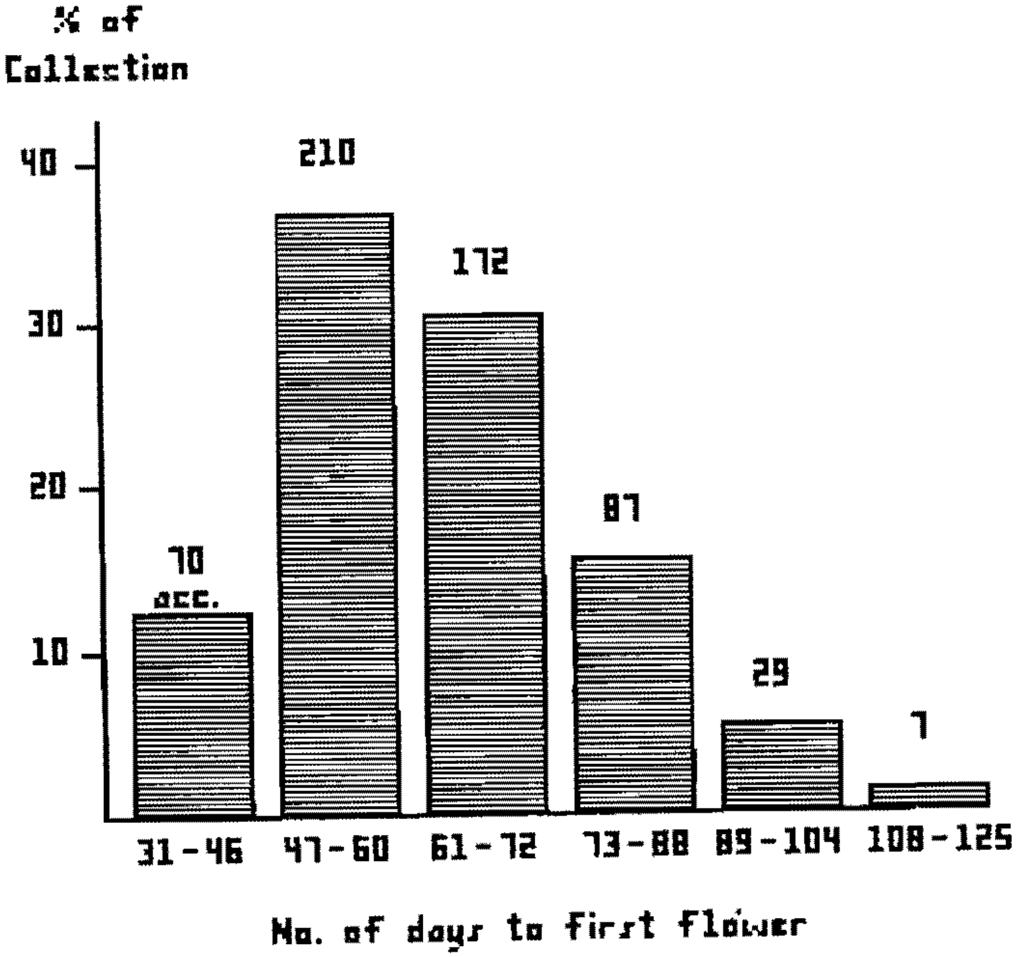


Figure 3. Classification of a 575-accessions collection of *C. pubescens*: Frequency distribution of number of days to first flower.

Table 5. Comparative evaluation of *C. tetragonolobum* and *C. brasilianum*.

Parameter	12 accessions *C. tetragonolobum* Mean	Range	*C. brasilianum* CIAT 5234	CIAT 5657
Days to first flower (No.)	73	61- 92	50	35
Seed yield (g/plot)	50	8- 161	79	180
DM yield (g/m^2)	509	390- 662	330	375
Leaf proportion (%)	58	52- 63	43	46
Leaf crude protein (%)	23.5	21.2-25.0	23.1	23.6
Leaf IVDMD (%)	60	56- 64	57	58
Tannins in leaves (%)	0.12	0.05-0.16	0.06	0.13
P in leaves (%)	0.20	0.18-0.22	0.20	0.17
Ca in leaves (%)	0.62	0.50-0.74	0.57	0.60
Mg in leaves (%)	0.27	0.23-0.30	0.21	0.24
S in leaves (%)	0.25	0.20-0.28	0.24	0.25
Zn in leaves (ppm)	20	17- 23	23	21
Cu in leaves (ppm)	16	13- 20	14	12
Na in leaves (ppm)	80	30- 183	417	448

closely related to C. brasilianum, is being compared with C. brasilianum CIAT 5234 and CIAT 5657 (Table 5). C. tetragonolobum is somewhat later flowering, and its higher DM production and proportion of leaves are a consequence of better tolerance to RFB. Whereas there are no major differences regarding nutritive value components and concentrations of most minerals in leaves, it is noteworthy that the Na concentration in C. tetragonolobum is considerably lower than in C. brasilianum.

4. Centrosema pubescens
A comprehensive collection of 575 C. pubescens accessions is presently being evaluated in Quilichao. Most characters are highly variable. As an example, the number of days to first flower covered a wide range of 31 to 125 days (Figure 3).

5. Pueraria phaseoloides
The number of days to first flower has also been very variable in a 96-accession collection of P. phaseoloides where a wide range between 90 and 319 days was recorded (Figure 4). Control accession CIAT 9900 was in the 146-156 days group. Seed production was also quite variable; 55% of the collection were in the very low-yielding group of 0-16 g/plot. Some accessions reached rather high levels of seed production under Quilichao conditions. The highest yielding group (210-270 g/plot) is composed of CIAT 7978, 8042 and 8171; control accession CIAT 9900 falls into the second most productive group (120-184 g/plot). A similarly wide range of DM production was observed where the highest yielding group comprised accessions CIAT 744, 7182, 7978, 17291, 17294 and 17323; control accession CIAT 9900 is represented in the second highest yielding group (0.71-0.90 kg/plot).

6. Dioclea guianensis and D. virgata
D. guianensis and D. virgata are represented by a 143-accession collection which showed considerable variation. As an example, in Figure 5 the seed yields are given. Whereas 21 accessions did not produce any seed at all (five of them did not flower), seed yields as high as 685 g/plot were recorded.

Grasses
Both major grass collections which are presently in the field, Panicum maximum (approx. 440 accessions) and Brachiaria spp. (approx. 400 accessions), are primarily used as a source of seed and vegetative material. Characterization and preliminary evaluation of both collections will start in 1988.

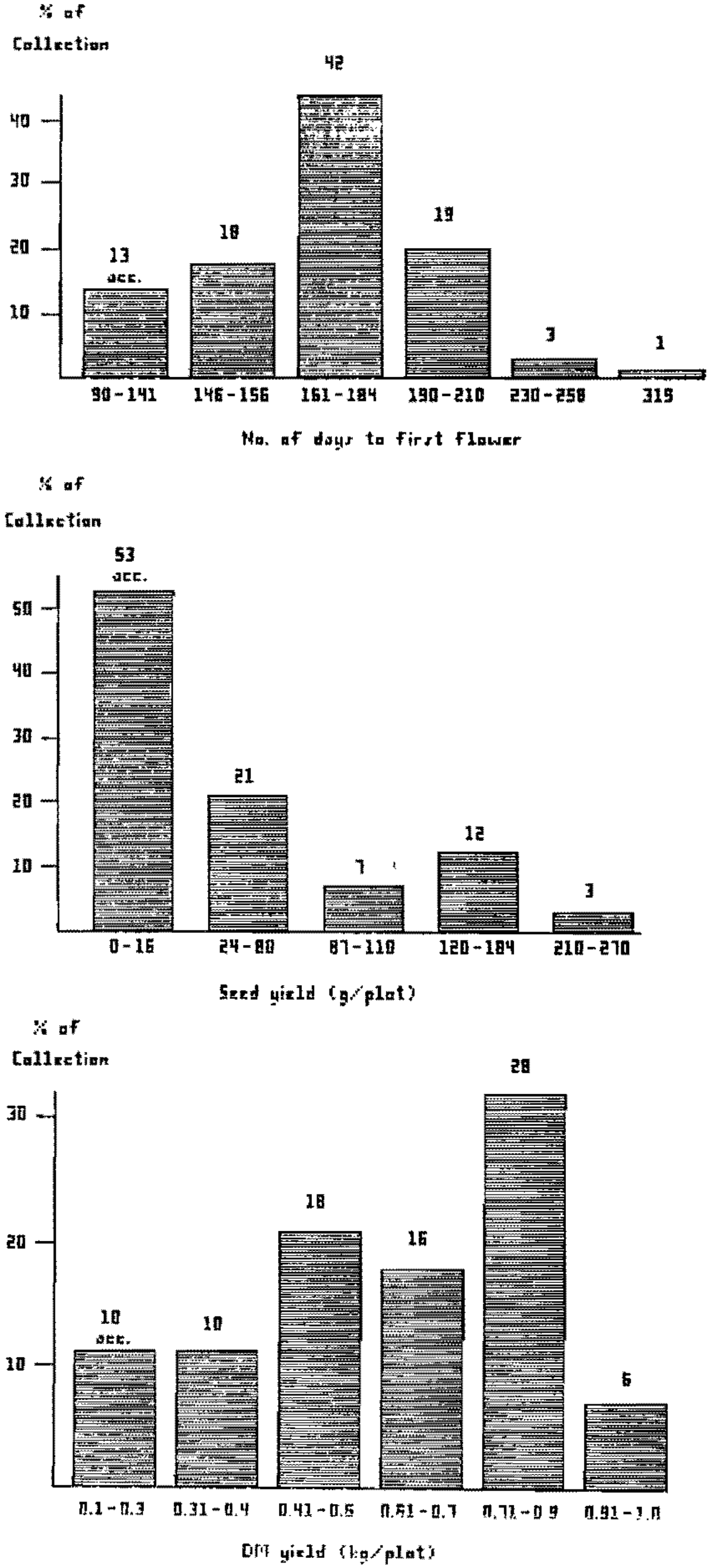


Figure 4. Classification of a 96-accession collection of Pueraria phaseoloides: Frequency distribution of number of days to first flower, seed and DM yield.

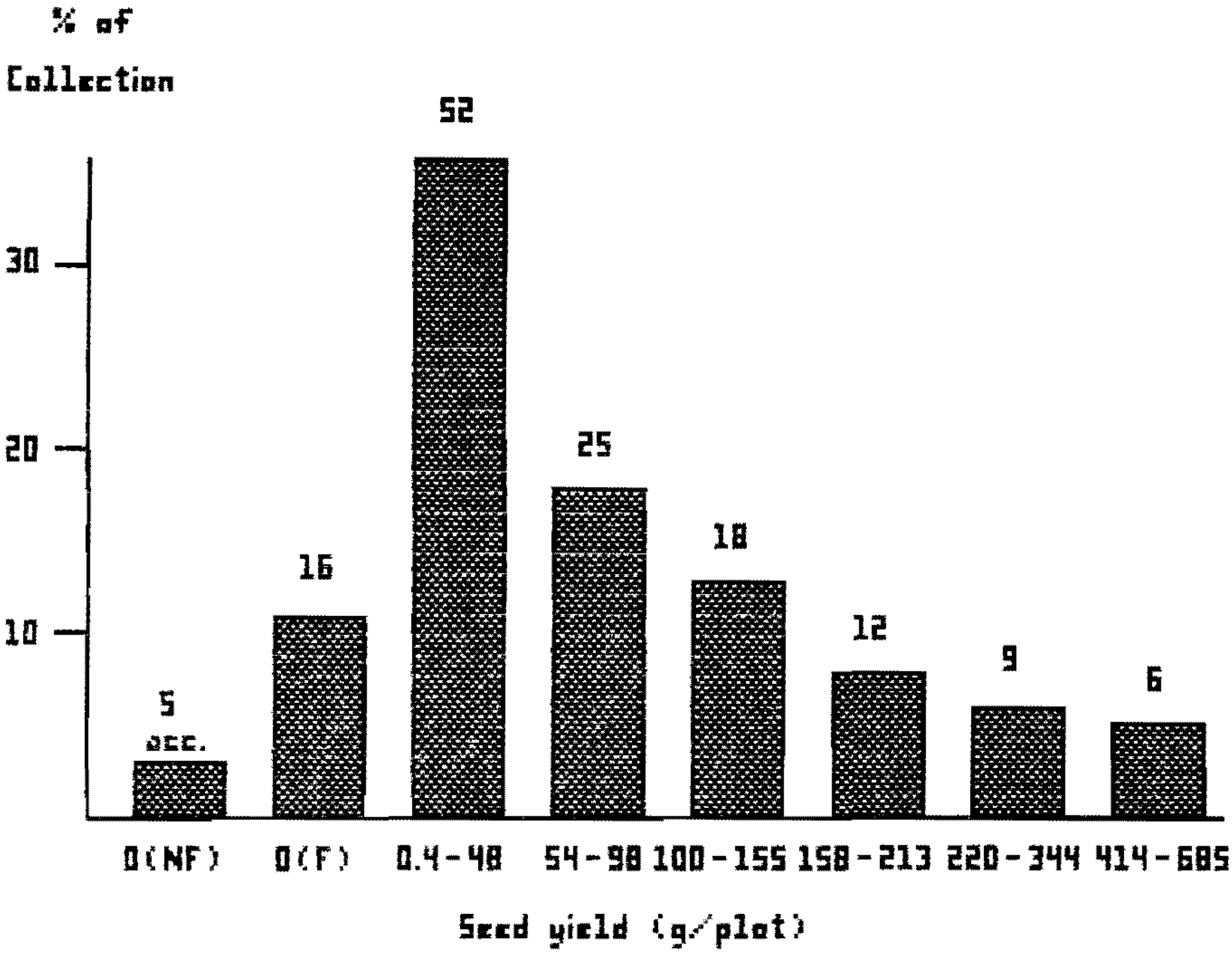


Figure 5. Classification of a 143-accessions collection of Dioclea guianensis and D. virgata: Frequency distribution of seed production.

2. PLANT BREEDING

INTRODUCTION

The basic objective of the Section remains that of producing genetically improved lines of a limited number of key species while generating information on the genetics and breeding of largely unknown species. The major breeding project remains that which seeks to enhance disease and insect resistance in Stylosanthes guianensis. A more modest breeding project seeks to alter the plant architecture of Andropogon gayanus to improve compatibility with legumes.

Distribution of the first products of the S. guianensis breeding project for wider testing through the Regional Trials network was initiated during 1987, while further improvement through systematic recurrent selection was continued. An M_3 progeny test identified a number of possible seedling markers in S. guianensis which should greatly improve the efficiency of the recurrent selection scheme. A thorough characterization of these mutants is underway.

Open pollinated (half-sib) progenies of second cycle parental clones of the short-stature A. gayanus population were established at Quilichao and Carimagua for further selection. The first evidence on the relative importance of genetic or non-genetic factors influencing A. gayanus seed quality and seedling vigor was obtained. A large genetic component is suggested.

A number of new Centrosema hybrids have now been confirmed on the basis of F_1 phenotype. A major effort to elucidate the conditions under which reaction to Rhizoctonia foliar blight can reliably be assessed was initiated with two field trials in collaboration with the Plant Pathology Section.

Exploratory studies on hybridization involving apomictic Brachiaria species were initiated in 1987.

BREEDING PROJECTS

Stylosanthes guianensis

Diallel crosses

The diallel series of crosses, which was initiated in 1981, has been advanced by pedigree, by bulk advance, and by natural selection under grazing.

Pedigree. Fifty F_4 lines selected for first season survival and seed set at Carimagua were tested for seed yield at Quilichao during 1986-87. Mean seed yield in this trial was low. However, yields of var. vulgaris lines approached 200 kg/ha (Table 1). Significant differences among var. pauciflora lines were not detected, nor between these and the standard check cultivars CIAT 2031 and CIAT 10136.

On the basis of these seed yield data 15 var. vulgaris lines were selected for wider testing through the Regional Trials program (Table 1). While it is

Table 1. Seed yields recorded on selected Stylosanthes guianensis lines at Quilichao, 1986-87 (FM-01-86).

Variety		Entry	Cross (CIAT acces. Nos.)	Seed yield (kg/ha)
vulgaris				
		14	0015 x 1539	190.5
		4	0015 x 1539	136.7
		6	0015 x 1539	134.1
		15	0015 x 1539	113.7
		5	0015 x 1539	111.7
		16	0015 x 1539	107.2
		2	0015 x 1539	104.1
		25	1122 x 1539	95.6
		13	0015 x 1539	89.5
		3	0015 x 1539	70.0
pauciflora				
		28	1808 x 10136	29.1
		44	10136 x 2031	28.9
		41	10136 x 2031	27.7
		29	1808 x 10136	24.1
		9	1317 x 1808	23.6
Checks:				
	CIAT 2031		-	22.0
	CIAT 10136		-	12.8

recognized that these lines do not have sufficient anthracnose and/or stem borer resistance to survive more than two years at Carimagua, all are substantially better in this regard than the standard var. vulgaris accessions, CIAT 136 and CIAT 184, and ought to be better than these lines also in seed yield. It is anticipated that one or more of these lines ought to prove superior in areas where anthracnose pressure is not so intense as at Carimagua.

Five of the var. pauciflora lines reselected on the basis of second season performance at Carimagua were included in a more detailed evaluation of seed yield at Carimagua in 1987 (Table 1). Check var. pauciflora accessions CIAT 2031 and CIAT 10136 were also included. A plus or minus insecticide treatment will be imposed from initiation of flowering in an attempt to elucidate the degree of reduction in seed yield of the different lines owing to Stegasta bud worm damage. Observations to date (1 Nov. 1987) suggest that at least two of the lines are as productive as CIAT 2031 and as anthracnose resistant as CIAT 10136. Flowering has not begun on any of the seven entries as yet.

Several of these var. pauciflora lines have been included for wider testing in a series of regional trials established in the Colombian llanos in 1987.

Natural Selection. Grazing treatments have continued on the native savanna association where a S. guianensis population is undergoing natural selection. The rapid decrease in S. guianensis plant numbers observed in the first two years seems to have leveled off. No attempt to sample the surviving S. guianensis population was made this year, following the failure last year of sampled plants to survive and produce seed. Seed was hand harvested directly from surviving plants in the grazed paddocks during February and March, 1987, in each of the grazing treatments. One hundred seedlings were obtained from the seed harvested from each of the grazing treatment paddocks. These seedlings were space planted in the field at Quilichao, along with 10 plants each of CIAT 2031, CIAT 10136 and four pedigree-derived lines. Seed will be harvested on a single plant basis and seed yield of the survivors of natural selection compared with the check accessions and lines. Subsequent small-plot progeny tests should give some indication of the efficacy of natural selection to the present.

Bulk Advance. A fourth generation of bulk generation advance was realized during 1986-87. Establishment problems resulted in the complete loss of the plots of three of the seven surviving populations. Seed harvests from the other four plots give no indication that seed yield has increased over generations of bulk advance since the first generation (Table 2). A repeat of fourth generation bulks for populations 1, 2, and 3, and fifth generation bulks for populations 4, 10, 11, and 12 were planted in May, 1987.

Recurrent Selection. It is anticipated that continuing progress towards the objective of stable resistance to anthracnose, stem borer, and bud worm combined with commercially acceptable seed yield (on the order of 100 kg/ha) can be made through recurrent cycles of selection and genetic recombination. Two S. guianensis populations are being subjected to recurrent selection: a S. guianensis var. vulgaris and a S. guianensis var. pauciflora population.

a) var. vulgaris. Forty progenies from white-flowered plants were selected from the 1986 crossing block on the basis of single-plant seed yield. Two hundred twenty seedlings from each progeny (8,800 plants in total) were transplanted to the field at Quilichao for the purpose of identifying yellow-flowered outcrosses and to produce S_1 seed on these. The same 40 progenies were also established in a small plot trial at Carimagua to assess their resistance to anthracnose.

Following a trend described in last year's Annual Report to a decreasing level of outcrossing at Quilichao over the years since 1982-83, the yield of yellow-flowered outcrosses was very low in this year's plant-out (0.41%). The S_1 progeny resulting from the seed harvested from these (S_0) outcrosses will be evaluated for survival and seed set at Carimagua during 1988 and 1989 to select progenies for subsequent recombination.

b) var. pauciflora. One hundred eighty S_1 progenies from the var. pauciflora population were established in a direct seeded, three-replicate, single-row plot trial at Carimagua in May, 1987. Establishment was excellent. Assessment of survival and seed set on these progenies will be

Table 2. Seed yield, by cycle, of <u>Stylosanthes guianensis</u> bulk advance populations.

Bulk population	Approximate harvest date	Cycle: First	Second	Third	Fourth
		kg/ha			
1	01 Oct.	0.43	9.07	2.11	-[A]
2	15 Oct.	4.38	19.69	6.43	-
3	29 Oct.	3.48	8.28	9.07	-
4	12 Nov.	0.08	0.60		
5	26 Nov.	0.13	0.06		
6	10 Dec.	0.12	0.04	1.05	0.49
7	24 Dec.	0.15	0.09		
8	07 Jan.	0.12	1.27		
9	21 Jan.	0.36	0.19		
10	04 Feb.	0.36	6.02	4.04	0.37
11	18 Feb.	0.26	10.11	5.42	2.43
12	04 Mar.	1.33	5.38	11.13	7.24

[A] Establishment failure. No seed harvested.

carried out over two years before selections for recombination are made.

<u>Andropogon gayanus</u>

<u>Short Stature Population</u>:
The 200 second cycle parental clones established last year at Quilichao and Carimagua were reduced to 180 on the basis of assessment of plant height at both Quilichao and Carimagua. These clones were allowed to intercross and open-pollinated seed was harvested in January, 1987 at Quilichao. On the basis of seed yield and the general condition of the plants at Carimagua (vigor, freedom from disease, high leaf:stem ratio), these half-sib progenies were further reduced to 100. These 100 progenies were established in a field trial at both Quilichao and Carimagua in June, 1987. Two replicates of 10-plant, single-row plots were planted at each location. Approximately 100 single plants will be selected at each site and these will be propagated vegetatively to establish a replicated crossing block

in 1988, to initiate a third cycle of selection.

While substantial progress has been made in this project in decreasing plant height, the population is still very variable, both for plant height and for flowering response at the low-latitude sites in Colombia. Greater uniformity in flowering date will be an important objective in the next cycles of selection. This may require a two-year evaluation if flowering date in the first year is not reliable. Second year's data are being obtained this year on the replicated clonal trial at Carimagua which will guide a decision on this point.

Late Flowering Population:

A replicated clonal crossing block established at Carimagua last year with 22 clones obtained by the Forage Agronomy Section by selection from CIAT 621 on late flowering produced essentially no seed. This was due to the very late and weak flowering response of these clones. These clones have been vegetatively propagated to Quilichao where another attempt will be made to produce open-pollinated progenies so that these materials can be properly evaluated on the basis of a progeny test. A ten-replicate, single-plant-plot (1 x 1 m) crossing block was established in late-September, 1987. It is anticipated that half-sib seed can be harvested early in 1988 for progeny tests next year.

OTHER STUDIES

Stylosanthes guianensis

Mutation breeding project

Of 255 seedlings selected as chlorotic from a large M_2 screening (approx. 140,000 seedlings) conducted in sterile sand, fertilized without nitrogen, and inoculated with a *S. guianensis*-compatible Rhizobium strain (CIAT 71) 190 M_3 progenies were obtained. These M_3 progenies were evaluated in a two-replicate trial with 10-plant plots (20 seedlings per progeny), again in sterile sand, without nitrogen fertilizer, and inoculated with the same *S.guianensis*-compatible Rhizobium strain to confirm the heritability of the apparent Rhizobium incompatibility observed in the M_2 seedlings. Of the 190 progenies, only five were still uniformly chlorotic five weeks after planting. Several plants of each of these five lines were started from remnant M_3 seed in 15.24 cm plastic pots in unsterilized soil from CIAT-Quilichao. Seed harvested from these plants is being used to evaluate the range of Rhizobium strain incompatibility of the lines. Fifteen single-plant progenies, representing four of the five lines originally selected, plus the original *S. guianensis* accession [CIAT 0015 (= cv. 'Graham')], are being inoculated with 22 Rhizobium strains previously found to be compatible with CIAT 0015, plus a mixture of all 22 strains. The fifth line apparently has a very limited range of Rhizobium incompatibility as all plants growing in unsterilized soil appear to be fixing nitrogen normally. Crosses are being made with CIAT 0015 for subsequent studies of the heritability of the mutants. If the mutant phenotype is, in fact, conditioned by a single gene, a very useful genetic marker, identifiable within 30 days from planting and readily modified by adding or withholding fertilizer nitrogen to the growing medium, will have been achieved. These mutants ought to find considerable additional utility in studies of N-fixation.

A second type of mutant, exhibiting chlorotic newly expanded leaves, appeared in several M_3 lines originating from CIAT 2312. This mutant is clearly not a N-deficiency phenotype, and so is of a different sort than the apparent Rhizobium-incompatibility mutants. This mutant phenotype is obvious in even younger seedlings than for the Rhizobium-incompatible mutants (with the appearance of the first true leaves, approx. 10 days from planting) and nearly normal adult plants are obtained. The inheritance of this second mutant type is being studied.

Somaclone progenies:

A more complete quantitative analysis of the data on somaclone progenies reported in the Biotechnology Section of last year's Annual Report (TPP, 1986) has now been completed. In this experiment ten tetraploid and 66 diploid, first generation selfed *S. guianensis* lines derived from single plants regenerated from tissue culture and the original check genotype (CIAT 2243) were evaluated in the field at CIAT-Quilichao for eight traits in single plant plots in 15 replications (seven for leaf area) in randomized complete blocks. The check line was included four times in each block.

For most traits the mean of the diploid lines differed from that of the tetraploid lines (Table 3). One of the most interesting results of this study is the high rate of spontaneous generation of tetraploids in *in vitro* tissue culture.

Table 4 compares the check genotype (from which the tissue culture plants were derived) with lines from the diploid, tissue culture-derived plants. For all traits except 100-seed weight at least some of the diploid lines differed from the check genotype, demonstrating the *de novo* generation of heritable genetic variation through *in vitro* tissue culture. However, in most cases most of the lines different from the check were inferior (lower stem number, lower internode length, lower maximum plant radius, higher anthracnose rating, and lower seed yield). More lines had leaf area greater than the checks than had smaller leaf area. Whether greater leaf area is a positive, negative, or neutral trait from a *S. guianensis* improvement point of view is unknown. The fact that genetic variation was so readily generated in *in vitro* tissue culture is, in itself, interesting. However, the results do not suggest that somaclonal variation will be of any particular usefulness in *S. guianensis* improvement, unless the generation of this variation can be coupled with efficient *in vitro* selection procedures.

Table 5 summarizes the variation found among the tetraploid lines, simply demonstrating that, in addition to suffering tetraploidization, additional, heritable genetic variation for most traits was induced in these lines.

Andropogon gayanus

Seed quality and seedling vigor

Five random genotypes (clones) in each of three *A. gayanus* accessions (CIAT 621, CIAT 6053, and CIAT 6054) were established in 1986 in a four-replicate, split-plot field experiment with 0 vs. 180 kg/ha fertilizer N as main plots. The 15 genotypes were assigned to 1 x 1 m, single-plant subplots. The first seed harvest from this experiment was in January, 1987. Analysis of variance of crude seed yield, percent full spikelets [caryopsis content, transformed by arcsine $(X)^{1/2}$], and 100-caryopsis weight detected no effect of nitrogen level on any of the three response variables. However, large genetic effects were detected: for 100-caryopsis weight highly significant accession and clone-within- accession effects were detected (Table 6). The magnitude of the accession effect was approximately six times that of clones within accessions. Variation among accessions and among clones-within-accessions was also detected for crude seed yield. However, the magnitude of the accession effect for yield was

Table 3. Means[A] for eight traits of selfed progeny of diploid or tetraploid *Stylosanthes guianensis* plants regenerated from tissue culture.

Trait	Diploids (70)[B]	Tetraploids (10)
Leaf area[D] (cm^2)	0.818	1.142 ***[C]
Stem number[E]	3.3	3.3 n.s.
Internode length[F] (cm)	4.16	4.32 **
Maximum radius[G] (cm)	97.4	75.7 ***
% dry matter	50.14	54.03 ***
Anthracnose reaction (score)[H]	2.7	2.5 n.s.
Seed yield (gm/plant)	0.317	0.093 ***
100-seed weight (mg)	219.4	217.8 n.s.

[A] Means of 15 single-plant replicates.

[B] Number of lines in parentheses.

[C] n.s. = means not different ($P > 0.05$); **, *** means differ at $P < 0.01$ or $P < 0.001$, respectively.

[D] Mean of five leaves per experimental unit (plant).

[E] Number of branches arising from base of main stem.

[F] Mean of three internodes measured on each of 3 stems per experimental unit.

[G] Length of longest lateral branch.

[H] Mean of 6 visual evaluations of anthracnose severity taken over a 6-month period on a 7-point scale (0 = no symptoms; 6 = dead plant).

Table 4. Comparison of check progeny (CIAT 2243) with first generation selfed progenies of tissue culture derived diploid *Stylosanthes guianensis* plants for eight traits.

Trait	Check[A]	Range among Diploids	Number of diploid lines Less than[B]	Greater than
Leaf area[C] (cm2)	0.762	1.080 to 0.636	2	20
Stem number[D]	3.66	3.86 to 2.67	18	0
Internode length[E] (cm)	12.54	13.46 to 10.70	4	0
Maximum radius[F] (cm)	106.6	111.0 to 71.6	20	0
% dry matter	50.56	54.29 to 46.05	4	1
Anthracnose reaction (score)[G]	2.24	3.91 to 1.53	0	16
Seed yield (gm/plant)	0.479	0.886 to 0.074	24	1
100-seed weight (mg)	221.8	288.6 to 192.0	0	0

[A] Means of 60 single-plant replicates.

[B] Significantly different from check mean ($P < 0.05$).

[C] Mean of five leaves per experimental unit (plant).

[D] Number of branches arising from base of main stem.

[E] Mean of three internodes measured on each of 3 stems per experimental unit.

[F] Length of longest lateral branch.

[G] Mean of 6 visual evaluations of anthracnose severity taken over a 6-month period on a 7-point scale (0 = no symptoms; 6 = dead plant).

Table 5. Genetic variation for eight traits among tetraploid, first generation selfed lines from tissue culture-derived *Stylosanthes guianensis* plants.

Trait	Range among 4x lines		
Leaf area[B] (cm2)	1.03	to	1.39 **[A]
Stem number[C]	2.67	to	4.36 ***
Internode length[D] (cm)	11.40	to	14.45 **
Maximum radius[E] (cm)	69.73	to	84.91 n.s.
% dry matter	50.54	to	56.27 n.s.
Anthracnose reaction (score)[F]	1.53	to	3.29 **
Seed yield (gm/plant)	0.014	to	0.199 n.s.
100-seed weight (mg)	0.205	to	0.229 n.s.

[A] n.s. = means not different ($P > 0.05$); **, *** means differ at $P < 0.01$ or $P < 0.001$, respectively.

[B] Mean of five leaves per experimental unit (plant).

[C] Number of branches arising from base of main stem.

[D] Mean of three internodes measured on each of 3 stems per experimental unit.

[E] Length of longest lateral branch.

[F] Mean of 6 visual evaluations of anthracnose severity taken over a 6-month period on a 7-point scale (0 = no symptoms; 6 = dead plant).

Table 6. Means of 15 Andropogon gayanus genotypes (five clones in each of three accessions) for seed yield and quality attributes.

Accession	Clone	Crude seed yield	Caryopsis content[A]	100-caryopsis weight
		(gm/plant)		(mg)
CIAT 0621	1	32.1	0.549 [27.2]	100.0
	2	39.2	0.315 [9.6]	60.0
	3	51.6	0.518 [24.5]	126.3
	4	17.2	0.388 [14.3]	78.7
	5	32.4	0.591 [31.1]	77.5
Acc. means		34.5	0.472 [20.7]	88.5
CIAT 6053	1	28.9	0.444 [18.4]	113.8
	2	41.8	0.472 [20.7]	96.3
	3	32.5	0.476 [21.0]	76.8
	4	46.3	0.676 [39.2]	115.0
	5	17.0	0.670 [38.5]	111.3
Acc. means		33.3	0.548 [27.1]	102.6
CIAT 6054	1	22.1	0.466 [20.2]	161.3
	2	7.1	0.082 [0.7]	133.0
	3	16.8	0.664 [38.0]	142.5
	4	34.1	0.694 [40.9]	113.8
	5	55.3	0.670 [38.6]	112.5
Acc. means		27.1	0.515 [24.3]	132.6
LSD's:				
Bet. clones	.05	13.03	0.165	21.25
	.01	17.28	0.219	28.19
Bet. acces.	.05	5.82	_[B]	9.50
	.01	_[B]	_[B]	12.61

[A] Arcsin $(X)^{1/2}$ transformed values, where X = number of full spikelets in a 100-spikelet sample divided by 100, expressed in radians. [Retransformed values, expressed as percent full spikelets, in brackets]

[B] F-test not significant.

only about one-third that of the clones-within-accessions effect. Accessions did not differ for percent fulls, but highly significant differences among clones within accessions were found (Table 6)

Caryopses from first harvest seed were germinated in soil in 25 x 50 cm flats in the glasshouse. Two replicates of 50 caryopses from each plant (subplot) of the field trial were sown in single-row plots in the glasshouse. Response variables measured were percent germination [transformed by arcsine $(X)^{1/2}$], area under the cumulative germination curve (taken as a measure of speed of germination), and dry weight of seedlings (on a per seedling basis) at 20 days from sowing. Genetic effects predominated in germination response (Table 7). Differences among accessions as well as among clones within accessions were highly significant, with accession effects approx. three times larger than the clone-within-accesson effects for all traits. Nitrogen level in the field trial did not affect either seedling vigor (dry weight) nor speed of germination. A small effect attributable to nitrogen level was detected for percent germination [62.9% germination with nitrogen fertilizer vs. 67.3% without added N ($P < 0.05$)].

These first harvest results suggest a large genetic component in seed yield and quality of A. gayanus. They show no evidence of important non-genetic effects (nitrogen fertilizer level).

These conclusions are, of course, very preliminary. Quality and germination tests will be performed on seed from subsequent harvests of this experiment. Quality factors of A. gayanus seed from a high latitude site (Valledupar: approx. 10°N) still need to be compared with those of seed harvested at Quilichao (approx. 3°N).

Centrosema spp.

Rhizoctonia resistance in C. brasilianum

Last year we reported substantial difficulties in obtaining reliable assessment of differences among C. brasilianum accessions in reaction to Rhizoctonia foliar blight. Two field trials were established at Carimagua this year in an attempt to clarify the conditions necessary for reliable and uniform disease development.

In one experiment time of inoculation and defoliation are being evaluated. In the second experiment two row spacings (2.5 m vs. 0.625 m) and six inoculation methods (soil inoculation at planting; aqueous suspension of mycelium at high or low concentration; chopped, infected foliage applied as soil mulch or on foliage; natural inoculum (noninoculated check) are being compared. To date (1 Nov. 1987) disease development has not been sufficient reliably to assess the treatment effects.

Last year's trial of 14 promising C. brasilianum accessions has been continued this year with a + vs - fungicide treatment imposed on blocks in a split-plot design. No effect of fungicide on level of Rhizoctonia foliar blight can be detected as yet (1 Nov. 1987). However, this set of accessions continues to exhibit large differences in vigor and apparent resistance to foliar sucking insects. Particularly, one of the accessions which showed most promise last year (CIAT 5178) now appears to be rather susceptible to sucking insect damage. Two accessions continue to show outstanding performance: CIAT 5657 and CIAT 5671.

We still consider an evaluation of diallel cross progeny of C. brasilianum for Rhizoctonia reaction to be premature. However, recent

Table 7. Germination characteristics of caryopses of 15 *Andropogon gayanus* genotypes (five clones in each of three accessions).

Accession	Clone	Percent germination, 19 days[A]	Rate of germination[B]	Seedling dry weight, 20 days[C] (mg)
CIAT 0621	1	0.842 [55.6]	418.4	2.476
	2	1.045 [74.8]	548.1	1.894
	3	0.791 [50.6]	390.8	3.022
	4	0.840 [55.5]	414.4	1.973
	5	1.054 [75.6]	508.7	2.019
Acc. means		0.910 [62.3]	452.3	2.305
CIAT 6053	1	1.054 [75.6]	596.1	3.807
	2	1.072 [77.1]	568.6	3.161
	3	0.932 [64.4]	465.6	2.342
	4	1.110 [80.2]	544.1	2.946
	5	0.944 [65.6]	481.9	2.374
Acc. means		1.026 [73.1]	533.2	2.954
CIAT 6054	1	0.901 [61.5]	469.1	3.284
	2	0.753 [46.7]	341.7	2.643
	3	0.877 [59.1]	457.1	3.291
	4	0.877 [59.1]	437.3	2.708
	5	0.959 [67.0]	513.7	2.698
Acc. means		0.889 [60.2]	456.7	2.960
LSD's:				
Bet. clones	.05	0.072	47.16	0.410
	.01	0.095	62.32	0.542
Bet. acces.	.05	0.032	21.09	0.183
	.01	0.042	27.87	0.242

[A] Arcsin $(X)^{1/2}$ transformed values, where X = number of seedlings obtained from a 50-caryopsis sample divided by 50, expressed in radians. [Retransformed values, expressed as precent germination, in brackets].

[B] Area under the cumulative germination curve where number of caryopses germinated is plotted on time from planting in days. This area is taken as a measure of rate of germination.

[C] Seedling dry weight expressed on a per seedling basis.

advances in disease resistance assessment in the glasshouse (See Plant Pathology Section) may allow future advances in this area.

Interspecific hybridization in Centrosema

An important hybridization program was initiated in Centrosema last year with the objective of delimiting accessible gene pools in the genus. Putative F_1 seed of the 35 crosses available on 1 Jul. 1987 was planted along with samples of the parental accessions involved in each of the crosses. Visual comparison of putative F_1's with parents suggests that a majority is actually accidental selfs rather than true crosses (Table 8). However, one hybrid combination which had not previously been reported has now been achieved: C. brasilianum x C. tetragonolobum.

Apparent incompatibilities in crosses previously considered to be completely compatible were found (Table 8). It appears that none of the C. pubescens x C. acutifolium crosses was successful; in one cross (# 949) very abnormal, stunted F_1 seedlings were obtained. Likewise, in one of the C. acutifolium x C. macrocarpum crosses (# 1399) abnormal, stunted F_1 seedlings suggest incompatibility barriers between these two species which had not previously been reported.

A large number of additional crosses has been made and the progeny of these will be analyzed in due course.

Brachiaria spp.

The genus Brachiaria is certainly one of the most important sources of commercial forage grasses in the American Tropics. Breeding work has heretofore been inhibited by the fact that all commercially important species (with the exception of B. ruziziensis) were considered obligate apomictics. It now, however, appears feasible to make crosses utilizing an induced tetraploid B. ruziziensis as female and apomictic, tetraploid B. decumbens, B. brizantha, etc. as male. Recent results of C. do Valle (EMBRAPA/CNPGC, Campo Grande) suggest a substantial level of sexuality even in the "apomictic" species B. decumbens and B. brizantha (9.8 or 13.4%, respectively, based on embryo sac analysis) such that it may be possible to realize hybridizations directly between or within these species.

Critical to the progress of any hybridization work in Brachiaria spp. is the existence of a reliable genetic marker to identify hybrid progenies, particularly in crosses between predominantly apomictic genotypes. Recent collaborative work with the Biotechnology Research Unit initiated by Visiting Researcher R. Cruz (ICA, Cuba) shows that esterase isozyme bands can reliably discriminate genotypes within and among Brachiaria spp. (Fig. 1).

We are presently attempting to work out reliable crossing techniques utilizing a tetraploid B. ruziziensis accession (CIAT 16103, obtained from Dr. C. do Valle) as female with confirmation of hybrid progenies with the esterase markers. Future studies, once hybridization techniques are worked out, will focus on the inheritance of sexuality in advanced generations from these crosses. Additionally we seek to relate determinations of degree of sexuality based on embryo sac analyses with the recovery of hybrid individuals within the progeny obtained from crosses between predominantly apomictic Brachiaria spp. This line of research will depend critically upon reliable genetic markers.

It must be emphasized that these investigations of hybridization in Brachiaria spp. are of a strictly exploratory nature at the present

Table 8. Results of observation of putative interspecific *Centrosema* hybrids.

Female		Male	Cross	Result
C. pubescens	x	*C. acutifolium*	38	Prob. self
			105	Can't classify
			949	1/3 dead: 2/3 very stunted
			951	1/1 dead
			1028	1/1 dead
			2024	1/3 dead: 2/3 prob. self
C. acutifolium	x	*C. pubescens*	765	Prob. self
			766	1/3 dead; 2/3 may be true cross
			926	Prob. self
			2020	Prob. true cross
			2023	Prob. true cross
C. pubescens	x	*C. virginianum*	66	Prob. self
			176	Prob. self
C. virginianum	x	*C. pubescens*	179	Prob. self
			2018	Prob. self
C. pubescens	x	*C. schottii*	121	Prob. self
			261	Prob. self
C. pubescens	x	*C. brachypodum*	140	Prob. self
C. pubescens	x	*C. brasilianum*	576	Prob. self
C. pubescens	x	*C. arenarium*	2019	Prob. self
C. brasilianum	x	*C. tetragonolobum*	1055	Prob. true cross
			1092	Prob. true cross
			1093	Prob. true cross
			1094	Prob. true cross
			2207	3/3 stunted
			2261	Prob. true cross
C. brasilianum	x	*C. acutifolium*	1892	Prob. self
C. acutifolium	x	*C. schiedeanum*	1386	Prob. true cross
C. acutifolium	x	*C. macrocarpum*	1399	1/3 dead;2/3 very stunted
			1763	Prob. self

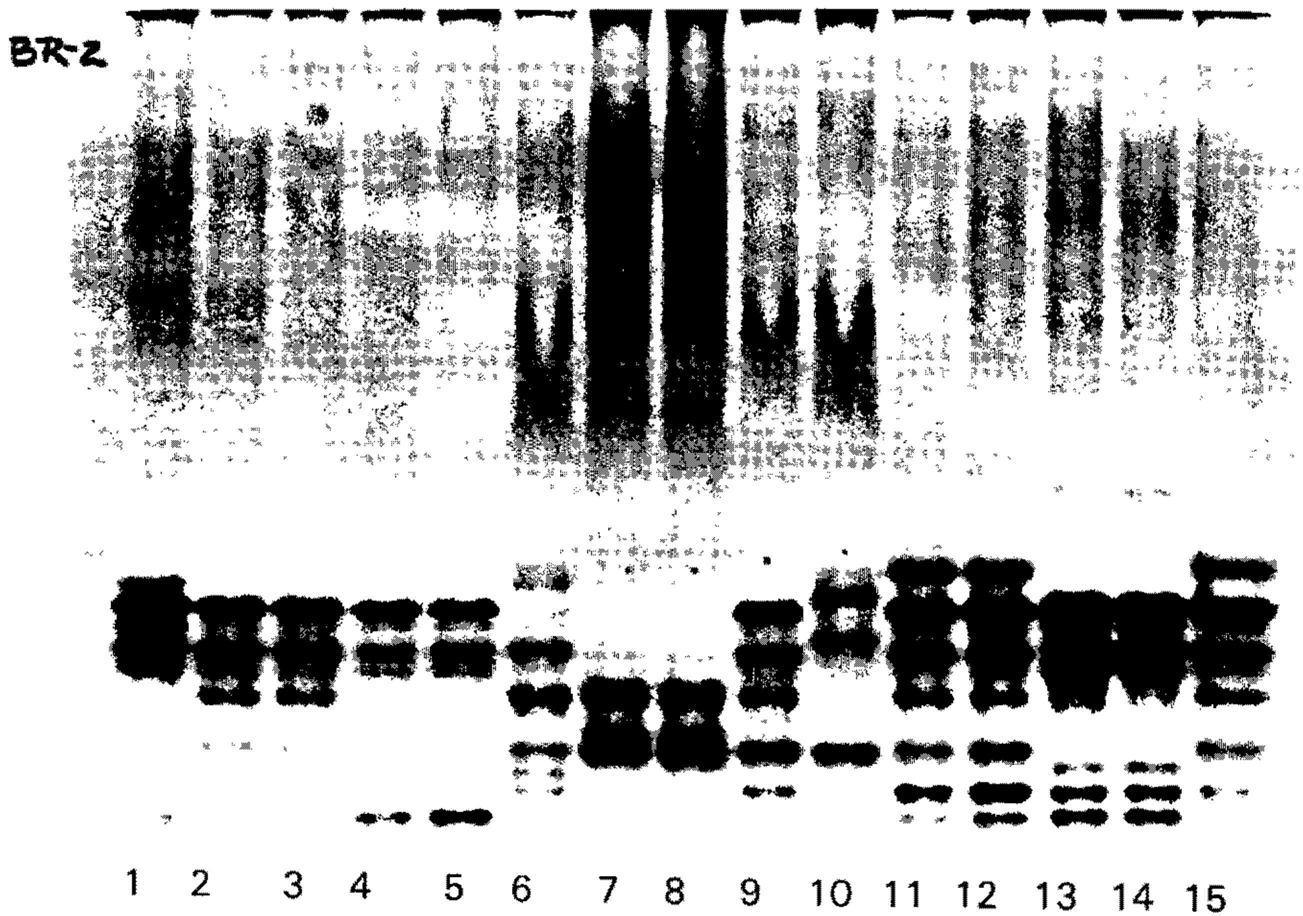


Figure 1. Esterase band patterns of 10 *Brachiaria* spp. accessions. Columns 1-5, *B. ruziziensis* (1 = CIAT 654; 2, 3 = CIAT 656; 4, 5 = CIAT 16103). Columns 6-10, *B. brizantha* (6 = CIAT 6297; 7, 8 = CIAT 6675; 9 = CIAT 6384; 10 = CIAT 6686). Columns 11-15, *B. decumbens* (11, 12 = CIAT 606; 13, 14 = CIAT 641; 15 = CIAT 6392).

time. An active program is underway to characterize and evaluate a large new collection of Brachiaria spp. germplasm accessions, particularly with regard to reaction to spittlebug (see Agronomy Sections and Entomology Section). We hope to be in a position to initiate breeding work, if this should prove warranted, without delay when the results of the agronomic evaluations are complete.

3. AGRONOMY LLANOS

The agronomy studies conducted at the Carimagua Research Station continued to focus on the selection of legumes and grasses for the "llanos" ecosystem.

AGRONOMIC EVALUATION OF GERMPLASM (CATEGORY II)

The aim of this stage of evaluation is to select accessions adapted to the climatic, edaphic and biotic factors in the environment. Accessions are grown in small plots in pure stands and subjected to periodic defoliation. Observations are made on vigor, flowering time, seed production potential, drought resistance, pest and disease incidence. Evaluation is being conducted at two sites "Yopare" and "La Alcancía". Between sites there is variation in soil texture and organic matter content (see Annual Report Tropical Pastures for 1986). Accessions under test are established in native pasture, without removal of vegetation from inter-plot areas. This technique allows for some plant competition and increases pest and disease pressure, thereby making Category II evaluation somewhat less artificial. In addition, the soil is protected from erosion and maintenance activities are reduced.

Stylosanthes macrocephala

In recent years, several accessions of the species have been attacked in a number of locations in the "llanos" by Rhizoctonia Foliar Blight. In order to screen the collection for resistance to the disease 111 accessions of the species were planted in May 1986. Accessions CIAT 1281 (cv. Pioneiro) and CIAT 1643 were included as controls. Most of the accessions were collected in the Brazilian states of Bahia and Minas Gerais.

In general, plants have shown relatively poor vegetative vigor and the disease incidence is similar at both sites. Some 4 per cent of plants are completely disease-free; accessions CIAT 10017, CIAT 10428 and CIAT 10431 being the only introductions showing no symptoms in all three replications at both sites. Some 33 per cent of the collection shows moderate to serious disease problems. It would appear that the species offers little agronomic potential for the "llanos" ecosystem. On the other hand, the species is promising in the drier savanna areas of Brazil, so information on resistance to Rhizoctonia Foliar Blight within the collection is of relevance to that ecosystem.

Stylosanthes scabra

In May 1986, 93 promising lines of S. scabra were planted at the "Yopare" and "La Alcancía" sites. These lines had been selected originally from a larger collection of over 500 accessions at Quilichao. Eighty-four of the 93 accessions were collected in Brazil (mainly the state of Bahia) and the remainder in Colombia and

Venezuela. The Australian commercial cultivars Seca and Fitzroy were included as controls.

There is marked variation in morphology in the collection with three main types recognized. Two are represented by the growth habits of cultivars Seca and Fitzroy, whilst a third group is a low-growing bush type of Venezuelan origin. Five accessions of this latter type have been selected as promising at both sites. Interestingly, although most of the collection is from Brazil, it is these Venezuelan types that are showing the best vigor and resistance to anthracnose and stem-borer. Nearly 40 per cent of the plants have died from the effects of disease and stem-borer, including cv. Seca and many plants of cv. Fitzroy. Only 9 per cent of the collection is disease-free; mainly the Venezuelan types.

The yields of edible dry-matter for the five selected accessions are presented in Table 1. There are marked differences in yield between the selected accessions and the cv. Fitzroy. Across accessions, differences between the two sites were not statistically significant.

Centrosema brasilianum

In June 1986, 18 accessions of this species from Brazil and Venezuela were sown at the "La Alcancía" site. C. brasilianum has shown considerable potential as a legume for savanna areas but Rhizoctonia Foliar Blight is a problem. Nine of the accessions (those with 4-digit CIAT numbers), including the control CIAT 5234, were selected previously at Carimagua, and evaluation of these under grazing is to commence in 1988. The other nine accessions (those with 5-digit CIAT numbers) are new and were selected in Quilichao.

Insect and disease problems were encountered in the first part of the wet season. None of the accessions is free of Rhizoctonia Foliar Blight, but 67 per cent were only slightly to moderately affected. All 18 accessions were badly attacked by leaf-sucking insects, but this is usually a temporary occurrence and plants recover well.

Yields of dry-matter are reported in Table 2. There was considerable variation between accessions, but only CIAT 15521 produced significantly more dry-matter than the control CIAT 5234.

Panicum maximum

A collection of 436 accessions was established at the two sites in May 1986. The collection was classified into groups representing the main commercial cultivars. Thirty-two per cent was similar to cv. Hamil, 40.6 per cent was similar to cv. Common, 27.1 per cent was similar to cv. Petrie green panic and 0.2 per cent was similar to cv. Embu.

It is usual to select grasses on the basis of total dry-matter yield with the most productive chosen for further study. However, in other tufted tropical grasses such as Andropogon gayanus, a high proportion (up to 40 per cent) of total dry matter produced even in the second part of the wet season consists of senescent material which is of no value to the animal. Furthermore, such high-yielding grasses are often incompatible with many legume species. Accordingly, in an attempt to select less aggressive, higher quality grasses it was decided to use "the yield of digestible dry-matter in green leaf" as the selection criterion. Eighty-six low to medium height, leafy accessions (including three controls) were chosen at the end of 1986 from within three of the four morphological groups. Accessions similar to cv. Hamil were not included as these giant types are difficult to manage under grazing and are more appropriate for cut-and-carry systems.

Table 1. Production of edible dry-matter in selected accessions of *S. scabra* at the "Yopare" and "La Alcancía" sites at Carimagua.

CIAT No.	Origin	DM yield (g/plant)† "Yopare"	"La Alcancía"	Mean
2808	Venezuela	239	211	225
1926	Venezuela	152	224	188
1526	Venezuela	198	134	166
1522	Venezuela	128	180	154
2818	Venezuela	117	150	134
cv. Fitzroy	Brazil	27	0	14
MEAN			144	150
LSD (Accessions)		55(**)	80(**)	
CV (%)		15.2	19.8	

† Sum of 2 cuts.

Table 2. Dry-matter yields of accessions of *C. brasilianum* at the "La Alcancía" site at Carimagua.

CIAT No.	Origin	DM Yield† (kg/ha)	CIAT No.	Origin	DM yield† (kg/ha)
15521	Brazil	3396 a	15526	Brazil	2339 cde
5486	Brazil	2774 b	5810	Brazil	2315 cde
15387	Venezuela	2647 bc	15520	Brazil	2257 de
15522	Brazil	2616 bc	15523	Brazil	2065 ef
15527	Brazil	2606 bcd	5657	Venezuela	1831 f
5725	Brazil	2586 bcd	15524	Brazil	1766 fg
5828	Brazil	2550 bcd	5667	Venezuela	1745 fg
15525	Brazil	2531 bcd	5671	Venezuela	1462 gh
5234 (control)	Brazil	2494 bcd	5178	Venezuela	1421 h

† Sum of two cuts.

Means with the same letter are not significantly different (Duncan's Multiple Range Test).

Five groups (Figure 1) were identified by cluster analysis, two of which contained five accessions performing well at both sites. Cluster analysis was conducted using data for the two locations on the basis of "yield of dry-matter in green leaf" since digestibility data were not available at the time of writing. The yields for the top five accessions are appreciably higher than those of the commercial controls (Table 3). None of these accessions was attacked by smut, which commonly is present on the inflorescences of P. maximum in the region.

New plantings

In June 1987, 264 accessions of species of Brachiaria were planted vegetatively at Carimagua. Plots were established within an existing pasture of B. humidicola in order to increase the spittlebug pressure. Fifty-three per cent of the collection is B. brizantha, 14 per cent is B. decumbens, 12 per cent is B. humidicola, 8 per cent is B. jubata, 6 per cent is B. ruziziensis, 2 per cent is B. dictyoneura and 5 per cent is miscellaneous Brachiaria species. Commercial cultivars have been included as controls. Promising accessions of Brachiaria selected in previous years have also been included. The collection shows considerable variation in morphology, and tolerance to spittlebug attack will be a high priority selection criterion. Establishment has been very variable and many plots had to be replanted. Most accessions have now established and detailed evaluations will begin in 1988. The collection has also been planted at the ICA "La Libertad" Research Station, near Villavicencio where populations of spittlebug are naturally higher than at Carimagua.

The Pueraria phaseoloides collection of 99 accessions has been established at the "Yopare" and "La Alcancía" sites. The collection contains the three botanical types var. javanica, var. phaseoloides and var. subspicata. The commercial cultivar, included as a control, shows poor adaptation to low soil fertility, a low tolerance of drought, and unreliable seed production. Other species sown during 1987 were Desmodium ovalifolium (37 accessions), Centrosema acutifolium (26 accessions) and C. "tetragonolobum" (10 accessions).

GRAZING EVALUATION OF GERMPLASM (CATEGORY III)

The main purpose of this stage of evaluation is to record the performance of promising legumes under grazing in small plots when associated with a companion grass. Of particular interest is legume persistence and grass-legume compatibility. At this level of screening there is a high level of co-operation with the Ecophysiology Section, and certain data from agronomy trials will be found in that part of the report.

Desmodium ovalifolium

Accession CIAT 350 has shown considerable promise for "llanos" conditions as a companion legume for vigorous species of Brachiaria. However, there have been problems with a stem-nematode (Pterotylenchus cecidogenus) and False Rust (Synchytrium desmodii). A number of new accessions have been selected for better resistance to these pests and diseases. Five accessions together with a control (CIAT 350) were established in July 1985 in association with Brachiaria dictyoneura CIAT 6133 (now cv. Llanero). Two grazing pressures are being imposed by variation in the number of days the plots are grazed.

Changes in the legume proportion across grazing pressures in the six associations are shown in Figure 2. In all treatments this year there has been a marked decline from over 70 per cent legume to less than 10 per cent

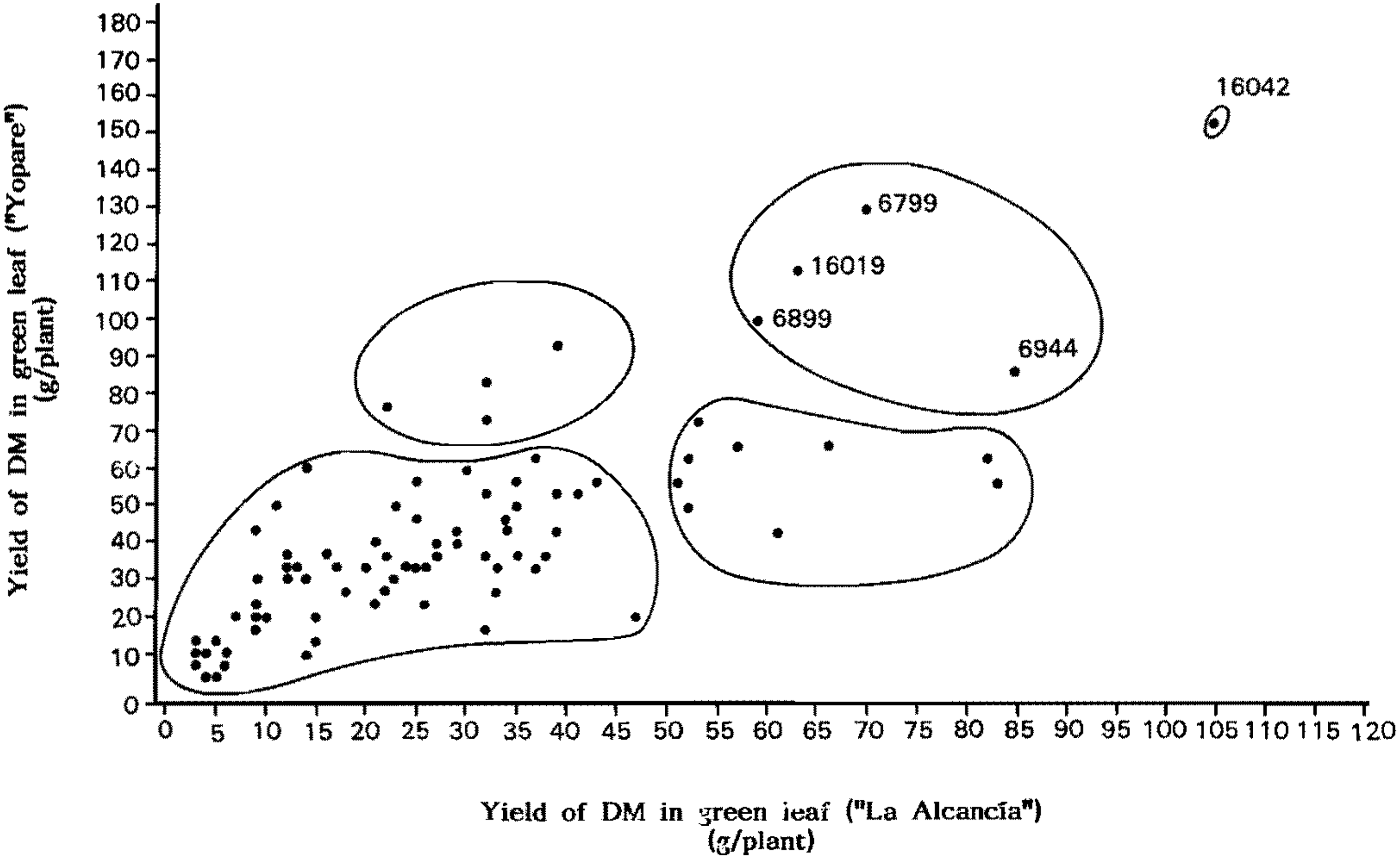


Fig. 1 Cluster groupings of accessions of P. maximum on the basis of yield of dry matter in green leaf at "Yopare" and "La Alcancia" sites at Carimagua.

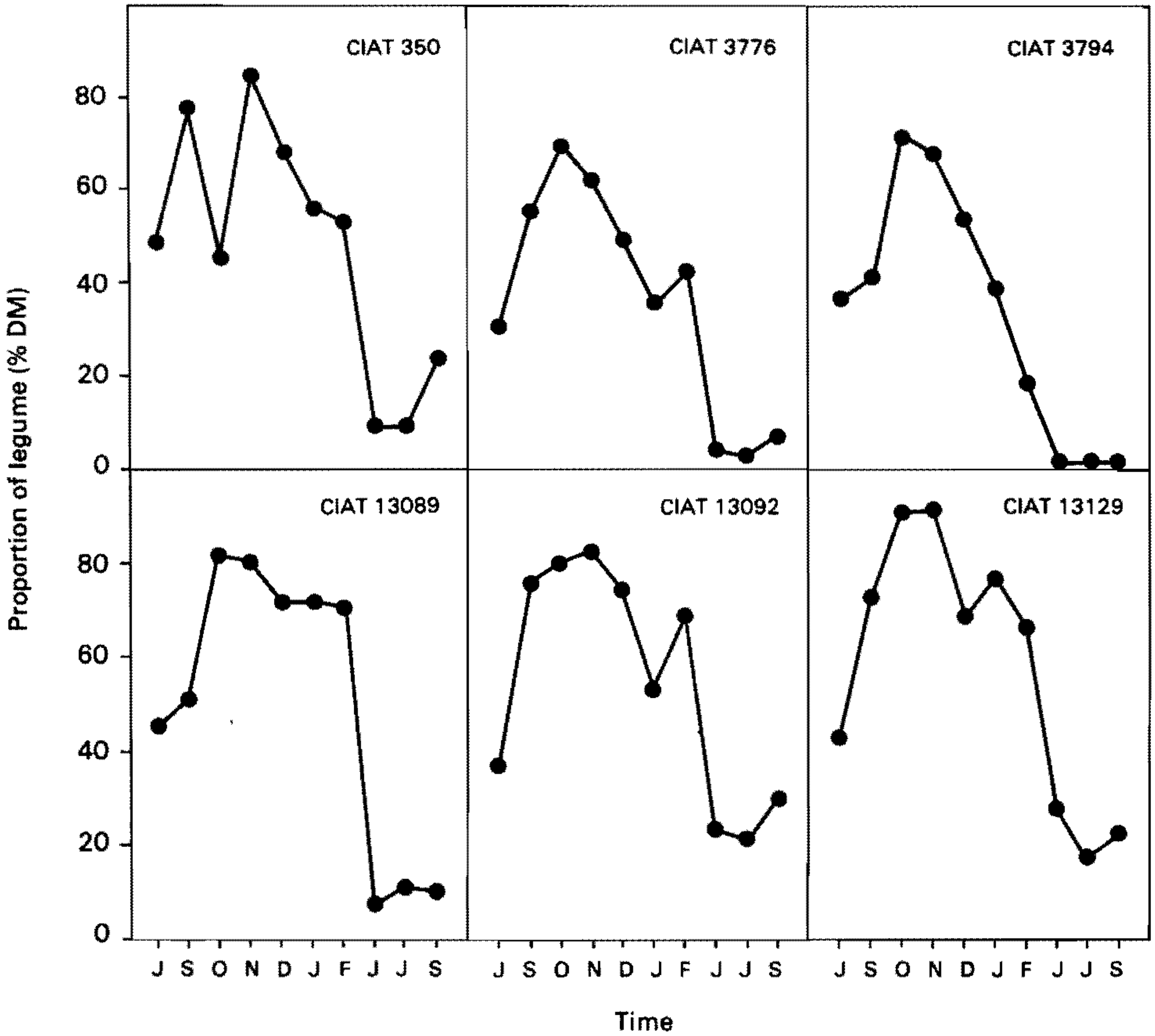


Fig. 2. Changes in legume content in six associations of B. dictyoneura and D. ovalifolium at Carimagua (mean of two grazing pressures).

Table 3. Yields of dry matter in green leaf (g/plant) in some promising accessions of *P. maximum* at "Yopare" and "La Alcancía" sites at Carimagua.

CIAT No.	Type*	"Yopare" (g/plant)	"La Alcancía" (g/plant)	Mean (g/plant)
16042	GP	212	140	176
16019	GP	174	88	131
6944	GP	148	139	144
cv. Petrie	GP	54	30	42
6799	C	260	158	209
6899	C	142	75	109
cv. Common	C	66	22	44

* GP = Green Panic; C = Common
Two cuts (August and December 1987).

in the cases of accessions CIAT 3776 and CIAT 3794. The highest legume contents were noted in the associations containing CIAT 350, CIAT 13092 and CIAT 13129. There were no differences between grazing pressures. This decline in legume yield does not appear to be related to the incidence of pests and diseases. Despite artificial inoculation, there were essentially no nematode problems even in CIAT 350, whilst the incidence of False Rust was low to moderate. CIAT 13089 continued to be the most tolerant accession (Table 4).

The legume selected by esophageal-fistulated steers varied markedly during the year, and declined over time (Figure 3). Animals tended generally to select less *D. ovalifolium* than appeared in the sward in all treatments. However, on average from August 1986 to July 1987, legume selection varied from 14 per cent at the low grazing pressure to 60 per cent at the high grazing pressure (Table 5). Across accessions, appreciably more legume was eaten at the high grazing pressure (where there was less opportunity for selection) than at the low grazing pressure.

Arachis pintoi

A. pintoi CIAT 17434 has shown considerable potential as a companion legume in associations containing vigorous species of *Brachiaria*. In October 1984, a trial was established in which the legume was associated with five accessions of *Brachiaria*, namely *B. humidicola* CIAT 679 (control), CIAT 6705, CIAT 6709, CIAT 6369 and *B. brizantha* CIAT 6294. Two grazing pressures are being imposed on the associations.

The changes in the proportion of legume in the four associations containing *B. humidicola* across grazing pressures are presented in

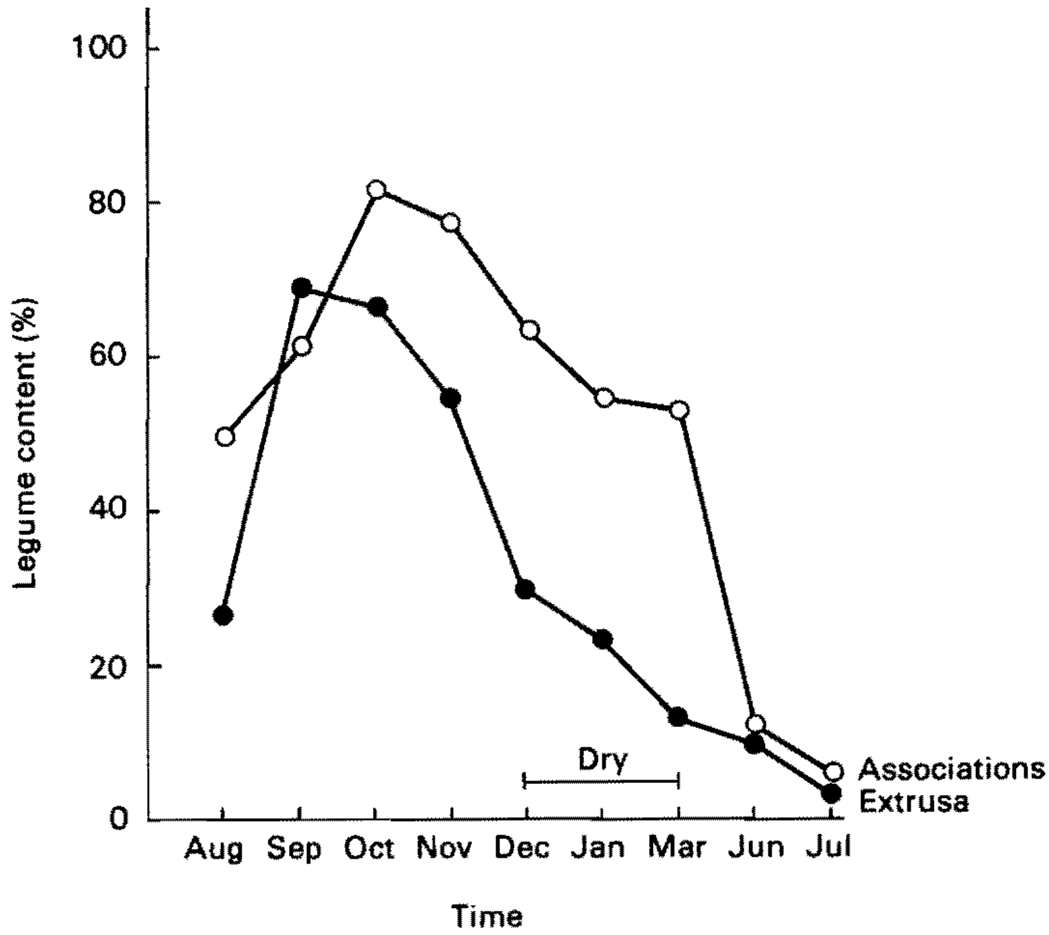


Figure 3. Changes in the proportion of legume in associations of B. dictyoneura and D. ovalifolium and in extrusa samples in Category III at Carimagua.

Table 5. Legume selected by fistulated steers in associations of B. dictyoneura and D. ovalifolium in Category III at Carimagua. August 2, 1986 - July 31, 1987.

CIAT	Grazing pressure High	Low	Mean
	Legume content (%)		
350	31	48	39
3776	24	31	28
3794	60	14	37
13089	40	19	30
13092	35	21	28
13129	51	41	46
Mean	41	29	

Table 4. The incidence of stem nematode and False Rust in accessions of *D. ovalifolium* with *B. dictyoneura* in Category III at Carimagua.

CIAT Accession No.	% Rows Affected				
	Stem Nematode Score	False Rust			
		0	1-2	3	4-5*
350	0	12	50	38	0
3776	0	0	87	13	0
3794	0	4	92	4	0
13089	0	23	77	0	0
13092	0	0	90	10	0
13129	0	0	76	24	0

* 0 = No symptoms; 1-2 = Low incidence; 3 = Moderate incidence; 4-5= High incidence.

Recorded 27 January 1987

Figure 4. *A. pintoi* continued to dominate the four associations. Only in the control, CIAT 679, was there a reasonable proportion of grass. There were no differences between grazing pressures. *B. humidicola* CIAT 679 is known to be of relatively low animal acceptability, and it is possible that the newer accessions may be of higher feeding value. Trials using animals in metabolism-crates are to be conducted to investigate this possibility.

Legumes in savanna

In June 1986 a trial was established in savanna with ten legumes (Table 6). Eight of these legumes, the exceptions being the controls *Centrosema acutifolium* and *C. brasilianum*, are known to be rather poorly consumed when grown with improved grasses of high acceptability. The purpose of the trial is to determine whether these species are better consumed when associated with poor quality native grasses. Establishment has been excellent and grazing will begin in December 1987. Species will be individually-grazed by esophageal-fistulated steers.

New plantings

A new Category III trial was established in June 1987 with nine

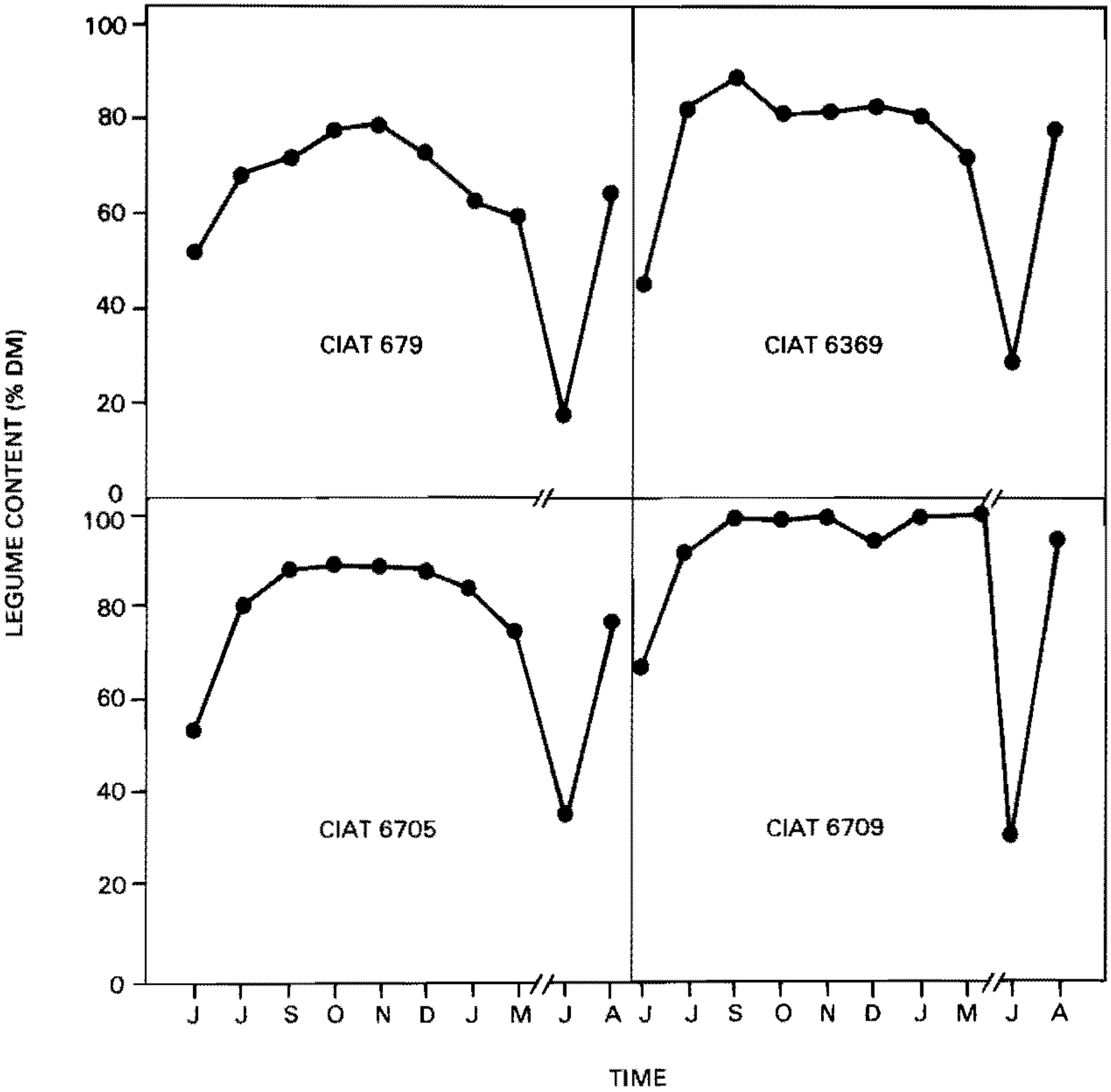


Figure 4. Changes in the proportion of A. pintoi CIAT 17434 in association with four accessions of B. humidicola at Carimagua.

Table 6. Legumes established in native pasture at the level of Category III at Carimagua.

Species	CIAT No.
Centrosema acutifolium	5277
Centrosema arenarium	5236
Centrosema brasilianum	5234
Desmodium incanum	13032
Desmodium strigillosum	13155, 13158
Desmodium velutinum	13204, 13213, 13215
Flemingia macrophylla	17403, 17407
Stylosanthes guianensis	2031
Tadehagi triquetrum	13276
Zornia glabra	8279

accessions of *Centrosema brasilianum* associated with *Andropogon gayanus* cv. Carimagua I and *Brachiaria dictyoneura* cv. Llanero. The accessions are CIAT 5234 (control), CIAT 5486, CIAT 5725, CIAT 5810, CIAT 5828 (all from Brazil); CIAT 5178, CIAT 5657, CIAT 5667 and CIAT 5671 (all from Venezuela). Seed was broadcast in 500 m^2 plots and establishment has been excellent. Low levels of Rhizoctonia Foliar Blight and Cylindrocladium Leaf Spot were observed in the *C. brasilianum* accessions and insect problems were negligible. Grazing will commence in 1988.

SEED MULTIPLICATION

Seed or vegetative material of a number of promising species continues to be produced for inclusion in future grazing trials (see Annual Report Tropical Pastures for 1986). Last season sufficient seed was produced of the nine *C. brasilianum* accessions to allow the new Category III trial to be sown. As much as 6 kg of seed was collected from some of the accessions.

4. AGRONOMY CERRADOS

Edaphically adapted legumes and grasses have already been identified for the Cerrados ecosystem. However, of the total number of legumes evaluated at CPAC prior to 1985, approximately 60% were accessions of Stylosanthes species. In addition, results of grazing experiments indicated the need for a wider range of legumes and grasses with better grazing tolerance. A broader range of genetic material of key species, including 12 species of Centrosema, was evaluated during the past two years. The current evaluation program at CPAC includes 351 legume accessions introduced in 1985/86 and 87 accessions of Centrosema spp. planted in 1986/87. The evaluation of 311 legumes established in 1984/85 was recently completed.

In the systematic search for new forage plants for the acid-infertile savannas of tropical America, emphasis at CIAT has been placed on the selection of adapted legumes. However, the low productivity and nutritive value of most of the native grasses, the high nutrient requirement of many commercial grass cultivars and the susceptibility of the widely grown B. decumbens to spittlebug make it necessary to concentrate on the search for suitable companion grasses as well.

At present, the genera Paspalum and Brachiaria are receiving special attention at CPAC. Species of Paspalum are particularly well adapted to poorly drained conditions and Brachiaria spp. have great economic significance in the acid-soil regions of Cerrados and cleared forest areas of Brazil. It has been estimated that approximately one half of the total area of thirty million hectares of improved pastures consists of Brachiaria species. A total of 322 accessions of grasses, including 287 accessions of 12 species of Brachiaria and 35 accessions of Paspalum spp. and a group of miscellaneous grasses, were established for preliminary characterization and evaluation during 1986/87.

Evaluation and characterization of Brachiaria spp.

In view of the high potential of Brachiaria species in the Cerrados, the evaluation of the collection at CPAC and subsequent testing of selected accessions in multi-locational trials is of primary importance. Two hundred and fifty-eight accessions were established at the Beef Cattle Center, Campo Grande, Mato Grosso do Sul.

Since the collection originated from a wide range of environmental situations, the enormous variability among accessions is not surprising. The 287 accessions were established at CPAC in replicated field plots during January and February, 1987. The objectives of Brachiaria species evaluation are: selection of superior accessions and development of cultivars adapted to the edaphic, climatic and biotic factors of the Cerrados.

Fifty-two percent of the collection presently under evaluation are ecotypes of Brachiaria brizantha, by far, the most promising and variable species in the collection. The majority of the accessions (87%) are erect or semi-erect plants. Approximately 50% of the total collection of this species is early flowering material. To date, no spittlebug damage was observed in the Brachiaria brizantha collection, although accessions of B. decumbens, B. ruziziensis and B. jubata were affected to various degrees. Some 26 accessions, including 19 of B. brizantha, were selected for further evaluation (Table 1).

Evaluation of Paspalum spp. in the várzea

Seasonally flooded lands with a high water table (várzea) constitute a significant portion of the Cerrados. It is estimated that there are 30×10^6 hectares of hydromorphic soils in Brazil with approximately 12×10^6 hectares of várzea situated in the Cerrados.

Paspalum is a large genus of more than 250 species distributed in the tropics and subtropics throughout the world. However, the majority of the species originates from the Americas. According to the literature most of the 160 species of Paspalum native to Brazil are acceptable to grazing animals. A collection of Paspalum spp. and other wet-land grasses was established in a small plot experiment in the várzea. This material was collected and supplied by Dr. J.F. Valls, curator of Gramineae at CENARGEN. Fifteen accessions of this collection were established in 3 randomized blocks for evaluation under a seasonal cutting regime. Samples were harvested for yield in periods of maximum and minimum precipitation during the year. The results showed that several accessions of Paspalum sp. aff. plicatulum are highly promising. Considerable variation was observed among these accessions in flowering date and seed yield. The high yielding and promising grasses were resistant to spittlebug and tolerant to seasonal flooding and a high water table (Table 2).

Table 1. Accessions of Brachiaria spp. selected at CPAC.

	CIAT No.		CIAT No.
B. brizantha	16107	B. brizantha	16307
B. brizantha	16121	B. brizantha	16311
B. brizantha	16128	B. brizantha	16315
B. brizantha	16253	B. brizantha	16318
B. brizantha	16168	B. brizantha	16319
B. brizantha	16288	B. brizantha	16339
B. brizantha	16294	B. brizantha	16467
B. brizantha	16301	B. brizantha	16473
B. brizantha	16306	B. brizantha	26110
B. decumbens	16488	B. decumbens	26181
B. decumbens	16500	B. serrata	16221
B. decumbens	26185	B. humidicola	26154
B. leucacrantha	16459		

Table 2. Dry matter yields (ton ha^{-1}) of 15 grass accessions produced during periods of maximum and minimum precipitation in a várzea at CPAC.

Species	BRA No.	Dry matter yields ton ha^{-1} Precipitation Maximum	Minimum
Paspalum sp. aff. plicatulum	009610	8.8a*	1.2 efg
P. urvillei	010686	7.6ab	1.7 cde
P. sp. aff. plicatulum	003913	7.6ab	1.6 def
P. sp. aff. plicatulum	009661	7.1abc	2.1 bcd
P. sp. aff. plicatulum	003638	6.8abc	1.0 fgh
P. urvillei	007323	5.8abcd	1.5 def
P. sp. aff. plicatulum	009431	5.7 bcd	1.4 ef
P. sp. aff. plicatulum	009628	5.1 cd	3.1a
Hemarthria altissima		5.1 cd	1.5 def
P. sp. aff. plicatulum	009407	4.0 d	2.5 b
P. sp. aff. plicatulum	008486	3.9 d	2.2 bc
P. oteroi	003905	1.5 e	0.7 ghi
P. pauciciliatum	003891	1.3 e	0.5 hi
P. modestum	006203	0.6 e	0.5 hi
Axonopus complanatus		0.4 e	0.4 i

* Mean values followed by a different letter are significantly ($P < 0.05$) different (Duncan's multiple range test).

Accessions of Paspalum sp. aff. plicatulum produced the highest dry matter yields during the wet season, the range for the November-March period (max. precipitation) was 3.8 to 8.8 t/ha (Table 2). A local a free seeding, self-propagating selection of P. urvillei also produced a high DM yield (7.6 t/ha). However, this accession was very stemmy in the "full seedhead" stage and at the time of sampling. Axonopus complanatus and other species of Paspalum produced low yields ranging from 0.5 t/ha to 1.5 t/ha in this experiment (Table 2).

Accessions of Paspalum sp. aff. plicatulum also produced high yields during the period of minimum precipitation. The range for the eight accessions was from 1.0 to 3.1 t/ha (Table 2). Considerable variability was observed in flowering date and seed yield, with early flowering accessions producing high seed yields. Mean yields of cleaned seed for five early flowering accessions of Paspalum sp. aff. plicatulum ranged from 214.4 to 917.6 kg/ha. Marked differences were observed in drought tolerance among species and ecotypes, and

Table 5. Chemical composition and *in vitro* digestibility (IVDMD) of 15 grasses in the dry season in a várzea in CPAC.

Species	BRA Accession No.	CP	Ca	P	Mg	K	IVDMD
		%					
Paspalum sp. aff. *plicatulum*	009661	8.6	1.16	0.17	0.98	0.93	55.8
Paspalum sp. aff. *plicatulum*	009628	7.1	0.38	0.12	0.46	1.45	40.1
Paspalum sp. aff. *plicatulum*	009610	8.4	1.13	0.18	1.04	1.20	51.8
Paspalum sp. aff. *plicatulum*	009431	9.5	1.09	0.17	0.97	1.30	50.5
Paspalum sp. aff. *plicatulum*	009407	7.6	0.73	0.15	0.59	1.39	41.1
Paspalum sp. aff. *plicatulum*	003913	7.4	1.01	0.16	1.06	0.89	55.0
Paspalum sp. aff. *plicatulum*	003638	9.0	0.97	0.17	0.75	1.12	45.1
Paspalum sp. aff. *plicatulum*	008486	7.1	0.65	0.14	0.80	1.46	49.1
P. urvillei	010685	7.8	0.44	0.16	0.35	1.33	50.6
P. urvillei	007323	7.9	0.38	0.16	0.50	1.26	46.7
P. pauciciliatum	003891	11.5	0.44	0.16	0.36	1.87	44.7
P. oteroi	003905	6.5	0.63	0.17	0.50	1.04	44.1
P. modestum	006203	5.2	0.40	0.09	0.36	0.75	48.9
Axonopus complanatus	n.a.*	8.2	0.51	0.18	0.42	1.23	44.3
Hemarthria altissima	n.a.*	8.6	0.32	0.18	0.48	1.18	53.1

* BRA numbers not available.

(CIAT 1122 x 1539), and 24-23 (CIAT 1639 x 1633).

Desmodium ovalifolium

In the second season following establishment, flowering and improved seed production were observed in a group of late flowering accessions of this legume. On the basis of these observations, 12 accessions were selected (CIAT 13081, 13087, 13088, 13089, 13090, 13103, 13104, 13111, 13113, 13114, 13132 and 13130).

Preliminary evaluation of Centrosema spp.

A total of 267 accessions of 12 species of *Centrosema* was established in October 1986. These include *C. acutifolium*, *C. arenarium*, *C. brasilianum*, *C. macrocarpum*, *C. pascuorum*, *C. pubescens* and *C. tetragonolobum*. Twenty-one accessions died during the observation period, mainly due to susceptibility to fungal leaf diseases, little leaf mycoplasma (LLM) or root knot nematode. Some species were badly affected by *Phoma* or *Phomopsis* and *Cercospora*; *Rhizoctonia* was also in evidence, although this disease caused relatively little damage. *C. rotundifolium* was more severely affected by *Rhizoctonia* than other species, and some damage was observed in accessions of *C. brasilianum* during the wet season. All 12 accessions of *C.*

Table 6. Accessions of S. guianensis var. pauciflora selected at CPAC.

Accession No.	Observations
CIAT 10287 (BRA 011542)	Erect, woody plant, first flower in February, mature plants defoliated.
CIAT 2708 (BRA 017591)	Erect, leafy type, first flowers in February, defoliated.
CIAT 2238 (BRA 035068)	Semi-erect, retained green leaves after maturity.
CIAT 2570 (BRA 017230)	Semi-erect, retained green leaves after maturity.
CIAT 10484 (BRA 028983)	Short, prostrate plant, defoliated.
CIAT 2684 (BRA 015971)	Semi-erect, retained green leaves after maturity.
CIAT 2769 (BRA 027839)	Large, sprawling plant, retained green leaves after maturity.
CIAT 2983 (BRA 027740)	Semi-erect, leafy after seed maturity.
CIAT 2511 (BRA 014001)	Semi-erect, defoliated.
CIAT 2974 (BRA 022381)	Erect, defoliated.

pascuorum were severely infected with root-knot nematode (Meloidogyne javanica) shortly after planting and all died before setting seed.

The most damaging disease on the dark-red latosol (LVE) site continued to be little leaf mycoplasma (LLM) of C. brasilianum. Practically all accessions of C. brasilianum were affected to some extent by LLM. The disease is severely reducing dry matter production and in most cases prevents seed setting, although it is not a problem under grazing. The least affected accessions were: C. brasilianum CIAT 5234 (BRA 006025), CIAT 5821 (BRA 006025), and CIAT 5234 x 5224 (BRA 006025 x 007145). Other Centrosema spp. are also affected by LLM including C. macrocarpum and C. pubescens, but not to the same extent as C. brasilianum. Of the recent introductions, two accessions (CIAT 15442, BRA 013412; CIAT 15443; BRA 013374) of C. tetragonolobum were less affected by LLM.

Flowering over a long period and good seed production was observed in C. brasilianum CIAT 15400 (BRA 013285), CIAT 15387 (BRA 013111), CIAT 15525 (BRA 013323), CIAT 15398 (BRA 013269).

In general, accessions of C. macrocarpum were more resistant to leaf diseases than other species of Centrosema. This species exhibited very good drought tolerance as well. Phoma/Phomopsis leaf spot was slight on C. macrocarpum but moderate to severe damage was observed on Centrosema acutifolium and C. pubescens.

The major problem with C. macrocarpum at CPAC is lack of flowering. The very few accessions that flowered in July failed to set seed. These were C. macrocarpum CIAT 15375 (BRA 012599), C. macrocarpum CIAT 15373 (BRA 012599), and C. macrocarpum CIAT 15376 (BRA 012599).

Excellent disease resistance but late flowering and poor seed production was recorded in C. acutifolium accessions CIAT 5287 (BRA 003221) and CIAT 15086 (BRA 012165). Centrosema acutifolium CIAT 15531 (BRA 009181) from Mato Grosso, remained green throughout the dry season and showed a high resistance to foliar diseases. Seed production, however, was light. Another group of late flowering and somewhat less productive, but highly disease resistant accessions of C. acutifolium (CIAT 15445 (BRA 013421), CIAT 15446 (BRA 013439) and CIAT 15447 (BRA 013447) originated from Amazonas, Venezuela.

Two accessions of Centrosema were selected for basic seed production; C. brachypodum CIAT 5850 (BRA 006572) and C. brasilianum CIAT 5234 x CIAT 5225 (BRA 012297). These accessions have shown field resistance to little leaf mycoplasma and produced high yields of seed. Small plots of each accession were established under irrigation in April 1987. C. brasilianum produced a good seed crop in spite of the late planting whilst little seed was produced by C. brachypodum.

Evaluation of Stylosanthes guianensis var. pauciflora under grazing

In December 1983, a small-scale grazing experiment was established on the LVE to evaluate 2 accessions of S. guianensis var. pauciflora CIAT 2243 (cv. Bandeirante) and CIAT 2245. Each legume was sown with A. gayanus cv. Planaltina, Brachiaria brizantha cv. Marandú and Panicum maximum CIAT 6116. The grass-legume treatments were combined factorially with two stocking rate treatments of 1.0 and 2.0 animals per hectare (low and high stocking rate (SR), respectively), obtained by adjusting plot size (high SR = 320 m^2 and low SR = 480 m^2). The design was a split-plot with associations as main-plots and SR as subplots. There were two replicates of each treatment. Plots were grazed by Gir cows, one per paddock, for 2 days every 3 weeks in the wet season and for 4 days every 6 weeks in the dry season. Grazing commenced in November 1984 and the experiment was terminated at the end of the dry season of 1987.

At 50 days after sowing both legumes averaged 8 plants per m^2. In the season following establishment, legume dominance was recorded in all treatments, except in the cv. Marandú - CIAT 2245 associations and in the high SR treatment. By May 1987 plant densities of CIAT 2245 were reduced to less than 5 plants per m^2 in both SR treatments and in association with all 3 grass species. An increase of cv. Bandeirante population was recorded at the low SR in association with P. maximum CIAT 6116. This grass has shown symptoms of extreme nutrient deficiency and a marked reduction in grass DM yield was recorded during the last two grazing seasons. At the end of the experiment legume contents were reduced at the high SR treatments in association with A. gayanus and P. maximum, and completely disappeared from associations with cv. Marandú at the high SR treatment (Table 7 and Figure 1).

Evaluation of C. brasilianum - grass associations

In December 1984 eight accessions of Centrosema, each legume in association with A. gayanus or Brachiaria brizantha cv. Marandú, were established for evaluation under grazing. The accessions were: C. brasilianum CIAT 5234, C. brasilianum CIAT 5523, C. brasilianum CIAT 5824, C acutifolium CIAT 5277, C. acutifolium CIAT 5568, C. pubescens x C. macrocarpum CIAT 5052 x 5062, and C. pubescens x C. macrocarpum CIAT 5189 x 5062 with A. gayanus.

The 16 treatment combinations were arranged in 2 randomized blocks and plot size was 250 m^2. The grazing

Table 7. Presentation dry matter yields (kg ha^{-1}) of 3 grasses grown in association with *S. guianensis* var. *pauciflora* cv. Bandeirante and CIAT 2245.

		Andropogon SR		Marandú SR		*P. maximum* SR	
		High	Low	High	Low	High	Low
S. guianensis cv. Bandeirante	11/84	2950(73)*	3930(79)	4220(80)	3680(84)	2940(71)	2640(57)
	05/85	2310(84)	3190(69)	3670(60)	3690(60)	2880(62)	3290(81)
	11/85	670(36)	2207(56)	1702(46)	1817(60)	1110(54)	2205(80)
	05/86	665(10)	2247(34)	1810(4)	3377(20)	1167(4)	1608(20)
	11/86	385(25)	590(18)	1047(0)	1000(1)	680(21)	565(24)
	04/87	1530(16)	1410(40)	2275(0)	2390(0)	1840(0)	1785(64)
S. guianensis CIAT 2245	11/84	3220(57)	2180(65)	2860(73)	2880(84)	3350(78)	2780(70)
	05/85	3190(82)	3160(67)	4440(26)	4040(75)	2530(66)	3130(78)
	11/85	1340(50)	2195(51)	2145(37)	3337(64)	1097(35)	2107(60)
	05/86	950(14)	3501(33)	2372(6)	2347(32)	790(15)	1985(58)
	11/86	545(4)	1377(24)	707(0)	1410(46)	365(29)	1845(70)
	05/87	2180(12)	1320(10)	2495(0)	2645(6)	1330(25)	2930(44)

* Values in parentheses are legume contents (% DM).

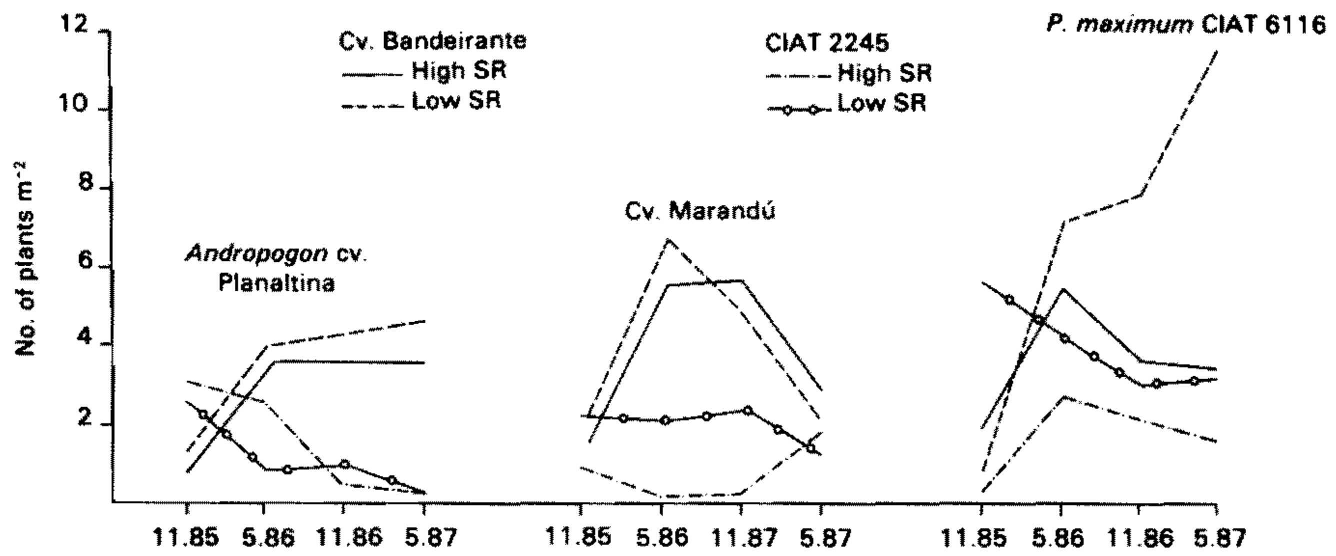


Figure 1. **Plant densities in *S. guianensis* var. *pauciflora* - grass associations grazed at two stocking rates (SR), 2 an/ha^{-1}, 1 an/ ha^{-1}. CPAC, Planaltina.**

schedule was one animal per plot for 2 days at 3-week intervals during the wet season and 4 days grazing by 1 animal at 6-week intervals during the dry season. The establishment of C. brasilianum accessions was good but stands of other species were poor. A higher legume content was observed in the associations with A. gayanus than with cv. Marandú.

The outstanding legume was C. brasilianum CIAT 5234; a high percentage of this legume was maintained in association with A. gayanus and periodic legume dominance occurred during the wet season when A. gayanus was preferentially grazed. The legume contents in the B. brizantha plots were initially 50 percent of those in the A. gayanus plots. In May 1987 only traces of legume were found in all other treatments. C. brasilianum CIAT 5234 was free from pests and diseases and has shown excellent drought tolerance remaining green during a 3 months dry period in 1987 (Table 8).

Evaluation of grass-legume associations in the várzea

Activities expanded in the várzea during 1987. A small-scale grazing experiment was established in this area in May, 1987. This trial comprises four selected accessions of each of the following legumes: Arachis pintoi (CIAT 18748 [BRA 015121], CIAT 18750 [BRA 015598], CIAT 18749 [BRA 015253], CIAT 17434 [BRA 013251]), Desmodium ovalifolium (CIAT 13085 [BRA 008389], CIAT 13110 [BRA 008157], CIAT 13137 [BRA 008141], CIAT 13289 [BRA 008168]), and Pueraria phaseoloides (CIAT 7182 [BRA 000582], CIAT 8042 [BRA 000612], CIAT 17300 [BRA 000761], CIAT 17320 [BRA 000817]). These legumes were planted in association with the following grasses: A. pintoi - B. dictyoneura (CIAT 6133 [BRA 001449]), A. pintoi - Paspalum sp. aff. plicatulum BRA 008486, D. ovalifolium - B. dictyoneura BRA 001449, D. ovalifolium - P. sp. aff. plicatulum BRA 008486, P. phaseoloides - Paspalum conspersum BRA 000159, P. phaseoloides - P. sp. aff. plicatulum BRA 001449.

Strong weed competition and invasion of some plots by a native Zornia species delayed establishment. However, a general improvement was observed at the end of the dry season. Accessions of Arachis pintoi exhibited excellent resistance to dry conditions in this situation.

Seed Production

Seed production of promising species was initiated during the season. One-hectare plots were established of cultivars Bandeirante and Pioneiro, S. capitata CIAT 1097 (BRA 005886), S. guianensis var. vulgaris CIAT 2950 (BRA 017817), Panicum maximum hybrid (BRA 008761) and Paspalum spp. aff. plicatulum (BRA 001449). The objective is to produce adequate amounts of seed for experimental work and on-farm validation trials. S. capitata CIAT 1097 (BRA 005886) was harvested in August with a combine-harvester. The area of 1.2 ha under this seed crop yielded 850 kg ha^{-1} of seed in the pod. The other species yielded smaller quantities of seed. The hybrid P. maximum yielded 16 kg ha^{-1} of clean seed. This guinea grass is a productive intermediate type and has a high leaf: stem ratio and excellent drought tolerance.

Eighteen accessions were planted between April 1 and May 15 (Table 9) for basic seed production in new area of LVE previously under wheat.

Supplementary irrigation was applied during the dry season. Good establishment was obtained at the first planting but emergence was variable due to low temperatures at the late planting. Seed of the C. brasilianum hybrid (CIAT 5234 x 5224) was hand-harvested in August/ September. The 3 x 10 m row-plot yielded 2.5 kg of clean seed. This accession is a

Table 8. Presentation dry matter yields (kg ha^{-1}) of 3 accessions of *C. brasilianum* in association with *A. gayanus* cv. Planaltina or *B. brizantha* cv. Marandú.

Legumes	A. gayanus				cv. Marandú			
	11/85	5/86	11/86)	5/87	11/85	5/86	11/86	5/87
C. brasilianum CIAT 5234	1130(60)*	2267(81)	955(66)	825(42)	1350(22)	1849(28)	547(27)	1025(7)
C. brasilianum CIAT 5523	1217(50)	1520(52)	712(41)	720(10)	1822(11)	1659(17)	769(2)	1410(3)
C. brasilianum CIAT 5824	1540(29)	1297(41)	635(1)	785(10)	1557(5)	1762(7)	480(5)	920(-)

* Values in parentheses are legume contents (% DM).

Table 9. Basic seed multiplication during 1986/87.

Plot No.	Species	CIAT accession No.	BRA	Plot size
1	D. ovalifolium	13103	007994	2 x 10 m
2	P. phaseoloides	17283	000697	2 x 10 m
3	D. ovalifolium	13130	008095	3 x 10 m
4	P. phaseoloides	17300	000761	3 x 10 m
5	S. capitata hybrid 56(EMH)*	-	-	3 x 10 m
6	D. ovalifolium	13104	008001	84 plants
7	S. capitata	10396	029084	3 x 10 m
8	D. ovalifolium	13135	008125	2 x 10 m
9	C. arenarium	5850	006572	22 plants
10	C. brasilianum hybrid	5234 x 5224	012297	42 plants
11	S. guianensis var. canescens (?)	10993	032826	3 x 10 m
12	D. ovalifolium	13110	008257	15 x 10 m
13	S. guianensis var. vulgaris	10926	031879	3 x 10 m
14	P. phaseoloides	7182	000582	17 x 10 m
15	D. ovalifolium	3266	007650	3 x 10 m
16	P. phaseoloides	17320	000817	17 x 10 m
17	D. heterocarpon	13178	008478	22 x 10 m
18	D. strigillosum	13156	008613	22 x 10 m

* Breeder's number.

particularly heavy seed producer and to date no LLM was observed in this plot. Multiplication plots of four accessions of Arachis pintoi were sampled for seed. Dehulled seed yields were in excess of 1 t ha^{-1}.

Regional Trials

Of the 12 regional trials established in 1983, 10 were concluded during the year and the remaining two at Vilhena (Rondonia) and Araguaina (Goiás) will be terminated shortly. The findings may now be summarized. Adapted species have been identified for a wide range of environmental conditions within latitudes 3°N and 22°S. Unquestionably, the key species for the low fertility, sandy soils of the northern Cerrados is Stylosanthes capitata. The best over-all performance was exhibited by S. capitata CIAT 1097 (BRA 005886) and CIAT 1019 (BRA 007257). Both accessions of S. capitata are free seeding types and production appears to be good in spite of attacks by bud-worm (Stegasta bosquella). S. capitata CIAT 1097 (BRA 005886) has been proposed for release in the coming year. The highly successful seed multiplication project for accession CIAT 1097 will facilitate the early commercial release of this promising species.

The performance of accessions of S. guianensis var. pauciflora has been variable at the different testing sites. Susceptibility to pests and diseases has been responsible for poor survival at some sites. In general, accessions CIAT 2245 and 1095 appear to be better in terms of persistence than the control cv. Bandeirante. On sandy soils at Boa Vista (Roraima), CIAT accessions 1095, 2191 and 2245 were the best. At Macapá CIAT 1095, 2203 and cv. Bandeirante were the superior accessions and CIAT 2245 was badly affected by anthracnose. In Piaui, CIAT 2244 was the best of the six accessions tested.

Accessions of S. macrocephala are even more restricted in their range of adaptation. Stand losses of 75% due to anthracnose were recorded even with one of the best accessions (CIAT 2039) in the northern Cerrado region.

The following ERB - Trials are planned for 1987/88:
Type B trials are planned for 1987/88 at Macapá, Amapa (UEPAT, Macapá); Goiania, Goiás (Universidade de Goiás), Lucas do Rio Verde (EMPA); Rondonópolis, Mato Grosso (EMPA); Canarana, Mato Grosso (EMPA); Campo Grande, Mato Grosso do Sul (CNPGC); Planaltina, DF (Colegio Agricola de Brasilia); Belém, Pará (CPATU) (Tables 10 and 11). Type C trials are also planned for 1988/89 in Amapá, Roraima and Mato Grosso do Sul.

Plans have been finalized to establish regional trials A and B in Paraguay and Bolivia. Contacts were made with MAG in Paraguay and in Bolivia with the Centro de Investigación Agrícola Tropical, Santa Cruz, and the Universidad Técnica del Beni. Planting materials supplied to ERA Paraguay and Bolivia are listed in Tables 12 and 13. In addition to a collection of East-African clovers, selected accessions of Brachiaria spp. (see Table 1) were sent to MAG, Paraguay.

Table 10. List of species for ERB trials in Brasil.

Treatments	CIAT	BRA
Stylosanthes guianensis var. vulgaris	2950	017817
S. guianensis var. vulgaris	2953	019097
S. guianensis var. pauciflora	1808	015628
S. guianensis var. pauciflora	2078	008150
S. guianensis var. pauciflora	2982	022861
S. guianensis var. pauciflora	2326	011932
S. guianensis var. pauciflora	1317	001333
S. macrocephala	2133	008419
S. macrocephala	10007	022781
S. macrocephala	10009	022837
S. viscosa	2903	022519
S. capitata No. 56*		
Centrosema brasilianum	5234	006025
Centrosema hybrid (C. pubescens x C macrocarpum)+		
Centrosema sp.** 343	-	009181
Centrosema sp. 352	-	009211
Centrosema sp. 354	-	009229
Centrosema sp. 372	-	009237
Panicum maximum	-	008826
Panicum maximum	-	008761
Panicum maximum	-	008788
Paspalum conspersum	-	000159
Paspalum sp. aff. plicatulum	-	001449

* Breeder's number (EMH) ** CNPGC No.'s. + CPAC No. 2519 (EMH) (BRA No.not available)

Table 11. Seed or vegetative material of *Brachiaria* spp. supplied to CPATU.

Species	BRA	CIAT
Brachiaria brizantha	002780	16119
Brachiaria brizantha	002917	16135
Brachiaria brizantha	002941	16142
Brachiaria brizantha	003051	16155
Brachiaria brizantha	003131	16164
Brachiaria brizantha	003271	16297
Brachiaria brizantha	003301	16300
Brachiaria brizantha	003387	16308
Brachiaria brizantha	003506	16322
Brachiaria brizantha	003735	16443
Brachiaria brizantha	003760	16448
Brachiaria brizantha	003816	16455
Brachiaria brizantha	004227	16829
Brachiaria brizantha	004235	16830
Brachiaria brizantha	002739	16113
Brachiaria brizantha	002861	16127
Brachiaria brizantha	n.a.*	16132
Brachiaria brizantha	002895	16133
Brachiaria brizantha	002976	16145
Brachiaria brizantha	003212	16289
Brachiaria brizantha	003298	16299
Brachiaria brizantha	003450	16316
Brachiaria brizantha	003468	16317
Brachiaria brizantha	003891	16467
Brachiaria decumbens	004553	26181
Brachiaria decumbens	004472	16497
Brachiaria decumbens	004529	16502
Brachiaria decumbens	004570	26185
Brachiaria decumbens	004651	26295
Brachiaria decumbens	004669	26296
Brachiaria ruziziensis	005541	16551
Brachiaria ruziziensis	005657	26180
Brachiaria humidicola	004812	16180
Brachiaria humidicola	004863	16867
Brachiaria humidicola	005126	26154
Brachiaria brizantha	002691	16107
Brachiaria brizantha	002801	16121
Brachiaria brizantha	002917	16135
Brachiaria brizantha	003158	16168
Brachiaria brizantha	003247	16294
Brachiaria brizantha	003310	16301
Brachiaria brizantha	003441	16315
Brachiaria brizantha	003476	16318
Brachiaria brizantha	003484	16319
Brachiaria brizantha	003638	16339
Brachiaria brizantha	003891	16467
Brachiaria brizantha	003948	16473
Brachiaria brizantha	004219	16827
Brachiaria brizantha	004300	26110
Brachiaria brizantha	004391	16488
Brachiaria brizantha	004502	16500
Brachiaria leucacrantha	005886	16549
Brachiaria humidicola	005126	26154

* BRA No. not available.

Table 12. List of species for ERA trials in Paraguay.

East African clovers - ERA, Paraguay	ILCA No.
Trifolium quartininianum	6300
Trifolium quartinianum	7675
Trifolium quartinianum	9428
Trifolium steudneri	9712
Trifolium steudneri	7637
Trifolium steudneri	9720
Trifolium decorum	6272
Trifolium decorum	6264
Trifolium decorum	7776
Trifolium rueppellianum	9690
Trifolium rueppellianum	9369
Trifolium rueppellianum	6218
Trifolium tembense	7102
Trifolium tembense	9681
Trifolium mattirolianum	6293
Trifolium mattirolianum	8406
Trifolium pichisermallii	8227
Trifolium pichisermallii	9960
Trifolium polystachyum	6298
Trifolium polystachyum	10220

Table 13. List of species sent to Bolivia - ERA.

Species	BRA
Panicum maximum	008761
Panicum maximum cv. Tobiata	
Panicum maximum cv. Coloniao	
Paspalum guenoarum	010707
Paspalum conspersum	000159
Paspalum sp. gr. *plicatula*	009610
Brachiaria brizantha	005591
Brachiaria humidicola	001546
Brachiaria dictyoneura	001449
Andropogon gayanus cv. Planaltina	000019
Stylosanthes capitata hybrid No.56 (EMH)	
Stylosanthes capitata	005886
Stylosanthes guianensis	035068
Stylosanthes guianensis cv. Bandeirante	003671
Stylosanthes guianensis (cv. Mineirao	017817
Stylosanthes guianensis	017230
Stylosanthes guianensis	015628
Desmodium ovalifolium	008401
Desmodium ovalifolium	008419
Pueraria phaseoloides	000582
Arachis pintoi	013251
Leucaena leucocephala cv. Cunningham	000027
Cajanus cajan	
Centrosema brasilianum hybrid	012297

5. AGRONOMY HUMID TROPICS

The principal objective of the INIPA/IVITA/CIAT collaborative project is the selection of legumes and grass germoplasm adapted to the humid tropic conditions, for the recovery of degraded areas through highly productive and established pastures. The studies are being carried out in the IVITA Experimental Station, near Pucallpa, Peru. The region's ecosystem is Tropical Forest Semi-evergreen Seasonal. The annual average temperature is 25.1 C and the annual average precipitation is of 1770 mm; its distribution is shown in Figure 1. Ultisols are the zone's typical soils. The soil's physical and chemical characteristics where germplasm evaluations are undertaken, are presented in Table 1.

The evaluations during 1987 included 486 legume accessions and 89 grass accessions (Table 2). None of the experiments have been concluded, thus, the information presented is still preliminary.

The year of 1987 has been extremely dry as shown on Figure 1. Water stress affected germplasm behaviour, causing defoliation, particularly in Zornia spp., Desmodium heterophyllum, Arachis pintoi and Pueraria phaseoloides collections.

Agronomic evaluation of legumes and grass germplasm (Category II)

This evaluation category is carried out in small plots to select legumes

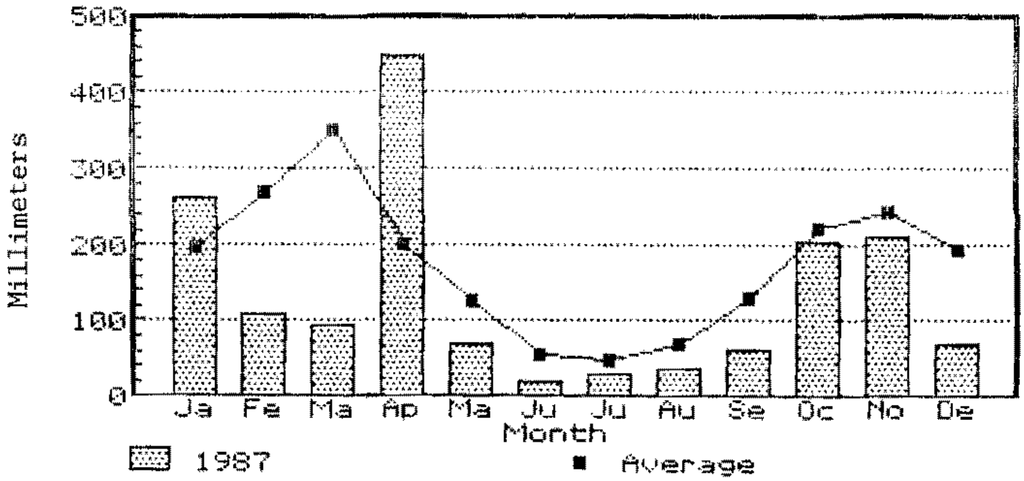


Figure 1. Climatic characteristics of the region of Pucallpa, Peru. (Source: Reyes, C. and Ordoñez, H., 1985).

Table 1. Physical and chemical characteristics of the soil (0-20 cm) for forage germplasm evaluation, IVITA Experimental Station, Pucallpa, Peru.

Clay	Mud	Sand	pH	DM	P	Interchang.Cations (meq/100g)				Al Sat.	S
---------%----------				%	ppm	Al	Ca	Mg	K	%	ppm
48	33	19	4.5	1.8	2.1	4.4	0.70	0.28	0.09	80	12

Table 2. Forage germplasm under Category II evaluation level during 1987.

Species	No. of accessions
LEGUMES	
Arachis pintoi	8
Centrosema acutifolium	22
Centrosema brasilianum	23
Centrosema macrocarpum	137
Desmodium heterophyllum	20
Desmodium ovalifolium	82
Leucaena leucocephala	22
Pueraria phaseoloides	75
Stylosanthes guianensis	18
Zornia glabra	23
Zornia latifolia	14
Zornia spp.	36
Especies varias	6
Total legumes	486
GRASSES	
Andropogon gayanus	1
Brachiaria spp.	65
Panicum maximum	23
Total grasses	89
TOTAL ACCESSIONS	575

and grasses adaptable to environmental conditions. Evaluations on plant vigor during the establishment, pests and disease resistance, dry matter yields, flowering period and seed production were carried out in plots with 575 accessions (see Table 2).

Desmodium ovalifolium

Most of the 82 accessions showed good vigor and adaptation to the ecosystem. Table 3 gives a preliminary characterization of the collection based on 1987 dry matter yields during the minimum and maximum precipitation periods. and shows considerable variability between accessions. The most vigorous accessions in the rainy season, including CIAT 350, were classified in clusters 2 and 4. Nevertheless, accessions in cluster 4 reduced their yield in a more drastic manner than group 2 materials during the minimum precipitation period. In the entire collection, reduction in production has been large during the dry season.

In the middle of the maximum precipitation season, various accessions showed little vigor in combination with unequal growth between plants of the same plot. This phenomenom was related to the presence of the root's node nematode detected in 12 accessions of clusters 5, 6 and 7,

Table 3. Preliminary characterization of 82 Desmodium ovalifolium accessions through cluster analysis based on 1987 dry matter yields during two precipi- ion seasons (experiment not concluded).

Cluster (R^2=0.90)	Accessions CIAT No.	DM yields g/m^2/3 months			
		Mx precipitation		Mn precipitation	
		Average	Range	Average	Range
1	3607- 3781- 3784 13093-13096-13103 13104-13118-13125 13133-13136-13137 13139-13648	369	(351-387)	104	(77-160)
2	13090-13111-13121 13124-13126-13127 13131-13132-13135 13302-13647	428	(401-458)	124	(111-162)
3	3652- 3663- 3666 3673- 3674-13089 13094-13100-13102 13105-13106-13107 13116-13289-13651 13654	409	(377-444)	73	(39-102)
4	350- 3608-13088 13092-13113-13129 13130-13400-13653	492	(460-535)	104	(67-161)
5	3668- 3776- 3793 3794-13081-13082 13083-13095-13097 13098-13099-13122 13128-13134-13305 13307-13649	331	(277-368)	74	(22-117)
6	3778- 3780-13030 13085-13091-13101 13108-13109-13115 13117-13120-13370	235	(204-263)	56	(33-97)
7	3788-13110-13114	165	(147-179)	46	(37- 61)

Table 4. Group of 20 *Desmodium heterophyllum* accessions through cluster analysis based on 1987 dry matter yields and plant height during the maximum and minimum precipitation seasons.

Cluster (R^2=0.94)	Accessions CIAT No.	DM yields (g/m^2/3 meses) Mx ppt. Average	Range	Mn ppt. Average	Range	Plants height (cm) Mx ppt. Average	Range	Mn ppt. Average	Range
1	3774- 3779- 3782- 3783 3789- 3791- 3792-13190 13191-13197-13200-13202 13203	12	(0- 35)	2	(0- 8)	4.4	(2.8- 7.9)	4.8	(3.9- 6.4)
2	349-13192-13196-13198	75	(59- 96)	7	(5-13)	12.9	(8.9-16.9)	8.1	(5.9-11.3)
3	13194-13195-13383	148	(131-171)	13	(10-18)	21.3	(18.8-23.3)	10.9	(9.7-12.8)

with only one exception. CIAT 3788 was the most affected accession in spite of having been promising during the year of establishment. Nevertheless, most of the affected accessions have recovered from this problem. In general, the collection did not show other problems of diseases and pests.

It is well known that this species does not have good acceptance by the cattle. Thus, an evaluation on relative preference will be done in 1988 in order to obtain another important criterion for material selection besides the one pertinent to its general adaptation.

Desmodium heterophyllum

Most of the 20 accessions of this collection had a very low production of dry matter. Table 4 shows a group of accessions based on dry matter yields and plant height attained in the minimum and maximum precipitation seasons. In conglomerate 1, very prostrated growth accessions are found with extremely low production of dry matter. In the maximum precipitation season, CIAT accessions 13194, 13135 and 13383 (cluster 3) of semi-bunch growth had superior yields to those of the witness cv. Johnstone (CIAT 349). Nevertheless, its productivity was also very low in the minimum precipitation season when strong defoliation ocurred. In general, the recovery of accessions in the rainy season was very slow. Regarding diseases, there was a low foliar blight occurrence in the entire collection caused by Rhizoctonia sp.

Centrosema macrocarpum

This species continued to stand out because of its generally good adaptation to the ecosystem. The 137 accessions did not show considerable leaf loss during the severe dry season of 1987. Flowering and seed production were better than those of the previous year. There is a group of 13 accessions that combine good dry matter yields with high seed production potential. There were only 7 accessions that did not produce any seed at all. Foliar blight because of Rhyzoctonia, foliar stain because of Cercospora and leaf eaters were observed in the collection but its incidence was in general low.

Centrosema acutifolium

This year, flowering begun earlier and was more abundant than that of the previous year. Most of the accessions begun flowering in April and May, while a few accessions, CIAT 5897 among them, initiated their flowering in March. Flowering ended in July when most of the accessions had their maximum seed production. CIAT accessions 5112, 5277, 5564, 5610, 5897 and 15086 showed a high seed production potential in combination with good dry matter yields. During the rainy season, foliar blight because of Rhyzoctonia was detected in all the of the accessions; nevertheless, in general, a good recovery was registered shortly after infestation.

Centrosema brasilianum

CIAT accessions 5657, 5671, 15387 and 15524 had superior dry matter yields. Besides, their susceptibility to foliar blight because of Rhyzoctonia was from low to moderate, showing good capacity to recover from the damage caused by this fungus.

Flowering mainly occured from March till August, reaching a maximum in the month of June. Seed production considerably varies between accessions.

Pueraria phaseoloides

Most of the accessions proved to be vigor during the maximum precipitation season, but their dry matter production declined drastically in the minimum precipitation season when notable defoliation was observed. The collection showed considerable differences regarding dry matter production (Table 5). During the maximum precipitation season, accessions in clusters 6 (outstanding) and 2, and in a lower level, 3, had greater yield than the witness (CIAT 9900), nevertheless, in the minimum precipitation season, the differences between these groups were not as sharp.

There was a slight foliar stain occurrence because of Cercospora, and some accessions showed Rhyzoctonia symptoms or anthracnose in 81% of the collection. In regard to insects, leaf eaters were observed in the entire collection with slight to moderate damage in most of the accessions.

Flowering mainly begun in May and June, and for some accessions in April and July. The maximum flowering was observed in July and its end in September. In general, flowering was abundant, but seed production was extremely low in 59 accessions due to an excessive abortion of flowers. 16 of the 75

Table 5. Preliminary classification of 75 Pueraria phaseoloides accessions through cluster analysis, based on 1987 dry matter yields during maximum and minimum precipitation seasons (experiment not concluded).

Clusster (R^2=0.91)	Accessions CIAT No.	DM yields (g/m^2/3 months)			
		Min. precip. Average	Range	Max. precip. Average	Range
1	8042- 8047- 8171- 9021- 9900 17278-17279-17287-17291-17296 17300-17301-17311-17315-17316 17322-17324-17327-17433-18034	123	(98-140)	41	(13-74)
2	736- 7182- 8352- 9261-17283 17284-17292-17295-17303-17310 17321-17325-17765	203	(179-218)	41	(23-52)
3	744- 815- 829- 7978- 9020 9188- 9279-17285-17286-17288 17290-17293-17302-17305-17308 17314-17320-17323-17326-18029	164	(152-183)	52	(19-88)
4	4600- 8834-17281-17298-17304 17307-17328-18030-18031-18032 18038-18380	65	(48- 84)	32	(0-55)
5	17282-18028-18033-18037-18039 18378	27	(19- 37)	15	(0-37)
6	7979-17297-17466-17766	271	(246-303)	53	(38-71)

evaluated accessions did not have any seed production at all.

Arachis pintoi

Vigor of the 8 evaluated accessions decreased drastically during the minimum precipitation season. Nevertheless, CIAT accessions 17434 (control), 18747, 18748 and 18752 showed less defoliation than the others and showed to be faster in their capacity to regrowth from the stolons with the beginning of rains. In the maximum precipitation season, CIAT 18747, followed by 17434 and 18752, proved to be the most vigor accessions. A slight incidence of foliar stain because of Cercospora and foliar blight because of Rhyzoctonia was observed in all of the accessions.

Leucaena leucocephala

During the year of establishment, none of the accessions showed an adaptation acceptance to the edaphic conditions.

Zornia glabra

Regarding vigor and general adaptation, the collection proved to be excellent in the maximum precipitation season. Vigor decreased considerably in the minimum precipitation season. In a cutting effected during the dry season, none of the accessions were significantly superior to the witness in regard to the dry matter yields. A strong defoliation was caused because of the prolonged absence of rains. CIAT accessions 235, 286, 7847, and 8348 appeared among the most resistant to drought. With the exception of CIAT 8858 which morphologically differs from the other accessions, the entire collection recovered rapidly with the first rains, and a good germination of fallen seeds was observed. During the maximum precipitation season, in most of the collecion, there was slight ocurrance of foliar stain symptoms due to Drechslera, foliar blight due to Rhyzoctonia and COSTRA due to Sphaceloma. Major problems because of insects were not encountered.

Zornia latifolia

In general, the accessions of this species showed less vigor and adaptation than most of those in the Z. glabra collection. The damage due to suckers was common in all of the collections and these caused greater damage during the maximum precipitation season in CIAT accessions 728 (control), 9282 and 14053. In regard to diseases, foliar stain due to Drechslera and COSTRA due to Sphaceloma, caused slight damage in the collection, while foliar blight due to Rhyzoctonia was registered in 10 accessions without observing major damage. The dry season caused notable defoliation. CIAT 8049 and 8417 disappeared but recovered with rains because of the germination of fallen seeds. CIAT accessions 7690, 7772, 9225 and 9226 were more tolerant to drought.

Zornia spp.

Great morphological variability was observed in this collection. Nevertheless, the dry matter production potential was considered very low in most of the accessions. Foliar stain due to Drechslera has been detected in the entire collection and with a few exceptions, foliar blight due to Rhyzoctonia and COSTRA due to Sphaceloma. Leaf eaters and suckers were registered in all of the accessions. A strong defoliation ocurred in most of the accessions during the minimum precipitation. The accessions most tolerant to drought included CIAT 7196, 9915, 9925, 9926, 14070 and 14073.

Before effecting selection of the most adapted accessions of the 3 Zornia collections, a study should be

Table 6. Characterization of 23 *Panicum maximum* accessions through cluster analysis based on soil covering and foliage height after 4 months of establishment.

Cluster (R^2=0.85)	Accessions CIAT No.	Coverage (%)		Foliage height (cm)	
		Average	Range	Average	Range
1	689-6106-6118-6140 6172-6175-6567-6798 6799-6822-6860-6900 6907-6947	79	(68-93)	97	(80-113)
2	6836-6967-16022	45	(42-49)	87	(79- 98)
3	6176-6534-16065	68	(62-73)	57	(46- 69)
4	6179-6922	34	(27-42)	44	(43- 45)
5	6863	74	(74)	148	(148)

considered on the relative cattle palatability.

Panicum maximum

In this collection of 23 accessions that include the Makueni, Uganda and Enana Peluda cultivars, exists morphological variation regarding height, foliage abundance, stem and leaf pubescens, leaf size and a number of inflorescences. Table 6 shows a group of the accessions according to their covering of the soil and foliage height, 4 months after the establishment, and reflects a part of the morphologic variability. Slight symptoms of *Cercospora* have ocurred in the entire collection.

Brachiaria spp.

The collection includes 65 accessions of 9 *Brachiaria* species, mainly of *B. brizantha*, *B. decumbens*, *B. humidicola* and *B. jubata*. Morphologic variability was observed between accessions within species regarding plant height, leaf pubescence and size, and stoloniferous capacity. During the establishment phase that has recently ended, differences regarding the celerity of covering the soil were encountered, being outstanding some *B. humidicola* and *B. decumbens* with a very postrated growth habit. Attack of the spittlebug was not observed. The collection will be complemented during 1988 with approximately 300 more accessions that were introduced in 1987 as meristems and spreaded cultivations.

Agronomic evaluation of germplasm under the African Palm

The objective of this evaluation is to select germplasm under shade conditions for its use as a covering cultivation on plantations or in silvopastoril systems.

The experiment, that has the design of a regional B trial; includes 24 accessions of 11 legumes species and 9 accessions of 8 grass species. During 1986, evaluations regarding establishment were effected, and in January of 1987, production evaluations begun. Tables 7 and 8 show the behavior of legumes and grasses, behaviour, respectively, in relation to their production of dry matter during 12 weeks in the minimum and maximum precipitation seasons. The dry matter yields of all of the accessions in the minimum precipitation season were much lower than those attained in the maximum precipitation season, which reflects the intensity of the dry season in 1987. Among the legumes, the most productive accessions in both seasons included Desmodium ovalifolium CIAT 350, Centrosema macrocarpum CIAT 5065, 5452, 5713, 5735 and C. acutifolium CIAT 5112. On the other hand, D. heterophyllum CIAT 349, promising during the establishment, lost its vigor after the first cutting. So did D. heterophyllum CIAT 3782, and accessions of C. pubescens CIAT 413, 438, 5126 and 5189 were the legumes with the lowest dry matter yield. The C. pubescens accessions showed high susceptibility to Cercospora. Among grasses, there were no significant differences between accessions, during the minimum precipitation season. Nevertheless, during the maximum precipitation season, Brachiaria brizantha CIAT 6780 and Andropogon gayanus CIAT 621, outstanded as the most productive accesions.

Germplasm evaluation under grazing (Category III)

The main objective in this evaluation category is the study of the persistence and compatibility under grazing, of promising grass and legume associations.

Planting of the following associations was carried out in March of 1987: 1) Brachiaria dictyoneura CIAT 6133 cv. Pasto Llanero, with Centrosema macrocarpum CIAT 5674-5735; 2) B. dictyoneura CIAT 6133 with Desmodium ovalifolium CIAT 350; and 3) B. brizantha CIAT 6780 cv. Marandú with C. macrocarpum CIAT 5674- 5735. The establishment of the associations was affected by a very prolonged absence of rains and by the attack of an unidentified worm that appeared abundantly in May, causing damage particularly in the seedlings of the 2 grassses and those of D. ovalifolium. Regardless, during the present rainy season, the associations are in a recovery process. Grazing will begin in 1988. Three livestocks will be used at 2, 3 and 4 UA/ha in a rotational grazing system with 6 days of occupation and 30 days of rest.

Seed multiplication

Seed multiplication of promising germplasm for future research begun in 1987. Up to this date, this activity includes various accessions of Arachis pintoi, Centrosema acutifolium, C. macrocarpum and Pueraria phaseoloides, and it will be increased in 1988, when more information of the present experiments in Category II is available for the selection of accessions.

Table 7. Dry matter production of 24 legumes accessions under Palma Africana shade conditions (first year of evaluation).

Species	CIAT No.	DM yield kg/ha/12 weeks Mn precipitation	Mx precipitation
Arachis pintoi	17434	121 cde[1)]	507 defghi
Centrosema acutifolium	5112	258 abcd	843 abcd
Centrosema acutifolium	5277	221 abcde	656 bcdefgh
Centrosema acutifolium	5568	83 de	667 abcdefgh
Centrosema brasilianum	5234	148 bcde	525 defghi
Centrosema brasilianum	5671	108 cde	324 ghi
Centrosema brasilianum	5810	132 bcde	561 cdefghi
Centrosema macrocarpum	5065	310 abc	964 ab
Centrosema macrocarpum	5452	278 abcd	817 abcdef
Centrosema macrocarpum	5713	266 abcd	932 abc
Centrosema macrocarpum	5735	356 a	836 abcde
Centrosema pubescens	413	45 e	297 hi
Centrosema pubescens	438	45 e	283 hi
Centrosema pubescens	5126	68 de	310 hi
Centrosema pubescens	5189	88 de	395 ghi
Desmodium heterophyllum	349	22 e	220 i
Desmodium heterophyllum	3782	11 e	208 i
Desmodium ovalifolium	350	333 ab	1043 a
Desmodium ovalifolium	3788	210 abcde	787 abcdef
Flemingia macrophylla	17407	154 abcde	452 efghi
Pueraria phaseoloides	9900	80 de	710 abcdefg
Pueraria phaseoloides	-125[2)]	127 bcde	597 bcdefghi
Zornia latifolia	728	118 cde	359 ghi
Zornia glabra	7847	148 bcde	441 fghi
MEAN ± D.E.		155 ± 106	572 ± 199

1. Averages with the same letter in each precipitation season are not statistically different to P = 0.01 (Duncan Multiple Range Trial).

2. Local No.

Table 8. Dry matter production of nine grass accessions under African Palm shade conditions (first year of evaluation).

Species	CIAT No.	DM Yield kg/ha/12 weeks	
		Mn precipitation	Mx precipitation
Andropogon gayanus	621	294 a[1)]	1213 ab
Axonopus compressus	-20[2)]	141 a	461 bc
Brachiaria brizantha	6780	275 a	1851 a
Brachiaria decumbens	606	79 a	373 c
Brachiaria dictyoneura	6133	103 a	569 bc
Brachiaria humidicola	679	336 a	890 bc
Brachiaria subquadripara	16740	76 a	262 c
Panicum maximum	673	184 a	559 bc
Panicum maximum	6299	455 a	890 bc
MEAN ± D.E.		216 ± 185	758 ± 409

1/ Averages with the same letter in each season are not statistically different to P = 0.01 (Duncan Multiple Range trial).

2) Local No.

6. AGRONOMY CENTRAL AMERIC AND THE CARIBBEAN

As it was announced in the 1986 Annual Report, activities of the fourth major selection center of the Tropical Pastures Program, based in Costa Rica and corresponding to Central America and the Caribbean, begun in April of 1987.

Prior to the selection of sites, recognition trips together with members of the Forage Program and of the Soils Department of the MAG (Ministry of Agriculture and Livestock of Costa Rica), personnel of the Animal Production Program of the CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) were effected, as well as consultations to various organisms such as the School of Agronomy, Metereologic National Institute, CATIE Library, and to authorities of IICA, where this project is based. The collected information allowed the identification of the priority areas and those in most need of research. Finally, with the cooperation of the TPP's Soils-Plant Nutrition Section and with that of CIAT's Agroecological Studies Unit, an approximate soils and climate characterization of the areas was carried out.

Three regions were selected in Costa Rica, those which represent the main agroecological zones of the Central American and Caribbean area, which are: Tropical rain forest (TRF), Tropical semi-evergreen seasonal forest (TSSF), and Subhumid tropics (SHT).

The principal characteristics of each of the mentioned regions are described below, as well as preliminary results of the May-December 1987 period.

HUMID TROPICS - TRF: ATLANTIC ZONE

The work is carried out in the Centro de Cría e Investigación "Los Diamantes", belonging to the MAG. Such Experimental Center is located at 10°13' of latitude N and 83°47' of longitude W, at 250 masl, in the Province of Limón, 5 km from the city of Guápiles. The average annual precipitation is of 4260 mm and its average annual temperature is of 24.6 C. It does not present any period that could be considered dry, with May being the month of less precipitation, with 164 mm, and December, of the major precipitation with 525 mm.

The soil is classified as Typic Dystropets (Inceptisol) of sandy loam texture (70% sand; 25% lime; 5% clay and of good drainage. Tables 1 and 2 show the main chemical characteristics of "Potrero Mayo's" soil profile and of its plowable layer.

The principal activities that are carried out in each of the three working areas are: seed multiplication and germplasm evaluation, those which will be so-called from here on.

Table 1. Chemical characteristics of the soil's profile in the Potrero Mayo, Estación Experimental "Los Diamantes", Guápiles, Costa Rica.

Soil profile				Interchang. Cations(meq/100g)				Al			Micronutrients (ppm)			
Horizon	Depth (cm)	OM %	pH	Al	Ca	Mg	K	Sat. %	Bray 2 avail. (ppm)		Zn	Cu	Fe	Mn
A_1	0- 20	10.8	5.5	0.2	5.44	2.30	1.27	2.2	8.3	65	1.52	0.39	3.86	32.4
A_2	20- 70	3.0	6.2	0.0	2.01	0.25	0.24	0.0	4.6	48	0.09	0.47	3.16	5.1
B_1	70- 90	1.2	6.5	0.0	1.01	0.16	0.05	0.0	21.1	19	0.11	0.69	6.27	4.0
B_2	90-110	0.6	6.5	0.0	0.97	0.14	0.07	0.0	58.3	12	0.16	0.78	15.55	2.9
C	> 110	0.4	6.5	0.0	0.86	0.13	0.08	0.0	72.0	7	0.16	0.68	22.60	2.6

Source: Salinas, J.G. and Pizarro, E.A. 1987.

Table 2. Chemical characteristics of the plowable layer (0-20 cm) in the Potrero Mayo. Estación Experimental "Los Diamantes", Guápiles, Costa Rica.

Site	OM (%)	pH	Interchang.Cations (meq/100g) Al	Ca	Mg	K	Al Sat. (%)	P available (ppm)	S available (ppm)	Macronutrients (ppm) Zn	Cu	Fe	Mn
Bottom area	9	5.4	0.25	3.91	1.10	0.38	4.4	7.3	52	1.80	0.29	9.88	17.4
Intermediate area	10	5.5	0.25	3.94	1.00	0.26	4.6	6.6	51	0.96	0.26	2.62	18.0
Front area	11	5.6	0.10	5.31	1.40	0.32	1.4	7.4	58	1.11	0.40	3.05	32.8

Source: Salinas, J.G. and Pizarro, E.A. 1987.

Works effected in the seed multiplication area

The materials described in Table 3 were planted in the area, with the fertilization levels presented in Table 4.

The evaluations first effected are given in Table 5. The germplasm planted up to this date, presents good behaviour and excellent production, slight damage caused by insects and of diseases. All of the materials have germinated with A. pintoi 17434 standing out because of its precocity in the flowering initiation 40 days from planting, D. ovalifolium, being the latest among the legumes, with variations between ecotypes; the most precocious, CIAT 350 and the latest, CIAT 13089 (at 135 and 161 days from planting, respectively). The grasses, as it can be observed (Table 5), began flowering within 56 and 94 days after having been planted.

Works carried out in the germplasm evaluation area

The germplasm of grasses and legumes in evaluation, is shown in Tables 6, 7, 8. The germplasm was transplanted and/or directly planted beginning October, which has enabled the possibility of presenting experimental results. The good germination of planted legumes should be pointed out, as well as the total failure of the accessions of P. maximum planted via CIAT seeds No. 604, 622, 673, 6000, 6097, 6110, 6112, 6115, 6118, 6119, 6178, 6179, 6181, 6299, 6461, 6531, 6532, 6536, 6600, 6786, 6798, 6871, 6872, 6880, 6923, 6942, 6949, 6956, 6964, 6968, 6986, 6988, 16011, 16065, 16067. The mentioned germplasm has again been planted.

SEASONAL TROPICS - TSSF: SOUTH ZONE

The experimental field belongs to the Agroindustrial Livestock Cooperative of San Isidro "COOPEAGRI", located at 9°22' of latitute N and 83°42' of longitude W at 700 masl in the Province of San Jose', 28 km South of San Isidro de Pe'rez Zeledón. The average annual precipitation is of 2950 mm and the average annual temperature of 22.8°C. It presents a 3 month dry period, with January, February and March being those of less precipitation (44, 13 and 38 mm, respectively) and October, that of major precipitation with 534 mm.

The soil is classified as Ustoxic Palehumult (Ultisol), of clay texture, the middle and lower zones (24% sand; 32% lime; 44% clay) and the high part as sandy loam (38% sand; 33% lime; 29% clay).

Tables 9 and 10 show the main chemical characteristics of the soil's profile and of the plowable layer of the field in use.

Works undertaken in the seed multiplication area

The materials as well as the planted area are presented in Table 11, with the fertilization levels being specified in Table 12.

The first evaluations (Table 13) show that up to this date, the germplasm presents an excellent adaptation level, in spite of a severe attack during its establishment of the complex PULGUILLA-HOMOPTERA in B. decumbens CIAT 606.

Works effected in the germplasm evaluation area

The germplasm of the planted grasses and legumes is shown in Tables 8 and 14. A summary of the evaluations that have been effected is given as follows:

Grasses
Table 15 summarizes the preliminary results, being outstanding the low incidence of pests and diseases, as well as a variation in the adaptation

Table 3. Germoplasm and planted area for seed multiplication in "Los Diamantes", Guápiles.

Germplasm	CIAT No.	Area m^2	Density kg/ha	Planting date	Replanting Method	%	Fertiliz. Date
LEGUMES							
*A. pintoi**	17434	1000	8	9-VI-87	MV**	5	20-VII-87
D. ovalifolium	13089	510	3	9-VI-87	-	-	21-VII-87
D. ovalifolium	3788	610	3	9-VI-87	-	-	18-VII-87
D. ovalifolium	350	2000	3	11-VI-87	-	-	20-VII-87
D. heterophyllum	349	500	3	11-VI-87	-	-	17-VII-87
GRASSES							
B. humidicola	6705	300	3	11-VI-87	MV	2	17-VII-87
B. humidicola	679	340	3	11-VI-87	MV	3	21-VII-87
B. dictyoneura	6133[a]	2500	3	19-VI-87	S***	20	29-VII-87
B. brizantha	6780[a]	2500	3	18-VI-87	S	30	30-VII-87
B. brizantha	664	2040	3	19/20-VI-87	S	10	23-VII-87
PLANTED AREA		12300					

* All legumes were inoculated with the strains recommended and prepared by recommended and prepared by the Rhyzobiology Section of CIAT's Tropical Pastures Program.

** VM = Vegetative material.

*** S = Seeds

a/ Livestock entered, 29-VI-87.

Cuadro 4. Nivel de fertilización usado en el área de multiplicación de semillas y evaluación de germoplasma.

Nutrient	Source	Grasses	Legumes
		kg/ha/nutrient	
N	Urea	50	-
P	SFT	10	10
K	KCL	20	20
S	Flor de S	10	10
Cu	SO_4Cu	2	2

Table 5. Evaluation of planted germplasm for seed multiplication. Guápiles.

Germplasm	CIAT No.	Germi-nation	Flow-ering	Adapt-ation*	Insect damage		
		---- days ----			TM**	PH**	E**
LEGUMES:							
A. pintoi	17434	7	40	E	-	-	1
D. ovalifolium	350	3	135	E	-	-	1
D. ovalifolium	3788	5	142	G	2***	-	2
D. ovalifolium	13089	4	161	E	-	-	1
D. heterophyllum	349	4	83	E	1	-	-
GRASSES:							
B. humidicola	679	6	67	G	-	2	-
B. humidicola	6705	6	56	E	-	1	-
B. dictyoneura	6133	6	76	E	-	-	-
B. brizantha	664	8	88	G	-	2	-
B. brizantha	6780	7	94	E	-	1	-

* E = Excellent; G = Good.
** TM = Trips-Mites; PH = PULGUILLA-HOMOPTERA; E = Eaters.

*** 1 = Presence; 2 = Slight damage.

Table 6. Legume accessions planted in Guápiles.

Legumes	CIAT No.				
Arachis pintoi	17434				
Centrosema acutifolium	5277	5278	5564	5568	5609
	5610	15084	15353	15446	
C. arenarium	5236	5599			
C. brachypodum	5803				
C. grandiflorum	5989				
C. capitatum	15680				
C. macrocarpum	5065	5434	5452	5620	5629
	5674	5713	5733	5735	5744
	5887	5911	5957	5990	15014
	15108	15121	15232	15238	15362
	15451	15652	15806		
C. pubescens	438	442	5050	5053	5126
	5172	5189	5720	5878	5914
C. plumieri	5099	5194	5229		
C. rotundifolium	5283				
C. schottii	5077	5079			
C. tetragonolobum	15087				
C. vexillatum	15079				
C. virginianum	474				
Clitoria fairchildiana	18724				
Codariocalyx gyroides	3001	13548	13979		
Cratylia floribunda	8034	18516			
Desmodium heterocarpon	13178	13189			
D. heterophyllum	349	3774	3779	3782	3791
	13190	13191	13195	13197	13198
	13202	13203	13666	13669	
D. ovalifolium	350	3607	3608	3668	3673
	3776	3780	3781	3784	3788
	3793	13030	13082	13083	13085
	13086	13089	13091	13092	13096
	13097	13099	13102	13113	13115
	13122	13123	13127	13129	13289
	13305	13370	13371	13400	
D. strigillosum	13153	13155	13158		
D. velutinum	13218				
Flemingia macrophylla	801	7184	17400	17403	17407
Pueraria phaseoloides	736	829	4600	7182	7979
	8042	8171	9021	9188	9900
	17278	17281	17292	17293	17303
	17322	17323	17326	17433	17466
	17765				
Stylosanthes guianensis	15	21	64	64A	136
	184	191	1175	1280	1283
	2031	2191	2203	2243	2244
	10136	11362	11363	11364	11365
	11366	11367	11368	11369	11370
	11371	11372	11373	11374	11375
	11376				
S. macrocephala	1281	2133			

Table 7. Grass accessions planted in Guápiles.

Grasses	CIAT No.				
Brachiaria brizantha	664	665	667	6294	6387
	6780				
B. decumbens	606	6012			
B. dictyoneura	6133				
B. humidicola	679	6369	6705		
B. ruziziensis	6019				
Brachiaria spp.	(271 new accessions)				
Panicum maximum	604	622	673	6000	6063
	6094	6095	6097	6109	6110
	6112	6114	6115	6118	6119
	6164	6171	6172	6175	6177
	6178	6179	6180	6181	6215
	6299	6600	6531	6532	6536
	6554	6868	6601	6786	6798
	6828	6890	6871	6872	6875
	6880	6945	6898	6907	6923
	6942	6969	6949	6956	6964
	6968	6988	6971	6974	6983
	6986	16039	16011	16017	16020
	16028	16067	16051	16061	16062
	16065	Local			
P. coloratum	6461				
Paspalum plicatulum	600	600A	6046		
P. coryphaeum	16080				
P. secans	16081				
Pennisetum purpureum	16076				
Setaria anceps	6043				
S. sphacelata	609				

Table 8. Accessions of *Leucaena* spp. planted in Guápiles, San Isidro de Pérez Zeledón and Atenas.

Accessions	CIAT No.				
Leucaena leucocephala	734	7984	9437	17473	17493
	751	7985	9438	17474	17494
	766	7986	9441	17475	17495
	785	7987	9442	17476	17496
	871	7988	9443	17477	17498
	932	8069	9464	17478	17499
	937	8815	9904	17479	17500
	7356	9101	9993	17480	17501
	7384	9119	17217	17481	17502
	7385	9132	17218	17482	18477
	7415	9133	17219	17483	18478
	7452	9377	17222	17484	18479
	7453	9379	17223	17486	18480
	7872	9383	17224	17488	18481
	7929	9411	17263	17489	18482
	7930	9415	17389	17491	18483
	7965	9421	17467	17492	
L. diversifolia	17388	17461	17485	17503	
L. shannonii	17487				
L. pulverulenta	17490				

Table 9 Chemical characteristics of the soil's profile in the Finca "El Porvenir", San Isidro del General, Costa Rica.

Soil's profile		OM	pH	Interchang.Cations (meq/100g)				Al Sat.	P Bray 2	S avail.	Micronutrients (ppm)			
Horizon	Depth %	(%)		Al	Ca	Mg	K	(%)	(ppm)		Zn	Cu	Fe	Mn
A	0- 25	8.1	4.6	4.30	0.26	0.08	0.05	79	1.8	72	0.06	1.61	27.80	6.9
B_1	25- 70	2.8	5.0	2.20	0.24	0.04	0.07	86	1.2	82	0.10	1.34	11.05	2.8
B_2	70-120	1.1	5.1	0.75	0.30	0.08	0.10	61	1.4	116	0.03	1.51	4.26	1.3
C	> 120	0.2	5.4	0.10	0.24	0.03	0.05	24	1.8	148	0.03	0.63	6.62	0.3

Source: Salinas, J.G. and Pizarro, E.A. 1987.

Table 10. Chemical characteristics of the experimental field's plowable layer at the Finca "El Porvenir", San Isidro del General, Costa Rica.

Site	OM (%)	pH	Interchang. Cations(meq/100g) Al	Ca	Mg	K	Al Sat. (%)	P available (ppm)	S	Micronutrients (ppm) Zn	Cu	Fe	Mn
Sloping area	8.4	4.6	2.70	0.60	0.22	0.18	73	2.4	67	0.63	1.05	22.6	8.8
Intermediate area	9.0	4.6	3.25	0.91	0.38	0.17	69	1.5	70	0.74	1.45	32.6	10.2
Plain area	18.6	4.5	2.90	1.30	0.47	0.16	60	1.9	81	0.70	1.37	19.8	19.2

Source: Salinas, J.G. and Pizarro, E.A. 1987.

Table 11. Germplasm planted for seed multiplication in the finca "El Porvenir".

Germplasm	CIAT No.	Area m^2	Density kg/ha	Planting Date	Fertilization Date
GRASSES:					
B. decumbens	606	950	4	20-V-87	26-VI-87
B. dictyoneura	6133 (1)**	950	4	21-V-87	26-VI-87
	(2)***	600	4	15-VI-87	15-VII-87
A. gayanus	621	1100	10	22-V-87	24-VI-87
LEGUMES*:					
D. ovalifolium	350	950	4	21-V-87	25-VI-87
C. acutifolium	5277	970	5	21-V-87	24-VI-87
A. pintoi	17434	400	8	21-VIII-87	23-X-87
PLANTED AREA:		5920			

* All legumes were inoculated with strains recommended and prepared by the Rhyzobiology Section of CIAT's Tropical Pastures Program.

** Area 1

***Area 2

Table 12. Fertilization level used in the area of seed multiplication and germplasm evaluation.

Nutrient	Source	Grasses	Legumes
		-------- kg/ha/nutrient	----------
N	Urea	50	-
P	SFT	20	20
K	KCl	20	20
S	Flor de S	10	10
Zn	ZnO	3	3

Table 13. Evaluation of the planted germplasm for seed multiplication. San Isidro.

Germplasm	CIAT No.	Germ-tion (days)	Flow-ering (days)	Adapt-ation*	Damage level due insects			Damage level due to diseases	
					TM**	PH**	E**	B**	R**
GRASSES:									
A. gayanus	621	5	117	E	-	-	-	-	-
B. decumbens	606	7	57	E	-	2	-	-	2
B. dictyoneura	6133	4	61	E	-	-	-	-	1
LEGUMES:									
A. pintoi	17434	7	27	E	-	-	-	-	1
C. acutifolium	5277	5	-	E	1***	-	1	1	1
D. ovalifolium	350	18	149	E	-	-	1	-	-

* E = Excellent.

** TA = Trips-Mites; PH = PULGUILLA-HOMOPTERA; E = Eaters; B = Bacteriosis; R = Rhyzoctonia.

*** 1 = Presence; 2 = Slight damage.

Table 14. Germplasm planted in the "El Porvenir", San Isidro de Pérez Zeledón.

LEGUMES	CIAT No.			
Arachis pintoi	17434			
Calopogonium mucunoides	8118			
Canavalia brasiliensis	18515			
Codariocalyx gyroides	3001			
Chamaecrista rotundifolia	8201	8202		
Centrosema acutifolium	5277	5568		
C. arenarium	5236			
C. brasilianum	5178	5234	5365	5487
	5514	5657	5671	5810
C. macrocarpum	5065	5452	5620	5674
	5713	5733	5735	5737
	5740	5744	5887	5957
	15014			
C. pubescens	438	442	5126	5172
	5189			
C. schiedeanum	5161	5201		
Centrosema híbrido (P x M)	5930	5931	5932	5933
	5934	5935		
Desmodium heterocarpon	3787			
D. heterophyllum	349	3782		
D. ovalifolium	350	3673	3776	3781
	3784	3788		
D. strigillosum	13153	13155	13158	
Dioclea guianensis	7351	7801		
Pueraria phaseoloides	9900			
Stylosanthes capitata	1019	1078	1097	1441
	2044	2252	10137	10280
S. guianensis	21	136	184	1275
	1280	1539	1639	1873
	2031	2362	10136	
S. macrocephala	1643	2133	2286	2756
Zornia glabra	7847	8279	8283	
Z. latifolia	728	9199		
GRASSES:				
Andropogon gayanus	621	6053	6766	
Brachiaria brizantha	6387	6780		
B. decumbens	606			
B. dictyoneura	6133			
B. humidicola	679	6769		
Hyparrhenia rufa	Local			
Melinis inutiflora	Local			
Panicum maximum	622	673	695	6000
	6179			

Table 15. Evaluación de adaptación de gramíneas forrajeras tropicales en Centroamérica: SEGSTF - San Isidro.

Grasses	CIAT No.	Grade of adaptation	Damage level due insects**		Damage level due diseasess**
			1	2	1
A. gayanus	621	E*	PH + E***		
	6053	E	E + S		
	6766	E			
B. brizantha	6387	E		PH	Cs
	6780	E		PH	Cs
B. decumbens	606	E		PH	Cs
B. dictyoneura	6133	E			
B. humidicola	679	E	PH		
	6369	E			
H. rufa	Local	R	PH		
M. minutiflora	Local	E			
P. maximum	622	E			Cs
	673	G		PH	
	695	E		PH	Cs
	6000	E	PH		Cs
	6179	G		PH	Cs

* E = Excellent; R = Regular; G = Good.

** 1 = Presence; 2 = Slight damage.

*** PH = PULGUILLA-HOMOPTERA; E = Eaters; S = Spittlebug; Cs = Cream stain.

level, which ranges from "regular" in H. rufa, to excellent for 88% of the accessions in the evaluation.

Legumes
A summary is presented in Tables 16 to 20. As it can be observed, the germplasm with less incidence of pests and diseases is that of genera Desmodium spp. (Table 19), and that of major incidence because of pests and diseases, C. brasilianum (Table 17). Genera Stylosanthes spp. (Table 20) immediately stands out because of its development, and most especially the planted S. guianensis, because of its vigor and low incidence of anthracnose.

In regard to the evaluation of Leucaena spp., it should be pointed out, that almost all of the accessions directly planted did not establish, and presented irregular germination, which made it obligatory that the planting be done in plastic bags for future transplanting. Table 21 presents the evaluation effected at 140 days from planting, with only three CIAT accessions standing out, Nos. 871, 7415 and 17474, which are the only ones that maintain the plot complete. In spite of this, the seedling vigor is low, without surpassing 40 cm of height in any of the cases.

SUBHUMID TROPICS - SHT: CENTRAL ZONE

The experimental field is located in the Central American School of Livestock (ECAG). It is situated at 9°58' latitude N and at 84°23' longitude O at 200 mosl in the Province of Alajuela, 1 km from the poblado Balsas and 10 km from the city of Atenas.

The average annual precipitation is of 1600 mm and the average annual temperature is of 23.7 C. It presents a five month dry period, with December, January, February, March and April being those of least precipitation (27, 13, 7, 14 and 36 mm, respectively). Within the rainy period, the month of least precipitation November (100 mm), and May, that of major precipitation (277 mm).

The soil is classified as Inceptisol, of sandy loam texture (56% sand; 33% lime; 11% clay) with good drainage. Table 22 shows the main chemical characteristics of the plowable layer.

Works carried out in the seed multiplication area

The germplasm, as well as the planted area, are presented in Table 23, with the fertilization levels specified in Table 24.

The first evaluations effected (Table 25) in general indicate good behaviour up to this date. It should be pointed out that 40 kg of raw seed were harvested, equivalent to a 160 kg/ha production, prior to the first cutting effected in B. decumbens CIAT 606, in September of 1987. At the moment the four planted legumes present an adequate number of sheaths and low incidence of pests and diseases, with C. pubescens CIAT 438, being the only one with bacteriosis (< 5%) in the sheaths.

The only grass that had to be replanted (70%) has been A. gayanus CIAT 621, while the replanting level ranged between 0 and 5% for the rest of the materials (Table 23).

Works carried out in the germplasm evaluation area

The germplasm of legumes and grasses planted is shown in Tables 8, 26 and 27. A summary of the evaluations is given below:

Grasses
The total accessions of C. ciliaris, H. rufa, S. sphacelata and S. anceps, was not established due to bad quality of the seeds (Table 28). A. gayanus (Table 29) presents low incidence of

Table 16. Adaptation evaluation of tropical forage legumes in Central America: SEGSTF - San Isidro.

Grasses	CIAT No.	Grade of adaptation	Damage level due insects**		Damage level due diseases**	
			1	2	1	2
A. pintoi	17434	G*	PH***		R	
C. mucunoides	8118	E	PH	E		
C. brasiliensis	18515	E	PH		CY + R	
C. gyroides	3001	E	E		R + RN	
C. rotundifolia	8201	E	E		R	
	8202	E	E		R	
D. guianensis	7351	G	E			
	7801	G	E			
P. phaseoloides	9900	G		E		
Z. glabra	7847	G		PH		R
	8279	D				
	8283	G	TM	PH		R
Z. latifolia	728	E		PH	R	
	9199	E		PH	R	

* G = Good; E = Excellent; D = Disappeared.

** 1 = Presence; 2 = Slight damage.

*** PH = PULGUILLA-HOMOPTERA; E = Eaters; TA = Trips-Mites; R = Rhyzoctonia; CY = Cylindrocladium; RN = Root Nematode.

Table 17. Adaptation evaluation of tropical forage legumes in Central America SEGSTF. San Isidro.

Legume	CIAT No.	Grade of Adaptation	Damage level due to insectos**			Damage level due to diseases**		
			1	2	3	1	2	3
C.acutifolium	5277	E*	TM+PH+C***			B		
	5568	G	TM	E		R		
C. arenarium	5236	R	TM+PH					R
C.brasilianum	5178	R	E	TM	PH		R	
	5234	R	E	TM	PH		R	
	5365	R		TM+E	PH		R	
	5487	R	E	TM	PH			R
	5514	R		TM	PH		R	
	5657	G	E	TM	PH	R		
	5671	R		TM	PH			R
	5810	R		TM	PH		R	
C. schiedeanum	5161	G	TM+E	PH		Ce+R		
	5201	G	E	PH		Ce		
Centrosema híbrido	5930	E	TM+PH+E			Ce+CY		
	5931	G	TM+PH+E			R	CY	
	5932	E	PH+E			CY		
	5933	G	TM+PH+E			Ce	R	
	5934	E	TM+PH+E			CY		
	5935	G	TM+PH+E			R	CY	

* E = Excellent; R = Regular; G = Good.

** 1 = Presence; 2 = Slight damage; 3 = Moderate damage.

*** TM = Trips-Mites; PH = PULGUILLA-HOMOPTERA; E = Eaters;
B = Bacteriosis; R = Rhyzoctonia; Ce = Cercospora;
CY = Cylindrocladium.

Table 18. Adaptation evaluation of tropical forage legumes in Central America: SEGSTF. San Isidro.

Legumes	CIAT No.	Grade of Adaptation	Damage level due to insects**			Damage level due to diseases**		
			1	2	3	1	2	3
<u>C.macrocarpum</u>	5065	G*	TM***	PH+E		CY	R	
	5452	G	TM+PH+E			CY	R	
	5620	G	TM+PH	E		CY+B	R	
	5674	R	TM+PH	E		B+R	CY	
	5713	G	TM+PH	E				R
	5733	R	TM+PH		E	B+R	CY	
	5735	G	TM+PH		E	CY	R	
	5737	R	TM+PH		E	B+R		
	5740	G	TM+PH	E		CY+B	R	
	5744	G		E			R	
	5887	R	TM+PH		E		R	CY
	5957	G	TM+PH		E	Ce+R		
	15014	R	PH	TM	E		CY+R	
<u>C. pubescens</u>	438	G	TM+PH+E			CY+R		
	442	G	TM+E	PH		R	CY	
	5126	G	TM+PH+E				CY+R	
	5172	G	TM+E	PH		R	CY	
	5189	G	E	PH		Ce	R	

* G = Good R = Regular.

** 1 = Presence; 2 = Slight damage; 3 = Moderate damage.

*** TM = Trips-Mites; PH = PULGUILLA-HOMOPTERA; E = Eaters;
CY = Cylindrocladium; B = Bacteriosis; R = Rhyzoctonia;
Ce = Cercospora.

Table 19. Adaptation evaluation tropical forage legumes in Central America: SEGSTF. San Isidro.

Legumes	CIAT No.	Grade of Adaptation	Damage level due insects**	Damage level due diseases**
			1	1
D. heterocarpon	3787	E*	E***	
D. heterophyllum	349	B	E	
	3782	G		
D. ovalifolium	350	E	E	R
	3673	G	E	R
	3776	E	E	R
	3781	E		R
	3784	G	E	R+CY
	3788	G	E	R
D. strigillosum	13153	R		
	13155	G	E	R
	13158	G	E	R

* E = Excellent; G = Good; R = Regular; B = Bad.

** 1 = Presence.

*** E = Eaters; R = Rhyzoctonia; CY = Cylindrocladium.

Table 20. Adaptation evaluation of tropical forage legumes in Central America: SEGSTF. San Isidro.

Legume	CIAT No.	Grade of Adaptation	Damage level due insects**			Damage level due to diseases**	
			1	2	3	1	2
S. capitata	1019	E*		PH***			
	1078	G			PH	A	
	1097	G			PH	A	
	1441	G		PH		R	
	2044	E	PH			A	
	2252	E	PH			R	
	10137	E		PH		A	
	10280	E	PH			A	
S. guianensis	21	G	PH				
	136	E	PH			R	
	184	E				A+R	
	1275	E				R	
	1280	G				A	
	1539	G				A+R	
	1639	E	PH			A	
	1873	E	PH			A+R	
	2031	E	PH			R	
	2362	E	PH				
	10136	G				A	
S. macrocephala	1643	E		PH			
	2133	E		PH			
	2286	R		PH			R
	2756	E		PH			

* E = Excellent; G = Good; R = Regular.

** 1 = Presence; 2 = Slight damage; 3 = Moderate damage.

*** PH = PULGUILLA-HOMOPTERA; A = Antracnoses; R = Rhyzoctonia.

Table 21. Number of *Leucaena* spp. plants that have persisted in San Isidro.*

Number of Plants per site and percentage of the total of accessions under evaluation	*Leucaena* spp. CIAT No.			
0	7929	7965	7987	9101
(8%)	9442	17479	17491	
1	751	785	8069	9119
(22%)	9132	9377	9379	9415
	9421	9464	17218	17224
	17461	17467	17476	17477
	17492	17494	17499	17500
2	932	7385	7872	7930
(29%)	7986	8815	9438	9441
	9443	17217	17222	17473
	17475	17477	17480	17482
	17483	17485	17488	17493
	17496	17501	17503	18478
	18480	18482		
3	766	7984	7988	9383
(18%)	9904	9993	17223	17388
	17481	17484	17487	17489
	17490	17495	17498	17586
4	7356	7384	7452	9133
(13%)	9411	9437	17219	17263
	17389	17478	17502**	18483
5	734	937	7453	7985
(7%)	18479	18481		
6	871	7415	17474	
(3%)				

* Planting 18-V-87. Evaluation 3-X-87 (140 days).

** cv. "Cunningham".

Table 22. Chemical characteristics of the plowable layer of the Potrero San José, Central America School of Livestock, Atenas, Costa Rica.

Site	OM (%)	pH	Interchang. Cations(meq/100g)				Al Sat. (%)	P available (ppm)	S available (ppm)	Micronutrients (ppm)			
			Al	Ca	Mg	K				Zn	Cu	Fe	Mn
Potrero San José*	7.6	5.9	0.00	9.50	6.0	0.24	0.00	3.6	52	0.22	1.51	3.50	28.4

* Given the great variability found once the land was prepared, new analyses are being carried out.

Source: Salinas, J.G. and Pizarro, E.A. 1987.

Table 23. Germplasm and planted area in ECAG for seed multiplication.

Germplasm	CIAT No.	Area m^2	Density kg/ha	Planting date	Re-planting area	%	Fertilization date
LEGUMES*							
C. pubescens	438	2500	6	1-VI-87	7-VII-87	5	8-VII-87
C. macrocarpum	5713	2500	6	1-VI-87	7-VII-87	5	8-VII-87
C. brasilianum	5234	2500	6	1-VI-87	7-VII-87	5	8-VII-87
C. acutifolium	5277	2500	6	1-VI-87	7-VII-87	5	8-VII-87
GRASSES							
B. decumbens	606	2500	4	28- V-87		0	8- VII-87
B. dictyoneura	6133	2600	4	29- V-87	7-VII-87	3	8-9-VII-87
A. gayanus	621	2800	11	29- V-87 1-VI-87	7-VII-87	70	9- VII-87
TOTAL AREA		17900					

* All legumes were inoculated with recommended and prepared strains by the Rhyzobiology Section of CIAT's Tropical Pastures Program.

Table 24. Fertilization level used in the area of seed multiplication and evaluation of germplasm.

Nutrient	Source	Grasses	Legumes
		kg/ha	kg/ha
N	Urea	50	-
P	SFT	20	20
K	KCl	20	20
S	Flor de S	10	10
Zn	ZnO	3	3

Table 25. Agronomic evaluation of the germplasm planted for seed multiplication.

Germplasm	CIAT No.	Germination	Flowering	Grade of adaptation	Damage lev. due to ins.		Damage level due to diseases				
		---- days ----			PH**	TA**	A**	Ce**	R**	Os**	B**
LEGUMES											
C. acutifolium	5277	6	119	G*	1**	-	-	-	-	-	2
C. brasilianum	5234	4	91	G	2	-	-	-	2	-	-
C. macrocarpum	5713	3	150	E	-	-	-	1	1	-	-
C. pubescens	438	3	101	E	-	-	1	-	-	-	1
GRASSES											
A. gayanus	621	6	-	G	-	1	-	-	-	1	-
B. decumbens	606	5	49	E	1	-	-	-	-	-	-
B. dictyoneura	6133	6	69	E	-	-	-	-	-	-	-

* G = Good; E = Excellent.

** PH = PULGUILLA-HOMOPTERA; TM = Trips-MITES; A = Antracnosis; Ce = Cercospora; R = Rhyzoctonia; Os = Orange stain; B = Bacteriosis.

*** 1 = Presence; 2 = Slight damage.

Table 26. Accessions of legumes planted in ECAG.

Legumes	CIAT No.				
Clitoria fairchildiana	18724				
Cratylia sp.	8034				
C. floribunda	18516				
Codariocalyx gyroides	3001	13548	13979		
Flemingia macrophylla	801	7184	17400	17403	17407
Centrosema acutifolium	5277	5278	5564	5568	5609
	5610	15084	15353	15446	
C. brasilianum	494	5055	5178	5184	5234
	5247	5365	5487	5657	5671
	5698	5712	5810	15387	15524
C. grazielae	4042	5121	15439		
C. macrocarpum	5065	5434	5452	5620	5629
	5674	5713	5733	5735	5744
	5887	5911	5957	5990	15014
	15108	15121	15232	15238	15362
	15451	15652	15806		
C. pascuorum	5230	5545			
C. pubescens	438	442	5050	5053	5126
	5172	5189	5720	5878	5914
C. schiedeanum	5066	5161	5201	5920	5921
Stylosanthes capitata	1019	1078	1097	1315	1318
	1342	1405	1441	1693	1728
	1943	2044	2252	10280	
S. hamata	114	118	124	147	1040
	2270				
S. humilis	1304	2420			
S. sympodialis	1043	1044			
S. guianensis	15	21	64	64A	136
	184	191	1095	1175	1280
	1283	2031	2191	2203	2243
	2244	2747	10136	11362	11363
	11364	11365	11366	11367	11368
	11369	11370	11371	11372	11373
	11374	11375	11376		

Table 27. Accessions of grasses planted in ECAG.

Grasses	CIAT No.				
Andropogon gayanus	621	6053	6054	6200	6201
	6202	6207	6208	6214	6216
	6218	6219	6220	6221	6224
	6233	6234	6265	6368	6377
	6694	6695	6697	6757	6759
	16974	16975	16978	16979	16983
	16984	16985	16986	16991	
Cenchrus ciliaris	678	6245			
Hyparrhenia rufa	601				
Setaria sphacelata	609				
S. anceps	6043	6147			
Brachiaria brizantha	664	667	6294	6387	6780
B. decumbens	606	6012			
B. dictyoneura	6133				
B. humidicola	679	6369	6705		

Table 28. Adaptation evaluation of tropical forage grasses in Central America: Dry Tropics - Atenas.

Gramíneas	CIAT No.	Grade of adaptation	Damage level due to insects**	Damage level due to diseases**		
			1	1	2	3
C. ciliaris	678	D*(1)				
	6245	D (1)				
H. rufa	601	D (1)				
S. sphacelata	609	D (1)				
S. anceps	6043	D (1)				
	6147	D (1)				
B. brizantha	664	B				R
	667	E			R	
	6294	E			R	
	6387	E			R	
	6780	E			R	
B. decumbens	606	E			R	
	6012	D (1)				
B. dictyoneura	6133	E				
B. humidicola	679	E	PH			
	6369	B		Bs		
	6705	B				

* D = Disappeared; G = Good; E = Excellent; (1) = Bad seed.
** PH = PULGUILLA-HOMOPTERA; Bs = Brown stain; R = Rhyzoctonia.

Table 29. Adaptation evaluation of tropical forage grasses in Central America: Dry Tropics - Atenas.

Grasses	CIAT No.	Grade of Adaptation	Damage level due to insects**		Damage level due to diseases**
			1	2	1
A. gayanus	621	E*			
	6053	E			
	6054	G			Os
	6200	G	PH*		Os
	6201	G		PH	
	6202	E	PH		
	6207	E			Os
	6208	D			
	6214	E	PH		Os
	6216	E	PH		Os
	6218	E			Os
	6219	G		PH	
	6220	E	PH		Os
	6221	R	PH		
	6224	E			
	6233	R			
	6234	E	PH		Os
	6265	G	PH		
	6368	E	PH		
	6377	E	PH		Os
	6694	G			Os
	6695	G	PH		Os
	6697	E			Os
	6757	E			Os
	6759	R		PH	Os
	16974	E	PH		Os
	16975	E	PH		Os
	16978	E			
	16979	E	PH		Os
	16983	E	PH		
	16984	E	PH		
	16985	E		PH	
	16986	D			
	16991	E	PH		Os

* E = Excellent; G = Good; R = Regular; D = Disappeared.

** PH = PULGUILLA-HOMOPTERA; Os = Orange stain.

pests and/or diseases in the evaluated accessions, 65% shows an excellent adaptation level, 20% good level, 9% regular and 6% bad adaptation.

Legumes

The adapatation evaluation of S. guianensis is shown in Table 30. It is observed that at this moment, only 9% of the evaluated accessions have a level below good and 76% are found with an adaptation level superior to good.

Of the rest of the planted legumes (Table 26), the outstanding materials are C. macrocarpum, C. acutifolium and C. pubescens (Tables 31 and 32).

General conclusions

At present, the effected evaluations indicate that the Southern Zone (TSSF) presents the major incidence of pests and diseases. Minor soil fertility, high Al saturation, low pH and older age of plants, can be part of the responsible agents. In general, Stylosanthes spp. presents good behaviour in all of the locations, with only one exception represented by the presence of anthracnose. The major damage due to pests detected up to now, is the one caused by the Complex PULGUILLA-HOMOPTERA, specially in Centrosema spp. and Brachiaria spp.

MAIN FACTS DURING 1987 OF THE SECTION AGRONOMY CENTRAL AMERICA AND THE CARIBBEAN

- The new major selection center of the TPP for Central America, initiated its activities in April of 1987, with base in Costa Rica.

- Since its beginning, various national and international organisms, such as IICA, CATIE, MAG, ECAG, and COOPEAGRI, have been part of the project.

- Germplasm introduction and evaluation trials have been established, as well as seed multiplication in three agroecological zones.

- The number of accessions, as well as the planted area for seed multiplication, are shown in Table 33.

- Regarding the germplasm in evaluation, the effort carried out among CIAT sections (Biotechnology and the TPP) stands out because of preparing the new African collection of Brachiaria spp. in form of tissue culture of terminal apexes. Up to this moment, 54% of the total of the 271 new collections received in test tubes, have been established in the Atlantic Zone which represents the humid tropics.

Table 30. Adaptation evaluation of *S. guianensis* in Central America: Dry Tropics - Atenas.

		GRADE OF ADAPTATION*	CIAT No.		
Disappeared	Bad	Regular	Good	Excellent	
1095	2203	64	64A	15	11365
2191		10136	191	21	11366
2243			1280	136	11368
2244			1283	184	11370
2747			11367	1175	11371
			11369	2031	11372
			11376	11362	11373
				11363	11374
				11364	11375
Percentage (%)	15	3	6	21	55

* PULGUILLA-HOMOPTERA + Trips-Mites + Eaters + Rhyzoctonia + Antracnoses < 1

Table 31. Adaptation evaluation of tropical forage legumes in Central America: Dry Tropics - Atenas.

Legumes	CIAT No.	Grade of Adaptation	Damage level due insects**		Damage level due to diseases**	
			1	2	1	2
C. macrocarpum	5065	E*	PH***	E		
	5434	E	E		Ce+R	
	5452	G	E			R
	5620	E	PH+C		Ce+R	
	5629	E	PH		A	
	5674	E				
	5713	G	E		Ce	
	5733	E	PH	E	Ce+R	
	5735	E		E	Ce	
	5744	E	PH	E	Ce	
	5887	E	PH+E		Ce	
	5911	E	TM			
	5957	E	E			
	5990	G		E	Ce+R	
	15014	E			R	
	15108	E	TM+E			
	15121	G	PH+E		Ce+R	
	15232	G			Ce	
	15238	E			Ce	
	15362	E	E		A+CY	
	15451	G	PH	E	Ce+R	
	15806	E		E	Ce+R	

* E = Excellent; G = Good.
** 1 = Presence; 2 = Slight damage.
*** PH = PULGUILLA-HOMOPTERA; E = Eaters; TM = Trips-Mites; Ce = Cercospora; R = Rhyzoctonia; A = Antracnoses; CY = Cylindrocladium.

Table 32. Adaptation evaluation of tropical forage legumes in Central America: Dry Tropics - Atenas.

Legumes	CIAT No.	Grade of Adaptation	Damage level due to insects**	Damage level due to diseases**	
			1	1	2
C. acutifolium	5277	G*	E***	R	
	5278	G		A+Bs	G
	5564	G	TM+E		
	5568	E	TM	Bs	
	5609	E	E	Bs	
	5610	E	E	Bs	
	15084	R		B+A	Bs
	15353	G	E	A+Bs	
	15446	R	E	Bs+R	
C. pubescens	438	E	PH	B+R	
	442	R	PH+E		Ce+R
	5050	E		R	
	5053	E		Ce+B+A	
	5126	G	E	Ce	R
	5172	E	PH+E		
	5189	G	PH+E	Ce	
	5720	G		Ce	
	5878	G	PH+E	B+R	
	5914	E		R	

* E = Excellent; G = Good; R = Regular.

** 1 = Presence; 2 = Slight damage.

*** PH = PULGUILLA-HOMOPTERA; TM = Trips-Mites; E = Eaters;
B = Bacteriosis; R = Rhyzoctonia; Bs = Brown stain; A = Antracnoses;
B = Bacteriosis; Ce = Cercospora.

Table 33. Number of accessions and area* for seed multiplication planted in Costa Rica during 1987.

Site	Number of Accessions		Area for Multiplication
	Grasses	Legumes	m^2
Atenas	51	225	17.900
Guápiles	362	268	12.300
San Isidro	16	176	5.920
Total	429	669	36.720

7. PASTURES PROJECT IN PANAMA (INDIAP/U. RUTGERS/CIAT)

The objectives of the Tropical Pastures' Program in Panama were defined in an agreement between the Institute of Agriculture and Livestock Research of Panama (IDIAP) and the University of Rutgers (New Jersey), initiated in 1983 and concluded in 1987. They may be summarized as follows: a) selection of promising forage germplasm for ecosystems of economic importance in the country, b) agronomic studies of adapted species particularly related to low levels of fertilizer, c) multiplication seed of promising species, and d) weed control and evaluation of potential animal production with promising species adapted to acid soils of moderate to low fertility.

INTRODUCTION AND SELECTION OF GERMPLASM

The project started in 1983 with the introduction and selection of forage species. A total of 84 ecotypes of legumes and of 87 grasses, of which 19 were either naturalized or came from previous introductions, were evaluated in various sites to assess their adaptation and other agronomic factors. The methodology used was similar to that described by the Tropical Pastures Program for Regional Trials Types A and B. Approximately 60% of Panama soils are acid and of low fertility (Inceptisols and Ultisols), and the species selected for introduction and evaluation were primarily those with a record of adaptation to similar systems in elsewhere in Latin America.

Evaluations were undertaken in the tropical humid forest (T-hf), the very humid premontane forest (P-vhf), the tropical humid forest derived from savanna (T-hfds), the dry tropical forest (T-df), and the pluvial premontane forest (p-pf). These ecosystems occur all along the Pacific coast of Panama, where the major agricultural and livestock activity is concentrated. The general characteristics of the sites are presented in Table 1. The rainfall varies from 1,000 mm/year in Río Hato, situated at sea level, to 5,920 at Bijao (Chiriquí) at 1,100 m altitude; similarly, for the same sites, the mean annual temperature varies from 27.5 to 20.7°C. Most of the soils are clayey and vary from acid to neutral, and with low to average values of organic matter. With the exception of Divisa, most of the sites have low to average phosphorous (P) values, and variable aluminium saturation.

Following is the list of species and ecotypes introduced and established in one or several of the mentioned sites:

a) Grasses:
Andropogon gayanus CIAT 621 and 6200; Brachiaria dictyoneura CIAT 6133, B. humidicola CIAT 679, 6707, 675, 6369, 6705, 6709 and 682; B. brizantha CIAT

Table 1. The climate and soil characteristics of sites in Panama where tropical forage introductions were evaluated during 1983-1987.

Site	Precipitation mm/year	Mean temp. (°C)	Ecosystem	Soil texture	Soil: pH (H_2O)	Soil: M.O. (%)	Soil: P (ppm)	Soil: Al Sat (%)	Soil: Classification
Los Santos (Ejido)	1,090	27.0	T-df	Sandy-loam	5.9	2.8	3.3	Tr	Alfisol
Calabacito	2,500	27.0	T-hfds	Clayey	4.8	2.9	2.5	70	Ultisol
Soná (La Soledad)	2,750	26.5	T-hf	Clayey	5.1		1.1	65	Ultisol
Tortí	2,450	27.0	T-hf	Loamy	6.4	3.5	7.8	Tr	Inceptisol
Río Hato	1,003	27.5	T-df	Sandy loam	6.7	0.9	6.0	Tr	Inceptisol
Divisa	1,702	27.0	T-df	Sandy loam	5.6	-	53.5	Tr	Inceptisol
Chiriquí	3,348	27.0	T-hfds	Clayey	4.5	4.3	2.0	60	Ultisol
Gualaca	5,100	25.5	P-vhf	Clayey	4.7	3.0	6.0	8	Inceptisol
Volcán (Bijao)	5,919	20.7	P-pf	Clayey	5.4			5	Inceptisol
Chepo	2,090	26.6	T-hfds	Clayey	4.4	2.8	1.3	64	Ultisol

6009, 6012, 664, 6298, 6016 and 6780; B. decumbens CIAT 606, 6132 and 6131; B. ruziziensis CIAT 6291, 654, 6419, 6134, 655 and 6130; B. eminii CIAT 6241 and B. arrecta CIAT 6020; Cenchrus ciliaris CIAT 678, Molopo, Nunbank, Gayndah and Nueces; Panicum maximum CIAT 604, 0685, 6103, 0694, 6141, 6104, 0696, 6113, 6116, 6178, 6183, 6112, 6145, 6161, 6176, 0691, 0697, 0621, 6114, 6119, 0684, 6179, 6163, 0693, 6215, 6101, 0698, 6175, 0669, 6128, 6146, 6162, 6165, 6142, 6045, 0699, 0690, 0688, 6166, 6123, 6180, 6129, 6182, 6126, 6109, 6105, 6001, 6122, 6125, 6165, 6163, 6144, 6117, 0692 and 6140, all of which were compared with local commercial materials, or with previously introduced B. radicans, Digitaria swazilandensis, D. decumbens (Pangola and Transvaal), Dichatium aristatum, Cynodon spp., Panicum maximum, Pennisetum spp. and Hyparrhenia rufa.

b) Legumes:
Aeschynomene histrix CIAT 9690 and 9666; Arachis pintoi CIAT 17434; Centrosema brasilianum CIAT 5234, 5247, 5487 and 494; C. macrocarpum CIAT 5062, 5434, 5065, 5478A, 5452, 5274, 15366, 5713 and 15106; C. pubescens CIAT 5189, 438 and 5126; C. acutifolium CIAT 5112 and 5278; C. pascuorum CIAT 5190 and 5192; Desmodium incanum 13032; D. ovalifolium CIAT 3184 and 350; D. heterophyllum CIAT 349 and D. gyroides CIAT 3001; Galactia striata CIAT 964; Neonotonia wightii CIAT 204 and 206; Macroptilium sp. CIAT 506; Pueraria phaseoloides CIAT 9900; Stylosanthes capitata CIAT 1019, 10280, 1441, 2044, 1315, 1693 and 1728; S. macrocephala 1643 and 2133; S. guianensis CIAT 136, 184, 1280, 1283 and 1020; S. hamata 118 and 147; S. scabra CIAT 1047; S. leiocarpa 1087; S. sympodialis CIAT 1044; Zornia glabra CIAT 7847 y Zornia latifolia CIAT 728; Leucaena leucocephala CIAT 17467, 17488, 17502 (Cunningham), 17498, 17475, 17477, 17495 y 17491; L. pulverulenta CIAT 17490 and 17489; L. sp. CIAT 17478; L. diversifolia CIAT 17503, 17461, 17388 and 17485 and L shannoni CIAT 17487; Trifolium stenderi ILCA 6253; T. tembense ILCA 5274; T. guartinuanum ILCA 6301; T. decorum ILCA 6303, T. rueppellianum ILCA 6260 and Medicago sativa Florida 77.

Part of this germplasm is still being evaluated in sites with ecosystems of IDIAP's interest such as Toabré (Coclé), Arena de Quebro (Veraguas) and Cuesta de Piedra (Chiriquí). Panicum material was established in Gualaca and its evaluation has been programmed for Bugaba (Chiriquí).

A summary of the most outstanding germplasm in the Regional Trials is presented in Table 2. Grasses A. gayanus CIAT 621 and 6200, B. dictyoneura CIAT 6133, B. decumbens CIAT 606, B. humidicola CIAT 679 and 6369, had a wider range of adaptation with respect to climate, soil, pests and diseases. At Volcán, at 1,100 m altitude and 20.7°C mean temperature, B. decumbens CIAT 606, was superior to the other Brachiarias, while in other sites this ecotype was susceptible to diseases and to pests such as spittlebug (Aenolamia sp.). The legumes Centrosema, Pueraria and Stylosanthes were widely adapted; nevertheless, C. macrocarpum did not perform well at Volcán, possibly because of combined high rainfall and low temperatures. On the other hand, S. capitata CIAT 10280 adapted very well to very acid soils with high aluminum content and a precipitation not greater than 2,500 mm, such as in Calabacito. S. guianensis CIAT 184 showed the widest range of adaptation in both the savanna and humid forest ecosystems, and it was also the legume most tolerant to anthracnose (Colletotricum gloesporiodes). P. phaseoloides CIAT 9900 (tropical kudzu) was also widely adaptated but suffered much leaf fall during the summer, and in ecosystems such as Calabacito, showed symptoms of nutrient deficiencies and poor nodulation.

Table 2. Adaptation of new forage germplasm to different ecosystems in Panama. Regional trials A, 1983-87.

Grasses	Volcán	Calabacito	Tortí	Los Santos	Chepo	Soná
Andropogon gayanus CIAT 621	-	Excellent	Fair	Excellent	Excellent	Excellent
Andropogon gayanus CIAT 6200	-	Excellent	-	Good	-	Excellent
Brachiaria dictyoneura CIAT 6133	Fair	Excellent	Good	Excellent	Excellent	Excellent
Brachiaria humidicola CIAT 679	Fair	Good	Good	Good	Good	Excellent
Brachiaria humidicola CIAT 6369	Fair	Good	-	-	Good	Excellent
Brachiaria decumbens CIAT 606	Good	Good	Good	Good	Good	Good
Leguminosas						
Arachis pintoi CIAT 17434	-	Fair	Good	-	-	Excellent
Centrosema macrocarpum CIAT 5434	Poor	Excellent	Excellent	Excellent	Excellent	Good
Centrosema macrocarpum CIAT 5062	Poor	Good	Good	Excellent	Excellent	-
Centrosema macrocarpum CIAT 5065	Poor	Good	-	Good	-	-
Centrosema acutifolium CIAT 5278	Poor	Good	Good	Good	-	Regular
Pueraria phaseoloides CIAT 9900	Poor	Good	Excellent	Good	Good	Excellent
Stylosanthes guianensis CIAT 184	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Stylosanthes guianensis CIAT 136	-	Good	Good	Fair	-	Excellent
Stylosanthes capitata CIAT 10280	-	Excellent	-	Poor	Good	Good

AGRONOMIC EVALUATION OF PROMISING GERMPLASMM

Forages that were well adapted and produced well in the preliminary trials were evaluated further in Regional Trials Type B (RTB), using an adaptation of the methodology described by CIAT's Tropical Pastures Program. Experiments were conducted in Chepo (Eastern Region), Río Hato, Penonomé, Divisa, Los Santos, Soná, and Calabacito (Central Region) and Gualaca, Chiriquí and Hornito (Western Region). Following are oustanding results of these evaluations.

a) Andropogon gayanus CIAT 621

This material was introduced into Panama in 1979 by the Banco Nacional, and was commercially liberated in 1983 as cv. Veranera, jointly sponsored by of IDIAP/U. RUTGERS/CIAT, the School of Agronomy and the Banco Nacional. Agronomic trials were carried out in Calabacito and Finca Chiriquí, representing ecosysems with high soil acidity and low nutrient status, particularly of phosphorous (P). In Calabacito there was no response ($P > 0.05$) of cv. Veranera, either alone or associated with S. capitata CIAT 10280, to applications up to 60 kg/ha of P_2O_5 (Table 3), and adaptation of the species to climate and soil conditions of the site was outstanding. In Chiriquí where cv. Veranero was associated with C. macrocarpum CIAT 5062, only sulphur and its interaction with P and K gave significant yield increases ($P < 0.05$), which indicates that this may be the most important element for A. gayanus in these soils (Table 4). Nevertheless, yields of A. gayanus were very satisfactory even without fertilizers.

There are an estimated 1000-1500 ha of A. gayanus in Panama, concentrated in the Central Provinces where there are prolonged periods of drought and/or acid soils. Joint action by IDIAP and the Banco Nacional has contributed greatly to the commercial promotion of cv. Veranera.

b) Brachiaria spp.

Species of Brachiaria have been evaluated at different sites in Panama for seasonal dry matter yields, tolerance to spittlebug, to drought, and to diseases (Annual Report 1985, 1986, CIAT-Tropical Pastures Program). On an Ultisol at Calabacito, characterized by 4-5 months of dry season and a low incidence of the spittlebug, the yield of the B. brizantha material varied from the highest to the lowest (Table 5). The ecotype CIAT 6016, characterized by a low proportion of leaves, semi-bunch growth and abrasive leaf and stem texture, is unattractive forage species. In contrast, B. humidicola CIAT 679 (commercial type in Panama) and the local B. decumbens (CIAT 606 type), as well as a considerable number of other entries, including B. dictyoneura (CIAT 6133), performed well in this ecosystem.

B. dictyoneura CIAT 6133 and B. humidicola CIAT 6369 and 6707 were selected for further evaluation. The effects of nitrogen, phosphorous and sulphur on their yields were determined in Gualaca (Inceptisol) and Finca Chiriquí (Ultisol) (Table 6). It is noteworthy that there has been little variation in the yield of B. humidicola, CIAT 6369 over many observations in both Gualaca and Chiriquí. The only significant yield increases in Gualaca were found in the interactions at high levels of N, P, and S. Although the yields at both sites were similar, later cuttings at Finca Chiriquí had lower yields, possibly caused by the lower fertility and higher acidity of its soil. Moreover, B. humidicola CIAT 6707 at Chiriquí has given sustained yields with only small responses to fertilizer treatments. In Gualaca B. dictyoneura CIAT 6133 has similarly

Table 3. Responses to phosphorus at Calabacito, Panama, of A. gayanus CIAT 621 alone or associated with S. capitata cv. Capica.

P_2O_5 level (kg/ha)	DM yields (kg/ha)		
	S. capitata*	A. gayanus* kg DM/ha	A. gayanus + S. capitata*
0	1052.3 a**	2841.0 a	1751.7 a***
15	1364.0 a	2969.0 a	2500.7 a
30	1294.0 a	3092.6 a	2605.3 a
60	1743.0 b	3343.3 a	3132.0 a

* Mean of three cuts during the rainy season..

** Values followed by the same letter are not significantly different ($P > 0.05$)

*** The mean proportion of S. capitata was 11.1% (Range 7.2 - 15.8%).

Table 4. Effect of sulphur, phosphorous and potassium on the yields of Andropogon gayanus CIAT 621 and Centrosema macrocarpum CIAT 5062 grown on an Ultisol at Chiriquí, Panamá.

Fertilizer (kg/ha)			DM Yields (kg/ha)		
S	P	K	A. gayanus	C. macrocarpum	Total
0	0	0	1882 c	253 c*	2135 c
0	0	60	2660 bc	332 cd	2992 bc
0	100	0	1958 c	435 cd	2393 c
0	100	60	2489 bc	283 de	2772 bc
40	0	0	3835 a	462 bc	4297 a
40	0	60	4023 a	620 a	4643 a
40	100	0	3403 ab	506 abc	3909 ab
40	100	60	3840 a	681 a	4521 a

Basal fertilizer: 20 kg/ha Mg, 2 kg/ha Zn, 1 kg/ha B, 0.1 kg/ha Mo. The legume was inoculated with Rhizobium.

* Data followed by the same letter are not significantly different ($P > 0.05$). Harvest was 96 days after planting.

Table 5. Yields of *Brachiaria* ecotypes grown on an Ultisol at Calabacito, Panama.

Ecotype	CIAT No.	Yields (kg DM/ha)*
B. brizantha	6016	2942.2 a
B. humidicola	679	2848.2 ab
B. decumbens	Local	2259.3 abc
B. ruziziensis	6134	2234.1 abc
B. humidicola	6709	2122.2 bcd
B. dictyoneura	6133	2088.2 cd
B. humidicola	675	1887.2 cde
B. humidicola	682	1847.8 cde
B. humidicola	6369	1806.7 cdef
B. humidicola	6707	1694.9 cdef
B. ruziziensis	655	1627.1 cdef
B. humidicola	6705	1610.1 cdef
B. ruziziensis	Local	1531.1 cdef
B. decumbens	6132	1520.0 cdef
B. decumbens	6131	1509.1 cdef
B. ruziziensis	6291	1493.9 cdef
B. ruziziensis	6130	1483.7 cdef
B. ruziziensis	6419	1414.6 def
B. brizantha	6012	1238.0 ef
B. ruziziensis	654	1230.7 ef
B. brizantha	664	1221.9 ef

* Means of 3 cuts taken each 6 weeks during the rainy season.

** Values followed by the same letter are not significantly different ($P > 0.05$).

Table 6. Effect of nitrogen, phosphorus and sulphur on the yields of two *Brachiaria humidicola* (B.h.) and *B. dictyoneura* (B.dic.) ecotypes in Gualaca and Finca Chiriquí, Panamá, 1987.

Treatments (kg/ha)				B.h. CIAT 6369		B.h.CIAT 6707	B.dic.CIAT 6133
				Gualaca	Finca Chiriquí	Finca Chiriquí	Gualaca
	N	P	S	(10 cuts)*	(3 cuts)	(4 cuts)	(4 cuts)
1.	0	0	0	1829.9 bc**	1825.9 a	1897.8 ab	3559.4 a
2.	50	0	0	1963.1 b	2252.2 a	1720.6 b	3270.8 a
3.	0	20	0	1867.4 bc	2483.6 a	2056.3 ab	3736.4 a
4.	50	30	0	1826.7 bc	1923.3 a	1973.9 ab	3576.7 a
5.	0	0	20	1844.4 bc	2623.0 a	2019.2 ab	3420.6 a
6.	50	0	20	2144.5 b	1714.6 a	2192.3 ab	3313.8 a
7.	0	30	20	1296.8 c	2006.1 a	2362.9 ab	3653.2 a
8.	50	30	20	1815.4 bc	1923.3 a	2561.0 ab	3671.7 a
9.	25	15	10	1785.8 bc	2009.1 a	2491.7 ab	3628.1 a
10.	75	15	10	2332.7 ab	2213.9 a	1823.8 ab	3336.3 a
11.	25	45	10	1795.3 bc	2036.7 a	2478.2 ab	3913.2 a
12.	25	15	30	1801.4 bc	2325.0 a	2216.5 ab	3693.8 a
13.	150	90	60	2749.1 a	2828.4 a	2591.2 a	4003.6 a

* Cuts each 35 days during the rainy season.

** Values followed by the same letter are not significantly different ($P > 0.05$).

given sustained, but lower, average yields than those of the other Brachiarias. Nevertheless, all of them have been outstanding because of their good yields without fertilizer application, which indicates their good adaptation and high potential productivity to these ecosystems.

RHIZOBIOLOGY

The productive performance of adapted legumes depends on good initial establishment, on the capacity to make efficient use of the soil's nutritional resources, on satisfactory correct nodulation and effective nitrogen fixation. Therefore, the evaluation of germplasm adaptation has been complemented with studies of the requirement for Rhizobium inoculation. The response of 30 ecotypes of forage legumes to applied nitrogen was evaluated at Calabacito as an indirect way of judging the need for inoculation, since a species with a large response to nitrogen suggests problems of nodulation with native strains of rhizobium. There was variation between and within species to nitrogen response (Figure 1), but on the whole the biggest responses were in C. macrocarpum, C. pubescens, C. brasilium, C. acutifolium, P. phaseoloides 9900, D. heterophyllum and D. ovalifolium. Stylosanthes capitata, S. macrocephala and S. guianensis responded little to nitrogen, indicating adequate nodulation with native Rhizobium strains and need for inoculation. In contrast, Leucaena leucocephala produced poorly in spite of inoculation, indicating that it is poorly adapted to ecosystems such as that of Calabacito.

In a complementary greenhouse trial, using soils from Calabacito, El Coco and Los Santos, C. macrocarpum CIAT 5062 and P. phaseoloides CIAT 9900 responded significantly to inoculation with CIAT strains 3101 and 2434 respectively, particularly when molybdenum was added (Table 7). The response in both species was greater for the Calabacito soil (acid Ultisol with high aluminium saturation), although significant effects were also measured in El Coco soil. Inoculation stimulated nodule formation but these were effective only when molybdenum was added. In Los Santos soil there was no response to molybdenum nor an interaction of molybdenum with inoculation, which indicates adequate nodulation by the native rhizobium of this soil, which is of higher fertility and has no problems of acidity or aluminum. The results agree with field observations of these and other species in the sites above and demonstrate the advantage of inoculation with effective rhizobium strains when establishing pasture legumes in unfertile acid Ultisols.

WEED CONTROL

Weed control has included two activities: control of shrubby weeds and narrow-leaved weeds in established fields, and the use of pre- and post-emergent herbicides for weed control during the establishment of tropical kudzu (Pueraria phaseoloides) and Centrosema macrocarpum (Annual Report 1984-1986, CIAT Tropical Pastures Program).

The adaptation of C. macrocarpum CIAT 5062 to various ecosystems of Panama has been outstanding, but like many forage legumes, its initial growth is slow, allowing considerable competition from annual weeds, particularly in the higher fertility soils of humid forest ecosystems. A field trial with pre- and post-emergent herbicides was carried out in IDIAP's Gualaca Experimental Station - pH 5.4, clay-mud Inceptisol soils, an average temperature of 26 C and an annual precipitation of 4,000 mm. The herbicides used (application rate in kg/ha active ingredient) were: pendimentalin (1.0, pre), alaclor (2.24, pre), metolaclor (1.40, pre),

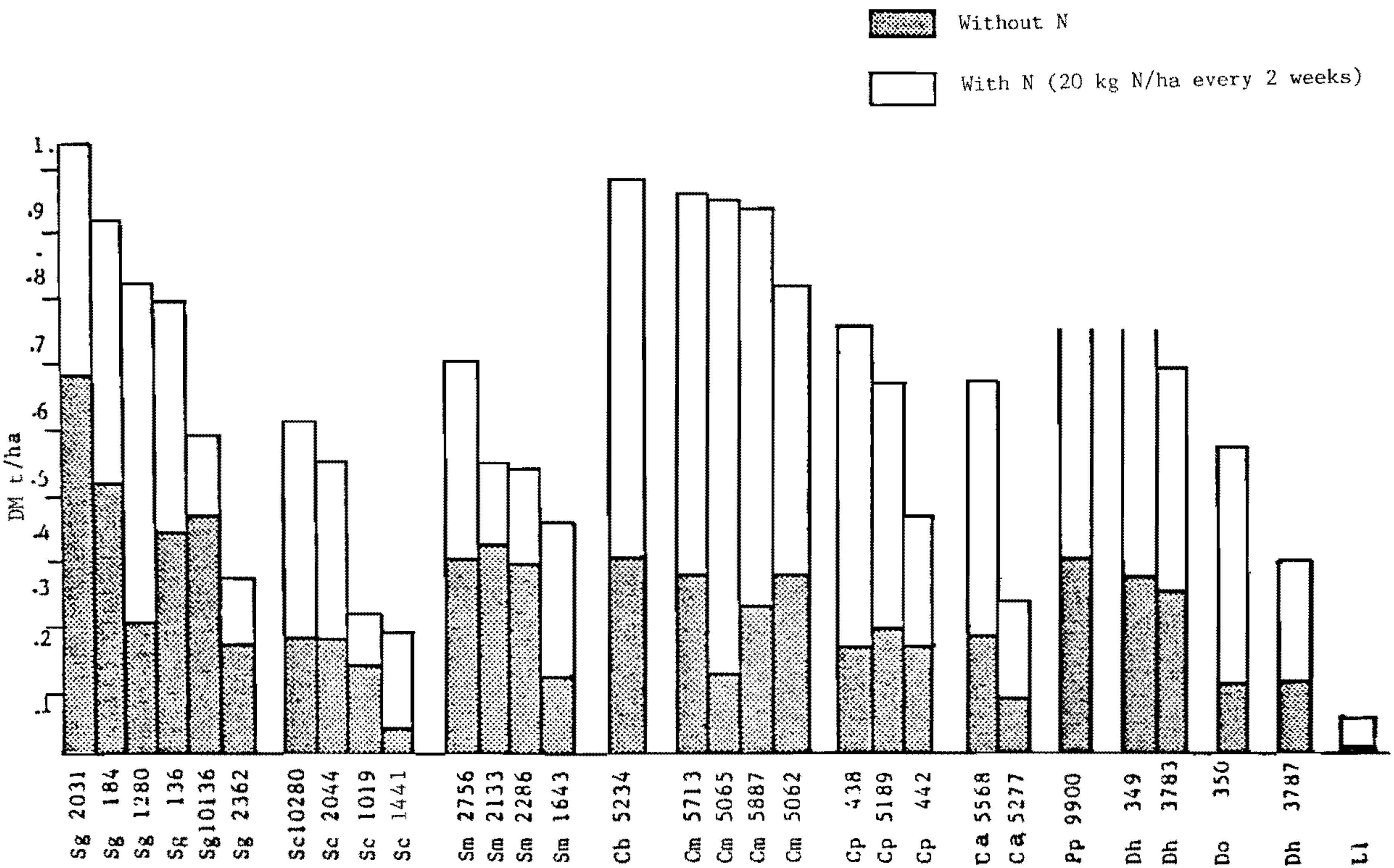


FIGURA 1. Nitrogen effect (N) on yields of 30 forage legumes ecotypes 12 weeks after establishment at Calabacito (Panama) (Sg: *Stylosanthes guianensis*; Sc: *S. capitata*; Sm: *S. macrocephala*; Cb: *Centrosema brasilianum*; Cm: *C. macrocarpum*; Xp: *C. puvwaxwna*; Ca: *C. acutifolium*; Pp: *Pueraria phaseoloides*; Dh: *Desmodium heterophyllum*; Do: *D. ovalifolium* and Ll: *Leucaena leucocephal*); Dhe: *D. heterocarpum*).

Table 7. Effect of molybdenum and of inoculation with CIAT strains 2434 and 3101 on the number of nodules per plant, andon the dry matter yields of *P. phaseoloides* 9900 and *C. macrocarpum* 5062 grown in three different Panama soils.

Treatment	*C. macrocarpum* 5062*		*P. phaseoloides* 9900*	
	g/plant	Nodules/plant	g/plant	Nodules/plant
Calabacito Soil (pH 4.5; Al Sat. 70%)				
Without inoc. - With Mo	0.89 b	1	1.71 b	10
With inoc. - With Mo	2.85 a	17	3.28 a	25
High N - With Mo	3.42 a	1	3.64 a	12
Without inoc. - Without Mo	0.54 b	1	0.88 c	10
With inoc. - Without Mo	1.14 b	44	1.23 bc	33
El Coco Soil (pH 5.2; Al Sat. 1%)				
Without inoc. - With Mo	3.16 b	15	3.23 b	38
With inoc. - With Mo	4.37 a	37	4.03 a	38
High N - With Mo	4.42 a	11	4.44 a	35
Without inoc. - Without Mo	1.91 c	20	-	-
With inoc. - Without Mo	2.15 c	56	-	-
High N - Without Mo	4.18 a	15	-	-
Los Santos Soil (pH 6.4; Al Sat. Tr.)				
Without inoc. - With Mo	4.52 b	21	4.94 a	15
With inoc. - With Mo	5.17 b	32	5.58 a	35
High N - With Mo	6.10 a	14	5.44 a	18

* Mean of five replicates 12 weeks of growth.
Means followed by the same letter are not significantly different ($P > 0.05$).

oxyfluorfen (0.50, pre), bentazon (1.0, post), fluazyfopbutyl (0.75, post) and 2,4-D amine (0.40, post). A manual grub treatment was also included with only one control. The treatments were evaluated 30 and 60 days after application of the herbicide, including damage to the Centrosema seedlings and their yield, and yield of weeds at 110 days when the observations were concluded. The herbicide with best selectivity and weed control was pendimentalin applied pre-emergent at 1.0 kg ai/ha (Table 8), giving good yields of Centrosema and few weeds. The manual grub treatment obviously produced the best yields by totally removing weeds, but demanded a considerable amount of hand labor.

Herbicides such as alaclor and particularly metolaclor had a similar performance with respect to selectivity but were less effective against the complex of weeds present. Oxyfluorfen, which has been highly selective in kudzu, was very toxic for Centrosema, thus significantly reducing seedling population. The post-emergent herbicides, which were applied 20 days after the planting of Centrosema, and with the exception of 2,4-D amine, fluazyfophbutyl and bentazon, were selective to legumes, but not very effective against weeds, which were dominated by narrow-leaved species such as Panicum rudgei and by the broad leaved species Borreria alata and Mimosa spp. Bentazon was more effective against broad-leaved weeds, while fluazyfopbutyl was effective against narrow leaved weeds. The different selectivity would give different results if the complexes of weeds differed from those observed in this experiment.

SEED MULTIPLICATION

The availability of promising germplasm should be accompanied by increasing efforts to multiply basic seed, otherwise it is difficult for the evaluation process to have any impact in the short or medium terms. Therefore, seed multiplication and the development of the technology of production of seed of tropical forages was one of the main activities in the IDIAP/U.RUTGERS/ CIAT agreement. Table 9 summarizes the multiplication of basic seed of promising forages and of seed commercially liberated in Panama, such as A. gayanus CIAT 621, of wuich 3,868 kg of basic seed was produced in those parts of the country where IDIAP has direct impact. There is variability in the reported yields because of the effect of different sites, the management of crop harvest, and the efficiency of seed collection. Nevertheless, the observed yields are within the range reported for other sites of the Latin American tropics.

C. macrocarpum has been selected as a promising forage legume for various ecosystems in Panama, but the seed yields obtained up until now have been quite variable. In Gualaca in 1986 CIAT ecotypes 5062 and 5434 produced high yields, since it was a year with a well defined and stable dry period that favoured flowering and seed formation, which did not occur in Calabacito and thus explains the low yields there. Other promising legumes such as C. acutifolium, S. guianensis and S. capitata, flower and set seeds in different parts of the country, mainly where annual precipitation in less than 2,500 mm.

B. dictyoneura CIAT 6133 is possibly the most promising grass among the new collections. It has been observed to flower and set seed better than other Brachiarias in Chepo, Calabacito and Gualaca. Nevertheless, during the first six months after harvesting, the seed has appears to have pronounced dormancy and germination is low.

Seed harvested of all the forages enumerated in Table 9 has been reserved for the planting of

Table 8. Weed control during the establishment of *Centrosema macrocarpum* CIAT 5062, Gualaca (Panama), 1987.

Treatment	Rate kg/ha ai	Application	Control % 30 days	Control % 60 daus	Centrosema Seedlings 20 days	Centrosema kg/ha DM 110 days	Weeds* kg/ha MS 110 days
Pendimentalin	1.00	PRE	80	83	15	1263	564
Alaclor	2.24	PRE	70	47	15	838	1028
Metolaclor	1.40	PRE	48	25	14	838	2259
Oxyfluorfen	0.50	PRE	88	87	5	500	1220
Bentazon	1.0	POS	77	50	15	900	1087
Fluazyfopbutyl	0.75	POS	78	67	15	463	2377
2,4-D amina	0.40	POS	60	73	15	31	3063
Manual grub	-	-	100	100	15	1625	0
Control	-	-			15	296	2288

* Predominant weeds: *Panicum rudgei*, *Sida* sp., *Borreria alata* and *Mimosa* sp.

Table 9. Yield of basic seed and production of tropical forages in Panama, 1984-1986.

Species	Harvest site	Annual yields of raw seed (kg/ha) 1984	1985	1986
A. gayanus CIAT 621 (Veranero)	Gualaca	431 (862)+	192 (384)	-
	Finca Chiriquí	-	190 (247)	-
	Río Hato	-	-	250 (250)
	Soná	-	355 (355)	170 (424)
	Chumpaíto	-	-	182 (546)
	Calabacito	-	210 (350)	180 (450)
P. phaseoloides (Kudzú)	Gualaca	22 (22)	11 (11)	-
	Calabacito	-	-	
C. macrocarpum CIAT 5065	Gualaca	-	25 (10)	60 (24)
C. macrocarpum CIAT 5062	Gualaca	-	-	457 (15)
	Calabacito	-	-	50 (50)
C. macrocarpum CIAT 5434	Gualaca	-	-	521 (7)
	Calabacito	-	-	15 (15)
C. macrocarpum CIAT 5278	Calabacito	-	-	30 (30)
C. brasilianum CIAT 5234	Calabacito	-	-	25 (25)
C. guianensis CIAT 136	Gualaca	45 (7)	-	-
S. capitata "Capica"	Gualaca	589 (194)	-	-
	Calabacito	-	50 (150)	70 (180)
B. humidicola "Comercial"	Finca Chiriquí	75 (375)	-	75 (150)
	Calabacito	-	-	100 (100)
B. dictyoneura CIAT 6133	Gualaca	-	-	221 (36)
	Calabacito	-	-	175 (175)
Total harvested		(1460)	(1507)	(2517)

+ In parenthesis total kg harvested.

experimental plots, to new multiplication lots and in the case of Veranero, for sale to local producers. Basic seed is also being used for planting of demonstration plots of S. capitata "Capica", C. macrocarpum and B. dictyoneura in producers' farms.

The effect of nitrogen and of sulphur has been tested in B. decumbens (CIAT 606 type) and B. humidicola (CIAT 679 type) in Gualaca and Calabacito. Table 10 shows the results of a two year evaluation with B. decumbens. It is noteworthy that in neither year did fire increase seed yields. Application of nitrogen in two dressings, 40 kg/ha applied at the beginning of the flowering and 40 kg/ha two months earlier, only increased yields compared with the control during the second year. Nevertheless, the best production of seed was obtained with the application of 80 kg/ha of N, independent of burning, and principally in the second year yields. It is interesting to note that fire tended to reduce the plant population in the first year, probably because the soil was wet at the time of burning. However, in the second year all the plots performed equally.

In Panama it is possible to make two harvests each year of both B. decumbens and B. humidicola. The first flowering occurs between June and July and is the most abundant, while the second occurs in September-October and gives lower yields. In Calabacito, B. humidicola responded very well to nitrogen (N) in combination with sulphur (S) (Table 11). The greatest yields were obtained with the application of 100 kg/ha of N and 40 kg/ha of S, which is also reflected in a greater number of floral stems/m^2. In this case it was not possibly to make the first harvest of seed, but judging by observations of this and other sites, it is probable that greater yields would have been obtained.

PASTURE EVALUATION UNDER GRAZING

Pastures evaluated under grazing constituted the most difficult research activity to carry out during the development of the present agreement. There were difficulties in the establishment and management of grazing experiments due to administrative and financial problems. Nevertheless, three experiments with promising germplasm were established in Chiriquí (School of Agronomy), Calabacito and Gualaca. In the first experiment the objective is to measure persistance under grazing of B. humidicola-kudzu and of H. rufa and A. gayanus CIAT 621, associated with C. macrocarpum CIAT 5065 and S. capitata CIAT 10280. Grazing was a rotational scheme of 7 days on and 35 days rest days with three stocking rates (1.25, 2.0 and 2.5 UA/ha). This experiment was suspended because of lack of water for the experimental animals, but is expected to be continued in the future, depending on the resources available.

In the experiment in Calabacito the objective was to measure liveweight gain in B. dictyoneura CIAT 6133 and B. humidicola (CIAT type 679) grown in association with Kudzu, and in H. rufa and A. gayanus CIAT 621 grown in association with S. capitata CIAT 10280 and C. macrocarpum 5062. Observations made in both experiments suggest that S. capitata is the most persistent legume at both sites. Kudzu showed severe nutrient deficiencies at establishment, which was attributed to the lack of adequate nodulation, particularly in Calabacito. On the other hand, the plant population of C. macrocarpum was significantly reduced when in association with A. gayanus, probably due to the severe competition of this grass for nutrients and water. This did not occur when the legume was associated with H. rufa, a less competitive grass, in Chiriquí.

Table 10. Effect of nitrogen fertilizer on seed yields of *Brachiaria decumbens* in Gualaca (Panamá).

Treatments	Raw seed yields (kg/ha)					
	1986			1987		
	1st Harvest	2nd Harvest	Total	1st Harvest	2nd Harvest	Total
Control	-	-	-	88	91	179 bc
Basal*	128	59	187 ab	60	87	147 c
Basal + Burning	55	64	119 b	86	91	177 bc
Basal + 40 kg of N + 40 kg of N	155	82	237 a	121	91	212 b
Basal + 80 kg of N	182	69	251 a	176	92	268 a
Basal + 80 kg of N + Burning	149	100	249 a	194	91	285 a

* Basal: K_2O 30 kg/ha, P_2O_5 25 kg/ha.

Values with a same letter in the same column do not differ significantly (P > .01).

Table 11. Effect of nitrogen and sulphur on seed yield of Brachiaria humidicola (CIAT type 679), Calabacito, Panama, 1987.

Treatments kg/ha		Yield kg/ha+		Floral stems/m^2	
		1st Harvest (July)	2nd Harvest (September)	1st Harvest	2nd Harvest
N	S				
0	0	-	15.4	-	22
0	40 + basal*	-	35.2	-	78
50	20 + basal	-	161.0	-	406
100	0 + basal	-	171.0	-	517
100	40 + basal	-	234.0	-	575

* Basal fertilizer: 30 kg/ha of K_2O and of P_2O_5.

+ Raw seed.

In Gualaca, B. humidicola CIAT 639 was established to be grazed with two stocking rates, 1.0 and 2.0 UA/ha, in an alternate grazing system (28/28 days). This grass has recently been selected in Panama because of its stoloniferous habit, high drought tolerance, moderate tolerance to spittlebug and high leaf proportion (Annual Report 1986, CIAT Tropical Pastures Program). Grazing treatments were recently initiated.

CONCLUSIONS AND GENERAL RECOMMENDATIONS

During the development of the present agreement it was possible to identify and select forage plants adapted to acid soils and tolerant to pests and diseases common in Panama. Species and ecotypes of Brachiaria, Andropogon, Centrosema, and Stylosanthes were the most outstanding. Fertilizer requirements were defined, mainly for phosphorus (P) and sulphur (S), for the establishment of promising germplasm.

The possibility for seed multiplication of promising germplasm was demonstrated in various locations, which will allow in the future the selection of the most appropriate sites for commercial seed production.

Methods and appropriate herbicides for effective weed control were found for the establishment of Centrosema macrocarpum and tropical kudzu, and for the control of Paspalum virgatum in grazed pastures.

Efforts on weed control should give emphasis to development of methods and systems to eliminate weeds highly tolerant to herbicides (such as Curatella americana, Psidium sp., Pteredium aquilinum.

Based on the above the following recommendations are suggested: a) to continue the selection and evaluation under grazing of promising germplasm to define its commercial value. The establishment and evaluation of grass/legume pastures in farmers fields should be of high priority.

Effects on seed multiplication and development of seed technology should continue with the hope of concentrating this activity in suitable sites within Panama.

Finally, in the short term, priority should be given to pasture evaluation under grazing due to the increased availability of new forage germplasm. These trials should obviously be of manageable size without sacrificing relevant information on persistence and productivity.

8. ENTOMOLOGY

During 1987, effort has been concentrated on screening the Brachiaria collection for host plant resistance to species of spittlebugs (Zulia colombiana and Aeneolamia varia). This has required development of new methodologies for field and glasshouse screening and implementation on a large scale. The Section has developed a simplified, innovative method for mass rearing spittlebugs that provides a dependable, year-round source of eggs, nymphs, and adults for experimental use and resistance screening in the glasshouse. A detailed study of host plant resistance in a few selected accessions has given new insights into possible mechanisms of resistance present in Andropogon and Brachiaria. The techniques developed for that study have been applied to large scale screening of the Brachiaria and Panicum collections for host plant resistance (antibiosis and tolerance) to spittlebug.

Progress in laboratory studies of egg biology and response to environmental conditions now permits storage of spittlebug eggs for longer periods than previously possible. Together with an improved system of egg collection, this technique will solve the problem of insect availability for glasshouse screening purposes and may provide a powerful tool for manipulating experimental insect populations in the field. Work has been started to identify an appropiate deployment technique to allow uniform placement and survival of spittlebug eggs in field plots.

In 1987, 265 accessions of the Brachiaria collection were established at three sites (Carimagua and Villavicencio in Colombia, and Pucallpa, Peru) in collaboration with the Agronomy Carimagua Section to evaluate edaphic adaptation and reaction to spittlebug. Natural populations of spittlebug at the evaluation sites have been higher than previously achieved and will allow for more meaningful selection of materials in a shorter period of time. A subset of resistant, well-adapted materials will soon be available for more extensive evaluation at regional trial locations.

Leaf- and grass-cutting ants (Atta laevigata and Acromyrmex landotti, respectively) have been less noticeable during 1987 as a result of the heavier than normal rainfall of 1986. The visit of an experienced ant specialist, Dr. Malcolm Cherrett from the University College of North Wales, stimulated a fresh analysis of the problem and a new research strategy has been formulated. Unfortunately, the first stage of the plan, a survey of ant populations in native savanna, has been greatly reduced due to restrictions on travel at Carimagua.

Progress has been made in identifying specific components of the sucking insect complex that attacks forage legumes such as Centrosema. As key pests are identified, specific screening methodologies can be developed.

SPITTLEBUG

1. Mass rearing

The various genera and species of spittlebugs (Cercopidae) native to Latin America are considered to be the principal limiting factor in the utilization of Brachiaria as a forage grass in Latin America. Spittlebugs are capable of causing severe damage to susceptible grasses thereby reducing forage availability and quality and hastening pasture degradation due to weed invasion. Recent introduction of a large collection of Brachiaria accessions from Africa has stimulated the search for host plant resistance to spittlebugs. A system for rearing all stages of spittlebug has been developed to facilitate studies of resistance mechanisms and basic insect biology.

Mass rearing methodology

Adults of Zulia colombiana are collected from plots of Brachiaria decumbens at Santander de Quilichao and introduced into an oviposition cage. The sides of the wooden cabinet are covered with nylon mesh and the bottom of the cage is fitted with a removable drawer to allow insertion and removal of trays containing an oviposition substrate. The substrate consists of clay soil (pH 4.5) collected from areas of natural spittlebug infestations, in this case CIAT's experimental farm located at Santander de Quilichao. The soil is suspended in water, sieved through fine cheesecloth, spread on a linen cloth support to a depth of approximately 0.5 cm, and allowed to air dry. When the soil has dried to a sticky consistency (40-60% water by weight), it is placed in the bottom of the oviposition chamber. The soil is imprinted with a reticulate pattern to increase oviposition sites and encourage more uniform distribution of oviposition in the soil. Adults collected from the field or adults emerging from the glasshouse colony are placed in the chamber and allowed to oviposit. The trays can be removed and replaced to obtain eggs of a particular age.

The tray with soil and eggs is removed after one to several days, suspended in water, sieved, and a flotation technique is used to separate eggs from organic material. The linen cloth support is washed in a large beaker with water to suspend the soil. Floating organic material is skimmed off and the suspended soil is sieved through a fine mesh screen leaving only spittlebug eggs and some solid material. The sieved material is place in a 30% saline (NaCl) solution. Eggs are then decanted from the surface and collected on cheesecloth. To reduce fungal contamination, the eggs can be disinfected in 0.5% sodium hypoclorite for 5 minutes and washed in distilled water.

Eggs are incubated in the laboratory at 23°C and when ready to eclose, are placed on pieces of moist filter paper at the base of potted grass plants. We have found that by simply covering plastic pots with aluminum foil, secondary root development at the soil surface is stimulated resulting in abundant feeding sites for eclosing spittlebug nymphs. In addition, the foil provides excellent conditions of temperature, relative humidity, and reduced light for nymph development. As an additional measure, grass plants are placed on top of an inverted plastic petri dish with a small amount of soil at transplanting. This forces lateral growth of exposed roots and insures availability of roots as feeding sites for nymphs. When nymphs attain fifth instar, pots are fitted with organdy cages to trap emerging adults. In this way, adults of known age can be collected, used for experimental purposes, or introduced into an oviposition chamber.

Of the total number of eggs obtained (31,727) from 654 female and 752 male field-collected adult Z. colombiana, 28,194 (89%) were oviposited in the soil and 3,533 (11%) were retained by and recovered from dead females. During 1986-87, the glasshouse colony as described produced an average of 85 adults/day. The male:female ratio of emerging adults was approximately 1:1. Incubation period of spittlebug eggs varied from 12 to 15 days and nymphs completed 5 instars in approximately 45 days.

The aluminum foil cover had no effect on relative humidity inside pots compared to the glasshouse room (Table 1). The glasshouse is cooled by a radiator-type convective cooling system that maintains conditions of constant moderate temperature and high relative humidity compared to the screenhouse where no active cooling system is used and both temperature and humidity fluctuate widely. In the screenhouse, the foil cover resulted in significantly higher relative humidity inside pots compared to ambient conditions.

Higher temperatures were measured in

Table 1. Effect of aluminum foil cover on temperature and relative humidity in plastic pots of Brachiaria plants in the glasshouse and in the screenhouse.

	Temperature (°C ± standard deviation)		
Time of day	Room conditions	Under foil	Prob. of a greater t
Glasshouse			
7:30	23.56 ± 0.95	24.81 ± 1.13	< 0.0001
13.00	24.84 ± 1.25	26.83 ± 0.97	< 0.0001
16.00	24.41 ± 1.24	25.41 ± 0.68	0.0005
Screenhouse			
7:30	25.02 ± 2.14	24.40 ± 1.65	.2138
13.00	30.35 ± 1.25	29.99 ± 1.88	.3859
16.00	27.63 ± 1.95	27.13 ± 1.82	.3427

	Relative Humidity (% ± standard deviation)		
Time of day	Room conditions	Under foil	Prob.of a greater t
Glasshouse			
7:30	92.89 ± 3.66	94.50 ± 3.64	.1017
13.00	92.23 ± 4.76	91.03 ± 4.31	.3096
16.00	92.97 ± 4.76	94.44 ± 1.80	.1345
Screenhouse			
7.30	80.67 ± 9.77	92.23 ± 4.77	0.0001
13.00	61.70 ± 5.76	82.97 ± 6.08	0.0001
16.00	65.85 ± 6.34	88.52 ± 6.87	0.0001

the screenhouse compared with the glasshouse during afternoon hours. The aluminum foil cover had no effect on temperature inside pots in the screenhouse while temperatures inside pots were slightly but significantly higher in the glasshouse (Table 1).

These results suggest that this method is particularly useful in screenhouses or locations with low ambient humidity. It is possible that an even greater positive effect on nymph survival results from stimulation of superficial rooting due to low light intensity afforded by the aluminum foil.

Using the technique described here, we are currently maintaining two spittlebug colonies: Z. colombiana and A. reducta. This rearing method allows for year-round production of eggs, nymphs, and adults of known age for experimental purposes.

The technique facilities studies of basic biology and provides a dependable source of insects during times when spittlebugs are not available from the field. Variability in laboratory and glasshouse experiments associated with field-collected adults is avoided. The rearing technique requires no special equipment and eliminates contamination problems we have experienced with other techniques.

The oviposition chamber is of simple construction and can be modified to suit local conditions and availability of materials. The production and recovery of eggs is rapid and efficient. Such a technique is well-suited to use by national research programs interested in producing spittlebug adults for experimental purposes or for collecting spittlebug eggs from reared or field-collected adults.

2. Spittlebug egg storage, biology, and deployment

During egg development, egg weight increases due to absorption of water from the environment (Figure 1). Eggs of the spittlebug Z. colombiana contain between 30% and 50% water when oviposited and lose water rapidly through the corion (egg shell) when exposed to drying conditions of low humidity or high temperature. Survival of eggs under dessicating conditions (0% RH, 25°C) is proportional to water loss (Figure 2). Fifty percent egg mortality occurred when water loss was approximately 25%, or after 8 hours at 25°C and 0% RH.

Various studies have been initiated to understand how conditions of temperature and relative humidity determine spittlebug egg dormancy. In one study, sections of soil from oviposition cages with undisturbed eggs of three developmental stages (1 day, 3 days, and 6 days of development at 23°C) were dried and stored at two temperatures (15 and 23°C). As a control, eggs were kept in moist mud at 23°C. Four replications (soil sections) were removed from the experimental conditions periodically, extracted, and incubated at 23°C on moist filter paper to determine survival and stage of development as indicated by number of days to eclosion. All eggs in moist soil at 23°C (control) eclosed within 20 days with 93.5% survival. Eggs in moist soil at 15°C continued developing although at a slower rate and with increasing mortality as time of storage increased. Complete mortality occurred at 90 days while by 60 days, 43.9% of eggs had already eclosed during storage at 15°C. In dry soil, mortality was high after only 20 days of storage regardless of developmental stage (98, 100, and 79% for eggs of 1, 3, and 6 days respectively). However,

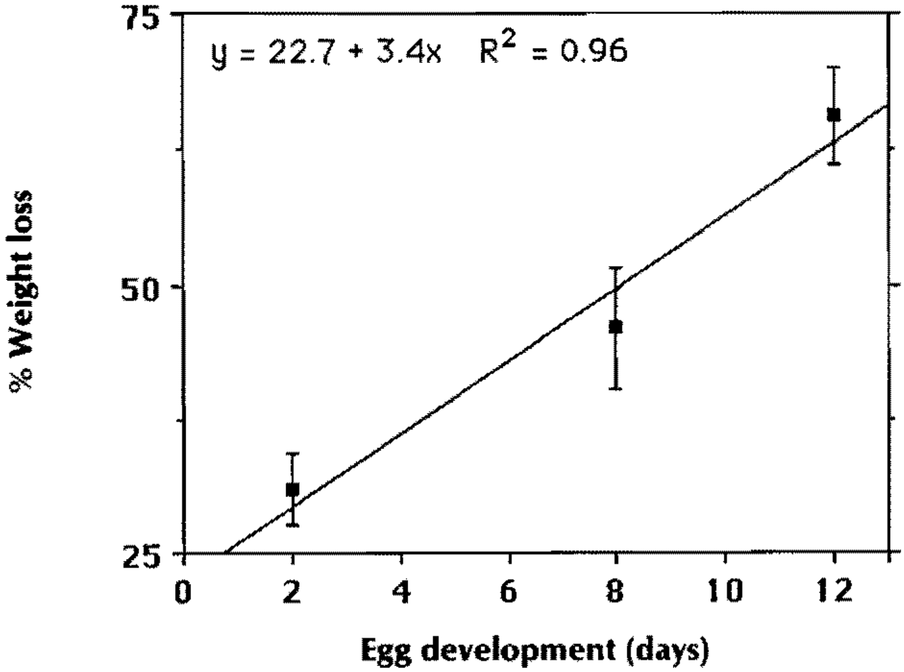


Figure 1. Relationship between physiological age of eggs of Z. colombiana and weight loss under drying conditions (20 hours at 45°C).

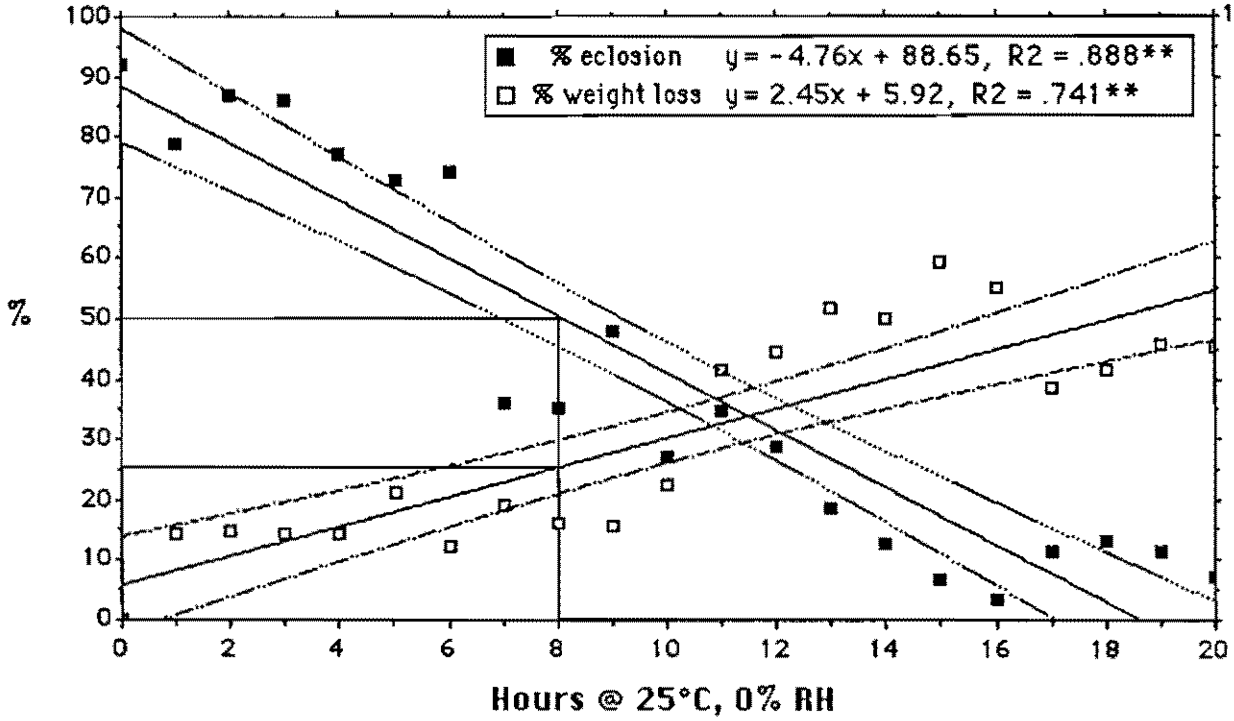


Figure 2. Correlation of percent eclosion and percent weight loss of eggs of Z. colombiana with number of hours held under drying conditions. Curved lines represent 95% confidence bands for the true mean of y.

eggs stored dry soil at 15°C maintained viability for longer periods. One-day-old eggs at 15°C suffered low mortality and did not eclose until 75 days when mortality reached 72%. Three-day-old eggs experienced moderate mortality (on the order of 25%) until 60 days when mortality was 30%, but 59% of the eggs had already eclosed. Similarly, 6-day-old eggs showed 86% eclosion by 45 days. Clearly, dormancy was not induced by any of these treatments since development continued even at 15°C and dryness caused high mortalities. The best treatments for storing eggs in soil was one day old eggs in dry soil at 15°C.

Another study was conducted with extracted eggs that were placed under conditions of controlled temperature and relative humidity using saturated salt solutions to maintain a constant relative humidity within the storage chamber. In this study, eggs were placed on plastic trays and stored in closed plastic boxes above a saturated salt solution for different periods at constant temperature and relative humidity. To date, the best survival has been obtained by storing eggs at 20 or 25°C and 90 ± 5% RH using a satu- rated solution of $MgSO_4$. A study is in progress to identify the develop- mental threshold temperature for eggs of Z. colombiana and A. reducta.

3. Characterization of resistance to spittlebug in accessions of Brachiaria spp.

3a. Antibiosis

Twelve grass accessions including 11 accessions of Brachiaria were evaluated in a glasshouse for host plant resistance to nymphs of Z. colombiana using an evaluation technique that provided uniform environmental conditions and abundant feeding sites. B. brizantha CIAT 6294 (cv. Marandú) was the most resistant of the accessions tested based on nymphal mortality, duration of nymphal stadia, and weight of adult females.

Andropogon gayanus, resistant to spittlebug attack in the field, was susceptible under the conditions of this study. Growth habit and rooting characteristics may contribute to field resistance. However, it is clear that other resistance factors are present within the genus Brachiaria, particularly in the case of B. brizantha cv. Marandú.

Egg eclosion and early instar survival were high on all accessions tested. Figure 3 shows survivorship by stage for a group of 5 accessions that represents the range of response obtained. In general, first and second instar survival was high and the greatest mortality occurred during third and fourth instars.

With the exception of B. decumbens, the lowest rate of survival occurred on B. brizantha CIAT 6294 (47%) (Table 2). In general, nymphs reared on B. brizantha CIAT 6294 produced a small spittle mass and migrated frequently within the pot. In contrast, nymphs reared on B. dictyoneura, B. humidicola, and A. gayanus produced abundant spittle and did not migrate. Nymphs reared on B. brizantha CIAT 6294 developed more slowly than those on other accessions (Table 2). Nymphs reared on B. brizantha CIAT 6294 emerged as adults on the average 14 days later than those on B. dictyoneura CIAT 6133.

Adult females reared on B. brizantha CIAT 6294 weighed on the average 24% less than those emerging from B. ruziziensis CIAT 6419 (Table 2). Correlations were highly significant between nymphal survival to adult and duration of nymphal stadia (Figure 4) and between adult female weight at emergence and duration of nymphal stadia (Figure 5). No correlation between nymphal survival to adult and adult female weight at emergence detected $P > 0.05$).

Survival of first and second instar nymphs in this study was high for all

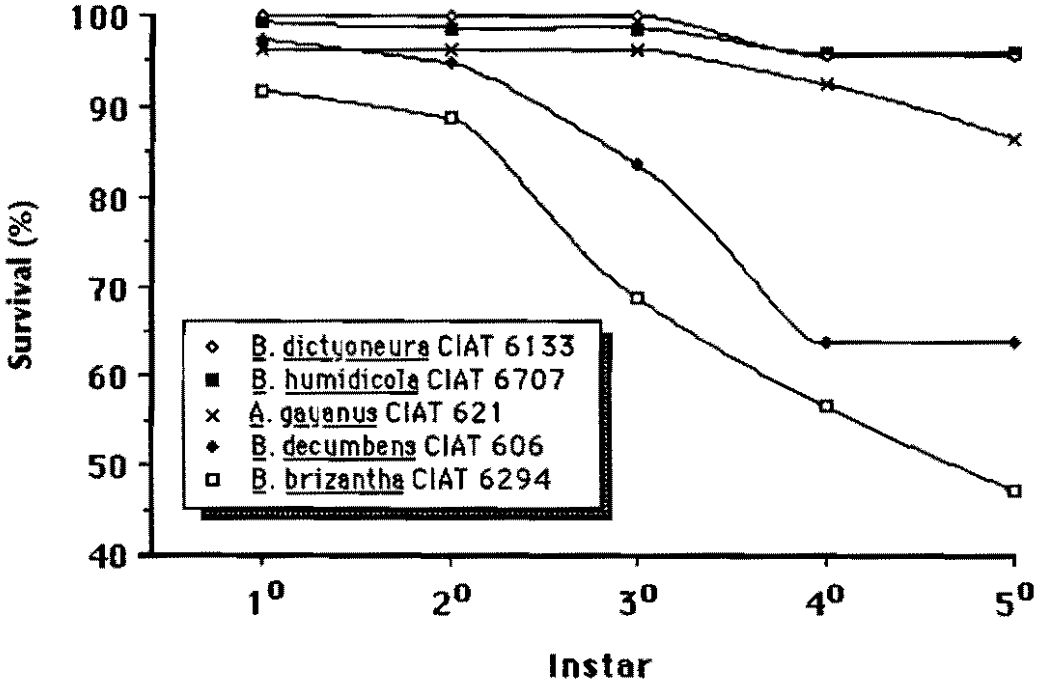


Figure 3. Stage-specific survivorship curves for Z. colombiana reared on 5 grass accessions in the glasshouse.

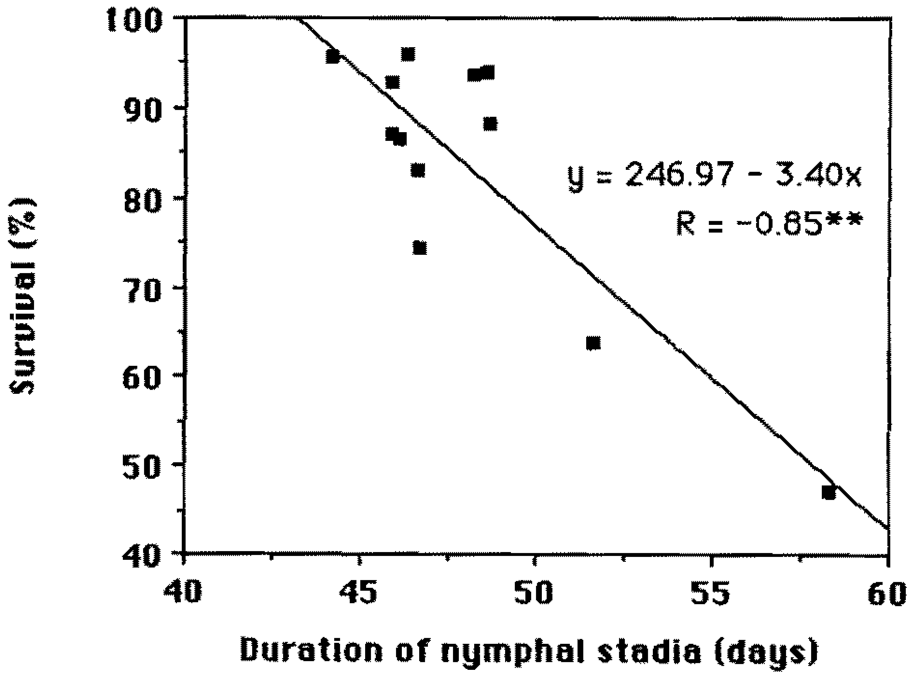


Figure 4. Correlation between survivorship of nymphs to adult and nymphal development time for Z. colombiana reared on 12 grass accessions.

Table 2. Vital statistics of *Z. colombiana* reared on various tropical forage grasses.

Species	Accession	Survival to adult (%)*	N	Duration of nymphal stadia (days)*	N	Weight of Female adults (mg)*	N
B. humidicola	6707	95.9 a	145	46.3 ab	140	14.5 abc	68
B. dictyoneura	6133	95.7 a	141	44.2 a	135	14.9 ab	73
B. humidicola	6705	94.0 a	138	48.6 ab	133	12.8 cd	65
B. brizantha	665	93.6 a	118	48.2 ab	103	12.6 cd	46
B. humidicola	675	92.9 a	130	45.9 ab	125	14.2 abc	69
B. humidicola	6369	88.3 a	122	48.7 ab	111	13.8 abc	59
B. ruziziensis	654	88.3 a	122	48.7 ab	111	13.8 abc	59
A. gayanus	621	86.6 a	107	46.1 ab	93	13.9 abc	48
B. decumbens	6132	83.0 ab	140	46.6 ab	122	13.4 abc	61
B. ruziziensis	6419	74.5 ab	118	46.7 ab	89	15.2 a	42
B. decumbens	606	63.7 bc	106	51.6 b	67	12.9 cd	25
B. brizantha	6294	47.3 c	105	58.3 c	51	11.5 d	24

* Means followed by the same letter do not differ (α = 0.05, Duncan's Multiple Range Test).

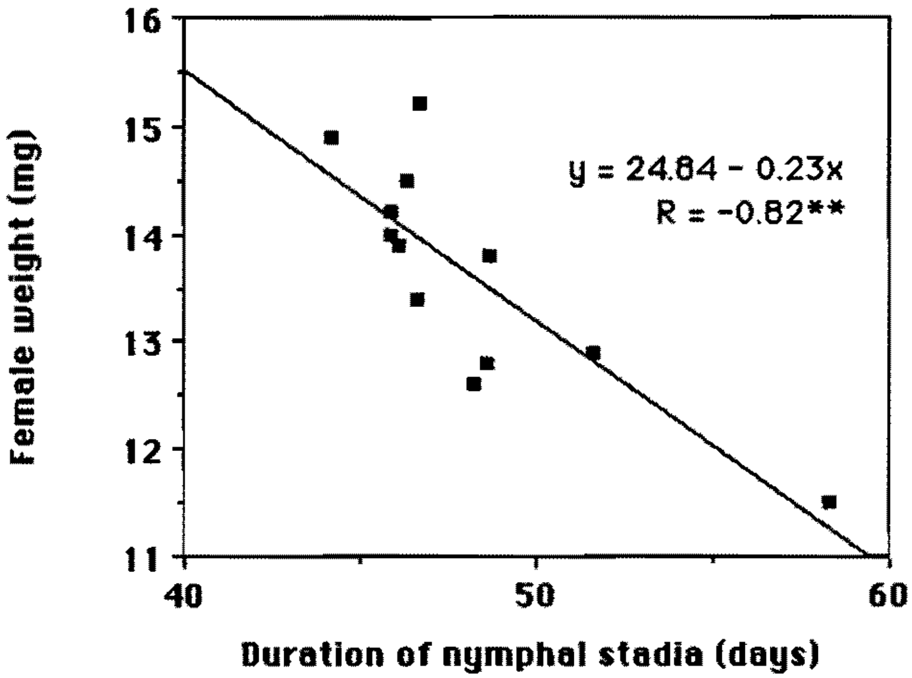


Figure 5. Correlation between adult female weight at emergence and nymphal development time for Z. colombiana reared on 12 grass accessions.

the accessions studied. Other authors have reported high early instar mortality. It is possible that in those studies factors such as relative humidity and availability of feeding sites had a large effect on survival of young nymphs. In this study, we assume that such mortality factors were largely excluded due to near optimal conditions of relative humidity and abundance of available feeding sites afforded by the aluminum foil cover.

It is interesting to note the high survival of nymphs reared on A. gayanus. Under field conditions, this grass is highly resistant to spittlebugs. Various authors have reported antibiosis as the category of resistance in A. gayanus. It has been suggested that the presence of catequines and cyanogenic glycosides in leaves, stems, and roots of A. gayanus may be related to resistance to spittlebug. The results of this study suggest that the resistance exhibited by A. gayanus in the field may not have a chemical basis. A more likely explanation is that under field conditions, the growth habit of A. gayanus (deep-rooting, tufted type) does not provide feeding sites and microclimatic conditions adequate for development of spittlebug nymphs. It is important to note that the aluminum foil cover used in this study stimulated proliferation of rootlets and provided uniform conditions of temperature, light, and relative humidity experienced by the nymphs. Microclimatic differences that exist in the field between grasses with differing growth habits were minimized and results obtained in this study may be attributed to other plant defenses including physical defenses, allelochemicals, and nutritional factors.

Growth habit and its influence on

microclimatic factors near the soil surface may be an important character for selection of resistant germplasm. However, from the results of this study it appears that additional resistance factors are present within the genus Brachiaria. B. brizantha cv. Marandu is another grass that is resistant to spittlebugs in the field. Unlike A. gayanus, however, Marandú retained its relatively high level of resistance under the conditions of this study. High nymphal mortality has also been observed for Z. entreriana (Berg) in Brasil on B. brizantha cv. Marandú. The mechanism(s) of resistance will be of particular interest if a breeding program for Brachiaria is initiated.

The high mortality of nymphs on B. decumbens CIAT 606 may not be related to an antibiotic plant defense mechanism. Plants of this accession suffered an accentuated chlorosis and necrosis during the period of infestation. Deterioration of the plants probably contributed to nymphal mortality and is an indication of the high susceptibility of this species to damage caused by spittlebug nymphs.

3b. Tolerance

Among species of tropical pasture grasses, there is considerable variation in the amount of visible foliar damage caused by a given insect density, perhaps as a result of tolerance to toxins contained in spittlebug saliva. A study of tolerance to adult spittlebug feeding damage was conducted in the glasshouse. Tolerance was measured in units of insect-days (product of the number of adult spittlebugs and the number of days at that level of infestation, summed over the period of infestation) required to achieve severe feeding damage.

There was a positive correlation ($R^2 = 0.77$, $P = 0.01$) between biomass (grams dry weight/plant) and days of infestation required to cause severe feeding damage. Therefore, biomass was used as a covariable in the analysis of means by ANOVA and Duncan's Multiple Range Test. The number of insect-days causing severe damage in the most tolerant accessions (B. dictyoneura CIAT 6133, B. humidicola CIAT 6705) was approximately 2.5 times greater than that necessary to cause the same level of damage to the most susceptible accessions (B. ruziziensis CIAT 654 and 6419, B. decumbens CIAT 6132) (Figure 6).

No difference was found ($\alpha = 0.05$, ANOVA) in regrowth capacity between infested and noninfested plant. However, there was a significant positive correlation between number of insect-days causing severe damage and regrowth ($R^2 = 0.69$, $P = 0.0009$) (Figure 7). No significant difference was found in daily adult mortality ($\alpha = 0.05$, ANOVA).

It has been suggested that tolerance to spittlebug in Cynodon dactylon (Coastal Bermuda grass)is due to either preferential feeding or tolerance to salivary toxin. In this study, daily adult mortality on individually caged plants did not differ by accession although adult feeding was not directly measured. Regrowth capacity of individual accessions was unaffected by the experimental infestations but tolerance was correlated with plant regrowth capacity.

A wide range of tolerance exists within the accessions of Brachiaria studied. The danger inherent in selecting germplasm solely on the basis of tolerance has been demonstrated by the case of B. humidicola in the humid tropics of Brazil. However, tolerant materials such as B. humidicola and B. dictyoneura will be useful where insect populations are maintened below an economic threshold by other biotic

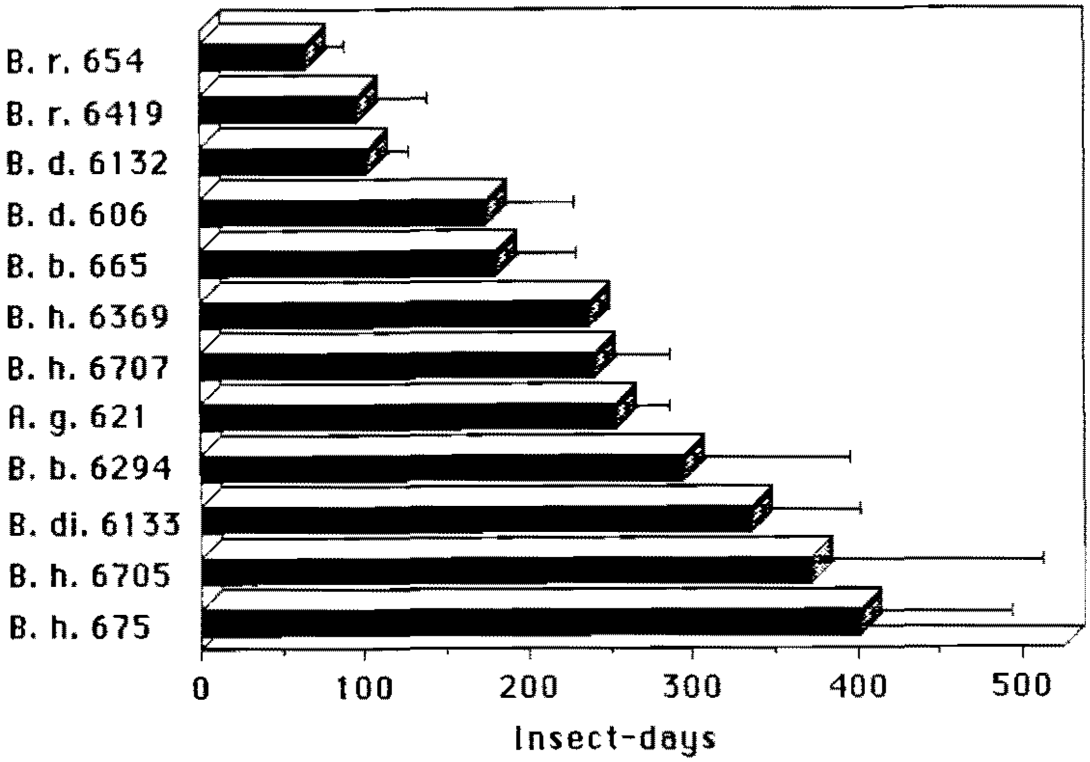


Figure 6. Mean number of insect-days resulting in severe foliar damage to 12 grass accessions in the greenhouse. A.g.: A. gayanus, B.b.: B. brizantha, B.d.: B. decumbens, B.di.: B. dictyoneura, B.h.: B. humidicola, B.r.: B. ruziziensis. Bars are standard deviation.

or abiotic factors. In areas where the potential for spittlebug population growth is high, an ideal cultivar would be one that possesses an antibiotic type of resistance acting to suppress insect populations and tolerance to insect feeding should insect populations become significant. Results of these studies suggest that B. brizantha is such a grass. It is the most resistant of the accessions of Brachiaria tested to date and possesses a moderate degree of tolerance to adult feeding damage. Using the evaluation techniques developed here together with field evaluations of edaphic adaptation and response to natural spittlebug infestations, we hope to select from the expanded Brachiaria collection accessions that are adapted to the acid, infertile soil conditions of the lowland American tropics and resistant to spittlebug.

4. Glasshouse evaluation of host plant resistance to spittlebug in Brachiaria spp.

The evaluation methodology described above is being used to evaluate the Brachiaria collection in the glasshouse for host plant resistance to Z. colombiana. Currently, 101 accessions are being evaluated for tolerance to damage caused by spittlebug nymphs, tolerance to adult feeding damage, and antibiosis to nymphs. This information, together with field evaluations, will facilitate rapid identification of accessions processing useful levels of resistance in a much shorter period of time than that required for field evaluations alone. Also, information gained from glasshouse trials will be

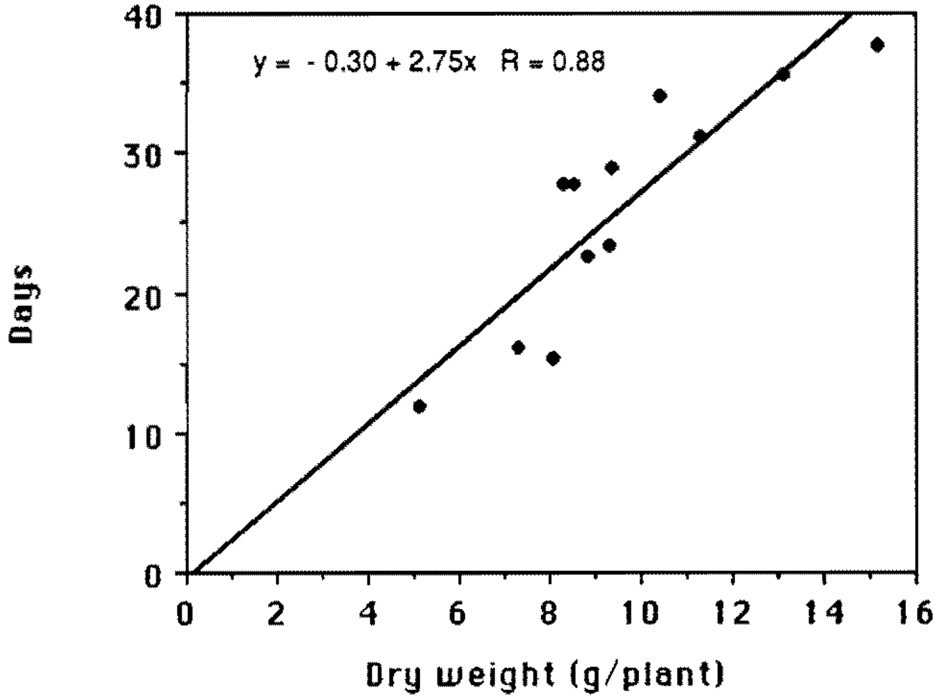


Figure 7. Correlation between plant biomass (dry weight) and tolerance to adult spittlebug damage as measured by days of infestation necessary to cause severe foliar damage to plants grown in a glasshouse.

particularly useful if a Brachiaria breeding program is initiated. A case in point is that of B. jubata CIAT 16531. In general, B. jubata is not a vigorous species and would tend to be discarded from any field trial. However, B. jubata CIAT 16531 has a high level of antibiosis resistance to Z. colombiana and may be of value in a breeding program.

Table 3 includes data from the initial glasshouse screen for tolerance to spittlebug nymphs. These accessions with high levels of tolerance will be subjected to further screening for antibiosis and tolerance to adult feeding damage.

5. Glasshouse evaluation of host plant resistance to spittlebug in Panicum maximum

The methodology used for screeing Brachiaria spp. for resistance to Z. colombiana is being used to evaluate the collection of Panicum maximum for resistance to A. reducta. Accessions of Brachiaria spp. will be included as controls and as basis for comparing resistance in Brachiaria to the two species of spittlebugs.

6. Field evaluation of host plant resistance to spittlebug in Brachiaria spp.

In cooperation with the Agronomy Carimagua section, 265 accessions of Brachiaria were planted at three locations: Carimagua and Villavicencio in the department of Meta, Colombia, and at Pucallpa, Peru. Fifteen accessions were selected from the previous Brachiaria collection to be included as controls based on dry matter production, general adaptation, and response to spittlebug (Table 4).

Table 3. Ranking of Brachiaria accessions based on damage rating caused by spittlebug nymphs (Z. colombiana) in the greenhouse at Palmira and field rankings for establishment vigor and damage caused by spittlebug adults (A. reducta) at Carimagua.

		Glasshouse		Carimagua field evaluation 30/9/87	
Species	Accession	Nymphal Damage[1,2] Mean	St.Dev.	Establishment Rating[3]	Adult Damage Rating[1]
B. humidicola	16869	1.1	0.3		
B. humidicola	16892	1.4	0.5	1.5	2.0
B. brizantha	16341	1.6	0.7	1.0	2.0
B. brizantha	16138	1.7	0.5	1.5	2.5
B. humidicola	16882	1.7	0.5	1.5	2.5
B. dictyoneura	16187	1.8	0.4	1.5	2.0
B. brizantha	16320	1.8	0.6	0	1.0
B. brizantha	16329	1.8	0.4		
B. jubata	16531	1.8	0.4		
B. humidicola	16883	1.8	0.4	1.0	2.0
B. humidicola	16885	1.8	0.4	1.5	2.0
B. brizantha	6294	1.9	0.3	4.0	2.8
B. brizantha	16125	1.9	1.2	0.5	2.0
B. brizantha	16443	1.9	0.6	2.0	2.3
B. brizantha	16779	1.9	0.6	2.0	2.5
B. brizantha	16842	1.9	0.7	2.0	2.3
B. brizantha	16106	2.0	0.7	2.0	2.5
B. brizantha	16154	2.0	0	2.0	2.5
B. brizantha	16173	2.0	0.8	2.0	2.0
B. brizantha	16318	2.0	0	2.0	2.0
B. brizantha	16469	2.0	0.7	0.5	1.5
B. brizantha	16771	2.0	0		
B. brizantha	16829	2.0	0.5	2.0	2.0
B. bovonei	16847	2.0	0	0.5	1.5
H. filipendula	26032	2.0	0.5		
B. dictyoneura	6133	2.1	0.3	2.0	2.0
B. brizantha	16119	2.1	1.2	2.0	2.0
B. brizantha	16121	2.1	0.3	3.0	2.5
B. brizantha	16827	2.1	0.6	3.0	3.0
B. brizantha	16832	2.1	0.9		
B. arrecta	16844	2.1	0.6	2.0	3.0
B. humidicola	16868	2.1	0.3	2.5	2.0
B. humidicola	16879	2.1	0.6	3.0	2.0
B. humidicola	16880	2.1	0.3	1.0	2.0
B. humidicola	16889	2.1	0.6	1.5	2.5
A. gayanus	16987	2.1	0.7		
B. humidicola	16180	2.2	0.4	2.0	2.0
B. humidicola	16181	2.2	0.4	2.0	2.0
B. humidicola	16343	2.2	0.6		
B. platynota	16553	2.2	0.6		
B. humidicola	16891	2.2	0.4	1.5	2.0
B. subulifolia	16961	2.2	0.6	1.5	2.5
Paspalum dilatatun	26066	2.2	0.6		
Setaria lindenbergiana	26076	2.2	0.4		
B. brizantha	16143	2.3	0.5	1.5	3.0
B. brizantha	16162	2.3	0.5	2.0	2.0
B. brizantha	16171	2.3	1.5	2.5	2.0
B. humidicola	16182	2.3	0.5	3.0	2.0
B. jubata	16359	2.3	0.7	0.5	1.5
B. brizantha	16487	2.3	0.5	2.0	2.0
B. humidicola	16873	2.3	0.5	3.0	2.3
B. humidicola	16874	2.3	0.5	1.5	2.0
B. humidicola	16877	2.3	0.5	2.0	2.0
B. ruziziensis	26178	2.3	0.8	2.5	4.3
B. brizantha	16290	2.4	0.7	0.5	1.5

Table 3 (cont.)		Glasshouse		Carimagua field evaluation 30/9/87	
Species	Accession	Nymphal Damage[1,2]		Establishment	Adult Damage
		Mean	St.Dev.	Rating[3]	Rating[1]
B. brizantha	16441	2.4	0.5	2.0	2.5
B. brizantha	16477	2.4	0.5	1.5	2.8
B. brizantha	16478	2.4	0.7	2.5	2.8
B. humidicola	16866	2.4	0.5	1.5	2.0
B. humidicola	16884	2.4	0.5	1.5	2.0
B. humidicola	16887	2.4	0.5	2.5	2.0
B. ruziziensis	26175	2.4	0.7	3.0	4.5
B. platynota	26199	2.4	0.5	0	1.0
B. brizantha	16122	2.5	0.5	2.5	2.3
B. brizantha	16292	2.5	1.4	0	1.0
B. brizantha	16299	2.5	0.5	2.0	2.8
B. brizantha	16476	2.5	0.5	2.5	2.0
B. humidicola	16886	2.6	0.5	2.5	2.0
B. humidicola	16894	2.6	0.5	2.0	2.3
B. brizantha	16107	2.7	0.7	2.0	2.0
B. brizantha	16457	2.7	0.5	1.0	1.8
B. brizantha	16770	2.7	0.5	1.5	2.0
B. arrecta	16845	2.7	0.5	2.0	3.3
B. humidicola	16890	2.7	0.5	1.0	2.0
B. brizantha	16442	2.8	0.8	1.0	1.5
B. brizantha	16485	2.8	0.9	2.5	2.0
B. arrecta	16846	2.8	0.4	3.0	3.8
B. ruziziensis	26177	2.8	0.6	2.5	4.3
B. brizantha	16499	2.9	0.3	2.5	2.3
B. jubata	16542	2.9	0.6	1.5	2.0
Panicum repens	26264	2.9	0.3		
B. brizantha	16460	3.0	0.5	3.0	2.8
B. humidicola	16888	3.0	0	3.0	2.3
B. ruziziensis	26170	3.1	0.6	3.0	4.0
B. brizantha	16458	3.2	1.1	2.5	2.3
B. decumbens	26303	3.2	0.9	2.0	3.5
B. decumbens	16498	3.3	0.5	2.0	2.5
B. platynota	26200	3.3	0.5	3.0	3.3
B. decumbens	26293	3.3	0.5	1.0	2.0
B. decumbens	26300	3.3	0.7	2.0	2.8
B. decumbens	26308	3.3	0.5	3.0	3.0
B. bovonei	26353	3.3	0.8	2.5	2.3
B. decumbens	606	3.4	0.5	3.5	2.8
B. ruziziensis	16552	3.4	0.8	2.0	4.3
B. mutica	26201	3.5	0.5	1.5	2.0
B. ruziziensis	26347	3.5	0.7	2.0	4.0
B. decumbens	26295	3.6	0.7	2.5	3.5
B. decumbens	26292	3.8	0.4	2.5	3.5
B. decumbens	26306	3.8	0.4	3.0	3.8
B. nigropedata	16903	3.9	0.7	0.5	1.5

[1]Spittlebug damage rating: 1, no damage; 2, slight; 3, moderate; 4, severe; 5, plant death.

[2]Ten replications.

[3]Establishment rating: 0, no establishment; 1, poor; 2, moderate; 3, good; 4, excellent.

Table 4. Brachiaria accessions selected from previous collection to be evaluated with new accessions at 3 field sites.

Species	CIAT accessions
B. brizantha	665, 6297, 6370, 6686, 6687, 6690
B. decumbens	606, 6693, 6701
B. dictyoneura	6133
B. eminii	6241
B. humidicola	679, 6705, 6709
B. ruziziensis	655

B. decumbens CIAT 606 and B. ruziziensis 655 were included as susceptible checks, B. brizantha 6297 as the resistant check. Other B. brizantha accessions that performed well at the various evaluation sites last year were also included.

The collections were planted in previously established pastures of B. decumbens CIAT 606 where spittlebug populations were known to occur. Two meter wide strips were plowed with 2 meter wide alleyways of B. decumbens left intact. Two by three meter plots of each accession were then established in the prepared strips and B. decumbens was allowed to reestablish between plots.

Higher adult populations have been observed in the collection this year than in previous years, apparently a result of planting the collection into an existing field of B. decumbens. Most notable have been high nymph populations in accessions of B. ruziziensis.

The collection was planted at Carimagua in June, 1987 and evaluations were made of establishment vigor and damage suffered due to spittlebug adults (Table 5). By October, establishment was incomplete and the majority of accession had not yet completely covered the 2 x 3m plots. Establishment was rated as excellent in one or both replications in only 11 of 265 accessions. Fifty-seven accessions failed to establish in one or both replications.

7. In vitro rearing of spittlebug

As a possible method for rapid screening of germplasm for resistance to spittlebug, a new technique is being developed that will allow rearing of spittlebug nymphs on Brachiaria plants propagated in vitro. Sterilized spittlebug eggs are introduced into test tubes containing plants regenerated from meristem cuttings. Tests are currently underway to determine if his technique will be useful as a rapid screeing tool.

Table 5. Evaluation of establishment vigor and damage caused by adult spittlebugs (A. reducta) in 264 accessions of Brachiaria at Carimagua, 30 September, 1987. Planting date: June 1987.

Species	Accession	Establishment Rating[1]	Spittlebug Damage Rating[2]
B. ruziziensis	26168	4.0	3.0
B. decumbens	6693	4.0	1.0
B. brizantha	6297	4.0	1.8
B. brizantha	26559	4.0	1.5
B. decumbens	606	3.5	1.8
B. brizantha	665	3.5	2.0
B. brizantha	6370	3.5	1.5
B. brizantha	16135	3.5	1.5
B. brizantha	16163	3.5	1.0
B. brizantha	16298	3.5	1.0
B. brizantha	26111	3.5	1.0
B. ruziziensis	16551	3.0	2.8
B. ruziziensis	26163	3.0	3.0
B. ruziziensis	26166	3.0	3.0
B. ruziziensis	26167	3.0	3.3
B. ruziziensis	26170	3.0	3.0
B. ruziziensis	26175	3.0	3.5
B. platynota	26200	3.0	2.3
B. humidicola	679	3.0	1.3
B. humidicola	6705	3.0	1.3
B. humidicola	16182	3.0	1.0
B. humidicola	16873	3.0	1.3
B. humidicola	16876	3.0	1.0
B. humidicola	16879	3.0	1.0
B. humidicola	16888	3.0	1.3
B. decumbens	6701	3.0	1.8
B. decumbens	26299	3.0	1.5
B. decumbens	26306	3.0	2.8
B. decumbens	26308	3.0	2.0
B. brizantha	6686	3.0	1.3
B. brizantha	6690	3.0	1.0
B. brizantha	16121	3.0	1.5
B. brizantha	16168	3.0	1.0
B. brizantha	16300	3.0	1.3
B. brizantha	16317	3.0	1.3
B. brizantha	16338	3.0	1.5
B. brizantha	16438	3.0	1.5
B. brizantha	16447	3.0	1.0
B. brizantha	16460	3.0	1.8
B. brizantha	16463	3.0	1.3
B. brizantha	16472	3.0	1.0
B. brizantha	16827	3.0	2.0
B. brizantha	26557	3.0	1.5
B. brizantha	26561	3.0	1.5
B. brizantha	26565	3.0	2.0
B. arrecta	16846	3.0	2.8
B. ruziziensis	655	2.5	3.3
B. ruziziensis	26162	2.5	2.8
B. ruziziensis	26174	2.5	3.3
B. ruziziensis	26177	2.5	3.3
B. ruziziensis	26178	2.5	3.3
B. humidicola	16868	2.5	1.0
B. humidicola	16886	2.5	1.0
B. humidicola	16887	2.5	1.0
B. eminii	6241	2.5	2.0
B. decumbens	16489	2.5	2.0
B. decumbens	16493	2.5	2.0
B. decumbens	16496	2.5	2.3
B. decumbens	26185	2.5	2.0
B. decumbens	26292	2.5	2.5
B. decumbens	26294	2.5	2.0
B. decumbens	26295	2.5	2.5
B. decumbens	26298	2.5	2.0
B. decumbens	26302	2.5	2.0
B. decumbens	26568	2.5	2.0
B. brizantha	16111	2.5	1.5
B. brizantha	16118	2.5	1.0
B. brizantha	16122	2.5	1.3
B. brizantha	16171	2.5	1.0
B. brizantha	16311	2.5	1.5
B. brizantha	16315	2.5	1.8
B. brizantha	16337	2.5	1.0
B. brizantha	16440	2.5	1.3
B. brizantha	16451	2.5	1.3
B. brizantha	16458	2.5	1.3
B. brizantha	16476	2.5	1.0
B. brizantha	16478	2.5	1.8
B. brizantha	16480	2.5	1.3
B. brizantha	16485	2.5	1.0
B. brizantha	16499	2.5	1.3
B. brizantha	26112	2.5	1.0
B. brizantha	ICA	2.5	2.5
B. bovonei	26353	2.5	1.3
B. ruziziensis	16552	2.0	3.3
B. ruziziensis	26164	2.0	3.3
B. ruziziensis	26347	2.0	3.0
B. ruziziensis	26350	2.0	2.5
B. jubata	16896	2.0	1.3
B. humidicola	6709	2.0	1.0
B. humidicola	16180	2.0	1.0
B. humidicola	16181	2.0	1.0
B. humidicola	16348	2.0	1.3
B. humidicola	16871	2.0	1.3
B. humidicola	16877	2.0	1.0
B. humidicola	16894	2.0	1.3
B. humidicola	26575	2.0	1.0
B. dictyoneura	6133	2.0	1.0
B. dictyoneura	26570	2.0	1.0
B. decumbens	16495	2.0	2.0
B. decumbens	16497	2.0	1.5
B. decumbens	16498	2.0	1.5
B. decumbens	16501	2.0	1.5
B. decumbens	16502	2.0	1.8
B. decumbens	16503	2.0	1.8
B. decumbens	16504	2.0	2.5
B. decumbens	26291	2.0	2.3
B. decumbens	26300	2.0	1.8
B. decumbens	26303	2.0	2.5
B. decumbens	26569	2.0	1.8

Table 5. Cont'd.

Species	Accession	Establishment Rating	Damage Rating
B. brizantha	6687	2.0	1.0
B. brizantha	16106	2.0	1.5
B. brizantha	16107	2.0	1.0
B. brizantha	16116	2.0	1.0
B. brizantha	16119	2.0	1.0
B. brizantha	16126	2.0	1.0
B. brizantha	16145	2.0	1.0
B. brizantha	16149	2.0	1.3
B. brizantha	16152	2.0	1.0
B. brizantha	16154	2.0	1.5
B. brizantha	16156	2.0	2.3
B. brizantha	16162	2.0	1.0
B. brizantha	16173	2.0	1.0
B. brizantha	16289	2.0	1.3
B. brizantha	16299	2.0	1.8
B. brizantha	16306	2.0	1.3
B. brizantha	16308	2.0	1.5
B. brizantha	16318	2.0	1.0
B. brizantha	16324	2.0	1.5
B. brizantha	16339	2.0	1.0
B. brizantha	16441	2.0	1.5
B. brizantha	16443	2.0	1.3
B. brizantha	16449	2.0	1.0
B. brizantha	16453	2.0	1.0
B. brizantha	16455	2.0	1.0
B. brizantha	16459	2.0	1.3
B. brizantha	16461	2.0	1.0
B. brizantha	16466	2.0	1.0
B. brizantha	16487	2.0	1.0
B. brizantha	16779	2.0	1.5
B. brizantha	16829	2.0	1.0
B. brizantha	16842	2.0	1.3
B. brizantha	26560	2.0	2.0
B. arrecta	16844	2.0	2.0
B. arrecta	16845	2.0	2.3
B. subulifolia	16961	1.5	1.5
B. serrata	16221	1.5	1.8
B. mutica	26201	1.5	1.0
B. jubata	16208	1.5	1.0
B. jubata	16530	1.5	1.0
B. jubata	16542	1.5	1.0
B. humidicola	16866	1.5	1.0
B. humidicola	16870	1.5	2.0
B. humidicola	16874	1.5	1.0
B. humidicola	16882	1.5	1.5
B. humidicola	16884	1.5	1.0
B. humidicola	16885	1.5	1.0
B. humidicola	16889	1.5	1.5
B. humidicola	16891	1.5	1.0
B. humidicola	16892	1.5	1.0
B. dictyoneura	16187	1.5	1.0
B. dictyoneura	16191	1.5	1.0
B. decumbens	16492	1.5	2.0
B. decumbens	16494	1.5	2.0
B. decumbens	26186	1.5	1.3
B. brizantha	16113	1.5	1.3
B. brizantha	16114	1.5	1.0
B. brizantha	16136	1.5	1.0
B. brizantha	16138	1.5	1.5
B. brizantha	16142	1.5	1.0
B. brizantha	16143	1.5	2.0
B. brizantha	16155	1.5	1.3
B. brizantha	16158	1.5	1.0
B. brizantha	16169	1.5	1.5
B. brizantha	16301	1.5	1.3
B. brizantha	16302	1.5	1.0
B. brizantha	16322	1.5	1.0
B. brizantha	16332	1.5	1.0
B. brizantha	16333	1.5	1.3
B. brizantha	16342	1.5	1.8
B. brizantha	16452	1.5	1.3
B. brizantha	16477	1.5	1.8
B. brizantha	16479	1.5	1.0
B. brizantha	16483	1.5	1.0
B. brizantha	16505	1.5	1.0
B. brizantha	16770	1.5	1.0
B. brizantha	16797	1.5	1.5
B. brizantha	16830	1.5	1.5
B. brizantha	26122	1.5	1.0
B. brizantha	26127	1.5	1.5
B. brizantha	26316	1.5	1.0
B. subulifolia	16962	1.0	0.5
B. platynota	26332	1.0	1.3
B. leucorantha	16549	1.0	1.3
B. jubata	16204	1.0	1.0
B. jubata	16205	1.0	0.8
B. jubata	16512	1.0	1.0
B. jubata	16532	1.0	1.0
B. jubata	16534	1.0	1.0
B. jubata	16536	1.0	1.0
B. jubata	16539	1.0	1.0
B. jubata	16710	1.0	0.5
B. humidicola	16880	1.0	1.0
B. humidicola	16883	1.0	1.0
B. humidicola	16890	1.0	1.0
B. dictyoneura	16188	1.0	1.0
B. decumbens	16491	1.0	2.0
B. decumbens	16500	1.0	1.3
B. decumbens	26293	1.0	1.0
B. decumbens	26304	1.0	0.8
B. decumbens	26305	1.0	0.5
B. brizantha	16123	1.0	1.0
B. brizantha	16132	1.0	0.5
B. brizantha	16144	1.0	1.5
B. brizantha	16151	1.0	1.0
B. brizantha	16164	1.0	0.5
B. brizantha	16295	1.0	0.8
B. brizantha	16307	1.0	0.5
B. brizantha	16309	1.0	0.5
B. brizantha	16325	1.0	2.0
B. brizantha	16334	1.0	0.5
B. brizantha	16341	1.0	1.0
B. brizantha	16436	1.0	1.0
B. brizantha	16442	1.0	0.5

Table 5. Cont'd.

Species	Accession	Establishment Rating	Damage Rating
B. brizantha	16457	1.0	0.8
B. brizantha	16823	1.0	1.8
B. platynota	26343	0.5	0.5
B. nigropedata	16903	0.5	0.5
B. jubata	16358	0.5	0.8
B. jubata	16359	0.5	0.5
B. jubata	16518	0.5	0.5
B. jubata	26198	0.5	0.5
B. humidicola	16878	0.5	0.5
B. decumbens	16488	0.5	1.0
B. brizantha	16120	0.5	0.5
B. brizantha	16124	0.5	0.5
B. brizantha	16125	0.5	1.0
B. brizantha	16128	0.5	0.5
B. brizantha	16153	0.5	0.8
B. brizantha	16288	0.5	0.8
B. brizantha	16290	0.5	0.5
B. brizantha	16303	0.5	0.8
B. brizantha	16305	0.5	0.5
B. brizantha	16312	0.5	0.5
B. brizantha	16335	0.5	0.5
B. brizantha	16340	0.5	0.5
B. brizantha	16437	0.5	0.8
B. brizantha	16469	0.5	0.5
B. bovonei	16847	0.5	0.5
B. platynota	26199	0	0
B. jubata	16197	0	0
B. jubata	16203	0	0
B. jubata	16522	0	0
B. jubata	16524	0	0
B. brizantha	16110	0	0
B. brizantha	16117	0	0
B. brizantha	16133	0	0
B. brizantha	16167	0	0
B. brizantha	16292	0	0
B. brizantha	16304	0	0
B. brizantha	16310	0	0
B. brizantha	16320	0	0
B. brizantha	16462	0	0
B. brizantha	16773	0	0
B. brizantha	16833	0	0
B. brizantha	26110	0	0

[1]Establishment rating: 0, no establishment; 1, poor; 2, moderate; 3, good; 4, excellent.

[2]Spittlebug damage rating: 0, no damage; 1, slight; 2, moderate; 3, severe; 4, plant death.

CYRTOCAPSUS

Since cultivation of Centrosema is not yet widespread, very little information is available concerning identification and biology of arthropod pests. During the dry season of 1986-1987, plots of Centrosema species in Carimagua under evaluation by the Plant Pathology Section experienced a heavy infestation of a small, black hemipteran that has been identified as Cyrtocapsus sp., pos. femoralis Reuter (Hemiptera: Miridae). Specimens have been collected from Centrosema in Brazil (Felixlandia, Minas Gerais and Braganca, Pará), and from Stylosanthes and Centrosema in southern Colombia (Quilachao, Cauca) and the Llanos Orientales (Carimagua, Meta). Chlorosis is due to insect feeding and very high insect populations were observed in Centrosema plots at Carimagua in February, 1987. Given the apparently wide geographic range of this insect in Latin America, it is considered to be a potentially serious pest of Centrosema.

There was a high correlation between the natural log of Cyrtocapsus population density and visual damage rating ($P < 0.0001$, $N = 56$) (Figure 8). C. brasilianum CIAT 5178 was the most heavily infested accession while C. acutifolium was least infested and suffered the least damage (Figure 9). C. brasilianum CIAT 5178 was also most heavily infested of C. brasilianum accessions under evaluation by the Plant Breeding and Plant Pathology Sections at Carimagua (Figure 10). C. brasilianum CIAT 5234 and 5247 were least infested.

There is a wide range of host plant resistance to Cyrtocapsus among Centrosema species and among accessions of C. brasilianum. If Cyrtocapsus proves to be a major insect pest, consideration to screeing for host plant resistance in Centrosema breeding programs should be considered.

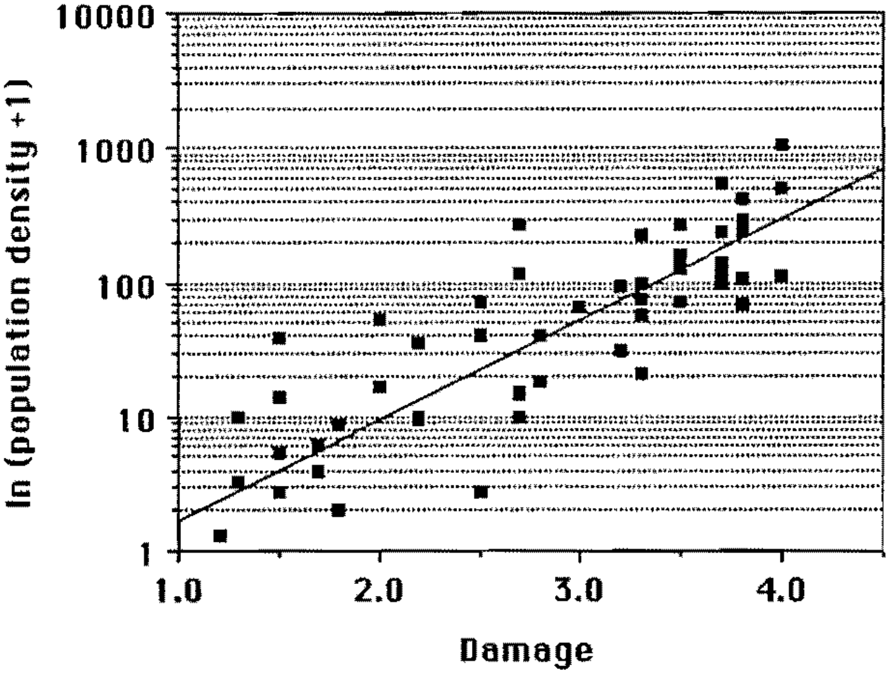


Figure 8. Correlation of visual damage and natural log of population density (number of insects per square meter)of Cyrtocapsus in eight accessions of Centrosema at seven sites.

ANTS

There are at least 3 species of leaf-cutting ants in the Colombian savanna. Acromyrmex landolti cuts only grasses and produces large numbers of small nests in open pastures. Atta cephalotes seems to be confined to the gallery forest, cuts only broad leaved plants - mainly woody vegetation - and will only become a pest if suitable crops (e.g.citrus) are planted in its environment. Atta laevigata, an inhabitant of open pastures cuts both grasses and broad leaved vegetation. Both Acromyrmex landolti and Atta laevigata present significant pest problems on the Carimagua research station. To determine if this is typical of agricultural holdings in general, surveys are being conducted of population of Atta and Acromyrmex in natural savanna using quadrat counts. Attempts will be made to correlate differences found with edaphic factors (light, water level, soil). The ideal outcome of such an exercise should be the construction of Hazardous Population Keys by which a given piece of land can be assessed for the likely population of Atta and Acromyrmex nests to be found there.

Deliberate breeding for ant resistance would benefit from an understanding of the characters which confer resistance in currently resistant species (e.g., B. humidicola). This would be a major study but distinguishing the roles of chemical and physical resistance would be a useful first step. Looking for variability of resistance within species would show the potential of breeding for host plant resistance. Observation colonies of Atta and Acromyrmex are being established in order to facilitate behavioral studies to determine the effect of plant genotype on ant preference.

Since it is expected that Aldrin will

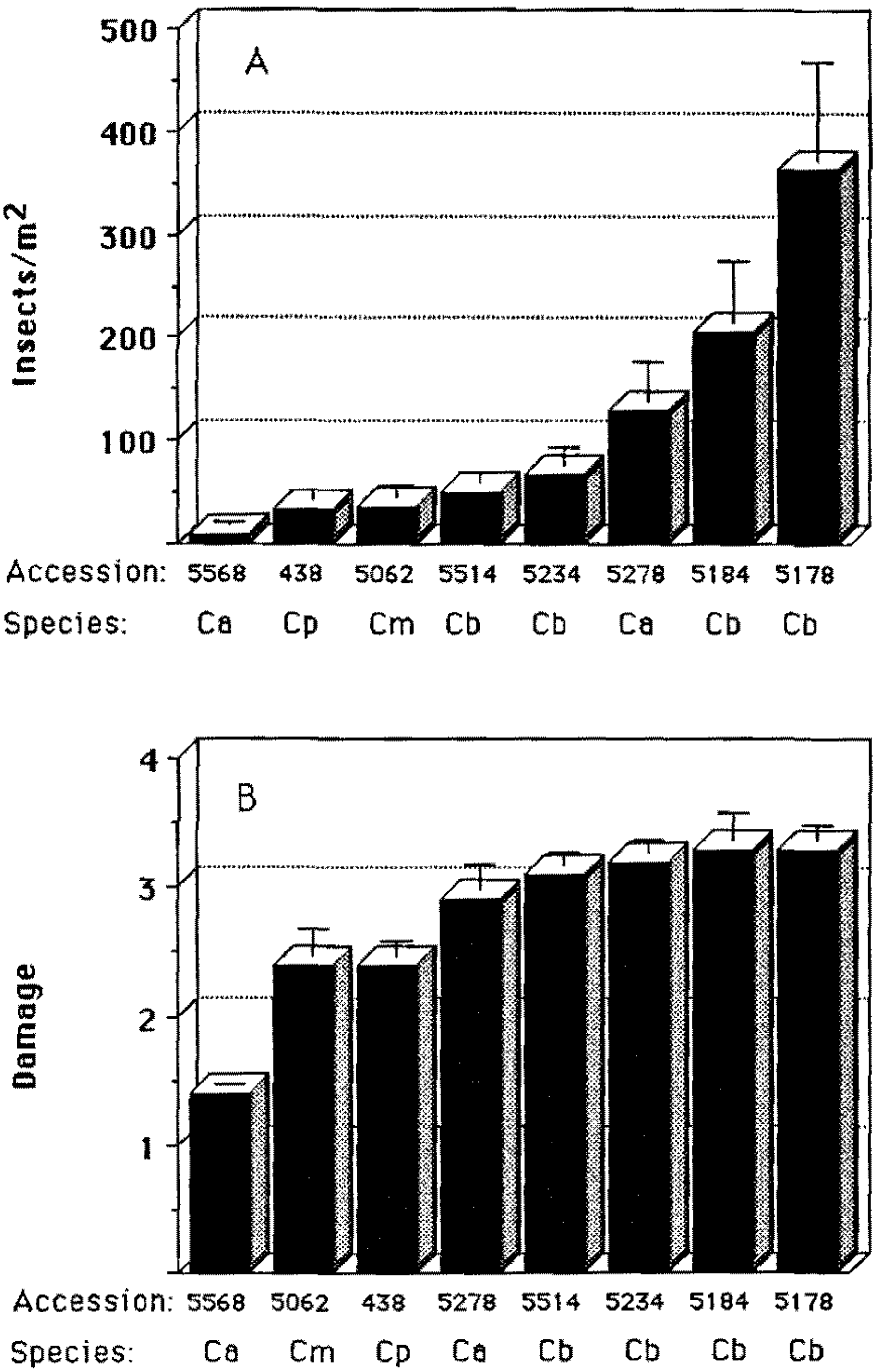


Figure 9. Population density of Cyrtocapsus sp. (A) and visual foliar damage (B) on eight accession of Centrosema spp. at Carimagua. (Ca: C. acutifolium, Cb: C. brasilianum, Cm: C. macrocarpum, Cp: C. pubescens).

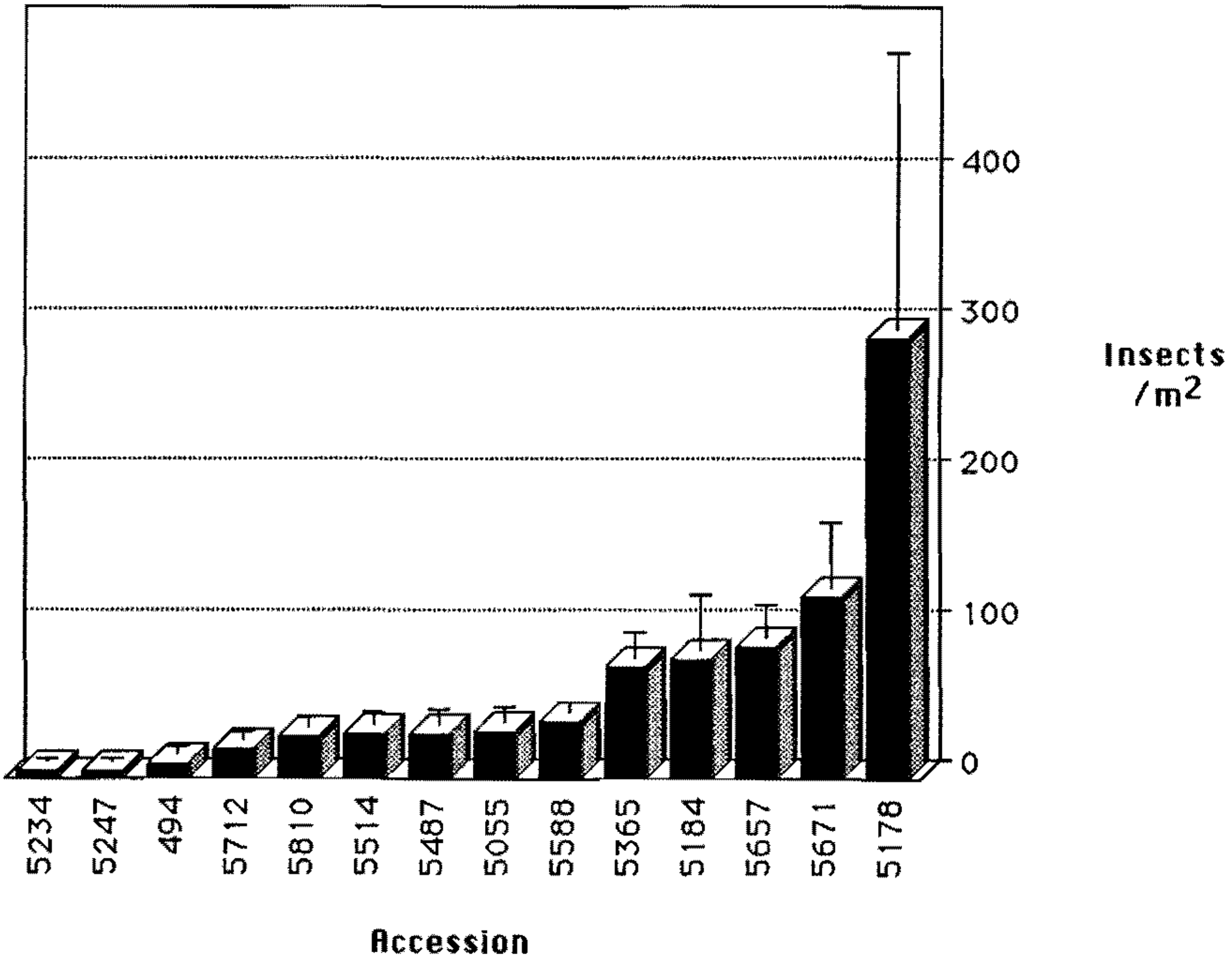


Figure 10. Population density of Cyrtocapsus sp. on 14 accessions of C. brasilianum at Carimagua.

soon be unavailable, a small study was undertaken to test the efficacy of Lorsban 2.5% dust as an alternative to Aldrin. Fifteen nests of Atta laeviegata between 2 and 6 years old were selected and randomly assigned to one of three treatments: Aldrin or Lorsban pumped into the nest, or control (no treatment). Nests were observed after treatment to detect activity. All nests treated with insecticide showed no activity 5 days after application. All control nests were active. Lorsban thus appears to be an acceptable alternative to Aldrin. In addition, Lorsban is less readily absorbed through the skin than Aldrin and may present a slightly smaller health hazard to applicators.

9. PLANT PATHOLOGY

INTRODUCTION

The section continued this year within the framework of aims of previous years:

1. Evaluation of germplasm for reaction to diseases at major screening sites in major ecosystems (Carimagua-Llanos, Brasilia-Cerrados, Pucallpa-Humid Tropics and Costa Rica-Moderately Acid Soils).

2. Evaluation and development of control measures for the most important diseases of promising pasture species.

Research was carried out on disease problems of Stylosanthes, Desmodium, Arachis and, particularly, Centrosema. Specific research was concentrated in the llanos and humid tropic ecosystems while disease surveys were carried out in the cerrados and the moderately acid soils ecosystem (Central America - Costa Rica).

Diseases of Centrosema

Investigations continued on Centrosema Mosaic Virus, Rhizoctonia Foliar Blight and Cylindrocladium Leaf Spot while assessments began on the importance of these and other diseases in promising accessions under grazing.

a) Centrosema Mosaic Virus (CenMV)

CenMV was re-classified as Soybean Mosaic Virus. Further work is in progress using monoclonal antibodies to determine the strain of the virus. This information will facilitate future research work with the virus. As in past years, this problem continues to be severe only in Quilichao and principally on C. macrocarpum.

b) Rhizoctonia Foliar Blight (RFB)

RFB caused by Rhizoctonia solani and related fungi is the most serious disease of Centrosema spp., especially C. brasilianum, in the tropical American lowlands. Research was carried out this year on improving methodologies for working with this disease in the laboratory, glasshouse and field and on various aspects of its importance in the llanos and humid tropic ecosystems.

(i) Improved methodologies for isolation, classification, storage and inoculation of isolates of Rhizoctonia spp.

An improved method for efficient isolation of Rhizoctonia was developed by taping leaves to the inside lids of petri dishes of potato dextrose agar (PDA). The fungus grows down to the culture medium and pure isolates are readily obtained in 4 to 6 days. This method eliminates contamination by other fungi and bacteria.

Purified cultures are reinoculated onto susceptible leaves for storage purposes. Leaves with well-developed lesions are dried, packed in paper bags and stored in plastic boxes with silica gel at $5^{o}C$. Isolates can be stored for more than one year in this way and no loss of pathogenicity has been detected.

An improved method of inoculum preparation has also been developed. Problems with non-uniform inoculation results due to uneven fragmentation of mycelium using the traditional method of homogenization were overcome by macerating Rhizoctonia mycelium in a blender with ice cubes. Resulting suspensions showed even-sized small mycelial fragments which gave uniform lesion development on inoculation.

Initial comparative pathogenicity tests on selected Centrosema spp. accessions using mycelial suspensions sprayed onto young plants gave excellent disease development. However, uneven plant colonization and defoliation make comparative evaluation difficult. An improved technique was developed using 5 mm diameter filter paper discs placed in the center of leaflets of 8- to 12-week-old plants of Centrosema. These were inoculated with 2 µl of a mycelial suspension of Rhizoctonia (5 grams of mycelium per 100 ml of water). Inoculated plants were placed in a mist room for 48 hr and evaluated 48 hr after being taken from the room. Disease development was readily compared. Relative differences in pathogenicity among isolates were easily differentiated quantitatively (% area affected) or qualitatively (scale 0 to 5). At present, the collection of more than 200 Rhizoctonia isolates is being evaluated on a selected group of Centrosema species accessions.

Starch gel electrophoresis of isozymes from isolates of Rhizoctonia spp. is being used routinely by the Section as an aid in classifying the isolate collection. Isozyme systems being successfully used include acid phosphatase, malate dehydrogenase, peptidase, hexokinase, in Histidine and Tris-Citrate buffer systems.

(ii) Evaluation of field methodologies for improving screening for resistance to RFB among Centrosema species accessions.

Confident evaluation of resistance to RFB among the Centrosema species accessions in the field is limited by lack of uniformity in disease incidence and development.

In close collaboration with the Plant Breeding Section, several methodological experiments were initiated in Carimagua with the general aim of developing an improved field methodology for screening for resistance to RFB. These include comparison of various inoculation (mycelium, infected leaves as mulch or canopy, natural inoculum) and evaluation (quantitative and qualitative) methods for RFB; comparison of rows versus plots for disease development; evaluation of the effect of inoculation times (single and multiple inoculations during the wet season) and defoliation frequencies (0, 2, 4 and 8 week frequencies) on RFB development; as well as the effect of mixing accessions of C. brasilianum and C. acutifolium with different susceptibilities to RFB on disease incidence and severity. As yet, no obvious trends have been detected. Evaluations will continue.

(iii) Evaluation of RFB in the llanos ecosystem.

Although initially thought to be caused solely by multinucleate Rhizoctonia solani, several isolates obtained in 1984 from blighted leaves proved to be binucleate. From 1985 to 1987, the population of Rhizoctonia species causing Foliar Blight in the llanos ecosystem was surveyed in order to evaluate the importance of the various components detected (multinucleate vs. binucleate). In total, 161 isolates were obtained from

Centrosema species. Chances of obtaining isolates pathogenic to Centrosema was facilitated by planting a selected collection of Centrosema species at seven different sites at Carimagua. These sites were representative of the many soil types present in this region.

Of the 161 isolates classified to date, three groups have been identified:

Rhisoctonia solani	54.2%
Rhizoctonia zeae	1.3%
Binucleate Rhizoctonia-like fungi (BNR)	44.5%

The BNR isolates were almost as commonly associated with foliar blight as was R. solani.

Among R. solani isolates, three anastomosis groupings have been identified: AG-1 and AG-4 most frequently and AG-2 occasionally. On the other hand, to date, it has not been possible to classify the BNR isolates with available American and Japanese testers. This suggests that the tropical BNR's belong to one or more unidentified species of Mycelia Sterilia.

Attempts are being made to relate the frequency of occurrence of R. solani and the binucleates to various characteristics such as host species, climatic conditions and soil characters in order to understand the importance of these two groups of pathogens.

With respect to the frequency of isolates of each group obtained from various Centrosema spp. hosts, although in many cases similar frequencies of R. solani and BNR's were obtained (Figure 1), BNR's were more frequently isolated from blighted C. macrocarpum CIAT 5062 and C. brasilianum CIAT 5514 while C. brasilianum CIAT 5184 was almost exclusively colonized by R. solani. This may be related to differential susceptibility among Centrosema species and accessions to the two groups of fungi and subsequent inoculation tests will clarify the situation.

In relation to climatic conditions prevailing at various sampling dates, although BNR's and R. solani were obtained at all sampling dates, BNR's were more consistently and frequently isolated during wetter months of June to August than R. solani (Figure 2). R. solani was more frequently isolated during the dryer months of April, October and November.

Site characteristics including edaphic factors such as % sand, % organic matter, Al saturation and pH were also considered. However, no clear trend was obvious. Two sites, "Pista 2" and "Agronomia", where high frequencies of R. solani were obtained have a longer history of cultivation than other sites. BNR's were more frequently obtained from sites with a shorter history of cultivation.

Using the newly developed inoculation methodology, comparative pathogenicity tests are in progress. To date (Nov. 87), results show that R. solani isolates are more pathogenic than BNR isolates while R. zeae isolates are not pathogenic. In addition, using the new methodology mean disease severity ratings on selected Centrosema species in the glasshouse are similar to field ratings.

In collaboration with the Plant Breeding Section, a collection of 14 accessions of C. brasilianum has been under evaluation in Carimagua since May, 1986. The most vigorous accessions to date are CIAT 5178, 5657, 5671 and 5365 (Table 1) while CIAT 5247, 5234, 5588, 494 and 5712 are the least vigorous. Although Rhizoctonia foliar blight has not built-up greatly during the past two years, the most susceptible accession

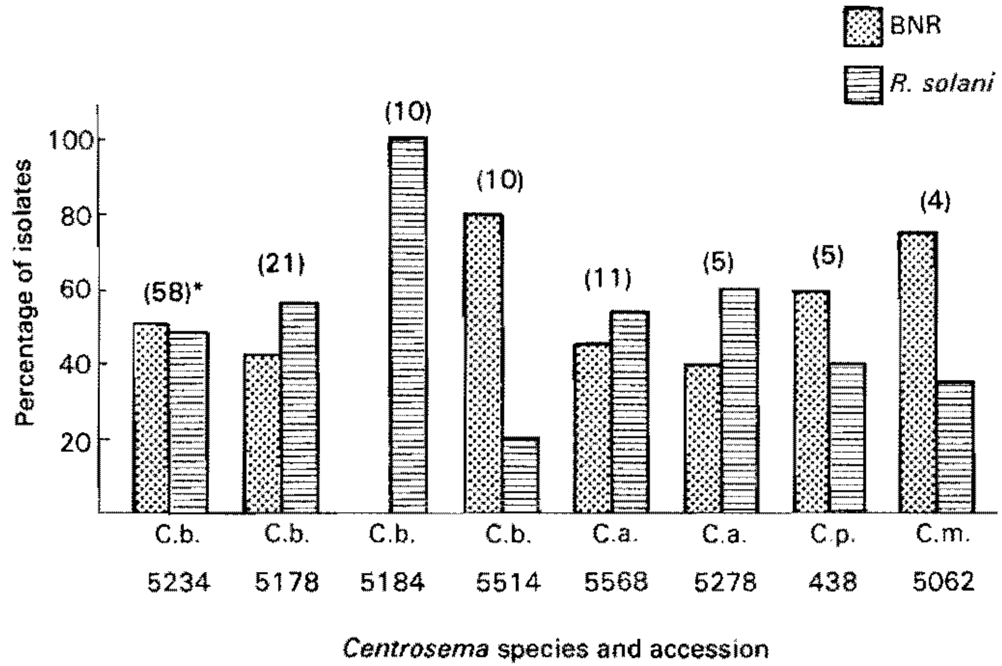


Figure 1. Percentage of isolates of *Rhizoctonia* spp. obtained from various species and accessions of *Centrosema* in the savannas of Colombia from December 1985 to November 1986.

* Number in parenthesis indicate numbers of isolates obtained from each accession.

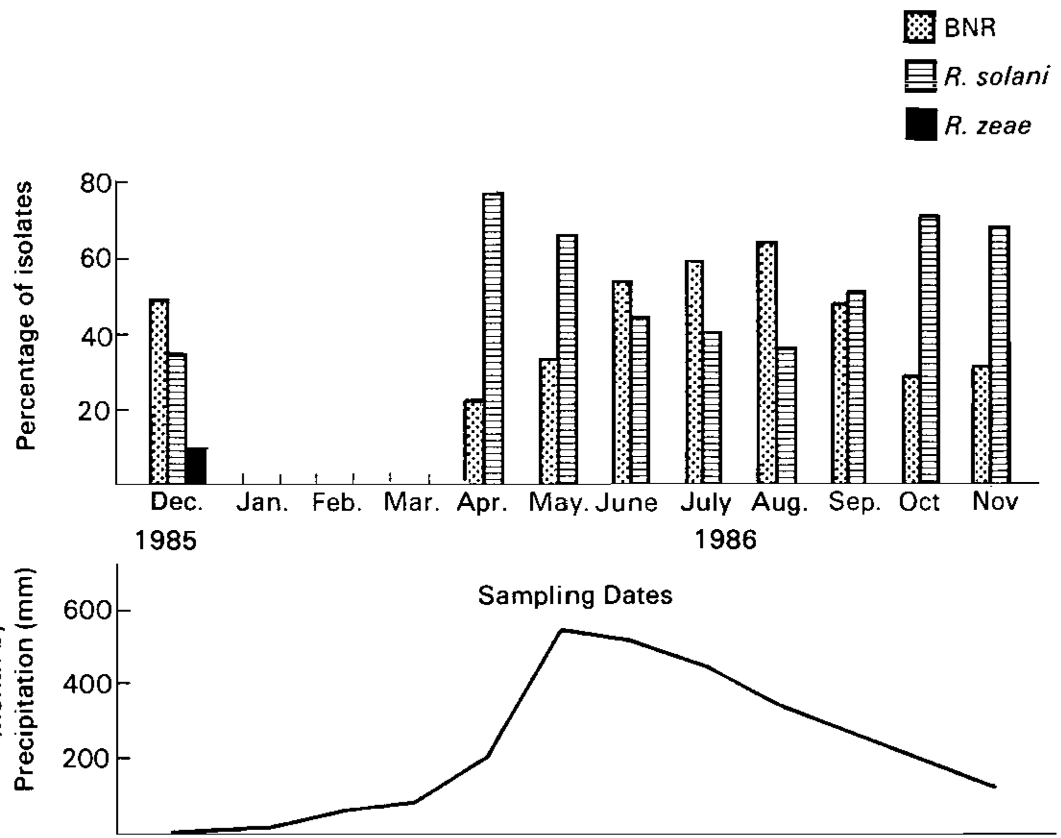


Figure 2. Percentage of isolates of *Rhizoctonia* spp. obtained on various collection dates from *Centreosema* spp. in the savannas of Colombia.

Table 1. Mean vigor and reaction to Rhizoctonia Foliar Blight of 14 accessions of Centrosema brasilianum from June, 1986 to September, 1987 in Carimagua.

Accession No.	Mean Vigor*	Mean Reaction***
5178	3.7	4.00
5657	3.4	2.75
5671	1.9	2.75
5365	1.7	2.75
5055	1.5	2.40
5514	1.4	2.30
5184	1.3	2.30
5810	1.1	2.25
5487	0.9	2.25
5712	0.6	2.15
494	0.6	2.10
5588	0.6	1.90
5234	0.4	1.40
5247	0.1	1.00

* Vigor scale:
1 = bad; 2 - fair; 3 - good; 4 = excellent.

** Reaction scale:
0 = no disease; 5 = plant death.

to date is CIAT 5178 and the least susceptible are CIAT 5184, 5247 and 5055 (Table 1).

In an attempt to assess the effect of cultural controls on RFB, the effect of different methods of soil preparation and ammendment on yield of C. brasilianum CIAT 5234 at two sites in Carimagua was evaluated (Table 2). Yields were greater at the "Alegria" site with 60% sand, than at "Pista 2" with 20% sand. Across sites, use of A. gayanus mulch gave the greatest yields while application of dolomitic limestone gave relatively high yields (Table 2). Of particular interest was the fact that solarization, recommended for control of soil-borne diseases, did not increase yield and that the use of Benlate was differentially effective across sites. Although Benlate had a positive effect (relative to the control) at "Pista 2", in the sandier soil site of "Alegria" Benlate decreased yield (Table 2). This may be due to a differential effect of Benlate on micorrhizae and other soil micro-organisms at the two sites.

(iv) Evaluation of RFB in the humid tropics ecosystem*.

From September 1986 to April 1987, a survey of diseases of Centrosema species and identification and characterization of potential pathogens was carried out in Pucallpa, Peru, the major screening site for the humid tropics. This was the first attempt at detailed disease characterization of tropical pasture germplasm in this ecosystem.

The Centrosema species germplasm was divided into five evaluation trials in Pucallpa, Peru:

a) Evaluation of various forage legumes under African palm shade (C. pubescens, C. macrocarpum, C. acutifolium and C. brasilianum) (14 acc.).
b) Evaluation of C. acutifolium (19 acc.).
c) Evaluation of C. macrocarpum (137 acc.).
d) Evaluation of C. brasilianum (8 acc.).
e) Evaluation of C. brasilianum (23 acc.).

Centrosema pubescens CIAT 413 was used as a control in all trials.

Centrosema species were principally affected by three diseases:

* Master Thesis Project of Ing. Hugo Ordoñez, IVITA, Peru & University of New Mexico, Las Cruces, NM, U.S.A.

Table 2. Effect of method of soil preparation and ammendment on yield of Centrosema brasilianum CIAT 5234 at two sites in Carimagua.

Treatment	Yield (gms/plot)	
	Pista 2	Alegria
A. gayanus Mulch	1566 a	5804 a
Cal. dol. 10 t/ha	1101 b	2885 bc
Benlate	934 b	243 d
Recomm. fertilizer x 4	540 c	3358 bc
Preparat. minimal**	539 c	1800 bcd
Burning	492 c	2041 bcd
Preparat. traditional	469 c	3752 b
Inoc. Trichoderma	467 c	3098 bc
Preparat. discing	458 c	3128 bc
Control*	427 c	1151 cd
Inoc. Rhizoctonia	355 c	1123 cd
Solarization	344 c	2012 bcd

* Control: Native savanna cut + herbicide
** Minimal: Chisel plough + offset disc
*** Traditional: Disc + 2 offset disc
Values within columns followed by the same letter do not differ (Duncan's Multiple Range Test, $\alpha = 0.05$).

Rhizoctonia foliar blight (RFB), Cercospora leaf spot (CLS) and bacteriosis.

Both interspecific and intraspecific differences were observed in the reaction of Centrosema to these diseases. CLS was most important on C. pubescens and especially severe under shade; bacteriosis was initially more important on C. acutifolium while RFB caused more damage to C. brasilianum. No potentially important disease was detected on C. macrocarpum. RFB was the most important disease of Centrosema in Pucallpa causing damage to C. brasilianum, C. acutifolium, C. pubescens and C. macrocarpum in decreasing order of severity.

Seventy-nine isolates from RFB affected Centrosema leaves were collected for further study. Of these, 41 were R. solani and 38 were binucleate Rhizoctonia- like fungi (BNR). The greatest number of R. solani isolates was obtained from C. macrocarpum (Table 3) while the greatest number of BNR isolates was from C. brasilianum. More than 90% of R. solani isolates were classified as AG-1, in contrast to isolates from Carimagua which were classified as AG-1, AG-4 and AG-2. In agreement with results from Carimagua, with one exception classified as CAG-5, none of the BNR's could be classified with the Japanese and American testers. This suggests that the tropical BNR's belong to as yet undescribed species of Rhizoctonia. An appropriate set of testers is being developed from local isolates.

Overall, isolates of R. solani (mean pathogenicity = 1.9) were more pathogenic than BNR isolates (mean pathogenicity = 1.6). Sixty percent of isolates of R. solani showed disease severity ratings of greater

Table 3. Number of multinucleate and binucleate *Rhizoctonia* isolates obtained from *Centrosema* species and other forage legumes and grasses leaves in Pucallpa, Peru.

	Multi-nucleates	Binu-cleates
C. acutifolium	4	3
C. brasilianum	11	25
C. macrocarpum	18	5
C. pubescens	1	3
P. phaseoloides	2	1
A. pintoi	3	1
D. ovalifolium	0	1
B. brizantha	1	0
B. decumbens	1	0
Total	41	38

than 2.0 (scale 0 to 5) while only 34% of BNR isolates did. This was positively correlated with growth rate of the fungus *in vitro*.

Among *Centrosema* species accessions, the two groups of fungi differed in mean disease severity ratings on particular accessions. *C. brasilianum* CIAT 5178 was most affected by *R. solani* with *C. macrocarpum* CIAT 5713, *C. brasilianum* CIAT 5234 and *C. acutifolium* CIAT 5568 being least affected (Figure 3). On the other hand, both *C. acutifolium* CIAT 5277 and *C. brasilianum* CIAT 5178 were most affected by the BNR isolates with the same accessions as listed above being least affected (Figure 4).

Results from this study have considerably increased our understanding of RFB in the humid tropics ecosystem.

c) Cylindrocladium Leaf Spot

Cylindrocladium Leaf Spot caused by the fungus *Cylindrocladium colhounii* was first detected on *C. acutifolium* and *C. pubescens* in 1985. This disease has increased in importance especially on *C. acutifolium* CIAT 5277 (cv. Vichada) during the past year. The causal agent has now been isolated and grown in pure culture. Koch's postulates have been successfully performed and screening on the *C. acutifolium* collection and other *Centrosema* species is in progress, in a attempt to find potential sources of resistance to this pathogen.

d) Evaluation of diseases of *Centrosema* under grazing. This year emphasis was placed on evaluation of the importance of diseases of *Centrosema acutifolium* under grazing in two grazing trials. This was achieved by spot evaluations of diseases incidence and severity along fixed transect lines.

(i) Evaluation of diseases in *C. acutifolium* CIAT 5277 and 5568 in association with *Andropogon bicornis* under continuous and rotational grazing at high, medium, and low stocking rates.

In CIAT 5277, Cylindrocladium Leaf Spot (CylLS) and Bacteriosis (B) were most frequently detected. In general, the incidence of B increased over time (Figure 5), with higher incidence under continuous grazing and low stocking rate (LSR) than at medium (MSR) and high stocking (HSR) rates. B incidence was also high under rotational grazing at HSR. Mean disease severity peaked in June with continuous grazing at LSR and rotational grazing at HSR showing the highest disease levels. The incidence of CylLS remained high during the wet season. Lowest disease incidence and severity was recorded under continuous grazing at HSR (Figure 6).

In CIAT 5568, RFB and CylLS were most frequently detected. The incidence and severity of RFB was highest under rotational grazing at HSR (Figure 7).

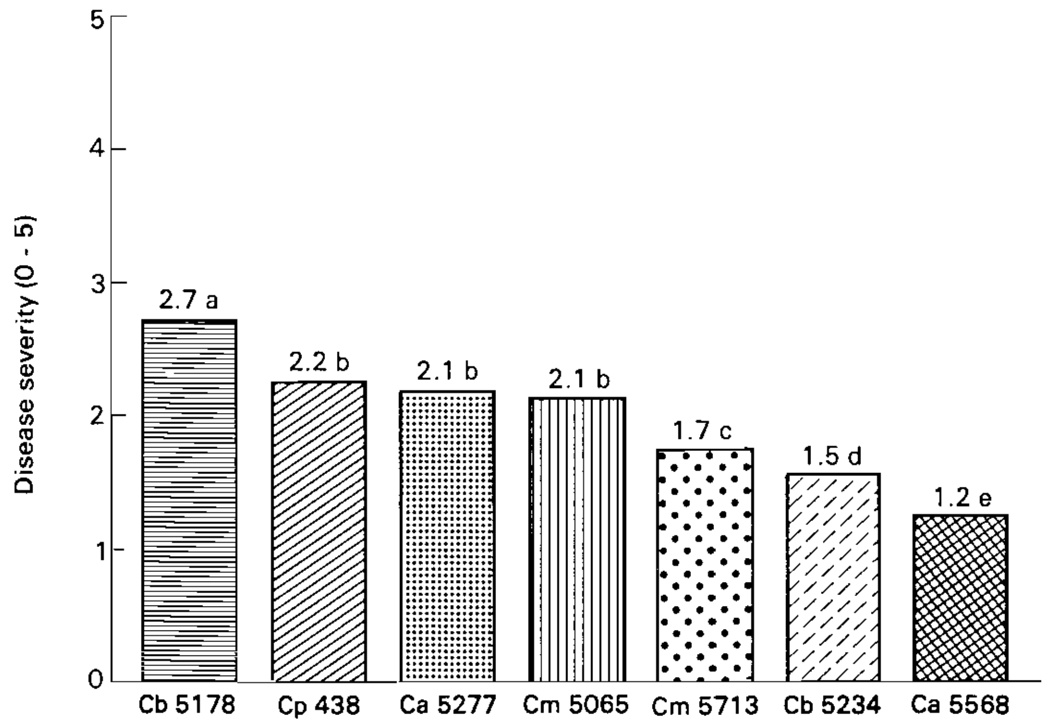


Figure 3. Mean disease severity on *Centrosema* species caused by *Rhizoctonia solani*.

Bars followed by the same letter not significantly different at 5% level according to Duncan's Multiple Range Test.

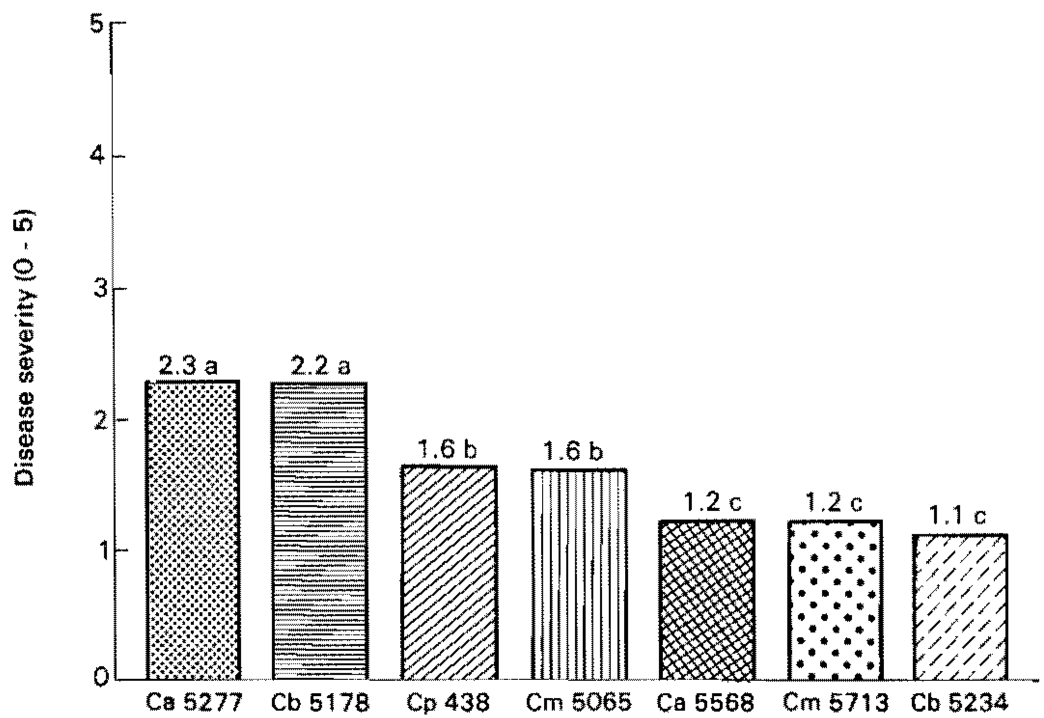


Figure 4. Mean disease severity on *Centrosema* species caused by binucleate *Rhizoctonia*-like fungi.

Bars followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

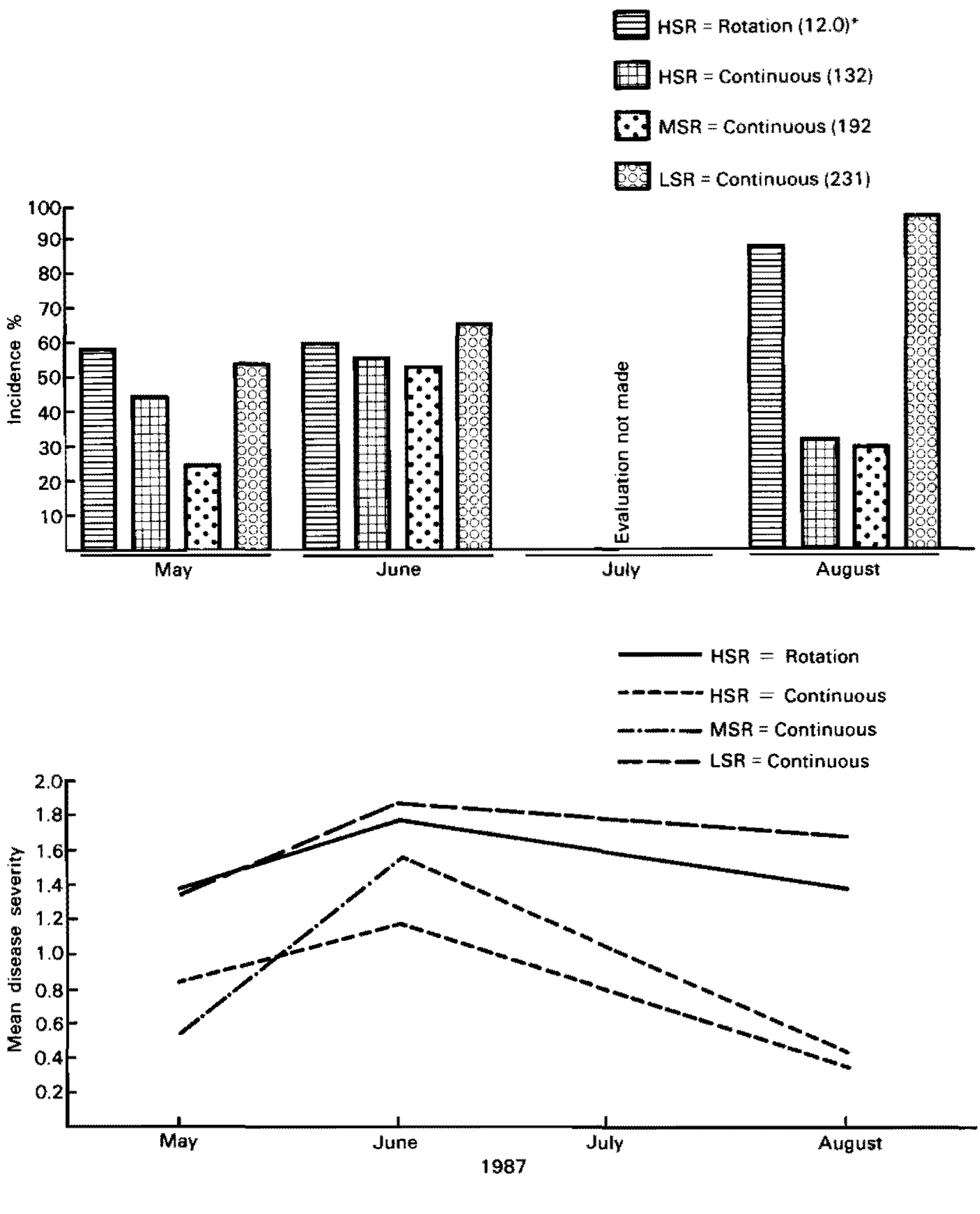


Figure 5. Incidence and mean severity of bacteriosis in *Centrosema acutifolium* CIAT 5277 from May to August 1987 under four grazing treatments in Carimagua.

* Number of evaluation points per treatment.

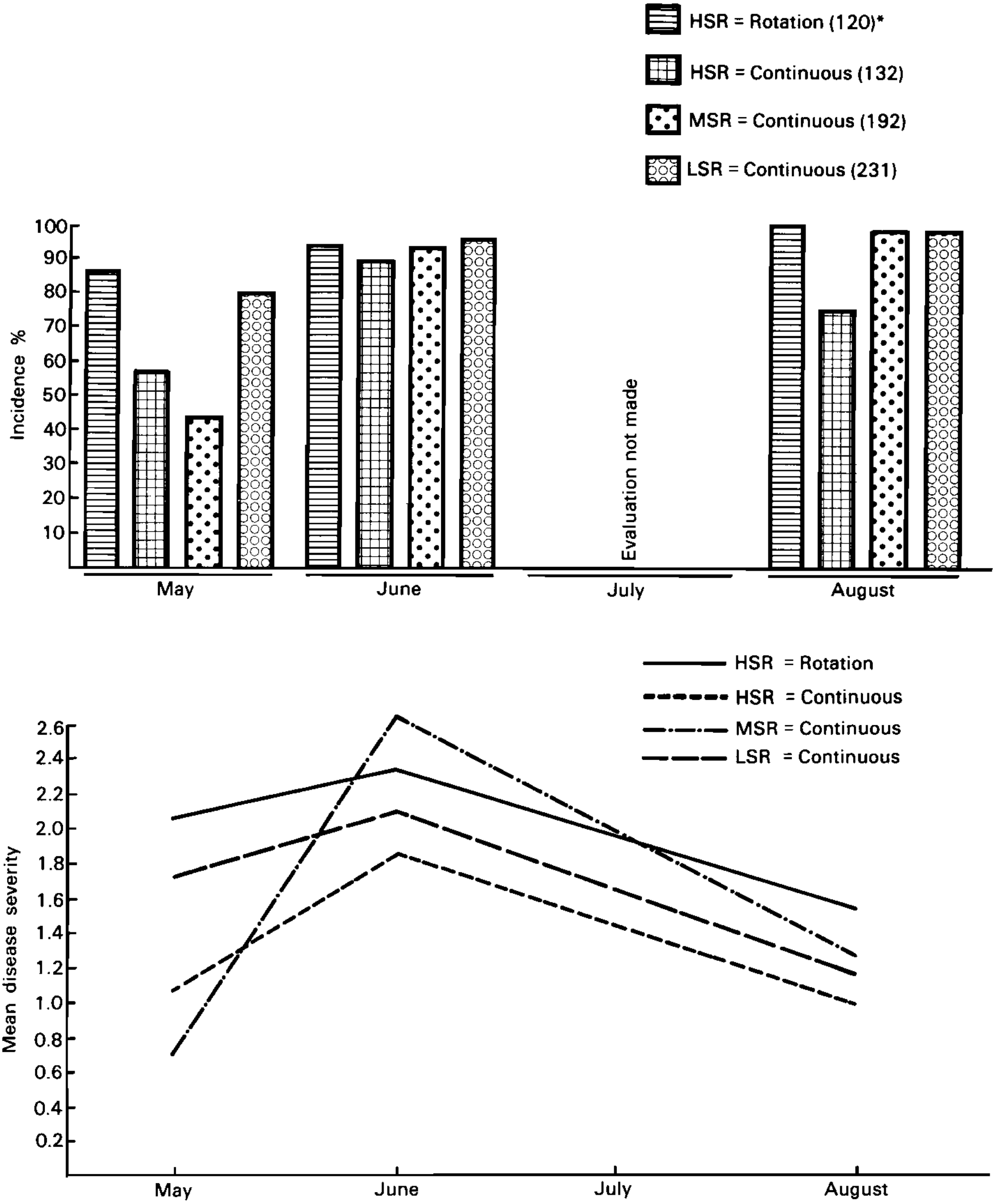


Figure 6. Incidence and mean severity of *Cylindrocladium* leaf spot on *Centrosema acutifolium* CIAT 5277 from May to August under four grazing treatments in Carimagua.

* Number of evaluation points per treatment.

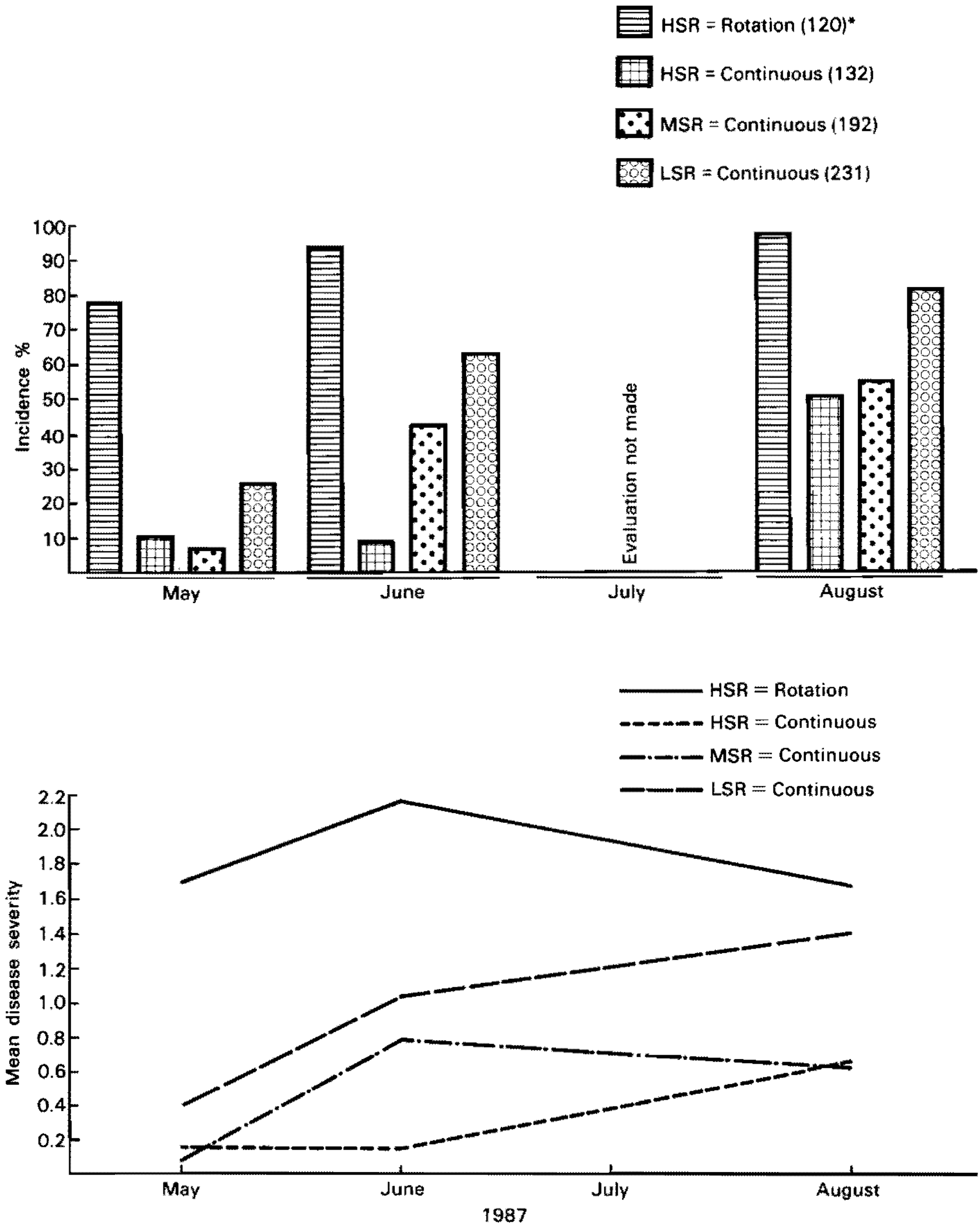


Figure 7. Incidence and mean severity of Rhizoctonia foliar blight of <u>Centrosema acutifolium</u> CIAT 5568 from May to August 1987 under four different grazing treatments in Carimagua.

* Number of evaluation points per treatment.

This was related to the predominance of Centrosema in this treatment. Both incidence and severity of RFB in the continuous grazing treatments followed the same trend of decreasing disease with increasing stocking rate (Figure 7).

The incidence of CylLS in CIAT 5568 increased over time (Figure 8). Lower incidence and severity were recorded under continuous grazing at MSR and HSR. As for RFB, LSR under continuous grazing and HSR under rotational grazing favored higher levels of CylLS (Figure 8).

Losses due to the combination of diseases present on CIAT 5277 and 5568 are also being monitored in this experiment. Using fungicides to control CylLS, RFB and B, dry matter losses of 31.6% were measured in CIAT 5277 due to CylLS and B and of 22.6% in CIAT 5568 due to RFB and CylLS under rotational grazing at HSR (Table 4). These losses relate to moderate levels of disease severity. Further assessment is needed to determine if this level of dry matter loss will affect long term pasture productivity and persistence.

(ii) Evaluation of diseases of C. acutifolium CIAT 5277 in association with Brachiaria decumbens under two rotational grazing treatments (7/7 and 21/21).

Both CylLS and B were detected in CIAT 5277. B remained high during the wet season (Figure 9) while CylLS increased in incidence from May to September (Figure 10). For both diseases, the shorter rotation of 7/7 favoured disease severity in contrast to the longer rotation of (21/21) however mean disease severity remained slight to moderate (Figures 9 & 10). Further evaluation is necessary in this experiment to determine if the effects detected are stable over time.

Diseases of Stylosanthes

a) Anthracnose

(1) Effect of grass association on anthracnose of S. guianensis Previous work has shown that anthracnose develops more rapidly and severely on S. guianensis in association with grasses such as A. gayanus than when not associated (Annual Report 1981, 1983). It had been expected that grass would

Table 4. Effect of various diseases* on dry matter yield of Centrosema acutifolium CIAT 5277 and 5568 under rotational grazing in Carimagua.

Accession	+ Fungicide				- Fungicide				
	Mean disease			Dry matter	Mean disease			Dry matter	DM loss
	CylLS	B	RFB	kg/ha	CylLS	B	RFB	kg/ha	%
5277	2.5	0.3	-	1394 a	3.5	1.8	-	953 b	31.6
5568	0.7	-	1.5	1050 a	0.8	-	3.0	813 b	22.6

* 5277: Cylindrocladium leaf spot; bacteriosis.
5568: Rhizoctonia foliar blight; Cylindrocladium leaf spot.

Values followed by the different letters in the same line are significantly different at $P < 0.05$.

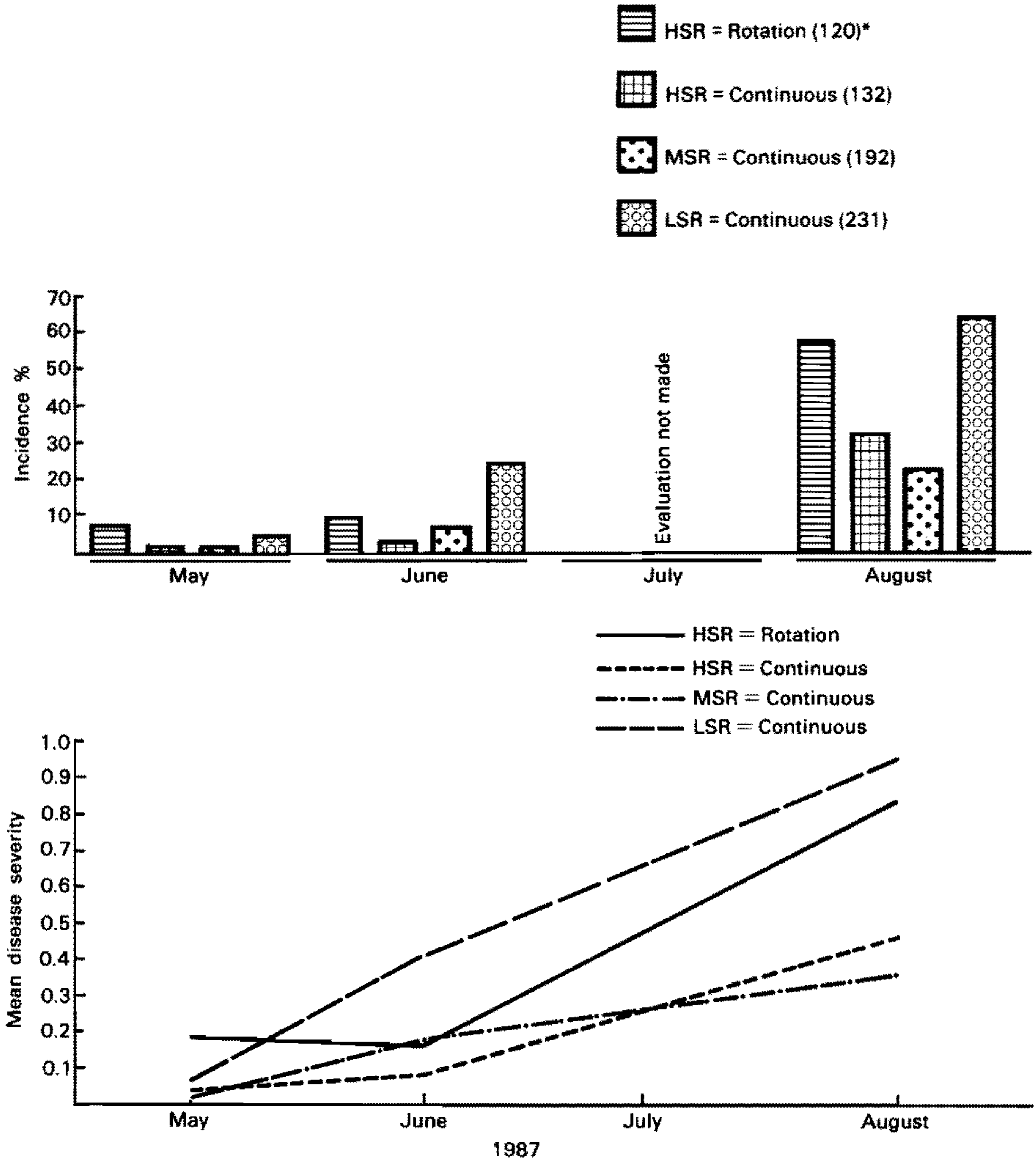
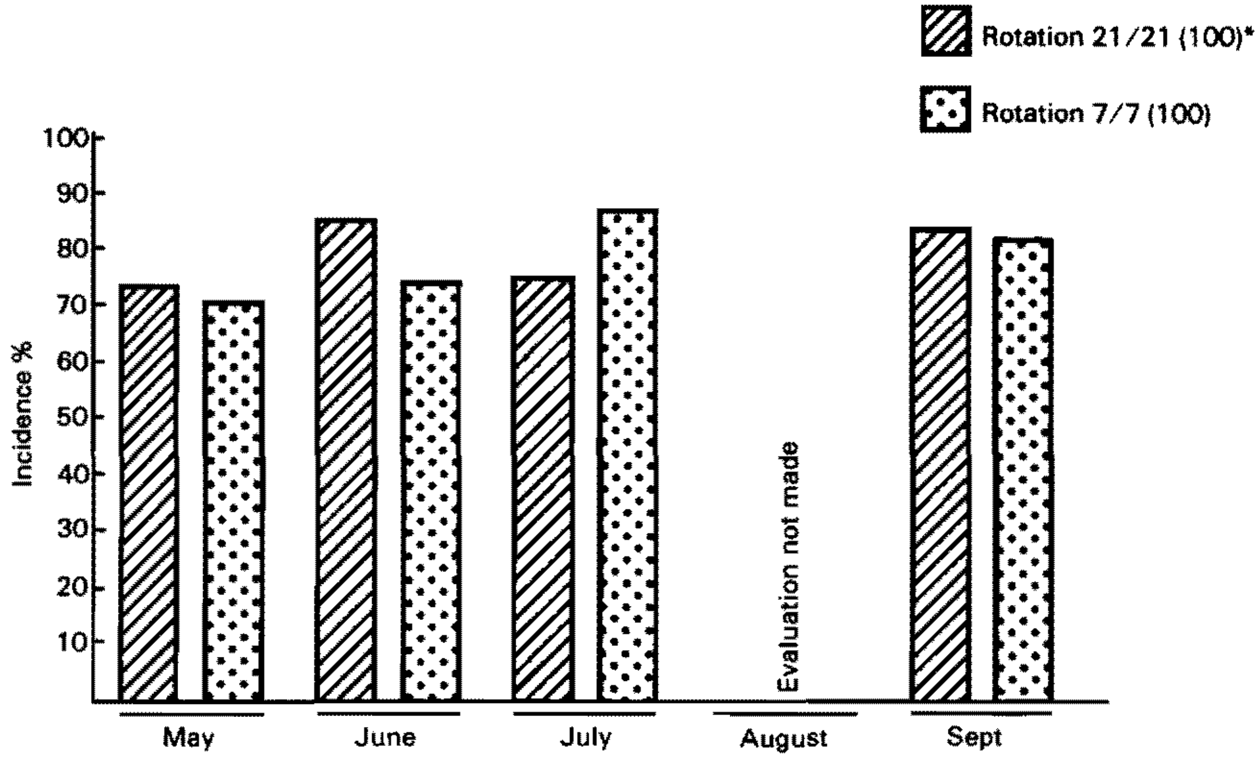


Figure 8. Incidence and mean severity of *Cylindrocladium* leaf spot on *Centrosema acutifolium* CIAT 5568 from May to August, 1987 under four grazing treatments in Carimagua.

* Number of evaluation points per treatment.



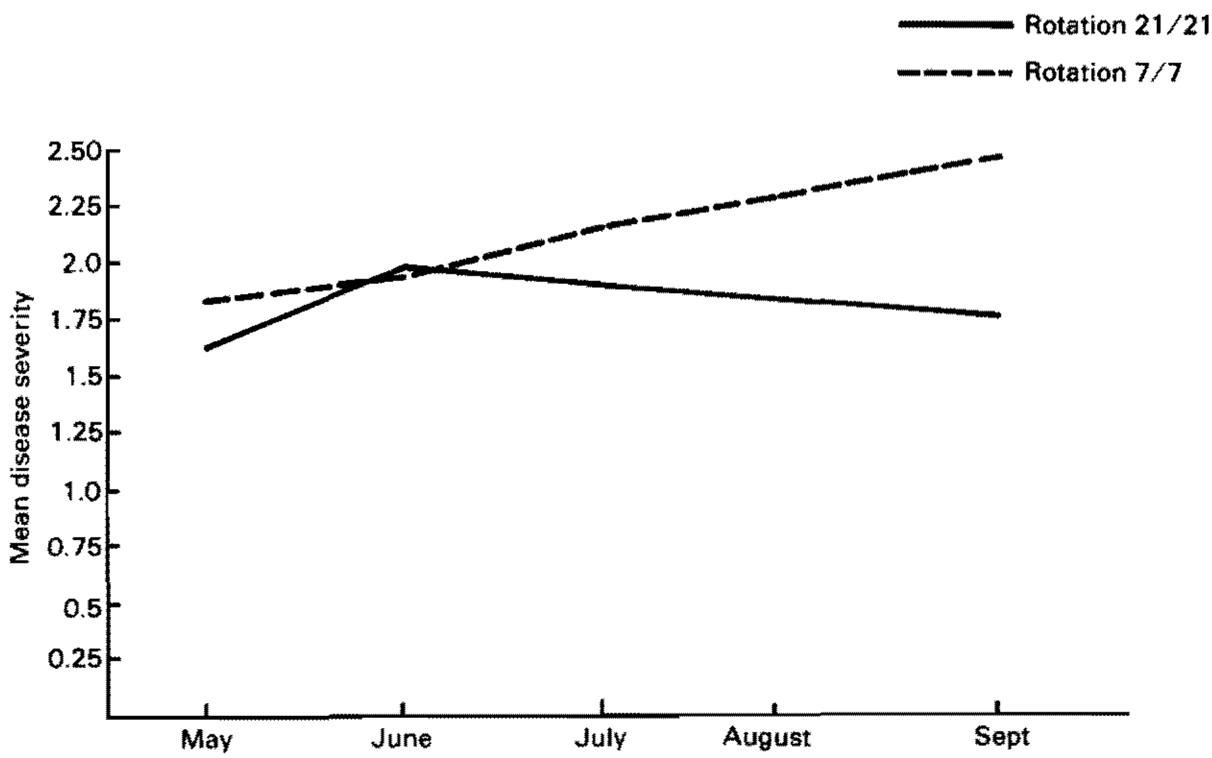


Figure 9. Incidence and mean severity of bacteriosis in *Centrosema acutifolium* CIAT 5277 from May to September, 1987 under two rotational grazing treatments in Carimagua.

* Number of evaluation points per treatment.

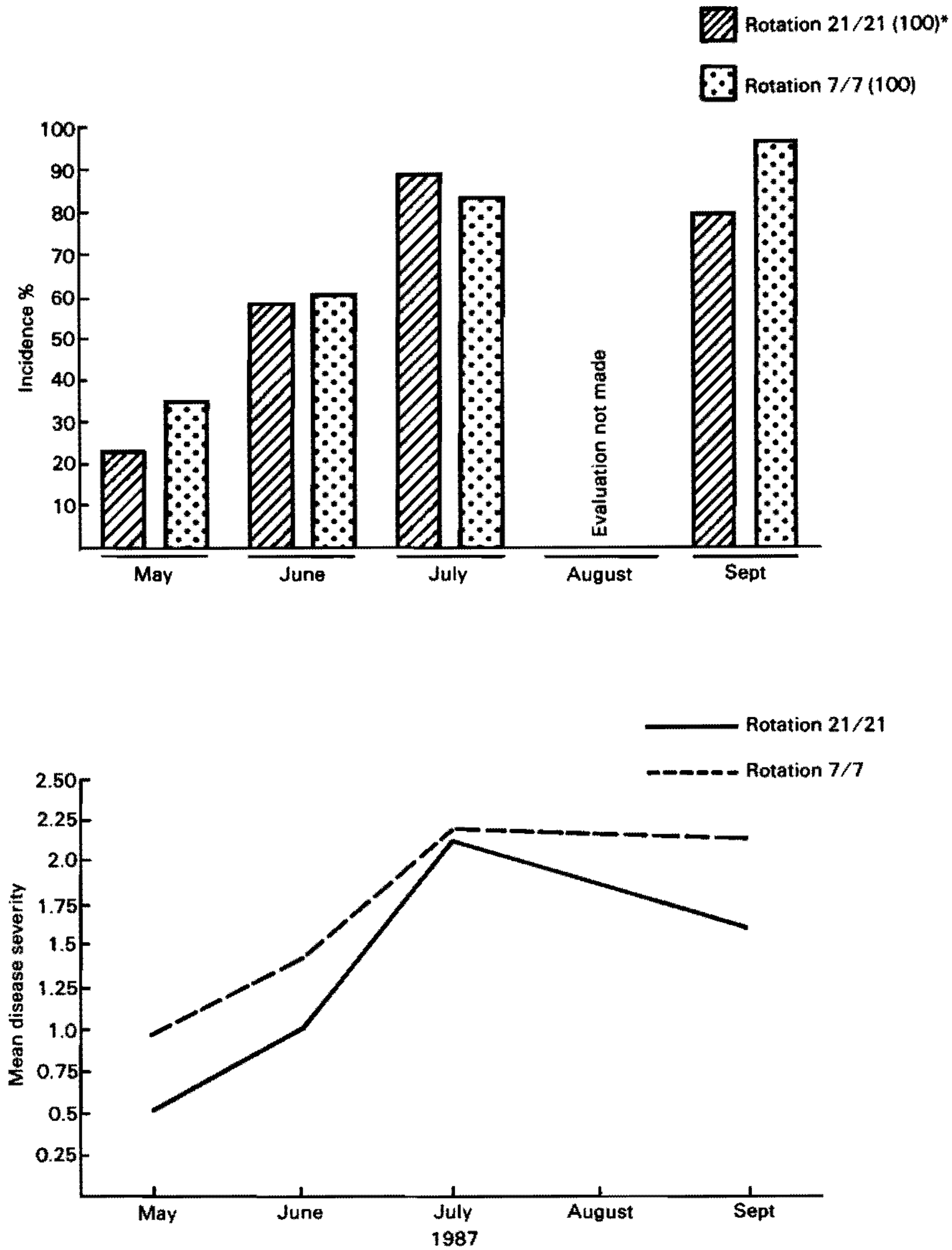


Figure 10. Incidence and mean severity of *Cylindrocladium* leaf spot in *Centrosema acutifolium* CIAT 5277 from May to September 1987 under two rotational grazing treatments in Carimagua.

* Number of evaluation points per treatment.

act as a barrier to movement of spores of C. gloeosporioides. Apparently, the aggressive and competitive characters of A. gayanus had stressed S. guianensis sufficiently to reduce its ability to resist anthracnose. In another experiment where artificial barriers were used to reduce aerial inoculum movement and mulch was used to reduce soil inoculum spread, the rate of anthracnose development was effectively reduced by both barriers (Annual Report 1983).

The effect of grass association on anthracnose development in S. guianensis CIAT 136 and 1283 was further evaluated during 1987 using A. gayanus as aerial and soil barriers. Two different plot sizes were used 25 and 100 m^2. Results to date show that use of A. gayanus mulch as a soil barrier to inoculum spread reduces anthracnose development especially in CIAT 136 irrespective of plot size and the presence or absence of aerial barriers (Table 5). However, higher anthracnose levels are present in all treatments with aerial barriers of A. gayanus irrespective of plot size as has been noted in previous experiments with this grass (see above). The grass's expected role as barrier to movement of aerial inoculum has not been fulfilled. Its character of stimulating anthracnose development either by aggressive competition with the legume and/or due to microclimate effects merits further evaluation.

(ii) Effect of anthracnose and other factors on survival of a segregating S. guianensis population in several grazing environments.

In close collaboration with the Plant Breeding Section, a segregating population of S. guianensis in several associations and grazing environments was evaluated in Carimagua from 1985 to 1987 (see Annual Reports 1985 & 1986). Three thousand marked plants - 500 plants in each of six treatments (+ A. gayanus at low, medium and high stocking rates and + Carimagua savanna at low, medium and high stocking rates) were evaluated. Anthracnose was rated on a scale of 0 to 5 while isolates of Colletotrichum gloeosporioides were collected from anthracnosed plants during the experimental period. All evaluation and isolate collection ceased in the A. gayanus association and the savanna association in August 1986 and February 1987, respectively, when all marked plants had died.

Frequency distributions of the reaction to anthracnose of all 500 plants in each cohort in each treatment were prepared (Figures 11 & 12) from February 1985 to 1986. For all three stocking rates (SR) in both associations - A. gayanus (Figure 11a, b, c) and savanna (Figure 12a, b, c) the major change in the structure of the frequency distributions was the increase in % of dead plants. At the same time there was no evidence to show that anthracnose was the major cause of plant death (Figures 11 & 12). The % of dead plants increased more rapidly in both associations at LSR than at HSR, especially in the savanna association. This is probably related to greater plant competition at LSR. There was no indication that SR treatment or association had any effect on the structure of the populations with respect to reaction to anthracnose alone.

The C. gloeosporioides population was sampled in all treatments several times during 1985 and 1986. Isolates were separated into groups according to reaction to a differential set of 12 S. guianensis accessions. Different groups were distinguished among isolates from the different grass associations (Figure 13). Of greater interest was the finding that >40% of isolates from the savanna association and >30% from the A. gayanus association (Group 1) were virulent to ten of the twelve S. guianensis differentials. This is contrary to what is

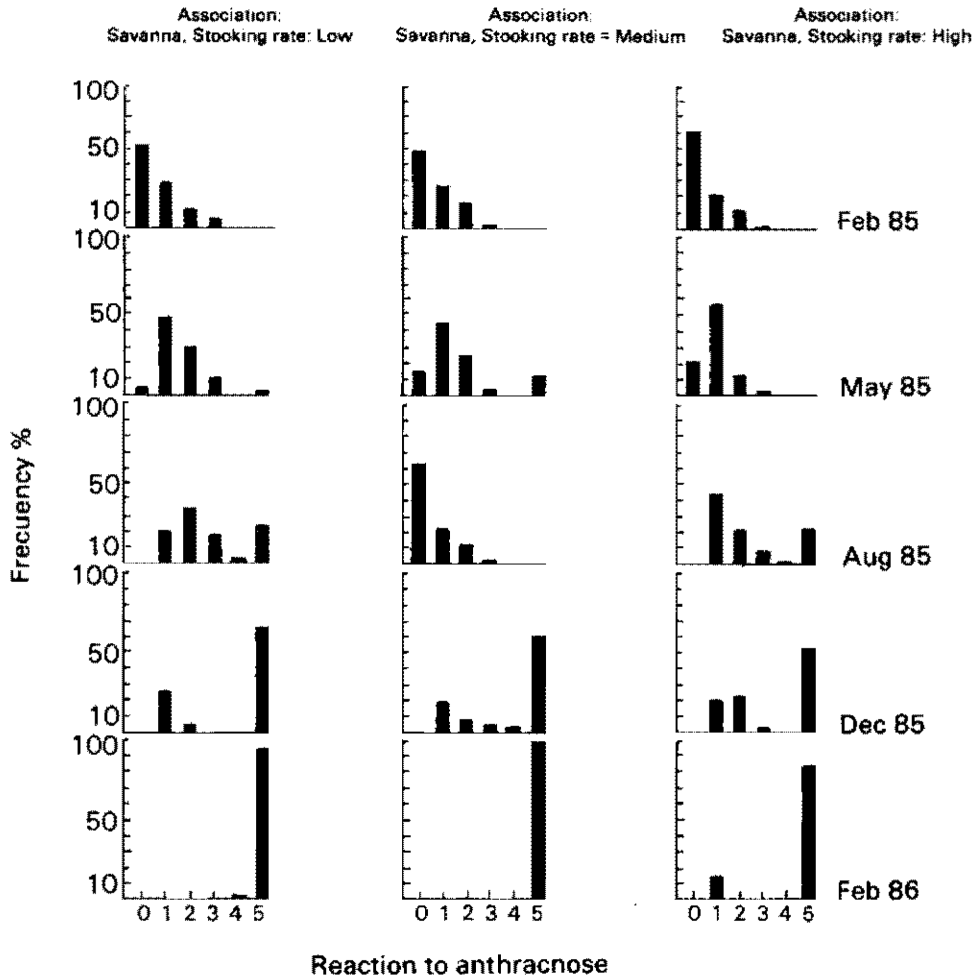


Figure 11a. Figure 11b Figure 11c.

FIGURE 11. 11a. 11b. 11c. Frequency distributions of the reaction of a cohort of 500 plants to anthracnose from February 1985 to February 1986.

Note: Reaction value 5 indicates plant death due to a complexity of actors. Anthracnose was not necessarily the major cause of death.

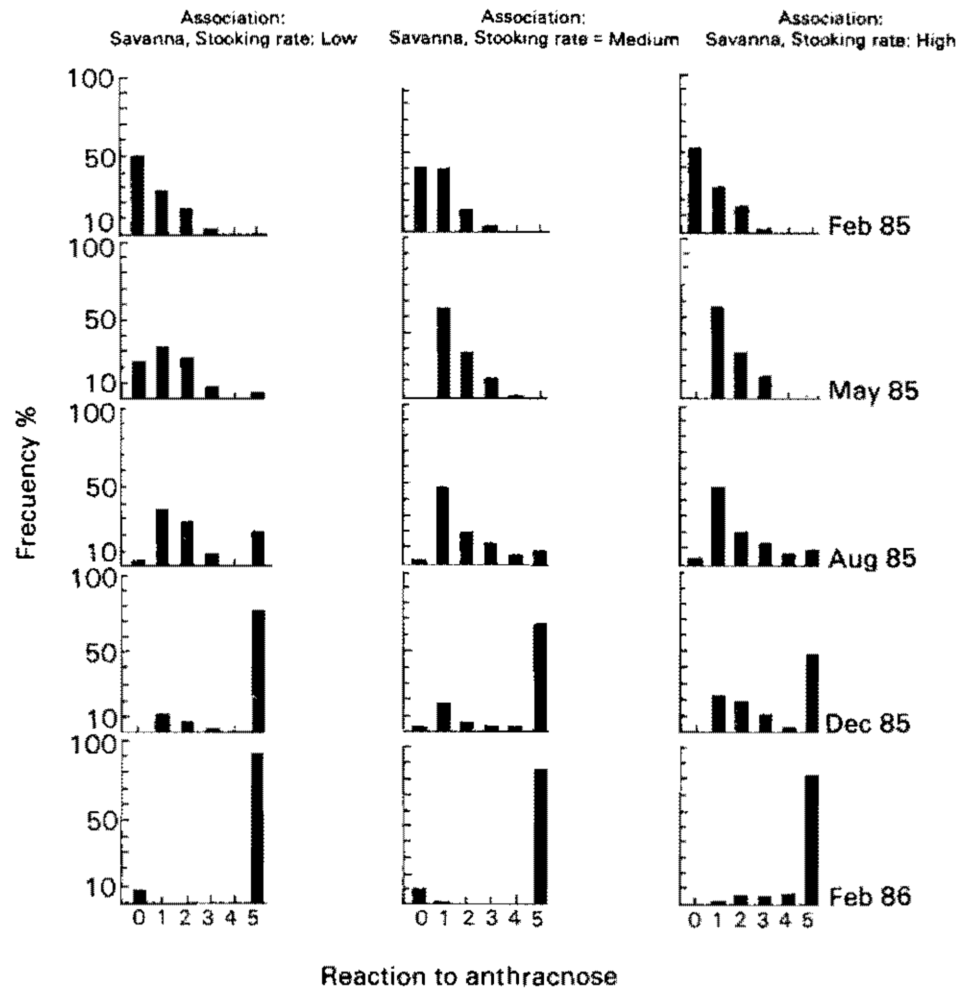


FIGURE 12. Figure 12a. Figure 12b. Figure 12c.

12A, 12B, 12C **Frequency distributions of the reaction of a cohort of 500 plants to anthracnose from February 1985 to February 1986.**

Note: Reaction value 5 indicates plant death due to a complexity of factors. Anthracnose was not necessarily the major cause of death.

Table 5. Effect of barriers to movement of aerial and soil inoculum of Colletotrichum gloeosporioides on development of anthracnose in Stylosanthes guianensis CIAT 136 and 1283. Evaluation: September, 1987.

Accession	Mulch	Small plot	Large plot	Mean
		+ Aerial Barriers		
1283	+	3.2	3.0	3.10
1283	-	3.6	3.5	3.55
136	+	1.5	1.5	1.50
136	-	3.0	2.6	2.80
		- Aerial Barriers		
1283	+	2.3	2.0	2.15
1283	-	3.1	3.0	3.05
136	+	1.1	1.1	1.10
136	-	2.1	2.1	2.10
Mean		2.49	2.35	

Rating scale anthracnose: 0 = no disease; 5 = plant death.

expected in mixed populations. Various researchers have hypothesized that "super-races" capable of affecting a wide range of genotypes are not selected in mixed populations of their hosts. In the highly heterogeneous S. guianensis population, these races were present (Figure 13) however anthracnose was not the major factor affecting S. guianensis survival.

In this experiment, grass competition shown by decreased legume survival at LSR in both associations and particularly the A. gayanus association, was the major factor affecting survival of the segregating heterogeneous S. guianensis population. Anthracnose and stemborer were contributing factors to plant death.

It is clear that even though disease may be the most important factor affecting survival of a legume under small plot monoculture, in the complex perennial pasture ecosystem disease may only be a contributing factor to lack of legume survival.

Diseases of Desmodium

a) Synchytrium wart or false rust disease.

In the well-drained isohyperthermic savannas (WDHS) or llanos, the most severe symptoms of wart disease or false-rust, caused by Synchytrium desmodii, are seen during the wet season from May to November. Damage distribution is usually patchy with lowlying areas of paddocks where water accumulates showing severe symptoms. Because Synchytrium affects different strata of the perennial pasture legume Desmodium ovalifolium differently, the study of its effect on pasture persistence and productivity was carried out in two parts:

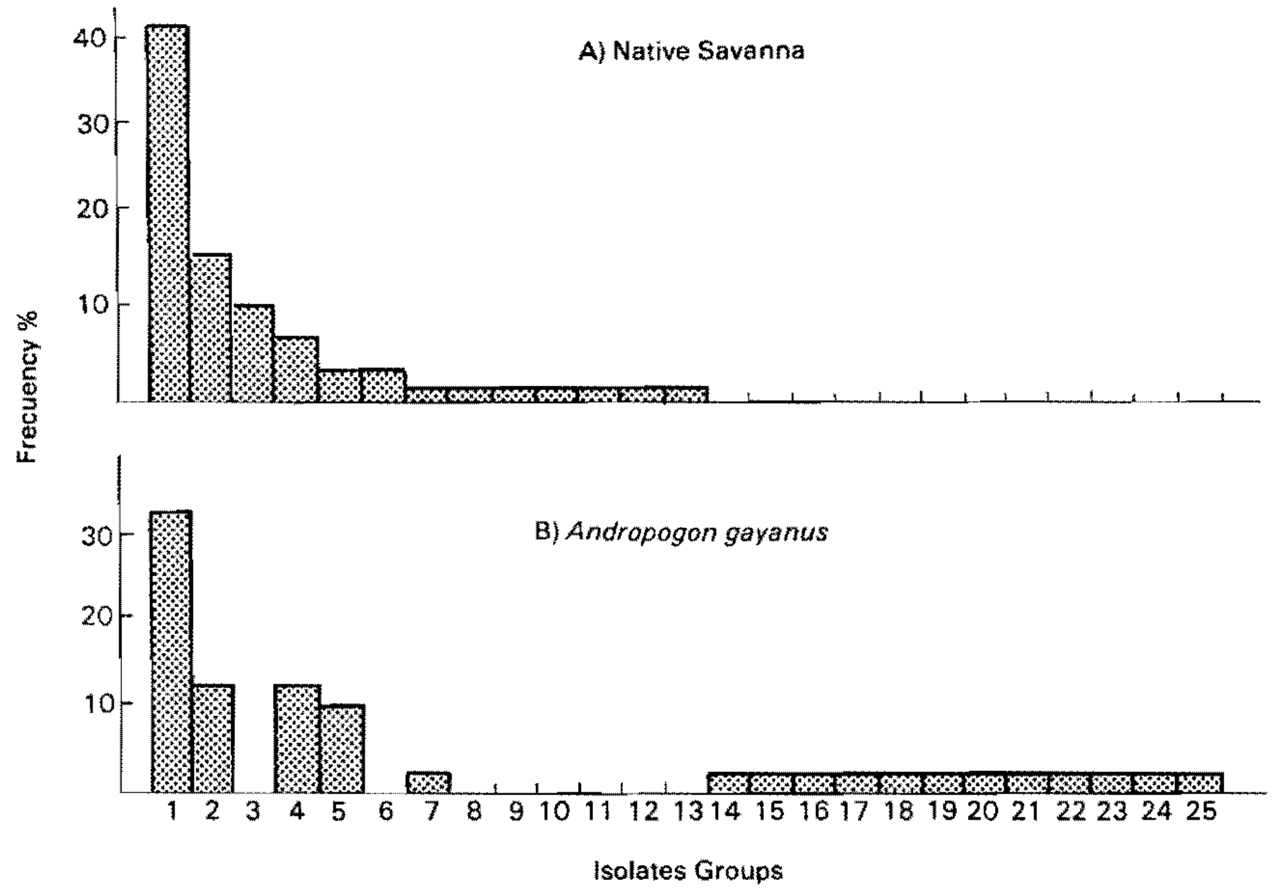


Figure 13. Frequency of different isolate groups of *C. gloeosporioides* obtained from *Stylosanthes guianensis* from the A) native savanna association and B) *Andropogon gayanus* association in Carimagua.

i) Effect on adult plant yield (Annual Report, 1986).

ii) Effect on seedling survival and recruitment to the adult plant population.

With the onset of the wet season, large numbers of seedlings of *D. ovalifolium* emerge, around 500-700/m^2. In wart affected areas, seedlings are usually severely affected within a few weeks of emergence and the mortality rate is high. From May 1986 to 1987, 32 one meter square plots in both wart-affected and wart-free areas were studied in a five year-old *D. ovalifolium* - *Brachiaria decumbens* pasture. Each month, seedlings were counted in each plot. From May 1986 to 1987, 21 plants were recruited from the seedling population to the adult plant population in wart-free areas (Figure 14), while no seedlings survived in wart-affected areas.

In another set of 20 subplots in the same pasture, seedling survival, recruitment to the adult plant population and soil seed reserves were monitored from May 1985 to 1987. In none of the three wet seasons, 1985, 1986 and 1987, did seedlings survive for more than five months (Figure 15). At the same time, soil seed reserves in the top 5 cm decreased from 1480 seed/kg of dry soil to 8 seed/kg of dry soil from May 1985 to May 1987.

Synchytrium wart disease therefore has a major effect on seedling survival, recruitment into the adult plant population and subsequent long-term persistence of *D. ovalifolium*. In addition, previous studies (Annual Report 1986), have shown that wart disease reduces adult plant yield by 73% under flooded conditions. Under non-flooded conditions, yield was not significantly reduced (Annual Report 1986).

These findings are being used to develop more appropriate screening methodology to further test the *D. ovalifolium* collection for resistance to this disease. At the same time, avoiding low-lying areas when planting susceptible *D. ovalifolium* in wart-affected areas will reduce losses due to this disease.

b) Stem-gall nematode

Although stem-gall nematode populations in the llanos remained low again in 1987, further work continued in evaluating this problem.

Comparison of Benlate and Furadan as seed treatments against stem-gall nematode found Benlate to be more effective in reducing the rate of multiplication of nematodes in inoculated plants arising from treated seed (Table 6).

Effect of flooding on reaction of accessions of *D. ovalifolium* to *P. cecidogenus* has been evaluated in Carimagua from 1986 to 1987. Again, low populations of *P. cecidogenus* prevented sound selection of the most promising accessions during 1987 (Table 6). Lower levels of stem galling were general under periodic

Table 6. Effect of seed treatment with 500 ppm of Furadan and Benlate for 60 min on multiplication of *P.cecidogenus* in inoculated seedlings grown from treated seed.

Weeks after inoculation	Number of Nematodes Furadan	Benlate
1	8 a	1 a
2	12 a	2 a
4	35 b	2 a
8	35 b	5 a

Values followed by the same letter in the same columns are not different ($P < 0.05$).

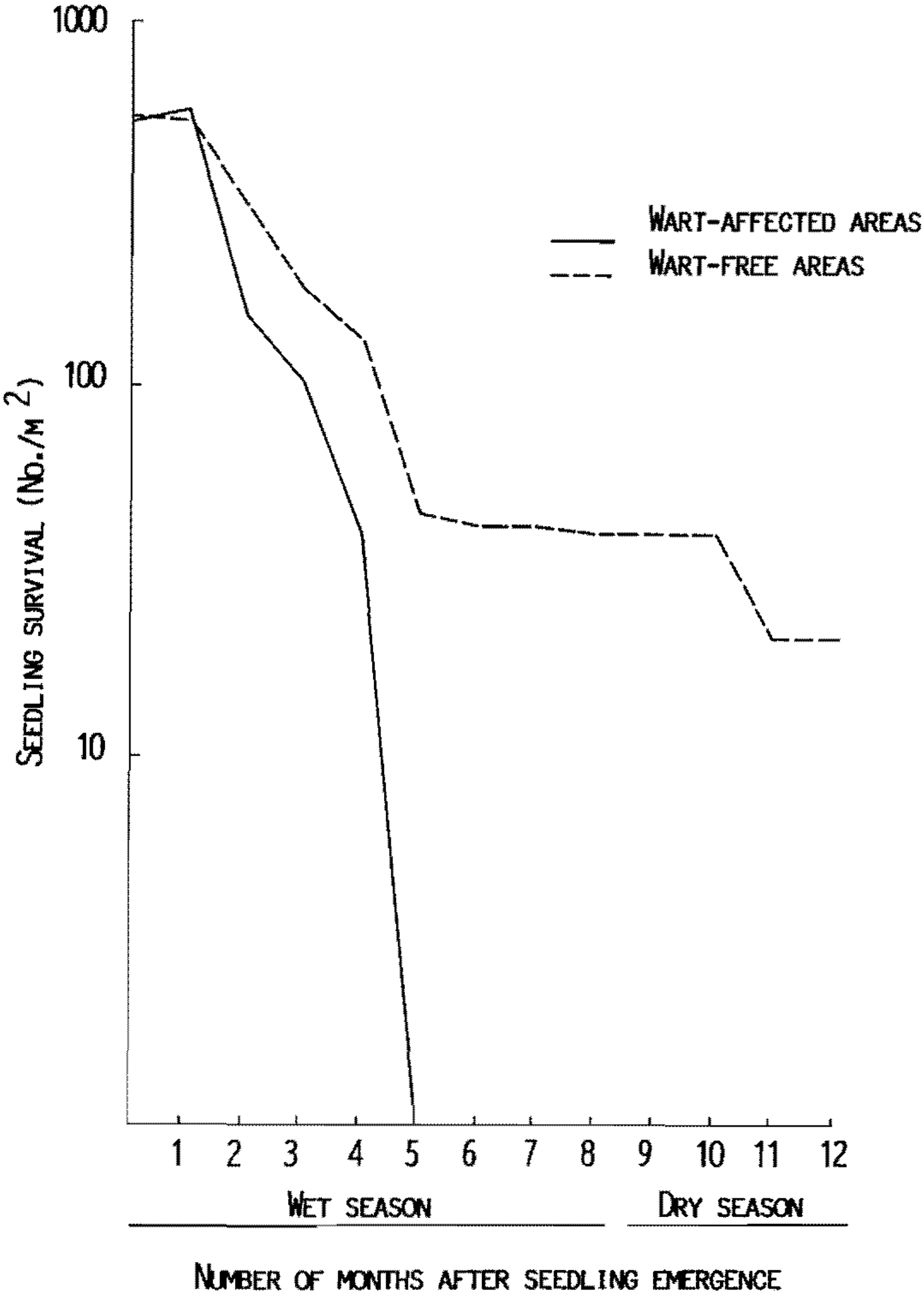


Figure 14. Effect of *Synchytrium desmodii* on seedling survival of *Desmodium ovalifolium* under grazing May 1986 to May 1987.

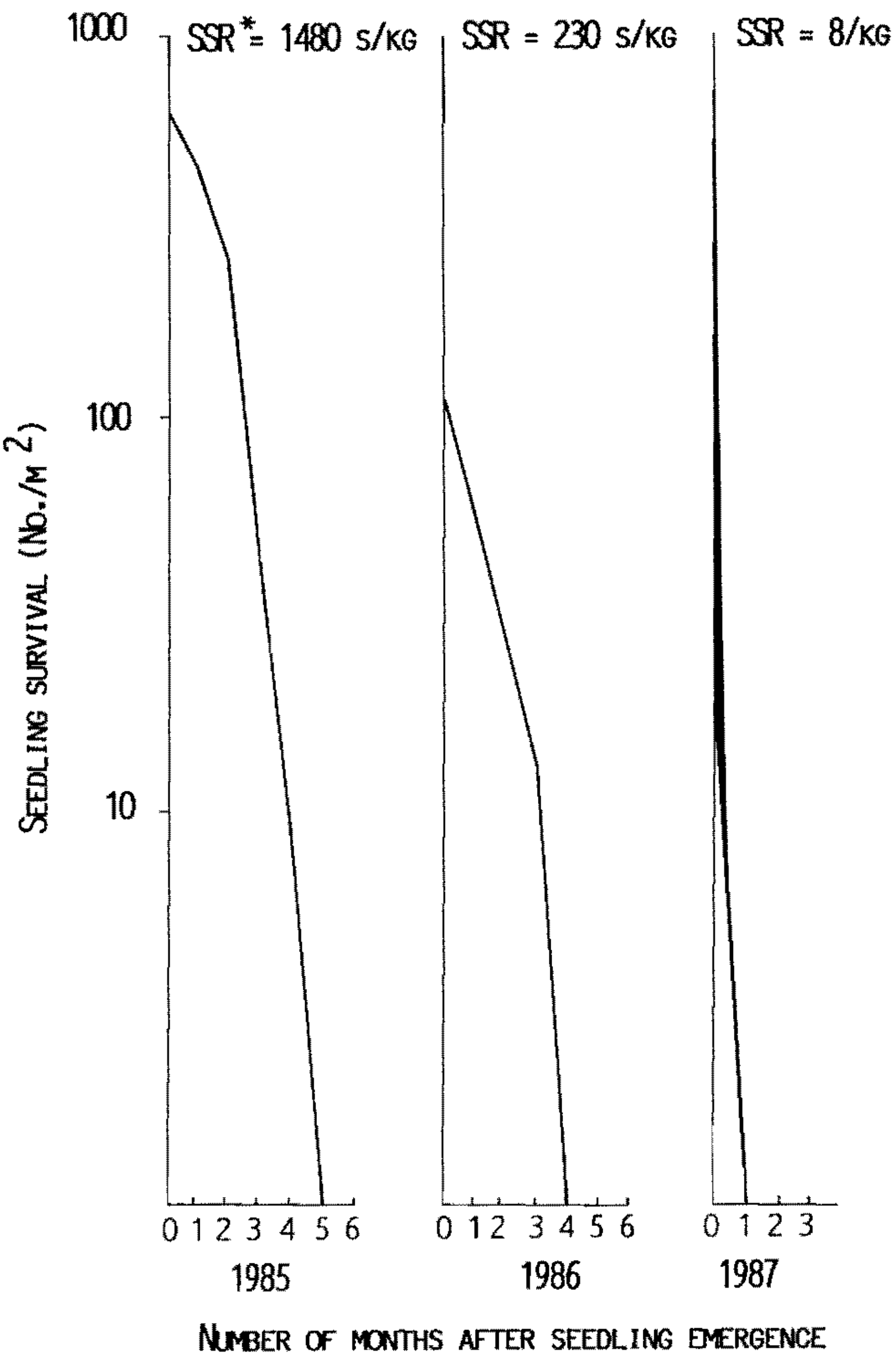


Figure 15. Effect of *Synchytrium desmodii* on seedling survival of *Desmodium ovalifolium* under grazing from May 1985 to June 1987.

*SSR = soil seed reserves.

flooding than under well-drained conditions. The most vigorous accessions under well-drained conditions were 13115, 13092, 350, 3793 and 13139. The most vigorous accessions under periodic flooding were 3793, 13091, 3776, 3666 and 3674 (Table 7).

Evaluation of reaction of selected accessions of D. ovalifolium to P. cecidogenus under grazing also continued. Again, extremely low levels of galls were observed (Table 8). Synchytrium wart disease ratings were also low. Under low grazing pressure, the most vigorous accessions were 13129, 350 and 13089 while under high grazing pressure 13089 was far more vigorous than any other accessions (Table 8).

In studies on the dynamics of stem gall nematode, evaluation of the lateral spread of P. cecidogenus in D. ovalifolium has shown that it can advance 30 cm along the stem in one year (Figure 16). Evaluation of gall development in the same experiment has shown no advance since the end of the 1986 wet season (Figure 17).

Both glasshouse and field evaluations of new accessions of D. ovalifolium over the past year have found nothing more resistant than CIAT 13089. Further evaluations will continue on new germplasm in Carimagua during 1988.

Diseases of Arachis

During 1987, several diseases were recorded on Arachis pintoi in Colombia.

a) A potyvirus causing mottling of leaflets has been found in most A. pintoi plantings in Colombia. It is not Peanut Mottle Virus the most wide-spread virus of this genus. Further work is in progress to identify the virus. At present, it is not causing problems in regions where the potential of this legume is great (eg. llanos of Colombia).

b) Sphaceloma scab caused by Sphaceloma arachidis was detected in plantings of A. pintoi CIAT 17434 in the Cauca valley this year. Previously known only from Argentina and Brazil, this fungus causes scabby lesions on petioles and leaflets resulting in leaf rolling, distortion and defoliation. Work is in progress on isolation of the fungus; determination of losses and evaluation of the collection of A. pintoi for resistance.

c) Other minor diseases detected included: Leptosphaerulina or Pepper spot and a leaf roll syndrome associated with invasion of roots by Rhizoctonia species.

At present the collection of eight accessions of A. pintoi is being evaluated for reaction to these diseases under controlled conditions. It is expected that more germplasm will be available in the near future to increase the variability in this as yet, small collection.

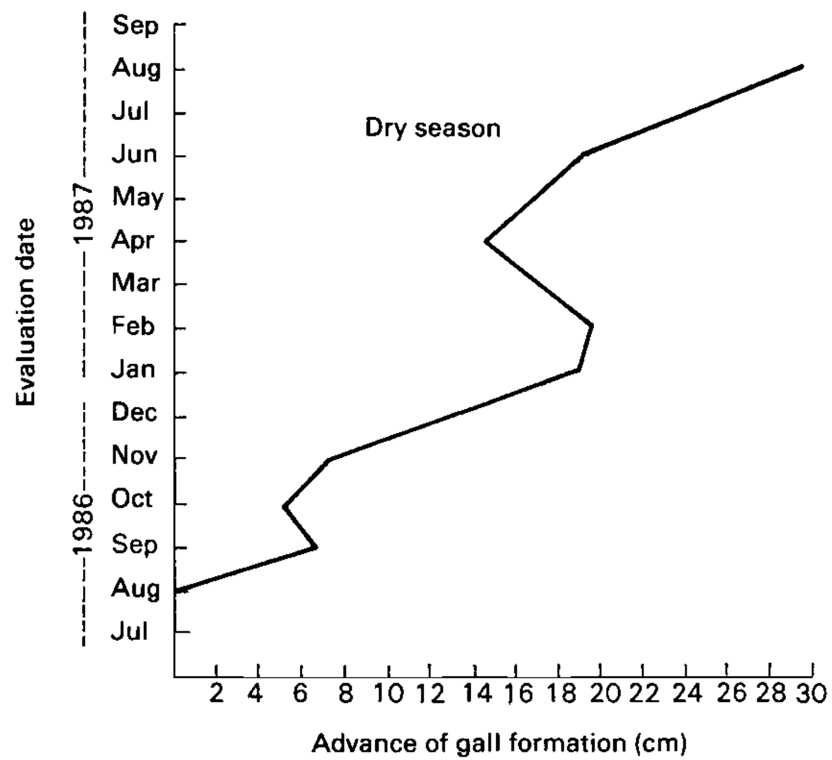


Figure 16. Evaluation of lateral spread of *T. cecidogenus* in *Desmodium ovalifolium* CIAT 350 in Carimagua.

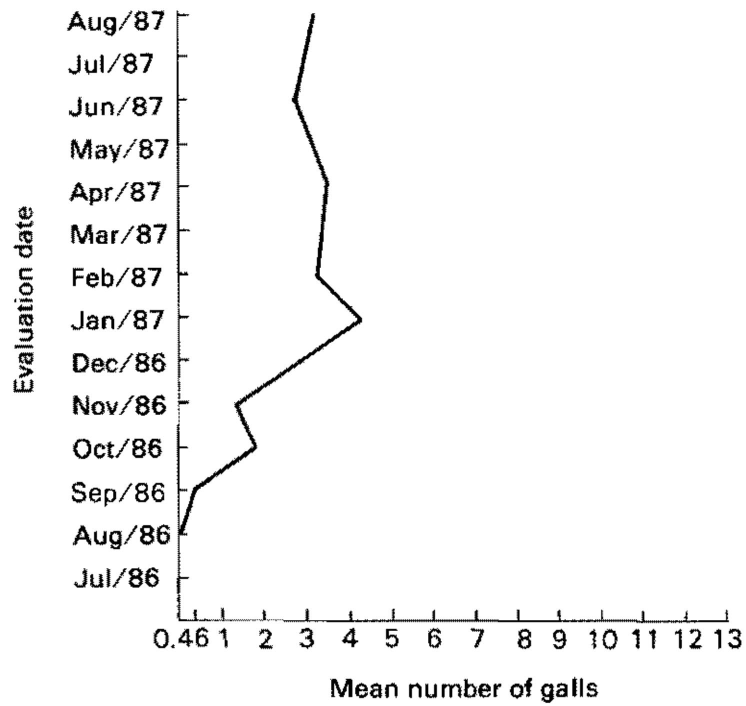


Figure 17. Evaluation of gall development caused by *P. cecidogenus* in *Desmodium ovalifolium* CIAT 350 in Carimagua.

Table 7. Effect of flooding on reaction of D. ovalifolium to P. cecidogenus.

Accession	Well drained				Periodic flooding			
	+ Inoculum		- Inoculum		+ Inoculum		- Inoculum	
	Mean vigor	Mean gall rating	Mean vigor	Mean gall rating	Mean vigor	Mean gall rating	Mean vigor	Mean gall rating
350*	2.5	0	2.5	0	1.5	0.1	1.0	0.1
3666	2.1	0.5	1.5	0	2.1	0.6	1.3	0
3674	2.0	1.8	1.9	0	2.0	0.8	1.0	0
3776**	1.5	0	1.1	0	2.3	0.3	0.8	0
3788	2.1	0	1.0	0	0.6	0.1	1.0	0
3793	2.3	0.5	2.0	0	2.6	0.4	1.3	0
3794**	1.3	0.3	1.0	0	1.1	0.1	1.1	0
13088	1.9	0	1.0	0.5	1.6	0	1.1	0
13089**	2.1	0.8	2.1	0.5	1.4	0.5	1.1	0
13091	1.3	0	2.0	0	2.3	0.1	2.0	0
13092**	2.9	0.3	2.1	0	1.5	0.6	1.3	0
13093	2.1	0.7	2.1	1.4	1.6	0	1.4	0
13098	2.1	0.3	2.0	0.6	1.8	0	1.3	0
13114	1.0	0	1.8	0.1	1.1	0.3	1.8	0
13115	3.1	0	1.3	0	1.5	0	1.1	0
13129**	2.1	0.8	2.3	0.3	1.4	0.4	2.6	0
13139	2.3	0.3	3.3	0	1.0	0.1	1.8	0.1

* Control　　Gall rating: 0 = no galls　4 = many galls.
** Promising accessions　　Vigor rating: 0 = poor　4 = excellent.

Table 8. Evaluation of reaction of selected accessions of Desmodium ovalifolium to stem-gall nematode Pterotylenchus cecidogenus and wart disease under grazing.

Grazing pressure	Accession	Mean* vigor (0-4)	Mean gall** rating (0-5)	Mean reaction to Synchytrium wart disease (0-5)
GPI (Low)	13092	1.1	0.02	0.5
	3776	1.1	0.0	0.6
	3794	0.8	0.04	0.7
	13089	1.4	0.0	0.6
	350	1.4	0.0	0.8
	13129	1.9	0.03	0.9
GP2 (High)	13092	1.3	0.04	0.7
	3776	1.0	0.0	0.6
	3794	0.7	0.0	0.6
	13089	3.2	0.0	0.2
	350	1.0	0.0	0.6
	13129	1.2	0.04	0.6

* Vigor rating = 0 = poor; 4 = excellent.
** Gall rating = 0 = no galls; 4 = many galls.

10. SOIL MICROBIOLOGY

During 1987 The Soil Microbiology Section has worked in three areas:

I) Evaluation of the legume-rhizobium symbiosis,
II) Role of pre-cropping, phosphorus source and vesicular-arbuscular mycorrhizas in the growth and nutrition of tropical pasture species and in cropping systems,
III) Evaluation of factors affecting N_2 fixation and N mineralization rates in savanna soils.

I - EVALUATION OF THE LEGUME-RHIZOBIUM SYMBIOSIS IN TROPICAL FORAGE LEGUMES

This work is being carried out with the collaboration of a network of scientists working in Peru, Brazil, Mexico, Colombia, Cuba and Panama, and which is expected to expand to include other countries and institutions. The aim of this network is to evaluate the effectivity of the legume-rhizobium symbiosis at different sites within the RIEPT which represent a range of conditions within the impact area of the Tropical Pastures Program. The objectives of the network are:

a) To permit biological nitrogen fixation (BNF) to be included as a legume selection/evaluation parameter.
b) To make rhizobial inoculation recommendations for tropical pasture legumes being used commercially in the different ecosystems and subecosystems covered by the RIEPT.
c) To determine the extrapolability of information regarding need to inoculate different legumes and effectivity of particular strains.

A workshop, funded by the UNDP, was held at CIAT in September 1987, where results of experiments carried out by the network participants were presented. Different aspects of the methodology were discussed in working group sessions, and plans for future work were made. An audiotutorial unit entitled The Legume-Rhizobium Symbiosis, which explains the principles of the methods being used in the network, was produced in Spanish, and will shortly also be available in English, together with a Methods Manual.

At each selected site a "team", consisting of at least one agronomist who works on legume selection, and a microbiologist, are working together to evaluate the legume-rhizobium symbiosis. The network has been developed in collaboration with the Bean Program and in addition to the six teams working on forage legumes, includes others working on beans. Thus the participants learn how to evaluate BNF in both grain and forage legumes.

The work is carried out in stages:

<u>Stage I_R</u>

Rhizobium strain isolation, characterization, and production of inoculants for agronomic experiments.

Stage 1_L: Evaluation of need to inoculate legumes in representative soils, breeding for effective nodulation with native strains (where necessary).

Stage 2: Strain selection for legumes which need inoculating; breeding for improved BNF (where necessary).

Stage 3: Effect of other limiting factors on inoculation response and/or BNF; on farm evaluation of inoculants.

Stage 4: Inoculant production methods; inoculant distribution and use; inoculation methods.

Stage 1_R

The rhizobium collection has been divided into 3 parts (A, B and C) on the same basis as used by the CSIRO (A = inoculant strains; B = effective strains which could be used to substitute inoculant strains; C = rest).

Strain Recommendations

On the basis of further strain screening work on a wider range of legumes and results from the network, some changes have been made in the strain recommendations for inoculation of Regional Trials B, C and D, and other experiments of the Tropical Pastures Program. Table 1 shows the previous and current recommendations ("A" collection).

Strain Characterization

Further work on strains which contain two colony forms has shown that this phenomenon ("dimorphism") can be quantified, and that the rate of change between the two types (wet and dry or large and small) varies between strains. Some strains show faster switching from wet to dry than from dry to wet, whereas others show similar rates in both directions, or switch faster from dry to wet (see Table 2). Details of the method used are described by Sylvester-Bradley et al, (in press)[1].

The practical implications of this work are that strains with dimorphism must be distinguished from those containing stable mutants or those which are contaminated. The method described can be used for this. More than half of the strains in the "B" collection demonstrate dimorphism (Table 3).

Etapa 1_L

Selected data from Carimagua and two other sites within the network on response of uninoculated legumes to N fertilization are shown in Table 4. The responses of these legumes were different at the three sites. For example the large differences between the two ecotypes of D. heterophyllum (349 and 3782) and of C. acutifolium (5568 and 5277) observed at Carimagua, were not so marked at Calabacito and Bayamo. The response to N of Leucaena leucocephala and Centrosema pubescens was much larger at Carimagua and Calabacito than at Bayamo. On the other hand Stylosanthes capitata responded much more to N at Bayamo than at Carimagua or Calabacito.

These experiments show that the N nutrition of legumes is an important factor when making selections on the basis of yield, and that effectivity of native strains varies between sites. For example lack of vigor of Stylosanthes capitata has been observed at many sites in the RIEPT and has not been attributed to any

1/ Sylvester-Bradley, R. Thornton, P. and Jones, P. (in press). Colony dimorphism in strains of Bradyrhizobium. Applied and environmental Microbiology.

Table 1. Strain recommendations for inoculation in Regional Trials B, C, D and other TPP experiments.

Legume	Recommended strain (CIAT No.)		
	Previous (1987)	Current (1988)	
		Ciat No.	Origin
Arachis pintoi	3101	3101	*C. plumieri*, Colombia
Centrosema acutifolium	3101	3101	"
C. brasilianum	3101	3101	"
C. macrocarpum	3101	3101	"
C. pubescens	1670	3101	"
Desmodium heterocarpon	3418	4099	CB 2085
D. heterophyllum	2469	4099	CB 2085
D. ovalifolium	3418	4099	CB 2085
Leucaena leucocephala	1967	1967	ST 71, Australia
Pueraria phaseoloides	2434	3918	UMKL 56 (TAL 647)
Stylosanthes capitata	870+995+2138	995	Venezuela
S. guianensis	71	4103	CB 82
Zornia glabra	71	71	*Stylosanthes sp.* Colombia
Z. latifolia	71	71	"

Table 2. Switching probabilities of ten dimorphic *Bradyrhizobium* strains.

Strain	Switching Probability x 10^{-3}		Predicted Proportion of wet cells at equilibrium
	Wet → Dry	Dry → Wet	
2469	9.3	0.2	0.0216 a
3411	12.5	1.0	0.0498 a
1780	11.6	1.0	0.0675 ab
2434	11.3	2.4	0.1845 ab
USDA76	37.4	13.7	0.2429 b
711	4.4	6.4	0.5630 c
4412	12.9	18.4	0.5889 c
3030	0.0005	11.2	0.9925 d
2372	0.002	24.4	0.9998 d
2383	0.002	28.2	0.9999 d

Table 3. Proportion of 63 strains in collection B in different growth categories, and which have shown dimorphism.

Growth Category	Dimorphic	Non-Dimorphic
	% of total	
V	0	11
W	0	6
X	6	24
Y	37	2
Z	12	2
TOTAL	55	45

Table 4. Need to inoculate forage legumes in three soils from Colombia, Panama & Cuba (selected combinations for comparison).

Legume	Carimagua, Colombia[1]	Calabacito, Panamá [2]	Bayamo. Cuba[3]
	........................NRI[4]	....	
Centrosema acutifolium 5568	88	68	53
Centrosema acutifolium 5277	56	63	48
Desmodium heterophyllum 349	88	60	43
Stylosanthes capitata 10280	41	65	82
Stylosanthes capitata 1441	57	79	53
Desmodium ovalifolium 350	56	77	35
Pueraria phaseoloides 9900	38	56	29
Leucaena leucocephala 17495	85	83	14
Centrosema macrocarpum 5713	74	69	61
Centrosema pubescens 438	53	76	4

1/ Field, 3 cuts, N yield

2/ Field, 1 cut, DM yield

3/ Greenhouse, cores, N yield

4/ $NRI = \frac{(Yield + N) - (Yield - N)}{Yield + N} \times 100$

specific cause. The data shown here suggest that this lack of vigor may be due to the lack of appropriate inoculants. Further trials of this type are being conducted to obtain data from a wider range of sites and using more consistent methodology (i.e. the trials will be carried out in the greenhouse using soil cores, with more closely controlled levels of fertilization).

Stages 2 and 3

Strain evaluation in soil cores

An experiment to test the host range of rhizobium strains known to be effective on different accessions of *Desmodium* spp. showed that strain No. CIAT 4099 was effective on all the accessions tested, whereas some of the other strains were more specific (Table 5). CIAT 4099 was also effective on several accessions of *D. ovalifolium* (Table 6). CIAT 4099 was obtained from CSIRO, Brisbane (Dr. R.A. Date) as CB 2085. It is now recommended as a standard strain for testing on *Desmodium* spp. at a wider range of sites in the network.

Field evaluation of inoculation responses (Carimagua)

A field experiment in a sandy soil at Yopare, Carimagua, showed improved growth of seedlings of *D. ovalifolium* 13089 due to inoculation (Figure 1), although even with inoculation, establishement was very slow. Two inoculation methods were used in this experiment. Since the seeds of *D. ovalifolium* are so small (600/g) only a relatively small quantity of inoculant adheres to each seed when they are pelleted by the traditional method using a gum arabic slurry, and 50 g inoculant/kg seeds (i.e. 0.08 mg/seed). A second treatment where 1.0 g inoculant were mixed with sawdust and applied/10 m of furrow before placing the seeds on top was included in order to determine whether the traditional inoculation method limits inoculation response in *D. ovalifolium* as compared to this heavier inoculation rate. The results indicate that the heavier inoculation rate gives a somewhat better response. However, pelleting also gave a good response and is more practical than inoculation in the furrow.

At the same site another experiment with seven forage legumes showed that although the response to inoculation was marked in some cases, the response to molybdenum was small or even slightly negative (Figure 2). The source and rate of molybdenum used (400 g Mo/ha as ammonium molybdate) should not be toxic to rhizobia. It therefore appears that Mo did not limit establishment of most legumes in this very sandy soil (N mineralization was controlled by sowing a grass (*Melinis minutiflora*) in alternate rows with the legume). There was a slight response to Mo by *S. capitata*, and any response of *D. ovalifolium* may have been masked due to its poor establishment. A Mo response in *D. ovalifolium* has previously been detected in a greenhouse experiment (CIAT, 1986[1]). A slight Mo response may therefore occur with these two small-seeded legumes. Carimagua soil is being analysed for its total Mo content. Experiments carried out by ICA with soybeans in the Piedemonte region of the Llanos Orientales have also shown no or a slightly negative response to Mo[2].

Inoculation responses at other sites in the network

Data from the Costa de Chiapas (Mexico), Itabela, Bahia, (Brazil) and various sites in central Panama have

1/ Annual Report 1985, Tropical Pastures Program, p. 217.

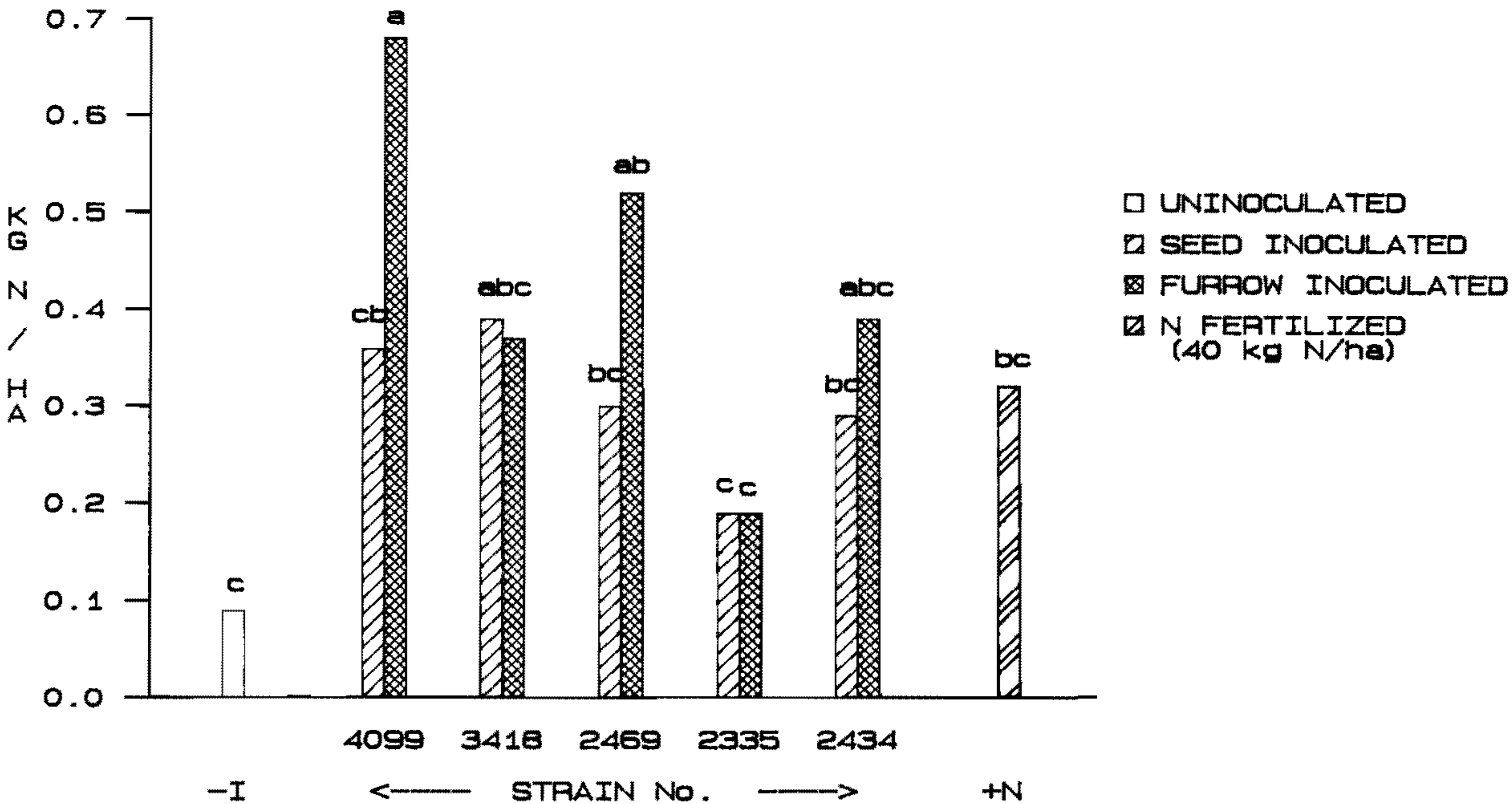
2/ Personal communication, Dr. Luis Fernando Sanchez, Head, Soils Department, La Libertad, Villavicencio.

Table 5. N yield of 7 ecotypes of <u>Desmodium</u> spp. inoculated with rhizobium strains and grown in undisturbed soil cores (MSPT 240). Different letters represent significant differences within ecotypes.

	D. ovalifolium			*D. heterophyllum*		*D. heterocarpon*	
STRAIN	13089	350	3788	349	3782	365	3787
	....	....	....	...mg N/core...	....	....	....
2469	13.7c	24.5ab	26.8b	42.7f	32.6b	28.8bcd	14.9cd
2434	31.7a	28.4ab	30.7b	57.2e	50.5a	42.2ab	33.8b
109	14.8c	24.3ab	29.7b	79.4d	39.8ab	25.5cd	19.2c
2335	20.1bc	25.9ab	27.0b	84.9d	37.7ab	29.3bcd	12.5cde
3101	35.7a	23.7b	38.3b	105.8c	41.7ab	30.2bcd	7.0de
3418	30.0ab	25.6ab	37.9b	138.9b	49.9a	36.5abc	3.8e
4099	36.9a	36.9a	51.9a	154.6a	49.5a	44.9a	44.2a
- inoc.	18.2c	10.7c	13.4c	26.3g	31.3b	15.7d	12.2cde

Table 6. Evaluation of 3 preselected strains on ecotypes of <u>Desmodium ovalifolium</u> in cores of Carimagua soil (mg N/core). Different letters represent statistical differences within ecotypes.

	INOCULANT			
ECOTYPE	- Inoc	2434	3418	4099
3776	39.33b	91.68a	94.71a	91.57a
3794	38.69b	100.73a	104.77a	112.08a
13089	60.22b	102.20a	107.27a	102.38a
13092	56.13b	100.47a	104.11a	105.29a
13129	66.05b	97.29a	92.90a	105.46a



10-7

FIG. 1. EFFECT OF INOCULATION AND N FERTILIZATION TREATMENTS ON N YIELD OF <u>DESMODIUM</u> <u>OVALIFOLIUM</u> 13089, 12 WEEKS AFTER PLANTING AT CARIMAGUA. LETTERS (a, b, c) REPRESENT SIGNIFICANT DEFFERENCES BETWEEN TREATMENTS (DUNCAN p=0.05)

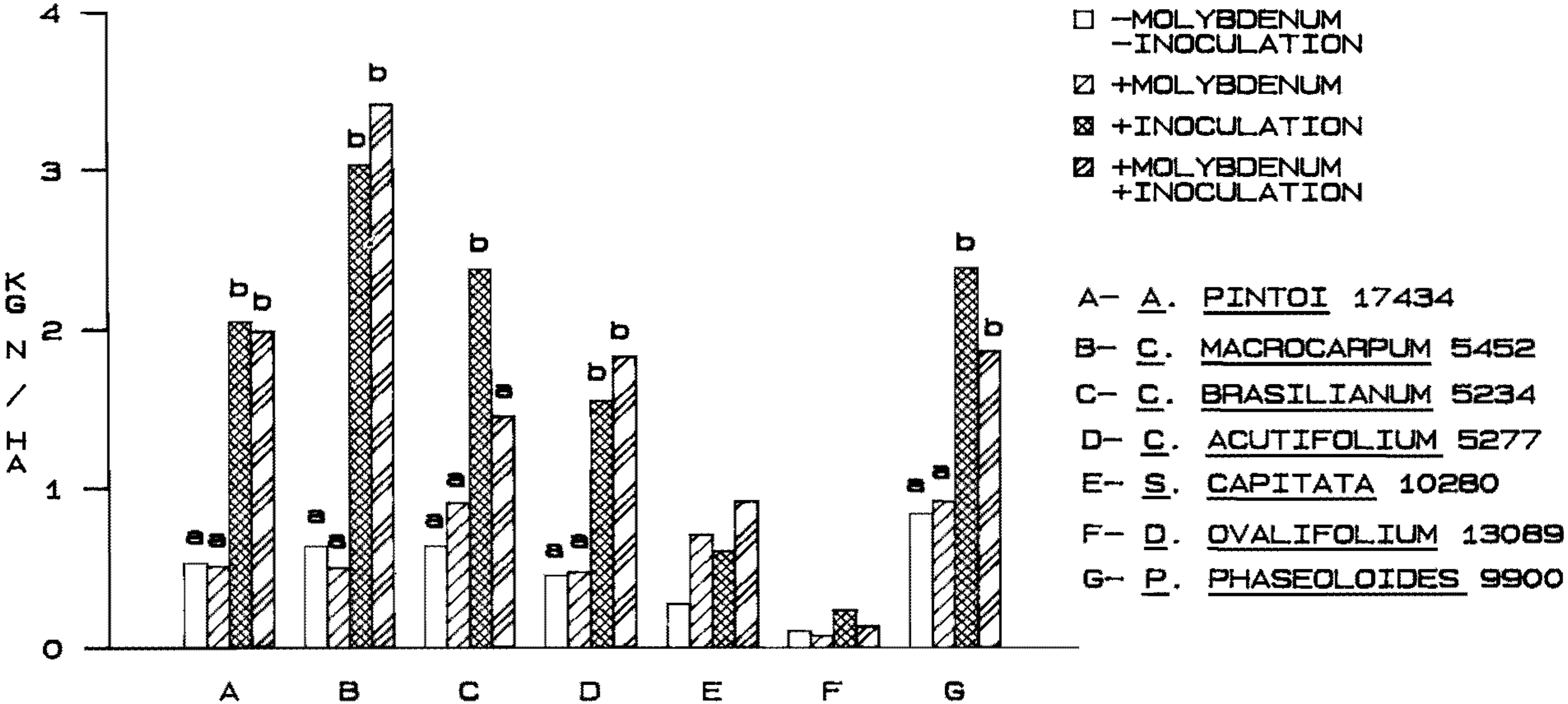


FIG. 2. EFFECT OF MOLYBDENUM AND INOCULATION ON N YIELD OF SEVEN FORAGE LEGUMES 8 WEEKS AFTER PLANTING AT CARIMAGUA. LETTERS (a, b) REPRESENT SIGNIFICANT DIFFERENCES WITHIN LEGUMES (DUNCAN p=0.05)

shown significant responses to inoculation of kudzu, although not always with the same strain. In Panama, marked responses to both inoculation and Mo application were observed in kudzu and Centrosema macrocarpum. These results have stimulated interest in commercial inoculant production in Panama. In Pucallpa, Peru, responses to inoculation of D. ovalifolium, P. phaseoloides, S. guianensis and C. macrocarpum were not significant. However, marked deficiencies of other nutrients occurred in this experiment, and it should be repeated. In Pinar del Rio, Cuba difficulties with establishment of a field experiment occurred due first to flooding and then to drought. Field experiments were also lost in the Costa de Chiapas, Itabela, and Pucallpa due to a wide range of problems (quails, ants, drought, accidental burning etc). However, scientists from all participating institutions except one, were able to present some data at the workshop.

Stage 4

Further studies on freeze-dried inoculants have confirmed that mortality during freeze-drying is often less than 50% of the cells initially present in the vial, leaving at least 10^{10} cells, which is adequate for inoculation of 1 kg seeds. A medium containing glycerol and a high concentration of yeast extract (Balatti, personal communication) gave five times more cells in the broth than the traditional yeast mannitol medium, and this difference was reflected in a larger number of cells per vial after freeze-drying (Table 7). However, high mortality during storage after freeze-drying has been observed in some cases. Further testing is needed to determine factors affecting survival during storage. Freeze-dried inoculants will therefore no longer be distributed in the network until these problems have been solved.

When reconstituted in peat and matured for a week, freeze-dried rhizobia showed good recovery, regardless of the suspending agent (Table 8). A comparison of survival of rhizobia on seeds using inoculant made with Australian and Colombian peat showed better survival with Australian peat (Table 9). However, over 10^4 cells were present per seed after 3 days even with Colombian peat, which is probably adequate.

Alternative stickers and coatings to the traditional gum arabic and rock phosphate may be needed due to high prices or unavailability of these products. Table 10 shows that Calfos used as a coating agent is toxic to rhizobia. However, molasses as a sticker, and/or charcoal as a coating agent may be acceptable substitutes. On the other hand, charcoal, being black, may not support good survival in the field if inoculated seeds are left lying on the soil surface in direct sunlight. Further studies are therefore needed to select suitable alternative coating materials to rock phosphate, which is not generally available. A coating material is likely to be necessary, since inoculated seeds are often mixed directly with fertilizers such as Calfos.

Another problem which has arisen with use of inoculants on farms is the need to inoculate vegetative material of Arachis pintoi, for which sufficient quantities of sexual seed are not yet available. Experiments at Carimagua have shown that where stolons are planted at a distance of 75 cm, in furrows 75 cm apart, 1 kg inoculant/ha is sufficient to obtain an inoculation response e.g. for 1000m of furrow, 750 stolons and 75 g (one packet) of inoculant are required.

In one experiment two sources of vegetative material were used (Pista and Fistulados) and different suspending agents for the inoculant were compared. Figure 3 shows that

Table 7. Mortality of rhizobia on freeze-drying using methyl cellulose as cell support.

Date freeze-dried	Strain	% death on freeze-drying	No./vial after freeze-drying
10 Feb. 87	3101	76	3.3×10^{9}
18 Feb. 87	2434	83	1.4×10^{10}
17 Feb. 87	71	14	6.9×10^{7}
24 Feb. 87	3101	75	1.3×10^{10}
10 Mar. 87	2469	54	1.1×10^{10}
4 Mar. 87	2183+995+870	99	1.1×10^{10}
18 Mar. 87	1670	58	1.8×10^{10}
18 Apr. 87	2434*	43	6.5×10^{10}
10 Apr. 87	3101*	50	5.7×10^{10}
24 Apr. 87	4099*	39	5.8×10^{10}

* "Balatti" (glycerol) growth medium

Table 8. Viable cells of rhizobium strain CIAT 2335 in vacuum sealed freeze-dried preparations with different suspending agents, and one week after reconstitution in sterile Australian peat.

Suspending Agent	Rhizobia/Vial	Rhizobia/Packet of Peat (72g)	Fold Increase
Tap Water	$14.4 \pm 6.8 \times 10^{9}$	$27.4 \pm 10.8 \times 10^{10}$	19.0
Distilled Water	$19.0 \pm 5.4 \times 10^{9}$	$48.2 \pm 27.4 \times 10^{10}$	25.4
1 % Sucrose	$9.4 \pm 3.6 \times 10^{9}$	$29.5 \pm 3.6 \times 10^{10}$	31.4
10% Sucrose	$12.6 \pm 1.4 \times 10^{9}$	$36.0 \pm 5.8 \times 10^{10}$	28.6

Table 9. Survival of rhizobia (Strain CIAT 3101) in Australian and Colombian peat in the packet and on seeds of *Stylosanthes capitata*.

Peat Source	No. rhizobia/ g. inoculant	No. rhizobia/seed 0 days	3 days	% survival
Australian	1.74×10^9	5.7×10^5	2.9×10^5	50
Colombian	1.86×10^9	8.0×10^5	2.8×10^4	3.5

Table 10. Effect of sticker and coating on survival of rhizobia (Strain CIAT 3101) on seeds (Australian peat).

Legume	Sticker	Coating	Rhizobia/ seed (0 days)	% Survival on Seed (3 days)
C. macrocarpum	gum arabic	rock phosphate	9.1×10^5	26
Capica	gum arabic	rock phosphate	1.3×10^5	34
Capica	gum arabic	charcoal	3.2×10^5	26
Capica	gum arabic	calfos	6.8×10^3	1
Capica	milk	charcoal	2.1×10^4	8
Capica	molasses	charcoal	1.9×10^5	15

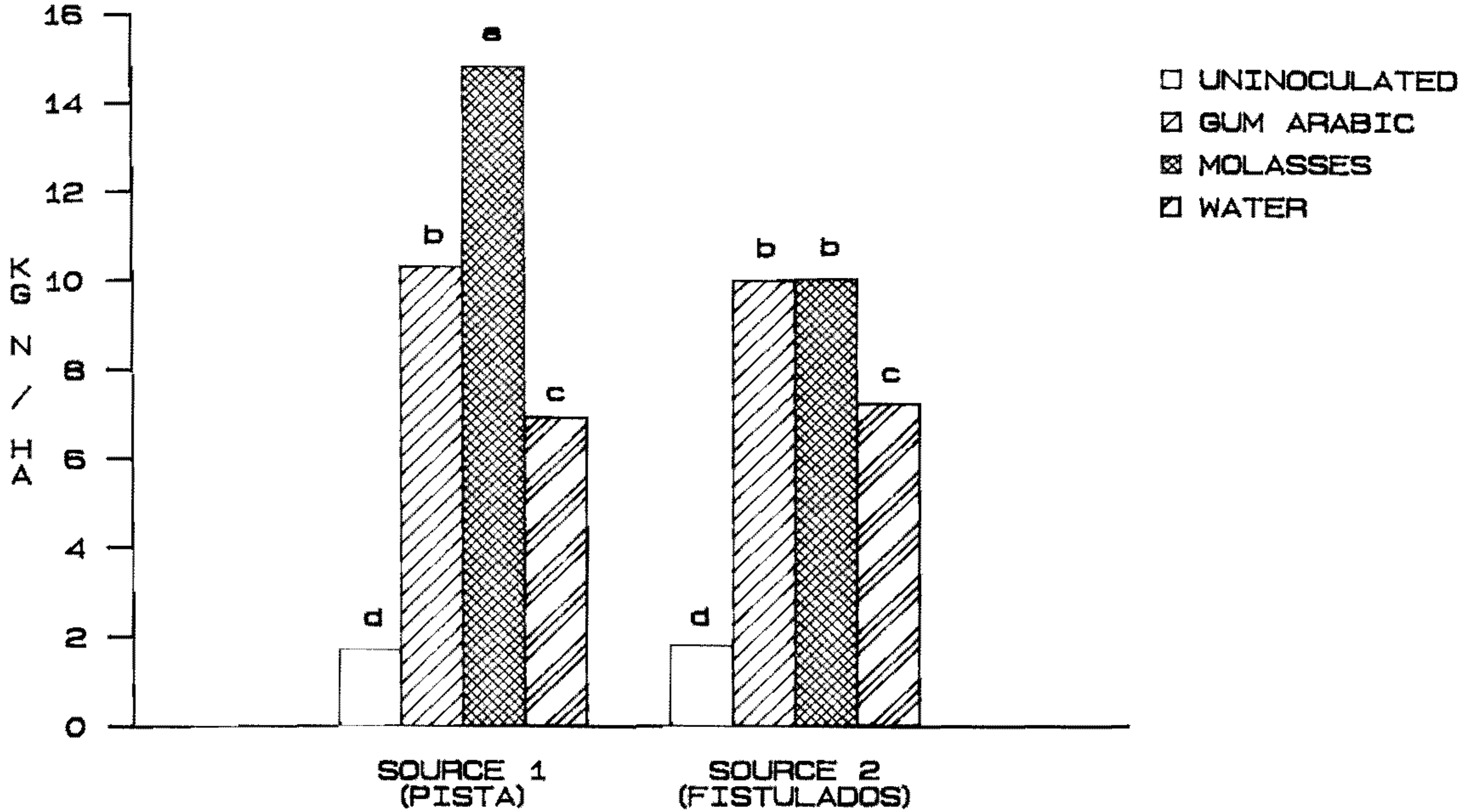


FIG. 3. EFFECT OF INOCULATION (CIAT 3101) ON N YIELD 13 WEEKS AFTER PLANTING *ARACHIS PINTOI* AT CARIMAGUA USING TWO SOURCES OF VEGETATIVE MATERIAL AND THREE SUSPENDING AGENTS FOR THE INOCULANT. DIFFERENT LETTERS REPRESENT SIGNIFICANT DIFFERENCES (DUNCAN p=0.05)

after thirteen weeks all three suspending agents (water, gum arabic and molasses) appeared to be effective. However, water gave somewhat inferior yields, whereas molasses was better than or similar to gum arabic, indicating that molasses could be used as an alternative to gum arabic when this is not available.

II - THE ROLE OF PRE-CROPPING, PHOSPHORUS SOURCE AND VESICULAR-ARBUSCULAR MYCORRHIZAS IN THE GROWTH AND NUTRITION OF TROPICAL PASTURE SPECIES AND IN CROPPING SYSTEMS

This EEC-funded collaborative project was initiated to investigate the effects of pre-cropping on the population dynamics of native and introduced vesicular-arbuscular mycorrhizal (VAM) fungi and the subsequent growth of crop and forage legumes. This changed the emphasis of previous work (CIAT Annual Reports 1982-85) on VAM inoculation to the potential manipulation of native populations for the benefit of mycorrhizally-dependent pasture and crop species.

Evaluation of field trials established in July 1986 at two sites in Carimagua, La Pista (24% sand) and Yopare (40% sand), continued throughout 1987.

Stage I (July 1986 - April 1987)

Cassava (cv. MVEN 77), sorghum (cv. 5DX), tropical kudzu, *Brachiaria dictyoneura* (CIAT 6133) and kudzu/*B. dictyoneura* in association were established as the original pre-crop treatments at two sites (sandy-clay). These were inoculated or non-inoculated (+M or -M) with a VAM inoculant of *Glomus manihotis* and *Glomus occultum* (1:1), along with either Huila rock phosphate (RP) or triple superphosphate (SP) as P-sources. Each pre-crop received its recommended fertilizer regime, whilst kudzu was inoculated with rhizobial strain CIAT 2434. There were two savanna controls, one of untouched savanna and the other receiving the sorghum fertilizer regime in broadcast form, again with RP and SP treatments. There were four replicate blocks at each site.

Stage II (May 1987 - September 1987)

Pre-crop treatment plots were divided in two (2 x 10 m^2) with one half sown to the crop legume cowpea (*Vigna unguiculata* cv. Cabecita Negra), and the other to forage legume *Stylosanthes capitata* (CIAT 10280). Half of the fertilized savanna plots from Stage I were also sown to the legumes and designated savanna-86 (RP/SP) treatments (the other half remained as fertilized savanna); similarly half of the non-fertilized savanna plots received 20 kg ha^{-1} P as either RP or SP (designated savanna-87) and sown with cowpea and *S. capitata* (the other half remained as non-fertilized savanna). All treatments received a minimum fertilizer application (without P) to maximize the possibility of observing direct responses to VAM infection and to assess possible residual effects of the RP source applied in Stage I. All treatments also received the rhizobial strain CIAT 2434 applied as a spray. The following pre-cropping treatments were therefore established:

B. dictyoneura
Cassava
Kudzu
Kudzu + *B. dictyoneura*
Sorghum
Savanna-86
Savanna-87

Pre-crop nutrition, yields and VAM infection

Stage I

The complete absence of VAM infection in -M cassava roots after 50 days was associated with stunted growth of the plants and yellowing of the foliage, especially with RP (Figure 4). At this stage +M plants were twice the height of corresponding -M plants. Fifty kg N ha^{-1} was applied to all treatments essentially to prevent death of -M plants and subsequently -M plant growth improved, paralleling a rapid increase in VAM root infection (Figure 4). This lack of early infection was caused by the low numbers of VAM infective propagules (spores and infected root fragments) found in these soils and the sparse root system of -M RP plants, possibly accentuated by the extremely high rainfall in Carimagua in 1986. In contrast -M kudzu (Figure 4), *B. dictyoneura* and sorghum (RP/SP) all became infected soon after germination because of their more extensive root systems, although infection was generally significantly lower than in the roots of +M plants (Figure 4). +M kudzu plants, however, significantly outyielded -M plants at the 14 week harvest at Yopare, the same non-significant effect being noted at La Pista (Table 11). The same results were recorded for kudzu in association. Yields of foliage of +M *B. dictyoneura* were also higher than -M plants after 14 weeks but this effect was not significant. As with cassava early stunting of -M RP sorghum compared with +M plants was also noted up to 50 days after sowing. This again was alleviated by the second part of a split application of N and K, although the effect was reflected in the final harvest data (October 1986) where +M plants (RP) produced significantly more seed than -M plants (Table 12). The early responses to inoculation in cassava had diminished by final harvest after 10 months (April 1987), however +M plants produced significantly more propagative stakes per plant (SP), taller plants, greater total root production (SP) and root weights (RP) (Table 13). At this time there were no significant differences in yields between *B. dictyoneura* treatments, alone or in association. Similarly for kudzu, although SP plants significantly outyielded RP plants. This disappearance of the VAM inoculation effect after 6-9 months supports earlier work (CIAT TPP Annual Reports 1984-85) which showed similar results with kudzu and *Andropogon gayanus* in Carimagua. It should be noted, however, that there was significantly increased nutrient uptake of all elements by +M kudzu plants with the SP source source over the first two harvests at Yopare (Table 14). The effect of the significantly increased N-uptake by +M kudzu with SP at Yopare reflected higher shoot concentrations of this element. Recent work has suggested that this synergistic response of dual VAM/rhizobial inoculation is due to increased supply of nutrients such as P by the fungus to the nodules as well as uptake of N possibly as NH_4^+ from the soil. This frequently observed effect in forage legumes deserves further study in sandier soils in Carimagua, such as Yopare and Alegria, where dependency on the VAM symbiosis appears to be greater.

Stage II (1987 planting)

No significant effects of VAM inoculation or P-source, applied to the pre-crops in 1986, on vegetative growth of cowpea and *S. capitata* were noted, however cowpea plants with SP produced significantly more seed than those with RP across all pre-crops. Results presented here, therefore, represent pre-crop treatment effects alone. All pre-crops significantly increased VAM infection levels in the roots of both legumes compared with savanna controls (Table 15). This was reflected in results of harvests of both legumes where fresh weight yields of the savanna controls (86/87) were significantly less than either that of cassava, kudzu or sorghum (Table 16). The improved growth of these legumes following cassava and sorghum crops could be explained in terms of their higher fertilizer inputs in stage I

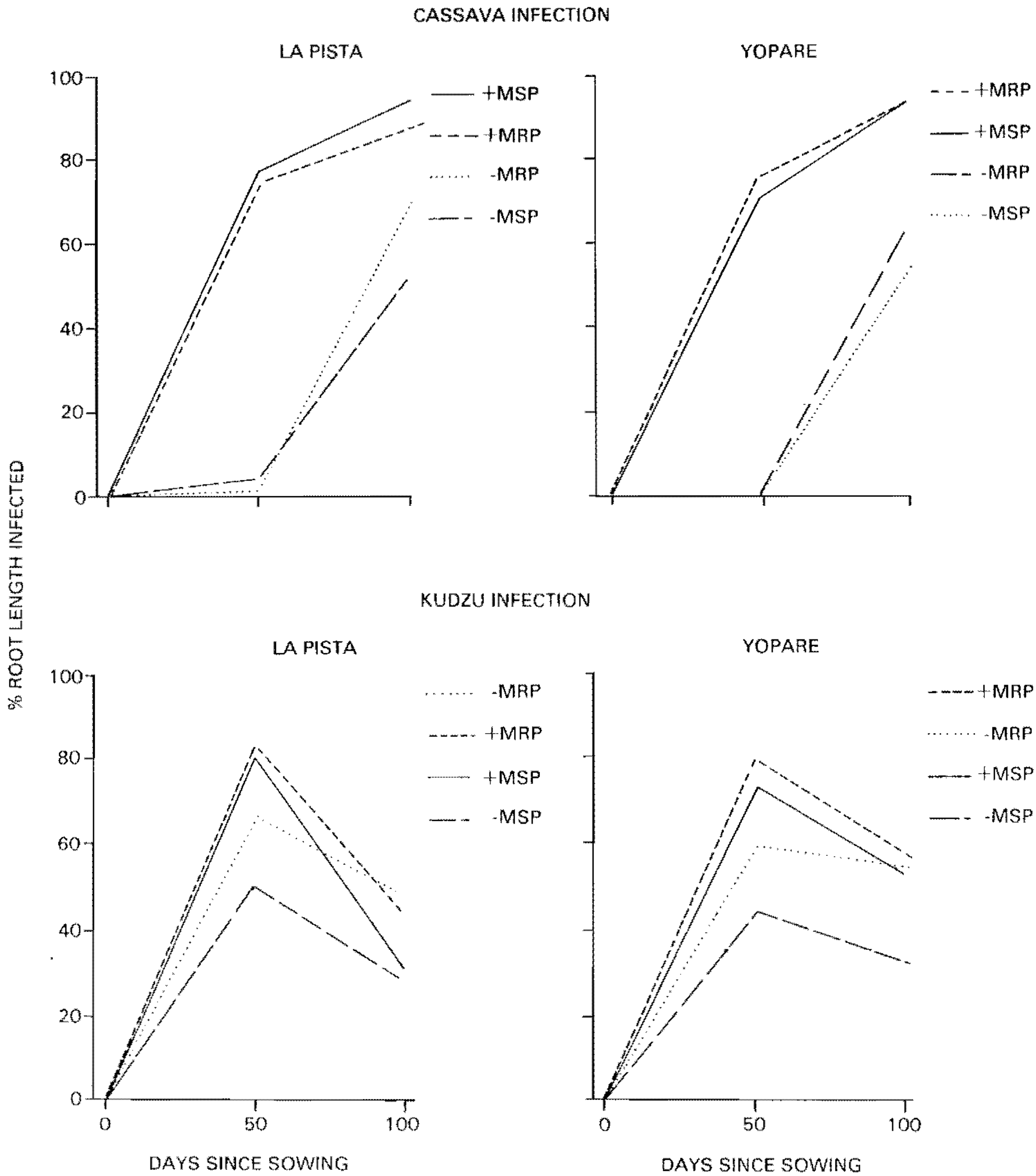


Figure 4. Percentage root length infected of cassava and kudzu root systems up to 100 days after sowing at La Pista and Yopare.

Table 11. Dry weight yields (kg ha^{-1}) of kudzu foliage after 14 weeks at La Pista and Yopare.

Treatment	La Pista	Yopare[1]
+ MRP	585b*	460c*
- MRP	440b	215d
+ MSP	2350a	1533a
- MSP	1953a	863b

a - Poor establishment due to above average rainfall in May-July 1986.

* - Means within a column with different letters are significantly different ($P < 0.05$).

RP = Rock Phosphate
SP = Superphosphate
+M = with VAM inoculation
-M = without VAM inoculation

Table 12. Dry weight yields (kg ha^{-1}) of sorghum seed and foliage for combined La Pista/Yopare data.

Treatment	Seed	Foliage
+ MRP	1023b*	1595b
- MRP	375c	1688b
+ MSP	2648a	2713a
- MSP	2428a	2445a

* - Means within a column with different letters are significantly different ($P < 0.05$).

Table 13. Final harvest data of cassava after 10 months growth for combined La Pista/Yopare data.

Treatment	Height (cm)	No.Stakes per plant	Commercial roots	Total roots	F.W. (kg) foliage	F.W. (kg) roots	D.W. (kg) roots
- MRP	102c	1.0c	18c	37c	4.6b	8.8c	3.0c
+ MRP	114b	1.2c	21cb	48c	5.1b	11.4b	3.8b
- MSP	121ab	2.3b	31a	72b	9.1a	18.0a	5.8a
+ MSP	129a	2.9a	26ab	103a	10.2a	19.5a	6.2a

* Means within a column with different letter are significantly different ($P < 0.05$).

Table 14. Nutrient uptake (kg ha^{-1}) of kudzu foliage during stage I at Yopare.

Nutrient	Treatment	14 Weeks	31 Weeks	Total
N	- MRP	5.75 d*	27.68 ab	33.53 c
	+ MRP	14.10 c	24.34 b	38.44 c
	- MSP	23.00 b	31.72 ab	54.72 b
	+ MSP	43.80 a	36.58 a	80.38 a
P	- MRP	0.50 d	1.07 ab	1.57 c
	+ MRP	0.65 c	0.80 b	1.45 c
	- MSP	1.18 b	1.35 a	2.53 b
	+ MSP	2.32 a	1.46 a	3.78 a
K	- MRP	1.85 c	9.98 a	11.83 c
	+ MRP	4.25 bc	10.32 a	14.57 bc
	- MSP	6.75 b	9.29 a	16.04 b
	+ MSP	11.50 a	9.51 a	21.01 a
Ca	- MRP	2.02 d	5.50 ab	7.52 c
	+ MRP	4.19 c	4.45 b	8.64 c
	- MSP	8.20 b	7.06 a	15.26 b
	+ MSP	12.41 a	6.04 ab	18.45 a
Mg	- MRP	0.45 d	2.05 a	2.50 d
	+ MRP	1.05 c	2.05 a	3.10 c
	- MSP	1.80 b	2.18 a	3.98 b
	+ MSP	2.75 a	2.66 a	5.41 a

* Means within a column with different letters (for each nutrient) are significantly different ($P < 0.05$).

Table 15. Percentage root length infected (% I) of Cowpea and Stylosanthes root systems six weeks after sowing - Analysis using combined La Pista/Yopare data.

Stylosanthes	% I	Cowpea	% I
Kudzu/Brachiaria	58 a*	Kudzu/Brachiaria	65 a
Kudzu	55 a	Cassava	65 a
Brachiaria	54 a	Brachiaria	62 a
Cassava	50 ab	Kudzu	61 a
Sorghum	45 b	Sorghum	57 a
Savanna - 87	36 c	Savanna - 86	47 b
Savanna - 86	31 c	Savanna - 87	43 b

* Means within a column with different letters are significantly different ($P < 0.05$).

Table 16. Fresh weight yields of cowpea foliage (6 weeks) and seed (10 weeks) and Stylosanthes foliage (13 weeks) following pre-crop treatment ($g.m.^{-2}$) - Analysis using combined La Pista/Yopare data.

Pre-crop Treatment	Cowpea Foliage	Cowpea Seed	Pre-crop Treatment	Stylosanthes Foliage
Sorghum	250 a*	63 b	Kudzu	413 a
Cassava	211 b	81 a	Cassava	409 a
Kudzu	184 bc	82 a	Sorghum	329 b
Kudzu/Brachiaria	158 cd	47 c	Savanna-87	228 c
Savanna-87	131 de	48 c	Kudzu/Brachiaria	228 c
Brachiaria	127 de	38 cd	Savanna-86	219 c
Savanna-86	111 e	31 d	Brachiaria	216 c

* Means within a column with different letters are significantly different ($P < 0.05$).

(e.g. lime, P and N) compared with the pasture species B. dictyoneura. The latter, however, alone and in association with kudzu appeared to have an inhibitory effect on subsequent legume growth (Table 16) which could not be explained in terms of lack of VAM infection (Table 15) or nodulation. An analysis of soil under kudzu and B. dictyoneura plots revealed little difference in nutrient status apart from higher levels of $N\text{-}NO_3^-$ under the former. The possibility exists that certain brachiarias may immobilize N (see CIAT TPP Annual Report Microbiology Section 1986), alter soil microfloral populations, produce toxins or physically change the soil environment in some way which is detrimental to subsequent legume growth.

Pre-crop effects on VAM spore populations

Figures 5-9 show the changes in total VAM spore populations and those of individual species through the 15 month trial period in the top 20 cm of soil under different crop and savanna treatments. Results presented are the means of combined data for RP and SP treatments in each pre-crop treatment. VAM inoculation increased total spore numbers in the soil at both sites after 5 months compared with the savanna control (RP/SP) (Figures 5 and 6). Sorghum, however, was especially efficient at increasing spore numbers at La Pista in -M plots chiefly due to the stimulation of the native G. occultum and/or Acaulospora myriocarpa isolates (Figure 7). Similarly +M plots contained a high proportion of G. occultum, probably the isolate used in the original inoculant. At Yopare kudzu produced the highest total spore populations in -M plots. Cassava selectively increased the introduced G. manihotis isolate in +M plots at both sites (Figure 8). It should be noted that -M cassava plants with SP stimulated spore production of Acaulospora appendicula at both sites after 5 months.

After 10 months (April 1987), at the end of the dry season, spore production declined dramatically at both sites and in both +M and -M plots, an effect also noted in the Kenyan savannas (Newman et al., 1986)[1] (Figures 5-9).

After 15 months (late September 1987), following the cowpea harvest, total spore numbers had declined further at La Pista, however, all pre-crops supported higher populations than the savanna controls sown to cowpea and the native savanna even in -M plots (Figures 5 and 6). At Yopare spore production after cowpea was greater than at La Pista, with kudzu supporting the highest total population followed by sorghum in both +M and -M plots (Figures 5 and 6). The +M kudzu plots contained a substantial component of E. colombiana/A. mellea/A. morrowae spores (morphologically very similar) at both sites (Figure 9).

G. occultum appeared to be the most persistent of the two introduced species in terms of spore survival at both sites (Figures 7 and 8). Spore absence, however, does not necessarily signify the complete absence of a species since infected root fragments often constitute the primary source of VAM inoculum in the field.

This work indicates a certain degree of plant specificity for VAM species in both introduced and native populations. This was supported by sampling a legume in savanna trial established by the Agronomy (Carimagua) section (sited in Yopare) during 1986. Ten different forage legumes and the native savanna were

1/ NEWMAN, E.I., CHILD, R.D. and PATRICK, C.M. (1986). Mycorrhizal infection in grasses of Kenyan savanna. Journal of Ecology, 74, 1179-1183.

LEGEND

Figures 5-9

(+)	VAM inoculation
(-)	non-inoculated
SV	untouched savanna (RP/SP)
86	savanna-86 (RP/SP)
87	savanna-87 (RP/SP)
S	sorghum
C	cassava
K	kudzu
KB	kudzu/*B. dictyoneura*
B	*B. dictyoneura*
5M	5 months
10M	10 months
15M	15 months

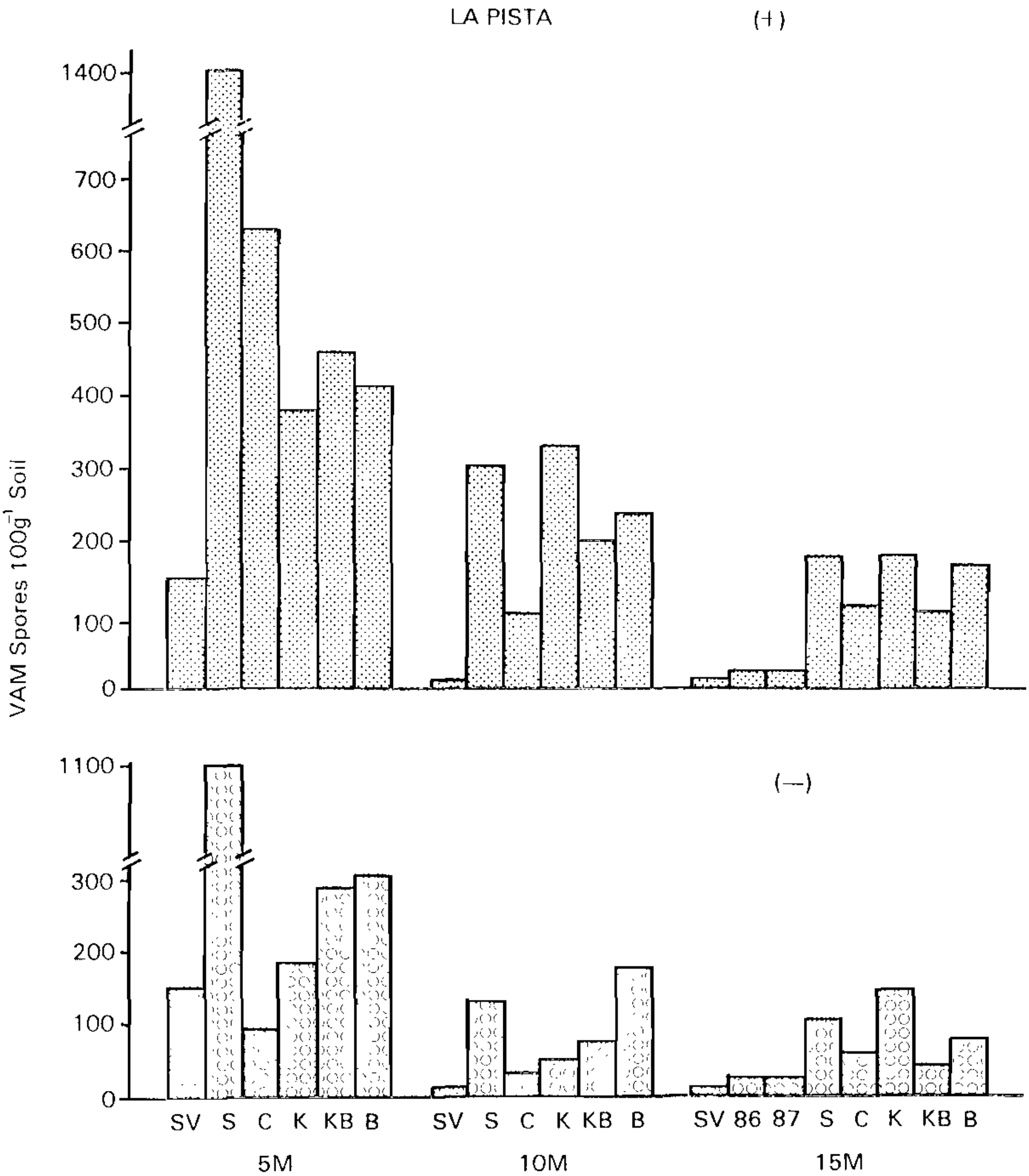


Figure 5. Total spore numbers isolated from precrop treatments during period July 1986-September 1987 at La Pista site, Carimagua.

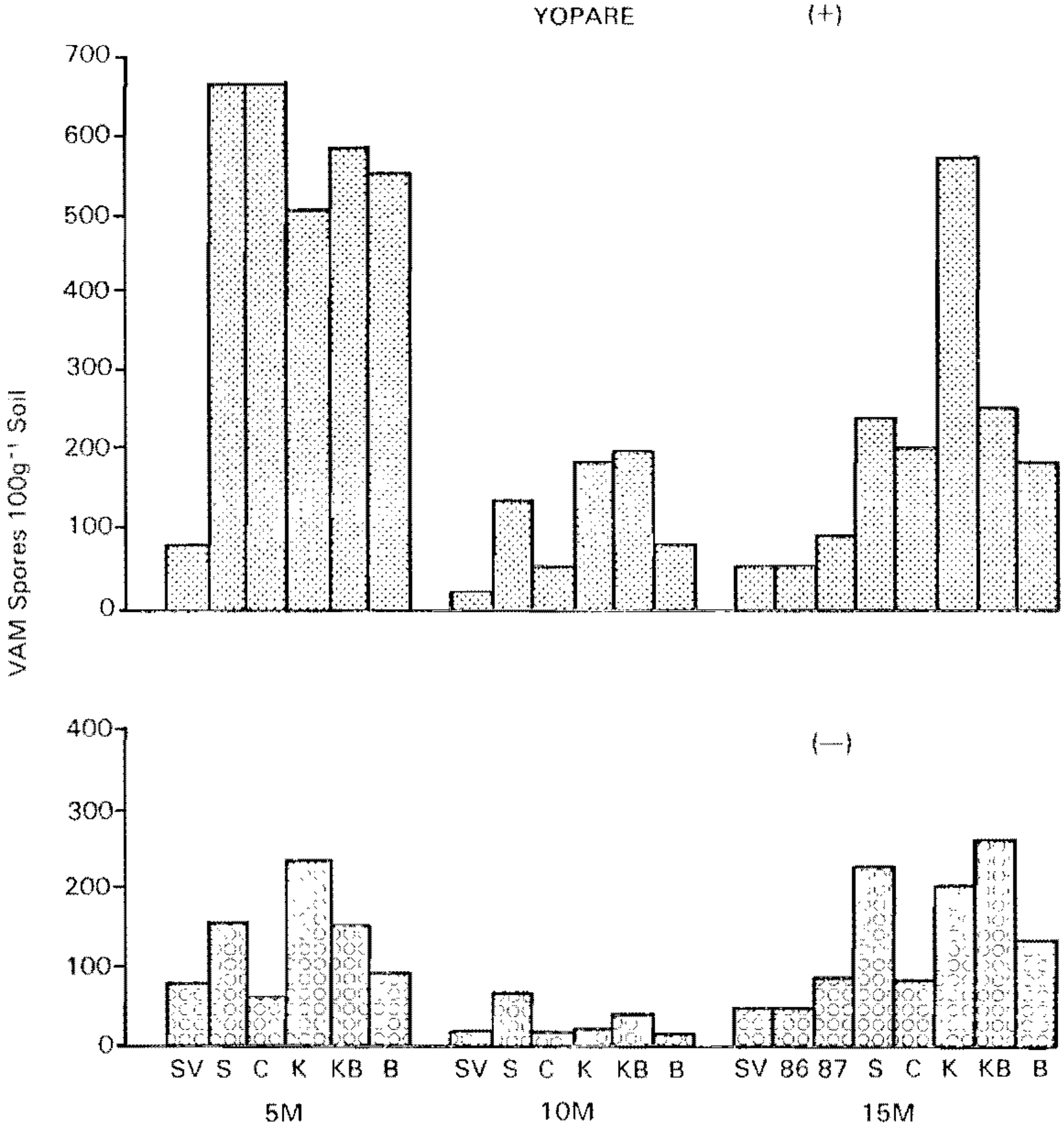


Figure 6. Total spore numbers isolated from precrop treatments during period July 1986-September 1987 at the Yopare site, Carimagua.

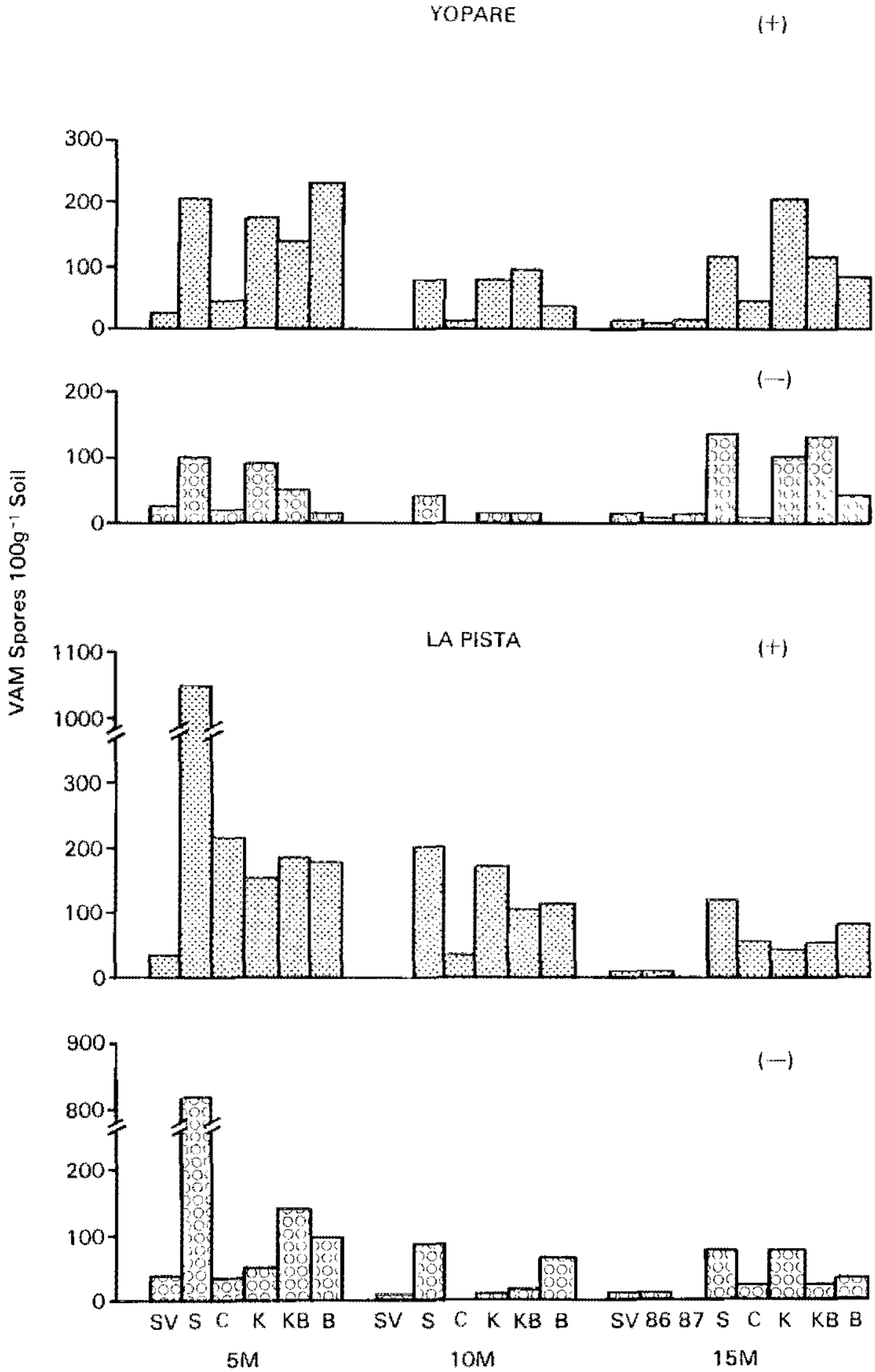


Figure 7. *Glomus occultum/A. myriocarpa* spore numbers isolated from precrop treatments during the period July 1986-September 1987 at La Pista/Yopare sites in Carimagua.

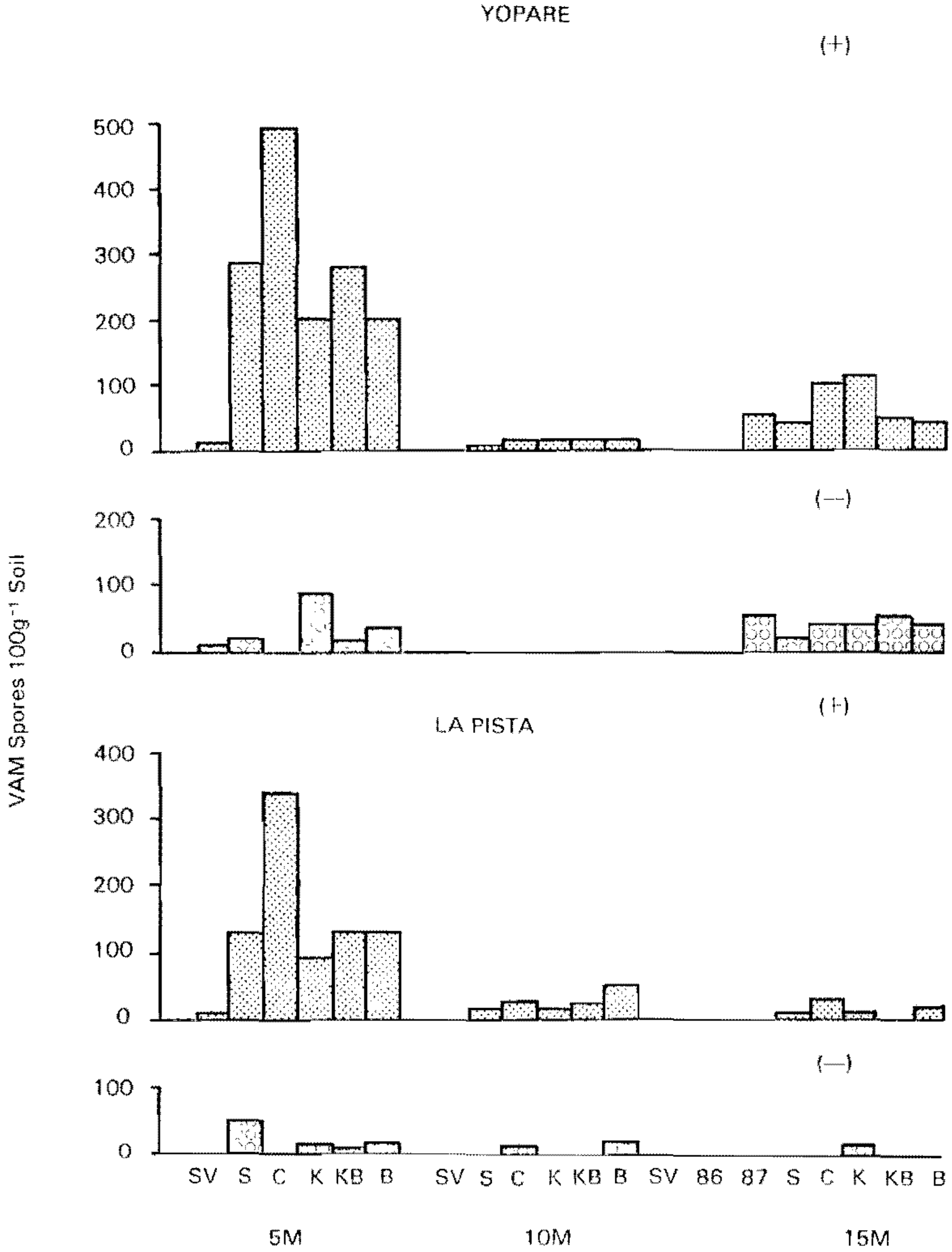


Figure 8. *Glomus manihotis* **spore numbers isolated from precrop treatments during period July 1986-September 1987 at La Pista/Yopare sites in Carimagua.**

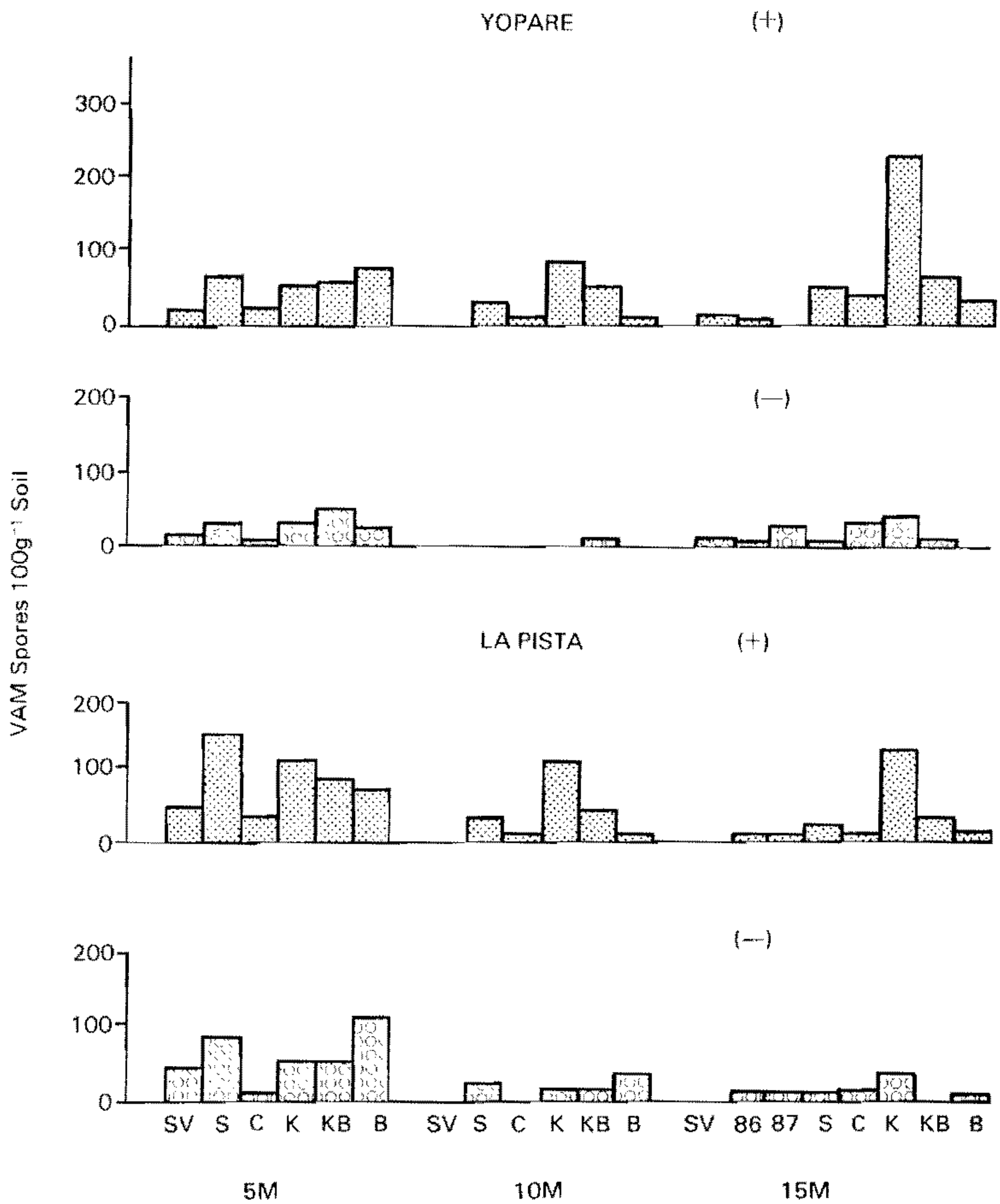


Figure 9. *Entrophospora colombiana, Acaulospora mellea* and *Acaulospora morrowae* spore numbers isolated from precrop treatments during the period July 1986-September 1987 at La Pista/Yopare sites in Carimagua.

sampled in August 1987 to investigate the VAM spore populations in the soil. Results showed that nearly 50% of the spore population below Tadehagi triquetrium (CIAT 13276) consisted of Scutellospora heterogama. Stylosanthes guianensis var. pauciflora (CIAT 2031) and Desmodium incanum (CIAT 13032) had 88% and 74% of their spore populations consisting of G. occultum. All plants sampled had higher total spore numbers than the native savanna control, whilst all three Centrosema spp. sampled, C. acutifolium (CIAT 5277), C. arenarium (CIAT 5236) and C. brasilianum (CIAT 5234) supported almost identical spore populations in both number and species.

The "quality against quantity" aspect of manipulated VAM populations needs further investigation since it is still uncertain, from these results, if merely increasing total VAM populations is sufficient for subsequent crops to gain maximum benefit from the symbiosis, or if stimulating efficient individual VAM species within populations could further increase the response to VAM infection. Future research should therefore investigate the effect of increasing numbers of individual species within the native populations, in non-sterile soil, followed by bioassaying the manipulated species with VAM-dependent plants such as cassava and forage legumes (e.g. kudzu) to find the efficient VAM species (some information is already available from earlier studies CIAT Annual Reports 1982-85). This would have to be done in different soil types but screening could be initiated in greenhouse studies. The determination of which plant hosts stimulate which VAM species in different soils could easily be accomplished by sampling field trials and "on-farm" crops and pastures already established.

Manipulation vs. Inoculation

These results infer that pre-cropping can alter and increase native VAM populations in the acid infertile soils of the Llanos. Sorghum can increase spore populations and produce sufficient soil inoculum to increase VAM infection in a subsequent crop even with a four month dry season in between. This, rather than kudzu, could be considered as a potential crop for "opening-up" savanna ecosystems, on a small-scale, to aid the subsequent establishment and early growth of improved pasture species. Alternatively, dual inoculation of forage legumes with efficient VAM/rhizobial inoculants could be more suited to the small-farm subsistence systems characteristic of areas such as Mondomo in Cauca, also on acid soils. With the increasing interest in integrated crop/pasture systems on these poor soils both manipulation and inoculation of VAM fungi could be considered worthy of incorporation into agronomic practices to aid growth and establishment of VAM-dependent crops and/or forage legumes.

III - FACTORS AFFECTING N_2 FIXATION AND N MINERALIZATION RATES IN SAVANNA SOILS

An experiment designed to measure N mineralization rates in soil from under Brachiaria humidicola, B. dictyoneura and B. decumbens with and without N fertilization, in association with Arachis pintoi and from A. pintoi alone showed very low rates in all treatments. The only treatment which showed appreciable N mineralization was bare ploughed soil kept free of weeds. The objective of this experiment was to confirm previous results showing higher N mineralization rates in soil from N fertilized B. decumbens than B. humidicola, that legumes stimulate N mineralization, and to determine whether B.dictyoneura inhibits N mineralization. However, since for some reason very little mineralization occurred at this site in 1987, further evaluations will be needed before definitive conclusions can be drawn regarding the effect of B. dictyoneura on N mineralization.

On the other hand, at another site (fistulated) it was found that A. pintoi stimulated N mineralization whereas B. humidicola inhibited it, confirming the previous observations. In a mixture of B. humidicola with A. pintoi intermediate N mineralization rates were observed.

These data imply an additional and important role for legumes in mixed pastures. It seems that pure grasses, when not N fertilized, tend to lock up the organic N in the soil and thus become N deficient even when total N levels in the soil are high. The legume appears to be able to stimulate the N-cycling process either because of or in addition to its ability to fix nitrogen. Thus the difference in N yield between grasses in pure stands and in association with legumes may be greater than the amount of N fixed by the legume, but in any case is an important contribution of the legume to the sustained yield of the pasture. This observation may explain the degradation of pure grass pastures even in soils which are apparently not N deficient.

It is expected that greater emphasis will be given to this area of research in the future, in addition to on-farm evaluation of both rhizobial and VAM inoculants.

11. SOIL/PLANT NUTRITION

The general objectives of the Section has been to achieve a more efficient use of essential nutrients in pasture establishment and the maintenance of pastures productivity. During 1987, research was concentrated on three aspects: (1) efficient use of P in the establishment of grasses and legumes in advanced categories of evaluation of grasses and legumes (since this research has been carried through collaborative work, the results are included in the Pasture Development Section); (2) development of an evaluation methodology for the quantification of gains and losses of nutrients in pastures, and (3) determination of factors and strategies for the reclamation of degraded pastures.

NUTRIENT RECYCLING IN PASTURES (EVALUATION METHODOLOGY)

Results from the association *A. gayanus* cv. Carimagua 1 and *S. capitata* cv. Capica in Carimagua, were presented in the 1986 Annual Report. The main changes at the beginning and end of each occupation period in forage availability, nutrient availability in the forage and gaoms and losses obtained through plant residues, were mainly attributed to animal management, expressed in terms of stocking rate, and not to maintenance fertilization with K. During 1987 the experimental area and its boundary zone were strongly affected by puddling due to a high ground water table that made it necessary to suspend activities at the beginning of July.

Based on the Carimagua experience, another trial was installed in Quilichao. Four situations were considered for this ecosystem: a) an association pasture (*A. gayanus* cv. Carimagua I + *C. macrocarpum* 5713, b) an improved grass (*B. dictyoneura* cv. Llanero), c) native grasses (*Paspalum* sp.), and d) bare soil. Grazing management for each treatment was considered as an integral factor in the studies. For (a) an area belonging to the Pasture Quality and Productivity Section under flexible grazing management at a low forage allowance was used. For (b) an area grazed rotationally (7 occupation days and 21 rest days) at an intermediate stocking rate was utilized. Grazing in (c) is intermittent or occasional and obviously there is no grazing in the bare soil treatment. The principal objective of this study is to determine the changes produced throughout time in the nutrient "pool" in order to be able to quantify possible advantages of associatons in terms of productivity and stability.

PASTURE ESTABLISHMENT IN DEGRADED AREAS

The effect of location or site, previous soil managment, level of slope and fertilizer application on the establishment of *B. decumbens* cv. Basilisk, *B. dictyoneura* cv. Llanero, and *B. humidicola* cv. Common, each associated with *A. pintoi* CIAT 17434 and *D. ovalifolium* CIAT 350, was evaluated on ten farms located in the regions of Mondomo (1500 masl) and

Pescador (1600 masl), Cauca. The distances between plants was 80 cm, and the grass was alternated with the legume. Fertilization consisted of 20 kg P/ha, 20 kg Mg/ha and 20 kg S/ha, applied at planting sites. In almost all of the farms, legume growth was very poor, so grass behaviour was the only factor evaluated. In order to facilitate the presentation of results, data for the two farms ("Las Lajas" and "El Socorro") representing the extrems of soil acidity and fertility are given together with results from the farm "Mano del Oso" which represents an intermediate type. A summary of the three soils and level of slope is presented in Table 1. Some of the chemical properties of the top soil are shown in Table 2. It can be observed clearly that all three soils contained high sulphur contents but very little available phosphorous. The "Las Lajas" soil turned out to be the most acid and the poorest in dry matter content. The soil of "Mano de Oso" had the highest aluminum saturation (90%), while the "El Socorro" soil did not present problems of exchangeable aluminum.

The results obtained at 12, 16 and 20 weeks expressed in terms of cover around the planting site and in the spaces, are shown in Figures 1 and 2. Their was a notorious effect of soil type on the growth of all three grasses. The soil at of "El Socorro" allowed a more vigorous growth. In the highly degraded soil of "Las Lajas", growth was very slow. B. decumbens produced the most growth and was also the species that most responded to applied fertilizer. At the three sites, The behavior of B. dictyoneura was similar to that of B. humidicola, and responded to fertilizer even in "El Socorro" soil. At this site B. humidicola did not respond to fertilizer. The canopy of the three grasses in the between-site spaces (Figure 2), as a result of stolon development, was most pronounced in B. dictyoneura and in S. humidicola at "El Socorro". In the absence of fertilizer, there was no development of the grasses or weeds at "Las Lajas". These preliminary results suggest that: 1) the three grasses we adapted to most of the soils in the region, 2) in general, fertilizer application is necessary for establishment, particularly when the level of soil degradation increases, 3) it is essential to intensify legume germplasm evaluation for the establishment of associations in the region.

Recovery of degraded pastures

Native species

A field experiment was initiated in a MESON soil located in the Amazonian piedemont region of the Caqueta (humid tropical forest), with the objective of developing low cost, low risk technology for the recovery of pastures composed of low productivity species.

Using as a starting point, a pasture dominated by Homolepsis aturensis, it is intended to study through a factorial arrangement the effects of type, frecuency and intensity of control of native vegetation on the establishment of associations of B. decumbens cv. Basilisk with A. pintoi CIAT 17434 and B. dictyoneura cv. Llanero with D. ovalifolium CIAT 3788.Species will be established with vegetative material at low planting densities, and phosphorous (20 kg P/ha) will be applied.

Improved species

A B. decumbens pasture, close to the Quilichao Experimental Station, used commercially for more than ten years was selected. The objective is to study the flexibility of reclaiming a degraded pasture and increase its productivity. Two discings were carried out in the paddock. The two treatments were: 1) a pure grass stand, 2) the grass reinforced with a

1:1 legume mixture (C. macrocarpum 5713 and C. acutifolium cv. Vichada). The legume was established in 2.5 m wide strips in 50% of the area. The soil preparation and the grass control in the rows consisted of one pass with rotovator, followed by herbicide application (Trifluralina) and its immediate incorporation in the soil with a harrows. Legumes were planted in rows with a band application of 20 kg P/ha. Fertilization was also in the other 50% of the area and in the pure grass treatment. The establishment of the legumes was characterized by the following sequence of events: Late planting in November 1986 at the end of the wet season (four weeks), a dry season with periodic rainfall during four months and, finally, six additional weeks of active growth in the new wet season.

The area occupied by each treatment was divided in half to facilitate the use of the flexible grazing management system. In both treatments, the first 189 days of grazing consisted of a cycle of seven days occupation alternating with seven days of rest. The proportion of legumes in the association has gradually increased from 20% at the beginning to 30% at the end of the grazing period. The variations in stocking rates for each treatment, affected by the availability of forage in the season wet, are shown on Figure 3. It can be observed that the association has allowed a marked increase in stocking rate compared with the pure grass treatment. After deducting the cost of legume introduction, the net productivity accumulated during the first 27 weeks of evaluation, was equivalent to 100 kg of meat (Figure 4). The daily differences per hectare have remained relatively constant at one kilogram in favor of the association. At approximately 18 weeks of utilization, the association is equal to that of the pure grass in net productivity.

These preliminary results indicate that it is possible with adequate management to regain the invested pasture reclamation in a very short time.

Table 1. History of utilization and slope on three soils in the Mondomo and Pescador regions (Cauca).

Farm-Soil	Previous utilization	Duration (years)	Slope (%)
Las Lajas	Yuca	2	25-50
Mano de Oso	Rastrojo	5	25-50
El Socorro*	Yuca fertilizada	1	25-50

Table 2. Chemical properties of the three top soils (0-20 cm) in the Mondomo and Pescador regions (Cauca).

Farm-Soil	pH	OM	P (Bray II)	S	Ca	Mg	K	Al	Al Sat.
		%	ppm	ppm	meq x 100 g^{-1}				%
Las Lajas	4.3	2.8	1.2	97	0.48	0.30	0.11	3.2	80
Mano de Oso	4.6	4.5	1.5	73	0.27	0.14	0.04	3.6	90
El Socorro*	5.2	8.4	1.9	186	1.81	0.20	0.12	0.3	13

* Pescador.

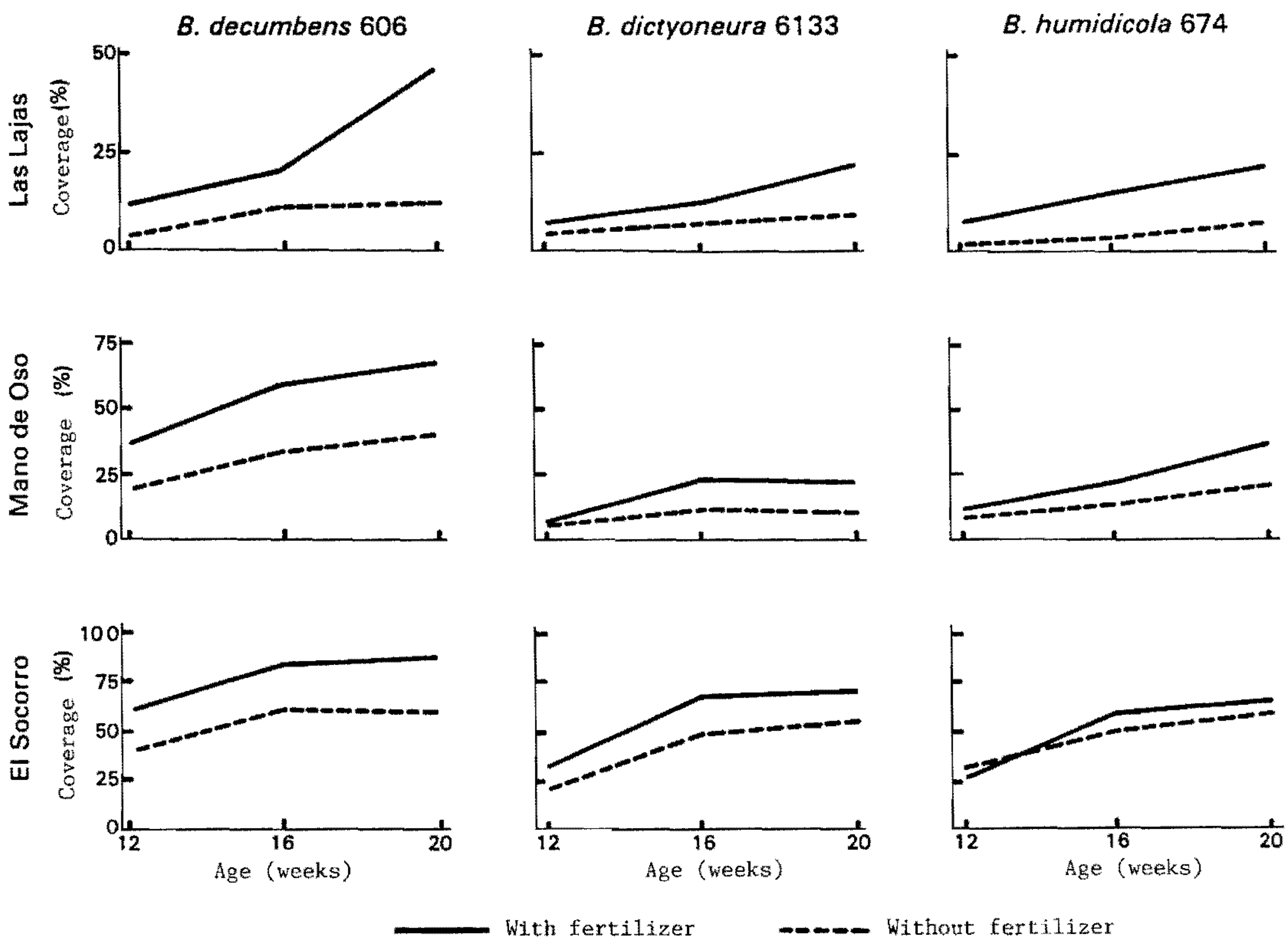


Figure 1. Plant cover around the planting site in three grasses grown on acid soils of Northern Cauca.

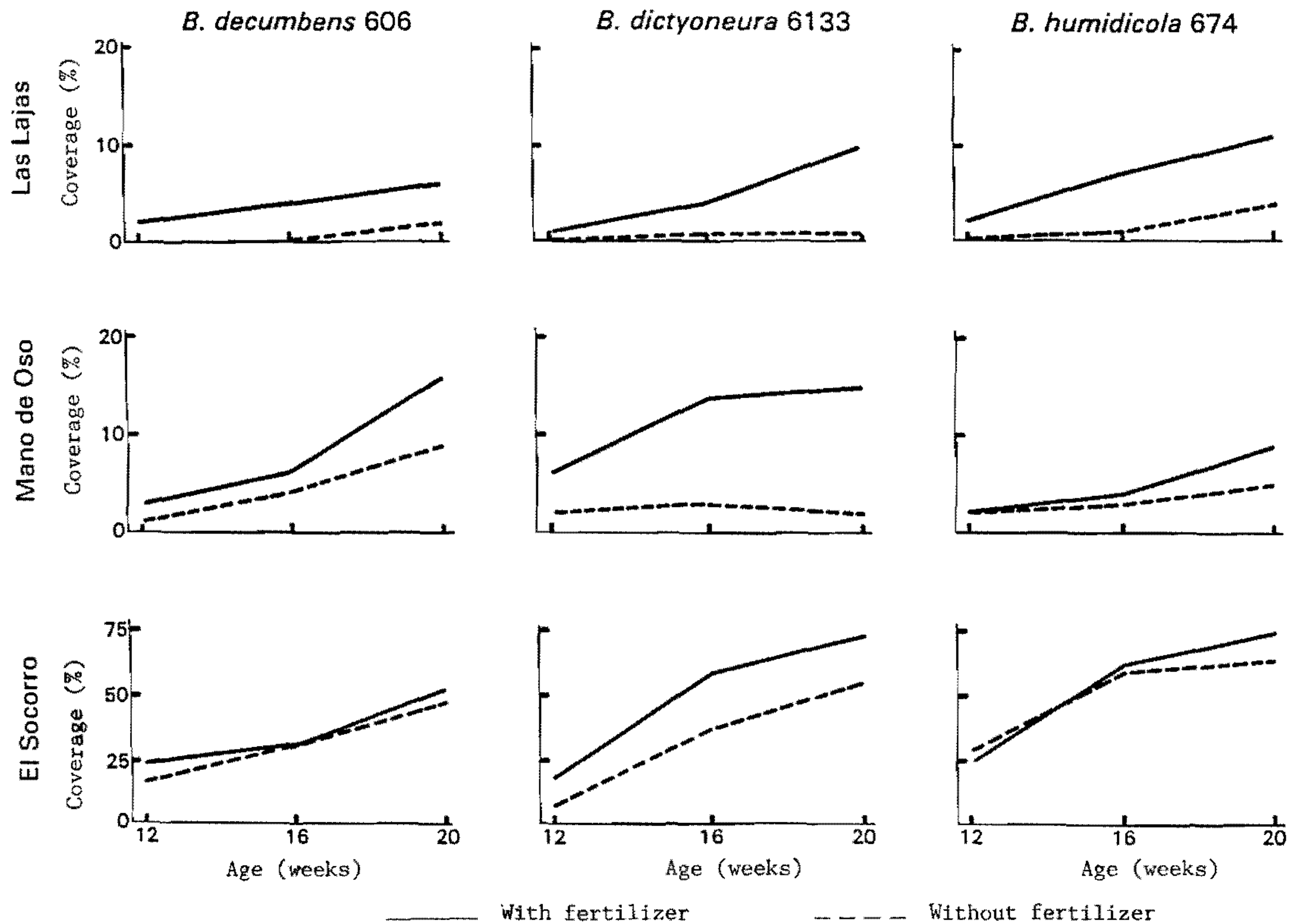


Figure 2. Plant cover in the intermediate spaces between planting sites in three grasses growing in acid soils of northern Cauca.

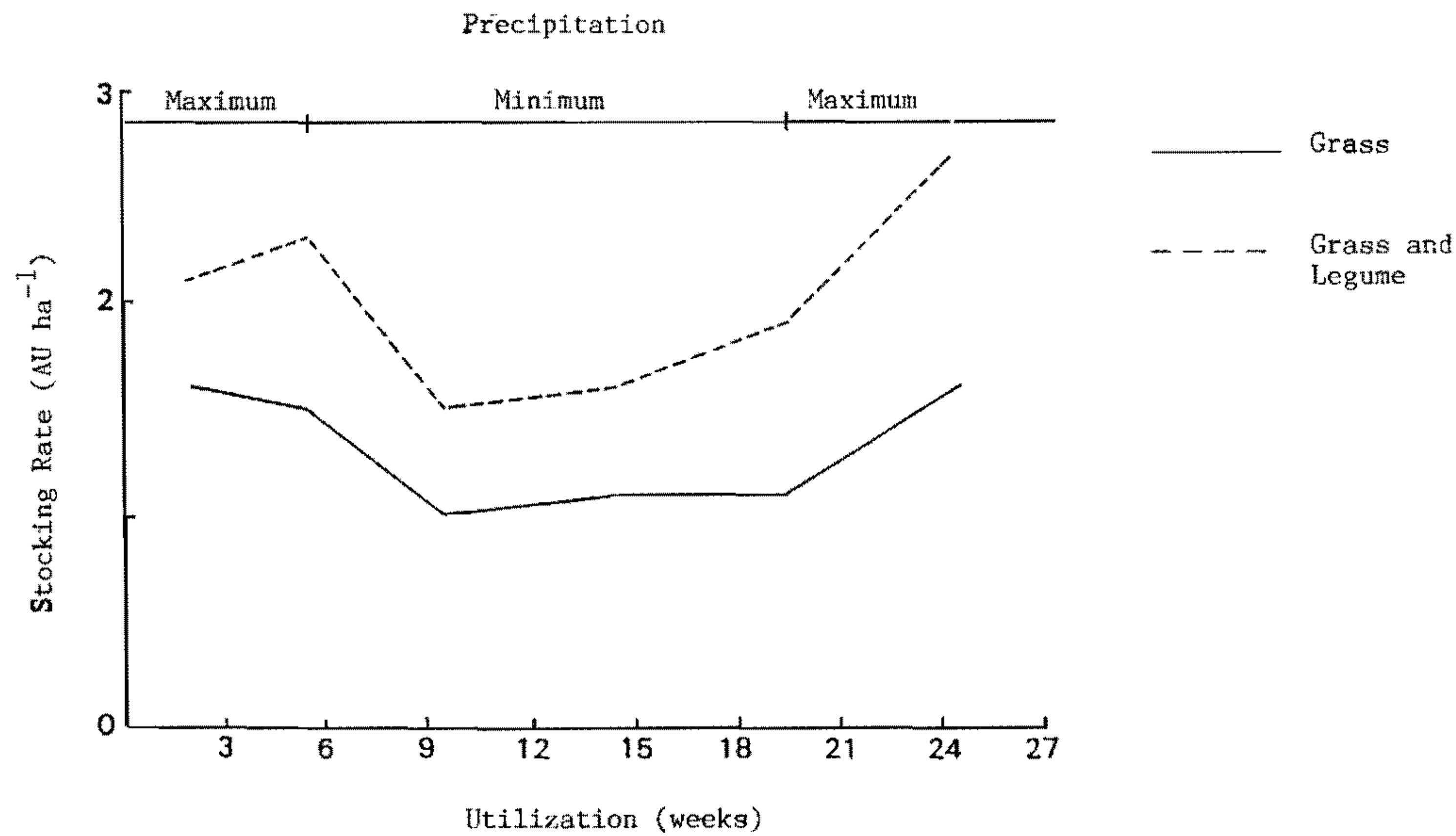


Figure 3. Evaluation of stocking rate in a reclaimed pasture of B. decumbens. Flexible management, Quilichao.

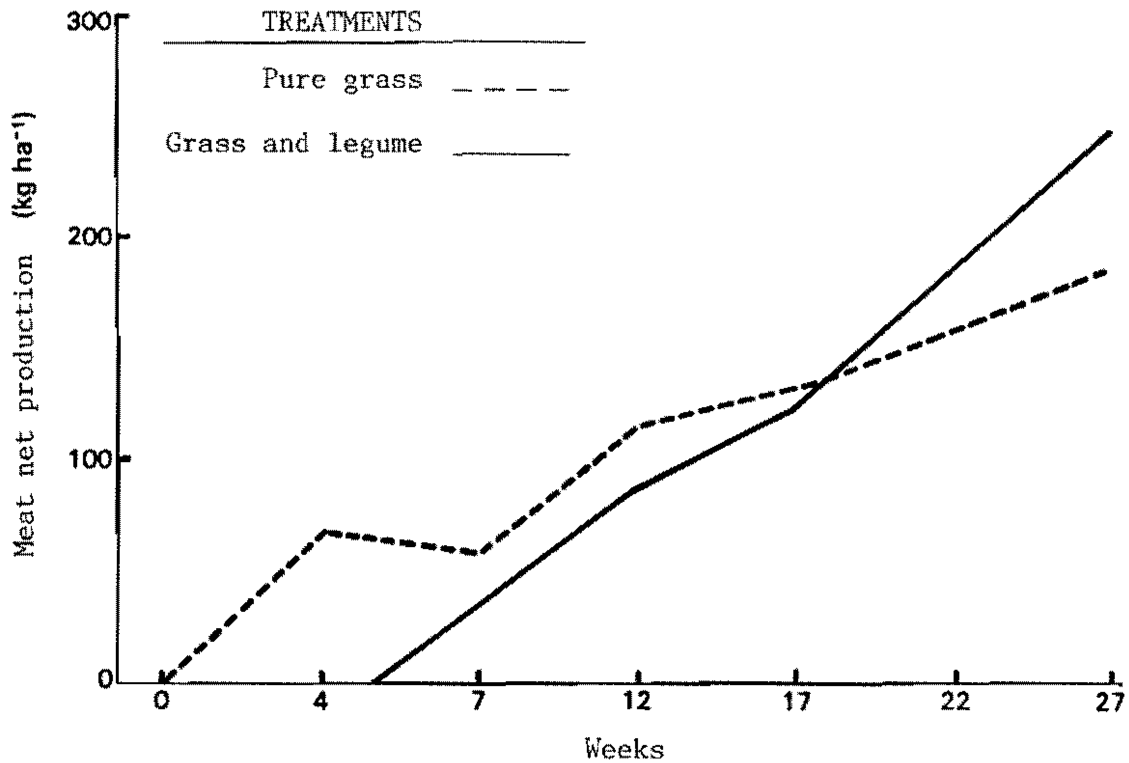


Figure 4. Net accumulated animal productivity on a reclaimed pasture B. *decumbens* (Quilichao).

12. PASTURE DEVELOPMENT LLANOS

INTRODUCTION

The activities of the section in Carimagua were essentially terminated during the 1986 calendar year with the section leader moving to the Cerrados Center of EMBRAPA (CPAC) in Planaltina in June, 1987. The emphasis in the cerrado ecosystem will be on the use of annual crops in pasture establishment and renovation, and a number of pasture development projects were approved for initiation in late 1987. These will be reported on next year.

This will be the last annual report on pasture development research conducted in Carimagua, therefore, certain emphasis will be given to synthesis of the experience gained over the past ten years. Results from on-going trials will also be reported.

Method and date of planting

A small trial, which was planted opportunistically at the end of the 1986/87 dry season, yielded results concerning early planting and planting method. The results presented in Figures 1 and 2 show the advantage of early planting and row seeding with band application of fertilizer. Seedling vigor and early plant growth were excellent in the early planted plots, weed growth was less and plant vigor was higher with row planting.

Experience suggests that early seedbed preparation (at the end of the rainy season in October or November for the Llanos ecosystem), has a number of potential advantages including:

1. conserving moisture in the soil profile during the dry season;
2. the recently tilled land, free of weed growth and well supplied with moisture is an excellent environment for mineralization of organic matter and accumulation in plant available forms of nitrogen, sulfur, phosphorus and other nutrients during the dry season since there is no rainfall to leach the more mobile nutrients down the profile;
3. the elimination of vegetation which leaves the soil exposed to sun and wind during the dry season appears to reduce ant and other insect populations (al-(though sandy soils, especially on sloping land may be vulnerable to erosion);
4. land preparation done late in the rainy season does not compete with other activities for labor and machinery and weather conditions are more favorable for land preparation than they are early in the season when excess moisture and rainy days are often serious obstacles to field work.

Early planting at the end of the dry season or immediately after the first rains also has a number of advantages:

1. weather conditions may be more favorable for germination and seedling growth than they are later in the season when waterlogging, especially on heavier soils, can be a problem in some years;

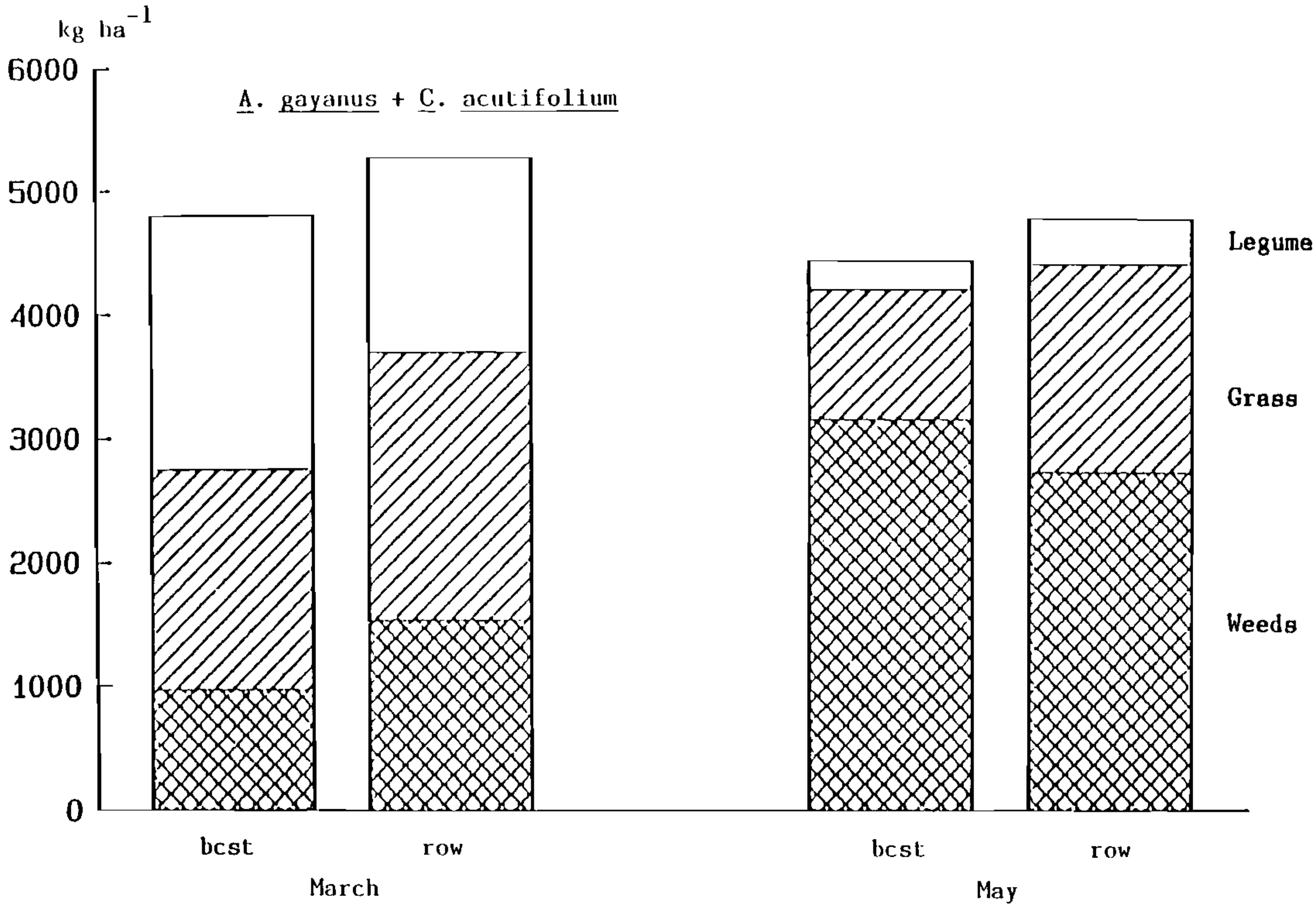


Figure 1. The effect of date and system of planting/fertilizing on the initial growth of a grass and a legume in association, cut 20 weeks after planting.

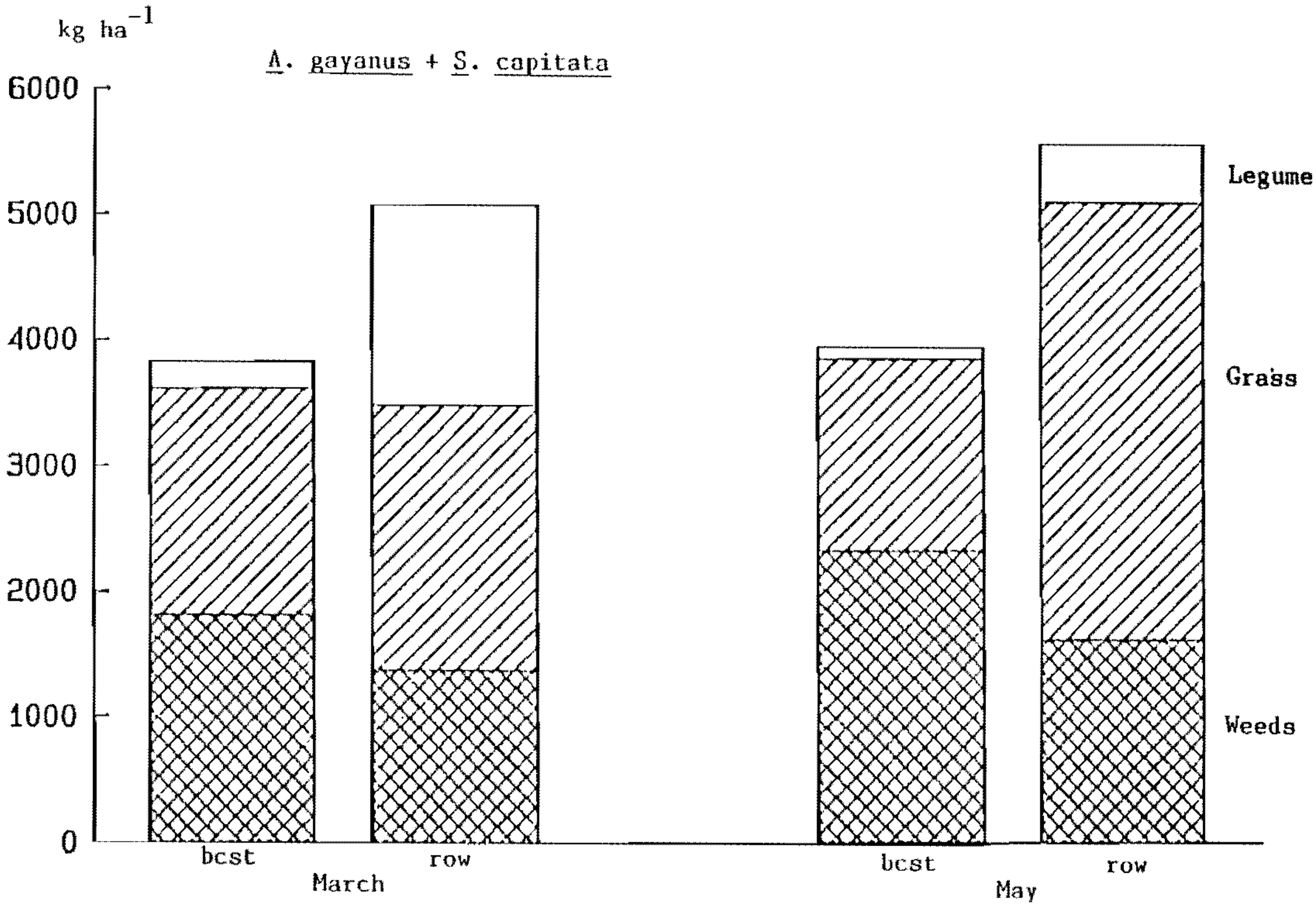


Figure 2. The effect of date and system of planting/fertilizing on the initial growth of a grass and a legume in association, cut 20 weeks after planting.

2. soil conditions and weather are favorable for the planting operation;
3. If there is a slow build-up of insect populations after the season breaks, early planting may lessen ant and other insect predation of seedlings;
4. early planting reduces the competition for labor and machinery, especially if done in the dry;
5. with early planting it is often possible to begin grazing during the first year.

Planting in rows with band application of fertilizer offers a number of advantages:

1. optimum fertility conditions for the growth of young plants can be created with minimum amounts of fertilizer;
2. fertilizer use is more efficient in many tropical soils in which P fixation is a serious problem;
3. weed growth is reduced by concentrating fertilizer in the row near the planted species, with minimum stimulation of weeds between rows.

It is obvious that early planting has its risks, especially in areas where the rainfall pattern is somewhat erratic and false starts to the rainy season followed by several weeks of dry weather are frequent. This is the concern most often expressed by colleagues and farmers in the Llanos ecosystem; that planting in March followed by rain in late March or early April sufficient for germination but followed by a long drought until late April could lead to almost total loss of the planting. Experience has shown this not to be the case with the germplasm presently being used in the Tropical Pastures Program. The probability of a prolonged dry spell after the 1 April is very low, but if it does occur, species such as Stylosanthes capitata, Andropogon gayanus, Brachiaria decumbens are capable of rooting deeply enough to survive very lengthy dry periods. With early land preparation, moisture is conserved in the soil profile and if sufficient rain falls to bring about germination, the moisture from the surface will reach moist soil at 15-20 cm depth, thus minimizing the danger from drought. If unscarified seed were to be used, some of the dormant fraction could germinate later and thus insure against total loss, even in regions where the probability of severe drought is much higher. However, the extra cost of the greater quantities of seed necessary may make this option unattractive.

Phosphorus fertilizer use efficiency

Phosphorus fertility is almost always the first limiting factor in soils of the tropical savannas. Phosphorus fertilizer is an expensive input, especially in remote regions where transportation costs are high. Many highly weathered tropical soils are characterized by high P fixing capacity which leads to reduced P efficiency. It is of utmost importance to achieve the highest efficiency possible with this high cost input.

In 1986, a P efficiency trial was established in collaboration with the Soils/Plant Nutrition Section. Due to extreme weather conditions (excessive rainfall and high watertable), the interpretation of the results of that experiment was quite difficult. A simplified version of the experiment was established collaboratively again in 1987. The hypotheses on which the experiment is based are the following:

1. P-fixation is very much controlled by fertilizer-soil contact; band application of fertilizer reduces contact and thus should reduce the amount of P fixed by the soil;
2. row seeding and band applied fertilizer can achieve optimum fertility conditions for the

seedling with a minimum of fertilizer;

3. well-adapted forage species have different P requirements at different stages of development:
   a) requirements are highest for the seedling but only required in a small volume of soil;
   b) P requirements are lower after the seedling phase because of the development of the root system and important symbioses between the plant and micro-organisms in the soil, increasing the capacity of the plant to absorb P and other nutrients and increasing the effective rooting volume;
   c) after the pasture is fully established (production phase), recycling efficiency becomes important in determining nutrient requirement;
   d) pastures have an inherently low rate of export since most of the nutrients contained in the forage are returned to the pasture;
   e) in a well managed legume-grass pasture biologically fixed nitrogen should be sufficient to maintain microbial activity at a high level, thus leading to a high O.M. turnover rate to supply nutrients for both plant and microorganisms.

Soil factors affect fertilizer P efficiency (sandy soils normally have much lower P fixing capacity than heavier textured soils), therefore the experiment was established on a sandy-loam soil (60-70% sand), and on a clay-loam soil (10-12% sand). Two planting patterns were used: in one, the grass and legume were planted in separate rows; in the other, the two species were mixed in the same row.

Vigorous stands of Andropogon gayanus associated with Centrosema acutifolium and Brachiaria decumbens associated with Desmodium ovalifolium were obtained with P applications as low as 5 kg/ha. Satisfactory yields were achieved during the establishment phase with low phosphorus rates at row spacings of 50 and 100 cm, on the clay loam (Reserva) soil (Figure 3).

Grass and legume growth was satisfactory in both planting systems. There were apparently less weeds in this trial when grass and legume were mixed in the same row. The mixed pattern may have other advantages, for example grazing animals may be less likely to trample the less aggressive species, usually the legume, especially with a bunch grass like Andropogon than when planted separately. However, some species may not be very compatible in this type of planting pattern due to interspecific competition during the establishment phase.

There was more weed growth in the broadcast treatments than in treatments planted in rows with fertilizer banded on the clay loam soil, but there were few weeds in any of the treatments on the sandy loam soil. Growth of the sown species during the establishment phase was much less on the sandy loam soil than on the clay loam. Experience suggests that growth of the sown species on the sandy soil subsequently increases markedly, presumably once nitrogen fixation by the legume becomes established.

Use of seed coated macro-pellets for planting

One of the serious limitations to the use of macro-pellets discussed in the 1986 annual report was low solubility. Two new pellets were formulated and tested in the greenhouse and field during 1987. The new pellets use a woody peat for binding material and are much more soluble than the old type pellets which used gypsum as a binder. In Table 1, the effects of

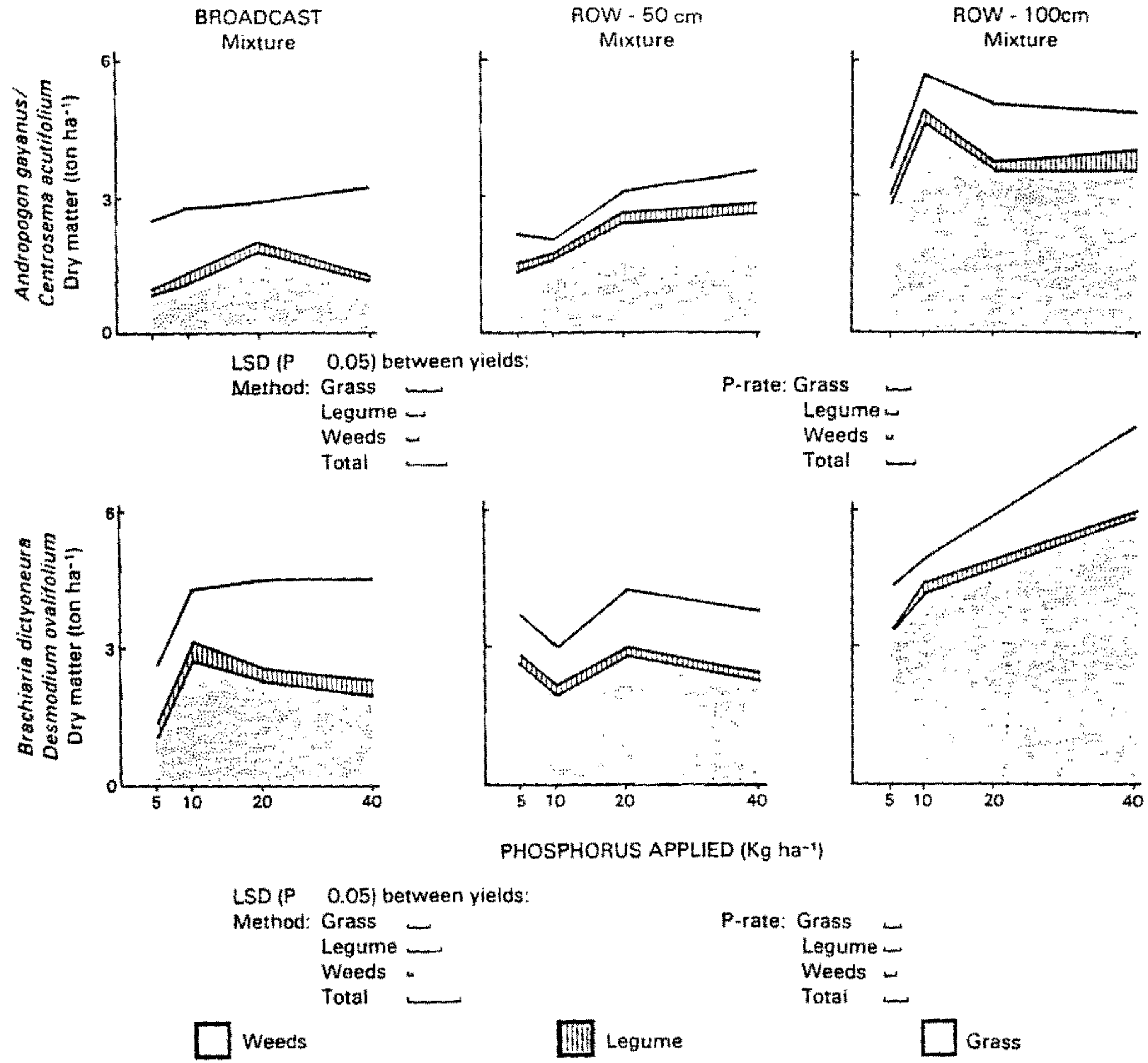


Figure 3a. The effect of rate of P fertilizer and method of fertilizer application and planting on yields of two associations of forage legumes and grasses on a sandy loam soil (Alegria).

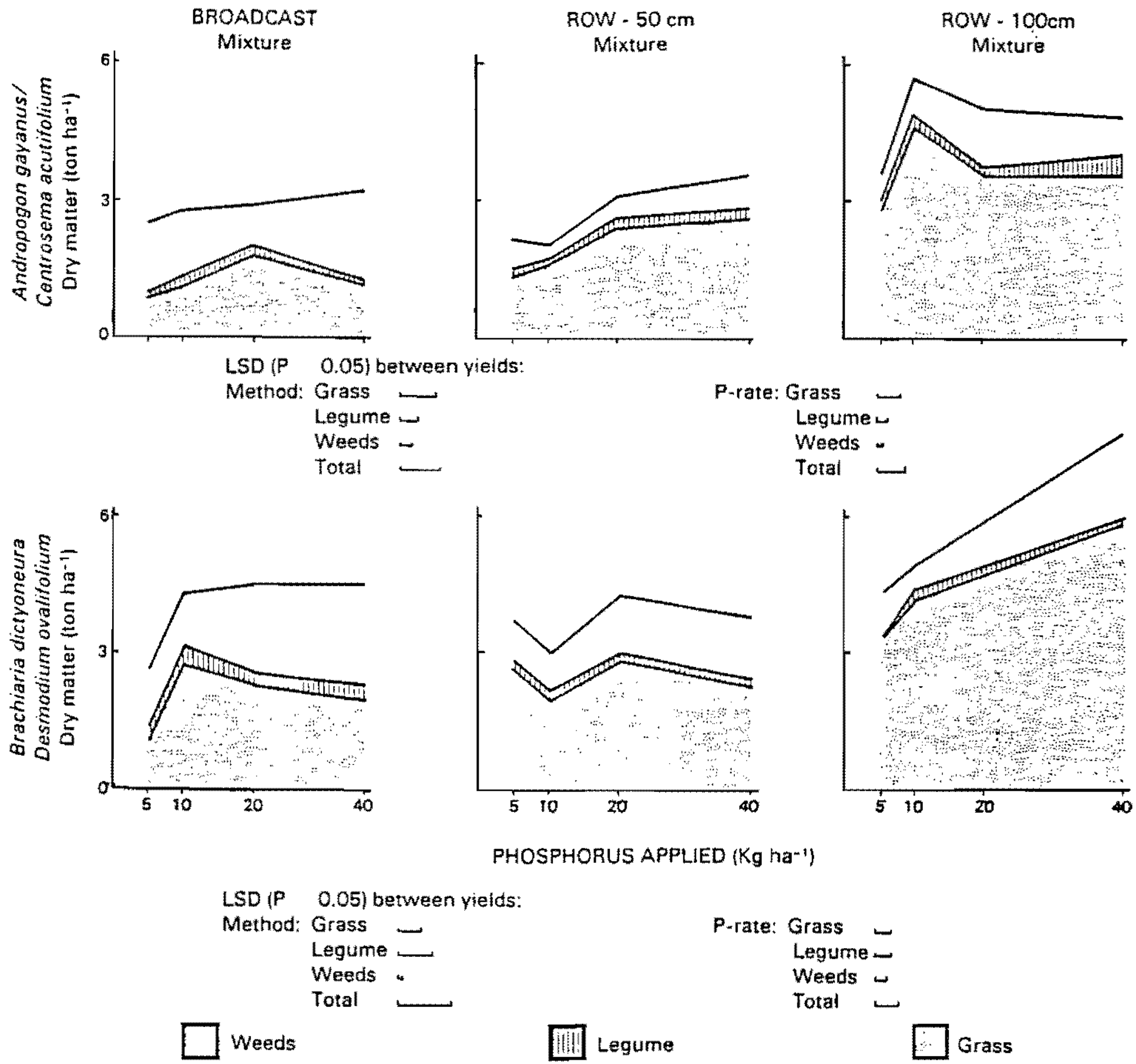


Figure 3b. The effect of rate of P fertilizer and method of fertilizer application and planting on yields of two associations of forage legumes and grasses on a clayey soil (Reserva).

Table 1. The effect of type of macro-pellet and land preparation on the establishment of legumes four weeks after planting at two sites in Carimagua (Planting: April 29, 1987).

Land preparation	Species	Type of soils: Fertilizer source:	Clay loam 1	Clay loam 2	Clay loam 3	Sandy loam 1	Sandy loam 2	Sandy loam 3
			% of sites with plants					
Zero tillage with chemical control	*C. acutifolium*		6.7	86.7	93.3	2.2	48.2	82.2
	D. ovalifolium		22.2	42.2	75.5	15.6	33.4	91.1
Minimum tillage without chemical control	*C. acutifolium*		82.2	77.8	91.1	46.7	76.7	91.1
	D. ovalifolium		86.7	57.8	86.7	62.2	26.7	71.1
Minimum tillate with chemical control	*C. acutifolium*		80.0	85.5	95.6	50.0	82.2	84.4
	D. ovalifolium		91.1	48.9	86.7	46.7	22.2	51.1

1/ Control spot-sowing system: Using a mixture of conventional fertilizer having the same P and K contents as the new pellet.

2/ Seed coated fertilizer macro-pellet system with the old pellet: The old pellet was cut in half to supply the same level of P and K as the new pellet.

3/ Seed coated fertilizer macro-pellet system using the new pellet.

type of pellet, soil and land preparation on seedling establishment are shown for two promising legumes. The new pellets were equal or superior to the old pellets and to conventional fertilizer in all combinations of factors. The advantage was greatest in the zero tillage, chemical control treatment. In other trials, the new pellets also appear to have overcome the problem of solubility.

The renovation of a degraded B. humidicola pasture through the introduction of legumes using macro-pellets was reported in 1986. The trial has continued and at present is being managed under alternate grazing. Initially Desmodium ovalifolium spread slowly but has now increased to as much as 33% cover in the minimum tillage treatment and is considered to be adequate in all treatments. In contrast, Centrosema brasilianum has been reduced drastically in all treatments, although it is unclear whether this is due to excessive consumption by grazing animals, competition from the grass or disease. A. pintoi has almost entirely disappeared.

The effects of fertilizer rate and the proportion of the planted area sprayed with herbicide on legume cover one year after planting with macro-pellets are shown in Figures 4 and 5. The effect of herbicide is especially large. D. ovalifolium achieved near maximum cover in the sandy soil with 3.4 g of fertilizer/hill (0.17 g of each P and K) and with 3.4 to 6.8 g in the clay loam soil. Stylosanthes capitata was less aggressive than D. ovalifolium as expected, but achieved surprisingly good cover for a zero tillage system. The trends in response to the two factors were similar for the two legumes.

The new pellets and the best combinations of species and land preparation methods were used to establish a four hectare experiment to be managed under grazing on a clay loam soil in Yopare. Good populations were achieved for both Desmodium ovalifolium and C. acutifolium with somewhat better stands (over 90%) in the minimum tillage treatments than with chemical control of the vegetation (65-75% stand). This is the first large scale test of the pellet system for planting legumes in native savanna.

Flexible management

Pastures of A. gayanus and C. acutifolium continue to be productive and stable in the original Carimagua flexible management trial first described in 1984. Figure 6 shows the composition of the pasture during 1987. Legume, grass and weed content and the management adjustments required to maintain the pasture within the limits considered desirable are shown.

In the second plot, animal numbers were reduced to increase the forage allowance (F.A.) expressed in terms of green dry matter (G.D.M.)/100 kg animal live weight. The F.A. was probably too low during most of 1987 as reflected in marked reductions in animal gains. The grazing system (G.S.) will also be adjusted to favor the legume with shorter rest/grazing periods. This adjustment should have been made earlier to counter the sharp decline in legume content and corresponding increase in savanna content. The results correlate well with those of other trials at the advanced level using more traditional methodology.

The association of B. dictyoneura and A. pintoi, which was renovated in 1986, continues to be unstable and unproductive, apparently due primarily to the failure of the legume to develop vigorously in this trial. These results also correlate well with other experiences with this association in Carimagua. A. pintoi appears to be favored by more fertile and/or more humid soil conditions than those found in the Yopare site.

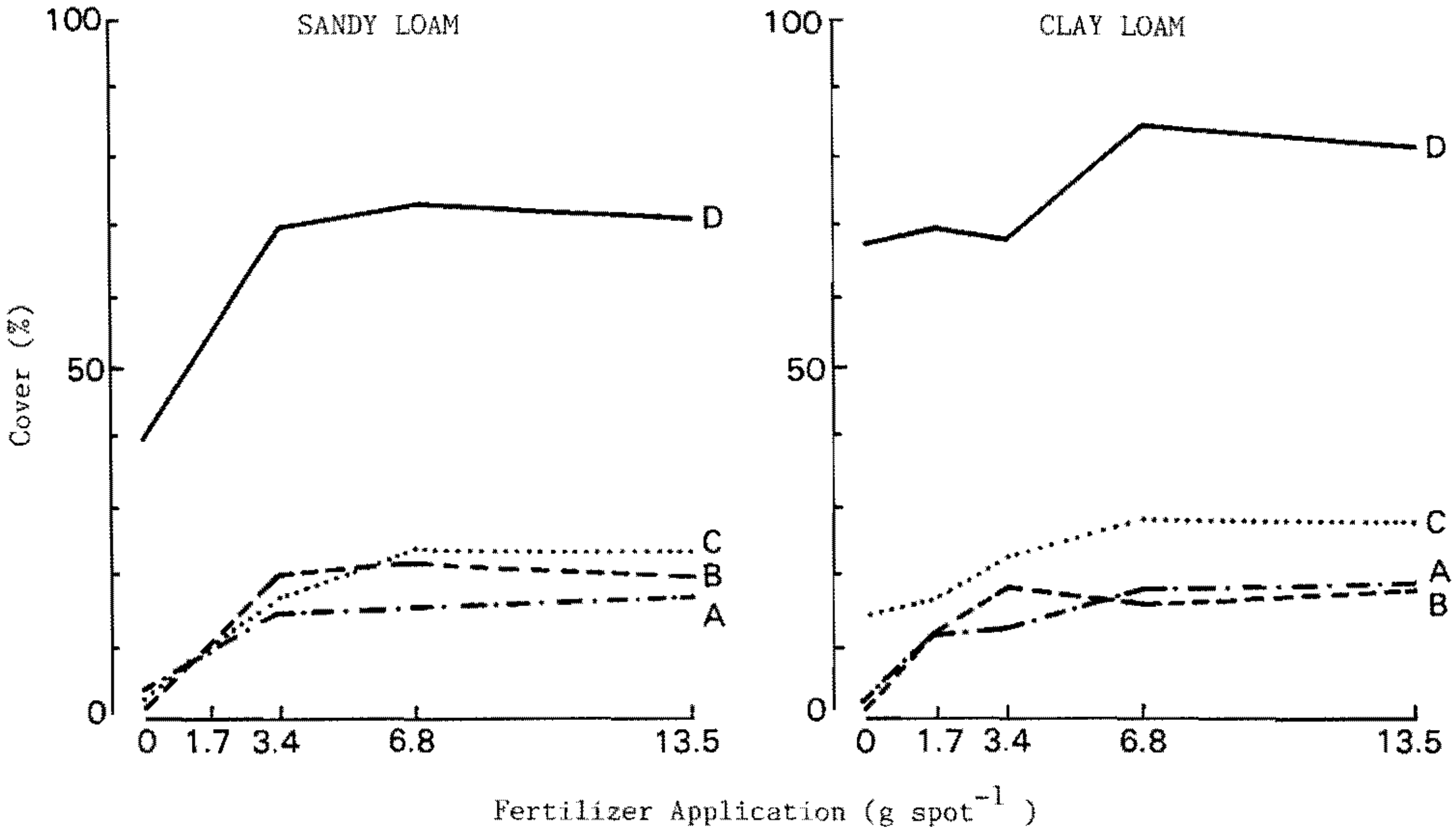


Figure 4. The effect of fertilizer and herbicide rates on the cover of D. ovalifolium planted in a 2 x 2 meter pattern on two savanna sites. Observations taken on July 27, 1987, one year after planting. A-D = different herbicide applications: A = Nil, B = 3%, C = 30%, D = 100% of the total area).

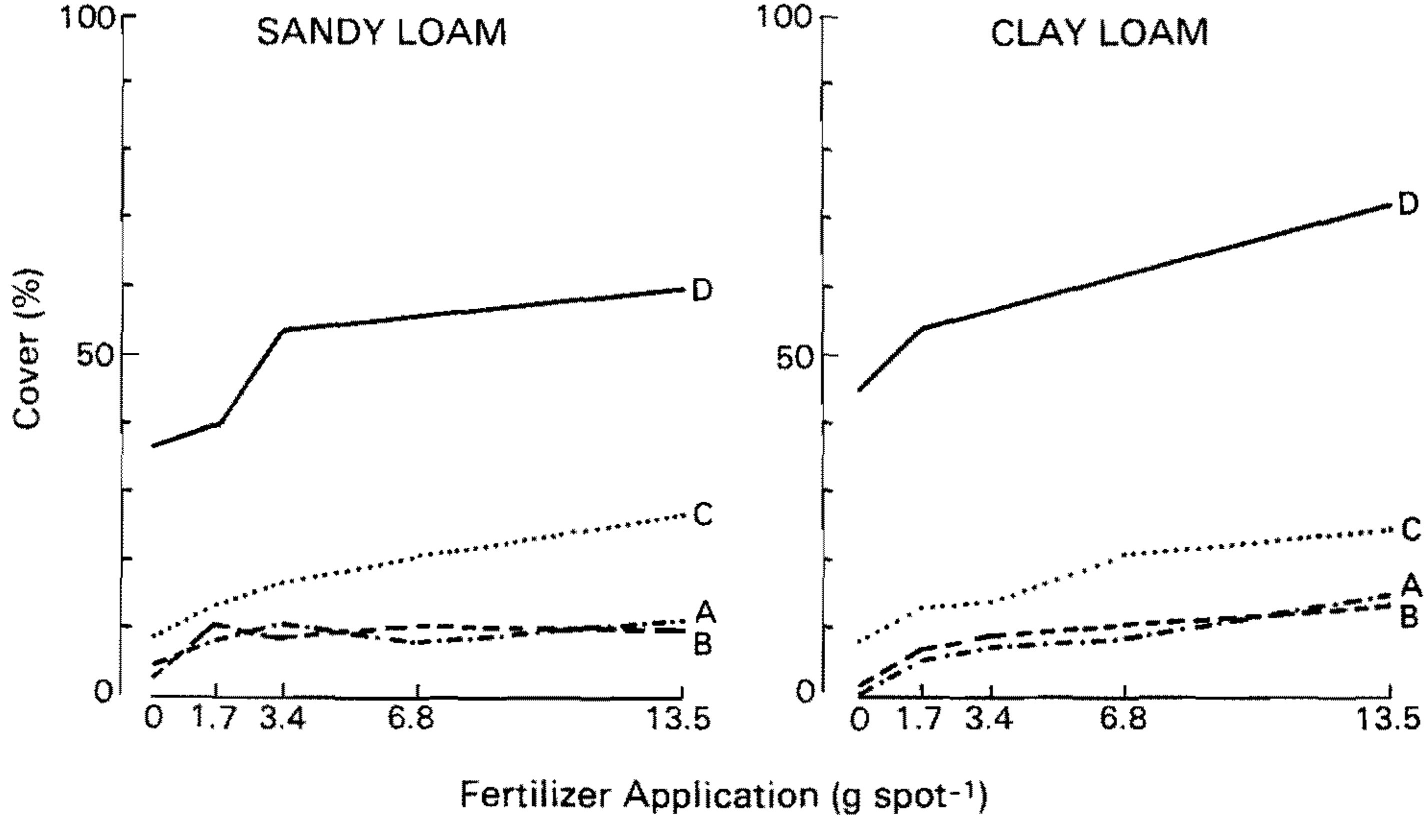
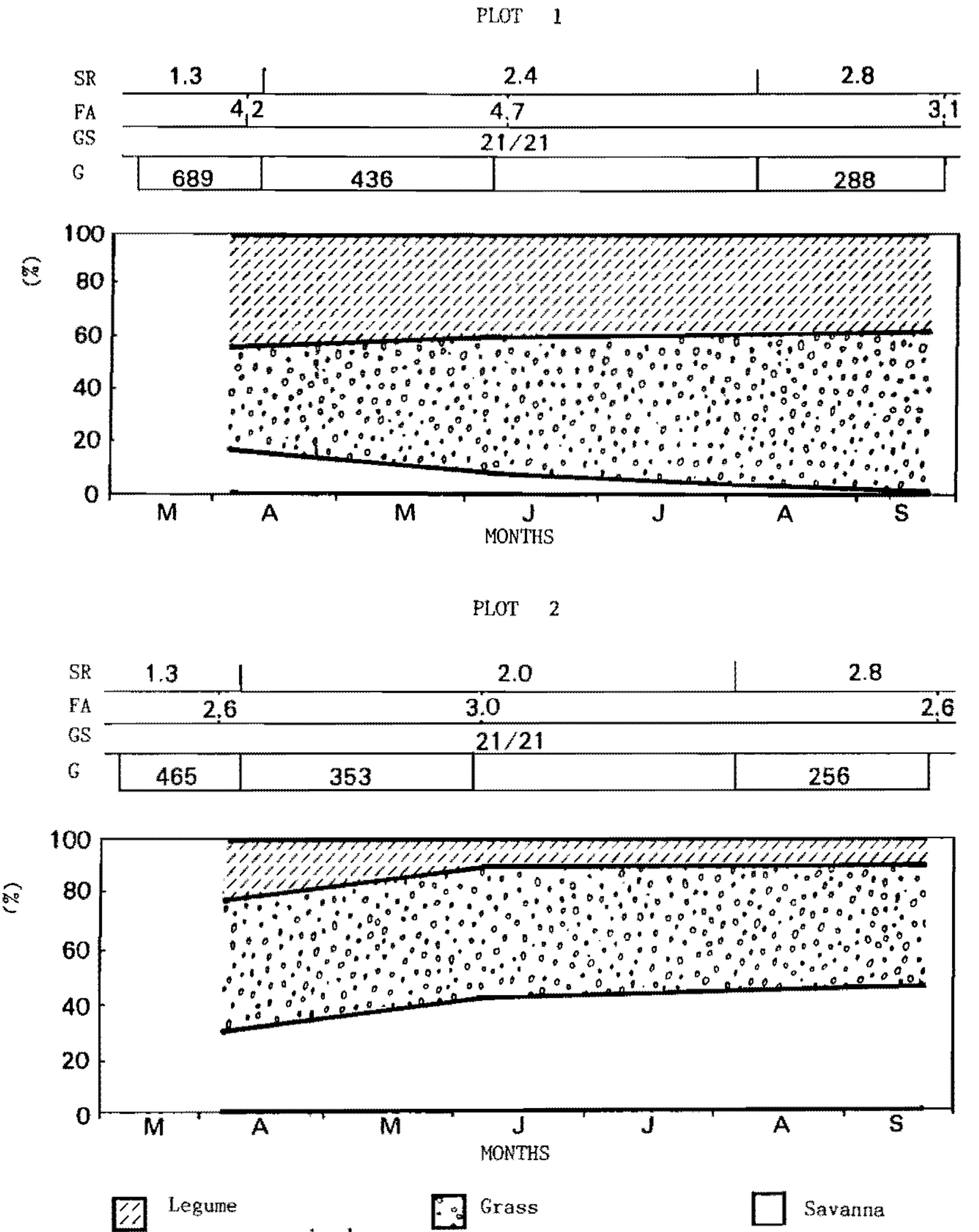


Figure 5. The effect of fertilizer and herbicide rates on the cover of S. capitata planted in a 2 x 2 meter pattern on two sites of savanna. (Observations taken on July 27, 1987, one year after planting. A-D = different herbicide applications: A = Nil, B = 3%, C = 30%, D = 100% area^{-1}.



SR = Stocking Rate (AN^{ha-1}); FA = Forage on offer; green dry matter (kg); live weight 10^{-2}; GS = Grazing System, grazing (day) rest^{-1} (day); G = Live weight gain (g an day^{-1}).

Figure 6. Composition of two A. gayanus and C. acutifolium pastures and the management adjustments made to maintain them within a good management "screen". Carimagua, 1987.

13. PASTURE RECLAMATION HUMID TROPICS

The research activities of the new Pasture Reclamation Section began on July 1, 1987 at the IVITA Experimental Station, located 59 km from the city of Pucallpa, Peru. The research activities are carried out through a cooperative agreement between IVITA/INIAA/CIAT.

The objectives of the project are: 1) to develop a low risk and low cost technology for the reclamation of degraded areas through the utilization of highly stable pastures with sustained productivity, and 2) to document pasture degradation through the study of soil conditions (physical and chemical) as well as documenting the biomass observed under contrasting conditions.

After various discussions between members of the National Institutions (IVITA and INIAA) and the Tropical Pastures Program, two matrices (Tables 1 and 2) were assembled and analyzed in order to elaborate by consensus, the research program to be undertaken. Table 1 analises the level (High, Medium, Low) of priorities for the investigation of six possible conditions of degradation (Secondary forest more than 10 years old; Secondary forest 5-10 years old; Secondary forest less than 5 years old; degraded improved pastures, native pastures and degraded native pastures). In the same manner, Table 2 analyses and priorizes the investigation in relation to topographic conditions - the other dimension of the problem of reclamation of degraded areas.

As a result of this analyses, short- and long-term priorities were determined as follows:

1. High priority: To carry out research on reclamation techniques in degraded areas in native pastures (Torourco) as well as on degraded Torourco (degraded native pastures).

2. Medium priority: Reclamation of improved pastures, mainly based on Brachiaria decumbens, through the incorporation of better adapted grasses and legumes.

3. Medium to low priority: Investigate reclamation techniques for secondary forests (Purmas) through the use of better adapted pasture species.

On the other hand, general priorities were defined in accordance with the emphasis given to different topographic conditions:

1. High priority: Areas with low slopes 10 to 25.

2. Medium priority: Flat areas (less than 10%) and those with medium slopes (25 - 50%).

3. Low priority: Areas with steep slopes (more than 50%).

The major priority defined for degraded areas of native pastures and improved pastures in degradation, complies with the major importance that these degraded conditions represent in the region due to the fact that these are ecosystems from

Table 1. Characterization of problems and definition of research priority for the reclamation of degraded areas in the Humid Tropics (Pucallpa, Peru).

Degradation Conditions	Importance in área	Soil Condition		Weed control	Level of difficulty		Solution PossibilitIES				Implicacions			Priority for Research					
							Use of Pioneer crops	Fertilizing and corrections	Germplasm availability	General actual advantage	Ecological	Socioeconomic	Political	Reclamation techniques		Dynamics of pastures nutriments		General	
		chemical	physical		mechanization	general								Short*	Long	Short	Long	Short	Long
1. Secondary forest > 10 years (High Purma)	B	A-M	A	M-B	A	B	A	B	A	A	B	M-B	A	B	B	A	B	B	B
2. Secondary forest 5-10 years (Low Purma)	M	M	A-M	A-M	A	M-B	A	B	A	M	B	M-B	A	B	B	A	B	B	B
3. Secondary forest < 5 years (Young Purma)	A	B	M-B	A	A-M	A[1]	A-M	A	M-B	B	M	A-M	M	B	M	B	M	B[1]	M
4. Improved pasture in degradation (*B. decumbens*)	M-B (Peru Colombia) A (Brasil)	B	M-B	M-B	B	M	B	A-M	A-M	B	A	A-M	A	A-M	M	M	A	A-M	A-M
5. Native pasture (Torourco)	A	B	B	A	B	A-M	A-M	A	A-M	B	A	A	A	A	A	A	A	A	A[1]
6. Degraded native pasture (*H. aturensis*, *I. brasilensis* y/o *Pteridium* sp.)	A	B	B	A	B	A	A	A	A-M	B	A	A	A	A	A	A	A	A	A[1]

* Term.

1/ A = High level; M = Medium level; B = Low level.

Table 2. Characterization of problems and priority definition for research on degraded areas according to topography.

		Limitations		Solutions		Positive Implications		Research Priorities			
Topografic Condition	Importance	Erodability	Mechanizing difficulty	Pioneer crops	Trees	Germplasm maximum canopy	Ecological	Socio-economic	Short*	Long	General
High slopes (>50%)	B[1]	A[1]	A	B	A	A	B	B	B	M	B
Average slopes (25-50%)	A-M	A	A	B	A	A	B	M	M	A	A-M
Low slopes (10-25%)	A	M	M	A	M	M	M	A	A	A[1]	A[1]
Flat zones (< 10%)	M	B	B	A	M	B	A	A	A	M	A-M

* Termn.

1/ A = High level; M = Medium level; B = Low level.

medium to high stability, but with low productivity (0.5-1 animal/ha).

Likewise, the criteria for giving priority to the areas of low slopes are: a) they represent the most important in terms of area, b) ecologically most accepted, and c) they have advantages for the implementation of pioneer crops (financing) and inputs (fertilizers, herbicides, improvements, etc.). Less priority is given to the areas with slopes greater than 50% based on the argument that these areas must return to forest and be areas of protection.

Finally, medium priority is given to the study of the dynamics of nutrient recycling in relation to the development of techniques for the reclamation of degraded areas. The monitoring will be initiated in some areas of secondary forest more than 5 years old as well as in degraded areas of "Torourco" in order to document the starting point for reclamation and have recycling checks in contrasting vegetation.

The establishment of experiments was initiated during the months of October to December, 1987. These trials have as the general objective the generation of possible solutions for the identified problems in degraded areas. A summary of such trials is given as follows:

1. Relative importance of fertilization and tillage effects on "degraded Torourco", and on improved forage species

Under the indicated conditions, the soil generally presents slight to severe superficial compaction. Soil fertility is low particularly in N, P, K, Mg and S.

Hence, it is important to determine differential responses to such nutrients utilizing species of "Torourco" and improved species in order to adjust the fertilizer requirements for successful pasture establishment. This exploratory study should also analyse the effect of tillage on soil compaction, on mineralization of soil nutrients and on the competitive capacity of improved and native pasture species.

The trial is a mixed factorial: fertilization x tillage x species. Fertilization is based on the missing element technique that utilizes N, P, K, Mg, Ca and S as key elements. There are two types of land preparation, conventional land preparation with two discings and no land preparation (disturbing only the planting sites). The species to be sown are Brachiaria dictyoneura cv. Llanero and Desmodium ovalifolium CIAT 13089. These species were selected because of their relatively low fertilizer requirements and a medium to low rate of establishment. The measurements to be carried out are: rate of growth in height and canopy of both improved and native species, broad-leaf weed invasion and production of biomass of all species at 6 months.

2. Fertilization and physical conditioning of the soil for pioneer cash crops in areas of "degraded Torourco"

Another significant problem is the producers, relatively poor access to capital, particularly in mixed production systems in areas of less than 100 ha. This is reflected in their low use of fertilizers and herbicides for pasture establishment. The possibilities for mechanization are also scarce and expensive. Keeping this in mind, the total reclamation costs must be reduced to economically and biologically efficient levels in order to guarantee the adoption of new technologies. The utilization of annual pioneer cash crops has also been considered.

This trial includes the planting of an

unknown African rice variety, maize (variety PMV-747) and cowpea (var. Chiclayo). Rice and Maize were planted in November 1987, and the planting of cowpea is projected for the end of April, 1988. The experiment is a split-plot design with the main plot's the pioneer crop, the land preparation method the sub-plots, and fertilization land (high, medium and low) as sub-sub-plot. A control is also included. The high and low fertilization treatments received either 50% more or 6% less respectively than the medium level (60, kg N, 40 kg P, 50 kg K, 20 kg Mg and 20 kg S/ha). The tillage method included three types of soil preparation: 1) total tillage (2 discings to 20 cm soil depth), 2) minimum tillage (1 discing to 20 cm soil depth), and 3) without tillage (planting done with TACARPO, disturbing only the planting site). The factors to be measured are: grain yield of each crop, weed invasion and forage production of improved species established with the cash crops.

3. Optimum doses of herbicide required for the control of vegetation in "degraded Torourco"

When associated pastures (grasses and legumes) are established to replace native vegetation, the possibilities of a selective control of the invading vegetation (broad-leaf weeds and grasses) is more complex. Several alternatives have been identified including the use of pre-emergence herbicides for the destruction of the original vegetation and post-emergence application to give advantage to the establishing sown species.

A split-plot design was used. The main plots were the associations *Andropogon gayanus* cv. Carimagua 1 with *Stylosanthes guianensis* cv. Pucallpa, and *Brachiaria dictyoneura* cv. Llanero with *Desmodium ovalifolium* CIAT 13089. The herbicide Round-up" was applied. Six doses of herbicide were sprayed in the subplots (high-4 liters/ha; recommended 3 liters/ha; medium - 1.5 liters/ha and minimum 0.75 liters/ha). The treatments were applied after a burning of the "Torourco" and 15 days after weed regrowth. Rice was planted in these plots in untilled-rows in both associations at the same time. The effectiveness of vegetation control, weed invasion, crop yield and forage production of both associations are to be evaluated. The duration of this trial will be one year.

4. Characterization of the potential aggressiveness of promising germplasm at establishment

Previous regional research (RIEPT) and preliminary studies of the major selection sites carried out by the Agronomy Section in Pucallpa have identified some grasses and legumes well adapted to soil, climatic and biotic factors in the humid tropics. These vary in aggressiveness and potential compatibility that must be taken into consideration in the adjustment of pasture reclamation techniques - including the minimization of costs and risk at establishment.

The present trial consists of associations of various grasses (*A. gayanus* cv. Carimagua 1, *B. brizantha* cv. Marandu, *B. decumbens* cv. Basilisk, *B. dictyoneura* cv. Llanero) and legumes (*A. pintoi* CIAT 17434, *C. acutifolium* cv. Vichada, *C. macrocarpum* CIAT 5713, *C. pubescens* CIAT 438, *D. ovalifolium* CIAT 13089, *S. guianensis* cv. Pucallpa). Both vegetative material and seed were sown. Treatments were arranged in Randomized Complete Blocks, replicated four times. The land was uniformly prepared with two discings and a herbicide was applied 30 days after weed regrowth. Fertilizer was applied at the rate of 20 kg/ha P, 30 kg/ha K, 100 kg/ha Ca, 20 kg/ha Mg and 20 kg/ha S. The legumes were inoculated with the respective strain of *Bradyrhizobium*. The growth rate of planted species (height and canopy) was recorded every 3 weeks, whilst canopy, weed and forage biomass were noted at 2, 4, 6, 8 and 10 months after planting and forage.

5. Reclamation of improved pastures through weed control and seed harvesting for reduction of costs

Considering that large areas of degraded pastures, especially species of *Brachiaria* exist in the humid tropics. A medium priority was established for the reclamation process of these pastures. In general, due to bad grazing management, the pastures invasion by broad-leaf weeds (eg. *Cassia tora*) is common. A proposed alternative is to reclaim these pastures through the utilization of a herbicide and to reduce costs by harvesting seed before grazing. The use of fertilizers to increase seed production is also considered.

The trial consists of utilizing a degraded pasture of *B. decumbens* established 15 years ago and invaded by *Cassia tora*. In this case, the herbicide 2,4-D was used and fertilization treatments consisted of Mg, K and S arranged factorially with two nitrogen levels (50 and 100 kg N/ha). The measurements in this trial are: Growth rate of *B. decumbens* every 30 days, flowering stage, number of inflorescences, seed and forage production. The second phase of this trial will be the introduction of a legume in strips (*C. macrocarpum* CIAT 5713), and pasture persistence and stability under grazing will then be evaluated. Similar trials introducing other improved grasses and legumes into degraded *B. decumbens* and native pastures on farms are projected for 1988.

Greenhouse and field experiments which will complement work already initiated and explore in more detail the factors that affect reclamation technology in degraded areas (on research stations as well as on farms) will be defined from 1988 onwards.

14. ECOPHYSIOLOGY

The objective of the Ecophysiology section is to develop an understanding of the factors that influence the reaction of grass-legume associations to grazing in order that:

(i) Management practices appropriate to new germplasm are applied during its evaluation and hence is available as a package at the time of the release of successful material.

(ii) The consequences of other management practices may be forecast.

(iii) The factors responsible for the success or failure of new germplasm may be elucidated in order that ideotypes of plants likely to be successful may be more clearly identified.

(iv) Processes that are critical to the satisfactory extrapolation of results both within the ecosystem in which the evaluation was made, and to other, similar ecosystems are understood.

A description of the population dynamics of various associations during the evaluation process did not seem to offer much prospect of satisfying these objectives. Moreover the extreme variability encountered in pastures of Andropogon gayanus, especially when grazed continuously by cattle, made the likelihood of any understanding of the physiological principles underlying the behaviour of the pastures very remote using conventional techniques. Therefore, an analysis was undertaken to determine the feasibility of describing a grass-legume association in terms of a limited number of discrete response functions, and combining them in a conceptual model, which would describe the behaviour of any pair of grasses and legumes. The exercise was described in some detail in the 1986 Annual Report.

Briefly, the functions chosen were

(i) Leaf area index as a function of biomass;
(ii) Growth rate as a function of leaf area index;
(iii) Senescence rate as a function of biomass;
(iv) Competition as a function of composition;
(v) Consumption as a function of biomass on offer;
(vi) Diet selection as a function of the feed on offer; and
(vii) The proportion of new recruits of one component in the association as a function its proportion of the adults in the population.

Functions (i)-(iv) between them describe the relations between the components during vegetative growth, functions (v) and (vi) describe the effects of the animals by grazing, while (vii) describes the population dynamics.

In the 1986 Annual Report the synthesis of these functions and their interrelation was described, and the consequences of the higher growth rates of C_4 grasses compared with C_3 legumes leading inevitably to grass dominance, was discussed. Brief reference was made to the design of an experiment to validate the approach. The major task of the section during the year was the further development of the experiment culminating in the initiation of grazing in June.

The experiment consists of four associations:
Andropogon gayanus cv. Carimagua 1 - Stylosanthes capitata cv. Capica
Andropogon gayanus cv. Carimagua 1 - Centrosema acutifolium cv. Vichada
Brachiaria dictyoneura CIAT 6133 - Arachis pintoi CIAT 17434
Brachiaria dictyoneura CIAT 6133 - Desmodium ovalifolium CIAT 3788

Each of these associations were established in three ratios of grass/legume (high, medium and low), and until grazing started the ratios were maintained, relatively easily, by differential defoliation of one or other of the components as necessary. This treatment was facilitated by the planting pattern used in which the two components were planted in alternate rows. In June grazing of the two associations of Andropogon gayanus started, and one cycle (five weeks) later of the two Brachiaria dictyoneura associations. Each association/proportion combination is grazed by fistulated cattle at each of three levels of forage allowance (3-4, 5-6, and 8-9kg dry matter/100kg liveweight) in a rotation of nominally 3-1/2 days of occupation in each cycle of five weeks. Forage allowance is varied by reducing time of occupation, or by adding an additional (entire) animal, as necessary. The same group of animals rotate through all nine plots of each association, and, when not grazing the plots, they are withdrawn to a bulk pasture of the appropriate association. In this way, the animals continuously graze the same type of pasture in order to avoid problems of changing selectivity brought about by having different species in their diet. In order to improve efficiency of sampling, sites for clipped samples are selected using the technique of ranked sets and samples, stratified by height, are clipped to ground level immediately before and after grazing. Plant, stolon and tiller numbers, seedling recruitment and soil seed bank are being followed using marked plants in the associations with S. capitata and C. acutifolium, and sod samples with the strongly stoloniferous legumes D. ovalifolium and A. pintoi. Studies of tissue turnover in order to assess rates of senescence and leaf appearance will be initiated shortly.

Other work carried during the year has included collaborative studies of the growth of several associations in Category 3 experiments of the Agronomy section, the initiation of a series of studies to determine the resistance to fire of selected germplasm in advanced categories, the initiation of studies on the reproductive biology of Centrosema species, and studies on the nature of edaphic adaptation.

Resistance of Stylosanthes capitata to burning

Fire is commonly used in the management of native savannas, and for this reason species used to supplement or replace them must be tolerant of the effects of the practice. Stylosanthes capitata is well adapted to the llanos of eastern Colombia, but its resistance to fire is not well known. Therefore a series of studies was initiated to seek understanding of its ability to resist burning. Because fire temperatures can vary so widely depending on the environmental conditions, state and quantity of the fuel, and so on, it necessary to replicate burning experiments in time, in order to sample as widely as possible the range of conditions likely to be encountered. In the experiment reported here there were only two burning treatments, so that the results must be interpreted with caution. In 1983, S. capitata was established in, amongst other treatments, rows 3.3 m apart in a native savanna at Carimagua, dominated by Andropogon bicornis and Trachypogon vestitus. During the five years since its establishment, the legume had spread widely into the savanna. Two burning treatments were superimposed and compared with an unburned control in the amount of damage caused to living plants of S. capitata, ranked for size, the number of plants surviving, together with the site and number of regrowing buds, soil seed reserves and germinating seedlings. Observations were taken both within the original rows and within the savanna.

Fire temperature was assessed using thermal crayons applied to aluminium plates, 20cm square. The plates were placed face down both within the rows and within the savanna, and the height of the savanna adjacent to each was ranked. The burns were timed to sample different conditions of soil water, to determine whether soil water content influenced the ability of the plants to survive. The first burn (Q1) was carried out when the soil had dried for three days after 54mm of rain (gravimetric water 15.9%, 0-10 cm), and the second during the day following 24mm of rain, while the surface soil was still moist (gravimetric water 18.1%).

The soil temperatures were higher in Q_2 compared with Q_1 (187 compared with 134C), and higher where the savanna was tall (216C) than

where it was short (122C). Seven days after the fire less than 2% of the legume plants were unaffected by the treatments, with no differences between the savanna and the rows, nor between Q1 and Q2. Nevertheless, after 49 days 74% of the plants had regrown with 3.5 new shoots per plant. It is of particular interest that 97% of the regrowth occurred from the crown, which is at the soil surface, and there was no regrowth from the roots of the plants.

Fire reduced soil seed reserves from 157 to 84 seeds/m^2, but seedling emergence following the fire was 5.8 and 8.6 plants/m^2 in Q1 and Q2 respectively, compared with 3.7 in the control.

It was concluded on the basis of these data that S. capitata is resistant to fire, at least to that in the early part of the wet season. Moreover, the plant does not appear to be more vulnerable when the soil is wet, compares to when it is somewhat drier. Obviously, further work is necessary to define more closely the reaction of the plant to fire under a wider range of conditions, including during the dry season.

Seed biology of Centrosema species

During a workshop on the biology of Centrosema held in CIAT in February, 1987, one of the recommendations was that a deeper understanding of the factors controlling the reproductive behaviour of species of Centrosema was necessary. This recommendation was prompted by two considerations:

- Long term survival of a component of a pasture depends both upon the longevity of the original plants, and upon their ability to create new ones, either vegetatively or from seed. In those components where individuals are short lived, regeneration is vital to the component's success. Moreover, the ability of a component to survive a catastrophe, or mismanagement, either of which may kill the existing plants, inevitably will depend on adequate reserves of germinable seed.

- For new germplasm to enter successfully into commercial practice, a technological package of seed production is essential. Knowledge of the environmental factors that control seed production is therefore necessary in order to define those areas suitable for production of seed.

In many tropical legume species, reproduction is controlled by a variety of daylength responses, such that some areas where the critical daylength conditions are not met are inappropriate for growth of seed (and perhaps of the plant) of particular species, without some genetic manipulation of its daylength response. In the first of the series of experiments initiated in the greenhouse at Palmira, the daylength responses of a range of Centrosema species is being investigated in collaboration with the Seed section.

In the first experiment, plantings of selected material are being made each 4 weeks. At this site (3.5 degrees N latitude), the annual variation in daylength is about 40 minutes, so that flowering will be inhibited in germplasm with shortday requirement less than about 11.5h, or with longday requirement more than about 12.5 h. The group of material in the experiment is:

Accession	Time to flower (August planting)
Centrosema pubescens CIAT 438	9 weeks
Centrosema brazilianum CIAT 5234	9 weeks
Centrosema arenarium CIAT 5236	9 weeks
Centrosema macrocarpum CIAT 5452	12 weeks
Centrosema macrocarpum CIAT 5713	14 weeks
Centrosema acutifolium CIAT 5568	14 weeks
Centrosema acutifolium CIAT 5277	14 weeks

Growth of associations under grazing in Category 3

In the 1986 Annual Report, the behaviour of associations of Centrosema species in mixtures with Andropogon gayanus under grazing was reported. Similar studies are being carried out in two other associations of interest, Arachis pintoi in mixtures with accessions of species of Brachiaria, and a range of Desmodium ovalifolium germplasm in mixtures with Brachiaria dictyoneura. This work is being carried out in collaboration with the Agronomy section at Carimagua.

In the experiment with Arachis pintoi, the legume (CIAT 6133) was sown with five accessions of Brachiaria humidicola (CIAT 679, 6294, 6369, 6705, and 6709). In the experiment with Desmodium ovalifolium six accessions of the legume (CIAT 350, 3776, 3794, 13089, 13092, and 13129) were sown with Brachiaria dictyoneura (CIAT 6133). Both were grazed at two levels of forage allowance, obtained by using different periods of occupation in a similar rotation (28/7 and 32/3 days of rest/occupation, respectively). The experiments were sampled at ground level immediately before the entry of the animals and after grazing. At each occasion, the dry matter yield of each component was determined, and the proportion of leaf, stem and dead material together with the leaf area.

Both experiments have been sampled for more than one year, and provide an opportunity to examine in some detail the differences in growth of the component species of the two associations. Accordingly, the data were combined on the same time scale in order to examine whether there were any common trends. It should be noted that the two experiments were not formally replicated in the same design, and that therefore the comparisons lack formal rigor. However, the experiments were separated by a distance of only a few hundred metres, so that there was the opportunity to compare the data of the two experiments, which were conducted under similar management.

Total dry matter yield between the two associations (Figure 1) shows remarkable similarity in pattern during the wet season 1986 and until grazing was suspended in February 1987. The main effect, as might be expected, was the forage allowance treatment. In the early part of the 1987 growing season, however, the associations with Arachis pintoi were clearly superior. The data for yields of green grass (Figure 2) show that the forage allowance treatment had little influence on the yield of grass during 1986, nor in the in the associations with Arachis pintoi in 1987. In the associations with Desmodium ovalifolium in 1987, however, grass yields were affected by the forage allowance treatment. In contrast, the yields of green legume (Figure 3), were greatly affected by the forage allowance treatment until grazing was suspended in early 1987. When grazing recommenced, the legume content of the associations with Desmodium ovalifolium accessions had fallen to a low level, while Arachis pintoi remained high.

The growth rates of both grass and legume in the two associations were calculated for the rest periods of each grazing cycle, and plotted against mean leaf weight for the same period. In the grasses, there was remarkable concurrence between the two associations, with the majority of data in each forage allowance treatment showing a linear trend (Figures 4 and 5). The outliers from the general trend are identified in the figures with the date of observation. Whilst it is only possible to speculate on the reasons why the outlying data do not conform, it appears that they are for the very wet times during the year (both 1986 and 1987 had above average rainfall with periods of very wet weather, during which the soil was saturated). It is plausible that some factor associated with the extreme wetness caused the low growth rates, but it is also obvious that some other factors could have been responsible. Nevertheless, it appears that for much of the period covered by these data, the growth rate of the grasses was controlled by the amount of leaf, irrespective of the species of Brachiaria, or of the associated legume. The unit leaf rate (the slope of the relation, growth rate per unit mass of leaf) was higher in the treatment with the low forage allowance. This treatment invariably had lower leaf masses, and hence presumably a younger mean leaf age.

Similar relations were derived for the legumes, although here there were rather more outliers, and the relation with wet conditions could not be made so plausibly (Figures 6 and 7). Unit leaf rate for the two different forage allowance treatments were similar, but substantially less than for the grasses, which is consistent with their different photosynthetic pathways.

Factors affecting edaphic adaptation

It is commonly observed that there are substantial differences between the behaviour of germplasm between sites in the same ecosystem. For example, there are large differences in the performance of Centrosema acutifolium and Centrosema macrocarpum in sites at Carimagua such as La L and Yopare, which are located only 2-3 km apart. This observation raises the question of edaphic adaptation, and its causal mechanisms. While all the germplasm for use on the isohyperthermic savannas is broadly screened for tolerance to acid soils and high aluminium saturation, and hence is regarded as adapted to these conditions, the specific characteristics that fit plants for growth in these soils have not been defined.

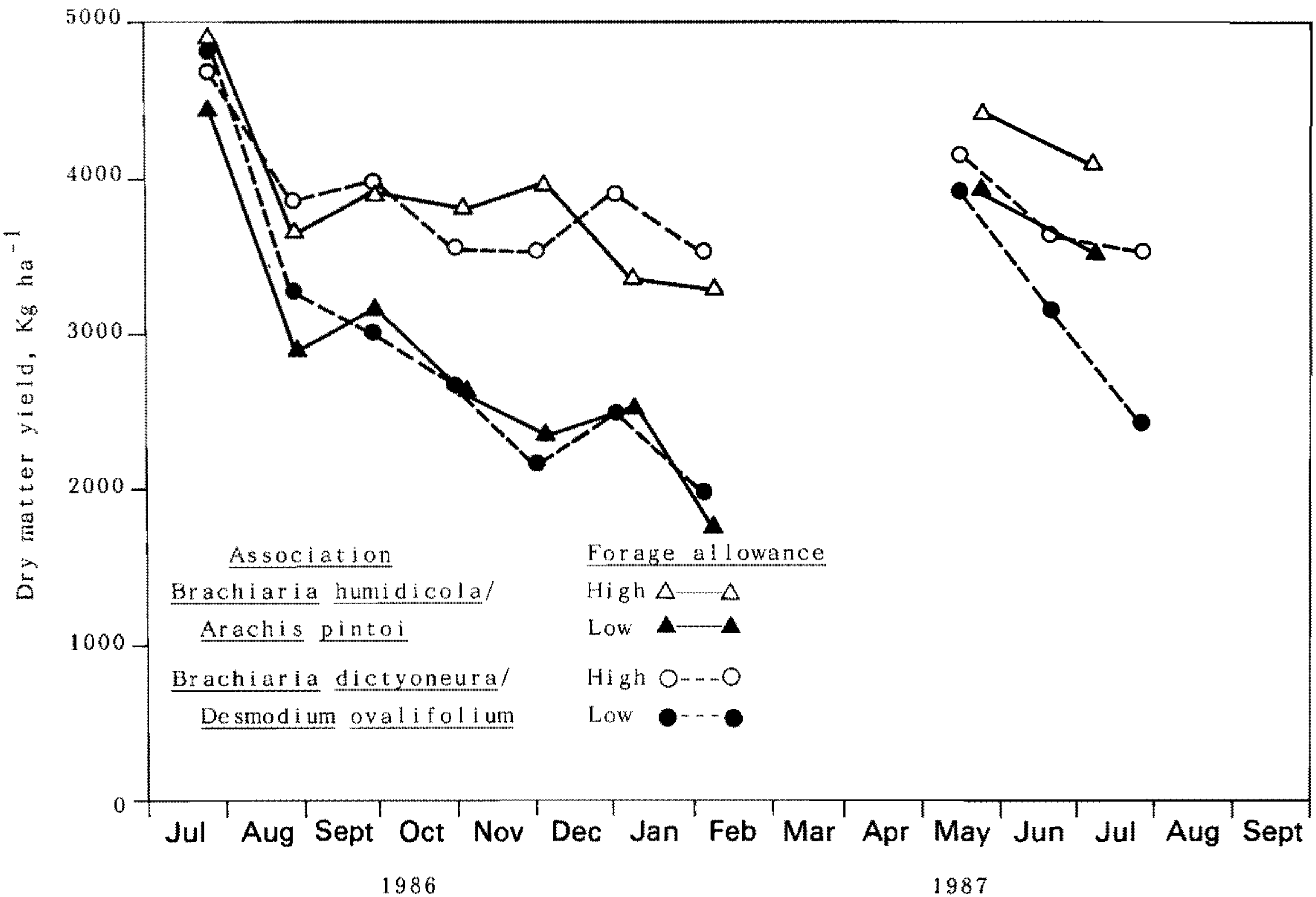


Figure 1. Total dry matter yield of two associations at Carimagua grazed at two levels of forage allowance. Data are means of accessions.

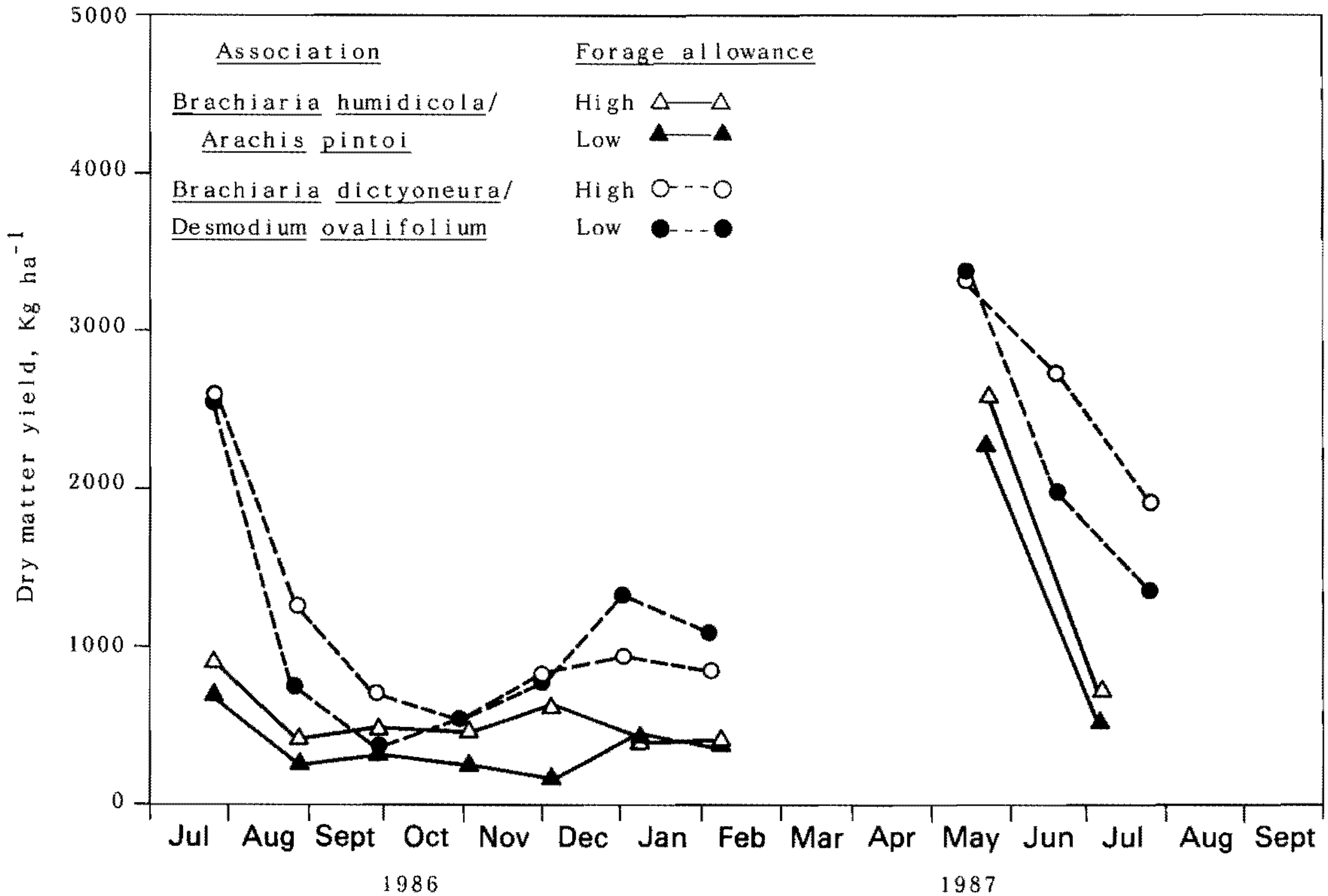


Figure 2. Yield of live grass in two associations at Carimagua grazed at two levels of forage allowance. Data are means of accessions.

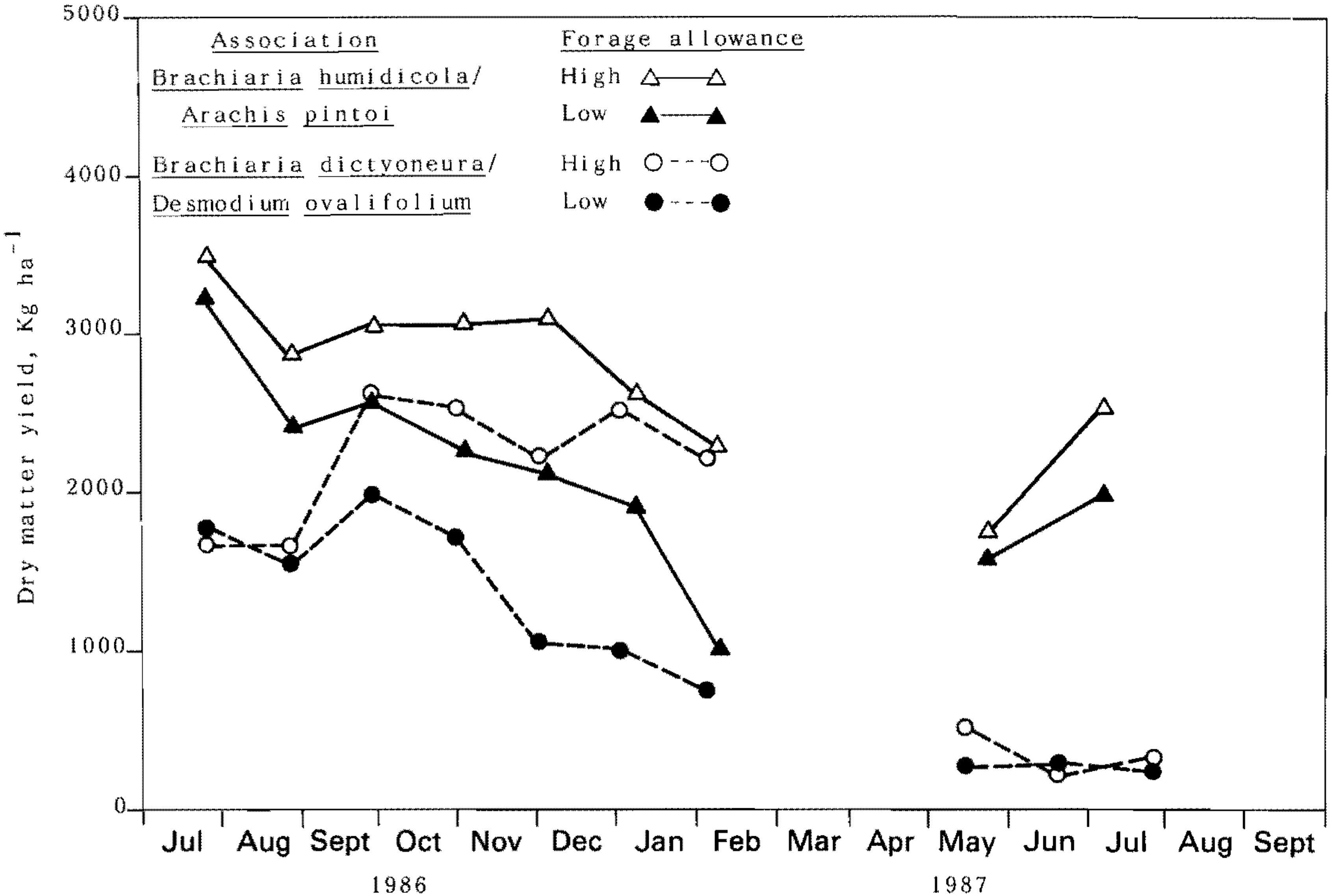


Figure 3. Yield of live legume in two associations at Carimagua grazed at two levels of forage allowance. Data are means of accessions.

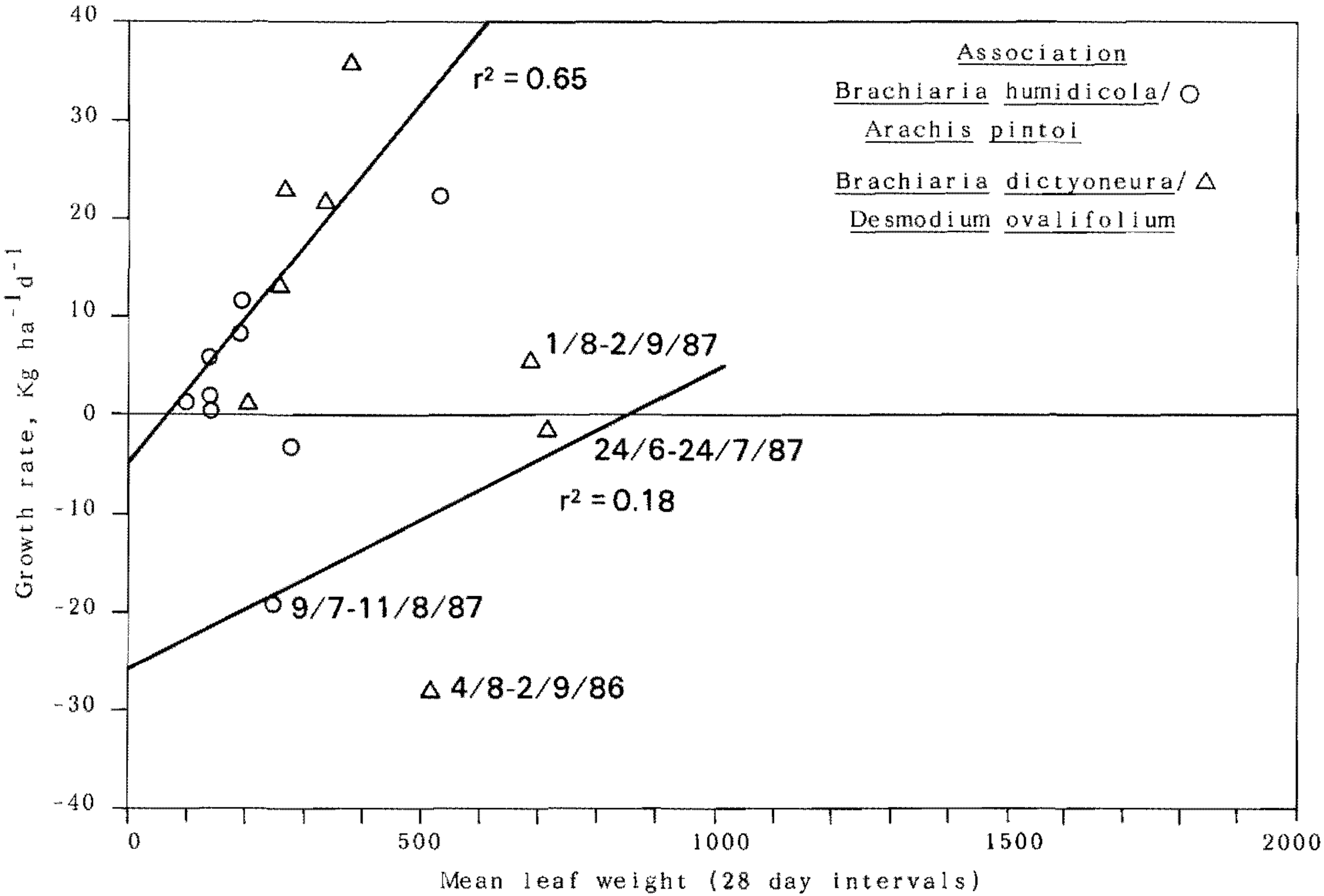


Figure 4. Relation between growth rate and mean leaf weight of the grass component of two associations at Carimagua grazed at low forage allowance. Data are means of accessions.

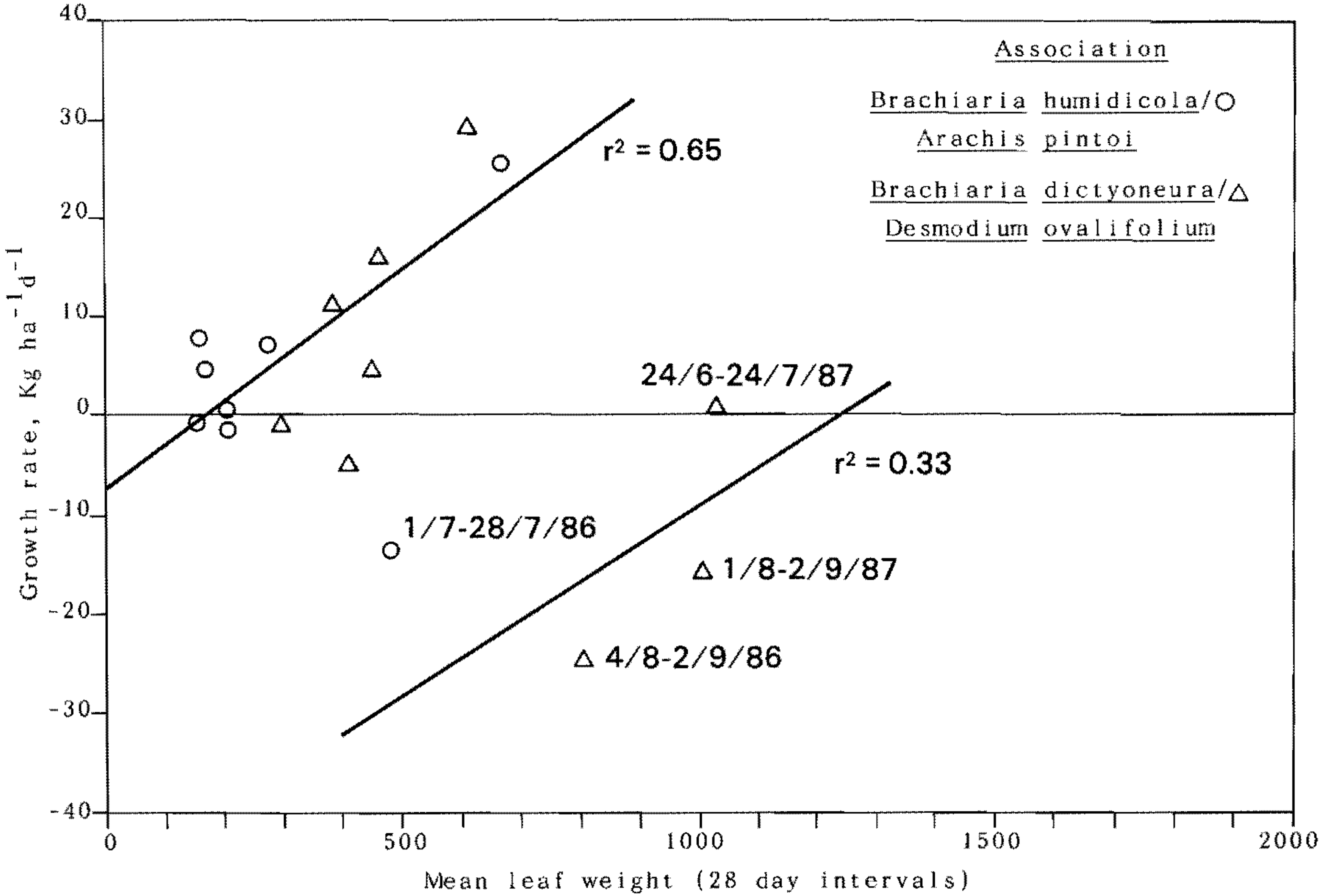


Figure 5. Relation between growth rate and mean leaf weight of the grass component of two associations at Carimagua grazed at high forage allowance. Data are means of accessions.

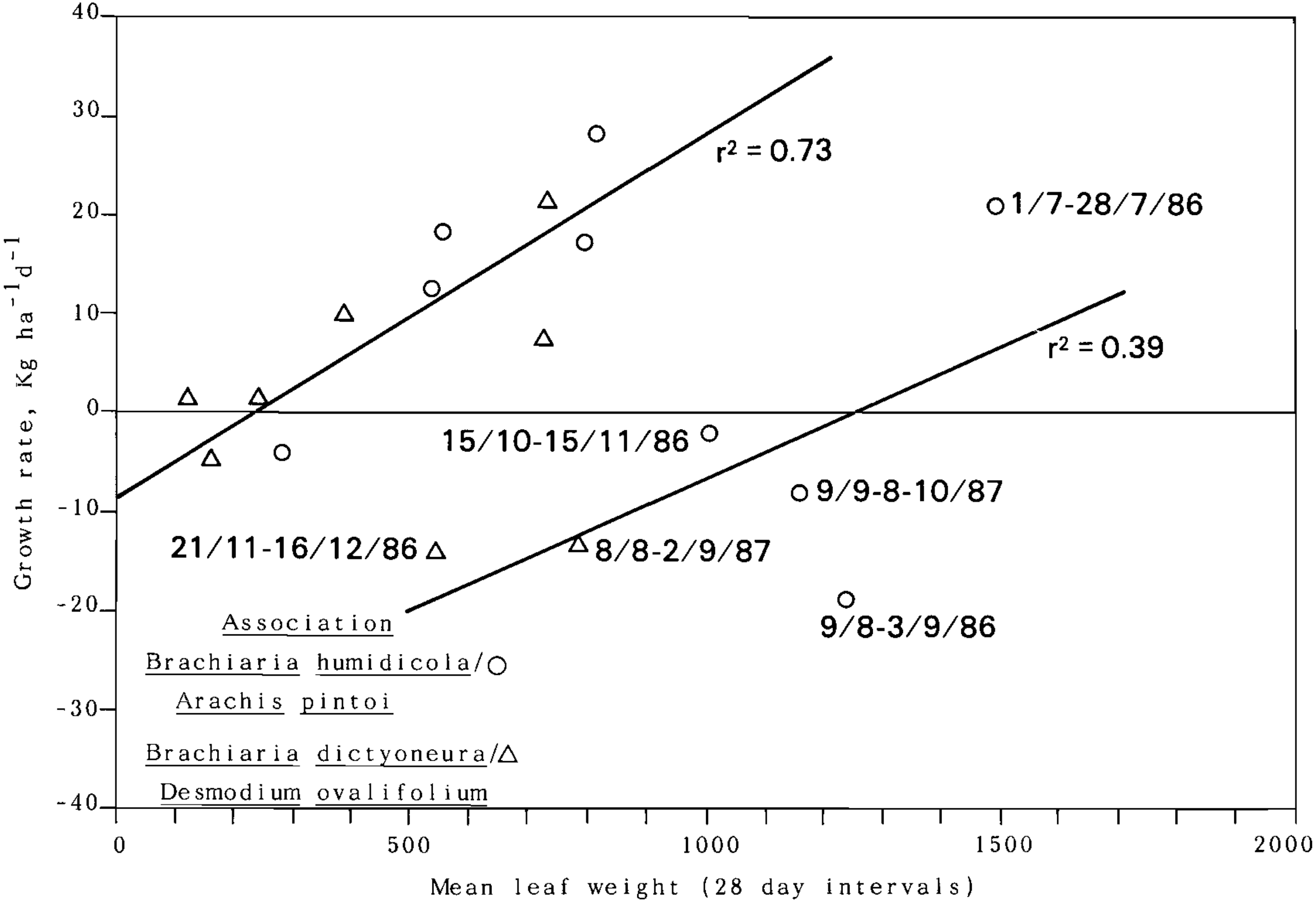


Figure 6. Relation between growth rate and mean leaf weight of the legume component of two associations at Carimagua grazed at low forage allowance. Data are means of accessions.

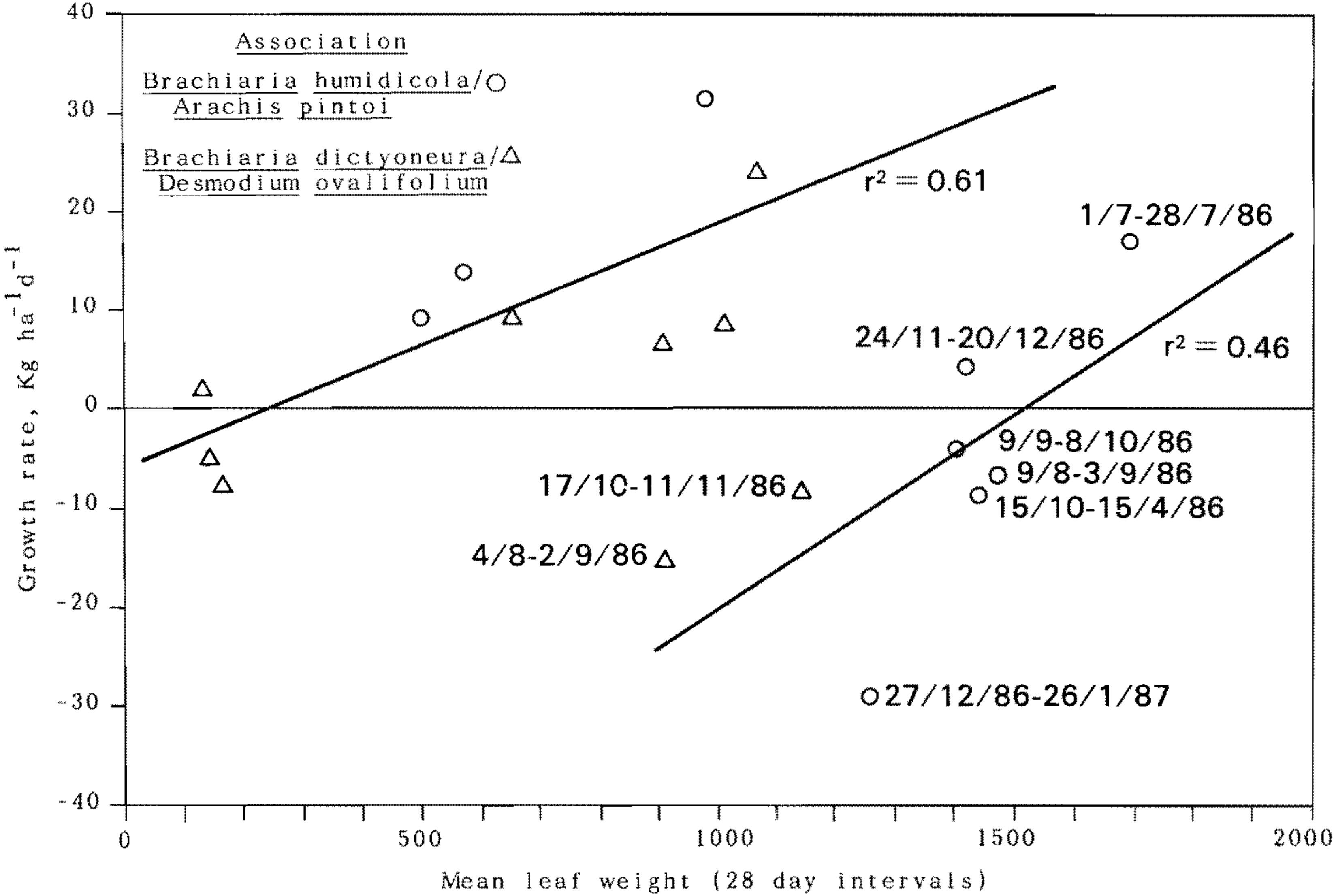


Figure 7. Relation between growth rate and mean leaf weight of the legume component of two associations at Carimagua grazed at high forage allowance. Data are means of accessions.

The major difference between the two sites described above seems largely to be in texture of the soils rather in their chemical characteristics. However it is not easy to understand how differences in soil texture could influence plant growth to the extent that they appear to do, and it is hypothesized that other factors, correlated with soil texture, are responsible and operate by influencing the competitive relations between the two components of the sown pasture.

In order to obtain some preliminary data about the nature of edaphic adaptation and its influence on plant relations, an experiment to examine competitive relations between the components of selected grass-legume associations was established in July-August at Carimagua on four sites with contrasting soil texture. The sites were Alcancia (12 percent sand), two sites at Yopare (24 and 36 percent) and Alegria (50 percent). At each site the following five associations were established as main plots:

Andropogon gayanus cv. Carimagua 1
- Stylosanthes capitata cv. Capica

Andropogon gayanus cv. Carimagua 1
- Centrosema acutifolium cv. Vichada

Brachiaria dictyoneura CIAT 6133
- Arachis pintoi CIAT 17434

Brachiaria dictyoneura CIAT 6133
- Desmodium ovalifolium CIAT 13089

Brachiaria dictyoneura CIAT 6133
- Centrosema Acutifolium cv. Vichada

The sub-plots were a replacement series between the two components with establishment ratios of: 1.0/0.0, 0.75/0.25, 0.50/0.50, 0.25/0.75, and 0.0/1.0.

Measurements will be made in order to assess across the four sites changes in relative replacement rate between the components with time, as well their chemical composition, root distribution, and water relations. Further treatments and measurements, for example, the influence of fertilizer treatments on relative replacement rate and the form of the competitive relations between the components of the associations, will be developed as the data are obtained.

15. PASTURE QUALITY AND PRODUCTIVITY

The Pasture Quality and Productivity Section has continued to concentrate its efforts on the evaluation of quality factors of promising germplasm and in determining the requirements of grazing management and levels of animal productivity in pastures with category IV germplasm. In addition, the Section has been working on the development of pasture evaluation methodologies under grazing relevant to the RIEPT. This report summarizes the results of grazing trials in progress and of methodological work experiments already concluded.

PASTURE MANAGEMENT AND PRODUCTIVITY

During 1987 a grazing experiment with Brachiaria dictyoneura (6133) in association with Desmodium ovalifolium (350) continued to be evaluated at the CIAT-Quilichao Substation. Evaluation of B. decumbens alone and in association with Kudzú and with pastures based on C. acutifolium (5277-5568) continued at the Carimagua Station. The evaluation of B. decumbens alone and in association with Stylosanthes capitata cv. Capica + C. acutifolium cv. Vichada was initiated at Carimagua.

Grazing trial - Quilichao

Grazing of B. dictyoneura/D. ovalifolium

This report presents results of 3.5 years of grazing, always using a rotational system of 7 days of occupation and 21 days of rest.

Figure 1 shows average daily weight gain for the three stocking rates; the effect of grazing intensity and the reduction in gains over time are clearly evident. Complementary measurements conducted in this trial show that the lowest weight gain obtained under high stocking rate was associated with a lower availability of green grass dry matter (Figure 2). On the other hand, the decline in weight gains over time in this pasture have been associated with a drastic reduction of D. ovalifolium 350 in the forage on offer and in the selected diet (Figure 3), thus determining a reduction in the level of crude protein in the selected forage (Figure 4).

Obviously, this pasture has had low stability over time, particularly for the legume component; this is greatly due to an earthworm (Euetheola sp.) attack during the second year of grazing. Frequent and prolongued dry periods during the third year of grazing have also contributed to D. ovalifolium's low regeneration through new plant recruitment from soil seed reserves. The trial will continue for one more year and final analysis of results will seek to establish the relationships between pasture attributes and weight gains.

Grazing Trials - Carimagua

Grazing of B. decumbens with and without Kudzú

The grazing trial with B. decumbens

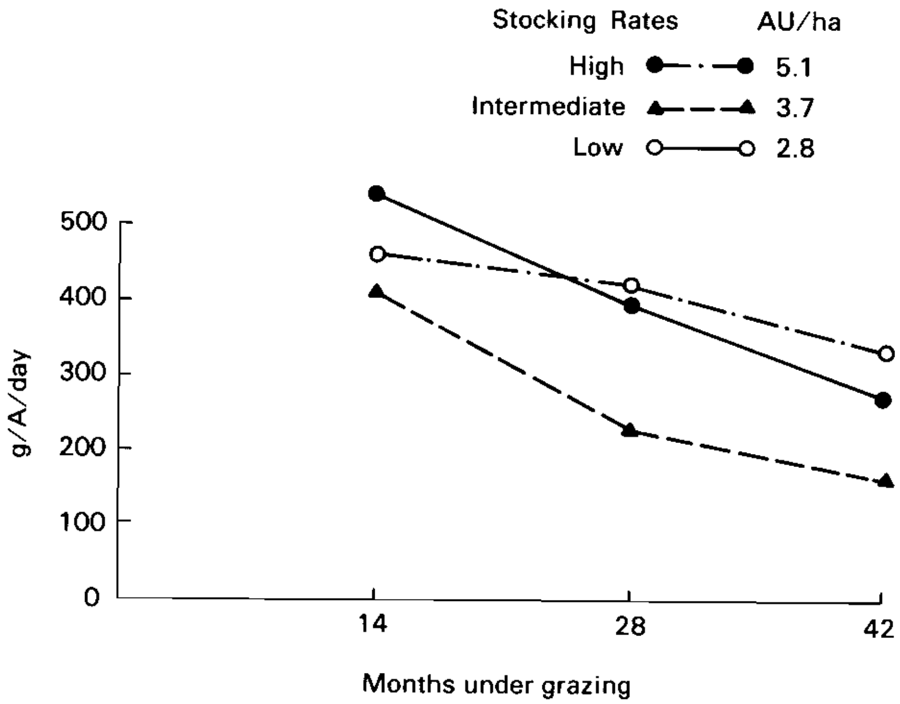


Figure 1. Average daily weight gain in B. dictyoneura/D. ovalifolium 350 under rotational grazing with three stocking rates (Quilichao).

alone and in association with Kudzú entered its ninth year of evaluation. In the 1986 Report information was given on a severe spittlebug attack on the two replications of B. decumbens + Kudzú, which was associated with a high accumulation of biomass, possibly due to recycling of nitrogen from the legume. This spittlebug attack on B. decumbens determined that the association be grazed during the rainy season of 1986 under a lower stocking rate (1.5 A/ha) than that used for the pure stand (2.5 A/ha). However, during the dry and rainy seasons of 1987 both treatments were grazed under the same stocking rate (1.0 A/ha and 2.0 A/ha during the dry and wet periods, respectively). This decision was based on an excellent recovery of B. decumbens and Kudzú in both replications (Figure 5). Recovery was possibly influenced by the lower stocking rate used during the rainy season of 1986 when the spittlebug attack took place and also by a maintenance fertilization (10 kg P, 10 kg K, 10 kg S, and 5 kg Mg/ha) applied to all pastures at the beginning of the rainy period of 1987.

Weight gains obtained during 1987 are presented in Table 1. During the dry season, weight gains were greater for the association than for the grass alone; these results are consistent with what has been observed others years. It must be pointed out that the 1987 dry season was not severe, determining relatively high weight gains. In contrast, rainfall during the year was very high (> 2700 mm until October), which resulted in puddling of the paddocks and yellowing of B. decumbens and, thus, low weight gains for all treatments. However, even during this period weight gains in the association were two-fold greater than those in the pure grass.

Grazing of B. decumbens with and without legumes (S. capitata and C. acutifolium

In the grazing trial with B. decumbens

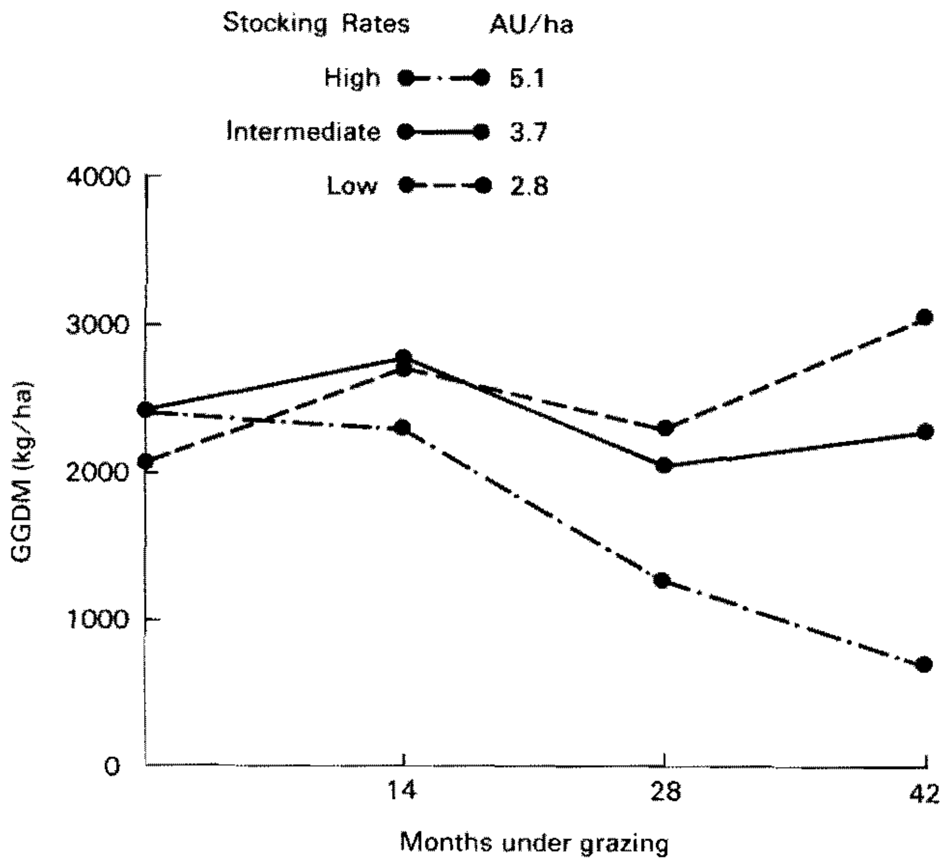


Figure 2. Availability of grass green dry matter (GGDM) in B. dictyoneura/D. ovalifolium 350 under rotational grazing with three stocking rates (Quilichao).

with and without Kudzú, weight gains have been consistently greater in association than in monocrop (130 vs. 180 kg/A/year). However, it has been interesting to observe that productivity of B. decumbens without the legume has been relatively stable over time (see 1985 Annual Report). This is contrary to what would be expected in a grass pasture grown in a soil with low organic matterwithout nitrogen application. On the other hand, it would be postulated that the productivity of B. decumbens would decline rapidly in soils with relatively high sand content and consequently less organic matter. In order to prove this hypothesis, a grazing trial was established in a sandy soil (30% sand) in which B. decumbens was included alone and in association with S. capitata/C. acutifolium, and managed under the same stocking rate (2 A/ha) and two alternate grazing systems (7/7 and 21/21, days of occupation/rest). Grazing began during the dry season of this year, with similar management for all pastures; treatments were imposed at the beginning of the rainy period. Differences in weight gain among treatments have been quickly evidenced, with greater gains in the association (556 g/A/day) than in the

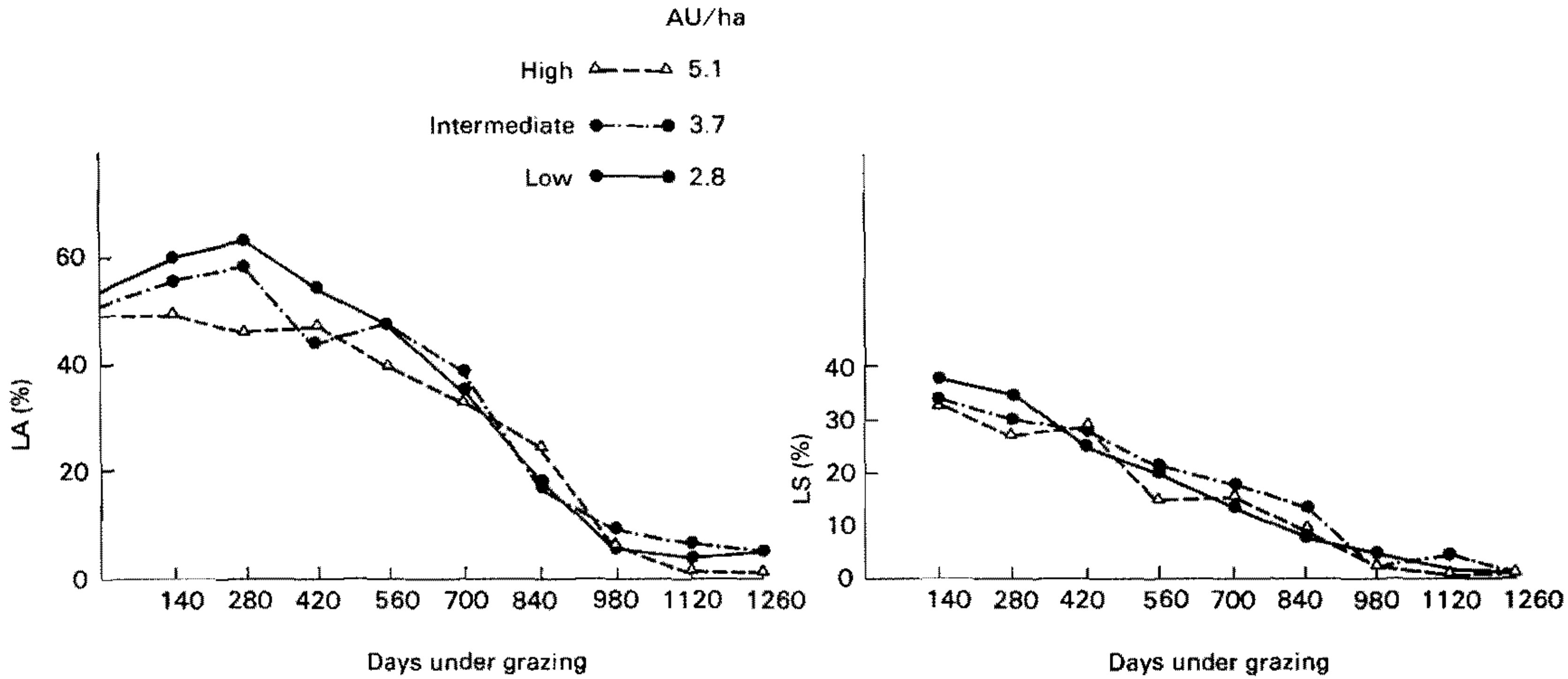


Figure 3. Proportion of selected and available legume in B. dictyoneura/D. ovalifolium 350 under rotational grazing with three stocking rates (Quilichao).

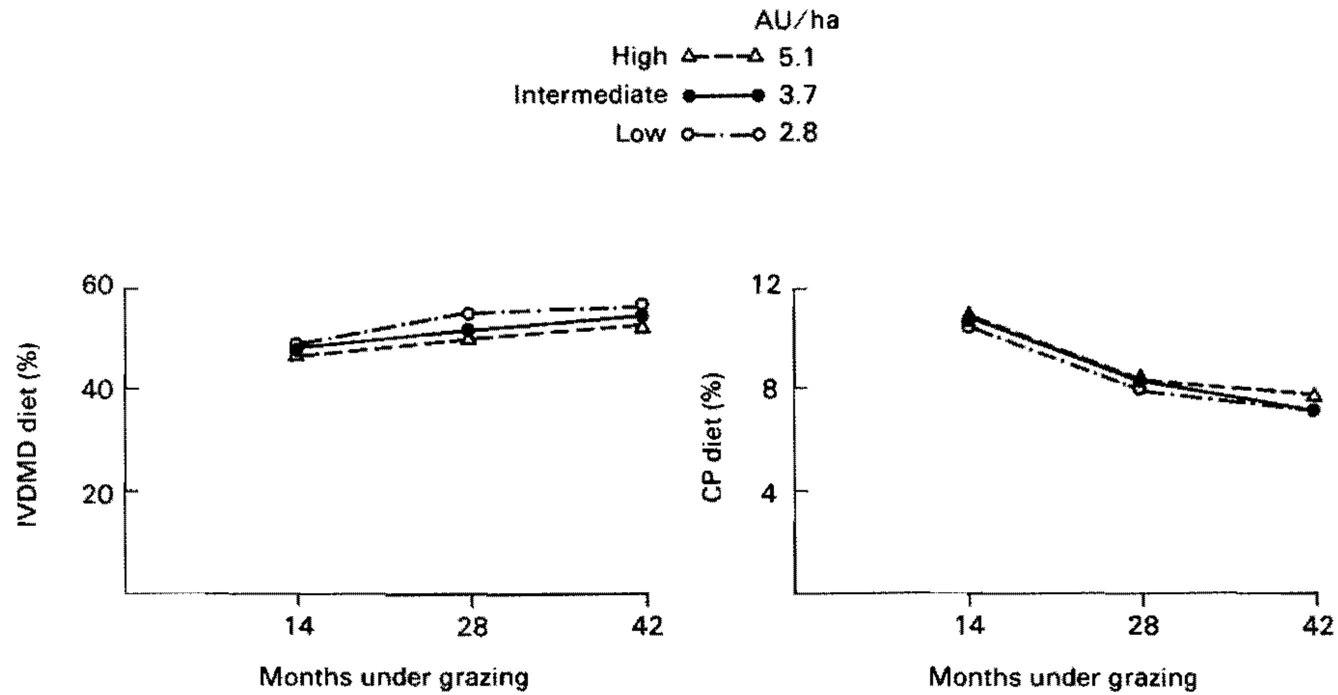


Figure 4. *In vitro* dry matter digestibility (IVDMD) and crude protein (CP) of the selected diet in *B. dictyoneura*/*D. ovalifolium* 350 under rotational grazing with three stocking rates (Quilichao).

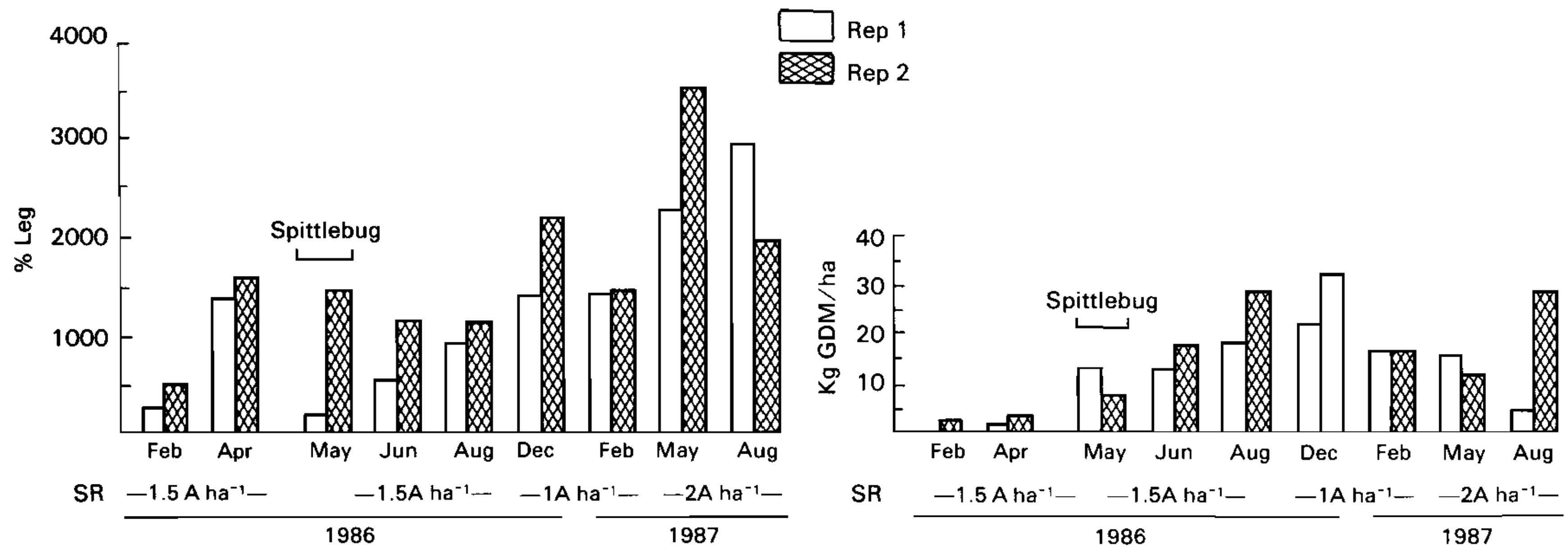


Figure 5. Availability of green dry matter (GDM) and legume (%) in a *B. decumbens*/Kudzu association under continuous grazing (8th and 9th year of grazing - Carimagua).

Table 1. Seasonal weight gains in B. decumbens alone and in association with Kudzu (1987-9th year of grazing - Carimagua).

Pasture	Stocking rate D/R (A/ha)	Period		Year (kg/A)
		Dry[1]	Rainy[2]	
		------- g/A/día) -----		
B. decumbens	1/2	450^{b}	172^{b}	94
B. decumbens/Kudzú	1/2	522^{a}	389	157
	$\bar{x}$	486	281	

1/ 111 days
2/ 254 days
a, b, Different means (P > .07)

grass alone (437 g/A/day) (Table 2). In addition, a tendency for greater weight gains was observed in the 7/7 system over the 21/21 system. Availability of forage, measured during the rainy period, has been similar for both grazing systems, but greater in the association (2113 kg DM/ha) than in the monocrop (1460 kg DM/ha). It is expected that larger differences in the availability of forage between treatments be observed over time, which in turn would reflect on animal productivity.

Grazing of Native Grasses with C. acutifolium

In 1984, a Category IV grazing trial was established in Carimagua with A. gayanus in association with C. acutifolium (5277-5568) under different grazing managements. The trial was initiated in April 1985 and data on weight gain were reported until the end of 1986 (See 1986 Annual Report). A severe ant attack (Acromyrmex sp.) resulted in the loss of A. gayanus in all treatments, being replaced by native grasses, mainly A. bicornis. Given the high proportion of C. acutifolium in all treatments it was decided to continue the trial during 1987. Weight gain results (Table 3) show that both during the dry as well as the rainy seasons, weight gains were influenced by management, but acceptable in all cases. With the intermediate stocking rate (1.0 A/ha) under continuous grazing, animals gained more weight than during the high stocking rate (1.5 A/ha) under rotational grazing, with no differences observed in the low stocking rate (0.75 A/ha) under continuous grazing. The greater weight gain with the intermediate stocking rate was associated with a higher proportion of A. gayanus in the forage on offer.

An interesting result of this trial has been the high proportion of legume in the diet selected by the grazing animals, particularly during the rainy season (Table 4), contrary to what was observed when the predominating grass was A. gayanus (see 1986 Annual Report). These results indicate that to a great extent, animals have substituted low-quality-native grasses for legume, thus resulting in acceptable weight gains. It is postulated that the legume is contributing not only a high level of protein to the animals but also energy. With the introduction of C. acutifolium cv. Vichada in a better-quality savanna (i.e. T. vestitus) in

Table 2. Weight gain *Brachiaria decumbens* alone and associated with legumes under two grazing systems (1987 - Carimagua) [1].

Pasture	Grazing system Stocking rate A/ha ------- g/A/day ---------	7/7[2]	21/21	$\bar{x}$
B. decumbens	2.0	479	399	439b
B. decumbens/S. capitata/ C. acutifolium	2.0	559	540	550a
$\bar{x}$		519	470	

1/ 243 rainy days - 1st. year of grazing.
2/ Alternation (days occupation/days rest).
a, b Different means (P < .08).

Table 3. Seasonal weight gains in *C. acutifolium* 5277-5568 associated with native grasses (1987 - Carimagua).

Grazing management (Stocking rate)	Period of the year Drought[1] (g/A/day)	 Rainy[2]	$\bar{x}$
Continuous grazing (0.75 A/ha)	424	449	437 a,b
Continuous grazing (1.0 A/ha)	464	530	479a
Rotational grazing (1.5 A/ha)	371	407	389b
$\bar{x}$	419	462	

1/ 112 days
2/ 252 days
a, b, Different means (P < .10)

Table 4. Proportion of C. acutifolium 5277 + 5568 in the forage on offer and forage selected in associations with native grasses (1987 - Carimagua).

Grazing management (Stocking rate)	Period of the year			
	Drought[1]		Rainy[2]	
	On offer	Diet	On offer	Diet
	% leg.		% leg.	
Continuous grazing (0.75 A/ha)	20	27	29	63
Continuous grazing (1.0 A/ha)	19	4	26	33
Rotational grazing (1.5 A/ha)	71	56	48	91

1/ Samplings December 86 and February 1987
2/ Samplings May-August 1987

the absence of burning, substitution of the grass for the legume would be less.

The trial will continue and measurements on botanical composition will be moded to determine the dynamics of native grasses and of the legume.

New Trials in Category IV

During 1987 new grazing trials with Category IV legumes were established in Carimagua. The first trial includes B. humidicola 679 alone and in association with D. ovalifolium 13089, which is an ecotype selected for its tolerance to the stem-gall nematodes. The experiment has been replicated in two sites with different soil textures (0 and 30% sand) and also replicated within each site, including the following treatments in a completely randomized design with an incomplete factorial arrangement:

1. Association and grass alone.
2. Variable stocking rates for season of the year with 2 and 3 A/ha during the dry period and 3 and 4 A/ha during the rainy season, for the association. For the grass alone, only the high stocking rate of the dry (3 A/ha) and rainy (4 A/ha) periods are included.

The grazing system to be used will be alternate and flexible, depending on the grass/legume balance in the forage available.

A second replicated trial includes B. dictyoneura cv. Llanero (6133) and B. humidicola 679 alone and in association with A. pintoi 17434. Three stocking rates are included as management factors 4 ha in B. humidicola (2.3 and 4 A/ha) and in B. dictyoneura (2, 2.5, and 3.0 A/ha) with an alternate and flexible grazing system depending on the grass/legume balance of the pasture.

METHODOLOGICAL STUDIES

The Section has been working the host years on the development of methodologies for pasture evaluation under grazing relevant to the RIEPT. The following is a summary of the trials in progress and of studies already concluded.

Flexible Grazing Management - Carimagua

Both in the Carimagua Station as well as in Quilichao, trials are in progress to evaluate the strategy of flexible grazing management proposed as an alternative for the RIEPT. In the Carimagua trial, contrasting grasses (A. gayanus cv. Carimagua and B. dictyoneura cv. Llanero + B. brizantha cv. Marandú) are being evaluated in association with Centrosema spp. (C acutifolium 5277, C. macrocarpum 5452, and C. brasilianum 5234) under two ranges of grazing pressure (3-5 and 6-8 kg GDM/100 kg LW/day). Planting was done in 1985 and grazing was initiated in April 1986, initial weight gains having been reported in the 1986 Annual Report. During 1987 the trial continued to be grazed and large differences in weight gains have been recorded between treatments. The legume proportion in the forage on offer with the two grasses under the low and high pressures is presented in Figure 6. Evidently C. acutifolium cv. Vichada is the most productive legume with both an erect (A. gayanus) as well as a stoloniferous grass (B. dictyoneura). On the other hand, it is interesting to observe that C. brasilianum 5234 has been favored by the high grazing pressure with both grasses, while C. macrocarpum has persisted more with B. dictyoneura + B. brizantha than with A. gayanus, both under low and high pressures.

The difference in the proportion of the legumes in the forage on offer has determined different grazing management strategies (Table 5). During the dry period all the pastures were managed with a 7/7 system, to favor the ability of the animals to selct. However, during the rainy period different managements had to be imposed to favor the grass or legume. The 21/21 system was used with A. gayanus/C. acutifolium under low pressure to favor the grass, in view of the tendency of legume dominance. This same tendency is being observed in B. dictyoneura + B. brizantha/C. acutifolium under low grazing pres sure, which will dictate a change from the 14/14 system actually used to a 21/21 alternate system. In the case of associations with B. dictyoneura + B. brizantha under high grazing pressure it has been necessary to impose a 21/21 alternate system, not because of an excess of the legume but due to the low availability of the two grasses since the establishment phase. Relatively frequent grazing (14/14) of C. brasilianum 5234 and C. macrocarpum 5452in association with A. gayanus and B. dictyoneura + B. brizantha have not favored the legume productivity of these legumes has been more affected by the companion grass and the grazing pressure used than by grazing frequency. Specifically, C. macrocarpum 5452 has practically disappeared in the associations with A. gayanus, independently of the grazing pressure used. In contrast C. brasilianum has persisted with both grasses, but its productivity has been greater under high grazing pressure.

In this grazing experiment legume proportion in the pastures has been positively related to weight gains (Table 6). During the first grazing period (rains 1986), no differences in weight gains were observed among associations. However, during 1987, weight gains were higher for the associations with C. acutifolium, both during the dry and the rainy periods as compared with the other associations. These greater weight gains in C. acutifolium-based pastures were associated with a high legume proportion in the diet selected both during the dry as well as the rainy periods (Table 7).

Flexible Grazing Management - Quilichao

During 1985, a grazing trial was established in the Quilichao Station

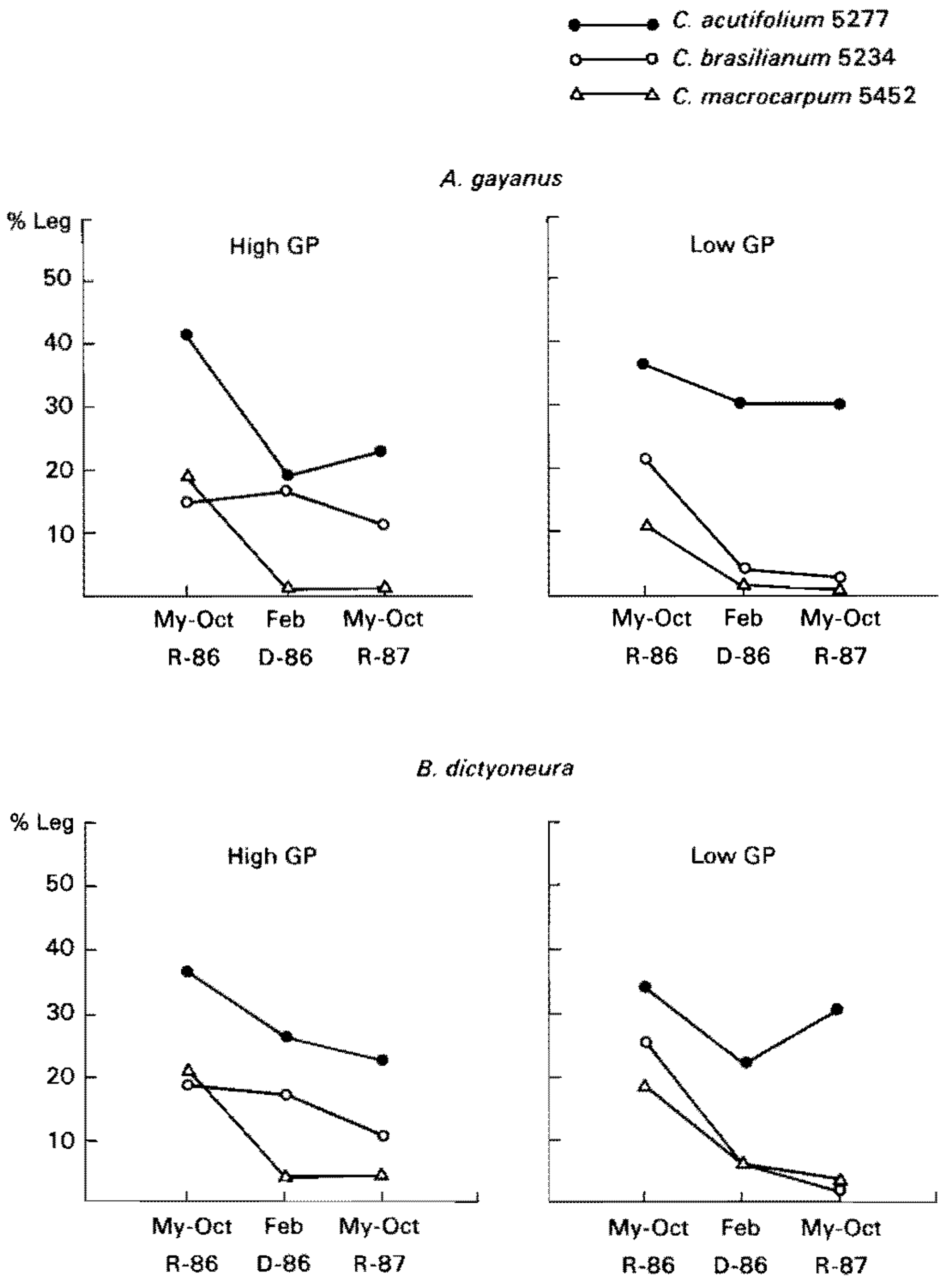


Figure 6. Legume proportion in associations with two grasses and Centrosema spp. undeer alternative/flexible grazing (Carimagua).

Table 5. Grazing management in associations of two grasses with *Centrosema* spp. under flexible grazing (1987 - Carimagua).

Association	Grazing pressures			
	High		Low	
	D-87	R-87	D-87	R-87
	Alternation system (Days of grazing/days of rest)			
A. gayanus				
+ *C. acutifolium* 5277	7/7	14/14	7/7	21/21
+ *C. brasilianum* 5234	7/7	14/14	7/7	14/14
+ *C. macrocarpum* 5452	7/7	14/14	7/7	14/14
$\bar{x}$	7/7	14/14	7/7	16/16
B. dictyoneura/*B. brizantha*				
+ *C. acutifolium* 5277	7/7/	21/21	7/7	14/14
+ *C. brasilianum* 5234	7/7	21/21	7/7	21/21
+ *C. macrocarpum* 5452	7/7	21/21	7/7	14/14
$\bar{x}$	7/7	21/21	7/7	16/16

1/ Dry period.
2/ Rainy period.

Table 6. Seasonal weight gains in different grass/legume associations under alternate/flexible grazing (1987 - Carimagua).

Pasture	Period of the year		
	Rainy 86 (216 days)	Drought 87 (110 days)	Rainy 87 (243 days)
	g/A/day		
A. gayanus			
- *C. acutifolium* 5277	469	498a	535a
- *C. brasilianum* 5234	450	132d	350b
- *C. macrocarpum* 5452	481	209cd	427b
$\bar{x}$	467	280	437
B. dictyoneura/*B. brizantha*			
- *C. acutifolium* 5277	345	441a	487a
- *C. brasilianum* 5234	426	316bc	466ab
- *C. macrocarpum* 5452	427	261c	274b
$\bar{x}$	399	339	409

a, b, c, d, Different means in the same column ($P < .05$).

Table 7. Legume selectivity in associations of two grasses with Centrosema spp. under alternate/flexible grazing with two pressures (1987 - Carimagua).

Associations	High pressure			Low pressure		
	R/86[1]	D/87[2]	R/87[3]	R/86	D/87	R/87
	(% leg.in diet)			(% leg.in diet)		
A. gayanus						
- C. acutifolium 5277	4	23	19	32	78	54
- C. brasilianum 5234	5	0	1	13	2	3
- C. macrocarpum 5452	19	1	0	2	0	0
B. dictyoneura/B. brizantha						
- C. acutifolium 5277	26	38	43	21	59	21
- C. brasilianum 5234	4	6	33	8	14	7
- C. macrocarpum 5452	9	6	4	12	20	22

1/ Average of 2 samplings (August/October 1986)
2/ Average of 1 sampling (February 1987)
3/ Average of 2 samplings (May/September 1987)

to be managed with the flexible grazing approach. The trial includes associations of A. gayanus with C. acutifolium 5277-5568 and C. macrocarpum 5713 under two ranges of grazing pressure (3-5 and 6-8 kg GDM/ 100 kg LW/day). The grazing system being use is alternate/flexible, depending on the grass/legume balance of the pastures. Great differences in botanical composition were quickly observed between associations and between grazing pressures in each association. The legume proportion in each period of the year for both associations and grazing pressures is ppresented in Figure 7. It is evident that C. macrocarpum 5713 has been more productive than C. acutifolium 5277-5568 under the two grazing pressures imposed. However, C. macrocarpum has been observed to be more affected by grazing pressure than C. acutifolium the low grazing pressure, the C. macrocarpum has tended to dominate the grass, thus a 28/28 grazing system was imposed to favor the grass. Productivity of this legume has been significatintly affected in the high grazing pressure and relatively frequent grazing (16/16) has not favored the legume. Similarly, very frequent grazing (7/7) has not favored C. acutifolium under the low or high grazing pressures.

Weight gains in this trial have been high during periods of minimum and maximum rainfall periods (Figure 8). During the period of minimum precipitation, weight gains were greater for the association of A. gayanus with C. macrocarpum than with C. acutifolium, this being associated with a greater legume proportion in the forage on offer and selected by the grazing animals. On the other hand, during the period of maximum rainfall,

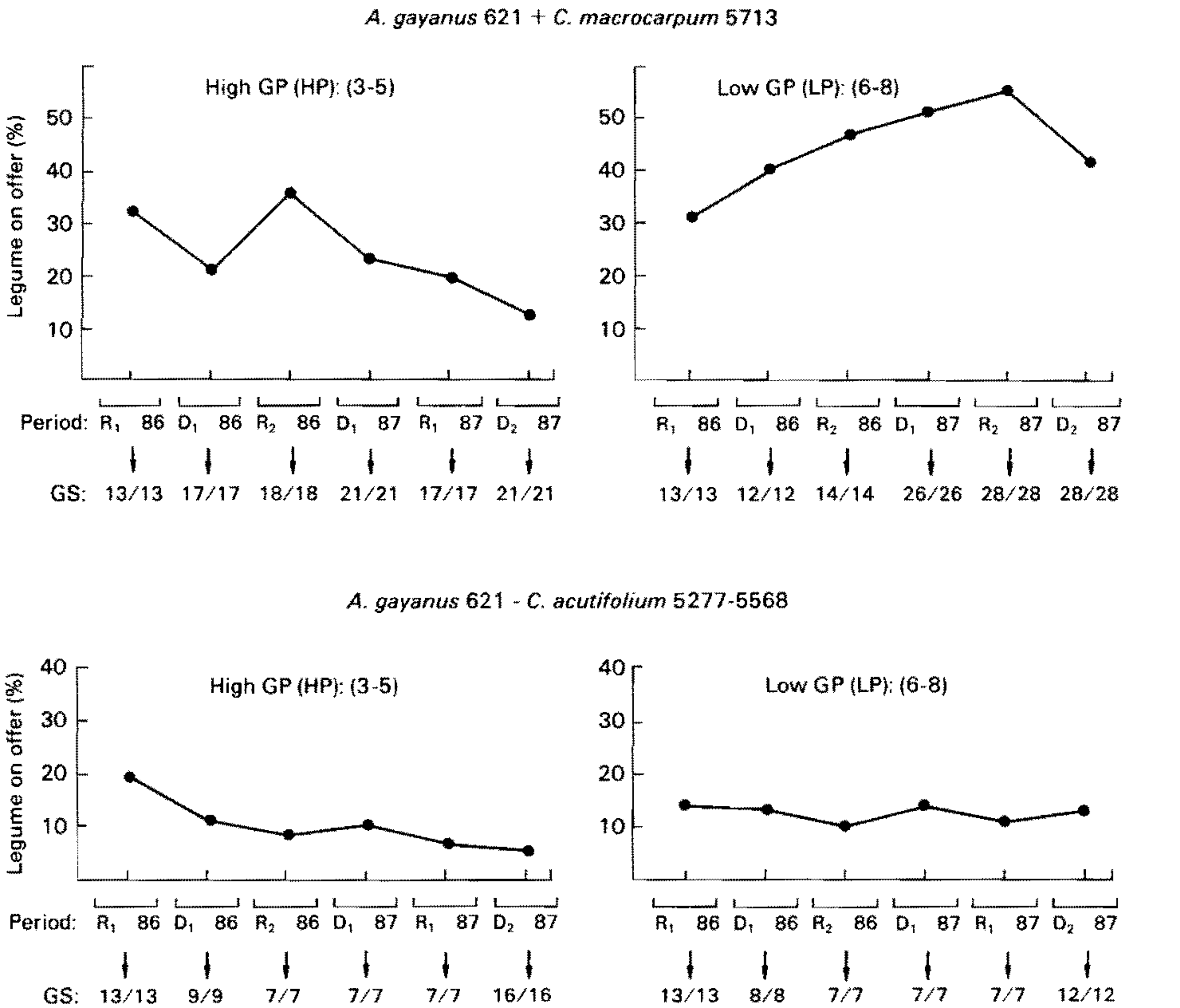


Figure 7. Legume proportion on offer in two associations under alternate/flexible grazing with two pressures (GS=Grazing System; days of occupation/days of rest).

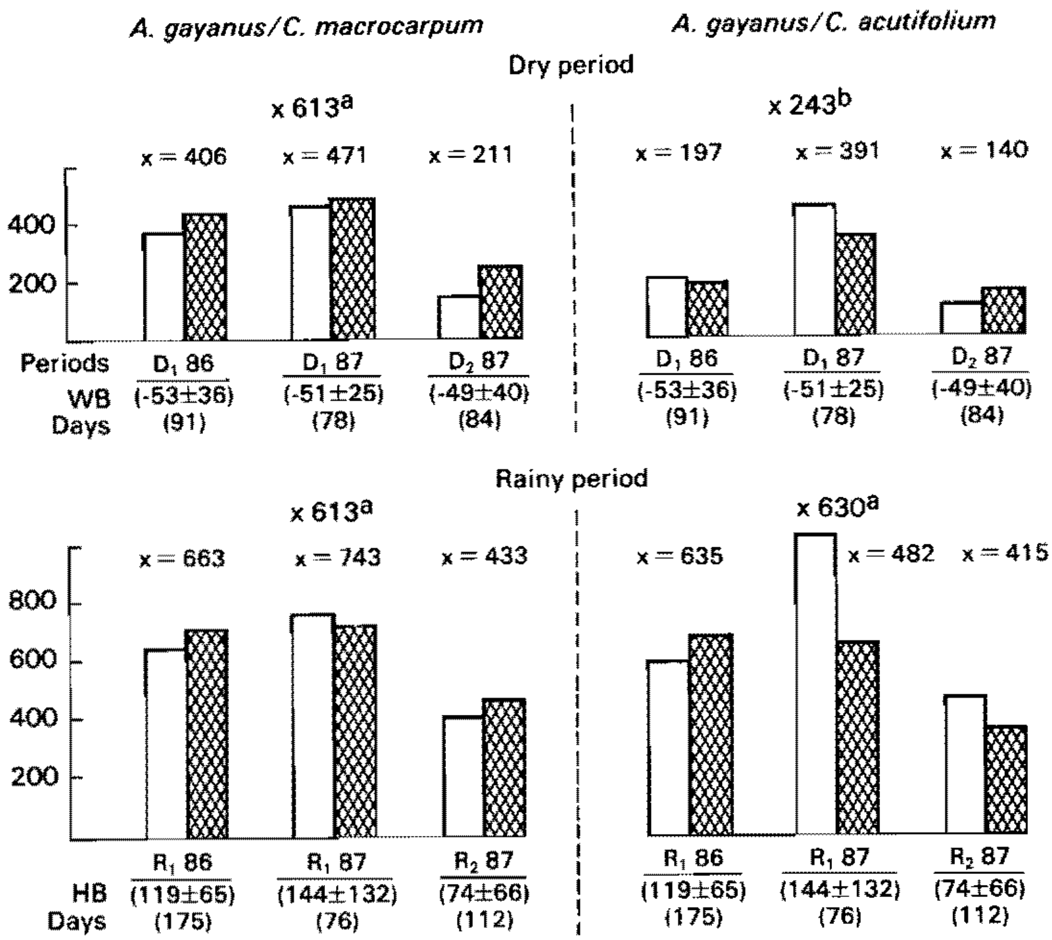


Figure 8. Seasonal weight gain of two associations under alternate/flexible grazing with two pressures [(WB = Water Balance) (Quilichao) a.b. different means ($P < .05$); High pressure (3-5 kg GDM/100 kg LW/day); Low pressure (6-8 kg GDM/100 kg LW/day).

weight gains have been similar in both associations with little difference due to grazing pressure.

Results obtained to date in the two flexible grazing trials (Carimagua and Quilichao) clearly show germplasm x environment x management interaction. In Carimagua, C. acutifolium cv. Vichada has proved to be a very well adapted and productive legume in association with grasses of contrasting growth habit and under different grazing managements. In contrast, in Quilichao, C. macrocarpum 5713 is more productive than C. acutifolium but very sensitive to high grazing intensities.

Overall, the strategy of flexible grazing has allowed to:

1. Reduce the experimental area and/ or increase the number of treatments.
2. Determine the degree of compatibility between grasses and legumes.
3. Select more productive associations for the two sites (i.e. Carimagua and Quilichao) under contrasting grazing intensities.
4. Define in some cases an occupation/rest scheme for the pastures to maintain an adequate grass/legume balance in the forage on offer.
5. Define a carrying capacity range for the more productive associations.
6. Determine potential animal production of the associations under study.

Finally, it must be mentioned that less frequent grazing (i.e. 21/21 or 28/28) has favored the grass only when well adapted legumes tend to dominate. More frequent grazing (i.e. 7/7 or 14/14) has not resulted in an increase in the proportion of those legumes poorly adapted to the site or that are very sensitive to high stocking rates. In the latter case, it is possible that a less frequent grazing system or continuous grazing is required to favor the legume.

Grazing Management and Legume Persistence/RTC

With the object of studying the compatibility and persistence of the species palnted as a function of grazing management factors, it has been proposed that grazing trials be carried out in small plots (RTC) in certain sites of the RIEPT which are representative of a particular ecosystem.

In the Quilichao Station a prototype RTC trial was established, including the following treatments in a split plot design with two replications:

1. Main plot: rest periods of 2, 4, and 6 weeks and fixed occupation of 3.5 days.
2. Subplot: associations of A. gayanus with S. guianensis 1283, Z. glabra 7847, C. macrocarpum 5048 - 5451, and C. acutifolium 5277 - 5568.
3. Sub-subplot: low (2.4 AU/ha) and high (3.6 AU/ha) stocking rates.

The legumes S. guianensis 1283 and Z. glabra 7847 were not persistent, regardless of the management treatments imposed. In the case of S. guianensis 1283 plants suffered from a severe anthracnose attack during the first year; Z. glabra 7847 plants also disappeared at the end of the first grazing year due to competition with A. gayanus and/or lack of tolerance to grazing.

The two Centrosema species were subjected to grazing during three years and a summary of the results obtained follows. A strong grazing system x stocking rate interaction was observed in terms of the availability of A. gayanus green dry matter (Figure 9). The stocking rate effect on the availability of A. gayanus in both associaweight gains have been similar in both associations with little difference due to grazing pressure.

Results obtained to date in the two flexible grazing trials (Carimagua and Quilichao) clearly show germplasm x environment x management interaction. In Carimagua, C. acutifolium cv. Vichada has proved to be a very well adapted and productive legume in association with grasses of contrasting growth habit and under different grazing managements. In contrast, in Quilichao, C. macrocarpum 5713 is more productive than C. acutifolium but very sensitive to high grazing intensities.

Overall, the strategy of flexible grazing has allowed to:

1. Reduce the experimental area and/ or increase the number of treatments.
2. Determine the degree of compatibility between grasses and legumes.
3. Select more productive associations for the two sites (i.e. Carimagua and Quilichao) under contrasting grazing intensities.
4. Define in some cases an occupation/rest scheme for the pastures to maintain an adequate grass/legume balance in the forage on offer.
5. Define a carrying capacity range for the more productive associations.
6. Determine potential animal production of the associations under study.

Finally, it must be mentioned that less frequent grazing (i.e. 21/21 or 28/28) has favored the grass only when well adapted legumes tend to dominate. More frequent grazing (i.e. 7/7 or 14/14) has not resulted in an increase in the proportion of those legumes poorly adapted to the site or that are very sensitive to high stocking rates. In the latter case, it is possible that a less frequent grazing system or continuous grazing is required to favor the legume.

Grazing Management and Legume Persistence/RTC

With the object of studying the compatibility and persistence of the species palnted as a function of grazing management factors, it has been proposed that grazing trials be carried out in small plots (RTC) in certain sites of the RIEPT which are representative of a particular ecosystem.

In the Quilichao Station a prototype RTC trial was established, including the following treatments in a split plot design with two replications:

1. Main plot: rest periods of 2, 4, and 6 weeks and fixed occupation of 3.5 days.

2. Subplot: associations of A. gayanus with S. guianensis 1283, Z. glabra 7847, C. macrocarpum 5048 - 5451, and C. acutifolium 5277 - 5568.

3. Sub-subplot: low (2.4 AU/ha) and high (3.6 AU/ha) stocking rates.

The legumes S. guianensis 1283 and Z. glabra 7847 were not persistent, regardless of the management treatments imposed. In the case of S. guianensis 1283 plants suffered from a severe anthracnose attack during the first year; Z. glabra 7847 plants also disappeared at the end of the first grazing year due to competition with A. gayanus and/or lack of tolerance to grazing.

The two Centrosema species were subjected to grazing during three years and a summary of the results obtained follows. A strong grazing system x stocking rate interaction was observed in terms of the availability of A. gayanus green dry matter (Figure 9). The stocking rate effect on the availability of A. gayanus in both associa-

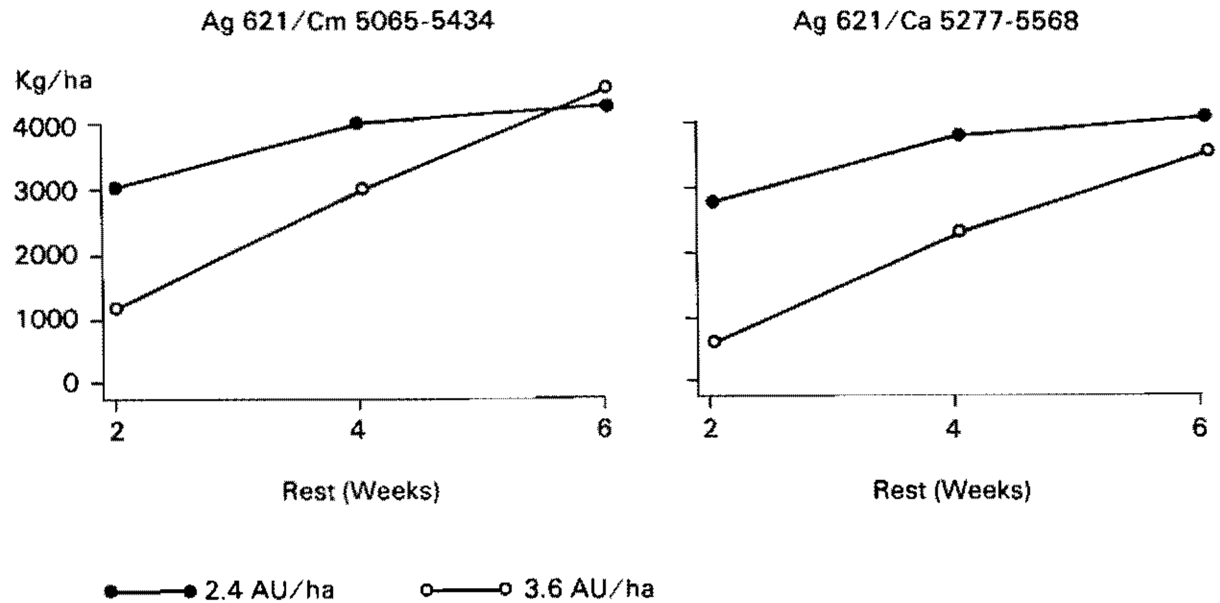


Figure 9. Effect of grazing frequency and stocking rate on the availability of green dry matter (GDM) in two associations (3 years of grazing).

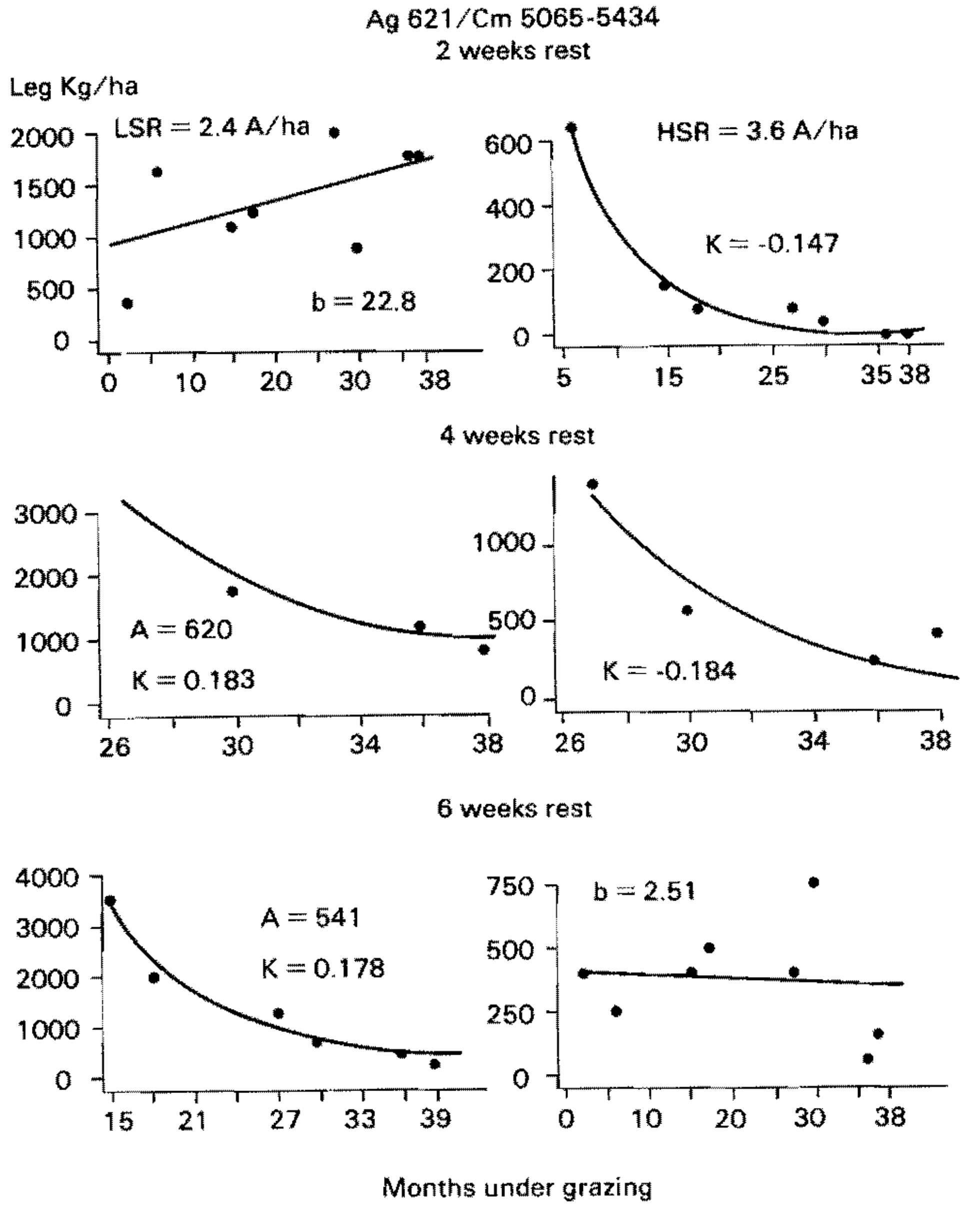


Figure 10. Dynamics of C. macrocarpum 5065-5434 in association with A. gayanus under different grazing management (2, 4, and 6 weeks of rest and low and high stocking rates) starting at the point of maximum availability (Quilichao).

tions was greater as grazing frequency increased. These results clearly indicate the need to apply rotational grazing systems when using high stocking rates in pastures based on A. gayanus.

To analyze the effect of grazing management factors on the persistence of the two Centrosema species under evaluation, data on legume availability (kg/ha) vs. months of grazing data were adjusted using appropriate models. Conceptually, the models which could be used to quantify legume persistence under grazing, are:

1. $y = a + bt \quad b \geq o$: stable legume, tending to increase over time

2. $y = A + B e^{-kt}$: stable legume after a given period of time

3. $y = A e^{-kt}$ or a - : legume, tending to disappear over time

The dynamics of C. macrocarpum 5065 - 5434 under the different managements evaluated is presented in Figure 10. It is evident that this legume persisted under the low stocking rate, but in different degrees, depending on the grazing system used. The legume was favored under a 2-week frequency, but declined under 4- and 6-week frequencies at a similar rate (k) and reached stable levels of availability (asymptote) of 620 and 541 kg/ha, respectively. Under the high stocking rate, availability of C. macrocarpum was seriously affected, particularly in the 2- and 4-week frequencies where the legume practically disappeared after three years of grazing. Under the highest stocking rate, the 6-week frequency resulted in low legume levels and with a tendency to disappear over time.

The dynamic, of C. acutifolium 5277 - 5568 is shown in Figure 11. The grazing management that resulted in greater legume availability was observed to be the low stocking rate (2.4 AU/ha) with 4 weeks of rest. In this case, grazing every 2 or 6 weeks did not favor the legume. On the other hand, the high stocking rate used resulted in a loss of the legume, regardless of the grazing frequency used.

In general, these results indicate that stocking rate was the grazing management factor that had the greatest effect on the persistence of the two Centrosema species under evaluation. Under the high stocking rate the two legumes had low persistence, independently from the grazing system used. However, under the low stocking rate used, grazing system had a different effect in terms of persistence of the two Centrosema species. With a 2-week frequency C. macrocarpum was favored, while with a 4-week frequency, C. acutifolum was favored. The 6-week frequency was detrimental for both legumes possibly due to competition effect by A. gayanus and/or because of greater legume consumption by the grazing animals due to overmaturity of the grass.

The results of this trial in small plots to a large extent are consistent with what has been observed in the flexible grazing trial in Quilichao. As indicated, before, in that trial grazing high pressure significantly affected the availability of C. macrocarpum. However, under low grazing pressure, the rest period had to be extended in order to favor the grass, since frequent grazing would tend to favor the legume as shown in the RTC. Frequent grazing has not favored C. acutifolium (see Figure 7), suggesting that maybe longer rest periods are needed with this legume.

From a methodological point of view, RTC trials in small plots are recommended not only to select productive associations, but also to define management requirements. This in turn

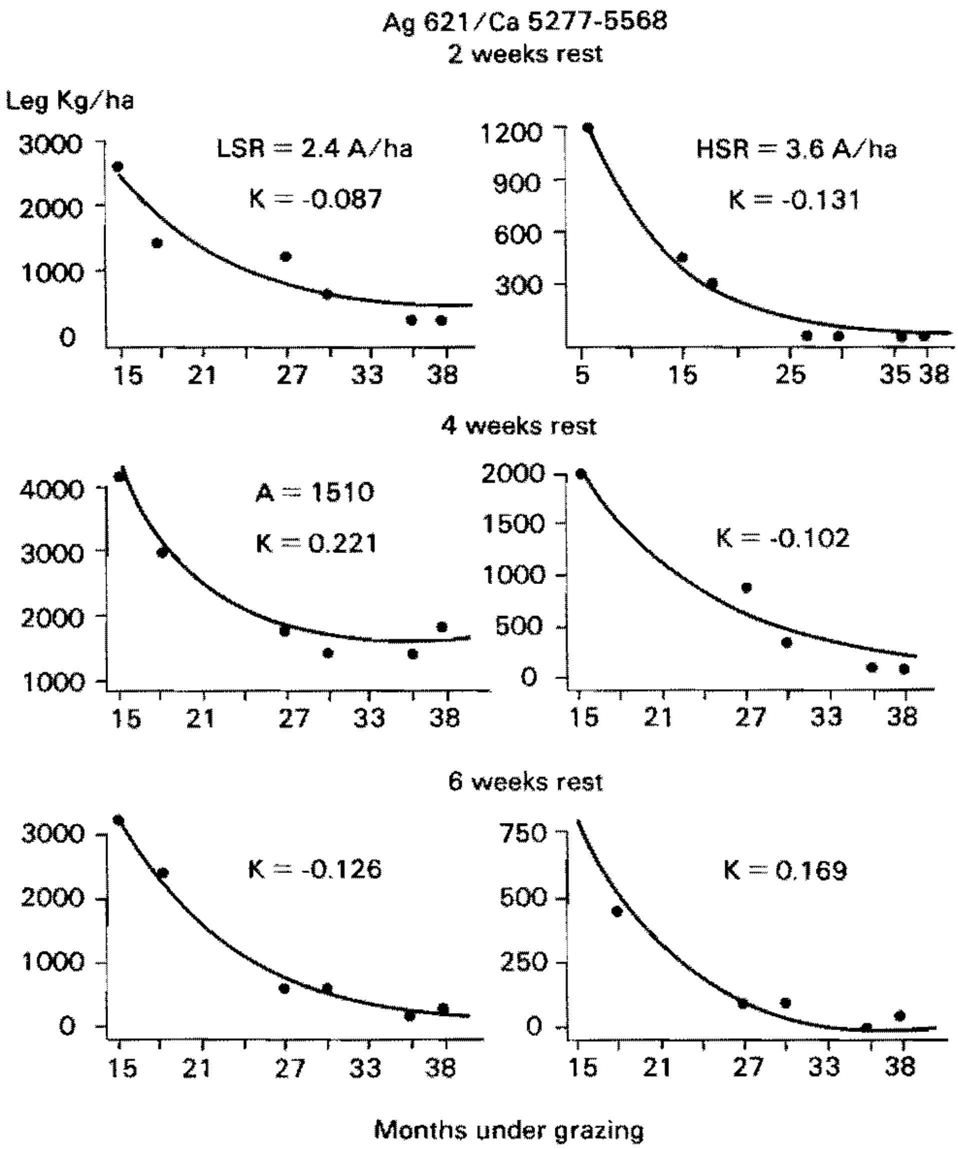


Figure 11. Dynamics of C. acutifolium 5277-5568 in association with A. gayanus under different grazing managements (2, 4, and 6 weeks of rest and low and high stocking rates) starting at the point of maximum availability for adjustment with exponential models (Quilichao).

would serve the purpose of keeping visualize schemes of utilization of selected pasture within a given production system.

Effect of Individual and Common Grazing on Legume Persistence

As mentioned, type C trials have been proposed within the RIEPT. However, these, trials require infrastructure that can be expensive. An alternative to reduce infrastructure costs and seed requirements in RTC to evaluate different genera and/or legume species under common grazing. Normally, this practice is not recommended, since there is a risk that palatable legumes may be eliminated, while selecting those that are less palatable.

To evaluate the possibility of using common grazing in the evaluation of legume persistence, a trial was conducted in Carimagua with 5 legumes (*S. guianensis* 1283, *S. macrocephala* 1643, *S. capitata* cv. Capica, *C. macrocarpum* 5065, and *C. brasilianum* 5234) in association with *A. gayanus* and under common (5 legumes in the same grazing plot) and individual (1 legume per grazing plot) grazing. After 3 years of grazing, legume availability over time (kg/ha) was adjusted using appropriate models and the resulting parameters are summarized in Table 8. It observed that with the exception of *C. brasilianum* 5234, the rate can be of decline (k) of legume availability over time was similar under individual and common grazing. On the other hand, of the 5 legumes included in the trial, 2 did not persist either under individual or common grazing. *S. guianensis* 1283 was affected by anthracnose and disappeared after 18 months of grazing. Likewise, *C. macrocarpum* 5065 did not persist, possibly due to its poor adaptation to the edaphic conditions of the Colombian plains.

Table 8. Parameters (A = asymptote y -k or b = slope) of models adjusted to the amount of legumes available (kg/ha) after three years of grazing individually or common (1987 - Carimagua).

Legume	Individual grazing[1]		Common grazing[2]	
	A (kg/ha)	-k ó b	A (kg/ha)	-k ó b
S. capitata cv. Capica[3]	133	-0.15	14	- 0.14
S. macrocephala 1643[3]	3	-0.13	9	- 0.19
S. guianensis 1283[4]	-	-41.6	-	-58.1
C. brasilianum 5231[4]	59	-0.09	41	-0.27
C. macrocarpum 5065[5]	-	-0.22	-	-0.15

1/ One legume/grazing plot.
2/ Five legumes/grazing plot.
3/ Model $y = A + B - e^{-kt}$ (months) where y = kg/legume/ha
4/ Model $y = a - bt$ (months)
5/ Model $y = Be^{-kt}$ (months)

The availability of the three legumes that persisted was very low at the end of the third year, both under individual and common grazing; however, under individual grazing the legume tended to have a greater availability particularly in the case of S. capitata cv. Capica.

The degree of persistence of the legumes included in individual and common grazing trials was also evaluated in terms of the number of plants/m^2 (Figure 12). The number of plants/m^2 at the end of the third year of grazing was similar under individual and common grazing for the three legumes that persisted.

In general, the results of this experiment indicates that the "ranking" of persistence of the 5 legumes included in the trial was siimlar under individual and common grazing, although individual grazing favored a greater availability of legume in the pasture. Based on this, it is suggested that legume persistence under grazing could be evaluated including different genera and/or species of legumes in small plots under common grazing. However, in order to reach a more definite conclusion, these type of trials must be repeated with a broader range of legumes, differing in growth habit and relative palatability, and hopefully in association with grasses of contrasting growth habits.

Grazing of Associations with Sheep and Cattle

Sheep may be used in grazing trials in small plots as an alternative to evaluate grass/legume associations which are designed to be grazed by cattle, provided that the results are similar. Obviously, the use of sheep in this type of trial has the advantage of requiring less land, seed, and overall infrastructure.

A trial was established at CIAT-Quilichao to evaluate grass/legume pastures with sheep and cattle. In the first trial, two contrasting associations (A. gayanus/C. acutifolium 5277 and B. dictyoneura/D. ovalifolium 350) were included for each animal species under two ranges of grazing, pressure (3-5 and 6-8 kg GDM/100 kg LW/day).

The results of this evaluation indicated that C. acutifolium grazed by sheep disappeared 4 months after initiation of grazing, despite a relatively high initial proportion legume (27%). In the case of the mixture of A. gayanus/C. acutifolum grazed by catle, the legume also disappeared, but this was associated with initial low availailability in the pastures(12%). The associations based on D. ovalifolium showed a different response when grazed by sheep and cattle. In the case of sheep, D. ovalifolium constituted a very low proportion of the pasture while the proportion of this legume being high in the case of pastures grazed by cattle.

In order to better interpret the results obtained in the first experiment, a second study was carried out using esophageal-fistulated sheep and cattle. These fistulated animals simultaneously grazed contrasting grass-legume associations. Samples of forage selected by both animal species were used to estimate the botanical composition of the diet. Results of this work are summarized in Table 9. It is evident that sheep selected more C. acutifolium 5277 and C. macrocarpum 5713 than cattle. With these two legumes, the selection index was greater than 1 in the case of sheep and less than 1 in the case of cattle. This indicates that sheep selected in favor of the legume while cattle selected against the legume. In contrast, the selectivity for D. ovalifolium was similar for both animal species, with the index selection being less than 1. This low selectivity for D. ovalifolium is associated with the presence of

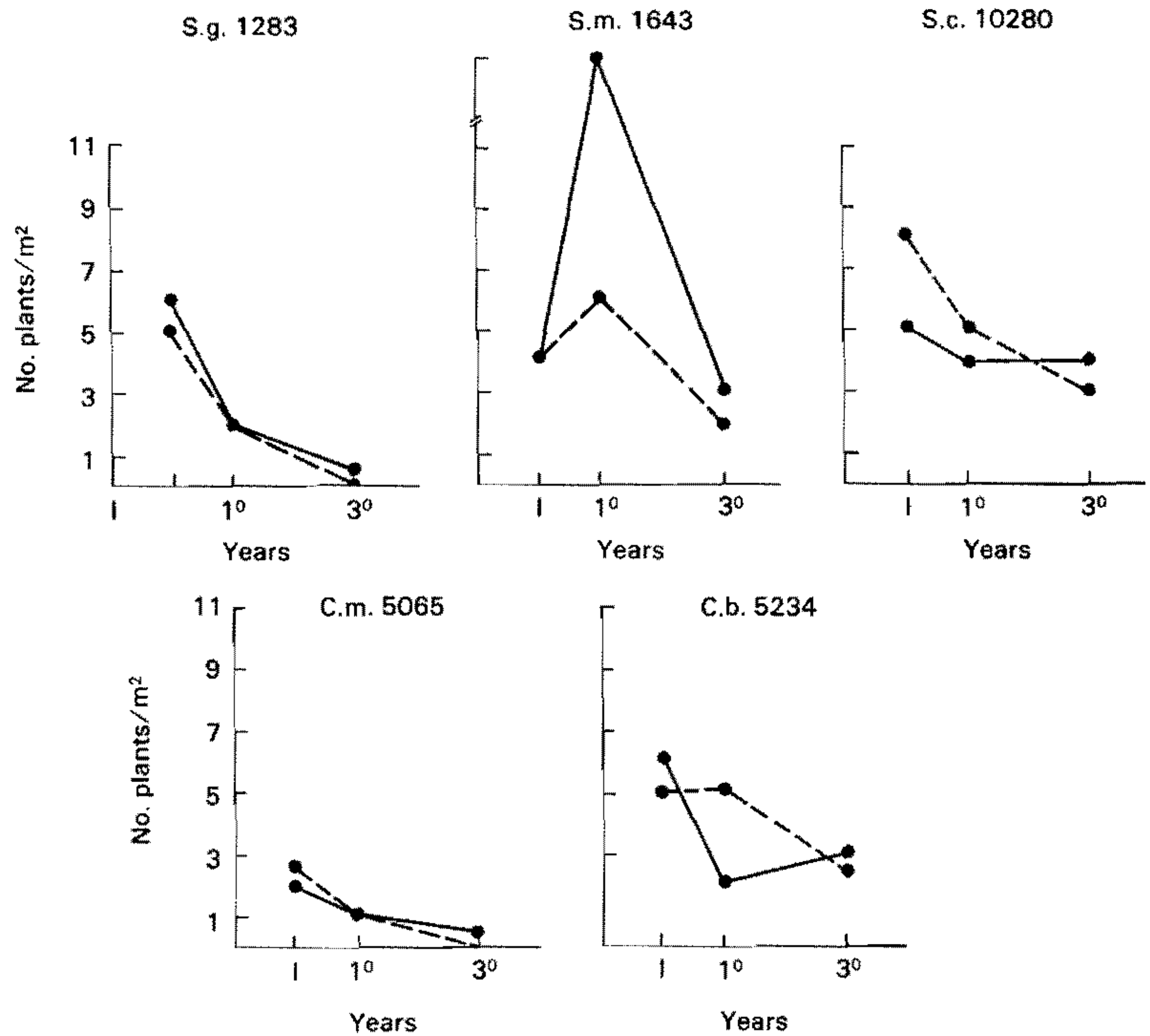


Figure 12. Number of plants of five legumes associated with A. gayanus under individual ( ) and common grazing, at the beginning of grazing (I), after the first (1st) and third (3rd) year of grazing (Carimagua).

Table 9. Legume proportion in the selected diet by sheep and cattle in grass/legume associations (Quilichao).

Association	Animal species	Legume in diet (%)	SI[1]
B. dictyoneura/ D. ovalifolium 350	Sheep	8.8a	0.35
	Cattle	10.5a	0.41
A. gayanus/ C. acutifolium 5277 + 5568	Sheep	24.4a	1.80
	Bovinos	10.4b	0.77
A. gayanus/ C. macrocarpum 5713	Sheep	50.6a	1.17
	Cattle	30.0b	0.66

1/ SI (Selective index) $= \frac{\text{\% legume in diet}}{\text{\% legume on offer}}$

2/ a, b Different means ($P < .05$)

tannins, as has been documented in various studies. However, it must be indicated that the selectivity of sheep for D. ovalifolum could have been underestimated in this study, since the fistulated animals used were not previously accustumed to the legume.

Overall, the results of this work indicate that sheep could not recommended to evaluate grass/legume associations designed to be grazed by cattle, since there are marked differences between animal species in grazing habit and forage selectivity.

16. SEED PRODUCTION

INTRODUCTION

During 1987 the Seed Production Section continued with the activities of, seed multiplication and distribution; applied research; technical collaboration; and training. These activities are summarized in the following progress report.

SEED MULTIPLICATION AND DISTRIBUTION

As in previous years, field production activities were continued at both Quilichao and Carimagua. Support facilities for greenhouse propagation, seed conditioning, seed testing, seed storage and distribution were centered at Palmira. Activities at Valledupar were conducted by the production and purchase contract mechanism and are described in greater detail under the leading of Technical Collaboration.

The multiplication of legume species and accessions are summarized in Table 1. A total of 74 accessions of 21 species were under some degree of multiplication, with an emphasis upon accessions of Centrosema spp., D. ovalifolium and P. phaseoloides. Principally during the November 1986 - February 1987 harvest period, a composite total of 1,662 kg of graded seed, including significant amounts of A. pintoi, C. brasilianum, C.macrocarpum, C. acutifolium, D. strigulosum and S. capitata. During the year 5 ha of new seed crops were established to provide a total of 19.6 ha of seed crops presently under management.

The multiplication of grass species and accessions are summarized in Table 2. A total of 32 accessions of 11 species are under some degree of multiplication. The major effort was concentrated up B. dictyoneura CIAT 6133. A composite total of 780 kg of clean seed was produced during the June-July harvest period in Carimagua, mainly of B. dictyoneura CIAT 6133.

A summary of composite seed multiplication activities is presented in Table 3. In relative terms, Carimagua provided the largest volume, Quilichao provided small volumes of many accessions and Valledupar produced large volumes of three accessions.

Seed distribution involved responding to a total of 302 requests and the delivery of a composite total of 1,671 kg of seed, predominantly of legume accessions (see Table 4). Most seed was utilized by Program members and National Research Institutions in the conduct of germplasm and pasture evaluation experiments. There was some increase in the volume of basic seed distributed to national seed multiplication programs.

APPLIED RESEARCH

a) Seedling emergence of S. capitata

A seed crop management experiment conducted on-farm with a grazier collaborator on a sandy loam soil type, provided an opportunity to study variables affecting seedling emergence. Plant population at two months post

Table 1. Summary of seed multiplication activities of legume species and accessions between October 1986-1987.

Species	Total Accessions (No.)	Areas of Multiplication New (ha)	Areas of Multiplication Total (ha)	Seed produced[1] (kg)
Arachis pintoi	1	-	2.53	60.86
Centrosema brasilianum	4	0.575	3.13	476.61
Centrosema macrocarpum	4	0.261	1.882	166.06
Centrosema acutifolium	2	0.98	4.07	327.0
Centrosema schiedeanum	1	-	0.005	1.06
Cannavalia brasiliensis	1	-	0.001	2.33
Cratylia floribunda	1	-	0.002	2.39
Chamaecrista rotundifolia	2	-	0.01	1.35
Desmodium heterocarpon	2	-	0.026	0.74
Desmodium heterophyllum	3	-	0.03	5.15
Desmodium ovalifolium	15	3.17	6.479	12.0
Desmodium strigillosum	4	-	0.08	59.27
Dioclea guianensis	2	-	0.024	9.52
Flemingia macrophyla	2	-	0.128	8.95
Leucaena sp.	3	-	0.008	0.0
Pueraria phaseoloides	11	-	0.2415	18.57
Stylosanthes capitata	1	-	0.3	465.0
Stylosanthes guianensis	4	-	0.521	14.5
Stylosanthes viscosa	7	-	0.0588	6.0
Tadehagi sp.	2	-	0.008	0.32
Zornia glabra	2	0.057	0.125	24.78
Total	74	5.043	19.660	1662.46

1/ Classified seed with > 90% pure seed content.

planting responded positively to planting density and acid escarification of pods (Table 5), and most dramatically to planting and covering in rows as opposed to broadcast and uncovered (Table 6). Level of fertilizer application had no effect on seedling emergence (Table 6).

b) Seed Crop management of *B. dictyoneura*

Two elements of management were studied utilizing various established seed multiplication areas at Carimagua. These were (i) fertilizer application, and (ii) timing of precutting and fertilizer application.

An incomplete factorial design was used to compare the effect of levels of N and S and also a high complete fertilizer treatment, upon yield of pure seed. These treatments were not affected by renovation with offset discs. Without S, there was a positive response to 50 but not to 100 kg/ha N. Without N, there was no response to 20 kg/ha of S. The treatment of 50 kg/ha N + 20 kg/ha S provided a higher yield than either element by itself. Additional amounts of N or other elements provided little further response (see Table 7).

Table 2. Summary of seed multiplication activities of grass species and accessions between October 1986-1987.

Species	Total Accessions (No.)	Areas of Multiplication New (ha)	Areas of Multiplication Total (ha)	Seed produced[1] (kg)
Andropogon gayanus	2	-	0.015	1.04
Brachiaria brizantha	5	0.25	1.73	2.95
Brachiaria decumbens	3	-	1.11	0.07
Brachiaria dictyoneura	1	-	11.5	761.1
Brachiaria humidicola	5	-	0.472	6.37
Melinis minutiflora	4	-	0.016	0.05
Panicum maximum	6	0.01	0.1525	6.35
Paspalum spp.	3	-	0.0120	1.85
P. purpureum	1	-	0.004	-
King grass	1	-	0.88	-
Forage sugar cane	1	-	0.03	-
Total	32	0.26	15.92	779.78

1/ Classified seed with > 40% pure seed content.

Table 3. Summary of seed multiplication activities at different locations for all grass and legume accessions between October 1986-1987.

Location	Total Accessions (No.)	Area of Multiplication New (ha)	Area of Multiplication Total (ha)	Seed produced Grasses (kg)	Seed produced Legumes (kg)	Seed produced Total (kg)
Santander de Quilichao, Cauca	96	1.753	5.933	22.18	505.11	527.29
Carimagua, Meta	22	3.55	28.547	757.6	580.75	1338.3
Valledupar, Cesar	3	-	1.1	-	576.6	576.6
Total	105	5.303	35.58	779.78	1662.46	2442.19

Table 4. Seed distribution between October 1986 y 1987.

Seed Request		Seed Volume		
Objective/Source	(No.)	Grasses (kg)	Legumes (kg)	Total (kg)
A. Germplasm and Pastures Evaluation				
1) TPP Members	126	137	555	692
2) Regional Trials (RIEPT)	28	75	85	160
3) National Institutions	86	223	418	641
4) Other CIAT programs	12	2	10	12
5) Individuals	37	7	12	19
Subtotal	289	444	1080	1524
B. Seed Multiplication				
1) CIAT Seed Unit	3	60	8	68
2) National Institutions	10	12	67	79
Subtotal	13	72	75	147
C. Total	302	516	1155	1671

Table 5. The effect of seed treatment and planting density upon seedling emergence in Stylosanthes capitata cv. Capica.

Planting density[1]	Seedling Emergence ('000/ha, 2 mo post planting)		
	Seed treatment		
	Nil	Acid Scarified	Mean
Low	50	83	67c[2]
Medium	100	167	133b
High	167	283	225a
Mean	106b	178a	

1/ Treated seed in pod (kg/ha)

	Nil	Acid Scarified (kg/ha)
Low	2	1
Medium	6	3
High	12	6

2/ Means followed by the same letter are not statistically different at $P < 0.05$.

Table 6. The effect of planting systems and fertilization upon seedling emergence of *Stylosanthes capitata* cv. Capica.

Fertilization [1]	Seedling Emergence ('000/ha, 2 mo post planting)		
	Seed treatment		
	Row	Broadcast	Mean
Control	355	26	191 a[2]
Calfos	367	40	203 a
Complete	278	40	159 a
Mean	330 a	36 b	

1/ Control: Without
Calfos: 50 P_2O_5 (kg/ha)
Complete: 50 P_2O_5 + 50 K_2O + 20 Mg + 12 S (kg/ha)

2/ Means followed by the same letter are not statistically different P < 0.05).

Table 7. The effect of renovation, nitrogen and sulphur on the pure seed yield in *B. dictyoneura* CIAT 6133 at Carimagua, 1987.

Treatments kg/ha					Pure Seed Yield[1] (kg/ha)		
					Renovation		
N	S	P_2O_5	K_2O	Mg	Without	With	Mean
100	20	25	30	20	148.0	85.5	116 a[2]
100	20				124.5	93.0	109 ab
50	20				107.0	85.2	96 b
50	0				72.2	54.2	63 c
100	0				71.2	41.6	56 c
0	20				39.1	30.7	35 d
0	0				35.0	32.2	34 d
				Mean	85.3 a	60.3 a	

1/ Area sampled: 412 m^2 in each of three replications.

2/ Means followed by the same letter are not statistically different at P < 0.05.

The application of a pre-cut (by heavy grazing) followed by fertilizer application (50-100 kg/ha N + 25 kg/ha S) was applied to four different seed multiplication areas at the beginning of the rainy season. The actual time of completion of this management package ranged from April 6 to until May 28. At the time of harvest maturity, the highest inflorescence densities and yield of pure seed were associated with the earliest date of management indicating the importance of early application (Table 8).

c) Seed harvesting methods in *B. dictyoneura*

During the harvesting of various seed multiplication areas in Carimagua comparisons were made of alternative harvesting methods.

Two separate comparisons of manual versus combine harvesting indicated that the combine delivers approximately 50% of the pure seed as harvested by the manual method (Tables 9 and 10).

A more detailed comparison involved a beater harvestor as a third harvest method. This beater harvestor consists essentially of a tractor mounted rotating reel of PVC pipes which flail the inflorescences and a screen box which collects dislodged spikelets. The beater harvestor delivered significantly less yield of pure seed that the combine, but both the combine and the beater harvestor delivered a larger seed size (or average weight of caryopsis) than the manual method. Somewhat surprisingly, the tetrazolium viability of pure seed at 2 months post harvest was similar for all three methods. Seed viability and yield of pure viable seed will continue to be monitored.

d) Role of physical support in *Centrosema* spp.

Seed yield in *C. brasilianum* CIAT 5234 at Quilichao, responded positively to post-wire trellis and king grass stakes (Table 11), but not to increased height of trellis. In Carimagua, the post-wire trellis resulted in higher yields than both stakes and no support (Table 12).

Seed yield of *C. acutifolium* CIAT 5277 at Quilichao also responded to post-wire trellis of conventional height (1.8 m) and king grass stakes. Seed harvested from the ground was smaller and of lower viability (Table 13).

e) *C. acutifolium* cv. Vichada

The release in Colombia during the latter half of 1986 of CIAT 5277 as cv Vichada has focussed attention upon the challenge of and prospects for future development of commercial seed supply.

The available data on seed yield is summarized in Table 14. Potential yields of 700 kg/ha are attainable but average yield is more in the range of 50-200 kg/ha, even with physical support and repetitive hand harvesting. While this data base is very restricted, these relatively low yields and high variability indicate the need for an expanded research effort to explore means of seed crop management and location, so as to provide consistently higher seed yields. In addition to research efforts, only strong and sustained demand from graziers will stimulate investment in commercial seed production.

TECHNICAL COLLABORATION

This activity has the general objectives of (a) widening participation in seed multiplication to include National Institutions, seed enterprises and new producers, and (b) increasing production at the national level, to provide seed of promising accessions for further evaluation and basic seed of new cultivars.

Table 8. Pure seed yield of *B. dictyoneura* CIAT 6133 according to precutting and fertilizing period at Carimagua 1987.

Multiplication Field	Pre-cutting and Fertilizing period (date)	Harvest maturity (date)	Inflorescence Density (No./m^2)	Pure Seed Yield[1] (kg/ha)
Acuario 83	April 6	June 23	300	190
Acuario 85	May 16	July 22	185	85
Acuario 86A	May 28	July 27	218	95
Acuario 86B	May 28	July 29	197	88

1/ Manual harvested trials lots with plots of 500 m^2 area and minimum 3 replications.

Table 9. Comparation of harvest methods (manual and combine) on pure seed yield of *B. dictyoneura* CIAT 6133 at Carimagua.

Harvest method	Inflorescence Density (No./m^2)	Pure seed yield[1] (kg/ha)
Manual	300 a	190 a[2]
Combine	306 a	98 b

1/ Mean values from two experiments. Area sampled: 500 m^2 in each of 3 replications, in both experiments.

2/ Means followed by the same letter are not statistically different at $P < 0.05$.

Table 10. The effect of harvest method on pure seed yield and quality in *B. dictyoneura* CIAT 6133 in Carimagua.

Harvest method Treatments	Pure Seed Yield[1] (kg/ha)	Pure Seed Caryopsis Unit Weight (mg/100)	Pure Seed TZ Viability 2 months (%, No.)	Yield of Pure-viable seed 2 months (kg/ha)
Manual, technified	60.9 a[2]	255.5 b	92	56.3 a
Combine	31.8 b	298.6 a	93	29.4 b
Reel-beater	18.8 c	303.9 a	92	17.5 b

1/ Area sampled: 1000 m^2 in each of three repetitions.
2/ Means followed by the same letter are not statistically different at $P < 0.05$.

Table 11. Evaluation of various support systems on seed yield of *Centrosema brasilianum* CIAT 5234 in Santander de Quilichao.

Type of Support	Pure Seed Yield[1] (kg/ha)	Seed Unit weight (g/100)	Viability** Tetrazol (%,N°.)
1. Post/wire trellis, 1.8 m high	321.1 a	2.222 a	76.6 a
2. Post/wire trellis, 2.5 m high	278.5 a	2.244 a	76.0 a
3. Mature King grass stakes	219.8 a	2.296 a	69.6 a
4. Without support (ground sward)	50.5 b	2.078 b	65.6 a

* Area sampled: 76 ml in each of 3 replications.

** Six month post-harvest.

Table 12. Evaluation of different systems of support on seed yield of *Centrosema brasilianum* CIAT 5234, Carimagua 1986-1987.

Type of Support	Pure Seed Yield[1] (kg/ha)	Seed Unit weight (g/100)	Tetrazol* Viability[2] (%,N°.)
1. Post/wire trellis, 2.5 m high	134.0 a	2.191 ab	77.7 abc
2. Post/wire trellis, 1.8 m high	116.0 a	2.229 a	69.0 c
3. Tree branches	66.5 b	2.257 a	70.5 bc
4. Mature King grass	39.0 c	2.222 a	78.7 ab
5. Inverted green King grass	35.5 c	2.189 ab	83.2 a
6. Without support	15.5 c	2.103 b	84.5 a

1/ Area sampled: 67.2 ml in each of 3 replications (Acuario 86).

2/ 6 months post-harvest.

Table 13. Evaluation of various systems of support on seed yield of *Centrosema acutifolium* CIAT 5277 in Santander de Quilichao.

Type of Support	Pure Seed Yield[1] (kg/ha)	Seed Unit Weight (g/100)	Tetrazol[2] Viability (%,N°.)
1. Post/wire trellis, 1.8 m high	401 a	4.593 a	91.5 a
2. Post/wire trellis, 2.5 m high	313 b	4.631 a	92.2 a
3. Mature stakes of King grass	481 a	4.531 a	92.7 a
4. Mature stakes of King grass (inverted)	368 ab	4.589 a	92.5 a
5. Without support (ground sward)	94.8 c	3.654 b	83.7 b

1/ Area sampled: 94 ml, in each of 4 replications.

2/ Six months post-harvest.

Table 14. An evolving profile of seed yield of *C. acutifolium* cv. Vichada, at different locations[1].

YEAR	COLOMBIA								MEXICO	
	Quilichao 4°N		Carimagua 3°N		El Viso 3°N		Valledupar 10°N		Iguala 18°N	
	n[2]	$\bar{x}$[3]	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
1983-84	1	335								
1984-85	5	68(±9)	2	163(±48)						
1985-86	6	217(±39)	4	68(±14)						
1986-87	7	117(±39)	6	24(±8)	1	150	1	150	1	716
Mean	19	147(±25)	12	62(±17)	1	150	1	150	1	716

1/ Values in kg/ha of seed field multiplication from 0.01 to 2.0 ha with physical support and manual harvest with several passes.

2/ Number of independent observations (values of different multiplication fields) included in the seed yield mean.

3 Average calculated (±EE).

Two complementary strategies have been applied to achieve the objectives, these being,

- initiate and develop seed multiplication programs within selected National Research Institutions (NRI's) of the RIEPT, and
- where available, utilize expertise and resources of existing seed enterprises, via seed production and purchase contracts.

1. New seed multiplication programs within NRIs

Durig the year a major effort was directed towards initiating and developing pasture seed multiplication projects in Peru, Ecuador, Mexico and Costa Rica. These countries were chosen because of advances made therein in systematic germplasm evaluation, the desire of the national institutions to expand seed activities and the availability of human and field resources.

In each case, a multiplication plan was defined before the planting season. This included, the identity of the species and accessions to be multiplied, the multiplication targets, production locations, seed crop management and harvesting method, etc.

In Ecuador, Mexico and Costa Rica, the

project involved one NRI only as project organizer and producer (INIAP, INIFAP, MAG, respectively). In Peru, however, two NRI's (INIPA and IVITA) were the project organizers, local graziers were involved as novice-producer-collaborators, and two regional development corporations contributed to funding. In Ecuador, IICA provided funding to INIAP.

First year achievements were highly variable, ranging from over 1,200 kg of composite seeds produced in Peru to almost total failure at establishment in another project. In all cases, however, participants gained valuable experience in seed crop agronomy and project management. An improved appreciation of the role of basic seed was also attained and projects will evolve into their second year with better planning, improved selection and involvement of collaborators and with limitations better identified in each case.

2. Seed production and purchase contracts

These projects are conducted in collaboration with the CIAT Seed Unit. In each case, finance, contract specifications, provision of basic seed, field supervision, seed condition and seed analysis are shared between the Section and Seed Unit. The participating seed grower (usually a seed producing enterprise) provides land and resources to establish, manage, harvest and deliver the specified pasture materials, according to contract specifications.

Semillano Ltda. is a seed enterprise producing rice and *Brachiaria decumbens* seed in the Villavicencio region of Colombia. Since 1986 they have participated in contracts with CIAT. Distribuidora del Valle Ltda. is a seed enterprise producing seed of sorghum and *Andropogon gayanus* in the Valledupar region of Colombia. During 1986-87 they participated in a contract involving three *Centrosema* spp. The materials involved, crop areas, seed yields and seed produced are summarized in Tables 15 and 16.

These contract projects have proven very productive, not only in the context of seeds produced but also in the generation of crop performance data, management experience and contacts with the seed enterprises.

3. Participation in on-farm pasture research

The Section has continued to collaborate in an expanding number of on-farm research and validation projects. Contributions have included technical assistance in seed crop management and contract harvesting of *S. capitata*.

TRAINING

During the year two professionals (from Dominican Republic and Bolivia) participated in the Section as their specialization phase following the Course in Tropical Pastures. In addition, three short-term special trainees (from Bolivia, Antigua and Cuba) also spent from two weeks to two months in in-service training.

In October, the Section contributed to a Workshop on Pastures organized by INIPA at Pucallpa, Peru.

During the year, plans were developed for in-country Pasture Seed workshops. These include Panama in December 1987 and Peru in June 1988.

Where possible during travel, contact was maintained with participants of the 1984 and 1986 pasture seed courses.

Table 15. Materials, crop areas and seed yield and production in production and purchase contracts with Semillano Ltda. 1986-1987.

Period	Material	Crop Area (ha)	Basic Seed Yield (kg/ha)	Basic Seed Production (kg)
1986-87	*S. capitata* cv. Capica	2.0	110	220
	C. acutifolium cv. Vichada	0.5	150	75
1987-88	*C. acutifolium* cv. Vichada	0.5	-[1]	-
	S. guianensis cv. Pucallpa	1.0	-	-
	D. ovalifolium CIAT 13089	1.0	-	-

1/ Seed harvest still pending.

Table 16. Materials, crop areas and seed yield and production of three *Centrosema* spp. in production and purchase contract with Distribuidora del Valle Ltda. during 1986-87.

Centrosema material	Crop Area (ha)	Based Seed Yield (kg/ha)	Based Seed Production (kg)
C. acutifolium cv. Vichada	0.97	150	146
C. brasilianum CIAT 5234	0.55	769	384
C. macrocarpum CIAT 5713	0.55	93	46
Totals	2.07		576

17. LIVESTOCK SYSTEMS

The objective of this Section is to document the potential role of sown pastures on livestock production systems that are primarily based on grazed pastures. In this context, priority is assigned to those improved pastures resulting from the sistematic screening carried out by the Tropical Pastures Program in cooperation with national research institutions.

In order to accomplish this objective, a number of research activities are carried out: experimentation in Carimagua and at the on-farm level, as well as the monitoring of on-farm commercial pastures, either used by themselves or in combination with other forage resources. The on-farm research and monitoring activities are carried out both in the Eastern Plains of Colombia, where the primary objective is to identify and test appropriate methodologies, as well as in other countries in cooperation with research and development institutions.

RESEARCH IN CARIMAGUA

A potential use of sown pastures in cattle production systems is the improvement of the breeding herd's reproductive performance, realized through qualitative and quantitative improvements of the nutritional status. Such an improvement can be achieved by grazing the breeding herd, or a selected part of it, on sown pastures or some combination of introduced and native pastures. Alternatively, early weaning of the suckling calves allows maintaining the breeding cows on savanna, provided a good quality forage is available for the weaners.

Reproductive performance on *B. humidicola*

Large areas sown to *B. humidicola* exist in most of Tropical America. The inherent quality of this grass is low, although there exists experimental evidence that suggests that soil fertility and the presence of an associated legume may improve its nutritional value. Nevertheless, its high carrying capacity, ease of establishment by vegetative means and its competitive ability with weeds make it highly appreciated by farmers. A long term experiment with replicates over time begun in 1981, with the aim of studying the reproductive performance of heifers raised on this species, and when subjected to different rates of weight gain from weaning to 270 kg liveweight. Residual effects of these treatments are also being studied. Partial results have been reported in previous annual reports. The evolution of the liveweights of three groups of animals, uncorrected for the effect of age and physiological condition, is shown in Figure 1. It is clear that the effect of treatment has dissapeared over time.

A similar trend can be observed in terms of reproductive performance. The rate of weight gain had a marked

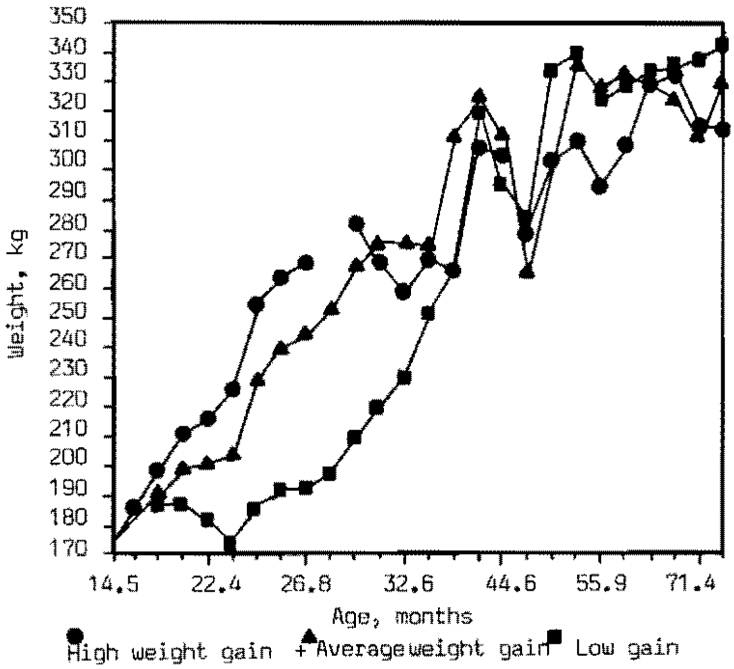


Figure 1. Liveweight evolution of cows that reached 270 kg of weight with a high, average or low rate of gain.

effect during the first conception (Table 1), but those effects tended to dissapear during the second (Table 2) and third (Table 3) gestations. A preliminary analysis, based solely on treatment means, confirm the existence of a compensatory effect on reproductive performance (Figures 2 and 3), althought there remains some differences among treatments.

The above results suggest that even with its well known nutritional limitations, this grass can provide levels of reproductive performance above those of the native savanna (Table 4). Similarly, these results suggest that for extensive cow-calf systems, where modest levels of weight gain and reproductive performance can easily exceed those of the savanna, the existence of long term compensatory effects can be used to compensate temporary nutritional constraints. This issue is being investigated in the second temporal replication of this experiment. Three groups of heifers raised on B. humidicola from weaning were subdivided in two groups each upon reaching 270 kg liveweight: one group continued on this grass, while the second group of animals is being grazed on B. decumbens to achieve higher weight gains. Thus, at present there are six groups made up of the combination of three levels of nutrition (high, medium and low) from weaning to 270 kg, and two levels thereafter. Reproductive performance of these animals will be evaluated until the second calving.

Table 1. Number of parturitions and abortions as a result of the first conception of heifers grazed on B. humidicola and subject to three growth rates during puberty.

Gain in weight during puberty	No. of cows	No. of parturitions	No. of abortions
High	16	15	1
Medium	17	15	2
Low	17	17	0

Table 2. Number of parturitions and abortions as a result of the second conception of heifers grazed in B. humidicola and subject to three growth rates during puberty.

Gain in weight during puberty	No. of Cows	No. of parturitions	No. of abortions	Interval weaning-conception
High	16	16	0	106
Medium	17	17	0	46
Low	16	11	0	n.a.

Data to August 1987

n.a. = Data not yet available

Table 3. Number of parturitions and abortions as a result of the third conception in heifers grazing B. humidicola and subject to three growing rates during puberty.

Gain in weight during puberty	No. of cows	No. of parturitions
High	16	5
Medium	17	2
Low	16	0

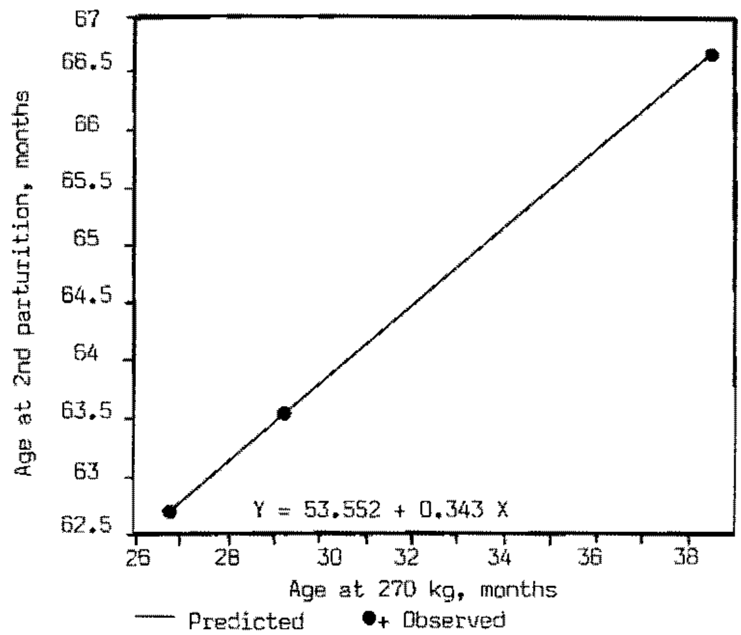


Figure 2. Regression of age at second calving on age at 270 kg.

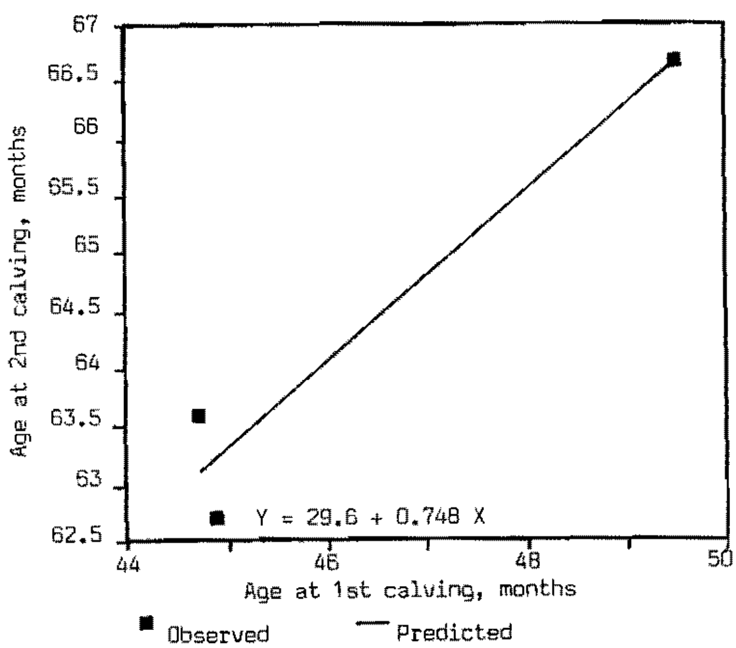


Figure 3. Regression of age at second calving on age at first calving.

Table 4. Reproductive performance of heifers at B. humidicola grazing, subject to three growing rates during puberty.

Gain in Weight during puberty	n	First calving interval (months)	Parturition %
High	15	19.4	61.9
Medium	16	18.9	63.5
Low	11	18.8	63.8

Reproductive performance on B. decumbens

As indicated above, B. decumbens has an inherently higher nutritional value than B. humidicola. Also, when the available nutritional status is improved, the introduction of more sohpisticated management practices become feasible; such is the case for controlled mating.

The present experiment constitutes the positive control for all the trials reported in this chapter. Its aim is to document the reproductive performance of heifers raised since the age of one year on a B. decumbens pasture, supplemented with a S. capitata bank. The mean stocking rate is 1.2 AU/ha, and the protein bank represents 15% of the available area; nevertheless, the legume pasture was invaded on the second year by B. decumbens, thus becoming a grass-legume association dominated by the grass. Mating is limited to two periods of 90 and 45 days respectively per year.

The evolution of mean, uncorrected, liveweights is shown in Figure 4. Despite marked oscillations in liveweight, generally associated with changes in physiological status of the cows, the weights have tended to stabilize at a level much higher than those achieved on B. humidicola (see Figure 1). Reproductive performance (Table 5) is consistent with the evolution of liveweights; it is important to note that the levels of production achieved in this experiment are similar to those of a contemporary trial run by ICA and using continuous mating, thus supporting the hypothesis mentioned above regarding the nutrition-management interaction.

Strategic use of sown pastures for breeding herds

In the context of the present experiment, "strategic use" of sown pastures implies the utilization of small areas of grass-legume associations for selected categories of the breeding herd, for short periods of time, with the aim of stimulating the reconception of cows in certain physiological conditions. The rest of the time such pastures can be used for other purposes, such as fattening, etc.

The experiment compares five different systems, in two replicates. The treatments are the product of the factorial combination of two different areas of sown pastures and two systems of management, plus a negative

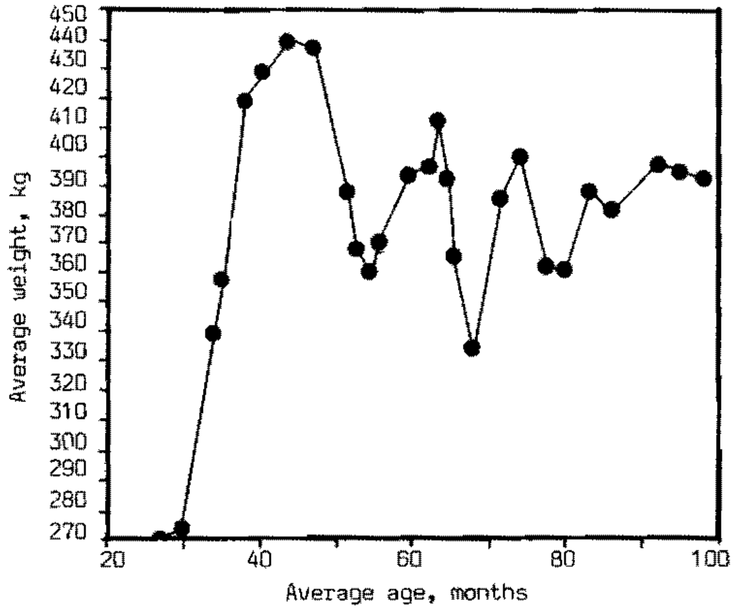


Figure 4. Liveweight evolution of cows grazed in B. decumbens.

Table 5. Age at parturition and calving interval (CI) parturitions (IPA) of cows grazed in B. decumbens.

Parturition No.	Age at parturition (months)	s[1]	CI (months)	s
1	47.8	4.6	-	-
2	63.3	5.5	15.3	4.9
3	77.7	6.6	14.1	3.3
4*	89.9	5.9	12.8	2.1
5*	95.8	4.7	12.5	0.5

* Partial data to August 1987.

1/ Standard deviation.

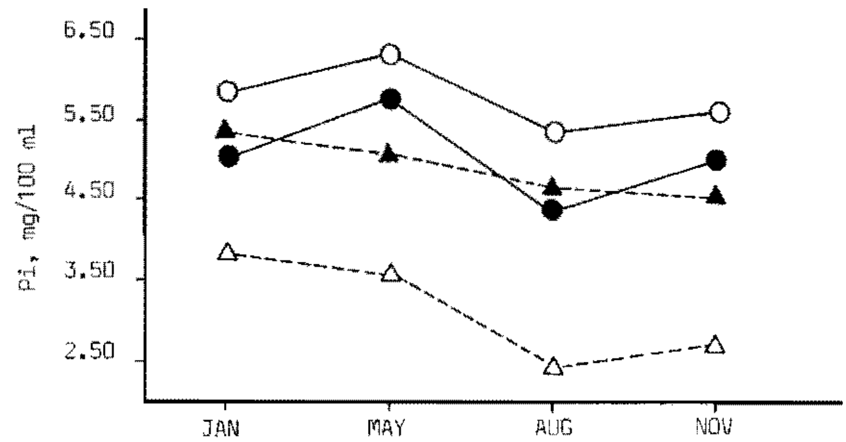
control. The latter is the traditional cow-calf system based exclusively on savanna, with a complete mineral supplement (8% P) and uncontrolled mating. The areas of sown pastures are 900 and 1800 square meters of pastures per AU, and the management systems have been identified as "minimum" and "intensive" respectively. Minimum management implies uncontrolled access to the sown pastures throughout the year; given the existence of two grass-legume associations, free access is allowed to each one in alternating periods of 15 days. The other components of minimum management are uncontrolled mating and a mineral supplement consisting of only NaCl during the first two years of the experiment, and a complete supplement with 4% P thereafter. Intensive management involves the supply of a complete mineral supplement (8% P) and controlled access to the sown pastures. The latter are available for the pregnant cows during the last 60 days of pregnancy and initial 90 days of lactation; during this second period, controlled mating is practiced. During the remaining of the year, the pastures are used for fattening.

In addition to measuring parameters of animal production, the mineral status of pregnant and suckling cows has been evaluated by means of the collection of serum, liver, rib bone and fecal samples in cows that in January of each year are in their last trimester of pregnancy.

For purposes of analysis, two periods of two years each are considered; these periods coincide with the changes in the mineral supplement used in the minimum mamagement system. The change in serum inorganic phoshorus (Pi) are shown in Figure 5; given that there were no statistically significant differences between the two areas of sown pastures, weighted means are presented. The negative effect of the lack of mineral supplement in the minimum management system during the first two years is obvious; as indicated in previous reports, it led to a large number of abortions. A similar trend is observed in the specific gravity of rib bone biopsies (Figure 6), which is taken as an index of the levels of stored P and Ca. In this context, differences in favor of intensive management were significant; the same applies to other parameters directly correlated with mineral status, such as the Ca, P and ash contents of rib bone samples, and parameters inversely related, such as dry matter and lipid contents of these same samples (Table 6). From the point of view of the cow's mineral status, it was concluded that associated pastures, used either as "banks" (minimum management) or strategically used, were unable tu supply the P and Ca requirements of lactating cows in the absence of a mineral lick. On the other hand, and in the presence of a complete mineral supplement, the improved pastures when utilized strategically, had a gradual and cumulative effect on the level of mineral reserves which was significantly greater than that of cows of the control system despite the higher consumption of the supplement observed in the latter; this phenomenon suggests an interaction of energy by P in the diet.

Large and significant differences in animal performance were observed between replicates. This is probably due to one of them being located in a very sandy soil, where a savanna vegetation of low carrying capacity and quality predominates. Nevertheless, even under these conditions, access to 1800 square meters/AU of sown pastures strategically utilized induced significant improvements in cow and calf liveweights, and significantly decreased suckling calves mortality.

As indicated above, the minimum management system gave rise to low cow



Figures 5. Inorganic phosphorus (Pi) in blood serum. ●, intensive management;● control;▲ minimum management period 2;▲ minimum management period 1.

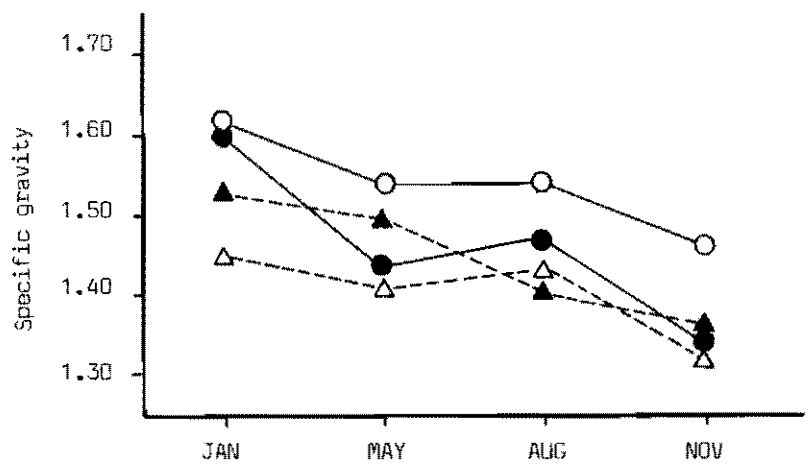


Figure 6. Specific weight of rib biopsies; ○, intensive management;● , control; ▲, minimum management period 2;△ , minimum management period 1.

Table 6. Average parameters of serum's mineral composition and rib biopsies of cows in four production systems.

Parameter	C[1]	MM1	MM2	MI	P<
SERUM					
P, mg/100 ml	5.13	3.12	4.93	5.80	0.01
Ca, mg/100 ml	10.5	8.8	9.3	10.4	N.S.
RIB					
P, fresh %	6.65	5.42	6.30	6.91	0.05
Ca, fresh %	14.5	12.4	15.1	15.6	0.05
Specific weight	1.46	1.40	1.44	1.53	0.002
Ash, fresh %	41.6	35.0	41.1	45.1	0.05
Ether extract, fresh %	18.6	19.7	19.6	13.5	0.001
Water, %	17.7	22.5	16.6	15.4	0.01

1/ C = Control
MM1 = Minimum management period 1
MM2 = Minimum management period 2
MI = Intensive management

and calf weights, and high rates of abortion and neonatal deaths during the first two-year period. Animal performance improved dramatically during the second period, when the complete mineral supplement containing 4% P was introduced; thereafter there was a trend towards diminishing differences between the minimum and intensive management systems (Table 7). Nevertheless, the differences between the control and intensive system with 1800 sq. m. persisted throughout the four years analyzed (Table 8).

Nevertheless the above differences in cow's liveweights did not reflect in increased reproductive performance, since the controlled mating (90 d) practiced in the intensive management treatments equalized the conception, calving and weaning rates of these treatments with those of the minimum management and control systems. On the contrary, and once the mineral deficiencies of the minimum management system were overcome, the continuous mating practiced in them, together with continuous access to improved pastures, induced a significant

Table 7. Average weight of cows at conception, parturition and weaning.

Systems	Period 1	Period 2	Average
		Weight at conception	
Minimum	333	331	332 b
Intensive	369	366	366 a
		Weight at parturition	
Minimum	333 b	356 ab	343
Intensive	375 a	353 ab	372
		Weight of weaning	
Minimum	308	327	314
Intensive	323	331	326
		Calves weight at weaning	
Minimum	159	151	157 b
Intensive	173	175	174 a

Averages followed by different letters differ with $P < 0.05$.

Table 8. Average weight of cows and calves in the control system as well as in the intensive management.

Area of improved management	Cow weights			Weight of calves at weaning (270 d)
	Conception	Parturition	Weaning	
0	320 b	322	290 b	157 b
900	347 a	335	301 b	150 b
1800	348 a	341	320 a	174 a
P <	0.01	N.S.	0.01	0.001

increase in conception (P<.02), calving (P<.09) and weaning (P<.03) rates over the rest of the treatments. As an example, weaning rate in minimum management during the second experimental period was 61%, versus 50% in the remaining systems. Once again, and as previously mentioned, theses results suggest a marked interaction between feeding level and animal management practices. The results of this experiment continue to be analyzed.

Early weaning

An experiment was initiated during the second half of 1987 with the aim of comparing grass-legume associations with a pure grass for beef calves weaned at the age of three months. The associations were *A. gayanus*-*P. phaseoloides*, *A. gayanus*-*C. acutifolium* and *B. dictyoneura*-*A. pintoi*, while the grass was *A. gayanus*. A variable stocking rate was used with the objective of mantaining grazing pressure of approximately 6 kg grass green dry matter per 100 kg liveweight. The experiment is in progress.

Simultaneously, the reproductive performance of dams weaned at various ages during previous years has been monitored. Table 9 shows definitive data on several groups of cows; calving intervals have decreased as a consequence of early weaning, and this in turn appears to be related with a larger liveweight of the cows, which tends to increase with earlier weaning. This process results in shorter calving-conception intervals (Table 10). It is also very interesting to note that the weight at calving and reconception of cows weaned at 110 days, approach those of cows maintained on *B. decumbens* and subjected to a traditional suckling period of 9 months. Similarly, the calving intervals of the former approach those on *B. decumbens* (see Table 5). Clearly then, the strategic use of sown pastures for early weaned calves would be a powerful tool in decreasing, or even eliminating, the need to provide breeding cows access to sown pastures, although at the cost of a more complex management of the calves.

ON-FARM RESEARCH

On farm research in the Eastern Plains of Colombia is conducted with the objective of documenting the performance of grass-legume associations made up of accessions in advanced categories and/or cultivars recently released by ICA, when subjected to farmer's management. A second group of activities refer to the cooperation provided to ICA on the implementation of a pilot program on pasture technology transference. In this case, the main objective is to develop a methodology suitable for technology transfer in an environment where very few precedents, other than those involving supervised credit, are available.

A similar project begun in 1987 in cooperation with EMBRAPA/CPAC; its aim is to validate on-farm associated pastures, planted in the Municipio of Silvania, Goias, Brazil.

Lastly, the Section is involved in other on-farm activities, in several regions of Colombia, part of which are reported by Economy.

Pilot project in the Eastern Plains

The origin and methodology of this project was outlined in the 1986 Report.

As a result of the promotion of on-farm seed multiplication carried out during 1985 and 1986, by the end of the latter year a total of 9 tons of Capica (*Stylosanthes capitata*) seed was available in the Colombian market. All of this seed, as well as that of several grasses provided by commercial enterprises, was used in plantings

Table 9. Reproductive performance of cows with weaning at different ages.

Age of weaning days	Date of weaning	CI[1] months	s	Parturition %
280 ± 29.4	February 85	23.2	1.7	52
266 ± 68.4	October 85	21.4	4.0	56
166 ± 9.7	November 84	17.7	3.3	68
110 ± 7.9	May 85	15.5	4.1	77

1/ CI = Calving interval
S = Standard deviation

Table 10. Parameter of reproductive performance and weight of cows weaned at different ages.

Age of weaning days	CI[1] months	Weight at weaning kg	Weight close to reconception kg	Interval weaning-reconception days
280	23.2	280	310	148
266	21.4	304	323	101
166	17.7	279	329	87
110	15.5	341	355	79

1/ CI = Calving interval.

carried out during 1987 for which the pilot project provided technical assistance.

New plantings were made in about 50 ranches of the Eastern Plains of Colombia, involving 86 separate paddocks and a total of 2800 has. Table 11 summarizes plantings made with pure swards, some of which are expected to be used as seed multiplication lots in the next few years. Grass-legume associations (Table 12) constituted the majority of the area planted during 1987; the main associations were based on Capica in mixture with four different grasses; it should be noted that the associations were selected mostly by the ranchers.

Table 13 summarizes the areas in which each of the planted species is represented, either as pure species or in mixtures.

Based on the areas planted, and the unsatisfied demand, the project appears to be succesful. The future challenge is to increase its coverage and impact without committing even more resources from the Institutions involved in it, but involving other credit, promotion and development agents.

From the point of view of the promotion of seed multiplication, the project appears to have had a positive effect also; it is expected that by late 1987 and early 1988, larger areas be harvested for seed.

On-farm pasture monitoring

During 1987 monitoring of animal production in several new pastures begun. The pastures, used esclusively for fattening, are located in three different ranches. The grass-legume associations that are being monitored are as follows: A. gayanus-C. acutifolium, A. gayanus-C. acutifolium-C. brasilianum, A. gayanus-C. brasilianum-S. capitata and B. decumbens-S. capitata.

In addition to the above pastures, we continue to measure the reproductive performance of breeding cows in relation to pasture use, in two farms monitored since 1980.

On-farm validation in Silvania, Goias, Brazil

This new project, conducted in cooperation with the Centro de Pesquisa Agropecuaria do Cerrado (CPAC, EMBRAPA) is part of a larger one carried out exclusively by CPAC, and whose general objective is to study the technical and economic efficiency of selected production systems in the Cerrado region, with priority assigned to those develop by medium and small farmers. The project is located in the Silvania Municipio, State of Goias, and the region is influenced by two large population centers, Goias and Brasilia respectively. The mean size of farms in that area is 228 has, and the cattle herd has an average of 77 heads. Cash crops, maize and rice primarily, occupy 9% of the area, sown pastures 19% and native pastures 56%.

The joint CPAC/CIAT project has the specific objective of generating on-farm technical and economic coefficients for selected grass-legume pastures in the context of existing production systems. With the above aim, farmers who were already planning to establish new pastures were identified in the region. They were offered the possibility of incorporating as part of these new plantings, selected new species and mixtures. The new pastures are: Leucaena leucocephala to be used as a protein bank during the wet season complemented with Stylosanthes guianensis for the dry period but in a separate pasture and the A. gayanus-S. macrocephala association. A third alternative is the reclamation of degraded pastures of B.

Table 11. Areas planted with pure species by the pilot project for technology transference 1987.

Species	No. of farms	Total area (ha)	Maximum area (ha)	Minimum area (ha)
A. gayanus	3	180.1	100	0.1
A. pintoi	2	0.6	0.5	0.1
B. dictyoneura	11	232.6	150	0.1
B. humidicola	1	0.1		
C. acutifolium	3	1.1	0.5	0.1
C. brasilianum	1	0.1		
D. ovalifolium	1	0.1		
S. capitata	6	122.1	30	0.1

Table 12. Areas planted with associations by the pilot project for technology transference in 1987.

Association	No. of farms	Total area (ha)	Maximum area (ha)	Minimum area (ha)
Ag/Ca[1]	2	14	8	6
Ag/Sc	31	1718	190	5
Ag/Sc/Ca	2	27	17	10
Bbr/Sc/Pp	1	20		
Bd/Ca	4	64	30	4
Bd/Cb	2	25	15	10
Bd/Sc	8	297	100	4
Bdic/Ap	2	1.5	1	0.5
Bdic/Sc	3	80	40	20

1/ Ag = *Andropogon gayanus* cv. Carimagua 1
Ca = *Centrosema acutifolium* cv. Vichada
Sc = *Stylosanthes capitata* cv. Capica
Bbr = *Brachiaria brizantha* cv. La Libertad
Pp = *Pueraria phaseoloides*
Bd = *Brachiaria decumbens*
Cb = *Centrosema brasilianum* CIAT 5234
Bdic = *Brachiaria dictyoneura* cv. Llanero
Ap = *Arachis pintoi* CIAT 17434

Table 13. Areas in which each species planted in 1987 is present.

Species	Planted hectares Pure	Associations	Total
A. gayanus	180	1759	1939
B. decumbens	-	386	386
B. dictyoneura	233	315	548
B. brizantha	-	20	20
S. capitata	122	2142	2264
C. acutifolium	1.1	105	106
C. brasilianum	0.1	25	25

decumbens or B. ruziziensis through the introduction of S. capitata, C. brasilianum and/or Calopogonium spp.

All of the farms selected are medium sized and dedicated to the dual production of beef and milk; nevertheless, and for convenience, the pastures will initially be evaluated with growing animals and in terms of weight gain only.

18. ECONOMICS

Activities during this year were focused on the development of institutional approaches for on-farm testing of pasture technology and the development of local seed multiplication as well as the characterization of candidate regions for collaborative OFR efforts.

At the major screening site for the Humid Tropics, Pucallpa/Peru, a postdoctoral fellow initiated OFR activities in cooperation with IVITA. The study will generate baseline data on existing farming systems, particularly on aspects related to traditional pasture establishment and management as well as expose farmers to legume grass pastures.

The diagnostic survey of smallholder farming systems in the evergreen rainforest of Napo/Ecuador conducted in collaboration with several Ecuadorian and international institutions has been completed and is in press. A follow-up project to monitor farms using improved agroforestry techniques has been planned and negotiations for funding are under way.

In Colombia, activities were expanded to two new areas: the Amazon Piedmont area of Caqueta and the Southern Valle/Northern Cauca region with about 200,000 ha of acid soils at altitudes between 1000 and 1700 meters.

Additional activities of the section included the collaboration with ICA (Instituto Colombiano Agropecuario) on the economic analysis of native savanna versus Brachiaria pastures in cow-calf operations and the preparation of a prefeasibility study on small-scale farm settlement in the Eastern Plains of Colombia.

The fifth annual RIEPT-survey of input and output prices related to pasture establishment and livestock production was analyzed and results were distributed to collaborting institutions.

The collaborative project on analysis of the demand for meats (beef, pork, poultry) undertaken jointly with FAO/RLAC was completed and is presently in print.

UNDERSTANDING THE ROLE OF PASTURES IN MIXED FARMING SYSTEMS OF THE WESTERN AMAZON: AN ON-FARM APPROACH

Colonization of the lowland humid tropics by small farmers leaving the overcrowded highlands is a continuing social and demographic phenomenon in the Andean countries bordering the Amazon Basin: Peru, Ecuador, Bolivia, Colombia and Venezuela. In planned colonization schemes, and more commonly in spontaneous migration following lumbering or petroleum exploration activities, these farmers find themselves in an unfamiliar environment facing great challenges and hardships. Yet the agrarian and demographic realities of the highlands will continue to be a significant and growing "push" factor inducing this population movement, as will the "pull" of large tracts of under-utilized and sparsely populated lands.

The acid infertile soils of the Amazon Basin pose serious constraints to economically viable, sustained yield agriculture. The Tropical Pastures Program has as its mandate the development of pasture technology (germplasm and management systems) to increase the productivity of this agricultural frontier and promote its rational and ecologically sound exploitation.

Cattle raising is an integral part of small farmer agricultural strategies in the humid lowlands. In general both recent and more settled colonists view livestock as an important component in their mixed farming systems. These farming systems generally also include annual crops (maiz and rice), longer cycle crops (yuca and platanos), and perennial crops (citrus, coffee and a variety of other tree and fruit crops). It is important to understand the role of pastures and livestock within these mixed farming systems in order to design appropriate technologies which are more likely to meet farmers needs and hence be adopted.

The goal of the research reported here is to understand the agricultural strategies of small farmers in the region through intensive monitoring of farming activities and through testing promising grass-legume pasture species under on-farm conditions. It is expected that these on-farm trials will be a rigorous test of promising pasture species under realistic conditions, providing insights into their performance that can be integrated into the process of agronomic evaluation and research. In addition, the reactions of the farmers to the technology will provide valuable information on management techniques and the needs of small farmers that will also aid the research process.

Scope of the Inquiry

This research, supported by the Rockefeller Foundation and IDRC in collaboration with CIAT and Peruvian national research institutions (IVITA, INIPA), focuses on the role of pastures in mixed farming systems of the humid tropics, using the area around Pucallpa, Peru as its geographic base. The principal activity is the on-farm trial of promising grass-legume pastures, with a secondary emphasis on general characterization of farming systems and investigation of potential arboreal components of silvopastoral and agroforestry systems. All activities are carried out from the principal research station of IVITA (Instituto Veterinario de Investigación en el Trópico y Altura) in collaboration with personnel of IVITA and INIPA (Instituto Nacional de Investigación y Promoción Agrícola).

The on-farm trials of promising grass-legume associations is intended to test several interrelated hypotheses:

1. Well-adapted grass-legume associations are capable of forming stable associations that are competitive biologically with aggressive native species of lower productivity (weeds).
2. Grass-legume associations can be established under low input conditions in a manner that is economically attractive to small farmers.
3. Appropriate grass-legume associations are more productive than either native or introduced grasses alone.
4. Any increased costs of grass-legume mixtures (seed, maintenance) are offset by gains in productivity over grass alone.

In order to test these hypotheses the project is collecting data on the costs of establishment and maintenance of grass-legume associations compared with the introduced grass pastures currently in use (mainly Brachiaria decumbens), as well as comparative productivity and persistence over time.

In the process of implementing this research, two interesting "side hypotheses" for testing have emerged. The first involves the feasibility of seed multiplication of forage legumes by small farmers. This will be investigated through a small pilot project using small farmers to produce seed with careful monitoring of labor inputs and costs versus potential profit through sale of seed. The project is providing technical assistance, seed and a guaranteed market for the purchase of seed. A second hypothesis involves testing farmer reactions to the use of inoculant to enhance the nitrogen-fixing capability of forage legumes. The Microbiology Section of the Tropical Pastures Program has identified productive strains of Rhizobium bacteria for increased root nodulation and symbiotic activity. We will be looking at the reaction of farmers to this technology through comparing the performance, and farmer assessment, of innoculated versus non-inoculated pastures. We expect that other equally interesting research topics will emerge in the course of this project.

Research Strategy and Methodology

On-farm trials are currently in progress on twelve farms in the Pucallpa area. In addition, seed multiplication plots, have been planted on two farms. Two different germplasm mixtures have been planted (see Table 1). The Brachiaria-based mixture has been planted on ten farms covering a total area of 13 hectares. The Andropogon-based mixture has been planted on two farms with a total of 7 hectares sown. All trials have been planted on land the farmers had previously chosen for planting of pastures. In all cases, these areas were covered with secondary vegetation (shrubs and small trees) having been cultivated previously and left fallow for four to ten years. Areas to be cleared varied from two to ten hectares, of which half has been planted in grass-legume associations and the other half in pure Brachiaria decumbens using traditional techniques. The project provides seed, barbed wire for fencing the experimental plot and technical assistance. The farmers provide land, labor and animals for grazing the paddocks once the pastures are established.

The project is collecting data on the costs and labor inputs involved in each phase of pasture establishment: clearing, burning, sowing and weeding. This information is collected for both the grass-legume association and the pure grass pasture in order to document comparative costs of the two techniques. This data is obtained through multiple visits and informal interviews with producers. In addition, we will be closely monitoring the rate of establishment of the pastures using standard agronomic sampling techniques to measure botanical composition, plant growth rates, vigor and presence of pests and diseases.

Once established productivity of the grass-legume versus pure grass pastures will be compared through measuring comparative milk production of cows alternately grazed in each type of pasture. Cows will be permitted to graze the pure grass association for a week to ten days. A registry of milk production for each individual cow will be maintained. The cows will then be shifted to the paddock with the grass-legume association and milk production from the same cows will be tabulated. It is hypothesized that the better diet provided by the grass-legume mixture will lead to significantly higher milk production.

Table 1. Grass legume associations planted in onf-farm trials in Western Amazonia

ASSOCIATION #1	
Grass:	Brachiaria decumbens 606 B. dictyoneura 6133
Legumes:	Stylosanthes guianensis 136 & 184 Centrosema acutifolium 5277 C. macrocarpum 5713 C. pubescens 438 & 442 Desmodium ovalifolium 350
ASSOCIATION #2	
Grass:	Andropogon gayanus
Legumes:	Stylosanthes guianensis 136 & 184 Centrosema acutifolium 5277 C. macrocarpum 5713 C. pubescens 438 & 442

Simultaneously with the initiation of grazing trials, data will be gathered regarding pasture performance. A crucial aspect of improving cattle production in the lowland humid tropics is pasture persistence and stability over time. Data will be gathered on botanical composition, plant vigor, forage on offer and other standard measures of pasture performance elaborated by the Tropical Pastures Program. In order to get an accurate prognosis of pasture persistence, these measurements should be carried out for at least five years after the initiation of grazing trials.

Progress to Date

Since initiating the research in March 1987, the project has selected participants through a series of interviews carried out with farmers in April and May 1987. These interviews led to the integration of thirteen farmers into the project. Farms were selected in order to include a range of socioeconomic and agroecological conditions among project participants.

The second phase of the project was implemented in June and July with the characterization of the second growth vegetation prior to clearing and burning. The ecological condition of these areas, especially soil and vegetation, was studied in order to obtain baseline data for subsequent study of the evolution of soil fertility and botanical composition over time. Within each parcel, a sample plot of 10x50 meters was delimited. Within this sample plot soil samples were taken and soil permeability was measured through a test of rate of water infiltration. The literature on pasture degradation has implicated changes in both soil nutrients and physical composition of the soil as key factors in declining productivity. The areas sampled were clearly marked with metal stakes so that the same areas can be repeatedly sampled over time in order to study the evolution of chemical and physical condition of the soil.

In addition, data was collected on botanical composition (species present) and biomass (diameter and height of woody vegetation). Additional information on leaf litter cover, presence/absence of grasses or aggressive pasture weeds and site topography was recorded. It is expected that this information will provide a clear picture of the conditions prior to burning, and may even lead to a predictive model regarding the agricultural potential of different types of secondary growth. Already a second set of soil samples has been taken after the burning of the parcels in order to gauge the effects of the burn on soil nutrient composition. These data are currently being analyzed. The process of clearing and burning was also monitored in order to obtain information on labor inputs involved.

The sowing of grass-legume associations was timed to coincide with the onset of the rainy season which usually occurs in September. The initiation of the rains was delayed this year with only sporadic rainfall until late October. This caused several farmers to lose cultivated crops (mostly maize) planted in September. Twelve grass-legume pastures were planted from 28 October through 28 November. (One trial has yet to be planted due to delay by the farmer in clearing and burning). Planting methods and rates of seeding were determined in conjunction with agronomists from INIPA and IVITA, as well as local farmers, with experience in the sowing of grass-legume associations. All parcels were sown broadcast by farmers with technical assistance from the project. Half of the area planted to grass-legumes mixtures was planted with legume seed inoculated with Rhizobium bacteria in order to judge the effect of this treatment on pasture performance under on-farm conditions.

The rate of establishment of these pastures is currently being monitored. It is expected that some areas may have to be resown. Already we have learned much regarding techniques of sowing pastures on-farm. For example, rates of germination of Centrosema species seems to be low when they are sown broadcast. This genera has rather large seeds that tend to sit exposed on the soil surface where they are subject to desiccation after initial germination. If initial germination is not followed by steady rain, the seed often does not survive. Therefore some areas will be resown with Centrosemas using a machete or digging stick to plant the seed in the ground and enhance successful germination. This is of course more labor intensive than simple broadcast sowing, but this kind of information is an important criterion for judging the suitability of different species under varying on-farm conditions. Another lesson we have learned is the desirability of making legume inoculant a different color other than the current black (greyish black once pelletized with rock phosphate). The current color makes the seed extremely hard to see when it is sown in recently burned fields and therefore makes even distribution of broadcast sown seed difficult to achieve. This is the kind of information that can only be generated by on-farm trials in which relatively large areas are being planted by the farmers themselves.

Future Plans

It is expected that grazing trials will begin at the earliest in June 1988 or more probably in September/ October 1988. Initiation of grazing trials depends on a variety of exogenous factors, especially weather. Under current management techniques pastures planted at the initiation of the rainy season are usually not ready for grazing until the end of the rainy season (May/June). At that time they are subject to a light grazing during the early part of the dry season, then intensively weeded and frequently burned before the onset of the rains. The rain induced regrowth is then ready for extended grazing. Behavior of the grass-legume pastures under this management regime is problematic due to the possible sensitivity of legumes to fire. In any case, it would probably be unwise to submit the newly planted pastures to intensive grazing during the dry season a time of plant stress due to prolonged moisture deficiency.

Several questions remain regarding the scope and nature of future work in the field. For example, do we wish to expand the number and area of on-farm trials a year from now, at the onset of the 1988 rainy season? A more critical question is the long-term monitoring of the persistence and stability of pastures sown this year. Much of the promise and potential impact of grass-legume pasture depends on their stable productivity over time. To be successful grass-legume pastures must be persistent. Persistence is contingent upon their ability to tolerate acid infertile soils and to compete with aggressive native species of low productivity, weeds. The germplasm planted in the on-farm trials has undergone agronomic selection for these qualities. It is extremely important that these species confirm their potential under on-farm conditions. Only then we can confidently move forward towards the transfer of these species, and techniques for their management, on a more massive scale.

USE OF BRACHIARIA DECUMBENS IN DUAL PURPOSE FARMS IN THE ANDEAN PIEDMONT OF CAQUETA, COLOMBIA

Within the general objective of the program of exposing promising technology to relevant farming systems, adaptive on-farm research activities were started in a collaborative project with several public and private institutions of the region.

The Andean Piedmont of Caqueta is one of the largest continuous areas of cleared Amazon forest with about 1.2 million ha of pastures. It is an old settlement region with mainly small to medium-sized owner operated farms. Cattle is by far the predominant enterprise, with dual purpose beef-milk production being particularly important among medium and smaller farms.

Ecologically the region is an evergreen rainforest with about 3500 mm annual rainfall without a marked dry season. Soils are mainly Ultisols with low pH, low base saturation and a high content of exchangeable aluminum. These physical conditions and the distance to major population concentrations limit the number of production alternatives, making the system particularly dependent on pastures and cattle production.

Settlers initially introduced pasture germplasm (Hyparrhenia rufa, Axonopus scoparius) from their regions of origin (generally the more fertile Andean valleys) and initially succeded in getting pastures established following the burning of the primary forest. With the subsequent leaching of nutrients out of the topsoil, these pastures rapidly degraded and were replaced by a mixture of less productive species (Paspalum spp., Axonopus spp., etc.) locally called "criaderos".

Since the mid-seventies the region has seen a very rapid adoption of the grass Brachiaria decumbens, which has now become the major improved pasture. It has made possible a substantial increase in carrying capacity but farmers still face a series of problems:

- Spittlebug (Zulia colombiana) is becoming an increasing problem as B. decumbens areas expand, pinpointing the risk of basing the

livestock economy of the region almost exclusively on one species.
- Milk production levels are still low and drop during the peak rainfall period.
- Establishment of B. decumbens pastures is costly using the traditional labour intensive vegetative multiplication and pastures are showing signs of degradation.

The objective of this study was to document the autonomous diffusion process of B. decumbens, to extract lessons from this process for the generation and effective diffusion of other materials and to identify constraints of the existing B. decumbens technology which could be overcome through appropriate research and development activities.

A random sample of 118 farms (10% of all farms delivering milk to the main dairy plant) were interviewed, B. decumbens pastures were sampled by estimating pasture coverage, weed and legume share of canopy, taking plucked samples of B. decumbens forage for protein content determination, obtaining soil samples from the same pastures and recording the previous history of the pasture. Additionally the dairy plant supplied information on monthly milk delivery during the year 1986 for the farms surveyed. Information is presently being analyzed and only selected preliminary results are reported here.

Table 2 presents an overview of the resource base of these farms. The mean farm size was of 130.5 ha. Pastures are clearly the major form of land use, degraded pastures, "criaderos", being the largest share thereof. B. decumbens follows in importance covering 27% of the area of pastures on average. H. rufa, the grass originally introduced by the settlers still covers 2.7 ha per farm. Small areas of several other grasses are found, but in the aggregate they only represent 5% of the pasture area of the average farm.

On average crops cover only 3.7 ha of the farm area, the major part being subsistence crops (rice, plantains, cassava). Maize is the only annual cash crop, frequently grown after burning in the process of establishing pastures. Permanent crops (cocoa, rubber and sugar cane) were only encountered on 13% of the farms, comprising very small areas in each. It is known that coca growing is an important sideline enterprise in many of these farms. Due to its illegality questions about this enterprise could not be included in the survey; its existence must nevertheless be taken into account for the interpretation of the survey results.

The extent of deforestation in the region is shown by the limited amount of primary forest remaining on the farms. It had completely disappeared on 25 farms and on average amounted to less than 10% of the farm area for the whole sample. The average farm had 22.4 ha or 17% of its land in fallows. Degrading pastures can evolve either to "criaderos" or to fallows depending on the management. If land is not a very binding constraint, fallows are the preferred way to reclaim pastures.

The average farm was stocked with a herd of 121 head, of which the operator owned 72. This documents the relative scarcity of capital of settlers, which are therefore willing to accept cattle on a share-cropping basis, a mechanism which gives these settlers access to capital markets. This share-cropping arrangement can be expected to reduce optimum feeding intensity but will make innovations which increase stocking rate attractive. Given the scarcity of cattle in the region, cattle owners have enough bargaining power to insure adequate feeding of their animals.

Table 2. Factor endowment of survey farms. Caquetá 1987.

Factor Endowment	Mean Values ($\bar{x}$)	Percentage (%)
Land (ha)	130.5	100.0
Flat	42.5	32.6
Sloping	88.0	67.4
Area of pastures (ha)	95.3	100.0
"Criaderos"	61.9	64.9
B. decumbens	25.9	27.2
H. rufa	2.7	2.8
Others[1]	4.8	5.0
Cropping area (ha)	3.7	100.0
Subsistence crops	1.4	37.9
Maize	1.6	43.2
Permanent crops	0.7	18.9
Fallow land (ha)	22.4	17.1
Primary forest (ha)	9.1	7.0
Cattle		
Total number on-farm	121.2	100.0
Cows	48.5	40.0
Fattening steers	6.7	5.5
Labor (ME)		
Total man equivalents employed	3.8	100.0
Family labor	2.0	52.6

1/ Includes *B. humidicola*, *P. maximum*, *B. mutica*, *E. polystachya*, *A scoparius* and *P. purpureum*.

Source: Survey on Dual Purpose Production Systems and adoption of *B. decumbens* in Caquetá, Colombia.

Cows make up 40% of the total herd on average with a slight tendency to find proportionally more cows in smaller farms. Conversely more fattening steers are found in larger farms reflecting changing factor proportions.

Contrasting with the ownership situation of cattle, most farms are owner operated, most owners have legal titles to the land they farm, and only two farmers surveyed were tenants.

Family labor supplied slightly more than half (53%) of the total labor input to the farm. Thus, in spite of being family farms, labor supply is limited and has an opportunity cost, a fact to be taken into account in the search for technological innovations.

Table 3 presents estimates of herd performance indicators. Productivity levels achieved are similar to those encountered in other dual purpose systems of Latin America. Per hectare performance is better than in many other regions due to the absence of a marked dry season, a fact which allows farmers to maintain relatively high stocking rates year round.

The survey documented that farmers apply most herd management practices usually recommended such as internal and external parasite control, vaccinations, mineral supplementation, etc. This and the fact that farmers have autonomously adopted B. decumbens supports the hypothesis that quality of forage is a major constraint in this system.

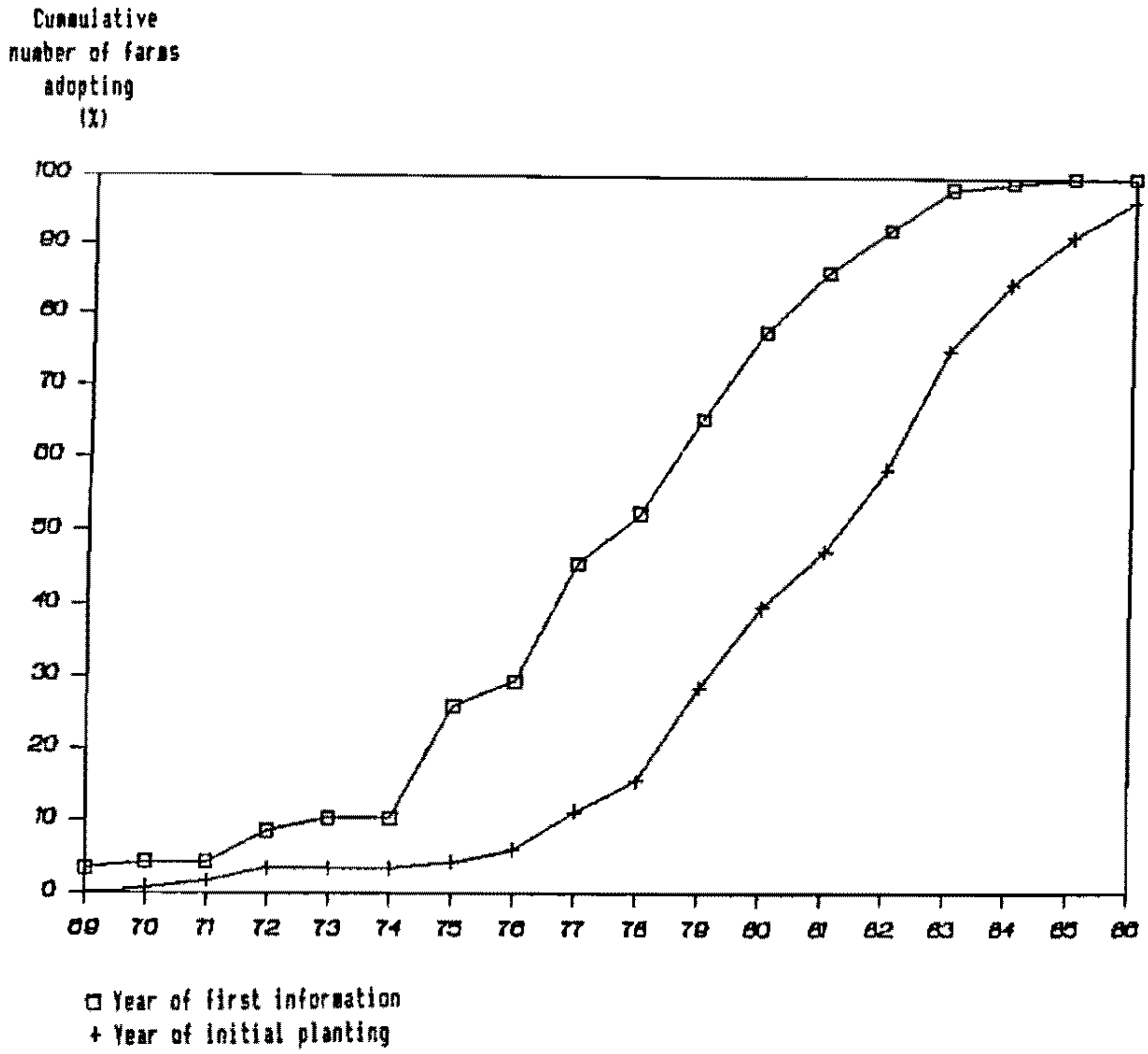
The first plantings of B. decumbens reported in the survey took place in the year 1969. Ten years later the number of farmers with plantings of the grass had increased slowly to less than 20% of the population (Figure 1). At the time of the survey, after another nine years 97% of the farmers have adopted it. This pattern of a slow initial phase can clearly be related to the lack of research and extension in the region. Efforts to shorten the trial and error process of farmers and to communicate results of this learning process to the farming community might have had a high social pay-off. More in depth analyses of this process and particularly the performance of B. decumbens as well as its shortcomings are under way and shall be reported at a later point in time.

Table 3. Herd performance indicators, Caquetá 1987.

Parameter	Mean	Range	CV (%)
Calving rate (%)	61.2	14.1-100.0	30.1
Calf mortality (%)	9.5	0- 75.0	127.1
Adult mortality (%)	2.7	0- 37.5	183.5
Off take rate (%)	17.3	0- 87.1	82.1
Liters of milk per:			
. Lactation[a]	577	48-1008	29.2
. Cow in herd	308	21- 880	56.1
. ha pastures/year	883	49-4986	67.2
Beef:			
. kg/head/year	83.1	0- 120	41.1
. kg/ha pastures/year	121.7	0- 476	66.5
Stocking rate (animals/ha)	1.50	0.3- 5.6	51.7

a/ Lactation length = 240 days

Source: Survey.



Source: Survey

Figure 1. Diffusion of Brachiaria decumbens among dual purpose farms in Caquetá, 1987.

COLLABORATIVE ON-FARM RESEARCH IN SOUTHERN VALLE AND NORTHERN CAUCA REGION OF COLOMBIA

In 1986 a group of farmers from the Cauca and Valle Departments approached the program to explore possibilities of making pasture technology developed at the Quilichao Research Station available to the surrounding farming community. The research conducted there had mainly been considered of methodological nature, used for the program's training activities but had not specifically been targeted at making an impact to the region, mainly because conditions of the region were not representative of major ecosystems of tropical Latin America due to the combination of very acid soils, altitude of about 1000 m above sea level and a strongly bimodal rainfall pattern.

Initial conversations with interested regional institutions, Fondo Ganadero del Valle del Cauca (FGV), Instituto Colombiano Agropecuario (ICA) and Corporación Autónoma Regional del Cauca (CVC) focused the potential contribution this technology could make in two distinct settings: medium sized beef and dual purpose operations on acid soils with flat to slightly hilly topography at altitudes very similar to that of the Santander de Quilichao region and small farms on similarly acid soils in the hilly region of Northern Cauca at altitudes between 1400 and 1700 m. The former situation was one similar to the research station's conditions allowing extrapolations at low risk. From work at the station and some farmer trials it was inferred that the major problems related to pasture establishment and particularly weed control in mixed legume-grass stands. Several farm trials were established to test alternative strategies to tackle this problem.

The development of pasture technology for the small, mixed crop-livestock farms in Northern Cauca was recognized as a much more difficult challenge, but of high priority to regional institutions due to the lack of development options for this sector, the rapid outmigration, serious erosion problems and recent social unrest.

A task force was created with participants from all four institutions involved to undertake a rapid rural appraisal of the existing production systems and the potential contribution of improved pasture technology. The major findings of this group were:

- About 200,000 ha of acid soils at altitudes between 1000 and 1700 m above sea level. Important areas or land heavily eroded due to annual cropping on sloped land, particularly of cassava, one of the few crop options in this region.
- Large number of small farmers (5-20 ha), cropping systems based on cassava, coffee, beans and small plots of vegetables, particularly tomatoes grown with heavy use of chicken manure and mineral fertilizers.
- In spite of the small farm size, a high percentage of the land is in fallows.
- The region has good road infrastructure and is relatively close to the Cali market.
- The naturalized grass Melinis minutiflora is the predominant pasture found, with limitations of carrying capacity, dry season production and tolerance of burning. Farmers are undertaking informal trials of establishing B. decumbens, mainly in association with or after cassava cultivation. Very few farmers have obtained B. humidicola, originally introduced to the region via the Santander de Quilichao Station and are testing it.
- Cattle production is presently of limited extent, mainly oxen for animal traction and some dairy cows. A local market exists for milk and farmers are interested in expanding dairy production. Access to appropriate cattle seems to be an additional constraint.

Labor availability seems to be a serious constraint, due to the outmigration of young people and the very marked bimodal rainfall pattern making timeliness in farming activities very critical. These problems are compounded by the hilly topography causing high costs of land preparation which can frequently only be done with animal traction or by hand.

Given this diagnosis, an action plan for a collaborative program was set up. The objective was to contribute to develop the region through a strategy of livestock production on improved pastures within the context of a mixed farming system. The expanded use of pastures is expected to contribute to the sustainability of the system through reduced soil erosion and a more diversified income structure.

The strategy comprised:

1. Development of appropriate pasture technology (particularly germplasm and establishment) through early interaction with farmers.
2. Production and delivery of sexual seed and vegetative materials of the cultivars in demand.
3. Extension of results through field days, leaflets, etc.
4. Provision of mechanisms to make available appropriate cattle for dual purpose milk production (sale with access to official credit programs, cattle loans through cattle bank, e.g. Fondo Ganadero).
5. Contribution to the identification of further bottlenecks and their solution as needed (potentially milk marketing, supply of bulls or artificial insemination, purchase of fertilizers, etc.).

The approach to achieve this involved agreement among all participating institutions on a very focused objective considered of high priority by all involved parties, the recognition of the comparative advantages of each institution and the segmentation of the whole program into specific activities for which individual institutions and persons within them assume responsibility and credit if successful. Progress is reviewed in periodic meetings of all participants. These meetings additionally serve the purpose of generating peer pressure to achieve results and recognition for the work done.

After the initial diagnosis the following activities were started:

1. Multilocational small plot trials of three Brachiaria species (B. dictyoneura, B. humidicola and B. decumbens) with a mixture of two legumes (D. ovalifolium and A. pintoi) with and without fertilizer were established at ten (10) different locations across the region including different soils, slopes, previous cropping histories and microclimatic conditions. Response variables were coverage of individual species including weeds over time and forage production during a two month period in the rainy season one year after establishment. Results obtained up to now indicate the good adaptation of the grasses, the survival but limited growth of the legumes tested, a very variable response to fertilization.

2. Expansion of the germplasm base, particularly of legumes through the establishment of a regional trial type B with heavy emphasis on Centrosema species.

3. Development of low cost pasture establishment techniques through establishment of pastures in combination with cassava. The trial involves introduction of the legume and the grass components at varying points in time during the production cycle of cassava.

4. Commercial scale plantings of pastures of a mixture of B. dictyoneura, B. decumbens and D. ovalifolium have been established by three farmers. These pastures should allow farmers to assess the merits and drawbacks of these cultivars under grazing. The need to test pasture options under realistic grazing conditions incorporates a substantial time lag between the initial agronomic work and the relevant farmer feedback. Therefore, the project has emphasized the

urgency to initiate this phase.

5. Seed multiplication efforts by the program involve two sets of activities. Pilot project scale multiplication (2 ha) of sexual seed of two Centrosema materials, D. ovalifolium and vegetative material of A. pintoi is being undertaken by FGV. CVC with support of CIAT and FGV have established two plots for the production of vegetative material of three Brachiaria species, D. ovalifolium and A. pintoi at two locations in the target region comprising a total area of 5 ha. This material should be available to farmers by mid 1988.

One year after the first small plot trials were planted is too short a period to assess results but already important lessons were learnt.

The constraints of topograpy, soil fertility and marked dry seasons limited the potential of the existing germplasm more than initially expected, thus leading to an expansion of the germplasm base under testing.

The short duration of the rainy seasons make appropriate timing very critical, thus increasing the opportunity cost of labour and animal traction during these short periods. This has important implications for the establishment techniques to be developed. Both the timeliness problem, the high cost of land preparation and lack of fertilizer use for pastures pinpoint the need to develop techniques to combine pastures and crops.

As stated initially, this activity involves a wide range of institutions and individuals of these institutions. Within CIAT personnel from several Tropical Pastures Program sections was involved with individual activities (e.g. systems, plant nutrition, seed production); IFDC staff and CIAT Cassava Program personnel contributed to the initial diagnostic survey. The role of the Economics Section has been to act as a focal point to coordinate activities both within CIAT and with other institutions and to provide continuity to the effort.

EXTENT OF SUBSTITUTION AMONG MEATS AND OUTLOOK FOR THE YEAR 2000

During 1987 the collaborative FAO-RLAC/CIAT project on the demand for meats in Latin America was completed. A major objective of the study was the econometric estimation of demand parameters (income, price and cross-price elasticities) for beef, pork and poultry for selected Latin American and Caribbean countries (see previous annual reports).

This information was used to estimate the extent to which the observed marked reduction of real poultry prices has induced a substitution of beef by poultry in the consumer diets (Table 4). Using the initial price of poultry and all other variables at the observed levels of the last year of the period under analysis, estimates of the expected beef consumption without poultry substitution were obtained. Comparing this level of beef consumption to the actual one in the last year of the period of analysis gives the amount of beef demand replaced by poultry. Such an analysis was undertaken for Brazil, Colombia and Mexico; countries for which positive and significant cross price elasticities were estimated.

Brazil is the country with the largest substitution effect. If the price of poultry had remained at 1960 levels in real terms, Brazilians would now consume 7.8 kg of beef more than they actually did, i.e. poultry replaced 47% of the beef. This is mainly due to the drastic change in price of poultry while the cross price elasticity is the lowest of the three countries studied (0.42). In

Table 4. Extent of substitution of beef by poultry in selected Latin American countries.

Country	Period		Real consumer price poultry[a]		Relative consumer price poultry/beef		Observed beef consumption (kg/capita)[b]		Expected per capita beef consumption[b]	Beef substituted (kg per capita in	Beef substituted and percentage of observed consumption	Gross price elasticity
	Initial Year (t_o)	Final Year (t_n)	Initial Year (t_o)	Final Year (t_n)	Initial Year (t_o)	Final Year (t_n)	Initial Year (t_o)	Final Year (t_n)	(t_n)	t_n)[c]	(t_n)[d]	
Brazil	1960	1982	13.30	5.85	1.80	0.49	18.8	16.5	24.3	7.8	47.3	0.42
Colombia	1960	1984	23.4	10.9	1.20	0.70	22.7	25.4	32.3	6.9	27.2	0.50
Mexico	1966	1982	40.7	32.7	0.67	0.47	8.9	8.6	10.5	1.9	22.1	0.74

a/ Expressed in units of domestic currency (Brazil: 1970 cruzeiros, Colombia: 1975 pesos, Mexico: 1978 pesos).
b/ Poultry price assumed constant at t_o level for all t_n. Other variables at observed levels.
c/ Difference between beef consumption in t_n with constant and poultry price (t_o) and observed quantity in t_n.
d/ Difference in consumption as percentage of historical consumption level in t_n.

Source: Own calculations.

aggregate terms this corresponds to 966 thousand metric tons of beef representing 40.5% of the total production of that year.

For the case of Colombia in spite of a somewhat higher cross price elasticity, the quantity of beef replaced only amounts to 27% of 1984 actual beef consumption. This is due to smaller reduction of the relative poultry price in Colombia than in Brazil. Additionally beef consumption levels have historically been higher in Colombia and have been increasing over the period studied.

Mexico presents the lowest level of substitution of beef by poultry (22%) in spite of presenting the highest cross price elasticity (0.74). Poultry price only dropped by 20% over the period 1966/82.

Computing the national volume of beef substituted by Brazil, Colombia and Mexico, and putting it in relation to the total beef production of Latin America of 8.2 million metric tons in 1984, we arrive at the estimate of at least 16% of the production substituted. This clearly is a lower bound because it assumes zero substitution for the countries where no significant positive cross price elasticity could be estimated and for the countries not included in the study. It is clear that the fact of not being able to quantify those elasticities does not imply their inexistence.

The estimated demand parameters were also used to project supply demand balances for the year 2000 under alternative scenarios of income growth and changes in real prices (Table 5). Production of meats was assumed to grow at the average rates of the sixties and seventies for all scenarios.

Scenario 1 represents a situation of zero income growth and constant real prices. Changes in the balances are thus only due to the difference between the growth rate of the population and that of the supply of individual meats. This results in small beef surplusses (less than 3% of domestic production in the year 2000), pork deficits in Brazil and Colombia and poultry surplusses in all three countries. Scenario 2 incorporates an assumption of moderate per capita income growth (3% p.a.), other variables evolving at historical growth rates. This leads to substantial beef deficits in all three countries; the Colombian deficit is particularly large due to the high income elasticity of beef estimated for that country. Poultry deficits occur in all countries; Brazil's deficit is of over one million MT due to the very high poultry elasticity. (This is probably a substantial overestimation due to the change in size of the coefficient that can be expected to go along with a change in per capita consumption of the magnitude implied here).

While the previous scenarios incorporated negative growth rates of poultry prices, Scenario 3 involves a 2% annual growth rate of poultry prices, depicting a situation of higher international grain prices, further devaluation of domestic currencies in countries that are net grain importers. Income growth is again set at 3%, other variables growing at historical rates. This scenario would imply the existence of large beef deficits in all three countries analyzed ranging from 19% of domestic consumption in Mexico to 30% in Brazil as well as poultry and pork deficits in Brazil and Colombia.

These scenarios, which are projections and not forecasts, pinpoint the sensitivity of the regions meat supply demand balance to economic growth and the need to take poultry increasingly into account in the design of policies related to the meat sector.

Table 5. Supply demand scenarios for meats in selected Latin American countries, year 2000.

Scenarios	Country	Balance Production-Demand ('000 tn)		
		Beef	Pork	Poultry
I Per capita consumption constant at 1984 level*	Brazil	51	-123	545
	Mexico	14	226	161
	Colombia	32	-17	16
II Real per capita income growing at 3% p.a.	Brazil	-220	-194	-1016
	Mexico	-68	68	-52
	Colombia	-375	-28	-53
Other variables growing at historic rates**				
III Real poultry prices growing 2% p.a. Income growing 3%.	Brazil	-881	-158	-339
	Mexico	-161	197	14
	Colombia	-422	-24	-43
Other variables growing at historic rates.				

* Brazil at 1982 level.

** Period Brazil: 1960/82
Period Colombia: 1960/84
Period Venezuela:1956/84

19. TRAINING

During 1987, in accordance with one of its main objectives, the Tropical Pastures Program (TPP) offered, in collaboration with the Scientific Training Program, to 55 professionals from 19 countries training in 15 research disciplines. This training was accomplished in various categories, as observed in Table 1. The Sections that dedicated most time to training were: Pasture Development with 41.2 man/months, Agronomy with 34.6 man/months, and Soils/Plant Nutrition with 23.2 man/months (Table 1). The number of researchers trained in 1987 according to country of origin is presented in Table 2.

From February 2 to March 8, the Intensive Multidisciplinary Phase of the Tenth Scientific Research Training Program for tropical pasture production was carried out with the participation of 31 professionals from twelve tropical American countries (Table 3). Of these 31 professionals, 22 took part in the Specialization Phase in different disciplines according to their specific interests and specialty. The duration varied from 2 to 6 months, depending on the Section where the work was conducted.

Support to Special In-Country Courses

Following many years of strengthening the scientific capacity of national research institutions through annual courses in CIAT, a need has been identified for further support through in-country courses to train professionals from research, extension and livestock development institutions. Accordingly, two special training courses were carried out during 1987. The first took place in Pucallpa, Ucayali, Peru entitled "Course-Workshop on the Establishment, Maintenance and Production of Pastures in the Peruvian Tropics". Thirty-three professionals from different official organizations attended (Table 4). The Instituto Nacional de Investigación y Promo- ción Agropecuaria (INIPA), the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), the Corporación de Desarrollo de Ucayali (CORDEU) and the Centro Internacional de Agricultura Tropical (CIAT) participated in the organization of this event.

Rodolfo Schaus A. and Jorge W. Vela A., and Veterinarian Washington Alvarez G. participated on behalf of INIPA; Luis Alberto Pinedo S., Mariano Gonzalo Echavarria R., César Augusto Reyes A. and Miguel Ara for IVITA; Julio César Alegre O. and Kenneth Reátegui on behalf of the NCSU/INIPA project; Salomón Helfgott Lerner for the Universidad Agraria "La Molina"; Leonardo Fulvio Hidalgo for the Universidad Nacional de Ucayali; Juan de Dios Zúñiga Q. for CIPA XXIII; J. Palacios Ramos for the Banco Agrario del Perú; and J.G. Salinas, John E. Ferguson, William Loker, Raul Vera, and Lourdes Mariella van Heurck and Ramón Gualdrón for CIAT's Tropical Pastures Program.

The second course, "Meeting to define the present status and outline strategies to improve the supply of pasture seeds in the Republic of Panama" took place in Santiago, Veraguas. The meeting was attended by 15 participants from Panama, and two from Costa Rica, who represented different official institutions and entities in the private sector presently participating in seed production activities. The Instituto de Investigación Agropecuaria de Panamá (IDIAP) and the Centro Internacional de Agricultura Tropical (CIAT), were responsible for the organization of this event. Presentations were given by Miguel Avila, Héctor Aranda and José Albán Guerra from IDIAP; Víctor Prado and Juan Carlos Jiménez from the Ministry of Agriculture and Livestock of Costa Rica, and J. E. Ferguson, Raul Vera and Carlos Iván Cardozo from CIAT's Tropical Pastures Program.

TRAINING ACCOMPLISHMENTS IN THE TPP

A total of 436 professionals have received research training in the Tropical Pastures Program at CIAT-Palmira in the period between 1978 and 1987(Table 4). As shown in Table 5, the Programs of Scientific Training and Tropical Pastures, have trained between 1986 (initiation) and 1987, 66 professionals through special in-country courses.

The training offered at CIAT-Palmira includes different categories: thesis to obtain an M.S. or Ph.D.., research specialization, specialization plus an Intensive Multidisciplinary Course, Multidisciplinary Intensive Course or Short Course.

Table 6 presents information on trained professionals by country that have participated in the ten Tropical Pasture Training Programs. The largest number of professionals trained come from Brazil, Colombia, Peru, Bolivia, Mexico, Nicaragua and Panama. This is in agreement with the priority given to countries on the basis of their areas of acid, infertile soils.

Table 1. Professionals trained during 1987 in the Tropical Pastures Program according to categories and man/months in each Section.

DISCIPLINE (Section)	Training Category: Visiting Research Associate	Visiting Researcher			Multi-disciplinary Course Participants	
	Ph.D. Theses	M.S. Theses	Special-ization	Special-ization + Multid.-Intensive Course		Sub-totals
	No.(M/M*)	No.(M/M)	No.(M/M)	No.(M/M)	No.(M/M)	No.(M/M)
Germoplasm			3(1.9)			3(1.9)
Agronomy			1(1.7)	6(32.9)		7(34.6)
Entomology		1(5.8)	1(1.0)			2(6.8)
Plant Pathology			1(3.3)			1(3.3)
Soils/Plant Nutrition				3(23.2)		3(23.2)
Microbiology	1(12.0)		3(11.0)			4(23.0)
Biotechnology				1(4.9)		1(4.9)
Ecophysiology		1(4.0)		2(11.0)		3(15.0)
Pastures Development		1(12.0)	1(4.9)	4(24.3)		6(41.2)
Animal Nutrition			2(1.9)			2(1.9)
Seed Production			(3.1)	1(5.6)		4(8.7)
Livestock Production Systems	1(3.0)		1(1.9)	4(16.4)		6(21.3)
Economics			3(9.2)			3(9.2)
Administration Exper. Stations				1(3.9)		1(3.9)
Intensive Phase (Short Course)				9(16.9)	9(16.9)	
TOTAL PROGRAM	2(15.0)	3(21.8)	19(39.9)	22(122.2)	9(16.9)	55(215.8)

* Equivalent to training man/months.

Table 2. Profesionals trained in the Tropical Pastures Program during 1987 by country of origin.

	Training Category					
	Visiting Research Associate	Visiting Researcher			Multi-disci-plinary course parti-cipants	
COUNTRY	Ph.D. Theses	M.S. Theses	Special-zation	Special-lization + Multid. Intensive Course		Sub-totals
	No.(M/M*)	No.(M/M)	No.(M/M)	No.(M/M)	No.(M/M)	No.(M/M)
LATIN AMERICA AND THE CARIBBEAN:						
Antigua			1(1.9)			1(1.9)
Argentina			1(1.3)		2(4.0)	3(5.3)
Barbados			1(1.0)			1(1.0)
Bolivia		1(5.8)	3(6.2)	2(13.3)		6(25.3)
Brazil			2(8.8)	2(12.1)		4(20.9)
Colombia	1(3.0)	1(4.0)		2(9.9)	6(11.0)	10(27.9)
Costa Rica				1(3.9)		1(3.9)
Cuba			1(0.3)	4(20.8)		5(21.1)
Ecuador			2(3.2)	1(4.4)	1(1.9)	4(9.5)
Guatemala				1(3.9)		1(3.9)
Honduras				1(6.2)		1(6.2)
Mexico			2(3.0)	4(25.3)		6(28.3)
Nicaragua				2(15.5)		2(15.5)
Paraguay			1(0.4)			1(0.4)
Perú		1(12.0)	2(2.8)	2(6.9)		5(21.7)
Venezuela			1(3.3)			1(3.3)
OTHERS COUNTRIES:						
Uganda			1(1.7)			1(1.7)
DEVELOPED COUNTRIES:						
Germany (F.R.)	1(6.0)			1(6.0)		
Switzerland	1(12.0)					1(12.0)
TOTAL PROGRAM	2(15.0)	3(21.8)	19(39.9)	22(122.2)	9(16.9)	55(215.8)

* Equivalent to training man/months.

Table 3. Information on the participants in the Tenth Scientific Training Program in Tropical Pastures (1987).

Name	Country	Institution	Profession	Work areas[a]	Time % in tropical past.activ.	Training Area	Duration (weeks) Short course	Duration (weeks) Specializ. phase
1. Julio C. Mombelli	Argentina	INTA	Agronomy	1 - 3 - 9 - 12b - 13	20	S.C.[b]	8	-
2. Agustín Pérez	Argentina	M.A.A.M.	Agronomy	3 - 9 - 13	20	S.C.	8	-
3. María Lucy Rivera	Bolivia	SEFO	Agronomy	3 - 12a - 12c	60	S.C.+ Seed Production	8	13
4. Mario Veizaga	Bolivia	Univ.San Simón	Agronomy	3 - 7 - 9 - 12a	50	S.C.+ Soil/Plant Nutrition	8	26
5. Miguel Paredes	Brasil	EPAMIG	Agronomy	9	100	S.C.+ Pasture Quality and Productivity	8	9
6. Newton de Lucena Costa	Brasil	EMBRAPA	Agronomy	1 - 4 - 7 - 8 - 9	100	S.C.+ Pasture Quality and Productivity	8	26
7. Javier García	Colombia	CENICAFE	Agronomy	1 - 4	10	S.C.	8	-
8. Eduardo Hernández	Colombia	CENICAFE	Agronomy	1 - 3	10	S.C.	8	-
9. Efraín Ponce	Colombia	ICA	Anim.Sci./Vet.Med.	3 - 9 - 11 - 16	30	S.C.+ Pasture Quality and Productivity	8	12
10. Yezid Hernández	Colombia	ICA	Anim.Sci./Vet.Med.	9 - 11 - 13	30	S.C.+ Pasture in Livestock Prod.Systems	8	9
11. Jorge Medrano	Colombia	ICA	Anim.Sci.	9 - 11 - 13	30	S.C.	8	-
12. Lino Torregruza	Colombia	ICA	Agronomy	3	100	S.C.	8	-
13. José A. Mila	Colombia	ICA	Agronomy	1 - 3 - 4 - 5 - 6 - 7	100	S.C.	8	-
14. Elías Correa	Colombia	ICA	Anim.Sci.	-	-	S.C.	5[c]	-
15. Antonio Pérez	Cuba	Deleg.Prov.MINAG	Agronomy	3 - 9 - 11 - 12c - 16	100	S.C.+ Ecophysiology	8	22
16. Aldain García	Cuba	MINAG	Agronomy/Anim.Sci.	3 - 9 - 11 - 12c - 13	100	S.C.+ Ecophysiology	8	22
17. Roberto Juan	Cuba	IIPF	Agronomy	1 - 3	100	S.C.+ Forage Agronomy	8	13
18. Raimundo Cruz	Cuba	Inst.Ciencia Animal	Anim.Sci.	15	100	S.C.+ Biotechnology	8	13
19. David Fallas	Costa Rica	ECAG	Anim.Prod.	11	20	S.C.+ Research Administration	8	9
20. Lorenzo González	Ecuador	INIAP	Anim.Sci.	1 - 4	80	S.C.+ Pastures in Livestock Prod.Systems	8	9
21. Enrique Piguave	Ecuador	PROFOGAN-GTZ	Agronomy	9 - 11 - 13 - 14	30	S.C.	8	-
22. Carlos E. Saavedra	Guatemala	ICTA	Anim.Sci.	3 - 13	60	S.C.+ Pastures in Livestock Prod.Systems	8	9
23. Gersan Laínez	Honduras	MRN-DARS	Anim.Sci.	1 - 3 - 9 - 11 - 12 - 16	25	S.C.+ Pasture Quality and Productivity	8	26
24. Sergio Amaya	Mexico	INIFAP	Agron./Appl.Botany	4 - 16	100	S.C.+ Forage Agronomy	8	22
25. Isaías López	Mexico	INIFAP	Agronomy/Anim.Sci.	3 - 4 - 9 - 13	70	S.C.+ Forage Agronomy	8	22
26. Alejandro Ayala	Mexico	INIFAP	Agronomy/Anim.Sci.	1 - 3 - 4 - 9 - 11 - 13	95	S.C.+ Forage Agronomy	8	13
27. José A. Fernández	Mexico	CIEEGT-UNAM	Anim.Sci./Vet.Med.	1 - 9 - 13	80	S.C.+ Forage Agronomy	8	22
28. Samuel Sandoval	Nicaragua	EGRA	Anim.Sci.	9 - 11	100	S.C.+ Soils/Plant Nutrition	8	22
29. Edmundo Nicaragua	Nicaragua	EGRA	Agronomy	11	25	S.C.+ Soils/Plant Nutrition	8	22
30. Lourdes M. van Heuck	Peru	CIAT Pucallpa	Anim.Sci.	1	100	S.C.+ Forage Agronomy	8	5
31. Luis A. Capuñay	Peru	Pichis Palcazu	Anim.Sci.	13	30	S.C.+ Pastures in Livestock Prod.Systems	8	9

a/ Code of working areas: 1 = Germplasm Evaluation; 2 = Plant Breeding; 3 = Agronomy Tropical Pastures; 4 = Regional Trials-RIEPT; 5 = Plant Pathology; 6 = Entomology; 7 = Soils/Plant Nutrition; 8 = Soil Microbiology; 9 = Pasture Quality and Productivity; 10 = Ecophysiology; 11 = Pasture Development; 12a = Seed Production Research; 12b = Basic Seed Production; 12c = Commercial Seed Production; 13 = Livestock Production Systems; 14 = Economics; 15 = Biotechnology; y 16 = Others.

b/ S.C. = Short Course.

c/ Only attended the Multidisciplinary Intensive Course.

Table 4. Information regarding the participants in the Course-Workshop on "Establishment, Maintenance and Production of Pastures in the Peruvian tropics".

No.	Nombre	Work Department	Institution	University Title	Activity in the Institution	Discipline or Specialty	Time dedicated to tropical pastures, %
1.	Liliana Rosa Acosta Zevallos	Ucayali	IVITA-CIID	Ing.Zoot.	Research	Animal Production	100
2.	Tomás Ricardo Apaza Vera	Huanuco	IVITA-CIPA XIV	Méd.Vet.	Extension and/or Promotion	Extension	20
3.	Ermes Arce Lazo	Pasco	Fundo Gan."Los Cóndores"	Técn.Agrop.	Technical Assistance	Pasture Management	100
4.	José Antonio Baldeón Salcedo	San Martín	INIPA-CIPA XIII	Ing.Zoot.	Extension and/or Promotion	Extension	70
5.	José Luis Angel Calvo Tintaya	Ucayali	INIPA-CIPA XXIII	Ing.Zoot.	Extension and/or Promotion	Livestock Development	50
6.	Pío Enrique Castro González	San Martín	Proy.Exp.Huallaga	Ing.Agr.	Extension and/or Promotion	Tropical Pastures	100
7.	Luis Alberto Cubas Pérez	Ucayali	Bco.Agr.del Perú	Ing.Agr.	Credit Supervision	Auxiliary Expert	70
8.	Florencio Dávila Calderón	Ucayali	INIPA-CIPA XXIII	Ing.Zoot.	Research/Extension	Tropical Pastures	100
9.	Edner Roberto Díaz Navarrol	San Martín	INIPA-CIPA XIII	Méd.Vet.	Research/Extension	Tropical Pastures	80
10.	José Abraham Díaz Sandoval	Ucayali	INIPA-CIPA XIII	Ing.Zoot.	Research/Extension	Animal Production	15
11.	Abel Enriques Gutiérrez	Madre de Dios	INIPA-CIPA XXIV	Ing.Agr.	Research	Agric.Dev.-Tropical Pastures	10
12.	Gabriel Angel Espíritu Jiménez	Pasco	Proy.Esp.Pichis Palcazu	Ing.Zoot.	Extension	Animal Production	0
13.	William Gallegos Arévalo	San Martín	Bco.Agr.del Perú	Ing.Agr.	Extension	Agr.& Livestock Credits	10
14.	Gremil Antonio Garay del Mar	Ucayali	Centro Desar.Ganadero	Ing.Zoot.	Extension	Tropical Pastures	50
15.	Luis Eduardo Hernández Salas	Ucayali	CIAT Pucallpa	Ing.Zoot.	Research	Production Systems	80
16.	Leonardo Fulvio Hidalgo Ríos	Ucayali	Univ.Nal.Ucayali	Ing.Agr.	Extension/Teaching	Seed Production	50
17.	Emilce Eva Ibazeta Valdivieso	Huanuco	INIPA-CIPA XIV	Ing.Cienc.Agr.	Research	Tropical Pastures	100
18.	Deisy Lara Carretero	Loreto	INIPA Yurimaguas	Ing.Zoot.	Research	Tropical Pastures	100
19.	Luis Alberto Manrique Gutiérrez	Madre de Dios	CORDEMAD	Ing.Zoot.	Rural Development	Planning and Development	20
20.	George Navarro Córdoba	Loreto	INIPA-CIPA XII	Est.Téc.Agr.	Research	Agricult.& Livestock Techn.	100
21.	Ayax Akileo Navarro Zacarías	Lima	Univ.Nal.Agr."La Molina"	Ing.Zoot.	Livestock Management	Animal Production	10
22.	Mauro Esteban Paredes López	Ucayali	Bco.Agr.del Perú	Ing.Agr.	Extension	Agr.& Livestock Credits	10
23.	Iván Paredes Sánchez	San Martín	Proy.Espec.Huallaga	Ing.Zoot.	Extension	Extension	40
24.	Ronal Pérez Hidalgo	Pasco	Proy.Espc.Pichis Palcazu	Ing.Zoot.	Research/Extension	Animal production	80
25.	Víctor Manuel Racchumi Andrade	San Martín	Bco.Agr.del Perú	Ing.Agr.	Extension	Agr.& Livestock Credits	10
26.	Julio Melcíades Rosales Conde	Ucayali	IVITA-CIID	Ing.Zoot.	Research/Extension	Animal production	90
27.	Román Ruiz Navarro	Pasco	Proy.Esp.Pichis Palcazu	Ing.Agr.	Research	Tropical Pastures	100
28.	Jorge Saavedra Del Aguila	San Martín	Bco.Agr.del Perú	Ing.Agr.	Research/Extension	Agr.& Livestock Credits	10
29.	Jorge Daniel Sihuay Lindo	Lima	INIPA-SENASE	Ing.Zoot.	Research/Extension	Extension	90
30.	Eloy Tenazoa Del Aguila	Loreto	Bco.Agr.del Perú	Ing.Agr.	Research/Extension	Health Protection	0
31.	Angel Luis Tuesta Pinedo	San Martín	Est.Exp."El Porvenir"	Ing.Agr.	Research	Pasture Agronomy	90
32.	Lourdes M. van Heuck Barrionuevo	Ucayali	CIAT Pucallpa	Ing.Zoot.	Research	Pasture Agronomy	100
33.	Jorge Washington Vela Alvarado	Ucayali	INIPA-CIPA XXIII	Ing.Zoot.	Research and Teaching	Pasture Production	100

Table 5. Information on the participants of the "Meeting to define the present status and outline strategies to improve the supply of pastures seed in the Republic of Panama".

Name	Country	Institution
José A. Tribaldos A.	Panama	ANAGAN
Iván Santamaría	Panama	ANAGAN
Alex B. Castillero R.	Panam	ANAGAN
Sergio Dominguez B.	Panama	Comité Nacional de Semillas
Rafael Córdoba	Panama	Comité Nacional de Semillas
Gonzalo González	Panama	Comité Nacional de Semillas
Emigdio González V.	Panama	MIDA
Jorge Luis Barrios	Panama	B.D.A.
Ana E. Rodriguez V.	Panama	Universidad de Panamá
Teódulo Moreno	Panama	INA
Miguel Avila Z.	Panama	IDIAP
Efraín Vargas	Panama	IDIAP
José A. Guerra H.	Panama	IDIAP
Héctor O. Aranda V.	Panama	IDIAP
Santiago Ríos	Panama	IDIAP
Juan Carlos Jiménez V.	Costa Rica	MAG
Víctor M. Prado A.	Costa Rica	MAG

Table 6. Visiting researchers trained during the period 1978-1987 trained and type of training in the Tropical Pastures Program.

Year	Training Category							Total/Year
	Visiting Research Associate Ph.D.Theses	Visiting Researcher						
		MS Theses	Special-ization in research	SC+ Special-ization	Short course (SC)	Seed Prod. Course	Thesis Scholar. Students	
1978	1	2	9	20				32
1979	3	6	12	24				45
1980	2	2	13	17	8			42
1981	3		12	12	5			32
1982		3	18	15	2			38
1983	1	4	4	19	3			31
1984	2	1	6	19	2	25		55
1985	1	2	13	13	4			33
1986	3	4	17	18	2	28	1	73
1987	2	3	19	22	9			55
Sub-Totals	18	27	123	179	35	53	1	436
(%)	45(10.3)		302(69.3)		35(8)	53(12.2)	1(0.2)	

Table 7. Professionals trained in-country during the period 1986-1987, by country year.

Year	Country	Training Event	Participant Institutions	Professionals
1986	Panama	Seminar-Workshop Acid soils and pastures establishment.	IDIAP/U. Rutgers/CIAT	17
1987	Peru	Course-Workshop: Establishment, maintenance and production of pastures in the Peruvian tropics.	INIPA/IVITA/CORDEU/ CIAT	33
1987	Panama	Work Meeting: Define the present status and outline strategies to improve the supply of pastures seeds in the Republic of Panama.	IDIAP/CIAT	17
			TOTAL:	67

Table 8. Participants of the ten tropical pastures training programs carried out in CIAT during 1978-1987*, by country.

Country	Training Program										Total	%
	I	II	III	IV	V	VI	VII	VIII	IX	X		
Argentina	1									2	3	1.4
Bolivia	1	2	2	1		1	3	1	2	2	15	6.9
Brazil	7	3	5	4	5		3	1	1	2	31	14.4
Belize		2									2	0.9
Colombia	4	4	5	3	3	2		3	5	8	37	17.1
Costa Rica			1	1	1					1	4	1.9
Cuba	1		2				1		1	4	9	4.2
Ecuador		2	1			1		1		2	7	3.3
Guatemala								1		1	2	0.9
Holland						1					1	0.5
Honduras			2	1	1	1				1	6	2.8
Haiti				1							1	0.5
Mexico				1			2	3	5	4	15	6.9
Nicaragua	2	1	2		1	3	2	1	1	2	15	6.9
Panama	1		2	3		6	2	1			15	6.9
Paraguay							1	1			2	0.9
Peru	3	4	3	2	1	3	4	4	3	2	29	13.4
Dominican Rep.		1	1		4	2	1	1			10	4.6
Venezuela	1	5	2	1			1		2		12	5.6

* Professionals that carried out postgraduate research for M.S., Ph.D. or involved in other research specializations not included.

20. AGROECOLOGICAL STUDIES UNIT

The Agroecological Studies Unit is involved in an investigation to describe and understand the different environments where pastures and other crops are, or can be produced, throughout Central America and the Caribbean. To do this, the Unit is collecting and processing information useful to the Pastures Program as well as the other CIAT commodities in the area mentioned above. The initial objective is to carry out a thorough literature review and then to compile in the different countries publications and maps on topics such as: Agricultural census, soils (classification, surveys, analyses...), climate data, land use surveys, topography, political divisions, etc.

The project started in April 1987 and so far there has been a literature review in CIAT, in the Land Tenure Center of the University of Wisconsin, and in a few of the major international databases. Collection of information has been carried out in Panama, Costa Rica, Honduras, Dominican Republic, Haiti and Cuba (Fig.1).

In general terms, good soil maps are being obtained in Panama (Proyecto Catapán) as well as computer data tapes of daily climatic information and soils which are being recorded for forwarding to CIAT. In Costa Rica tables of extracts of the 1984 Agricultural Census were collected; the actual census will probably be published in 1989. It was also possible to obtain maps of an Agroecological Classification of pastures (potential use) as well as a recorded climatic database with daily information. Institutions in Honduras are also supplying a recorded climatic database with daily records as well as a whole range of detailed maps on soils, pastures, land use, etc. In Dominican Republic it was possible to compile several types of maps and information derived from air photographs taken in 1983-1984 with a coverage of more than 80% of the country. Also an approval to record on computer tape a database with daily data has been obtained. In Haiti the Agricultural Development Support II (ADS-II)/USAID team provided some information for the whole country and offered at a low cost the software and a database of their project which comprises of information on soils, pastures and crops for most of the country. Cuban institutions provided detailed maps of soil classification, several types of statistics and information on planted areas and/or production of pastures, rice, beans and cassava for 1987.

It is surprising, but very reassuring, that such quantities of basic data exist in machine readable formats in these Central American countries. It is highly pleasing that they have proved to be so readily available to CIAT.

The remaining countries - Nicaragua, El Salvador, Belize, Guatemala, Mexico - will be covered in February 1988 to collect similar types of information.

Once collected the materials are incorporated in a bibliographic database (CDS-ISIS). The following step is to process the information with standardisation where necessary, to start producing the different maps needed, and feed the information into CIAT's database. Maps of pasture distribution, pasture type and an environmental classification are the logical products of this study and the major emphasis during the data analysis phase will be to produce these hard copy outputs. However, it is not intended to produce a definitive report; rather, the information will become part of a dynamic database, responsive to new data as they appear and ready to answer new questions in the future.

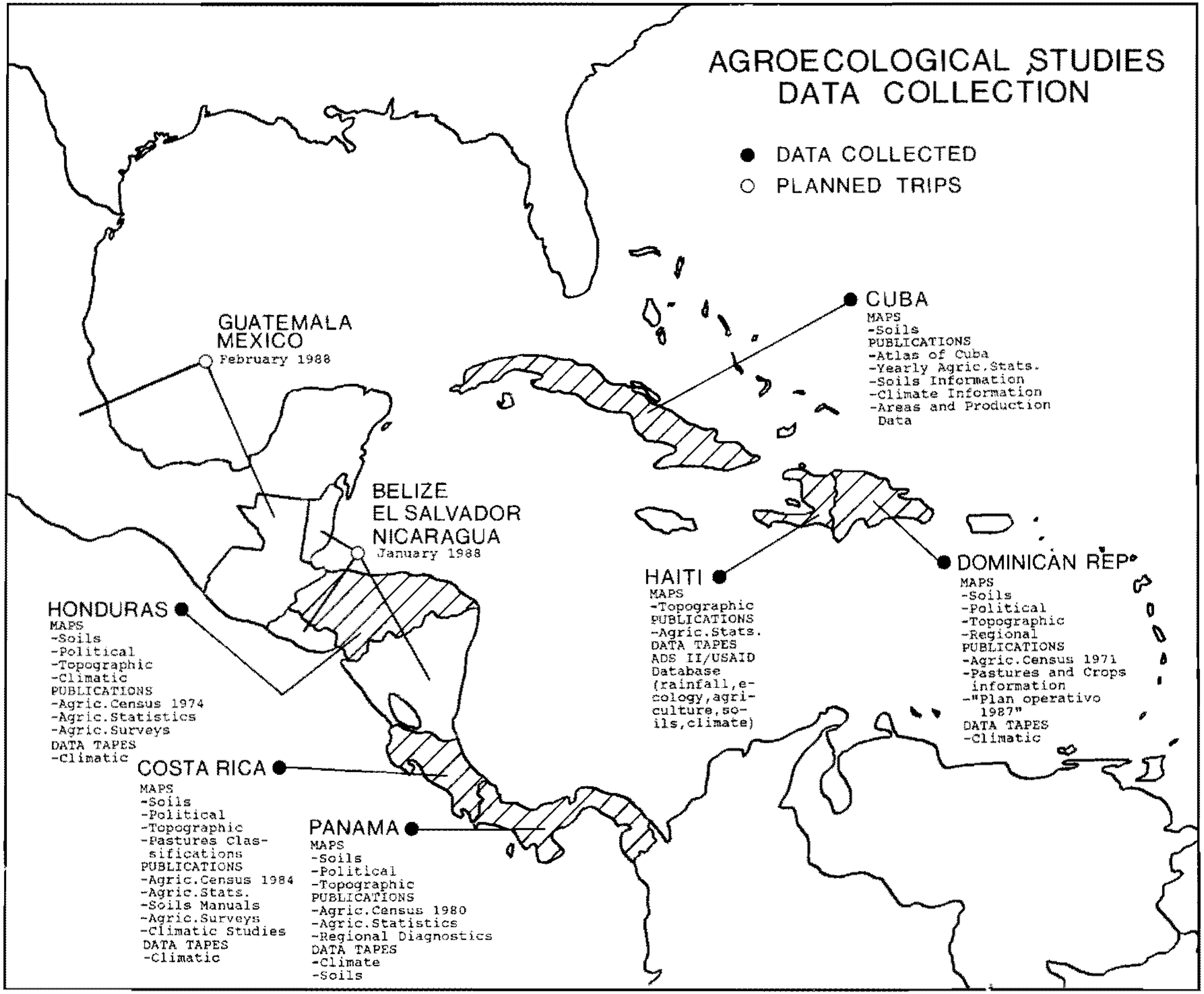

AGROECOLOGICAL STUDIES
DATA COLLECTION
DATA COLLECTED
PLANNED TRIPS
GUATEMALA
MEXICO
February 1988
BELIZE
EL SALVADOR
NICARAGUA
January 1988
CUBA
MAPS
-Soils
PUBLICATIONS
-Atlas of Cuba
-Yearly Agric.Stats.
-Soils Information
-Climate Information
-Areas and Production
Data
HONDURAS
MAPS
-Soils
-Political
-Topographic
-Climatic
PUBLICATIONS
-Agric.Census 1974
-Agric.Statistics
-Agric.Surveys
DATA TAPES
-Climatic
HAITI
MAPS
-Topographic
PUBLICATIONS
-Agric.Stats.
DATA TAPES
ADS II/USAID
Database
(rainfall,e-
cology,agri-
culture,so-
ils,climate)
DOMINICAN REP
MAPS
-Soils
-Political
-Topographic
-Regional
PUBLICATIONS
-Agric.Census 1971
-Pastures and Crops
information
-"Plan operativo
1987"
DATA TAPES
-Climatic
COSTA RICA
MAPS
-Soils
-Political
-Topographic
-Pastures Clas-
sifications
PUBLICATIONS
-Agric.Census 1984
-Agric.Stats.
-Soils Manuals
-Agric.Surveys
-Climatic Studies
DATA TAPES
-Climatic
PANAMA
MAPS
-Soils
-Political
-Topographic
PUBLICATIONS
-Agric.Census 1980
-Agric.Statistics
-Regional Diagnostics
DATA TAPES
-Climate
-Soils

FIGURE 1.

21. PUBLICATIONS

ALVAREZ, A. y C. LASCANO. 1987. Valor nutritivo de la sabana bien drenada de los Llanos Orientales de Colombia. Boletín Pasturas Tropicales 9(3): 9-17.

AMEZQUITA, M.C., E.A. PIZARRO y J.M. TOLEDO. (en impresión). Rango de adaptación de Andropogon gayanus. En: Toledo, J.M. et al. (eds.). Andropogon gayanus Kunth: su biología, manejo y utilización en suelos ácidos. CIAT, Cali, Colombia. 1987.

CIAT. 1987. Simbiosis Leguminosa-Rizobio. Manual de métodos de evaluación, selección y manejo agronómico. Sección de Microbiología de Suelos del Programa de Pastos Tropicales y Sección de Microbiología de Suelos del Programa de Fríjol.

CIAT. 1987. Simbiosis Leguminosa-Rizobio. Evaluación, selección y manejo. Guía de Estudio.

FERGUSON, J.E. 1987. Estudio de casos en el proceso de liberación de nuevos cultivares de pastos tropicales. XII Seminario Panamericano de Semillas, 2-6 de Noviembre, 1987, Montevideo, Uruguay.

FERGUSON, J.E. y C. REYES. 1987. Integración de la multiplicación y la investigación de semillas dentro de la RIEPT. En: Necesidad de investigaciones de apoyo en la evaluación sistemática de pasturas dentro de la RIEPT. Taller, CIAT. Cali, Colombia. Octubre 1985.

FISHER, M.J. and P.J. SKERMAN. 1986. Salt tolerant plants for summer rainfall areas. Reclamation and Revegetation Research 5: 263-84.

FISHER, M.J. and D. THOMAS. 1987. Environmental and physiological limits to tropical forage production in the Caribbean Basin. In: Forage-Livestock Research Needs for the Caribbean Basin (eds. J.E. Moore, K.H. Quesenberry, M.W. Michaud). University of Florida, Gainesville, USA. pp. 3-19.

FRANCA-DANTAS, M.S., B. GROF, M.A. SOUSA. 1987. Novo germoplasma de Brachiaria introduzido no Brasil. In: Anais da XXIV Reuniao Anual da Sociedade Brasileira de Zootecnia. p. 219.

GROF, B., A. FLORES, P. MENDOZA, and E.A. PIZARRO. 1987. Regional Experience with Centrosema: northern South America. (submitted for publication).

GROF, B., M.S. FRANCA-DANTAS, R.P. ANDRADE, B.F. SOUZA, and J.F.M. VALLS. 1987. Avaliacao preliminar de espécies perenes de Arachis para várzeas. In: Anais da XXIV Reuniao Anual da Sociedade Brasileira de Zootecnia. pp. 229.

GROF, B. and D. THOMAS. (in press). The agronomy of Andropogon gayanus J.M. Toledo, C. Lascano, R. Vera and J. Lenné (eds.). 1987.

KEATING, B.A.; R.W. STRICKLAND; and M.J. FISHER. 1986. Salt tolerance of some tropical pasture legumes with potential adaptation to cracking clay soils. Australian Journal of Experimental Agriculture 26: 181-85.

KITAJIMA, L.C.B., L.C.B. NASSER, and B. GROF. 1987. Superbrotamento em Centrosema brasilianum associado a microorganismos do tipo micoplasma no Distrito Federal. Revista de Fitopatologia Brasileira, Vol. 13 No.3. pp. 281-283.

LASCANO, C. 1987. Canopy structure and composition in legume selectivity. In: Moore, J.E., Quesenberry, K.H. and M.W. Michaud (eds.) Proceedings Forage-Livestock Research needs for the Caribbean basin. Tampa, Fla. 9-12, February 1987. p. 71-80.

LASCANO, C. 1987. Manejo del pastoreo en asociaciones de gramíneas y leguminosas en el trópico. VI Encuentro Nacional de Zootecnia, Segunda Conferencia Nacional de Producción y Utilización de Pastos y Forrajes. Cali, Octubre 28-31. 11 pp.

LASCANO, C. y J.M. TOLEDO. 1987. Desarrollo y potencial de pasturas mejoradas para América tropical. VI Encuentro Nacional de Zootecnia, Segunda Conferencia Nacional de Producción y Utilización de Pastos y Forrajes. Cali, Octubre 28-31. 14 pp.

LASCANO, C. and D. THOMAS. (in press). Andropogon gayanus: quality and animal production. J.M. Toledo et al. (eds.), Andropogon gayanus Kunth: su biología, manejo y utilización en suelos ácidos. CIAT, Cali, Colombia. 1987.

MENDOZA, P.; D. THOMAS; J.M. SPAIN, and C. LASCANO. (in press). Establishment and Management of Centrosema. Paper presented at International Workshop on Centrosema -- Biology, Agronomy and Utilization, 23-28 February 1987. CIAT, Cali, Colombia. 1987.

MILES, J.W. and J.M. LENNE. 1987. Effect of frequency of defoliation of 40 Stylosanthes guianensis genotypes on field reaction to anthracnose caused by Colletotrichum gloeosporioides. Australian Journal of Agricultural Research 38(2): 309-315.

MORALES, M.L. 1987. Aislamiento y selección de rizobacterias promotoras de crecimiento en algunas plantas forrajeras. Tesis de Grado. Facultad de Agronomía. Palmira.

PERALTA, A., R. SCHULTZE-KRAFT, J.M. MARTINEZ, J.F. AGUIRRE, H.S. AMAYA, and J. ENRIQUEZ. 1987. Recolección de leguminosas forrajeras nativas en el trópico de México. Pasturas Tropicales - boletín 9(11): 21-26.

PEREZ, R.C.; FERGUSON, J.E. y LOPEZ, W. 1987. Producción de semillas de tres especies forrajeras en Tarapoto, Perú. Pasturas Tropicales- Boletín 9(2): 18-23.

PIZARRO, E.A. and D. THOMAS. (in press). Introduction and evaluation of forages in tropical America. In: The Feeding of Ruminants in Tropical Humid Conditions. INRA Symposium, Guadeloupe, French West Indies. 1987.

RIBEIRO DE SANTANA, J.; J. M. PEREIRA; M.A. MORENO; J.M. SPAIN. 1987. Efeito do pastejo sobre a persistencia e productividade da consorciacao Brachiaria humidicola e Desmodium ovalifolium CIAT 350. In: Anais da XXIV Reuniao Annal da Sociedade Brasileira de Zootecnía. p. 242.

SALINAS, J.G. and C.E. CASTILLA. (in press). Strategies implied on the use and management of tropical acid soils. 23 p. In: L. Gourlay and J.G. Salinas (ed.). Sorghum for Acid Soils. INTSORMIL Publication, Cali, Colombia. 1987.

SALINAS, J.G. and R. GUALDRON. (in press). Adaptation and nutrient requirements of some Stylosanthes species. In: D.L. Plucknett and H. Sprague (eds.). Detecting Mineral Nutrient Deficiencies that affect Production of Crop Plants in Temperate and Tropical Regions. 1987.

SALINAS, J.G., P.C. KERRIDGE, and R.M. SHUNKE. (in press). Mineral nutrition of Centrosema. 51 p. In: R. Schultze-Kraft and R.J. Clements (eds. Centrosema - Biology, Agronomy and Utilization. 1987.

SALINAS, J.G. and S.R. SAIF. (in press). Nutrient requirements of Andropogon gayanus. Centro Internacional de Agricultura Tropical (CIAT), Tropical Pastures Program, Cali, Colombia. 74 p. 1987.

SANCHEZ, M., y FERGUSON, J.E. 1986. Medición de calidad en semillas de Andropogon gayanus. Revista Brasileira de Sementes 8(1): 9-28.

SCHULTZE-KRAFT, R. (in press). Centrosema species for acid soils. Paper presented at International Workshop on Centrosema -- Biology, Agronomy and Utilization, 23-28 February 1987. CIAT, Cali, Colombia. 1987.

SCHULTZE-KRAFT, R. (in press). Germplasm collection and evaluation of tropical legumes. Paper presented at CASAFA/IRRI symposium on Sustainable Agriculture - the role of green manure crops in rice farming systems. 25-29 May 1987, IRRI, Manila, Philippines. 1987.

SCHULTZE-KRAFT, R., B. BENAVIDES, and A. ARIAS. 1987. Recolección de germoplasma y evaluación preliminar de Centrosema acutifolium. Pasturas Tropicales - Boletín 9(1): 12-20.

SCHULTZE-KRAFT, R., A. GANI, and M.E. SIREGAR. 1987. Collection of native forage legume germplasm in Sumatra, Indonesia. IBPGR-SEAN 11(1): 4-6.

SCHULTZE-KRAFT, R., R.J. WILLIAMS, and L. CORADIN. (in press). Biogeography of Centrosema. Paper presented at International Workshop on Centrosema -- Biology, Agronomy and Utilization, 23-28 February 1987. CIAT, Cali, Colombia. 1987.

SHARMA, R.D. and B. GROF. (in press). Root disease of Centrosema pascuorum caused by the Javanese root-knot nematode in the Cerrado region of Brazil. 1987.

SHERIFF, D.W.; M.J. FISHER; G. RUSITZKA and C.W. FORD. 1986. Physiological reactions to an imposed drought by two twining pasture legumes: Macroptilium atropurpureum (dessication sensitive) and Galactia striata (dessication insensitive). Australian Journal of Plant Physiology 13: 431-45.

SPAIN, J.M. and W. COUTO. (in press). Monografía de Andropogon gayanus. Capítulo 5. Establecimiento y desarrollo inicial de pasturas de A. gayanus en sabanas tropicales. 1987.

SUAREZ, S., J. RUBIO, C. FRANCO, R.R. VERA, E.A. PIZARRO y M.C. AMEZQUITA. 1987. Leucaena leucocephala; producción y composición de leche y selección de ecotipos con animales en pastoreo. Pasturas Tropicales - Boletín. 9(2): 11-17.

SYLVESTER-BRADLEY, R.; S.M. Souto; and R.A. DATE. (in press). Rhizosphere biology and nitrogen fixation of Centrosema. Paper presented at International Workshop on Centrosema -- Biology, Agronomy and Utilization, 23-28 February 1987. CIAT, Cali, Colombia. 1987.

SYLVESTER-BRADLEY, R. and F. MUNEVAR. (in press). Evaluación de la simbiosis leguminosa-rizobio en la selección de leguminosas forrajeras. In: Motta, F. (ed.) Investigaciones de Apoyo para la Evaluación de Pasturas. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. pp. 29-50. 1987.

SYLVESTER-BRADLEY, R.; D. MOSQUERA; and J.E. MENDEZ. 1987. Uso de cilindros con suelo no disturbado y establecimiento por labranza reducida para la evaluación de cepas de rizobio en leguminosas forrajeras tropicales. In: Proc. XIII Reunión Latinoamericana de Rhizobium, Panamá. Octubre 1986.

SYLVESTER-BRADLEY, R.; D. P. THORNTON; and P. JONES. (in press). Colony dimorphism in strains of Bradyrhizobium. Applied and enviromental Microbiology. 1987.

SYLVESTER-BRADLEY, R.; D. MOSQUERA: and J. E. MENDEZ. 1987. Inhibition of nitrate accumulation in tropical grassland soils: effect of nitrogen fertilization and soil disturbance. Journal of Soil Science.

TANG, M. and R. SYLVESTER-BRADLEY. 1986. Selección de cepas de rhizobium para Centrosema pubescens en jarras de Leonard (arena) y dos suelos de Colombia. Pastos y Forrajes 9: 111-118.

TOLEDO, J.M., H. GIRALDO y J.M. SPAIN. 1987. Efecto del pastoreo continuo y el método de siembra en la persistencia de la asociación Andropogon gayanus/Stylosanthes capitata, Pasturas Tropicales Boletin. CIAT, Colombia, Vol. 9, No.3, pp. 18-24.

TOLEDO, J.M. (en impresión). Necesidad de descentralizar la red internacional de evaluación de pastos tropicales, Memorias IV, Reunión Comité Asesor RIEPT. Santiago, Panamá, Mayo. 1987.

TOLEDO, J.M. y M. FISHER. (en impresión) Aspectos fisiológicos de Andropogon gayanus y su compatibilidad con las leguminosas forrajeras. En: Toledo, J.M. et al. (eds.). Andropogon gayanus Kunth: su biología, manejo y utilización en suelos ácidos. CIAT, Cali, Colombia. 1987.

TOLEDO, J.M. y E.A. SERRAO. 1987. Pastures after humid forest clearing in the Amazon. Proceedings of the International Symposium on Grassland in Forest Area. Harbin, China.

TOLEDO, J.M. (en impresión). Sugerencias para futura investigación con el género Centrosema. International Workshop on Centrosema: Biology, Agronomy and Utilization. CIAT, Cali, Colombia. Febrero 22-28. 1987.

TOLEDO, J.M. y P.E. MENDOZA (en impresión). Pasturas tropicales de mínimos insumos para sistemas de doble propósito en áreas con suelos pobres y ácidos. Seminario Internacional Sistemas de Doble Propósito, Bogotá, Septiembre. 1986.

THOMAS, D. 1986. Development of forage species for the acid, infertile soils of tropical South America. In: Potential for Pasture Production in Acid Tropical Soils. CARDI-EDF Seminar, Trinidad, West Indies. pp. 1-26.

THOMAS, D., C.E. LASCANO and R.R. VERA. 1987. A tropical pasture legume for poor soils. Span, 30(2): 59-61.

THOMAS, D. and M.I. PENTEADO (in press). Regional experience with Centrosema: Brazil - savannas. In: Centrosema: Biology, Agronomy and Utilizacion (Eds. R.J. Clements and R. Schultze-Kraft). 1987.

THOMAS, D., R.R. VERA, C. LASCANO, and M.J. FISHER (in press). Use and improvement of pastures in neotropical savannas. Invited paper. IVBS, Venezuela. 1987.

TRUJILLO, W. 1987. Efecto de la capacidad de campo de dos oxisoles de los Llanos Orientales sobre el crecimiento y fijación de nitrógeno de Stylosanthes capitata Vog. y Stylosanthes guianensis Sw. Tesis de Grado en Biología, Pontificia Universidad Javeriana. Bogotá. 146 pp.

ZOBY, J.L.F., B. GROF, R.P. ANDRADE, F.B. SOUZA, E. KORNELIUS, J.F.M. VALLS, and M.S. FRANCA-DANTAS. 1987. Selecao de Paspalum spp. para producao dos Cerrados. In: Anais da XXIV Reuniao Anual da Sociedade Brasileira de Zootecnia. p. 228.

WEST, D.W.; G.J. HOFFMAN; and M.J. FISHER. 1986. Photosynthesis, leaf conductance and water relations of cowpea under saline conditions. Irrigation Science 7: 183-93.

22. LIST OF THE STAFF MEMBERS

Senior Scientists

José M. Toledo, Ph.D., Pasture Agronomist, Leader

Rosemary S. Bradley, Ph.D., Soil Microbiologist, Microbiology
John Ferguson, Ph.D., Agronomist, Seed Production
Myles Fisher, Ph.D., Ecophysiologist, Ecophysiology
Bela Grof, Ph.D., Agrostologist, Agronomy (CPAC, Brasilia, Brazil)
Gerhard Keller-Grein, Dr. agr., Humid Tropic Agronomy (INIPA/IVITA/CIAT, Pucallpa, Perú)
Stephen Lapointe, Ph.D., Entomologist, Entomology
Carlos Lascano, Ph.D., Animal Scientist, Pasture Quality and Productivity
Jillian M. Lenné, Ph.D., Plant Pathologist, Plant Pathology
John W. Miles, Ph.D., Plant Breeder, Agronomy/Forage Breeding
Esteban A. Pizarro, Ph.D., Agronomist, Agronomy Central America and the Caribbean (San José, Costa Rica)
José G. Salinas, Ph.D., Soil Scientist, Pasture Reclamation (INIPA/IVITA/CIAT, Pucallpa, Perú)
Rainer Schultze-Kraft, Dr. agr., Agronomist, Germplasm
* Carlos Seré, Dr. agr., Agricultural Economist, Economics
James M. Spain, Ph.D., Soil Scientist, Pasture Development (CPAC, Brasilia, Brazil)
Derrick Thomas, Ph.D., Forage Agronomist, Agronomy (Carimagua)
Raul R. Vera, Ph.D., Animal Scientist, Livestock Systems

Senior Research Fellow and Postdoctorals

*** Pedro Argel, Ph.D., Collaborative Work in Panama (IDIAP/Rutgers University/CIAT) (David, Panama)
** Peter Cookson, Ph.D., Microbiologist, UNDP Project
*** John Dodd, Ph.D., Microbiologist, Microbiology
*** David Harris, Ph.D., Biological Fixation Nitrogen
** William Loker, Ph.D., Anthropologist, Economics (INIPA/IVITA/CIAT, Pucallpa, Peru)
Yasuo Ogawa, M.Sc., Pasture Development
** Roberto Saez, Ph.D., Economist, Livestock Systems (CPAC, Brasilia, Brazil)
*** Philip K. Thornton, Ph.D., Livestock Systems

---

* On sabbatical leave.
** Joined the Program during 1987.
*** Left during 1987.

Visiting Research Associates
Amparo de Alvarez, BS, Agr., Plant Pathology
Raul Botero, M.Sc., Economics
Obed García, D.V.M., Livestock Systems (Carimagua)
Ramón Gualdrón, BS, Agr., Soil/Plant Nutrition
Silvio Guzmán, M.Sc., Livestock Systems
Libardo Rivas, M.Sc., Economics
Hernán Giraldo, BS, Agr., Ecophysiology (Carimagua)

Research Assistants
Guillermo Arango, Lic. Biol., Entomology
*** José Ancizar Arenas, Ing. Agr., Germplasm
Alvaro Arias, Ing. Agr., Germplasm
Patricia Avila, Animal Scientist, Pasture Quality and Productivity
Gustavo Benavides, Ing. Agr., Germplasm
Javier Asdrubal Cano, Lic. Econ., Administrative Assistant to the Leader Office
Carlos Iván Cardozo, Ing. Agr., Seed Production
Fernando Díaz, Ing. Agr., Legume Agronomy (Carimagua)
Martha Lucía Escandón, Ing. Agr., Forage Breeding/Agronomy
Luis H. Franco, Ing. Agr., Regional Trials
Manuel Arturo Franco, Ing. Mec., Systems Analyst, Office of the Coordinator
Cesar Augusto García, Ing. Agr., Entomology and Plant Pathology (Carimagua)
*** José M. Gómez, Zoot., Pasture Quality and Productivity
Luis Eduardo Hernández, Zoot., Economics (INIPA/IVITA/CIAT, Pucallpa, Peru)
Mariella van Heurck, Ing. Zoot., Agronomy Humid Tropic (INIPA/IVITA/CIAT, Pucallpa, Perú)
Phanor Hoyos, Zoot., Pasture Quality and Productivity (Carimagua)
*** Jesús A. Méndez, BS, Agr., Microbiology
Carlos H. Molano, MS, Agr., Plant Breeding
Diego Molina, BS, Agr., Ecophysiology (Carimagua)
Dacier Mosquera, BS., Agr., Microbiology
Gloria Navas, BS, Agr., Entomología
Carlos E. Perdomo, BS, Agr., Soil and Plant Nutrition (Carimagua)
Carlos A. Ramirez, M.V.Z., Livestock Systems (Carimagua)
*** Fabiola de Ramirez, BS, Bacteriology, Microbiology
*** José Ignacio Roa, BS, Agr., Agronomy/Forage Breeding-Seed Production (Carimagua)
Edgar Salazar, BS, Agr., Agronomy (Carimagua)
Manuel Sánchez, BS, Agr., Seed Production
Blanca Torres G., BS, Bacteriology, Livestock Systems
Celina Torres, BS, Agr., Plant Pathology
*** Pedro Zapata, BS, Agr., Microbiology (Carimagua)
*** Carmen Rosa Salamanca, BS, Agr., Biological Fixation Nitrogen