Annual Report 1985

Tropical Pastures

Working Document No. 17, 1986

CIAT Centro Internacional de Agricultura Tropical

Index

Introduction

The mandate of the Program was defined by the External Panel Review in 1984 as "The acid poor soils in the lowlands under subhumid to humid climates, with emphasis in tropical America".

Tropical America's cattle inventory adds to more than 200 million head --17% of the total cattle population of the world.

In contrast to other tropical regions of the world, beef consumption in tropical America is higher. It ranges from 7 to 38 kg/capita/year. The percentage of food expenditures for beef and milk is high in most Latin American cities, even among the poor. In the lowest income quartile of the population, beef expenditures ranged from 12.4% to 26%, while expenditures on milk and dairy products ranged from 7 to 13%. The income elasticity for beef and dairy products is high throughout Latin America at all income levels. Recent studies in different regions of Colombia and in urban and rural areas indicate that food expenditure shares for beef and milk are also high for rural populations: 28.2% for urban areas vs. 24.4% for the rural population. This indicates that beef and milk are staple food commodities for the Latin American urban and rural populations.

The socioeconomic characteristics of beef and milk in tropical America clearly indicate the importance of price fluctuations in these commodities. Lower prices will benefit particularly the poor.

In countries of tropical America, the growth rate of demand for beef and milk increases at a faster degree than the growth rate of production (Table 1). This disequilibrium induces an increase in prices for these commodities, negatively affecting the nutritional level and the economy of the lower income populations. Productivity of tropical livestock is low (Table 2) as compared with that reached in developed countries and under temperate conditions. This low productivity is due to the extensive-

Table 1. Beef: Annual growth rates of demand and production in Latin American countries, 1970-1981.

Region, country	Growth rates (%)	
	Demand	Production
Tropical America	5.3	2.2
Bolivia	4.9	4.9
Brazil	6.1	1.5
Colombia	4.9	3.5
Dominican Republic	6.0	3.4
Ecuador	8.9	5.3
Mexico	4.4	3.3
Paraguay	4.4	-1.1
Peru	3.0	-1.3
Venezuela	4.2	5.4
Central America	4.0	3.3
The Caribbean	3.2	2.0
Temperate Latin America	1.7	3.2

Table 2. Livestock population and animal productivity in the United States and selected countries of Latin America, 1981.

Region, country	Population (million animal units)	Productivity (kg/animal/ year)
United States	114	90
Tropical Latin America	199	24
Brazil	93	24
Colombia	24	24
Venezuela	11	31
Temperate Latin America	69	52
Latin America	267	31

Latin America: Trends in CIAT Commodities, 1983.

ness of production systems, to genetic factors of the herd, is linked to climatic constraints and, mainly, to edaphic constraints conditioning the low quality and availability of the primary resource (pastures), especially in marginal areas, where cattle raising is an economically favorable activity (low opportunity cost of the land).

Contrasting with the large agricultural frontier areas (more than 1000 million hectares), where land is evidently under-utilized and where cattle raising constitutes an incipient and pioneer agricultural activity, is the fact that even today a large proportion of the cattle in tropical America is found competing with crops in fertile lands suitable for agriculture.

These large agricultural frontier areas offer an excellent production potential since solar radiation, length of growing season, and the predominantly good physical and topographical soil characteristics are not limiting factors. However, predominant chemical characteristics (excessive acidity and aluminum toxicity, as well as low levels of exchangeable cations) constitute the most important limiting factor which explains why these areas have not been colonized and used for the production of food crops throughout history.

IMPACT AREA OF THE PROGRAM

The Program's mandate up to date has circumscribed the low lands (< 1000 masl), acid, infertile, soils under subhumid to humid climates, of tropical America, including the countries of the Caribbean, the southern part of Mexico, Central America, and South America north of the tropic of Capricorn. The region includes countries such as Brazil, Colombia, Peru, Venezuela, Bolivia, Guyana, Surinam, French-Guiana, Panama, Jamaica, Trinidad, Guadaloupe and Martinique where Oxisols and Ultisols account for more than 40% of their territories. Based on existing information from climatic and soil studies, the tropical savannas (> 200 millions ha) and humid tropics (> 500 millions ha) of South America were classified into large ecosystems creating the basis for development of a decentralized germplasm evaluation approach.

OBJECTIVE

The Tropical Pastures Program is essentially a strategy for the pioneer rural development of the largest agricultural frontier of the continent.

Its general objective is "to develop low-cost low input pasture technology for the acid and low fertility soils of tropical America".

Through the development of this technology, beef and milk production are expected to increase by incorporating areas into marginal production. Also it is expected that fertile lands now dedicated to cattle raising would become free for the expansion of crop production.

CONSTRAINTS FOR PASTURE DEVELOPEMENT

The program recognizes that several problems for pasture development exist in tropical America. The main ones are:

- Lack of adaptation of commercial cultivars of tropical pastures selected in other continents to the predominantly acid poor soils and the prevalence of negative biotic factors in the lowlands of tropical America. This has been responsible for the failure of many introduced grasses and legumes.

- The variation in ecosystems and germplasm/parasite interactions will require diverse germplasm to suit the environment with adapted materials. In addition, the range of existing farming systems will require different kinds of adapted pastures playing one or several roles at the farm level.

- It is also recognized that cattle farmers have only limited cash to invest in new technology when the fluctuating relationship between the price of outputs (beef & milk) to inputs (fertilizers, seeds, salts, drugs, machinery, etc.) is in their favor. Prices are greatly influenced by political decisions that often fluctuate from benefiting farmers to benefiting industry or consumers. This unstable economic situation is further aggravated in marginal and frontier areas due to deficient infrastructure and high transportation costs.

These problems call for a low-cost low-risk pasture technology based on adapted germplasm, that will persist and efficiently produce in times of national, regional or individual negative socioeconomic conditions and will spread by adoption and increase productivity under favorable conditions.

RESEARCH STRATEGIES

The strategies of the program to tackle these problems are:

- To develop a broad enough germplasm base and to systematically screen it to select adapted materials to the diversity of ecosystems of tropical America.

- Low-input philosophy; implying the development of technologies based on adapted materials that will make efficient use of the naturally available resources and limited purchased inputs. This includes the development of low-cost pasture establishment; pastures associating grasses with effective N-fixing legumes, and optimizing nutrient recycling through appropriate fertilizer and grazing management.

- The farming systems perspectives; the feed back of farmers' view points and evaluation of the performance at the farm level, including farmers management, is important to recognizing the needs of farmers and to understanding problems which might hinder adoption.

- The wide variability of environmental and farming system conditions to which pasture germplasm should be adapted and management technology should be developed require a multilocational and decentralized approach. ¡The Network approach!

ORGANIZATION

The first main strategy of the TPP is <u>to develop a broad germplasm base</u> and to systematically screen it to select materials adapted to the diversity of ecosystems of tropical America. The program has already established three major screening sites and will establish a fourth in 1987 in cooperation with National Research Programs. These are the Carimagua Research Station in cooperation with ICA in Colombia, representing the Llanos or isohyperthermic savanna ecosystem; the Centro de Pesquisa Agropecuária dos Cerrados (CPAC) near Brasilia in cooperation with EMBRAPA, representing the Cerrados or isothermic savanna ecosystem; and the humid tropics site in cooperation with INIPA and IVITA at Pucallpa, Peru. In 1987, a fourth major screening site will be established in Costa Rica, in Central America and the Caribbean, representing the moderately acid soils in cooperation with CATIE and IICA. These major screening sites constitute the base of germplasm development. Here, germplasm experts, agronomists, plant pathologists, entomologists and breeders work collaboratively in efficient agronomic characterization, evaluation and selection of germplasm (natural and bred) for adaptation to soil and climatic factors and resistance/tolerance to prevailing pests and diseases (Figure 1).

Selected germplasm passes into the pasture development phase where a low-input philosophy is emphasized in the development of technologies based on adapted germplasm that will make efficient use of naturally available resources and limited purchased inputs. In this phase, grasses and legumes are evaluated in associations with the development of low-cost pasture establishment methods; pastures associating grasses with N-fixing legumes and optimization of nutrient cycling through appropriate fertilizer use and grazing management (Figure 1). The plant nutritionist, soil microbiologists, animal production scientist, ecophysiologist and pasture establishment specialist collaborate directly with each other and other program scientists to develop promising adapted germplasm into adapted productive pastures as efficiently as possible.

On-farm research and economic evaluation of pastures in production systems give the opportunity for feed back from farmers including their management and utilization preferences which is most important to keep the appropriate farming system perspective and to the recognition of their needs and to understanding problems which might hinder adoption. The economist and farming systems specialist interact closely to ensure the efficient movement of productive pasture germplasm into farming systems. This farming systems perspective is an essential approach and strategy for the program in order to reliably and effectively deal with the complexities of ecosystem/farming system conditions where the adaptation and different role of pastures will require different sets of germplasm and management. Although the man-power resources in this group are limited, close collaboration with national research programs not only in on-farm trials and adoption surveys but also in methodological research is collaboratively developing simple reliable techniques for assessment of the potential role and evaluation of new pasture technology at farm level.

A major constraint to the efficient flow of germplasm through a continuing pasture evaluation process can be inadequate seed production to service the scientists working at various levels in the program, i.e., on-farm research, and, especially in the case of CIAT's Tropical Pasture Program, collaborative work with national research programs through the RIEPT. At the same time, the range of ecosystem/farming system complexes means that at any one time a wide range of legumes and grasses often

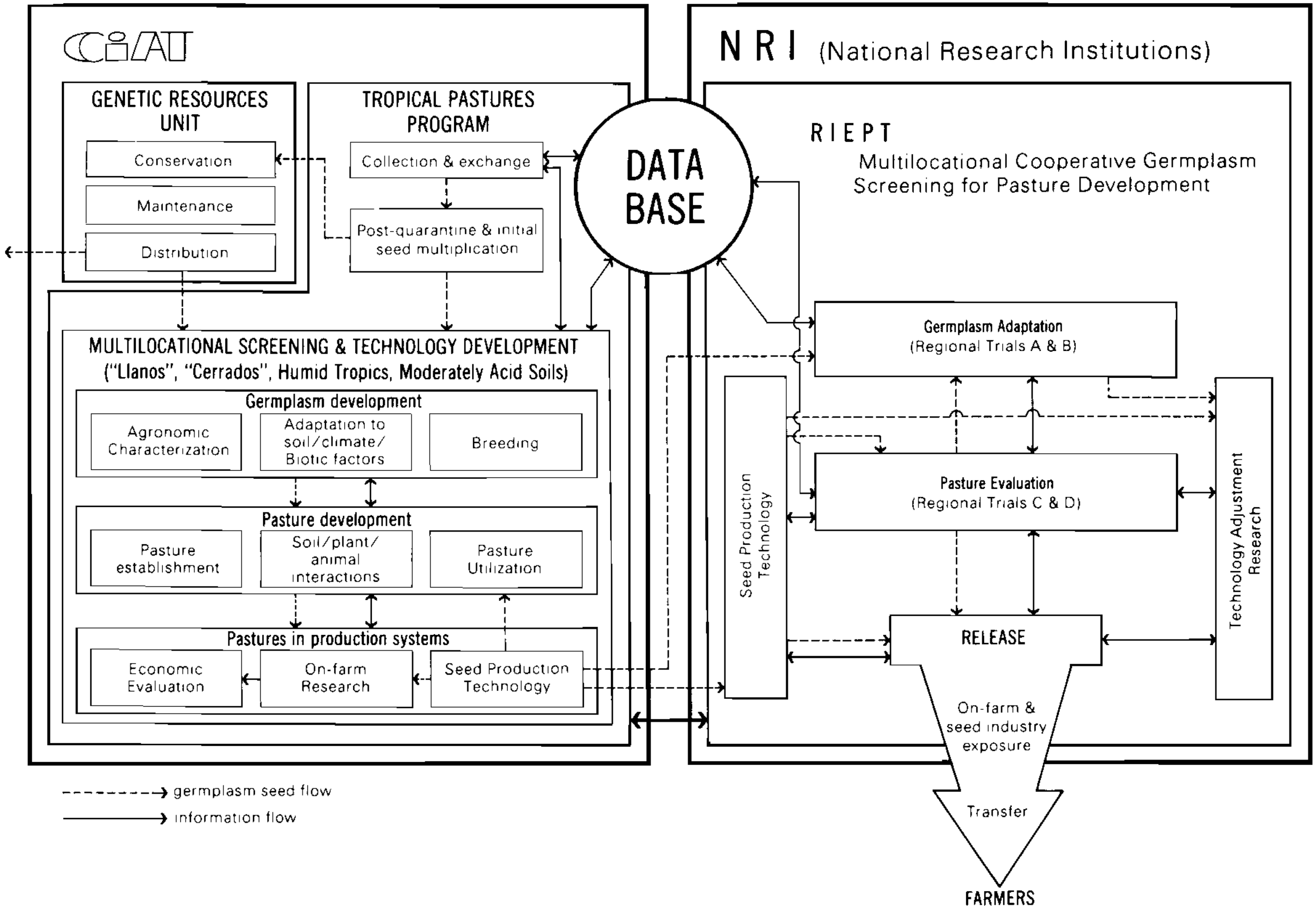


Figure 1 Pasture germplasm flow in the evaluation process in tropical america

with quite different seed production requirements are under multiplication. This implies working at a number of different sites to satisfy these requirements. The seed production specialist collaborates closely with the economist and production systems specialist in the Pastures in Production Systems Unit to fulfill both the research role as well as the basic seed production role to move germplasm efficiently.

A multilocational and decentralized network approach is essential to moving germplasm as efficiently as possible from the major screening sites in each ecosystem into the wide variety of environmental and farming system conditions in the marginal and frontier lands of tropical America. RIEPT, the International Tropical Pasture Program Evaluation Network, was created by National Research Programs and CIAT's Tropical Pastures Program after recognition of the need for *in situ* pasture development. National pasture research programs, large and small, are joined together and geared towards efficient germplasm evaluation and flow and development of new pasture technology based on adapted germplasm.

RIEPT efficiently screens large numbers of experimental germplasm through a sequence of regional trials A, B, C and D at over 170 sites covering the acid low-fertility lowland region of tropical America. As only those materials which have passed through initial screening at CIAT's major screening sites in the specific ecosystems pass to the RIEPT, germplasm with little value as pasture plants is eliminated from wide-scale evaluation. This improves the efficiency of the process. Selections from RIEPT adaptation and agronomic evaluation trials (RT's A and B) are passed by National Research Programs into small plot pasture management trials under grazing (RT-C) and finally to large plot pasture productivity and persistence trials under grazing (RT-D) prior to release by the national program to on-farm and seed industry exposure (Figure 1).

Seed production technology and pasture technology adjustment research is carried out collaboratively between national research programs and CIAT's Tropical Pasture Program during the advancement of *in situ* selected germplasm through the different stages of evaluation (Figure 1). This ensures that released germplasm has the back-up of solid pasture technology for its use by farmers and helps in the efficient movement of germplasm. This is particularly important in the case of seed production. With the growth of RIEPT and the advancement of new materials to grazing trials and eventual releases, there is increasing pressure to develop pasture seed production projects to produce promising experimental and basic seed to prevent bottlenecks to the efficient germplasm flow to release and farmer adoption.

Through this network, important economies of scale are being achieved and national research programs are not only rapidly advancing promising germplasm into pastures, but are also exchanging methodologies for local adjustments of technology especially with respect to management to better suit the environmental and farming systems conditions encountered in areas of immediate influence.

The organization of workshops, training courses and the opportunity to exchange experiences through the CIAT bulletin "Pasturas Tropicales", an excellent communication mechanism, ensures continuous interaction among members of this network and fosters more efficient germplasm utilization.

Information flows freely in both directions from both parts of the evaluation process (TPP and RIEPT). In addition, all data coming from evaluations made directly by RIEPT and

CIAT's TPP are **linked** in a common data base. The data base is important to TPP in storing all information from germplasm evaluation and development trials at major screening sites in each ecosystem, that is, detailed characterization of germplasm from collection site data, adaptation to specific soil and climatic conditions, agronomic characters, reaction to pests and diseases, soil-associated plant - animal interactions, seed production potential, etc.

At the same time, the development of the RIEPT data base and the methodologies for statistical processing of large numbers of data and information coming from national programs in close collaboration with the CIAT Data Service Unit has been instrumental and essential to the cross-locational analysis and documentation of the performance and thus secure advance of germplasm throughout the network.

As a result of this collaborative continental effort on multilocational evaluation, screening, selection, technology development and transfer, new cultivars of grasses and legumes have been released by national research programs in tropical America. In 1980, Andropogon gayanus CIAT 621 was released by ICA in Colombia and EMBRAPA in Brazil; in 1982 and 1983 it was also releasedin Venezuela, Panama and Peru. It is estimated that at present more than 200,000 ha have been planted to this grass in tropical America, especially for its tolerance to poor acid soils, drought and the major pest spittlebug.

In 1983, the first legume Stylosanthes capitata was released by ICA in Colombia and named Capica (CIAT 10280). This is a blend of five accessions selected for its resistance to anthracnose, the major problem for Stylosanthes spp. in tropical America and its excellent performance under grazing increasing animal productivity in association with A. gayanus in the isohyperthermic savannas.

Similarly in 1985, IVITA, Pucallpa, Peru released Stylosanthes guianensis CIAT 184 as cv. Pucallpa for its resistance to anthracnose in the humid tropics ecosystem and its good performance under grazing in association with Hyparrhenia rufa, A. gayanus and native grasses. Several promising grasses and legumes are presently at the pre-release stage and being exposed to farmers. Among others these are Centrosema brasilianum CIAT 5234, Centrosema sp. nov. CIAT 5277, Arachis pintoi CIAT 17434 and the grass Brachiaria dictyoneura CIAT 6133.

Germplasm

During 1985 the Germplasm section continued concentrating its efforts on:

1) Assembly of germplasm through direct collection and through exchange of materials with other institutions.
2) Multiplication and maintenance of existing germplasm.
3) Characterization and preliminary evaluation of new introductions.

COLLECTION AND INTRODUCTION OF GERMPLASM

Collection

Much of the efforts and resources of the section continued to be devoted to germplasm collection activities, particularly in connection with the project to increase the genetic diversity of Brachiaria spp. through direct collection in Africa.

Germplasm collection activities during 1985 took place in three continents:

- Tropical America:

a) Panama: In collaboration with the Instituto de Investigación Agropecuaria de Panamá (IDIAP) and USAID/ Rutgers University a major portion of the Panamanian provinces were sampled along a west-to-east transect (Fig. 1). With the objective of increasing the genetic base of drought-tolerant, late-flowering legumes, particularly of the genus Centrosema, a total of 320 samples were collected, 20% accounted for by Centrosema spp. (Table 1).

b) Venezuela: A collecting mission, carried out in collaboration with the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP), was also aimed at late-flowering, drought-resistant and acid soil-tolerant legumes, particularly within the genus Centrosema. During this mission, in addition to a north-to-south transect from Caracas to the Orinoco river, the northern part of the Bolívar state was sampled along a west-to-east transect south of the Orinoco river. Furthermore, some collecting was done in the Federal Territory Amazonas on the east bank of the Orinoco river, opposite the Colombian Vichada region (Fig. 2). During this mission, 371 legume samples were collected, with Centrosema accounting for 27% of the germplasm (Table 1).

c) Colombia: Within a training program for a visiting researcher from the People's Republic of China, a major collection excursion was carried out in the Huila department, and a minor one within the Valle del Cauca department. 83 legume samples were collected (Table 1).

- Southeast Asia

A collecting mission, funded by the International Board for Plant Genetic Resources (IBPGR), was carried out in collaboration with the Sukarami Research Institute for Food Crops (SARIF). Its aim was to collect legume germplasm native to Sumatra, particularly species of Desmodium and allied genera as well as Pueraria

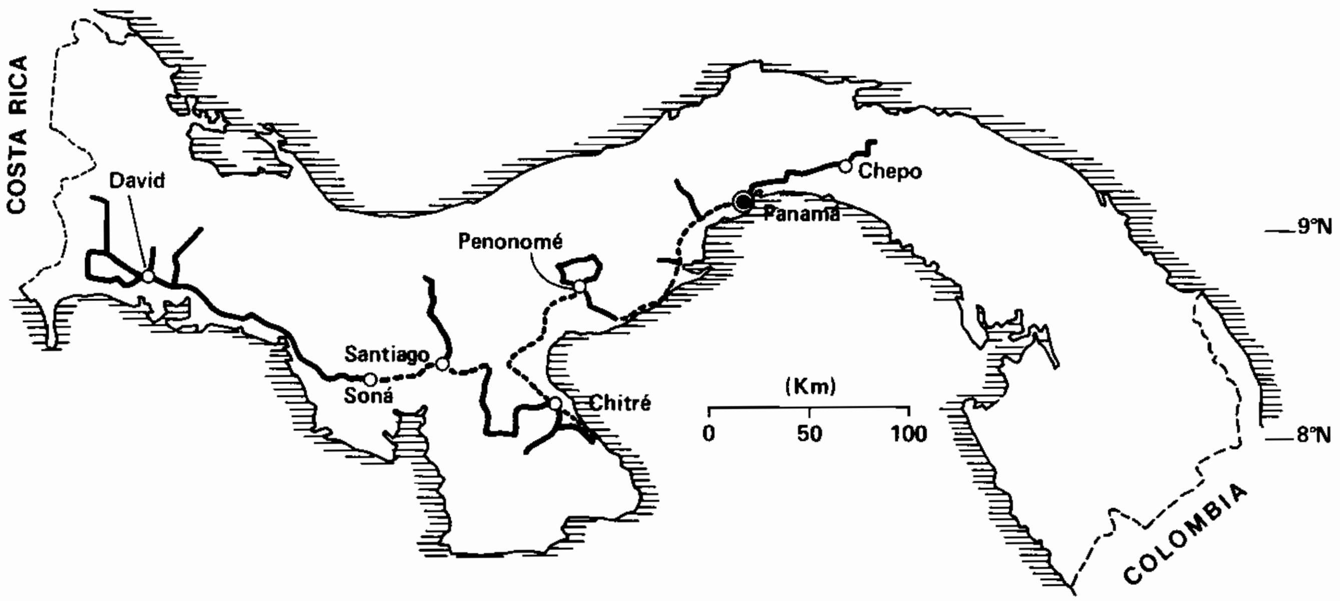


Figure 1. Routes of systematic collection of tropical legume germplasm in Panama (February 1985; IDIAP-USAID/Rutgers Univ. - CIAT).

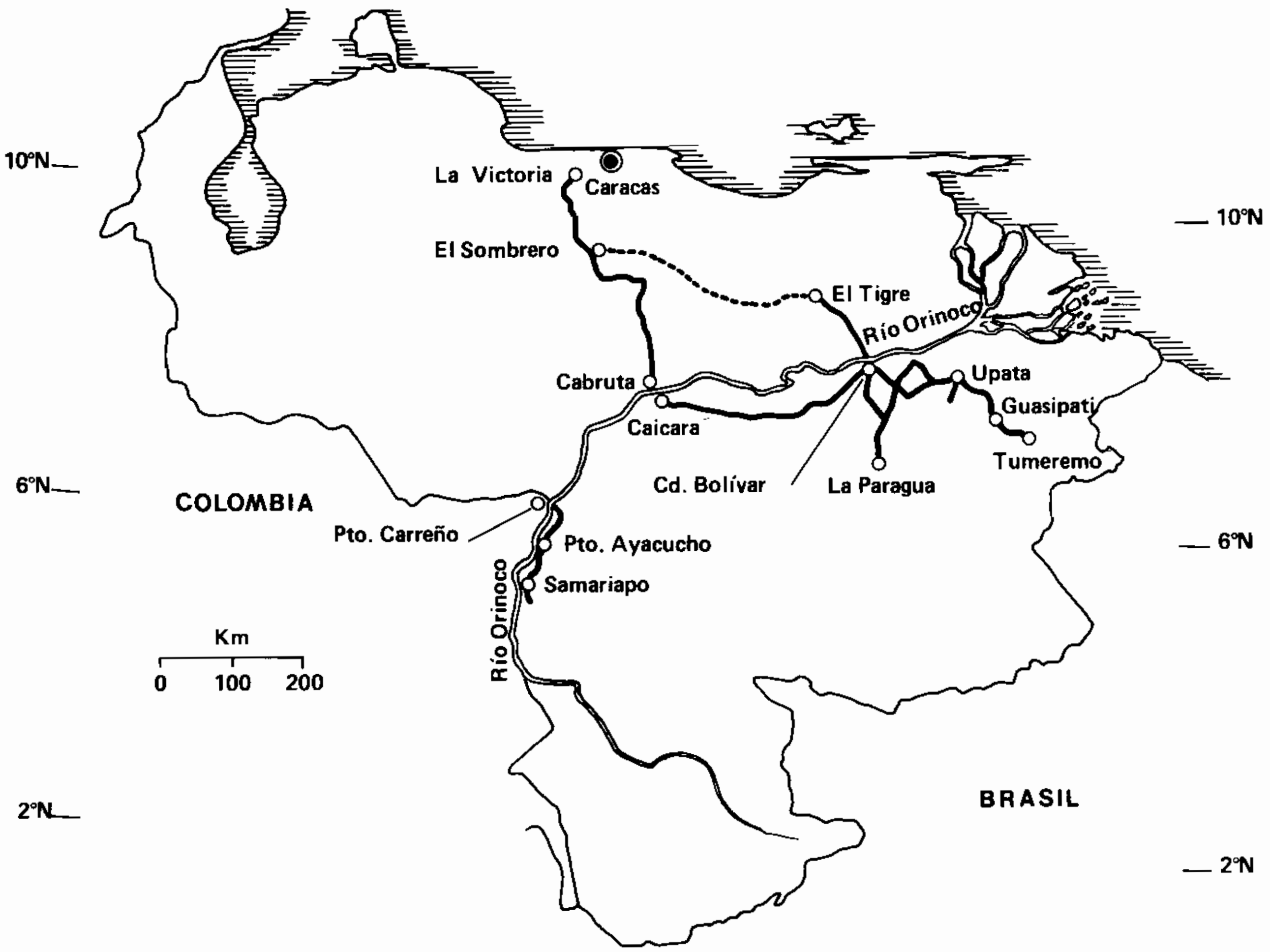


Figure 2. Routes of systematic collection of tropical legume germplasm in Venezuela (March 1985; FONAIAP-CIAT).

Table 1. Summary of tropical forage legume germplasm collected in Panama, Venezuela and Colombia during 1985.

Genera	Panama	Venezuela	Colombia	Total
	No. of samples			
Aeschynomene	26	32	7	65
Calopogonium	33	10	2	45
Centrosema	64	99	9	172
Desmodium	52	40	16	108
Galactia	14	27	5	46
Macroptilium/*Vigna*	20	24	10	54
Stylosanthes	25	56	11	92
Zornia	8	18	2	28
Miscellaneous legumes	78	65	21	164
Total	320	371	83	774

phaseoloides. The central-southern part of the island was sampled along a northwest-to-southeast transect (Fig. 3) and altogether 172 samples were collected (Table 2). More than half were accounted for by high priority germplasm (77 samples of *Desmodium* spp., 11 samples of its allied genera *Codariocalyx*, *Phyllodium* and *Tadehagi*, and 6 *P. phaseoloides* samples).

- Tropical Africa

Within the project to increase the genetic base of African grasses in the CIAT collection, particularly *Brachiaria* spp., systematic collection continued in several countries. Collecting missions covered extensive areas of Zimbabwe (Fig. 4), Burundi and Rwanda (Fig. 5), and Tanzania (Fig. 6). They were carried out in collaboration with the Grassland Research Station Marondera, the Institute des Sciences Agronomiques du Burundi (ISABU), the Institute des Sciences Agronomiques du Rwanda (ISAR), and the Tanzania Livestock Research Organization (TALIRO) respectively, as well as the International Livestock Centre for Africa (ILCA). A summary of the results of the four collecting missions is presented in Table 3. Altogether 905 samples were collected, 81% accounted for by grasses. Of these, 452 samples were *Brachiaria* germplasm of which a high proportion (37%) was *B. brizantha*.

Unfortunately, for most of the *Brachiaria* samples only vegetative material could be collected which, for eventual transfer, necessitated seed multiplication in nurseries or glasshouses in their respective countries of origin. In an attempt to short-cut this process in collaboration with the CIAT Biotechnology Unit, ILCA, the Muguga Plant Quarantine Station in Kenya, and the University of Zimbabwe arrangements were made to propagate and eventually transfer to Colombia the collected material in the form of plantlets derived from meristem tissue culture. Consequently, an appropriate methodology was developed by the CIAT Biotechnology Unit and, in the meantime, the major part of the *Brachiaria* collection has been transferred to Colombia in the form of propagules in glass vials (Fig. 7).

With the afore-mentioned collection

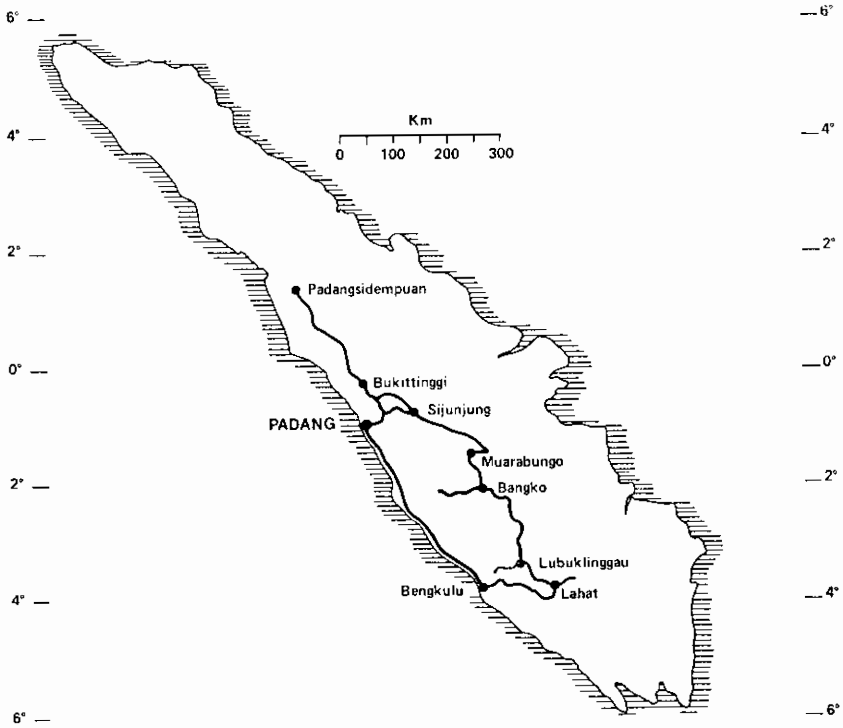


Figure 3. Routes of systematic collection of tropical legume germplasm in Sumatra, Indonesia (September 1985; SARIF-IBPGR-CIAT).

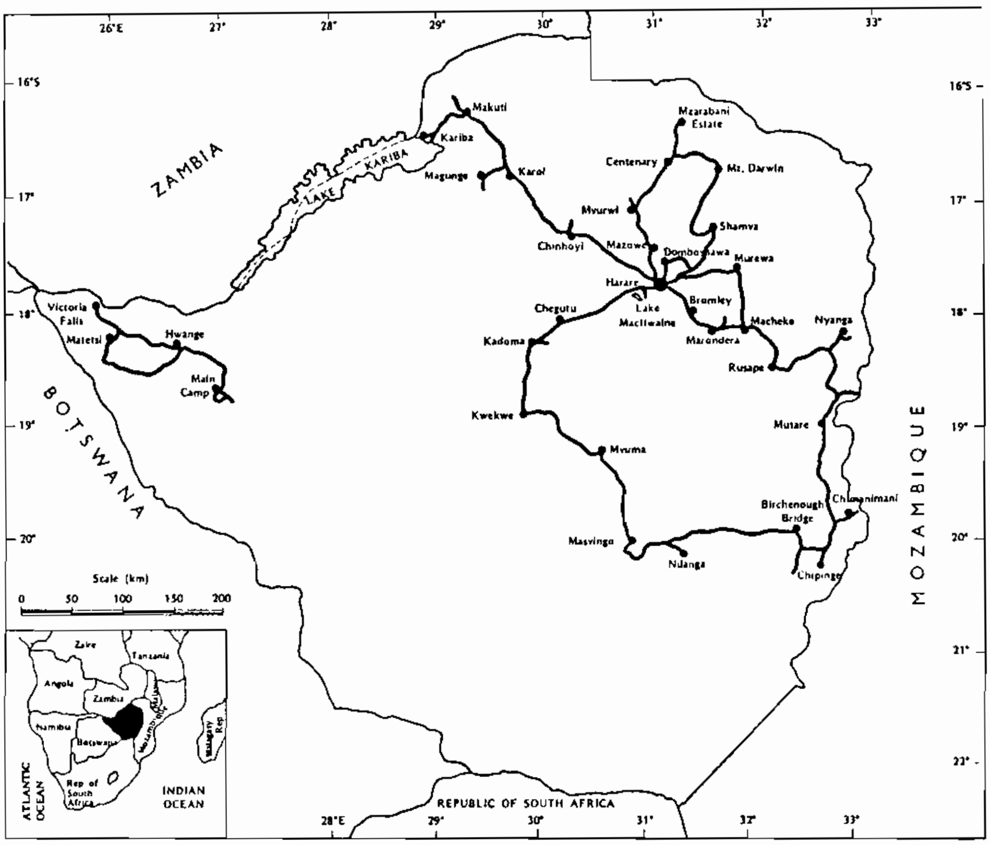


Figure 4. Routes of systematic collection of tropical forage germplasm in Zimbabwe (February-March 1985; Grassland Research Station Marondera - CIAT).

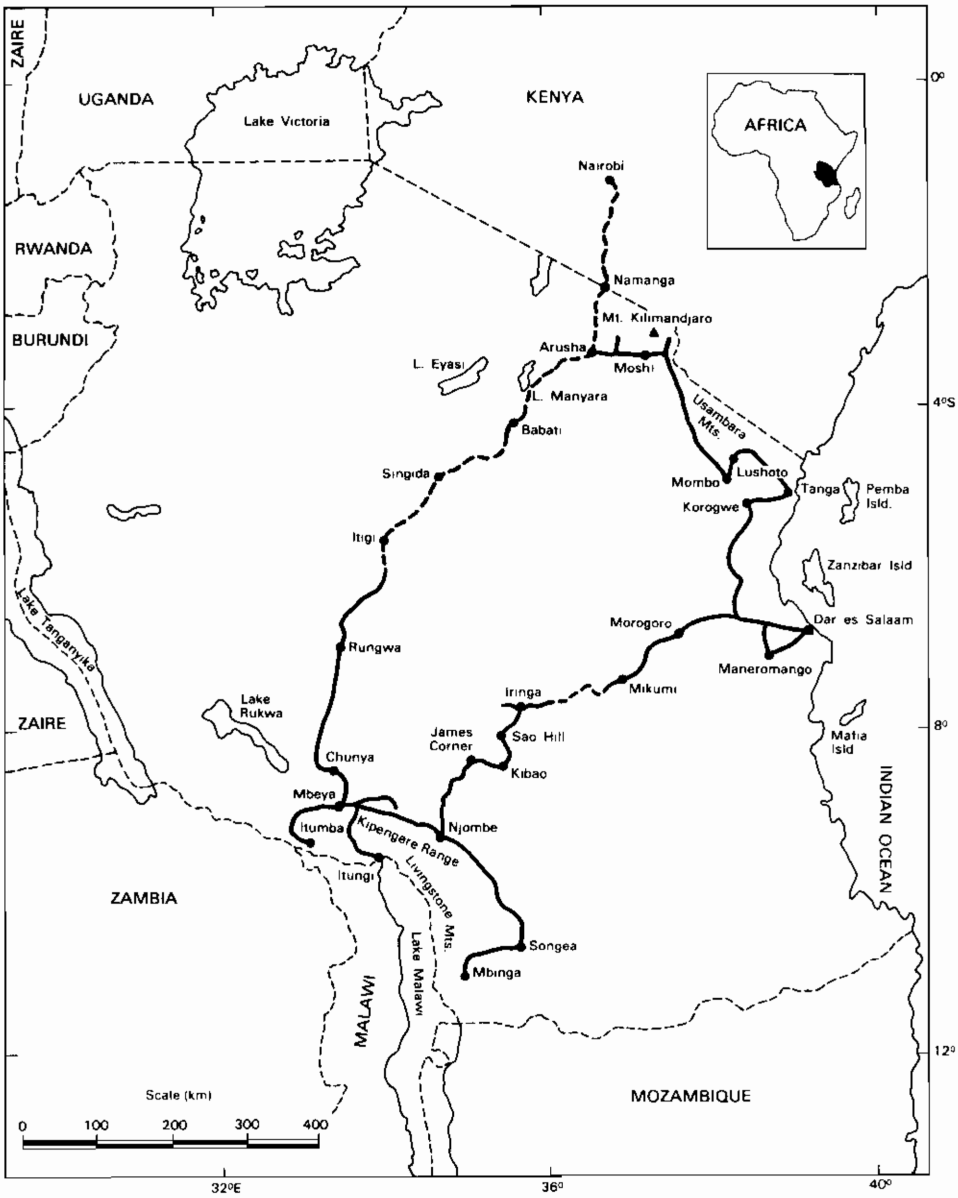


Figure 5. Routes of systematic collection of tropical forage germplasm in Burundi and Rwanda (April - May, 1985; ISABU-CIAT and ISAR-CIAT, respectively).

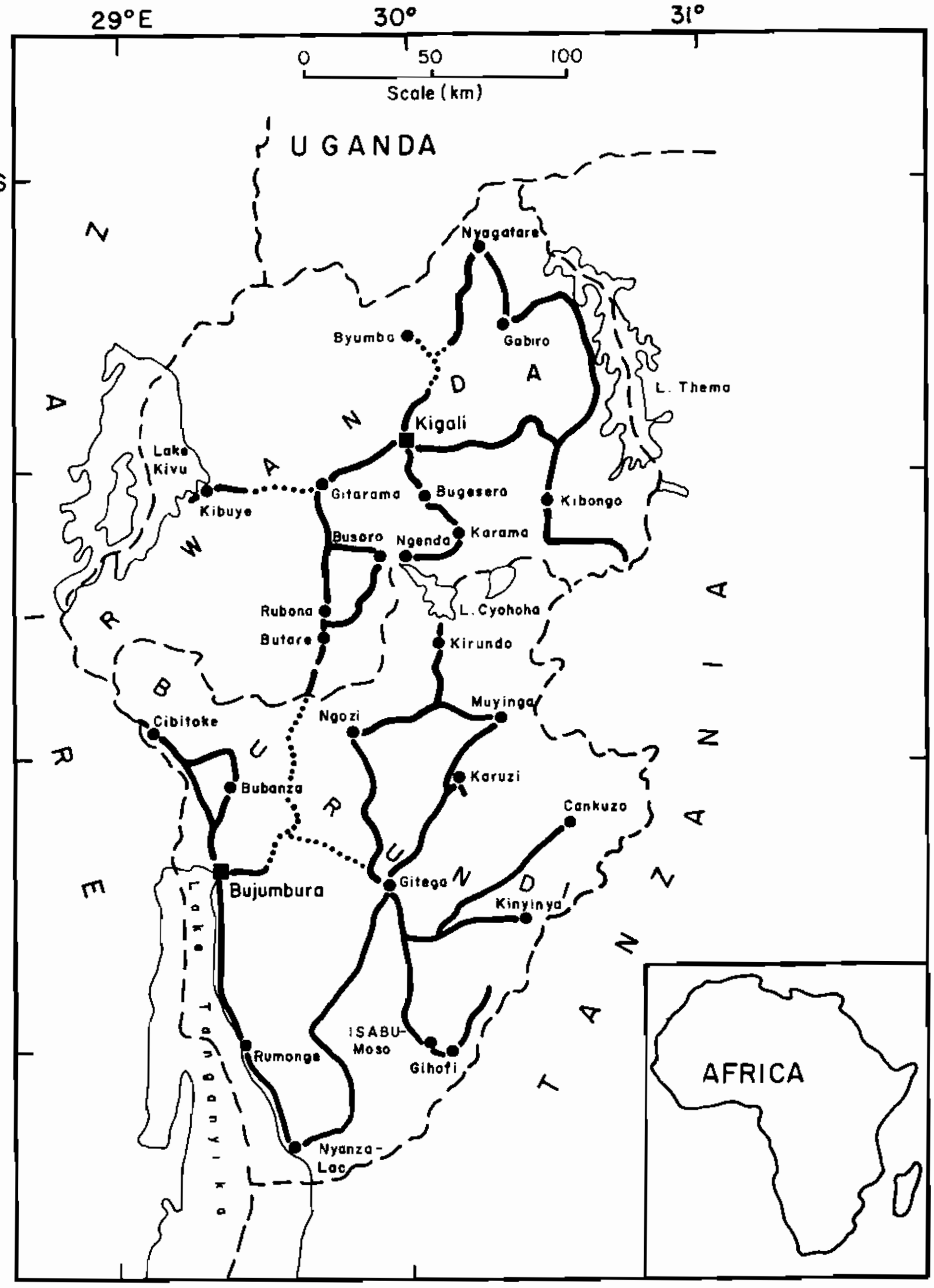


Figure 6. Routes of systematic collection of tropical forage germplasm in Tanzania (July-August, 1985; TALIRO-ILCA-CIAT).

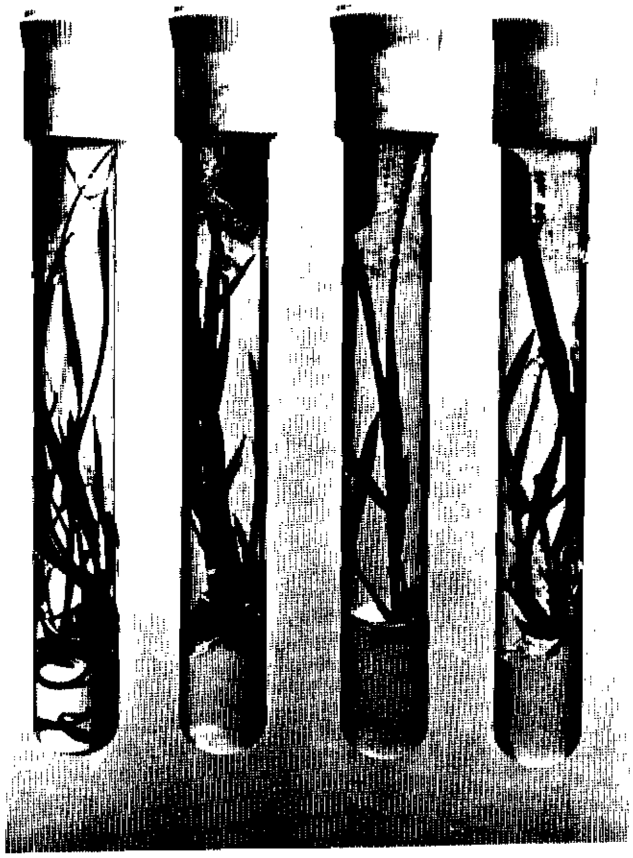


Figure 7. *Brachiaria* spp. plantlets derived from meristem tissue culture.

Table 2. Summary of tropical forage germplasm collected in Sumatra, Indonesia (September 1985).

High priority species	No. of samples	Other genera	No. of samples
Desmodium gangeticum	6	Abrus	1
D. heterocarpon	18	Aeschynomene	9
D. heterophyllum	27	Alysicarpus	8
D. laxiflorum	7	Atylosia	2
D. ovalifolium	4	Calopogonium (naturalized)	1
D. styraciolium	4	Centrosema (naturalized)	4
D. triflorum	5	Clitoria	7
D. velutinum	5	Crotalaria	3
D. sp. (unidentified)	1	Dunbaria	2
Total Desmodium spp.	77	Flemingia	9
		Pseudarthria	3
Codariocalyx gyroides	1	Pycnospora	2
Phyllodium elegans	7	Teramnus	1
Tadehagi triquetrum	3	Uraria	15
		Vigna	8
		Unidentified genus	1
Pueraria phaseoloides	6		
		Axonopus (grass)	1
		Paspalum (grass)	1
Total	94	Total	78
Total samples 172			

trips in Africa, the 1984/85 project to increase the CIAT collection of African grasses, particularly of Brachiaria spp., has concluded. Including material gathered in Kenya and Ethiopia during 1984, altogether 1364 samples representing more than 40 genera were collected (Table 4). Particularly for Brachiaria, the genetic base has been considerably broadened and there are now more than 900 accessions available, representing 24 species (Table 5).

Introduction

With respect to the introduction of germplasm through exchange with other institutions, an important contribution was made by IBPGR in the form of original seed collected in Indonesia. The donation consisted of 338 samples, mainly legumes native to or naturalized in Indonesia, of which 31% were Desmodium spp.

With the additions made during the year (approx. 2300 accessions), the collection of the CIAT Tropical Pastures Program has now increased to approximately 16.000 accessions, 15% of which is grass germplasm (Table 6). The particular value of this collection lies in the fact that the majority of accessions originate from regions with acid, low-fertility soils. The collection is maintained by the CIAT Genetic Resources Unit. In Table 7 a summary is presented of the inventory of germplasm of those species which the Tropical Pastures Program considers as "key" species on

Table 3. Summary of tropical forage germplasm collected in Zimbabwe, Burundi, Rwanda and Tanzania during 1985.

Genera, species	Zimbabwe	Burundi	Rwanda	Tanzania	Total
	No. of samples				
A) GRASSES: *Brachiaria* spp.					
B. bovonei	5	-	4	2	11
B. brizantha	77	40	11	41	169
B. decumbens	1	7	22	-	30
B. dictyoneura	-	-	-	3	3
B. humidicola	30	20	4	27	81
B. jubata	3	7	6	2	18
B. nigropedata	41	-	-	-	41
B. platynota	-	2	17	-	19
B. ruziziensis	-	19	4	2	25
Other *Brachiaria* spp.[1]	46	5	1	3	55
Total	203	100	69	80	452
B) GRASSES: Other genera					
Andropogon	29	2	1	7	39
Chloris	7	-	3	10	20
Hyparrhenia	8	31	2	6	47
Panicum	29	17	2	1	49
Paspalum	8	4	-	5	17
Pennisetum	-	13	-	14	27
Setaria	11	-	-	-	11
Urochloa	5	-	-	-	5
Other genera[2]	40	13	1	13	67
Total	137	80	9	56	282
C) LEGUMES					
Alysicarpus	2	1	-	6	9
Desmodium	6	16	-	12	34
Neonotonia	1	-	3	7	11
Rhynchosia	-	-	2	6	8
Sesbania	-	4	2	3	9
Stylosanthes	12	1	1	11	25
Tephrosia	6	1	-	1	8
Vigna	9	3	1	10	23
Other genera[3]	12	12	1	19	44
Total	48	38	10	75	171
GRAND TOTAL	388	218	88	211	905

1/ *B. arrecta*, *B. comata*, *B. deflexa*, *B. eruciformis*, *B. mutica*, *B. scalaris*, *B. serrata*, *B. subulifolia*.

2/ *Cenchrus*, *Cynodon*, *Digitaria*, *Eragrostis*, *Melinis*, *Sorghum*, *Themeda*, etc.

3/ *Aeschynomene*, *Cassia*, *Clitoria*, *Eriosema*, *Pseudarthria*, *Teramnus*, *Zornia*, etc.

Table 4. Summary of collections of forage grass germplasm in tropical Africa, 1984-1985.

Genera	No. of samples	Genera	No. of samples
Andropogon	42	Paspalum	44
Bothriochloa	4	Pennisetum	57
Brachiaria	792	Rhynchelytrum	2
Cenchrus	29	Rottboellia	3
Cynodon	15	Setaria	42
Chloris	53	Snowdenia	3
Dactyloctenium	2	Sorghum	10
Digitaria	17	Sporobolus	11
Echinochloa	7	Themeda	2
Enteropogon	2	Urochloa	21
Eragrostis	21	Unidentified genera	9
Heteropogon	2	Other genera (1 sample each)	11
Hyparrhenia	56	Chrysopogon, Eleusine,	
Hyperthelia	2	Eneapogon, Eriochloa,	
Ischaemum	3	Exotheca, Hemarthria,	
Loudetia	2	Schmidtia, Stereochlaena,	
Melinis	10	Tetrapogon, Themeda,	
Panicum	90	Tristachya	
Total			1364

the basis of their performance in experiments in the major ecosystems. The figures indicate that with the exception of Arachis pintoi, Centrosema sp.n. and Zornia glabra, fairly large numbers of accessions are now available. With the diversity which can be observed among accessions in introduction plots, these numbers represent a good potential for successful selection and/or breeding work.

MULTIPLICATION AND MAINTENANCE

As in previous years, the multiplication of legume and grass germplasm continued to be one of the important service functions of the Germplasm section. During 1985, the seed multiplication activities consisted essentially of:

- Germplasm multiplication from potted plants in the Palmira greenhouse and/or from individual plants in specific germplasm multiplication fields in CIAT-Palmira or CIAT-Quilichao: approximately 1550 accessions.

- Initial seed increase of all germplasm material under preliminary evaluation at CIAT-Quilichao: approximately 1970 accessions.

Multiplied seed is handed over to the CIAT Genetic Resources Unit which is responsible for (a) maintaining germplasm stocks under appropriate cold-storage conditions and (b) germplasm distribution.

Table 5. Accessions of *Brachiaria* spp. in the CIAT collection of tropical forage germplasm.

Species	African collections 1984/85	New Inventory Dec. 31, 1985
	---------- No. of Accessions	----------
a) Perennials		
B. arrecta	4	5
B. bovonei	11	11
B. brizantha	351	408
B. decumbens	47	64
B. dictyoneura	16	18
B. humidicola	101	113
B. jubata	75	76
B. lachnantha	6	6
B. longiflora	2	2
B. mutica	1	1
B. nigropedata	41	42
B. plantaginea	1	1
B. platynota	20	20
B. ruziziensis	27	44
B. serrata	23	23
B. subulifolia	10	10
B. sp.	4	4
b) Annuals		
B. comata	5	5
B. deflexa	14	15
B. eruciformis	21	22
B. leucocrantha	8	8
B. obtusiflora	2	2
B. scalaris	1	1
B. semiundulata	2	2
Total	792	903

CHARACTERIZATION AND PRELIMINARY EVALUATION

During the characterization and preliminary evaluation phase germplasm of priority or "key" species and new, agronomically unknown or 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 (a) yield potential on a very acid, infertile Ultisol, including regrowth after cutting and performance during the two rather short but severe dry seasons that prevail in Quilichao, (b) disease and insect resistance and (c) seed production potential. Establishment and evaluation methodology is that of Category I used at the Program's major

Table 6. Introduction of tropical forage germplasm through collection and exchange with other institutions during 1985 (No. of accessions).

Genera	Collections			Introductions through exchange	Total 1985	Total Collection Dec. 31, 1985
	Tropical America	Indonesia (Sumatra)	Tropical Africa			
Aeschynomene	65	9	4	19	97	733
Calopogonium	45	1	1	30	77	375
Centrosoma	172	4	-	65	241	1488
Desmodium	108	77	34	118	337	1901
Galactia	46	-	-	3	49	504
Macroptilium/Vigna	54	8	23	18	103	1058
Pueraria	-	6	-	26	32	117
Stylosanthes	92	-	25	5	122	3095
Zornia	28	-	2	4	34	911
Miscellaneous legumes	164	65	82	117	428	3492
Total legumes	774	170	171	405	1520	13674
Andropogon	-	-	39	-	39	104
Brachiaria	-	-	452	29	481	903
Panicum	-	-	49	-	49	716
Miscellaneous grasses	-	2	194	35	231	694
Total grasses	-	2	734	64	800	2417
Grand total	774	172	905	463	2320	16091

testing sites, and is based upon unreplicated rows of spaced plants.

These preliminary observations assist 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) and, more recently, the humid tropics (Pucallpa).

In some cases, principally for Centrosema and Zornia germplasm, selected accessions also undergo agronomic evaluation at the Category II level (cutting trials in replicated plots with spaced plants).

Preliminary evaluation

Table 8 reports all Category I trials which existed during 1985 at CIAT-Quilichao. Some key observations on these trials are:

- Growth of Arachis pintoi is rather poor. Establishment vigour of accessions CIAT 17434 and 18751 is superior to that of other accessions.

- The results of an evaluation trial, now concluded, with 130 Centrosema brasilianum accessions were used to classify the collection into six cluster groups on the basis of their Rhizoctonia

Table 7. Inventory of germplasm of key species in the CIAT tropical forage collection (December 31, 1985).

Species	No. of accessions originating from: Tropical America	Southeast Asia	Tropical Africa
Arachis pintoi	10		
Centrosema brasilianum	182		
C. macrocarpum	234		
C. sp.n. var. *matogrossense*	20		
C. sp.n. var. *orinocense*	9		
Stylosanthes capitata	281		
S. guianensis var. *pauciflora*	209		
S. macrocephala	115		
Zornia glabra	23		
Desmodium heterophyllum		59	
D. ovalifolium		97	
Pueraria phaseoloides		117	
Andropogon gayanus			104
Brachiaria spp.			903
Panicum maximum			716

Table 8. Multiplication and characterization of germplasm in CIAT-Quilichao at Category I level during 1985 (No. of accessions).

A. Known and priority species			B. "New" species		
Legumes:	*Arachis pintoi*	8	Legumes:	*Centrosema arenarium*	2
	Centrosema brasilianum	62		*C. brachypodum*	5
	C. macrocarpum	174		*D. heterocarpon*	73
	C. sp. var. *matogrossense*	20		*D. strigillosum*	9
	C. sp. var. *orinocense*	9		*Periandra* sp.	27
	Desmodium heterophyllum	36		*Stylosanthes scabra*	575
	D. ovalifolium	84			
	Pueraria phaseoloides	97	Grasses:	*Axonopus compressus*	22
	Stylosanthes capitata	71		*Paspalum* spp.	32
	S. macrocephala	55			
	Zornia spp.	68			
Grasses:	*Brachiaria* spp.	100			
	Panicum maximum	444			
Total		1228	Total		745

resistance and resulting dry matter yields (Table 9). Cluster 6 comprised the promising accessions CIAT 5541, 5671 and 5698.

- Centrosema macrocarpum: In a preliminary evaluation trial now concluded, of an earlier part of the collection, the 67 accessions tested were classified by cluster analysis into eight distinct groups on the basis of (1) their dry matter production potential and (2) their capacity to root at the nodes of trailing stems (Fig. 8). Accessions within clusters 3, 4 and 5 seem to be of particular interest because of their stoloniferous growth habit.

- Within the new, yet undescribed Centrosema species, the differences between the two forms ("var. matogrossense" and "var. orinocense") have become increasingly evident, particularly in terms of disease resistance. The var. orinocense accessions, as represented by CIAT 5277, are considerably more resistant to Pseudomonas bacterial blight.

- All Centrosema arenarium as well as C. brachypodum accessions show low establishment vigour.

- Although there are no major morphological differences among the 84 Desmodium ovalifolium accessions, considerable variation was recorded in flowering time, dry matter production and crude protein content in the leaves.

- Considerable morphological variation can be observed in the Pueraria phaseoloides collection, where var. subspicata accessions stand out because of their narrower, lobate leaflets and low productivity. Drought resistance is excellent in these types.

- In the Panicum maximum collection (444 accessions) considerable morphological diversity is evident in the part of the collection which originates from East Africa.

- The Stylosanthes scabra collection also shows very large variation, not only in terms of plant morphology but also with respect to flowering time, anthracnose resistance, vigour and seed production potential.

Agronomic evaluation

Table 10 shows the final results of the agronomic evaluation of 15 selected Zornia glabra accessions. Although there is not very much variation amongst accessions in dry matter yields, accessions CIAT 8278, 8279 and 8283 showed a performance superior to the control accession CIAT 7847. The leaf percentage in the DM ranged from 32% to 52%; the generally high crude protein and P concentrations in the leaves are noteworthy.

The results of an agronomic evaluation trial with six selected Dioclea guianensis accessions are presented in Table 11. There were no major differences with respect to DM yields, leaf percentage, number of rooted stolon nodes and nutritive value. All accessions are vigorous climbers, very well adapted to acid, infertile soils and exhibited outstanding drought resistance. Their acceptability by cattle, however, proved to be very low during a grazing test conducted at the end of the trial.

FUTURE PLANS

Multiplication and characterization work will continue in a routine way. Continuing involvement in germplasm collection activities in Southeast Asia (Indonesia) and tropical America (Mexico, Venezuela) is also projected for 1986. All trips will be planned and eventually executed in collaboration with the respective national institutions.

Table 9. Classification of a *Centrosema brasilianum* collection (130 accessions) by cluster analysis. based on dry matter yields during five harvests (Quilichao 1983-1984).

Cluster	No. of Accessions		DM yield/accession (g/m^2) Harvest 1	2	3	4	5	Cumulative Yields
1	40	Range	35-151	0-74	0-40	0-16	0	
		Mean	88	38	5	2	0	130
2	19	Range	48-161	31-110	0-36	0-27	0-20	
		Mean	100	70	14	9	3	195
3	23	Range	67-271	20-135	4-27	0-76	0-74	
		Mean	131	73	13	28	17	260
4	27	Range	76-240	44-136	13-46	15-79	0-151	
		Mean	131	85	22	49	64	350
5	18	Range	89-182	38-156	15-50	18-120	33-156	
		Mean	134	102	32	69	95	430
6	3	Range	148-203	64-204	18-48	44-131	78-187	
		Mean	170	130	36	92	150	575

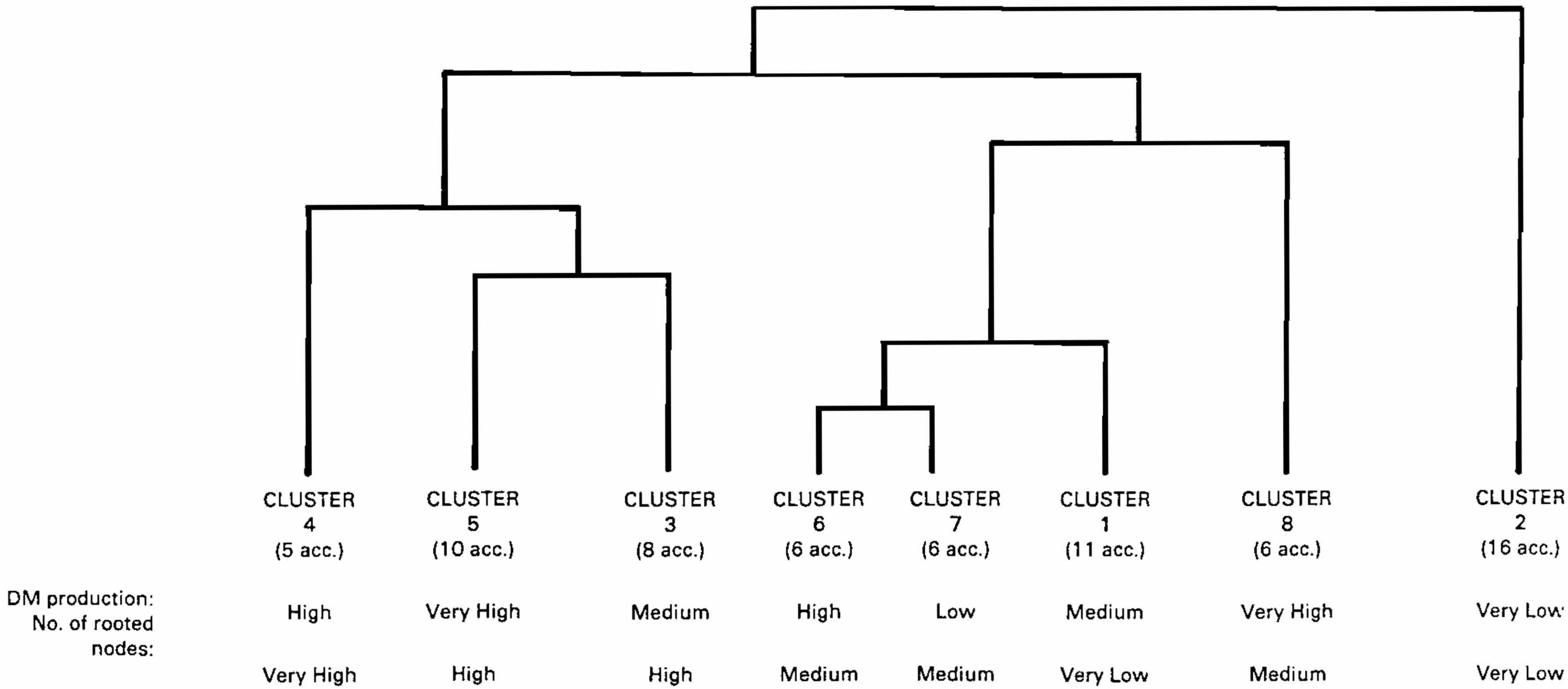


Figure 8. **Classification of a *Centrosema* macrocarpum collection (67 accessions) by cluster analysis based on dry matter production and No. of rooted stolon nodes.**

Table 10. Dry matter production and nutritive value of 15 Zornia glabra accessions in CIAT-Quilichao.

Accession No.	Cumulative DM yield (g/m^2)[1]	% Leaf in DM[2]	Concentration in leaves (%)[3] Crude Protein	P	Ca
8278	1454 a[4]	41 cdef	24.3	0.28	0.79
8279	1348 ab	44 cd	26.7	0.32	0.73
8283	1274 abc	43 cde	25.7	0.31	0.83
8346	1216 bcd	41 def	24.6	0.33	0.72
8307	1212 bcd	36 gh	25.2	0.33	0.64
281	1089 cde	32 h	27.3	0.34	0.83
8297	1051 cde	45 cd	23.5	0.31	0.73
278	1038 cde	52 a	26.7	0.34	0.81
7847	1035 cde	51 ab	23.4	0.28	0.88
8308	1020 de	42 cdef	26.7	0.35	0.65
8343	1013 def	39 efg	24.4	0.32	0.72
255	1001 ef	37 efg	26.1	0.32	0.75
8273	927 ef	43 cdef	26.0	0.36	0.71
280	924 ef	43 cdeT	25.4	0.35	0.68
283	774 f	46 bc	26.2	0.36	0.74

1/ Nine harvests at 3-month intervals.
2/ Mean of 5 harvests.
3/ Mean of 6 harvests.
4/ Means followed by the same letter do not differ significantly at $P < 0.05$.

Table 11. Evaluation of Dioclea guianensis during 18 months in CIAT-Quilichao: Cumulative DM yields, leaf percentage, stoloniferous growth habit and nutritive value of 6 selected accessions.

Accession No.	Cumulative DM yield (g/m^2)[1]	% Leaf in DM[2]	No. of rooted stolon nodes[1]	Concentration in leaves (%)[2] Crude Protein	P	Ca
8193	1086 a	56	18.4 ab	17.2	0.13	0.49
9311	1068 a	61	9.2 b	17.9	0.15	0.44
7351	1029 a	57	14.4 a	18.3	0.14	0.46
7801	1028 a	56	14.4 a	18.1	0.13	0.52
828	806 ab	60	19.2 ab	17.8	0.15	0.62
8008	635 b	54	25.6 a	19.7	0.15	0.53

1/ Six harvests at 3-month intervals.
2/ Mean of 3 harvests.
3/ Means followed by the same letter do not differ significantly at $P < 0.05$.

Plant breeding

INTRODUCTION

During 1985, the Plant Breeding Section continued to make advances in the ongoing genetic improvement projects of *Stylosanthes guianensis* and *Andropogon gayanus*. Collaborative projects were initiated this year with Plant Pathology in *Zornia latifolia* and with Microbiology in *Centrosema* spp.

Our overall objective is twofold: first, we seek to produce, through directed genetic recombination and selection, improved genotypes of a limited number of the Program's key species. Additionally, we se seek to generate useful information on the genetics and breeding of species that are essentially unknown from a plant breeding point of view. We feel that this information is essential to improving the efficiency and effectiveness of present and future genetic improvement projects at CIAT. Further, this information ought to be highly transferable to national program breeding projects as these develop.

BREEDING AND GENETICS

Andropogon gayanus

A selection project aimed at producing a short statured *A. gayanus* synthetic was initiated in 1983 with the objectives of (i) improving compatibility with well adapted but less vigorous legumes (e.g. *Stylosanthes capitata* and *S. macrocephala*) and (ii) improving ease of management under grazing.

Clones originally obtained in 1983 from the germplasm collection and tested, as clones, at Quilichao have now been evaluated as clones at Carimagua and by open-pollinated progeny ("polycross") test at Quilichao and Carimagua. These trials sought to evaluate the stability of the short stature trait over environments and over a generation of sexual reproduction.

Results of these trials show a more complex situation than originally anticipated. Plant stature was highly consistent among clones over two evaluation periods at a single site (Quilichao) (r = 0.87). However, performance at Carimagua was somewhat different from that at Quilichao, whether clones or progenies were compared between the two locations. Firstly, mean plant height was much greater at Carimagua than at Quilichao (Table 1), probably due to a greater growth rate induced by higher ambient temperatures and greater availability of water at Carimagua than at Quilichao. Further, the correlation over genotypes was low (r = 0.34 or 0.31 for selected clones or progenies, respectively).

This low correlation is, in part, due to comparing a relatively narrow range of selected genotypes. CIAT 621 was included as a check in the progeny trial at both Quilichao and Carimagua and was the tallest entry at both sites (Table 1). When CIAT 621 is included in the correlation analysis, the correlation coefficient over entries between sites increases substantially (Table 1). However, these data would suggest that results from Quilichao are not directly extrapolable to Carimagua.

The correlation between parental clone and progeny was moderately high whether measured at Quilichao or, particularly, at Carimagua (r = 0.31 or 0.58, respectively) suggesting that continued selection ought to be effective in further decreasing plant stature.

In spite of these new complexities, the fact remains that after only a single cycle of selection and recombination we now have A. gayanus genotypes that are substantially shorter than the standard CIAT 621. Many progenies contain plants that appear to be productive and leafy.

Individual plants are being selected from the first cycle open-pollinated progenies on the basis of visual evaluation of stature, vigor (forage yield), and leafiness. A total of 200 plants will be selected to initiate a second cycle of selection. These plants will be propagated

Table 1. Plant height of *Andropogon gayanus* parental clones selected for short stature or their open-pollinated progeny at Quilichao or Carimagua.

Genotype Identification	Parental Clone		O.P. Progeny	
	Quilichao	Carimagua	Quilichao	Carimagua
01	146.8	-	157.4	203.3
03	157.0	153.3	149.6	163.1
04	142.0	244.7	140.0	186.6
05	160.3	248.7	151.1	189.4
06	139.5	170.0	133.7	-
07	164.4	248.7	149.6	183.9
08	149.6	180.7	141.3	164.9
09	93.5	187.7	140.8	144.4
10	158.1	236.0	151.6	180.3
11	146.6	180.7	140.9	174.5
12	144.3	198.0	132.6	163.0
13	150.9	173.3	136.7	161.9
14	155.6	212.3	146.1	187.8
17	145.2	194.7	135.9	186.4
18	153.9	204.0	136.9	202.7
19	146.2	194.0	129.5	179.6
Mean of Selections	147.1	201.8	142.1	178.1
CIAT 621			194.5	213.5
Correlations between Locations:	r = 0.34 (n = 15)		r = 0.31 (n = 15, excluding CIAT 621) r = 0.56 (n = 16, including CIAT 621)	

vegetatively to establish replicated trials for clonal evaluation and polycross recombination at both Quilichao and Carimagua in 1986.

Stylosanthes guianensis:

The major activity of the Plant Breeding Section remains the breeding project in S. guianensis which seeks to develop persistent, productive genotypes with stable, enhanced disease and pest resistance combined with acceptable seed yield (See Annual Reports 1981-1984).

An initial 10-parent diallel series of crosses was formed in 1982 from lines selected primarily for persistence at Carimagua during 1979-1981. While over 500 crosses, involving 54 germplasm accessions as parents, have now been made in an ongoing breeding project, progenies of the first diallel set of crosses represent the most advanced breeding material.

Three major approaches to handling segregating generations were initiated with this first set of crosses -- pedigree, bulk advance, and natural selection -- in order to be able to compare the effectiveness of different breeding methods in S. guianensis while simultaneously generating improved genotypes. Improved breeding procedures are being tested, refined, and incorporated into the main breeding project.

The Stylosanthes guianensis breeding project advanced significantly in 1985 with the establishment of a large screening trial at Carimagua for the preliminary evaluation of over 1.000 lines, including F2 and bulk F3 progenies, and F3 and F4 families, generated by the project since 1983. In a large scale "natural selection" experiment the base population of S. guianensis was sampled and grazing was initiated. Basic studies on genetic marker traits and outcrossing rates in S. guianensis, conducted by the Section over the past several years, are bearing fruit as a systematic recurrent selection scheme involving massive genetic recombination has advanced from the theoretical, to the practical, field stage.

Initial Diallel Crosses

Pedigree advance

In 1983 the 45 F2 populations resulting from the initial 10-parent diallel series of crosses were established in a replicated small-plot experiment at Carimagua. Small quantities of F3 seed were harvested from selected progenies to establish a space planted F3 nursery at Quilichao in 1984. A total of 454 F3 individuals, deriving predominantly from 5 crosses but representing a total of 33 of the 45 crosses, were planted. These were harvested individually over a period of six months between August, 1984, and January, 1985, to produce seed of F4 families. Where sufficient seed was obtained (1 gm) F4 families were established in May, 1985 in a three-replicate, small plot trial at Carimagua. A total of 392 F4 families was included in this trial. These families are being visually evaluated for anthracnose and stem borer resistance, relative maturity (time of flowering), seed set, and forage productivity. By the late dry season (March, 1986) approximately 50 F4 progenies will be selected, to produce at least 1 kilogram of seed during 1986 for small-plot grazing trials at Carimagua in 1987. Seed multiplication plots will be established with remnant F4 seed at Quilichao. Second season data on the F4 families from Carimagua and seed yields will be used to reduce the number of materials passing to the stage of small plot grazing trial to approximately 10-20.

The pedigree advance program has fully maintained the schedule of activities which was outlined in the 1982 Annual Report. In fact, we have about three times more F4 families under evaluation than we had originally anticipated.

Bulk Advance
With the same initial 10-parent diallel series of crosses, a bulk advance scheme was initiated in 1983 to investigate the potential of this simple and inexpensive mass selection procedure, particularly in improving harvestable seed yield. It is assumed that, in addition to seed yield potential *per se*, the bulk advance scheme ought to result in an improvement in resistance to Stegasta bud worm which reduces seed yields drastically at Carimagua.

An initial bulk population formed by mixing equal quantities of F2 seed from the 45 diallel crosses has now undergone two generations (F2 and F3) of bulk seed harvest. The bulk F2 plot was subdivided into 12 sub- plots which were harvested on 12 different dates over a 6-month period between October, 1983 and March, 1984. The resulting 12 subpopulations were planted separately in the F3 generation in 1984 and they were harvested on the same schedule as in the F2 generation, thus maintaining the 12 subpopulations.

Seed yields have not been high, particularly for the middle harvest dates from mid-November to late January. However, it is encouraging to note that yields were substantially greater in the second than in the first generation (Table 2).

The bulk F4 subpopulations were planted at Carimagua in May, 1985, and the harvest series began on 1 October. As seed yields on the F3 sub-populations were so low between November and January, subpopulations 4 through 9 were bulked to plant a small plot of a "midseason bulk" this year. It appears that these mid-season genotypes may be lost altogether.

One hundred F4 lines derived from the bulk advance subpopulations are under initial agronomic evaluation at Carimagua this year. As a general observation, the bulk advance derived lines appear to be vigorous and many have excellent seed set, as would be expected: the largest plants with the best seed yields contribute most to

Table 2. First and second cycle seed yields of *Stylosanthes guianensis* bulk advance subpopulations.

Subpopulation	Approximate Harvest Date	Seed Yield First Cycle	Seed Yield Second Cycle	Percent Gain from First to Second Cycle
		kg/ha	kg/ha	%
1	01 October	0.43	9.07	2009.3
2	15 October	4.38	19.69	349.5
3	29 October	3.48	8.28	137.9
4	14 November	0.08	0.60	650.0
5	26 November	0.13	0.06	-53.8
6	10 December	0.12	0.04	-66.7
7	26 December	0.15	0.09	-40.0
8	08 January	0.12	1.27	958.3
9	21 January	0.36	0.19	216.7
10	04 February	0.36	6.02	1572.2
11	18 February	0.26	10.11	3788.5
12	04 March	1.33	5.38	304.5

the succeeding generation. Further, though the individual subpopulations are becoming more uniform in terms of maturity, they remain highly heterogeneous for other traits so that additional genetic gain ought to be possible. However, as selection pressure for anthracnose resistance is not strong in this generation advance scheme (any plant that has just enough resistance to produce seed at Carimagua in the establishment year will contribute to the succeeding generation), lines with sufficiently high levels of resistance for persistence at Carimagua are not being obtained. Some of these bulk advance derived lines may be of value directly in environments such as the humid tropics where anthracnose pressure is lower than at Carimagua, or as parents in the breeding program as sources of genes for high seed yields.

As with the pedigree advance, the bulk advance scheme has exceeded the schedule of activities as projected in 1982. We have maintained a larger number of subpopulations and have begun to derive lines for agronomic evaluation at an earlier generation than originally anticipated.

Natural Selection

In 1984 a four hectare grazing trial was established at Carimagua with two principal objectives: first, we aim to obtain persistent S. guianensis lines highly adapted to the grazed pasture environment. We seek simultaneously to study the effects of natural selection on an initially highly heterogeneous S. guianensis population formed by blending F2 seed from most of the diallel crosses. Natural selection will be allowed to act on the heterogeneous S. guianensis population under six different environmental conditions defined by a factorial combination of two associations (native savanna vs. A. gayanus) and three grazing pressures ("high" vs. "intermediate" vs. "low").

S. guianensis seed was planted at a rate of approx. 1 kg/ha either in prepared and fertilized rows in native savanna or in association with A. gayanus.

There was a depletion of the original population of seed of approx. 90% during the early establishment phase. Surviving plants were sampled early in June, 1985, approximately one year after planting, and before grazing treatments were imposed. These will provide a base-line against which to compare populational changes which occur over time under grazing.

Pastures of the six association-by-stocking rate treatments will be sampled yearly so as to be able to document genetic changes in the persisting S. guianensis populations by treatment over time.

Grazing began in June, 1985, initially with an average stocking rate of one or two 150 kg animals per ha on the association with native savanna or A. gayanus, respectively. High or low stocking rates were 25% higher or 25% lower than the average (Table 3). Due to very vigorous growth of A. gayanus, additional animals were introduced 6 weeks following the initiation of grazing to bring average stocking rate to 5 animals per ha. Subsequently average stocking rate on the A. gayanus association has been reduced to 3 animals per ha. Stocking rate treatments are grazed on a 7/14 day rotation, with the same group of animals always on the same association. Stocking rate effects on pasture condition, while not yet documented, are obvious.

New Crosses

Subsequent to the first diallel set of 45 crosses a total of 494 additional crosses have been realized. The strategy with these new crosses is to select intensively among crosses in the F2 or bulk F3 generation, then

Table 3. Stocking rates on native savanna or <u>Andropogon gayanus</u> associations with a heterogeneous population of <u>Stylosanthes guianensis</u>.

Association	Date Initiated	Stocking rate*		
		High	Intermediate	Low
Native Savanna	14-V-85	1.25	1.00	0.75
<u>Andropogon gayanus</u>	14-V-85	2.50	2.00	1.50
	04-VI-85	6.25	5.00	3.75
	06-VIII-85	3.75	3.00	2.25

* Number of animals of approximately 150 kg initial weight.

concentrate selection <u>within</u> selected crosses in subsequent generations. Owing to the very diverse set of parents being used, variation among F2 or bulk F3 populations is much greater than the residual, within population variation.

Seventy new crosses were established as transplanted F2 plots at Quilichao in 1984 for bulk harvest of F3 seed within F2 populations. More than one bulk harvest was made on each F2, and a total of 236 bulk F3 entries were produced and advanced to a direct seeded, field evaluation trial (3 replicates of 3 m, single-row plots) in Carimagua in 1985.

We have now found it feasible to produce sufficient F2 seed (one gram, or approximately 450 seeds) on individual, glasshouse-grown F1 plants to take F2 populations straight to replicated, direct-seeded field trials at Carimagua, eliminating the need for seed multiplication in the F2 generation at Quilichao and saving one year in the evaluation process. In 1985, 192 new F2 progenies were included in evaluation trials at Carimagua.

More than 200 crosses are presently in the stage of F1 plants in the glasshouse.

Crosses made to date involve a total of 54 parental accessions from the CIAT collection of <u>S. guianensis</u>.

Procedures followed in early generations of these new crosses are outlined in Table 4.

<u>Recurrent Selection Scheme</u>

Since 1982 the Section has been actively engaged in research into the inheritance of possible genetic marker traits and in the estimation of natural outcrossing rate in different seasons and using different genetic materials of <u>S. guianensis</u>. This "basic" research is now bearing fruit with the implementation of a practical recurrent selection scheme, as proposed in last years's Annual Report, involving the massive genetic recombination necessary to achieve radical improvement in such quantitative traits as disease and insect resistance and seed yields. The recurrent selection scheme can be implemented on a practical, field level since it relies on natural outcrossing rather than tedious hand crossing to achieve the genetic recombination phase. The scheme requires an easily identifiable, single gene, marker trait. A yellow /white flower color contrast is presently being used.

Table 4. Routine procedures for handling early generations of Stylosanthes guianensis crosses.

Year	Generation	Activity
1	F_1	Production of F_2 seed on glasshouse-grown F_1 plant. Attempt to obtain at least 1 g of F_2 seed.
2 & 3	F_2	Preliminary field evaluation of populations in direct seeded trial at Carimagua. Harvest of small quantities of seed from selected plants within selected populations.
3	F_3	Space planted nursery for seed increase of F_4 families, Quilichao. Selection on seed yield and second year F_2 performance.
4 & 5	F_4	Small plot, agronomic trials to evaluate F_4 families at Carimagua and other sites as seed supplies permit. These are approximately the equivalent of Category II agronomic trials.

In 1984 more than 100 white flowered plants (homozygous recessives) were systematically interplanted in the space planted, F3 nursery at CIAT-Quilichao. Open-pollinated progenies of 97 of these white flowered plants were transplanted at Quilichao this year with approximately 45 or 90 plants per progeny depending on seed supplies. A total of more than 6,000 plants was included in this plant-out. These progenies are predominantly white flowered, but contain some yellow flowered individuals. As flower color is identified, white flowered (self-pollinated) individuals are being eliminated to leave only yellow flowered plants. These yellow flowered individuals are the result of outcrosses to yellow flowered plants which occured in the 1984 space planted nursery. They are the equivalent of F1 (or S0) plants. As of 20 October, a total of 5,355 plants had flowered of which 350 (6.5%) were identifiable outcrosses. Identifiable outcrosses within progenies range from 0 (in 14 of 97 progenies) to a high of 37.5%.

Seed, equivalent to F2 (or S1) seed, is being harvested from the yellow flowered plants. These progenies will be included in direct seeded, agronomic evaluation trials at Carimagua in 1986.

It should be noted that with relatively little effort we shall obtain 400-500 new F1 individuals (and F2 progenies) this year. This is about double the previous yearly maximum number of crosses obtained by hand pollination. And the number of outcrosses could easily be increased several times more simply by increasing the size of the plantout.

With the implementation of this applied recurrent selection procedure a major bottle neck in Stylosanthes breeding has been overcome. However, the scheme as presently carried out has one important drawback: identification of outcrosses in open-pollinated progenies of homozygous recessive plants requires transplanting large populations to the field since the flower color marker is not identifiable in the seedling stage. With a good seedling marker outcrossed plants could be identified within very large open-pollinated progenies in the seedling stage in the glasshouse. Only the outcrossed individuals would need to be transplanted to the field for F2 seed production. This would represent a considerable improvement in the efficiency of the scheme.

Other Studies

Induction of seedling marker trait

As no single-gene marker trait, identifiable in the seedling stage, has been found in the S. guianensis germplasm collection we have embarked on a mutation breeding project to induce, isolate, and characterize such a seedling genetic marker.

A preliminary trial of gamma radiation dosages was conducted to discover an appropriate range for mutation induction. Dosages of 0, 20, 40, 60, 80, or 100 kRad were applied to air dried seed of two germplasm accessions (CIAT 15 and CIAT 10136). One hundred seeds of each of the two accessions were treated with each of the dosages at the Instituto de Asuntos Nucleares in Bogotá. Treated seed were pre-germinated and, when the primary root emerged, transplanted to flats in the glasshouse, beginning on 30 April 1985. Two weeks following transplanting to flats a count of surviving seedlings was made.

Seedling survival was highly correlated with gamma radiation dosage, with a 50% lethal dose (LD50) of 37.1 or 58.8 kRad for CIAT 15 or CIAT 10136, respectively (Figures 1 and 2).

A range of doses between 20 and 40 kRad was chosen for a larger project to induce and isolate a seedling mutant. A total of 11,500 M1 seedlings of accessions CIAT 15 and CIAT 2312 (two very early-flowering accessions) were transplanted to the field at Quilichao on 8 October. M2 seed will be bulk harvested from these and resulting M2 seedlings will be screened in the glasshouse for off-types identifiable within the first 4-6 weeks of growth.

Collection of native bees

A collection of native bees encountered on S. guianensis flowers has been made over the past year to document possible pollinator species present at CIAT-Quilichao and at CNIA-Carimagua. While the domestic honey bee (Apis mellifera) is a predominant species at both sites, at least during certain times of the year, a large number of wild species have also been obtained. Samples are being sent to the USDA, Beltsville for identification. Several species appear to be previously unidentified.

Nodulation of Centrosema spp. accessions

Twenty Centrosema spp. accessions, including 14 C. macrocarpum, 5 Centrosema sp., and 1 C. pubescens were direct seeded in prepared strips in native savanna at Carimagua in May, 1985, under two N fertilizer levels: 0 or 20 kg/ha every two weeks. None of the plots was inoculated with Rhizobium in order to determine effectiveness of nodulation with native strains. Observation of top growth indicates that only three of the accessions are nodulating normally: CIAT 5277 and CIAT 5278, both Centrosema sp. accessions native to the Colombian Llanos, and CIAT 5053, a C. pubescens accesion native to Venezuela. None of the C. macrocarpum accessions, nor the Brazilian Centrosema sp. accessions nodulated readily. Crosses are being planned on the basis of this information to study the inheritance of nodulation effectiveness in the Colombian Llanos. It may be feasible to transfer nodulation effectiveness from native Centrosema sp. accessions to the more productive

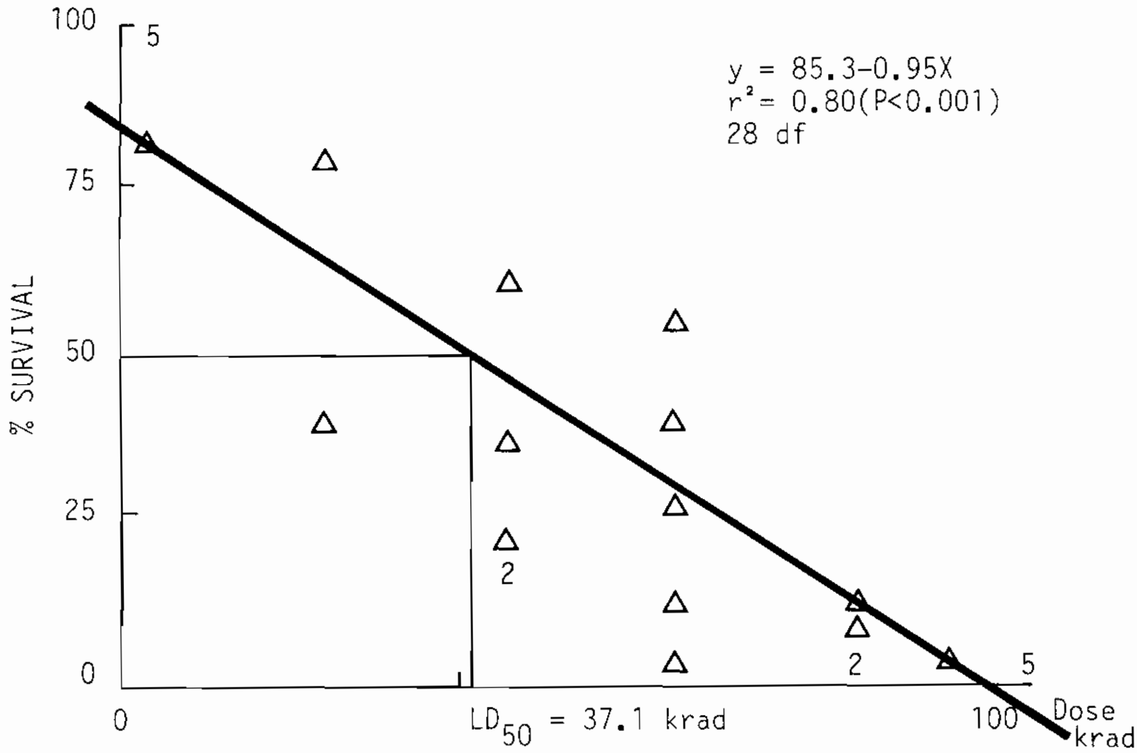


Figure 1. Percent survival vs. Gamma radiation dose, CIAT 0015

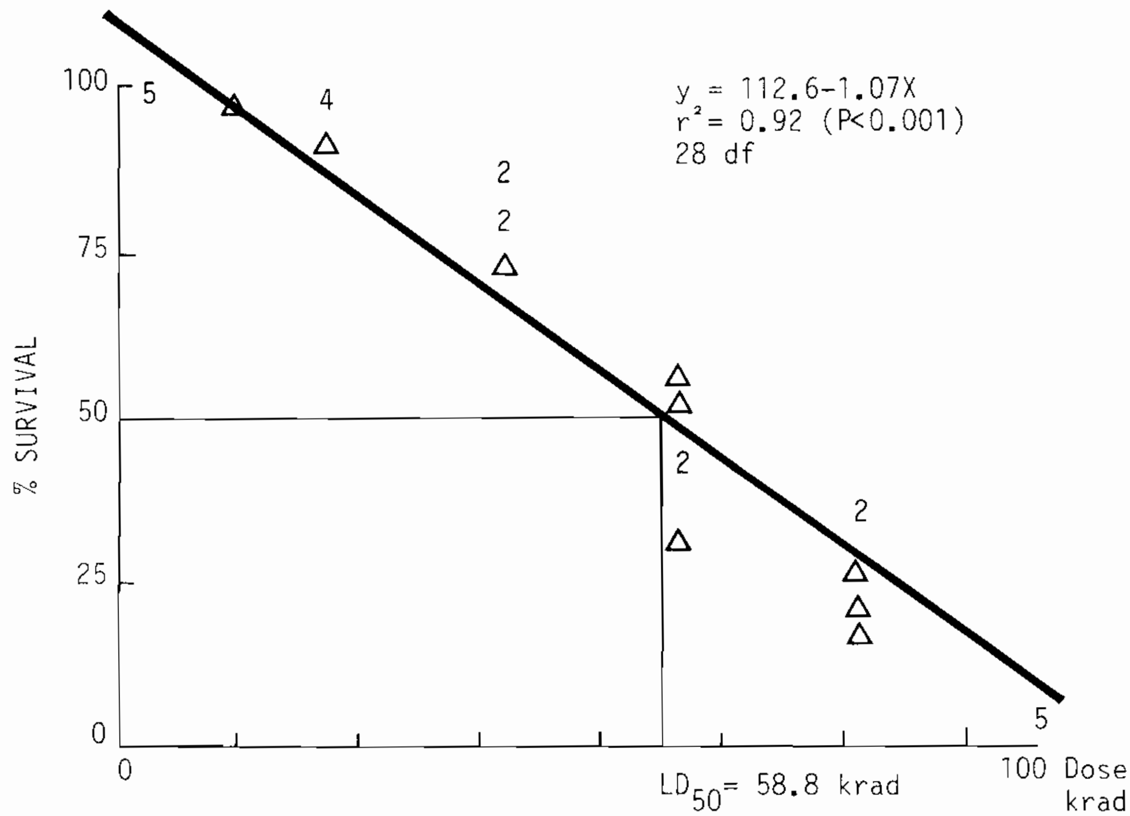


Figure 2. Percent survival vs. gamma radiation dose, CIAT 10136

C. macrocarpum types.

Selection for disease resistance within Zornia latifolia CIAT 728

Preliminary information obtained by the Plant Pathology Section (Annual Report, 1984) indicates that the Z. latifolia accession CIAT 728 is genetically heterogeneous for reaction to Sphaceloma scab. Results obtained with selections from a very small initial population suggest that a more extensive project ought to yield productive lines of Z. latifolia resistant to Sphaceloma as well as to other diseases.

A total of 621 seedlings were transplanted at 1 x 1 m on 8 May, 1985. Seedlings were from three sources: (1) CIAT 728, seed from the Seed Production Section (503 plants); (2) CIAT 728, seed from surviving plants in an 8-year-old grazing trial from which Z. latifolia had largely disappeared (68 plants); and (3) CIAT 9199, a Z. latifolia accessions previously identified as being Sphaceloma resistant (50 plants). Apparently contaminated seed of CIAT 728 yielded approximately 50% Z. glabra plants.

Plants are being evaluated for growth habit,and reaction to Sphaceloma scab, Drechslera leaf spot, anthracnose, Pseudocercospora, Rhizoctonia foliar blight, and sucking insects. Seed is being harvested on individual plants for progeny trials in 1986.

There was a wide range among individual plants within species and seed sources for Sphaceloma scab and anthracnose scores in early October (Figures 3 and 4). Sphaceloma scab was much less severe in CIAT 9199 than in CIAT 728. However, approximately one-half the CIAT 728 individuals showed no Sphaceloma symptoms indicating an opportunity to select more resistant lines within this accession. Approximately one-quarter of the CIAT 728 plants showed no symptoms of anthracnose.

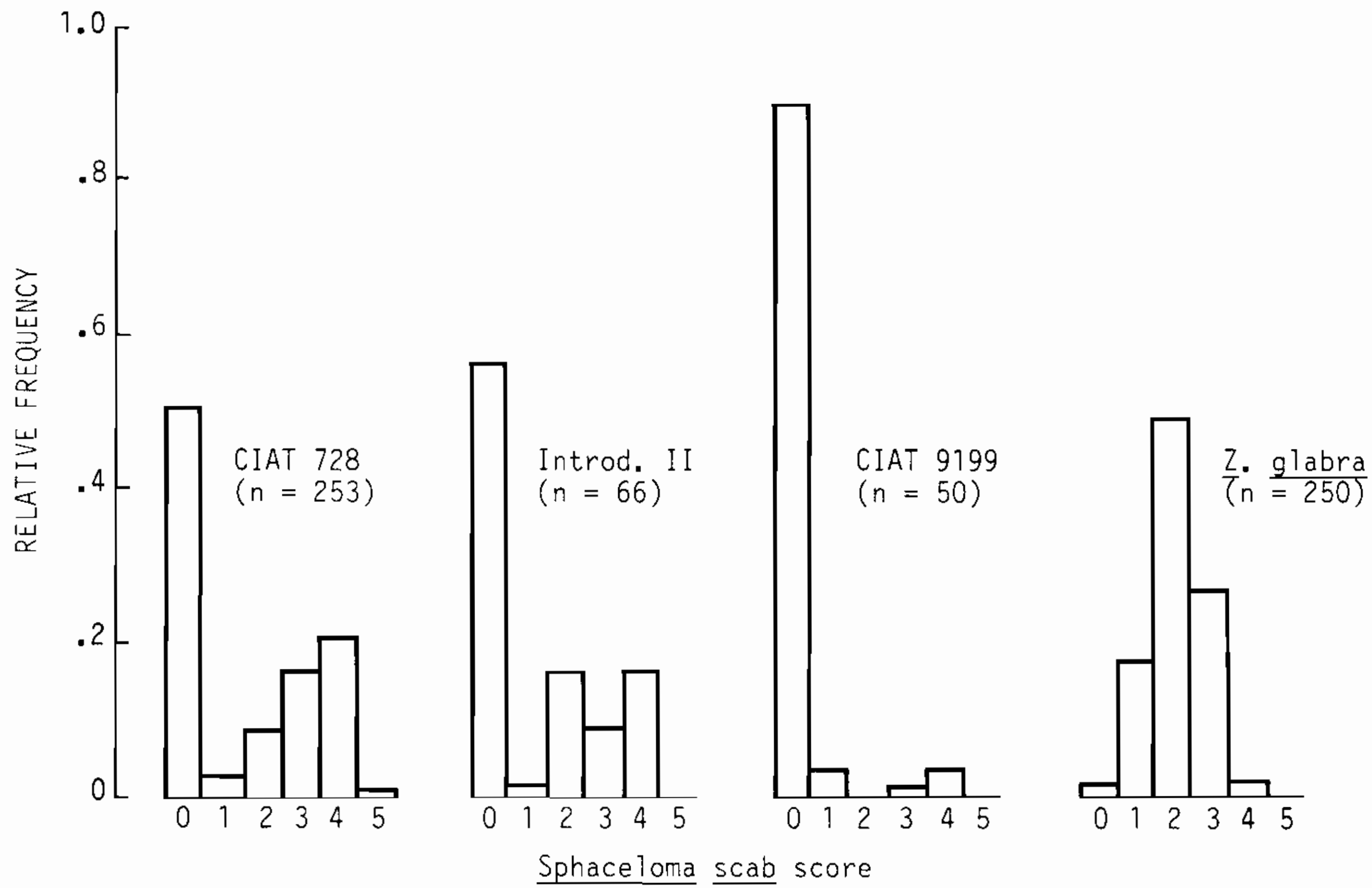


Figure 3. Relative frequency of *Sphaceloma scab* scores (0 = no disease; 5 = dead plant) on individual plants of four *Zornia* spp. populations.

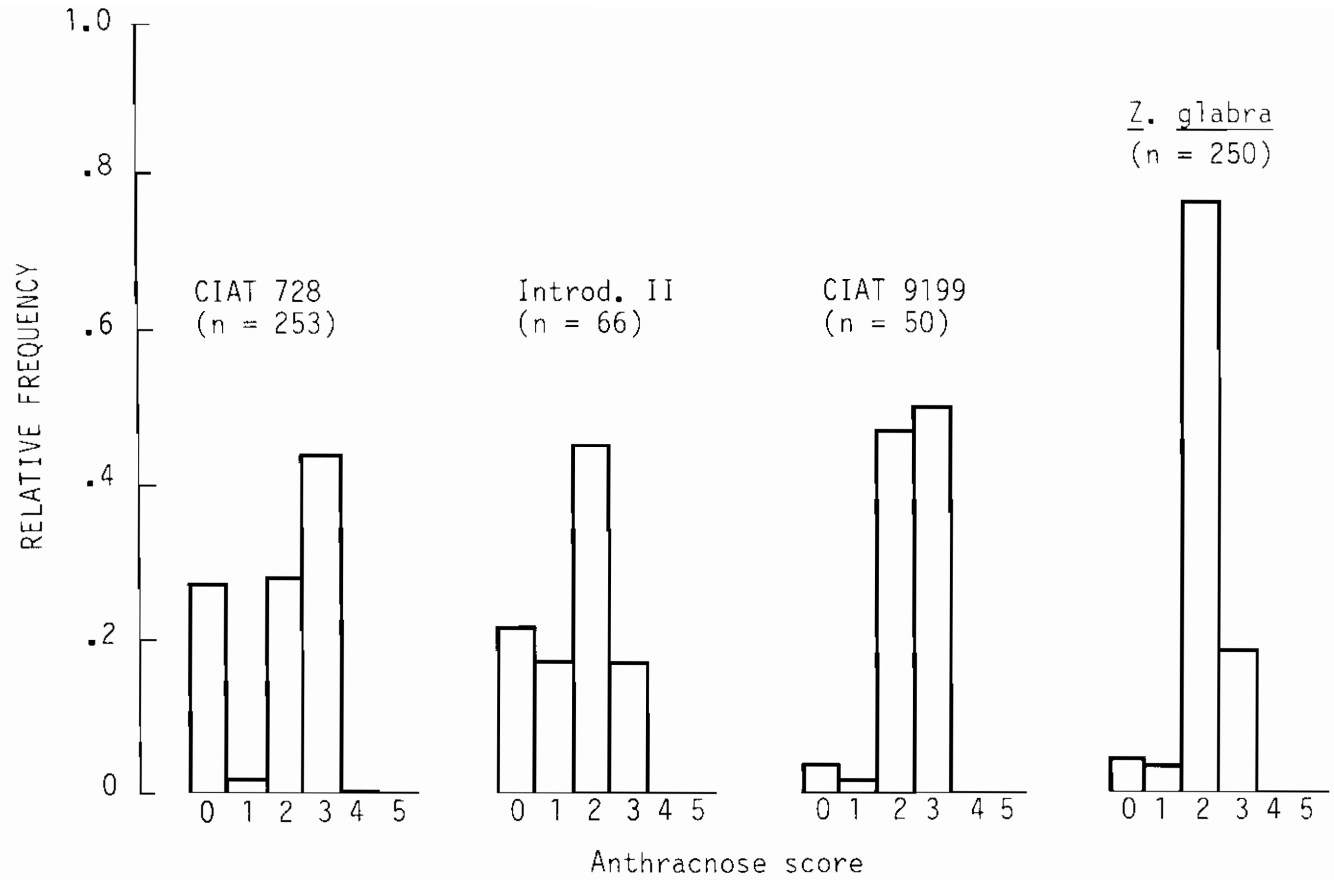


Figure 4. Relative frequency of anthracnose scores (0 = no disease; 5 = dead plant) on individual plants of four *Zornia* spp. populations.

Biotechnology

As stated in the document "CIAT in the 1980s Revisited", the Biotechnology Research Unit (BRU) will deal primarily with those new technologies that can significantly increase the efficiency of plant improvement methods or help resolve problems that escape solutions through traditional procedures. While emphasis is on applied research, the Unit also assumes responsibility for selected research with high potential pay-off in terms of technology development. In the development of these activities, close interaction with CIAT commodity programs and Units especially with the breeders, will be established. On the other hand, the Unit will seek complementarity with advanced institutes and national program scientists through special research projects.

In 1985, the major activity in the Unit involved research in cell and tissue culture for clonal propagation and for the generation of useful variability. This activity included work carried out at CIAT and at collaborating institutions abroad. Work at CIAT continued to develop tissue culture applications with CIAT crops. Research was initiated abroad to tackle potentially useful areas that require higher specialization at this stage.

TROPICAL PASTURES

Tissue Culture Regeneration of *Stylosanthes* spp.

In the last few years, methodologies for plant regeneration of *S. guianensis*, *S. capitata* and *S. macrocephala* accessions from leaf and epicotyl-derived callus and cell suspensions have been developed at CIAT. This year, the techniques for consistent regeneration of *S. guianensis*, var. *pauciflora* (CIAT 2243) and var. *guianensis* (CIAT 136) have been standardized. Thus, 4-8 mg/l BAP and 0.5 mg/l NAA were found optimal for callus induction from leaf segments, and 0.05 mg/l BAP, 0.01 mg/l NAA and 0.05 mg/l GA for organogenesis. Regenerated shoots could be easily rooted in a simpler salt-medium and transferred to pots and to the field readily.

Phenotypic stability of regenerated plants.- In collaboration with the Breeding Section of the TPP, an experiment was set up to determine the extent of variability in tissue culture regenerated (*S. guianensis*, CIAT 2243, Bandeirante) plants.

Two types of explants were obtained, (a) leaf segments (1 x 1 cm) from plants (R_0 plants) grown in the greenhouse; (b) portions of hypocotil (0.5 x 0.5 cm) from germinated seed (R_0 plants), and cultured in a single callus induction medium. Sixty petri plates (5 x 1 cm) containing 3 explants each, were used per explant type. One third of the calluses were transferred to a medium for regeneration (S_0) and the remaining was subcultured in callus medium. After one month, half of the calluses were removed for regeneration (S_1) holding the remaining in a fresh callus medium; on the second month, half of the calluses were transferred for regeneration (S_2). A total of 96 regenerated plants (R_1 plants) were potted and grown to maturity in the glasshouse.

At a later date another set of 44 R_1 plants were regenerated from sub-cultures S_3 and S_4 of CIAT 2243. Along with this, 31 plants regenerated from leaf-derived callus and 36 plants from gamma-irradiated suspension cultures of CIAT 136 were also potted for evaluation.

Preliminary evaluations of the 96 R_1,CIAT 2243,plants comprised: root-tip chromosome counts, morphology, seed production and seed size; the reaction to inoculation with Colletotrichum gloeosporioides strains was also studied.

The first striking finding was that 25% of the regenerated plants have doubled their chromosome complement from 20 (2X) to 40 (4X) chromosomes; there was no difference in the percentage of chromosome doubling between the two explant types, but there was a tendency for increasing doubling frequency with sub-culturing (Table 1). Some of the most obvious morphological changes observed were associated with the increase in ploidy, e.g. taller plants but with fewer stems, as well as wider flower buds and more pubescence of 4X than 2X somaclones and control plants (Table 2 and Figs. 1 and 2). Seed production is an important agronomic parameter in Stylosanthes. Most 2X and all 4X somaclones produced (on two month harvest basis) less than 400 seeds per plant; a few 2X somaclones yielded up to 800 seeds per plant as compared to an average of 300 seeds per control plant. The 4X clones had, however, larger seeds than the 2X clones and the control plants (Tables 3 and 4). Thus, 4X plants yielded lower number but larger seeds, while some diploid somaclones had higher seed production than the control plants. In addition, there were some 2X and 4X somaclones which did not set seed at all in spite of having flower buds; this may be a case of sterility.

Since anthracnose is a very important problem in Stylosanthes, a total of 95 2X and 4X somaclones and the six control plants were inoculated in the greenhouse with three strains of Colletotrichum gloeosporioides with the collaboration of the TPP's Pathology Section. Table 5 shows the

Table 1. Number of diploid and tetraploid S. guianensis CIAT 2243, plants (R_1) regenerated from callus cultures, with three sub-cultures and two explant types.

Explant type	Sub-culture	No. plants			4X
		Total	2X	4X	%
Leaf	S_0	42	35	7	
	S_1	16	8	8	
	S_2	3	2	1	
	Subtotal	61	45	16	26
Hypocotil	S_0	27	22	5	
	S_1	3	3	0	
	S_2	5	2	3	
	Subtotal	35	27	8	23
	TOTAL:	96	72	24	25

CONTROL: 6 plants = 20 chromosomes (2X).

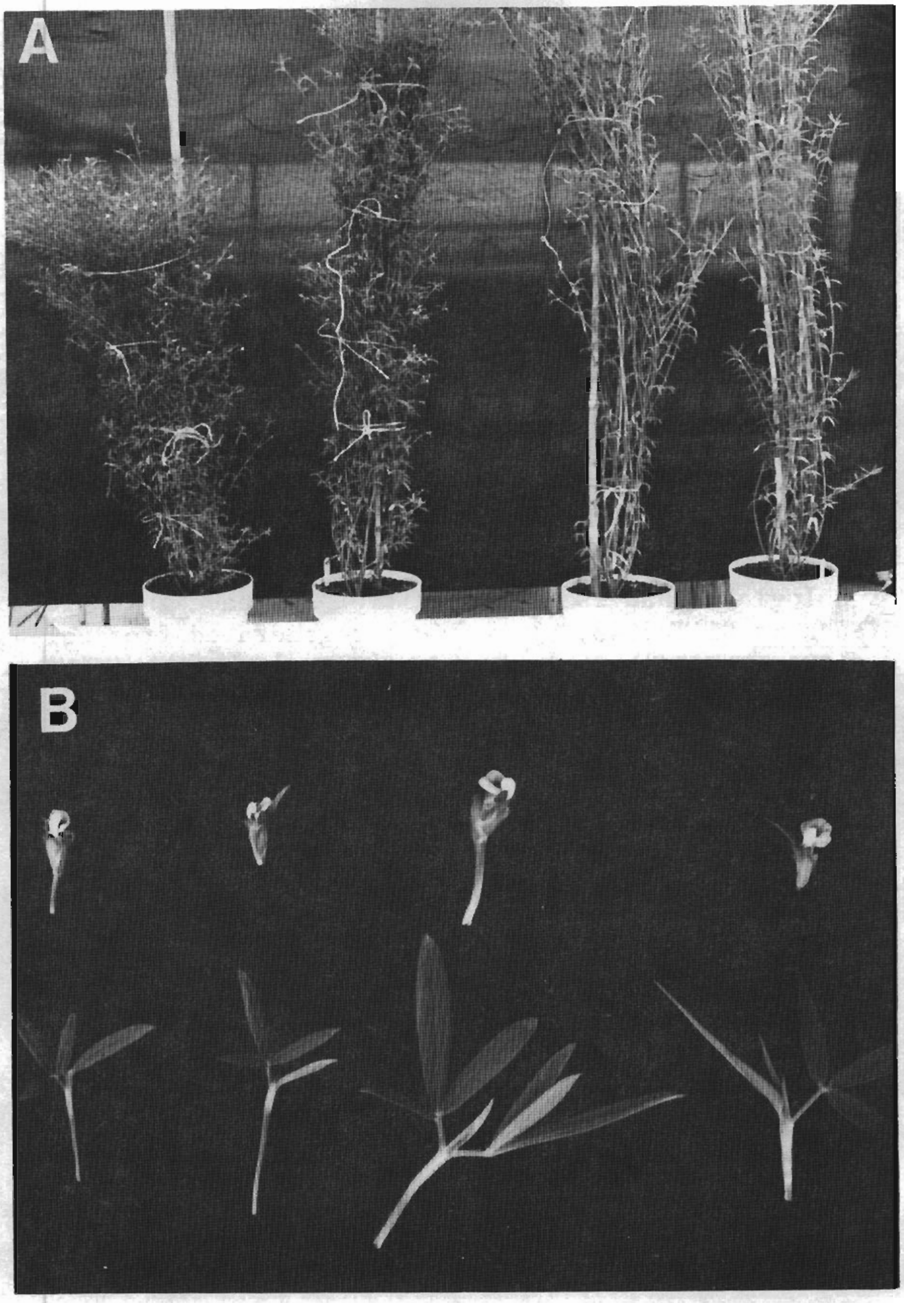


Figure 1 . Variability in morphology and ploidy of S. guianensis, CIAT 2243, (R_1) plants regenerated from callus cultures.

A. Left to right: Control plant grown from seed. Three somaclones: diploid (2X = 20), tetraploid (4X = 40) and diploid, respectively.

B. Flower buds and apical leaves of plants as at A. From left to right: control; three somaclones: diploid, tetraploid and diploid, respectively.

Figure 2. Morphological changes as a result of increase in ploidy of S. guianensis CIAT 2243, plants (R_1) regenerated from callus cultures.

A. Flower morphology, left: from control plant; right: from tetraploid somaclone.

B. Leaf morphology, left: from control plant; right: from tetraploid somaclone.

C. Chromosome root-tip squashes, left: from control plant (2X = 20); right: from tetraploid somaclone (4X = 40).

Note profuse pubescence and deep green color of tetraploid sepals (A) and leaves (B).

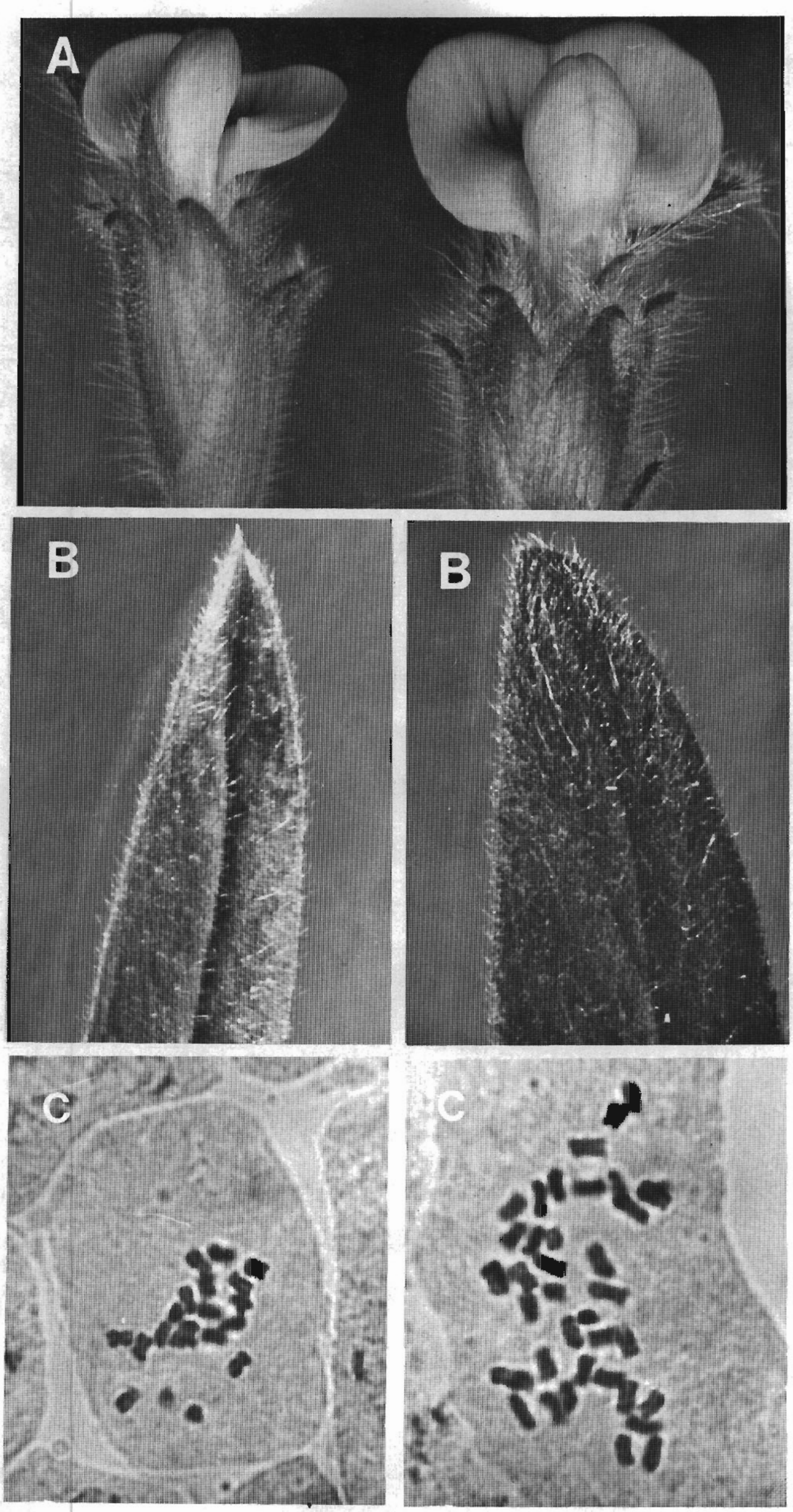


Figure 2

Table 2. Morphology of diploid and tetraploid S. guianensis, CIAT 2243, plants (R_1) regenerated from callus cultures in relation to control plants.

No. Plants		Plant heigth	Internode lenght	No. shoots per stand	Ratio width/length		
					Leaf	Flower	Pubescence*
Control	6	1.2m	3.6cm	23	0.20	0.50	2
2X	72	1.3	4.5	23	0.13	0.46	3
4X	24	1.5	5.5	17	0.21	0.60	4

Evaluation in 5 month old plants.
* 1 = abscent; 2 = low; 3 = moderate; 4 = high; 5 = very high.

Table 3. Seed production* of S. guianensis CIAT 2243, plants (R_1) regenerated from callus cultures and distribution by ploidy.

Range seed No. per plant**	Total No. plants	No. Plants	
		2X	4X
1 - 100	23	16	7
101 - 200	16	14	2
201 - 300	13	10	3
301 - 400	6	6	0
401 - 500	-	-	-
501 - 600	1	1	0
601 - 700	2	2	0
701 - 800	2	2	0
Total	63	51	12

* Seed harvested for two months.
CONTROL X = 300 seeds.

** To December 1985, 9 diploid and 4 tetraploid somaclones did not set seeds in spite of having formed flower buds.

evaluation of anthracnose symptomatology. Diploid somaclones and the control plants showed in general a similar reaction distribution to the less (A), medium (B) and highest (C) pathogenic strains of the fungus. However, there was a clear tendency to a higher tolerance reaction of the tetraploid somaclones inoculated with the three fungal extracts than diploids and controls.

Since these are the first observations ever made on phenotypic stability of Stylosanthes regenerated plants, it was worth to make a preliminary recording of them. The changes observed in the R_1 plants may or may not pass to the sexual offspring (R_2 plants); on the other hand, selfing of R_1 plants to produce the R_2 generation may untap changes not seen in the R_1 plants, especially if these are recessive. Collaborative work with the TPP's Breeding Section is underway to look at the sexual generation

Table 4. Size of seeds* of S. guianensis CIAT 2243, plants (R_1) regenerated from callus cultures and distribution by ploidy.

Weight of 100 seeds (gr)	Total No. plants	No. plants	
		2X	4X
0.24 - 0.26	46	46	0
0.29 - 0.32	6	0	0

* Seed harvested for two months.
CONTROL: 0.26 gr.

of the R_1 plants in the field.

Stylosanthes Protoplast and Cell Suspension Cultures

The successful agricultural application of various somatic cell genetic technologies depends, to a considerable extent, on having an efficient technique for plant regeneration from isolated protoplasts. Until now, reports on legume protoplast cultures have been scarce and no reported results on leaf mesophyll protoplast culture of Stylosanthes are available. Leaf mesophyll tissue can provide a genetically uniform protoplast source with good morphogenetic potential. Work in this area was carried out this year at CIAT.

Cell suspension cultures.- Callus cultures were readily obtained from leaf explants. Pipetable suspension cultures could be produced from friable callus in one week (Fig.3A). When plated on agar-solidified medium and cultured in light, colonies produced multiple green shoots and these gave rise to plants (Fig. 3B).

Protoplast isolation and culture. Protoplasts were isolated using pectolyase Y23, Onozula R_{10} cellulase, and hemicellulase for digesting cell walls of mesophyll cells (Fig. 4A) and suspension cells (Fig. 4B), respectively. Protoplast yields were good when young, fully expanded, leaves of two month old seedlings were used and when the cell cultures used as protoplast source were sub-cultured twice weekly. After washing, protoplasts were cultured in a more complex medium in which 30-50% of them regenerated cell walls within 1-3 days. First cell division were observed after 2-3 days of culture (Fig.4C). At 12 days after isolation, 4- % of the cultured protoplasts divided; and serial

Table 5. Reaction of S. guianensis CIAT 2243, plants (R_1) generated from callus cultures, to inoculation with extracts of three strains of Colletotrichum gloeosporioides in the greenhouse, and distribution by ploidy.

Reaction scale*	(A) 46B - CPAC			(B) 2315			(C) 1808 CPAC		
	Control	2X	4X	Control	2X	4X	Control	2X	4X
A	0	1	8	0	0	0	0	0	0
B	4	25	11	1	0	3	0	1	3
C	2	36	3	4	19	17	1	6	8
D	0	11	0	1	54	2	5	66	11
E	0	0	0	0	0	0	0	0	0

* A = no damage; B = small lesions; C = medium size lesion; D = large lesions and defoliation; E = tissue death.
** Total No. plants inoculated: Control = 6, 2X = 73; 4X = 22.
(Inoculation and evaluations carried out with the collaboration of the TPP's Pathology Section).

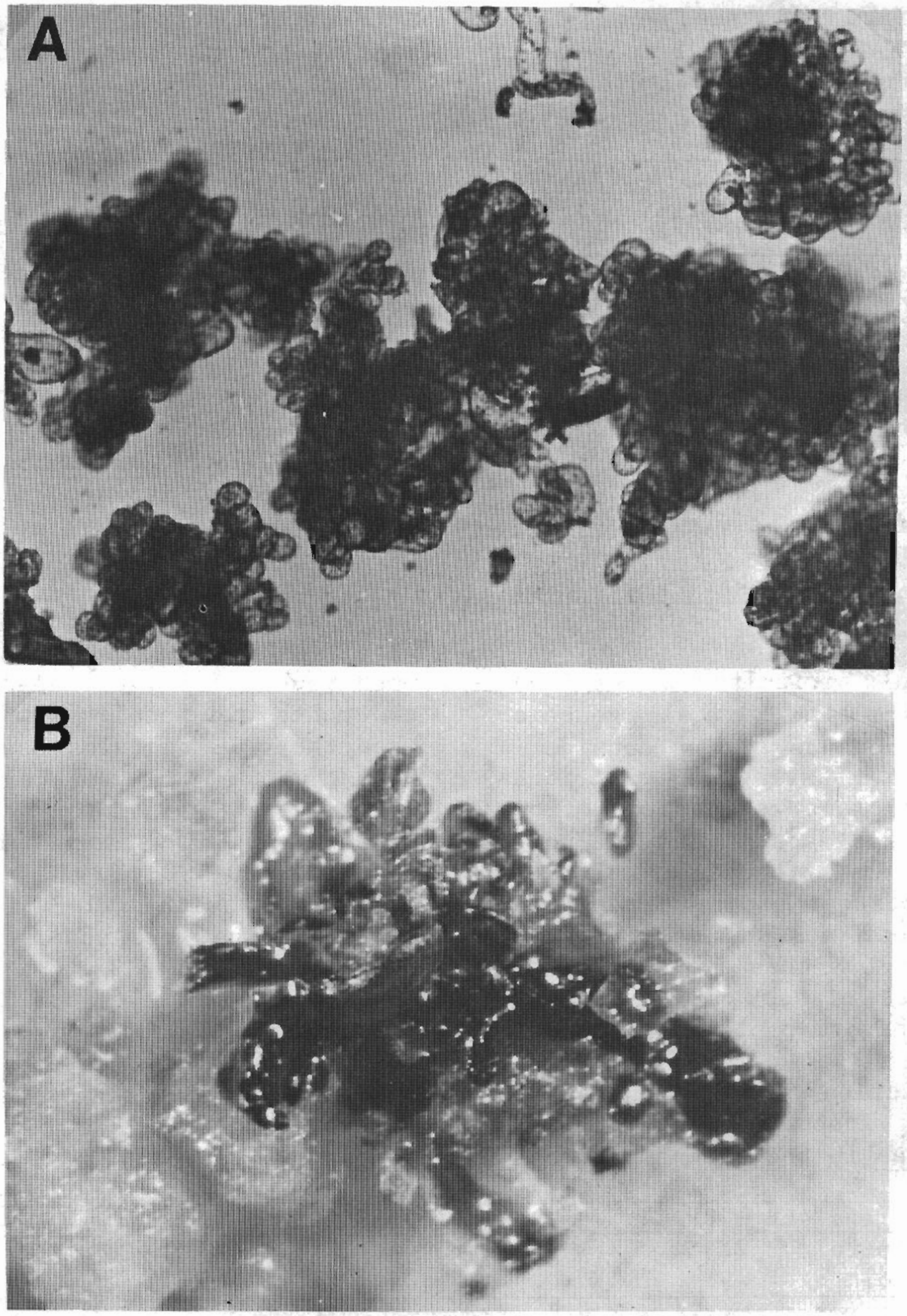


Figure 3. Regeneration of Stylosanthes guianensis, plants from cell suspensions.

A. Cell suspension culture showing pipetable cell clusters (CIAT 2243).

B. Shoot differentiation from cell suspension colonies (CIAT 136).

Figure 4. Protoplast isolation, cell colony formation and plant regeneration in Stylosanthes guianensis.

A. Protoplast isolated from leaf mesphyll tissue of CIAT 2243.
B. Protoplasts isolated from cell suspension cultures of CIAT 2243.
C. First cell division in an isolated mesophyll protoplast.
D. Cell colony formation from mesophyll protoplasts.
E. Shoot differentiation in protoplast-derived callus of CIAT 136.
F. Potted plants regenerated from mesophyll protoplasts of CIAT 2243.

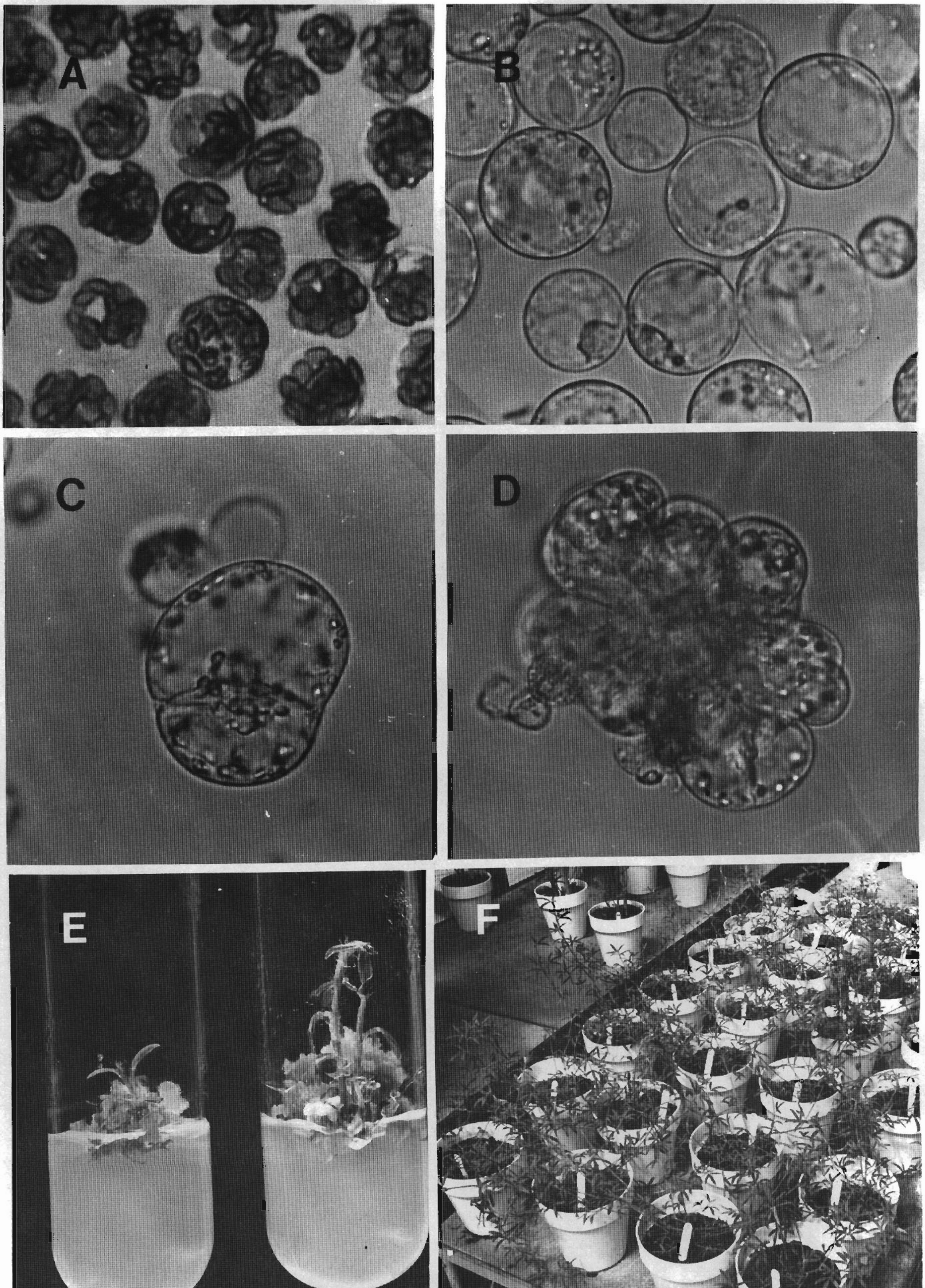

A
B
C
D
E
F

Table 6. Effect of three gelling agents on plating efficiencies of protoplast derived minicolonies of Stylosanthes guianensis*.

Gelling agents	0.8% agar	0.5% agarose	0.15% gelrite
Plating efficiency	2.5	31.5	55.2

* CIAT 2243 and CIAT 136.

addition of fresh medium was found necessary for subsequent divisions and rapid growth of protoplast-derived colonies (Fig.4D). When sub-cultured on solid medium, the colonies produced yellow (CIAT 2243) or yellow and light green (CIAT 136) calluses. The efficiency of callus formation from protoplast-derived colonies was greatly influenced by the gelling agent used to solidify the medium. Agar (Difco bacto agar) was always inferior than agarose (Sigma, Type VII) or gelrite (Kelco). Gelrite gave similar or better results than agarose (Table 6).

Plant regeneration from protoplast cultures.- Protoplast-derived calluses were transferred to regeneration medium. Green patches appeared in this medium after 2-4 weeks of culture, which then developed into shoots (Fig. 4E). Numerous shoots appeared on 40-50% of the calluses (Table 7). Regeneration frequency was lower when protoplasts were derived from old cell suspensions. Nearly 90% of the regenerated shoots formed roots when transferred to a rooting medium. Rooted plantlets were potted and transferred to the glasshouse for further growth (Fig. 4F).

The probability of getting variants from protoplast derived callus cultures may be high. A total of 31 CIAT 2243 and 66 CIAT 136 plants regenerated from protoplasts have been transplanted to the glasshouse for seed production and subsequent evaluation in the field.

Interspecific hybridization of S. guianensis with other Stylosanthes species (S. capitata, S. macrocephala) may be desirable but is prevented by incompatibility reactions. Somatic hybridization can help bypass the incompatibility barriers. Recently, shoot initiation of protoplast-derived callus has been obtained with S. capitata at CIAT.

Response of Stylosanthes Cell Suspensions to Pathogenic Stress

Agronomic characteristics can be affected by several different mechanisms, some acting at the cellular level, and others only at the whole plant level. If a trait is expressed by the whole plant as well as by cultured cells, it is possible to develop selection systems for alterations of these cellular functions. On the other hand, if a toxin produced by a microbial pathogen is the primary responsible for disease symptoms, the challenge of large cell populations with the pathotoxin, or with less purified culture extracts, can be used to select cells expressing tolerance to such substance.

In collaboration with the TPP's Pathology Section, culture filtrates of Colletotrichum gloeosporioides were mixed with cell culture medium in different concentrations, and cell suspensions of S. guianensis were plated on petri dishes using these toxic media. Such filtrate of C. gloeosporioides has been used in the TPP for inoculation of seedlings and found to be toxic. Necrosis and death of the cultured cells indicated the toxicity of the fungal culture filtrate at higher concentrations (Fig. 5). Decrease of plating efficiencies of cell suspensions of four S. guianensis genotypes were compared (Fig. 6). The less sensitive was

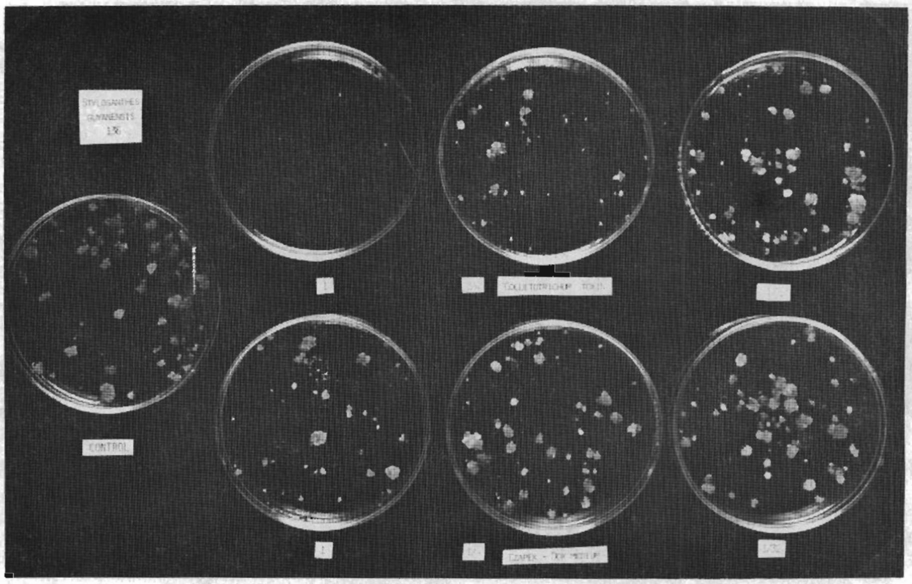


Figure 5 . Effect of <u>Colletotrichum gloeosporioides</u> culture filtrate mixed in various concentrations with cell culture medium on the plating efficiency of <u>S</u>. <u>guianensis</u> cell suspensions.

<u>Top</u>: Gradual increase in plating efficiency with dilution of fungal filtrate (left to right).

<u>Botton</u>: Almost no effect of medium used for fungal culture without the toxin.

<u>Control</u>: Standard medium for cell colony formation.

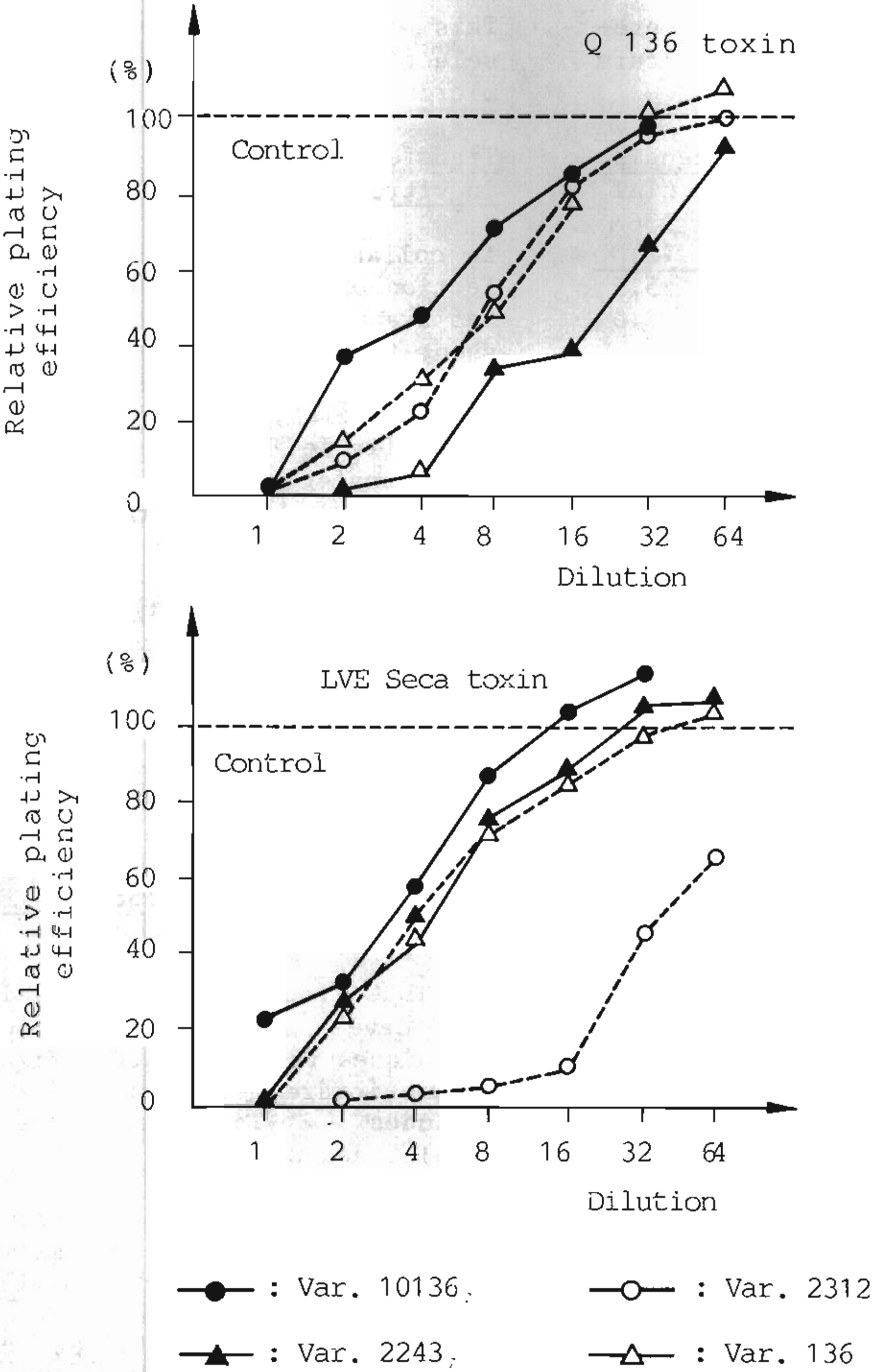


Figure 6 . Comparison of relative plating efficiencies of <u>Stylosanthes guianensis</u> cell suspensions in the presence of <u>Colletotrichum</u> toxins.

Table 7. Efficiencies in two representative leaf protoplast culture experiments.

	S. guianensis CIAT 2243 (%)	S. guianensis CIAT 136 (%)
Division frequency	6.4	5.5
Colony formation	1.5	2.5
Growth of minicolonies on solid medium	42.0	39.0
Shoot formation on p-calluses	32.0	46.0
No.of shoots on regenerating colonies	3.7	5.6
Rooting of regenerated shoots	84.0	80.0
Frequency of plant regeneration from protoplasts	0.17	0.39

CIAT 10136, a genotype which is regarded as one of the most anthracnose-resistant ones. Of the other, CIAT 2243 was the most sensitive to Q 136 toxin, and CIAT 2312 was very sensitive to LVE-Seca toxin.

These experiments show that anthracnose tolerance and sensitivity of the various S. guianensis genotypes is expressed to a certain extent at the cellular level. Work is necessary to further refine these correlations using fine cell suspension cultures with the view to use in vitro selection of anthracnose tolerant cells.

This approach could be rewarding for selecting sexual recombinants from F_1 microscopore cells.

Transfer of Tropical Grass Germplasm in vitro

In collaboration with the TPP, a collection of grass germplasm from Africa was transferred to CIAT in the form of shoot-tip cultures in test tubes. A total of 431 accessions comprising 35 grass species, from five African countries (Table 8) were put into culture for transfer. The in vitro work was carried out in ILCA for the material procedent from Rwanda, Burundi and Ethiopia; at the Quarantine Station of Maguga, Kenya and at the University of Zimbabwe. Per accession, 4-5 test tubes were prepared and brought to CIAT for further growth in the lab (Fig. 7A). Potted plantlets are being placed in the glasshouse (Fig. 7C) for phytosanitary control before multiplication for the field.

Genotype Identification by Electrophoresis

The IDRC funded project also includes the development of electrophoretic techniques for the characterization of legume forage germplasm. The project includes Stylosanthes, Desmodium, Zornia, and Centrosema.

Research at the University of Manitoba, Winnipeg, Canada, has recently began with Stylosanthes accessions. Figure 8 shows discrimination of six S. capitata accessions based on polyacrylamide gel separation of seed proteins.

Table 8. Number of species and accessions of tropical pasture grass germplasm introduced to CIAT using *in vitro* techniques.

Genera	No. of Species	No. accessions per country of procedence				
		Ethiopia	Kenya	Burundi Rwanda	Zimbabwe	Total per genera
Andropogon	2	-	-	-	17	17
Bothriochloa	2	-	1	-	1	2
Brachiaria	14	133	101	56	95	385
Eragrostis	2	-	1	-	1	2
Hyparrhenia	2	-	1	-	1	2
Ischaemum	1	-	-	-	1	1
Panicum	4	-	4	-	3	7
Paspalum	3	-	2	-	1	3
Setaria	3	-	1	-	2	3
Stereochlaena	1	-	-	-	1	1
Urochloa	1	-	-	-	1	1
Unknown grasses		-	1	-	6	7
Total/country	35	133	112	56	130	
TOTAL:						431

Figure /. Transfer of tropical pasture grass species germplasm from Africa to CIAT using <u>in vitro</u> te niques.

<u>A</u>. Collection of 432 grass accessions in culture tubes under controlled growth at CIAT.

<u>B</u>. Three-week old culture ready for potting.

<u>C</u>. Potted plants of <u>Brachiaria</u> spp. growing under phytosanitary conditions in the glasshouse.

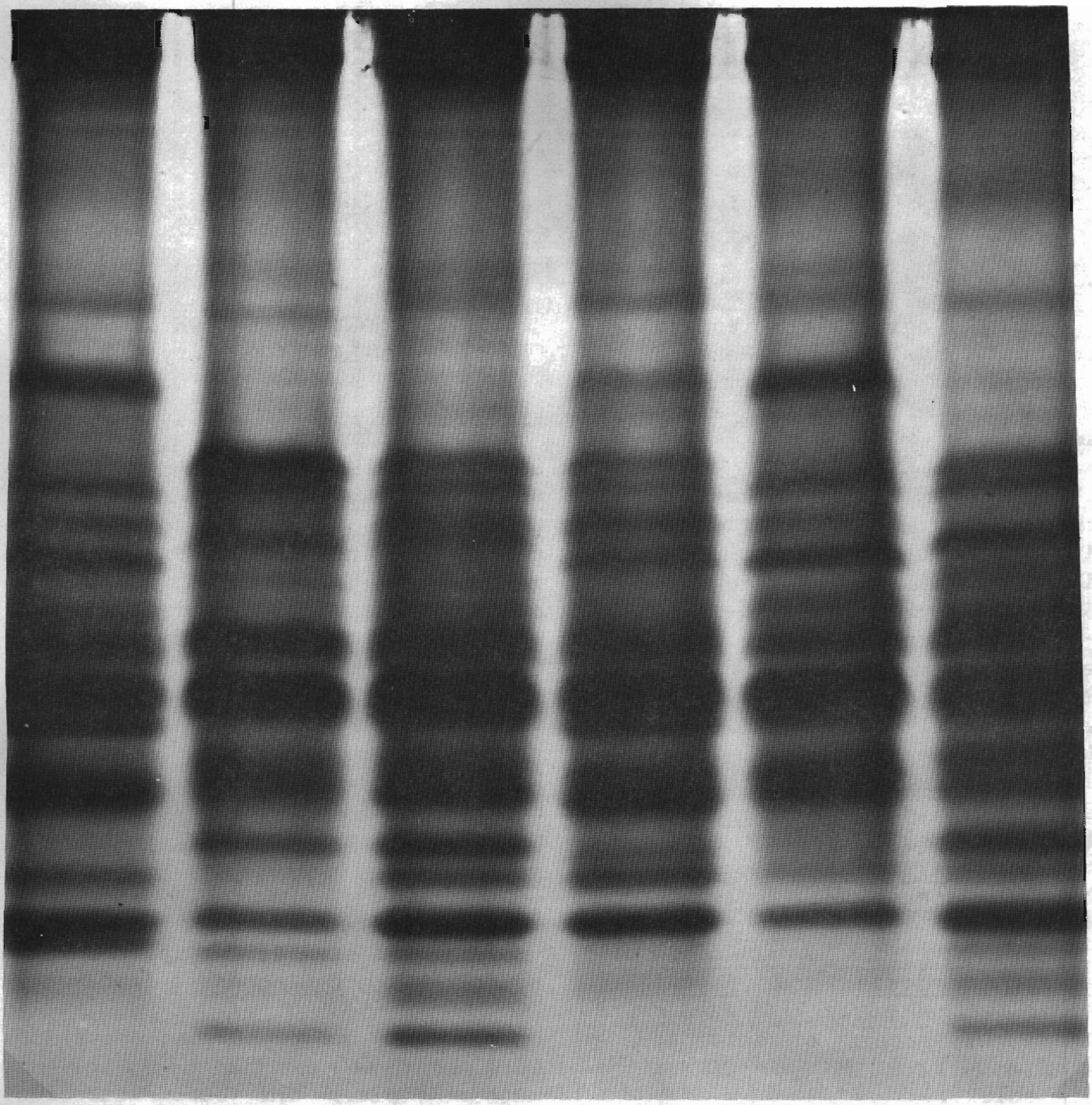


Figure 8. Electropherogram showing discrimination of *S. capitata* genotypes by electrophoretic separation of seed proteins in polyacrylamide gel. Note the differences in banding pattern between lanes. Each lane represents a *S. capitata* accession.

Agronomy (Carimagua)

During 1985, agronomic research conducted at the Carimagua Research Center continued the search for superior germplasm for the llanos ecosystem.

Since 1977, a total of 4300 accessions have been tested at Carimagua. Following preliminary evaluation, 136 accessions representing 15 leguminous and 7 gramineous species have been tested in small-scale grazing trials. Of eleven small-scale grazing experiments in progress in 1984/85, six have recently been concluded. Evaluation of the grass and legume accessions established in 1981/82 was concluded after the usual 3-year evaluation period. Selected accessions of Brachiaria dictyoneura, B. humidicola, Andropogon gayanus, Centrosema sp. nov., Centrosema macrocarpum, Desmodium ovalifolium, Stylosanthes capitata and Arachis pintoi have reached advanced stages of evaluation. A summary of introductions evaluated from 1981 to 1985 is shown in Table 1.

Table 1. Forage introduction in Carimagua, 1981-1985

Year of Introduction	No. of accessions Legumes	Grasses
1981-82	1109	70
1982-83	900	200
1983-84	106	305
1984-85	83	102
Total:	2198	677
Grand total: (Legumes + Grasses)	2875	

PRELIMINARY EVALUATION OF GRASS GERMPLASM (Category II)

Panicum maximum

Since late 1983, some 492 accessions of P. maximum have been evaluated at Carimagua. This comprehensive collection includes accessions from institutions in Australia, Kenya, Cuba and Brazil. Also included are many accessions from ORSTOM in the Ivory Coast. The collection contains growth forms of each of the three botanical varieties varying from the stoloniferous creeping Guinea grass, cv. Embu, to the "giant" and "intermediate" Guinea grass types of P. maximum var. typica.

Considerable inter- and intra-varietal differences were recorded in yield; leaf: stem ratio; resistance to spittle-bug and Cercospora leaf spot.

One hundred and twenty-one accessions were compared on the basis of dry matter yield. The best accessions were medium growth forms of P. maximum and two accessions CIAT 6172 and 6177 were selected. These are similar in agro-morphological characteristics to the control CIAT 673 which is in the second highest yielding group. Another accession selected for further evaluation is CIAT 6179 a leafy, short growth form of P. maximum var. coloratum or "purple top" Guinea grass (Table 2). In this experiment, the "giant" Guinea grass types were less tolerant of defoliation and were more susceptible to Cercospora leaf spot and spittle-bug attacks than the above

Table 2. Dry matter yields (g/plant)* of 121 accessions of Panicum maximum in Carimagua, Llanos Orientales of Colombia (WDHS).

Cluster	CIAT Accessions	Range (g/plant)	Mean (g/plant)
8	6299-699-693 6553	(201-252)	213
7	698-6172-6123 6177-673-685 6588	(150-181)	163
6	6175-6563-6121 690-696-6126-692 688-689-6215-6551 6118-6160-6485 6511-6181-6601-6516 6179-6590-6095-6531	(110-142)	123
4	6124-6560-6125-6142 6094-6645	(86- 89)	95
5	6487-6540-6171-6533 695-694-6490-6143- 6532-6113-6513-6122 6525-6104-6092-6000 6151-6168-6608-6664- 6163-666	(74- 85)	79
2	6144-6643-6554-6507 6141-6114-6500-6567 6526-6127-6488-6589 6162-6045-6534-6539 6165-6486-6115-6117 6108-6607	(55- 71)	63
1	6609-6653-6106-6642 6763-6059-6109-6489 6119-6182-6180-6107 6575-6001-6105-6612 6541-697-6103-622 6110-6598	(37- 51)	40
3	6183-6584-6101-6112 6097-6637-6100-6002 6600-6602-6454-6461 6478-6472-6476-6063	(1- 25)	13

* Harvest 6.

selections. Accessions of P. maximum var. trichoglume, or "green panic", performed poorly being affected by leaf diseases and showing severe symptoms of nutrient deficiency.

Selected accessions of Guinea grass were established with various Centrosema species in the flooded savanna experimental area for further evaluation.

Brachiaria spp.

Agronomic assessment of accessions of Brachiaria spp. introduced prior to 1983 has been concluded. Several species were found to be well-adapted to the Llanos ecosystem. Four accessions of B. humidicola have shown promise in small plot clipping experiments and under grazing. In addition to field resistance to spittle-bug, they are productive, aggressive, mat-forming grasses. Accessions CIAT 679, 6705 and 6709 are aggressive, strongly stoloniferous types. They are moderately palatable in the advanced stages of growth; seed production is low. CIAT 6369 is a distinct form of B. humidicola. It is a broad-leafed, mat-forming accession and is highly palatable. All four of the above accessions are compatible with Arachis pintoi and formed productive grass-legume associations. Brachiaria humidicola CIAT 679 was introduced into the Llanos in 1976 and became a rather popular species due to its tolerance of poor soils and heavy grazing. CIAT 679 is also compatible with the legume D. ovalifolium.

In chronological order the introduction of B. dictyoneura followed that of B. decumbens cv. Basilisk and B. humidicola. The latter two species were introduced in the early and mid-seventies, respectively. B. dictyoneura CIAT 6133 was first established in nursery plots at Carimagua in the 1979/80 season.

One accession of B. dictyoneura has shown good adaptation to the Llanos ecosystem. Morphologically, B. dictyoneura resembles B. humidicola, however, the former is rhizomatous and stoloniferous whereas the latter is strongly stoloniferous. Seed yields and caryopsis content of the florets in B. dictyoneura CIAT 6133 were significantly higher than in B. humidicola CIAT 679.

B. dictyoneura (CIAT 6133) was also more resistant to spittlebug than B. brizantha (CIAT 644), B. humidicola (CIAT 679) or B. ruziziensis (CIAT 6291). B. dictyoneura (CIAT 6133) recovered faster after a spittlebug attack than the other three species in the experiment.

A set of 19 new accessions of B. brizantha, B. decumbens, B. ruziziensis, B. nigropedata and B. humidicola were included in a small-plot clipping experiment in 1983. The six top-yielding accessions were those of B. brizantha and showed high resistance to spittlebug (Table 3).

Andropogon gayanus

Selection of a uniformly late-flowering cultivar of A. gayanus continued during 1985.

Late-flowering genotypes were selected by recurrent selection from two successive generations reproduced by sexual seed. The progenies of the best late-flowering genotypes were compounded in Synthetic II. A final selection for desirable plant types was carried out under grazing.

PRELIMINARY EVALUATION OF LEGUME GERMPLASM (Category II)

Stylosanthes capitata

Evaluation of hybrid derivatives of diallel crosses of two accessions with different flowering dates was started in the 1984. One particular hybrid, CIAT 1097 x 1019 yielded F_7's of

Table 3. Yield of 19 accessions of *Brachiaria* spp. in Carimagua, Llanos Orientales (WDHS) of Colombia.

Cluster	Accessions	Means of 5 harvests kg/ha
4	B.b.** 6674, 6385	5747.58
3	B.b. 6681, 6675, 6387, 6384 B.d. 6702	4842.08
2	B.n. 6386, B.d. 6698, 6392	3857.60
1	B.b. 6735, B.d. 6421, 6701 B.r. 6713, 6677, 6692, 6778 B.h. 6678, B.b. 6738	2663.24

** Abbreviation: B.b. = *Brachiaria brizantha*
B.d. = *B. decumbens*
B.r. = *B. ruziziensis*
B.n. = *B. nigropedata*
B.h. = *B. humidicola*

considerable promise. A few selected lines exhibited a long season of growth and retained green leaf well into the dry season. They were outstanding in DM yield and seed production late in the season. Several hybrids produced significantly more dry matter than cv. "Capica" and its component accessions (Fig. 1).

Stylosanthes viscosa

This species of *Stylosanthes* is well adapted to Oxisols and several accessions were only slighty affected by anthracnose. The majority of accessions showed symptoms of little-leaf-mycoplasma, but in many cases plants recovered well. A small plot experiment containing 117 accessions was concluded. The highest yielding accessions which also exhibited good resistance to pests and diseases over the 3 years were grouped in clusters 12 and 14 (Table 4).

Centrosema spp.

It has been clearly demonstrated in several experiments that *Centrosema* contains species and forms adapted to acid, infertile soils. Some species were also found to be highly resistant to pests and diseases. Accessions of *Centrosema macrocarpum* and *Centrosema* sp. nov. resisted severe drought conditions during the 1985 dry season, and showed rapid recovery during the opening rains.

Agronomic assessment of *Centrosema* spp. was initiated in 1978 with a series of clipping experiments. A wide range of species and forms were tested. Twenty-one accessions were evaluated in two follow-up experiments. Trailing, non-stoloniferous forms of *C. macrocarpum* produced high dry-matter yields. Accessions were found to be highly palatable and resistant to the major foliage

Table 4. Dry matter (g/plant) of 117 accessions of *Stylosanthes viscosa* (means of 4 harvests).

Cluster	CIAT Accessions	Range (g/plant)	Mean (g/plant)
12	2889-1524-1011-1544	(160-185)	170.3
14	1051-1094-2158-2644 2888	(132-182)	165.8
13	2887-2900-0009	(140-151)	144.3
10	1348-1538-1541-1785 2072-2880	(125-147)	129-8
9	2368-2592-1405-1070 2038-2374	(110-129)	125.2
7	2498-1547-1988-1787 2372-1900-2516-2430 1703-1353-1439	(89-121)	102.2
3	2123-2171-2569-2418 2117-2425-2729-2045	(56-124)	99.5
4	2528-2872-2110-0008 2486-2621-1697-2868 2524-2582-1436-2073 1695-2891-1716-1783	(78-110)	93.6
1	1960A-0012-0013-1074-2901	(16-203)	80.7
5	2651-2881-2384-2882 1790-2525-2871-2462 2443-2629-2761-2867 24721764-2380-1638- 24552501-2609-1430 2628-2367-1807	(47-106)	71.0
	1904-2120-2230-1346 2635-1435-2126	(54- 78)	70.2
6	2101-2573-2879-2460 2878-2562-1216	(29- 54)	43.6
8	2294-2371-2466-2479 2773-2786-2883-2885 2886	(25- 51)	37.7
11	2295-2685-1954-0010 2475-1527-2060	(3- 32)	24.3

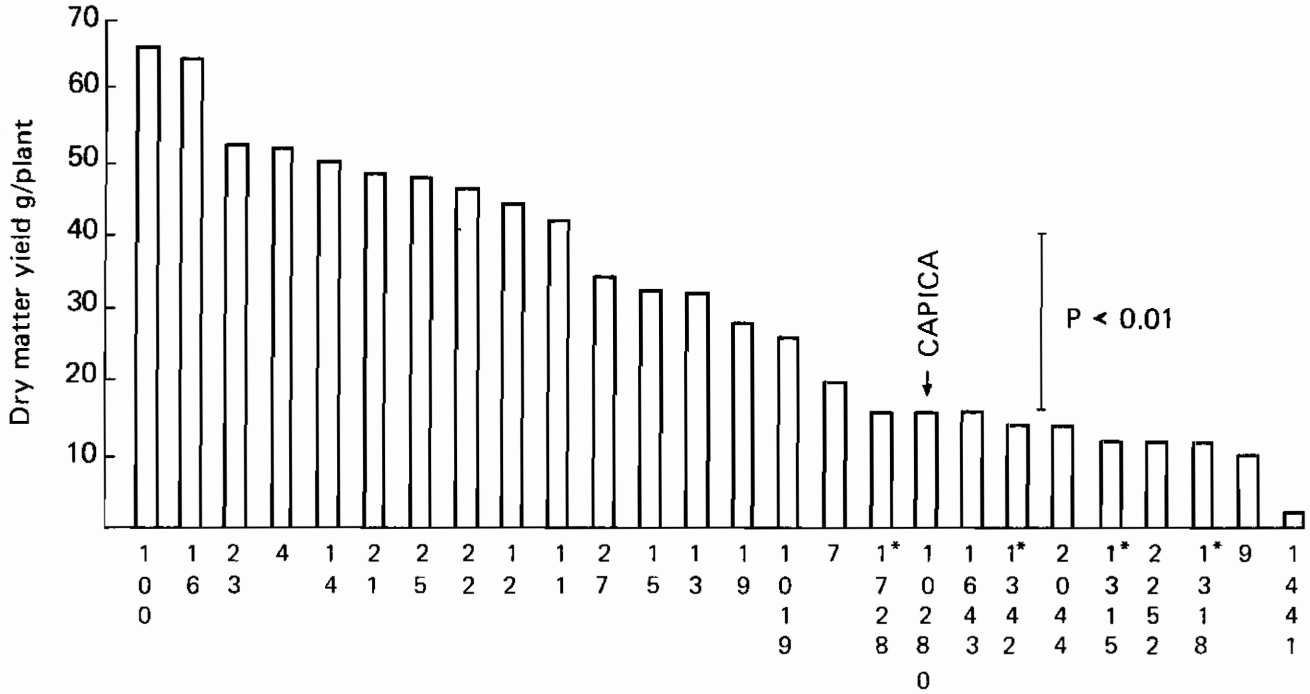


Figure 1. **Dry matter yields (g/plant) of *S. capitata* hybrids vs. Capica, Its components and accessions (One to three digits denote hybrids; * = components of cv. Capica, others are accessions).**

diseases affecting most other species of the genus. Under a cutting regime over three growing seasons, three stoloniferous forms of Centrosema sp. nov. and one stoloniferous accession of C. macrocarpum CIAT 5396 produced more dry matter than seven other accessions (Table 5).

In another clipping trial, two Centrosema sp. nov. were the highest yielding accessions. The strongly stoloniferous accession C. macrocarpum CIAT 5452 also proved to be highly tolerant of close defoliation. In these experiments, six of the highest yielding accessions were stoloniferous forms of Centrosema sp. nov. (CIAT 5277, 5278, 5568, 5610, an accession of unknown origin and C. macrocarpum CIAT 5396). It was concluded that stoloniferous forms of the new species of Centrosema and C. macrocarpum resisted defoliation better than the non-stoloniferous forms.

In follow-up experiments stoloniferous root development was also studied. Rooted stolon density of 100 accessions showed a very wide range of variation from 0 to $197/m^2$. Accessions in the highest clusters 1, 2 and 3 included C. macrocarpum CIAT 5452, 5418, 5735 and Centrosema sp. nov. (Table 6). These accessions were selected for further evaluation.

The stoloniferous accession Centrosema sp. nov. CIAT 5277, exhibited several desirable forage traits - resistance to heavy grazing, to drought and compatibility with Andropogon gayanus. In compari- son to other accessions of this species, CIAT 5277 showed better seedling vigour and resistance to Rhizoctonia.

Pueraria spp.

Seventy-six accessions of Pueraria, with commercial Kudzu (CIAT (9900) as the control, were evaluated over a two-year period which included one of the most severe dry seasons on record (Table 7). Further selection work should be concentrated on accessions in clusters 6 and 1 which contain some high yielding accessions with good drought tolerance. Accessions CIAT

Table 5. Mean yields of dry matter (kg/ha/yr) of accessions of *Centrosema* spp.

Species/accession No.	Yield (kg/ha/yr)
a) Experiment I	
C. macrocarpum CIAT 5396	12667 a*
Centrosema sp. nov. CIAT 5568	11072 a
Centrosema sp. nov. CIAT 5278	10726 a
Centrosema sp. nov. origin unknown	9613 a
C. macrocarpum CIAT 5743	6623 b
C. macrocarpum CIAT 5674	6356 bc
C. macrocarpum CIAT 5744	5684 bcd
C. macrocarpum CIAT 5392	5201 bcd
C. pubescens x *C. macrocarpum* F_2 (67-1)	4536 bcd
C. pubescens x *C. macrocarpum* F_2 (67-16)	3217 cd
C. pubescens x *C. macrocarpum* F_2 (6-19)	3124 d
b) Experiment II	
Centrosema sp. nov. CIAT 5610	11921 a*
Centrosema sp. nov. CIAT 5277	11218 ab
C. brasilianum CIAT 5234	10962 ab
C. brasilianum CIAT 5487	10712 ab
C. macrocarpum CIAT 5452	10360 ab
C. brasilianum CIAT 5712	9452 ab
C. macrocarpum CIAT 5434	9293 ab
C. macrocarpum CIAT 5065 (control)	9183 ab
Centrosema sp. nov. CIAT 5568	8822 ab
Centrosema sp. nov. CIAT 5118	8132 b

* Values within experiments followed by a different letter are significantly different ($P < 0.05$) by Duncan's Multiple Range Test.

Table 6. Rooted stolon density (No/m^2) of <u>Centrosema</u> spp. under a seasonal cutting regime.

Cluster	Accessions	Mean No. of Rooted Stolon Sites/m^2	Range
1	5450-5275	183	(197 - 170)
2	5904-5733-5735 5395-5736-5460 5452-5713-5645	126	(147 - 114)
3	5418-5798-5888 5739-5864-5278 5732-5620-5730	95	(106 - 83)
4	5956-15050-5396 5674-5944-5901 5740-15177-5954 5887-5947-15083 5946-5941-5953 5949	57	(77 - 39)
5	15115-XX-5952 5685-5948-15084 5743-15120-5741 15086-5731-5065 15048-15077-5434 5737-15094-5942 15114-15053-15072 15063-5960	24	(33 - 18)
6	5940-66-19-5673 15085-15057-5951 5959-5234-5955 5392-5639-(67-1) 5629-5487-15093 15047-15038-15032 5738-5277-15059 5633-5744-15041 5961-561015061 5118-5568 15056-15095-5734 15091-15071-15122 5411-15123-15040 5712-15087-15090 15089	7	(16 - 0)

17392 and 17283 were among the moderately productive types but these two showed strong stoloniferous root development (Table 7)..

Desmodium heterophyllum

Although D. heterophyllum cv. Johnstone (CIAT 349) was the highest yielding accession in the small plot evaluation trial all accessions performed poorly during the dry season and most of them died by the end of the long dry season in 1985. Some regeneration from self-sown seed occurred early in the wet season. It is now clear that the species is not adapted to the high savannas. On the other hand, cv. Johnstone performed very well in a trial in the flooded savanna.

Desmodium ovalifolium

Sixty-seven accessions, including introductions from Southeast Asia and previously introduced selected material, were established in small plots in 1983. Considerable intra-specific variation was recorded in DM yield and disease resistance. A large number of accessions were infected by stem-gall nematode, false-rust, and little-leaf-mycoplasma. Dry matter production of diseased accessions was severely reduced. Cluster analysis grouped the accessions into 7 clusters with a yield range from 600 to 3480 kg/ha (Table 8). High-yielding, disease-resistant accessions were found in clusters 7, 6, 2 and 5 with accessions CIAT 13089, 3794 and 3776 showing promise.

EVALUATION OF FORAGES IN THE FLOODED SAVANNA (Category II)

Seasonally flooded areas constitute a high percentage of the savannas and represent an important source of feed during the dry season. Grass species adapted to seasonal flooding and impeded drainage are available for a range of situations, however, there is a paucity of information on the tolerance of tropical pasture legumes to such situations.

A series of experiments was established between December 1983 and May 1984 near the Carimagua lake. Analysis of the soil of this "bajo" showed high organic matter content and, in general better soil fertility conditions relative to those of the high savanna. The primary aim of these trials was to evaluate species tolerance to a range of soil moisture conditions i.e. the flooded section of the trial area was under water for some months while the higher terraces of the flood plain normally have saturated soil conditions only during the wet season. The experimental area included the well-drained slopes as well. This section was sown to a range of Centrosema spp. with accessions of Panicum maximum. The saturated soils were sown to Desmodium ovalifolium, Arachis pintoi, D. heterophyllum, Centrosema pubescens and C. vexillatum.

D. ovalifolium CIAT 3794, 3793, 3788 and Arachis pintoi performed best under saturated soil conditions. Centrosema spp. produced high yields in association with Panicum maximum on the well-drained higher terraces and Desmodium heterophyllum has exhibited excellent growth and dry matter production in the periodically flooded section, but suffered badly from drought on the well-drained soils (Table 9). Of the grasses a range of Brachiaria brizantha accessions showed excellent performance during the dry season (Table 10).

In the seasonally flooded area 217 accessions of Aeschynomene, representing 15 species of this genus, were established. This experiment was decimated during the first year mainly by the fungal diseases, anthracnose and leaf blotch (Polythrincium). Stemborer also caused severe damage and the tall, woody types were

Table 7. Dry matter yields of Pueraria spp. (means of 4 harvests).

Cluster	Accession No.	Range (DM kg/ha)	Mean (DM kg/ha)
6	17277-9019	(3490-3530)	3510.5
1	9900-736-744 17322-17290-17304 17286-8047-9188 9279-4600-8042 17585-17279-17321 17306-17288-17466	(2780-3111)	2892.3
4	17293-17311-815 17433-17296-17301 17314-17325-17307 17305-17299-7979 17291-17303-17278 17308-17310-17324 8834-9020-9261 17289-17390-17319 17283-17766-17292 17328-7978-17323	(2296-2802)	2516.4
3	8171-8352-17285 17287-17316-17775 17318-17309-17315 829-17302-9021 17300-17327	(2246-2435)	2350.8
2	17281-17295-17298 17326-17284-17282 17317-17294-17313 17297-17765-17320	(1819-2215)	1999.0
5	7182-7724	(1054-1720)	1476.6

intolerant of defoliation by cutting.

Some 18 months after establishment only 14 accessions (6.4% of the total) were still alive. The majority (62% of the resistant accessions were *A. brasiliana*. The other promising accessions belonged to *A. histrix*, *A. americana* and *A. falcata*.

ADVANCED TESTING UNDER GRAZING (Category III)

Centrosema spp. - *Andropogon gayanus*

C. macrocarpum CIAT 5065 was established with *Andropogon gayanus* Carimagua 1 as the companion grass in a small-scale grazing trial during the wet season of 1982. The experimental area of 2 ha was subdivided to provide duplicate sets of low (1.5 an/ha) and high (3 an/ha) stocking rates. In

Table 8. Dry matter yields (kg/ha) of accessions of <u>Desmodium</u> <u>ovalifolium</u> (final harvest).

Cluster	CIAT Accessions	Range (kg/ha)	MEAN
7	13132	(3480)	3480
6	13089-13118-13088 13106	(2880-2535)	2960
2	3776-13092-13127 13111-13096-13098 13306	(2210-1940)	2078
5	13128A-13136-13128 3794-13131-13135 13105-13100	(1866-1530)	1697
1	13083-13133-13095 13097-13093-3780 3666-13091-13126 13085-13113-13116 13087-13086-13121 13107-13115-13124	(1405-1156)	1276
4	13094-13104-13102 13123-13114-13129 13101-13119-13137 13082-13103	(1106- 870)	979
3	13081-13139-13030 3793-13117-13099 13112-13125-13130 13090-13122-13109 13110-13108-13120 13140-13138	(803- 180)	614

each main plot, four accessions (<u>C.</u> <u>macrocarpum</u> 5062 and 5065, <u>C.</u> <u>brasilianum</u> CIAT 5234, and <u>Centrosema</u> sp. nov. CIAT 5568) were also established as sub-plots. These treatments were arranged in a 4 x 4 latin square design, and were established in both replications of the two stocking rate treatments. The experiment was rotationally grazed by 3 Criollo x Zebu cattle on a one week in and three-weeks out system.

Higher yields and legume contents were recorded in the <u>C.</u> <u>macrocarpum</u> CIAT 5065 - <u>A.</u> <u>gayanus</u> pasture grazed at 1.5 an/ha than in the high stocking rate treatment of 3 an/ha (Fig. 2). In the high stocking rate treatment overall presentation yields were significantly higher for the stoloniferous <u>Centrosema</u> sp. nov. CIAT 5568 than those of the <u>C.</u> <u>macrocarpum</u> accessions. All three accessions outyielded <u>C.</u> <u>brasilianum</u>. In the low stocking rate treatment, there was no

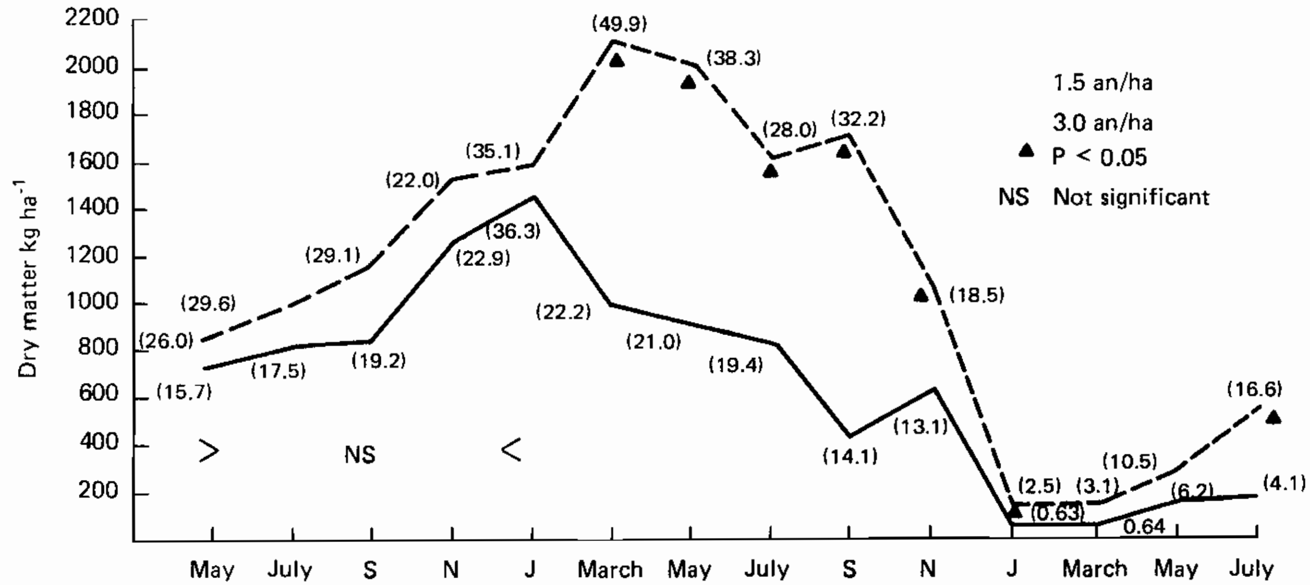


Figura 2. Dry matter yield (kg/ha) of *Centrosema macrocarpum* CIAT 5065 in association with *Andropogon gayanus* Carimagua 1 grazed at two stocking rates. (Values in parenthesis represent legume content (w %) of the mixture).

Table 9. Herbage dry matter production in various legume species in the flooded savanna during the dry season.

Legumes	Acces. No.	DM kg/ha
I. DESMODIUM		
D.ovalifolium	3793	3894.8a*
D.ovalifolium	3788	3177.5ab
D.ovalifolium	3794	3090.0ab
D.heterophyllum	349	2253.0 b
II. CENTROSEMA		
C.macrocarpum	5793	2480.0a
C.pubescens	Porvenir	2144.6a
Centrosema sp.nov.	5568	1902.0ab
Centrosema sp.nov.	5277	1814.7ab
C.macrocarpum	5418	572.3 b
C.vexillatum	5484	559.0 b
III.ARACHIS, PUERARIA		
A. pintoi	17434	3898.8a
P. phaseoloides	7182	2930.0a

* Means followed by a different letter are significantly ($P < 0.05$) different

difference between Centrosema sp. nov. and the two accessions of C. macrocarpum. Again all three accessions produced higher yields than C. brasilianum (Figs. 3, 4).

Centrosema macrocarpum and spp. - Andropogon gayanus

Eleven accessions of C. macrocarpum, two Centrosema sp. nov. and C. pubescens were established in May 1984. A. gayanus was sown as the companion grass and 3 stocking rate treatments were superimposed on the 14 treatment combinations. Presentation yields, stoloniferous root development were measured in this experiment during the first semester under grazing. C. pubescens, Porvenir type, C. macrocarpum CIAT 5452, 5620 and 5735 produced the highest number of rooted stolons per unit area (Table 11).

Stylosanthes guianensis var. pauciflora - Andropogon gayanus I

Two accessions of this legume, CIAT 10136 and 2031 were established for grazing evaluation. In each grass-legume association 3 stocking rate treatments were superimposed namely 1.0 an/ha, 1.7 an/ha and 2.4 an/ha.

Table 10. Herbage produced in species of Brachiaria in the flooded savanna during the dry season.

Species	CIAT No.	Total (2 harvest, Febr.and May) t/ha
B. brizantha cv. Marandu	6294	14.30 a*
B. brizantha	6413	13.75 a
B. brizantha	6387	13.51 a
B. brizantha	6684	12.20 a
B. brizantha	6674	12.03 a
B. brizantha	6385	11.60 a
B. decumbens	6392	11.52 a
B. humidicola	6396	11.20 a
B. humidicola	6705	7.01 b
B. humidicola	6709	5.98 b
B. dictyoneura	6133	5.94 b
B. humidicola	679	5.34 b

* Means followed by a different letter are significantly ($P < 0.05$) different.

CIAT 2031 was poorly accepted by grazing animals in the year of establishment and the associated A. gayanus was heavily grazed in all 3 stocking rate treatments. Legume contents were 69%, 60% and 52% for

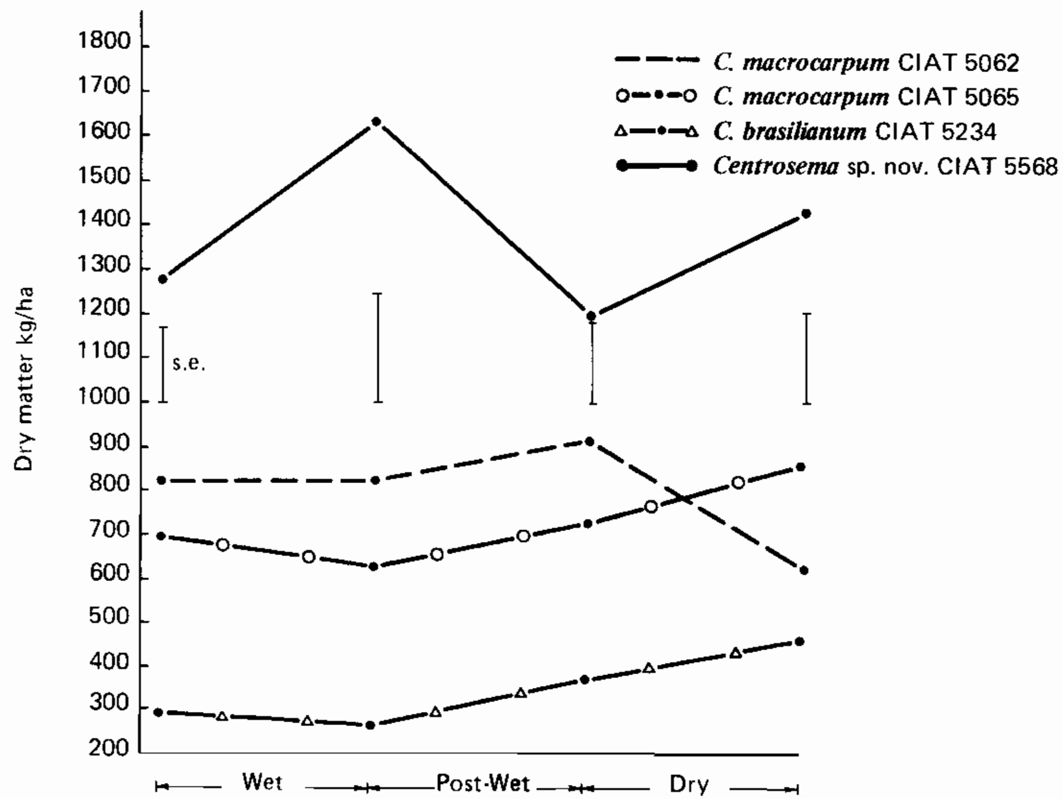


Figure 3. Presentation yields of *Centrosema* spp. in association with *Andropogon gayanus* cv. Carimagua 1. Stocking rate 3 an/ha.

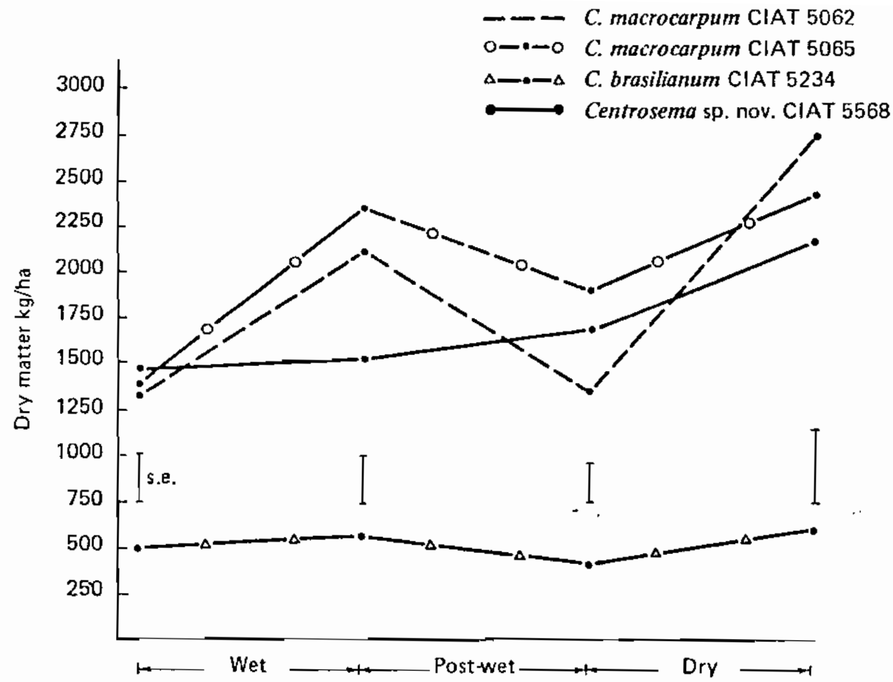


Figure 4. Presentation yields of Centrosema spp. in association with Andropogon gayanus cv. Carimagua 1. Stocking rate 1.5 an/ha.

high, medium and low stocking rate treatments, respectively.

Three accessions of S. guianensis ver. pauciflora and a mixture of four accessions were included as sub-plots in this experiment. Accessions CIAT 10136 and 2362 significantly out-yielded CIAT 2031 and the mixed lines of this legume (Table 12). Legume yield and percentage composition were not affectes significantly by stocking rate.

Stylosanthes guianensis var.pauciflora CIAT 10136 - Andropogon gayanus II

This experiment was established in 1983 and was grazed at 3 stocking rates e.g. 1.0, 1.7 and 2.4 an/ha. Legume dominance was recorded in the year of establishment followed by rapid decline of legume content in the 2nd and 3rd seasons. Treatments were grazed on a 1 week-in and 5 weeks-out schedule. Stocking rate effects were not significant and legume yields were very low in all three treatments ranging from 343 kg/ha/year at 2.4 an/ha to 492 kg/ha/year at 1.7 an/ha.

Desmodium canum - Brachiaria spp.

Several accessions of D. canum had been established in association with Brachiaria decumbens cv. Basilisk and A. gayanus cv. Carimagua 1. In these pilot experiments, D. canum persisted without maintenance fertilization for 8 years.

A small-scale grazing experiment was sown in July 1982 and comprised 2 accessions of D. ovalifolium (CIAT 350 and 3784) and one accession of D. canum CIAT 13032. Each was associated with a companion grass B. brizantha CIAT 664, CIAT 6370 or B. humidicola CIAT 6369. There were two replicates of the 9 treatment combinations arranged in a randomized block design. The experiment was grazed by 2 an/ha for five consecutive days in every six weeks during the dry season and for 5 days in every four weeks during the wet season. Presentation yields and botanical composition were determined on 23 harvest/grazing dates from March 1983 to March 1985. Dry matter yields and the initially high legume content of the mixtures containing D.

Table 11. Density of rooted stolon sites (mean No./m^2) of 14 Centrosema accessions grazed at 3 stocking rates in the second wet season after establishment.

Species	CIAT No.	Rooted stolon sites (No./m^2)
C. macrocarpum	5452	42.2 a
C. pubescens	El Porvenir	42.2 a
C. macrocarpum	5620 + 5735	41.3 a
C. macrocarpum	5744	39.8 a
C. macrocarpum	5434	36.4 ab
Centrosema sp.	5277	33.8 abc
C. macrocarpum	5645	33.6 abc
C. macrocarpum	5633 + 5713	33.1 abc
C. macrocarpum	5674	32.2 abc
C. macrocarpum	5065	31.8 abc
C. macrocarpum	5740	30.9 abc
Centrosema sp. nov.	5568	27.6 bcd
C. macrocarpum	5629	24.7 cd
C. macrocarpum	5887	17.1 d

* Means followed a different letter are significantly (P < 0.05) different.

Table 12. DM yields and percentage composition of accessions of S. guianensis var. pauciflora in association with A. gayanus.

CIAT Accession No.	DM yield (kg/ha/year)	Legume (%)
10136	6.887.7 a*	21.6 a
2362	6.301.7 a	16.0 b
2031	3.662.2 b	13.5 bc
Mixed lines	2.914.2 b	10.1 c

Stocking rate animal/ha	DM (kg/ha/year)	Legume (%)
2.4	4.119.4 a	14.9 a
1.7	5.080.3 a	17.5 a
1.0	5.866.5 a	14.0 a

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

ovalifolium declined rapidly due to stem-gall nematode. A final yield estimate was taken in March 1985 and legume contents of the six treatment combinations of D. ovalifolium were almost zero (Table 13).

A satisfactory legume content was maintained in each one of the three D. canum /Brachiaria spp. associations, and the legume demonstrated its ability to combine with these high yielding, mat-forming grass species. The highest yields of the legume were recorded in associations with the two B. brizantha accessions (Table 14).

Desmodium ovalifolium - Brachiaria spp

A small-scale grazing experiment was established in 1981 to evaluate 8 accessions of D. ovalifolium in association with 5 Brachiaria spp. The 40 treatment combinations were arranged with legumes in main plots and grasses in sub-plots. Grazing was started in the dry season in February 1982. Stocking rate was 1.7 an/ha during the four dry months and increased to 2.5 an/ha during the wet season. The experiment was concluded in April, 1985. Changes were recorded in the legume content of several associations due to the rapid decline of D. ovalifolium accessions susceptible to stem-gall nematode and Synchytrium (Fig.5).

Accessions CIAT 3793, 3794 and 3788 showed the best overall performance during the trial period. Accession CIAT 3793 maintained its contribution to the sward throughout the trial period. In associations containing CIAT 3794, an increase of legume content was recorded over time. Brachiaria humidicola produced the highest and B. dictyoneura the lowest presentation yields. This appeared to be due to selective grazing of this palatable and nutritious grass (Table 15).

Visually, the effect of the legume on the associated grass was very marked. The Brachiaria spp. associated with those accessions of D. ovalifolium that persisted were deep green in

Table 13. Legume content (W%) of nine pasture associations of Desmodium/Brachiaria spp. prior to the 1st. and 23rd. grazing period.

Association	Legume content (W%) 1st.	Prior to grazing period	23rd.
D. ovalifolium CIAT 350/B. brizantha CIAT 6370	54		1
D. ovalifolium CIAT 350/B. humidicola CIAT 6369	38		0
D. ovalifolium CIAT 350/B. brizantha CIAT 664	30		0
D. ovalifolium CIAT 3784/B. humidicola CIAT 6369	21		0
D. ovalifolium CIAT 3784/B. brizantha CIAT 6370	17		1
D. ovalifolium CIAT 3784/B. brizantha CIAT 664	8		3
D. canum CIAT 13032/B. humidicola CIAT 6369	17		29
D. canum CIAT 13032/B. brizantha CIAT 664	6		11
D. canum CIAT 13032/B. brizantha CIAT 6370	5		11
L.S.D. $P < 0.05$	10		12
$P < 0.01$	14		18

Table 14. Dry matter yields (kg/ha) of Desmodium canum CIAT 13032 and D. ovalifolium accessions CIAT 350 and 3784 during the second grazing/harvesting period.

Association	DM kg/ha Harvest 10-23
D. canum CIAT 13032/B. brizantha CIAT 664	10884 (19)*
D. canum CIAT 13032/B. brizantha CIAT 6370	8701 (15)
D. canum CIAT 13032/B. humidicola CIAT 6369	5271 (19)
D. ovalifolium CIAT 3784/B. brizantha CIAT 6370	4860 (6)
D. ovalifolium CIAT 350/B. brizantha CIAT 6370	2386 (4)
D. ovalifolium CIAT 3784/B. brizantha CIAT 664	2385 (5)
D. ovalifolium CIAT 3784/B. humidicola CIAT 6369	1031 (4)
D. ovalifolium CIAT 350/B. brizantha CIAT 664	892 (2)
D. ovalifolium CIAT 350/B. humidicola CIAT 6369	202 (1)
L.S.D. P < 0.05	3129 (5)
P < 0.05	4552 (8)

* Values in parentheses are legume contents of the dry matter.

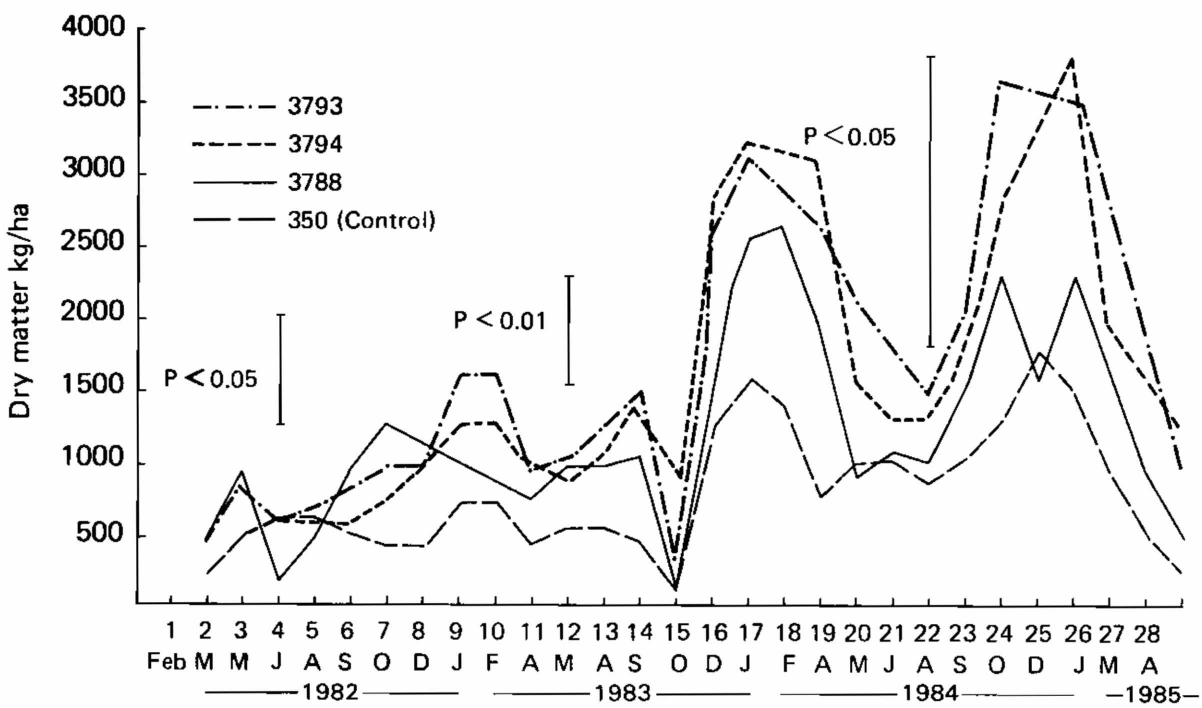


Figure 5. Presentation yields of *Desmodium ovalifolium* accessions CIAT 3793. 3794. 3788 and control CIAT 350, Febreruary. 1982 - April, 1985.

Table 15. Presentation herbage yields of 8 Desmodium ovalifolium and 5 Brachiaria spp. prior to the final grazing date. Harvest 28 (15-IV-1985).

CIAT Accession No.	DM yield kg/ha	Mean legume content (W%) in 5 grass/legume associations
D. ovalifolium CIAT 3794	1.072 a*	70
3793	772 b	50
3784	284 c	23
3788	280 c	22
3780	128 cd	9
350	72 d	5
3652	44 d	3
351	0 d	0
B. humidicola CIAT 679	3.473 a	
B. brizantha CIAT 665	144 b	
B. brizantha CIAT 664	718 c	
Brachiaria sp. CIAT 6298	630 c	
B. dictyoneura CIAT 6133	555 c	

* Mean values followed by a different letter are significantly different ($P < 0.05$).

color and obviously well supplied with nitrogen.

Arachis pintoi - Brachiaria spp.

This legume continued to perform impressively under grazing in association with Brachiaria spp. The good compatibility of a stoloniferous legume with stoloniferous grasses was very much in evidence in four Brachiaria spp. - Arachis associations.

Plant replacement by volunteer seedlings was exceptionally good following the long and severe drought in 1985. Some 1.5 million established, new plants per ha were recorded in the Brachiaria humidicola/A. pintoi association.

Legume content of each of the four A. pintoi/Brachiaria spp. associations increased with time (Table 16). The crude protein content of B. humidicola in association with A. pintoi ranged from 7% to 9% (mean of 3 years) and it was above the maintenance level for beef cattle (Tables 17 and 18). In mono-specific swards the CP content of this grass in the dry season is below the maintenance requirement of the grazing animal. The mean CP% of A. pintoi ranged from 15% to 22%.

Table 16. Range in legume contents of 4 Arachis pintoi/Brachiaria spp. associations under grazing.

Association	Legume Contents (%) 1st.	2nd. Year	3rd.
A. pintoi CIAT 17434/B. humidicola CIAT 679	(5-25)	(8-45)	(18-56)
A. pintoi CIAT 17434/B. dictyoneura CIAT 6133	(6-29)	(10-26)	(7-34)
A. pintoi CIAT 17434/B. brizantha CIAT 664	(4-25)	(5-72)	(19-54)
A. pintoi CIAT 17434/B. ruziziensis CIAT 6291	(11-40)	(16-69)	(33-73)

Table 17. Changes in the crude protein content of Brachiaria humidicola grown in association with Arachis pintoi.

Year	Dry season	Wet season
1st.	6	7
2nd.	5	8
3rd.	9	12
	X: 6.8 ± 2.0	X: 8.8 ± 2.0

Table 18. Crude protein content of Brachiaria humidicola CIAT 679 and B. dictyoneura CIAT 6133 in pure stand and in association with Arachis pintoi CIAT 17434 during the wet season.

Species	Crude protein %
B. humidicola	6
B. humidicola + A. pintoi	12
B. dictyoneura	9
B. dictyoneura + A. pintoi	9

Agronomy (Cerrados)

The objective of the collaborative project CIAT-EMBRAPA-IICA at CPAC is to select germplasm that (i) is adapted to the climatic, edaphic and biotic factors in the Brazilian cerrados and (ii) will persist under grazing. The main EMBRAPA-CPAC colleagues involved in these studies are R.P. de Andrade, C.M.C. da Rocha and F.B. de Sousa.

AGRONOMIC EVALUATION OF LEGUME GERMPLASM IN SMALL PLOTS (Categories I and II)

The number of legumes introduced and evaluated at CPAC since 1978 is 1553, of which 57 per cent are species of *Stylosanthes* (Table 1). Some correction in numbers of accessions has been made from previous reports to allow for duplication. Recent collections by CIAT in Southeast Asia have realized new accessions of *Desmodium* and *Pueraria*, which were sown at CPAC this year for the first time. The preliminary observations made on germplasm since 1978 are now included in the computerized data bank at CIAT along with similar observations on their performance in other ecosystems. *Stylosanthes guianensis*, *S. capitata*, *S. macrocephala*, *S. viscosa*, *Centrosema brasilianum* and *C. macrocarpum* are "key" species for the cerrados.

S. guianensis

Seventeen accessions of *S. guianensis* var. *pauciflora* and *S. guianensis* var. *vulgaris* have been selected for further evaluation. In December 1983, eight of these accessions for which seed was available plus a control (cv. Bandeirante) were established with *Andropogon gayanus* (cv. Planaltina) and *Brachiaria brizantha* (cv. Marandú) in plots 9 m^2. Four anthracnose-susceptible lines CIAT 1062, CIAT 1095 (BRA-006602), CIAT 2046 (BRA-007935) and CIAT 2203A were included to increase *C.gloeosporioides* inoculum. Following the establishment year, the area was grazed by a mob of Gir cows for two days every six weeks.

The presentation dry-matter yields for the legume accessions are shown in Table 2. It should be emphasized that the trial is in its early stages so no firm conclusions can yet be drawn. At each sampling there were significant differences between accessions in dry-matter yield. In May 1985, two accessions CIAT 1062 and CIAT 2203A produced more dry-matter than cv. Bandeirante in the *Andropogon* associations. Although both lines are anthracnose-susceptible, anthracnose development has been slow in the trial. In the *Brachiaria* associations, cv. Bandeirante was by far the highest yielding accession in the May sampling. Accession CIAT 2078 (BRA-008150) was consistently the lowest yielding line

Table 1. Legume germplasm introduced since 1978.

Stylosanthes		Centrosema		Desmodium		Zornia		Pueraria		Other Genera	
S. capitata	217	*C. brasilianum*	158	*D. ovalifolium*	79	*Z. glabra*	18	*P. phaseoloides*	36	*Calopogonium*	21
S. guianensis	175	*C. macrocarpum*	58	*D. heterophyllum*	18	*Z. brasiliensis*	9	Others	11	*Aeschynomene*	17
S. scabra	174	*C. pubescens*	19	Others	31	Others	88			*Galactia*	12
S. viscosa	169	Others	29							*Dioclea*	11
S. macrocephala	117									*Vigna*	10
S. humilis	7									*Leucaena*	8
S. hamata	4									Others	19
Others	18										
Totals	881*		264*		128		115		47		98*

* These totals refer only to collected germplasm and do not include accessions evaluated from *Stylosanthes*, *Centrosema*, and *Leucaena* breeding programs.

Table 2. Presentation dry-matter yields in the second wet season of 13 accessions of S. guianensis associated with A. gayanus or B. brizantha under grazing.

Accession No.	Legume Presentation Dry-Matter Yields (t/ha)			
	A. gayanus		B. brizantha	
S. guianensis var. pauciflora	5.11.84	19.5.85	5.11.84	19.5.85
cv. Bandeirante (control)	0.87	2.21	0.68	3.45
CIAT 1062	0.67	3.23	0.51	1.71
CIAT 1095 (BRA-006602)	0.48	2.05	0.52	1.64
CIAT 2046 (BRA-007935)	0.90	1.52	0.76	1.87
CIAT 2078 (BRA-008150)	0.13	1.07	0.27	1.08
CIAT 2191 (BRA-012386)	0.70	2.87	0.53	2.13
CIAT 2203 (BRA-012327)	0.65	2.34	0.53	2.51
CIAT 2203A	0.63	3.12	0.64	2.50
CIAT 2244 (BRA-003093)	1.01	1.58	0.54	1.88
CIAT 2245 (BRA-012378)	0.66	1.67	0.47	1.09
CIAT 2315	0.26	1.08	0.33	1.39
CIAT 2328 (BRA-014958)	0.29	1.43	0.36	2.18
S. guianensis var. vulgaris				
CIAT 2953 (BRA-019119)	0.71	2.16	0.52	1.59
S.E.	0.16	0.46	0.08	0.25

in both associations. There was some variation in flowering time.

Stylosanthes guianensis var. vulgaris CIAT 2953 (BRA-019119) commenced flowering in the second part of March. Stylosanthes guianensis var. pauciflora accessions CIAT 2046 (BRA-007935), CIAT 2078 (BRA-008150), CIAT 2203A, CIAT 2315, CIAT 2328 (BRA-014958) and CIAT 2244 (BRA-003093) initiated flowering in the first two weeks of April. All other accessions started flowering in May.

Ten new accessions were introduced in 1985. At this stage all were less vigorous than the control cv. Bandeirante. All lines commenced flowering in May. Only slight anthracnose was observed in the plots.

S. capitata

Four accessions have been selected CIAT 1019 (BRA-007251), CIAT 1097 (BRA-005886), CIAT 2853 (BRA-011720) and CIAT 2935. The first two accessions are in advanced testing in Category IV. Twenty-three new accessions were introduced in 1985 and compared with cv. Capica. 65% of the accessions were scored as low-yielding, 20% as moderate and 15% as high-yielding. Cultivar Capica was in the high- yielding group. Two new accessions CIAT 2959 (BRA-014427)and CIAT 2960 (BRA-007579) were outstanding. Little anthracnose was noted on accessions. All lines commenced flowering from February onwards, with CIAT 2959 (BRA-014427) and CIAT 2960 (BRA-007579) initiating flowers in early April.

In January 1983, an experiment was established to determine the effects of anthracnose on S. capitata cv. Capica and its five component accessions. CIAT 1019 (BRA-007251) was also included and a border of the highly anthracnose -susceptible CIAT 1405 was sown around the trial. The production of dry- matter and seed yields in the two seasons subsequent to the establishment year are shown in Table 3. There were no significant

Table 3. Dry matter production and pure seed yields of cv. Capica, its five components and S. capitata CIAT 1019 (BRA-007251).

CIAT No.	DRY MATTER YIELD (kg/ha) 1983-84	1984-85	PURE SEED YIELD (kg/ha) 1983-84	1984-85
1315 (BRA-001791)	4900	4298	63	74
1318 (BRA-001805)	3350	4308	98	158
1342 (BRA-000850)	3950	4550	131	97
1693 (BRA-006742)	4233	4321	65	115
1728 (BRA-006751)	3483	4439	130	102
(Mean of 5 components)	(3983)	(4383)	(97)	(109)
cv. Capica	4177	4787	132	144
1019 (BRA-007251)	4017	4537	90	161
S.E.	535	504	8	17

differences in dry-matter production between cv. Capica, the components of the blend or CIAT 1019 (BRA-007251) in either season. In both seasons there were significant differences between accessions in seed production. Overall seed yields were low because of frequent defoliation. In the first season, seed production in cv. Capica was not appreciably different from that of accessions CIAT 1342 (BRA-000850) or CIAT 1728 (BRA-006751), but was twice that of accessions CIAT 1315 (BRA-001791) and CIAT 1693 (BRA-006742). The new cultivar also yielded 35 and 47% more seed respectively than accessions CIAT 1318 (BRA-001805) and CIAT 1019 (BRA-007251). In the second season seed yield in cv. Capica was of a similar order to that of accessions CIAT 1019 (BRA-007251) and CIAT 1318 (BRA-001805). In both seasons cv. Capica was amongst the highest yielders. Only slight levels of anthracnose were detected, and there were no significant dif- ferences between treatments in anthracnose reaction. Slight to moderate anthracnose levels only were also recorded in the border of CIAT 1405.

S. macrocephala

Six accessions had previously been selected as promising and are in different categories of the evaluation program. Forty-two new accessions were introduced in 1985 and compared with cv. Pioneiro. Three of these new accessions CIAT 10004 (BRA-022641), CIAT 10015 (BRA-023339) and CIAT 10016 (BRA-023345) were outstanding and more vigorous than cv. Pioneiro. All accessions flowered from February onwards and anthracnose scores were very low.

S. viscosa

Four accessions have been selected as promising CIAT 1094 (BRA-012475), CIAT 2368 (BRA-024899), CIAT 2903 (BRA-022519) and CIAT 2923 (BRA-024201). Multiplication of seed is most advanced for CIAT 1094 (BRA-012475). However, passage of promising accessions from introduction plots to small-plot grazing trials has been hampered by a relatively low rate of seed multiplication.

C. brasilianum

Five accessions have been selected and three are under grazing in Category III. In 1985, forty-one new lines were introduced and compared with a control CIAT 5234 (BRA-006025). There was considerable variation between accessions in vigour and yield. Accessions CIAT 5178 (BRA-007081), CIAT 5370, CIAT 5372, CIAT 5507 (BRA-003492), CIAT 5795 and CIAT 5825 (BRA-006271) were scored as being more productive than the control CIAT 5234 (BRA-006025). Rhizoctonia foliar blight was detected on all accessions but only nine were moderately damaged. Pseudocercospora leaf spot attacked three accessions only, but was moderately severe on CIAT 5370. Some 75% of accessions flowered from April onwards. None of the accessions was early-flowering (December-January).

C. macrocarpum

Fifty-eight accessions have been hitherto evaluated and have shown excellent adaptation to climate and soil conditions. However, problems of flowering and seed production have limited the potential of these introductions. On the other hand, hybrids between C. macrocarpum and C. pubescens have shown a high seed production potential.

In 1985 seven accessions of C. macrocarpum collected in Mato Grosso and Para the previous year were introduced together with one local selection. Although vegetative development was good, accessions were moderately to severely attacked by "die-back" probably caused by Cylindrocladium species. Only the local collection was producing flowers.

Other Centrosema species

Sixteen other Centrosema accessions collected in 1984 in Mato Grosso and Para were sown at CPAC. There were four accessions of C. bifidum, five accessions of C. pubescens, one accession of C. acutifolium and six of an unnamed C. species. A number of accessions showed good vegetative development but Phomopsis leaf spot, Rhizoctonia foliar blight and Centrosema mosaic virus caused moderate to severe damage. Accessions of C. pubescens particularily were badly attacked by diseases.

Pueraria species

Fourty-six accessions of P. phaseoloides, were sown in 1985 at two sites. The commercial cultivar CIAT 9900 was included as the control. It is presently too early to comment on de- velopments in the low-lying "varzea" site, so observations refer only to the dryland site on the dark-red latosol. There was considerable variation in vigour and yield between accessions but morphological differences were small. Eighty-nine percent were scored as low to moderate yielding with 11% as high yielding. Four accessions CIAT 744, CIAT 7182, CIAT 8834 and CIAT 9020 were markedly more productive than the control CIAT 9900. None of the accessions had produced flowers by the end of the wet season. There was slight damage due to thrips and leaf-eating insects. Anthracnose was present as a foliar disease rather than as a pod spot and caused some terminal die-back. Two accessions, CIAT 17281 and CIAT 17282, were moderately to severely attacked by the disease.

Desmodium species

In December 1984, 78 accessions of D. ovalifolium were sown on the dark-red latosol together with a control CIAT 350 (BRA-001996). Later in the wet season accessions were sown in the "varzea". The following observations refer only to the accessions on the dark-red latosol. Establishment was much slower than for accessions of Stylosanthes, Centrosema or Pueraria. Twenty accessions showed better early vigour than CIAT 350 (BRA-001996), and accession CIAT 3673 (BRA-004235)was the best of the group. Only CIAT 3674 (BRA-007676) produced flowers; flowering commenced in early April. No diseases or pests were recorded although some accessions were chlorotic.

Other Desmodium species sown at both sites were D. heterophyllum (18 accessions), D. strigillosum (4 accessions), D. heterocarpon (2 accessions) and D. velutinum (1 accession). Most accessions of D. heterophyllum were poor, but D. strigillosum accessions CIAT 13155 (BRA-008605) and CIAT 13159 (BRA-008630) together with D. heterocarpon CIAT 13189 (BRA-008567) were excellent. No diseases or pests were recorded on these species, and none of the accessions was flowering.

Zornia glabra

Twenty accessions were established this season at both sites along with a control Z. latifolia CIAT 728 (BRA-000841). The most vigorous accessions on the dark red latosol were CIAT 8273 (BRA-008761), CIAT 8278 (BRA-003603), CIAT 8308 (BRA-008834) and the control CIAT 728 (BRA-000841). Slight levels of damage due to thrips, leaf miner and Drechslera leaf spot were noted, but symptoms of Sphaceloma scab and virus were absent.

REGIONAL EVALUATION OF GERMPLASM

Visits were made during 1984-85 to twelve regional trials (type B) established in 1982 and 1983 between latitudes 3° north and 22° south. The network continues to function impressively and trials were well-maintained. The experiments are under defoliation and data on dry-matter yields are being collected. The outstanding species at every site is S. guianensis (var. pauciflora and var. vulgaris) with cv. Bandeirante amongst the top lines. The impressive performance of S. capitata CIAT 1097 (BRA-005886) throughout the network confirms observations at CPAC. Although S. macrocephala cv. Pioneiro is performing well in some trials, accessions CIAT 2039 (BRA-011118) and CIAT 2053 (BRA-011126) appear to be more vigorous at most sites. In all twelve locations the grasses A. gayanus cv. Planaltina and B. brizantha cv. Marandú are showing excellent adaptation. New germplasm from the genera Centrosema, Stylosanthes and Zornia has been sent to sites in Bahia and Piaui. Of particular interest in these two locations will be the performance of S. scabra.

AGRONOMIC EVALUATION OF GRASS-LEGUME PASTURES UNDER GRAZING IN SMALL PLOTS (Category III)

Promising germplasm from the earlier categories is evaluated in individually grazed plots to determine legume persistence.

Associations of Andropogon gayanus with S. macrocephala and species of Zornia.

This trial was established in 1981 and was terminated this year after four seasons. Seven replicated Andropogon-legume associations were grazed at two stocking rates, obtained by varying plot size (320 and 480 m^2). Each plot was grazed for two days every three weeks in the wet season and four days every six weeks in the dry season.

The total dry-matter yields as influenced by legume accession and stocking rate are found in Table 4. The new selections of S. macrocephala CIAT 2039 (BRA-011118) and CIAT 2053 (BRA-011126) were very vigorous and outyielded both accessions CIAT 10138 and cv. Pioneiro (the control). At the end of the trial there were no significant differences between the two new accessions, and legume dry-matter yield averaged 1.12 t/ha

Table 4. Presentation dry-matter yields and legume contents of accessions of *Stylosanthes macrocephala* and *Zornia* species associated with *Andropogon gayanus* under grazing at two stocking rates.

Legume Accession with *Andropogon*	Presentation Dry-Matter Yields (t/ha) of *Andropogon*-Legume Associations					
	3.11.82	30.5.83	7.11.83	24.5.84	8.11.84	20.5.85
Stylosanthes macrocephala						
cv. Pioneiro (control)	1.20 (21)[1]	3.64 (11)	1.34[2]	2.57 (5)	1.66[2]	3.76 (7)
CIAT 10138	1.29 (18)	2.65 (15)	1.06	2.41 (3)	2.50	4.63 (2)
CIAT 2039 (BRA-011118)	1.54 (71)	2.94 (51)	1.00	1.96 (22)	1.63	5.34 (22)
CIAT 2053 (BRA-011126)	1.18 (68)	3.08 (54)	0.73	2.48 (25)	2.05	5.06 (21)
Zornia latifolia						
CIAT 728 (BRA-000841) (control)	1.35 (69)	2.28 (39)	0.84	2.46 (2)	2.08	5.41 (2)
Zornia brasiliensis						
CIAT 7485 (BRA-010103)	1.55 (59)	4.51 (98)	-	-	-	-
CIAT 8025 (BRA-002801)	1.42 (27)	3.47 (44)	-	-	-	-
S.E.	0.092	0.484	0.125	0.336	0.118	0.412
Low stocking rate	1.39 (52)	3.97 (45)	1.18	2.76 (4)	2.68	5.79 (5)
High stocking rate	1.33 (41)	2.48 (64)	0.81	1.91 (19)	1.29	3.89 (16)
S.E.	0.101	0.675	0.131	0.234	0.283	0.472

1/ Values in parenthesis are legume contents (% dry-matter).
2/ In sampling on 7.11.83 and 8.11.84 legumes were present but were below sampling height of 10 cm.

compared to 0.26 t/ha for cv. Pioneiro. The content of Z. latifolia CIAT 728 (BRA-000841) declined substantially with time and had almost disappeared from plots by May 1985. Grazing of Z. brasiliensis was terminated in 1983 because (i) animals refused to consume the species at any time and (ii) alkaloids were discovered following studies in Colombia. Differences in dry-matter yield between stocking rate treatments became more pronounced from 1983 onwards. Yields were higher at the lower stocking rate but legume contents were lower. For example, the legume contents of S. macrocephala CIAT 2039 (BRA-011118) and CIAT 2053 (BRA-011126) at the high stocking rate in May 1985 were 32 and 29% respectively compared to 11% for both accessions at the low stocking rate.

There is some evidence to suggest that the better persistence of S. macrocephala CIAT 2039 (BRA-011118) and CIAT 2053 (BRA-011126) may be associated with better seedling recruitment. For example, at the start of the third wet season the average number of seedlings in the plots was 324 per m^2 for CIAT 2039 (BRA-011118) and CIAT 2053 (BRA-011126) compared with only 30 per m^2 for cv. Pioneiro and CIAT 10138. Survival rate at the end of the season for all accessions was 45 per cent.

Ranges for chemical composition and digestible dry-matter content in the legume accessions are shown in Table 5. There was variation between species and accessions. Of particular interest was the very low calcium contents in species of Zornia compared with those of Stylosanthes. This result is consistent with analyses conducted by other workers at CPAC.

The incidence of diseases was low throughout the experiment. Mild symptoms of Sphaceloma scab and Drechslera leaf spot were observed on Z. latifolia CIAT 728 (BRA-000841). All accessions of Zornia were slightly attacked by the virus-Meliola complex.

Associations of three grasses with S. guianensis var. pauciflora.

In 1983 a further trial was established employing the same design as in the previous experiment. Two accessions of S. guianensis var. pauciflora cv. Bandeirante and CIAT 2245 (BRA-012378) were associated with A. gayanus cv. Planaltina, B. brizantha cv. Marandú and P. maximum CIAT 6116.

The stands of B. brizantha have improved considerably this season from seed produced by the older plants in the establishment year. The presentation dry-matter yields and legume contents in the second season are illustrated in Table 6. Grazing was with-held in the establishment year and commenced in November 1984. It is not possible to draw conclusions at present as the experiment is in an early stage. There were significant differences between associations but stocking rate effects were not statistically significant. B. brizantha associations appeared to be more productive than the other associations, but as yet there are no consistent differences in the performance of the two legumes. In almost all cases associations were legume dominant.

Associations of two grasses with species of Centrosema

In December, 1984 a new experiment was established to evaluate a number of accessions of Centrosema undergrazing. Three accessions of C. brasilianum: CIAT 5234 (BRA-006025), CIAT 5523 BRA-003662), CIAT 5824 (BRA-006254), two accessions of Centrosema sp.: CIAT 5277, CIAT 5568 (BRA-004821) and three C. pubescens x C. macrocarpum hybrid lines were each combined with A. gayanus cv. Planaltina and B. brizantha cv. Marandú, with plot size of 250 m^2. Next season the plots will be grazed every three weeks for two consecutive days in the wet season and

Table 5. Range in chemical composition of accessions of *Stylosanthes macrocephala* and *Zornia* species under grazing.

Legume	Chemical Composition (on a DM basis)[1] %N	%Ca	%P	% DDM[2]
S. macrocephala				
cv. Pioneiro (control)	1.09 - 2.30	0.94 - 1.17	0.05 - 0.17	28.17 - 50.14
CIAT 10138	1.04 - 2.36	0.72 - 1.14	0.06 - 0.17	29.37 - 52.83
CIAT 2039 (BRA-011118)	0.94 - 1.91	0.74 - 1.17	0.05 - 0.15	21.56 - 49.60
CIAT 2053 (BRA-011126)	0.98 - 1.88	0.74 - 1.08	0.05 - 0.16	28.07 - 50.26
Mean	1.01 - 2.11	0.79 - 1.14	0.05 - 0.16	26.79 - 50.71
Z. latifolia				
CIAT 728 (BRA-000841) (control)	1.33 - 2.18	0.26 - 0.52	0.05 - 0.14	30.93 - 46.64
Z. brasiliensis				
CIAT 7485 (BRA-010103)	2.16 - 2.73	0.33 - 0.50	0.11 - 0.20	30.90- 58.29
CIAT 8025 (BRA-002801)	1.31 - 2.47	0.25 - 0.48	0.06 - 0.19	30.67 - 60.41
Mean	1.74 - 2.60	0.29 - 0.49	0.09 - 0.20	30.79 - 59.35

1/ Range of 4 samples taken in second and third seasons (two in wet season and two in dry season).
2/ DDM = Digestible Dry-Matter *in vitro*.

Table 6. Presentation dry-matter yields and legume contents of accessions of *Stylosanthes guianensis* var. *pauciflora* associated with three grasses at two stocking rates at the end of the second season.

Associations	Presentation Dry-Matter Yields (t/ha) (1.11.84)				(16.5.85)			
	Stocking Rate (Low)	Stocking Rate (High)	Means	S.E.	Stocking Rate (Low)	Stocking Rate (High)	Means	S.E.
A. gayanus + *S. guianensis*								
cv. Bandeirante	3.93 (79)[1]	2.95 (73)	3.44 (76)		3.19 (69)	2.31 (84)	2.75 (77)	
CIAT 2245 (BRA-012378)	2.18 (65)	3.22 (57)	2.70 (61)		3.16 (67)	3.19 (82)	3.18 (75)	
P. maximum + *S. guianensis*								
cv. Bandeirante	2.64 (57)	2.94 (71)	2.79 (64)	0.22	3.29 (81)	2.88 (62)	3.09 (72)	0.31
CIAT 2245 (BRA-012378)	2.78 (70)	3.35 (78)	3.06 (74)		3.13 (78)	2.53 (66)	2.83 (72)	
B. brizantha + *S. guianensis*								
cv. Bandeirante	3.68 (84)	4.22 (80)	3.95 (77)		3.69 (60)	3.67 (58)	3.68 (59)	
CIAT 2245 (BRA-012378)	2.88 (84)	2.86 (73)	2.87 (79)		4.04 (75)	4.44 (26)	4.24 (51)	
Means	3.02 (72)	3.26 (72)			3.42 (72)	3.17 (63)		
S.E.	0.36				0.43			

1/ Values in parenthesis are legume contents (% dry-matter).

every six weeks for four consecutive days in the dry season.

Establishment of B. brizantha was very good. Fifty days after sowing, plant density was 11 plants per m^2. On the other hand, A. gayanus established poorly and had to be re-sown. However, at 50 days after the second sowing, plant density had improved appreciably to 16 plants per m^2. In Centrosema accessions, densities averaged 8 plants per m^2. Subsequent development of plants of C. brasilianum was excellent and all accessions have spread rapidly through the plots. Legume contents (on a dry-matter basis) in the A. gayanus plots in May, at the end of the wet season, were estimated at 67% for CIAT 5824 (BRA-006254) and 82% for accessions CIAT 5234 (BRA-006025) and CIAT 5523 (BRA-003662). Legume contents of Centrosema sp. and Centrosema hybrids were much lower and ranged from 21 to 51%. Legume contents in the B. brizantha plots were approximately 50% of those in the A. gayanus plots. Symptoms of a nutrient deficiency were noted in plots of Centrosema. sp. and Centrosema hybrids. This was identified as magnesium deficiency and was corected by application of the element. C. brasilianum showed no symptoms of the deficiency.

EVALUATION OF ANIMAL PRODUCTION FROM GRASS-LEGUME PASTURES (Category IV)

Promising germplasm selected in Category III passes for final evaluation into large-scale grazing trials in Category IV. Animal performance is monitored in addition to pasture parameters using the computing procedure "Botanal".

Associations of Andropogon gayanus with species of Stylosanthes

In 1981-82, a trial was established to evaluate pastures of A. gayanus cv. Planaltina in association with S. guianensis cv. Bandeirante, S. macrocephala cv. Pioneiro, S. capitata CIAT 1019 (BRA-007251) and CIAT 1097 (BRA-005886). Results for twelve months of the second grazing year (1984-85) are presented in Table 7. These were again divided on a dry and wet season basis, each of six months duration. Although the rains commenced at the end of October 1984, November was regarded as the first month of the wet season. Mean annual stocking rates were approximately 9% lower than in the previous year.

The general trend was similar to that in the first grazing season (1983-84). The association containing S. guinanensis cv. Bandeirante again gave the highest gains in the dry season. However, animal gains were lower than in 1983-84. With the exception of the association containing S. macrocephala cv. Pioneiro, which had a very low legume content, animals gained some weight in all treatments in the dry season. Across pasture treatments there was an inverse relationship between animal gains and increasing stocking rates. In the wet season, animal gains increased markedly and were slightly higher across stocking rates than in 1983-84. The negative relationship between animal gain and increased stocking rate was highly significant. The highest mean gains in the wet season were recorded in the Andropogon-S. capitata CIAT 1097 (BRA-005886) association which contained a high proportion of legume at all stocking rates. A marked decline in the content of S. guianensis cv. Bandeirante occurred during the wet season.

Association of B. brizantha and S. macrocephala.

In December 1982, a further trial was established with B. brizantha cv. Marandú and S. macrocephala CIAT 2039 (BRA-011118). Grazing began in May 1984. All paddocks are grazed continuously at three stocking rates. The results for this association in the first grazing year (1984-85) are found in Table 8.

Table 7. Animal performance from Andropogon-legume pastures during the dry-season (May to October 1984 inclusive) and the wet season (November 1984 to April 1985 inclusive).

Legume with Andropogon	Dry Season SR (AU/ha)[1] 0.60	0.81	1.02	Means	S.E.	Wet Season SR (AU/ha) 1.04	1.35	1.72	Means	S.E.
	kg gain/animal/day					kg gain/animal/day				
S. capitata CIAT 1019 (BRA-007251)	0.091	0.039	0.017	0.049		0.686	0.689	0.491	0.622	
S. capitata CIAT 1097 (BRA-005886)	0.100	0.027	0.023	0.050	0.027	0.723	0.780	0.685	0.729	0.021
S. guianensis cv. Bandeirante	0.115	0.103	0.043	0.087		0.764	0.637	0.668	0.690	
S. macrocephala cv. Pioneiro	0.033	-0.037	-0.045	-0.016		0.746	0.705	0.680	0.710	
Means	0.085	0.044	0.010			0.730	0.703	0.631		
S.E.		0.023					0.018			

1/ SR = Stocking Rate: 1 AU = 400 kg liveweight.

Table 8. Animal performance from a *Brachiaria brizantha* - *Stylosanthes macrocephala* pasture during the dry season (May to October 1984 inclusive) and the wet season (November 1984 to April 1985 inclusive).

Association	Dry Season SR (AU/ha)[1]			Means	S.E.	Wet Season SR (AU/ha)			Means	S.E.
	0.67	0.82	1.07			1.06	1.26	1.70		
	kg gain/animal/day					kg gain/animal/day				
B. brizantha cv. Marandú + *S. macrocephala* CIAT 2039 (BRA-011118)	0.137	0.086	0.051	0.091	0.013	0.534	0.475	0.441	0.483	0.021

1/ SR = Stocking Rate: 1 AU = 400 kg liveweight.

Stocking rates were of a similar order to those in the Andropogon-legume associations in 1984-85.

In the dry season, average gains were on a par with those recorded in the Andropogon - S. guianensis cv. Bandeirante association in 1984-85. As expected, gains increased in the wet season, but were lower than those in the Andropogon-legume associations during the same period. This difference is probably due to a lower availability of dry-matter in the B. brizantha pastures. At the levels of fertilizer application used in the experiments, the dry-matter production of B. brizantha was lower than that of A. gayanus. In both seasons, there was a significant inverse relationship between animal gains and stocking rates. Obviously, no firm conclusions can yet be drawn from this experiment yet.

SEED MULTIPLICATION

Multiplication of seed of fifty-three promising legumes and grasses reported in 1984 continues. A leaf-eating insect, identified as Sphacophilus centrus, has caused some damage in plots of accessions of S. guianensis var. pauciflora. This pest has attacked the species in previous years and appears to be specific to the "tardío" group. Control can be achieved with application of insecticide. Multiplication commenced this year of two new accessions of Paspalum guenoarum and P. conspersum which have shown promise previously on the red-yellow latosol.

Pastures Project in Panama (IDIAP/RUTGERS/CIAT)

The objectives of the Tropical Pastures Program in Panama are contemplated in an agreement between the University of Rutgers (New Jersey) and the Instituto de Investigación Agropecuaria de Panamá (IDIAP). These are summarized as follows: a) selection of promising germplasm for ecosystems of economic importance in the country, b) agronomic evaluation of adapted species, mainly regarding a response to low levels of fertilization, c) seed multiplication of promising species, and d) weed control and evaluation of animal production potential of promising species for their adaptability to low fertility, acid soils.

GERMPLASM

Regional Trials Type A (RTA)

The two-year evaluation period of the Regional Trials A established in 1983 in the localities of Soná (Humid tropical forest), Calabacito (Humid tropical forest- derived savanna subecosystem) and Los Santos (Dry tropical forest) has come to an end. A total of 22 grass and 54 legume entries, including native and/or naturalized germplasm were evaluated following the methodology described by the International Tropical Pasture Evaluation Network (RIEPT) for these types of trials (Annual Report 1983, Tropical Pastures Program, CIAT). A reduced number of species showed adaptation throughout the three sites mentioned. The most outstanding among the grasses introduced were Andropogon gayanus 621 and 6200, Brachiaria dictyoneura 6133, B. humidicola 679, and B. decumbens 606, in addition to the Cenchrus ciliaris varieties Nunbank and Molopo in the Los Santos ecosystem. The local ecotype of Digitaria swazilandensis showed poor adaptation in Soná and Calabacito, which are characterized by high acidity (pH 4.8-5.0) and high aluminum saturation (63-83%), while in Los Santos, with better soils (pH 6.3 and aluminum traits), the species showed an excellent performance.

The most outstanding legumes for their wide adaptability were Stylosanthes guianensis 184 and to a lower degree, S. guianensis 136; the same for Centrosema macrocarpum 5434 and 5062, Centrosema sp. 5112 and 5278, S. guianensis var. pauciflora 1280 and 1283, and Pueraria phaseoloides 9900 (kudzu), although the latter tends to defoliate severely towards the end of the dry season. S. hamata 147 and 118 adapted well to the Los Santos ecosystem, while S. capitata performed poorly, but was acceptable in Calabacito and moderate in Soná. Soná has acid Ultisols, high aluminum saturation, and higher rainfall levels and relative humidity than the other sites. This factor could be influencing the performance of S. capitata.

The incidence of leaf diseases was greater in Soná than in Calabacito and Los Santos. Anthracnose was high in Aeschynomene histrix and to a lower degree in common types of S. guianensis and in var. pauciflora. S. guianensis 184 showed greater tolerance than S. guianensis 136. Rhizoctonia was common and severe in Centrosema ecotypes, particularly C. brasilianum 5234, 5247, and 494; however, despite the severe defoliations caused by the disease during the rainy season, the species persisted through its seed, which is produced during most of the year. Small leaf (Mycoplasma sp.) affected C. macrocarpum 5062 and 5065 in Soná with greater severity, had moderate incidence in Calabacito, and was not observed in Los Santos. Inflorescence blight (Rizopus sp.) was observed in S. sympodialis 1044 in los Santos.

Common grass pests in the three sites were spittlebug (Aenolamia sp.) and scales (Antonina graminis) and were particularly severe in the case of Brachiaria spp. and Digitaria swazilandensis. Strong and sporadic attacks of Mocis sp. occurred in Soná and Los Santos, apparently associated with the occurrence of short dry periods within the rainy season. Ants were common at the three sites and showed preference for S. guianensis 184; furthermore, termite attacks were observed in adult plants of S. scabra 1047. Leaf sucking, rasping, and chewing insects were common in legumes, but their incidence was from slight to moderate. A summary of species adaptation is shown in Table 1.

Regional Trials Type B (RTB)

On the basis of promising germplasm from the RTA, Regional Trials B have been established in the localities of El Ejido (Los Santos), Soná, and Rio Hato. Establishment of RTB in El Ejido was initiated towards the end of 1983 (Annual Report 1984, Tropical Pastures Program, CIAT) and continues under evaluation, while the trials in the other two sites are in the establishment phase. Species in the Soná RTB include the grasses: B. decumbens 606, B. dictyoneura 6133, B. humidicola 6369, A. gayanus 621 and 6200, D. swazilandensis, and Hyparrhenia rufa (Faragua); and the legumes: S. guianensis 184, 136, and 191, S. guianensis var. pauciflora 1280, S. capitata 10280, Desmodium ovalifolium 350, C. macrocarpum 5062, Centrosema sp. 5278, Arachis pintoi 17434, and P. phaseoloides 9900 (kudzu).

The Rio Hato RTB is the responsibility of the Faculty of Agronomy (FAUP) and is located in the Experimental Station of that institution, in the Province of Coclé. The ecosystem is closer to a dry tropical forest, with an average annual rainfall of 1000 mm; clayey-sandy soils with pH 6.0 and low aluminum saturation, classified as Alfisols. The experiment began during the establishment phase in June and includes a total of 27 grass and legume ecotypes. The established grasses are: B. humidicola 6707, 679, and 6369; B. decumbens 606, A. gayanus 621 and 6200; H. rufa (local); and D. swazilandensis (local); and the legumes: C. macrocarpum 5065, 5062, 5434, and 5478; C. pubescens 438, 5126, and 5189; Neonotonia wightii 216; P. phaseoloides 9900 (Kudzu); S. capitata 10280; S. guianensis 184 and 136; S. scabra 1047; S. hamata 147 and 118; S. sympodialis 1044; S. macrocephala 2133, and a local ecotype of Leucaena leucocephala. During establishment, C. macrocarpum, C. pubescens, S. guianensis, P. phaseoloides, and ecotypes of the grasses A. gayanus and B. humidicola have been outstanding for their vigor, while S. capitata and S. macrocephala have shown poor growth.

Brachiaria Ecotypes

The 21 Brachiaria spp. ecotypes initially established in Gualaca, are also under evaluation in Finca Chiriquí, Calabacito, Soná and 12 of them in Chepo. The more advanced trials include the sites of Gualaca and Finca Chiriquí. Table 2 shows results of the visual estimation of tolerance to drought in these sites and the great variability of these

Table 1. Outstanding germplasm in three sites in Panama, after two years of evaluation. Panamá, 1985.

Species and CIAT No.	Site		
	Soná (BhT)	Calabacito (BhT-Sd)	Los Santos (BsT)
A. gayanus 621, 6200	E*	E	E
B. dictyoneura 6133	E	E	E
B. humidicola 679	E	E	E
C. ciliaris Nunbank y Molopo	-	-	E
D. swazilandensis	R	R	E
B. decumbens 606	R	R/B	R/B
S. guianensis 184	E	E	E
S. guianensis 136	R	E	B
C. macrocarpum 5434, 5062	R/B	E	E
C. sp. 5112, 5278	R/B	E	E
S. guianensis var. pauciflora 1280, 1283	R	E	R
P. phaseoloides	E	E	E
S. hamata 147, 118	-	-	E
S. capitata cv. 'Capica'	R	E	M

Table 2. Estimate of visual tolerance to drought of 21 Brachiaria ecotypes established in Gualaca and finca Chiriquí. Panamá, 1985.

Species	CIAT No.	Relative drought tolerance index*	
		Finca Chiriquí	Gualaca
B. dictyoneura	6133	91.0	65.0
B. humidicola	6369	89.0	77.0
B. humidicola	675	89.0	70.0
B. humidicola	679	86.0	72.0
B. humidicola	6707	85.0	73.0
B. humidicola	6705	84.0	70.0
B. humidicola	682	82.0	73.0
B. humidicola	6709	68.0	67.0
B. decumbens	(Control)	52.0	40.0
B. eminii	6241	51.0	30.0
B. ruziziensis	6134	51.0	32.0
B. ruziziensis	6130	49.0	33.0
B. ruziziensis	6419	43.0	32.0
B. brizantha	6298	40.0	40.0
B. brizantha	6012	38.0	52.0
B. ruziziensis	6291	35.0	32.0
B. brizantha	6009	33.0	52.0
B. brizantha	664	33.0	48.0
B. decumbens	6132	27.0	43.0
B. ruziziensis	654	25.0	33.0
B. decumbens	6131	24.0	40.0

* Visual scale: 0-30: poor; 31-60: moderate; 61-90: good; 91-100: excellent.

ecotypes to this natural phenomenom which lasts from 4 to 5 months on average. Species such as B. dictyoneura 6133 and the B. humidicola group are the most tolerant; furthermore, the range of variability is much greater in Finca Chiriquí than in Gualaca, since the stress generated by drought is much lower in the latter site.

Severe spittlebug attacks have been observed only in Finca Chiriquí, while the incidence of the insect is nil or insignificant in Gualaca. Table 3 shows variations in the population of spittle mass and nymphs in the different ecotypes of Brachiaria. It is clear that there is no direct relation between the number of spittle masses and the number of nymphs/m^2 and this is probably due to variations in the size of the mass, which could be associated with the different microclimates created by the species in their respective plots and the subsequent effect on the insect. More nymphs have been observed in B. humidicola and B. dictyoneura 6133, and less in B. decumbens 6131.

However, the degree of tolerance to the spittlebug is quantified by the productive capacity of the species under infestation conditions. Table 4 shows that in Finca Chiriquí under a high incidence of the insect, the highest yield (2.4 t DM/ha) was produced by B. humidicola 6707 which at the same time proved to be highly infested (109 nymphs/m^2), indicating acceptable tolerance to the insect.

Overall the B. humidicola group and B. dictyoneura 6133 have shown acceptable performance under high infestation of the spittlebug under the climate and soil conditions prevailing in Finca Chiriquí. Gualaca, having better soils, greater rainfall, and absence of the insect, has better forage yields and less variability among species, as indicated in Table 4; however, species such as B. eminii 6241, B. ruziziensis 6291, and B. brizantha 664, have shown relative low yield indexes in both sites.

Leucaena Ecotypes

In collaboration with the National Institute of Agriculture (INA) located in Divisa, seasonal production of edible dry matter (EDM) of 16 Leucaena ecotypes has been evaluated in an Inceptisol with pH 5.6 and aluminum traits. The germplasm is composed of 7 ecotypes of L. leucocephala, 4 of L. diversifolia, 1 of L. shannoni, 2 of L. pulverulenta hybrids, and 1 of each L. leucocephala and Leucaena sp. Cuts have been done every 8 weeks at 40 cm height, and the material separated in leaves and stems smaller than 5mm to form the edible dry matter. Table 5 shows variability among and within the ecotypes. During the dry season the highest yield was presented by Leucaena sp. (hybrid) 17478 with 122 g EDM/m^2m while Leucaena leucocephala 17491 obtained the lowest yield (36 g EDM/m^2). L. diversifolia had low yields while L. leucocephala showed a broad range of variation in yields with variety Cunningham occupying intermediate levels. A similar yield tendency was observed during the rainy season. However, L. leucocephala 17488 and L. pulverulenta (hybrid) 17490 increased their yields to levels comparable to those of the most outstanding ecotypes during the dry season. Both during the rainy and the dry season the three best-yielding ecotypes have been L. pulverulenta (hybrid) 17489, L. leucocephala 17467, and Leucaena sp. (hybrid) 17478, being Leucaena sp. outstanding for having a lower content of mimosine and greater regrowth capacity after cuts. The experiment will continue for one more year.

Seed multiplication

Seed multiplication of promising experimental lines and collection of information of reproductive and harvest parameters have continued with the objective of improving the

Table 3. Average population of spittle mass and nymphs/m^2 in 21 Brachiaria ecotypes established in finca Chiriquí, Panamá 1985.

Species	CIAT No.	No. of spittle mass*	No. of nymohs**
B. humidicola	6705	22.6	113.1
B. humidicola	675	23.3	113.0
B. humidicola	679	24.5	112.7
B. humidicola	6707	24.9	109.7
B. humidicola	682	23.4	107.6
B. dictyoneura	6133	17.7	89.0
B. brizantha	6298	17.7	78.1
B. humidicola	6369	16.4	74.4
B. eminii	6241	5.4	68.7
B. ruziziensis	654	6.7	46.7
B. brizantha	6012	12.3	44.0
B. brizantha	664	9.5	41.9
B. humidicola	6709	19.1	37.7
B. brizantha	6009	11.6	36.0
B. decumbens	6132	17.9	33.8
B. ruziziensis	6291	4.4	32.6
B. brizantha	6016	2.5	32.3
B. ruziziensis	6130	5.5	21.3
B. ruziziensis	6134	6.6	18.3
B. decumbens	6131	8.5	10.3
B. decumbens	(Control)	9.7	27.7

* Mean of 3 samplings every 20 days (July-August).

** Mean of 5 samplings every 20 days (May-August).

Table 4. Seasonal production of dry matter of 21 Brachiaria ecotypes established in Gualaca and Finca Chiriquí. Panamá, 1985.

Species	CIAT No.	Average dry matter production (t/ha)	
		Gualaca*	Finca Chiriquí**
B. decumbens	(Control)	3.5	0.5
B. ruziziensis	6130	3.1	0.3
B. humidicola	679	3.1	1.6
B. humidicola	675	2.9	1.8
B. humidicola	6707	2.8	2.4
B. humidicola	682	2.7	1.7
B. humidicola	6369	2.6	0.9
B. humidicola	6705	2.5	1.5
B. ruziziensis	6134	2.5	0.3
B. decumbens	6132	2.4	0.5
B. humidicola	6709	2.4	1.5
B. ruziziensis	6419	2.4	0.3
B. dictyoneura	6133	2.4	1.4
B. brizantha	6298	2.3	0.3
B. brizantha	6009	2.2	0.3
B. eminii	6241	2.2	0.1
B. brizantha	6012	2.2	0.4
B. ruziziensis	654	2.1	0.4
B. ruziziensis	6291	2.1	0.1
B. decumbens	6131	2.0	0.4
B. brizantha	664	1.8	0.1

* Mean of 4 cuts every 5 weeks

** Mean of 3 cuts every 5 weeks

production of forage seed. The largest number of observations have been carried out at the Experimental Station of Gualaca (Chiriquí). Table 6 shows yields of various species during the 1984 and 1985. S. guianensis 136 increased yields during the second year, but the plants did not survive after the harvest cutting; something similar had occurred in 1984, but a new generation of seed offspring made the 1985 harvest possible; however, this mechanism of persistence was not effective during the last year and the plot was invaded by weeds, making the recovery of the species impossible. Something similar occurred with S. capitata "Capica", due mainly to the loss in vigor of the mother plants and the low competition of the new gneerations growing from seed. The combination of high rainfall levels registered in the last years in Gualaca with the competition of annual broad-leaved weeds and grasses, resulted in Capica's low persistence.

C. macrocarpum 5065 did not form seed during 1984 due to unfavorable climate conditions. However, during 1985 the species flowered and beared fruit normally, reaching yields of 50 kg seed/ha, harvested in various passes. Last year was characterized by a marked difference in rainfall between the winter and summer seasons, which was not the case in 1984. Kudzu produced lower seed yields during the second year, but it is likely that the yields are underestimated because of harvest deficiencies and considerable loss of mature seed in the field. A. gayanus ('Veranero') yields also decreased during the second year, due to a decrease in plant population and loss in vigor of the species because of excessive rainfall (5139 mm in 1984) during the rainy season. This suggests that the ecosystem of Gualaca offers marginal growth conditions for Veranero and that the rainfall levels and the some times too slight difference between the winter and summer seasons, is a constraint to seed multiplication.

Weed Control

The selectivity of various pre- and post-emergent herbicides during the establishment of P. phaseoloides (kudzu) had been previously reported (Annual Report 1984, Tropical Pastures Program CIAT). Selected doses of the best herbicides were chosen to establish a new experiment with the species, including manual weeding as part of the treatments. Table 7 confirms the Kudzu selectivity of the herbicides oxyfluorfen, alachlor, and metachlor applied during pre-emergence. In all treatments similar populations survived application, a favorable performance in relation to 15 plants used as control.

Observations conducted 130 days after applying the pre-emergent herbicides indicate higher Kudzu yields for the manual weeding treatment, followed by metachlor 1.40 kg ia/ha plus one manual weeding (Table 8). Other outstanding treatments were alachlor 2.24 and oxyfluorfen 0.50 kg ai/ha both combined with manual weeding; that is, weed control by the pre-emergent herbicides alone was not acceptable; however, the amount of time spent in weeding in the treatment with pre-emergent herbicides was only half of that employed in the manual weeding treatment, implicating a reduction in labor employed in this operation. The relatively low yields of Kudzu are due in part to the high incidence of the native legume Calopo (Calopogonium mucunoides), which was not controlled by any of the herbicides applied in pre - or post-emergence; only the manual weeding eliminated this species.

Treatments with alachlor + acifluorfen (2.24 + 0.60 kg ai/ha) and oxyfluorfen + acifluorfen (0.50 + 0.60) applied pre- and post-emergence, respectively, reduced the weed population considerably, but did not control Calopo; besides, this treatment delayed the growth of Kudzu

Table 5. Yield parameters, mimose content, and height of regrowth of 16 *Leucaena* ecotypes during the first year of evaluation in Divisa, Panamá, 1985.

Species	CIAT No.	Yield ($g/EDM/m^2$) Summer*	Winter	Mimosine (%)**	Height of regrowth (cm)***
Leucaena sp.	17478 Hybrid	122	685	3.0	89
L. leucocephala	17467	111	931	4.1	46
L. pulverulenta	17489 Hybrid	109	699	3.9	51
L. shannoni	17487	97	618	4.1	57
L. leucocephala	17477	95	423	3.1	57
L. leucocephala	17475 Hybrid	94	446	3.5	43
L. leucocephala	17502 Cunningham	87	608	4.3	56
L. leucocephala	17495	83	404	4.8	50
L. leucocephala	17498	76	466	4.0	59
L. pulverulenta	17490 Hybrid	73	640	3.7	63
L. diversifolia	17503	69	536	3.2	55
L. diversifolia	17485	64	309	3.8	75
L. leucocephala	17488	63	620	4.6	81
L. diversifolia	17388	52	460	4.2	61
L. diversifolia	17461	49	402	3.5	43
L. leucocephala	17491	36	313	3.6	53

* Mean of 3 cuts in summer and 2 in winter, respectively.
** On a dry basis
*** Regrowth after 8 weeks in winter.

Table 6. Seed yield of forage species during the years 1984-85 in Gualaca, Panamá.

Species	Area harvest (ha)	Estimated yield kg/ha* 1984	1985
Stylosanthes guianensis CIAT 136	0.15	30.0 (4.5) +	45.3 (6.8)
Stylosanthes capitata 'Capica'	0.33	589.0 (194.5)	-
Pueraria phaseoloides CIAT 9900 (Kudzú)	1.00	22.5 (22.5)	11.0 (11.0)
Centrosema macrocarpum CIAT 5065	0.40	-	25.0 (10.0)
Andropogon gayanus 'Veranero'	2.0	431.0 (862.0)	192.0 (384.0)

* Manual yields of crude protein.
+ In parenthesis is the total amount of seed harvested.

Table 7. Average number of kudzu (*P. phaseoloides*) plantlets, 25 days after applying pre-emergent herbicides during the establishment phase. Gualaca, 1985.

Treatment	Dose (kg ia/ha)	X of plants/ treatment*	
A. Pre-emergence			S.E.
1. Oxyfluorfen	0.50	14	3.4
2. Alachlor	2.24	14	1.8
3. Metachlor	1.40	13	3.7
4. Oxyfluorfen + Alachlor	0.50 + 0.50	14	1.0
5. Oxyfluorfen + manual weeding	0.50	14	2.7
6. Alachlor + manual weeding	2.24	14	2.0
7. Metachlor + manual weeding	1.40	13	3.5
8. Oxyfluorfen + Alachlor + manual weeding	0.50 + 0.50	13	1.0
B. Pre + Post emergence**			
9. Oxyfluorfen + Acifluorfen	0.50 + 0.60	14	1.8
10. Oxyfluorfen + Fluazyfop-butyl	0.50 + 0.50	14	3.4
11. Oxyfluorfen + Pendimenthaline	0.50 + 1.30	10	3.5
12. Alachlor + Acifluorfen	2.24 + 0.60	13	0.9
13. Alachlor + Fluazyfop-butyl	2.24 + 0.50	12	5.2
14. Alachlor + Pendimenthaline	2.24 + 1.30	14	2.3
C. Post-emergence			
15. Acifluorfen	0.60	12	3.3
16. Fluazyfop-butyl	0.50	16	2.3
17. Pendimenthaline	1.30	15	1.4
18. manual weeding	-	15	1.3

* Twenty-one plants were planted per 2 x 3-m plot.
** Post-emergent products applied 35 days after planting.

Table 8. Relative yields of kudzu (P phaseoloides) and other species, 130 days after applying pre- and post- emergent herbicides for weed control during the establishment phase. Gualaca, 1985.

Treatment	Dose (kg ia/ha)	Yield kg DM/ha		
		Kudzú	Weeds	
			Calopo*	Other**
A. Pre-emergence				
1. Oxyfluorfen	0.50	308	705	628
2. Alachlor	2.24	294	586	892
3. Metachlor	1.40	368	486	947
4. Oxyfluorfen + Alachlor	0.50 + 0.50	255	885	774
5. Oxyfluorfen + manual weeding	0.50	560	14	226
6. Alachlor + manual weeding	2.24	606	22	424
7. Metachlor + manual weeding	1.40	675	0	327
8. Oxyfluorfen + Alachlor + manual weeding	0.50 + 0.50	515	0	395
B. Pre + Post-emergence +				
9. Oxyfluorfen + Acifluorfen	0.50 + 0.60	240	603	166
10. Oxyfluorfen + Fluazifopbutyl	0.50 + 0.50	350	512	1060
11. Oxyfluorfen + Pendimenthaline	0.50 + 1.30	280	321	742
12. Alachlor + Acifluorfen	2.24 + 0.60	355	564	206
13. Alachlor + Fluazifopbutyl	2.24 + 0.50	182	662	1141
14. Alachlor + Pendimenthaline	2.24 + 1.30	268	344	1258
C. Post-emergence +				
15. Acifluorfen	0.60	356	528	749
16. Fluazyfopbutyl	0.50	204	308	2102
17. Pendimenthaline	1.30	277	437	1229
18. manual weeding	Control	779	0	390

* Calopogonium mucunoides, is considered a weed in this case
** Weed complex dominated by Croton trinitatis, Borreria alata y Mimosa sp.
\+ Post-emergence products applied 35 days after planting.

because of the effect of acifluorfen. The post-emergent products had little effectivity over the weed complex; fluazyfopbutyl 0.50 was selective for Kudzu, but resulted in the highest infestation of the broad-leaf Croton triniatatis, Borreria alata, and Mimosa sp. weeds. On the other hand, the residual effect of the oxyfluorfen pre-emergent 0.50 was greater than that of alachlor 2.24 and metachlor 1.40 reflected by a greater control of wide-leaf weeds and intermediate and high values of Kudzu and Calopo, respectively.

Germplasm Collection

During February and March a trip was conducted to collect forage germplasm with emphasis on legumes. The trip covered the route between the province of Chiriquí (east) and the province of Panama (west). With the participation of a specialist from CIAT and the financial support of the Pastures Regional Group for Central America and the Caribbean (GREDPAC), a total of 2179 km were travelled partially covering the provinces of Chiriquí, Veraguas, Herrera, Los Santos, Coclé and Panamá. A total of 341 samples of forage legumes of 20 different genera were collected (Table 9), the genus Centrosema being outstanding. Of these, 15 samples from throughout the provinces visited correspond to C. macrocarpum, a highly promising species of Centrosema, One sample of C. brasiliaum was collected for the first time in Panamá in the province of Coclé. Germplasm collected was shared by IDIAP and CIAT, thus initiating the evaluation of promising species, such as C. macrocarpum which has lanceolated leaves and delayed flowering, in comparison with other ecotypes found in Latin America.

Table 9. Native legume germplasm collected in Panamá, provinces of Chiriquí, Veraguas, Herrera, Los Santos, Coclé, and Panamá. February 21- March 2, 1985.

Genus	No.Samples Collected
Aeschynomene	27
Alysicarpus	4
Calopogonium	32
Canavalia	11
Centrosema	66
Desmodium	54
Dioclea	9
Galactia	16
Mucuna	6
Rhynchosia	24
Stylosanthes	27
Teramnus	18
Vigna/Macroptilium	18
Zornia	18
Other genera (Desmanthus, Clitoria, Prosopis, Tephrosia, Crotalaria, Flemingia)	11
Total	331

PASTURES EVALUATION

During the present year grazing was initiated of associations established in collaboration with the Faculty of Agronomy in Chiriquí (Regional Trial C, RTC) and of the trial on productivity of pastures alone and in association in Gualaca (Regional Trial D, RTD) (Annual Report 1984, Tropical Pastures Program, CIAT). Heifers of approximately 250 kg of weight were used in the RTC and, as with steers of similar weight used in the RTD, the herd is passing through a period of adaptation in the field. Observations performed in the RTC in Chiriquí indicate an acceptable balance in the associations A. gayanus 621 and S. capitata "Capica"; B. humidicola and P. phaseoloides "Kudzú"; H. rufa

"Faragua" and S. capitata "Capica"; and H. rufa "Faragua" and C. macrocarpum 5065. Density of this last species had decreased in the association with A. gayanus 621. Death of the legume plants was observed in the dry period, which was probably due to the marked competition for humidity by the grass during this period. This did not occur in the association with the other grass, H. rufa "Faragua".

A new pasture experiment type RTD in the process of establishment in the Calabacito substation (Veraguas), characterized by acid Ultisols (pH 4.8) and high aluminum saturation. The treatments include 5 associations: A. gayanus CIAT 621 and H. rufa (local) associated with S. capitata "Capica"; B. dictyoneura CIAT 6133 and B. humidicola (local) associated with P. phaseoloides (Kudzú); and A. gayanus CIAT 621 associated with C. macrocarpum CIAT 5062. A stocking rate of 2 an/ha was applied during the rainy season and 1.3 an/ha during the dry season, in an alternate grazing system with 28 days of occupation and 28 of rest. Total area of the experiment was 15 ha and more than 50% is currently established.

International Tropical Pastures Evaluation Network

INTRODUCTION

The main objective of the Regional Trials Section is to evaluate new forage germplasm in the principal ecosystems of tropical America through a combined effort between the national research institutions and the CIAT Tropical Pastures Program. The International Tropical Pastures Evaluation Network (RIEPT) operates under a systematic evaluation program composed of four stages called Regional Trials A, B, C and D (RTA, RTB, RTC, and RTD) which allow for the introduction, agronomic evaluation, and evaluation under grazing of promising germplasm. The first two stages (RTA and RTB) are essentially agronomic; in these trials germplasm is fundamentally selected for its tolerance to climate, soils, pests, and diseases. Regional Trials A evaluate the survival of a large number of entries (80-150) in a few representative sites within the major ecosystems (well-drained isohyperthermic savannas "Llanos", well-drained thermic savanna "Cerrados", poorly drained savanna, tropical semievergreen seasonal forest, and tropical rain forest). Regional Trials B evaluate seasonal productivity under cutting of the best entries, selected in the previous stage, in a greater number of sites within each ecosystem. Regional Trials C and D study the effects of animals in order to assess characteristics such as stability and persistence of the components (grasses and legumes) of the pasture (RTC) and meat, milk and/or calf production under different management systems (RTD).

ADVANCES OF THE INTERNATIONAL TROPICAL PASTURES EVALUATION NETWORK

<u>Meeting of the RIEPT's Advisory Committee</u>

The fast progress experienced by the RIEPT in the last years has generated, as expected, the need to answer new questions in response to problems arising in the progressive and systematic evaluation of germplasm. With the object of discussing the criteria for research support in the systematic evaluation of pastures within the RIEPT, a workshop was carried out with representatives of national institutions, special guests and the RIEPT's Advisory Committee. This workshop received support from the International Development Research Centre (IDRC), the Food and Agriculture Organization (FAO), and CIAT, to discuss the "Research support needs in the systematic evaluation of pastures within the RIEPT". Thirty-five representatives of national and international institutions from 17 countries participated in the event (Table 1).

This meeting defined the most important aspects on fertilization adjustments in tropical pastures; the technique to evaluate nitrogen fixation in forage legumes; methodologies to be used in the evaluation of pests and diseases; and multiplication and research in seed

Table 1. Participants in the Workshop on "Research Support Needs in the Systematic Evaluation of Pastures within the RIEPT". Cali, Colombia, 15-18 October, 1985.

Country	Institution	Participants
AUSTRALIA	CSIRO	T.R. Evans
BRAZIL	CEPLAC/CEPEC	J. Marques Pereira
	EMBRAPA/CNPGC	W. Vieira Soares
	EMBRAPA/CPATU/IICA	M.A. Calderón
	EPAMIG	N.M. de Sousa Costa
	IPAGRO/MIRGEN	J. Soares Pereira
COLOMBIA	CIAT	J.M. Toledo, J.G. Salinas, J.M. Spain, R.S. Bradley, C. Seré, J. Lenné, R. Vera, M. Fisher, C. Lascano, R. Schultze-Kraft, G. Keller-Grein, D. Thomas, J.E. Ferguson, J.W. Miles, E.A. Pizarro, S.R. Saif, B. Grof, J. Stanton, P. Thornton, B. Maass, T. Mitamura, Ch. Hamilton, M.C. Amézquita
	CIID	H.H. Li Pun
	ICA	P.E. Mendoza, F. Munévar, L.A. Hernández
COSTA RICA	CATIE	R. Borel
	Min. of Agriculture	R. Argüello
CUBA	ICA	A. Barrientos, M. López
	Min. of Agriculture	J.J. Paretas
CHILE	U. Católica/CIAT	O. Paladines
ECUADOR	IICA	H. Caballero
GUATEMALA	IICA	G. Cubillos
HONDURAS	Sec. Rec. Naturales	C. Burgos
MEXICO	INIA/SARH	A. Ramos, A. Peralta
	INIP/SARH	J.A. Ortega
NICARAGUA	MIDINRA	J.A. Oporta
PANAMA	IDIAP	C.M. Ortega
	IDIAP/GREDPAC	C.G. Morán
	U. Rutgers/CIAT/IDIAP	P.J. Argel
PARAGUAY	Min. of Agriculture	R. Samudio, C. Romero de Villagra

Table 1. (Continued).

Country	Institution	Participants
PERU	INIPA INIPA/CIPA X	H. Ibazeta C.R. Valles
DOMINIC REPUBLIC	CENIP/SEA	M.Y. Soto
TRINIDAD	CARDI	P.O. Osuji
VENEZUELA	AGATUM CORPOZULIA/LUZ FONAIAP	L. Boscán I. Urdaneta A. Flores

production of forage plants. This set of methodologies was called "research support", and must be understood as parallel and complementary research.

The proposed methodologies and recommendations of the work groups will be published in the proceedings of the meeting, for subsequent distribution to the members and collaborators of the RIEPT.

III General Meeting of the RIEPT

The III General Meeting of the RIEPT was held on the 21-24 of October, 1985, with the economic support of IDRC, FAO and CIAT.

For the first time, participants had the opportunity to discuss, in addition to the RTA and RTB agronomic trials, the regional support and grazing trials (RTC and RTD) which reflects the progress achieved in the systematic evaluation of pastures within the RIEPT.

In this opportunity, 59 collaborators from 46 national research institutions in 18 countries (Table 2) presented a total of 111 papers.

Each group of presentations corresponding to the different ecosystems concluded with a discussion on results presented, with the active participation of assisting researchers.

Results obtained in the evaluation of germplasm in the major centers of EMBRAPA-CIAT (Planaltina, Brazil) and ICA-CIAT (Carimagua, Colombia) were presented, in addition to regional trials results. Likewise the supply of seeds and communication media in the RIEPT were discussed.

Evolution of the Regional Trials

The RIEPT has received to date partial information on 160 regional trials within the five ecosystems mentioned, with the following percentage distribution: RTA, 16%; RTB, 55%; RTC, 8%; RTD, 5%, and support RT, 16%.

Figure 1 presents the geographic distribution of the regional trials under execution to date and the evolution of the number of active regional trials reporting information for the period 1978-1985.

Tables 3, 4, 5, 6, and 7 show the country, locality, institution, collaborator, the ecosystem to which the regional trial belongs, and the types of trials (RTA, RTB, RTC, RTD, and RT-support, respectively).

Table 2. Participants in the III General Meeting of the International Tropical Pastures Evaluation Network (RIEPT). Cali, Colombia, 21-24, October, 1985.

Country	Institution	Participants
ARGENTINA	INTA	L.S. Verde
BOLIVIA	CIAT	G. Vega
	IBTA/CHAPARE	A. Vallejos
	UMSS	J. Espinoza
BRAZIL	CEPLAC/CEPEC	J. Marques Pereira, M. A. Moreno
	EMBRAPA/CPAC	C.M.C. da Rocha, A. O. Barcellos. J.R. Peres
	EMBRAPA/CNPGC	W. Vieira Soares, M.I.O.Penteado
	EMBRAPA/CPATU	E.A. Serrao
	EMBRAPA/CPATU/IICA	M.A. Calderón
	EPABA	L.A. Borges de Alencar
	EPAMIG	N.M. de Sousa Costa
	IPAGRO/MIRGEN	J. Soares·Pereira
	UFV/CEPET	C. Prates Zago
COLOMBIA	CENICAFE	S. Suárez, J. Rubio, L.F. Machado, C. Franco
	CIAT	J.M. Toledo, B. Grof, J.M. Spain, J.G. Salinas, R.S. Bradley, R. Vera, J. Lenné, J.E. Ferguson, C. Seré, J.W. Miles, R. Schultze-Kraft, C. Lascano, M. Fisher, D. Thomas, G. Keller-Grein, E.A. Pizarro, Ch. Hamilton, M.C. Amézquita, P. Thornton, B. Maass, J. Stanton, L.H. Franco, D.L. Molina, O. Sierra, A. Ramirez, E. Salazar, H. Giraldo
	CIID	H.H. Li Pun
	ICA	P.E. Mendoza, F. Baez, A. Mila, A.E. Acosta, J.A. Barros, R. Pérez, P.A. Cuesta
	SEMILLANO	S. Monsalve
	U. de la Amazonía	R. Angulo
	U. Nacional	L.A. Giraldo
	U. Tecn. de los Llanos	L.H. Lemus
COSTA RICA	Min. of Agriculture	R. Argüello, J. Gómez
CUBA	ICA	M. López, A. Barrientos
	Min. of Agriculure	J.J. Paretas, I. Hernández
CHILE	U. Católica/CIAT	O. Paladines

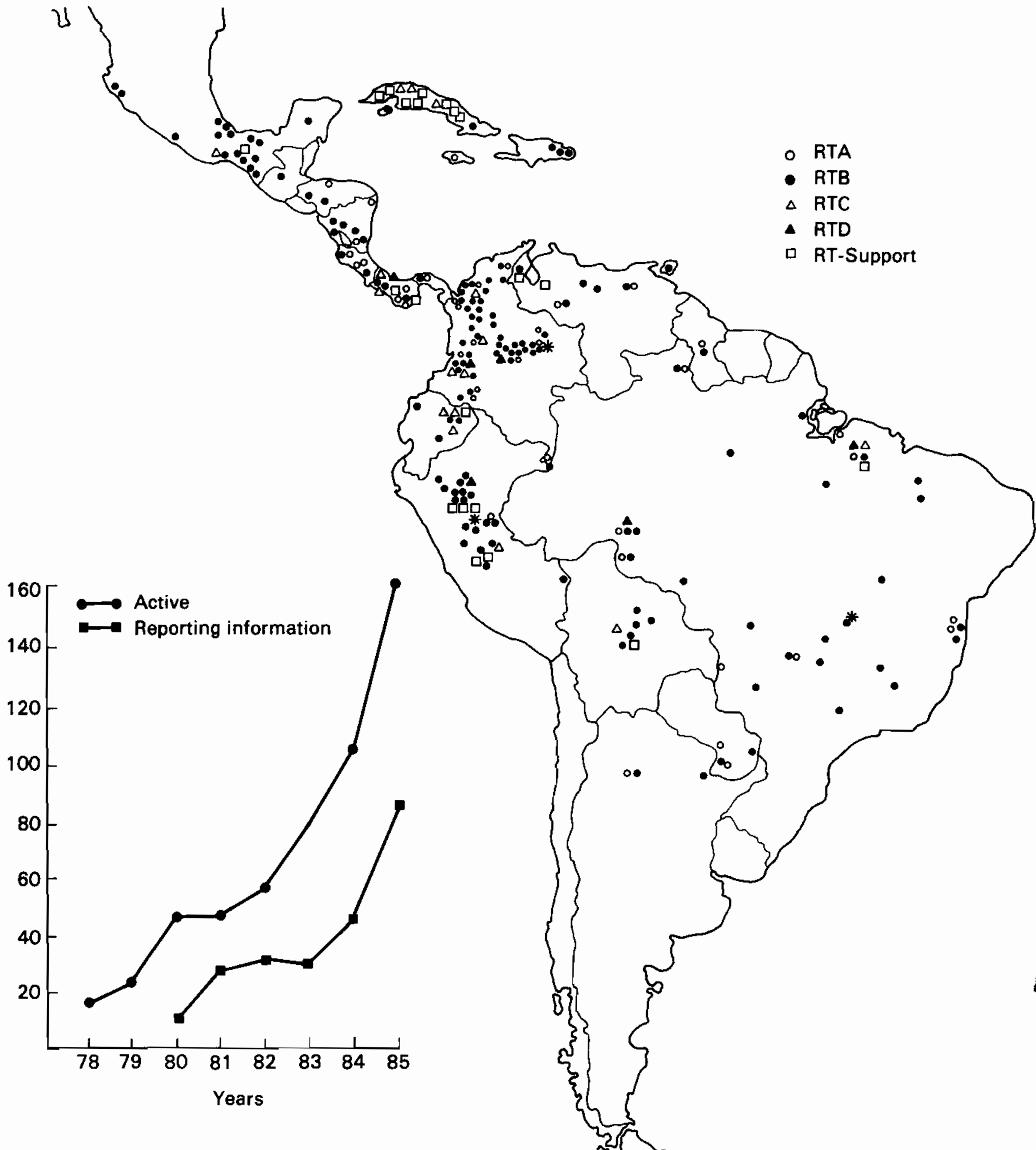


Figure 1. International Tropical Pastures Evaluation Network (RIEPT), 1985, and evolution of the number of active regional trials and those reporting information, 1978-1985.

Table 2. (Continued).

Country	Institution	Participants
ECUADOR	IICA	H. Caballero
GUATEMALA	C. Univ. del Norte	O. Pineda
	IICA	G. Cubillos
	ICTA	H.E. Vargas
FRENCH GUYANA	INRA	B. Moise
HONDURAS	CURLA/UNAH	G. Valle
	SEC. REC. NAT.	C. Burgos, H. Cruz
MEXICO	INIA/SARH	A. Ramos, A. Peralta, A. Córdoba, A. Cigarroa, J.F. Enríquez
	INIP/SARH	J.A. Ortega
NICARAGUA	MIDINRA	J.A. Oporta
PANAMA	IDIAP	C. Ortega, S. Ríos, O. Duque, E. Arosemena, D. Urriola, H.O. Aranda
	IDIAP/GREDPAC	C.G. Morán
	Rutgers U./CIAT/IDIAP	P.J. Argel
PARAGUAY	PRONIEGA/M. Agric.	C. Romero de Villagra, P. Valinotti
PERU	INIPA	H. Ibazeta, R. Schaus
	INIPA/CIPA X	C.R. Valles, W. López
	INIPA/CIPA XVI	R. Dextre
	INIPA/PEPP/NCSU	K. Reátegui
	IVITA	H.A. Huamán, C.A. Reyes
TRINIDAD & TOBAGO	CARDI	P.O. Osuji
VENEZUELA	AGATUM	L. Boscán
	CORPOZULIA/LUZ	I. Urdaneta
	FONAIAP	A. Flores, L.A. Millán
	U. Central Venezuela	P.J. Arias

RESULTS OF REGIONAL TRIALS BY ECOSYSTEM

Well-drained isothermic savannas "Cerrados"

Preliminary observations of the RTB established in 1983/84 are shown in Table 8. A large variation in the production at 12 weeks of accumulated dry matter can be observed among the legumes under evaluation, for the period of maximum precipitation as well as for the period of minimum precipitation. It is interesting to point out that the most productive

Table 3. Regional Trials A active during 1985.

Country	Site	Institution/Collaborator	Ecosystem*	Planting date
BRAZIL	Boa Vista II	EMBRAPA-UEPAT Boa Vista/ R. Perin. V. Gianluppi	WDIS	V-84
	Itabela II	CEPLAÇ-CEPEC/M. Moreno, J.M. Pereira, R. Cantarutti	TSSF	III-83
	Ouro Preto	EMBRAPA-UEPAE Belém/ C.A. Goncalves	TSSF	XI-83
	Porto Velho	EMBRAPA-UEPAE Belem/ C.A. Goncalves	TSSF	X-83
	Itajú	CEPLAC/M. Moreno	TRF	1984
COLOMBIA	Carimagua	CIAT/B. Grof, E.A. Pizarro	WDIS	XII-83
	La Romelia	CENICAFE/S. Suárez	TSSF	X-84
	Palmira	ICA-CIAT/D. Echeverry, Regional Trials	TSSF	VI-84
	Macagual II	ICA/A. Acosta	TRF	IV-83
	Tulenapa I	ICA/A. Mila	TRF	IV-84
	Tulenapa II	ICA/A. Mila	TRF	IV-84
	Turipaná	ICA	TRF	IV-84
	Motilonia	ICA/J. Barros	TSSF	IV-84
	Las Leonas	CIAT/Regional Trials	WDIS	VI-84
COSTA RICA	Guápiles	MINAG/O.Sánchez, G.Guevara	TRF	1983
	San Carlos	ITCR-MINAG/P. Chaverri. J. López, O. Sánchez	TRF	VI-83
	Turrialba	CATIE/R. Borel	TRF	III-83
HONDURAS	La Ceiba	CURLA-UNAH/G. Valle	TRF	VIII-83
NICARAGUA	Pto. Cabezas	MIDINRA/O. Miranda	TRF	VI-83
PANAMA	Calabacito	IDIAP/H. Aranda, M. Pinilla	TRF	VII-83
	Divisa	INA/G. Gonzalez, P. Argel	TRF	VI-84
	Los Santos	IDIAP/O. Duque, E. Vargas	TRF	IX-83
	Soná	IDIAP/E. Arosemena, L. Tasón, M. Flores	TRF	IX-83
	El Chepo	IDIAP/F. Garibaldo	TRF	IX-83
	Penonomé	IDIAP/E. Arosemena	TRF	VII-83
PARAGUAY	Eusebio Ayala	PRONIEGA-MAG/P. Valinotti, O.A. Molas	PDS	XII-83

* WDIS = Well-drained, isohyperthermic savanna; "LLanos"; WDTS = Well-drained, thermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical Rain Forest; TSSF = Tropical Semievergreen Seasonal Forest.

Table 4. Regional Trials B active during 1985.

Country	Site	Institution/Collaborator	Ecosystem*	Planting date
BOLIVIA	Peroto	IBTA/R. Baptista	TSSF	1984
	Yapacaní	CIAT/G. Vega, O. Velasco	TRF	II-85
	San Javier	CIAT/G. Vega	TRF	1985
BRAZIL	Boa Vista	EMBRAPA-UEPAT Boa Vista/ V. Gianluppi, R. Perin	WDIS	V-83
	Amarante	EMBRAPA-UEPAE Teresina/ G. Moreira	WDTS	I-84
	Barreiras	EPABA/L.A.B. de Alencar	WDTS	XI-82
	Campo Grande	EMBRAPA-CNPGC/M.I. Penteado	WDTS	XI-83
	Capinópolis	CEPET-UFV/C.P. Zago, M.E. da Cruz, C.M. da Rocha	WDTS	XII-83
	Felixlandia	EPAMIG/N.M. Sousa Costa	WDTS	XI-83
	Amapá	EMBRAPA-UEPAT Macapá/ A.P.Souza,P.R.Meirelles	WDTS	II-84
	Planaltina	EMBRAPA-CPAC/A.O. Barcellos, C.M.da Rocha, D.Thomas	WDTS	I-83
	Sao Carlos	EMBRAPA-UEPAE Sao Carlos/ L.A.Correa, R.Godoy,J.L. da Costa, C.M. da Rocha	WDTS	XII-83
	Vilhena	EMBRAPA-UEPAE Belém/C.A. Goncalves, C.M.da Rocha	WDTS	1984
	Teresina	EMBRAPA-UEPAE Teresina/L.C. Pimentel, G.M. Ramos	WDTS	1983
	Barrolandia II	CEPLAC-CEPEC/J.M. Pereira	TRF	III-83
	Barreiras II	EPABA/L.A.B. de Alencar	WDTS	XII-84
	Jaciara	EMPA/G.S. Lobo	WDTS	XI-83
	Goiania	EMGOPA/J.M. Sobrinho	WDTS	I-84
	Araguaina	EMGOPA/A. Braga	WDIS	XII-84
	Jataí	EMGOPA/E. Barbosa García	WDTS	1985
	Paragominas	EMBRAPA-CPATU/J.B. da Veiga, E.A. Serrao	TSSF	1983
COLOMBIA	Carimagua II	CIAT-La Reserva/P. Avila, R. Gualdrón	WDIS	IX-85
	Carimagua III	CIAT-La Alegría/P. Avila, R. Gualdrón	WDIS	IX-85
	Alto Menegua	CIAT/Regional Trials	WDIS	IV-83
	Bonanza	CIAT/Regional Trials	WDIS	IV-83
	Guadalupe	CIAT/Regional Trials	WDIS	IV-83
	Pachaquiaro	CIAT/Regional Trials	WDIS	IV-83
	Los Cerezos	ICA/J. Barros	WDIS	IV-84
	Magangué	CIAT/R.Botero, R.Posada	WDIS	V-84
	Amalfi	Sec.Agric.Ant./L.A. Giraldo	TSSF	IV-84
	El Rosario	CENICAFE/S. Suárez, H. Marín	TSSF	1984
	Gigante	CENICAFE/A. Suárez		

* WDIS = Well-drained, isohyperthermic savanna; "LLanos"; WDTS = Well-drained, thermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical Rain Forest; TSSF = Tropical Semievergreen Seasonal Forest.

Table 4. (Continued).

Country	Site	Institution/Collaborator	Ecosystem*	Planting date
	Paraguaicito	CENICAFE/S. Suárez, L.O. Arias	TSSF	V-83
	Supía	CENICAFE/S. Suárez, L.F. Machado	TSSF	V-83
	Palmira	ICA	TSSF	VI-84
	Quilichao II	CIAT/Regional Trials	TSSF	XI-82
	Quilichao III	CIAT/Regional Trials	TSSF	IV-85
	El Nus	ICA/F. Baez	TRF	IV-84
	Macagual (Florencia)	CIAT-ICA-U. Amazonía/ A.Acosta. R.Angulo, G.Collazos	TRF	IV-83
	La Libertad	ICA/P. Cuesta	TRF	IV-84
	Leticia	CIAT-Bat.Mixto/Regional Trials	TRF	XII-82
	Mutatá	ICA/H. Restrepo	TRF	IV-84
	Tulenapa	ICA/A. Mila	TRF	IV-84
	Villavicencio	CIAT-SEMILLANO/Regional Trials	TRF	IX-83
	Turipaná	ICA	TRF	V-84
	San Marcos	ICA	WDIS	V-84
	Motilonia	ICA/J. Barros	TSSF	V-84
	Caucasia	Sec.Agric.Ant./J. Marín	TSSF	1985
	Arboletes	Sec.Agric.Ant./E. Osorio	TRF	1985
	Puerto Berrío	Sec.Agr.Ant./O.Velásquez	TRF	1985
	Andes	Sec.Agric.Ant./A.Sánchez	TSSF	1985
	Villavicencio	CIAT-U.TECN.LLANOS/ J.C.Sánchez,G.Gómez	TRF	VI-85
	Las Leonas	CIAT/Regional Trials	WDIS	VI-85
COSTA RICA	Hojancha	MINAG-CORENA/J.J. Gómez, R. de Lucía	TRF	IX-83
CUBA	Las Tunas	ECP-MINAG/A. Gutiérrez, R.Juan, A.González	WDIS	1983
ECUADOR	El Napo II	INIAP/J.E.Costales, K.Muñoz	TRF	XI-83
	Coca	INIAP/J.E. Costales	TRF	1983
GUATEMALA	Alto Verapaz	CENTRO UNIV./O. Pineda	TRF	VIII-84
HONDURAS	La Esperanza	SEC.REC.NAT./L. Acosta, H. Cruz	TSSF	VI-83
	La Ceiba	CURLA/G. Valle	TRF	1983
MEXICO	Cintalapa	INIA-SARH/E. Espinoza, A. Peralta	WDIS	VII-84
	Huimanguillo	INIA-SARH/J.I. López	TSSF	VI-83

Table 4. (Continued).

Country	Site	Institution/Collaborator	Ecosystem*	Planting date
	Isla Veracruz	INIA-SARH/J.Enríquez	WDIS	VII-83
	Loma Bonita	INIA-SARH/J. Enríquez	WDIS	VIII-83
	Niltepec	INIA-SARH/A. Córdova, A. Peralta	WDIS	VII-83
	San Marcos	INIA-SARH/A. Peralta	WDIS	VI-84
	Tonalá	INIA-SARH/A. Cigarroa, J. Palomo	WDIS	VI-83
	Tomatlán	INIA-SARH/J.M. Mendoza	WDIS	VII-84
	Jericó	INIA-SARH/A. Cigarroa, J. Palomo	TSSF	VI-83
	La Huerta	INIA-SARH/H. Regla	TSSF	VII-85
	Villacorzo	INIA-SARH/J.G. Moreno, A. Peralta	TSSF	VIII-84
	Jalapa	INIA-SARH/S. Amaya	TRF	VII-83
	Acayucán	INIA-SARH/J. Enríquez	TSSF	VII-84
	Alvarado	INIA-SARH/J. Enríquez	WDIS	VIII-84
	Justicia Social	INIA-SARH/M. Sandoval	TSSF	VII-84
NICARAGUA	Puerto Cabezas	MIDINRA-DGTA/F. Zelaya, O. Miranda	TRF	1983
PANAMA	El Ejido	IDIAP/O. Duque, E. Vargas	TSSF	VII-84
PARAGUAY	Caapucú	PRONIEGA-MAG/P. Valinotti	WDIS	X-83
	Yguazú	AG.COOP.INT.JAPON/K. Yusa	TSSF	XII-84
PERU	Moyobamba	GECC-INIPA/E. Palacios, R. Díaz	TSSF	X-82
	Pucallpa II	IVITA/C. Reyes, H. Ordóñez	TSSF	I-83
	Tingo María	UNAS/E. Cárdenas	TRF	1983
	Pto. Bermúdez	INIPA-PEPP-NCSU/K. Reátegui	TRF	V-84
	Pumahuasi	INIPA-CIPA X/H. Ibazeta, K. Reátegui	TRF	1983
	Yurimaguas II	INIPA-NCSU/K. Reátegui	TRF	IX-83
	Tarapoto Coperholta II	INIPA-CIPA X/G. Silva, W. Lopez. J. Macedo	TSSF	I-83
	Tarapoto ESEP II	INIPA-CIPA X/G. Silva	TSSF	I-83
	Iscozacín	PEPP-PP/R. Pérez	TRF	V-84
	Satipo	UNA La Molina/E. Cuadros, M.Rosemberg, F.Passoni	TSSF	X-84
DOMINICAN REPUBLIC	Haras Nales.	CENIP-SEA/M. Germán	TSSF	XI-83
	Pedro Brand	CENIP-SEA/M. Germán	TSSF	VIII-83
	Valle Seybo	CENIP-SEA/M. Germán	TRF	IX-83
VENEZUELA	Colabozo	U.CENTRAL VENEZ./P. Arias	WDIS	V-83
	Espino	FONAIAP/L.A. Barreto	WDIS	VIII-82

Table 5. Regional Trials C active during 1985.

Country	Site	Institution/Collaborator	Ecosystem*	Planting date
BOLIVIA	Chimoré	CIF-UMSS/J. Espinoza, F. Gutiérrez	TRF	IV-82
BRAZIL	Barrolandia	CEPLAC-CEPEC/J. Ribeiro, J.M. Pereira, J.M. Spain, M. Moreno	TRF	XII-83
	Paragominas	EMBRAPA-CPATU/J.B. da Veiga, E.A. Serrao	TSSF	II-84
COLOMBIA	Quilichao II	CIAT/E.A.Pizarro, C.Lascano	TSSF	XI-83
	Caucasia	CIAT-UDEA/L.F. Ramírez	TSSF	XI-83
CUBA	San José de Las Lajas	ISCAH-MES/T. Ruiz, M. López, M. Monzote, L. Díaz	WDIS	1983
	San José de Las Lajas	ISCAH-MES/T. Ruiz, M. Monzote, G. Bernal	WDIS	1983
ECUADOR	El Napo	INIAP/K. Muñoz	TRF	VIII-83
MEXICO	Juchitán	INIA-SARH/A. Córdova, A. Peralta	WDIS	X-81
PANAMA	Chiriquí	FAUP/N. Pitty, M. Rodríguez, P. Argel	WDIS	VII-84
	Gualaca	IDIAP/C. Ortega, D. Urriola	WDIS	X-84
PERU	Pulcallpa	IVITA/H. Huamán	TSSF	X-83
	Pto. Bermúdez	INIPA-PEPP-NCSU/K. Reátegui	TRF	XII-84

* WDIS = Well-drained, isohyperthermic savanna; "LLanos"; WDTS = Well-drained, thermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical Rain Forest; TSSF = Tropical Semievergreen Seasonal Forest.

Table 6. Regional Trials D active during 1985.

Country	Site	Institution/Collaborator	Eco-system*	Planting date
BRAZIL	Boa Vista	EMBRAPA-UEPAT Boa Vista/ V.Gianluppi, J.D.Santos	WDIS	V-82
	Macapá	EMBRAPA-UEPAT Macapa/ E.A. Serrao, A.P. Souza	WDIS	1982
	Paragominas	EMBRAPA-CPATU/M.B. Dias, E.A.Serrao,J.B.da Veiga	TSSF	1982
	Rio Branco	EMBRAPA-UEPAE Rio Branco/ J. Pagani	TSSF	1984
	Porto Velho	EMBRAPA-UEPAE Porto Velho/ C.A. Goncalves	TSSF	IX-84
COLOMBIA	La Libertad	ICA/R. Pérez	TRF	1984
	La Romelia	CENICAFE/S.Suárez, J.Rubio, C. Franco	TSSF	XII-84
	Quilichao	CIAT/C. Lascano, E.A. Pizarro	TSSF	V-85
CUBA	Indio Hatuey	MES/C.A. Hernández, A.Alfonso, P.Duquesne	WDIS	IX-83
ECUADOR	El Napo	INIAP/K. Muñoz, J.Costales	TRF	1983
PANAMA	Calabacito	IDIAP-CIAT/E. Arosemena, P. Argel	TSSF	1984
	Gualaca	IDIAP/C. Ortega, D.Urriola	WDIS	X-83
PERU	Pucallpa I	IVITA/A. Riesco, C. Reyes, H. Huamán	TSSF	II-83

* WDIS = Well-drained, isohyperthermic savanna; "LLanos"; WDTS = Well-drained, thermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical Rain Forest; TSSF = Tropical Semievergreen Seasonal Forest.

Table 7. Support Regional Trials active during 1985.

Country	Site	Institution/Collaborator	Ecosystem*	Type of Trial
BOLIVIA	Chipiriri	IBTA/A.Ferrufino, F.Saavedra, A. Vallejos	TRF	Establishment and pests
BRAZIL	Paragominas	EMBRAPA-CPATU/J.B.Da Veiga, E.A. Serrao	TSSF	Fertilization
	Cerrados	EMBRAPA-CPAC/G.W. Cosenza	WDTS	Pests and diseases
	Diamantina	EPAMIG/N.M. Sousa Costa	WDTS	Diseases
CUBA	San José de Las Lajas	ISCAH-MES/T.Ruiz, L.E.Díaz	WDIS	Establishment
	San José de Las Lajas	ISCAH-MES/M.Monzote, T.Ruiz, M.López	WDIS	Establishment
	San José de Las Lajas	ISCAH-MES/T.Ruiz, M.Monzote, G. Bernal	WDIS	Evaluation of associated pastures
	San José de Las Lajas	ISCAH-MES/M.López	WDIS	Inoculation
	San José de Las Lajas	ISCAH-MES/A.Barrientos	WDIS	Pests and diseases
	Villa Clara	MES/J.Menéndez, H.Méndez	WDIS	Evaluation of associated pastures
	Indio Hatuey	MES/J.Menéndez, S.Vega	WDIS	Evaluation of associated pastures
	Indio Hatuey	MES/Y.González, C.Matías	WDIS	Seed production .
ECUADOR	El Napo	INIAP/K.Muñoz	TRF	Pests and diseases
MEXICO	--	INIA-SARH/J.I. López	WDIS	A.g. fertilization
	--	INIA-SARH/J.I. López	WDIS	B.d. fertilization
	Tabasco	INIA-SARH/S. Amaya	TRF	Fertilization
PANAMA	Calabacito	IDIAP/H.Aranda, P.Argel	TRF	Establishment
	Chiriquí	IDIAP/D.Urriola, P.Argel, C. Ortega	WDIS	Pests and diseases
PERU	Puerto Bermúdez	INIPA-PEPP-NCSU/K.Reátegui	TRF	Pests and diseases
	La Esperanza	INIPA-PEPP-NCSU/K.Reátegui	TRF	Pests and diseases
	Tarapoto	INIPA-CIPA X/C.Valles	TSSF	Pests and diseases
	Tarapoto	INIPA-IST/R.Hernández, W.López	TSSF	Pests and diseases
	Tarapoto	INIPA-CIPA X/C.Valles	TSSF	Pests and diseases
VENEZUELA	Guachí	LUZ-CORPOZULIA/I.Urdaneta, R.Paredes	TSSF	Evaluation of associated pastures
	Lago Maracaibo	LUZ-CORPOZULIA/I.Urdaneta	TSSF	Trials in pilot farms

Table 8. Average production of legumes in the Cerrados ecosystem. 1983-1984.

Legumes*	Maximum precipitation period kg DM/ha, 12 weeks	Minimum precipitation period kg DM/ha, 12 weeks
Centrosema sp.	1745 ± 8	1192 ± 339
S. capitata	3265 ± 421	535 ± 68
S. guianensis var. vulgaris	2898 ± 1061	1747
S. guianensis var. pauciflora	3659 ± 755	1356 ± 180
S. macrocephala	4532 ± 841	430 ± 74

* Centrosema sp. (CIAT 5112. local); S. capitata (CIAT 1019, 1097, 1318, 2252); S. guianensis var. pauciflora (CIAT 1095, 1297, 2191, 2203, 2244, 2245); S. macrocephala (CIAT 1281, 2039, 2053, 2271, 2732, 10325); S. guianensis var. vulgaris (CIAT 2746, 2747).

materials during the period of maximum precipitation have been the least productive during the dryest period (Table 9). Among these Centrosema sp. and S. guianensis var. pauciflora are the most outstanding with 40 and 27% of the production concentrated during the period of least precipitation, respectively.

Preliminary observations for this first year of the 12 RTB's established in this ecosystem in a range from 3°15'N to 22°01'S and from 15 to 1150 masl, in Oxisols and Ultisols, indicate that species considered "key" (S. guianensis var. vulgaris; S. guianensis var. pauciflora; S. capitata; S. macrocephala; S. viscosa) in the major selection center, EMBRAPA-CPAC (Planaltina, Brazil) have a broad adaptability and also shows that species selected under low fertility soil conditions seem to have the capacity to respond to conditions of higher fertility.

To date, few problems with pests and diseases have been observed, except for the severe incidence of anthracnose on S. capitata in some localities (i.e., Amarante-Piauí) where native plants of this species are abundantly found surrounding the trial.

Well-drained isohyperthermic savannas "Llanos"

Regional trials type B (RTB) have been established in various localities with a new list of germplasm. After competing two years of evaluation, analysis of variance were conducted to assess the accumulated production of DM at 12 weeks in each ecotype during the periods of maximum and minimum precipitation, the maintenance production index, and the efficiency of DM production in relation to the precipitation during the period for which it was estimated.

Table 10 summarizes mean dry matter production of two years of evaluation for forage grasses and legumes common to five localities. During the period of minimum precipitation, A. gayanus 6200 had a superior production when compared to the rest of the

Table 9. Percentage production of forage legumes during the period of minimum precipitation in the Cerrados ecosystem, 1983-1984.

Legumes*	%
Centrosema sp.	40 ± 7.1
S. capitata	14 ± 0.5
S. guianensis var. pauciflora	17 ± 3.9
S. macrocephala	9 ± 2.6

* Centrosema sp. (CIAT 5112. local): S. capitata (CIAT 1019, 1097, 1318, 2252); S. guianensis var. pauciflora (CIAT 1095, 1297, 2191, 2203, 2244, 2245); S. macrocephala (CIAT 1281, 2039, 2053, 2271, 2732, 10325).

Brachiaria spp., while during the period of maximum precipitation, Brachiaria spp. presented a mean productivity superior (1473 ± 594) to the overall media of the ecosystem. B. dictyoneura 6133 was the most outstanding with a yield almost twice that of the overall media of the ecosystem and four times greater than that shown by the native savanna.

Average dry matter production for legumes was almost three times less during the period of minimum precipitation than during maximum precipitation. This result is partly due to the drastic conditions during the second year of evaluation, when precipitation was almost null. In any case, this once more proved the persistence and production efficiency of certain materials, especially S. capitata (Tables 11 and 12).

Table 11 summarizes the production stability index (PSI) for grasses and legumes. During the period of minimum precipitation, grasses had a PSI= 0.2, being B. humidicola 6369 the most outstanding with a 0.6 value. For the period of maximum precipitation, almost all grasses maintained their production and again another ecotype of B. dictyoneura, 6133 was the most outstanding with a PSI = 1.6, which was superior to the overall average of the rest of the grasses under evaluation.

Legumes drastically reduced their production in the second year due in part to the already mentioned unusual dry period that lasted from the end of November, 1984, to mid-March, 1985. For the period of maximum precipitation, the average PSI was 0.9, ranging from 0.1 for D. incanum 13032 to 2.6 for S. capitata 1441. The only legumes with a PSI equivalent to or higher than 1 were the Stylosanthes ecotypes, with values of 1.1 for S. capitata 10280 cv. "Capica", 1.2 for S. macrocephala 1643, 1.5 for S. capitata 2044, and 2.6 for S. capitata 1441.

Table 12 has information on productivity efficiency expressed in kg DM/ha per millimeter of rainfall during the 12-week evaluation period. Four of 11 grasses under evaluation presented efficiencies superior to the average for the period of maximum precipitation: B. dictyoneura 6133, A. gayanus 6200, B. humidicola 679, and A. gayanus 621, with values of 4.7, 6.2, 7.7, and 10.0, respectively. During the period of minimum precipitation, the same materials are outstanding, this time including B. brizantha 6294 in the list. In both evaluation periods, ecotypes of A. gayanus 621 and 6200 obtained the highest indexes, duplicating the overall average. During the period of maximum precipitation, legumes showed an average of 1.89, ranging from 0.3 for D. incanum 13032 to 3.0 for S. capitata 10280 cv. "Capica". Legumes with an efficiency equal to or superior to the media are: C. macrocarpum 5062, 5065; Centrosema sp. 5278; D. ovalifolium 3784, P. phaseoloides 9900, and S. capitata 10280 cv. "Capica".

During the period of minimum precipitation, the average for all ecotypes under evaluation was 1.0; C. macrocarpum 5062; Z. glabra 7847, S. macrocephala 2133, and Centrosema sp. 5278 presented values superior to the

Table 10. Average dry matter production of forage grasses and legumes, 12 weeks after regrowth, during two years of evaluation in the Llanos ecosystem, 1983-1985.

Ecotype	CIAT No.	DM (kg/ha)	
		Min.precipitation	Max.precipitation
GRASSES			
A. gayanus	6200	1355 a	1591 b
B. humidicola	6705	758 ab	1839 b
B. dictyoneura	6133	742 ab	2802 a
B. brizantha	6294	695 ab	1349 bcd
B. humidicola	6369	673 ab	1099 cde
B. brizantha	664	636 b	1097 cde
B. decumbens	6699	560 b	1419 bc
B. decumbens	6700	551 b	1053 cde
B. humidicola	6707	460 b	1743 b
B. ruziziensis	6419	330 b	860 de
Native savanna	--	215 b	673 e
OVERALL AVERAGE		642	1453
LEGUMES			
S. capitata	2044	252 bc	1385 a
S. capitata	10280	473 abc	1364 a
Z. brasiliensis	7485	430 abc	1243 a
Centrosema sp.	5278	533 ab	1185 a
S. capitata	1441	400 abc	1153 a
S. macrocephala	1643	240 bc	1033 a
C. macrocarpum	5062	230 bc	924 a
S. macrocephala	2133	404 abc	828 ab
D. ovalifolium	3784	368 abc	694 ab
S. macrocephala	1582	401 abc	652 ab
Z. glabra	7847	587 a	633 ab
D. incanum	13032	200 c	164 b
OVERALL AVERAGE		382	995

average (1.3, 2.2, 2.4 and 3.1, respectively).

The average efficiency of dry matter production per millimeter of rain during the evaluation period for grasses and legumes, as well as the precipitation during the periods of evaluation are summarized in Table 13.

During the period 1980-1985 evaluations were carried out for pests and diseases in seven localities of the Llanos ecosystem (Table 14).

Over a period of five years, it is demonstrated that diseases are not a problem for grasses, even though chewing insects and especially spittlebugs have become an important problem. Overall, we can say the most important diseases by genera are: anthracnose in Stylosanthes guianensis; Sphaceloma scab and Drechslera leaf spot in Zornia; Cercospora leaf spot and Rhizoctonia foliar blight in Centrosema; and nematodes in Desmodium. Regarding pests, results show damages of importance caused by sucking insects

Table 11. Yield stability index (YSI)* of forage grasses and legumes in the Llanos ecosystem, 1983-1985.

Ecotypes	CIAT No.	Minimum precipitation kg DM/ha Year 1	YSI	Maximum precipitation kg DM/ha Year 1	YSI
GRASSES					
B. dictyoneura	6133	1242	0.2	1987	1.6
B. humidicola	6705	1114	0.3	1604	1.3
B. humidicola	6707	733	0.3	1561	1.2
A. gayanus	6200	2577	0.1	1685	0.9
B. decumbens	6699	1014	0.1	1412	1.0
B. brizantha	6294	1122	0.2	1254	1.2
B. humidicola	6369	792	0.6	1018	1.2
B. brizantha	664	1048	0.2	1002	1.2
B. decumbens	6700	843	0.3	1048	1.0
B. ruziziensis	6419	529	0.1	872	1.0
OVERALL AVERAGE		1101	0.2	1344	1.2
LEGUMES					
Centrosema sp.	5278	965	0.1	1470	0.6
Z. glabra	7847	1020	0.0	740	0.7
S. capitata	10280	945	0.0	1293	1.1
Z. brasiliensis	7485	837	0.0	1401	0.8
S. macrocephala	2133	794	0.0	1186	0.4
S. macrocephala	1582	801	0.0	762	0.7
D. ovalifolium	3784	673	0.1	920	0.4
S. capitata	1441	677	0.0	618	2.6
S. capitata	2044	503	0.0	1111	1.5
S. macrocephala	1643	480	0.0	952	1.2
D. incanum	13032	480	0.0	300	0.1
C. macrocarpum	5062	460	0.0	1259	0.5
OVERALL AVERAGE		720	0.02	1001	0.9

$$* \quad YSI = \frac{\text{kg DM/ha, 12 weeks, year 2}}{\text{kg DM/ha, 12 weeks, year 1}}$$

in genera of *Stylosanthes*, *Zornia*, *Centrosema*, *Desmodium*, *Pueraria*, and *Brachiaria*, and budworms in *Stylosanthes*.

Tropical forest ecosystems

Results of RTA's established in the tropical forest ecosystem are presented in Table 15. Information of the following localities is summarized: La Ceiba-Honduras; Itabela-Brazil; Macagual-Colombia; Paragominas-Brazil; and Puerto Cabezas-Nicaragua. Table 16 shows the percentage of forage grasses and legumes selected in each of the localities mentioned, having a degree of adaptability equal or superior to good and a degree of coverage of the area of the experimental plot equal to or greater than 40%. Values found in this evaluation period are similar to those obtained in RTA's in other localities within the same ecosystem (see Annual Report 1984, page 77).

Based on the information obtained from approximately 40 RTB's, in this ecosystem, which have been under

Table 12. Dry matter production efficiency in the Llanos ecosystem, 1983-1985.

Ecotypes	CIAT No.	DM (kg/ha/mm) Max. precip.	Min. precip.
GRASSES			
A. gayanus	621	10.0 a	--
B. humidicola	679	7.7 b	5.3 b
A. gayanus	6200	6.2 bc	13.3 a
B. dictyoneura	6133	4.7 cd	4.9 b
B. brizantha	664	3.8 de	3.5 b
B. humidicola	6705	1.8 ef	3.4 b
B. humidicola	6707	1.5 f	2.2 b
B. humidicola	6369	1.3 f	2.4 b
B. brizantha	6294	1.2 f	5.0 b
B. decumbens	6700	1.0 f	3.4 b
B. ruziziensis	6419	1.0 f	1.7 b
OVERALL AVERAGE		4.6	4.7
LEGUMES			
S. capitata	10280	3.0 a	0.9 cd
P. phaseoloides	9900	2.6 ab	0.0 d
C. macrocarpum	5062	2.5 ab	1.3 bc
D. ovalifolium	3784	2.3 abc	0.4 cd
Centrosema sp.	5278	1.9 abcd	3.1 a
C. macrocarpum	5065	1.8 abcd	0.0 d
Z. brasiliensis	7485	1.4 bcde	--
Z. glabra	7847	1.1 cde	2.2 ab
S. macrocephala	2133	1.0 cde	2.4 ab
S. capitata	2044	0.9 de	0.4 cd
S. macrocephala	1643	0.9 de	0.8 cd
S. capitata	1441	0.6 de	0.1 cd
S. macrocephala	1582	0.5 de	0.8 cd
D. incanum	13032	0.3 e	0.2 cd
OVERALL AVERAGE		1.8	1.0

evaluation for more than two years, the same type of analysis mentioned for the information collected in the Llanos ecosystem has been carried out.

Table 17 shows that A. gayanus 621 and B. humidicola 679 are the most stable grasses in terms of productivity over time, while B. decumbens 606, probably due to its susceptibility to the spittlebug, obtained values lower than 1 in both evaluation periods.

The most outstanding legumes for their yield stability are S. guianensis 136, C. macrocarpum 5065, C. pubescens 438, Z. latifolia 728, and D. ovalifolium 3784 which show a PSI superior to the overall average of the ecosystem during the period of maximum precipitation. During the period of minimum precipitation the PSI was smaller for almost all the legumes under evaluation.

Table 13. Dry matter production efficiency in the Llanos ecosystem.

Parameters	DM (kg/ha/mm)	
	Minimum precipitation	Maximum precipitation
GRASSES	4.7	4.6
CV (%)	70	33
Average precipitation (mm)	181 ± 155	815 ± 324
LEGUMES	1.0	1.8
CV (%)	82	45
Average precipitation (mm)	106 ± 46	815 ± 324

An analysis was conducted to evaluate the range of adaptability of the ecotypes common to the different localities. The method of Eberhart and Russel was used, whose reference, modification, and steps followed are described in the Tropical Pastures Program 1981 Annual Report, pp. 57-66. Table 18 shows the values of slope "b", representing the capacity of response of the ecotype to different environments within the ecosystem, and the intercept "a", representing the mean productivity of the ecotype for the ecosystem. A superior mean productivity is observed for grasses. A. gayanus 621 and B. humidicola 679 have values for "b" superior to the rest of the grasses during the period of maximum precipitation and smaller during the period of minimum precipitation. In average, the most productive legumes were: S. guianensis 64 A, 191, 1283, and 136 during the period of maximum precipitation, while during the period of minimum precipitation the productivity of legumes was very similar, with the exception of S. capitata 10280 cv. "Capica" which is the least productive. The same table presents the significative adaptability indexes "b" for both evaluation periods. These "b" values, the same as those in previous analyses (see Annual Reports 1983 and 1984) tend to be higher when the yields of the ecotype are higher.

Table 19 presents the results on production efficiency of dry matter accumulated during 12 weeks in relation to the precipitation occurred during the evaluation period. Overall, grasses and legumes are more efficient during the period of minimum precipitation, confirming results for this ecosystem obtained by various collaborators. Among grasses, A. gayanus 621 is the most outstanding during the period of maximum precipitation and A. gayanus 621, B. dictyoneura 6133 and B. decumbens 606 during the period of minimum precipitation. Among legumes, S. guianensis 64A is the most outstanding with an index two times superior to the overall average of all the legumes. During the period of minimum precipitation, 56% of the legumes evaluated showed an efficiency superior to the average.

In the period 1980-1985, the most important diseases detected were: Cercospora spp. leaf spot and Rhizoctonia foliar blight in Centrosema; root nematodes in Desmodium; Cescospora leaf spot and smut caused by Tilletia ayresii in Panicum. The most important pests in this ecosystem were: sucking insects for Stylosanthes, sucking and chewing insects for Centrosema spp., and spittlebug for Brachiaria spp. and Panicum spp.

Table 14. Diseases and pests detected and identified in the savanna ecosystem, 1980-1985.

Forages	Pests	Diseases
GRASSES		
B. decumbens	Spittle bug	--
B. dictyoneura	Chewing insects	--
LEGUMES		
A. histrix	Flea Beetles	Anthracnose
C. brasilianum	Thrips, Flea beetles, Chewing insects	Cercospora, Rhizoctonia
C. macrocarpum	Flea beetles, Chewing ins.	Cercospora
C. pubescens	Flea beetles, Chewing ins.	Cercospora
Centrosema sp.	Thrips, Flea beetles, Chewing insects	Bacteriosis
D. ovalifolium	Chewing insects	Nematodes
C. gyroides	Flea beetles, Chewing ins.	Cercospora, Rhizoctonia
P. phaseoloides	Thrips, Chewing ins.	Anthracnose, Cercospora
S. capitata	Flea beetles, Chewing ins.	--
S. guianensis	Flea beetles	Anthracnose
S. macrocephala	Flea beetles	--
S. leiocarpa	Flea beetles	Anthracnose
Z. brasiliensis	Flea beetles	--
Z. glabra	Thrips, Flea beetles, Chewing insects	Anthracnose
Z. latifolia	Thrips, Chewing insects	Anthracnose, Drechslera

Table 15. Forage grasses and legumes having a degree of adaptation equal to or better than "good" and coverage equal to or greater than 40% in Regional Trials A in the forest ecosystem, 1982-1985.

Ecotypes	CIAT No.
GRASSES	
Andropogon gayanus	621, 6053, 6054, 6265
Brachiaria brizantha	664
Brachiaria decumbens	606
Brachiaria dictyoneura	6133
Brachiaria humidicola	679, 6369
Brachiaria ruziziensis	6019
Panicum maximum	604, 622, 673, 697
LEGUMES	
Centrosema sp.	5112, 5118, 5277
Centrosema brasilianum	494, 5234
Centrosema macrocarpum	5062, 5065, 5434, 5452, 5629
Centrosema pubescens	438, 5126, 5172, 5189
Desmodium heterophyllum	349
Desmodium ovalifolium	350, 3673, 3784
Leucaena leucocephala	17475, 17488, 17491, 17498, 17502
Pueraria phaseoloides	7979, 9900, 17303
Stylosanthes guianensis var. vulgaris	136, 184, 1175
Stylosanthes guianensis var. pauciflora	1280, 1283
Zornia glabra	7847

Table 16. Percentage of forage grasses and legumes selected for their degree of adaptation equal to or better than "good" and coverage equal to or greater than 40% in Regional Trials A in the forest ecosystem, 1982-1985.

Sites	Grasses	Legumes
La Ceiba, Honduras	80	39
Itabela, Brazil	50	42
Macagual, Colombia	17	27
Paragominas, Brazil	70	41
Puerto Cabezas, Nicaragua	83	38
Overall average	60 ± 27	37 ± 6

Future activities

The strengthening of the RIEPT observed during past years has resulted in greater participation and leadership of the Advisory Committee. This was demonstrated in the III General Meeting of the RIEPT carried out during October, 1985. It was mentioned that a continuous growth and coverage of the trials at the grazing level could only be carried out when national institutions had a positive activity in seed multiplication of germplasm which demonstrated to be promising in each of the localities. At the same time a diagnosis study was suggested for the current status of pasture evaluation in each of the countries in the RIEPT and an analysis of the natural resources. This study was suggested by the national leaders and will be the main subject to be discussed in the IV Meeting of the Advisory Committee to be held in 1986.

Table 17. Yield stability index (YSI)* of forage grasses and legumes in the forest ecosystem, 1982-1985.

Ecotypes	CIAT No.	Max. precipitation		Min. precipitation	
		kg DM/ha Year 1	YSI	kg DM/ha Year 1	YSI
GRASSES					
B. dictyoneura	6133	5154	0.7	2815	0.7
A. gayanus	621	3227	1.2	2836	0.8
B. decumbens	606	3016	0.7	3251	0.5
B. humidicola	679	2178	1.0	1658	1.1
OVERALL AVERAGE		3394	0.9	2640	0.8
LEGUMES					
Z. latifolia	9199	4117	0.5	--	--
S. guianensis	64A	3202	0.7	2151	0.7
C. macrocarpum	5062	2440	0.9	904	1.1
S. guianensis	191	2338	0.9	2100	0.7
S. guianensis	1283	2373	0.8	1818	1.0
Z. glabra	7847	2182	0.9	1688	0.9
C. macrocarpum	5065	1845	1.1	--	--
Centrosema sp.	5112	2292	0.7	1798	0.8
A. histrix	9690	1861	1.0	1143	1.0
S. guianensis	136	1705	1.2	1739	0.6
D. ovalifolium	350	1752	1.0	2169	0.7
Z. latifolia	728	1371	1.3	1973	0.6
C. pubescens	5189	1452	1.0	1173	1.0
C. pubescens	438	989	1.4	1189	1.0
S. capitata	10280	1326	0.6	992	0.5
P. phaseoloides	9900	1037	1.1	1751	0.4
D. ovalifolium	3784	693	2.0	1125	0.7
C. brasilianum	5234	890	1.0	1240	0.7
OVERALL AVERAGE		1881	1.0	1560	0.8

$$* \text{ YSI} = \frac{\text{kg DM/ha, 12 weeks, year 2}}{\text{kg DM/ha, 12 weeks, year 1}}$$

Table 18. Adaptability index (b) of grasses and legumes in the tropical forest ecosystem[a], 1982-1985.

Ecotypes	CIAT No.	Maximum precipitation			Minimum precipitation		
		a (kg DM/ha)[b]	b	r^2 (%)	a (kg DM/ha)[b]	b	r^2 (%)
GRASSES							
A. gayanus	621	6985	1.35	58**	3513	0.68	56*
B. decumbens	606	5716	0.75	88**	4640	0.90	29NS
B. dictyoneura	6133	5432	0.49	51*	3168	0.84	73**
B. humidicola	679	4896	1.16	82**	1716	0.68	77*
LEGUMES							
S. guianensis	64A	5344	0.98	80**	1651	1.31	93**
S. guianensis	191	4899	1.10	96**	1951	1.22	99**
S. guianensis	1283	4217	0.95	95**	1818	0.89	91*
S. guianensis	136	4046	0.91	88**	1967	0.83	80**
D. ovalifolium	350	3828	0.90	95**	1927	1.55	89**
Centrosema sp.	5112	3461	1.10	99**	1766	1.01	81**
A. histrix	9690	3394	0.84	88**	1168	0.58	67**
C. macrocarpum	5065	3261	1.22	96**	--	--	--
C. pubescens	5189	3173	1.25	98**	1743	0.94	77**
D. ovalifolium	3784	2806	0.97	87**	1302	1.09	76**
C. pubescens	438	2724	1.04	97**	1524	0.77	83**
Z. glabra	7847	2667	0.97	92**	1980	1.33	57**
S. capitata	10280	2493	0.72	81**	902	0.41	43*
Z. latifolia	728	2375	0.81	48*	2014	1.32	90**
C. macrocarpum	5062	2036	0.88	87**	1248	1.22	62**
C. brasilianum	5234	1966	0.88	94**	1494	0.88	70**
P. phaseoloides	9900	--	--	--	1422	0.92	66**

a/ 95% confidence interval of b around 1:
Legumes: max. precipitation = (0.79, 1.21)
min. precipitation = (0.58, 1.42)

b/ At 12 weeks regrowth

* Significant regression at 95% confidence ($0.01 < P \leq 0.05$)
** Significant regression at 99% confidence ($P \leq 0.01$)
NS = Not significant.

Table 19. Dry matter production efficiency in the tropical forest ecosystem, 1982-1985.

Ecotypes	CIAT No.	DM kg/ha/mm	
		Max. precip.	Min. precip.
GRASSES			
A. gayanus	621	12.0 a	21.0 ab
B. dictyoneura	6133	9.0 b	22.0 ab
B. decumbens	606	8.0 b	27.0 a
B. humidicola	679	7.0 b	13.0 b
OVERALL AVERAGE		9.0	23.0
LEGUMES			
S. guianensis	64A	7.0 a	12.7 cde
S. guianensis	191	4.5 b	18.7 ab
S. guianensis	1283	4.4 b	13.2 cd
D. ovalifolium	350	3.9 bc	13.6 cd
Z. glabra	7847	3.8 bc	21.5 a
Centrosema sp.	5112	3.5 bcd	11.3 def
C. macrocarpum	5062	3.5 bcd	15.7 b
C. macrocarpum	5065	3.5 bcd	--
Z. latifolia	728	2.9 cde	12.7 cde
S. guianensis	136	2.8 cdef	10.3 def
C. pubescens	5189	2.5 def	13.1 cd
A. histrix	9690	2.5 def	8.8 ef
D. ovalifolium	3784	2.3 ef	11.7 def
S. capitata	10280	2.3 ef	4.4 g
C. pubescens	438	1.8 fg	10.2 def
C. brasilianum	5234	1.1 g	9.0 ef
P. phaseoloides	9900	--	8.0 f
OVERALL AVERAGE		3.0	11.7

Entomology

The Entomology section has continued the systematic evaluation of material from the germplasm bank, concentrating on the search for tolerance or resistance to the principal pests of pasture grasses and legumes: budworm, Stegasta bosquella; stemborer Caloptilia sp.; ants, Atta and Acromyrmex spp.; and various species of spittlebug. These studies, including studies of population dynamics and damage caused by these pests, cover the major ecosystems of tropical Latin America. Results from regional trials of RIEPT have been included with the cooperation of other national institutions.

EVALUATIONS OF THE BUDWORM Stegasta bosquella

In the greenhouse, several accessions of Stylosanthes capitata, S. macrocephala, S. guianensis, and S. leiocarpa were evaluated for oviposition preference, percent larval infestation, percent damage to inflorescences and seeds, and to validate the evaluation methodology.

During the 1984 and 1985 evaluations, significant differences were observed between species in oviposition preference. S. leiocarpa was least preferred and the most oviposition occurred in the S. capitata accessions (Table 1).

The species more preferred for oviposition were those that showed higher levels of damage in the inflorescences or buds, in this case the S. capitata accessions (97 and 75% damage). Since no differences were found in the percentage of damaged seed (Table 2), reduction of seed yield is determined by damage to inflorescences and buds.

Table 1. Preference of the oviposition of Stegasta bosquella in Stylosanthes spp. in greenhouse conditions.

Species	No.of eggs/10 buttons 1984	1985
S. capitata	2.4 a	2.1 a
S. macrocephala	2.3 a	2.0 a
S. guianensis	1.1 b	1.9 a
S. leiocarpa	1.5 b	1.5 b

Treatments with same letter are not statistically significant at $P < 0.05$.

Continuing with evaluations in the greenhouse with selected ecotypes of S. guianensis (Table 3), it was observed that accessions 1539 and 1639 were most preferred for oviposition. However, greater larval infestation was found in accessions 15, 1539 and 2031, accessions that also showed the highest percentage of damaged buds. Seed damage was much greater in accession 15 (42%) compared to accession 1539 (18.4%). The remaining accessions (e.g. 1275) had little or no seed damage.

Table 2. Damage caused by *Stegasta bosquella* to inflorescences and seed of *Stylosanthes* spp. in the greenhouse.

Species	1984 % Damaged Buds	1984 % Seed damage	1985 % Damaged Buds	1985 % Seed damage
S. capitata	97 a	38 a	75 a	35 a
S. macrocephala	88 ab	53 a	58 b	39 a
S. guianensis	56 b	31 a	69 a	29 a
S. leiocarpa	84 ab	56 a	26 b	–

Treatments with same letter are not statistically significant at $\alpha = 0.05$.

Table 3. Average evaluation* of *Stegasta bosquella* in ecotypes of *S. guianensis* in the greenhouse.

Identification	No. CIAT	% Damaged Buds	% Damaged seed	Eggs/ Bud	Larvae/ Bud	% Infestation
FM-12	2222	28.9	6.9	0.1	0.2	20.0
FM-32	1808	28.9	9.0	0.2	0.2	20.0
FM-36	1317	15.6	6.9	0.2	0.2	16.7
FM-52	15	57.8	42.6	0	0.5	53.3
FM-54	1539	53.3	18.4	0.5	0.3	33.3
FM-56	1639	23.3	8.2	0.3	0.2	20.0
FM-119	2031	35.6	12.4	0.2	0.3	33.3
FM-122	1275	0	0	0	0	0
FM-159	2639	24.4	6.7	0.2	0.1	13.3

* 3 Repetitions.

Accessions 15 and 1539 were most preferred and accessions 1275 and 2639 were least preferred among the material tested.

The highest populations of Stegasta occur during the dry season when Stylosanthes is in flower. S. guianensis is the most susceptible species.

In 1985, the population of Stegasta was less than the previous year at Santander de Quilichao, Cauca (Table 4). The presence of adults in the field is most easily observed.

However, it is necessary to observe larval infestations since the presence of adults does not necessarily correspond with damage to buds and seed. For example, C-161 (1122 x 2362) had 20% larval infestations resulting in 30% damaged buds and 32% damaged seed while C-162 (1122 x 2222) had 10% larval infestation, 82% damaged buds, and 35% damaged seed. C-179 (1122 x 1808 x 0015, F_3) had high levels of damage to buds and seed (73 and 62%), C-162 (1122 x 2222) had a high level of damaged buds but low seed damage (82% and 35%), and C-161 (1122 x 2362) had low levels of damage

Table 4. Average evaluation* of Stegasta bosquella, in crosses of S. guianensis F_2 to F_3, in Santander de Quilichao, 1985.

No.Cross	Parents (No.CIAT)	% damaged buds		Total No. seed/30 buds		% damaged seed		Larvae/ 30 buds		% Infestation	
		1**	2	1	2	1	2	1	2	1	2
C-161	1122 x 2362	30.0	20.0	51.0	59.5	32.4	14.3	6.0	4.0	20.0	13.3
C-162	1122 x 2222	87.1	18.3	56.5	48.0	34.6	13.5	3.0	4.0	10.0	13.3
C-163	1122 x 2222	55.0	18.3	55.5	56.5	23.8	10.6	4.0	3.0	13.3	10.0
C-179	1122 x (1808 x 0015, F_3)	73.3	38.3	108.0	94.5	61.7	18.0	8.5	8.0	28.3	25.6
C-334	10136 x desconoc.	53.3	15.0	57.5	57.5	48.6	12.2	9.0	4.5	30.0	15.0
C-381	10136 x (1808 x 0015, F_3)	55.3	11.7	70.5	54.5	25.1	10.1	3.5	2.0	9.1	6.7
C-383	10136 x (1808 x 0015, F_3)	41.7	16.7	83.5	75.0	25.1	7.9	3.0	2.0	10.0	6.7

* 2 repetitions.
** 15 day interval between evaluations 1 and 2.

to both buds and seed (30 and 32%). Evaluations are continuing and the methodology will be analyzed for possible improvements. Changes already implemented include increasing the initial infestation to 30 adults/plant to obtain greater oviposition and increasing the sample size to 30 buds/plant. Each bud must have at least 1 formed seed in order to measure damage.

EVALUATION OF STEMBORER, Caloptilia sp.

Field evaluations at Carimagua of stemborer in S. capitata and S. macrocephala associated Andropogon gayanus have shown that the greatest infestation occurs at the base of the plant. To avoid destructive sampling, infestation was measured by counting the number of entrance holes made by larvae in the stems (Table 5). A large amount of variation among ecotypes was observed ranging from no damage (e.g. S. macrocephala 1643), 1 to 20% damage (S. capitata 1318), and > 60% damage (S. capitata 25, 27, and 1693).

There was no relation between infestation and percent damage. We hope to obtain more information to correlate these parameters. The mean duration of the larval stage in the stem is 58 days. The larva destroys the vascular tissues and causes a decline in plant vigor, productivity, and persistence.

In trials of S. guianensis in 2 associations (native savanna and A. gayanus), the percentage of plants attacked was higher for those plants with larger stem diameter (Table 6). Plants with slender stems were less affected. Evaluations will continue in 1986 to confirm the relation between Caloptilia and stem diameter.

EFFECTS OF BURNING AND SOIL PREPARATION ON LEAF-CUTTINT ANTS

In Carimagua (Llanos Orientales), 2 genera of leaf-cutting ants have been identified. Atta laeviagata is larger and forms a conical mound commonly called "bachaquero" with soil extracted from the nest. Acromyrmex sp. are smaller and construct an entrance tunnel from pieces of straw.

Initiation of colonies occurs at the beginning of the rainy season. Precipitation is greatest during the months of June and July when the greatest number of ant colonies are observed. Fewer colonies are present during the dry months from January to March.

The effect of timing and type of land preparation on leaf-cutting ants was studied in an area of native savanna. Plots were prepared either in December 1984 at the end of the rainy season, or at the end of the dry season in March 1985.

The number of Acromyrmex colonies was considerably reduced beginning in March in plots were soil preparation occurred at the end of the rainy season (Figure 1). For Atta, the reduction was more gradual (Figure 2). Burning did not decrease the number of ant colonies of either species.

The number of colonies of Acromyrmex in plots prepared at the beginning of the dry season (1984) increased until July but did not reach the same level as plots prepared at the beginning of the rainy season (1985).

For Atta, the population in July is similar in both treatments. In both species, the population begins to decline in July. These results are similar to those observed in 1984 (1984 Annual Report).

Table 5. Effect of stemborer, *Caloptilia* sp., in 11 ecotypes and 15 hybrids of *S. capitata* associated with *A. gayanus*, Carimagua.

Hybrids* and Ecotypes	% Damage **	No. of larval entrance holes
4	67.3	1.94
7	40.4	1.57
9	57.7	1.10
11	75.0	2.05
12	71.2	2.05
13	46.2	1.96
14	82.7	2.26
15	69.2	1.58
16	78.8	1.98
19	42.3	2.45
21	71.2	2.03
22	63.5	2.03
23	50.0	1.96
25	76.9	1.90
27	75.0	1.87
1019	32.7	1.53
1315	40.3	1.19
1318	17.3	1.22
1342	36.5	1.74
1441	26.9	1.50
1693	71.2	1.46
1728	44.2	1.22
2044	46.2	1.38
2252	57.7	2.00
10280	43.6	1.06
1643***	0	0

* Hybrids of 1097 x 1078.
** For each accesion 13 adult plants were evaluated.
*** *S. macrocephala*.

Table 6. Response of 3 phenotypes of *S. guianensis* crosses in associations to attack by *Caloptilia* sp. at Carimagua.

Associated grass	Thick stem* % damage	Medium stem % damage	Thin stem % damage
Native savanna	68.5	40.3	13.1
A. gayanus	81.5	59.3	19.2

* Thick stem: Mean diameter: 1.09 cm (0.72 - 2.12 cm)
Medium stem: Mean diameter: 0.61 cm (0.50 - 0.70 cm)
Thin stem: Mean diameter: 0.36 cm (0.22 - 0.48 cm)
Between 162 and 472 plants of each phenotype were evaluated for each association.

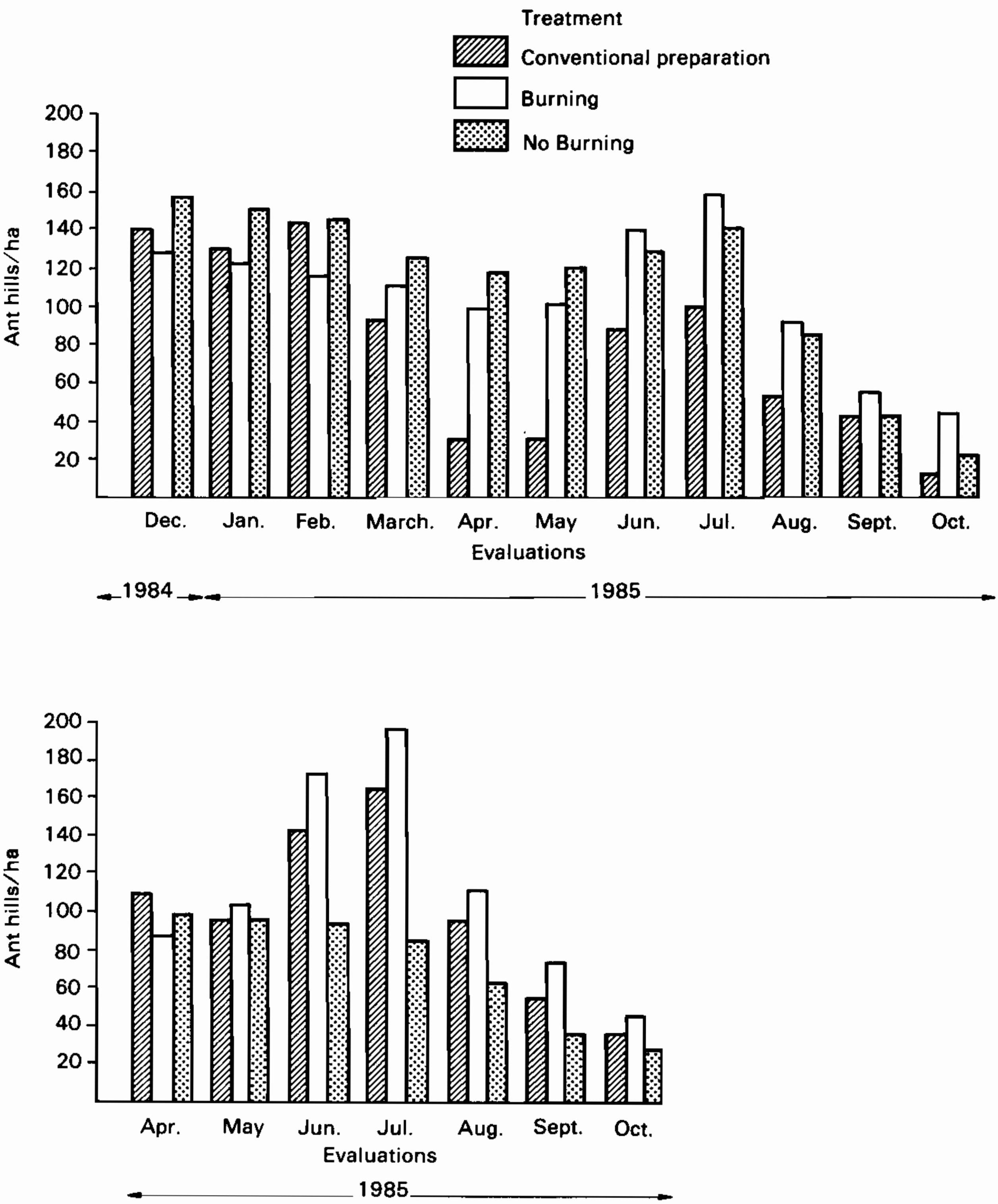


Figure 1. Population behavior of *Acromyrmex* sp. in areas prepared at the end of rainy season, December 1984 and at the beginning of rainy season April 1985. Carimagua.

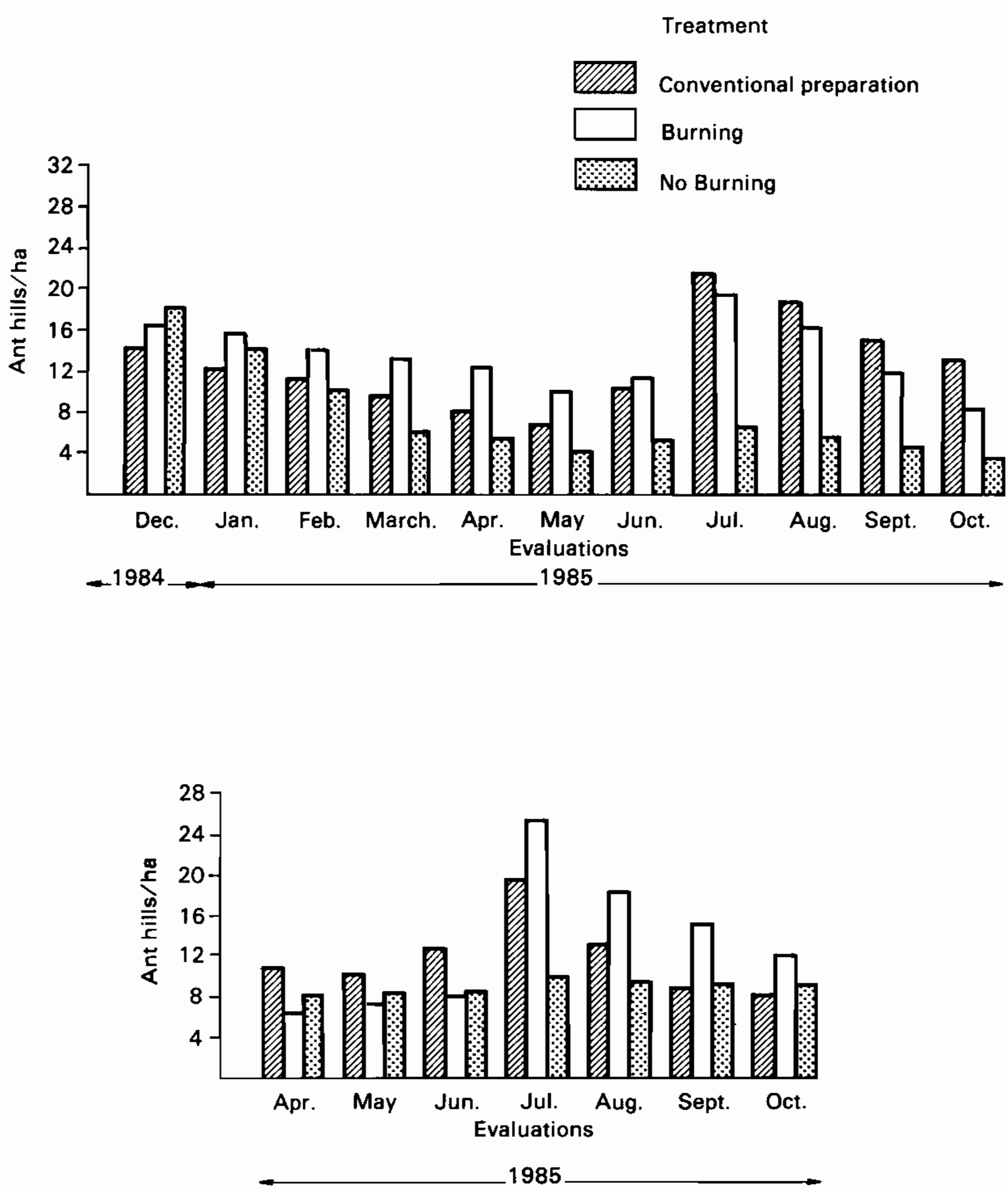


Figure 2. Population behavior of *Atta laeviagata* areas prepared at the end of rainy season December 1984 and at the beginning of rainy season April 1985, Carimagua.

In summary, the population of Acromyrmex is 80 to 90% greater than that of Atta laeviagata. The least number of ant colonies was observed in savanna where soil was prepared at the beginning of the dry season.

SPITTLEBUG

Little information is available related to life history, distribution across ecosystems, possible resistance mechanisms, and economic injury levels of the various spittlebug species on Brachiaria spp.

Rearing of nymphs of Zulia colombiana in the greenhouse and egg storage

An artificial rearing system for spittlebug nymphs together with egg storage is necessary due to the low availability of spittlebugs during the dry season. The rearing chamber is a wooden box (50 x 60 x 7· cm) in which Brachiaria is planted in Jiffy pots (Figure 3). The pots are placed in the upper section on top of a perforated plastic sheet through which the roots penetrate to the lower compartment which contains a nutrient solution. Once the chamber is prepared, eggs about to eclose are introduced. Eggs are stored and transferred on moist filter paper to avoid mortality associated with manipulation of young nymphs. Emerging adults are trapped in an inverted beaker placed over an opening in the upper part of the chamber. Fresh leaves are placed in the beaker daily to provide a temporary food source.

The first trial consisted of 8 rearing chambers containing from 109 to 300 first instar nymphs in order to measure survival to the adult stage (Table 7). Of a total of 1,540 nymphs, 1,146 adults emerged (75% survival). Efforts to perfect the technique are in progress.

In order to test the effects of temperature, relative humidity, and length of storage on the viability of stored eggs, 15 groups of 20 eggs each were collected. Temperature ranged from 20 to 30°C, relative humidity from 0 to 75%, and storage period from 6 to 59 days. At the end of each storage period, the eggs were incubated at 23°C and 95% RH until eclosion.

These preliminary data (Table 8) indicate that it is possible to store spittlebug eggs for 27 days at 25°C and 75% RH without excessive loss of viability (61% eclosion). These experiments are continuing with special efforts directed at conditions inducing diapause.

Study of resistance in some ecotypes of Brachiaria to spittlebug

Tests were carried out in the greenhouse under controlled conditions of temperature and relative humidity to study the possible negative effect of host plant on spittlebug development (antibiosis). Seven Brachiaria ecotypes and 10 replications/ecotype were used. Thirty mature eggs were obtained from an oviposition cage and placed on each plant and incubated at 27°C and 95% RH. Upon emergence of nymphs, percent eclosion and development time to adult were observed. The adults were measured for body length, body width, head capsule width, and width of thorax. Adults were sexed and placed in pairs on caged plants. Plant damage was assessed and the number of emerging nymphs recorded. This trial will be continued for 3 spittlebug generations.

Total life span (males and females) of spittlebugs on accession of Brachiaria varied from 89.0 days on B. dictyoneura 6133 and 88.7 days on B. brizantha 6297 to 82.4 and 81.9 days on B. humidicola 6707 and 6369, respectively (Table 9).

A = Nutrient solution for plants.
B = Jiffypots with *Brachiaria* spp. plants.
C = Trap for emerging adults.
D = Nymph rearing area.
E = Door of chamber.

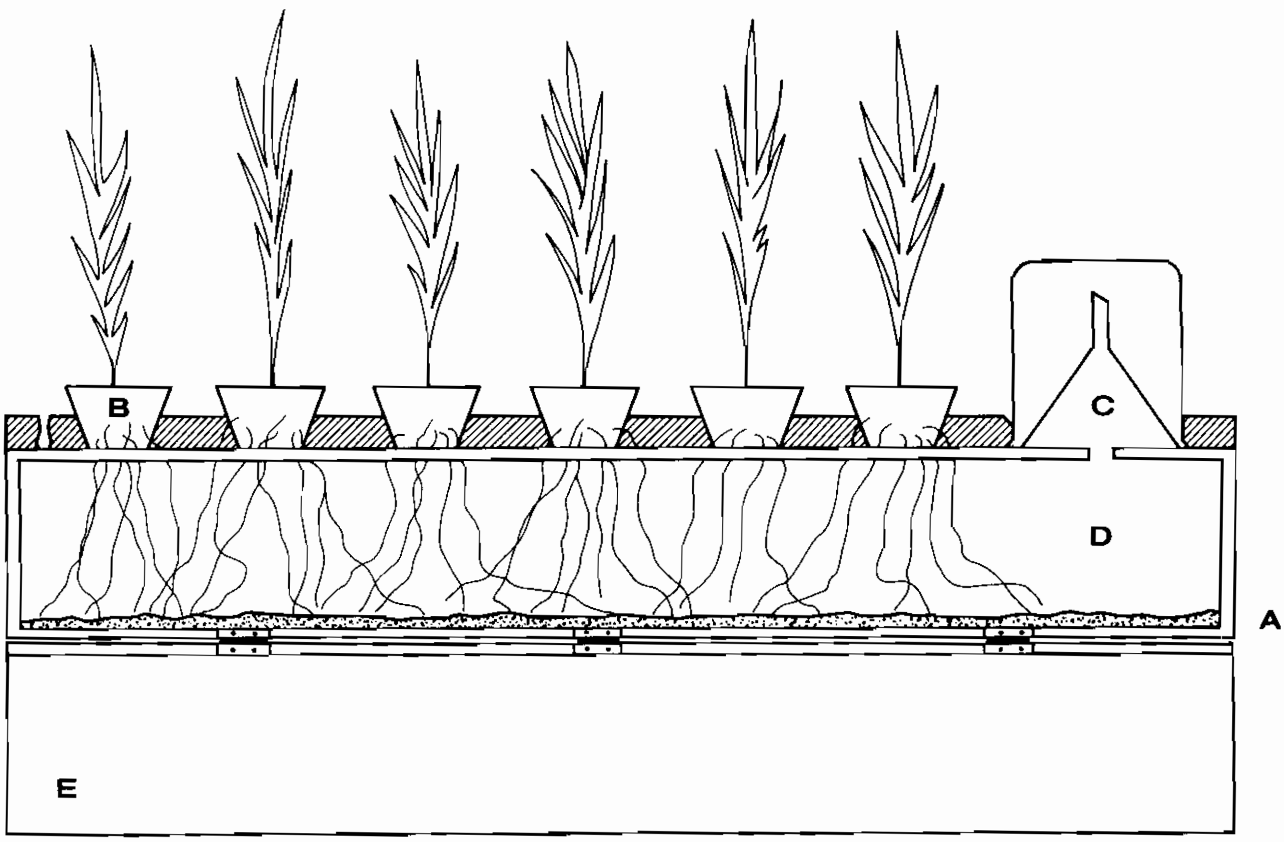


Figure 3. Schematic of spittlebug rearing chamber.

Table 7. Production of Z. colombiana nymphs in the greenhouse.

Chamber	Nymphs	No.adults emerged
1	300	220
2	274	228
3	270	115
4	200	167
5	109	94
6	116	104
7	111	95
8	160	125
Total	1540	1146*

* Adult survival was 74.4%.

Table 8. Effect of varying conditions of egg storage of Zulia colombiana.

Groups of 20 eggs	Treatments			% eclosion
	No. days in storage	Storage conditions		
		T (°C)	RH (%)	
1	6	23	20	0
2	17	23	60	1.7
3	21	23	60	0
4	27	20	0	0
5	27	20	20	0
6	27	25	70	50.0
7	27	25	75	61.5
8	27	26	75	14.2
9	27	28	65	0
10	38	23	60	0
11	38	25	75	0
12	41	28	65	0
13	48	20	75	0
14	49	23	60	0
15	59	23	70	0

3 repetitions.
After storage, eggs were incubated for 15 days at 23°C and 95% RH.

Table 9. Life span (days) of *Zulia colombiana* Lall. on accessions of *Brachiaria* spp. under constant conditions (T = 25.5°C, RH = 65 ± 5%).

Accession	Nymph			Adult			Total
	Female	Male	X	Female	Male	X	X*
	Days						
B. dictyoneura 6133	61.7	46.4	54.0	27.4	17.4	22.4	89.0
B. brizantha 6297	52.0	55.7	53.8	26.9	17.4	22.4	88.7
B. humidicola 679	56.8	59.6	58.2	17.6	13.1	15.4	86.1
B. brizantha 6294	50.1	51.8	50.9	27.4	17.4	22.4	85.8
B. decumbens 606	53.6	48.9	51.3	22.1	19.3	20.7	84.5
B. humidicola 6707	50.0	54.0	52.0	19.9	15.9	17.4	82.4
B. humidicola 6369	51.3	45.9	48.6	24.0	17.6	20.8	81.9

Mean egg incubation = 12.5 days (23°C, 90% RH).
Mean repetitions = 10

* Includes mean egg incubation period.

Female life span (nymphal and adult stages) was significantly less on B. humidicola 6707 (69.9 days) compared with B. dictyoneura 6133 (87.7 days) (Table 10).The low number of offspring per female may be attributed to unfavorable soil conditions, presence of predators, or environmental conditions.

Longevity and weight of spittlebugs as well as damage inflicted were greater on B. decumbens 6133, B. brizantha 6297 and 6294 compared with B. humidicola 6707 and 679 (Table 11).

Development time of Zulia colombiana on B. decumbens 606 was compared at 2 levels of relative humidity at a constant temperature of 26°C (± 0.5°C). At 85% RH, life span (nymphal and adult stages) was 57.7 days and at 65% RH life span was 75.7 days (Table 12).

Infestation of spittlebug in B. humidicola 679 and B. dictyoneura 6133

At Santander de Quilichao (Cauca), different levels of infestation of Z. colombiana in nymphal and adult stages are being studied in order to determine the critical level of damage in B. humidicola 679 and B. dictyoneura 6133.

To date, no significant differences have been found among levels of infestation for either nymphs of adults in terms of height of grass, forage production, and nutritional composition of foliage of the two species. This may be attributed to the high mortality of insects in the field cages. Modifications are being explored to overcome this problem.

Significant differences were found ($P<0.05$) between levels of infestation of adults in terms of the content of potassium in foliage of B. dictyoneura 6133. The level of infestation was negatively correlated with potassium content (Table 13) although all measurements were greater than those considered normal (0.8 - 1.0%). It is possible that the toxin injected into the plant during feeding by the spittlebug interferes with potassium synthesis.

Effect of plant height on spittlebug incidence

Incidence of A. reducta in plots of B. humidicola 679, B. decumbens 606, and B. dictyoneura 6133 was examined at three grass heights (20, 40, and 60 cm) at Carimagua (well-drained isohypothermic savanna). With increasing grass height, spittlebug population increased during both years in which evaluations were made (Figure 4). This effect may be due to the creation of a more favorable microhabitat in the taller grass plots.

Evaluations of Aeneolamia reducta in Brachiaria

The population of A. reducta was low during 1985. The insect was observed in Brachiaria plots with the exception of B. brizantha 6294 and 6780 (Table 14).

In associations of Brachiaria spp. and Arachis pintoi CIAT 17434,the greatest population of A. reducta was observed in B. humidicola 6369 and the least population in B. brizantha 6294 (Table 15).

In grazing trials of Brachiaria spp. associated with Arachis pintoi CIAT 17434, a slight increase in population of nymphs was observed in 1985 (Table 16). The greatest population was observed in B. brizantha 664 and the smallest population in B. humidicola 679. These evaluations will be continued in order to compare the population dynamics of the insect and the resulting damage to foliage.

Native hosts of A. reducta

A preliminary study was undertaken to

Table 10. Development, weight, and fecundity of female *Zulia colombiana* Lall. on accessions of *Brachiaria* spp. under constant conditions (T = 25.5°C; RH = 65 ± 5%).

Accessions	Nymph (days)	Std. Dev.	Adult (days)	Std. Dev.	Total X	Weight (g)	# Std. Dev.	Nymphs/Female
B. dictyoneura 6133	61.7	7.10	27.4	9.96	89.1	0.0087	25.72	6.0
B. brizantha 6297	52.0	6.81	26.9	6.18	78.9	0.0086	18.37	5.8
B. brizantha 6294	50.1	6.64	27.4	4.80	77.5	0.0103	19.88	4.0
B. decumbens 606	53.6	2.33	22.1	6.78	75.7	0.0091	23.77	2.7
B. humidicola 6369	51.3	4.31	24.0	7.33	75.3	0.0095	28.43	3.0
B. humidicola 679	56.8	5.56	17.6	4.49	74.4	0.0080	21.41	2.0
B. humidicola 6707	50.0	7.07	19.9	4.25	69.9	0.0082	21.82	2.0

10 repetitions.

Table 11. Longevity, weight, and feeding damage of adult *Zulia colombiana* on *Brachiaria* accessions under constant conditions (25.5°C, 65 ± 5% RH).

Accession	Longevity (days)	Std. Dev.	Weight (g.)	Std. Dev.	Damage* Rating
B. dictyoneura 6133	22.4	9.92	0.0080	24.85	3
B. brizantha 6297	22.3	8.18	0.0079	22.91	3
B. brizantha 6294	22.4	7.24	0.0090	23.17	3
B. humidicola 6269	20.8	7.15	0.0084	27.20	2
B. decumbens 606	20.7	10.61	0.0087	22.53	4-5
B. humidicola 6707	17.9	4.53	0.0075	21.51	2
B. humidicola 679	15.4	4.59	0.0075	20.44	3

* Scale for visual damage rating:
1 = No damage
2 = Slight damage
3 = Moderate damage
4 = Severe damage
5 = Complete damage

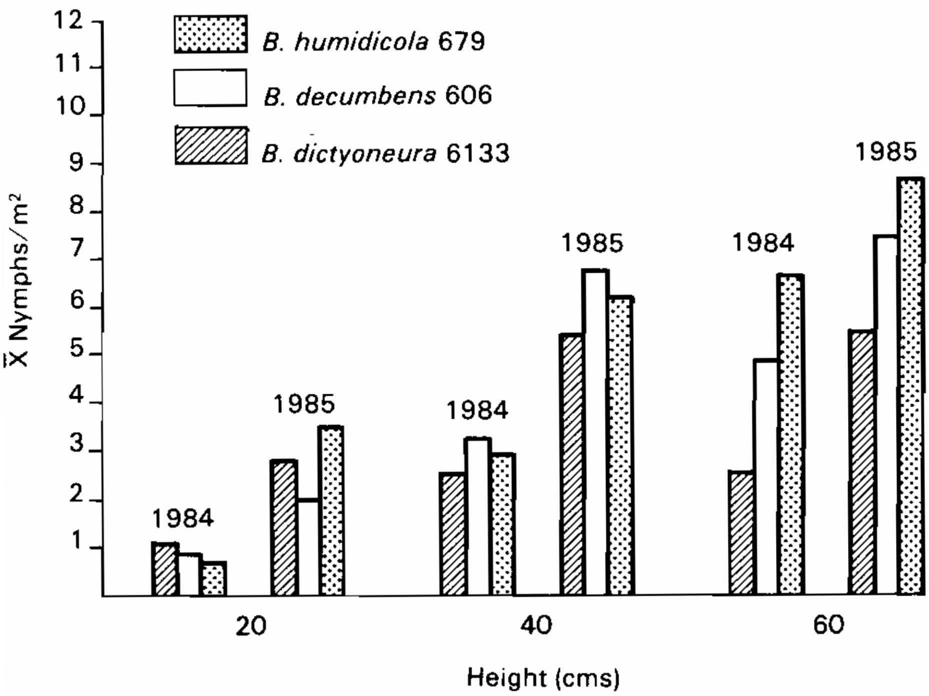


Figure 4. *Aeneolamia reducta* populations in *B. humidicola, B. decumbens* and *B. dictyoneura* during 1984 and 1985 with different grass heights in Carimagua.

Table 12. Effect of relative humidity on longevity and fecundity of *Zulia colombiana* on *B. decumbens* 606.

T°C (0.5%)	RH%	Life span (days)	Nymphs/ female
26	65	75.7	2.7
26	85	57.7	11.8

identify native savanna species that act as spittlebug hosts. Between 15 and 20 ha of savanna were sampled at three sites at Carimagua. All species infested with spittlebug were sent to the Colombian National University in Bogotá for identification.

Agronomic characteristics of *Brachiaria* spp. infested with spittlebug at Carimagua

Thirty-one accessions of *B. brizantha*, 12 accessions of *B. ruziziensis*, 11 accessions of *B. decumbens*, 9 accessions of *B. humidicola*, and 1 accession each of *B. arrecta*, *B. dictyoneura*, *B. eminii*, *B. nigropedata*, *B. jubata*, and *B.* sp. are being evaluated at Carimagua.

Table 13. K content in leaf tissue of *B. dictyoneura* 6133 under varying infestations of *Zulia colombiana* at Santander de Quilichao.

No.Adults/ m^2	K content in tissue Cuts 1	2	3
0	2.05	2.40	2.47
30	1.64	1.72	1.85
60	1.83	1.84	1.91
120	1.60	1.69	1.88

Considerable variation exists among accessions of *B. brizantha* (Figure 5). During July and September, 1985, relatively low spittlebug populations were found on accessions CIAT 6684, 6384, 6016, 6688, and 6687. No spittlebug were found on CIAT 6294, 6297, 6686, 6690, and 6735. *B. brizantha* was the most productive species in terms of dry matter per hectare (Table 17).

Nymphal populations on *B. ruziziensis* varied from 9 to 34 nymphs/m^2. CIAT 655, 6778, and 6711 had the lowest population with dry matter production ranging from 1,196 to 3,347 kg DM/ha (Figure 6, Table 18).

In *B. decumbens*, CIAT 606 and 6700 had high nymphal infestations and CIAT 6698, 6131, and 6693 showed little or no pupulation of nymphs. Forage production varied between 1,966 and 3,322 kg DM/ha (Figure 6, Table 18).

In *B. humidicola*, CIAT 6707 and 6738 had the lowest populations of nymphs with forage production between 1,955 and 3,518 kg DM/ha. *B. dictyoneura* CIAT 6133 and *B.* sp. CIAT 6008 had low spittlebug populations while no nymphal infestation was detected on *B. arrecta* CIAT 6020 and *B. jubata* CIAT 6409.

In general, the CIAT accessions that showed good agronomic characteristics and low spittlebug populations during the first year of evaluation were: *B. brizantha* 6684, 6384, 6016, 6688, 6687, 6297, 6686, 6690, and 6735; *B. decumbens* 6698, 6131, and 6693; *B. humidicola* 6707 and 6738; *B. arrecta* 6020 and *B. jubata* 6409.

Multilocational trials

In Colombia, material from the *Brachiaria* collection is being evaluated at Macagual (Florencia), La Libertad (Villavicencio), and San José del Nus (Antioquia) (Table 19).

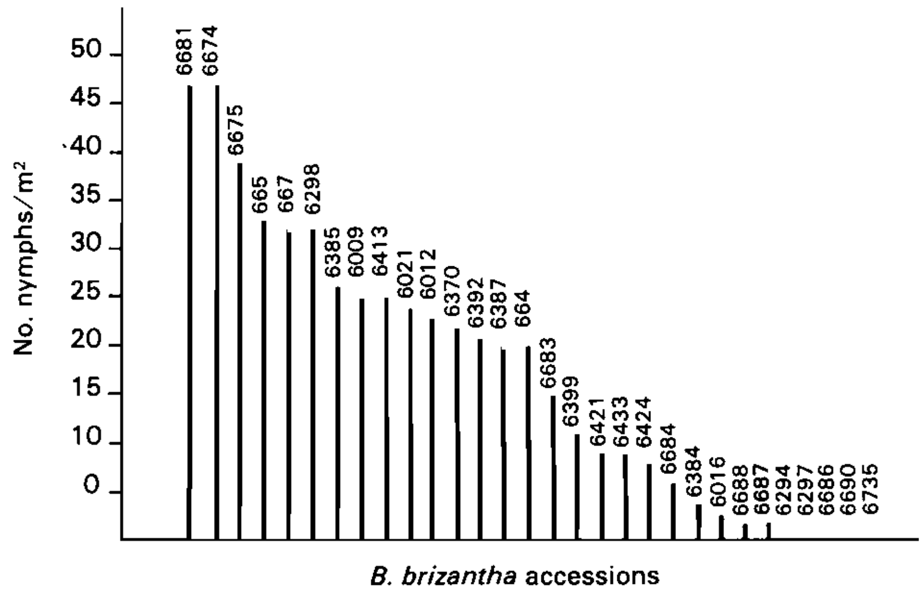


Figure 5. *Aeneolamia reducta*, nymphal populations on *B. brizantha* accessions in Carimagua (July and September 1985). Average of two evaluations.

Table 14. Response of 5 promising Brachiaria accessions to natural infestations of A. reducta (Carimagua 1985).

Species	Accession	Nymphs/m^2	Adults/m^2	Damage Rating
B. dictyoneura	6133	17	1.8	1.5
B. brizantha	6294	0	1.3	1.0
B. humidicola	6369	14	2.2	1.5
B. ruziziensis	6387	15	2.3	2.0
B. brizantha	6780	0	0.9	1.0

Evaluated monthly beginning May 1985. 3 replications.

Table 15. Incidence of A. reducta on Brachiaria spp. associated with Arachis pintoi CIAT 17434. Carimagua 1985.

Species	Accession	Nymphs/ m^2	Adults/ m^2	Damage	Height m.
B. brizantha	6294	3	0.5	1.0	0.2-0.3
B. humidicola	6369	9	2.1	2.0	0.3-0.4
B. humidicola	679	4	1.4	1.5	0.3-0.4
B. humidicola	6705	6	1.6	1.5	0.3-0.4
B. humidicola	6709	5	0.8	1.5	0.3-0.4

Evaluated monthly beginning May 1985. 3 replications.

Table 16. Populations of A. reducta on Brachiaria spp. associated with Arachis pintoi 17434 under grazing, Carimagua 1984-1985.

Species	Accession	Nymphs/m^2		Damage		Height (m)	
		1984	1985	1984	1985	1984	1985
B. brizantha	664	7.2	12.1	2.5	2.0	0.2-0.4	0.2-0.3
B. dictyoneura	6133	5.2	2.4	1.5	1.5	0.2-0.3	0.2-0.3
B. humidicola	679	3.1	5.2	1.5	1.5	0.2-0.3	0.3-0.4
B. ruziziensis	6291	6.8	10.8	2.0	2.0	0.2-0.4	0.3-0.4

Evaluations monthly beginning May 1985. 3 replications.

Table 17. Populations of *A. reducta* and dry matter (DM) production of *B. brizantha* accessions at Carimagua 1985.

Accession	Nymphs	D.M.(kg/ha)	Accession	Nymphs	D.M. (kg/ha)
664	20.5	2,324	6413	25.5	4,103
665	33.0	3,021	6421	9.8	4,074
667	29.5	1,560	6424	8.2	4,253
6009	25.2	1,810	6426	5.0	3,074
6012	23.7	2,008	6433	9.0	3,841
6016	3.0	3,122	6674	4.7	3,616
6021	24.5	1,848	6675	39.2	4,626
6294	0	4,409	6681	47.0	3,134
6297	0	6,103	6683	15.5	2,758
6298	29.2	1,704	6684	5.8	3.837
6370	22.7	2,287	6686	0	1,843
6384	4.3	3,760	6687	1.0	1,095
6385	25.8	5,345	6688	1.5	1,831
6392	20.8	3,277	6735	0	1,843
6399	11.5	3,993			

Average of 2 evaluations, July and September 1985.

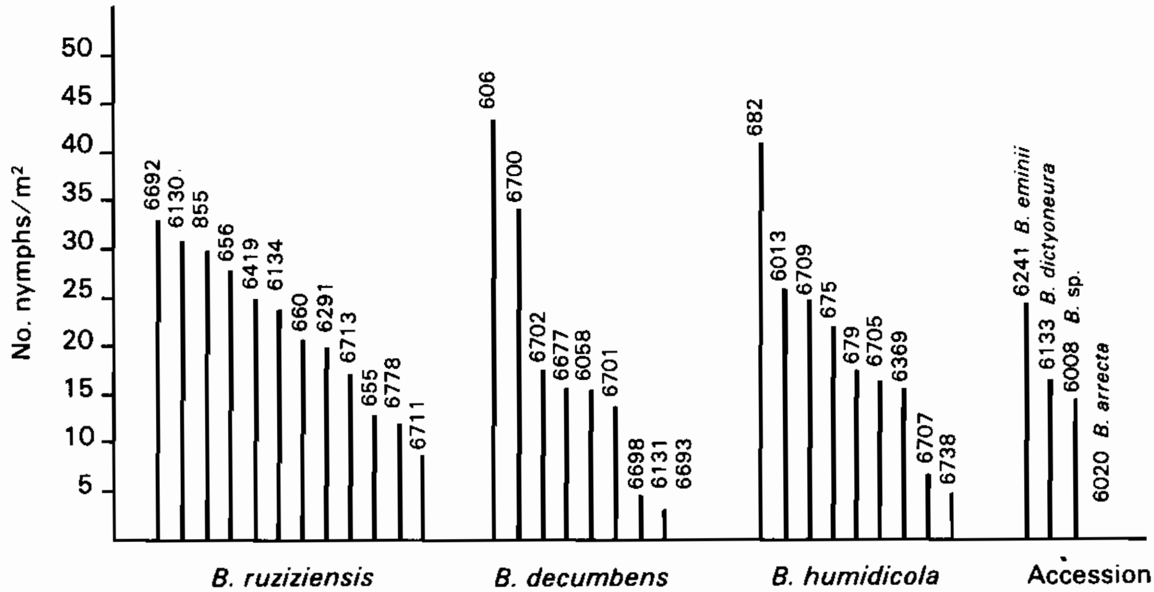


Figure 6. *Aeneolamia reducta* nymphal populations in accessions of *B. ruziziensis, B. decumbens, B. humidicola, B. eminii, B. dictyoneura, B.* sp. and *B. erecta* in Carimagua.

Table 18. Populations of *A. reducta* and dry matter (DM) production of *Brachiaria* spp. accessions at Carimagua (July and September, 1985).

Species	Accession	Nymphs/m^2	Std. Dev .	D.M. (kg/ha)
B. ruziziensis	654	30.8	31.01	1,196
	655	13.0	10.70	1,444
	656	28.5	25.30	2,826
	660	21.5	24.21	2,454
	6130	31.5	38.22	3,439
	6134	23.7	24.90	2,006
	6291	20.0	18.43	1,348
	6419	25.5	38.37	3,347
	6692	33.7	30.6	2,006
	6711	9.5	13.51	1,952
	6713	14.7	19.17	1,870
	6778	12.5	16.76	1,833
B. decumbens	606	41.0	44.89	3,322
	6058	15.8	19.88	1,846
	6131	3.3	4.85	3,690
	6132	16.3	16.47	2,086
	6677	15.3	15.02	3,136
	6693	0	-	462
	6698	5.0	6.42	3,318
	6700	34.5	18.01	1,966
	6701	14.6	15.80	2,244
	6702	18.2	14.76	2,544
B. humidicola	6369	11.5	15.05	2,674
	679	13.3	20.96	2,677
	6013	26.7	29.34	3,518
	675	20.8	34.17	2,880
	6705	11.7	13.42	3,338
	6707	7.2	9.94	2,822
	6709	25.3	18.84	1,955
	6738	5.8	7.35	2,117
Brachiaria sp.	6008	14.7	16.10	2,347
B. arrecta	6020	0	-	1,334
B. dictyoneura	6133	17.0	24.60	2,969
B. eminii	6241	25.0	25.99	2,393
B. jubata	6409	0	-	281

Table 19. Environmental conditions, spittlebug species present, and promising accessions of Brachiaria spp. at various evaluation sites.

Country	Site	Ecosystem	Annual mean temp. (°C) °C	Annual mean precipitat. mm	Months of max. precipitation	Predominant spittlebug species	Promising accessions
	Macagual (Florencia)	Tropical rain forest	26	4,000	March, April, May, June and July	Zulia pubescens	B. bri.6294 y 6297 B. dict.6133, and B. sp. 6008
COLOMBIA	La Libertad (Villavicencio)	Tropical rain forest	25.3	2,357	April, May, June, October	Aeneolamia varia	B. bri. 6294 and 6297; B. dec. 6131 and B. eminii 6241
	San José del Nus (Antioquia)	Semi-evergreen tropical forest	23	2,153	April, May, June, Sept. and October	Zulia colombiana Aeneolamia sp.	B. brizi.665, 6297 6413 and 6688; B. jub. 6409
	Chiriquí	Well-drained isohyperthermic savanna	26	2,348	May, June, July, Sept.,	Aeneolamia reducta Octubre	Newly established trial
PANAMA	Gualaca	Tropical rain forest	25.5	5,139	June, July, Sept., Oct.	Aeneolamia reducta	Well established trial
	Tarapoto	Tropical rain forest	26.6	1,230	January, February, March y April	Deois sp.	B. brizi. 6294 and 6297; B. ruz. 660; B.hum.679 6013 & and B. dict. 6133
PERU	Calzada	Semi-evergreen seasonal tropical forest	25.5	5,139	June, July, Sept., Oct.	Zulia pubescens	B. briz. 6294 and 6297; B. ruz. 6291 and 6130; B. hum. 6369; B. dic. 6133 B. arrecta 6020 & B. dict. 6133
	Yurimaguas	Tropical rain forest	26	2,376	Marzo, Abril, Agosto, Oct.	Deois sp.	B. briz. 665, 6294 y 6297; B. hum. 6369; B. ruz. 655 y B. dic. 6133
BOLIVIA	Chipiriri	Tropical rain forest	23.7	4,668	January, Febr. March y Dec.	Zulia sp. Aeneolamia astralis	B. ruz. 655, 6130 and 6711; B. bri. 664, 6012 & B.dec. 6132 and 6693.

Twenty-one accessions of Brachiaria were initially established at Macagual. B. ruziziensis CIAT 656 suffered the highest population of Zulia pubescens nymphs and accessions B. brizantha CIAT 6294 and 6297 the smallest populations (Figure 7).

At La Libertad, 36 accessions were established. As was observed at Macagual, B. brizantha CIAT 6294 and 6297 had the lowest populations of nymphs of spittlebug (Aeneolamia varia) (Figure 8).

At San José del Nus, 45 accessions are being evaluated. The largest populations of nymphs of Zulia colombiana and Aeneolamia sp. are found on B. brizantha CIAT 6419, 6130, 6297, and 655. The smallest populations are found on B. brizantha CIAT 6413, 6297, 677, and 688 and on B. ruziziensis CIAT 660 and 6409 (Figure 9).

At Macagual and La Libertad, the species with the greatest forage production were B. dictyoneura and B. humidicola (2.5 and 2.3 tons DM/ha, respectively). At San José del Nus the most productive species were B. brizantha and B. decumbens (9.1 and 8.6 tons DM/ha, respectively) (Table 20).

In summary, the CIAT accessions with the best agronomic characteristics and lowest spittlebug populations have been: B. brizantha 6294 and 6297, B. dictyoneura 6133, and B. sp. 6008 at Macagual; B. brizantha 6294 and 6297, B. decumbens 6131, and B. eminii 6241 at La Libertad; B. brizantha 665, 6297, 6413, 6688, B. ruziziensis 660, and B. jubata 6409 at San José del Nus.

Other countries. Twenty-six accessions of Brachiaria are under evaluation at three sites in Peru (Tarapoto, Calzada, and Yurimaguas) (Table 19). The spittlebug Deois sp. occurs at Tarapoto and Yurimaguas and Zulia pubescens at Calzada. Nymphal populations have been low at Tarapoto and Calzada (evaluated with 1 m^2 grid) and high at Yurimaguas (evaluated with 1/16 m^2 grid). B. brizantha 6294 and 6297 and B. dictyoneura 6133 were the accessions with the smallest populations of spittlebug nymphs (Table 21).

In Bolivia (Chipiriri), there are 36 accessions of Brachiaria under evaluation. Forage production has varied between 300 and 1,600 kg DM/ha. B. ruziziensis CIAT 655, 6130, and 6711, B. brizantha CIAT 664 and 6012, and B. decumbens CIAT 6132 and 6693 were the most productive. In the monthly evaluations of Zulia sp. and Aeneolamia astralis in B. decumbens 606 and B. humidicola 679, the greater population of nymphs was observed in B. decumbens 606 with light damage evident in the plots. It appears that the height of the pasture (38 and 80 cm, respectively) may account for the difference between the two grass species. Since B. decumbens 606 showed light damage with 11 nymphs/m^2 while B. humidicola 679 showed no damage at an infestation of 20 nymphs/m^2, it appears that B. humidicola is tolerant to spittlebug and is capable of supporting a higher insect population (Table 22).

Sampling for spittlebug on farms in the Llanos Orientales of Colombia

Due to the growing importance of B. decumbens on ranches in the piedmont area of the Llanos Orientales, the number of farms under evaluation for spittlebug was increased. The evaluations were made in June and October when population peakes of Aeneolamia varia and Zulia pubescens were expected. On the road to Puerto López, 3 farms were evaluated: La Maravilla, Aguas Claras, and San Antonio. The areas sampled varied from 3.5 to 8.0 hectares. On the first sampling date, nymphal populations were high and adult populations were low. On the second

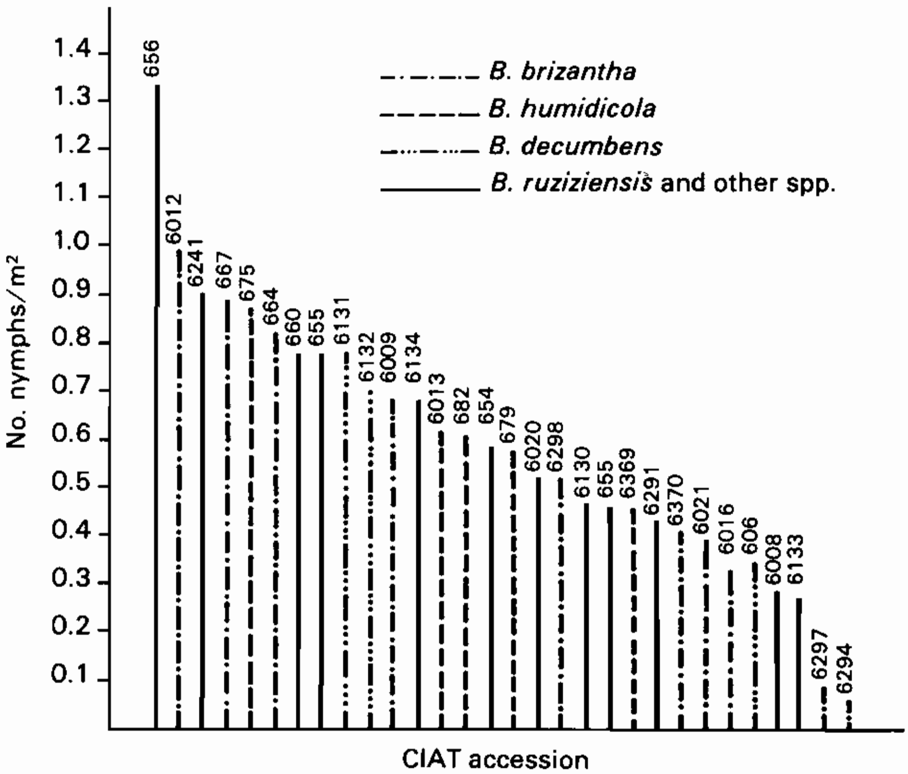


Figure 7. Average population (two years) of spittlebug nymphs in *Brachiaria* spp. at Macagual, Florencia.

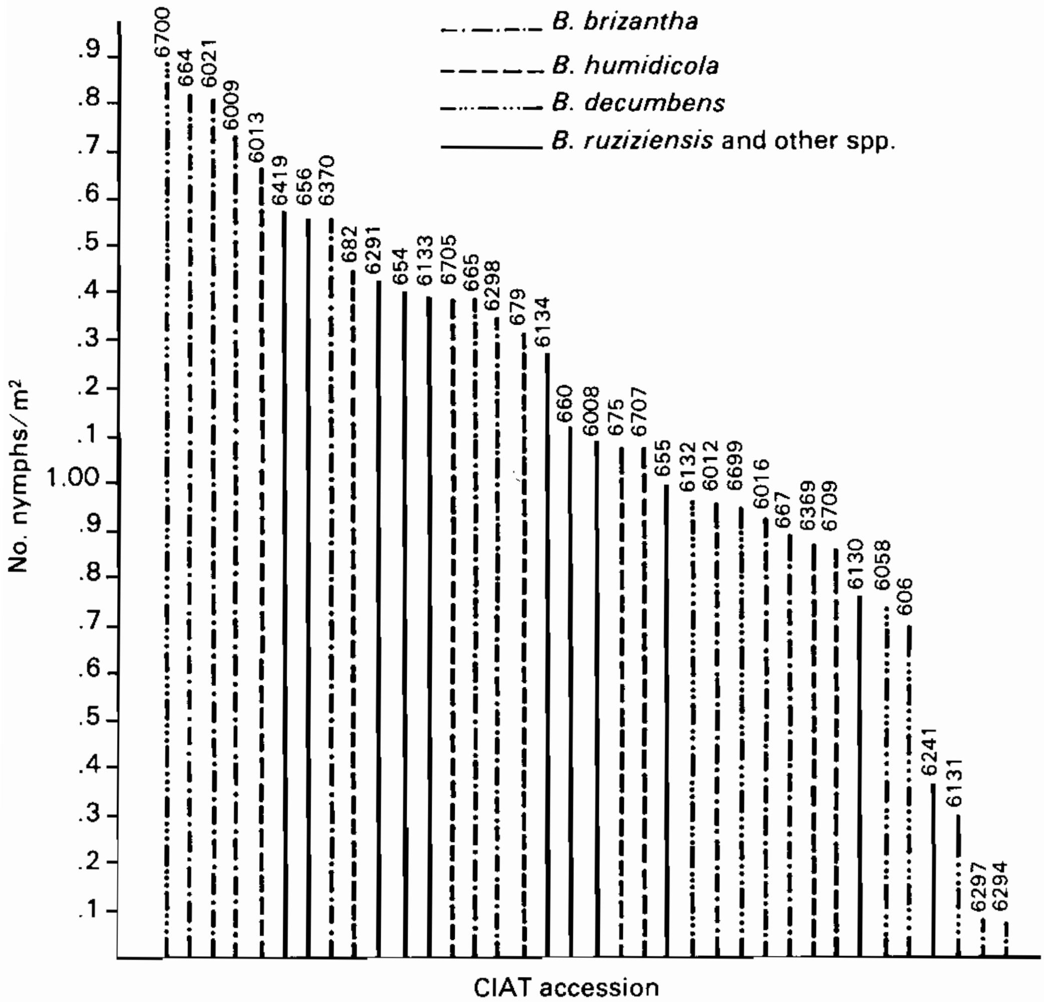


Figure 8. Average population (two years) of spittlebug nymphs in *Brachiaria* spp. at La Libertad, Villavicencio.

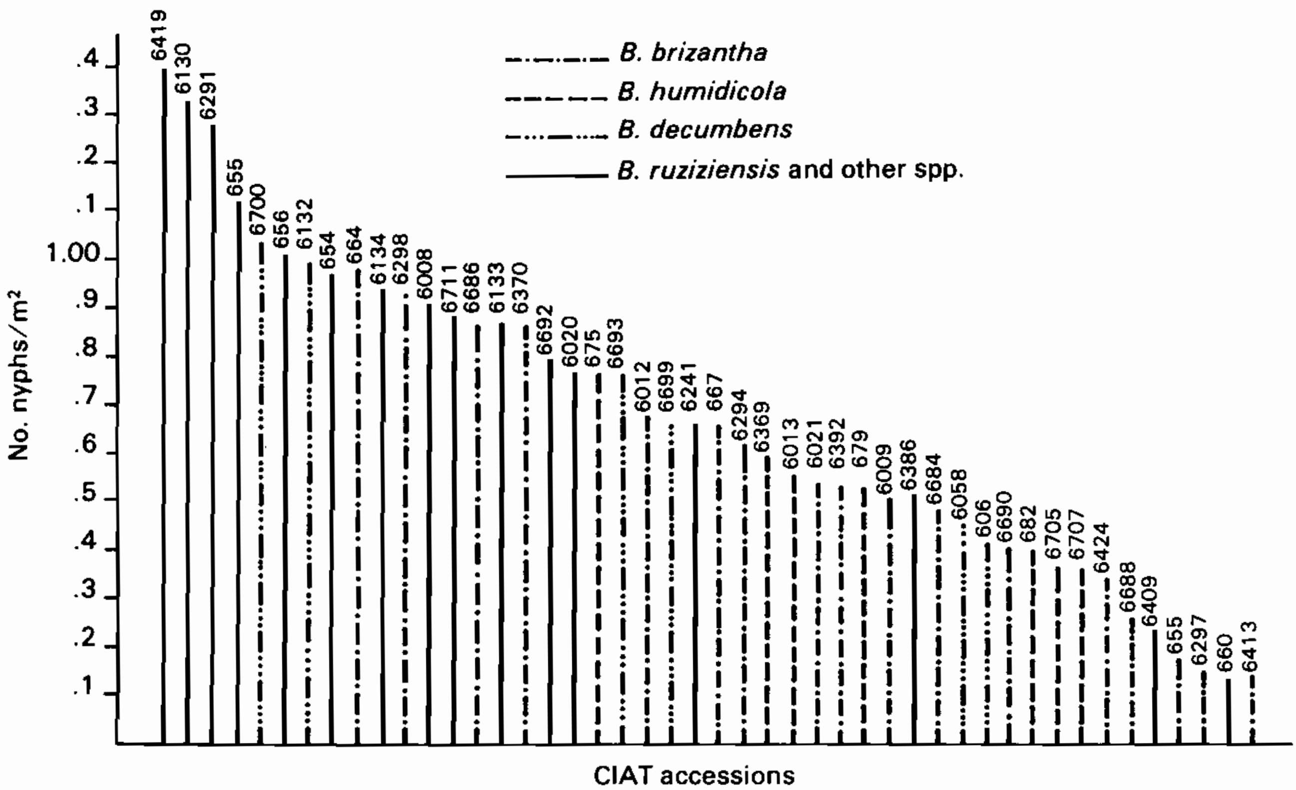


Figure 9. Average population (2 years) of spittlebug nymphs at San José del Nus, Antioquia.

Table 20. Dry matter (D.M.) production of *Brachiaria* spp. in response to spittlebug at 3 sites in Colombia.

Species	MACAGUAL (Florencia)		LA LIBERTAD (Villavicencio)		SAN JOSE DEL NUS (Antioquia)	
	Nymphs/m^2	D.M.(t/ha)	Nymphs/m^2	D.M.(t/ha)	Nymphs/m^2	D.M.(t/ha)
B. brizantha mean of 9 accessions	0.5	1.8	1.1	1.2	0.6	9.1
B. ruziziensis mean of 7 accessions	0.7	1.6	1.2	0.9	0.9	5.5
B. humidicola mean of 5 accessions	0.6	2.3	1.3	1.8	0.6	7.4
B. decumbens mean of 2 accessions	0.5	1.4	0.8	0.8	0.7	8.6
B. dictyoneura CIAT 6133	0.3	2.5	1.4	1.8	0.9	7.4
B. eminii CIAT 6241	0.9 0.9	2.3 2.3	0.4 0.4	0.7 0.7	0.7 0.7	7.0 7.0
B. sp. CIAT 6008	0.3	1.5	1.1	1.0	0.9	6.8

Table 21. Nymphal spittlebug populations on *Brachiaria* spp. at 3 sites in Peru.

Species	Accession	Tarapoto Nymphs/m^2	Calzada Nymphs/m^2	Yurimaguas Nymphs/m^2
B. brizantha	6294	0.0	1.0	6.0
B. brizantha	6297	0.0	2.0	4.0
B. brizantha	665	3.6	7.0	14.0
B. brizantha	6298	4.8	8.0	98.0
B. brizantha	6016	5.3	4.5	-
B. brizantha	667	7.0	5.0	48.0
B. brizantha	6012	8.1	7.0	52.0
B. brizantha	6009	9.9	5.5	40.0
B. ruziziensis	660	0.4	3.5	-
B. ruziziensis	6291	2.5	2.0	68.0
B. ruziziensis	6134	4.4	4.0	58.0
B. ruziziensis	654	8.5	7.5	-
B. ruziziensis	6130	8.7	2.0	88.0
B. ruziziensis	655	5.7	6.5	12.0
B. humidicola	679	0.4	4.5	80.0
B. humidicola	682	1.2	7.0	82.0
B. decumbens	6058	4.7	4.5	72.0
B. decumbens	6132	5.0	5.5	72.0
B. decumbens	6131	10.0	6.5	62.0
B. dictyoneura	6133	0.8	2.0	14.0
B. eminii	6241	6.5	3.5	48.0
B. arrecta	6020	1.2	2.0	26.0
B. sp.	6008	1.9	2.0	60.0

Collaborators:
- Tarapoto: Ing. César R. Valles
  Calzada: Ing. E. Palacios
  Yurimaguas: Ing. K. Reátegui

Material planted in October, 1983:
- = Failed to establish.

Table 22. Nymphal populations of *Zulia* sp. and *A. astralis* on *B. decumbens* and *B. humidicola* at Chipiriri, Bolivia*.

Month	Precipitation (mm)	*B. decumbens* 606			*B. humidicola* 679		
		Height (cm)	Nymphs/m^2	Damage	Height (cm)	Nymphs/m^2	Damage
Sept./83	213	39.0	74	3	19.6	20	1
Oct./83	376	38.0	41	3	19.0	5	1
Nov./83	922	46.0	11	2	32.8	8	1
Dic./83	645	53.0	19	2	26.0	1	1
Enero/84	814	73.0	11	2	25.0	1	1
Feb./84	873	65.0	30	3	22.0	0	1
Feb./84	873	65.0	30	3	22.0	0	1
Marzo/84	659	80.0	12	2	21.6	1	1
Abril/84	279	80.5	24	2	14.4	1	1
Mayo/84	122	39.0	11	2	15.0	3	1
Junio/84	222	39.4	17	3	18.0	4	1
Julio/84	51	58.0	19	3	16.2	0	1
Agosto/84	95	42.5	14	3	18.0	0	1

* Collaborator in Bolivia: Ing. A. Ferrufino.
Damage scale: 1-5; 1 = no damage; 2 = total damage.

sampling date (October) the pastures were recovering from grazing and the spittlebug populations had declined considerably except for one pasture (pasture 3) at La Maravilla. Pasture 3 was adjacent to and only separated by a fence from pasture 2 where both nymphal and adult populations were very low (Figure 10). Stocking rates were 8.7 animals/ha at La Maravilla and Aguas Claras, and 4.2 animals/ha at San Antonio.

On the road to Acacías, 2 farms were evaluated: La Candelaria and Mapiripan. On the first sampling date, high nymph populations and low adult populations were recorded. Both declined on the second sampling date (Figure 11).

With regard to the population density of insects in the piedmont zone, Homopterans in the families Cicadellidae and Cercopidae are predominant with a smaller proportions of Coleoptera and Orthoptera that are potential pests. The majority of insects in the orders Hymenoptera and Diptera are beneficial, acting as polinators or as biological control agents (Tables 23 and 24).

Daily activity patterns of Aeneolamia varia in Villavicencio

A one hectare plot of B. decumbens under grazing was selected for this trial. Initial spittlebug population was 12 adults/m^2. Counts were made every 2 days from 5 October until 24 October 1985. Samples were collected every 2 hours over a 24 hour period.

In the pasture, 10 sites were marked. At each site, 10 passes with a sweep net (35 cm diameter) were made. Captured adults were counted and returned to the site of collection. Pairs in copulo were also counted at each sampling site. To determine the sex ratio, 10 passes of the sweep net were made in a nearby location that had adult populations similar to the test plot. Samples were collected every 4 hours over a 24 hour period beginning at noon.

The initial adult population was 12/m^2 (Figure 12), decreasing to 2/m^2 at the end of the evaluation period (Figure 13). The reduction in population may have been the result of reduced number of rain days and the absence of rain in the second half of the evaluation period. However, the reduced population level does not appear to have influenced daily behavior patterns (Figure 14).

The maximum spittlebug population occurred at sunset (6 pm) (Figure 15). The number of adults captured at that time was approximately 40% greater than the number captured at the other sampling times. A slight increase in the catch occurred between 6 and 8 am. After 6 pm, there was a rapid reduction in the number of captured adults that may be associated with dew formation between 8 pm and 6 am. This may explain the small increase of activity at dawn as the dew decreases during the early morning hours.

The reduction of solar radiation appears to be the stimulus for emergence of adult spittlebug to the aereal parts of the plants for the purpose of mating. The number of copulating pairs increased dramatically at 6 pm and remained relatively high during the rest of the night, declining to very a very low level at 8 am (Figure 16). The number of copulating pairs remained very low during the day.

The sex ratio of captured spittlebug depends on the sampling time and exhibits a trend similar to the number of copulating pairs. The number of females was greater than the number of males except at 4 pm and 12 noon when approximately equal numbers were observed (Figure 17). Both sexes display a similar daily pattern of activity. The increase in activity of adults of both sexes at dusk and at

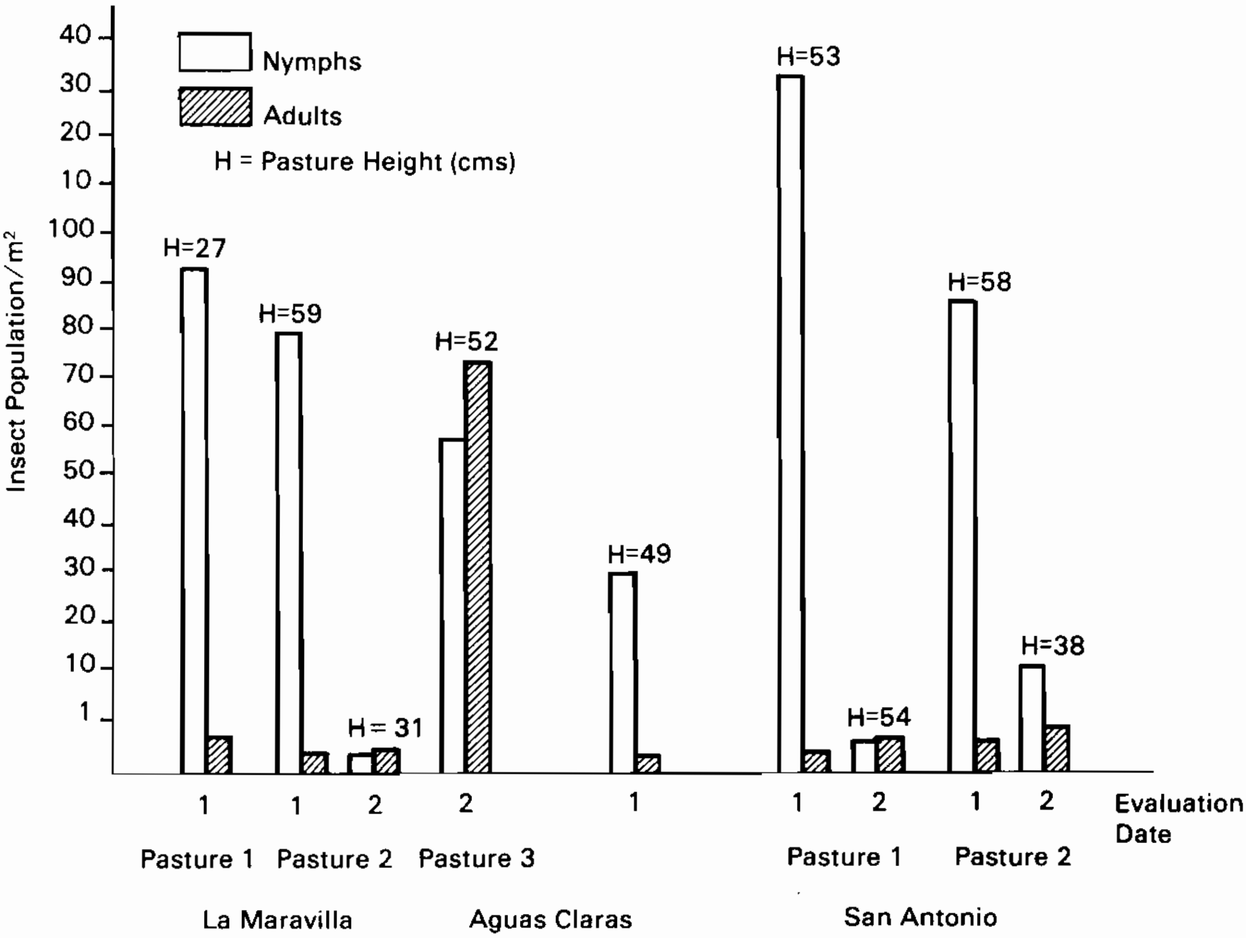


Figure 10. Evaluation of spittlebug populations in *B. decumbens* on 3 piedmont farms on the road to Puerto Lopez. Evaluation dates: (1) July/85, (2) October/85.

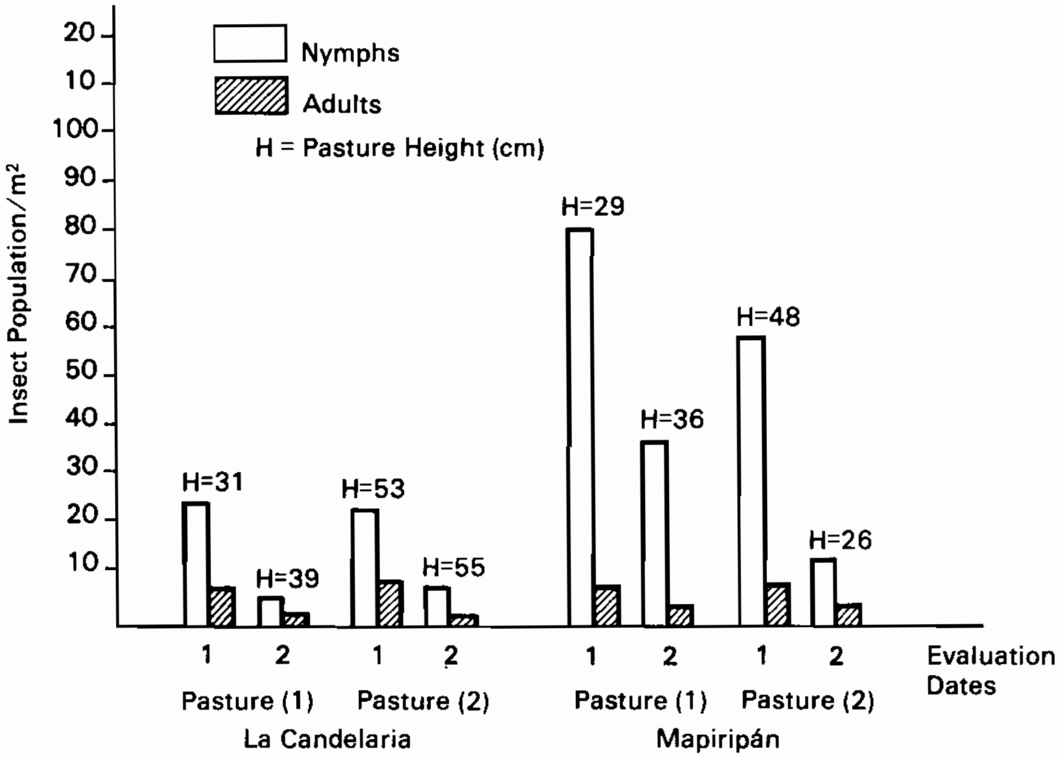


Figure 11. Evaluation of spittlebug populations in *B. decumbens* on 2 piedmont farms (1) July/85, (2) Oct./85.

Table 23. Insect population density (200 sweeps/ha) on 3 piedmont forms on the road to Puerto López. Evaluation dates: June and October, 1985.

Order	Family	Species	La Maravilla	Aguas Claras	San Antonio
				%	
Homoptera	Cercopidae	*Aeneolamia varia*	11.5	9.0	24.0
		Zulia pubescens	2.0	6.0	0.5
	Cicadellidae		56.0	68.0	39.5
	Membracidae		2.0	7.0	1.0
Hemiptera	Pentatomidae		0.4	5.2	1.0
Coleoptera	Chrysomelidae		1.0	1.6	9.2
	Other		3.4	2.4	0.5
Orthoptera	Acrididae		9.0	1.0	7.0
	Other		-	-	0.3
Lepidoptera	Geometridae		0.5	-	5.0
	Noctuidae		1.0	-	2.0
	Other		-	-	-
Others (Possibly beneficial):					
Hymenoptera	Braconidae		0.4	0.4	1.0
	Microhymenopterans		11.0	1.5	-
	Other		0.4	0.6	0.4
Diptera	Syrphidae		-	0.7	8.0
	Other		2.5	-	5.0

Table 24. Insect population density (200 sweeps/ha) on 3 piedmont forms on the road to Acacías, Evaluation dates: June and October, 1985.

Order	Family	Species	La Candelaria	Mapiripan	La CAstañeda
			%		
Homoptera	Cercopidae	Aeneolamia varia	11.0	7.0	8.0
		Zulia pubescens	4.0	9.7	2.0
	Cicadellidae		54.0	76.6	63.0
	Membracidae		8.0	0.5	2.0
Hemiptera	Pentatomidae		2.0	2.6	-
	Other		2.0	-	5.0
Coleoptera	Chrysomelidae		4.0	3.6	13.0
	Other		-	-	0.6
Orthoptera	Acridinae		3.0	-	2.0
	Other		1.0	-	-
Other (possibly beneficial):					
Diptera	Syrphidae		10.0	-	-
	Other				

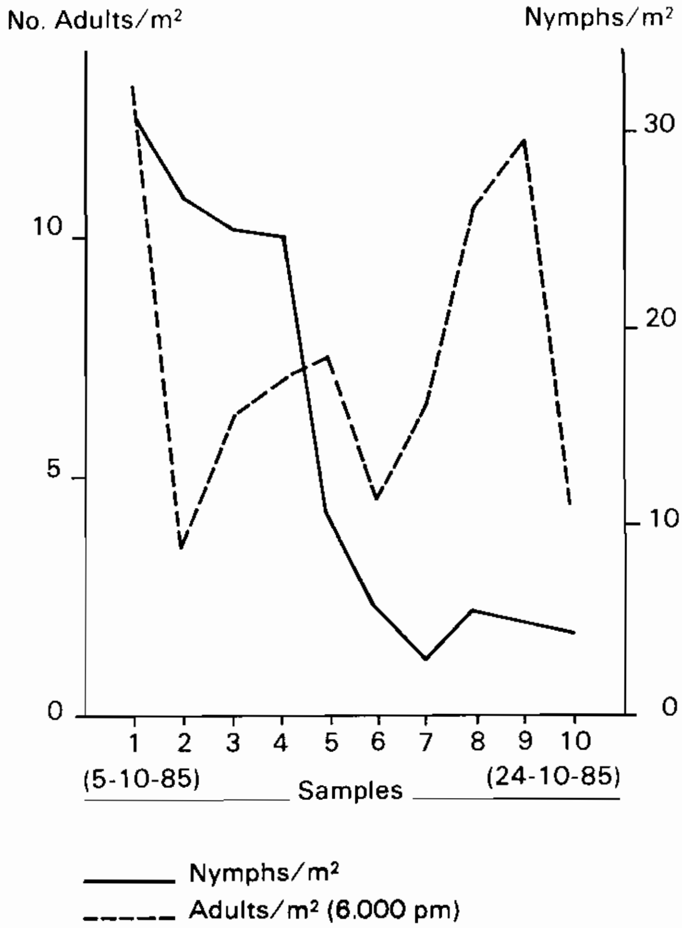


Figure 12. Fluctuation of populations of nymphs and adults of *A. varia* in *B. decumbens* at Villavicencio.

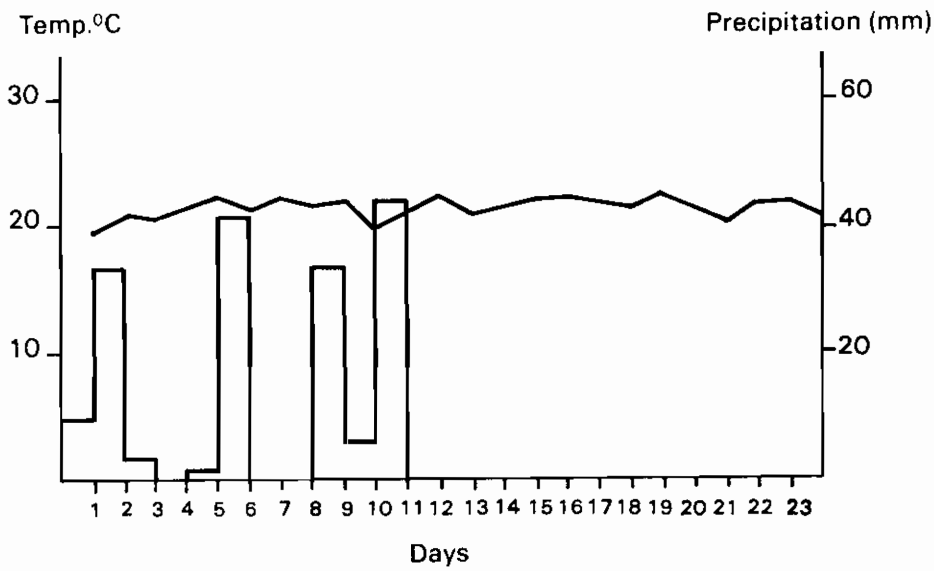


Figure 13. Mean temperature and rainfall during period evaluation (October 5-24/85).

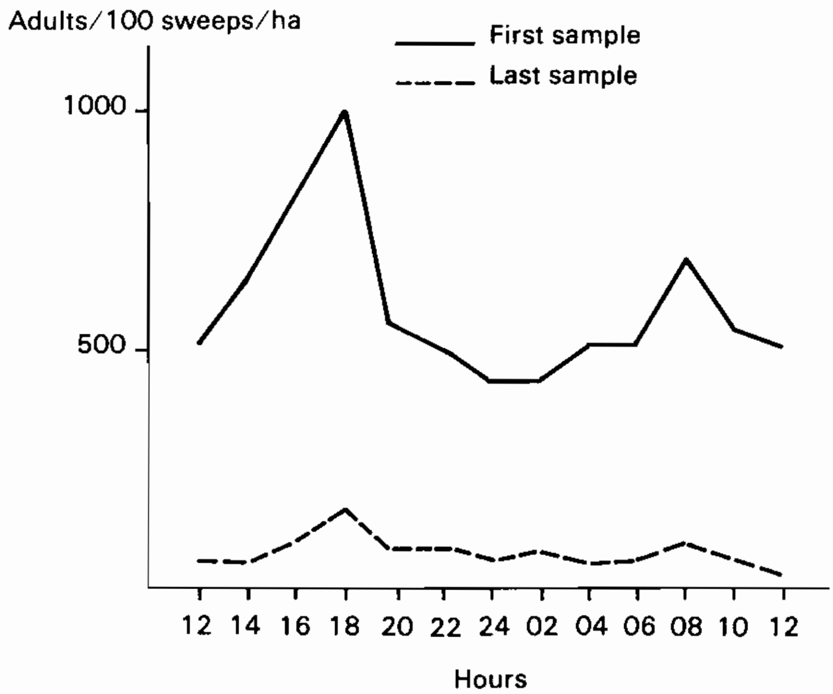
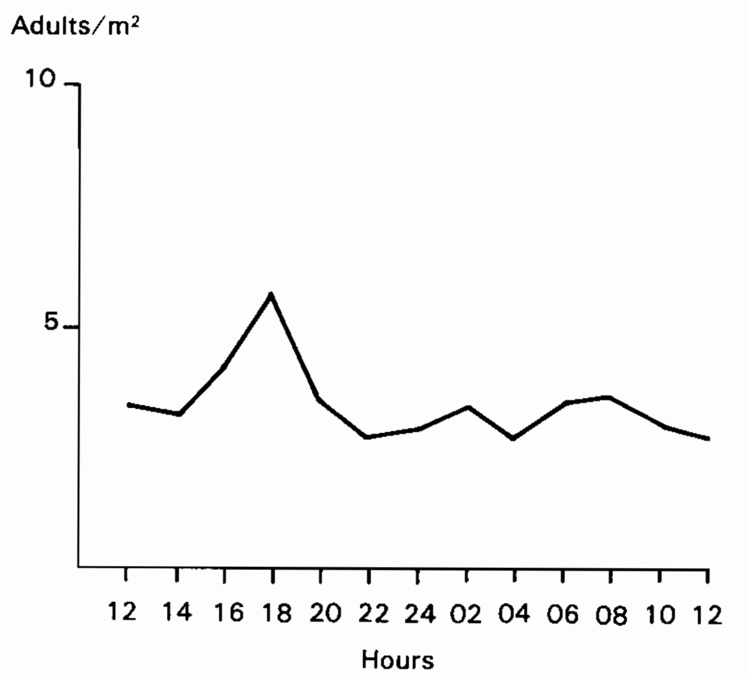


Figure 14. Daily activity fluctuation of adult *A. varia* (first and last sampling date).



Daily activity fluctuation of *A. varia.*

Figure 15. Estimate of *Aeneolamia varia* population in *B. decumbens* at two hour intervals.

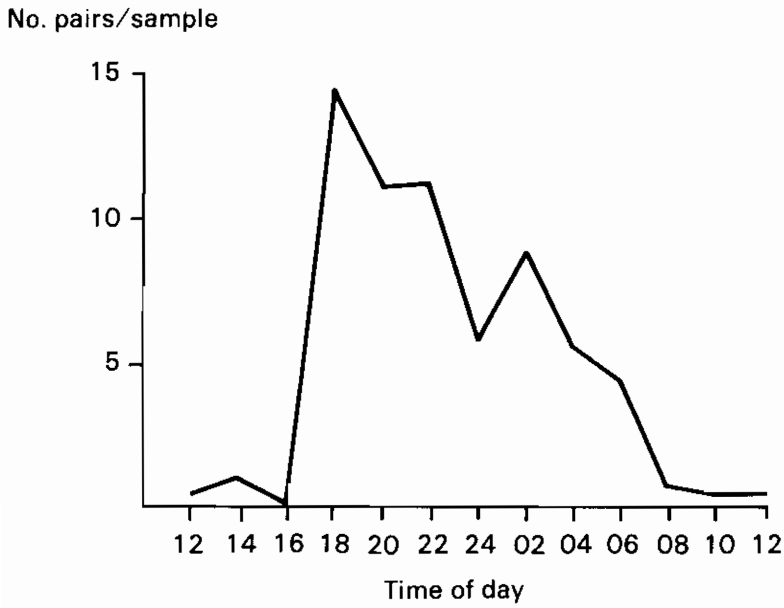


Figure 16. Mean number of copulating pairs of *A. varia* at two hour intervals over ten days of sampling in *B. decumbens*.

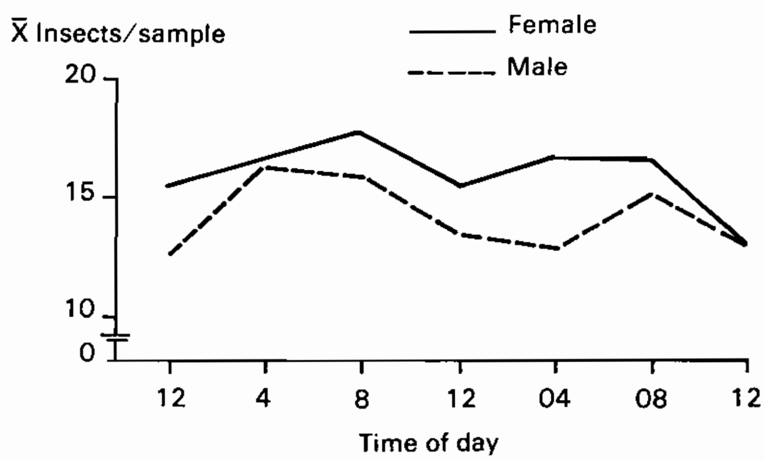


Figure 17. Mean number of adult females and males of *A. varia* during 9 days of sampling in *B. decumbens*.

dawn corresponds to the fluctuation observed for all spittlebugs during the sampling period.

EVALUATION OF GERMPLASM AT CARIMAGUA

Evaluations in the introduction garden at Carimagua will continue in 1986. Damage caused by leaf-chewing insects (Chrysomelidae and other Coleoptera families) was evaluated in C. macrocarpum. The best accessions were CIAT 5065, 5278, 5395, 5418, 5452, 5620, 5645, 5674, 5735, 5798, 5887, and 5984.

In D heterophyllum accessions CIAT 349 and 13199 and in Pueraria spp., accessions CIAT 4600, 17279, 17281, 17287, 17288, 17291, and 17390 were the most promising.

Damage caused by sucking insects (Homoptera and Hemiptera) was evaluated in C. brasilianum. CIAT 5474, 5486, 5492, 5510, 5511, 5517, 5530, 5822, 5884, and 5703 were the most promising materials.

Damage caused by stemborer (Caloptilia sp.) and budwormn (Stegasta bosquella) was evaluated in Stylosanthes spp. CIAT AJ1A, 2423, 2545, 10015, 10339, and 10342 of S. macrocephala showed the least damage from insect feeding.

With respect to the grass species under evaluation at Carimagua, no spittlebug populations were observed in accessions of Brachiaria spp. and Panicum maximum.

Plant Pathology

The responsibilities of the Plant Pathology section have continued unchanged during 1985:

1. The evaluation of germplasm for reaction to diseases in major screening and regional trial sites in major ecosystems.

2. The identification and assessment of diseases of germplasm under pasture evaluation.

3. The evaluation and development of control measures for the most important diseases of promising pasture species.

A. DISEASES CAUSED BY FUNGI, BACTERIA AND VIRUSES

GENERAL STUDIES

Disease Survey

From surveys made in native legume populations and planted germplasm evaluation trials, several diseases were found on new hosts.

The host range of stylo rust *Puccinia stylosanthis* was increased to include *Stylosanthes macrocephala* (stem rust) after surveys of native populations near Pirapora, Minas Gerais. This rust has now been found on *S. aurea*, *S. guianensis* var. *pauciflora* and *S. macrocephala* in Brazil and on *S. fruticosa* in various African countries.

The host range of *Cercospora stylosanthis*, the causal agent of Cercospora leaf spot, was extended to include *S. grandifolia* after native population surveys in Minas Gerais, Brazil. Although still considered as a minor pathogen, Cercospora leaf spot is more common on *S. guianensis* than previously thought. It was detected in both savanna ecosystems for the first time during 1985.

Binucleate isolates of *Rhizoctonia* sp. and one isolate of *R. solani* were found to cause severe foliar blight and root rot of several accessions of *S. macrocephala* in several locations in the Llanos and at Santander de Quilichao in Colombia. Detailed evaluation of this problem is in progress.

Collaborative projects with seed health testing laboratory-GRU

Using methodology developed by the Plant Pathology section, all seed lots of *Centrosema* spp. and *Zornia* spp. destined for regional trials outside Colombia were screened for *Pseudomonas marginalis* (*P. fluorescens* Biotype II) and *Corynebacterium flaccumfaciens* respectively. Of 49 seed lots of *Centrosema* spp., 9 were contaminated with *P. fluorescens* Biotype II (Table 1) while of 4 seed lots of *Zornia* spp., 2 showed the presence of *C. flaccumfaciens* (Table 2). All seed lots have been removed from seed destined for regional trials. Appropriate seed treatments will be made.

In collaboration with the Bean

Table 1. Survey of seeds of Centrosema spp. for Pseudomonas marginalis (P. fluorescens). (Collaborative project-GRU).

Species	Seed lots surveyed No.	Seed lots with P. marginalis No.
C. hybrids	9	2
C. macrocarpum	13	3
C. pubescens	7	1
C. sp.	11	1
C. brasilianum	7	0
C. schiedeanum	1	1
C. arenarium	1	1

Virology section, 34 seed lots of Centrosema spp. were screened for the presence of Centrosema Mosaic Virus. Using the Elisa technique, fourteen seed lots were found positive (Table 3). Growing-on tests with contaminated seed are in progress. Lots proven positively to be contaminated will be destroyed.

Table 2. Survey of seeds of Zornia spp. for Corynebacterium flaccumfaciens (Collaborative project-GRU).

Species	Seed lots surveyed No.	Seed lots with C.f. No.
Z. latifolia CIAT 728	2	1
Z. glabra CIAT 7487	1	0
Z. brasiliensis CIAT 7845	1	1

Effect of water stress on the development of anthracnose in three accessions of Stylosanthes spp.*

The effect of water stress on the incidence and severity of anthracnose caused by Colletotrichum gloeosporioides in S. guianensis var. vulgaris CIAT 136, S. guianensis var. pauciflora CIAT 1283 and S. capitata CIAT 1315 was evaluated under glasshouse conditions. At the same time, different morphological and physiological responses of the three ecotypes under water stress were studied.

* Student thesis project: Luis Enrique Núñez.

Table 3. Survey of seeds of Centrosema spp. for the presence of Centrosema mosaic virus.
(Collaborative project-GRU).

Species	Seed lots surveyed No.	Seed lots with CMV[a] No.
C. macrocarpum	21	8
C. brasilianum	3	1
C. pubescens	9	4
C. sp.	1	1

a By Elisa
All seed lots were harvested in Palmira or Quilichao.

Large differences in stomatal density were found among accessions (Table 4). Although S. capitata CIAT 1315 had the lowest stomatal density, it had larger stomata than S. guianensis. S. guianensis CIAT 136 had the highest stomatal density but the smallest stomata. Studies of stomatal resistance in the three accessions showed a direct relation between stomatal density and stomatal resistance. Under water stress, S. guianensis CIAT 136 and 1283 showed higher stomatal resistance than S. capitata CIAT 1315 (Table 5). Stylosanthes species with higher stomatal density apparently react rapidly to soil water deficit by closing their stomata, an important adaptation to dry conditions. In general, the three accessions showed high drought tolerance, exhibiting leaf water potentials as low as -26 bars at 6.25% field capacity in the

Table 4. Stomatal density (mm^2) of upper and lower leaf surfaces of three accessions of *Stylosanthes* spp.

Accession	Upper surface	Lower surface
	Stomata/mm^2	
S. guianensis CIAT 136	307 ± 63[a]	546 ± 111
S. guianensis CIAT 1283	266 ± 25	328 ± 79
S. capitata CIAT 1315	160 ± 21	182 ± 30

[a] Values are means ± standard deviation.

Table 5. Mean stomatal resistance of the upper and lower leaf surfaces of healthy plants under different levels of soil humidity and stomatal density in three accessions of *Stylosanthes* spp.

Available soil water[a] %	*S. guianensis* CIAT 136		*S. guianensis* CIAT 1283		*S. capitata* CIAT 1315	
	Upper 307[b]	Lower 546	Upper 266	Lower 328	Upper 161	Lower 180
	Stomatal resistance Sec cm					
100	7.4	21	6.3	17	5.0	9.0
50	7.0	29	8.0	10	5.0	9.0
25	55.0	82	29.0	60	13.0	16.0
12.5	49.0	107	68.0	67	25.0	68.0
6.25	89.0	98	83.0	100	28.0	54.0

a/ % field capacity.
b/ Number of stomata per mm^2.

soil, being consistent with those found for other *Stylosanthes* species.

The angle of leaf orientation was affected by water stress to a different extent in each accession (Table 6). *Stylosanthes guianensis* CIAT 1283 was insensitive to water stress and maintained leaf angles of 120°-150° from the vertical at soil water levels of 100% to 6.25% field capacity. In contrast, as water stress increased, *S. capitata* CIAT 1315 showed parahelionasty, orientating its leaves as vertically as possible. *Stylosanthes guianensis* CIAT 136, however, showed increased wilting as water stress increased (Table 6). Parahelionasty as shown by *S. capitata* CIAT 1315 could be an effective adaptation mechanism to severe water stress, minimizing incident radiation and consequent transpiration rate and water loss.

Increasing water stress greatly reduced

Table 6. Variation in the angle of leaf orientation of three accessions of Stylosanthes spp. under five levels of available soil water.

Available soil water	S. guianensis CIAT 136 Orientation	S. guianensis CIAT 1283 Orientation	S. capitata CIAT 1315 Orientation
100	2.4	3.0	2.1
50	2.1	2.5	2.5
25	2.3	3.0	2.9
12.5	1.6	3.0	3.4
6.25	0.9	3.0	3.3

[a] % Field capacity.
Evaluation scale: 0 = 0°- 60°; 1 = 60°-90°; 2 = 90°-120°; 3 = 120°-150°; 4 = 150°-180°.
MSE .05 = 0.53 in the interaction ecotype x level of available soil water.

forage production, root growth and foliar area in the three accessions to more than 70% (Table 7). Stylosanthes capitata CIAT 1315 and S. guianensis CIAT 1283 were more tolerant of water stress and less susceptible to defoliation than S. guianensis CIAT 136 and would be better adapted to survive and persist during periods of prolonged drought. Considering the origin of these three ecotypes, it is not surprising. Both CIAT 1315 and 1283 are from Maranhao, Brazil with approximately 1400 mm mean annual precipitation and six months dry season while CIAT 136 is from the Meta Department, Colombia with 2200 mm mean annual precipitation and four months dry season.

The incidence and severity of anthracnose caused by C. gloeosporioides varied over the experimental period depending on the susceptibility of the three accessions. Stylosanthes guianensis CIAT 136 showed a linear increase in both reaction to anthracnose and number of affected leaves. S. guianensis CIAT 1283 and S. capitata CIAT 1315 showed increased anthracnose levels until week four after which anthracnose remained stable in CIAT 1283 but decreased in CIAT 1315 (Figure 1). No significant differences in anthracnose development among water stress levels were found for S. guianensis CIAT 136 and S. capitata CIAT 1315 (Figure 2). In contrast, the development of anthracnose in S. guianensis CIAT 1283 was affected by water stress, being less at higher water stress (Figure 2). Although increasing water stress did not result in increased anthracnose development, the death of 75% of anthracnosed S. guianensis CIAT 136 plants at 6.25% field capacity in contrast to healthy plants showed an additive effect of anthracnose and water stress.

The greatest losses in dry matter of forage, roots, leaves and foliar area occurred at lower water stress levels (high levels of water in the soil) (Table 8). Stylosanthes guianensis CIAT 136, however, showed losses of leaf dry matter of 22% and of foliar area of 35% at 6.25% field capacity.

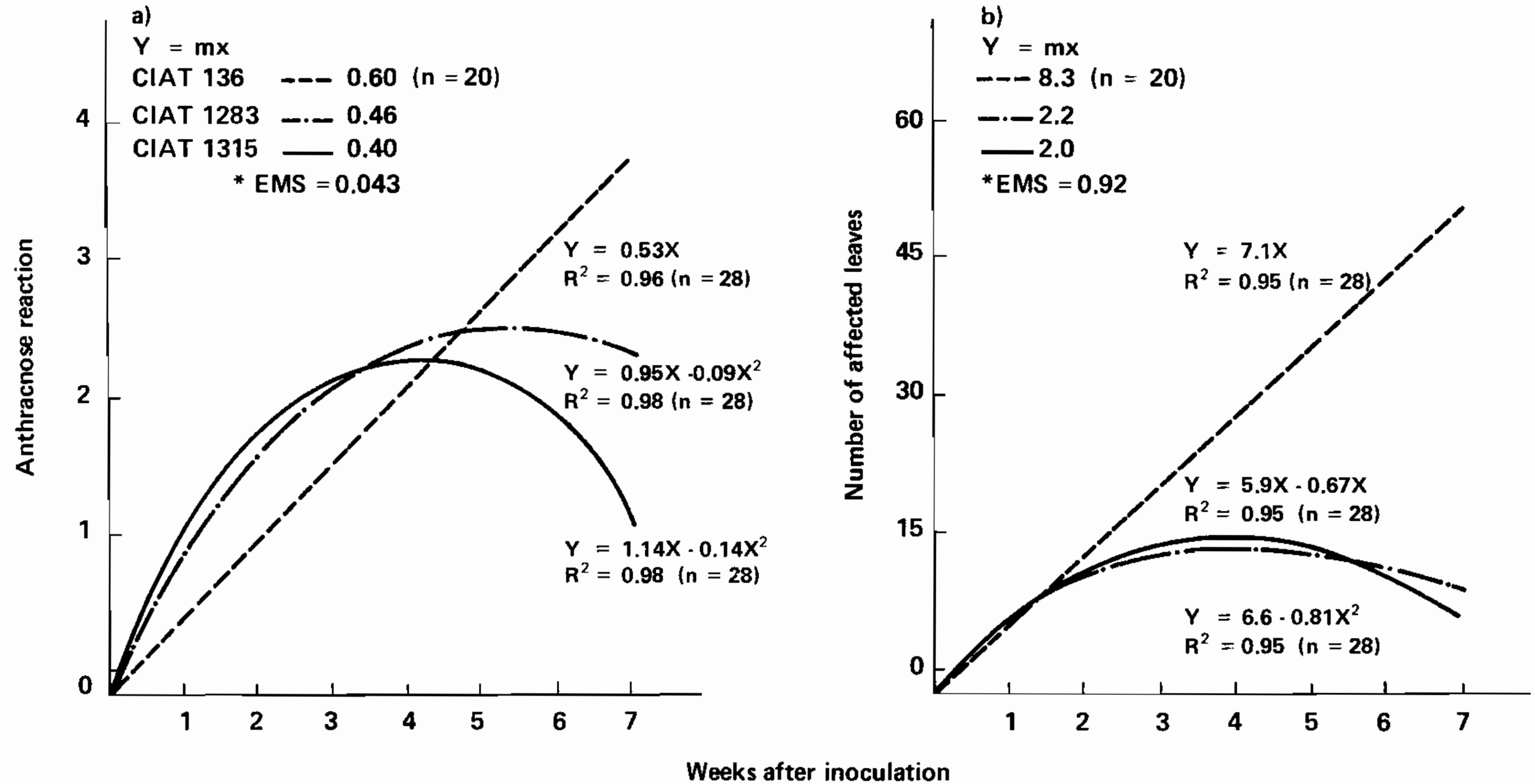


Figure 1. Development of anthracnose *C. gloeosporioides* (a) and number of affected leaves (b) over time in three accessions of *Stylosanthes* spp., *S. guianensis* CIAT 136 (– – – –), *S. guianensis* CIAT 1283 (._._._._) and *S. capitata* CIAT 1315 (———).

EMS ($P < 0.05$) between lineal slopes (m) of reaction and number of leaves during the first five weeks.

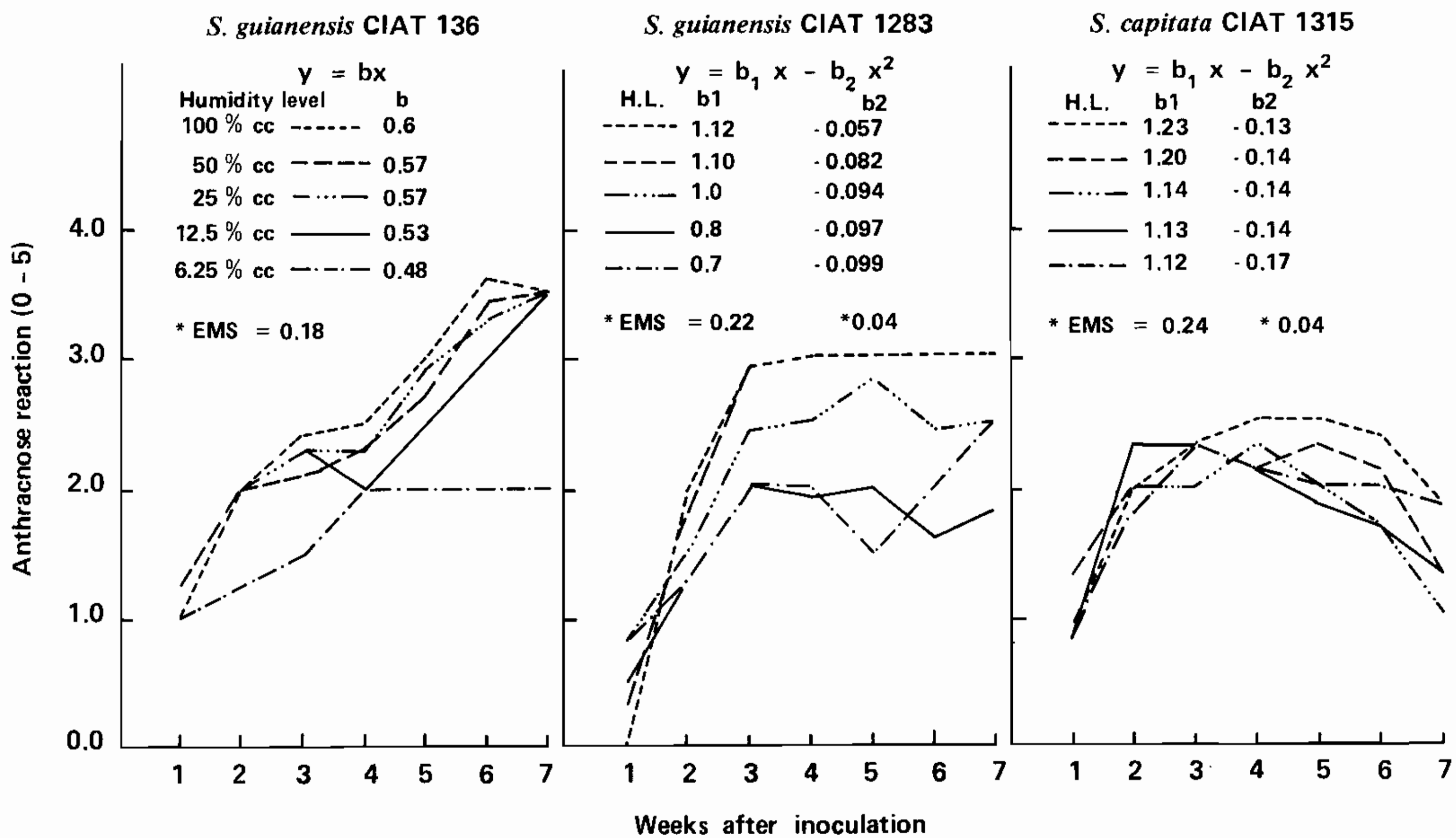


Figure 2. Effect of soil humidity levels on the development of active infections of anthracnose over time in three ecotypes of *Stylosanthes* spp. The coefficients that appear above the graphs are the slopes (reaction/week) of a linear model for *S. guianensis* CIAT 136 and a quadratic for *S. guianensis* CIAT 1283 and *S. capitata* CIAT 1315.

* DMS ($P < 0.05$) between slopes at humidity levels for each ecotype.

Table 7. Yield losses (DM) and defoliation in three accessions of Stylosanthes spp. at different levels of available soil water.

Ecotype	Available soil water	Dry Matter (y) Total aerial part	Roots	Leaves	Foliar area	No. Leaves
	(% field capac.)	------------ g	-------------		cm^2	
S. guianensis CIAT 136	100	10.1[a]	7.0	4.4	290	447
		------- % Reduction	-------	-------	-------	-------
	50	8	9	21	18	12
	25	38	34	43	35	28
	12.5	67	59	75	61	61
	6.25	70	57	73	54	58
S. guianensis CIAT 1283	100	10.8[a]	4.9	5.0	292	629
		------- % Reduction	-------	-------	-------	-------
	50	11	25	18	19	8
	25	38	59	32	30	2
	12.5	58	69	66	62	52
	6.25	76	71	74	64	66
S. capitata CIAT 1315	100	6.7[a]	3.0	3.0	308	437
		------- % Reduction	-------	-------	-------	-------
	50	9	17	0	12	1
	25	33	20	33	48	22
	12.5	66	37	63	65	50
	6.25	76	53	77	77	63

% Reduction = $\frac{\text{DM without I 100\% CC} - \text{DM without I}}{\text{DM without I 100\% CC}} \times 100$

a values: Dry Matter of healthy plants maintained at 100% of field capacity

DM = Dry Matter

I = Inoculum

In general, drought stress did not have a significant effect on the incidence and severity of anthracnose but the results indicated that once the pathogen is established in its host it is able to survive and develop under very low leaf water potentials (-26 bars).

Comparison of isolates of C. gloeosporioides collected from S. fruticosa and S. erecta in Africa.

Isolates of C. gloeosporioides collected from native populations of S. fruticosa in Nigeria and Ethiopia were virulent to both S. fruticosa and various accessions of S. guianensis (Table 9). Similarly, an isolate collected from S. erecta at IITA, Nigeria was also virulent to S. guianensis accessions. The findings cast doubt on the belief that anthracnose was introduced to Africa on seed of S. guianensis from other countries. The source of anthracnose on S. guianensis in Africa could be from native populations of S. fruticosa and S. erecta.

Table 8. Percentage dry matter loss due to C. gloeosporioides in three accessions of Stylosanthes spp. at different levels of available soil water.

Ecotype	Available soil water	Dry Matter			
		Total aerial part	Roots	Leaves	Foliar area
	% field capacity	%			
S. guianensis 136	100	15	23	32	31
	50	27	26	36	43
	25	12	16	21	25
	12.5	4	4	5	10
	6.25	5	9	22	35
S. guianensis 1283	100	16	45	10	12
	50	14	16	4	4
	25	9	0	14	14
	12.5	12	0	4	0
	6.25	0	4	8	11
S. capitata 1315	100	46	40	47	58
	50	31	10	37	31
	25	18	3	20	14
	12.5	9	3	17	17
	6.25	8	7	18	15

$$\%\ \text{Loss caused by anthracnose} = \frac{\text{DM with I} - \text{DM with I}}{\text{DM without I 100\% CC}} \times 100$$

DM = Dry matter
I = Inoculation

Effect of diurnal temperature fluctuations on the development of latent infection by seven isolates of C. gloeosporioides on two accessions of S. guianensis

Previous studies have shown the positive effect of increasing diurnal temperature fluctuations on the development of established latent infections by C. gloeosporioides in S. guianensis, thus supporting the hypothesis that lack of development of latent anthracnose infections in the humid tropics was partly due to the narrow ranges of diurnal temperature fluctuations prevailing during the wet season in this region (Annual Reports 1983-1984).

During 1984-1985, further studies were made with a range of selected latent infecting isolates from Colombia, Brazil and Peru. With the exception of I 12064, included as a non-latent infecting control in both S. guianensis CIAT 136 and 1283, initial infection levels were low, characteristic of these isolates (Table 10). One week after inoculation, two temperature treatments were imposed: day/night temperatures of 24°/6°C and 28°/18°C with diurnal temperature fluctuations of 18°C and 10°C, respectively. Only under diurnal temperature fluctuations of 18°C did considerable anthracnose development occur (Table 10). Lesions were small, rounded and numerous, characteristic of development of latent infections caused by this fungus. Lesion counts on the three leaflets of the youngest fully expanded leaf at the time of inoculation showed development of

Table 9. Comparison of isolates of Colletotrichum gloeosporioides collected from Stylosanthes fruticosa and S. erecta in Africa.

Accession	Reaction to Anthracnose				
	S. fruticosa 8C[a] Kaduna, N	S. fruticosa 7B[a] Kaduna, N	S. fruticosa 1B[a] Abernosa, E	S. erecta IITA, N	136 Q
Endeavour	2.0[b]	2.3	2.3	2.0	3.0
Graham	1.7	1.0	1.7	1.0	1.0
Schofield	1.7	2.3	2.7	3.0	3.7
Cook	1.3	1.0	2.0	3.0	1.7
136	2.0	1.0	2.3	1.7	3.3
1275	0	0	0	0	0
1875	0	0	0	0	0
1949	0	0	0	0	0
1283	1.7	1.0	2.7	-	2.0
2031	0	0	0	0	0
2243	0	0	0	0	0
10136	0	0	0	0	0
S. fruticosa CPI 41116	4.3	4.0	3.3	NP	NP

a Collections from native populations.
b Evaluation scale: 0 = no disease; 5 = plant death.
NP = no plant.

signficantly more lesions under 18°C diurnal temperature fluctuations than under 10°C fluctuations for all latent infecting isolates (Table 11). Results from this study further support the hypothesis that lack of development of anthracnose in the humid tropics is at least partly due to the prevailing temperature conditions.

Characteristics of isolates of Rhizoctonia spp. and their importance as pathogens of S. guianensis* and C. brasilianum

Considerable variation was found in growth rate, colour, zonation, sclerotia production, mycelial texture and virulence among isolates of Rhizoctonia spp. from both S. guianensis and C. brasilianum (Table 12). Both binucleate and multinucleate isolates were found; the multinucleate pertaining to R. solani (Thanatephorus cucumeris) and the binucleate to Rhizoctonia sp. (Ceratobasidium). Rhizoctonia zeae was isolated from soil near plants of C. brasilianum CIAT 5247. Most multinucleate isolates could be classified in anastomosis groups AG-1, AG-2 and AG-4 (Table 12). Starch gel electrophoresis revealed isozyme variation among isolates classified in the same anastomosis group. High band resolution was found for malate dehydrogenase (MDH) in the Tris-citrate EDTA system and for malate dehydrogenase and acid phosphatase (ACP) in the Histidine-HCl system. In the MDH-Histidine- HCl system, variation in banding patterns was found among isolates classified as AG-1 and AG-4. Although two AG-1 isolates from

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Table 10. Effect of diurnal temperature fluctuations on the development of latent infection by seven isolates of *Colletotrichum gloeosporioides* on two accessions of *Stylosanthes guianensis* one week and four weeks after inoculation.

Isolate	Origin	Anthracnose Reaction[a]							
		S. guianensis CIAT 136				*S. guianensis* var. *pauciflora* CIAT 1283			
		24°C/6°C[b]		28°C/18°C		24°C/6°C		20°C/18°C	
		1 w	4 w	1 w	4 w	1 w	4 w	1 w	4 w
11828	Leticia, C	1.4	2.8	1.0	1.0	1.0	2.2	1.0	1.0
11832	Leticia, C	1.4	2.2	1.0	1.0	1.0	2.4	1.0	1.2
11885	Paragominas, B	1.0	2.2	1.0	1.2	1.0	2.0	1.0	8.0
12064	Quilichao, C	2.2	2.8	1.8	2.6	1.2	2.2	1.2	1.2
12243	Tarapoto, P	1.6	2.0	1.0	1.2	1.2	2.2	1.0	1.0
12519	Quilichao, C	1.4	2.2	1.2	1.2	1.0	3.2	1.0	1.0
12890	Carimagua, C	1.4	3.0	1.0	1.4	1.0	2.4	1.0	1.2
		LSD = 0.48				LSD = 0.44			

a/ Anthracnose reaction was rated according to the scale 0 = no disease; 5 = plant death. Values are means of 5 replicates. The least significant differences between mean anthracnose ratings at $P< 0.05$ are given for CIAT 136 and 1283.

b/ Day/night temperatures.

Table 11. Number of lesions[a] produced from latent infections by seven isolates of Colletotrichum gloeosporioides in two accessions of Stylosanthes guianensis four weeks after inoculation under two regimes of diurnal temperature fluctuations.

Isolate (No.)	Origin	S. guianensis CIAT 136		S. guianensis var. pauciflora CIAT 1283	
		24°C/6°C[b]	28°C/18°C	24°C/6°C	27°C/18°C
11828	Leticia, C.	38.4	2.2	55.2	1.4
11832	Leticia, C.	18.0	2.8	41.2	2.2
11885	Paragominas, B.	22.0	3.2	55.6	0.6
12064	Quilichao, C.	11.6	8.0	44.4	1.2
12243	Tarapoto, P.	22.4	2.6	68.0	1.0
12519	Quilichao, C	35.0	3.0	62.6	1.0
12890	Carimagua, C	39.6	4.2	66.6	2.4
		LSD = 4.6		LSD = 9.2	

a. Number of lesions on the three leaflets of the youngest fully expanded leaf at the time of inoculation. Value are means of 5 replicated. Least significant differences between mean lesion count at $P< 0.05$ are given for CIAT 136 and 1283.

b. Day/night temperatures.

S. guianensis from Yurimaguas (I 1177) and Pucallpa (I 5583), Peru had identical banding patterns, they were different from R-43, the AG-1 tester isolate (Figure 3). Similarly, in the MDH-Tris- citrate EDTA and the ACP-Histidine-HCl systems, variation was found among isolates classified as AG-1 and AG-4, and, in the case of the latter system, also for AG-2 (Figure 3). In general, R. solani isolates with the same anastomosis groupings showed different banding patterns from their tester isolates. These results question the use of anastomosis groups as the only method of classifying and separating isolates of R. solani.

In pathogenicity tests, Centrosema spp. were generally more affected than S. guianensis, D. ovalifolium and S. capitata. Within the genus Centrosema, C. brasilianum was more susceptible than Centrosema sp., C. pubescens and C. macrocarpum.

A study of the effect of plant age on the severity of Rhizoctonia foliar blight showed a clear difference between two accessions of S. guianensis. In general, blight severity increased with age in S. guianensis var. pauciflora CIAT 1283 while it decreased or was independent of age in S. guianensis CIAT 184 (Figure 4). Stylosanthes guianensis var.pauciflora CIAT 1283 was probably more affected by age because of increased development of glandular trichomes and associated sticky secretions in older plants which may favour pathogen development. Although mean forage losses were not great (7.5% and 9.6% for CIAT 184 and 1283, respectively), losses as high as 46.5% dry matter were measured

Table 12. Cultural characteristics, anastomosis groups and nuclei status of isolates of *Rhizoctonia* spp. from *Stylosanthes guianensis* and *Centrosema brasilianum*.

Characteristic	Isolates from S. guianensis			Isolates from C. brasilianum												
	1283	1177	5583	5369	5173	5211	5234	5372	5178	5247A	5247B	5247C	5247B	5247E	5247F	5247G
Number nuclei per hyphal cell[a]	10	9	21	9	6	8	2	7	10	6	8	2	2	2	2	2
Growth rate, cm per 24 h[b]	5.31	4.79	5.25	6.17	5.50	5.50	5.00	6.25	5.90	7.20	6.00	3.96	5.00	5.50	5.00	4.00
Zonation[b]	+	+	+	+	+	+	+	+	+	-	+	-	-	+	-	-
Mycelian colour at 8 days[b]	Brown	Dk.brown	Dk.brown	Brown-grey	Brown-grey	Brown-grey	Brown	Brown	Yellow grey	Grey	Brown-grey	Brown-grey	Brown-grey	Brown-grey	Brown	Yellow-white
Mycelial texture[b]	Felty	Crusty	Crusty	Felty	Felty	Felty	(Cottn)	Felty	(Cottn.)	(Cottn.)	Felty	Felty	(Cottn)	Felty	(Cottn)	(Cottn.)
Presence of aerial mycelium[b]	++	+	+	++	+	+	++	+	+++	+++	+	+	+	+	+	++
Sclerotia[b]	+	++	++	+	+	+	+++	+	-	+++	+++	+	+	++	+	-
Anastomosis group[c]	AG-1	AG-1	AG-1	AG-1	AG-4	AG-4	-	AG-4	AG-2	?	-	-	-	-	-	-
Species	R.sol.	R. sol.	R. sol.	R. sol.	R. sol.	R. sol.	R. sp.	R. sol.	R. sol.	R. sol.	R.zeae	R.sp.	R.sp.	R.sp.	R.sp.	R.sp.

a - Mean of 15 observations
b - Mean of 5 observations
c - Mean of 10 observations
\+ - Trace
++ - Moderate
+++ - Abundant

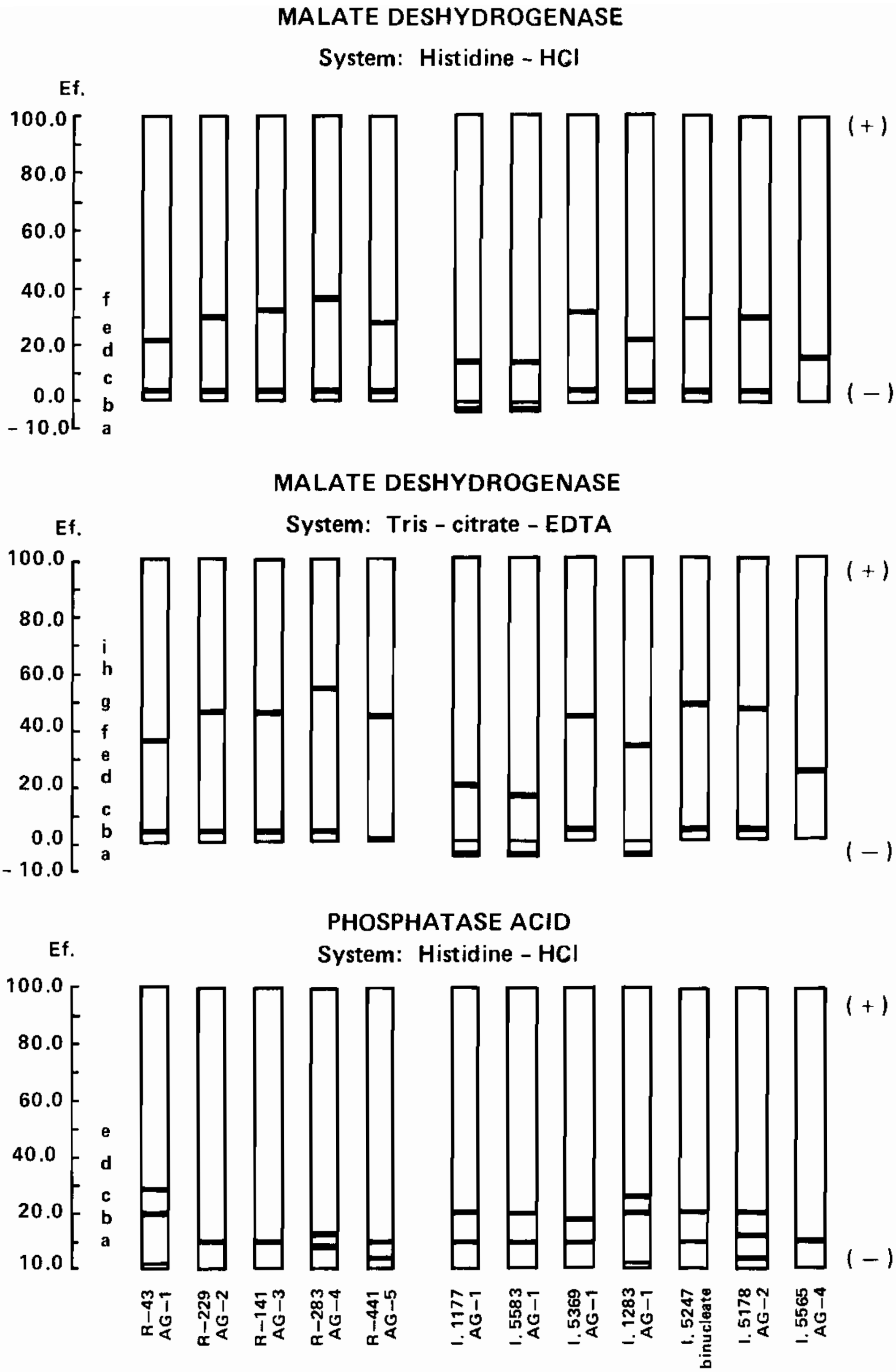


Figure 3. Isoenzyme banding patterns of *R. solani* isolates with defined anastomosis groups.

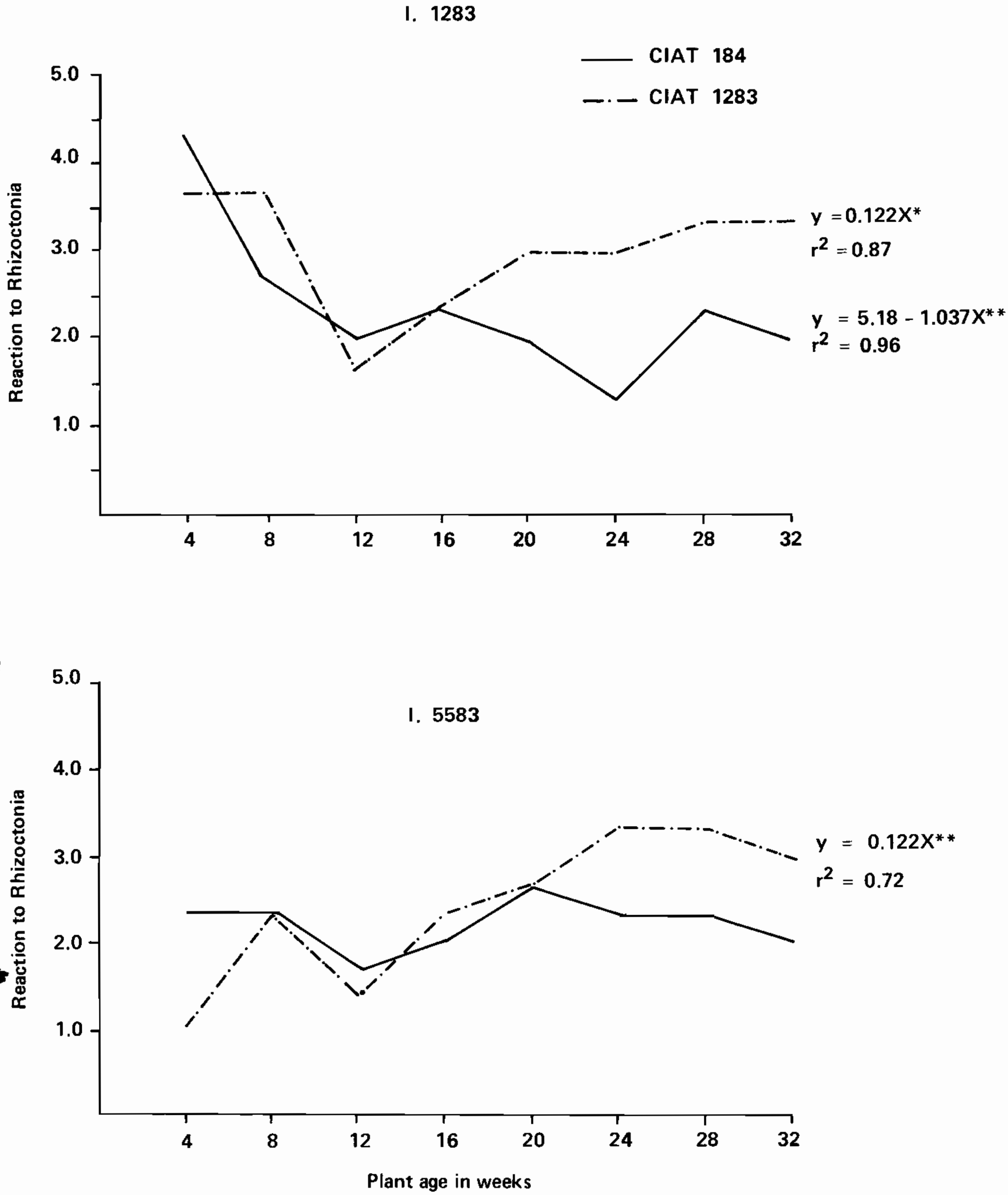


Figure 4. Effect of plant age on development of *R. solani* foliar blight (I 1283 and I 5583) in two accessions of *S. guianensis* CIAT 184 and 1283.

* from 12 weeks onwards
** from 4 weeks onwards

in older plants of CIAT 1283 and 32.2% in younger plants of CIAT 184. Although, nitrogen content was not significantly affected by disease, digestibility decreased significantly in younger and older plants of CIAT 1283 and in plants of 12 to 20 weeks of age of CIAT 184. Excellent regrowth was observed in CIAT 184 after removal of disease stress.

Plant height of S. guianensis and D. ovalifolium was increased by up to 107% with some isolates of R. solani (Figure 5). This suggests production of hormones by the fungus which consequently stimulate plant growth or stimulation of plant hormone production after the pathogen has entered the plant. Further studies are in progress.

Improved inoculation method for Rhizoctonia spp.

Inconsistent results in seedling inoculations with suspensions of Rhizoctonia mycelium prepared by the traditional method of homogenization of mycelium from solid culture-medium plates made necessary the search for an improved method. An enriched glucose-peptone liquid medium was produced (10 g peptone; 15 g glucose; 0.5 g $K_2H_2PO_4$; 0.25 g $MgSo_4$ $7H_2O$ per litre of water) on which cultures were grown for 5 days. Mycelium produced was collected by filtration and washed well.

Four methods were then compared:

1. Traditional: Homogenization in 50 ml of water for 4 min of mycelium scraped from 4 culture plates grown for 5 days.

2. Homogenization + Filtration: Homogenization in 100 ml of water for 10 min of 1.0 g of mycelium from the enriched liquid medium and filtered through double-layered gauze.
3. Homogenization - Filtration: As for method 2 without filtration.
4. Blending with ice: Processing in 100 ml of water plus 3 ice cubes for 6 min in a Waring blender of 1.0 g of mycelium from the enriched liquid medium.

Suspensions of mycelium were sprayed onto three-week-old plants of Centrosema spp. and reaction to Rhizoctonia foliar blight was evaluated after 4 days at 28°C and 100% relative humidity and after 3 additional days at 28°C and 50% relative humidity.

Blending of the mycelium with ice gave improved inoculation response in all accessions of Centrosema spp. in comparison to the traditional method and homogenization (Table 13). Microscopic examination of the processed mycelium showed that blending with ice breaks the mycelium into smaller more uniform fragments in comparison to homogenization where many larger mycelial masses remain.

Development of an inoculation methodology for evaluating Synchytrium desmodii in Desmodium ovalifolium

Because S. desmodii is a biotrophic fungus, a reproducible inoculation method using collections of zoospores from the field was sought. Comparison of different inoculum concentrations showed that approximately 10^4 zoospores/ml gave sufficiently uniform results with field inoculum (Table 14). At least six hours of leaf wetness were necessary for acceptable gall development (Table 15). This method is now being used to evaluate the collection of Desmodium ovalifolium for reaction to S. desmodii under controlled conditions.

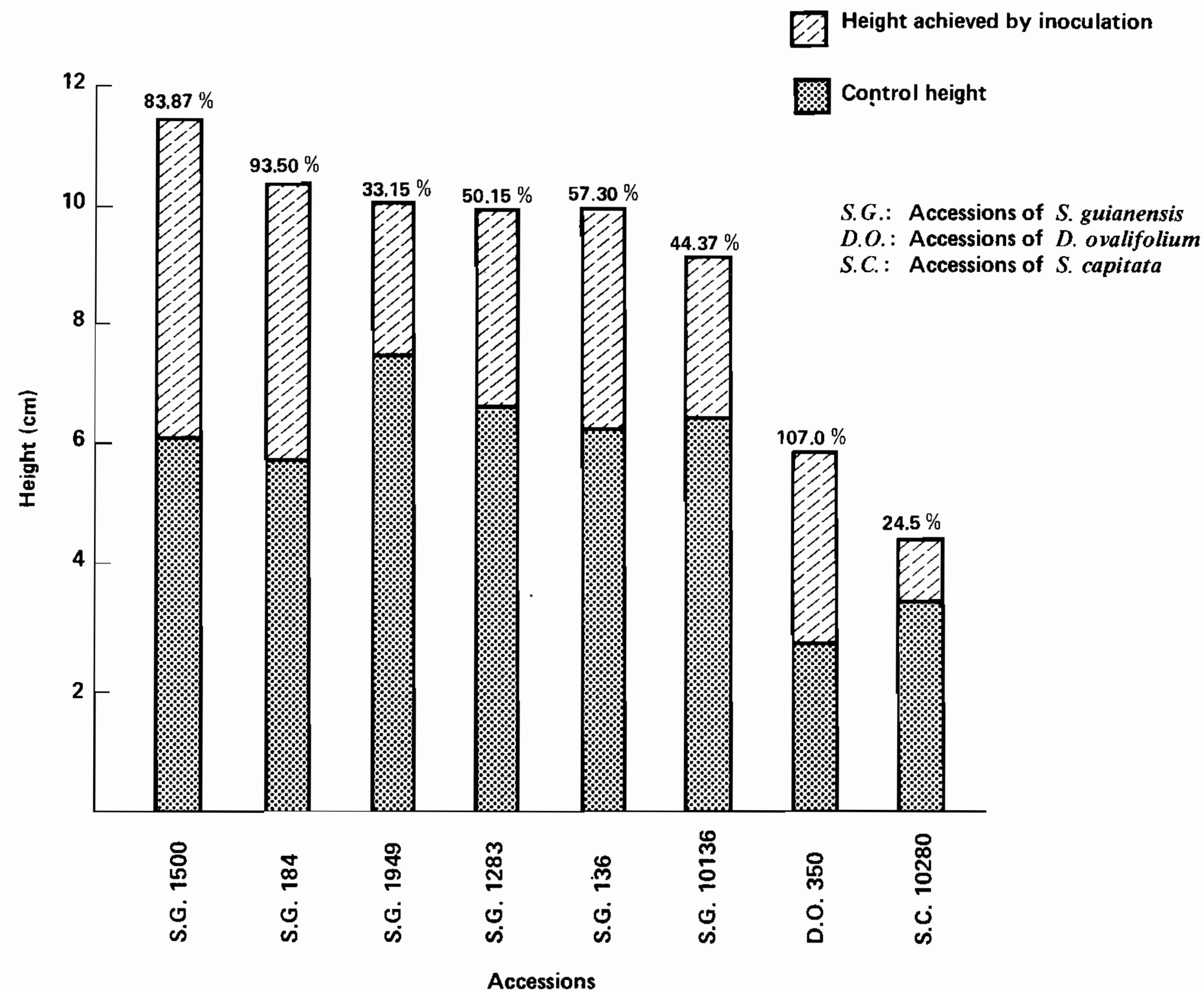


Figure 5. Percentage increase in height of accessions of *S. guianensis*, *S. capitata* and *D. ovalifolium*, obtained from stimulation by isolates of *R. solani*.

Table 13. Effect of different inoculation methods on the reaction of eight accessions of *Centrosema* spp. to I 5369 of *R. solani*.

Species	CIAT No.	Reaction to RFB			
		Traditional	Homogenization + Filtration	Homogenization - Filtration	Blending + ice
C. brasilianum	5234	2	0	2	3
C. brasilianum	5247	1	1	3	3
C. brasilianum	5178	2	1	2	3
C. brasilianum	5365	1	0	1	3
C. macrocarpum	5065	2	2	3	3
C. macrocarpum	5713	2	1	3	3
C. sp.	5277	2	1	2	3
C. pubescens	438	1	1	2	3
Mean		1.63	0.88	2.25	3.00

Table 14. Effect of inoculum concentration on infection of seedlings of *Desmodium ovalifolium* CIAT 350 by *Synchytrium desmodii*.

Plant No.	Inoculum concentration (zoospores/ml)					
	0	5.6×10^1	1.13×10^2	4.5×10^2	1.13×10^3	1.13×10^4
1	0	0	26	4	231	550
2	0	0	0	17	340	284
3	0	0	0	0	13	16
4	0	4*	0	4	12	412
5	0	0	Dead	3	37	223
6	0	0	9	15	NP	NP
7	0	0	0	5	3	470
8	0	0	0	9	251	360
9	0	0	Dead	17	0	262
10	0	3	0	8	353	Dead
11	0	0	28	8	47	674
12	0	9	0	0	0	891
Mean	0	1.3	5.4	7.5	117	414

* Total number of galls on the petiole and both sides of the first leaf.
NP = No plant.

Table 15. Effect of hours of leaf wetness on infection of seedlings of Desmodium ovalifolium CIAT 350 by Synchytrium desmodii.

Plant	Hours of leaf wetness 0	2	4	6	8	12	24
1	0	0	0	35	10	223	589
2	0	0	112*	117	164	0	738
3	0	0	13	259	2	902	273
4	0	0	0	4	89	12	535
5	0	NP	103	490	60	485	195
6	0	0	13	3	33	618	788
7	0	0	0	616	16	440	372
8	NP	0	0	29	4	623	316
9	0	0	153	296	0	0	311
10	0	0	0	867	178	11	389
11	0	0	0	0	753	489	189
12	0	0	0	467	1	390	954
Mean	0	0	33	270	109	349	471

* Total number of galls on the petiole and both sides of the first leaf.

STUDIES IN THE WELL-DRAINED SAVANNA ECOSYSTEM

Diseases of Stylosanthes spp.

The effect of mixtures of different proportions of three accessions of Stylosanthes guianensis var. pauciflora on anthracnose development*

The effect of mixtures, with 0 to 100% of two anthracnose resistant S. guianensis accessions CIAT 2031 and 10136, on anthracnose development of the susceptible component accession CIAT 1927 was studied in Carimagua during 1983 to 1984.

Treatments where the proportion of resistant material made up more than 60% of the mixture (that is less than 40% of CIAT 1927) showed significantly less anthracnose and higher mean survival than did treatments where the proportion of resistant material made up 20% or less of the mixture (Table 16). Similarly, live plant yields of the susceptible component CIAT 1927 were significantly greater in mixtures with resistant components than in pure stand (Table 16). At the same time, mixtures of 50% CIAT 1927 with CIAT 10136 as the resistant component were less affected by anthracnose than mixtures of 50% CIAT 1927 with CIAT 2031. This suggested that more protection is given by CIAT 10136 which is resistant to all races of C. gloesporioides in Carimagua (Table 17).

Fifty-eight C. gloeosporioides isolates were collected during the experiment; 32 of these were virulent and ten "isolate groups" or races were recognized by reactions on the S. guianensis differential set. With the exception of four groups found in the CIAT 1927 pure stand, the pathogen was most variable in association with the most diverse mixtures than with the least diverse (Table 18). This indicates that diverse host populations support diverse pathogen populations and exert less pressure on the pathogen to change.

* Student thesis project: Luis Alfredo Hernández

Table 16. Development of anthracnose, live plant yield and survival of S. guianensis CIAT 1927 in pure stand and in mixtures of different proportions in Carimagua 1983 - 1984.

% of CIAT 1927	Mean anthracnose reaction (0-5)	Mean survival %	Mean live plant yield gm/plant
20	3.8 b	31.0 a	3.5 a
40	3.8 b	29.0 a	3.9 a
80	4.5 a	21.0 b	3.7 a
100	4.4 a	18.0 b	2.7 b

Means followed by different letters in vertical columns are significantly different at $P < 0.05$.

Table 17. Development of anthracnose in S. guianensis CIAT 1927 in pure stand and in 50% mixtures of CIAT 2031 and 10136 in Carimagua 1983-1984.

Accession combinations	Mean Anthracnose (0-5)
1927 (50%) 10136 (50%)	3.8 a
1927 (50%) 2031 (50%)	4.2 b
1927 (100%)	4.4 b

Means followed by different letters are significantly different at $P < 0.05$.

Importance of cross-protection as a mechanism of disease reduction in mixed stands.

Cross-protection, where non-virulent isolates trigger an antibody-like reaction in a plant which protects it against virulent isolates, is said to be an important mechanism of disease reduction in mixed stands, but this has rarely been demonstrated in the field. Non-virulent C. gloeosporioides isolates are commonly obtained from apparently active anthracnose lesions in the field. The frequency of isolation of non-virulent isolates suggests that they could play a role in cross-protection.

To evaluate this, five non-virulent isolates were obtained from S. guianensis CIAT 1927 from the mixture experiment described above and pre-inoculated on CIAT 1927. One week later, the same plants were inoculated with a known virulent isolate. In all cases, pre-inoculated plants had less anthracnose than the control group which were pre-inoculated with water (Table 19). Pre-inoculation with I 12666, particularly, reduced subsequent anthracnose development to

Table 18. Effect of different mixtures of three accessions of S. guianensis on variation in the associated C. gloeosporioides population.

Components of the mixture % 1927	2031	10136	Isolate groups[a]
0	100	0	1
0	0	100	0
100	0	0	4
0	50	50	0
20	40	40	4
40	30	30	2
80	10	10	5
50	25	25	7
50	50	0	5
50	0	50	5

No. isolates collected = 58
No. of virulent isolates = 32
a = Total No. of different isolate groups = 10.

Table 19. Effect of pre-inoculation with five non-virulent isolates of C. gloeosporioides on development of anthracnose in S. guianensis CIAT 1927 following inoculation with a virulent isolate.

Non-Virulent isolate	Virulent isolate	Reaction to anthracnose[a]
Water	I 12734	3.0[b]
I 12646	I 12734	2.3
I 12679	I 12734	2.3
I 12670	I 12734	2.8
I 12666	I 12734	1.7
I 12662	I 12734	2.6

a Anthracnose Rating:
0 = no disease; 5 = dead plant.
b Mean of ten evaluations.

half that of the control, suggesting that cross-protection could be one of the mechanisms operating in reducing anthracnose build-up in CIAT 1927 in the mixture.

Evaluation of anthracnose development in a highly variable S. guianensis F2 population in association with Andropogon gayanus and native savanna under grazing.

In collaboration with the Plant Breeding section, anthracnose development and race structure in a highly variable S. guianensis F_2 population in association with Andropogon gayanus and native savanna under three stocking rates are being evaluated in Carimagua. No clear trends are yet apparent in the native savanna associations (Table 20). Increased plant death with decreasing stocking rate is probably due to anthracnose and mostly other causes with decreasing stocking rate is probably due to a combination of causes including competition, stemborer and anthracnose. effects. However, in the A. gayanus associations anthracnose tends to increase with decreasing stocking rate (Table 20). This is probably due to the effect of stocking rate on the relative abundance of A. gayanus which subsequently affects competition with and micro-climate on S. guianensis.

Evaluations are continuing four times a year. Two collections of anthracnose isolates have been made for race structure studies. Three hundred plants from the second generation have been collected and subsequent generations will also be tested to assess changes in population resistance over time.

Table 20. Development of anthracnose in a variable population of S. guianensis under grazing in two grass-legume associations and under three stocking rates after 17 months in Carimagua.

Treatment		Reaction to anthracnose					
Association	Stocking Rate[c]	0-0.5	1.0-1.5	2.0-2.5	3.0-3.5	4.0-4.5	Dead[a]
Native savanna	Low	0	35.2	32.8	8.4	0.1	23.6
Native savanna	Medium	0	44.8	27.1	7.9	1.4	16.1
Native savanna	High	1.1**	45.4	16.7	27.0	5.3	4.5
Andropogon gayanus	Low	0	19.2	34.8	20.8	1.6	23.6
Andropogon gayanus	Medium	0	32.4	23.0	17.8	3.0	23.8
Andropogon gayanus	High	0	46.0	22.0	7.0	2.0	23.0

a Due to anthracnose and/or other causes.
b % of plants in each category.
c Native Savanna LSR = 0.75 an/ha; MSR = 1.00 an/ha; HSR = 1.25 an/ha
A. gayanus LSR = 3.75 an/ha; MSR = 5.00 an/ha; HSR = 6.25 an/ha

Effect of association with A. gayanus and other grasses on development of anthracnose in various accessions of S. guianensis.

The stimulatory effect of A. gayanus on anthracnose development in three susceptible accessions of S. guianensis was shown several years ago. In 1985, similar results were found for eleven S. guianensis accessions. Anthracnose build-up was greater in association with A. gayanus than without the grass (Table 21). The ranking of accessions for anthracnose severity, however, was similar in both treatments.

The effect of grasses with different growth habit and aggressiveness on anthracnose development was evaluated with four S. guianensis accessions. In general, all grasses stimulated anthracnose development. However, A. gayanus had a greater effect than did B. humidicola or M. minutiflora (Figure 6). At the same time, different grasses had greater stimulatory effect on different S. guianensis accessions. For example, A. gayanus had the greatest stimulatory effect on anthracnose development in S. guianensis CIAT 136 whereas M. minutiflora had the greatest effect in CIAT 2812. Anthracnose development in CIAT 1950 was stimulated equally by the three grasses (Figure 6).

The stimulatory effect of associate grasses on anthracnose development in S. guianensis may be due to the stress of competition exerted by the grass on the legume making the legume relatively more susceptible to anthracnose. There could, however, be a microclimate effect whereby the associate grass increases the humidity and shading in the immediate microenvironment of the legume which-stimulates anthracnose build-up. Other interacting effects may also be involved. Further work is urgently needed to understand this phenomenon.

Table 21. Development of anthracnose in eleven accessions of S. guianensis with and without A. gayanus after six months in Carimagua.

Accession	Cultivar name	Mean anthracnose rating[a] + A. gayanus	- A. gayanus
13	Endeavour	4.7	2.3
15	Graham	4.3	3.0
1950	Cook	5.0	3.3
136		4.3	3.0
184		3.7	2.7
	Alupe I	4.0	2.7
1283		4.0	3.3
2540		3.3	1.7
1927		5.3	3.3
2812		5.3	4.3
2031		1.7	0.3
	Mean	4.15	2.72

a 0 = No disease; 6 = Plant death.

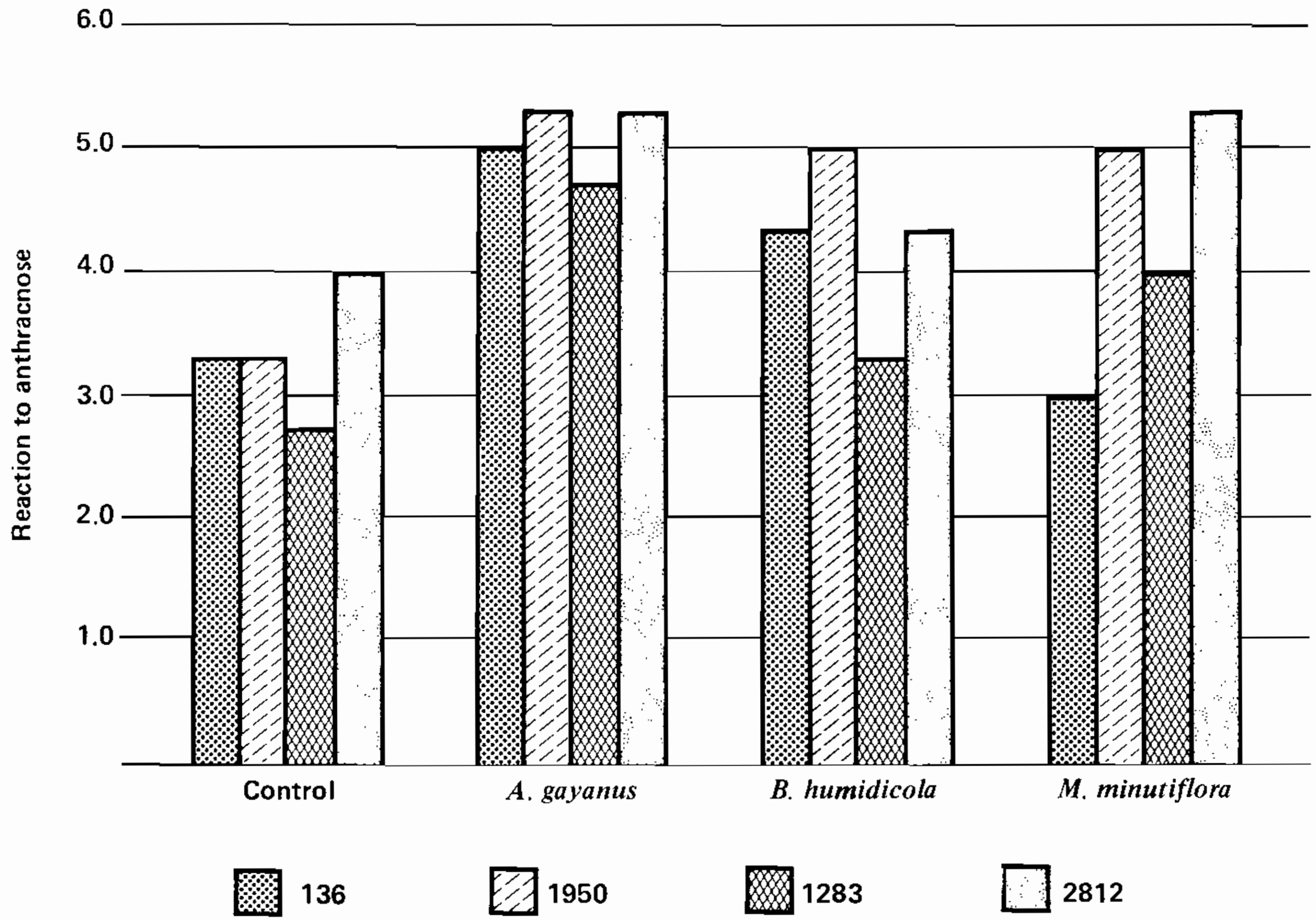


Figure 6. Development of anthracnose in four accessions of *Stylosanthes guianensis* with and without three grass associates after six months in Carimagua.

Effect of reducing soil and aerial inoculum movement of C. gloesoporioides on the development of anthracnose in three susceptible accessions of S. guianensis.

After 17 months of evaluation, the effect of both soil and aerial inoculum of C. gloeosporioides on anthracnose development in all S. guianensis accessions was clear. All accessions died within eight months when no protection was given (Figure 7). Anthracnose development was relatively slower when mulch was used to reduce soil inoculum build-up than when cloth barriers were used to reduce aerial inoculum movement. However, after 17 months, both treatments showed similar anthracnose levels, being lower than those of the control (Figure 7). Reduction of the movement of both soil and aerial inoculum decreased anthracnose development and after 17 months mean anthracnose levels were 2.3, 3.4 and 1.0 for S. guianensis CIAT 13, 1950 and 1283, respectively (Figure 7). Even though these plants have anthracnose, disease build-up, which is mainly from mostly auto-infection, is extremely slow. Apparently, reinfection from outside, alloinfection, is more important for anthracnose development in the field.

Results from this experiment suggest that it may be possible to reduce anthracnose build-up by the use of natural barriers to inoculum movement. Further investigation of this aspect is planned.

Reaction of 20 accessions of S. guianensis to anthracnose at seven different sites in Carimagua.

The representativeness of the "Pista" evaluation site for screening S. guianensis for anthracnose reaction is being evaluated in a collaborative project with the Plant Breeding Section in Carimagua. Seven sites, two in the "Pista", and one each in the "Acuario", "Campo de agronomia", "Torre", "Yopare" and "Alegria", were selected as representative of the range of environments, particularly in terms of soil characteristics. Results to date show that more anthracnose has developed in the "Pista 1" site where most screening of S. guianensis has been done and inoculum has obviously built-up (Table 22). The development of anthracnose in the "Acuario" and "Torre" sites is associated with past S. guianensis plantings near these sites. Aerial anthracnose inoculum has probably moved from the "Pista 1" site to "Pista 2". As inoculum must be presetn from previous S. guianensis plantings, the lack of anthracnose development at in the "Campo de Agronomía" site may be related to its considerably more fertile soil. The "Alegria" site is located far from all other sites and at present, it is anthracnose-free. Changes during the next year will be carefully monitored. The main objective will be to assess the value of highly productive but highly anthracnose susceptible accessions as evaluated at "Pista 1" in other Llanos environments.

Diseases of Centrosema spp.

Effect of Rhizoctonia foliar blight in C. brasilianum CIAT 5234 in association with A. gayanus and under grazing.

A trial to evaluate the effect of Rhizoctonia foliar blight on C. brasilianum CIAT 5234 in association with A. gayanus and under continuous grazing was initiated in June 1984 in an established grazing trial in Carimagua. A complete factorial with ± grazing, ± grass associate and ± fungicide (Benlate) was set-up to assess the effect of foliar blight on yield.

Dry matter losses (mean of five harvests) ranged from 29.4 to 53.6% (Table 23). Although there was no clear difference between associations treatments without grazing, under

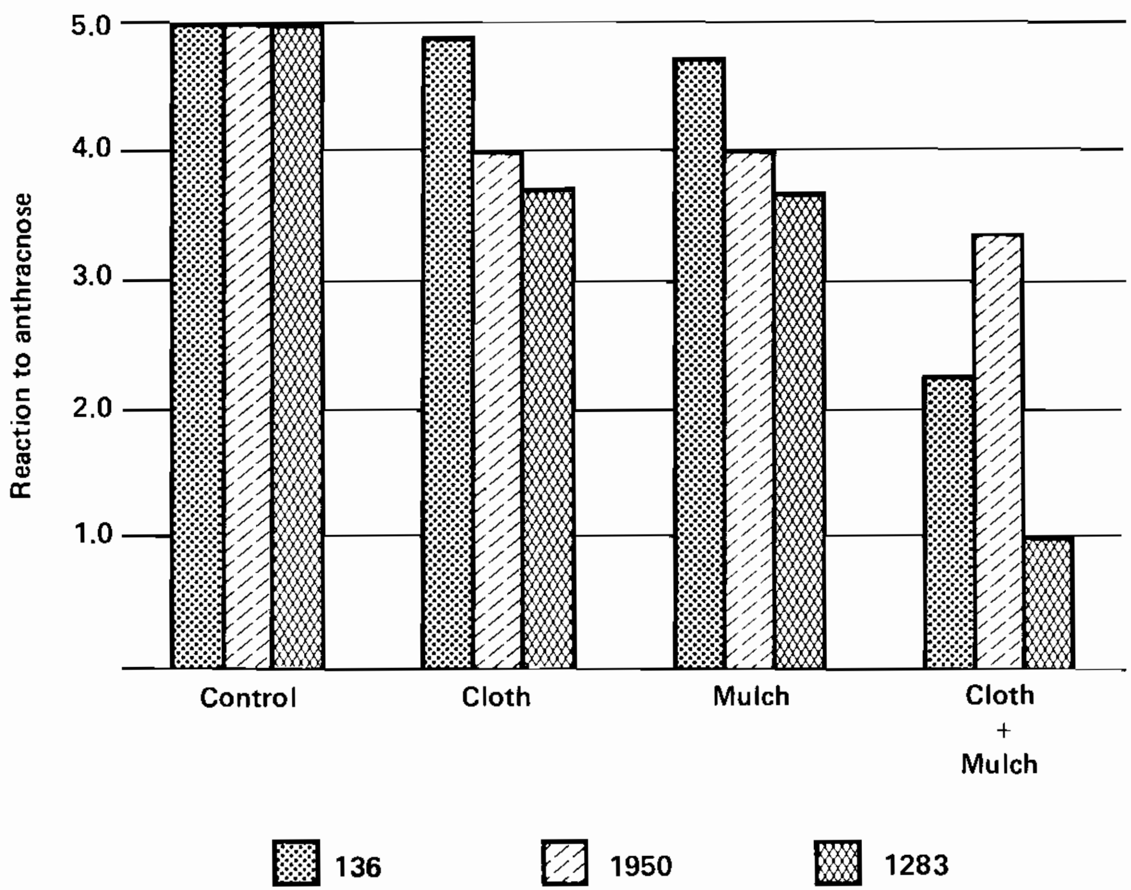


Figure 7. Effect of reducing movement of soil (mulch) and aerial (cloth barrier) inoculum of *C. gloeosporioides* on the development of anthracnose in three susceptible accessions of *S. guianensis* after 17 months in Carimagua.

Table 22. Reaction of 20 accessions of S. guianensis to anthracnose at seven different sites in Carimagua after 5 months.

Accession	Reaction to Anthracnose[a]						
	Pista 1	Pista 2	Acuario	Campo de Agronomia	Torre	Yopare	Alegria
S. guianensis var. vulgaris							
Endeavour	3.3	2.7	2.3	0	0	0	0
Cook	3.7	0.5	1.5	0	0	0	0
Graham	4.0	2.3	3.0	0	0.3	1.3	0
136	3.3	1.2	2.7	0	0	0	0
184	3.2	0.7	2.0	0	0	0	0
1275	0.7	-	1.0	0	0	0	0
1949	1.7	-	1.2	0	0	0	0
1875	4.0	-	3.7	0	0	0	0
1539	1.5	0.3	1.3	0	0	0	0
2312	4.7	2.3	4.3	0	1.0	0	0
S. guianensis var. pauciflora							
10136	0	0	0	0	0	0	0
2031	0.5	0	0	0	0	0	0
1283	4.7	1.7	0.5	0	2.8	0	0
2243	1.7	0	0.7	0	0.5	0	0
2812	4.3	2.0	1.3	0.8	3.0	0.5	0
2362	1.2	1.0	1.2	0.3	0	0	0
1927	3.7	0.5	1.3	0.5	1.8	0	0
2191	4.2	0	0	0	1.8	0	0
1280	1.7	0.3	1.3	0	0.5	0.3	0
1808	1.2	0.3	0.7	0	0.3	0	0
Mean	2.67	0.79	1.50	0.08	0.56	0.11	0

a Evaluation scale = 0 = no disease; 5 = plant death.

grazing foliar blight caused considerably greater losses in C. brasilianum under grazing in association with A. gayanus than without association. This is thought to be a microclimate and/or a competition effect.

Evaluation sites were selected for the presence of foliar blight and, consequently, estimation of the overall pasture losses caused by foliar blight must be interpreted with incidence data. During August, surveys of the incidence of foliar blight showed 81% in C. brasilianum alone and 65% in the C. brasilianum - A. gayanus association. Therefore, overall losses, without grazing, ranged from 19.1 to 29.5% and, under grazing, ranged from 27.2 to 34.8%. These sizeable losses this cast doubt on the future of C. brasilianum CIAT 5234 as a associate of A. gayanus under continuous grazing in this ecosystem.

Effect of various treatments on development of Rhizoctonia foliar blight in three Centrosema spp.

The use of mulch to control Rhizoctonia web blight of beans has been successful. Use of A. gayanus mulch, however, stimulated Rhizoctonia foliar blight of C. brasilianum CIAT 5234 and Centrosema sp. CIAT 5568 probably because the pathogen colo-

Table 23. Effect of Rhizoctonia Foliar Blight on C. brasilianum CIAT 5234 in association with A. gayanus and under grazing from June 1984 to September 1985.

Treatment	Evaluation of RFB[a] Under Grazing			Without Grazing		
	Damage[b] RFB (1-5)	DM Yield[c] g DM/m²	Loss %	Damage RFB (1-5)	DM Yield g DM/m²	Loss %
+ A. gayanus + Fungicide	1.03 (0-3)	22.2		0.90 (0-3)	46.9	
+ A. gayanus - Fungicide	1.51 (0-4)	10.3	53.6	1.49 (0-4)	33.1	29.4
- A. gayanus + Fungicide	1.03 (0-3)	21.7		1.19 (0-3)	58.2	
- A. gayanus - Fungicide	1.69 (0-4)	14.4	33.6	2.06 (0-4)	37.0	36.4

a/ RFB = Rhizoctonia Foliar Blight
b/ Mean of 12 evaluations; range in parentheses; 0 = no disease, 5 = plant death.
c/ Mean of 5 harvests.

Table 24. Effect of soil contact on development of Rhizoctonia foliar blight in three Centrosema species.

Treatment	Reaction to Rhizoctonia Foliar Blight[a] C. brasilianum CIAT 5234	Centrosema sp. CIAT 5568	C. macrocarpum CIAT 5065
Control	2.2	1.7	-
Mulch	3.0	2.0	-
Weeds	2.3	2.0	-

a 0 = No disease; 5 = plant death.

nized the mulch (Table 24). The success of mulch in controlling Rhizoctonia foliar blight might, therefore, be dependent on the type of material used.

Centrosema Mosaic Virus of C. macrocarpum.

Surveys of the C. macrocarpum collection continued in Carimagua during 1985. Although in 1984, 58% of the collection was affected, this year only 4 accessions of C. macrocarpum showed virus symptoms (Table 25). The level of infection is diminishing apparently due to the lack of re-infection under Carimagua conditions (aphid vectors are not present). At present, Centrosema Mosaic Virus is not be considered an important disease of Centrosema in this environment.

Table 25. Presence of Centrosema Mosaic Virus in Carimagua, 1985.

Species	Accessions No.	Presence of CMV
C. macrocarpum	43	4
C. brasilianum	63	0
C. sp.	2	0

1984 - 58% C.macrocarpum were affected.

Diseases of Desmodium ovalifolium.

Evaluation of D. ovalifolium collection for reaction to Synchytrium desmodii.

During 1985, periodic evaluations of reaction to false-rust caused by S. desmodii continued in the D. ovalifolium collection. Although the, promising accession CIAT 13089 was free from false-rust in 1984, slight levels were recorded this year (Table 26). Accessions CIAT 13089, 3776, 3794, 13088 and 13098 are presently the most promising with respect to their general adaptation, vigour, resistance to stem-gall nematode and relatively low levels of false-rust.

Effect of S. desmodii on D. ovalifolium CIAT 350 under grazing and in association with Brachiaria decumbens.

An attempt was made to assess the effect of false-rust (S. desmodii) on D. ovalifolium CIAT 350 under grazing using two fungicides, Brestan and Duter, and one surfactant, Tween 80 to control the disease. Although these

Table 26. Evaluation of Synchytrium desmodii on Desmodium ovalifolium in Carimagua 1984 - 1985.

Accession No.	Synchytrium Rating 0-5		Cover %	Vigour
	1984	1985	1985	1985
Category IV				
3788	NP	NP	NP	NP
13089	0	1.7	100	E/B
Category III				
3776	0.8	2.1	82	B/R
3793	1.3	3.0	35	R/M
3794	1.1	2.4	86	B
13092	1.0	3.3	70	B/R
13129	1.0	3.0	43	M/R
Others				
13088	0.7	0.7	100	E
13098	0.7	1.3	100	E/B

NP = No plants were evaluated.
E = Excellent
B = Good
R = Average
M = Bad

products had significantly reduced zoospore motility under laboratory conditions, none of them was successful in controlling false-rust under field conditions.

Indirectly, however, the devastating effect of false-rust on seedling populations of D. ovalifolium was evaluated. During June to October, 1985, seedling populations decreased from more than 600/m^2 to 12/m^2 or less under grazing and to 52/m^2 or less without grazing (Table 27). Most surviving seedlings were moderately to severely affected by false-rust and it is unlikely than they will become adult plants and set seed. As soil seed reserves are extremely low, it is expected that D. ovalifolium CIAT 350 may disappear from this pasture by next year. The major effect of false-rust was devastation of seedling populations and thus persistence.

Diseases of Zornia latifolia.

Effect of Sphaceloma scab and other diseases on selections of Z. latifolia CIAT 728.

Evaluation of the performance of selections made from the CIAT 728 population in Quilichao in 1981-82 continued in Carimagua during 1985. Selection FP5 continued to be outstanding with low levels of Sphaceloma scab and Drechslera leaf spot, excellent general vigour and twice the yield of other selections and the mean of CIAT 728 (Table 28). This selection will now be evaluated under grazing.

Diseases of Pueraria phaseoloides.

With the planting of a large collection of P. phaseoloides germplasm in Carimagua in 1984, diseases of this species were evaluated systematically for the first time. Three diseases were found: Pseudocercospora leaf spot, anthracnose as leaf spots and pod lesions and Rhizoctonia foliar blight (Table 29). The latter disease was the most widespread in the collection and caused the most damage. CIAT 9900, the commercial variety, was affected only by Pseudocercospora leaf spot. Evaluations will continue during 1986 to select the most disease resistant accessions.

B. DISEASES CAUSED BY NEMATODES

1. Pterotylenchus cecidogenus, the stem gall nematode on Desmodium ovalifolium

Work continued in 1985 on the stem gall nematode, Pterotylenchus cecidogenus, which has severely

Table 27. Effect of Synchytrium desmodii on Desmodium ovalifolium CIAT 350 under grazing and in association with Brachiaria decumbens.

Treatment	Young plants/m^2					
	With grazing			Without grazing		
	Jun.	Aug.	Oct.	Jun.	Aug.	Oct.
Control	512	37	11	629	107	46
Brestan	334	67	12	520	126	46
Duter	619	17	3	528	31	18
Tween 80	361	40	11	612	152	52

Seed soil reserves: May 1985 = 148 seed/100 gm DW soil.
Sept 1985 = 23 seed/100 gm DW soil.

Table 28. Effect of Sphaceloma scab and other diseases on selections from Zornia latifolia 728 in Carimagua 1984 - 1985.

Selection	Reaction to S.S	Reaction to D.L.S.	General Vigour	Yield[b] gm/plot
728	2.5[a]	1.7	R/B	138.8
FP 1	1.7	1.0	B	135.4
FP 2	3.0	2.1	R	90.1
FP 3	1.6	1.3	B/R	135.0
FP 4	4,0	1.7	M	27.6
FP 5	1.6	0.7	E	256.9

a Mean of 10 evaluations.
b Growth period of 2 months.
SS Sphaceloma scab
DLS Drechslera leaf spot.

Table 29. Evaluation of diseases of Pueraria phaseoloides in Carimagua 1984 - 1985

Disease	% Collection affected Moderately	Severely
Pseudocercospora leaf spot	8.9	0
Anthracnose	8.1	0
Rhizoctonia foliar blight	23.8	1.0

Control CIAT 9900 moderately affected by Pseudocercospora.
Accessions more affected by Rhizoctonia: 4600, 17279, 17280, 17285, 17289, 17294, 17298, 17304, 17311, 17317.
Accessions more affected by Anthracnose: 815, 4600, 17280, 17282, 17286, 17307, 17311, 17316, 17324, 17327.

affected Desmodium ovalifolium CIAT 350, one of the only legumes yet identified as promising in association with the aggressive, stoloniferous Brachiaria spp.

The objectives of this study remain as in 1984:

1. To develop screening techniques for evaluating resistance and tolerance of D. ovalifolium in the field and glasshouse.
2. To study the relationship between the stem gall nematode, D. ovalifolium and the grazing animal.
3. To determine the distribution and host range of the stem gall nematode.
4. To continue studing the importance of the seed in the disease.

A) Resistance and tolerance screening in the glasshouse

When looking at plant-nematode relationships, there are two main factors which may determine the outcome, viz.

1. Resistance - the ability of the plant to reduce reproduction of the nematode.
2. Tolerance - the ability of the plant to withstand damage caused by the nematode.

Of the two, resistance is generally considered to be more important as tolerance is not expressed in very susceptible genotypes. Resistance is also much easier to measure than tolerance. Therefore, assessment of the D. ovalifolium collection began with measurement of resistance.

Results show that the following accessions were more resistant, i.e. allowed less nematode reproduction per gram of plant tissue than CIAT 350:

3776, 3788, 3793, 3794, 13082, 13083, 13085, 13088, 13089, 13106, 13108, 13125, 13126, 13127, 13128, 13128A, 13129, 13130, 13131, 13132, 13133, 13135, 13137, 13139, 13302. Although many D. ovalifolium accessions possess some ability to reduce reproduction of P. cecidogenus compared with CIAT 350, this does not seem to be the only factor that determines the effect of the nematode on the plant. Some ac-accessions which had low gall ratings in the field allowed rapid nematode reproduction e.g. CIAT 13114, 13115, 3673, 13136, while others had high gall ratings under field conditions but allowed little nematode reproduction in the glasshouse e.g. CIAT 13099, 13128A, 13289, 3784. To determine whether tolerance may play a part in the outcome of the plant-nematode relationship, growth of CIAT 350, 3794 and 13129 were examined with and without inoculation with nematodes. CIAT 350 was susceptible and had high gall ratings in the field CIAT 3794 and 13129 were about equally resistant in the glasshouse but 3794 had the higher gall rating in the field.

Results obtained 40 days after inoculation (Table 30) were consistent with those obtained in the field screening trial. Growth of CIAT 13129 was not reduced by P. cecidogenus as was 3794 although both were less affected than 350 and produced fewer galls. CIAT 13129 produced fewer galls per plant than did 3794 although this was not significant. A difference may have been found if gall weights were obtained. The conclusion drawn from this is that CIAT 13129 was not stimulated as much by the nematode as was 3794 to produce gall tissue and, therefore, to redirect its resources away from plant growth and towards gall growth. Work is in progress to establish the correlation between gall production and plant growth reduction and to determine in the glasshouse the most tolerant accessions among the resistant group.

B) Resistance and tolerance screening in the field.

In June 1984, a screening trial was set up with 10 replicates with 33

Table 30. Growth after 40 days of three accessions of Desmodium ovalifolium uninoculated and inoculated with Pterotylenchus cecidogenus.

Accession		Stem length (mm)	Root length (cm)	No. leaves	Shoot dry wt. (mg)	Root dry wt. (mg)	Galls/ plant
350	C	52	282	19	112	18	0
	I	16***	118***	7**	21***	6**	1.8***
3794	C	37	256	13	61	13	0
	I	22	111**	8	32**	6**	0.75
13129	C	42	405	14	109	22	0
	I	48	456	18	112	25	0.2

, * significant effect of inoculation ($P < 0.01$, $P < 0.001$, respectively).

previously untested accessions using CIAT 350 as the control. The original aim was to extract nematodes from two plants from each plot at 2-4 monthly intervals to determine nematode reproduction in each accession (i.e. resistance). However, in the first sampling five months after inoculation, the variation within plots and between replicates was so high that it was decided that little could be gained by this destructive sampling. The mean number of nematodes per plant in various accessions ranged from 0 to nearly 6000 but none was significantly different from CIAT 350. Coefficient of variation was about 400%.

After the first sampling, evaluation continued on the basis of visual ratings of galls on plants (ie. tolerance), plant vigour and dry matter production.

In August 1985, those accessions which had significantly lower gall ratings than CIAT 350 were: 3673, 3776, 3788*, 13088*, 13089*, 13092*, 13114*, 13115, 13123*, 13129, 13131, 13134, 13136, 13139, 13371, 13400. The accessions marked with stars also had growth scores equivalent to those of CIAT 350.

This trial has not as yet been affected by Synchytrium. In an older trial, inoculated August, 1983, with 60 accessions of the D. ovalifolium, Synchytrium may now be a more limiting factor than P. cecidogenus as those accessions more susceptible to P. cecidogenus have died. The following accessions were the most promising in that trial in October 1985: 3776, 3794, 13088, 13089, 13098.

Comparison of gall rating between various evaluation times can define the best time for evaluation of promising accessions i.e. when the greatest difference is expressed between the best and worst accessions. Figure 8 shows the development of stem galls in the collection of 60 D. ovalifolium accessions. The trial was inoculated in August 1983. By February 1984 the disease was well developed. In May 1984, the majority of accessions had high gall ratings. However, by September 1984, affected plants of those accessions with high gall ratings had died with the survivors having low gall ratings. One year later the situation was similar. These observations show that the best time for evaluation of P. cecidogenus on D. ovalifolium is between 6 and 9 months after inoculation. This, of

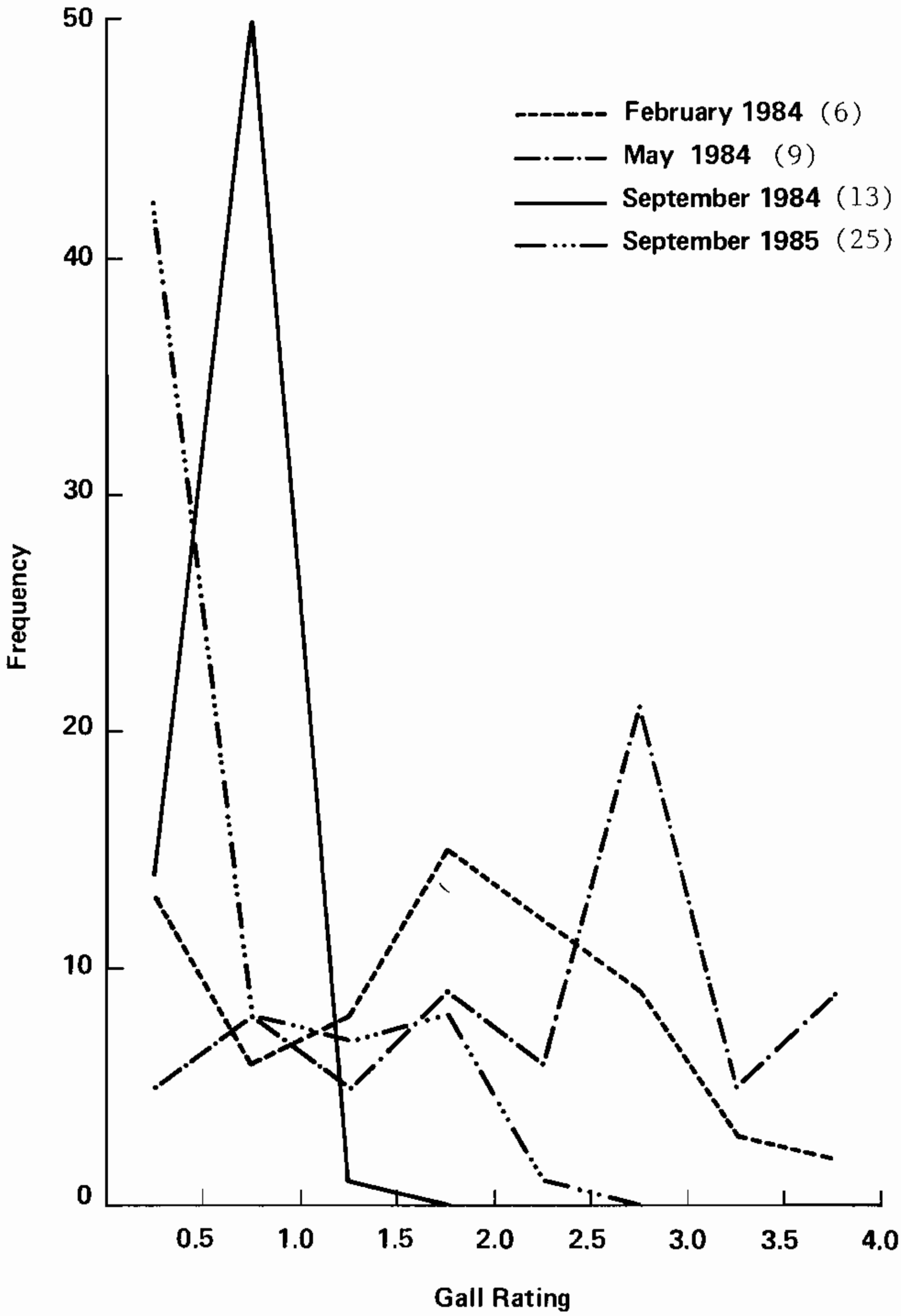


Figure 8. Development of stem galls (rating scale: 0-4) on 60 accessions of Desmodium ovalifolium sown in February 1983 and inoculated with galls of Pterotylenchus cecidogenus in August 1983 (numbers in parentheses show months after inoculation).

course, may depend on time of inoculation and environmental conditions.

Based on results from field and glasshouse screening we have been able to include several accessions in more advanced trials.

1) A collection of 16 of the better D. ovalifolium accessions have been sown on poorly drained savanna, with and without inoculation with P. cecidogenus, to assess their productivity under those conditions.

2) Five of the more resistant D. ovalifolium accessions have been sown in a Category III trial with CIAT 350 as the control to assess their performance in association with B. dictyoneura, under grazing and with stem gall nematode infestation.

C) Relationship between P.cecidogenus, D. ovalifolium, plant growth habit, resistance to the nematode and gall production

In June 1984, a trial was set up to test the following hypotheses:

1. Damage caused by grazing increases stem gall nematode.

2. There is an interaction between plant growth habit and grazing damage on the growth of plant and nematode.

3. There is an interaction between grazing damage and resistance to the nematode on growth of plant and nematode.

4. There is a direct relationship between growth of galls and resistance or tolerance to the nematode.

The trial has four replicates and four treatments with the combinations of +/- nematodes (artificial inoculation) and +/- grazing. In each plot are 12 subplots, separated by a row of Andropogon gayanus, consisting of 3 rows each of four D. ovalifolium accessions viz.

CIAT 350 - more erect, susceptible
CIAT 3780 - semi-erect, susceptible
CIAT 3788 - semi-erect, resistant
CIAT 13122 - prostrate, susceptible

As the original assessment of resistance was based on field performance, this may reflect tolerance rather than resistance.

Grazing began in July 1985 with 5-6 animals per plot for one day each month. At each evaluation time, plant vigour, nematode gall rating and Synchytrium rating were recorded. Before the first grazing, evaluations were made for each plant in each plot and an index obtained using the following formula:

$$\text{Index} = \frac{\text{rating of each plant}}{\text{maximum rating X No. of plants in the row}} \times 100$$

After that time it was not possible to distinguish between each plant in most plots so evaluations were made on whole plots with ratings of 0-4 (0 = no galls, 1 = galls on 25% of stems, 2 = 50%, 3 = 75%, 4 = 100%).

Before grazing, there was a significant effect (P 0.05) of inoculation on gall index being 34 in the "+N" treatment and 25 in the "-N" treatment. Unfortunately, the plots designated "-N" also received some inoculum. Since the first grazing the effect of inoculation has not been significant. Before grazing there were also effects of accessions on all three characters measured (Table 31). CIAT 3788 was most vigorous and had a low gall index. There was no correlation between plant growth habit and gall index. The other accessions were similar in vigour, gall and Synchytrium indices.

In September 1985, after two cycles of grazing, the following effects were found: 1) effects of accession on plant vigour, stem gall and

Table 31. Indices of plant vigour, stemgall nematode and Synchytrium before grazing.

Accession	Vigour	Gall	Synchytrium
3788	53 a	24 b	5 ab
13122	39 b	31 ab	4 ab
350	36 b	33 a	11 a
3780	33 b	30 ab	1 b

Values in each column not followed by the same letter are significantly different (P< 0.05).

Synchytrium ratings (Table 32). CIAT 3788 still showed best growth and CIAT 3780 the poorest. CIAT 3788 still had the lowest stem gall rating and there was no correlation between gall rating and plant growth habit. CIAT 3780 still showed the lowest Synchytrium rating and CIAT 3788 and 350 the highest with CIAT 13122 being intermediate; 2) there was no effect of grazing on stem gall or Synchytrium rating.

D) Interaction between wounding of D. ovalifolium and penetration by P. cecidogenus

A previous experiment showed that there was no effect of light wounding

Table 32. Ratings of plant vigour, stem galls and Synchytrium after two cycles of grazing (Scale: 0-4).

Accession	Vigour	Gall	Synchytrium
3788	2.5 a	1.2 b	1.2 a
13122	1.9 b	2.1 a	0.6 b
350	1.8 b	1.8 a	1.2 a
3780	1.3 c	2.0 a	0.1 c

Values in each column not followed by the same letter are significantly different (P< 0.05).

of young CIAT 350 plants on penetration by P. cecidogenus. To further test the hypothesis that wounding increases penetration by P. cecidogenus the following experiment was done: one centrimetre lengths of stems of intact one-year-old D. ovalifolium CIAT 350 plants were a) not wounded, b) cut through the epidermis or, c) cut through to the centre of the stem. Chopped gall pieces were wrapped around the wound with damp cotton wool and sealed with Parafilm. Two months later, nematodes were extracted from stem lengths including 2 cm to each side of the test piece. No difference was found between treatments with the mean number of nematodes per stem piece being 285, showing that wounding did not increase penetration by the nematode.

E) Behaviour of P. cecidogenus on D. ovalifolium

1) Movement of P. cecidogenus between host plants.

It has been previously observed that D. ovalifolium in field plots which had not been artificially inoculated with stem gall nematodes took a long time to develop enough galls for disease detection. This occurred with the original discovery of the nematode. It was two years after sowing of a seed production plot that galls were first detected. It seems that inoculum in native hosts such as D. barbatum was widely spaced and that nematodes spread very slowly from these plants to other host plants viz. D. ovalifolium.

In order to determine why this nematode spreads so slowly compared with other above-ground nematodes a trial was done in the glasshouse. A number of D. ovalifolium seedlings were sown and inoculated. After one month, these plants had developed galls and were resown one each with newly germinated plants. However, in one treatment, 20 galled plants were sown upside down, ie. dead plants; the other 20 were sown right way up, ie. live plants. One month later nematodes were extracted from the younger plants and counted to determine migration of nematodes from the galled plants. Plants sown with dead galled plants had an average of 112 nematodes per plant and those with live plants had significantly fewer with only 15 per plant. It seems, therefore that nematodes tend to remain at the same feeding site until conditions became unfavourable e.g. death of the plant part, before moving to new host tissue. This greatly reduces spread of infection.

2) Mechanism of resistance of D. ovalifolium to P. cecidogenus.
Some accessions have been shown in glasshouse screening to allow less nematode reproduction (ie. are more resistant than CIAT 350). A resistance mechanism for D. ovalifolium to P. cecidogenus could result from one of or a combination of a) reduced attraction to the plant stem, b) reduced movement along the stem, c) reduced penetration of the plant by the nematode, or d) physiological factors occurring after penetration. If the mechanism could be determined it might lead to a more accurate and/or rapid means of resistance screening.

a) Work thus far has included 5 D. ovalifolium accessions, D. barbatum (native host) and the native Mimosa sp., Galactia sp. and Euphorbia sp. Stem gall nematodes were mixed with 1% water agar in culture flasks and a 1 cm piece of plant stem placed at one end of each flask. After 24 hours, distribution of the nematodes in each flask was determined to compare attraction to different accessions and plant species. There was no relationship between resistance and attraction of the nematode to the stem piece.

b) Stems, 12 cm long, were cut from mature plants of 6 D. ovalifolium accessions with different degrees of resistance (i.e. ability to support nematode reproduction) as determined from resistance screening in the glasshouse. The stems were placed in soil at the bottom of test tubes containing 2000 nematodes each. After 16 hours stems were removed, cut into 3 cm sections, nematodes extracted and counted. No correlation was found between number of nematodes on stem sections and resistance.

c) Seeds of 6 D. ovalifolium accessions with different resistances were pregerminated for one week in petri dishes containing 1% water agar. Seedlings were then inoculated in the petri dishes with 130 nematodes each in 0.2 ml water. After 24 hours, seedlings were removed, stained and nematodes counted. No difference was found between resistance and number of nematodes penetrating seedlings.

d) It seems that resistance results from processes occurring after penetration and not before and that there is no easier way to measure resistance than by examining nematode reproduction in the plant.

F) Nematicide treatment of seed to control P. cecidogenus

As none of the D. ovalifolium accessions in the CIAT collection is completely immune to P. cecidogenus, an attempt was made to develop another control method for use along with resistance and/or tolerance. The method involved soaking scarified seed in the systemic nematicide, Furadan, at various concentrations for different times. The seeds were then washed and pregerminated for one week and sown in pots with 10 replicates. One week later (i.e. 2 weeks after treatment with Furadan) the plants were inoculated in the usual way. Four weeks after inoculation, the plants were harvested and the number of nematodes in each plant counted. Table 33 shows the mean number of nematodes per plant in each treatment.

Table 33. Number of *P. cecidogenus* in *D. ovalifolium* plants four weeks after inoculation and six weeks after seed treatment with Furadan.

Treatment time (mins)	Concentration of Carbofuran (ppm) 0	100	500	Mean
1	126	192	55	124
5	136	136	54	109
60	124	123	27	91
Mean	129	150	45	

L.S.D. between means for times and concentration = 23.

Although 100 ppm did not affect nematode numbers, treatment with 500 ppm significantly reduced nematode numbers in plants. This is an important finding and work is continuing to determine how long protection lasts and if other chemicals provide better or cheaper protection.

G) Storage of stem galls on *D. ovalifolium*

In order to determine the most efficient method of storing galls for greatest nematode survival for use in for glasshouse and laboratory experiments, various temperature and humidity combinations were tried for one month. Plastic and paper bags were used to effect high and low humidity, respectively.

Temperature treatments were constant 10, 24, 30 and 35°C and laboratory conditions fluctuating between 18 and 22°C. In general, nematode survival was reduced by high temperatures, fluctuating temperatures and high humidity (Table 34). The best conditions for storage were constant 10°C in paper bags. Reduction in nematode survival was related to reduction in standard deviation in body length (which was used to give an indication of life stages) of surviving nematodes. This indicated that fourth-stage juveniles (J4) were the best able to survive, followed by J3, females and J2.

H) Survival at high osmotic pressure

As tolerance to desiccation is probably related to tolerance to high osmotic pressure, nematodes were tested for 6 or 24 hours in 0.1 M, 1.0 M or 2.0 M NaCl. Nematodes survived in 2.0 M for up to 6 hours and in 1.0 M for up to 24 hours (Table 35). The standard deviations in body lengths of surviving nematodes showed that 24 hours' exposure to 1.0 M NaCl produced the narrowest range of body lengths, i.e. the narrowest range of growth stages, corresponding to fourth-stage juveniles.

This information may be useful in the study of the life cycle of this nematode. To study the life cycle of a nematode, it is necessary to inoculate plants with a certain stage of the nematode and extract nematodes at intervals to examine development. In stem galls, however, all stages of *P. cecidogenus* occur together. It may be possible to use treatment with NaCl solution to obtain a single stage for inoculation. Work is continuing on the life cycle.

I) Survival of isolated nematodes under desiccation.

Many above-ground nematodes are able to survive desic- cation when isolated, i.e. out of the

Table 34. Percent survival of Pterotylenchus cecidogenus and means and standard deviations of body lengths of motile nematodes following on month of storage in galls of Desmodium ovalifolium at different temperatures and humidities.

Storage % temperature (°C)	Humidity	% Survival Total	Females	Juveniles	Body length ( )[a] Mean	Standard deviation
10	Low	83	77	83	555.2a	55.7 b
	High	26**	71	24***	537.2b	61.6 b
20	Low	37	0	39	545.9bc	34.7 c
	High	0*** 0	0***	–	–	
24	Low	69	29	71	585.5a	64.9 b
	High	0***	0*	0***	–	–
30	Low	42	6	28	550.6ac	27.4 d
	High	0*	0	0**	–	–
35	Low	3	0	3	546.2bc	21.5 e
	High	0*	0	0*	–	–
Control	–	–	–	–	548.2abc	99.5 a

*, **, *** Significant difference between high and low humidities at each temperature ($P < 0.05$, $P < 0.01$, $P < 0.001$, respectively). # Mean of fluctuating temperatures at laboratory conditions between 18 and 22°C.

a Values followed by the same letter in each column are not significantly different (Mann-Whitney and F test, respectively).

plant tissue. To determine whether this is so for P. cecidogenus, extracted nematodes were air-dried to about 50% relative humidity in the laboratory on watch glasses for 1 to 48 hours. Percent motility and percent infectivity were determined - the latter by inoculating plants with surviving nematodes and re-extracting one week later. P. cecidogenus was very intolerant of desiccation to 50% RH. Even after 1 hour of desiccation, motility was reduced to 1% of that of undried nematodes. Work will continue under more controlled conditions using desiccators.

II. Root-Knot nematodes, Meloidogyne spp. on D. ovalifolium

Collaborative trials on Meloidogyne sp. on D. ovalifolium in Tarapoto, Peru have been evaluated during 1984.

1) Screening of 75 accessions to root-knot nematodes.
This trial was sown in February 1984. The results of the latest evaluation in August 1985 are shown in Table 36. Only 14 accessions have not yet developed root galls, viz. 350, 3666, 3794, 13081, 13088, 13092, 13094, 13095, 13098, 13116, 13121, 13125, 13131, 13132. However, only 3 accessions viz. 3652, 13108, 13114, have gall ratings of greater than 2 which is considered the level of practical resistance. Evaluations will continue during 1986.

2) Control of root-knot nematode in D. ovalifolium using Brachiaria spp.
D. ovalifolium CIAT 350 was sown in association with 4 Brachiaria spp. (Table 37) to assess efficiency of control of Meloidogyne sp. In all associations, except that with B.

Table 35. Percent survival of Pterotylenchus cecidogenus, means and standard deviations of body lengths of motile nematodes following exposure to NaCl solutions for 6 or 24 h.

Concentration of NaCl (M)	Time of exposure (h)	% Survival	Mean	Standard deviation
0	-	100	537.2	72.8
0.1	6	72	538.2	75.4
	24	75	537.9	87.2
1.0	6	60 (**)	535.7	72.2
	24	27 (***)***	523.1 (**)**	35.3 (**)***
2.0	6	27(***)	529.2	54.4 (**)
	24	0(***)***	-	-

, * Significant difference (P< 0.01, P< 0.001, respectively) between 6 and 24 h treatment.
(**), (***) Significantly different from control (P< 0.01, P< 0.001, respectively).

ruziziensis, the grass dominated the legume. This may be the result of the aggressiveness of the grass or of root-knot nematode attack on D. ovalifolium. Consistent with glass-house studies (Annual Report, 1983), B. ruziziensis permitted no galling of D. ovalifolium roots but the other grasses did. Application of the nematicide, Terracur, halved the infestation.

III. Other plant-parasitic nematodes

a) Pratylenchus spp. on pastures grasses

At several sites including Carimagua, Quilichao and Macagual in Colombia and Sete Lagoas, Minas Gerais, Brazil, Brachiaria spp., especially, have developed symptoms of leaf drying and much reduced productivity. The symptoms are very similar to those caused by spittlebug but do not appear to be associated with that insect. Extraction of nematodes from soil from these sites has revealed, in most cases, the presence of the lesion nematode. In Minas Gerais, this included Pratylenchus brachyurus and P. zeae at up to 2 per gram of soil and 100 ger gram of root, especially associated with B. brizantha cv. Marandu.

In Quilichao, although B. humidicola was not damaged, B. brizantha, B. ruziziensis, B. dictyoneura, B. nigropedata, B. soluta, B. radicans, and B. eminii presented the above symptoms. Many Panicum maximum accessions were also affected. Pratylenchus spp. were present in Brachiaria spp. and P. maximum plots at about 40 per 100 gram of soil. In Carimagua, various pastures of B. decumbens have developed the same symptoms with associated Pratylenchus sp. populations of about 60 per 500 gram of soil. In addition, the P. maximum in the germplasm collection at Carimagua had about 120 Pratylenchus spp. per 100 gram of soil. If roots had been sampled these numbers would have been much higher.

Pratylenchus spp. have been involved in interactions with many pathogenic fungi. They are probably the most important nematodes involved with

Table 36. Reaction of accessions of *D. ovalifolium* to root-knot nematodes, *Meloidogyne* spp. in Tarapoto, Peru, 16 months after establishment and inoculation.

Accession	Plant vigour (0-4)	Ground cover	Gall rating (0-5)	Accession	Plant vigour (0-4)	Ground cover	Gall rating (0-5)
350	2.7	97	0	13104	2.0	73	1.1
3607	2.3	83	1.0	13105	2.7	70	0.5
3608	2.7	97	0.3	13106	2.7	75	0.7
3652	3.0	100	2.3	13107	3.3	100	0.1
3663	3.7	87	1.4	13108	1.3	75	2.2
3666	4.0	100	0	13109	2.0	67	0.5
3668	3.0	100	1.3	13110	1.7	47	1.8
3673	3.0	83	0.1	13111	2.7	100	0.3
3674	*	80	1.1	13113	3.0	98	0.5
3776	1.0	28	1.1	13114	2.3	80	2.1
3778	2.0	43	0.8	13115	2.3	80	0.3
3780	1.7	42	0.5	13116	2.3	80	0
3781	3.0	100	0.7	13117	3.0	90	0.1
3784	2.3	87	0.7	13118	3.7	100	0.7
3788	0.7	5	0.3	13120	3.0	93	0.7
3793	1.7	57	0.2	13121	2.3	88	0
3794	1.7	67	0	13122	2.7	98	1.1
13030	1.7	23	0.3	13124	2.7	98	0.1
13081	2.0	40	0	13125	2.7	100	0
13082	3.0	100	0.3	13126	3.0	100	1.3
13085	3.3	100	0.6	13127	2.7	90	0.3
13086	2.7	98	0.6	13128	3.0	100	0.1
13087	3.0	100	0.4	13128 A	4.0	100	0.7
13088	3.0	98	0	13129	2.7	97	0.6
13089	2.7	83	0.7	13130	2.7	100	0.1
13091	0	0	-	13131	3.0	97	0
13092	3.0	62	0	13132	3.0	100	0
13093	3.0	80	0.9	13133	2.3	90	0.1
13094	3.7	100	0	13135	2.3	98	0.7
13095	3.7	98	0	13136	3.3	100	0.7
13096	2.3	80	0.3	13137	3.3	100	0.8
13097	4.0	100	0.3	13139	3.0	100	0.9
13098	4.0	100	0	13289	3.7	100	0.1
13099	3.3	93	0.1	13302	3.3	100	0.5
13100	3.3	100	0.4	13305	2.0	98	1.7
13101	1.3	57	1.0	13307	2.7	83	0.6
13102	2.7	83	0.9	13400	2.3	97	0.7
13103	2.0	75	0.7				

Table 37. Evaluation (May 1985) of root-knot nematode on D. ovalifolium CIAT 350 in association with Brachiaria spp. Tarapoto, Peru.

Association	% Ground cover	Plant Vigour (0-4)	% infestation of root-knot nematode
1. B. humidicola	95	4	
x			
D. ovalifolium	5	1	0
2. B. decumbens	95	2	
x			
D. ovalifolium	10	1	7
3. B. ruziziensis	30	1	
x			
D. ovalifolium	70	3	5
4. B. dictyoneura	100	3	
x			
D. ovalifolium	0	0	-
5. D. ovalifolium without nematicide[a]	100	3	48
6. D. ovalifolium with nematicide	100	2	22
7. B. humidicola	100	4	
8. B. decumbens	100	3	
9. B. ruziziensis	90	2	

a/ Nematicide = Terracur.

Verticillium wilt fungi. They have been known to interact with Rhizoctonia solani, Fusarium spp., Pythium spp. and Phytophthora spp. as well as bacteria such as Pseudomonas spp. Thus, although the populations of Pratylenchus found in plots affected by the drying symptoms are not extremely high, it is very possible that there is also some interaction between these nematodes and other plant pathogenic organisms could produce these symptoms. Work is underway at the moment to obtain cultures of Pratylenchus from affected plots to use for pathogenicity tests.

b) Survey of nematodes in tropical pastures

In August 1984, a survey of nematodes in tropical pastures was done under the consultancy of Dr. M. R. Siddiqi of the Commonwealth Institute of Parasitology, United Kingdom. This survey included most plant species under evaluation and native savanna species in Carimagua and Villavicencio, as well as Desmodium spp. and Brachiaria spp. in Quilichao. Although the final report is not yet available, some of the most important preliminary findings were:

1) Pratylenchus spp., the lesion nematodes, were found in large numbers under D. ovalifolium and most of the grasses in all three sites. These nematodes are other associated with many other plant parasitic organisms.

2) Helicotylenchus spp., the spiral nematodes, were found commonly under D. ovalifolium, D. heterophyllum, P. phaseoloides + A. gayanus, Centrosema spp. and Hyparrhenia rufa. These nematodes have been associated with plant pathogenic bacteria.

3) Longidorus spp., the needle nematodes, were found in very high numbers under B. brizantha growing poorly at La Libertad in Villavicencio. This nematode is one of the virus vectors.

4) Xiphinema spp., the dagger nematodes, were found in significant numbers under S. capitata and Centrosema spp. This nematode is also a virus vector.

Siddiqi's recommendations were to build-up cultures of these nematodes, to test hosts for pathogenicity and to investigate possible interactions between nematodes and other plant parasitic organisms. Most of this work is underway at the moment.

Soil Microbiology

The activities of the Soil Microbiology Section are carried out with 5 general objectives in mind:

1) Research to develop technologies for manipulating soil microorganisms to increase plant productivity.
2) Development of research methods for use in tropical soils.
3) Evaluate the role of soil microorganisms in germplasm selection.
4) Training and information.
5) Motivate commercialization of the technologies developed.

Activities in 1985 will be discussed as follows:

I. <u>Rhizobium strain selection and inoculation responses</u>

1) Strain collection and characterization.
2) Screening for inoculation responses in greenhouse and field.
3) Origin of effective/ineffective strains.
4) Inoculation/fertility interactions.
5) Rhizobiology in the RIEPT; training program; inoculant/strain supply service.

II. <u>Freeze-dried inoculants</u>

1) Oils for suspension, preinoculation and seed humidity.
2) Inoculation rates.
3) Inoculant distribution.

III. <u>N mineralization</u>

1) Effect of season and land preparation.
2) Effect of grasses.

IV. <u>Mycorrhiza</u>

I. <u>Rhizobium strain selection and inoculation responses</u>

1) Strain collection and characterization

In order to evaluate strain effectivity it is necessary to maintain a collection of rhizobia isolated from appropriate legumes and soil types. These isolates must be characterized so that their purity and genetic stability can be monitored.

At present there are approximately 3000 strains from tropical forage legumes in the collection. The 5 categories used for colony description were described in 1984.

It has been found that a small proportion of the isolates in categories X, Y and Z contain two colony types which are unseparable by the usual bacteriological methods, even after vigorous washing and shaking and repeated sub-culturing (Fig. 1, Table 1). Two types of individual colonies of one strain (CIAT 2469) were inoculated onto sterile <u>Desmodium heterophyllum</u> plants. All the inoculated plants nodulated (Table 2), and rhizobium isolates from the nodules all still contained two colony types. Apparently the colony variability does not affect the effectivity of the strain,

Figure 1.

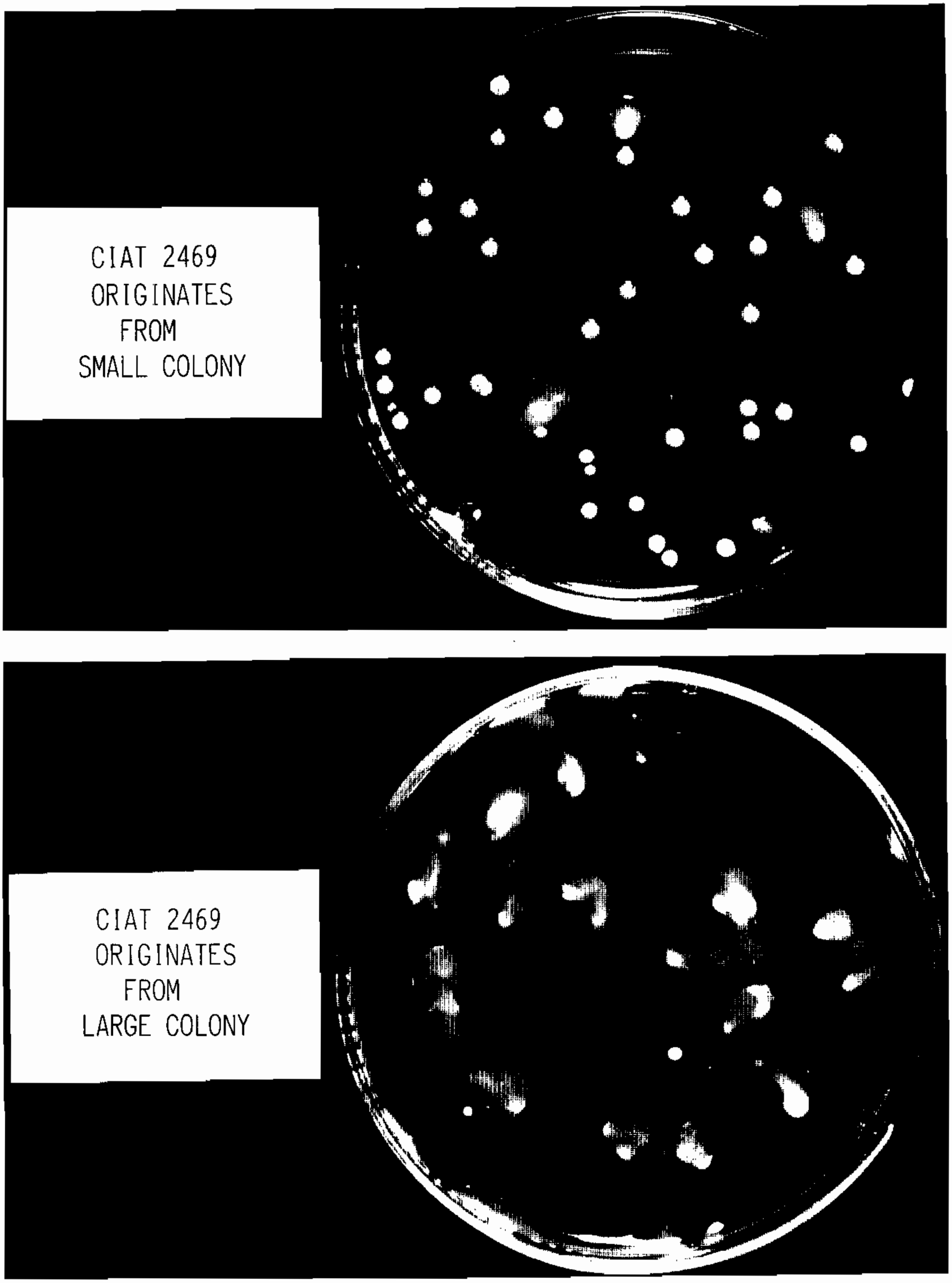

CIAT 2469
ORIGINATES
FROM
SMALL COLONY
CIAT 2469
ORIGINATES
FROM
LARGE COLONY

Table 1. Percentage of large colonies formed in sequential subculturings of CIAT 2469 from small colonies.

Original small colonies	% large colonies Subculture 1	2	3	4
A	4	4	4	11
B	2	5	8	7
C	4	6	5	15

which is one of the most effective on Desmodium spp.

This persistent appearance of two colony types in a relatively constant proportion (Table 1) implies the presence of an unstable mutation. This phenomenon has been observed in other gram negative bacteria, and could be studied further by producing antibiotic resistant mutants of representative strains.

2) Screening for inoculation responses in greenhouse and field

a) Greenhouse

In 1985 strain selection trials in undisturbed cores of Carimagua soil were carried out with Centrosema sp 5112, 5568 and 5277, C. macrocarpum 5744 and 5713 (among others), P. phaseoloides 9900 and Arachis pintoi 17434.

All three accessions of Centrosema sp. showed inoculation responses (Fig. 2), but the response was greater in No. 5568. All the strains were effective on No. 5112, but one strain (3713) was ineffective on Nos. 5277 and 5568.

Figure 3 shows the results of the screening experiment on two C. macrocarpum accessions. Some strain specificity can be seen. Nos. 3101 and 2348 were highly effective on both accessions.

A further screening experiment was carried out on P. phaseoloides 9900 because the previously selected strains (2434, 3221 and 2453) were found to be serologically identical. Forty-five strains which were serologically different to the control strains were screened. Seven of them were the same as or more effective than the control strains. Strain No. 79 (synonym CB 756), which is commercially recommended for inoculation of kudzu, was ineffective (no statistical difference from the uninoculated control).

Figure 4 shows that there were marked inoculation responses in A. pintoi, even though it nodulated well in the uninoculated control. This was expected since in the field at Carimagua this legume is slow-growing and chlorotic for some time after establishment.

b) Field

In 1985 several large field trials were carried out in Carimagua to test strains preselected in cores and also to evaluate and improve the methods recommended for inoculation trials in the RIEPT. Very few positive inoculation responses with tropical forage legumes are reported in the literature, and this is partly due to the lack of appropriate methods.

In one trial the effect of 8 serologically distinct rhizobium strains on the rate of establishment of 6 Centrosema accessions was evaluated. The accessions were chosen because of their designation as possible replacements for C. macrocarpum 5065 which has shown relatively low persistence under grazing. Table 3 shows marked inoculation responses in all three accessions of C. macrocarpum and one Centrosema sp accession (No. 5568). C. brasilianum 5234 and Centrosema sp 5277 showed much smaller responses to inoculation, although in previous core experiments they had shown approximately 1.5-fold increases in N

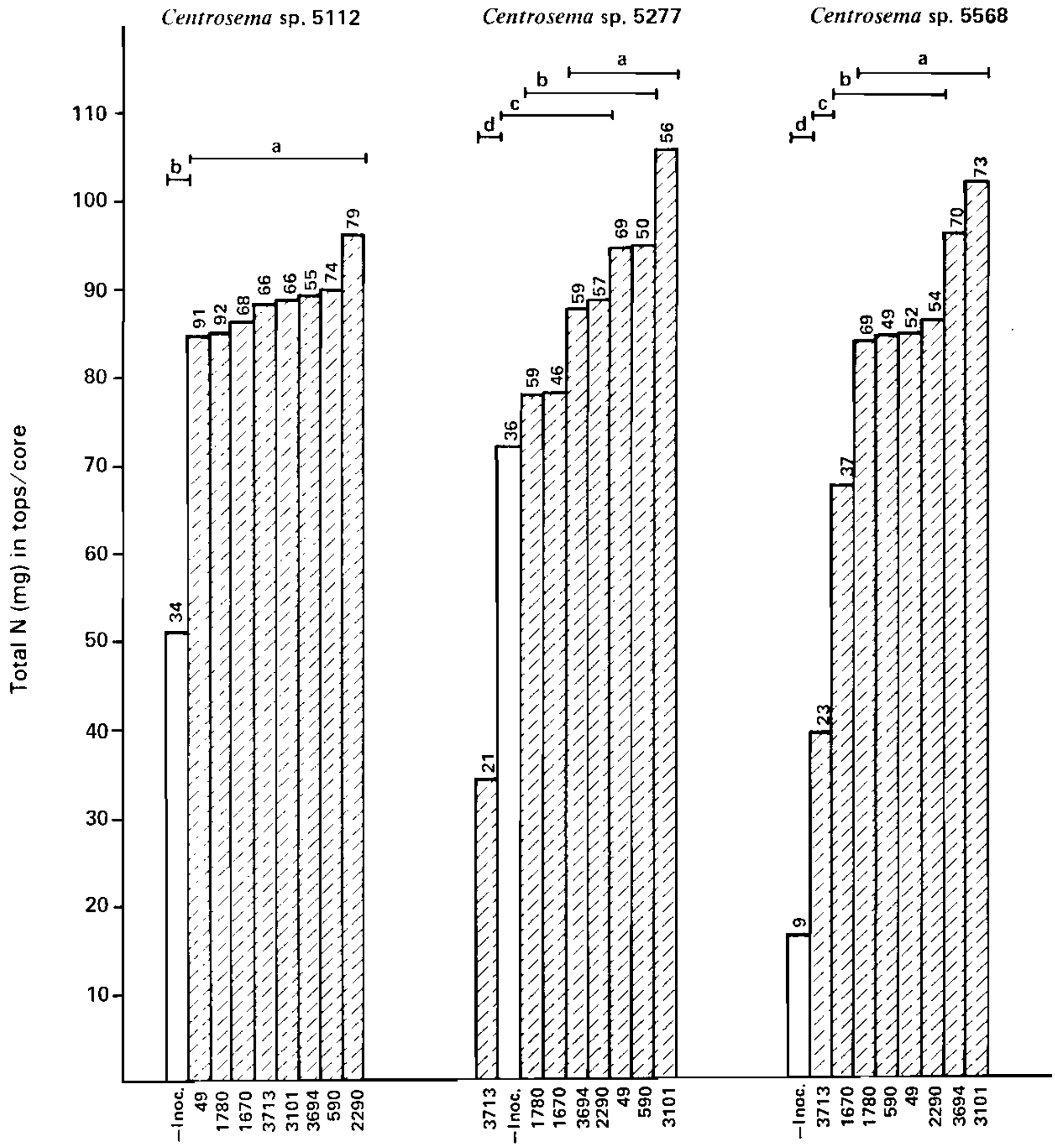


Figure 2. Total N in tops and nodule numbers (above bars) of 3 ecotypes of *Centrosema* sp., uninoculated (□), or inoculated with rhizobium strains (▨) in soil cores from Carimagua (MSPT-182-84).

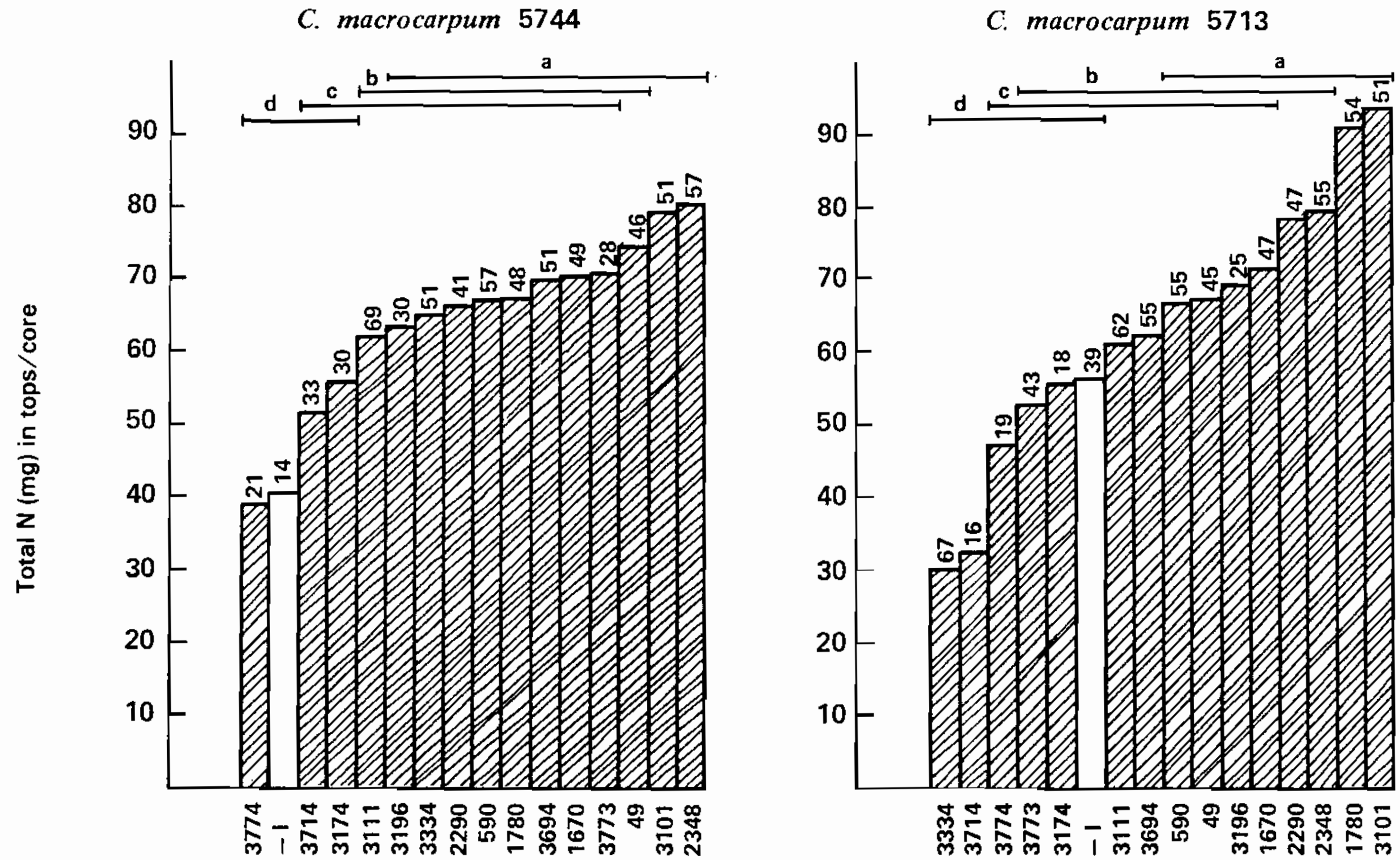


Figure 3. Total N in tops and nodule numbers (above bars) of two ecotypes of *Centrosema macrocarpum* uninoculated (□), or inoculated with rhizobium strains (▨) in cores of Carimagua soil (MSPT-185-85).

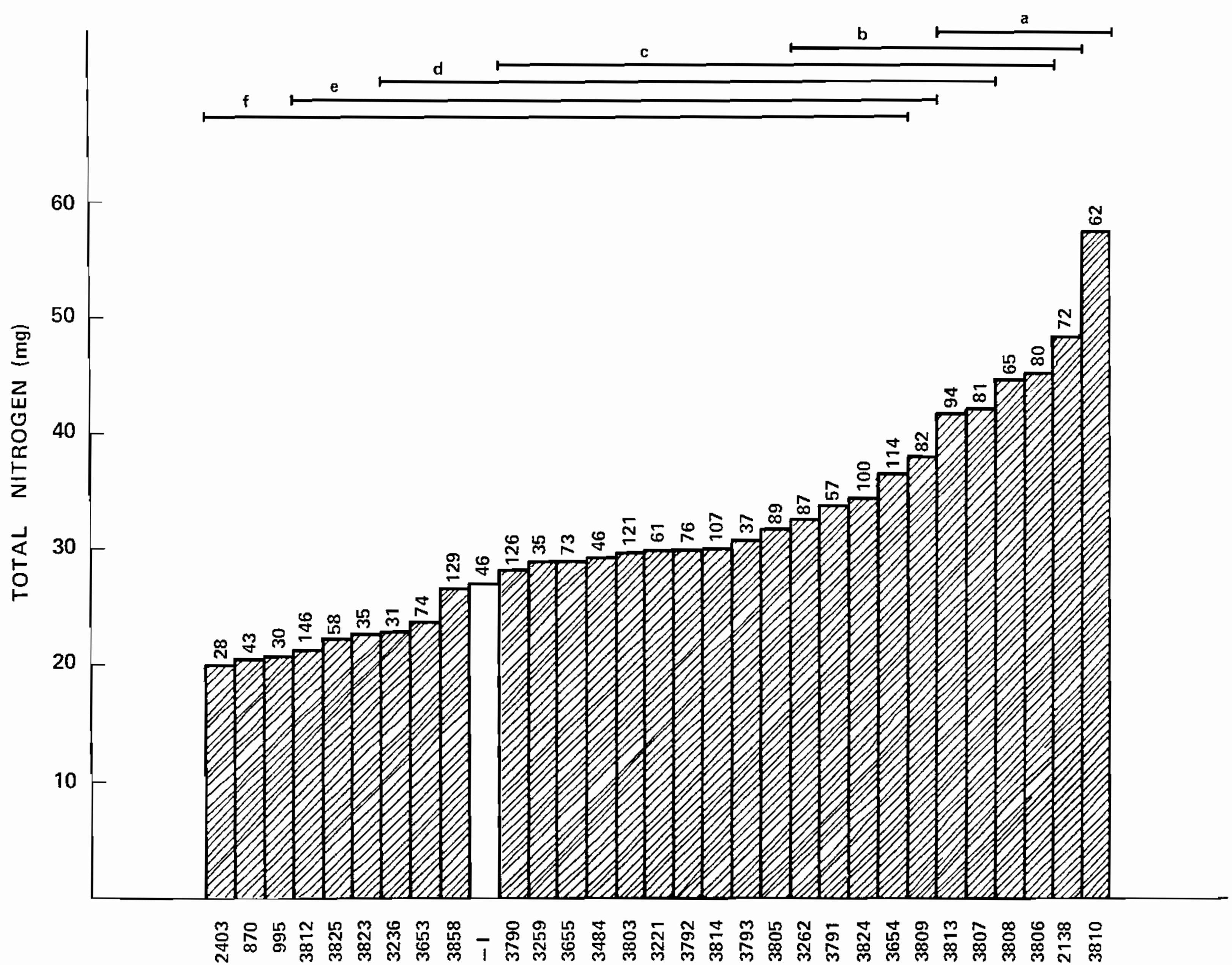


Figure 4. Total N in tops and nodule numbers (above bars) of *Arachis pintoi* 17434 inoculated with rhizobium strains in cores of Carimagua soil. (MSPT-183-85).

Table 2. Mean (n = 3) growth and nodulation of Desmodium heterophyllum inoculated with individual colonies of CIAT 2469 in Leonard jars.

Colony type	Parameter (per plant)	Individual colonies A	B	C	D	E	F	G	H
Large	g. dry wt.	0.40	0.53	0.43	0.41	0.21	0.27	0.35	0.47
	No. nodules	62	96	75	78	41	49	92	56
Small	g. dry wt.	0.43	0.36	0.57	0.37	0.54	0.60	0.53	0.55
	No. nodules	63	44	79	67	71	73	93	85

yield due to inoculation with the same strains. Although these two legumes showed the highest yield without inoculation, inoculation completely changed their importance relative to the other legumes in terms of yield (Table 3). This experiment demonstrates that different legumes may be selected in yield trials depending on whether they are inoculated or not. It is possible that the reason for the relatively low yield in the inoculated treatments of the legumes with relatively high yield in the uninoculated treatments is due to their more abundant nodulation with less effective native strains which compete with the inoculated strains for nodulation sites. This illustrates the possible disadvantage of selecting "promiscuous" legumes. Table 4 shows that strain 3101 was most effective across accessions. This strain was also highly effective in prescreening experiments in cores. The ineffective strains in the field (3174 and 3773) had also been relatively ineffective in cores. Strains 3773 and 3774 (synonyms BR C 101 A and C 102) are recommended as effective on C. pubescens in Brazil, but have been relatively ineffective in our experiments on different Centrosema spp. The same is true for strain No. 49 (synonym CB 1923) which is recommended for inoculation of C. pubescens in Australia.

Figure 5 shows the effect of inoculation with serologically different

Table 3. Effect of inoculation on 6 Centrosema accessions during establishment in the field (Carimagua, MSPT-189-85, 3rd cut).

Legume species	Accession CIAT No.	kg DM/ha uninoculated treatment	Best strain	kg DM/ha best strain	Fold increase due to best strain
C. brasilianum	5234	431.53	1670	556.33	1.29[1]
Centrosema sp.	5277	395.08	3101	446.61	1.13[1]
Centrosema sp.	5568	189.56	3101	715.39	3.77
C. macrocarpum	5713	144.50	1670	585.06	4.05
C. macrocarpum	5452	130.28	3101	567.78	4.36
C. macrocarpum	5744	56.11	3111	433.17	7.72

1/ Not significant P< 0.05.

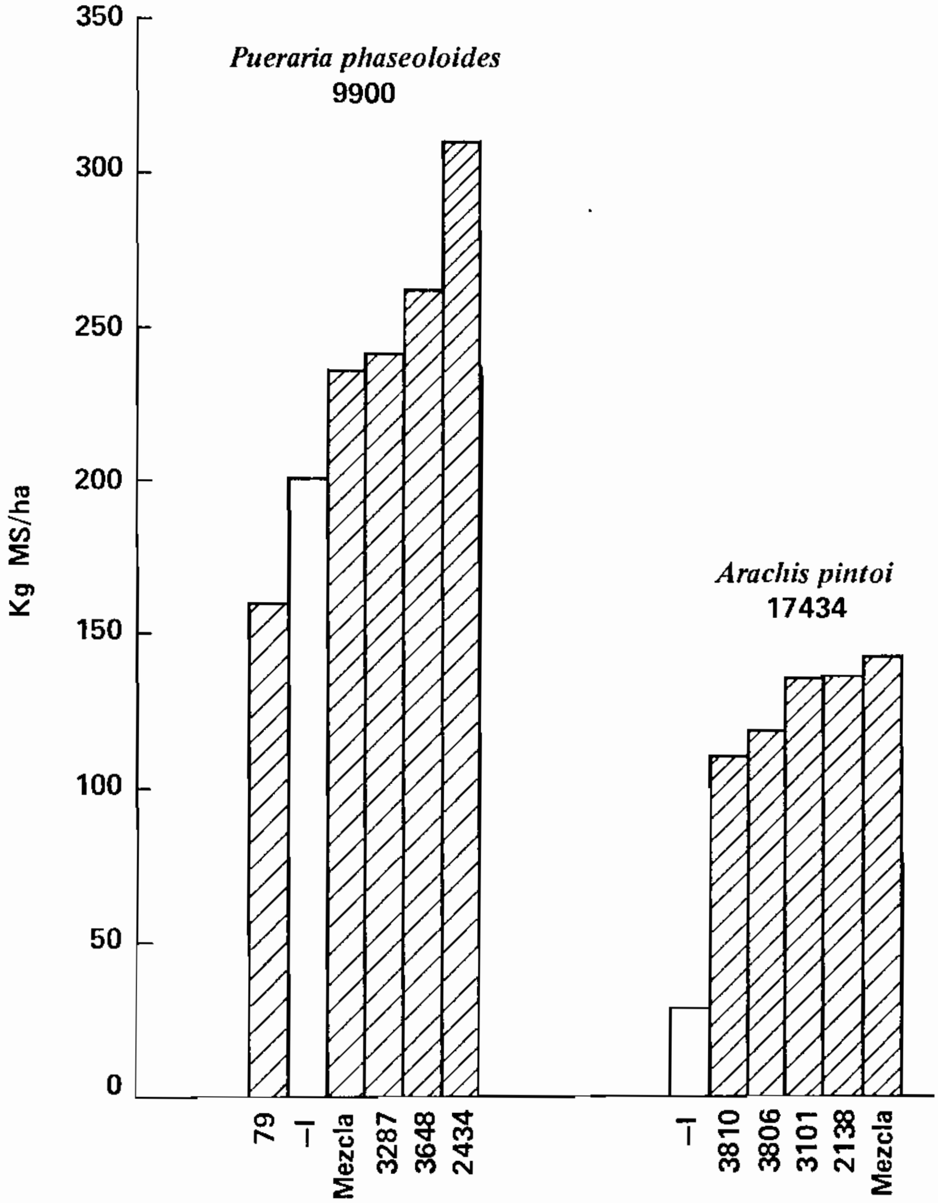


Figure 5. Effect of inoculation on yield of two forage legumes during establishment in Carimagua (MSPT-190-85). 1st. cut.

Table 4. Effect of rhizobium strains and N fertilization on yield (mean kg DM/ha across legumes) of Centrosema accessions in the field (Carimagua, 1985, MSPT-189).

+N	551.43 A
3101	498.77 AB
1670	490.33 AB
1780	446.07 B
3111	420.03 BC
3694	408.35 BC
49	353.38 C
3773	256.87 D
3174	241.90 D
-I	224.51 D

strains and strain mixtures on yield of *P. phaseoloides* and *A. pintoi*. *P. phaseoloides* has been shown previously to respond to inoculation with strain 2434 in the field; the aim of this experiment was to select additional strains serologically different from No. 2434 and compare them with No. 79 (synonym CB 756). It can be seen that all three strains were more effective than No. 79, but 2434 showed the greatest increase. Possibly the strain mixture showed only medium effectivity due to the dominance of the less effective strains over No. 2434. In *A. pintoi* all the inoculated strains and the mixture showed marked increases over the uninoculated control. In the uninoculated control abundant red nodules were observed, but the low yields and chlorotic color of the plants show that these nodules were ineffective. This large yield increase in response to inoculation of *A. pintoi* may at least partially explain its slowness to establish when it is sown without inoculation in Carimagua.

3) Origin of effective/ineffective strains

Table 5 shows the origin of some of the effective and ineffective strains in various screening trials in Carimagua soil. It can be seen that strains effective on one legume may also be effective on another (e.g. 3101 on *C. macrocarpum* and *A. pintoi*).

Strains from *C. pubescens* may be effective or ineffective on *C. macrocarpum*. Similar results were obtained for *Desmodium* spp. These observations indicate that strains which have been identified as effective on their host of origin have a relatively high probability of being effective on other hosts. This would mean that the overall number of strains being screened per legume could be reduced once a group of effective strains has been identified, thus permitting more legumes to be screened. On the other hand, commercially recommended strains have been relatively ineffective in our studies, possibly because the strains we have tested have been selected under different conditions, or because we have been unable to obtain the most effective strains from other laboratories. It can also be seen from Table 5 that it cannot be assumed that strains isolated from the site of origin of the legume will be effective. However, it has been observed on several occasions that the most effective strains originate from sites where a legume is especially green and well nodulated, and where it has been growing for a long time (e.g. Nos. 2469, 3649, 3796, 3810) lending support to the hypothesis that introduced legumes slowly select from the native rhizobium population for more effective strains.

4) Inoculation/fertility interactions

Studies are in progress to evaluate the effect of low nutrient inputs on N_2 fixation by tropical forage legumes. In addition, some interactions of inoculation with fertilizer responses have been observed. Here we report the effect of Mo and

Table 5. Origin of some effective and ineffective strains in screening trials in Carimagua soil.

Host plant tested	Origin of strains			
	Most effective strains		Least effective strains	
A. pintoi	2138	S. capitata, Goias, Brazil	2403	S. capitata, Manaus, Brazil
	3101	C. macrocarpum, S.Marta, Colombia	870	S. capitata, Australia (CB 2898)
	3810	A. pintoi, Carimagua (Pista)	3812	A. pintoi, Carimaguá
P. phaseoloides	3649	P. phaseoloides, El Refugio, Colombia	3347	P. phaseoloides, Carimagua (Surrales)
	3287	P. phaseoloides, Carimagua	3804	P. phaseoloides, Catama, Colombia
	2434	M. atropurpureum, Manaus, Brazil	3845	P. phaseoloides, Thailand
	3796	P. phaseoloides, Itabela, Brazil		
D. ovalifolium (CIAT 3666)	2335	D. ovalifolium, Belem Brazil	3270	D. ovalifolium, Orocué, Colombia
	3418	D. ovalifolium, Thailand	2487	D. canum, Carimagua
			2284	D. ovalifolium, Thailand
	2469	D. heterophyllum, Carimagua		
C. macrocarpum	3101	C. macrocarpum, S.Marta, Colombia	3714	Centrosema sp., P.Nariño, Colombia
	1670	C. pubescens, Mexico	3773	C. pubescens, Brazil (C101A)
	1780	C. pubescens, Pucallpa Peru		
			3774	C. pubescens, Brazil (C102)

Table 6. Effect of N fertilization, inoculation and Mo on yield and nodulation of D. ovalifolium CIAT 3784 grown in cores of Carimagua soil.

Treatment[1]		mg N/ core	% N in tops	Total nodules/ core	Crown nodules/ core
+N	OMo	85 bc	1.66 abcd	21.6 c	3.4 d
	MoO_3	105 a	1.80 a	33.6 c	5.0 d
	AMo	89 b	1.62 bcd	31.6 c	8.0 cd
+I	OMo	51 ef	1.53 d	93.6 b	15.6 b
	MoO_3	60 de	1.69 abc	115.6 a	22.2 a
	AMo	71 cd	1.75 ab	82.2 b	17.6 ab
-I	OMo	40 f	1.52 d	81.2 b	4.8 d
	MoO_3	50 ef	1.56 cd	84.0 b	11.4 bc
	AMo	45 ef	1.59 cd	73.8 b	15.0 b

1/ +N = 150 kg N/ha; +I = inoculated with mixture of strains 3418, 2469 and 2335; -I = uninoculated; OMo = without Mo; MoO_3 = 450 g Mo/ha as MoO_3; AMo = 450 g Mo/ha as ammonium molybdate. All other nutrients supplied at moderate levels.

inoculation on D. ovalifolium, and P and inoculation on S. capitata.

Table 6 shows that in D. ovalifolium 3784 Mo affected N yield of N fertilized and inoculated plants, but not of uninoculated plants. N concentration and nodulation (total) was also increased by a combination of inoculation and Mo but not by inoculation alone. The number of nodules on the primary root increased with inoculation and Mo application, but even without inoculation, Mo application increased the number of crown nodules. Thus crown nodules are not only derived from inoculated strains. Molybdenum applications may be required to obtain the full benefit of inoculation of Desmodium spp.

Table 7 shows a negative interaction between P fertilization and inoculation of S. capitata with selected strains. There was a positive inoculation and N response at low P, but at high P the response to inoculation was negligible. N increased yield but less so than at low P. P increased yield only in uninoculated plants.

Although P fertilization rates were 100 kg P/ha in the "high" P treatment, Table 7 shows that levels reached in plant tissue were not particularly high. This agrees with previous observations (Annual Report 1984) that nutrient levels become deficient in pots more quickly than in the field.

The negative interaction observed in this experiment may partially have been due to inhibition of mycorrhizae by high P levels, or preference for low P levels of the selected strains. The phenomenon should be investigated further.

The combined effects of inoculation and fertilization observed demonstrate the need to study inoculation and fertilizer responses together.

5) Rhizobiology in the RIEPT; training program; inoculant/strain supply service

The yield increases observed in response to inoculation mean that it is important to define clear objectives for the RIEPT with regard to whether or not inoculation should be included

Table 7. Effect of P levels, inoculation and N fertilization on yield and P content of of *S. capitata* cv. Capica grown in cores of Carimagua soil.

Treatment[1]	Low P[2]		High P[2]	
	g DM in tops/core	% P	g DM in tops/core	% P
+N	5.00 a	0.11	4.62 a	0.20
+I	3.44 b	0.10	3.29 b	0.18
-I	2.50 c	0.13	3.64 b	0.18

1/ +N = 150 kg N/ha; +I = mixture 10 strains; -I = uninoculated.
2/ low P = 25 kg P/ha; high P = 100 kg P/ha; all other nutrients supplied at moderate levels.

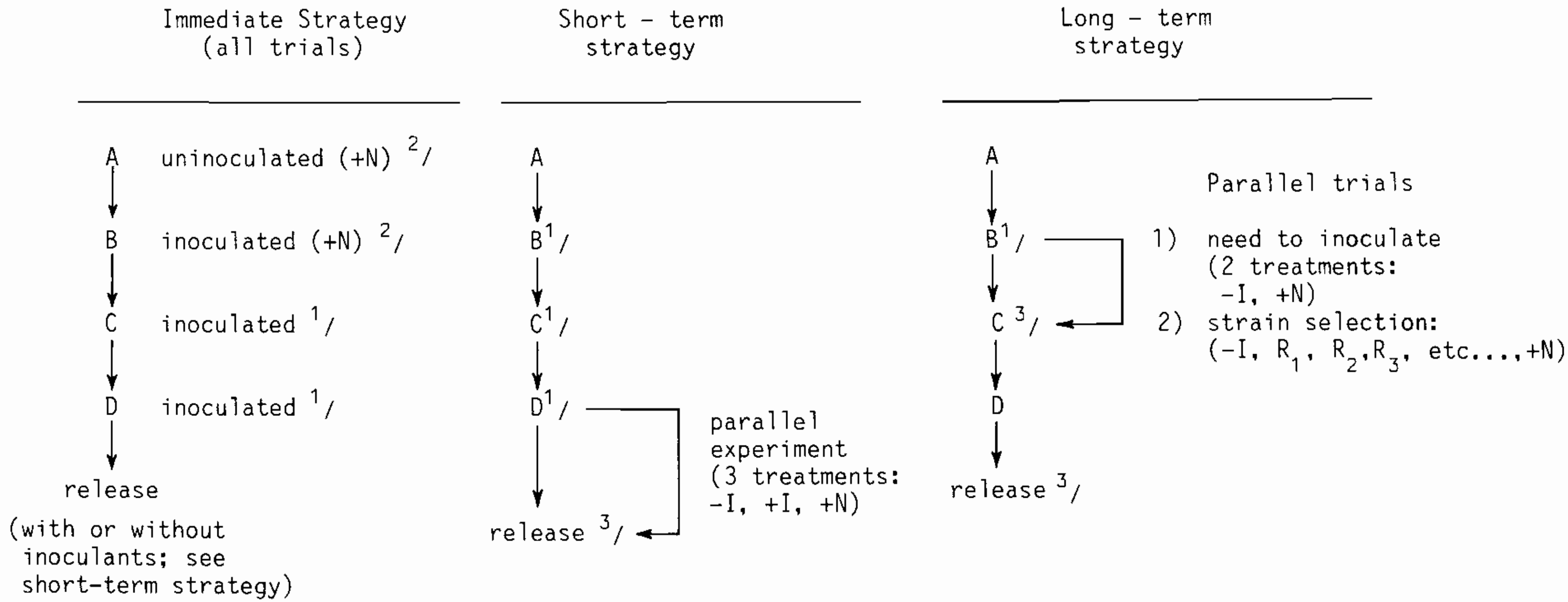
as part of the technological package. If legumes which respond to inoculation are not to be eliminated in the selection process, it is necessary to inoculate all the legumes in the regional trials with the best strains available, or fertilize with N if this is not possible. This would permit both legumes which respond to inoculation, and those which do not, to be selected. However, it would be necessary to carry out some parallel trials to determine whether the inoculants used during the selection of legumes which will be released to farmers do cause yield increases, so that appropriate recommendations can be made. Also, at least at some sites, the effectivity of different rhizobium strains should be tested to determine whether site specificity occurs.

In the meeting of the RIEPT held in October 1985 some recommendations for inoculation of the regional trials and for parallel experiments were made.

Figure 6 summarizes the recommendations. Inoculants will be supplied by CIAT to all those who request them. Also an interdisciplinary training program for microbiologists and agronomists has been initiated with UNDP funds, so that the short and long- term strategies can be adopted in the RIEPT at as many sites as possible. Eighteen agronomists and microbiologists from ten countries participated in an intensive practical course held in Brazil in November 1985, organized with the collaboration of MIRCEN and NifTAL. A Methods Manual and Study Guide were produced in English and Spanish for the course and are available from CIAT Publications Department.

The amount of inoculant requested and delivered by the section increases each year. For example, in 1984 37.77 kg inoculant were delivered in response to 77 requests. In 1985, 64.26 kg were delivered in response to 157 requests (Table 8). Many requests from farmers are received due to the lack of commercial inoculant production in Colombia, but only small amounts are supplied to those farmers who are willing to carry out simple experiments with and without inoculation. Many informal reports have been received from farmers of yield responses to inoculation. The demand for inoculants in the country is increasing, especially due to the expansion of soybean production. It is expected that commercial inoculant

Figure 6. Summary of recommendations for inoculation and parallel experiments in the RIEPT (detailed instructions available from CIAT)



1/ with the best strain available.

2/ fertilized with N in the case of chlorosis or lack of vigor.

3/ with or without inoculant depending on results of parallel experiments.

Table 8. Inoculant requests and deliveries in 1985.

	Program requests (tropical forage legumes)		Farmers requests	
	No.	Kg.	Legume (No.)	Quantity (g)
Colombia	118	52.16	Soybean (2)	750
			Leucaena (8)	435
Other countries	17	7.50	Alfalfa (6)	720
			Kudzu (3)	1600
			Clover (3)	1086
Total	135	59.66	(22)	4.591

production will begin in 1986.

Table 9 shows the current list of recommended strains for inoculation of tropical forage legumes. In addition, the strain catalog (3rd edition, 1985) is available to those who request it, and a new edition will replace it in early 1986.

II. Freeze-dried inoculants

1) Oils for suspension, preinoculation, and seed humidity

An experiment was carried out to evaluate different oils for the survival of the cells of a freeze-dried inoculant prepared with CIAT strain No. 3101, both in the serum vials in which the cells were freeze-dried, and coated onto seeds. The cells are maintained under vacuum in the vials until the oil is injected, and in this form (freeze-dried under vacuum) show long-term viability. Viability was also relatively good once the cells had been mixed with the oil (Table 10). However, the cells began to die when they were applied to the seeds and kept under normal atmospheric conditions in the laboratory. Our collaborators on this UNDP-funded project at the Boyce Thompson Institute report* that if the humidity of the cell suspension rises the rhizobia begin to die, whereas if they are stored with desiccant they remain viable on seeds for much longer. Since the seeds in our experiment were surface-sterilized (for the purpose of the counts) in an aqueous $HgCl_2$ solution, high seed humidity could explain the death of the cells. Experiments are in progress to determine optimum seed humidity for inoculant survival. The results in Table 10 imply that all 4 oils are adequate within the time span studied. However, it would be expected that vegetable oils might oxidize over longer times, so mineral oil is being used in current experiments.

2) Inoculation rates

The freeze-dried inoculants have the advantage that they can be applied at higher rates (cells/seed) than peat-based inoculants which is important especially for small-seeded legumes and where native rhizobium populations are high. (Eaglesham and Goldman, 1985).

* Eaglesham, A.R.J. & Goldman, B.: Oil-based inoculants for preinoculation of Centrosema macrocarpum. UNEP Workshop on Rhizobium/Legume Inoculants. Porto Alegre, Brazil, October 22-25, 1985

Table 9. Recommended rhizobium strains (July 1986) for inoculation of regional trials B, C and D and other experiments of the Tropical Pastures Program. (Inoculants can be obtained from CIAT on request).

SPECIE	CIAT No.	RECOMMENDED STRAIN
Arachis pintoi	17434	3101
Centrosema brasilianum	5234	3101
Centrosema macrocarpum	5065, 5744, 5887, 5713	3101
Centrosema pubescens	438, 442, 5189	1670
Centrosema sp.	5112, 5277, 5568	3101
Desmodium heterocarpon	3787	3418
Desmodium heterophyllum	349, 3782	2469
D. ovalifolium	350	2335
Leucaena leucocephala		1967
Pueraria phaseoloides	9900	2434
Stylosanthes capitata	1019, 1441, 2044, 10280	870 + 995 + 2138
Stylosanthes guianensis	64, 136, 184	71
Stylosanthes guianensis var. *pauciflora*	1280, 2031*, 2362*, 10136*	71
Stylosanthes macrocephala	1643*, 2133*, 2286*, 2756*	n.d.
Zornia glabra	7847*	71
Zornia glabra	8283	71
Zornia latifolia	728	71

* In the Eastern Plains of Colombia these legumes do not need inoculation

n.d.= not determined

Table 10. Effect of different oils on survival of rhizobia (CIAT 3101) in serum vials and on seeds of Centrosema macrocarpum 5887.

Oil	No. rhizobia/ml. oil				
	0 days (vial)	4 weeks (vial)	0 days (seeds)	4 days (seeds)	7 days (seeds)
Mineral	3.35×10^{12}	2.06×10^{11}	1.00×10^{7}	5.80×10^{2}	0
Sesame	2.67×10^{10}	3.18×10^{9}	8.58×10^{6}	5.30×10^{4}	0
Sunflower	5.55×10^{10}	1.11×10^{10}	1.64×10^{7}	5.94×10^{4}	0
Oil palm	2.90×10^{10}	3.10×10^{9}	1.15×10^{6}	7.24×10^{3}	0

3) Inoculant distribution

Due to their longer shelf-life, the freeze-dried inoculants do not need to be produced only shortly before planting. Stocks of each strain can be built up and distributed when requested. This facilitates the supply of a wide range of strains quite considerably. Also, there are no phytosanitary problems in sending freeze-dried inoculants to other countries. This will simplify inoculant supply to the Tropical Pastures Program and its collaborators.

III. N mineralization

In previous years results have shown that preparation of Carimagua soil stimulates N mineralization, and leaching of mineral N, if plant cover is not adequate. The rates of N mineralization and N uptake by the companion grass, affect the extent to which inoculation responses are observed during legume establishment. It is known that N_2 fixation and nodulation is stimulated by small quantities of mineral N and inhibited by higher levels. The effect of N mineralization in Carimagua soil on N_2 fixation, leaching, and N uptake by grasses, may play an important role in N-cycling in grazed pastures. Here some results of two further studies are reported.

1) Effect of season and land preparation

Figure 7 shows changes in NO_3^- levels during the year in one of the 3 sites studied, with different times of land preparation. Samples taken in the field where the soil had been prepared before the dry season (November) showed relatively high NO_3^- levels in March and April of the following year. In incubated soil the levels were higher than in the field, especially during the wet season, indicating that much of the NO_3^- produced in the field is lost by leaching. 35 ppm NO_3^- N accumulated during four months of the wet season. This quantity of mineral N (85 kg N/ha) would be sufficient for the establishment of a pure grass sward. On the other hand, in soil prepared at the beginning of the wet season (April) NO_3^- levels only began to increase at the end of June, and only reached high levels in August. This effect may explain the greater yields of grasses planted in soil prepared before the dry season reported previously (Annual Review, 1983). Clearly, this practice is risky if N leaching is to be avoided, and unnecessary if grass-legume mixtures are to be planted.

In undisturbed savanna soil a small amount of NO_3^- was produced in April, although generally this was not observed. This implies that the low levels of NO_3^- observed in undisturbed savanna may not be due to toxic

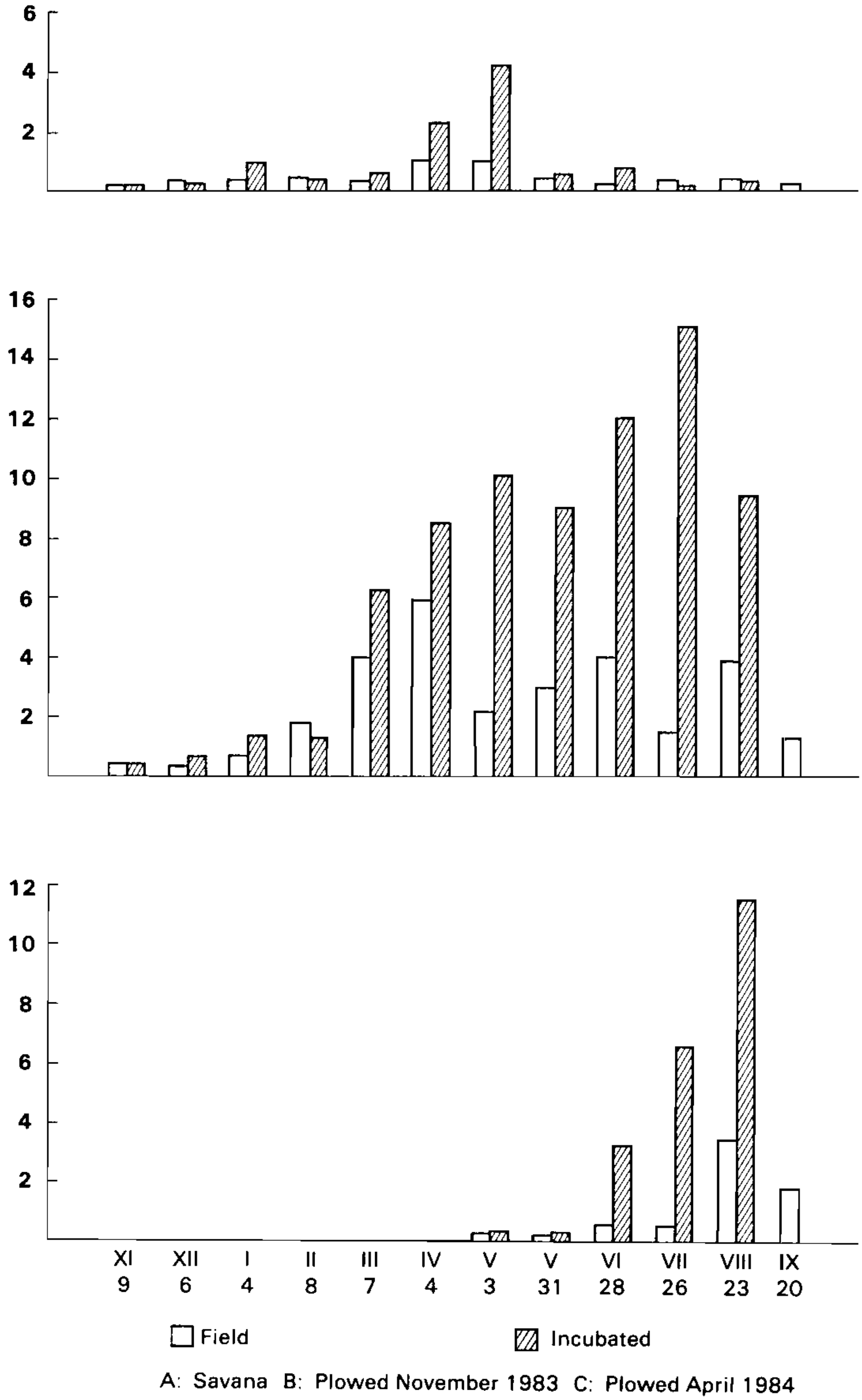


Figure 7. Effect of season and land preparation on NO^{3-} accumulation in Carimagua soil (Hato 3) in the field or incubated for 4 weeks in pots.

substances which inhibit nitrification, but rather to limited availability and rapid plant uptake of any mineral N produced.

2) Effect of grasses

To determine whether the lack of nitrate accumulation in grass rhizospheres which has been observed in previous experiments is due to substances toxic to nitrification or to competition for NH_4^+, an experiment was set up to study the effect of N fertilization on nitrification in soil associated with roots of four grasses and savanna vegetation. Soil samples were taken in undisturbed cores from N fertilized sites, and the number of nitrifying bacteria/g was counted. After 4 weeks inoculation the soil was analyzed for NO_3^- - N and NH_4^+ - N.

Table 11 shows that in *B. humidicola* soil no NO_3^- accumulated, but in the other soils, including soil from undisturbed savanna, NO_3^- levels were higher. This confirms the results of previous studies concerning the lack of NO_3^- accumulation in the rhizosphere of *B. humidicola*, and shows that savanna vegetation does not inhibit nitrification through release of toxic substances, but rather through N competition. The table also shows that there were fewer nitrifiers in the rhizosphere of *B. humidicola* than the other grasses. However, NH_4^+ levels were also low in *B. humidicola* soil. This indicates that one reason for the lack of NO_3^- accumulation in soil from under this grass may be a higher rate of NH_4^+ immobilization by the soil microflora.

The results show that rates of N transformations in the soil are affected by different grasses. Previously it has been shown that legumes stimulate NO_3^- accumulation. In grass-legume mixtures the availability of N to the grass must depend on plant preferences for NO_3^- or NH_4^+, N immobilization by soil microorganisms, the effect of grass and legume roots on N mineralization/immobilization activity in the soil, and whether this N originates from N_2 fixation by the legume or from the original soil N pool. These factors need to be studied in more detail, since even less is known about them in tropical than in temperate pastures.

Table 11. Nitrifying bacteria and mineral N content of Carimagua soil (0-10 cm) from N fertilized grass swards (180 kg N [urea]/ha).

Grass cover	No. nitrifiers/ g soil	ppm N (4 weeks incubation)	
		NO_3^-	NH_4^+
A. gayanus	2.7×10^8	51.59	64.16
M. minutiflora	6.0×10^7	10.50	76.59
B. decumbens	4.1×10^7	8.06	36.83
B. humidicola	6.0×10^4	0.82	24.84
Savanna	3.9×10^6	30.62	51.99
Raked savanna	9.0×10^7	37.65	54.11

IV. MYCORRHIZA

During 1985, mycorrhizal studies concentrated on: a) screening of VA mycorrhizal fungi for their effect on growth and mineral composition of forage plants; b) interaction between Rhizobium strains and mycorrhizal fungi in Centrosema macrocarpum CIAT 5065; c) interaction between mycorrhizal fungi, phosphorus and nitrogen levels, Rhizobium and Centrosema macrocarpum CIAT 5065; d) interactions between mycorrhizal fungi, two sources and rates of phosphorus and nitrogen on Brachiaria decumbens CIAT 606; and e) indigenous mycorrhizal fungi of native and sown pastures, their isolation, infectivity and efficiency tests.

SCREENING OF VA MYCORRHIZAL FUNGI

In earlier studies it was observed that some mycorrhizal fungi increased the growth and mineral uptake of forage plants more than the others. Therefore, it was necessary to screen a range of mycorrhizal fungi against forage legumes and grasses to determine the most productive host-fungus combinations. This experiment was conducted in a sterilized soil (Oxisol) from Carimagua and unsterilized was included in order to compare the performance of introduced with native mycorrhizal fungi. The test plants were: Centrosema macrocarpum 5065; Stylosanthes capitata 2252; Desmodium heterocarpon 3787; Zornia glabra 7847; Andropogon gayanus 621; Brachiaria decumbens 606; B. brizantha 6780, and B. humidicola 679. The mycorrhizal fungi tested were: Glomus fasciculatum (M_1); Gigaspora heterogama (M_2); Entrophospora colombiana (M_3); E. colombiana, a different strain (M_4), Acaulospora longula (M_5); G. occultum (M_6); A. apendicola (M_7); A. marrowae (M_8); A. mellea (M_9); G. manihotis (M_{10}); G. gregaria (M_{11}); G. nigra (M_{12}), and A. scorbiculata (M_{13}). Phosphorus was supplied at the rate of 30 kg P/ha as rock phosphate from Huila.

Results indicate that mycorrhizal fungi differ in their efficiency to increase dry matter production not only of different forage plants species but also of the same species. Shoot dry weight of Centrosema was increased significantly by only five mycorrhizal fungi, of Stylosanthes by ten, of Desmodium by eleven and of Zornia by ten mycorrhizal fungi. Percent increase in shoot dry weight caused by inoculation with best-yielding mycorrhizal fungi varied from 242 to 1087 and 499 to 4950 over non-mycorrhizal plants for legumes and grasses, respectively. The percent increase in dry weight was from 173 to 240 and 178 to 300 over plants infected with indigenous mycorrhizal fungi for legumes and grasses, respectively (Table 12).

Tables 13 and 14 show that mycorrhizal fungi also differ in increasing uptake of P, N and K by forage plants. All mycorrhizal fungi increased significantly the uptake of P, N and K by legumes and grasses, except with M_{11} and M_{12} in the case of legumes. Nitrogen and K concentration in shoots of legumes was also increased by some mycorrhizal fungi but had no significant effect on the P concentration in legume tissue and on the P, N and K concentrations in grasses. Percentage root length infected also varied depending on mycorrhizal fungi and was directly correlated to dry matter production. Utilization of soil P was significantly increased by mycorrhizal fungi (except M_{11} and M_{12} in legumes). The highest P utilization rates, both in legumes and grasses, were obtained by inoculation with M_4.

The results of this experiment clearly indicate that in sterile soil certain mycorrhizal fungi cause greater dry matter yield by forage plants than the indigenous mycorrhizal fungi in

Table 12 Percent increase in shoot dry weight of forage legumes and grasses caused by inoculation with best-yielding mycorrhizal fungi. NM, not inoculated; IMF, indigenous mycorrhizal fungi.

Plant species	Mycorrhizal fungi	CIAT Strain No.	Percent dry weight increase over NM	Percent dry weight increase over IMF
Legumes				
C. macrocarpum	*E. colombiana* (M_3)	C-10	242	173
S. capitata	*E. colombiana* (M_4)	C-11-2	1005	238
D. ovalifolium	*G. manihotis* (M_{10})	C-20-2	893	221
Z. glabra	*A. longula* (M_5)	C-12-1	1087	240
Grasses				
A. gayanus	*E. colombiana* (M_4)	C-11-2	4950	300
B. decumbens	*E. colombiana* (M_4)	C-11-2	1281	212
B. brizantha	*E. colombiana* (M_4)	C-11-2	571	203
B. humidicola	*A. scorbiculata* (M_{13})	C-76-1	499	178

Table 13. Main effect of inoculation with thirteen mycorrhizal fungi on growth, mineral composition and percent infected root length of four forage legumes.

Mycorrhizal fungi		CIAT Strain No.	Shoot dry weight (g/pot)	Mineral uptake (mg/pot)			Mineral concentration (%)			% infected root length
				P	N	K	P	N	K	
Control	(NM)		1.34	2.13	93.96	10.52	0.120	2.99	0.66	0
Indig. mycorrhizal fungi	(IMF)		3.49	4.61	140.67	43.78	0.130	3.94	1.23	40
Glomus fasciculatum	(M_1)	C-5	3.79	4.03	165.52	46.27	0.105	4.25	1.18	60
Gigaspora heterogama	(M_2)	C-9	6.35	5.47	162.18	51.17	0.131	3.80	1.24	54
Entrophospora colombiana	(M_3)	C-10	6.98	6.78	193.71	55.62	0.098	2.92	0.81	87
Entrophospora colombiana	(M_4)	C-11-2	7.12	6.82	206.31	57.20	0.096	2.93	0.81	86
Acaulospora longula	(M_5)	C-12-1	6.35	6.55	191.53	48.64	0.107	3.09	0.77	84
Glomus ocultum	(M_6)	C-12-2	3.47	4.22	149.07	38.42	0.120	4.10	1.07	15
Acaulospora apendicola	(M_7)	C-13-1	4.82	4.78	175.02	49.85	0.108	3.93	1.07	51
Acaulospora marrowae	(M_8)	C-14	3.40	4.06	135.92	33.14	0.116	3.76	1.00	35
Acaulospora mellea	(M_9)	C-15-2	2.37	3.67	128.58	29.81	0.118	4.12	0.96	8
Glomus manihotis	(M_{10})	C-20-2	6.16	5.66	203.13	55.56	0.093	3.45	0.93	83
Gigaspora gregaria	(M_{11})	C-48-1	1.45	0.94	118.57	15.94	0.065	3.72	0.50	3
Gigaspora nigra	(M_{12})	C-75-1	1.87	2.21	108.74	17.69	0.128	3.88	0.98	28
Acaulospora scorbicolata	(M_{13})	C-76-1	4.45	5.55	164.72	48.54	0.114	3.54	1.03	68
LSD 5%		0.45	0.95	22.79	7.68	0.017	0.40	0.16	13	

Table 14. Main effect of inoculation with nine mycorrhizal fungi on growth, mineral composition and percent infected root length of four forage grasses.

Mycorrhizal fungi		CIAT strain No.	Shoot dry weight (g/pot)	Mineral uptake (mg/pot)			Mineral concentration (%)			% infected root length
				P	N	K	P	N	K	
Control	(NM)		0.84	0.92	32.77	14.90	0.105	3.27	1.72	0
Indig. mycorrhizal fungi	(IMF)		3.17	2.16	35.82	31.96	0.073	1.32	1.06	68
Glomus fasciculatum	(M_1)	C-5	1.63	1.51	48.82	26.54	0.094	2.91	1.63	80
Gigaspora heterogama	(M_2)	C-9	2.82	2.05	64.63	37.90	0.083	2.24	1.37	61
Entrophospora colombiana	(M_3)	C-10	5.71	4.13	72.63	48.91	0.075	1.32	0.88	89
Entrophospora colombiana	(M_4)	C-11-2	6.36	4.21	77.51	50.18	0.068	1.23	0.79	82
Acaulospora longula	(M_5)	C-12-1	5.83	4.05	71.84	47.01	0.069	1.26	0.80	79
Acaulospora apendicola	(M_7)	C-13-1	3.03	2.14	69.75	39.83	0.077	2.19	1.41	52
Acaulospora marrowae	(M_8)	C-14	3.04	2.64	75.59	36.58	0.086	2.35	1.30	60
Glomus manihotis	(M_{10})	C-20-2	6.28	3.93	75.63	50.44	0.064	1.23	0.81	89
Acaulospora scorbicolata	(M_{13})	C-76-1	5.96	4.09	76.40	50.46	0.071	1.33	0.85	87
LSD 5%			0.53	0.53	8.82	6.13	0.014	0.31	0.16	11

non-sterile soil. Although the range of effectivity of the plants with different fungi varied, one (M_4) of the inoculated fungi gave highest yields across all legumes and grasses. This mycorrhizal fungi is also effective with cassava (Annual Reports for 1982 and 1983, Cassava Program). This clearly indicates that one mycorrhizal fungus can be used to inoculate a large variety of plant species which is not the case with Rhizobium.

RHIZOBIUM-MYCORRHIZA INTERACTIONS IN CENTROSEMA

In the previous experiments conducted in unsterile soil (Annual Reports for 1983 and 1984; Tropical Pastures Program) it was observed that mycorrhizal fungi increased nodulation by Rhizobium in forage legumes. However, it was not possible to determine if there exist specific interactions between Rhizobium strains and mycorrhizal fungi. To study these interactions pot experiments were conducted in sterilized soil (Oxisol) from Carimagua. The test plant was Centrosema macrocarpum CIAT 5065. Rhizobium strains and mycorrhizal fungi evaluated were: R-1780, R-1670, R-3334, Entrophospora colombiana (M_1), Acaulospora longula (M_2) and Glomus manihotis (M_3). Other treatments included a mixture of Rhizobium strains (R-Mix), a mixture of mycorrhizal fungi (M-Mix), without Rhizobium inoculation (-R) and nitrogen controle (+N, 150 kg N/ha). In the first experiment (Figure 8 and Table 15), P was supplied at the rate of 20 kg P/ha as rock phosphate, but due to very poor growth, after 6 weeks of transplanting,an additional 20 kg P/ha as soluble phosphate was applied. In the second experiment 40 kg P/ha as soluble phosphate were added at the beginning of the experiment.

Figure 8 shows that combined inoculation with Rhizobium and mycorrhizal fungi generally resulted in better growth and uptake of P and N compared to Rhizobium inoculation alone. Inoculation with mycorrhizal fungi gave much better yield than Rhizobium inoculation alone which indicates that plants inoculated only with Rhizobium suffered P deficiency. Among the three mycorrhizal fungi, M_3 was most efficient with all three Rhizobium strains. The efficiency of M_3 was further increased when supplied with nitrogen. Rhizobium and mycorrhizal fungi combinations differed with each other. Combined inoculation with R-3334 and M_3 gave the highest dry matter yield and uptake of P and N. Main effects of Rhizobium treatments on shoot dry weight and uptake of P and N did not show any significant differences (Table 15). However, nodule dry weights were significantly affected by different Rhizobium strains. Main effects of mycorrhizal fungi on shoot and nodule dry weights and uptake of P and N were significantly different. Inoculation with M_3 produced highest yields.

In another experiment, where soluble phosphate was given at the rate of 40 kg P/ha, the efficiency of Rhizobium as well as mycorrhizal fungi was different from that observed in the first experiment (Figure 9 and Table 16). In this experiment also, combined inoculation with Rhizobium and mycorrhizal fungi generally produced greater dry matter. Main effects of inoculation with Rhizobium strains on shoot dry weight were similar but significantly higher than non-Rhizobium plants (Table 16). In this experiment M_2 produced highest dry matter yields.

The results of these two experiments indicate that there exist an interaction between rhizobium strains and mycorrhizal fungi the exact nature of which should be studied further. Plants inoculated only with Rhizobium suffer P deficiency more than the N deficiency suffered by the plants

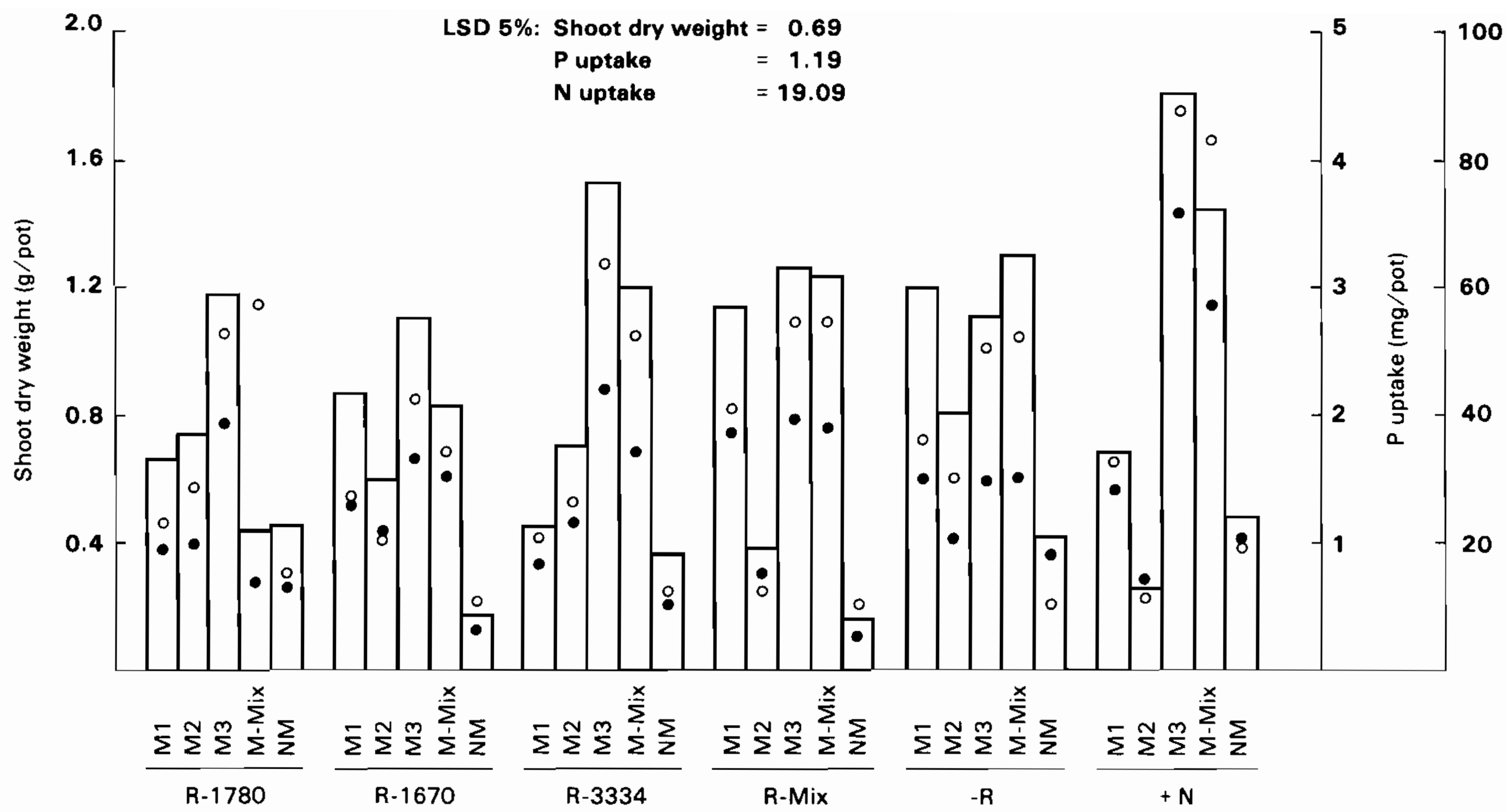


Figure 8. Effect of inoculation with *Rhizobium* and mycorrhizal fungi on shoot dry weight and P (o) and N (o) uptake of *Centrosema macrocarpum* CIAT 5065 grown in sterile oxisol. P source: Rock phosphate, 6 weeks after soluble phosphate was added. For explanation of mycorrhizal treatments see the text.

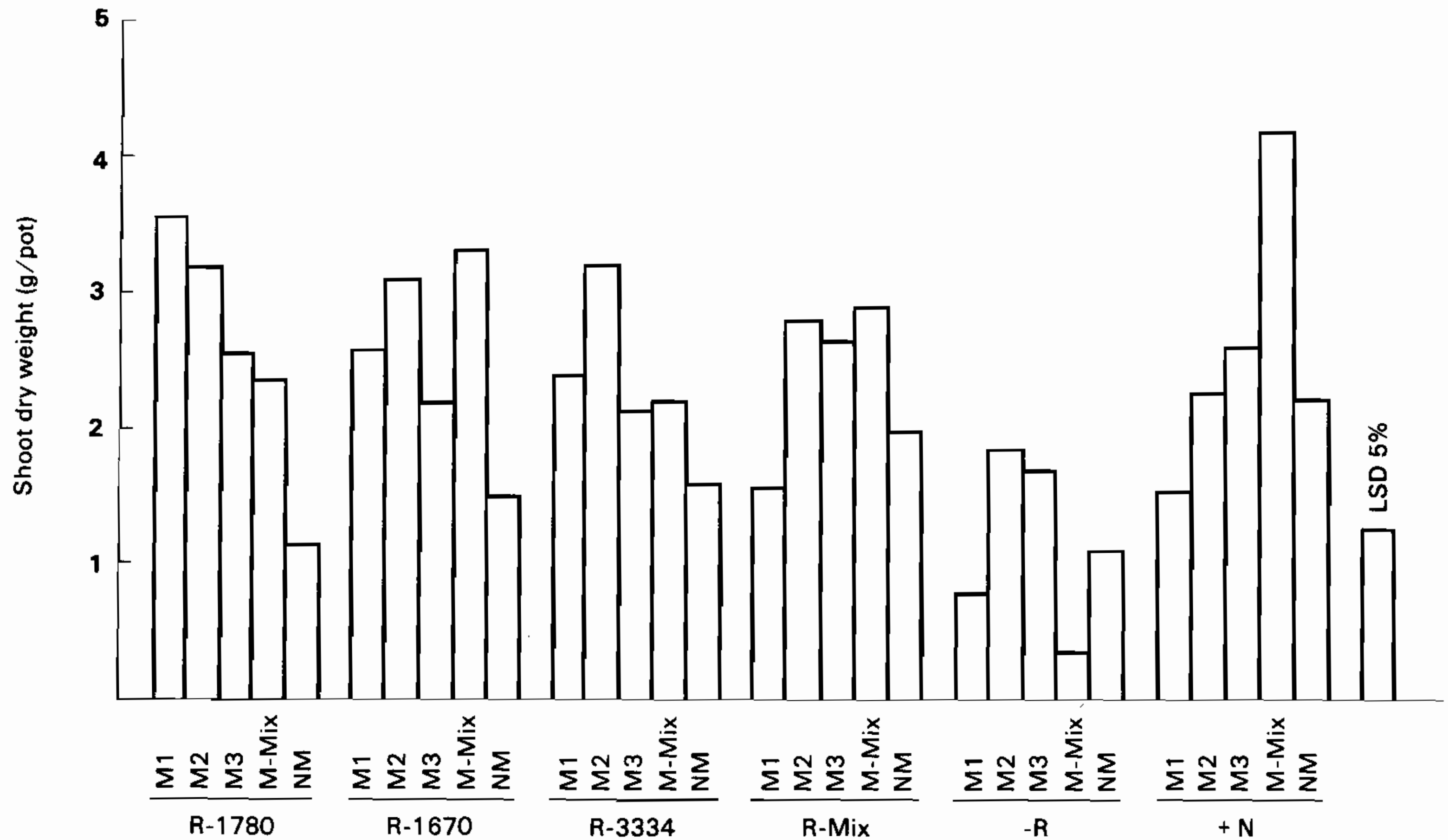


Figure 9. Effect of *Rhizobium* and mycorrhizal fungi on shoot dry weight of *Centrosema macrocarpum* CIAT 5065 grown in sterile oxisol. P source: soluble phosphate. For explanation of mycorrhizal treatments see the text.

Table 15. Main effect of inoculation with *Rhizobium* and mycorrhizal fungi on shoot dry weight and uptake of P and N by *Centrosema macrocarpum* CIAT 5065 grown in sterile Oxisol. P source: Rock phosphate, six weeks after transplanting soluble phosphate was added.

Treatments	Shoot dry weight (g/pot)	Mineral uptake (mg/pot) P	N
Rhizobium Inoculation			
+ Nitrogen	0.93 a	2.74 a	38.57 a
Rhizobium no. 1780	0.70 a	1.75 b	21.16 b
Rhizobium no. 1670	0.71 a	1.53 b	23.53 b
Rhizobium no. 3334	0.85 a	2.03 b	25.89 b
Rhizobium mixture	0.83 a	2.03 b	27.40 b
- *Rhizobium*	0.91 a	1.93 b	25.84 b
Mycorrhizal Inoculation			
E. colombiana	0.83 b	1.56 b	26.46 bc
A. longula	0.53 c	1.11 bc	19.29 cd
G. manihotis	1.33 a	2.93 a	43.20 a
Mixture of mycorrhizal fungi	1.08 ab	2.71 a	33.84 b
Non-mycorrhizal	0.34 c	0.70 c	12.54 d

Mean values for *Rhizobium* and mycorrhizal inoculation with different letters are significantly different ($P < 0.05$) by Duncan's multiple range test.

Table 16. Main effect of inoculation with *Rhizobium* and mycorrhizal fungi on shoot dry weight of *Centrosema macrocarpum* CIAT 5065 grown in sterile Oxisol. P source: soluble phosphate.

Treatments	Shoot dry wgt (g/pot)
Rhizobium Inoculation	
+ Nitrogen	2.55 a
Rhizobium no. 1780	2.55 a
Rhizobium no. 1670	2.55 a
Rhizobium no. 3334	2.30 a
Rhizobium mixture	2.37 a
- *Rhizobium*	1.17 b
Mycorrhizal inoculation	
E. colombiana	2.08 bc
A. longula	2.74 a
G. manihotis	2.30 ab
Mixture of mycorrhizal fungi	2.55 ab
Non-mycorrhizal	1.57 c

Mean values for *Rhizobium* and mycorrhizal inoculation with different letters are significantly different ($P < 0.05$) by Duncan's multiple range test.

inoculated with mycorrhizal fungi. However, if the soil is very poor in N, plants inoculated with mycorrhizal fungi have to be either inoculated with effective Rhizobium strains or supplied with N.

PHOSPHORUS-NITROGEN-MYCORRHIZA-RHIZOBIUM INTERACTION IN CENTROSEMA

The objective of this experiment was to study the effect of four levels of P and N on mycorrhizal and Rhizobium inoculation response of Centrosema macrocarpum CIAT 5065 grown in sterile soil (Oxisol) from Carimagua and to find out the optimum levels of P and N for the efficiency of mycorrhizal fungi and Rhizobium. Mycorrhizal inoculation was done with a mixture of three mycorrhizal fungi used in the above experiments. Rhizobium inoculation was done only with strain no. 3334. Phosphorus and N sources were monocalcium phosphate and urea.

Results (Figures 10 to 12) indicated that P and N levels have a strong effect on the growth and uptake of P and N of plants inoculated or not inoculated with mycorrhizal fungi and Rhizobium. Shoot dry weight of Centrosema was increased more by mycorrhizal inoculation at intermediate P levels (20 and 40 kg/ha). Phosphorus uptake was increased more at 40 kg P/ha. Non-mycorrhizal plants required more than double the amount of P to produce the same dry matter as mycorrhizal plants. At each N level, main effect of mycorrhizal inoculation (mean of P levels) on growth and mineral uptake of Centrosema was significant. No significant interaction between N levels and mycorrhizal treatments was observed. However, P levels and mycorrhizal treatments interacted significantly. Mycorrhizal response (M:NM x 100) for growth and mineral uptake was highest in plants given 20 kg P/ha and 30 kg N/ha. Table 17 shows that Rhizobium inoculation combined with a small amount of N significantly increased growth and mineral uptake by Centrosema. However, nodule number was not influenced by N levels.

The results indicate that inoculation with mycorrhizal fungi greatly increased the growth and mineral uptake of Centrosema at intermediate P and N levels. A combination of chemical and biological nitrogen produced more dry matter yield than either of them alone. In order to define optimum levels of P and N for other forage legumes, such experiments should be conducted in sterile and unsterile soil both under greenhouse and field conditions.

PHOSPHORUS-NITROGEN-MYCORRHIZA INTERACTIONS IN BRACHIARIA

This study consisted of two experiments: in one experiment soluble phosphate and in the other rock phosphate from Huila were used as P sources. Both pot experiments were conducted in sterile soil (Oxisol) from Carimagua. The test plant for both experiments was Brachiaria decumbens CIAT 606. A mixture of three mycorrhizal fungi (same as in Centrosema experiment) was used for inoculation.

Results in Figure 13 show that at all N levels shoot dry weight of inoculated and non-inoculated plants increased with increasing P levels. Highest dry matter production was achieved, both for inoculated and non-inoculated plants, at 80 kg P/ha combined with 100 kg N/ha. The only significant increase in shoot dry weight caused by mycorrhizal inoculation was observed at 20 and 40 kg P/ha with 100 kg N/ha. This was also evident from the main effect of mycorrhizal inoculation on shoot dry weight. The main effect of mycorrhizal inoculation on the uptake of P and K (0 kg N/ha), P, N and K (25 kg N/ha) and all mineral elements (100 kg N/ha) was significant.

Fig.14 shows that growth of Brachiaria

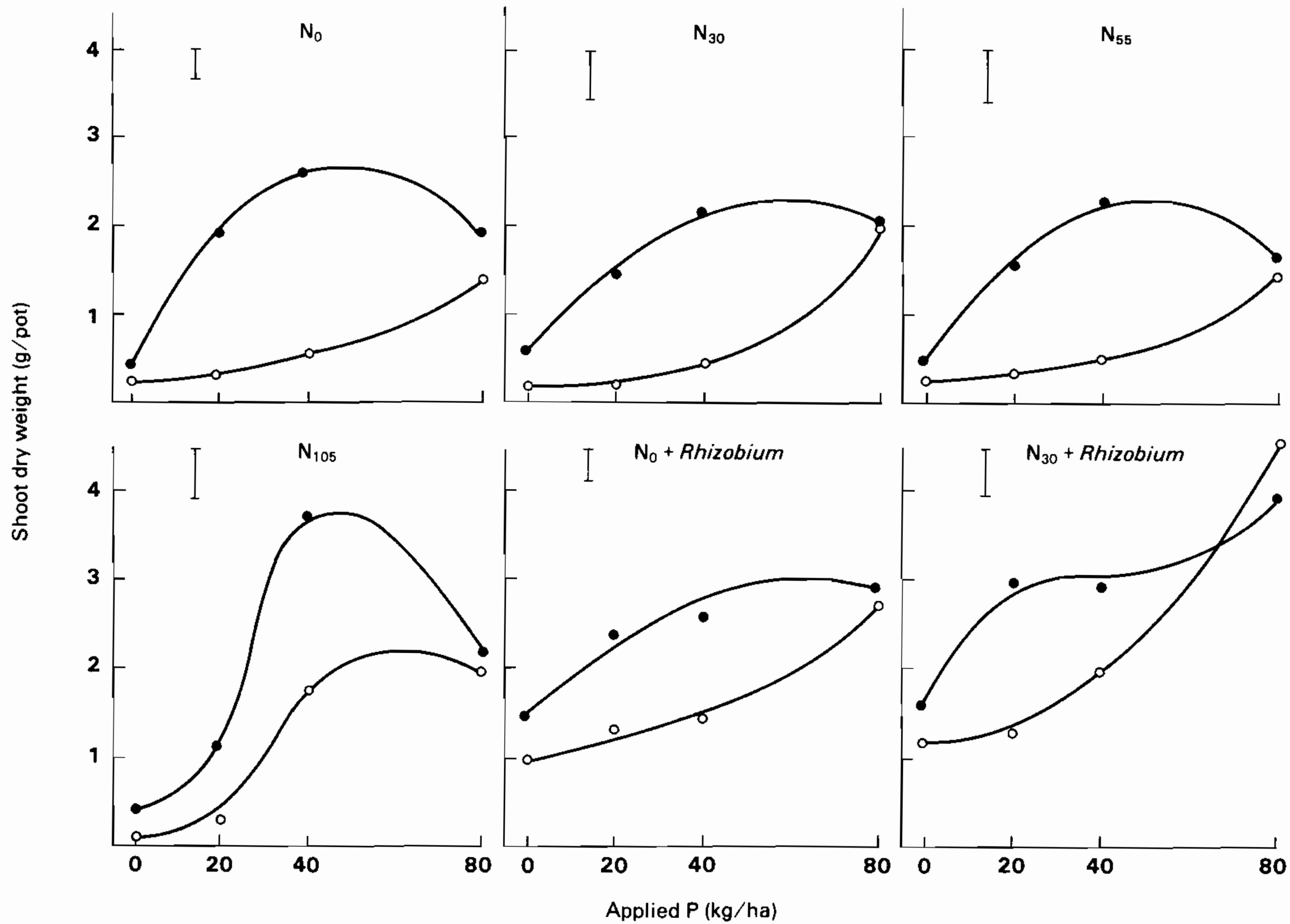


Figure 10. Shoot dry weight of *Centrosema macrocarpum* CIAT 5065 given different levels of phosphorus and nitrogen and either not inoculated (o) or inoculated (o) with VA mycorrhizal fungi. N^0 to N^{105}, 0 to 105 kg N/ha. Bars indicate LSD at 5%.

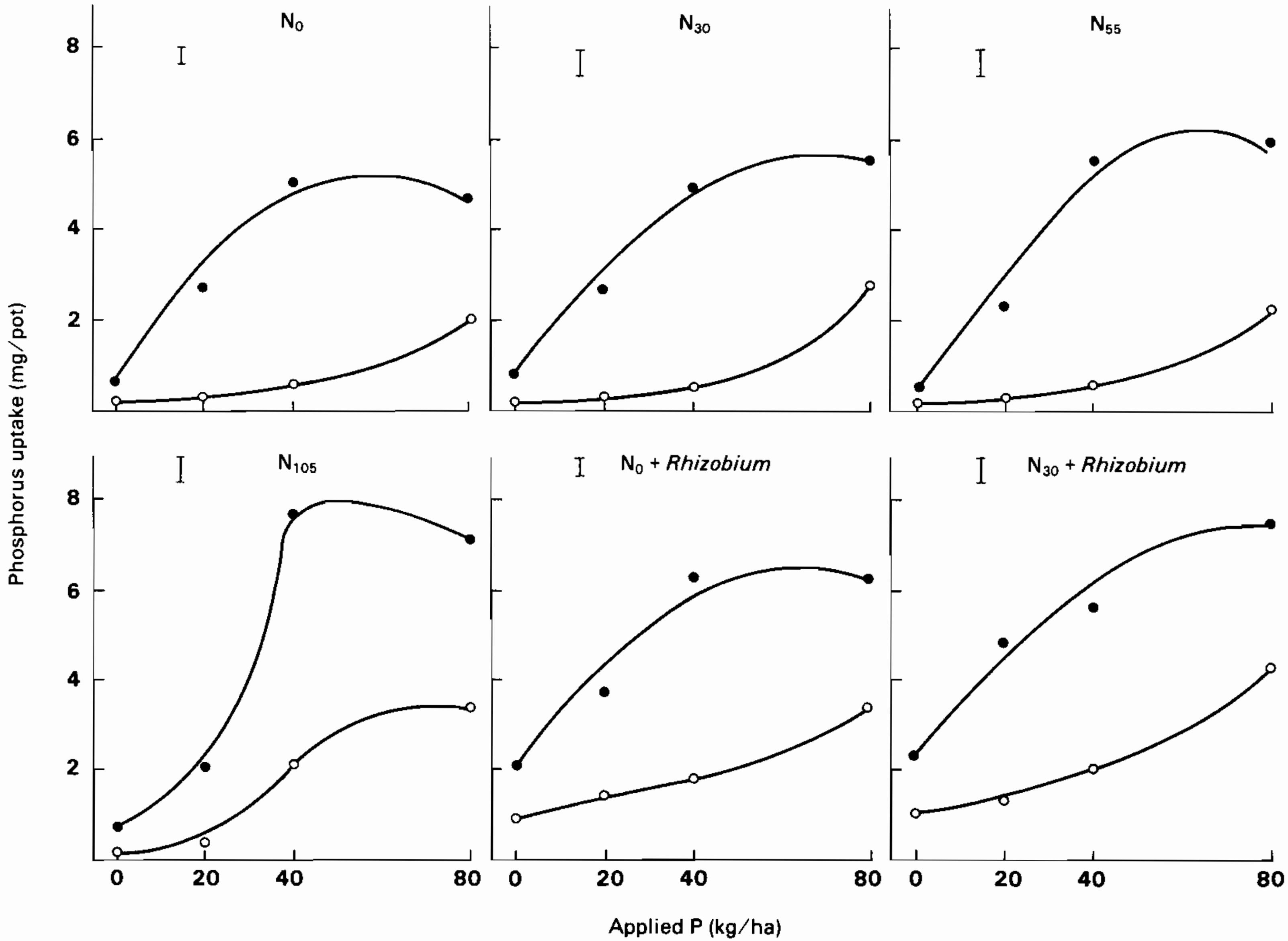


Figure 11. Same as Figure 10., but for phosphorus uptake.

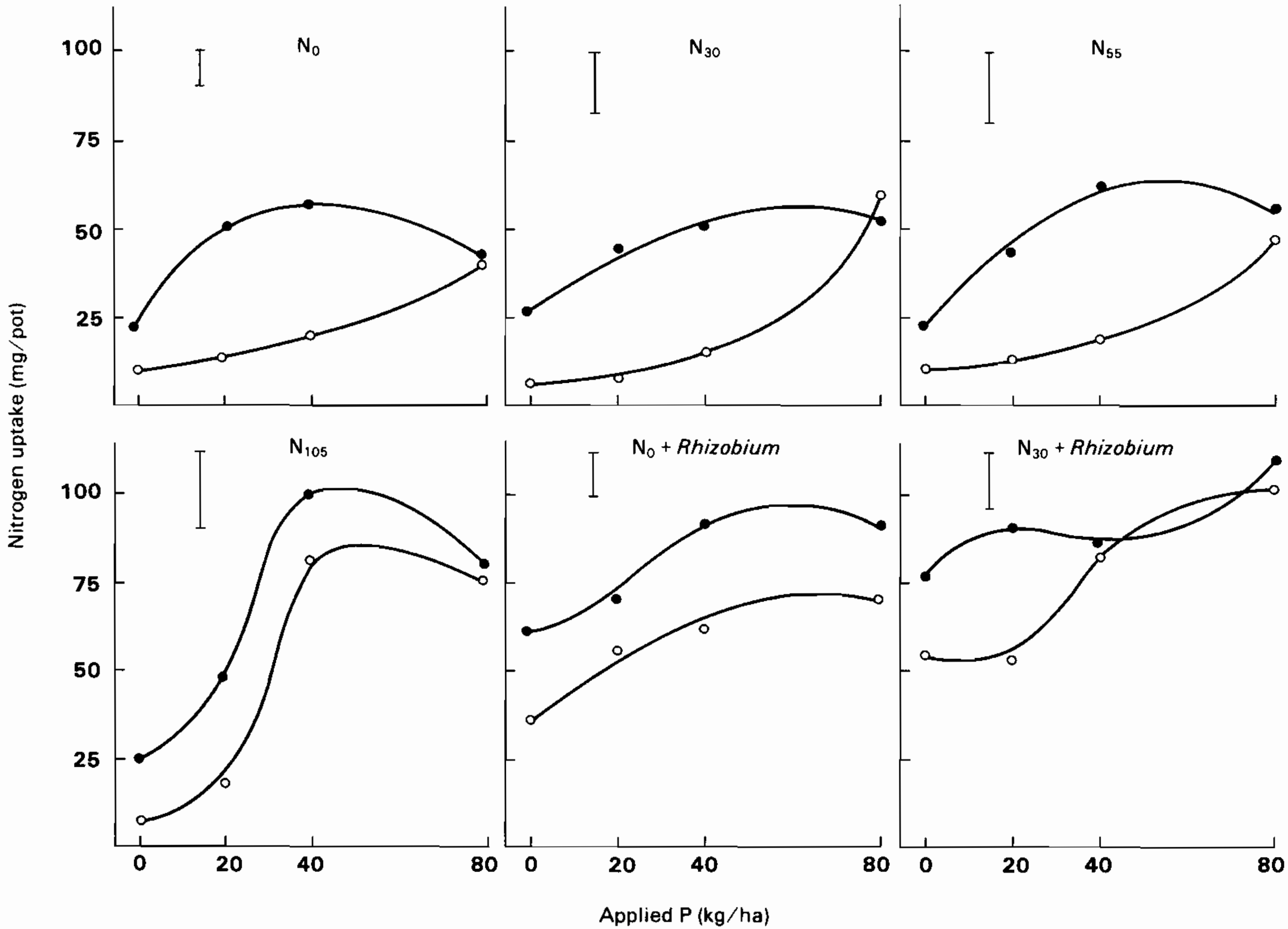


Figure 12. Same as Figure 10., but for nitrogen uptake.

Table 17. Main effect of nitrogen levels on the growth and mineral uptake of Centrosema inoculated with Rhizobium (mean of all phosphorus levels and mycorrhizal and non-mycorrhizal plants).

N applied kg/ha	Shoot dry weight (g/pot)	No. of nodules /pot	Dry weight of nodules (mg/pot)	Mineral uptake (mg/pot)				
				P	N	K	Ca	Mg
0	1.97 b	14.4 a	24 b	3.27 b	67.30 b	22.66 b	13.28 b	4.62 b
30	2.54 a	14.5 a	32 a	3.66 a	85.15 a	25.95 a	20.29 a	6.03 a

Means in a column with different letters are significantly different ($P < 0.05$)

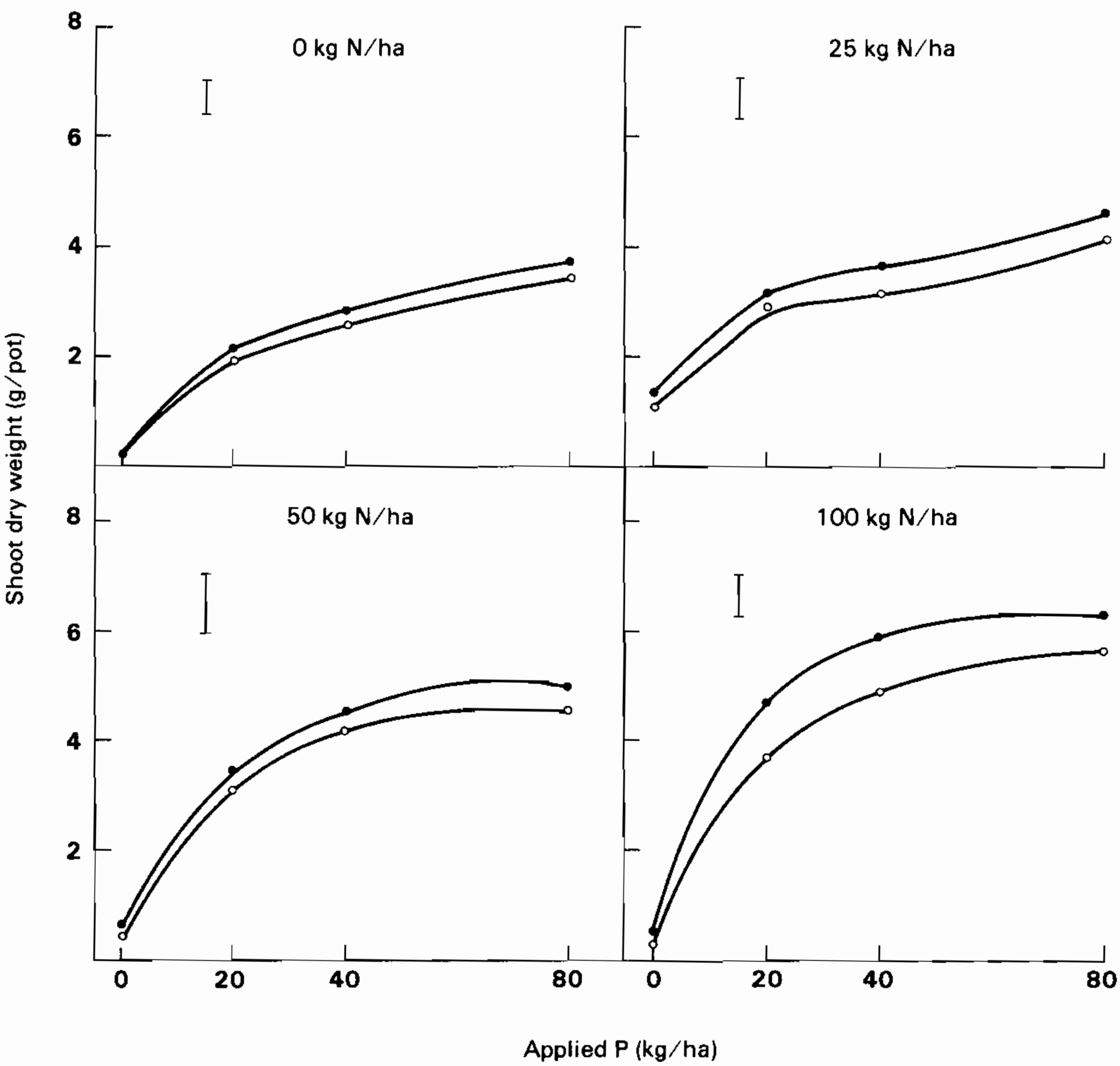


Figure 13. Shoot dry weight of mycorrhizal (o) and non-mycorrhizal (o) *B. decumbens* CIAT 606 given different levels of soluble phosphate and nitrogen. Bars indicate LSD at 5%.

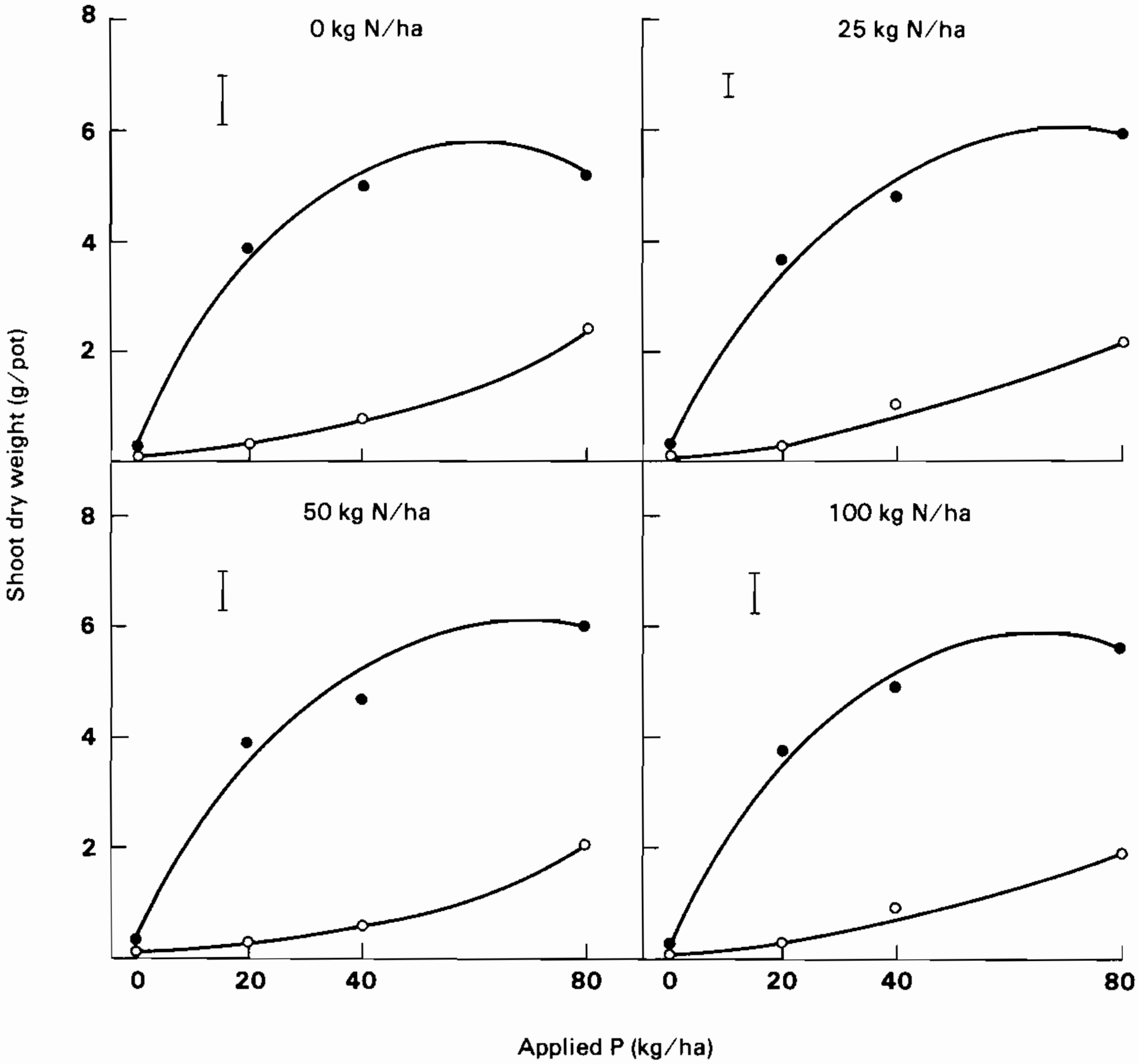


Figure 14. Shoot dry weight of mycorrhizal (●) and non-mycorrhizal (o) *B. decumbens* CIAT 606 given different levels of rock phosphate and nitrogen. Bars indicate LSD at 5%.

plants given rock phosphate was very poor unless they were inoculated with mycorrhizal fungi. At each N level, mycorrhizal inoculation increased significantly the dry matter production at all P levels except 0 kg P/ha. Inoculated plants required about three times less P than the non-inoculated plants to produce the same amount of dry matter. No significant interaction between N levels and mycorrhizal inoculation was observed. However, a significant interaction between P levels and mycorrhizal inoculation was observed (Figure 15). The main effect of mycorrhizal inoculation on shoot dry weight and uptake of mineral elements, at each N level, was significant. Mycorrhizal response was highest at 20 kg P/ha combined with 25 kg N/ha and decreased with increasing P levels.

The results of both experiments clearly indicate that P sources affect the efficiency of mycorrhizal fungi. Brachiaria plants given soluble phosphate benefitted less from mycorrhizal fungi than the plants supplied with rock phosphate. Mycorrhizal fungi were more efficient at intermediate levels of P and N. Such experiments should be conducted with other forage grasses in sterile and unsterile soil both under greenhouse and field conditions.

INDIGENOUS MYCORRHIZAL FUNGI

The population dynamics of indigenous mycorrhizal fungi in soils of tropical rangelands is an area that needs considerable attention. Since populations of mycorrhizal fungi vary greatly in size and species composition, ecological studies are fundamental to considerations on the possibilities of increasing the indigenous mycorrhizal population or of introducing more efficient species into a field with a view to improve and maintain pasture productivity. Also, the indigenous mycorrhizal fungi under native vegetation are most likely adapted to infertile soils and host plants with low P requirements and they may be quite inefficient. Conversion of native vegetation to sown pastures and fertilizer applications may change the effectiveness of these indigenous fungi.

To study some of the above-mentioned aspects, a large number of soil cores was collected from native vegetation and sown pastures under different management practices. The samples are being subjected to laboratory and greenhouse studies. It is hoped that information obtained through these studies will suggest management factors which affect indigenous mycorrhizal fungi with the objective of improving and maintaining pasture productivity.

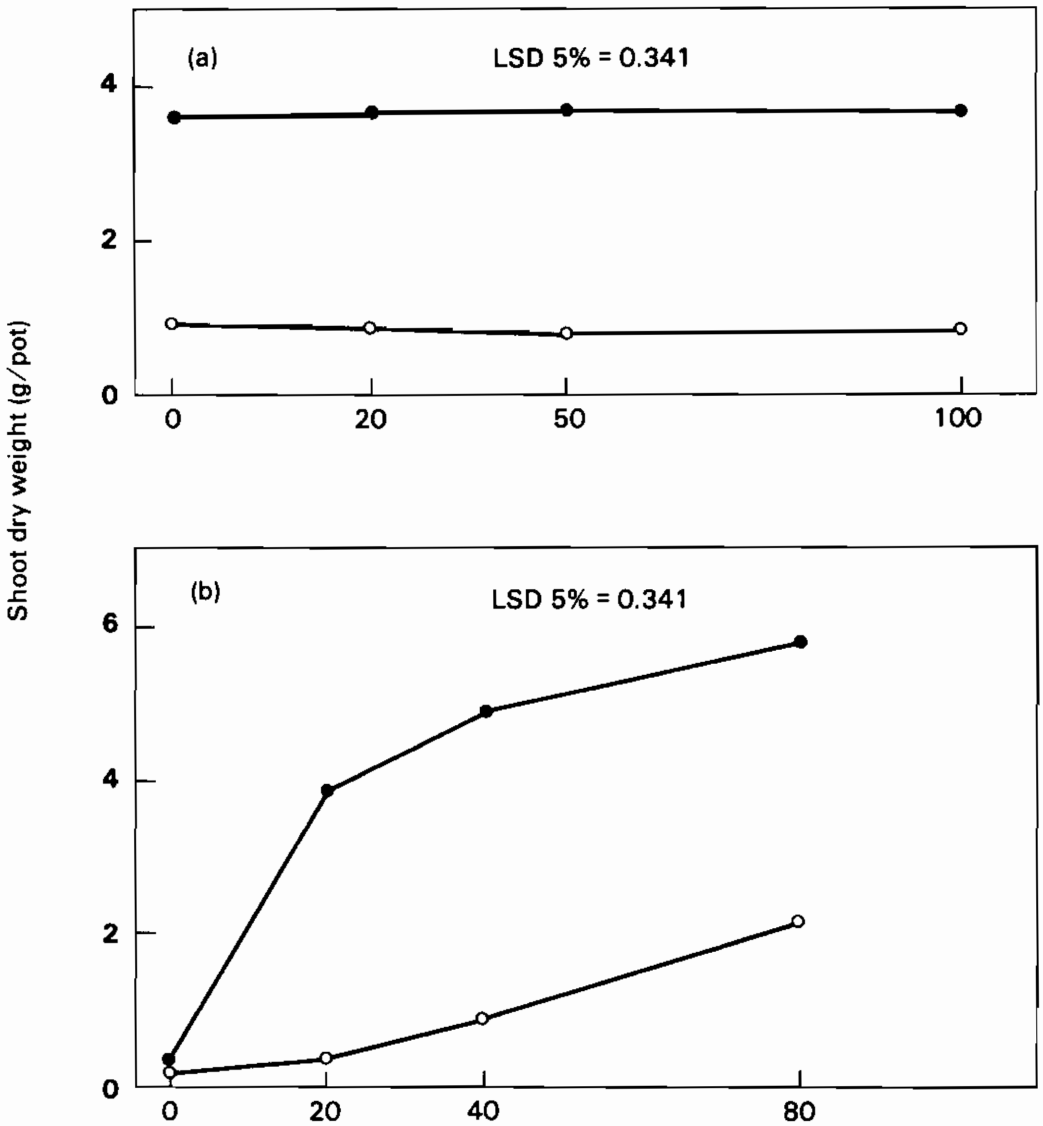


Figure 15. Shoot dry weight of mycorrhizal (•) and non-mycorrhizal (o) *B. decumbens* (a) N x mycorrhiza means; (b) P x mycorrhiza means. P source: Rock phosphate.

Soil/Plant Nutrition

During 1985 the section has intensified research work in 3 areas: (1) evaluation of several methods leading to the bionutritional diagnosis of forage germplasm; (2) nutritional requirements of grass-legume mixtures; and (3) the evaluation of nutrient recycling in pastures.

1. BIONUTRITIONAL DIAGNOSIS OF GERMPLASM

This type of evaluation takes into account three main aspects: (1) the fast flow of germplasm into categories III, IV and V making very difficult the evaluation of the nutritional requirements in the field; 2) the determination of nutritional requirements with Rhizobium inoculation; and 3) the determination of nutritional requirements in different soil types accounting for the chemical and physical variability in acid soils. As a result, several methodologies were evaluated aiming to identify, on the short term basis, the key elements needed for the adequate establishment of grasses and legumes. Once the bionutritional diagnosis is performed, more efficiency can be achieved in the field since these trials will include only the most limiting nutrients of each site.

The different diagnostic techniques included: the missing element, using as fertilizer the Arnon and Hoagland nutrient solution and the Soil Plant Nutrition Section (SPNS) recommended fertilizer rates; the single and the cumulative additional element; and the 2^3 factorial (K, Mg and S) with and without N, P, Ca as basic fertilizer.

The soil characteristics have been described in the 1984 annual report. One of the trials evaluated two species of the Brachiaria genera (B. decumbens 606 and B. miliiformis 16740). Figures 1, 2, and 3 show the relative dry matter yields obtained 45 days after the establishment of vegetative material with the different techniques.

Under greenhouse conditions the different techniques indicate that the nutritional requirements varied with the species tested.

Using the missing element technique, at different P levels (Figures 1a and 1b), it was determined for the Brachiaria genera that the main requirements, once P is supplied, are N and S followed by K. Using the single additional element technique (Figure 2a), the importance of P in the dry matter production was confirmed with respect to the other nutrients, thus in the absence of P their value could not be determined.

Using the technique of the cumulative addition of elements, B. miliiformis 16740 increased its yield gradually as more elements were applied. This in contrast with B. decumbens 606 (Figure 2b). The missing element and the additive techniques describe only simple type effects whereas the factorial technique (Figures 3a and 3b) allows for a more complete

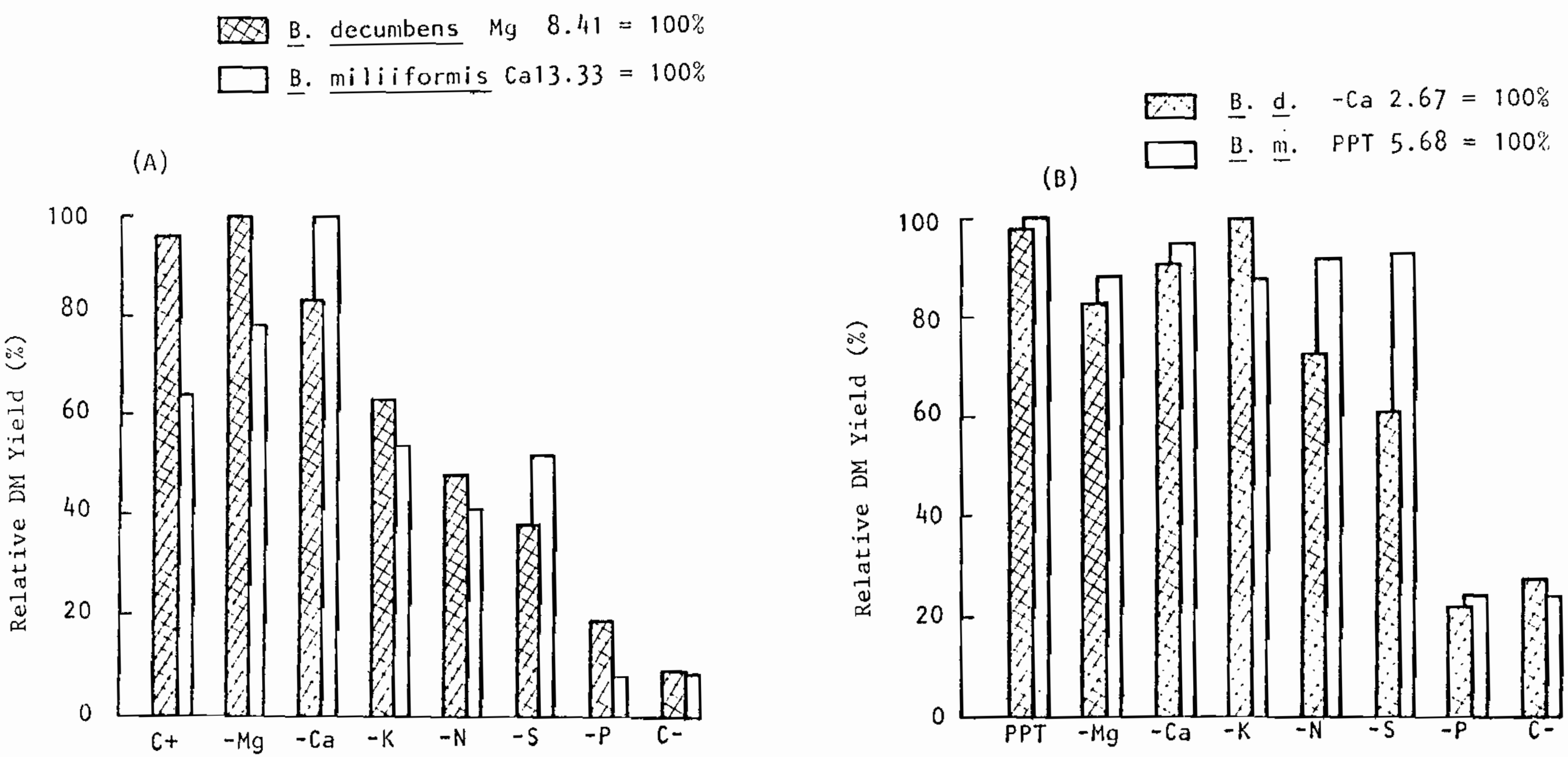


Figure 1. Relative dry matter (DM) yield of Brachiaria decumbens 606 and Brachiaria miliiformis 16740 using the missing element technique with the Arnon and Hoagland nutrient solution as fertilizer (A), and with the SPNS recommended fertilizer rate (B).

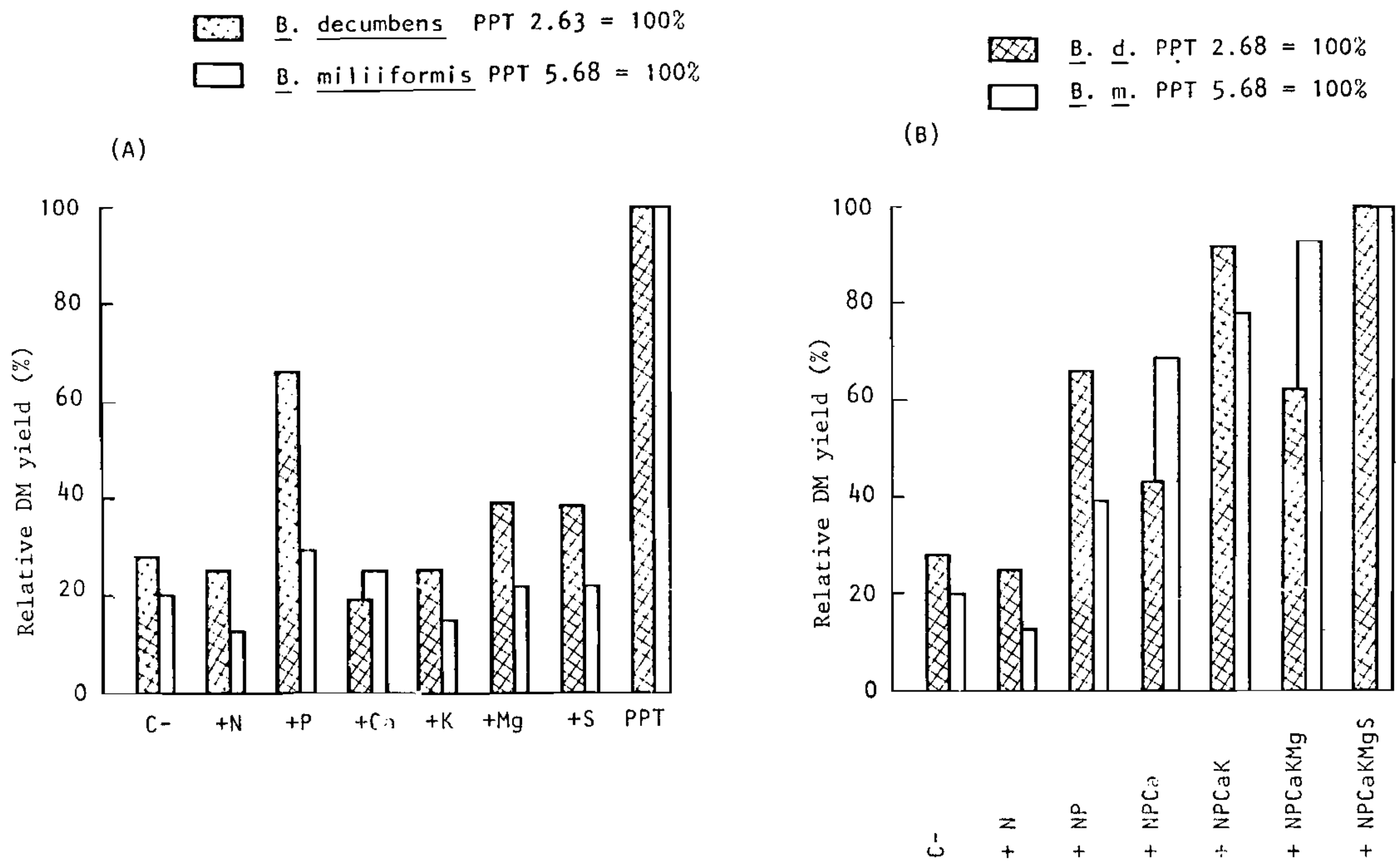


Figure 2. Relative dry matter (DM) yield of Brachiaria decumbens 606 and Brachiaria miliiformis 16740 using the single (A) and the cumulative (B) addition of elements techniques.

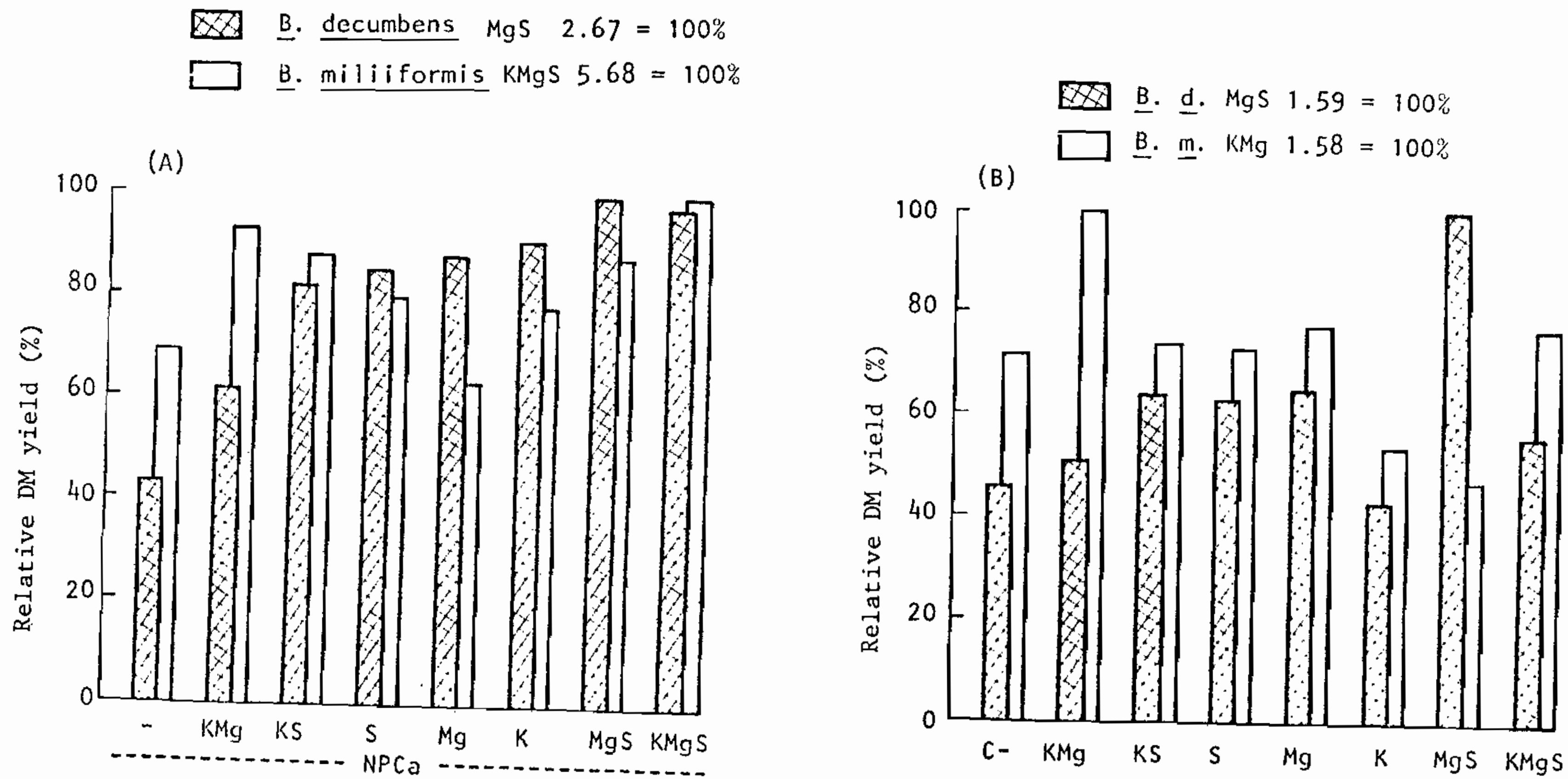


Figura 3. Relative dry matter (DM) yield of Brachiaria decumbens 606 and Brachiaria miliiformis 16740 using the 2^3 factorial treatment design with (A) and without (B) N, P, and Ca.

analysis since interactions can be studied.

The 2^3 factorial arrangement with N, P, Ca (Figure 3a) is a combination of the missing and the additive element techniques. Keeping in mind that without P other nutrients will not perform, it was considered that Ca comes together with P as rock phosphate or basic slag (local P sources) and that N will be supplied by the legume in an association. Therefore, N, P and Ca were applied as basic fertilizers plus all the combinations of 2 rates of K, Mg and S.

The relative efficiency of the different techniques tested compared with the 2^3 factorial with N, P, Ca is presented in Table 1. The missing element technique with nutrient solution as fertilizer is not taken into account as substancial changes in the soil fertility occurred. The techniques with less relative efficiency were those without P in the treatments such as the 2^3 factorial without N, P, Ca and the single additive element technique.

In another bionutritional diagnostic trial 5 forage legumes were tested with a wide range of adaptation to acid soils. Dry matter production of the legumes 85 days after planting is shown in Table 2.

The results show that native Rhizobium strains are effective for Stylosanthes capitata 10280 (Capica), Zornia glabra 7847 and Desmodium ovalifolium 3782. In addition, these species showed low P requirements (25 kg P ha^{-1}) since no response was observed to high P rates (80 kg P ha^{-1}). Potassium, K and Mg seem to be essential for the establishment of these legumes when compared to the controls.

Pueraria phaseoloides 9700 (tropical Kudzu) and Centrosema macrocarpum 5065 showed a specific Rhizobium requirement. These two species also responded to higher P rates (80 kg P ha^{-1}). C. macrocarpum 5065 showed requirements for Ca, K, Mg and S. P. phaseoloides required Ca, K and Mg.

In 1986 several trials will be established using the 2^3 factorial technique, with N or Rhizobium, P and Ca as basic fertilizer. The rates used are shown in Table 3. A wide range of germplasm and soils will be used to determine the bionutritional needs. These trials will also be an important component of the integration efforts between soil fertility and microbiology sections according to the scheme shown in Figure 4.

2. NUTRITIONAL REQUIREMENTS OF ASSOCIATED GRASSES AND LEGUMES

It is recognized that the stability of a grass-legume association can be determined by the nutritional needs of the components of the association. Thus, the identification of the nutritional demand of each component in monoculture and in association becomes quite important.

In order to see the effect of K and Mg in several promising associations, two simultaneously trials were conducted in Carimagua with rates of 0, 10, 20 and 40 kg of K and Mg ha^{-1}, respectively. From the K trial Mg was applied constant at 30 kg ha^{-1} while for the Mg trial, K was applied at 30 kg ha^{-1}. The following associations were studied: Desmodium ovalifolium 350 with Brachiaria decumbens 606, B. dictyoneura 6133, and B. humidicola 679; Pueraria phaseoloides 9900 with Andropogon gayanus 621 and B. decumbens 606; and Stylosanthes capitata 1693 with A. gayanus 621.

These trials were evaluated during two consecutive years after the establishment period in order to observe over time the estability of the associations.

Table 1. Relative efficiency of several nutritional diagnostic techniques using B. *decumbens* and B. *miliiformis* as test plants under greenhouse conditions.

Technique	D.F.	B. decumbens		B. miliiformis	
		MSE[1]	Relative efficiency (%)	MSE	Relative efficiency (%)
1 2^3 factorial with N, P, Ca	8	0.3737	100	0.3796	100
2 Cumulative addition of elements	7	0.3242	87	0.1296	35
3 Missing element	8	0.3095	83	0.2137	58
4 2^3 factorial without without N, P, Ca	8	0.2958	79	0.1621	44
5 Single addition of elements	8	0.2087	56	0.1429	39

1/ MSE = Mean square error.

Table 2. Bio-nutritional diagnosis for 5 promising forage legumes under greenhouse conditions. La Reserva soil.

Treatment	*S. c.* 10280		*Z. g.* 7847		*D. o.* 3782		*C. m.* 5065		*P. p.* 9900	
	DM g pot^{-1}	%	DM g pot^{-1}	%	DM g pot^{-1}	%	DM g pot^{-1}	%	DM g pot^{-1}	%
Control +N*	6.6	100	7.3	100	6.4	100	5.4	100	7.4	100
Control -N	5.9	89	6.9	95	4.7	73	4.9	90	6.1	82
Control +Rhiz	5.8	88	-	-	4.9	76	6.5	120	7.2	97
Control +Rhiz+80 P	6.7	102	7.5	103	5.9	92	8.0	148	11.3	152
Rhiz, P, Ca	5.6	85	5.6	77	5.0	78	7.3	135	7.7	104
Rhiz, P, Ca +2 Ca	4.0	61	5.2	71	4.4	69	5.6	104	5.8	78
Rhiz, P, Ca +K	5.0	76	5.6	77	4.8	75	5.6	104	5.8	78
Rhiz, P, Ca +Mg	5.1	77	5.6	77	4.2	66	6.2	115	6.2	84
Rhiz, P, Ca +KMg	5.7	86	5.9	81	6.0	94	6.3	117	7.4	100
Rhiz, P, Ca +MgS	4.9	74	5.9	81	4.2	66	6.9	128	6.9	93
Negative control	2.7	41	3.1	43	1.6	25	3.3	61	2.9	39

* Control +N = P-20 and Ca-80 (as basic slag), K-30 (KCl), Mg-20 (MgO), S-20 (Sulfur flower), N-15 (every 2 weeks as urea) kg ha^{-1} equivalent.

Table 3. Nutrients and rates used in the bio-nutritional diagnosis of promising forage germplasm.

Treatment	N*	P	Ca	K	Mg	S	Zn	Cu	B
	kg ha^{-1}								
Negative control	0	0	0	0	0	0	0	0	0
Negative control	15	20	100	30	20	20	31	2	1
NPCa + KMgS	15	20	100	30	20	20			
NPCa + KMg	15	20	100	30	20				
NPCa + KS	15	20	100	30		20			
NPCa + K	15	20	100	30					
NPCa + Mg	15	20	100		20				
NPCa + S	15	20	100			20			
NPCa	15	20	100						
NPCaKMgS + ZnCu	15	20	100	30	20	20	3	2	
NPCaKMgS + ZnB	15	20	100	30	20	20	3		1
NPCaKMgS + CuB	15	20	100	30	20	20		2	1
NPCaKMgS + Zn	15	20	100	30	20	20	3		
NPCaKMgS + Cu	15	20	100	30	20	20		2	
NPCaKMgS + B	15	20	100	30	20	20			1

* Applied every 2 weeks for grasses and legumes. When a specific Rhizobium strain is recommended N application is not necessary.

COMPLEMENTARY RESEARCH TO DETERMINE NUTRITIONAL AND MICROBIOLOGICAL REQUIREMENTS OF SELECTED FORAGE GERMPLASM IN REPRESENTATIVE SOILS

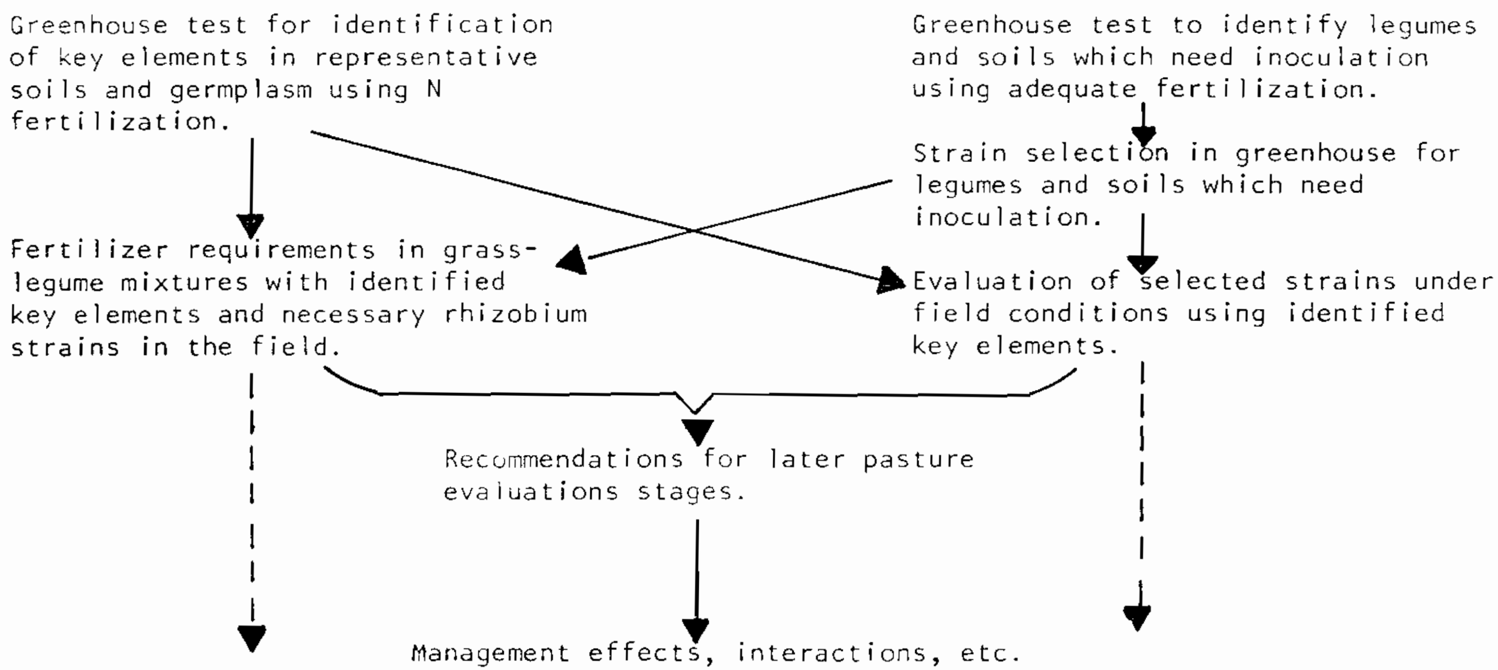


Figure 4. Basic complementary research for the bionutritional diagnosis of forage germplasm in representative soils.

The results showed that in general K applications did not significantly increase the dry matter of grasses alone, with the exception of *A. gayanus* 621 who responded to 10 kg ha^{-1}. On the other hand, pure legume stands responded to K and Mg applications.

Figure 5 shows the effect of K applications on the mixtures of *A. gayanus* with *S. capitata* and *P. phaseoloides*. Both grass-legume mixtures showed a positive response to K applications during the two years, but the grass obtained the greatest benefit as the K rate was increased. However, at low K rates (10 kg ha^{-1}) the legume seems to be able to effectively compete causing even a depression in the grass yield (Figure 5).

The response to Mg applications are shown in Figure 6. *Pueraria phaseoloides* 9900 has a greater requirement of Mg confirming previous results. In the association with *A. gayanus*, Mg applications improved the grass yield. On the other hand, where *A. gayanus* is associated with *S. capitata* the requirements of Mg seem to be low (10 kg ha^{-1}).

Figure 7 shows the effects of K and Mg applications on the components of the mixture of *B. decumbens* 606 and *P. phaseoloides* 9900. In the case of K, both grass and legume showed a response up to 20 kg K ha^{-1} during the two years. In contrast to this, the Mg applications did not show significative changes on forage yields during the first year, but during the second year the grass-legume mixture required 10 kg Mg ha^{-1}

The associations with *Desmodium ovalifolium* and the *Brachiaria* species were not better than the monoculture components during the first year (Figures 8 and 9). During the second year the associations improved as compared with the monocultures but this was mainly due to a reduction of the *D. ovalifolium* since there was no observed a response to Mg (Figure 9).

Results obtained up to date indicate that a competition for K exists in the *A. gayanus* - *P. phaseoloides*, *A. gayanus* - *S. capitata* and *B. decumbens* - *P. phaseoloides* mixtures. However, not all the grass-legume mixtures were more productive that the monocultures, especially the associations of *D. ovalifolium* and the *Brachiarias*. In this case, a Mg dressing favors to *D. ovalifolium* causing a greater competition which depresses the grass yield. This competition tends to be partially reduced by a high K rate which favors to the companion grass.

3. MAINTENANCE FERTILIZATION

3.1 Recovery, development, and persistence of *S. capitata* in association with *A. gayanus*

A. Evaluation under cutting

In several grazing trials with *A. gayanus* and *S. capitata*, seedlings of *S. capitata* have shown low vigor constituting a serious constraint for the persistence of this legume. A competition for nutrients seems to exist between *A. gayanus* and *S. capitata* in this association. Studies carried out (Annual Report 1983) indicated that P is not the element under competition but suggest that K, Mg, and/or S could be the possible elements competed for. Subsequent studies have shown the low vigor of *S. capitata* seedlings in association with *A. gayanus* is related to a nutrient competition for K (Annual Report 1984). Recently it was though that K fertilization and the defoliation of *A. gayanus* (cutting or grazing) interacted, making *S. capitata* seedlings to recover. To this respect two simultaneous trials were conducted. One of the trials was carried out on the Altagracia farm, near Carimagua, in an *A. gayanus* and *S. capitata* association where the legume showed low seedling vigor. The trial

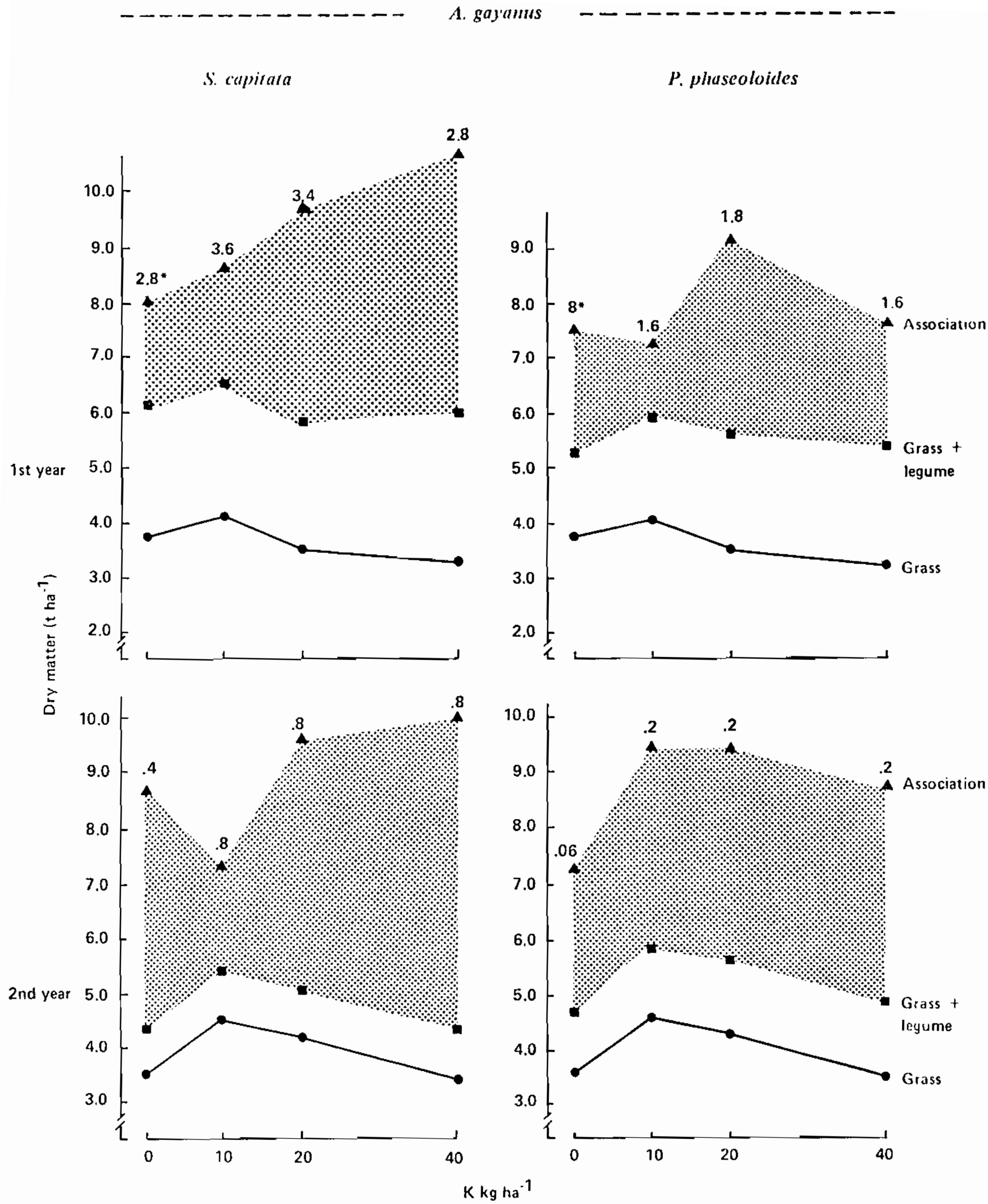


Figure 5. Effect of K on the components and the association of *A. gayanus* with *P. phaseoloides* and *S. capitata* during two rainy seasons.

* Values on the association line are for the legume component.

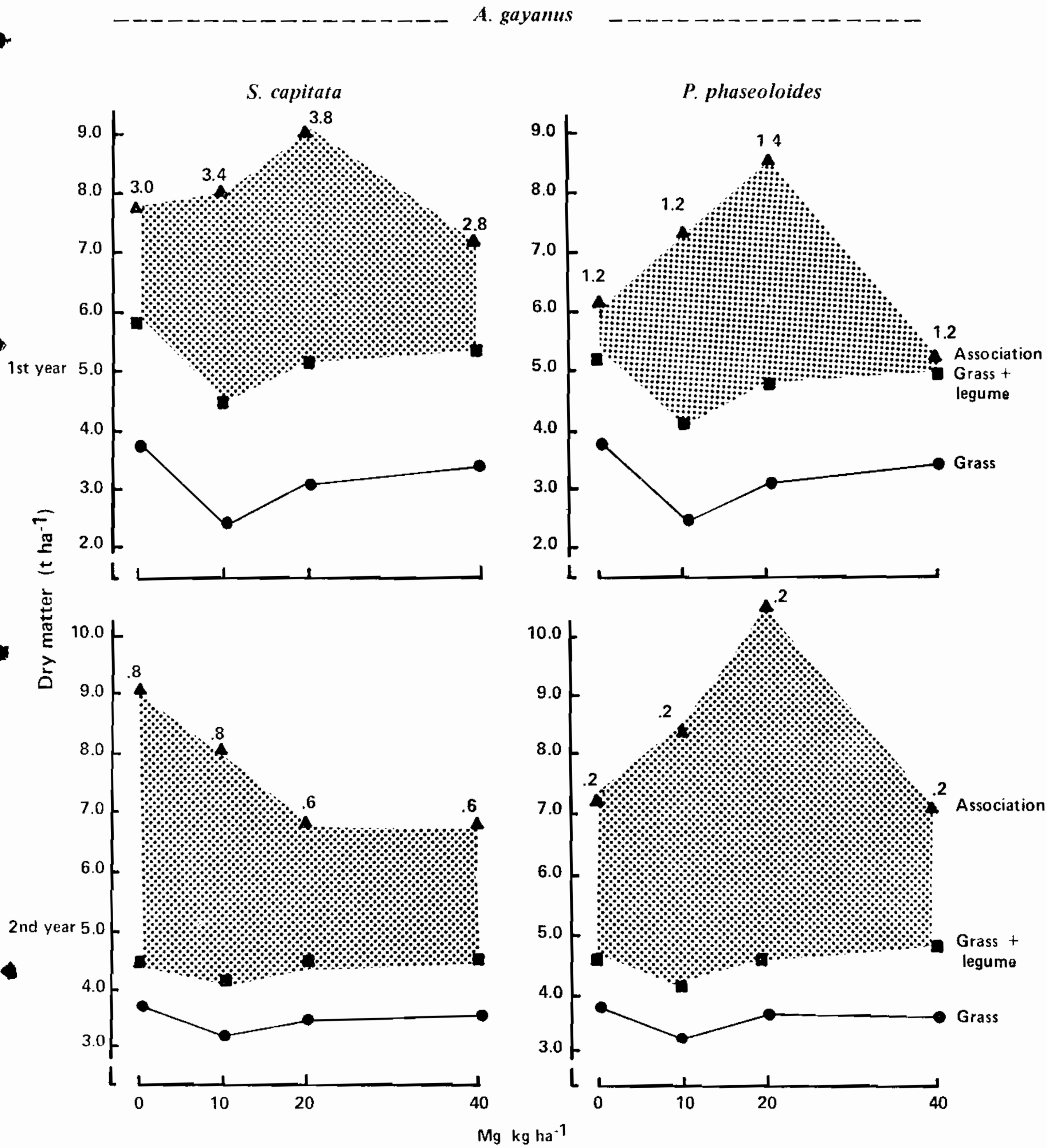


Figure 6. Effect of Mg on the components and the association of *A. gayanus* with *P. phaseoloides* and *S. capitata* during two rainy seasons.

*Values on the association line are for the legume component.

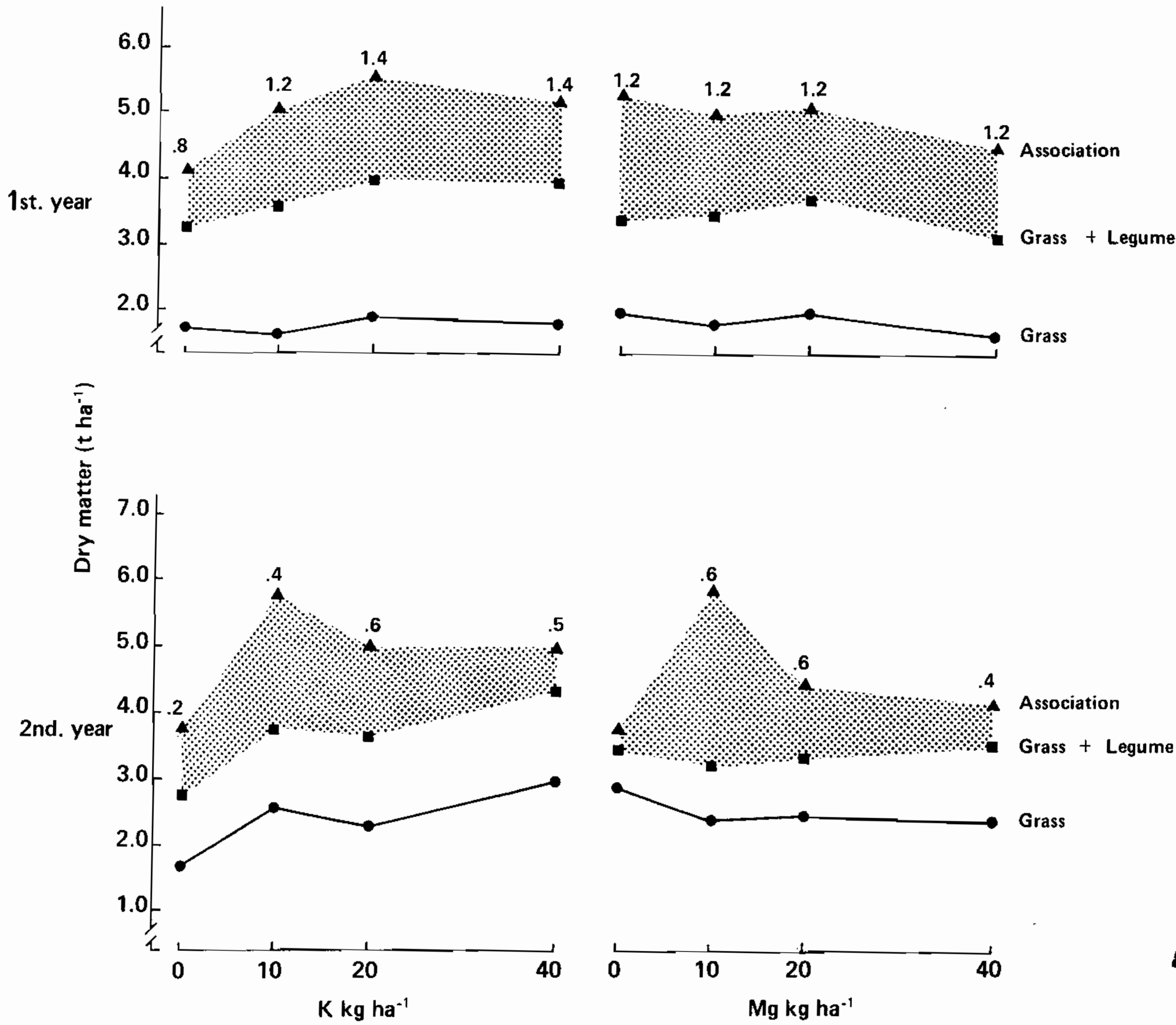


Figure 7. Effect of K and Mg on the components and the association of *B. decumbens* and *P. phaseoloides* during two rainy season.

* Values on the association line are for the legume component.

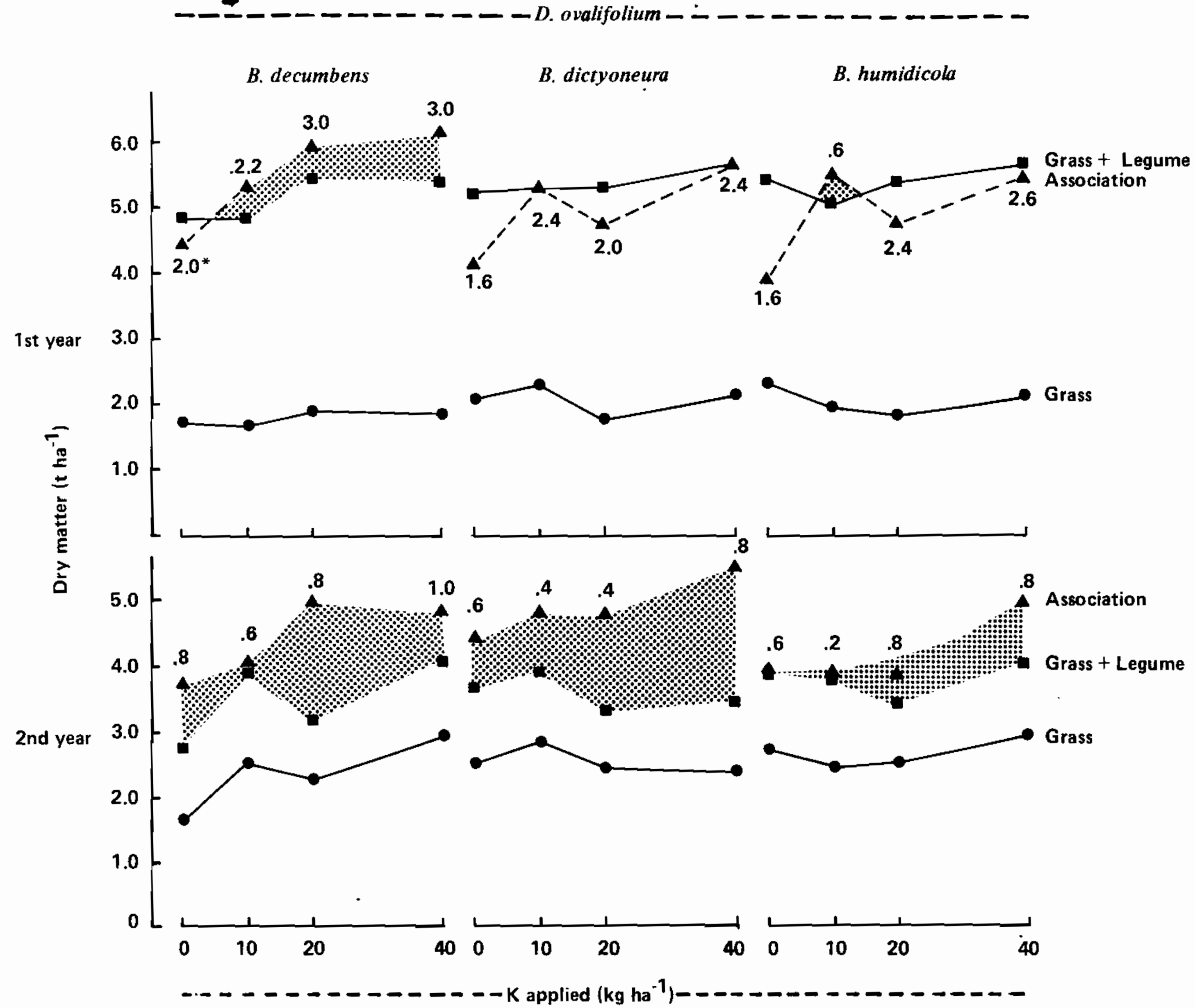


Figure 8. Effect of K on the components of the association of *D. ovalifolium* with 3 *Brachiaria* species, during two rainy seasons.

*Values on the association line are for the legume component.

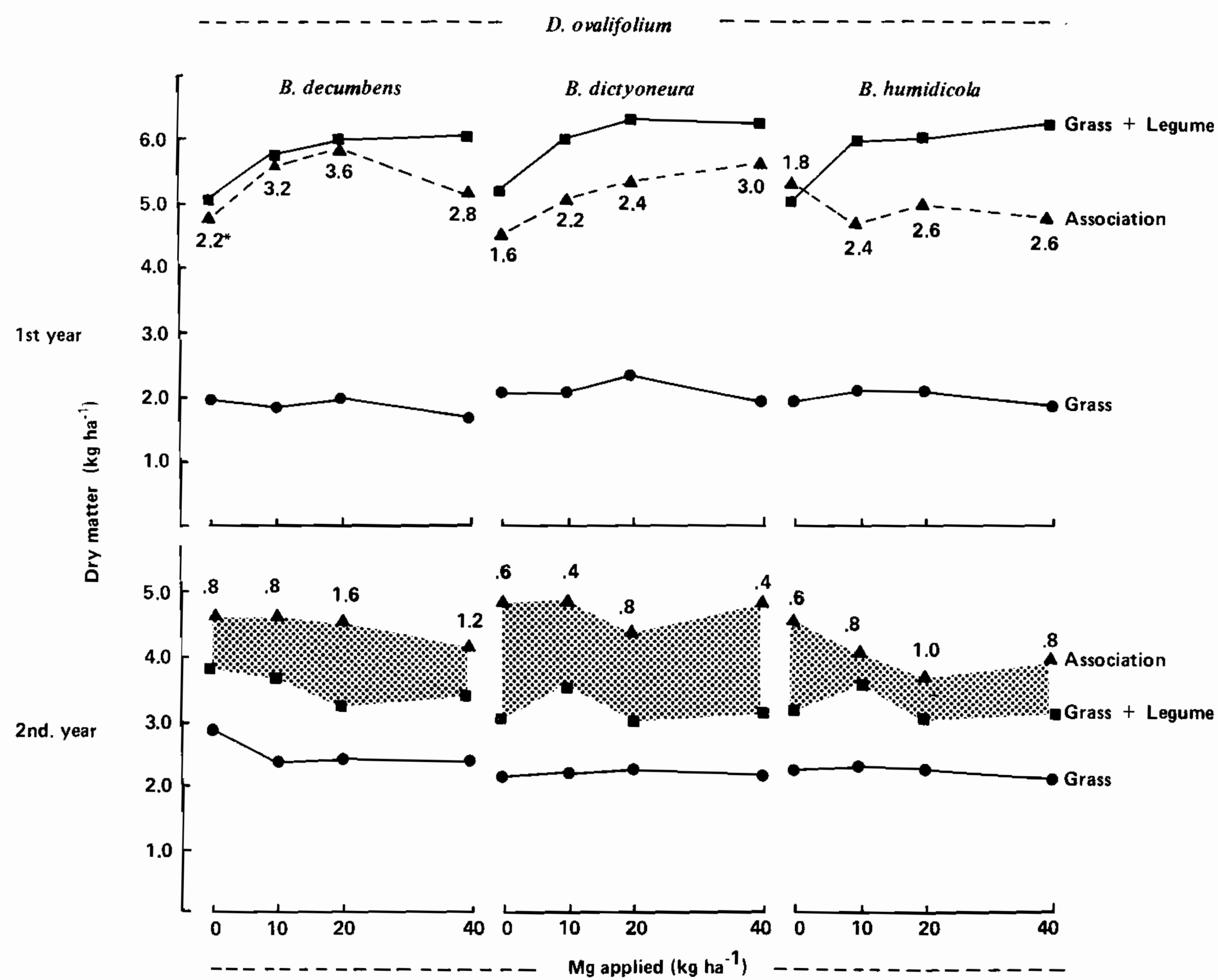


Figure 9. Effect of Mg on the components of the association of *D. ovalifolium* with 3 *Brachiaria* species, during two rainy seasons.

*Values on the association line are for the legume component.

included two defoliation levels (cutting height: 30 and 60 cm) and two cutting frequencies (28 and 42 days) of A. gayanus with or without maintenance fertilization. The fertilization treatments consisted of 0, 30, and 60 kg ha^{-1} and an additional treatment of 30 kg K and 10 kg P ha^{-1}, which is the SPNS recommended dose for maintenance every two years. The variable measured was the availability of S. capitata.

Dry matter production of S. capitata during the rainy and dry season of 1984-85 covered 9 and 6 cuttings for the 28- and 42-day frequency, respectively. Figures 10 and 11 show the effect of cutting height of A. gayanus and fertilization on the recovery and production of S. capitata at two cutting intervals.

In general, the effects of cutting height of the grass and of fertilization on the recovery of S. capitata were observed after the second cutting at both frequencies. This is due to the fact that during the first evaluation, the legume, although present, did not reach the cutting height (15 cm). Thereafter the recovery and production of the legume was observed as a function of K fertilization, as well as the combined application of K and P.

The effects of fertilization of the legume were more noticeable when A. gayanus was defoliated to 30 cm than to 60 cm of height, regardless of the cutting frequency. With the 42-day cutting frequency (Figure 11), the production of S. capitata with 60 kg K ha^{-1} remained almost constant in both seasons (rainy and dry) compared with the 28-day cutting interval in which the difference between treatments disappeared during the dry season. This could be related to the greater interval between cuttings and the high K fertilization, which favors legume development.

Less noticeable differences were observed in the recovery and production of S. capitata in response to the fertilizer treatments when A. gayanus was defoliated to a 60 cm height, indicating that under these conditions a competition for nutrients still persists favoring the grass over the legume.

In conclusion, the defoliation of A. gayanus by cutting it to a height of 30 cm and regardless of the cutting interval, reduces its vigor and in turn, lessens the competition with S. capitata, which showed recovery and development with K applications.

B. Evaluation under grazing

Another trial was carried out in Carimagua with the same association of A. gayanus and S. capitata, under three grazing pressures (high, intermediate, and low). The objective was to determine if under grazing exists an interaction between the degree of defoliation and potassium fertilization on the recovery and production of S. capitata seedlings. The pasture used had been under grazing for 5 years and had received at establishment a fertilization consisting of 20-100 P-Ca as Calfos and 20-10-20 kg K-Mg-S ha^{-1} as Sulpomag, in addition to a biannual maintenance fertilization of 10-50 kg P-Ca ha^{-1} as Calfos.

For the trial, 10, 40, and 80 kg K ha^{-1} were applied to paddocks of three different sizes (500, 800, and 1200 m^2), thus creating 3 grazing pressures (high, intermediate, and low) when 2 calves (± 200 kg live weight/animal) were introduced into each paddock in a rotational system which consisted of 7 days of grazing and 14 days of rest, with 2 replications.

With the grazing pressure treatments, marked differences in the availability of A. gayanus were generated to be able to determine the possible effects

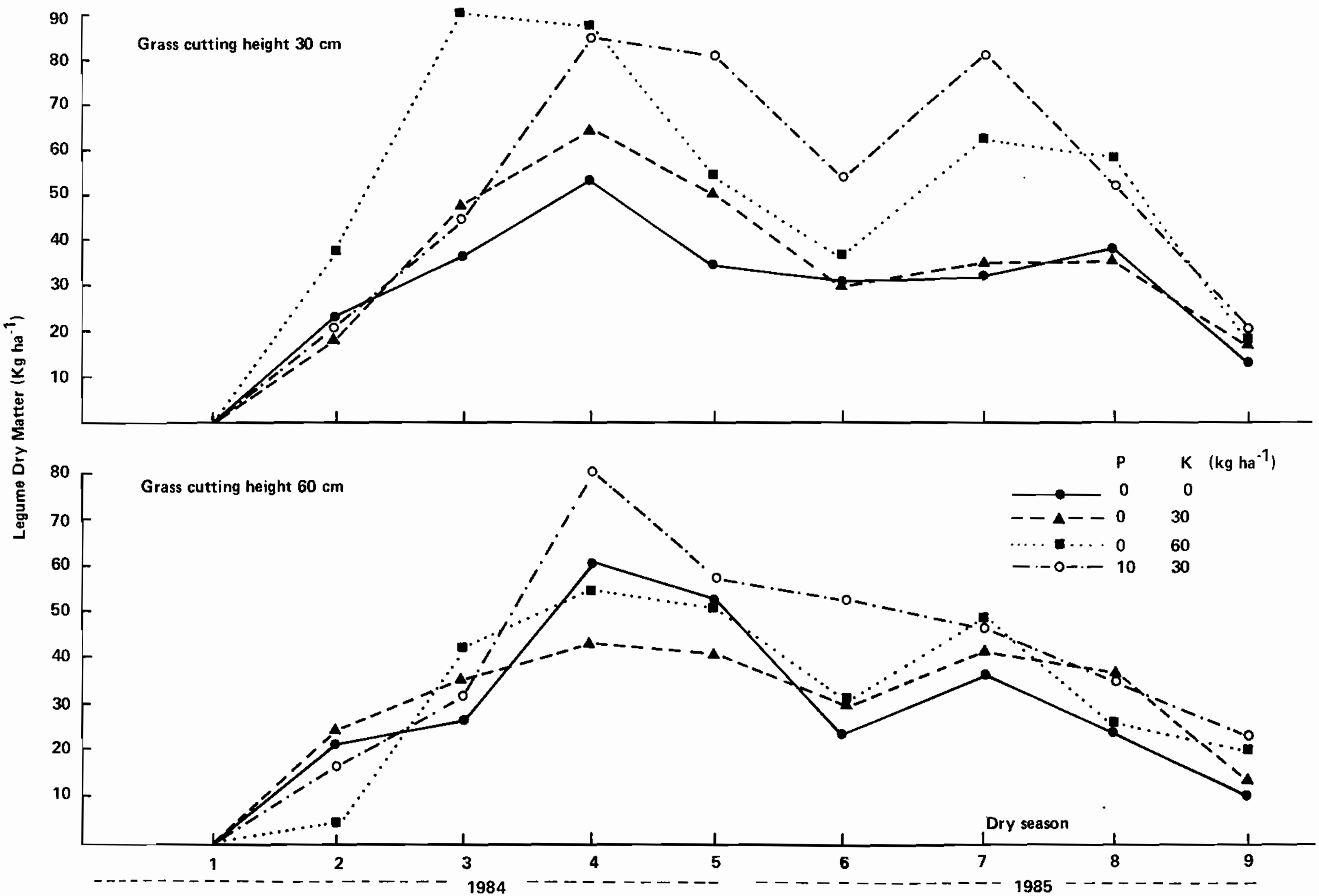


Figure 10. Effect of the cutting height of *A. gayanus* and several K fertilization rates on the recovery of *S. capitata*. Cutting frequency 28 days.

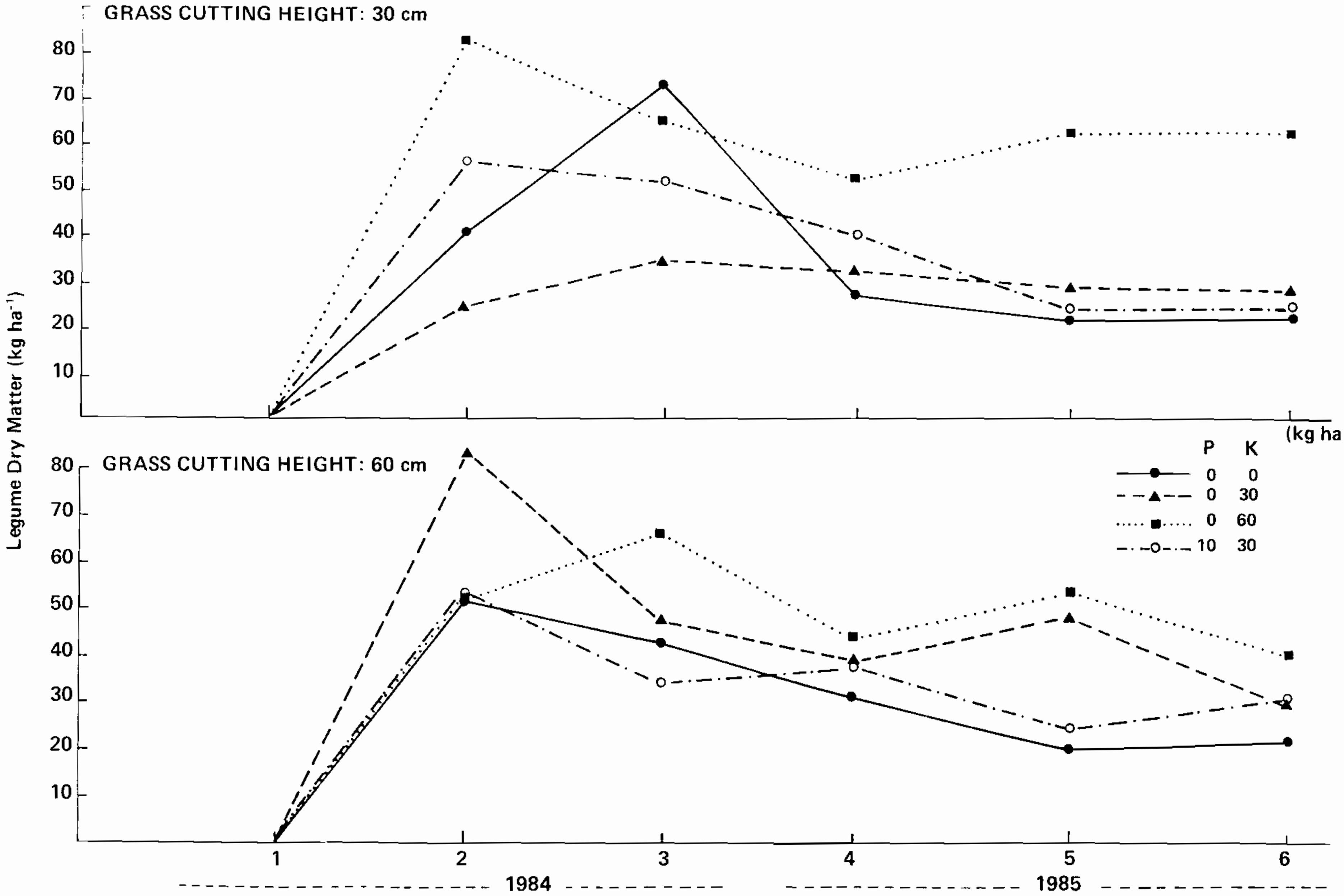


Figure 11. Effect of the cutting height of *A. gayanus* (30 and 60 cm) and several K rates on the recovery up *S. capitata*. Cutting frequency 42 days.

of competition on the recovery of S. capitata. The grazing pressure had a significant effect ($P < 0.05$) on the availability of the legume but in different ways (Figure 12). With low grazing pressure, equivalent to greater height and availability of A. gayanus, the legume disappeared over time. The K fertilization did not have a significant effect except during the first grazing cycle. On the other hand, the high grazing pressure, equivalent to lower height and availability of A. gayanus, favored the recovery and development of S. capitata over time; likewise, no effects of potassium fertilization were observed. Finally, the intermediate grazing pressure tended to maintain an almost constant availability of the legume, regardless of the K rate, although initially there was a considerable reduction in legume content.

The results obtained in relation to potassium fertilization have two possible explanations. The first is that grazing under different pressures inhibits the effects of fertilization, in contrast to that observed with the defoliation of A. gayanus by cutting. This suggests that the effects of fertilization in pastures under grazing should necessarily be observed both with and without the animal presence. The other explanation is that the 10 kg K ha^{-1} rate is sufficient to recover S. capitata seedlings, confirming early findings in cutting experiments (Annual Report 1984).

3.2 Evaluation of nutrient gain and loss in A. gayanus/S. capitata pasture--the case of potassium

The principles and methodologies of the evaluation of nutrient recycling in tropical pastures were indicated in the Annual Report of 1984.

Nutrient recycling was assessed in an 7 year old pasture of A. gayanus/S. capitata. It was used three grazing pressures and four fertilization treatments. In this report only 3 fertilization treatments with K (10, 40, and 80 kg ha^{-1}) were considered. The grazing system consisted of 7 days of occupation and 35 days of rest, using in each cycle the same 2 calves in each treatment of the 2 replicates.

The parameters evaluated in each grazing cycle were: (1) the forage on offer before and after grazing, obtaining utilization by difference; (2) accumulation of plant residues before and after each grazing cycle, obtaining the production of plant residues by difference; (3) effective amount of K in the forage used and in the plant residues of each grazing cycle; and (4) nutrient concentrations in the soil solution at various soil depths per grazing cycle. All of these parameters were used to obtain the relationships among themselves according to the procedure indicated by Karlovsky (1982)*.

Figure 13 shows: (A) the relationship between K inputs entry into the system (plant residues and fertilizers) and the relative use of the forage; (B) the relationship between the absolute and relative use of the forage; and (C) the relationship between the absolute use of forage and K extraction by the forage for each grazing pressure. The set of these relationships is relative to a net nutritional balance.

In spite of observing similar trends in the relationships between parameters, each grazing pressure allowed a range of effective K utilization and K return to the system. This type of balance between parameters with logarithmic transformation is important since it allows the net

* Karlovsky, J. 1982. The balance sheet approach to determine maintenance requirements. Fertilizer Research 3: 111-125.

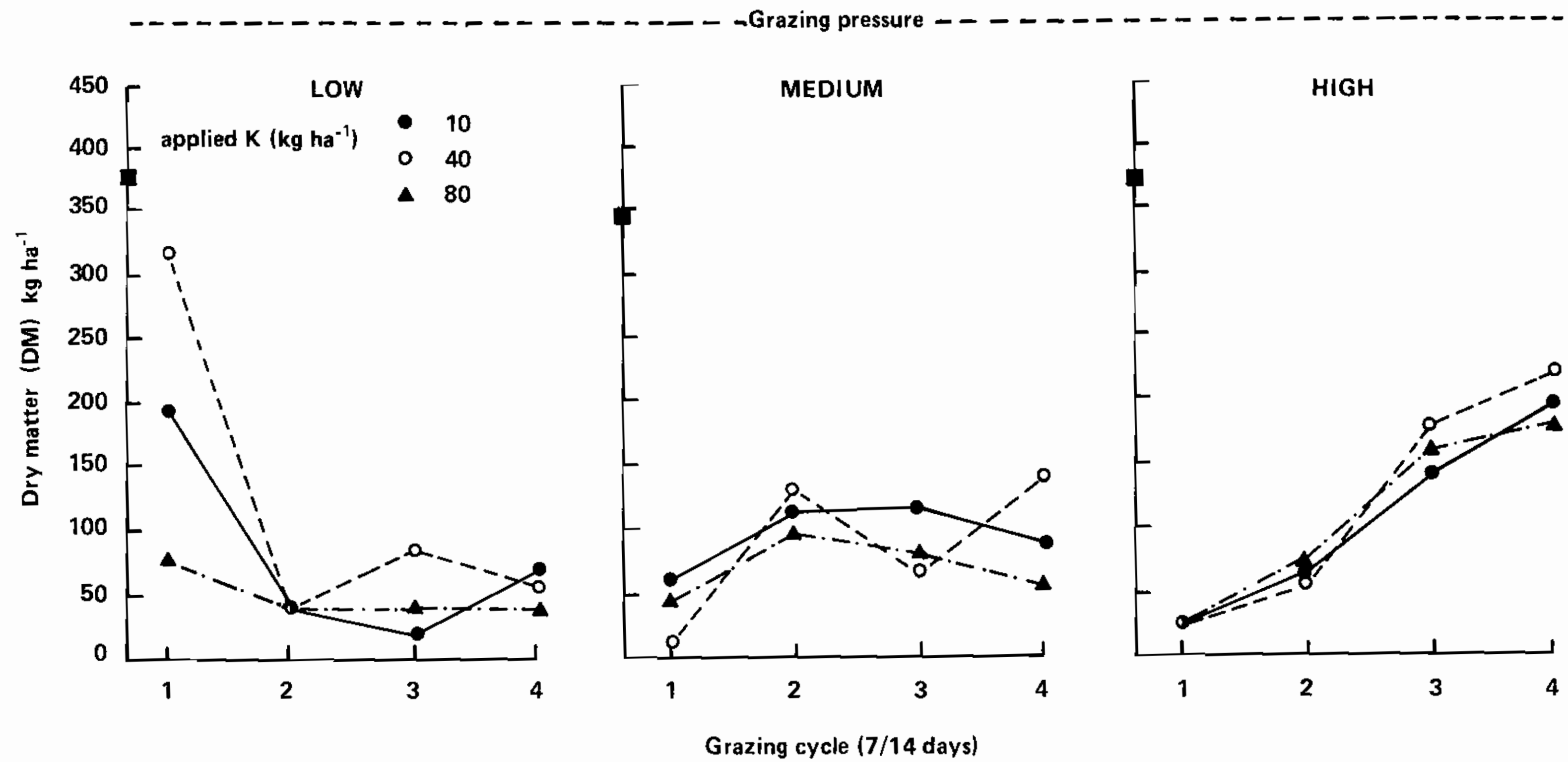


Figure 12. Effect of grazing pressure and K fertilization on the Dry Matter (DM) production of *S. capitata* associated with *A. gayanu* over time (grazing cycle).

Grazing pressure: Low = 1.4 AU ha^{-1}, Medium = 2.1 AU ha^{-1}, High = 3.3 AU ha^{-1}.

■ Initial available legume

Grazing pressure x Cycle ($P < 0.05$)
K Fertilization (NS)

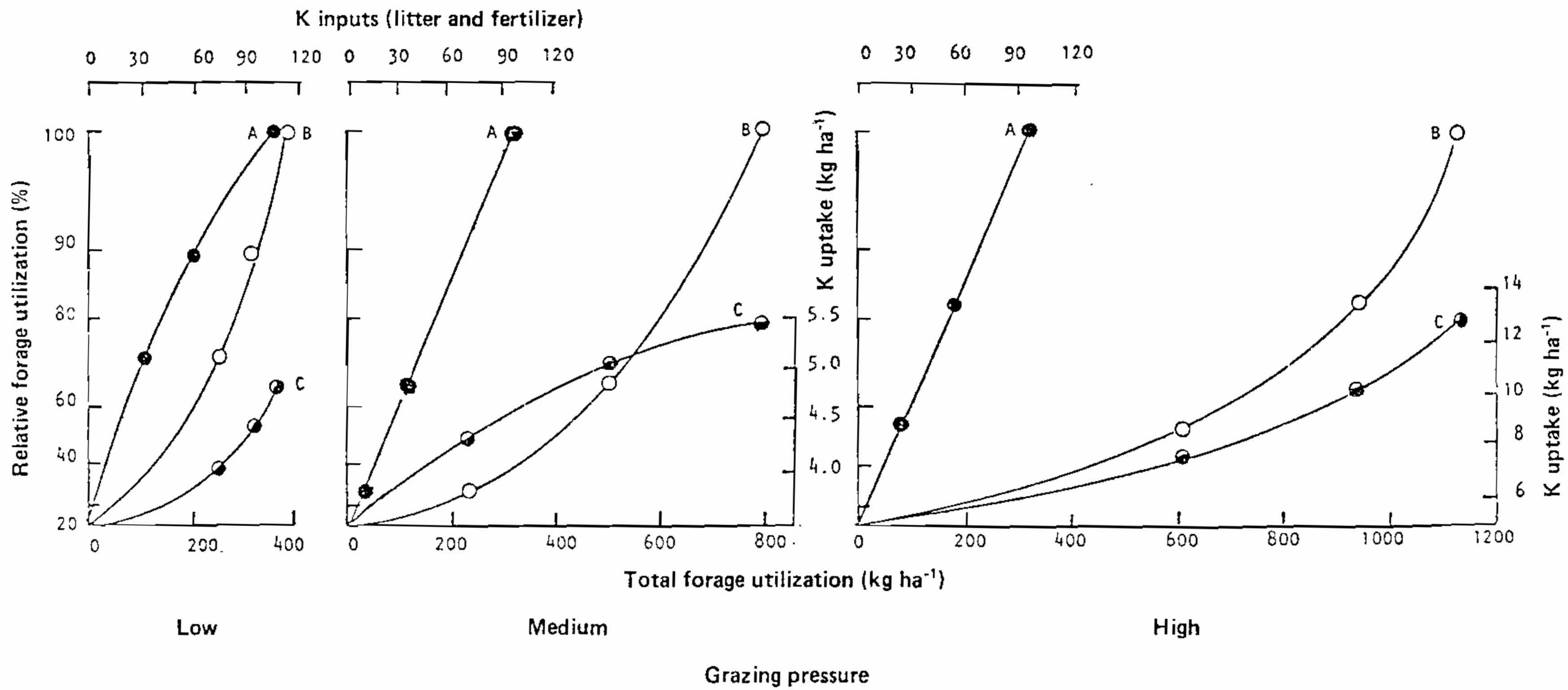


Figure 13. Relationships between (A) K inputs (litter and fertilizers) and relative forage utilization.
(B) Total and relative forage utilization.
(C) Total forage utilization and K uptake.

nutrient balance at each level of biomass production to be estimated. Therefore, based on these relationships the K nutritional balance was made for each different forage utilization under each grazing pressure (Table 4). The results show that the loss of K increased with grazing pressure, indicating that in the short term pastures under high grazing pressure would require a maintenance fertilization with potassium and/or change in pasture management. The main cause was the considerable reduction in plant residues due to a high forage utilization, directly related to a high grazing pressure.

The opposite situation occurred with the low grazing pressure: K loss was lower and sufficiently compensated with its return in plant residues. This indicates that there is no need to apply K for maintenance.

Based on these preliminary observations, the requirement of maintenance fertilization with K appears to be based on the percentages of return and utilization of this element in the pasture; if these are equal or less than the amount returned, K should be applied at a rate equivalent to the amount lost.

Dynamics of nutrients in soil solution

In order to observe the changes in nutrient concentrations in soil solution, ceramic capsules were placed at 5 different soil depths (15, 30, 60, 90, and 150 cm) and samples of the soil solution were obtained after each grazing cycle at three grazing pressures and in the 10 and 40 kg K ha^{-1} treatments, respectively. The native savanna was sampled for comparison. The results obtained belong to the rainy season.

In Figure 14 the changes that occurred in the N, P, and K concentrations in the soil solution in the three test situations (native savanna, low and Similar values in depth were found and greater values when compared with those of the native savanna. This could be associated with the higher concentration of N in the plant residues when rates of 40 kg K ha^{-1} were applied as compared to 10 kg K ha^{-1}.

It is interesting to observe the considerable increase of P in the soil solution in depth under both grazing pressures. This is probably due to the fact that *A. gayanus* has a fibrous and extensive root system penetrates to a great depth in the soil profile. Consequently, the increase of P in the soil solution appears to result from the decomposition of *Andropogon* roots and not from the movement of P in depth. Regarding K, there does not appear to be a high lixiviation since the pattern of movement is very similar to that of the native savanna and on the contrary, would be interpreted as an improved K content in this soil profile.

The dynamics of change as to Ca and Mg seem to be similar to that of K (Figure 15). Finally, in relation to S (Figure 16), the changes that are observed are quite similar to N. Lixiviation is also present in the rate of 40 kg K ha^{-1} under both grazing pressures. Similar evaluations are being carried out on the same pasture in order to have more detailed information on the dynamics of nutrients in soil solution (depth) and to be able to define more accurately which nutrients are lost by lixiviation.

4. RESEARCH ON FERTILIZATION ADJUSTMENT FOR PASTURE ESTABLISHMENT TO SUPPORT RIEPT

Among the support activities of the Tropical Pastures International Evaluation Network (RIEPT), the Pastures Program decided to develop a research methodology in order to adjust fertilization for pasture establishment.

Table 4. Potassium input, output, utilization and return in an *A. gayanus* and *S. capitata* pasture under 3 grazing pressures and 3 K rates.

Forage Utilization Relative	Forage Utilization Absolute	Grazing pressure	K Input (Litter + Fert.)	K Output (Extracting)	K Utilization (out/input (x 100)	Relative K return in the litter at each K rate (kg ha^{-1}) 10	40	80
(%)	(kg ha^{-1})		(kg K ha^{-1})	(kg K ha^{-1})	(%)	%		
	180	Low	18	3.2	18	85	84	89
50	240	Medium	19	3.8	20	68	76	68
	560	High	24	7.2	30	52	45	52
	250	Low	30	4.0	13	82	80	86
70	510	Medium	32	4.8	15	60	70	60
	800	High	52	10.0	19	33	23	33
	280	Low	42	4.3	10	80	78	85
80	600	Medium	46	4.8	15	60	70	60
	915	High	52	10.0	19	33	23	33
	320	Low	66	4.4	7	80	78	85
90	700	Medium	64	5.4	8	55	66	55
	1020	High	66	11.0	17	26	15	26

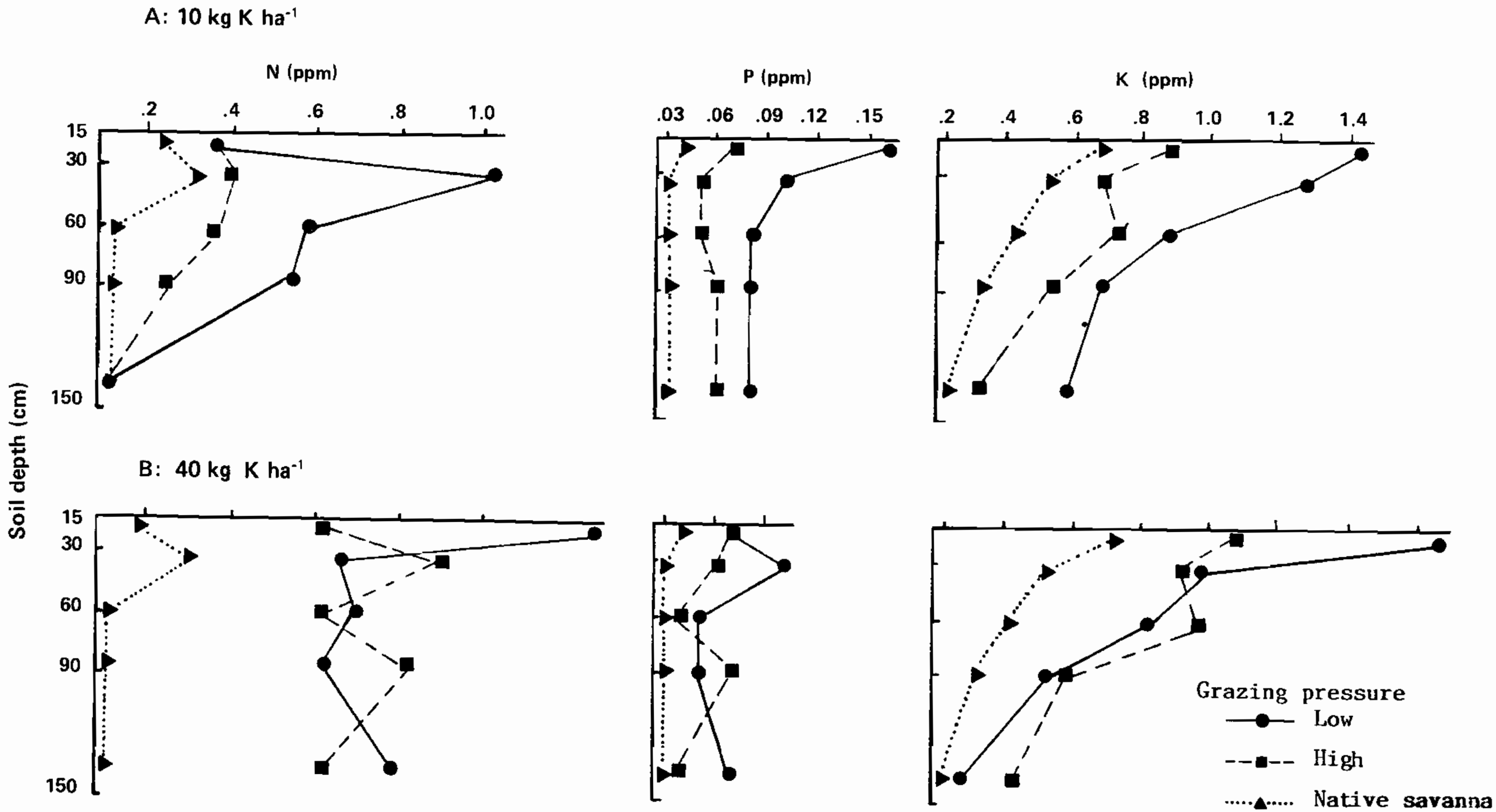


Figure 14. N, P, K contents of the soil solution as affected by grazing pressure and 2 K-maintenance rates (A and B).

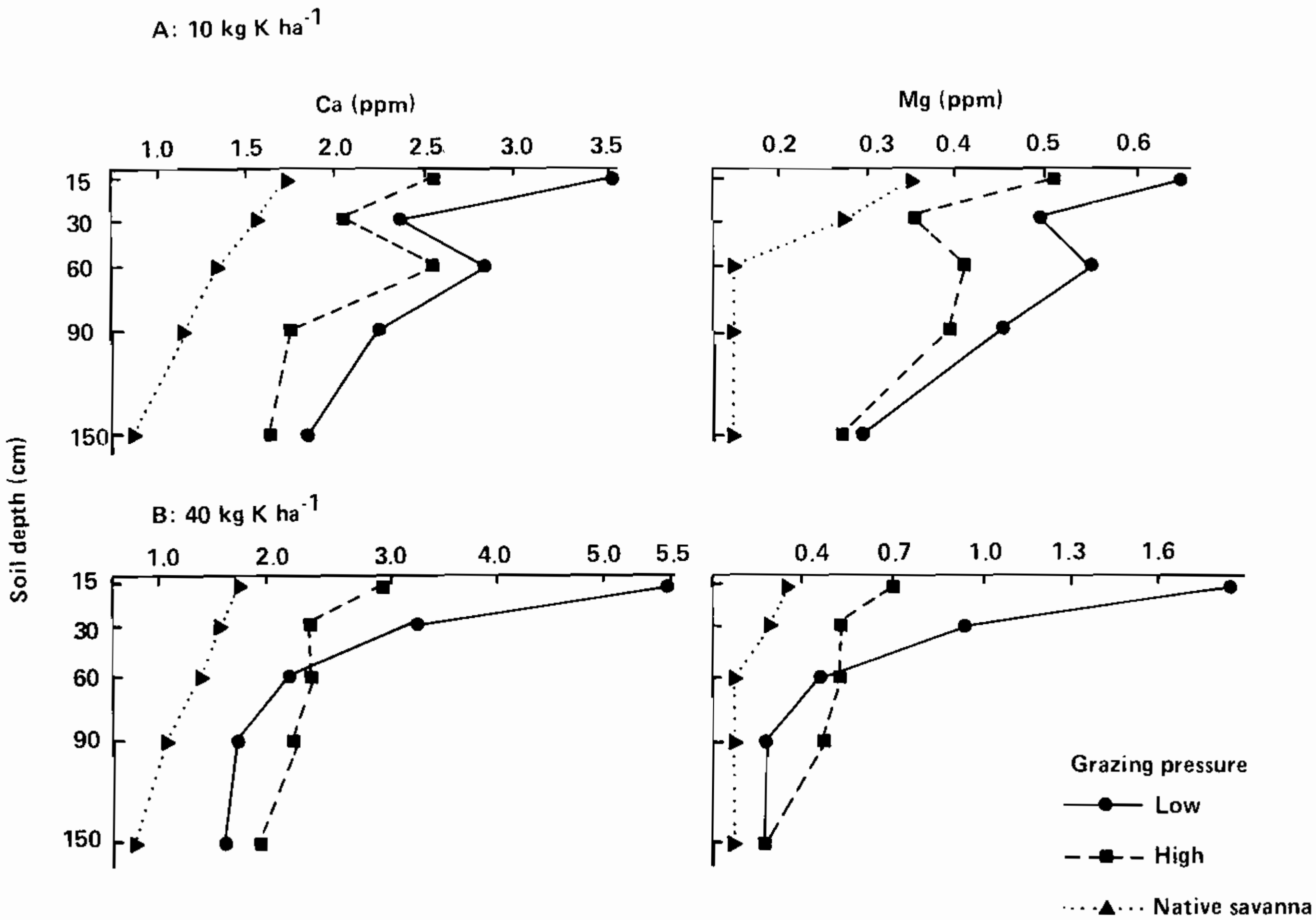


Figure 15. Ca and Mg contents of the soil solution as affected by grazing pressure and 2 K-maintenance rates (A and B).

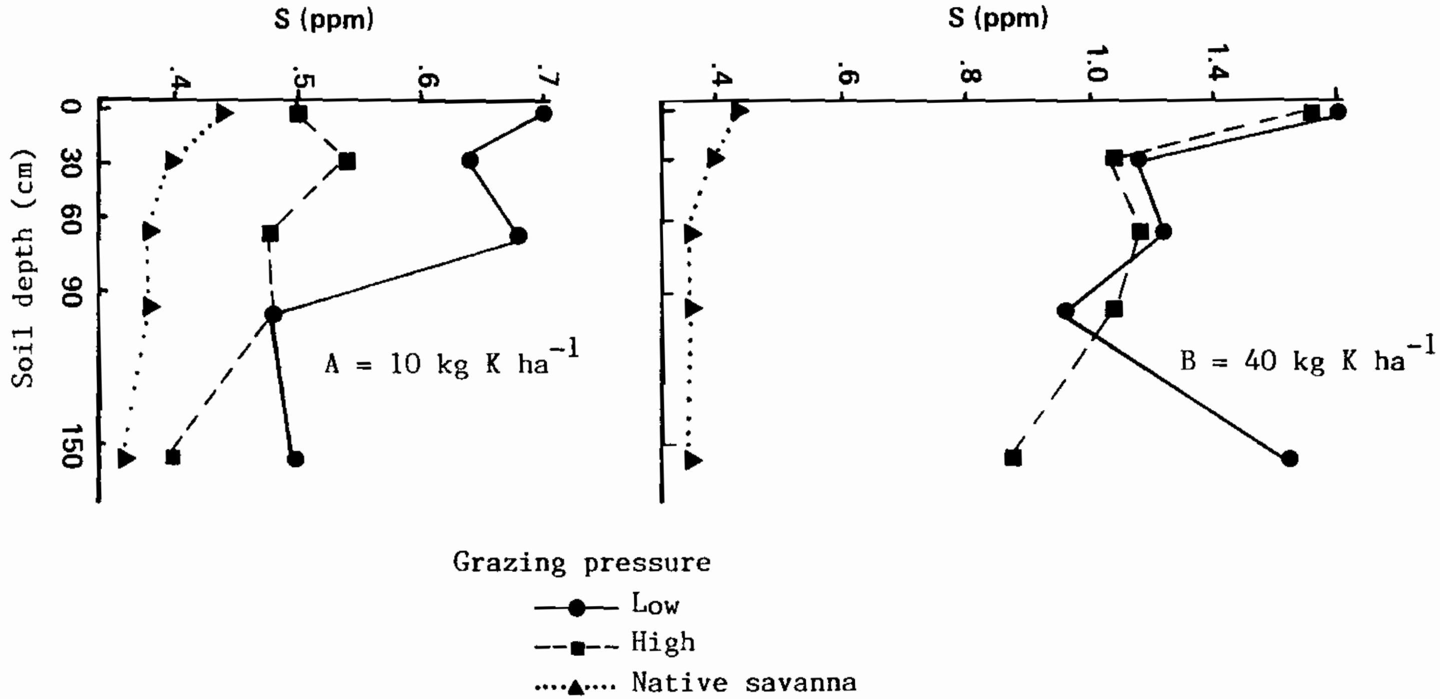


Figure 16. S content of the soil solution as affected by grazing pressure and 2 K maintenance rates (A and B).

high grazing pressure) were observed as a function of soil depth and potassium fertilization. With the 10 kg K ha^{-1} rate the highest concentrations of N, P, and K were observed in the low grazing pressure than in the high pressure; this is probably associated with the greater amount of plant residues under low grazing pressure conditions. However, with a higher K rate (40 kg ha^{-1}) no such difference existed; on the contrary, there was mainly lixiviation of N.

In spite of the dominant characteristics of acid soils - low pH, high Al saturation, low content of P and bases (Ca, K and Mg), there are physical and chemical differences that influence the production and performance of edaphically adapted plants. With this in mind, and recognizing that the adaptation trials (ERA and ERB) are only carried out on some representative soils, the need to evaluate the fertilizer recommendations on different soils becomes important to identify the requirements being identified for a successful establishment and the achievement of pasture persistence.

The basic scheme for these trials is given in Figure 17, indicating the origin of the germplasm to be evaluated, the soils to be used, and fertilizer management.

At the regional level, a preliminary survey will be conducted on the existing information that hopefully will cover (a) results of fertilization trials with grasses and legumes; (b) physical and chemical soil characterization; (c) data on regional tissue analysis of forage plants; (d) maps, description, and classification of soils; and finally (e) climatic conditions of the region. This information will be used as the basis for the design of fertilizer adjustment trials.

To facilitate the interpretation of the chemical characteristics obtained for the acid soils of the RIEPT for pasture production, some edaphic parameters have been determined that can identify the existence of nutritional problems. Thus, through numerous trials the minimum or maximum concentrations of elements (Table 5) that can imply deficiency or toxicity conditions have been determined. Using these data as guidelines, it is possible to determine the chemical limitations of the soil and their possible solution, as well as to determine the type of forage species that can be established.

Based on this information, several fertilizer adjustment trials are being carried out, identifying the 2 or 3 most limiting elements. To define the treatments to be used, simple experimental design with few treatments are being utilized (San Cristobal, 12 treatments; modified double square, 13 treatments). These designs include a wide range of plant response thus allowing fertilizer adjustment to be performed.

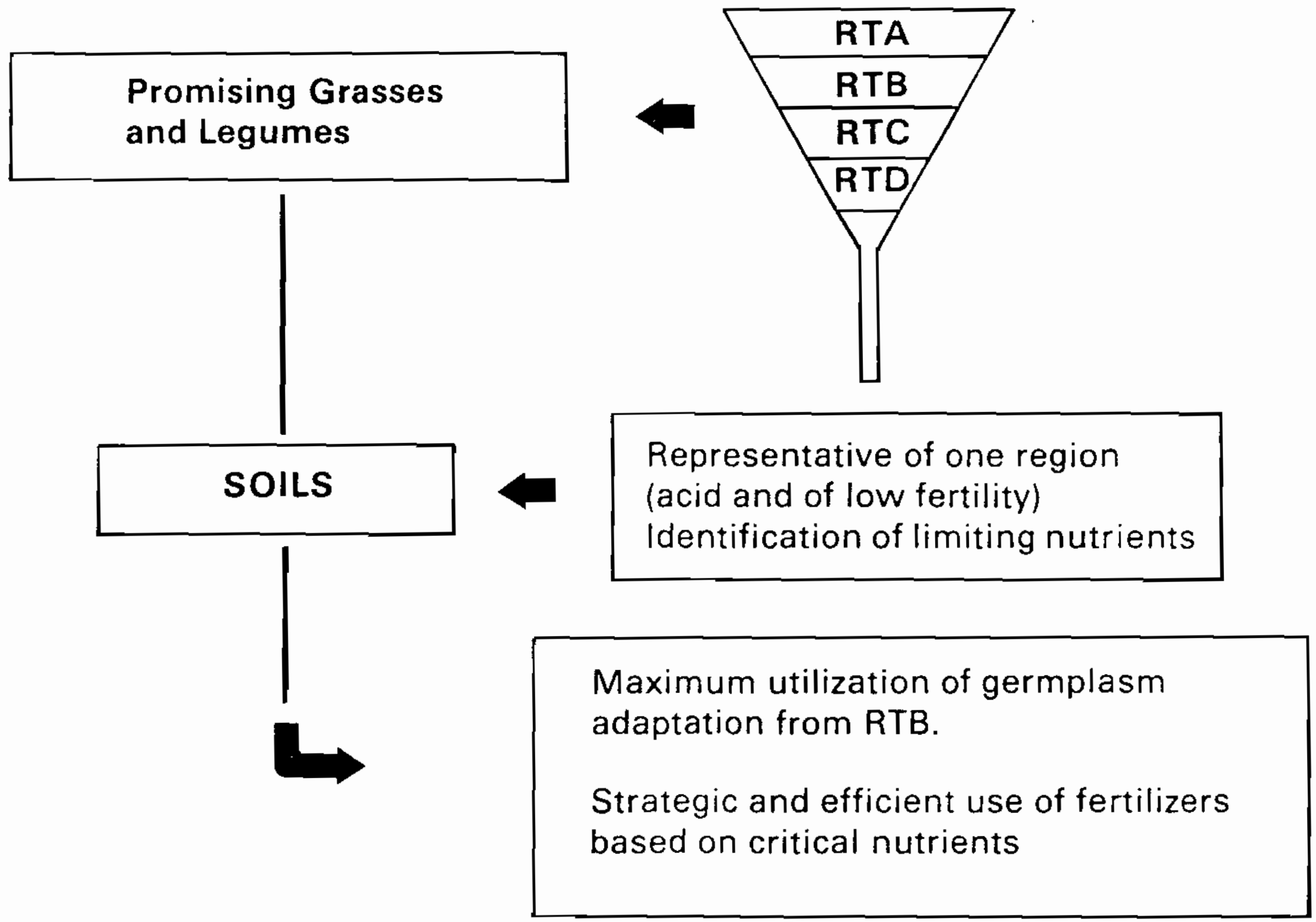


Figure 17. Basic scheme for fertility adjustment trials supporting RIEPT.

Table 5. Chemical characteristics of different level of acid soils and natural fertility for the establishment of tropical pastures

Soil parameter	Level of acidity (A) and fertility (F)						
	(A) Very acid (F) Low		Acid Medium	Sligh acid High	Neutral Very High	
pH	<	4,5	4,5-5,5	5,5-6,5	>	6,5
P (ppm)[1]	<	2	2-5	5-10	>	10
K (meq/100 g)[1]	<	0,05	0,05-0,10	0,10-0,15	>	0,15
Mg (meq/100 g)[2]	<	0,08	0,08-0,12	0,12-0,20	>	0,20
Al saturation (%)[2]	>	80	60-80	30-60	<	30
Ca saturation (%)[2]	<	20	20-40	40-60	>	60
Mg saturation (%)[2]	<	5	5-15	15-30	>	30
S (ppm)	<	10	10-15	15-20	>	20
Zn (ppm)[3]	<	0,5	0,5-1,0	1,0-1,5	>	1,5
Cu (ppm)[3]	<	0,5	0,5-1,0	1-3	>	3
B (ppm)[3]	<	0,3	0,3-0,5	0,5-1	>	1
Mn (ppm)[3])	<	1	1-5	5-10		10
Mn (ppm)[4]	>	80	50-80	20-50	<	20

1/ Bray-II extractant solution.

2/ Extractant with KCl 1N and individually calculated on the percent basis related to Al, Ca and Mg.

3/ Doubled acid xtractant 1:4.

4/ KCl 1N extractant. Mn contents are related to the element toxicity degree and not to the nutritional requirement.

Pasture Development (Carimagua)

INTRODUCTION

In the Pasture Development section research is concentrated on: 1) Establishment, and 2) Maintenance of pastures once established. The establishment phase is divided into two stages: Tillage and planting.

In practice, it is often difficult to separate these two components because of their interaction and strong interdependence. The selection of a planting system frequently defines the tillage system. For that reason, there is a certain amount of overlap in the treatment of these two areas. The maintenance of pastures consists of two major componentes: Pasture managegement and maintenance fertilization.

ESTABLISHMENT

Tillage and control of competition

Four basic types of tillage have been defined during recent years in Carimagua: (1) Traditional tillage based on the use of a disk plow and/or off-set- disk; (2) reduced tillage based on the use of a chisel plow and an off-set- disk; (3) minimum tillage consisting of one pass with a chisel plow equipped with either tines or stubble mulch sweeps; and (4) finally, zero tillage with and without chemical control of vegetation.

The effect of tillage on the establishment of four species in a sandy soil

Four types of tillage were compared with and without chemical control of native vegetation (with the exception of the traditional tillage treatment which left no vegetation to be controlled). In Figure 1 the effects of the different treatments and species planted on the native species are shown for the first harvest. With one exception, there was a consistent effect of the degree of tillage and of herbicide use in the control of native species. The lack of control in the case of *Pueraria phaseoloides* could be due to the very limited initial vigor of that legume, due in part to the late planting (September, 1984). In Figure 2 the effects of treatments on the yield of the four species is shown for the same harvest. The performance of *Stylosanthes macrocephala* at all levels of tillage and chemical control was outstanding. At the other extreme, *P. phaseoloides* performed very poorly with zero or reduced tillage and without chemical control. The two grasses performed very poorly in the zero tillage treatment without herbicide. With the application of herbicide or minimum tillage, both grasses developed well during the establishment phase.

In Figure 3, regression lines and correlations between production of planted species and production of native species are shown. Correlations are highly significant for the grasses and *S. macrocephala*; less so for *P. phaseoloides*. Grasses are much more affected by competition from the savanna species and/or nitrogen deficiency than are the legumes as

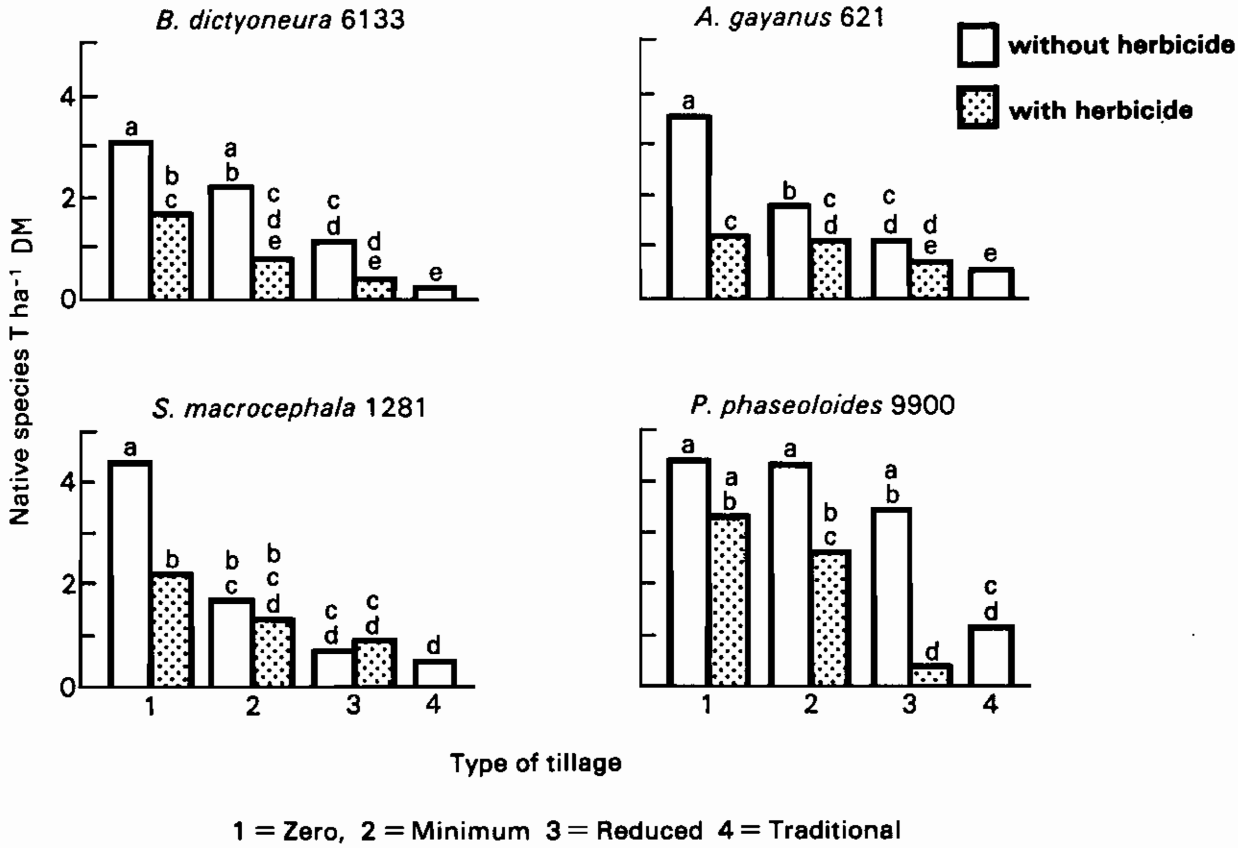


Figure 1. Effect of planted species, tillage and herbicide on production of native species, first harvest, sandy soil, Carimagua.

shown by the slopes of the regression lines.

The establishment of forage species with zero tillage or minimum tillage was much more successful in this sandy soil than in the medium- and fine-textured soils in which previous observations were made. This is probably due to the weaker structure of the sandy soil which facilitates root penetration of the surface planted species; and to reduced competition, given the nature of the native vegetation that is found in sandier savannas. The establishment of S. macrocephala was excep- tionally good even without tillage and without herbicide. This species appears to be promising as a "savanna legume", at least from the standpoint of ease of establishment.

The danger of over-preparing the soil as reflected in run-off and erosion observed in this trial is very great in soils of this type, even on slopes which are estimated to be in the range of 2 to 3% for the experimental site. What is defined as reduced tillage in a clay loam soil turns out to be a very adequate, "complete" tillage in the sandy soil and traditional tillage for the clay loam soil is obviously excessive in the sandy soil. Minimum tillage for the clay loam soil creates conditions comparable to reduced tillage when applied to the sandy soil. In summary, tillage types are relative and should be defined in relation to the type of soil on which they are used. Based on this experiment, it would seem that direct planting with minimum tillage would be feasible and recommendable for many sandy soils in savanna regions, resulting in less cost and reduced risk of run off and erosion during the establishment phase.

Progress has been made in the use of minimum tillage and zero tillage systems; both themes will be treated in the section on planting systems.

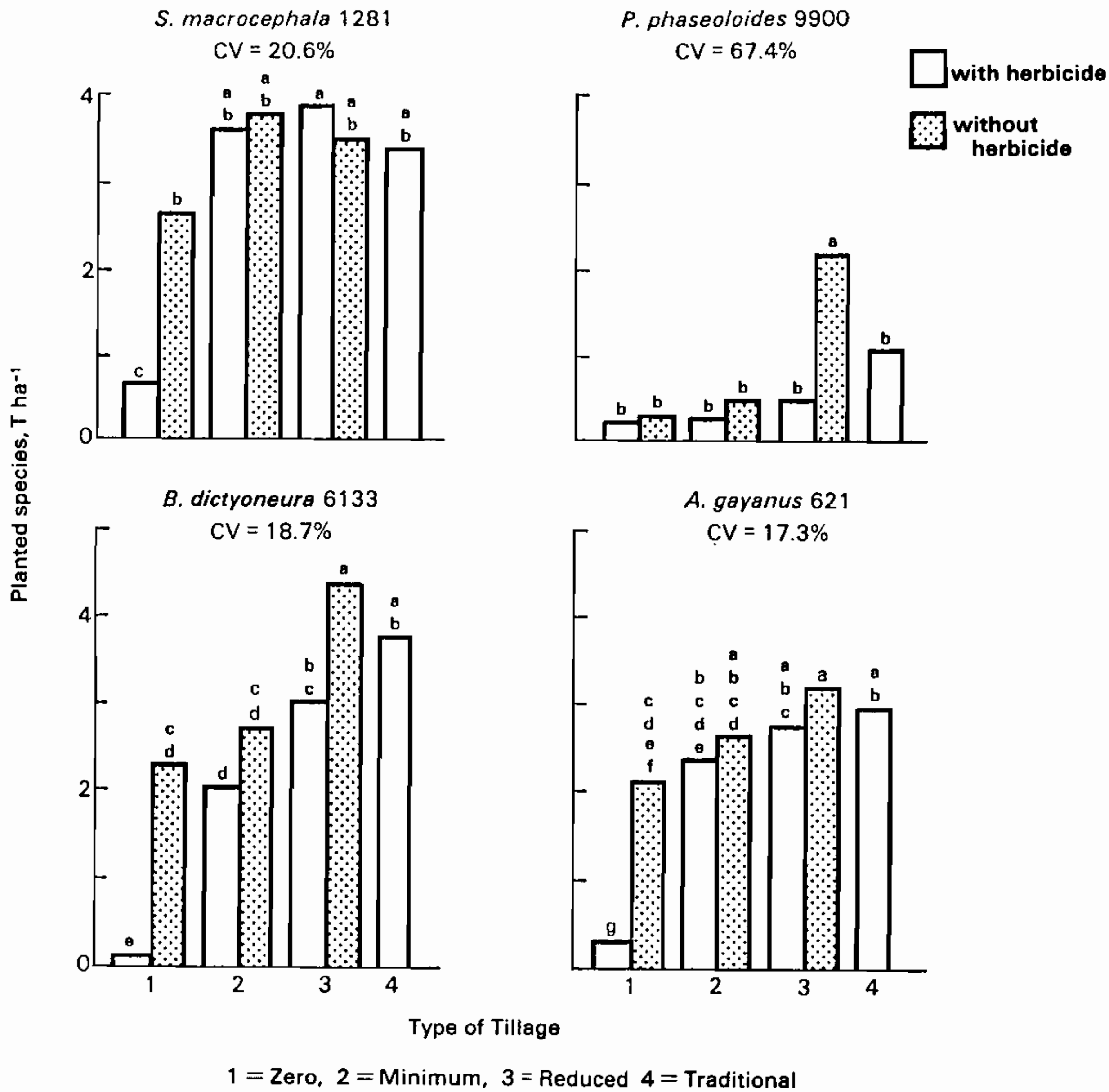


Figure 2. Effect of tillage and herbicide on planted species yield, first harvest, sandy soil, Carimagua.

Planting

A number of planting systems have been used in Carimagua. At the outset, a traditional system was utilized in which both seed and fertilizer were broadcast on land prepared in a traditional manner. After conducting experiments with row seeding and band application of fertilizer, this system was adopted for most of the plantings carried out at the Experiment Station.

Since 1976, research has been concentrated on non-traditional systems of tillage and planting due to the high cost of establishment of pastures using traditional systems and the risk of erosion during the establishment phase, especially on the more sloping and/or sandy soils.

A number of low density planting systems have been studied, which depend on the original population to cover the balance of the area via seed and/or stolons. Results have been presented in numerous Annual Reports.

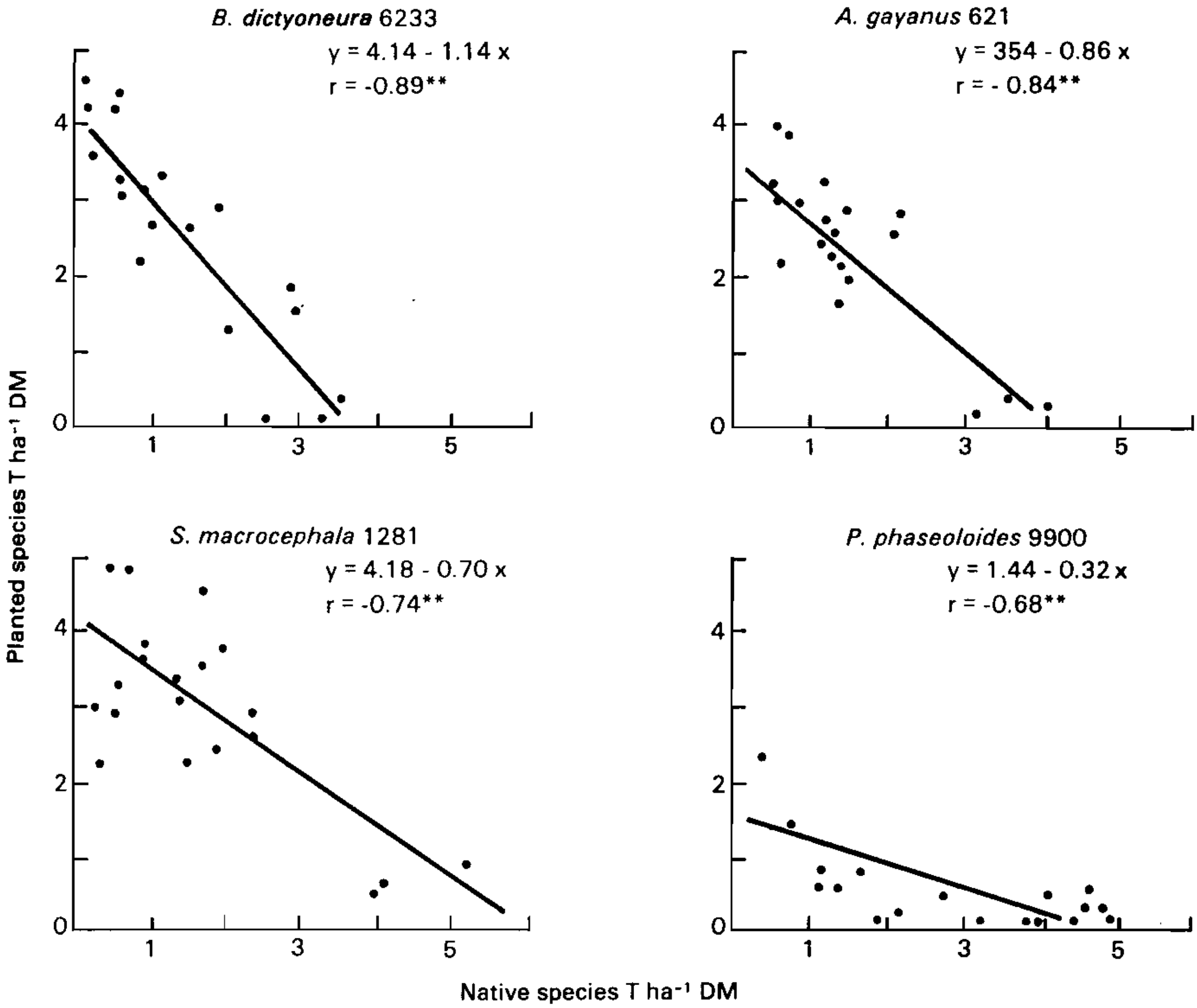


Figure 3. Planted species yield vs. native species, first harvest, sandy soil, Carimagua.

Planting patterns

In an experiment established in 1982 and described in previous Annual Reports, the populations of original plants of the five components of S. capitata cv. CAPICA have been followed in detail. In Figure 4 it can be seen that by July 1985, the original population had disappeared. However, Tables 1 and 2 show that a good seed reserve is still present in the soil, especially between rows of legume and even between legumes and grasses. Seed reserves in the space between rows of grass and legume have reduced notably over the past year. However, in the legume/legume site and the grass/grass site, seed reserves were maintained. Table 2 also shows a reduction between years two and three in the seed reserves for all of the three planting patterns and especially for the 1:1 pattern (1 row of legume, 1

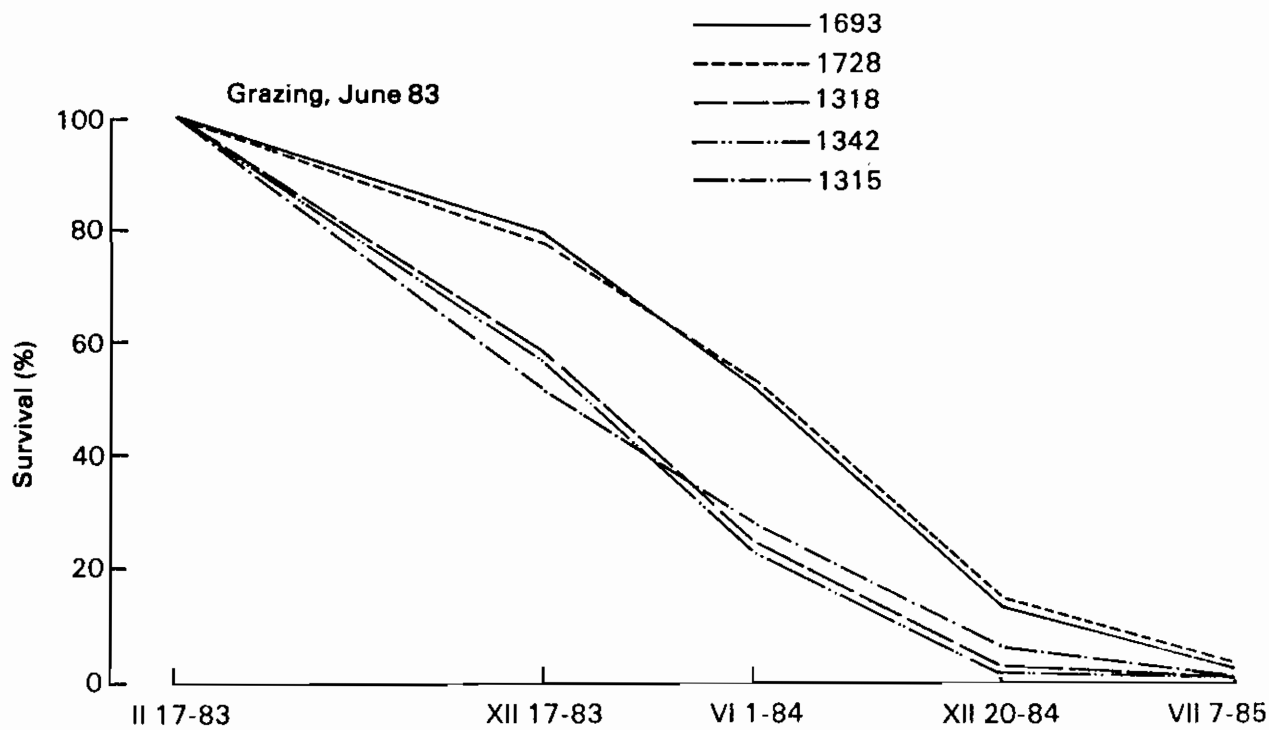


Figure 4. Survival of marked plants of S. capitata in association with A. gayanus. Data correspond to five ecotypes; components of the synthetic variety "Capica".

Table 1. Collection sites and seed quantities in the soil (0-5 cm) of S. capitata associated with A. gayanus, two and three years after establishment.

Site*	Seed quality ($kg\ ha^{-1}$)	
	Year 2	Year 3
Legume-legume	2,508a	2,239a
Legume-grass	1,739b	0,663b
Crass -grass	0,157c	0,131c

* Equivalent to area between rows corresponding to each species at planting time (July 1982)

a,b,c means in the same column with different letters are different ($P < 0.05$).

Table 2. Seed quantity in the soil (0-5 cm) of S. capitata associated with A. gayanus in different planting patterns, two and three years after establishment.

Planting pattern (rows)	Seed quantity ($kg\ ha^{-1}$)	
	Year 2	Year 3
1 legumes x 1 grass	2,143a	0,728b
2 legumes x 2 grass	1,365a	0,985a
3 legumes x 3 grass	1,437a	1,016a

* Planting date: July 14, 1982

a,b means in the same column with different letters are different ($P < 0.05$).

row of grass). It is possible that this is due to greater competition between grass and legume in this pattern than for others. Nonetheless, the reserve of 3/4 to 1 kg of seeds/ha of S. capitata should be sufficient for the stand maintenance if conditions favorable for the development of seedlings are achieved through grazing management and fertilization.

Savanna replacement

This experiment was established in 1980. It is based on a strategy of increasing the area fertilized by 20% each year. For background, see Annual Reports from 1981 through 1984. In Table 3, stocking rates and liveweight gains/animal/day are shown in a summarized form for both dry and wet seasons during 5 years. Both associations with B. humidicola have covered the entire area with the exception of 5 m strips planted and 20 m strips of native savanna. During the first 3 years, animal gains in these two associations were satisfactory, but in the last 2 years they have fallen sharply. This change could be related to climatic factors but it is probable that it is also related to the maturity of the grass in the case of associations of B. humidicola/P. phaseoloides and to reduced participation of the legume, especially during the last 2 years. The legume suffered from an unusually long dry season in 1984-85 and from increased competition from the grass with which it is basically incompatible in the Carimagua ecosystem.

The results of this experiment are very promising and confirm the validity of the strategy followed, but at the same time, emphasize the need for different germplasm options. What is needed is a grass equally aggressive as B. humidicola but of better quality and/or a legume which is more aggressive in order to be compatible

Table 3. Effect of association and year in weight gain of steers grazing in the savanna replacement trial. Carimagua, 1981-1985.

Treatment	Year	Stocking rate Dry/wet (a/ha)	Season Dry 150 days (g/a/day)	Season Wet 210 days (g/a/day)
	1981	-/1.0	-	384
B. humidicola	1982	1.5/1.5	87	474
+	1983	1.0/1.0	298	510
D. ovalifolium	1984	1.0/1.0	-29	340
	1985	2.0/2.0	112	276**
	1981	-/1.0	-	481
B. humidicola	1982	1.5/1.5	274	518
+	1983	1.0/2.0	443	455
P. phaseoloides	1984	2.0/2.0	129	222
	1985	2.5/3.5	13	211**
Complex*	1985	1.0/1.0	-50	288**

* Includes native savanna, D. ovalifolium and P. phaseoloides.

** 120 days.

with B. humidicola, thus bringing the quality of the forage up to an acceptable level.

Direct planting (commercial scale)

In order to test the strategy followed in the savanna replacement trial on a commercial scale, a machine was designed which permits the direct planting of grasses and legumes in strips in a single pass. The machine was described in the 1984 Annual Report. Initial establishment was successful as can be seen from seedling density two months after planting (Table 4). Nontheless, the development of the pasture during the last year has not been satisfactory. The grass covered all of the strip area to 2.4 m wide via stolons. However, these stolons are rather poorly anchored and somewhat weak, thus when subjected to grazing, a great percentage of the potential plants are lost to the grazing animals. The density of grass has increased, but only slightly during the year following establishment. In the case of P. phaseoloides, plant density has actually declined to only 1/5 of the initial density. This loss of population is due in part to insect problems as well as to the exceptionally severe and long dry season of 1984-85.

Table 4. Plant density in strips 2 and 14 months after a direct planting in a commercial lot. Tomo, Carimagua 1984-1985.

Species		Density (plants/m^2)*	
		2 months	14 months
P. phaseoloides	9900	7.9	1.7
B. dictyoneura	6133	3.2	5.3

* Means of 30 observations.

The strategy of savanna replacement appears to be valid, but the germplasm presently available is not entirely adequate. It would appear that a more rustic legume which is tolerant to long dry seasons along with a more aggressive grass are required.

Supplementation of savanna with legumes

This experiment has been described in Annual Reports for 1983-84. During the dry season of 1985, almost all of the P. phaseoloides population was lost, however, S. capitata populations were maintained. Nontheless, the grazing pressure on the legume appears to be too high and dry matter production was very low in 1985. Table 5

Table 5. Total dry matter availability during the wet season of 1985 in native savanna supplementation trial with planted legume strips (S. capitata).*

Planted and fertilized legume area por animal (m^2)	Stocking rate (an ha^{-1})			
	0.33	0.67	1.00	1.33
	DM kg ha^{-1}			
0	2082	-	-	-
1500	2480	2118	2033	1598
2250	-	2543	2068	-

* Means of 2 dates (June-August) using the Botanal-2 system.

shows the effect of the proportion of legume planted and fertilized/animal and stocking rate on total dry matter availability in the pastures, averaging June and August samplings.

Table 6 shows the effect of the same factors on the availability of legume, which varied from 19 to 51 kg dry matter/hectare. It appears that the legume is too palatable thus is consumed by the animal too aggressively and is unable to maintain a satisfactory growth rate in association with native savanna under the grazing pressures imposed.

Again, it would appear that germplasm is the limiting factor and that the species chosen to initiate this trial are not adequate under the climatic and edaphic conditions which prevail. On the basis of the experience gained in this trial, it is suggested that a successful savanna legume should have the following characteristics:

- It should be rustic, easy to establish, aggressive and persistent.

- It should not be too palatable nor adequate as the sole component of the animal diet.

- Its consumption should stimulate consumption of native savanna of relatively low quality; the protein content should be high enough to stimulate the intake of native savanna and to permit its efficient use by the animal.

- Due to the danger of fire in savanna, the legume should have certain tolerance to accidental fire or to infrequent fires used for management.

Planting with pellets

In the 1984 Annual Report the strategy of using fertilizer pellets of low

Table 6. Legume availability in the wet season of 1985 in native savanna supplementation trial with planted legume strips. (S. capitata).*

Planted and fertilized legume area per animal (m^2)	Replicate	Stocking rate ($an.ha^{-1}$) 0.33	0.67	1.00	1.33
		DM kg ha^{-1}			
1500	I	9	13	21	36
2250		-	34	49	-
1500	II	26	19	21	27
2250		-	51	49	-

* Means of 2 dates (June-August).

Table 7. Fertilizer source and chemical composition of slow release pellets used in Carimagua trials.

Ingredient	Composition (%)					
	N	P	K	Ca	Mg	S
IBDU (Isobutylidene Diurea)	31.0	0.0	0.0	0.0	0.0	0.0
Multiphosphate	0.0	13.0	0.0	10.7	4.8	0.0
Potassium silicate	0.0	0.0	8.6	5.7	2.4	0.0
Gypsum	0.0	0.0	0.0	23.2	0.0	18.6
Pellet composition:						
For legumes (no N)	0.0	5.2	5.0	9.6	3.0	2.5
For associations	2.5	4.3	4.2	8.6	2.8	1.8

solubility coated with seeds of forage species to be planted directly in native savanna or in planted pastures was presented. New pellets have been prepared with the characteristics shown in Table 7. Pellets for legumes do not include nitrogen. A granular form of fertilizer was prepared using the same ingredients as in the pellets, thus permiting a comparison between the large pellets and a conventional form of fertilizers. In Table 8, the effects of tillage and vegetation control on establishment and persistence of six forage species are shown for a sandy soil. The planting was done in September 1984. The establishment was successful for all species and at all levels of vegetation control. Persistence of these species as measured in April and May of 1985, revealed large differences due to species and degree of vegetation control. Percent cover (1 m^2 around planting site) was also determined during the first year after establishment. The effect of vegetation control was large for all species. However, there was little difference between chemical control and chisel tillage.

New experiments were established in 1985 utilizing the new materials. Five species were planted with two systems of planting and three levels of vegetation control. The experiments were carried out on a sandy loam soil and a clay loam soil, both sites located in Carimagua. Establishment was much more successful in the clay loam soil and was best with chisel tine tillage in the planting row as shown in Table 9. It is probable that the effect of tillage is related to very heavy rains during and immediately after the planting, giving rise to heavy run-off and the transport of seed quite far from the planting site. This effect can also be seen in the contrast between establishment with pellets and planting in the traditional way with granular or powdered fertilizer. Seeds stuck to pellets remained in the planting site while loose seeds were removed from the planting site due to the run-off. This was especially notable in the sandy soil which is more sloping and much less structurally stable. The establishment with pellets was

Table 8. The effect of tillage and vegetation control on the establishment and persistence of six forage species in a sandy soil. Alegría, Carimagua 1984 - 1985.

Species	Tillage - Vegetation control								
	Zero tillage			Chemical control			Chisel plow		
	11/84	4/85	7/85	11/84	4/85	7/85	11/84	4/85	7/85
	Sites with live plants								
S. capitata	92	89	82(6)*	86	94	97(33)	89	89	95(32)
S. macrocephala	100	94	86(3)	100	100	100(23)	100	100	100(23)
D. ovalifolium	86	33	42(4)	89	67	81(17)	100	78	83(23)
Centrosema sp.	89	22	22(2)	78	50	50(5)	100	72	72(11)
*P. phaseoloides***	86	17	17(1)	78	31	25(2)	97	39	42(2)
*B. dictyoneura***	42	33	53(2)	56	50	67(10)	92	97	97(18)

* Numbers in brackets represent the percentage coverage of 1 m^2 around the planting site.

** Combined on the same pellet.

Table 9. The effect of tillage and vegetation control on the relative population of plants one month after planting in two types of soils at Carimagua.

Species	Planting system	Zero tillage		Chemical control: Site		Chemical control: Band		Chisel plow	
		Sandy loam	Clay loam	Sandy loam	Clay loam	Sandy loam	Clay loam	Sandy loam	Clay loam
		%							
S. macrocephala	Site-1**	-	-	37	85	47	82	100	97
	Site-2**	-	-	52	80	-	-	93	98
	Pellet	95	95	95	85	90	98	93	100
Centrosema sp.	Site-1	-	-	5	53	7	62	83	90
	Site-2	-	-	2	48	-	62	90	100
	Pellet	90	100	77	95	78	96	99	100
P. phaseoloides	Site-1	-	-	10	42	2	45	83	82
	Site-2	-	-	10	35	-	-	97	95
	Pellet	72	90	75	90	68	95	100	98
P. phaseoloides*	Site-1	-	-	2	38	3	40	92	78
	Site-2	-	-	3	40	-	-	93	95
	Pellet	70	83	48	82	53	95	93	98
B. dictyoneura*	Site-1	-	-	5	36	0	25	97	61
	Site-2	-	-	2	23	-	-	95	88
	Pellet	78	92	62	92	68	85	95	97

* Combined in the same site or pellet.
** The fertilizer in the site-2 system is granular and has the same mineral composition as the pellet.
* The fertilizer in the site-1 system corresponds to a mixture of conventional fertilizers.

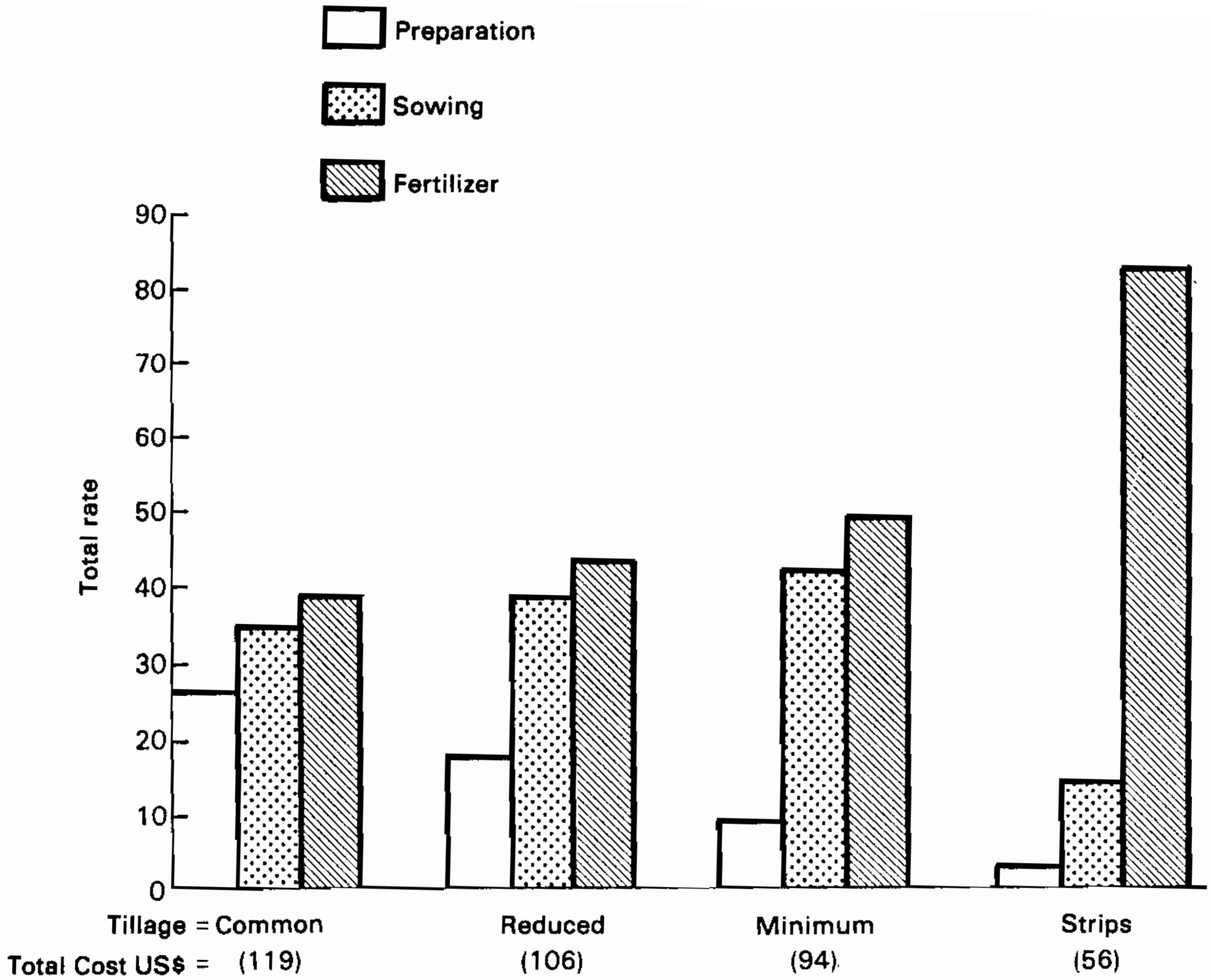


Figure 5. Commercial costs of establishment of an association in Carimagua and the participation of the 3 components in the total cost.

satisfactory with most species at all levels of vegetation control and tillage and it was successful with all planting systems when there was some type of tillage in the row. This system continues to be promising and interesting for the establishment of forage species in cultivated pastures or in native savanna. The new pellets are not sufficiently soluble and require further refinement.

Economic considerations

The importance of tillage and planting systems is illustrated by the data presented in Figure 5, in which the contribution of the three major components of establishment (land preparation, planting and fertilizer) to the total costs are shown. The total cost of the planting operation in US dollars is shown in parenthesis. In the case of strip planting, there is no previous tillage. Planting is done in a once over operation. This strategy cannot be compared directly with the other planting systems because of the time required for complete formation of the pasture.

Maintenance

In the last five years, large effects of grazing system and stocking rate have been observed, along with interactions between these two factors in associations of tropical grasses and legumes. These observations and others lead us to conclude that

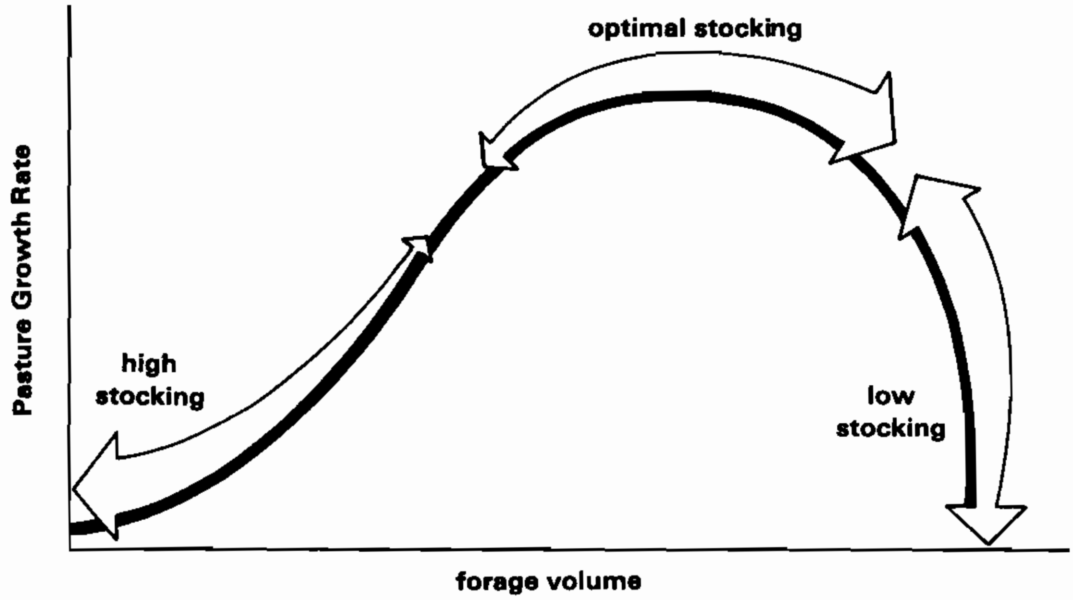


Figure 6. Stocking rate effects on forage volume, pasture growth rate and stability.

maintenance of pastures depends heavily on good pasture management. The well managed pasture will require relatively little fertilizer for maintenance. If this is true, then tropical pastures can serve as managed fallows which are highly productive and at the same time result in the accumulation of nutrients in more available forms and improve the physical conditions of the soil. In the Annual Report for 1984, data were presented concerning the effect of stocking rates and grazing systems in an association of P. phaseoloides/A. gayanus. These effects continue to be large in the current year, especially the stocking rate effects. It appears that associations with A. gayanus are especially susceptible to small stocking rate differences. This has been observed in a number of experiments. Figure 6 presents, in a very simplified form, some of the relations between growth rate, forage volume and stability of a pasture. It is obvious that a low stocking rate gives rise to low efficiency of utilization, but is a highly stable system. The optimum stocking rate attempts to achieve maximum use of the potential of the pasture, maintaining it in the range of maximum growth rate. Its stability increases from left to right as shown by the width of the arrow. Excessive stocking rates are especially unstable excepting to the extreme left where the pasture is totally degraded and reaches its lowest growth rate.

Flexible management

In 1984 a proposed methodology for evaluating germplasm under grazing was presented. This methodology is based on a philosophy of flexible management. The first experiment to test the methodology was established in Barrolandia, in the extreme South of Bahía, Brazil, by the Division of Animal Sciences of CEPLAC, with headquarters in Itabuna, Bahía. After 18 months of grazing, the association of P. phaseoloides/B. humidicola is stable and highly productive, supporting 3.75 animals/ha with liveweight gains of approximately 600 g /head/day averaged throughout the year. It has been necessary to adjust the grazing system twice to maintain the critical parameters within the "window" of good management described in the last Annual Report.

A new experiment was established in 1984 in Carimagua, including 5 associations, the development of which is shown in Figure 7 and Table 10. Management consist of two components: stocking rate and grazing system, and is defined in terms of two pasture parameters; percentage of legume and forage on offer. When the pasture approaches any limit of the parameters, adjustments are made in stocking rate or grazing system in order to maintain the association in the desired range.

In the development of the flexible management experiment in Carimagua, there have been a number of germplasm problems and it has been necessary to replace one of the Centrosemas and it may be necessary to replace S. macrocephala because of undue susceptibility to Rhizoctonia. In addition, Arachis pintoi has not been very vigorous during the establishment phase, possibly for lack of inoculation due to the planting with vegetative material. This problem is presently being studied along with other nutritional factors. The flexibility of management has allowed the adjustment for each association

Table 10. The effects of stocking rate and grazing system on the botanical composition of three associations during the uniformization period in the flexible management trial at Carimagua (105 days).

Asociation	Rep.	Medium stocking rate	Grazing system (grazing/rest) Initial 54 days	Final 51 days	Botanical composition Initial**	Final
		AU^*ha^{-1}	-------- Days	------	---- % legumes	---
A. gayanus 621 +	1	1.7	14-14	21-21	25	32
Centrosema sp. 5277	2	1.6	14-14	7-7	5	26
A. gayanus 621 +	1	1.9	28-28	21-21	54	29
S. macrocephala 1281	2	1.7	28-28	21-21	73	36
B. dictyoneura 6133	1	1.9	14-14	7-7	3	13
A. pintoi 17434	2	2.1	14-14	7-7	7	15

* AU = 400 kg liveweight.
** = June 1, 1985

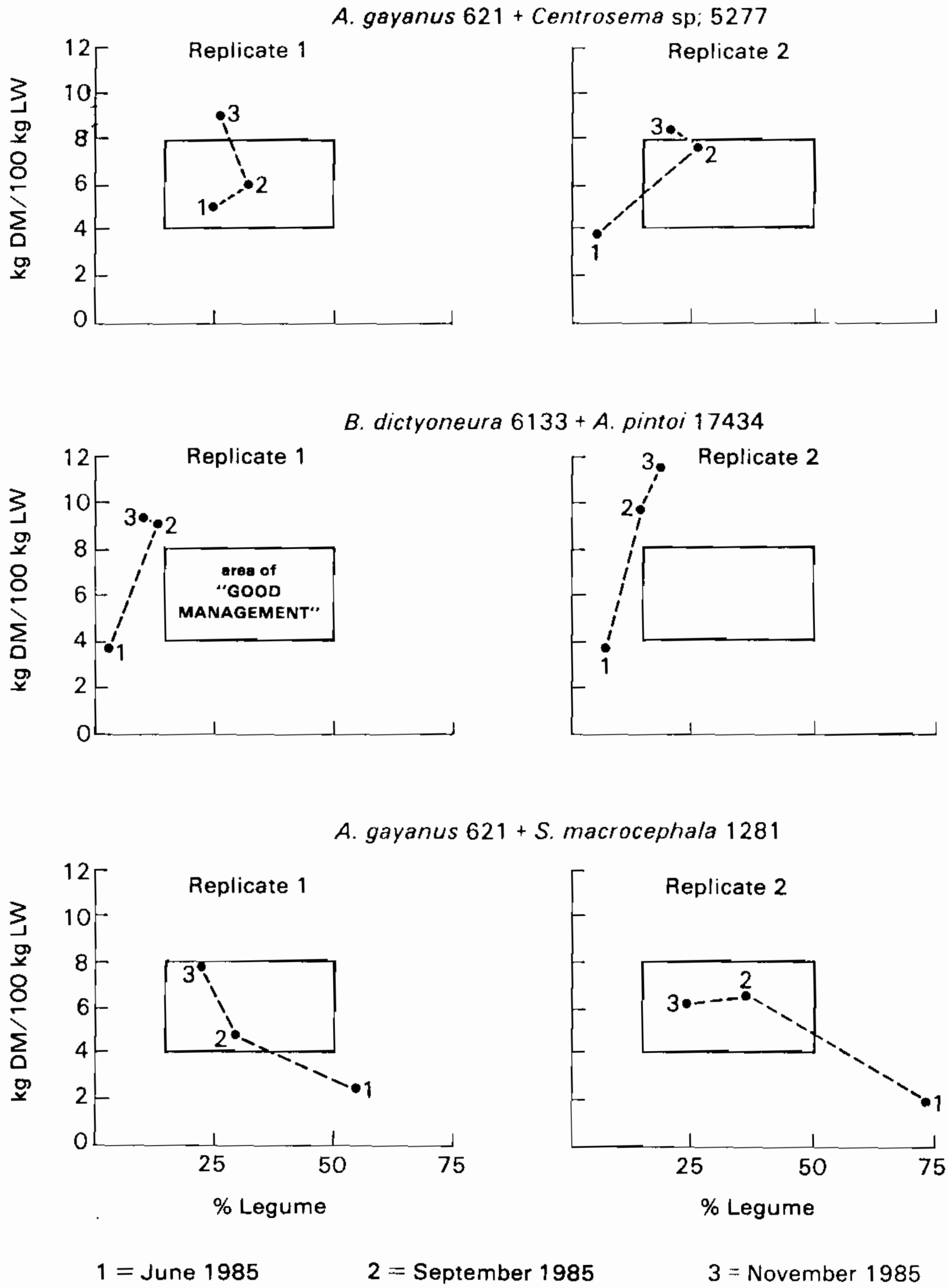


Figure 7. **Forage on offer and botanical composition of three associations of grasses and legumes in a flexible grazing trial in Carimagua. 1985.**

and each replication to compensate for establishment problems. As an example, it can be seen in Figure 7 that there is an extreme contrast between the two repetitions of *A. gayanus*/*Centrosema* sp. with regard to percentage legume and forage on offer. Repetition II began with only 5% legume vs. 25% legume in Repetition I. Repetition I has been managed with a grazing system of 21:21 days grazing/ days rest, while in Repetition II a grazing system of 7:7 has been used which has given rise to an improvement in legume proportion, which at last observation had reached 32% and 26%, respectively (Table 10). It is almost impossible to avoid this type of difference between associations and repetitions in the establishment phase and it is extremely difficult to correct or compensate these differences, utilizing fixed management systems for obvious reasons.

Pasture Quality and Productivity

Since 1985, the research activities of the Pasture Productivity and Management Section were transferred to the Pasture Quality and Nutrition Section. This change brought about the formation of the Pasture Quality and Productivity Section with the following research objectives:

1. To characterize promising germplasm in terms of nutritional quality factors.

2. To evaluate grazing management systems in terms of persistence and animal productivity of pastures assembled with Category IV and V germplasm.

3. To identify nutritional factors associated with animal productivity in native and improved pastures.

What follows is a summary of the results of research projects that have been completed and a progress report of on-going projects, including a methodological study that is being conducted in Carimagua.

GERMPLASM CHARACTERIZATION

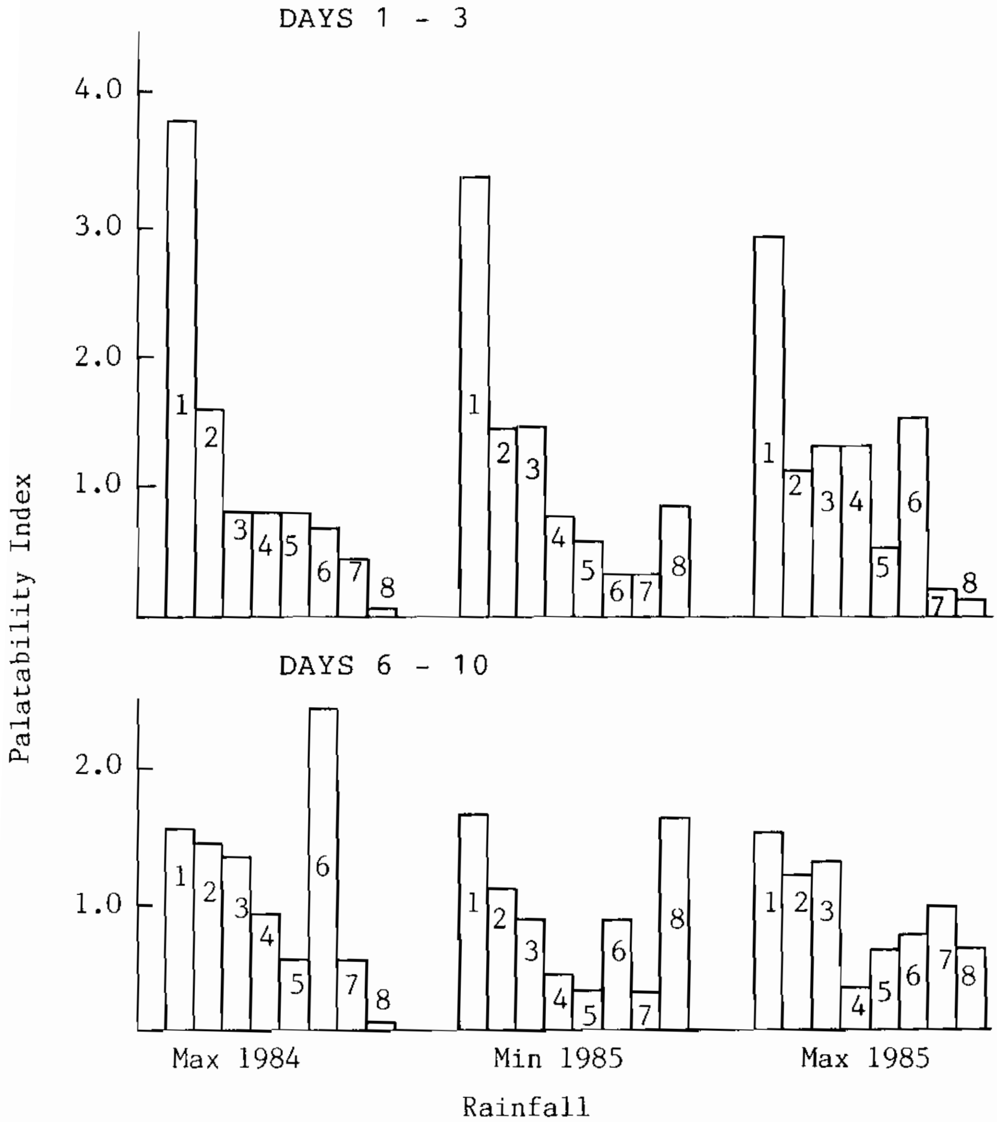
Research work on the characterization of germplasm quality factors continues to be conducted at CIAT-Quilichao Substation. The results of two projects are reported: (1) relative palatability of eight legumes, and (2) animal productivity in three genotypes of *Andropogon gayanus*.

Relative palatability of legumes

The relative palatability of eight legumes during maximum and minimum rainfall periods was assessed under grazing in a "cafeteria" system, in collaboration with the Germplasm Section. The first results of this project were reported in the 1984 Annual Report, and were obtained during a maximum rainfall period. Figure 1 summarizes the results of the three evaluations conducted. *Centrosema* sp. 5568 consistently appears as the most palatable legume in days 1-3 that are the most sensitive to detect differences in palatability. On the other hand, the relative palatability of *Tadehagi* sp. 13276, *Stylosanthes viscosa* 1353 + 1538 + 2405 and *Stylosanthes guianensis* var. *pauciflora* 2812 were low in all three evaluations. It is worthwhile noting that *Flemingia macrophylla* 17403 was much more consumed during the 1985 evaluations compared to evaluations in 1984 in which it was practically rejected. This difference could be due to less mature plants during 1985 as a result of uniformity cuttings prior to initiating the "cafeteria" test. In general, the palatability results in this study were fairly consistent and they indicate the need to conduct "cafeteria" tests with regrowths of different ages.

Animal productivity in genotypes of *A. gayanus*

As a background for this project, it should be mentioned that *A. gayanus*



No.	Leg	No.	Leg
1.	Centrosema sp (5568	5.	S.viscosa (1353+1538+2405)
2.	Zornia sp (8279 + 8283)	6.	Z. glabra (7847)
3.	D. velutinum (13204+13213+13215)	7.	Tadehagi sp (13276)
4.	S. guianensis (2812)	8.	Flemingia sp (17403)

Figure 1. Palatability index of 8 legumes in different seasons of the year (Quilichao).

genotypes selected by the Breeding Section based on leafiness were initially evaluated with wethers in metabolism crates (1983 Annual Report) and then under grazing (1984 Annual Report). In the trial with crated wethers it was observed that the leafier materials were more consumed and this was related to a reduced retention time of undigested residues within the digestive tract. However, when these genotypes were evaluated under grazing no differences were found in intake between entries, including the commercial cultivar (CIAT 621) as a control.

The project was re-designed with the objective of evaluating animal gains in the same area (1.2 ha) used in the trial to measure intake under grazing. The test includes all three genotypes of *A. gayanus* (leafy, stemmy and 621 as the control), each material in four 0.21 ha plots. The grazing system being used is rotational with seven days on and 21 days off, using two permanent animals per genotype and an additional one sporadically. Animals are weighed at 35-day intervals (one complete rotation + one pasture) and the following parameters are being measured: (1) available forage and plant part composition before and after grazing; (2) animal selectivity with esophageal-fistulated animals; and (3) quality of the available and selected forage.

The weight gains obtained during 420 days of evaluation have been similar for the three genotypes (Table 1). However, in the third evaluation, which corresponds partially to a minimum rainfall period, the weight gains were higher ($P < .05$) for the stemmy and 621 genotypes compared to the leafy genotype. This is due to the poor performance of the leafy genotype under water stress conditions. In terms of biomass production (Table 2) no differences have been found between genotypes and therefore the grazing pressures applied in all three entries have been similar (range 9.7 to 11.1 kg green DM/100 kg LW/day.

Contrary to what was expected, the proportion of leaves has been similar in the three genotypes, both before and after grazing (Figure 2). The proportion of leaves in the forage selected at the beginning of the grazing period has been similar in all three genotypes, but higher in the leafy genotype at the end of the grazing period (Figure 3). No differences have been found in terms of quality (crude protein and *in vitro* digestibility) between *A. gayanus* genotypes, in the forage on offer and forage selected.

The results obtained up to now, indicate that the greatest difference between genotypes of *A. gayanus* included in the trial is in terms of morphology (Figure 4) and not in the leaf:stem ratio or nutritional value. However, this difference in architecture between genotypes has not affected animal gains.

The comparative advantages of a low-statured leafy *A. gayanus* genotype under grazing could be in terms of ease of management and possibly greater compatibility with legumes, as compared with the commercial cultivar (CIAT 621). It is suggested that these hypotheses be tested before continuing with a program to select low-statured *A. gayanus* genotypes.

PASTURE MANAGEMENT AND PRODUCTIVITY

Research in pasture management and animal productivity is the main activity of the section. This work is being conducted in the CIAT-Quilichao Substation and in the Carimagua Station in the Colombian Llanos. Presently there are four grazing trials on which a progress report is presented.

Table 1. Liveweight gains in three *Andropogon gayanus* genotypes (Quilichao).

Evaluation period[1]	Stocking rate (UA ha^{-1})[2]	Genotypes		
		Leafy	Stemmy	621
		($g\ A^{-1} day^{-1}$)		
I	3.6	482	457	629
II	3.4	500	439	507
III	3.5	296[a]	400[b]	468[b]
Mean		426	432	535

1/ 140 days per evaluation period: (Complete rotation + 1 pasture).

2/ UA = 400 Kg PV.

a,b, different means ($P < .05$).

Table 2. Initial forage availability of *Andropogon gayanus* genotypes under grazing (Quilichao).

Evaluation period[1]	Stocking rate (UA ha^{-1})[2]	Genotypes		
		Leafy	Stemmy	621
		(kg GDM ha[1])		
I	3.6	4852	4584	4530
II	3.4	3331	4873	3656
III	3.5	2932	2845	3796
Mean		3705	4101	3994

Analysis: Genotypes (NS).

1/ 140 days per evaluation period: (Complete rotation + 1 pasture).

2/ AU = 400 kg LW.

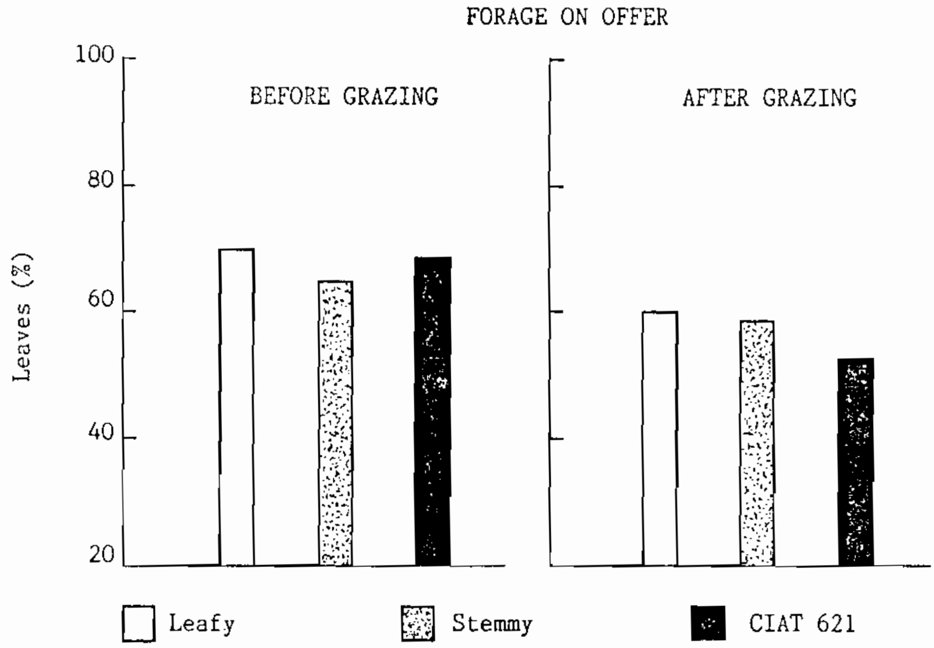


Figure 2. Proportion of leaves in the available forage on *A. gayanus* genotypes (Quilichao).

Grazing of *B. dictyoneura* + *D. ovalifolium*

In 1983, a grazing experiment was established at the CIAT-Quilichao Substation with *Brachiaria dictyoneura* 6133 in association with *Desmodium ovalifolium* 350. The objective of this trial is to establish relationships between pasture attributes and animal production. With this objective in mind, the treatments included three contrasting stocking rates under rotational grazing with seven days of occupation and 21 days of rest. The total area of the experiment is 1.1 ha, with areas for the high, intermediate and low stocking rates of 2482, 3723 and 4964 m^2, respectively. In order to obtain good estimation of pasture attributes, the following parameters are being measured every 28 days: (1) forage on offer, (2) botanical composition, (3) animal selectivity, and (4) quality of the forage on offer and forage selected by esophageal fistulated animals. Animals (two per stocking rate treatment) are weighed at 35-day intervals.

This report presents the results of 420 days of grazing, corresponding to 15 cycles of complete rotation. During the evaluation period, large differences have occurred between stocking rates in terms of total forage available expressed as green dry matter (Figure 5) and of legume availability (Figure 6). Because of the low palatability of *D. ovalifolium* it was thought that through selective grazing the legume would dominate the grass at the high stocking rate, but this has not happened. In Table 3 it can be seen that the lowest ($P < .05$) proportion of legume occurs at the high stocking rate. In spite of the large differences in stocking rates and therefore in grazing pressures, the proportion of selected legume has remained relatively constant for the three treatments.

In terms of the forage on offer, the largest differences due to stocking rate treatments have been in terms of dry matter *in vitro* digestibility (Table 4). The higher digestibility of the forage on offer at the high stocking rate is associated with better quality of the grass regrowth and to a lower proportion of *D. ovalifolium* that has a lower *in vitro* digestibility than the grass. In spite of these differences in quality

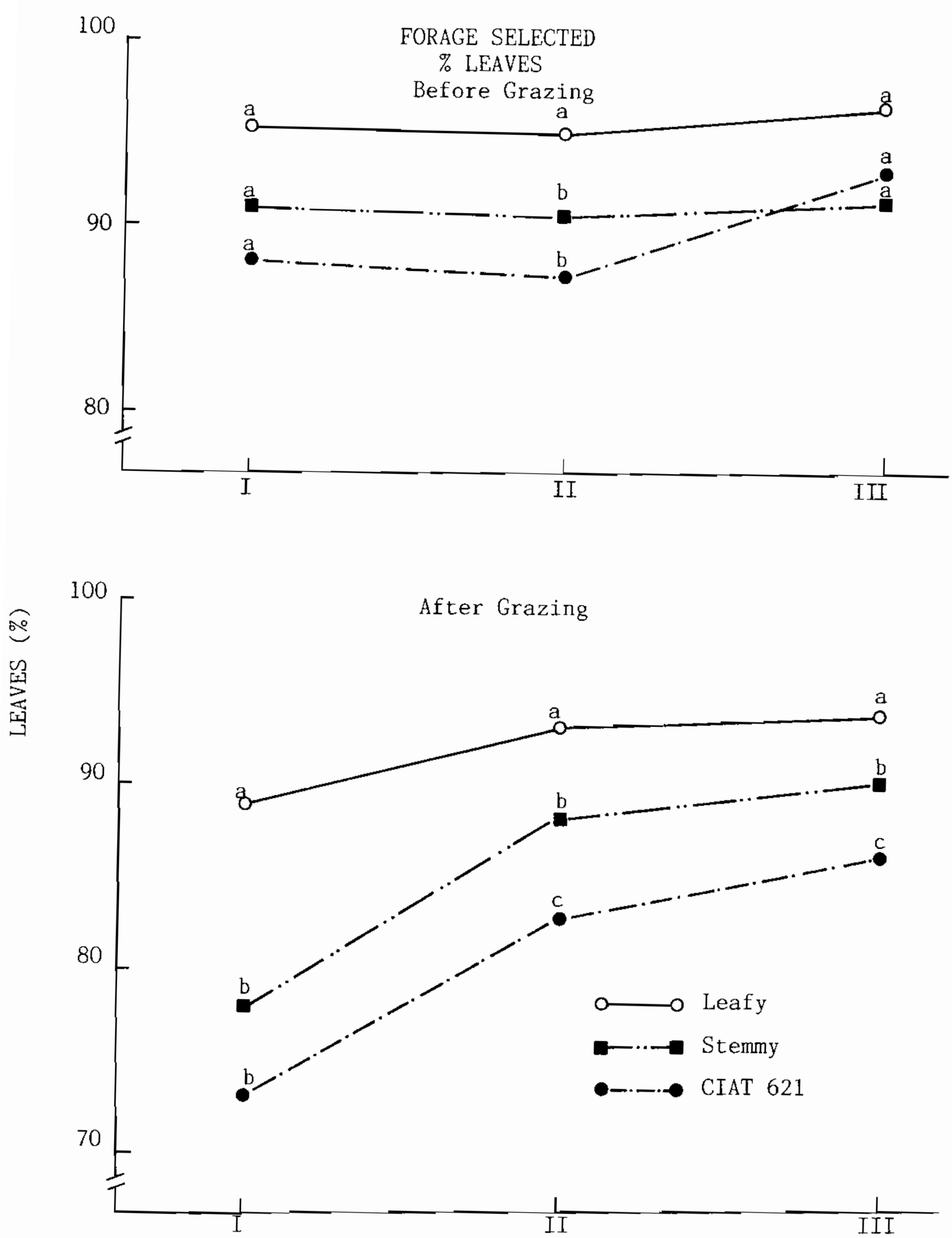


Figure 3. Leaf proportion of the forage selected by esophageal fistulated steers in genotypes of *Andropogon gayanus* (Quilichao).

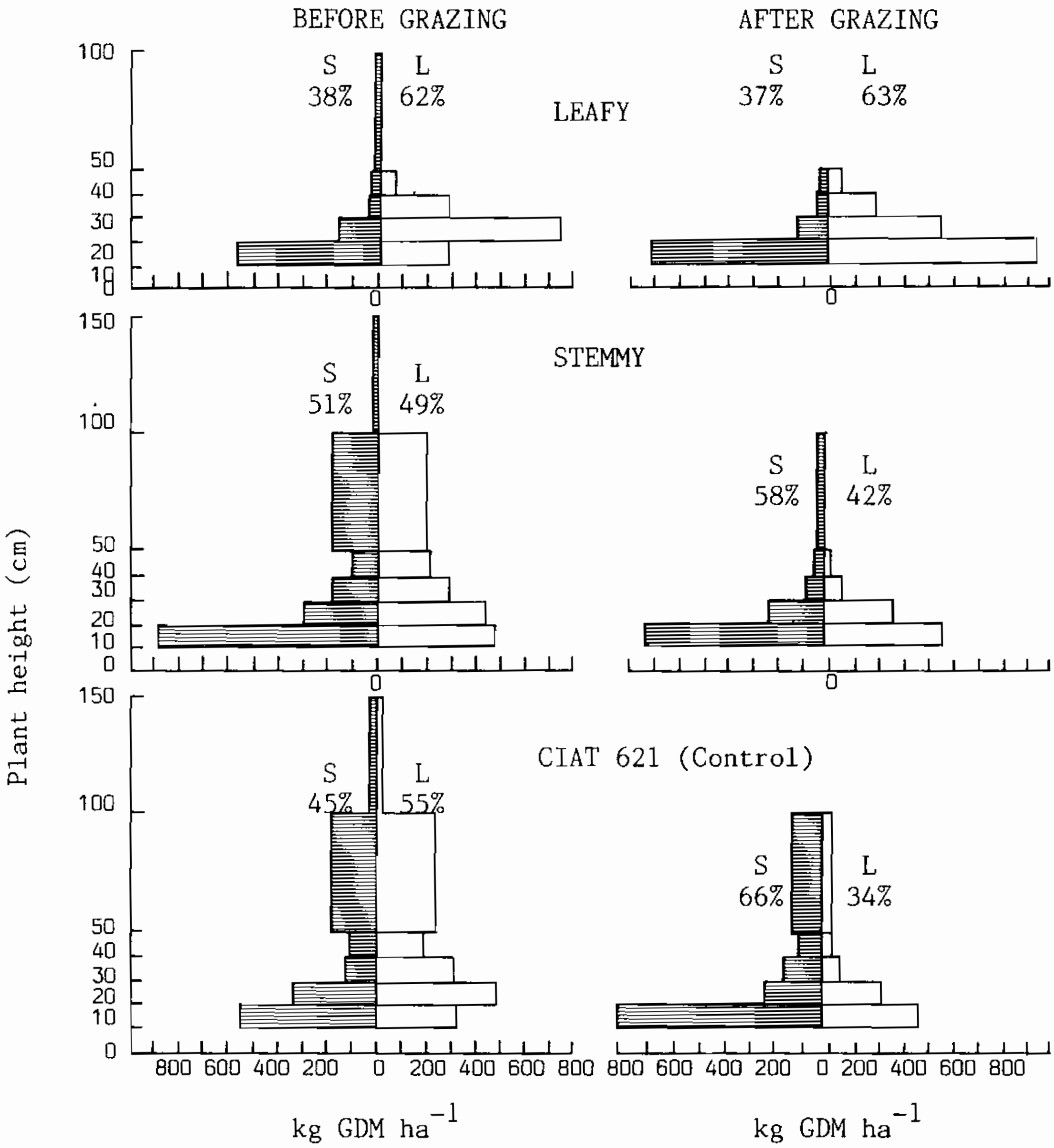


Figure 4. Leaf (L) and stem (S) distribution in genotypes of *Andropogon gayanus* under grazing (Quilichao).

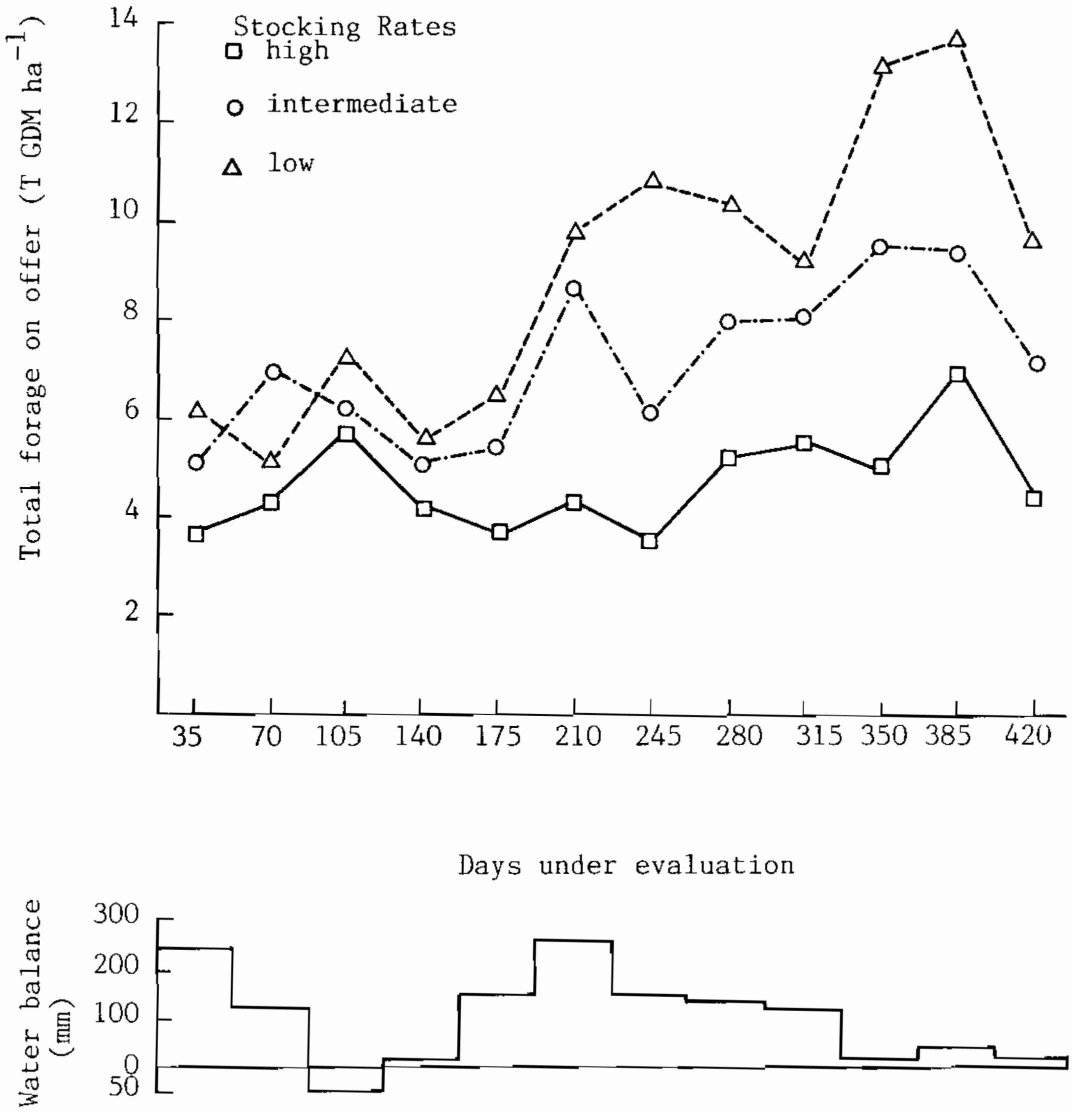


Figure 5. Changes over time of total forage on offer in a Brachiaria dictyoneura + Desmodium ovalifolium pasture under rotational grazing with different stocking rates (Quilichao).

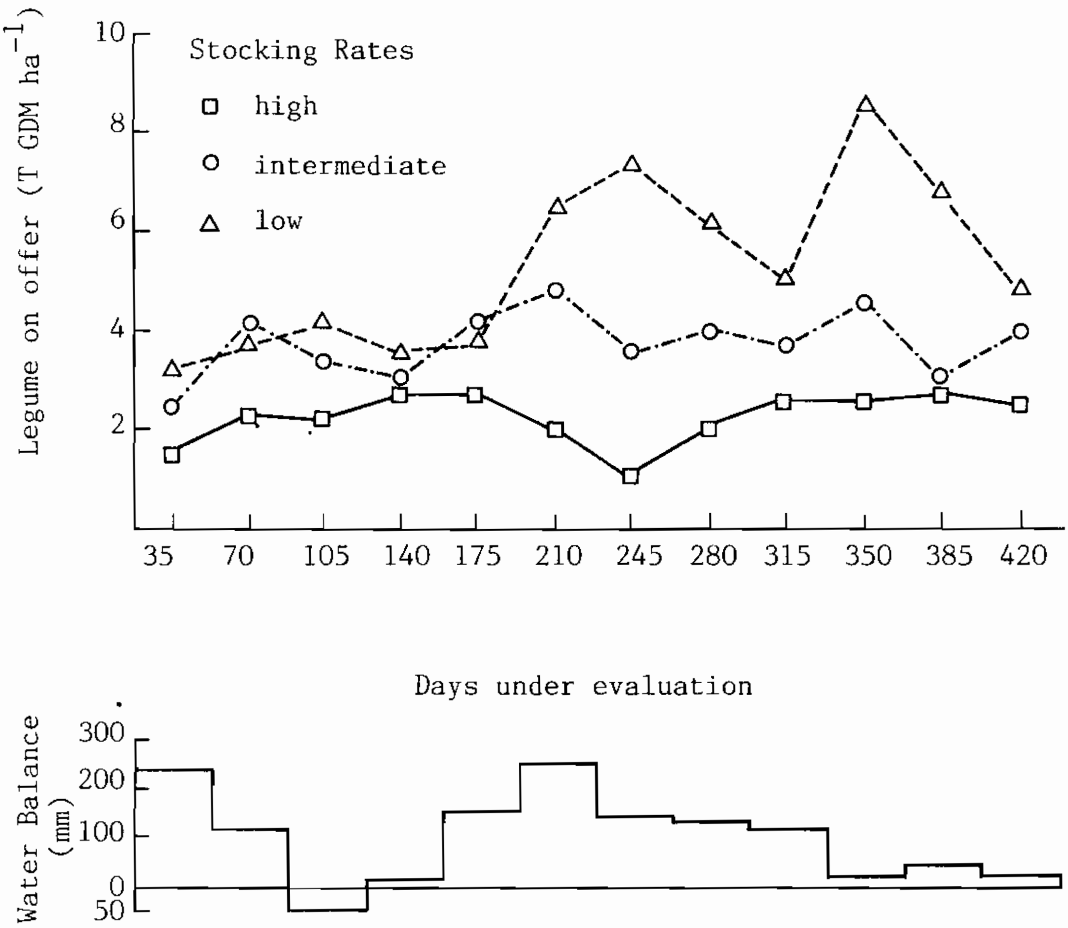


Figure 6. Changes over time of legume on offer in a *Brachiaria dictyoneura* + *Desmodium ovalifolium* pasture under rotational grazing with different stocking rates (Quilichao).

Table 3. Effect of stocking rate on the botanical composition of the available and selected forage in a Brachiaria dictyoneura + Desmodium ovalifolium 350 pasture (Quilichao).

Stocking rate (AU/ha^{-1})[1]	Legume		Selection index
	Available (%)	Selected (%)	
High (4.8)	48.0[a]	30.5	0.64
Intermediate (3.7)	53.2[a,b]	30.5	0.57
Low (2.8)	59.7[b]	32.5	0.57

a,b, different means (P < .05).
1/ UA = 400 kg LW.
2/ % legume selected - % legume available

Table 4. Effect of stocking rate on the quality of the forage on offer and selected by fistulated steers in a Brachiaria dictyoneura + Desmodium ovalifolium 350 pasture (Quilichao).

Stocking rate (AU ha^{-1})[1]	Forage			
	Available		Selected	
	CP (%)	IVDMD (%)	CP (%)	IVDMD (%)
High (4.8)	9.9	47.5[a]	11.0[a]	49.2
Intermediate (3.7)	9.6	45.5[b]	11.0[a]	49.2
Low (2.8)	9.5	43.8[b]	10.6[b]	49.0

a,b, different means (P < .05).
1/ AU = 400 kg LW

of the forage on offer, the quality of the forage selected has been similar on the three stocking rates (Table 4).

Eventhough large changes have occurred in the pasture, liveweight gains have been similar for all three stocking rates (Table 5), and as a result it has not been possible to establish any kind of relationship with measured pasture parameters.

Based on the results obtained up to now, it is evident that the association B. dictyoneura 6133 + D. ovalifolium 350 is very productive and with a high carrying capacity under Quilichao conditions. In order to be able to create differences in liveweight gains, it was decided to increase across treatments one animal.

Table 5. Effect of stocking rate on liveweight gains of steers grazing a Brachiaria dictyoneura + Desmodium ovalifolium 350 pasture (Quilichao).

Stocking rate (AU ha^{-1})[1]	Weight gains (g A^{-1} day^{-1})	
	Without fasting	With fasting
High (4.8)	400	392
Intermediate (3.7)	498	447
Low (2.8)	463	435

1/ AU = 400 Kg LW

Grazing of B. decumbens with and without a legume

The oldest grazing trial in Carimagua

is one where animal productivity is being measured in Brachiaria decumbens alone and in association with Pueraria phaseoloides (Kudzu) under continuous grazing with variable stocking rate by season of the year. The experiment is now in its seventh year and liveweight gains for 1985 are shown in Table 6. Weight gains during the dry and rainy seasons were higher ($P < .05$) for the association than for the grass alone. These results translated to annual gains are consistent with those obtained in previous years (Figure 7), where the associated grass produced 40-50 kg more gains per animal per year than the grass alone.

In this trial, the presence of the legume in the pasture contributed not only to increase protein consumption and grass quality (1984 Annual Report) but also resulted in an increased amount of forage on offer (Table 7). To take advantage of this increased forage availability in the association, stocking rates will be increased from 1 to 1.5 A ha^{-1} during the dry season and from 2 to 2.5 A ha^{-1} during the rainy season in both pastures. It is thought that with this new management, differences in productivity between B. decumbens with and without a legume will be even larger than have been recorded so far.

Grazing of A. gayanus with and without legumes

During 1985, A. gayanus alone and in association with legumes (S. capitata + C. brasilianum 5234 and S. capitata + C. macrocarpum 5065), continued to be evaluated in Carimagua under two grazing systems at a fixed stocking rate of 2 A ha^{-1}. The weight gain results (Table 8) indicate large weight losses during the dry season in A. gayanus alone, to a point that under continuous grazing it was necessary to remove the animals. In contrast, during the same season, the animals maintained weight in the associations both under continuous as well as under rotational grazing. It was interesting to observe the excellent performance of C. brasilianum 5234 during the dry season, which contrasts with the poor performance of C. macrocarpum 5065, that practically disappeared from the pastures.

During the rainy season, the weight gains have been higher in the associations than in the grass alone, with no differences between grazing systems. It must be recognized, however, that

Table 6. Liveweight gains on Brachiaria decumbens alone and in association with Pueraria phaseoloides (Kudzu) (1985[1] Carimagua).

Pasture	Stocking rate[2] (A ha^{-1})	Daily gains Dry ($g\ A^{-1}\ día^{-1}$)	Daily gains Rainy ($g\ A^{-1}\ día^{-1}$)	Annual gains ($kg\ A^{-1}$)
B. decumbens	2/1	222[a]	367[a]	116
B. decumbens + Kudzu	2/1	322[b]	489[b]	158

1/ Seventh year under grazing.

2/ Rainy/dry seasons.

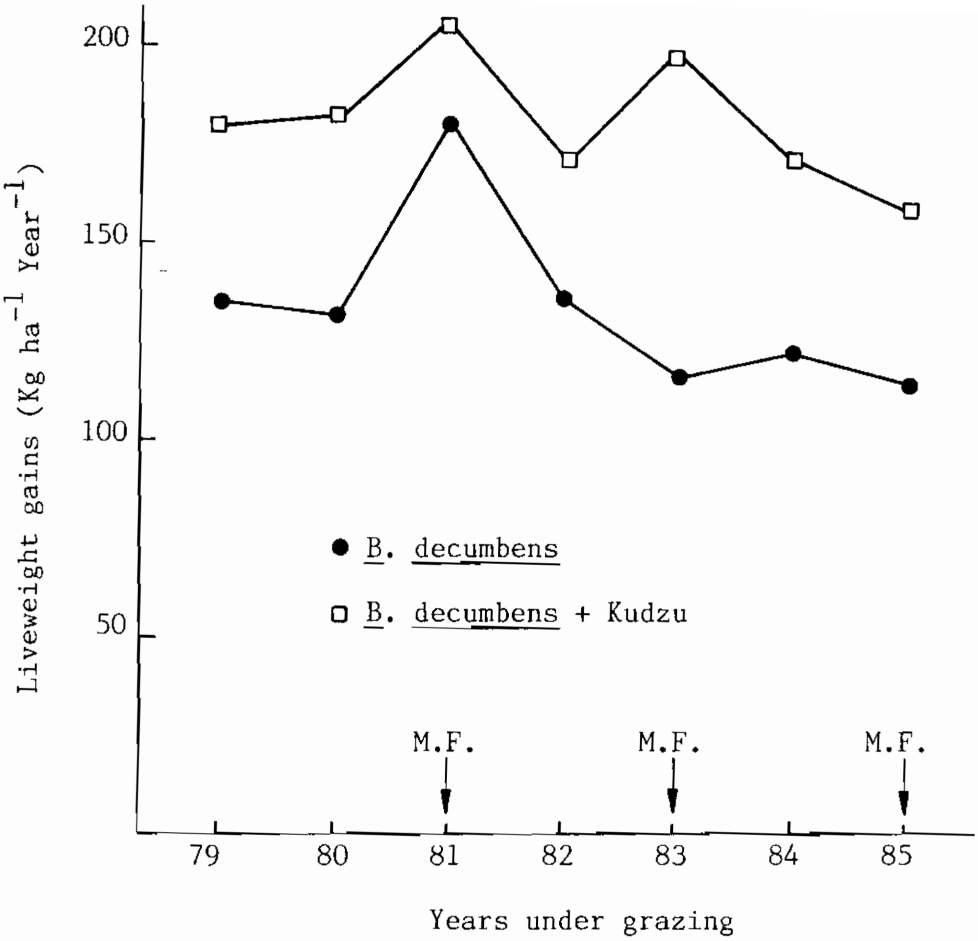


Figure 7. Animal productivity in B. decumbens alone and associated with Kudzu with maintenance fertilization (MF) every 2 years (Carimagua).

Table 7. Forage availability and botanical composition in *Brachiaria decumbens* alone and associated with Kudzu. (Carimagua).

Pasture	Season	Available grass (kg DM ha^{-1})	Legume (%)
B. decumbens	Transition[1]	1545	-
B. decumbens + Kudzu		2269	38.0
B. decumbens	Dry[2]	859	-
B. decumbens + Kudzu		1594	1.5
B. decumbens	Rainy[3]	1892	-
B. decumbens + Kudzu		2805	9.0

1/ Sampling Nov.-Dec. 1984. 2/ Sampling Feb.1985. 3/ Sampling Jun.1985.

Table 8. Liveweight gains in Andropogon gayanus alone and in association with legumes under continuous grazing (CG) and rotational grazing (RG). (Carimagua, 1985).

A. gayanus pastures	Stocking rate A/ha	Dry season CG ($g\ A^{-1} day^{-1}$)	Dry season RG	Wet season[2] CG ($g\ A^{-1} day^{-1}$)	Wet season[2] RG
Alone	2	-	-165[a]	495[a]	490[a]
+ C. macrocarpum + S. capitata	2	39	- 40[b]	708[b]	569[b]
+ C. brasilianum + S. capitata	2	34	45[b]	661[b]	677[b]
Mean				621	579

1/ December a April (141 days).
2/ May - November (209 days).
3/ Grazing discontinued
a, b, different means (P < .05)

the production potential of the A. gayanus pastures under rotational grazing is being underestimated in this trial because of the inflexible nature of the design in terms of stocking rate. This is evident when considering that the availability of grass leaves (on a dry matter basis) is almost twice under rotational grazing compared to the continuous grazing system, during the rainy season (Table 9).

Since in this experiment S. capitata and C. brasilianum 5234 are in a mixture, it has been interesting to observe the contribution of each legume in the dry and wet seasons (Figure 8). While the availability of C. brasilianum 5234 remained high during the dry season (January - March), that of S. capitata was very low. In contrast, in the rainy period the availability of C. brasilianum decreased considerably due to a severe

Table 9. Effect of season of the year and grazing system on the availability of Andropogon gayanus leaves (GL) alone or in association with legumes (Carimagua).

Pasture	Season	Grazing System: Continuous	Grazing System: Rotational
		($kgDM\ GL\ ha^{-1}$)	
A. gayanus	Dry[1]	163	166
	Rainy[2]	790	1325
A. gayanus + Legume[3]	Dry	248	179
	Rainy	970	1971

1/ January and March, 1985 sampling
2/ May - July, 1985 sampling
3/ S. capitata + C. brasilianum 5234

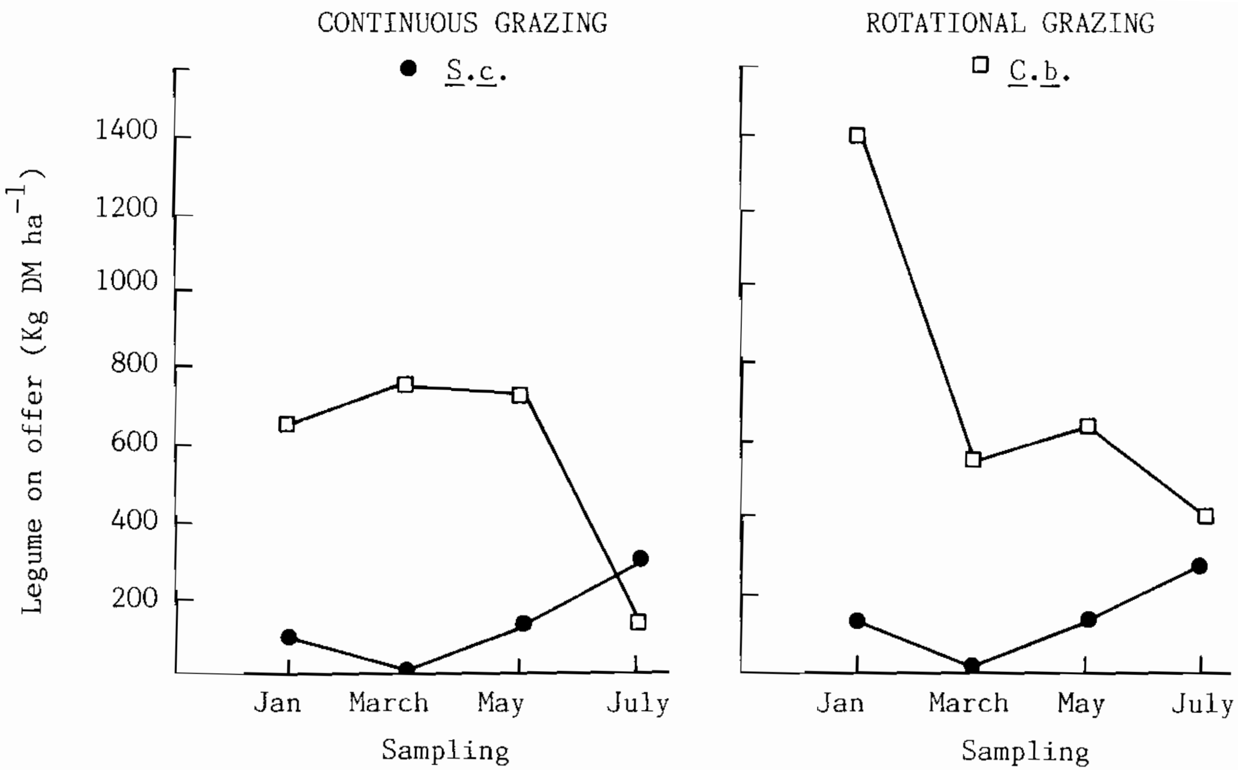


Figure 8. Availability of *Stylosanthes capitata* (*S.c.*) and *Centrosema brasilianum* (5234) in association with *Andropogon gayanus* under different grazing systems (Carimagua).

attack by Rhizoctonia, but the availability S. capitata increased. These results suggest that mixtures of legumes with different seasonal performance would be a recommendable practice at the farm level.

Based on the results obtained up to now, it is evident that the productivity and persistence of A. gayanus without legumes and under continuous grazing with moderate stocking rates (2 A ha^{-1}) is very low in the Colombian Llanos. It is also clear that A. gayanus with or without legumes responds significantly to grazing systems that involve rest periods, which should result in increased liveweight gains per hectare if the required adjustments in stocking rates are made. The advantages of including legumes in association with A. gayanus are not only reflected in a higher animal production but also in more production of edible biomass, as has been reported for other grasses.

Grazing of A. gayanus with legumes in Category IV

A new grazing trial with germplasm in Category IV was initiated in Carimagua in May of this year. During 1984 pastures of A. gayanus in association with Centrosema sp. 5277 + 5568 and Stylosanthes macrocephala 1643 were established in two sites (Yopare and La L) at Carimagua. Management variables included three stocking rates in continuous grazing and the highest stocking rate in rotational grazing (seven days of occupation and 21 days of rest) for a total four management treatments.

Soil analyses performed at both sites indicated that the only difference between them was texture. The soils at Yopare are more sandy (29%) than the soils at La L (4%). Liveweight gains obtained up to now are exceptionally high (Table 10), mainly due to compensatory gains by large framed (250 kg) animals at the initiation of the grazing period.

During the short time that the trial has been going on, a trend for higher animal gains in La L than in Yopare, has been observed. This appears to be associated with differences in grass availability between sites (Figure 9). The availability of A. gayanus even at the beginning of the grazing period was greater in La L than in Yopare, and these differences have increased with time. As a result of the lower availability of grass in Yopare, initially it was necessary to reduce the stocking rates and later to rest the pastures under continuous grazing with high and intermediate stocking rates.

In terms of legume productivity, it is interesting to note that an interaction has been observed with site. While Centrosema spp. 5277 is performing extremely well in Yopare its availability in La L is lower, particularly at the high stocking rate (Figure 10). These differences have been evident since the establishment stage, mainly as a result of a severe infestation of Panicum rugii in the legume rows at La L. The availability S. macrocephala has decreased at both sites, irregardless of grazing management.

New grazing trials

During 1985 new pastures were established in Carimagua as part of the germplasm flow of the Tropical Pastures Program. Materials sown included two grasses (A. gayanus and B. dictyoneura 6133 + B. brizantha cv. Marandu) in association with three Centrosema spp. (sp. 5277, macrocarpum 5452 and brasilianum 5234). Grazing management will include two grazing intensities using a flexible approach for grazing system in order to maximize the productivity of the pasture in terms of both persistence of the planted species and animal production.

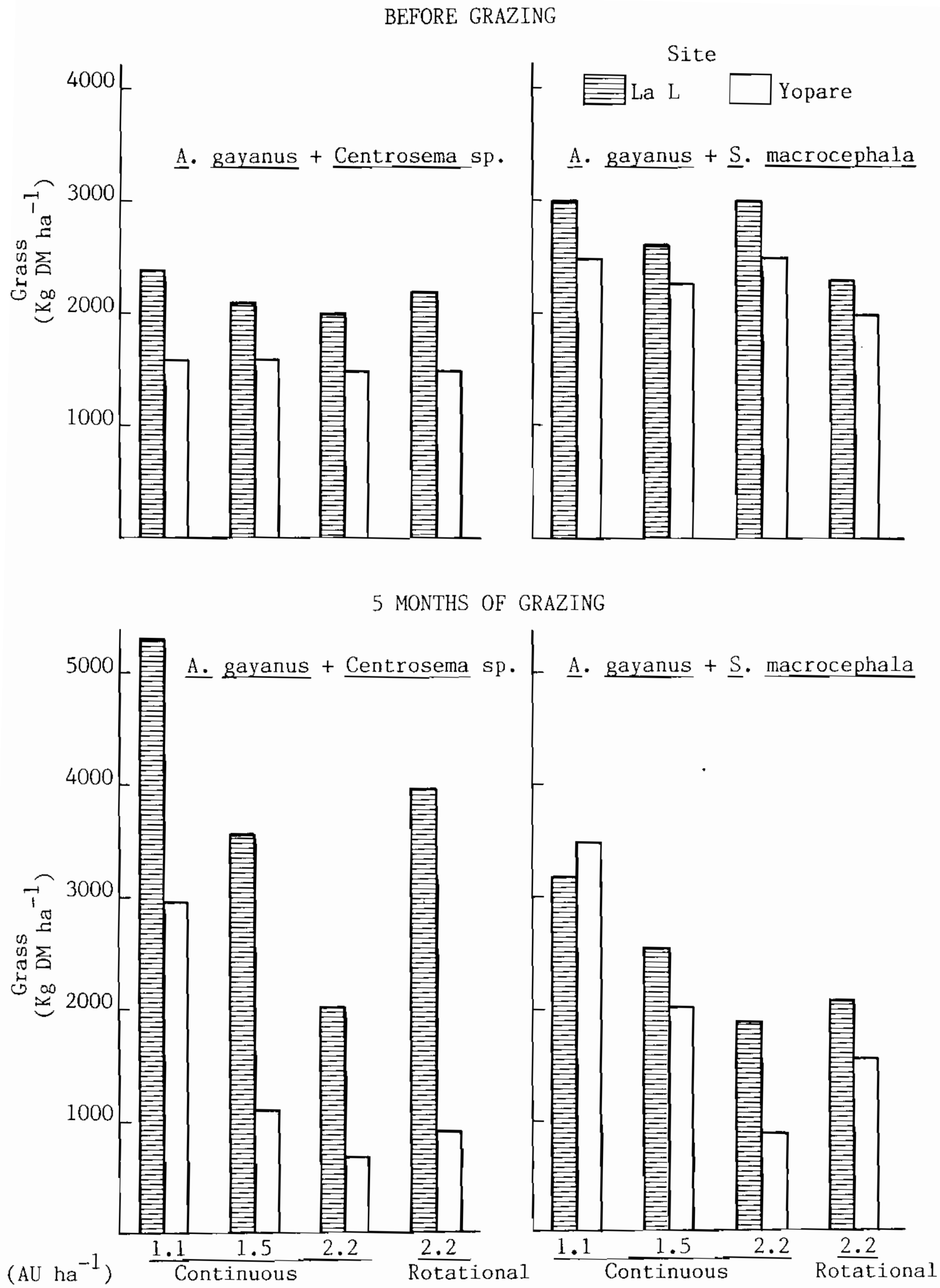


Figure 9. Grass availability in *Andropogon gayanus* + legume pastures at two sites and under different grazing management treatments (Carimagua).

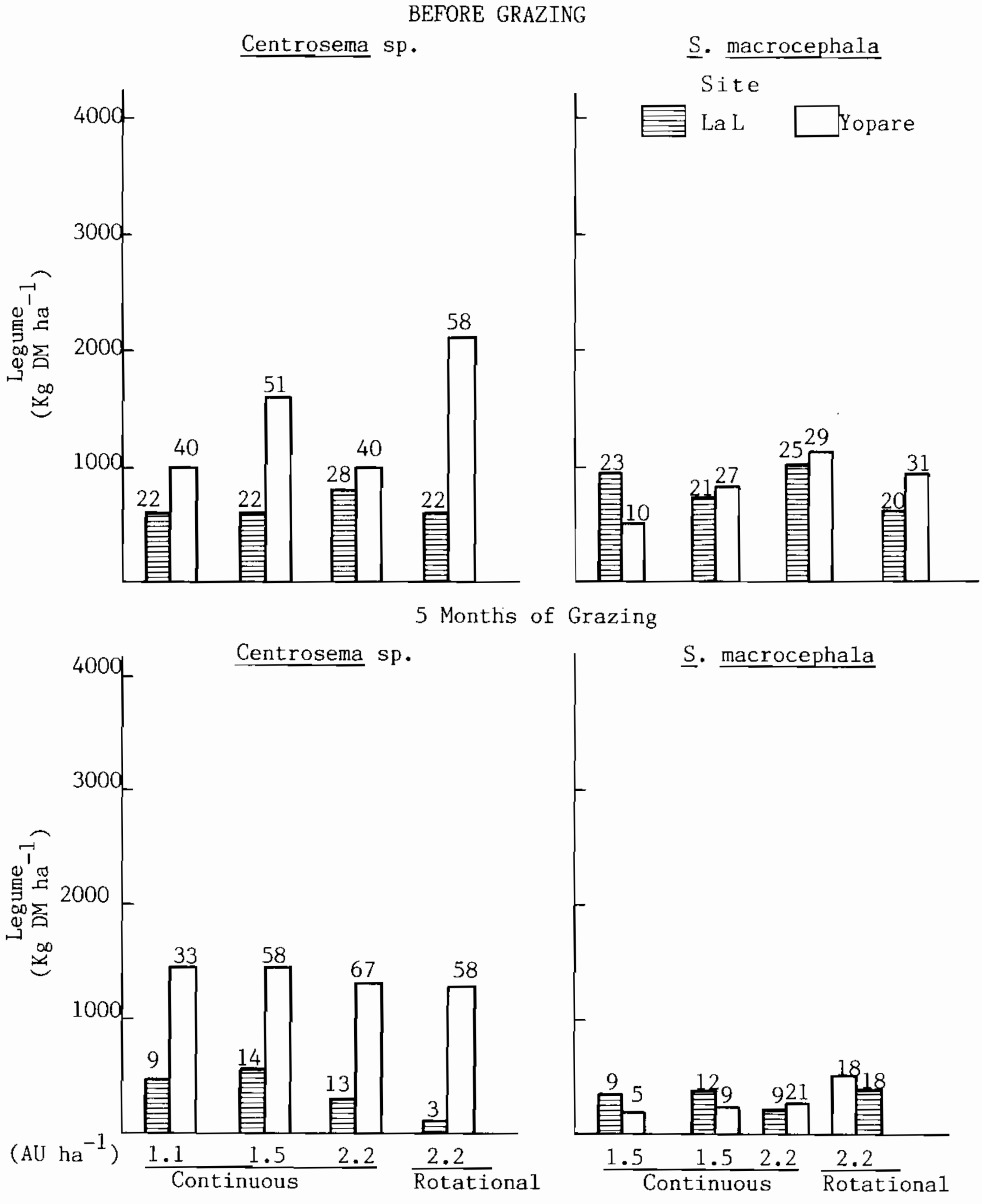


Figure 10. Legume availability in *Andropogon gayanus* pastures at two sites and under different management treatments (Carimagua).

Table 10. Liveweight gains in <u>Andropogon gayanus</u> with legumes under different stocking rates and grazing systems (110 days rainy season) (Carimagua).

Pasture	Site	Continuous			Rotational
		Stocking rates (AU ha^{-1})			
		1.1	1.5	2.2	2.2
		g A^{-1} day-1			
A. gayanus +	La L	1246	1177	1123	892
Centrosema spp.	Yopare	981	913	909	1054
(5277 + 5568)					
A. gayanus +	La L	1360	1396	948	930
S. macrocephala	Yopare	932	978	890	875
(1643)					

1/AU = 350 kg LW.

NUTRITIONAL STUDIES UNDER SAVANNA CONDITIONS

In order to integrate improved pastures into extensive production systems such as those in the Colombian Llanos, it is necessary to understand the nutritional constraints of the native pastures. With this objective in mind, detailed studies are being conducted in a well-drained savanna, managed with burning and initially supplemented with a legume bank (Annual Report 1984) and more recently with no supplement. From the first study it was concluded that in savanna + protein bank animal performance could be limited by an excess of protein intake relative to energy. This led to the hypothesis that in well-drained savannas managed with traditional burning energy could be as or more limiting than protein for animal production.

To prove the hypothesis a study was initiated in 1985, to determine the quantity and quality of forage on offer, animal selectivity, intake and animal weight gains on native savanna. The results obtained during the dry season and the beginning of the rainy season (Table 11) show that animals at the low stocking rate maintained their weight, but lost weight at the high stocking rate. These differences are related to a higher energy and protein intake at the low stocking rate compared to the high stocking rate. It is evident from these results that during the dry and early rainy seasons both energy and protein are limiting animal production in the savanna managed with burning. It is unlikely that intake was negatively affected by a protein deficiency per se, since the selected diet contained 6.4% and 7.7% of protein in the high and low stocking rates, respectively. Instead, it is thought that factors limiting consumption were low forage availability in the areas burnt at the end of the rainy season and the dry season where cattle preferentialy graze and low digestibility of the forage consumed.

Table 11. Nutritional characterization or a well-drained savanna managed with burning during the dry and early rainy savanna (Carimagua).

Variable	Dry-early rainy season[1]	
	Stocking rates	
	(0.37A ha^{-1}	(0.75A ha^{-1})
OM digestibility (%)	39.8	37.7
OM intake (kg/100 kg PV/day)[2]	1.5	1.3
Met. E. intake (MCAL/day)	2.0[a]	1.6[b]
Protein intake (g/day)	128.0[a]	93.0[b]
Change in weight (g/A/day)	+17	-58

1/ February-April, 1985.
a,b, different means ($P < .05$).

Since the daily consumption of mineral supplement is being monitored in this study, it was possible to calculate a mineral balance during the dry season and early rainy season. The intake of salt-mineral supplement with 8% P was 42 and 44 g for the low and high stocking rates, respectively. Considering the mineral contributions from the most selected plant part (leaves) and/or from the mineral supplement (Table 12) it is evident that minerals examined are close to or exceed the relatively high requirements of NRC (1976) for growing animals. From these results it is suggested that during the dry season mineral supplementation is required, since the forage alone cannot supply major elements such as P and S to meet the animal's requirements. However, in the best of cases, animals only maintain their weight even with mineral supplementation, most likely as a consequence of an energy and protein deficiency.

METHODOLOGICAL STUDIES

A complementary research activity of the Pasture Quality and Productivity Section is related to the development of methodology for germplasm evaluation under grazing. The first results of a methodological trial in Carimagua supported by IDRC of Canada were presented in the 1984 Annual Report. The objective of this trial is to evaluate the effect of individual and common grazing on legume productivity and persistence when in association with grasses. The trial entered its second grazing year and the following are the results obtained up to now.

Grazing of *Melinis minutiflora* was suspended since the legumes associated

Table 12. Minerals provided to growing steers grazing native savanna managed with fire and supplemented during the dry and early rainy seasons. (Carimagua, 1985).

Mineral Element	Source	Stocking rate ($A\ ha^{-1}$) High (0.75)	Low (0.37)	Req[1] (NRC)
	Available leaves	0.08	0.07	
P (%)	Supplement[2]	0.10	0.08	.18
	Total	0.18	0.15	
	Available leaves	0.12	0.11	
Ca (%)	Supplement	0.17	0.14	.18
	Total	0.29	0.25	
	Available leaves	0.06	0.06	
S (%)	Supplement	0.03	0.02	.10
	Total	0.09		0.08
Minor elements				
Cu (PPM)	Supplement	10	8	4
Zn (PPM)	Supplement	52	41	20-30
Co (PPM)	Supplement	0.10	0.08	0.5-1.0
I (PPM)	Supplement	0.98	0.78	-

1/ Requirements NRC (1976) for growing animals of 200 kg.
2/ Salt + mineral mix with 8% P.

with this grass practically disappeared independently from the treatments applied. In the case of the legumes associated with A. gayanus, S. guianensis var. pauciflora 1283 disappeared due to a severe anthracnose attack and C. macrocarpum 5065 due to poor persistence under grazing (Figure 11). On the other hand, the availability of S. capitata cv. Capica (10280) and C. brasilianum 5234 has decreased with time, while that of S. macrocephala 1283 has remained constant (Figure 11).

The analysis of legume availability data as a function of type of grazing, i.e. legumes grazed individually or in common is presented in Table 13. The

Table 13. Effect of individual and common grazing on the availability of three legumes associated with Andropogon gayanus[1].

Legume	Type of grazing Individual[2] ($kg\ DM.Leg\ ha^{-1}$)	Common[3]
S. capitata 10280	230	158
S. macrocephala 1643	331	171
C. brasilianum 5234	157	70

Analysis: Leg ($P < .25$); Type of grazing (TP) ($P <$ 10); TP x Leg ($P < .82$).

1/ August, 1985 evaluation (1.5 years of grazing). 2/ One legume sown per grazing plot. 3/ Five legumes sown per grazing plot.

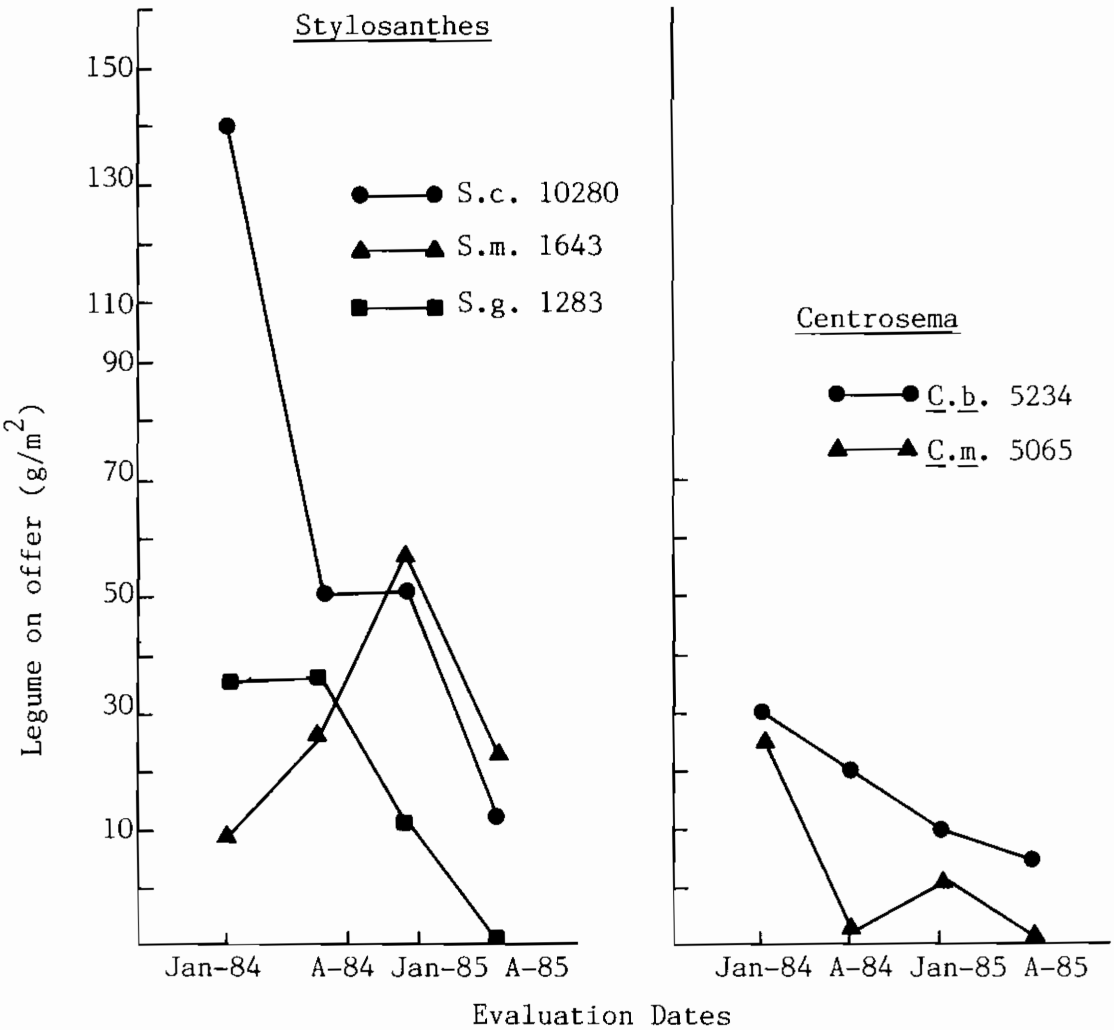


Figure 11. Changes over time on the amount of legume on offer when in association with Andropogon gayanus (Methodological study Carimagua).

availability of legumes has been higher ($P < .10$) under individual grazing than under common grazing (initially five legumes planted per plot), with no significant interactions for legumes x plot type or plot type x stocking rate. After 1.5 years of grazing legume availability has not been significantly affected by stocking rates. On the average, the amount of legume during the rainy season (August, 1985) was 179 kg/ha at the low stocking rate and 201 kg/ha at the high stocking rate.

The results up to now indicate that the productivity of legumes included in the trial has been affected by type of grazing (i.e. individual or common), the availability being higher when individual grazing is applied. However, the effect of type of grazing has not interacted with legume species or with stocking rate, which is contrary to what was suggested from the initial data reported in 1984.

The disappearance of some of the legumes planted in this trial, point out the need of using in methodological trials, germplasm of known adaptation and persistence, since otherwise interpretation of the results becomes considerably difficult.

Ecophysiology

Various new genera, species and ecotypes of grasses and legumes are moving to advanced evaluation under grazing. Consequently, it is necessary to define management practices that assure both high animal productivity and persistence of the germplasm under grazing. However, with most new germplasm there is insufficient information on which to formulate management systems. In order to address this deficiency, a programme of ecophysiology of pastures was initiated with the appointment of a new member of senior staff at mid-year.

The objectives of the programme are to seek understanding of the interactions between the germplasm and the grazing animal in order that the consequences of the various management options on both the productivity and the persistence of the components of a pasture may be predicted.

An attempt has been made to provide a conceptual framework by which these objectives may be achieved.

Consideration of the behaviour of grazing animals and the reaction of plants to being grazed suggests that in details the question is very complex. However, it appears to be possible to simplify the system into a small number of discrete functional relationships, which together describe the interactions.

1. The response of the amount of pasture consumed by the animal to the amount of pasture on offer (the consumption function).

2. The response of the proportion of legume in the diet of the animal to the proportion of legume in the feed on offer (the selectivity function).

3. The response of growth rate of each component to its residual leaf area (the growth rate function).

4. The proportion of dead material as influenced by total dry matter yield (the senescence function).

5. The response of the proportion of each component in the regrowth to its proportion in the herbage at the start of regrowth.

6. The trends with time in the proportion of meristems of each component as influenced by density, age and sward state.

Clearly these response functions have to be defined for each association. It is also necessary to determine the extent to which the responses are environment and density dependent. Once they are defined, it should be possible to simulate the behaviour of the pasture when the various management options are applied.

It is planned to define these functional relationship for the associations of <u>Stylosanthes capitata</u>/ <u>Andropogon gayanus</u>, <u>Desmodium ovalifolium</u>/ <u>Brachiaria dictyoneura</u>, <u>Centrosema</u> sp./

Andropogon gayanus, and Arachis pintoi/ Brachiaria brizantha, which are presently in Categories III and IV.

Small plots of a range of compositions of each association will be established during 1986. These will be grazed by cattle with oesophageal fistulae in a rotational system at a range of grazing pressures, which will be manipulated in order to maintain a range of sward states. Measurements will be made to estimate both the amount and composition of the pasture consumed. Supplementary measurements on smaller ungrazed plots will be required to estimate the growth, senescence and competition functions.

There are currently in Category III experiments with associations of Centrosema spp./ Andropogon gayanus, Desmodium ovalifolium/ Brachiaria dictyoneura and Arachis pintoi/ Brachiaria spp., to which some modifications can be made to the grazing management and sampling without compromising the original objectives. Although the plots in these experiments do not cover a wide range of compositions, which limits the range of the data, it is planned to graze these with cattle having oesophageal fistulae and to collect data towards defining the functions described above. The modification will be initiated early in 1986.

Stylosanthes capitata sown in savanna

In addition to the programme outlined above, work was undertaken during the year to understand the behaviour of Stylosanthes capitata cv. Capica sown in rows in a savanna.

In order to investigate low-cost methods of introducing legumes into savanna, in 1982 pairs of rows of S. capitata 0.5 m apart were planted at varying frequencies (termed savanna supplementation). Various management treatments (burning and stocking rates) were superimposed. Of critical importance to the success of the technique is the rapid spread of the legume into the adjacent undisturbed savanna, and the maintenance of a sufficient population of the legume. However, in general S. capitata has not been as successful in this experiment as was expected. Measurements of overall composition and rate of spread of S. capitata have been supplemented with a detailed study of the population dynamics of S. capitata in order to seek some understanding for its poor performance.

Overall composition

The botanical composition of each paddock is being monitored by means of the Botanal procedure (Tothill et al. 1978 Trop. Agron. Tech. Mem. No.8, CSIRO Australia). The initial survey (Fig.1) showed that all plots contained a suite of five major species: Andropogon leucostachys, Paspalum pectinatum, Leptocoryphium lanatum, Paspalum sp. and Andropogon bicornis. There were no clear trends in the composition between treatments except that the burned treatments had more Paspalum sp. and less Andropogon leucostachys than the unburned treatments.

Further observations will be made in early 1986.

Because Stylosanthes capitata was sown in a regular pattern, the systematic sampling system used underestimated its contribution to the composition.

Spread from sown strips

The spread of S. capitata into the savanna from the rows in which it was planted was assesed using twenty 4-m transects placed in each plot. Each transect extended 1 m to either side of the planted pair of rows. The results confirmed those of 1984 (Annual Report, page 172). In all

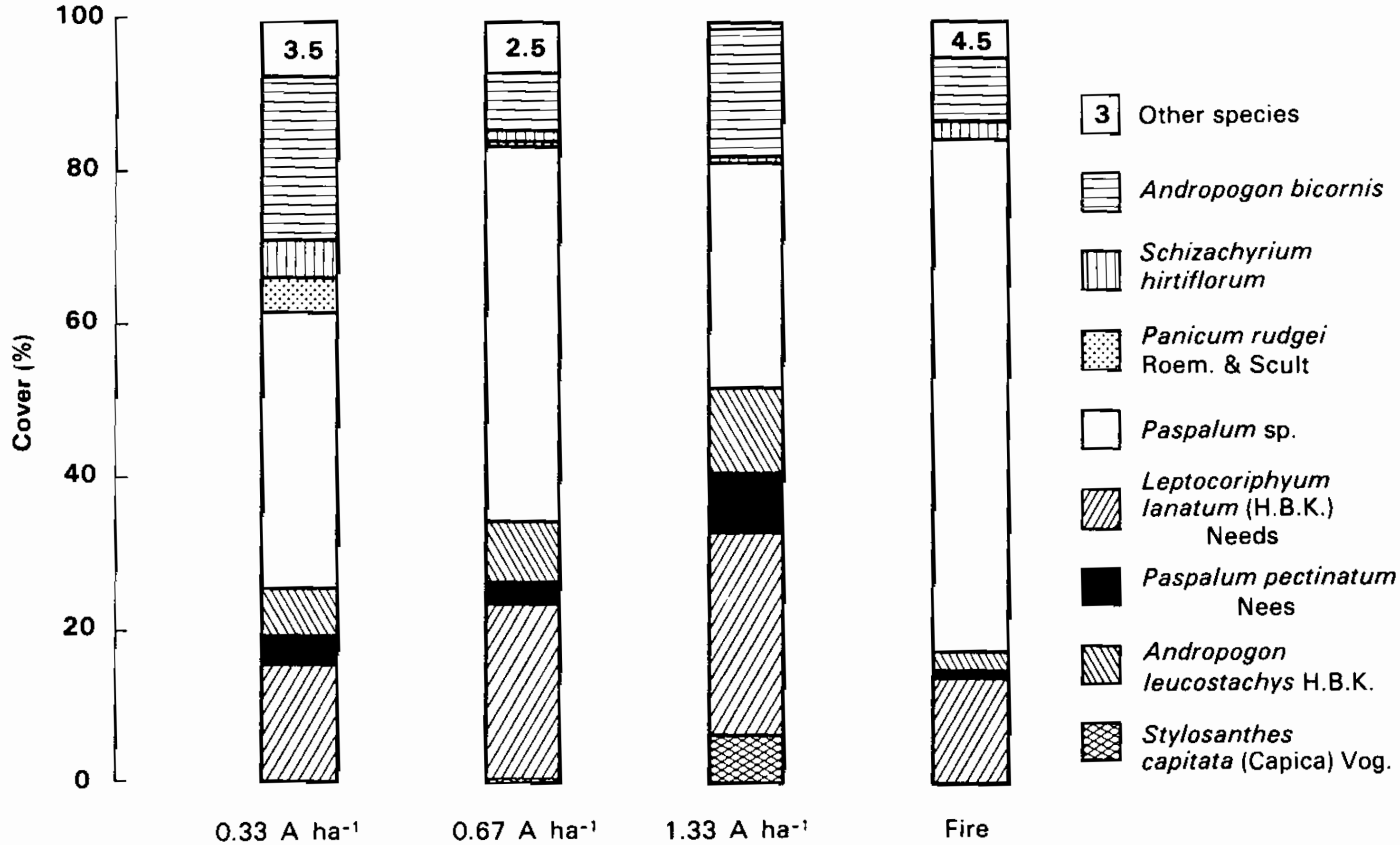


Figure 1. Species composition of savanna supplemented with *Stylosanthes capitata* sown in rows. The treatments superimposed were three rates of stocking and burning. Composition was estimated using the Botanal procedure.

treatments the spread of *S. capitata* from the planted strips is very limited, but it is greater at the higher stocking rate (Fig. 2).

It was also observed that *S. capitata* plants have established far from the strips, but they are so infrequent that much more intensive sampling than that used would be required to detect them.

Population dynamics

Ten permanent quadrats were established in each of two replicates of three treatments in the savanna supplementation experiment (Table 1), with the objective of following the fates of individual plants within them. The quadrats measured 1 m x 0.25 m and were selected so as to include where possible mature plants juveniles and seedlings within each population. The total population in the 60 quadrats was some 3000 plants.

Quadrats were mapped each month May-December, and each plant was scored for eleven morphological attributes including a primary classification into seedlings, juvenile plants, mature plants and dwarf plants. The latter are stunted plants with few short branches, small leaves and short internodes, which although they comprise less than ten percent of the legume component, are a cause of some concern because of their obvious low productivity.

The plants present at the start of the experiment (Cohort 1, Figure 3) were augmented by a decreasing number of new recruits (Cohorts 2, 3, 4) as the rainy season progressed, which is consistent with the behaviour of a hardseeded legume. So far as is possible to assess with the limited range of data, survivorship (the slope of the logarithmic transform of density with time) was constant between cohorts.

The survivorship within each of the four classes (figure 4) was more or less constant with time, although between classes the survivorship of juveniles > mature plants = seedlings > dwarf plants. However, differences in survivorship were small.

In the high stocking rate, which also had a higher proportion of the area sown to legume and fertilized, plant densities were about 4 times those of the medium stocking rate, which in turn were somewhat greater than those of the low stocking rate (Figure 5). Examination of the data for each cohort within the treatments shows that survivorship was similar, but the absolute numbers in each cohort was much higher in the high compared with the low stocking rate treatment (Figure 5).

Comparison of the class structure of the initial population (Cohort 1) shows that there are about twice as many juveniles as mature plants in the high stocking rate compared with about one-fifth as many juveniles as mature plants in the low stocking rate (Figure 6). Moreover both juvenile and mature plants in the high stocking rate live much longer than in the low stocking rate treatments (half lives of 251 and 131 compared with 164 and 95 days, table 2). It is plausible to speculate that these observations reflect historical trends, and that the lower recruitment at low stocking rate is a reflection of the greater mortality in this treatment.

In this experiment each plot is grazed by three animals and the different stocking rate treatments are achieved with different plot sizes. However, within each plot the same absolute area was sown with *S. capitata* and given fertilizer. Therefore not only is a greater proportion of the area in the high compared with the low stocking rate sown to *S. capitata* (Table 1), but it also received a higher mean level of fertilizer. The

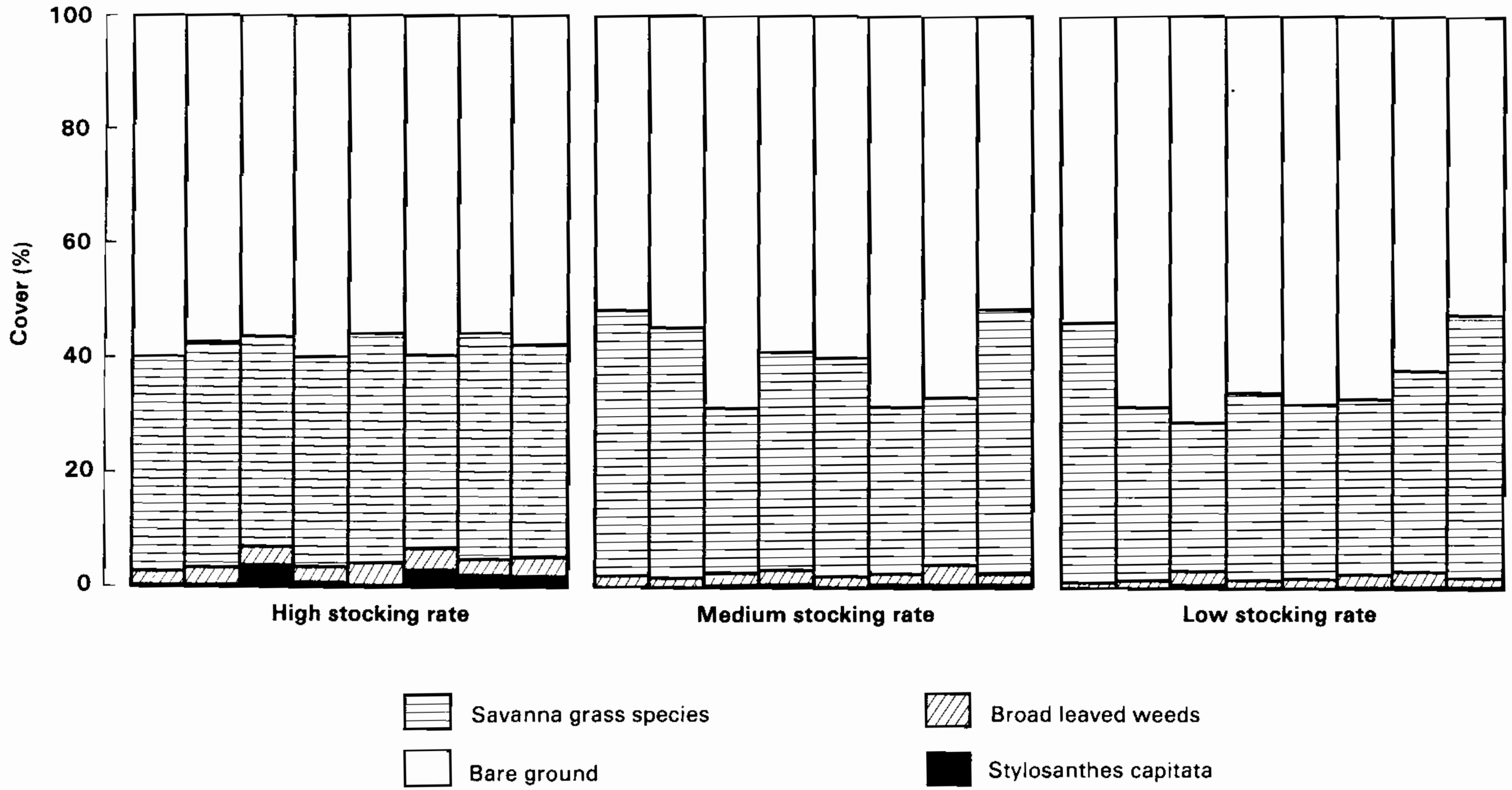


Figure 2. Percent cover in transects across rows of *Stylosanthes capitata* planted in a savanna, and grazed at 1.33, 0,67 and 0.33 animals ha^{-1}.

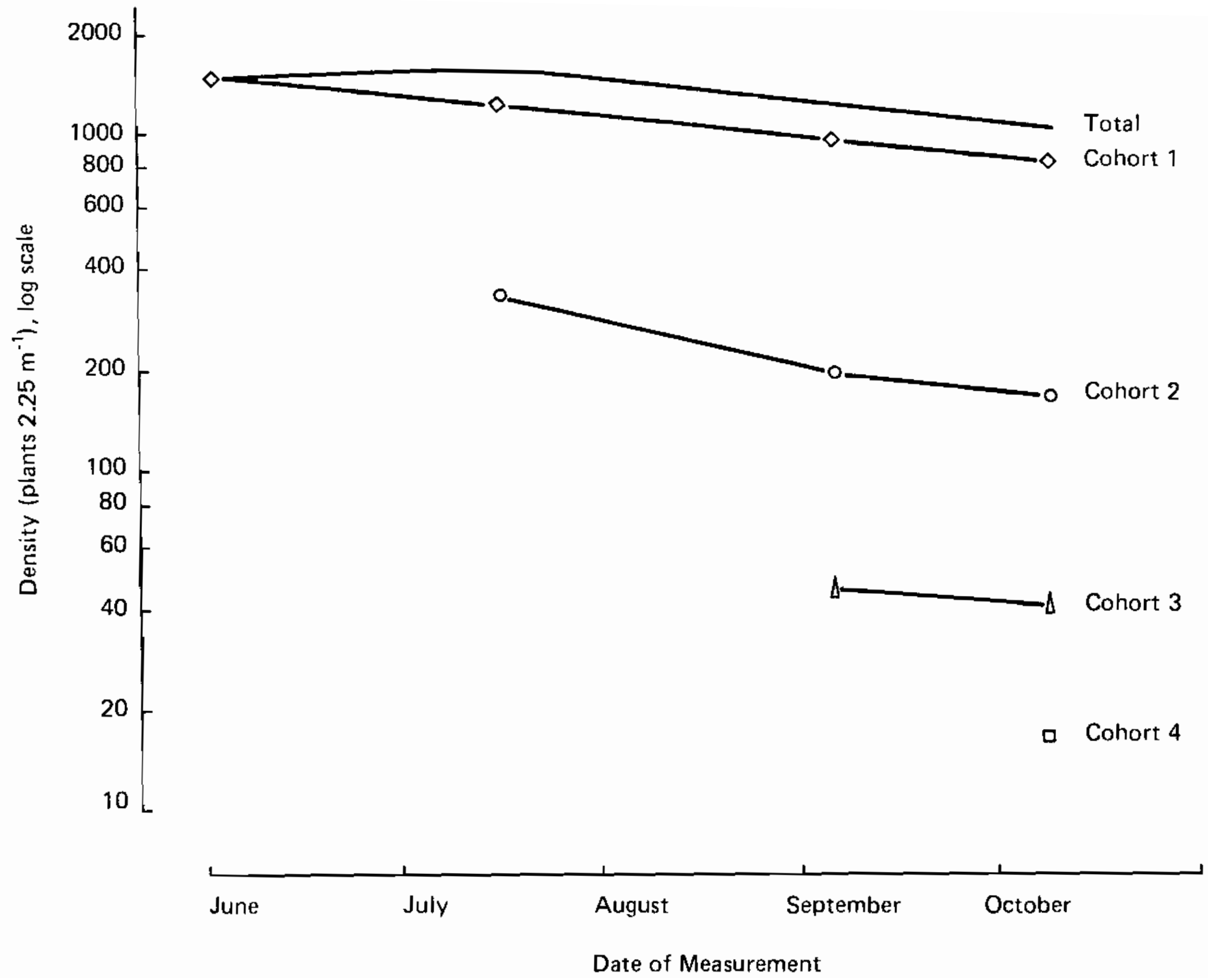


Figure 3. **Changes in density of cohorts of *Stylosanthes capitata* plants in a savanna. Cohort 1 was the initial population in May 1985, and Cohorts 2, 3 and 4 are new plants at subsequent times of measurement. Data are meaned over three stocking rate treatments.**

Table 1. Treatments of the savanna supplementation experiment at Carimagua in which permanent quadrats were established. *Stylosanthes capitata* cv. Capica was sown in May 1982 and resown in 1983, and the experiment has been grazed continuously since May, 1984. Each treatment contains the same total area of legume, and fertilizer was applied only to the sown area. There are two replicates, and ten quadrats were established in each plot

Stocking rate (animals ha^{-1})	Distance between planted rows of *S. capitata* (m)	Proportion of area fertilizer (%)
1.33	5	20
0.67	10	10
0.33	20	5

Table 2. Half lives (days) of four different calsses of plants of *Stylosathes capitata* cv. Capica sown into savanna and grazed at three stocking rates. Half lives were calculated for the period May to September 1985.

Plant Type	Stocking Rate A ha^{-1} 0.33	0.67	1.33
Seedling + cotyledons	119	-	107
Young plant	164	260	251
Mature plant	95	107	131
Dwarf plant	88	62	62
Pooled	97	140	191

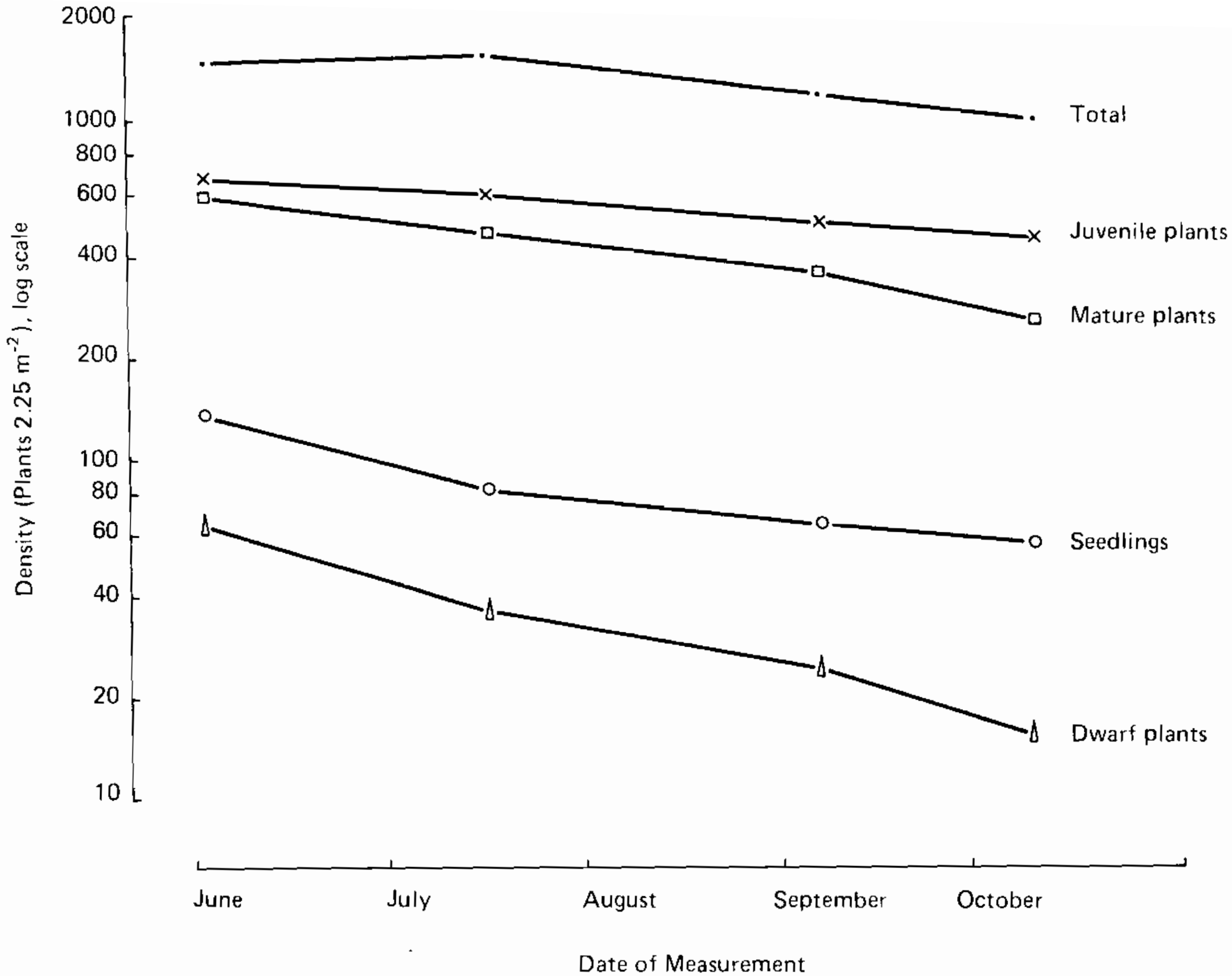


Figure 4. **Changes in density within each of four classes of *Stylosanthes capitata* that comprised the initial population in May 1985 (Cohort 1). Data are meaned over three stocking rate treatments.**

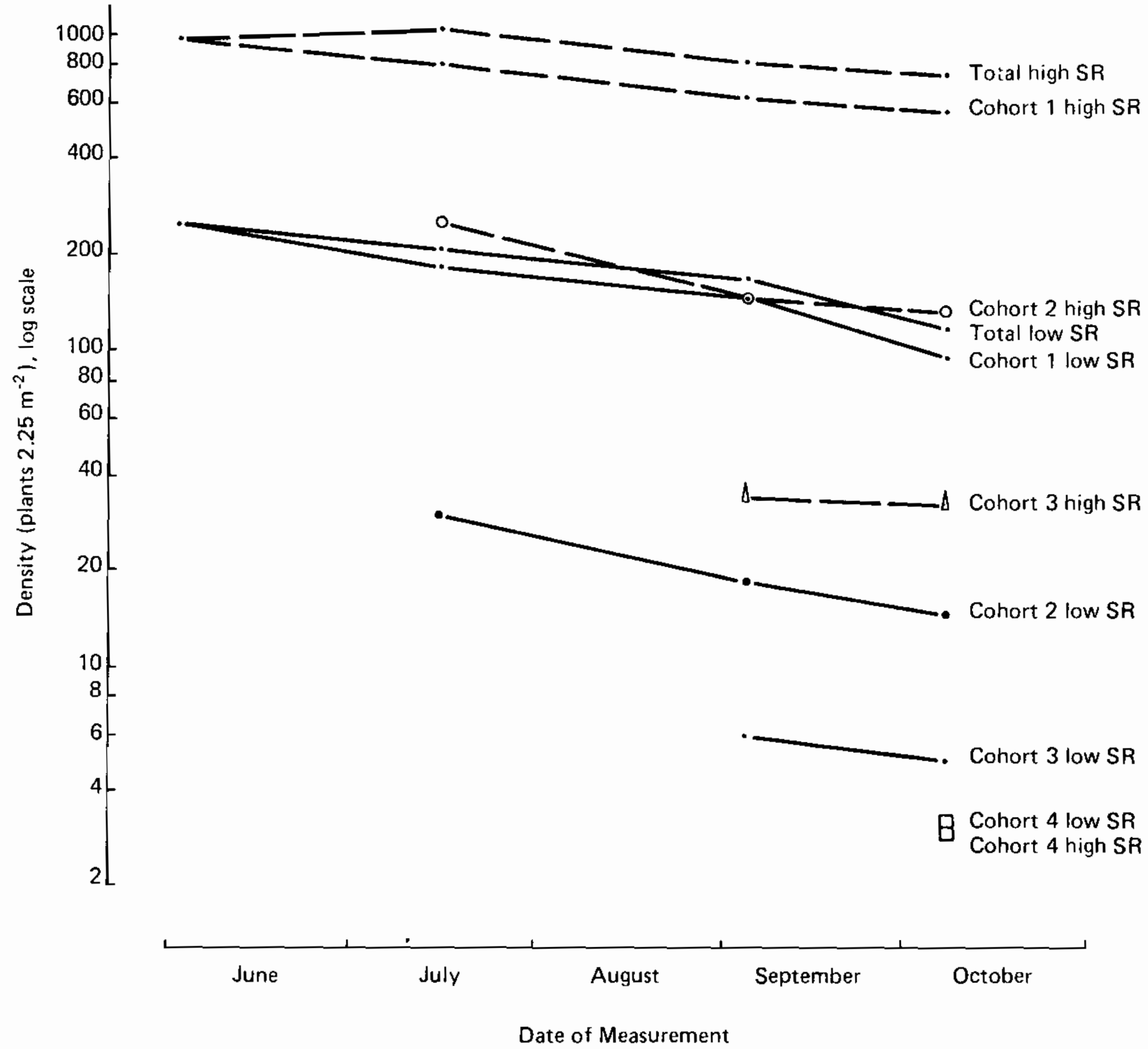


Figure 5. **Changes in the density of cohorts of *Stylosanthes capitata* plants in a savanna at high and low stocking rates (1.33 and 0.33 animals ha^{-1}).**

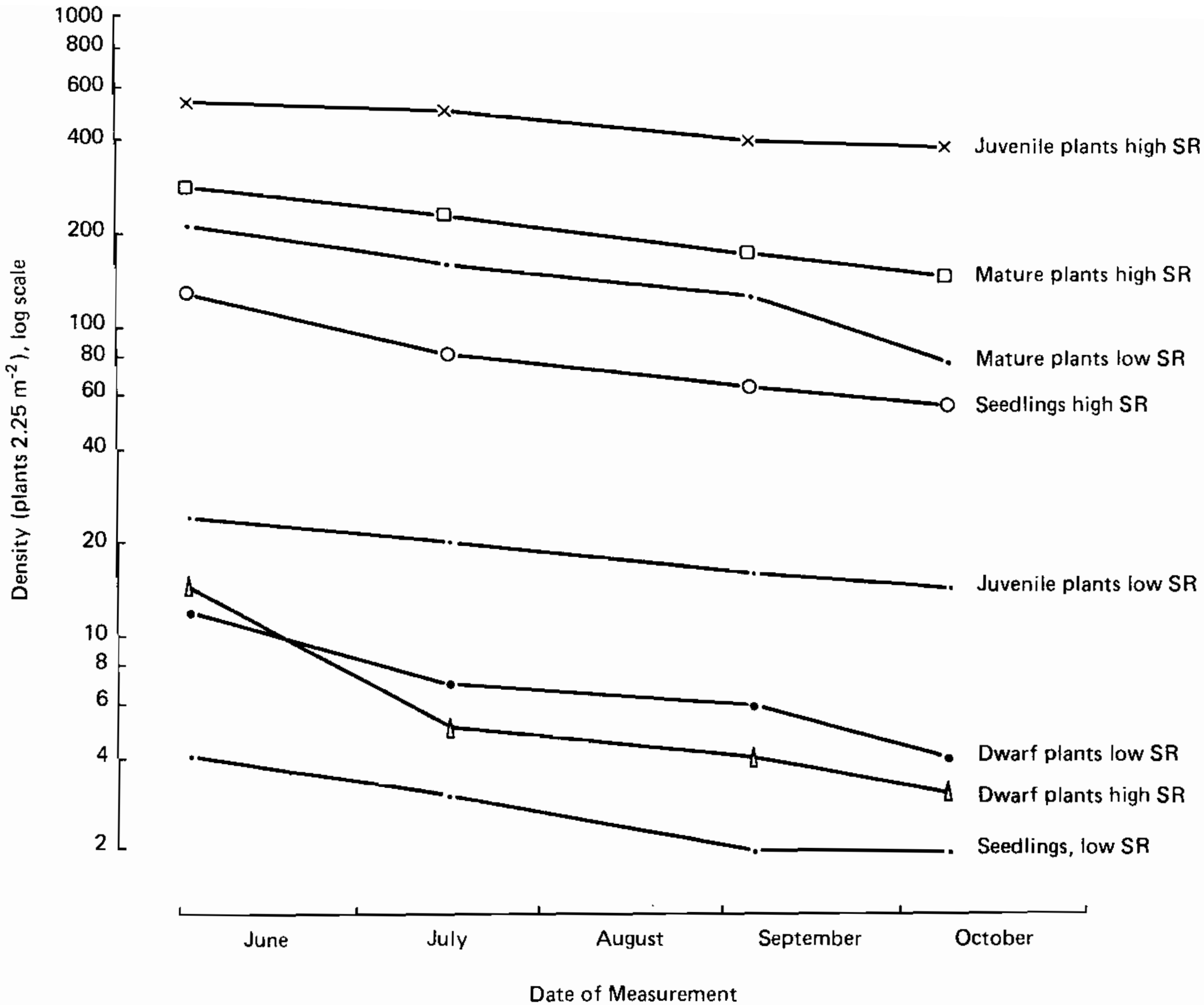


Figure 6. **Changes in density within each of four classes of *Stylosanthes capitata* that comprised the initial population in May 1985. (Cohort 1) within the high and low stocking rate treatment.**

observed behaviour of *S. capitata* in this experiment cannot therefore be attributed unequivocally to stocking rate. It is of interest however that seedling mortality is not influenced by stocking rate, although one can only speculate on the reasons.

There has been some concern about the occurrence of dwarf plants in associations of *S. capitata*. In this study they comprise only five percent,or less of the population. Close observation in the field suggests that incesant grazing by leaf cutting ants (*Atta* sp. and *Acromyrex* sp.) may be responsible in part.

Frequently dwarf plants are infested by sucking insects (tentatively identified as *Parallaxis donalsoni* or *P. gizmani*). In order to assess the general level of infestation, an evaluation of number of *S. capitata* plants affected was made during the rainy season. In August/September 3 to 8 percent of plants in the low and medium stocking rates were affected compared with 32 percent in the high stocking rate treatments. In October, however in excess of 30 percent of plants in all three stocking rates were affected.

Seed production

1. INTRODUCTION

During 1985 the Section continued an emphasis on a) seed multiplication of promising experimental materials; b) applied research on limitations to seed production of the species of major interest to the Program; c) technical collaboration with National Research Institutions.

2. SEED MULTIPLICATION AND DISTRIBUTION

Field activities were continued at Quilichao and Carimagua, while support facilities for greenhouse, seed conditions, seed analysis and distribution activities, were utilized at Palmira.

A total of 149 accessions, including 115 legumes and 34 grasses were under multiplication. With such as high number of accessions involved, the average amount of seed production per accession was reduced, in comparison to previous years.

New multiplication areas involving 9.6 and 3.5 ha for legumes and grasses, respectively were established. This included a significant expansion of areas of *Centrosema* spp. and *Brachiaria* spp. The total areas under multiplication was 32 ha.

The amounts of seeds produced of individual legume and grass species is shown in Tables 1 and 2, respectively. Total composite production was 672 kg of legume seeds and 158 kg of grass seeds, respectively.

Seed distribution was shared with the Regional Trials Section, which responds to requests from its collaborators. During the year, a total of 424 requests for seed were handled, involving the distribution of a total of 1,731 kg seed (Table 3). The vast majority of the requests and seeds delivered were related to germplasm and pasture evaluation activities. The number of requests for seed multiplication activities increased slightly in relation to those of last year.

At the end of 1985, the amounts of seed in short-term storage included a total amount of 3,500 kg of various legumes and 207 kg of various grasses.

3. APPLIED RESEARCH

a) Pre-harvest management of *B. dictyoneura*

An established seed multiplication area was utilized to compare aspects of the pre-harvest management of *B. dictyoneura* CIAT 6133 at Carimagua.

The experiment involved a factorial treatment design and a split plot experimental design. The treatments were: a) two methods of crop preparation, as main plots; b) five types of fertilizer application, as split-plots and; c) 2 times of fertilizer application, as split-split plots. The actual sampling area for

Table 1. Summary of activities in seed multiplication of legume species and accessions between October 1984-1985.

Species	Total Accessions (No.)	Multiplication areas New (ha)	Multiplication areas Total (ha)	Seed Produced[1] (kg)
A. pintoi	1	1.0	1.52	27.996
C. brasilianum	13	2.361	2.427	0.763
C. macrocarpum	18	0.36	1.324	56.397
C. pubescens	2		0.092	1.305
C. rotundifolium	1	0.005	0.007	0.141
Centrosema sp.	4	1.2	2.39	99.992
C. schiedeanum	2	0.005	0.009	
C. rotundifolia	2	0.01	0.01	
C. brasiliensis	1	0.002	0.002	
C. floribunda	1	0.002	0.002	
D. heterocarpon	4	0.057	0.127	1.395
D. heterophyllum	3	0.001	0.272	3.470
D. ovalifolium	13	0.958	1.426	40.235
D. strigillosum	4	0.087	0.087	
D. velutinum	1	0.004	0.004	
D. guianensis	2	0.024	0.024	
P. phaseoloides	11	0.185	3.185	
S. capitata	3	2.02	3.121	341.523
S. guianensis	9	0.317	0.317	7.835
S. guianensis var. *pauciflora*	8	1.04	2.309	33.053
S. macrocephala	5		1.35	36.161
Tadehagi sp.	2	0.008	0.008	
Z. latifolia	1	0.003	0.003	0.135
Z. glabra	1		0.58	10.604
Leucaena spp.	3		0.033	10.740
Totals	115	9.649	20.629	671.763

1/ Classified seed with more than 90% of pure seed.

Table 2. Summary of activities in seed multiplication of grass species and accessions between October 1984-85

Species	Total Accessions	Multiplication Area		Seed Produced[1]
		New	Total	
	(No.)	(ha)	(ha)	(kg)
A. gayanus	3	0.005	0.215	21.540
B. brizantha	5	0.001	1.451	4.834
B. decumbens	3	0.002	1.202	16.042
B. dictyoneura	1	3.2	7.6	104.7
B. humidicola	5	0.003	0.378	0.271
M. minutiflora	4	0.004	0.004	0.175
P. maximum	8	0.003	0.133	10.632
P. coryphaeum	1	0.001	0.001	
P. guenoarum	1	0.001	0.001	
P. secans	1	0.001	0.001	
P. purpureum	1	0.001	0.001	
King Grass	1	0.26	0.26	
Total	34	3.482	11.247	158.194

1/ Classified seed with more than 40% of pure seed.

Table 3. Seed distribution of grasses and legumes between October 1984-85

Type of request	No. of Requests	Seed volume (kg)		
		Grasses	Legumes	Total
A. Germplasm and Pastures Evaluation				
PPT members	143	128	949	1.077
Regional Trials	112	115	100	215
National Institutions	83	16	244	260
CIAT's other Programs	36	3	54	57
Private	23	2	8	10
Subtotal	397	264	1.355	1.619
B. Seed Multiplication				
CIAT Seed Unit	15	5	36	41
National Institutions	12	26	45	71
Subtotal	27	31	81	112
C. Total	424	295	1.436	1.731

seed yield within the sub-sub plots was 16 m^2, and there were three replications.

The results from the analysis of variance of pure seed yield are presented in Table 4. The two methods of crop preparation, ie. burning vs burning plus discing, did not differ statistically. Apparently, the additional practice of discing after burning does not increase seed yield. There was a significant interaction between type of fertilizer and time of application. When applied early, ie. immediately after crop preparation, those treatments including 100 kg/ha of nitrogen gave higher seed yields than those without nitrogen. In addition, the single application of 100 kg/ha of N was superior to the split application. The late application of fertilizers, ie. three weeks after crop preparation, showed only a response to basal application (P+K+Mg) and no response to nitrogen. The responses in pure seed yield were related to the density of inflorescences which showed similar response patterns to fertilizer applications, Table 5.

b) Harvest methods in B. dictyoneura

At Carimagua in July 1985 during the harvest of a seed multiplication area, comparisons were made of three alternative harvest methods (direct combining; hand harvest without heaping and hand harvest with heaping). In addition, several variations of the heaping phase were included. The experiment included a total of eight harvest treatments, with 3 repetitions in a randomized complete block design.

Pure seed yields of the various treatments are presented in Table 6. The hand harvest with heaping method (35.7 kg/ha) was significantly superior to both direct combining method (11.3 kg/ha) and hand harvesting without heaping (14.0 kg/ha). Apparently, hand harvesting with heaping methods favors the collection and separation of a higher amount of pure seed. The variations in form and duration of heaping did not result in any differences in pure seed yield. Measurements of tetrazolium viability and germination of pure seeds at 30 days post-harvest, showed no significant differences between the harvest treatments.

c) Post-harvest germination and viability in Brachiaria spp.

Three lots of similar age of each of B. decumbens, B. dictyoneura and B. humidicola were stored in favourable conditions. During the period until 210 days post-harvest (dph), determinations of germination and tetrazolium viability were made periodically. Germination was measured in three treatments: G_0= in water; G_1= KNO_3 (0,2% at first watering); and G_2= 15 minutes of acid sulphuric (Conc.H_2SO_4) scarification then KNO_3 (as in G_1). Results are presented in Figure 1.

During the 240 day period of the experiment, tetrazolium viability values were high and relatively constant in each of the three species.

In B. humidicola, the germination treatment G_0 increased over time to reach a maximum value of 30% at approximately 150 dph. G_1 gave the highest values at all times and gave values equivalent to tetrazolium after 90 dph. G_2 was higher than G_0 but slightly inferior to G_1.

In B. decumbens, the germination treatments G_0 and G_1 increased over time to reach a maximum value of 28% at 120 dph. The highest germination values were provided by G_2 which reached a maximum of 54% at 120 but did not reach the values for tetrazolium viability.

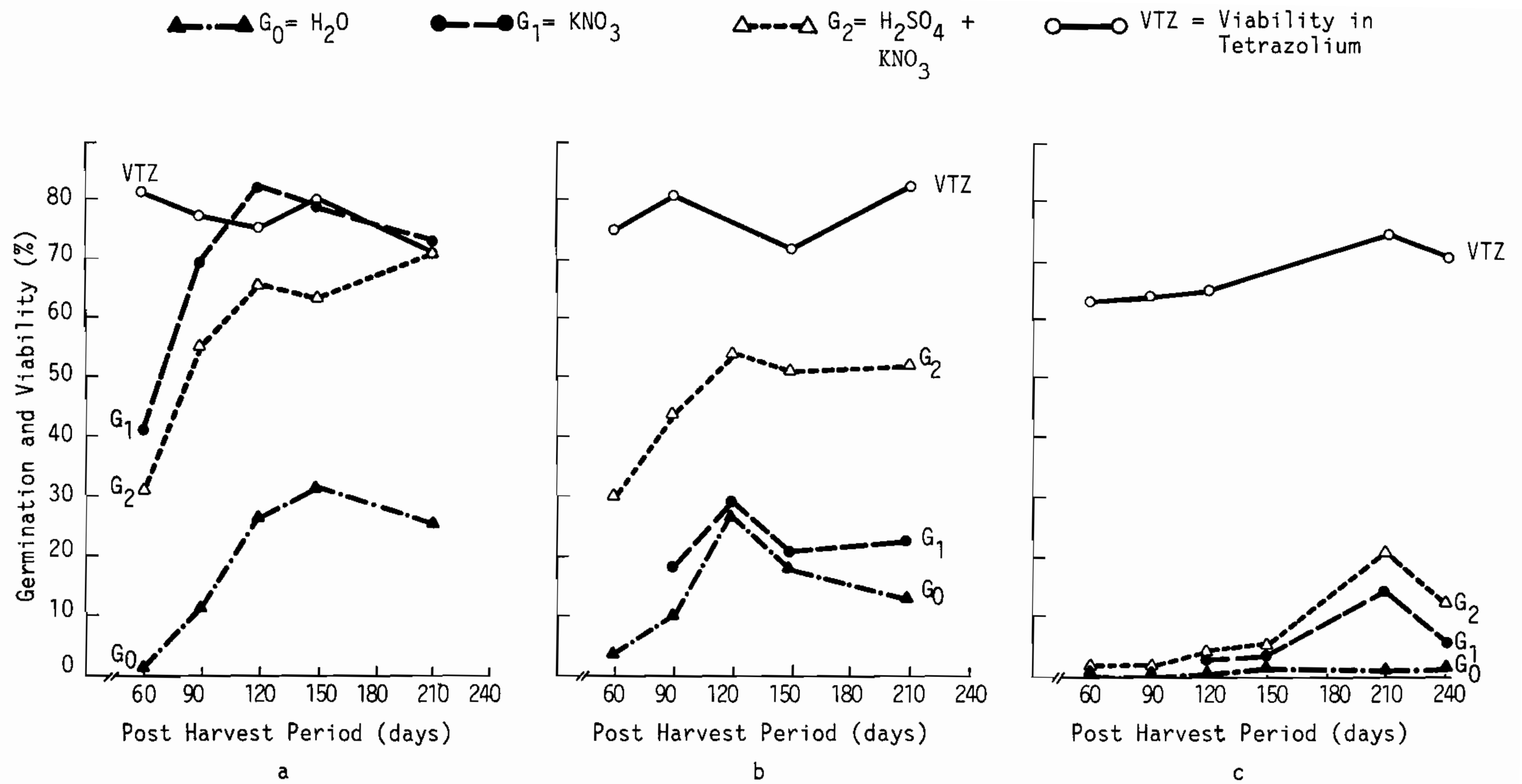


Figure 1. Comparison of seed viability and three germination treatments during the post-harvest period in three species of Brachiaria.

Table 4. Pure seed yield according to the pre-harvest management treatments in an established crop of Brachiaria dictyoneura CIAT 6133, Carimagua, July 1985.

Factor	Treatment Description	Pure Seed Yield ($g/16\ m^2$)	
A.	Method of crop preparation[1]		
	1. Burnt	161.7 A*	
	2. Burnt + disced	138.1 A	
B.	Type of fertilizer[2]		
	1. Nothing	99.1	
	2. Basal	130.4	
	3. 100 N	182.0	
	4. Basal + 100 N	188.6	
	5. Basal + 50 N + 50 N	149.3	
C.	Time to apply fertilizer[3]		
	1. Early	172.2	
	2. Late	122.5	
B x C	Type of fertilization x time of application		
		Early	Late
	1. Nothing	94.9 C	103.2 C
	2. Basal	124.9 C	135.9 BC
	3. 100 N	241.8 A	122.2 C
	4. Basal + 100 N	252.6 A	124.5 C
	5. Basal + 50 N + 50 N	172.0 B	126.7 C

1/ Burnt; March 27. Disced, April 26.
2/ All nutrients in kg/ha
Basal = 25 P_2O_5 + 30 K_2O + 20 Mg
3/ Early: April 26
Late: May 17

* Means with the same letter are not significantly different at $P < 0.05$ according to Duncan's test.

In B. dictyoneura, the germination treatment G_0 only reached a maximum value of 1%. while G_1 and G_2 increased slowly over time to record their maximum values of only 21% at 210 dph.

The differences between tetrazolium viability and germination at any point in time reflect the magnitude of dormancy. An indirect estimate of dormancy can be calculated as the difference between the tetrazolium viability and the maximum germination recorded at any time. On this basis; a) B. dictyoneura presented the highest relative degree of dormancy and the most prolonged (approx. 60% from 60-240 dph); b) B. decumbens showed intermediate relative dormancy values (45% at 60 dph declining to 25% at 120 dph) and c) B. humidicola showed intermediate relative dormancy but declining rapidly in time (40% at 60 dph but zero at 90 dph).

In the case of B. decumbens and B. dictyoneura, the germination treatments were no completely effective

Table 5. Inflorescence density according to the type of fertilizer and time of application in *B. dictyoneura* CIAT 6133, Carimagua, July 1985.

Type of fertilizer[1]	Inflorescence Density (No./m^2)		
	Time of application[2]		Mean
	Early	Late	
Nothing	71 B*	64 B	67
Basal	68 B	69 B	69
100 N	144 A	84 B	114
Basal + 100 N	154 A	80 B	117
Basal + 50 N + 50 N	127 A	69 B	98
Mean	113	73	

1/ All nutrients in kg/ha
Basal = 25 P_2O_5 + 30 K_2O + 20 Mg

2/ Early = April 26
Late = May 17

* Means with the same letter are not significantly different at P < 0.05, according to Duncan's test.

Table 6. Pure seed yield according to the harvest methods, in *B. dictyoneura* CIAT 6133, Carimagua, July 1985.

Harvest Method	Time of threshing	Pure Seed Yield kg/1.000 m^2
Direct combined	0 days	1.13 B*
Manual without heaping	3 days	1.40 B
Manual with heaping		
- horizontal 0.6 m	3 days	4.72 A
- horizontal 0.4 m	3 days	3.04 A
- vertical	3 days	3.34 A
- vertical + fungicide	3 days	3.51 A
- vertical	6 days	3.71 A
- vertical	9 days	3.11 A
- Average		3.57 A

* Averages having the same letter are not significantly different from P < 0.05 level, according to Dunca's test.

against dormancy. In such cases such germination treatments need to be complemented by a tetrazolium viability determination on the ungerminated seeds to obtain a direct estimate of dormant seeds.

d) Seed yield profiles

Throughout 10 years of seed multiplication activities, seed yield data has been compiled including information from several locations, but mainly from Palmira, Santander de Quilichao and Carimagua. The file includes the amount of seed produced (kg), harvested area (ha), maturity date, plot age and harvest method. From this information, calculations can be made of the average, range, and standard deviation of seed yields of each species for each age of crop. Initially, this information has been abstracted only for areas greater than 0.01 ha, and for those species having a minimum of 5 observations. Summaries for various grass and legume species are shown in Table 7 and 8, respectively.

Once a large number of these independent observations for a given species are available, a more detailed analysis could be carried out for each location, harvest and harvest method, (Tables 9 and 10).

Obviously, since these are independent observations the utility of such seed yield profiles are closely related to the number of observations and the location involved. In the future it is planned to include related information from other locations (i.e. from within the Regional Trial Network). Once the data bank is broadened, such statistics will be useful to offer seed yield estimations to official multiplication programs and for commercial operations.

e) Monitoring of the release process and initial adoption of new cultivars

i) Andropogon gayanus cv. Planaltina in Brazil

EMBRAPA-CPAC made the decision to release the accession CIAT 621 as cv. Planaltina in early 1980. SPSB and CPAC organized a meeting with seedsmen and graziers interested in seed multiplication in May 1980. Basic seed was purchased by SPSB from CIAT in late 1980 and distributed for contract production of fiscalized seed in 1980-81, 1981-82 and 1982-83. SPSB initiated sales of basic and fiscalized seed from November 1981

Table 7. Pure seed yield profiles for several grass species.

Species	CIAT No.	Pure Seed Yield 1975-1985 in Areas > 0.01 ha (kg/ha)			
		Observations No.	Average	Range	Standard Deviation
Andropogon gayanus	621	81	76	4-261	49
Brachiaria decumbens	606	29	16	1-81	13
B. dictyoneura	6133	17	27	0-85	19
B. humidicola	679	10	3	1-12	3
Panicum maximum	604	9	17	2-53	15
Panicum maximum	622	17	7	1-27	7

Table 8. Pure seed yield profiles for several legume species

Species	CIAT No.	Pure Seed Yield 1975-1985 in Areas > 0.01 ha (kg/ha)			
		Observations No.	Average	Range	Standard Deviation
Stylosanthes capitata	1019	23	131	7-252	65
Stylosanthes capitata	1315	21	214	42-451	87
Stylosanthes capitata	1318	10	112	13-344	62
Stylosanthes capitata	1342	12	117	4-301	94
Stylosanthes capitata	1693	11	137	22-337	76
Stylosanthes capitata	1728	15	201	25-522	83
Stylosanthes capitata	10280	13	194	2-1,133	163
Stylosanthes guianensis	136	21	27	1-147	19
	184	13	32	1-88	20
S. guianensis var. pauciflora	1283	7	38	1-126	42
S. guianensis var. pauciflora	2031	7	48	7-196	48
S. guianensis var. pauciflora	2362	3	34	19-63	21
S. guianensis var. pauciflora	10136	6	29	4-75	26
S. macrocephala	1643	22	60	2-203	36
Centrosema pubescens	438	13	55	7-162	38
Centrosema sp.	5277	9	112	8-355	74
Centrosema sp.	5568	8	79	3-377	96
C. brasilianum	5234	9	243	28-1,218	233
C. macrocarpum	5062	6	135	5-296	117
C. macrocarpum	5065	5	224	22-645	109
Desmodium ovalifolium	350	31	85	2-380	71
Desmodium ovalifolium	3784	10	160	38-535	63
Zornia latifolia	728	14	93	10-241	66
Z. glabra	7847	11	50	1-145	58
Pueraria phaseoloides	9900	8	81	8-457	8

Table 9. Detailed seed yield profile for *Andropogon gayanus* cv. Carimagua 1

Location	Parameter	Pure Seed yield (kg/ha), 1975-1985 in Areas > 0.01 ha								Place average
		First harvest				Other harvest				
		Manual	Combined	Manual/ Mechanical	Average	Manual	Combined	Manual/ Mechanical	Average	
PALMIRA	Observations (No.)	12	-	-	12	34	3	-	37	49
	Average	76.3	-	-	76.3	95.0	97.4	-	95.2	90.6
	Standard deviation	53.5	-	-	53.5	57.9	105.1	-	61.8	59.7
QUILICHAO	Observations (No.)	4	-	-	4	16	-	-	16	20
	Average	50.7	-	-	50.7	69.6	-	-	69.6	65.8
	Standard deviation	50.3	-	-	50.3	36.1	-	-	36.1	38.9
CARIMAGUA	Observations (No.)	6	-	-	6	5	1	-	6	12
	Average	41.6	-	-	41.6	27.5	3.87	-	23.6	32.6
	Standard deviation	30.8	-	-	30.8	16.2	-	-	13.5	22.2
OTHER										
	Harvest average	62.2	-	-	62.2	81.5	74.1		81.0	75.9
All	Observations (No.)				81					
	Average				75.9					
	Standard deviation				49.1					

Table 10. Detailed seed yield profile for *Stylosanthes capitata* cv. Capica.

Location	Parameter	Pure Seed Yield (kg/ha), 1975-1985 in Areas > 0.01 ha								Place Average
		First harvest				Other harvests				
		Manual	Combined	Manual/ Mechanical	Average	Manual	Combined	Manual/ Mechanical	Average	
PALMIRA	Observations (No.)	-	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-	-
	Standard Deviation	-	-	-	-	-	-	-	-	-
QUILICHAO	Observations(No.)	2	-	-	2	3	-	-	3	5
	Average	157.2	-	-	157.2	52.2	-	-	52.2	94.2
	Standard deviation	215.8	-	-	215.8	60.8	-	-	60.8	122.8
CARIMAGUA	Observations (No.)	3	2	-	5	1	2	-	3	8
	Average	31.1	3.0	-	19.8	738	607.4	-	650.9	256.5
	Standard deviation	6.4	1.8	-	4.6	-	743.6	-	495.7	188.8
OTHER										
	Harvest average	81.5	3.0	-	59.1	223.7	607.4	-	351.6	
All	Observations (No.)				13					
	Average				194.1					
	Standard deviation				163.4					

(the point of actual release) and continued to sell seeds until December 1983. Independent from EMBRAPA, regional marketing of commercial seed initiated at Goiania and Campo Grande in late 1981, reflecting an informal release process occurring in parallel with the formal. This also contributed to a wide initial distribution of seeds. The formal release process of cv. Planaltina included a open distribution of a large volume of basic seed by EMBRAPA in which the established seed enterprises did not receive any preference and in actual fact, showed little interest.

CPAC organized a field day on cv Planaltina in November 1982 and over 500 persons were in attendance. The graziers of the Cerrado region were very receptive to cv. Planaltina and this resulted in a high initial demand for seeds. In spite of the difficult morphological characteristics of the spikelets (awns, pubescence, etc.) and the difficulties to remove inert matter, the combination of high initial demand and favourable ecological conditions for seed formation provided a rapid stimulus to the supply of commercial seed of good quality. It is noteworthy that the larger seed enterprises were not the most active in the initial production, in part for lack of contact with the early adopters. The most active seed enterprises were those evolving enterprises who entered into share farming agreements with the early adopting graziers. In parallel with the growth of a commercial seed supply there was a lot of on-farm seed production. This phenomenon was partially influenced for the high price of seeds in 1981-82, but also occurred naturally as graziers became aware of the quantities of seeds present within their first pastures.

The adoption of cv. Planaltina expanded almost spontaneously with a minimum of technical promotion by researcher or extension organizations and without commercial promotion by seed enterprises. On the other hand, there were cases of individuals offering technical assistance who had a large influence on some grazing companies.

In March 1985, members of the pasture programs of CPAC and CIAT conducted a survey of seed enterprises operating within the Cerrado region. Seed sales of cv. Planaltina during 1982, 1983 and 1984 were estimated at 175, 422 and 496 tons, respectively. In addition, it was estimated that 35% of areas planted were from seeds grown on-farm. From these estimates, it was calculated that a minimum of 168,000 ha had been sown to cv. Planaltina by early 1985.

In conclusion, it should be noted that the time between the point of actual release and release becoming effective was only approximately two years. This is attributed mainly to a) large volumes of basic seed and their wide distribution, b) high interest by graziers causing a high initial demand for commercial seed and, c) favourable climatic conditions for high seed yields. The adoption of cv. Planaltina continues at a significant rate. These contacts with the seed enterprises also showed the need for better liaison between researchers and the seed industry to favour interest in new cultivars, especially as regards legumes.

ii) *Stylosanthes capitata* cv Capica in Colombia.

As a result of several years of evaluation research, the CIAT Tropical Pastures Program presented a release proposal for a cultivar of *S. capitata* to ICA in December 1981.

ICA made a study of the proposal and made the decision to release in early July 1982. A tour of on-farm trials in the llanos during the phase of revision of the release proposal had a very positive influence on the decision to release. ICA and CIAT, then organized a general plan to make the actual release of the cultivar named Capica by ICA. As S. capitata accessions had been in a pre-release strategy during the previous year, a minimum volume of basic seed was available for immediate distribution.

Actual release was accomplished in phases. ICA organized a meeting with pasture seed enterprises and offered basic seed. The first delivery of basic seed (175 kg of scarified seed) was made in August 1982, so defining the point of actual release of cv Capica. Later in April 1983, ICA made available a second distribution of basic seed (160 kg of scarified seed) but with a lack of demand from seed enterprises; however, seed was also distributed to a large number of graziers. In addition, ICA published a Technical Bulletin in May 1983 summarizing research results for graziers. Finally, in November 1983, ICA conducted a Field Day in CNIA-Carimagua to draw the attention of graziers seed enterprises and the general public to cv Capica.

The phase of post-release follow-up has been characterized mainly by a continuation of management research both at CNIA-Carimagua and in the on-farm trials. These trials are increasing the understanding of the behavior of cv Capica by researchers. A complete lack of technical promotion has also characterized this phase of the release process.

The amounts of commercial seed marketed have been very limited. While not precisely documented, only one seed enterprise offered a small quantity of seed in early 1983. In spite of the optimism generated by the sales of basic seed, the harvests of commercial seed in 1983 apparently were scant and as a result seed on offer in early 1984 amounted too little. The initial adoption of cv Capica in 1983 and 1984 did not involve more than 100 ha. Only one case is known of a grazier trying to extend his areas of cv Capica by on-farm seed production. A chronological summary of the main events in the phases of the release process of cv Capica is presented in Figure 2.

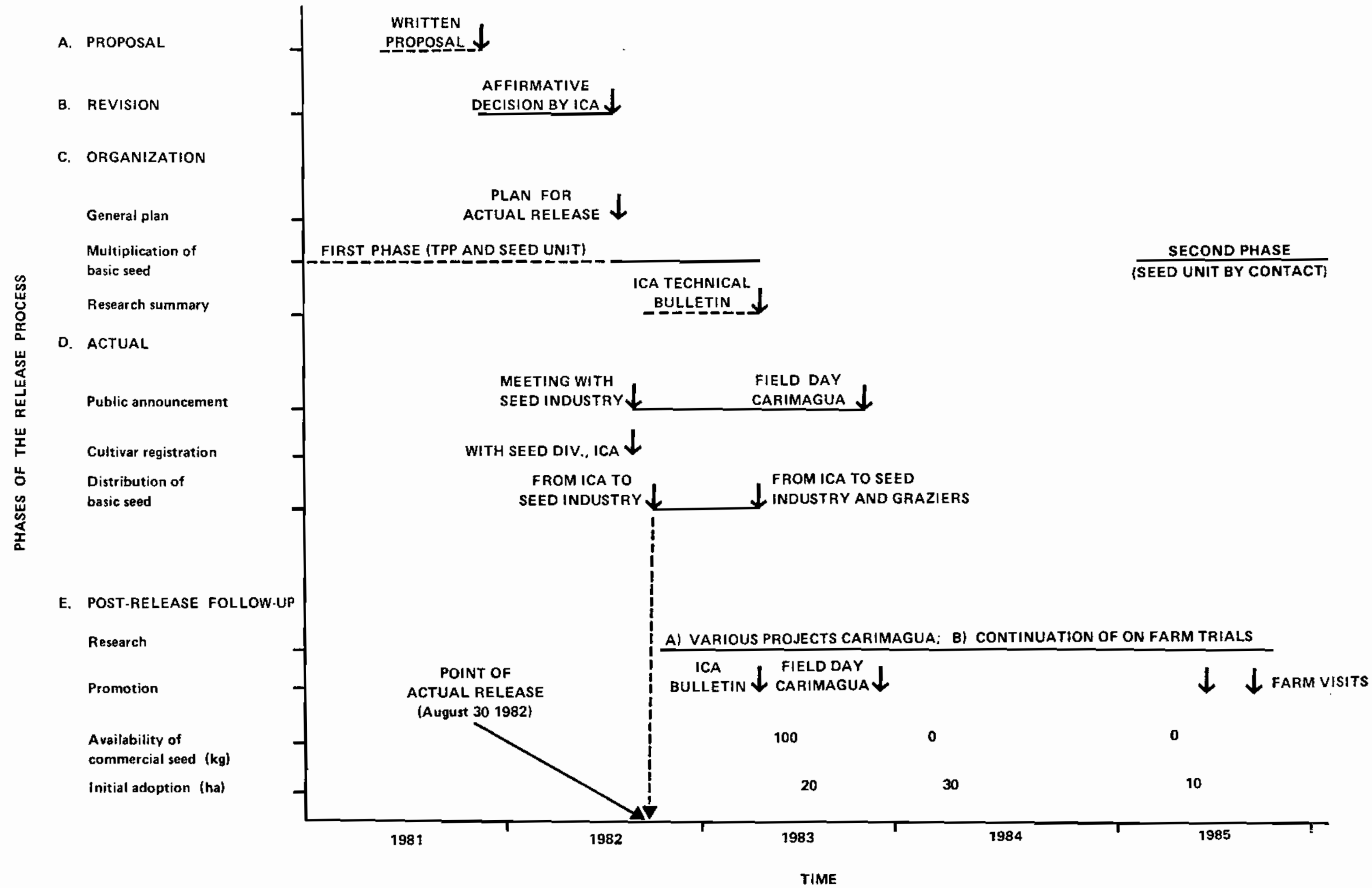
While this study is incomplete, the following comments can be made:

a) The release process still continues three years after actual release because an initial supply of commercial seed remains lacking. The process of adoption has not occurred spontaneously up to the present. While fully acknowledging the complexity of the process of adoption of a new forage legume within a region with socio-economic limitations such as the llanos, it has to be accepted that up to now the ICA-CIAT researchers have not convinced a small core of graziers (nor seed enterprises) of the merit or potential of cv Capica, sufficient to generate an initial of commercial seed.

b) In such cases, and especially with a product so novel without the benefit of technical and commercial promotion, the situation rapidly congeals into a vicious cycle of lack of demand for and lack of supply of seeds. The only way to change this difficult situation is by efforts to promote cv Capica, especially by on-farm demonstrations, and also by making more basic seed available. Both initiatives are now receiving the attention of CIAT and ICA.

c) The development of a commercial seed supply has to be seen as a response to demand for seed from graziers. With new forages, the majority of existing seed enterprises are not going to risk capital in starting commercial seed production until graziers are requesting seed and demand is strong. The only way to change this situation is to give a high priority in the technical

FIGURE 2. Chronological summary of principal events in the release process of *Stylosanthes capitata* cv. Capica in Colombia



promotion of a new cultivars to the seed enterprises as a special group. In addition, the first producers of commercial seed require technical assistance to improve their chances of success in their utilization of the scarce amounts of basic seed.

d) The formation of a national committee for the release of new cultivars would be very beneficial. It is obvious that candidate cultivars of often species without a history of domestication will soon enter the release process. An integral release committee should achieve the phase of effective release more rapidly, by means of integration and supervision of each of the phases of the release process. This in turn will contribute to improving the prospects for a rapid adoption.

4. Technical collaboration

a) CIAT Seed Unit

A very close and mutual collaboration was continued during the year. The presence in CIAT of various visiting scientists and workshops were utilized to exchange experiences and define future strategies for pasture seed issues. The Seed Unit expanded seed multiplication areas of various species which are at advanced stages of evaluation.

A new collaborative activity in 1985 was the multiplication of basic seed of *S. capitata* cv Capica by a production and purchase contract with three seed enterprises. The contract specified the selection of favoured production regions and sites and the application of various cultural practices. After seed harvesting by the seed enterprise, the Seed Unit organized the delivery of seed to CIAT and its conditioning. At the time of writing, the seed crops were developing very well. This activity, as well as generating more basic seed, is also providing orientation phase at low risk to new seed growers of a novel seed crop.

b) The RIEPT

The two Workshops of the RIEPT held at CIAT in September offered opportunities for:

i) Drawing attention to the need for expanded efforts in seed multiplication in each country, consistent with both advances made in the existing evaluation experiments and plans for future evaluation of germplasm and pasture materials.

ii) Define mechanisms to achieve this expansion on seed multiplication activities according to conditions at the national level.

Such a debate was very opportune for the RIEPT, taking into account its rapid expansion and the favourable perspectives for the next generation of regional trials of type C and D. The members of the RIEPT accepted the challenge to expand seed multiplication activities in the next few years.

Cattle Production Systems

During 1985 the primary objective of the section continued unchanged from previous years: the study of alternative ways of integrating sown pastures with savannas, aiming to find production systems that exhibit higher animal productivity and better economic returns. As has been noted in previous reports, this type of research involves experimentation at Carimagua, monitoring and documenting the productivity of farms that have sown improves pastures, mathematical, modelling studies, and collaboration with other sections of the program in carrying out adoption and impact assessment studies of the pasture cultivars released commercially by national research institutions. As germplasm moves to ever more advanced categories of evaluation in the RIEPT, so it is hoped that such production systems research methodology can be applied to other countries and other ecosystems.

Evaluation of Breeding Systems with Improved Pastures

This experiment was initiated in April 1983. The treatments involved were set out in the Annual Reports of 1983 and 1984, although there have been some modifications made to these, affecting principally the two "minimum management" treatments, and which were implemented during 1984. The results of this experiment are analyzed at intervals of two years, to avoid the well-known problem of annual cycles in the reproductive behavior of the breeding herd; it is thus not possible at this stage to discuss the effects of the modifications made to the experiment. However, the analysis of the first two years of the experiment has been carried out. Similarly, it was suspected that the differences between treatments could be confounded by differences between plots of savanna, due to their size (300 to 400 ha each); for this reason studies were started to characterize the plots to correct for such effects.

The analysis of animal weights, uncorrected for age, at three important stages of the reproductive cycle (Table 1) suggests that the strategic use of the small areas of improved pasture available in treatments 4 and 5 (900 and 1800 m per Animal Unit respectively) increased liveweight significantly ($P < 0.05$) at conception and parturition, times at which latating and gestating cows have access to these small areas. However, there appears to have been a residual effect of this management on the weight of cows at weaning in treatment 5, a time at which the animals have access only to savanna. On the other hand, such weight increases have not been seen in the "minimum management" treatments 2 and 3, in spite of continuous access to improved pastures. It is probable that the mineral deficiencies documented in previous reports, in particular phosphorus, are associated with the lack of significant differences in weights between these treatments and the control. The observed tendencies for birth weights are similar to those

Table 1. Average cow liveweight, unadjusted for age. Average of the first two years of the experiment (kg).

Treatament	Weight at		
	Conception	Parturition	Weaning
Replicate 1			
1. Control	341 b	362 b	318 bc
2. Minimum management	338 b	380 a	327 b
3. Minimum management	329 bc	360 b	310 c
4. Intensive management	356 a	377 a	320 bc
5. Intensive management	370 a	381 a	348 a
Replicate 2			
1. Control	312 d	328 c	282 d
4. Intensive management	318 cd	331 c	283 d
5. Intensive management	325 bcd	328 c	275 d
	$P < 0.05$	$P < 0.05$	$P < 0.05$

described above, although statistical differences were found: their size, however (differences between treatments of less than 1 kg), rather diminishes the importance of these results. On the other hand, the differences between treatments in the subsequent growth of calves are very important. As was noted in previous annual reports, pre-, peri- and post natal death rates in the "minimum management" treatments were very high and were part of the reason for introducing modifications to these treatments. However, important differences exist between the control treatment and the "intensive management" treatments; these (Tables 2 and 3) are not confounded with mineral supplementation effects, and so can be attributed to the use of improved pasture. Reconception rates in lactating cows and weaning percentages, on the other hand, do not differ significantly between treatment 5_2 (intensive management and 1800 m^2/AU improved pasture) and the control ($P > 0.05$ Table 4). This is a positive observation in view of the fact that the control treatment uses

Table 2. Postnatal calf losses. Average of two replicates and two years.

Treatment	Loss (%)
1. Control	10.81
4. Intensive management	6.98
5. Intensive management	2.20

$X^2 = 5.74$ ($P = 0.057$)

Table 3. Average weight of calves at weaning, adjusted to 270 days of age.

Treatment	Replicate	
	I	II
1. Control	165b	129d
2. Minimum management	172b	-
3. Minimum management	144c	-
4. Intensive management	167b	125d
5. Intensive management	181a	130d
	$P < 0.05$	

Table 4. Reconception rate of lactating cows and weaning percentage for the control treatment and the best intensive management treatment (%).

Treatment	Reconception	Weaning
1. Control	26.9	54.6
2. Intensive management	29.8 (N.S.)	53.8 (N.S.)

continuous mating whilst the breeding season in treatment 5 is restricted to 90 days only; it implies that the use of a small area of improved pasture can successfully concentrate conceptions and parturitions, which in its turn permits the introduction of other management practices, such as early weaning, which presuppose the existence of controlled mating, and which in their turn are capable of bettering reproductive performance.

The characterization of savanna paddocks, mentioned above, is being carried out by various means. Mapping and surveying was undertaken of the various types of savannas recognized, which include the high well-drained savanna and three types of lowland savanna differentiated by their microtopography and the amount of water in the soil during the dry season. In addition, a record is being kept of the periodic fires set in each type of savanna; combined with this, the rate of regrowth is being monitored up to 84 days post-fire, by cutting the total biomass accumulating in fenced plots. Oesophageally fistulated animals are also being used to sample the areas of savanna that are being grazed by the experimental herds at periodic intervals. Lastly, four weaned calves are being used to measure weight gains. The first characterization period has not yet run its course, so no results are included at this stage.

During the year observations were made over four periods of the grazing habits and the utilization of improved pastures by the animals in both "minimum management" treatments (numbers 2 and 3, with 900 and 1800 m^2/AU improved pasture respectively). The animals were observed between 6 am and 6 pm for three consecutive days in each of the four periods. The results have demonstrated the very intensive use of the areas of improved pasture, in spite of the generally low availability of forage on offer. The principal factor which affects the degree of use of the pasture is the number of days since the last burning of the surrounding savannas; indeed, with less than 40 to 50 days of regrowth on the savanna, the time spent grazing the improved pastures is very short or even zero. This indicates that the management and frequency of fires could be a useful tool to regulate the use of improved pastures with unrestricted access but this, of course, intensifies the management input to systems whose basic philosophy is one of "minimum management". As the savanna matures, so the time spent grazing improved pastures by practically the whole herd tends to increase; up to 3-4 hours average per cow per day is spent thus, indicating that at least a third of the animals' grazing time is spent in harvesting improved pasture, in spite of the low levels of forage availability already referred to above. Clearly the instantaneous stocking rates suffered by the improved pastures are extremely high, a fact reflected in the tendency of the association A. gayanus and P. phaseoloides to degrade. It is possible that the long-term stability of these systems will require the use of species of very different growth habits, more resistant to very intensive, almost continuous grazing.

Reproductive Performance on Brachiaria decumbens

This experiment constitutes a positive control for the systems experiment discussed above: the long term study of the reproductive performance of a herd maintained exclusively on improved pastures of Brachiaria decumbens, the grass most commonly sown in the savannas of tropical America, supplemented with a bank of B. decumbens - S. capitata (20% of the total area). The herd is subjected to intensive management, including full mineral supplementation and 90-day controlled mating. Table 5 presents preliminary information on reproductive performance up to the third gestation. It is interesting to observe that the second (and probably the third) gestation resulted in suboptimal performance, in spite of the generally high liveweights maintained, oscillating, depending on physiological status, between 350 and 450 kg. The latter figure is probably very close to the mature weight of Brahman cattle, but weight plummets during lactation, the time when the animals should be reconceiving. Without doubt it would be possible to improve reproductive rates significantly by lengthening the breeding season, as other experiments have demonstrated at Carimagua, but it is interesting to note that potential levels of reproductive performance have not been attained using this

Table 5. Reproductive performance of cows grazing Brachiaria decumbens supplemented with a bank of Brachiaria decumbens-Stylosanthes capitata. (percent).

	Parturition	Conception
First gestation	97	88
Second gestation	72	66
Third gestation*	72	-

* Preliminary data.

combination of pastures. However, weaning weights were high (Table 6), although these were less so during the second location, which coincided with an abnormally long and severe dry period. In spite of this, it is important to contrast these results with those obtained at the farm level, where in some cases the utilization of grass-legume associations is less intensive than in this experiment.

Table 6. Weight and age of calves at weaning.

	First parturition	Second parturition
Weight (kg)	186 ± 27	149 ± 20
Age (days)	238 ± 17	230 ± 13
Weight gain ($g\ d^{-1}$)	652 ± 105	519 ± 84

Early Weaning on Improved Pastures

It is well-known that early weaning at 3 to 5 months of age induces an increase in conception rates of dams by reducing the anoestrus associated with lactation. In view of the present availability of productive grass-legume mixtures of acceptable nutritive value, a series of preliminary observations was undertaken as a first step towards the design of an experiment to evaluate this alternative use of improved pasture. During the dry season of 1984/85 the first series of observations was made with animals weaned at 5.5 months of age on a pasture of A. gayanus - P. phaseoloides. In spite of the exceptionally dry and long summer, the results obtained (Table 7) were very positive, weights at 9 months of age being similar to those observed in animals weaned normally on savanna.

The same pasture was used from May

Table 7. Performance of calves weaned early on Andropogon gayanus--Pueraria phaseoloides, vs. calves weaned normally on savanna.

	Type of weaning	
	Early	Normal
Number of calves	10	15
Age at weaning	166 + 10	277 + 26
Weight at weaning (kg)	112 + 16	137 + 23
Weight at 277 days of age (kg)	130 + 15	137 + 23
Weight gains to 277 days of age (g/day)		
Milk	503	401
On pasture	169*	-

* 27 November 1984 to 12 March 1985, stocking rate 5 an/ha.

1985 (the start of the rainy season) for animals weaned at 3.5 months. The stocking rate used was rather exaggerated (8 animals/ha), and after 77 days it proved necessary to change the pasture to an association of A. gayanus and Centrosema sp. CIAT 5277. The subsequent weight gains (Table 8) were somewhat less than expected, in view of the fact that this was a period of active pasture growth; however, acceptable liveweights corrected to 9 months of age were obtained.

It is important to emphasize that there were no deaths and that levels of internal parasites were comparable

Table 8. Performance of early weaned calves on pastures of Andropogon gayanus-Pueraria phaseoloides, followed by Andropogon gayanus-Centrosema sp. CIAT 5277. March 30/85 to October 25/85. Stocking rate: 8 an/ha.

		Age (days)	Weight (kg)	Weight gain ($g\ d^{-1}$)
A. gayanus - P. phaseoloides	Initial	110	68	
	Final	187	83	
	No. of days	77		193
A. gayanus - Centrosema sp.	Initial	187	83	
	Final	257	97	
	No. of days	70		200
Total	Initial	110	68	
	Final	257	97*	
	No. of days	147		197

* Weaning weight adjusted to 277 days: 101 kg.

with those observed in normal weaning systems. One treatment for parasites at weaning was the only prophylactic measure taken.

Performance of Improved Pastures at the Farm Level

Approximately 900 hectares of improved pastures have been sown since 1979, with cooperation of collaborating farmers in the Llanos Orientales of Colombia (Figure 1).. During the first few years of this farm-level validation process, the main experimental association was A. gayanus and S. capitata (Figure 2). All these pastures, established on 7 farms, have persisted to date, in spite of great variation between farms in soils, method of use and management applied.

On the other hand the legume died out of the associations of D. ovalifolium CIAT 350 with B. decumbens and B. humidicola (Figure 2) from 1982 onwards, as the result of attacks of Synchytrium and stem gall nematode.

Germplasm newly promoted to Categories 4 and 5 was introduced to the farms from 1984 onwards, although in substantially smaller areas than had hitherto been used, in response to the availability of seed and previous experience (Tables 9 and 10).

Use of Improved Pasture for the Breeding Herd

On two collaborating farms the impact of the use of small areas of improved pasture is being monitored, as a supplement for herds being kept mainly on savanna.

Table 11 present the results for Farm 01, for which much information has been collected over the years. This table illustrates a very different type of herd development from those usually investigated under experimental conditions, and it is very interesting to compare these results with those outlined at the beginning of this report. The strategy followed on this farm has been to increase substantially the number of cows, to the extent of doubling the carrying capacity of the farm, in terms of animal units per hectare; this has been achieved with an area of improved pasture representing 5.5% of the farm. It is most likely that this great increase in stocking rate is responsible for the limited, though significant, increase in average liveweight, an essential

Table 9. Experimental seed multiplication areas established on collaborating farms in 1984 and 1985 (hectares).

Farm	Centrosema sp CIAT 5277	A. pintoi CIAT 17434	S. capitata cv. Capica	B. dyctioneura CIAT 6133
02	0.25	-	-	0.30
03	-	-	-	8.00
05	-	1.00	35	10.00
18	-	0.40	-	0.50
21	-	0.40	-	0.10

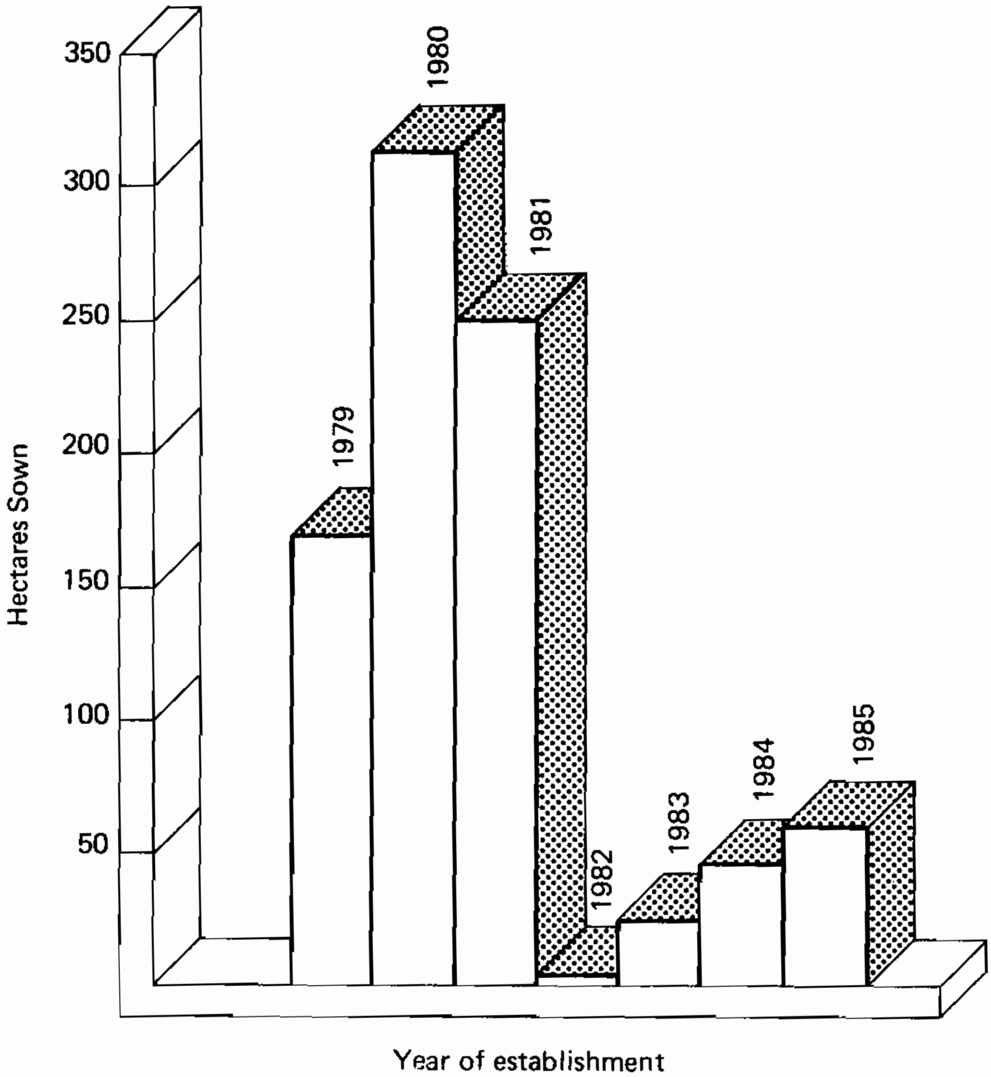


Figure 1. Total hectares sown per year on the collaborating farms of the Tropical Pastures Program.

requirement for an increase in reproductive performance. Conception rates, therefore, whilst having tended to increase, continue to demonstrate marked cyclical oscillations (Table 11).

The use and management of improved pastures reflect the decision taken by the farmer, particularly in the last four years. Whilst the animal performance data in Table 11 suggest that a reduction in the level of productivity could well come about if the high stocking rates of the last two years continue, samples taken from these pastures do not show the same tendency (Table 12).

Growth of Heifers on Improved Pastures

The performance of heifers, from weaning onwards, has been monitored on two collaborating farms since 1980, on grass-legume associations, in savanna managed according to the custom of the farmer, and in various intermediate systems.
Table 13 shows the age at parturition

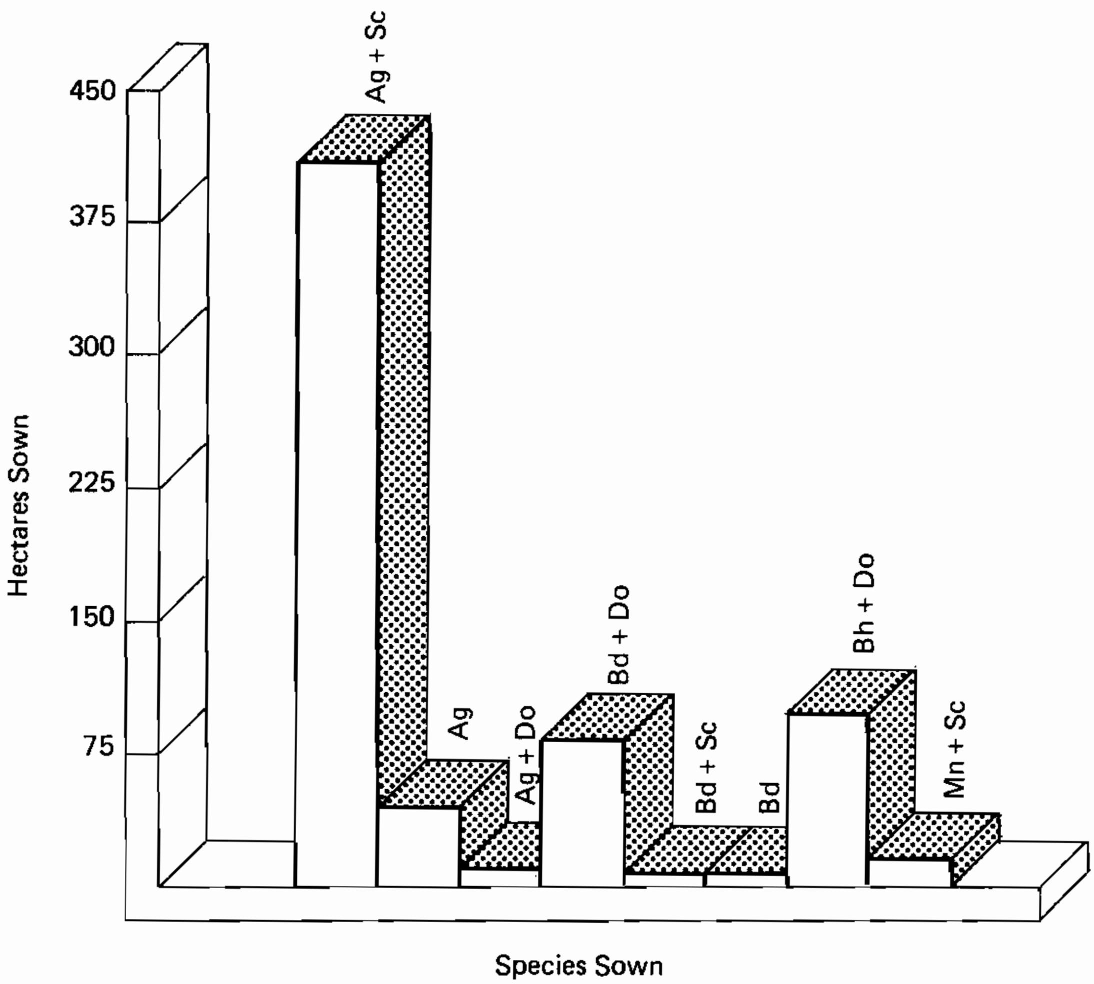


Figure 2. Total species sown in trials under grazing on collaborating farms in the Tropical Pastures Program.

Table 10. Areas and type of pasture sown in 1985 on collaborating farms (hectares).

	A. gayanus cv. Carimagua +			B. dictyoneura
	S.capitata	C.brasilianum	Centrosema sp.	CIAT 6133 + A.pintoi
Farm	cv.capica	CIAT 5234	CIAT 5277	CIAT 17434
02	20	-	-	1
04	47	2	5	2
22	-	4	6	2

Table 11. Reproductive performance of a commercial breeding herd after the introduction of improved pastures (5.5% of total area). Farm 01.

	Year					
	1979	1980	1981	1982	1983	1984
1. Number of cows	330	328	390	427	446	485
2. Stocking rate (AU ha^{-1})	.08	.13	.15	.16	.19	.19
3. Adjusted cow weight (kg)	233e	292d	303c	301c	332a	328b
4. Average cow weight (kg)	252	306	301	312	328	315
5. Conception rate (%)	(49.8)	63.9	62.4	76.2	53.0	60.4
6. Adjusted weaning weight (kg)	(109)	119	118	142	148	143

( ) Data from ETES study.

3. Weight adjusted to the status dry-empty, 73-84 months of age ($P < 0.05$).
5. Refers to cows that have been in the herd since 1980; also excludes heifers.
6. Weight adjusted to 277 days of age.

Table 12. Evolution of the availability of dry matter (DM), botanical composition and cover of a mixture of *Andropogon gayanus* + *Stylosanthes capitata* during five years on Farm 01 in the Llanos Orientales of Colombia.

	1981	1982	1983	1984	1985
Availability kg DM.ha^{-1}	1,061+256	1,713+585	1,155+275	511	1,470+200
Grass (%)	13	29	68	66	77
Legume (%)	87	71	32	34	23
Cover (%)	35	39	22	31	32

Table 13. Age at parturition of heifers on different combinations of savanna and *A. gayanus* + *S. capitata* pastures. Farm 04 (months).

Pasture	n	First parturition	Second parturition	Interval*
Savanna	15	51	-	-
AS until weaning + savanna	15	51	-	-
AS until breeding + savanna	40	41	-	-
Savanna (50%) + AS (50%)	20	38	57	16.8
AS	40	38	56	17.6

* Preliminary data up to August 1985

of five groups of heifers; to date, periods of grazing in savanna alternating with periods on improved pasture give similar results to those obtained on improved pasture alone; this applies equally o birth rates (Table 14), although these results are preliminary only.

Results are similar on the second farm, in spite of the considerable differences in the type of savanna and soil texture found between the two. Table 15 illustrates the differences in age at first and second parturition recorded to date, as well as the marked differences due to pasture type that are beginning to emerge (Table 16).

It should be noted that the percentage for the second parturition for

Table 14. Birth rates of heifers on different combinations of savanna and pasture of *Andropogon gayanus* + *Stylosanthes capitata* (AS). Farm 04 (percent).

Pasture	First parturition	Second parturition
Savanna	82	-
AS until weaning + savanna	82	-
AS until breeding + savanna	95	7
Savanna (50%) + AS (50%)	95	79
AS	85	89 *

Data to August 1985.

* Preliminary value. 17.5% of the animals were in their third gestation.

Table 15. Age at parturition of heifers on different pastures. Farm 05. Data up to August 1985 (months).

Pasture	n	First parturition	Second parturition	Interval*
Savanna	15	47.4	-	-
Brachiaria humidicola	80	47.3	-	-
A. gayanus/S. capitata	65	36.6	51.0	14

* Partial data.

Table 16. Birth rates of heifers in different pastures. Farm 05. Data up to August 85 (percent).

Pasture	First parturition	Second parturition
Savanna	86	-
B. humidicola	52	-
A. gayanus/ S. capitata	97	32 *

* Preliminary value.

A. gayanus and S. capitata is not complete, since a large number of animals were still gestating.

Fattening on Improved Pastures at the Farm Level

Fattening is generally the most attractive activity for a farmer, economically speaking, but this is only possible in the savannas of tropical America with the use of improved pastures. Tables 17 and 18 show the results obtained from two collaborating farms on which the respective farmers decided to use their areas of improved pasture for fattening during the rainy season. In both cases adult steers of 3 or more years of age are used and sometimes cull cows are fattened too. Again in both cases, the weight gains recorded per head are similar or even superior to those obtained under experimental conditions, and with a stocking rate generally higher than that used at Carimagua, but with the difference that at farm level, the use of these pastures has been markedly seasonal. Pasture samples taken at 3-4 month intervals have given no indications of degradation, but there are marked seasonal changes in botanical composition of the A. gayanus - S. capitata association. Figure 3 illustrates these changes for one of the case studies. Finally, it is important to note that in these cases all decisions regarding the use, stocking rate and management of the pastures have been taken by the farmer alone, thus limiting the kind of results that can be recorded from these farms.

Figure 3. Availability of dry matter and stocking rate per hectare in *Andropogon gayanus - Stylosanthes capitata* association. (Farm 03).

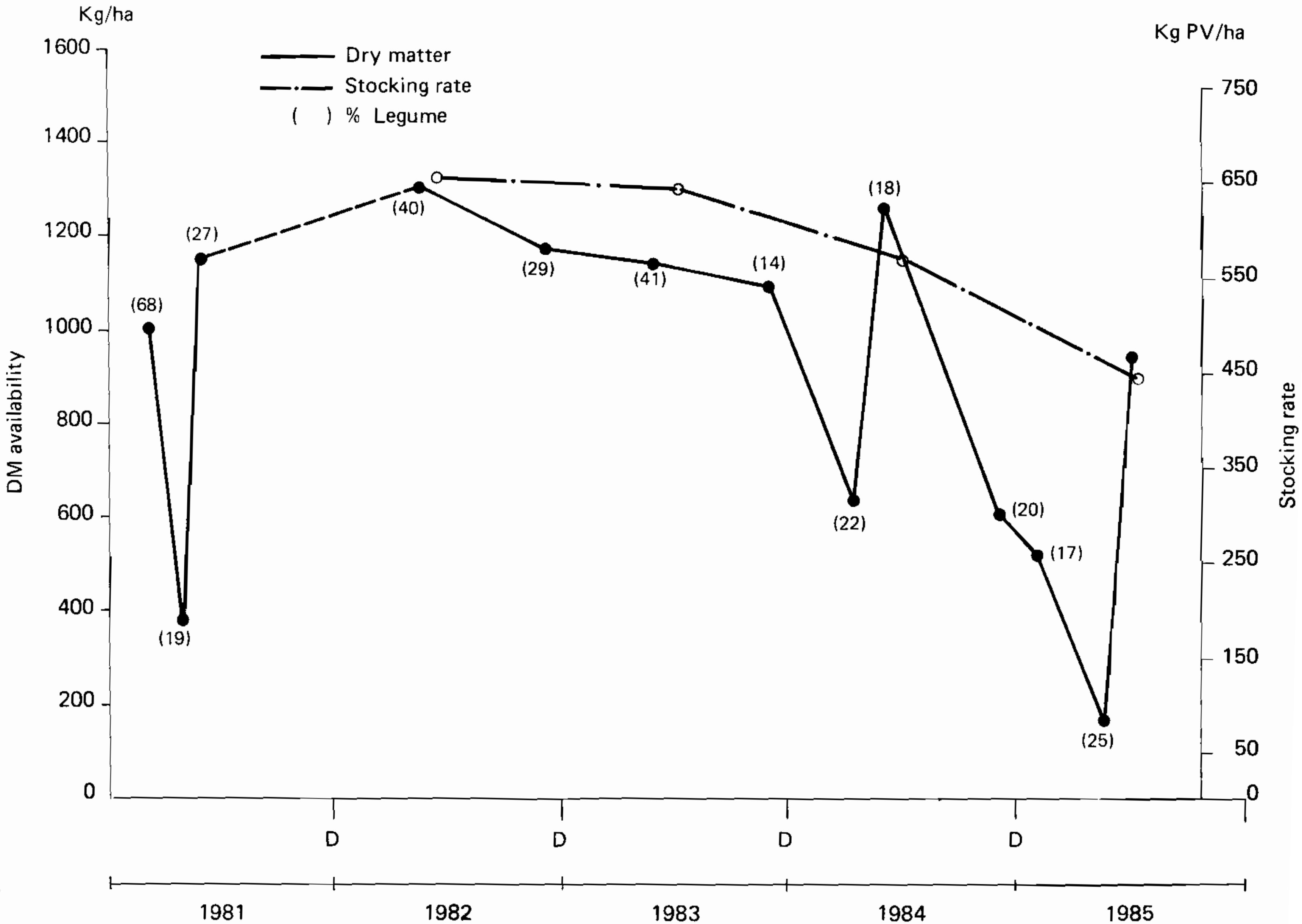


Table 17. Weight gain of steers on *Andropogon gayanus* + *Stylosanthes capitata*. Farm 03.

	1982	1983	1984	1985*
Grazing days	269	285	287	111
Initial weight, kg	284	312	306	337
Final weight, kg	424	493	496	443
Stocking rate, an/ha	1.72	1.53	1.40	1.14
Stocking rate, kg/ha	660	659	561	445
Weight gain, kg/ha	.522	.635	.590	.950
Weight gain, kg/ha	242	277	285	122

Table 18. Weight gain of steers and cull cows in *Andropogon gayanus* - *Stylosanthes capitata*. Farm 05.

	Steers				Cows
	1982	1983	1984	1985*	1984
Grazing days	183	218	193	119	93
Initial weight, kg	225	344	315	330	285
Final weight, kg	344	464	441	417	337
Stocking rate, an/ha	1.53	1.60	2.00	1.35	1.50
Stocking rate, kg/ha	436	646	756	504	467
Weight gain, kg/ha	.484	.550	.648	.725	.544
Weight gain, kg/ha	136	192	250	117	76

* Preliminary data up to August 1985.

SIMULATION PROJECT

Work during the year continued on the development of beef and forage models to allow the assessment of viable alternative uses of small areas of improved pasture in existing production systems in the Llanos Orientales.

Beef Model Development

The model used is an adaptation of that built at Reading University during 1980-82. The first objective was to develop a version of the model which could reproduce, with tolerable accuracy, important production parameters arising from a base-line pure savanna system and then, with as few modifications as possible, production from a permanent improved pasture system. These two systems may be taken as containing between them the whole gamut of production possibilities of interest. The essence is that there are certain parameters which, it is hypothesised, are sufficient to describe very different production systems and different types of animal. These are:

- feed quality, in terms of digestibility and crude protein content, and quantity available;
- standard energy expenditure on grazing;
- adult cow weight under non-limiting conditions;
- potential milk yield.

In view of the results obtained from the original validation runs for production systems in Botswana, Israel and the UK, there is reason to believe that this set of environmental and animal breed parameters goes some way to being able to differentiate between production systems with widely differing characteristics.

The dynamics of the system are represented by a flow of energy. Animal performance is treated on an individual basis, so that each animal's forage intake, growth, milk production, and conceptus growth (and the answers to questions such as "does the cow die now?" and "does she conceive now?") are derived at each time interval, itself variable from between 1 and 30 days. Many of the relationships in the model are deterministic, but the following events are stochastic: death, oestrus, conception following oestrus, calf sex at birth, abortion and sterility. Herd dynamics are illustrated in Figure 4. The structure of the model has been changed radically, and is now written in FORTRAN 77 and consists of a three-tier hierarchical structure. The structure and quantification of the model is described elsewhere.

Exploratory Validation

A large number of simulation runs have been carried out to test the model and the changes made to it: replicates of the base-line savanna system, runs where the run length, time step, herd size and herd structure were changed, and replicates of an improved pasture system. For all runs, the same set of management decision rules was operating in the model. The most important of these were: a year-long breeding

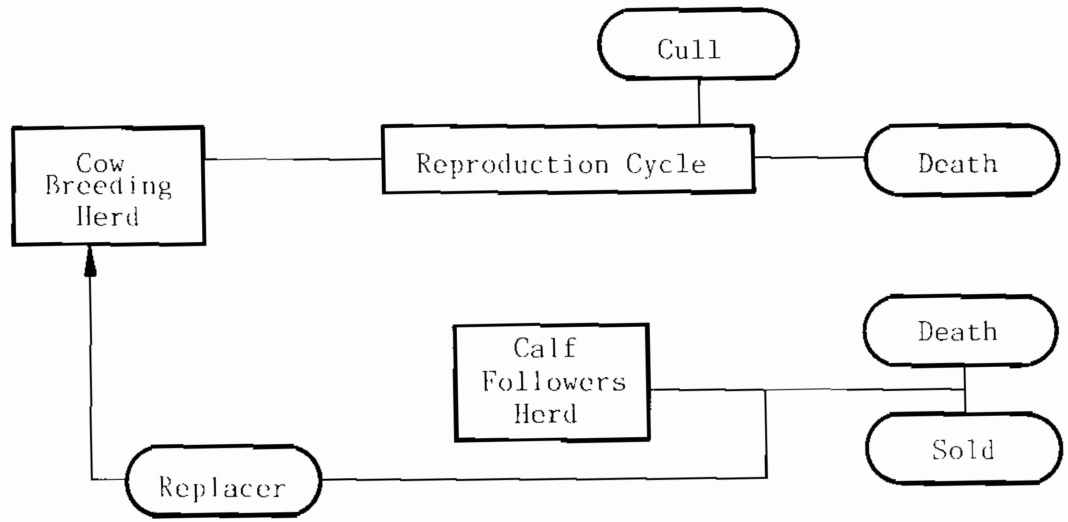


Figure 4. Herd Dynamics.

season, weaning took place at 9 months, pregnancy tests were performed in July and December, at which time also calves were sold, replacers were initialised into the herd, and culling took place. In general, any or all of these can be changed and any management imposed. For the base-line runs, a standard herd was assembled, numbering 34 animals. Its structure was based on the results of the ETES-Colombia project, in terms of both the age of individual members and the number in calf at any time, to approximate "real" conditions as nearly as possible, since it was found during earlier runs that starting conditions can have a large influence on short- to medium- term productivity. Run length was set at 10 years, and the time step was set at 10 days for both cows and calves. Data relating to the pure savanna diet were taken from the results of earlier work at Carimagua. Crude protein content was always in excess of 6 to 7%, the level at which protein limits intake in the model, and digestibility ranged from 40 to 48%, with a slight peak in April. For these runs, forage availability was assumed to be unlimiting, in the absence of pertinent data.

Table 19 shows the results within and between five replicates for a number of production parameters. The variation between replicates is small - this is to be expected, since diet quality is represented by unchanging monthly values from year to year. The variation between years is much greater, indicating that the herd is in the process of self-stabilisation (or inexorably crashing to extinction). Table 20 compares some simulated production parameters with those typically observed in the Eastern Plains. Figure 5 shows the liveweight evolution of cow #1 from replicate 1. This animal started the run as a newly-weaned 9 month old weighing 129 kg, and she died at the age of 8.5, having conceived thrice and produced 3 calves (one of which died prior to weaning). The gross changes in weight were brought about largely in response to reproduction cycles.

Of particular importance is the long term stability of the herd; death rates and management (e.g. culling policy) combined to produce the long-term average age of the herd, and it is desirable that the age structure show itself to be reasonably stable, at least over the length of simulation runs. Herd age structure at various times for replicate 1 is show in Figure 6; the distribution at year 10 is tolerably close to that at year 0, and the average ages are comparable: 4.4 at year 10, 4.0 at year 0. The low weaning percentages obtained are partially explained in Figure 7, which shows the fate of conceptions for one of the 5 replicates. Three things are worthy of comment:

- nearly half of all weaned calves became replacers (45%); the vast majority of the sale calves were thus male. This particular production system is thus close to the being the worst, in terms of reproductive ability, that could still be called a self-replacing herd.

- ten years is not a sufficiently long period (in terms of being able to build up a sufficient number of conceptions) for conceptions and suckling calves "on hand" at the end of the run to be ignored safely; together they account for more than 12% of all conceptions.

- orphans (calves whose dams have died prior to weaning) were, according to the decision rule operating in the model, sold off immediately after dam death. These amount to 11% of all conceptions, and these potential weaners are thus lost to the system. The high number of orphans is due in part to the

Table 19. Variability between and within replicates for five ten-year runs.

	Mean	Between years s	Between years cv%	Between Replicates s	Between Replicates cv%
Weaning weight (kg)	134.3	4.0	2.9	1.0	0.7
12-Month weight (kg)	139.3	3.5	2.5	0.3	0.2
24-Month weight (kg)	193.5	2.7	1.4	0.1	0.1
Conception interval (days)	610.1	103.9	17.0	20.3	3.3
Conception (%)	55.0	9.5	17.3	1.3	2.4
Weaning (%)	32.7	11.4	34.9	0.9	2.8
Age at first partum (years)	4.1	0.3	6.6	0.1	1.4
Cow mortality (%)	14.9	8.1	54.3	1.2	8.1
kg/AU/year[1]	42.4	13.7	32.4	1.3	3.0

1/ (no.cows * weaning % * 12-Month wt + no.yearlings * wt gain/yr)/AU

Table 20. Simulated and observed production parameter values in the Llanos - Savanna Systems.

	Simulated	ETES Project
Weaning (%)	33	35 - 64
Age at first partum (Mos)	49	45
Production (kg/AU/yr)	42	40 - 70
Weaning weight (kg)	134	125 - 130
Yearling growth (kg/yr)	54	62
Cow mortality (%)	15	10 - 16
Calf mortality (%)	11	10
Conception interval (days)	610	546

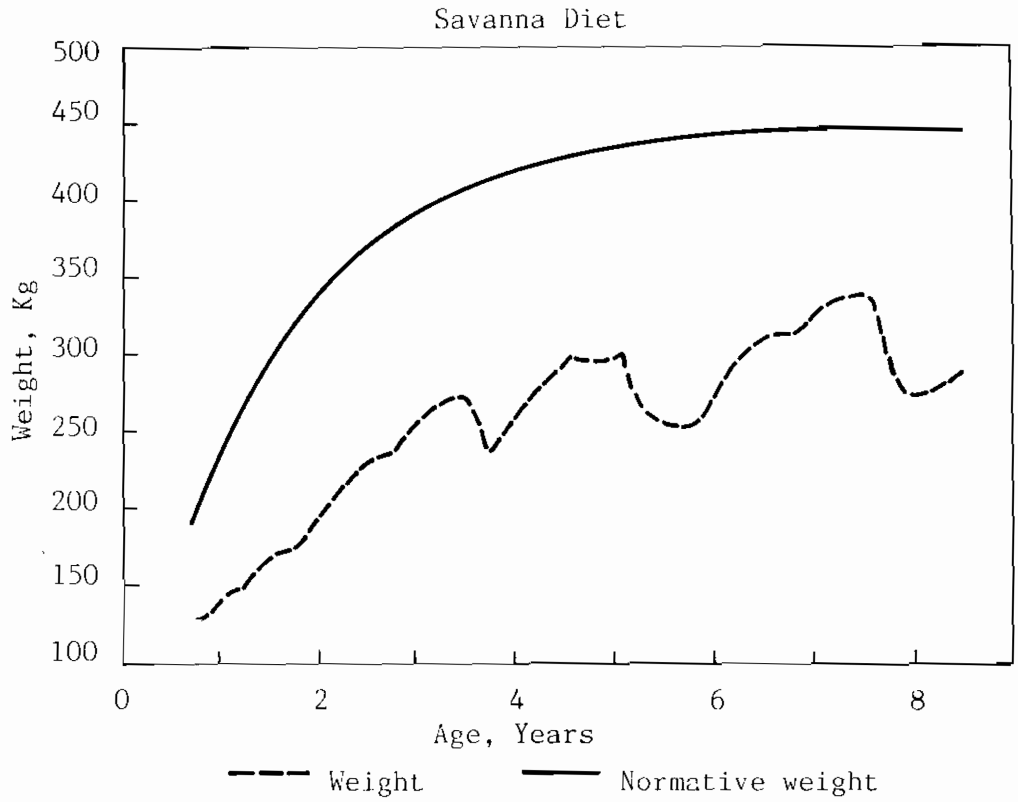


Figure 5. Cow liveweight evolution.

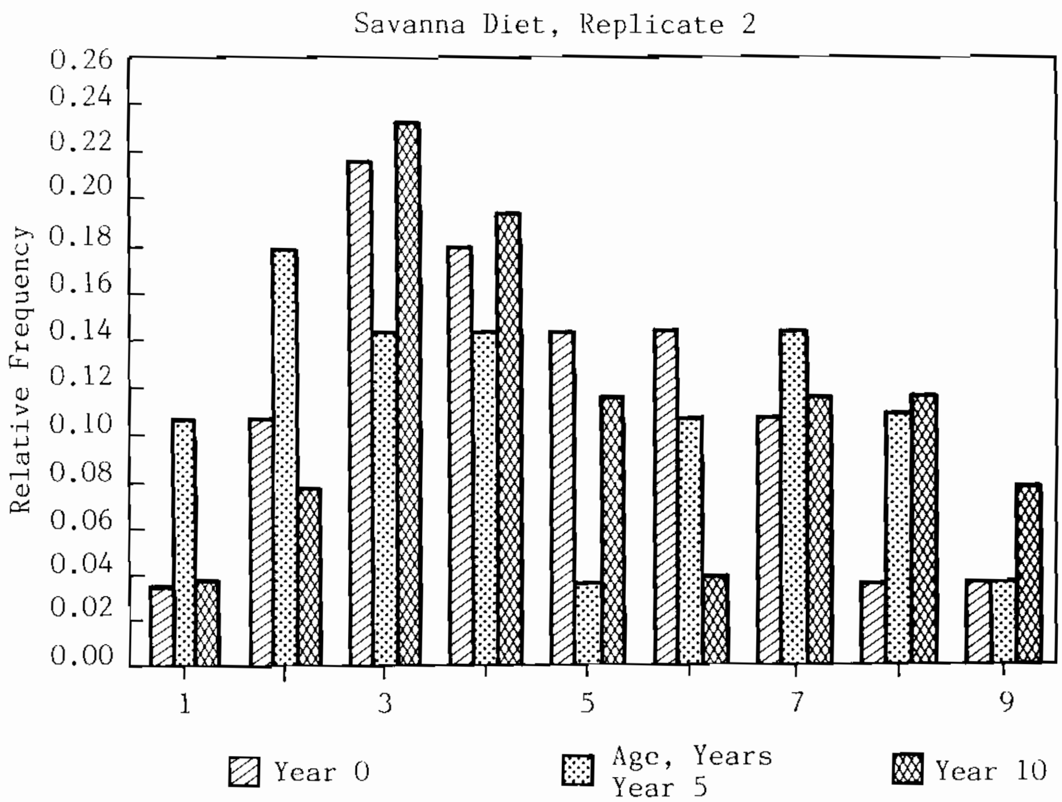


Figure 6. Herd age distribution.

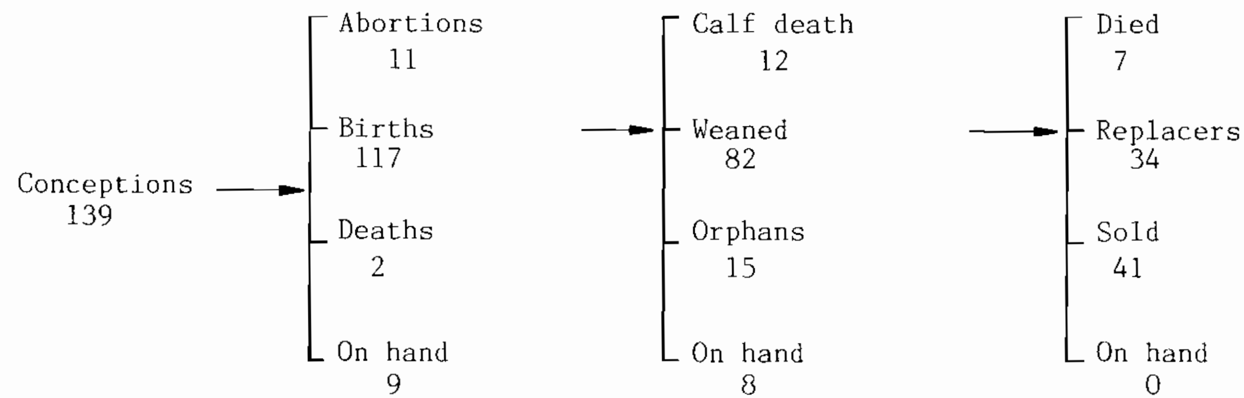


Figure 7. Fate of conceptions, replicate 1, savanna system

comparatively high death rate of old cows in the herd. In addition, the decision rule is probably overly-harsh; a large number of those orphaned, for example those over 4 months of age, would prob- ably survive, and could thus be made to enter the followers herd as the result of enforced early weaning, in effect. The question of whether high orphan rates are a feature of the model or of the real system is one which warrants further investigation - if the latter, then significant losses are accruing which could largely be avoided.

A further series of runs looked at changing the nature of the initial herd. Herd sizes of 10 and 50 individuals from the same age distribution lead to no real differences in production levels, with the exception of stochastic events such as adult death, which are obviously much less stable when the number of individuals is as low as 10 (1 death is then 10% of the herd, as opposed to 3%). On the other hand, the simulation of 50 cows (some 500 cow years) is wasteful of resources where a smaller number is still large enough to invoke the law of medium numbers. The most interesting results from this series of runs were obtained when a herd comprising 30 heifers, and then 30 old cows, were simulated over a period of 20 years, to investigate the age structure over time. Figure 8 shows that average age, even for heavily skewed distributions, quickly reaches values typical of realistic herd distributions, and tends to oscillate between these limits. It is noteworthy that the number of individuals in the cow herd fell markedly over time (in fact this herd is well on its way to extinction, Figure 9); untypical initial age distributions may have rather long-term effects on herd stability through the effect on numbers rather than on ages *per se*.

A final series of runs was carried out using the standard herd and much better forage, such as that from an improved pasture. Due to data difficulties, a crude estimate of average quality was obtained from animal performance data, and seasonal fluctuations were imposed. A monthly series of digestibilities was constructed with an average of 55% with a slight peak in March - April, as for savanna. Protein and availability were both assumed to be unlimiting, probably serious oversimplifications with regard to the dry season and/or older pastures. Table 21 shows results for the average of two replicates, and production levels observed on *Brachiaria decumbens* at Carimagua. The increase in productivity levels over the savanna system is immediately obvious - weaning weights are increased, calving intervals are reduced sharply, and meat production is increased threefold. Mortality rates are reduced, due to the absence of death by starvation in the improved system. Figure 10 shows the liveweight evolution for cow #1; weight oscillations are marked, and are characterised by a much short- er period than those seen in savanna systems. These cycles arise more in response to the seasonal quality variations of the forage than to the physiological status of the animal.

The preliminary model runs can be summarised as follows:

- a reasonable compromise between the desire for stability, efficiency and cost for model runs involves 30 or 50 animals, 10 year run lengths and time steps of 5 or 10 days. For maximum efficiency, starting conditions should be as unbiased as possible.
- the death rates presently used in the model preserve, to a large extent, the age structure observed in herds in the Llanos.
- simulated production parameters

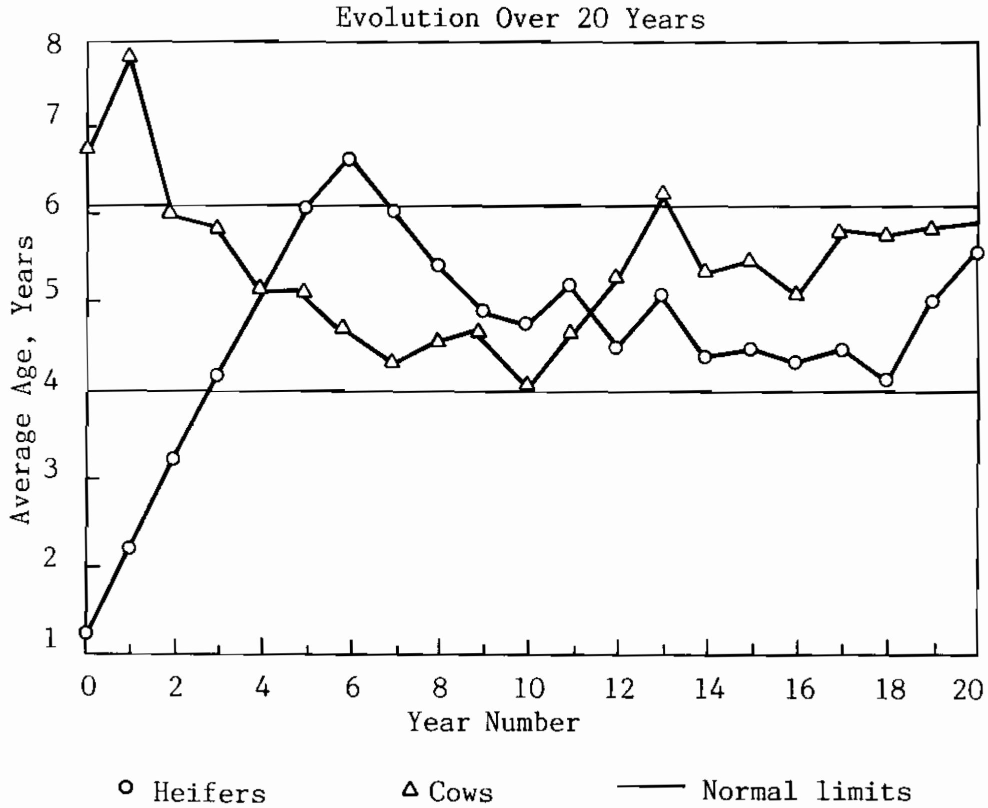


Figure 8. Herd average age.

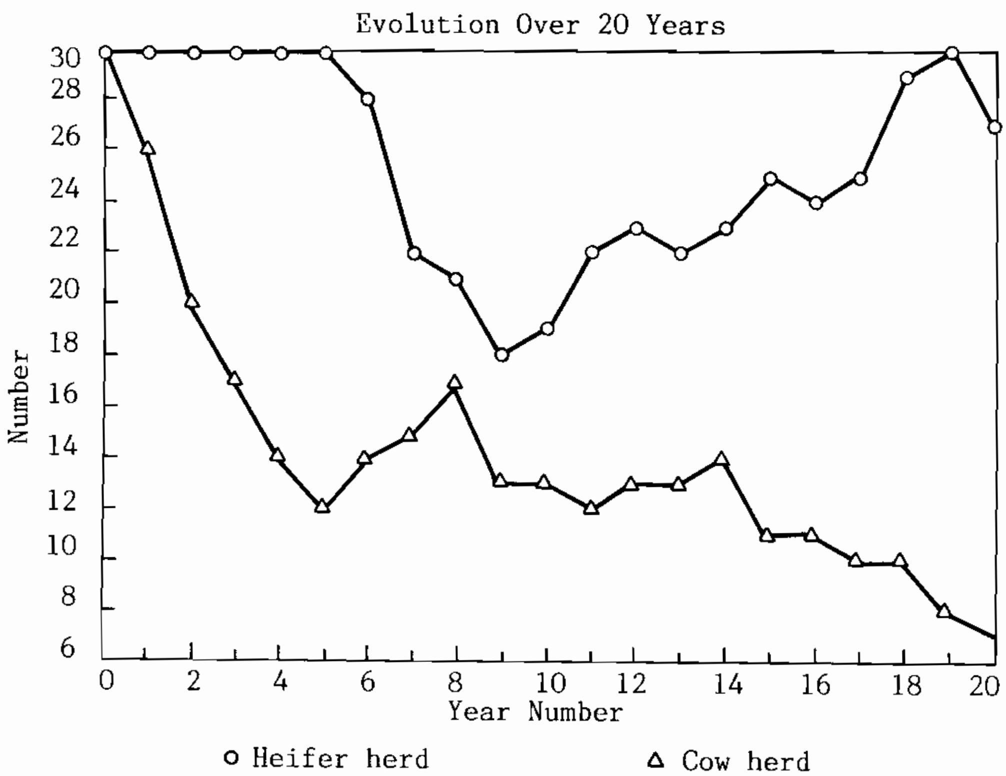


Figure 9. Animal numbers.

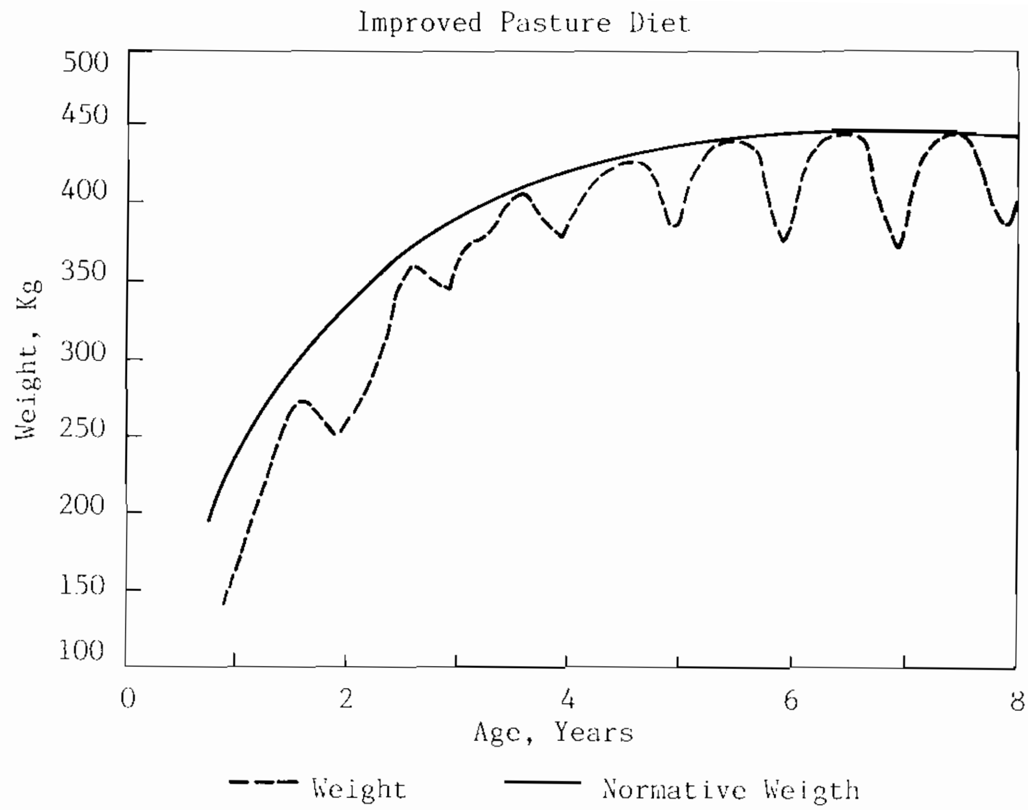


Figure 10. Cow liveweight evolution.

Table 21. Simulated and observed production parameter values in the Llanos - Improved Pasture Systems.

	Simulated	Observed*
Weaning (%)	80	80
Age at first partum (Mos)	35	39
Production (kg/AU/yr)	109	?
Weaning weight (kg)	201	180 - 220
Yearling growth (kg/yr)	85	115 **
Cow mortality (%)	12	?

* Brachiaria decumbens.
** Steers.

were of the right order of magnitude, although it is unknown how appropriate were the data used for forage quality (the model is sensitive to small changes); additionally, the influence of forage availability was not active in any of these runs.

- the improved pasture runs were not very satisfactory, but did highlight one or two problems which have been rectified. More rigorous experimentation will be undertaken at a later date.

Forage Growth

Problems with the use of simple tabulated monthly forage quality and quantity data include the following:

- it is desirable to include some degree of feedback between animal and pasture;

- the concept of availability, as it relates to total biomass, may be misleading in relation to savanna;

- it is not clear how to treat banks of different material and assemble them into a diet for the animal.

A general compartmental model of plant growth was constructed, capable of distinguishing between acceptable (to the animal) and unacceptable forage. New growth enters the edible fraction, which loses material through decay (out of the system of interest), through maturation to the next highest class (here the inedible but not dead fraction of the plant), and through grazing. In turn the inedible fraction losses material through decay and maturation to dead material. This sort of structure is a simplification of more complex models which have included more compartments with various fractions of edible material of different digestibilities. The advantage of a simple edible - inedible split is that the animal can drive such a forage model without the need for deriving relative intake functions for plant components withing the same forage. The growth function itself can be complex or simple, stochastic or deterministic. For example, a logistic function may be used to relate growth rate to biomass; such a function requires only two parameters to specify it, ceiling yield and relative growth rate at the point of maximum growth, and these can be made to be time-dependent, allowing seasonal changes in patterns of growth to be simulated as required. In addition to the parameters required for the logistic growth function, complete mathematical specification requires maturation and decay parameters or functions, also possibly with time-dependencies.

Some way is needed of deriving digestibilities as a valid by-product of the growth model. A hypothesis that is worth investigating is that digestibility is related in a straightforward way to the proportion of recent growth, defined in some manner, in the pasture. Recent growth might be defined as the sum of the last five days' growth; dividing this sum by the total biomass (or the non-dead material) gives a ratio between 0 and 1 which can then be used as the independent variable in a function to derive digestibility. The concept is reasonable, in that pastures with more new growth will have higher digestibilities, but it is currently in the process of being tested to see if a reasonable definition of new growth can be derived in conjunction with a suitable digestibility function.

There are two advantages to this kind of general model:

- one can be set up for each forage under consideration; this need be not only savanna versus one particular type of improved pasture, for example, but could also include the different types of savanna that animals might have access to at various times of the year, whose characteristics are sufficiently different - recently burnt versus unburned, for instance.

- secondly, it is possible to make the model more complex if required; one fruitful line of inquiry would be the incorporation of weather parameters on the growth function; given simulated time series of certain key parameters, weather-sensitive growth functions could be included without much difficulty, assuming they could be derived.

The final connecting link is that

which allows the animal to drive the forage modules, by allowing it to chose in some way between the resources on offer. There are two main ways in which this might be done: though the derivation and incorporation of explicit preference functions (i.e. relating the amounts on offer of species 1 and 2 to their relative intake by the animal), or through some behavioural aspect of the animal. It might be assumed that the animal maximises energy intake, within limits which recognise that this is unlikely to be strictly true when small amounts of one or other species of forage are present. The hypothesis could, theoretically, be examined under Llanos conditions since an animal which maximises its energy intake thereby reveals implicit preference functions for the various forages on offer. These revealed preference functions could be compared with explicitly derived preference functions (Figure 11 shows a function derived from a MS thesis in Carimagua), but in the immediate future data paucity is likely to restrict this line of inquiry.

It is clear that animal effects on pasture, in this schema, are limited to the removal of herbage only; it is possible that this is not such a far-fetched limitation as it would be under temperate grazing conditions, due to the extensive nature of the production systems under consideration. This is likely to be the case for savanna; whether it is so for the improved species is a matter for investigation.

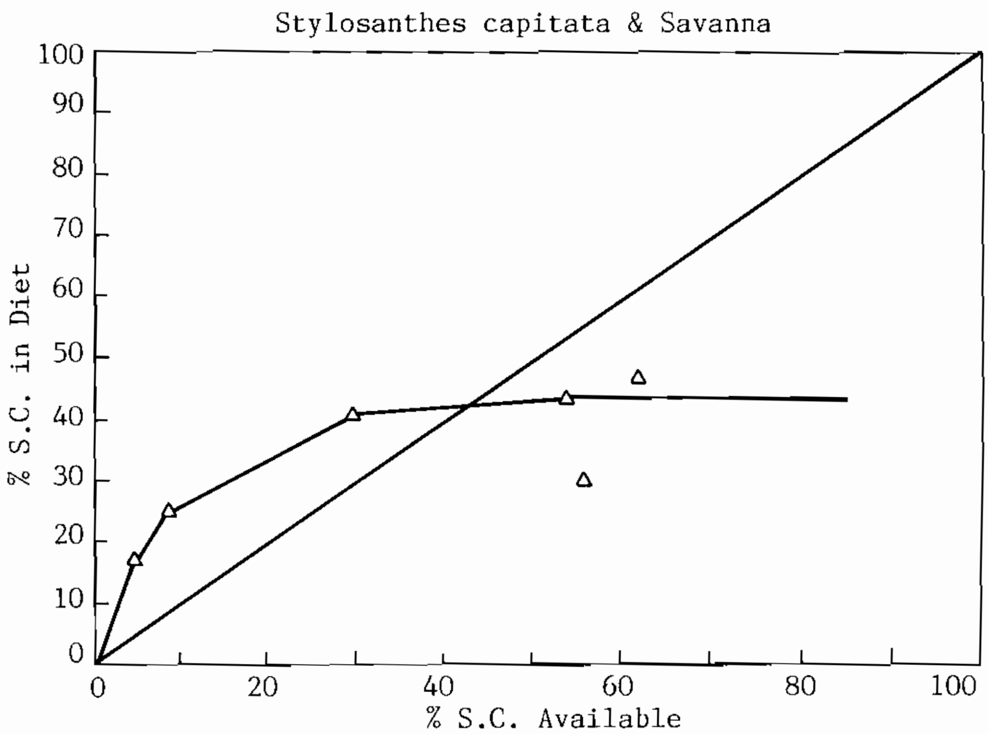


Figure 11. Preference function.

Economics

In 1985 the Economics Section continued working on the analysis of consumption patterns of different meats, the determination of demand parameters, and the presentation of possible scenarios of meat supply and demand in tropical Latin America up to the year 2000.

The major effort of the section has been concentrated on studies of the adoption of two grasses developed through the Tropical Pastures Program's screening process:

- Andropogon gayanus: with rapid expansion in the Brazilian Cerrados and on the North Coast of Colombia.

- Brachiaria humidicola: a material introduced by CIAT into Colombia in 1976, considered by CIAT's Tropical Pastures Program team a low quality grass of limited potential, which escaped from the screening process and is being adopted by farmers in the Llanos of Colombia.

1. Analysis of Consumption patterns of meats

Research in cooperation with FAO/RLAC on consumption patterns of beef, pork and poultry continued in 1985. Emphasis was placed on updating and improving econometric models for Colombia and Venezuela with data up to 1984. The methodology (principal components analysis and ridge regression) was unchanged and results were consistent with previous estimates.

Table 1 presents the updated estimates of price and income elasticities. All estimates exhibit the expected signs and all except one are significant at standard error probabilities. Income elasticities tend to be larger then price elasticities in absolute terms for beef and poultry, thus indicating the particular importance of the development of per capita incomes for forecasting future consumption levels. Both price and income elasticities are particularly low for pork, indicating that beef and poultry will dominate the meat scene in these countries in the coming years.

Poultry exhibits particularly high elasticities in all three countries. This is to some extent explained by the increasing urbanization and concomitant changes in consumption patterns; however, elasticities are also biased upward due to the collinearity caused by a simultaneous drop in relative price due to technological changes and agricultural policies, and by the continued trend of rising incomes during the seventies. A separate analysis of the last decade is being undertaken to assess more accurately these elasticities.

Cross price elasticities present a less clear picture, probably due to the different relative importance of different meats in terms of household expenditure and differences in price levels. Only 9 of the 18 possible substitution elasticities were signi-

Table 1. Income and price elasticities for meat demand in Colombia, Venezuela and Brazil.

	Colombia (1960/84)		Venezuela (1956/84)		Brazil (1964/82)	
Demand of:	Price	Income	Price	Income	Price	Income
Beef	-0.69***	0.72***	-0.5	0.37***	-0.23**	0.32***
Pork	-0.49**	0.45***	-0.31	0.31***	-0.26***	0.02
Poultry	-0.46***	0.88***	-0.92**	1.09***	-1.26***	1.60**

** Coefficient significant at the probability level α = 0.01
*** Coefficient significant at the probability level α = 0.05

ficant at a 10% error probability (Table 2). Additionally, estimates cannot be assumed to represent equally well movements of relative prices in both directions, due to the fact that they were estimated during a period in which prices moved only in one direction.

The overriding meats market trend in Latin America over the last decades has been the rise in beef and pork prices in relation to poultry. This tendency is not expected to continue in the future, particularly for Colombia and Venezuela, due to balance of payments problems affecting internal grain prices; additionally, in Venezuela the poultry industry's capacity seems to be fully utilized, leading to markedly rising marginal production costs.

Assuming slightly rising poultry consumer prices (1% p.a.) and historical tendencies for all other variables, projections were made for meat consumption in the years 1987, 1995 and 2000 (Table 3). Substantial increases in poultry consumption can be expected, particularly for Brazil. Projected levels probably overestimate demand potential due to the high income elasticity and income growth in the past. Colombia and Venezuela present more stable patterns with poultry growing at somewhat higher

Table 2. Cross-price elasticities of meats in Colombia, Venezuela and Brazil.

Country	Sustitution of	Cross elasticity
Colombia	Poultry x beef	0.42
	Beef x poultry	0.61
	Beef x pork	0.58
Brazil	Poultry x beef	0.50
Venezuela	Beef x poultry	0.44
	Beef x pork	0.61

rates than beef and, particularly, pork. Nevertheless, beef will continue to be a very important animal protein source.

2. Use of B. humidicola in the Colombian Llanos

B. humidicola was introduced to Colombia by CIAT in 1976. It is a material used extensively in the humid tropics, particularly in Brazil. It is known to have problems of spittlebug susceptibility low palatability and low quality.

Nevertheless this material escaped from the research stations at Carimagua and Santander de Quilichao

Table 3. Projections of per capita consumption of meat in Colombia, Brazil and Venezuela (kg/person/year)*

	Colombia			Brazil			Venezuela		
	1987	1995	2000	1987	1995	2000	1987	1995	2000
Beef	26.5	31.2	34.6	19.8	23.3	25.9	20.5	21.1	21.5
Pork	4.8	5.0	5.1	7.8	7.7	7.7	6.3	7.1	7.8
Poultry	4.9	5.3	5.6	11.8	25.4	41.1	19.2	22.4	25.1
Total	36.2	41.5	45.3	39.4	56.4	74.7	46.0	50.6	54.4

* Poultry prices increasing by 1% per year, other variables increasing according to historical trends.

and farmers are planting increasing areas of it. This demand led to a study of the B. humidicola on farms. The hypothesis to be tested was that the material fulfils a specific role in existing farming systems. A better understanding of this role would be useful in the assembling of pasture technology for present farming systems.

To this effect a survey was undertaken of 47 farms using B. humidicola in the Llanos. Information was obtained from qualified individuals (mainly farmers growing B. humidicola, and those giving away or selling vegetative material). In the course of the survey farmers were asked about others they knew who were using it. This led to the actual surveying of 47 farms with a total of 3,825 ha of B. humidicola and indirect reporting of another 98 farms giving a grand total of 7,600 ha of B. humidicola in the Llanos.

The survey covered general farm characteristics and detailed questions on B. humidicola (origin of the material, reasons for its use, subjective judgements of its merits and drawbacks, establishment procedures, management and performance, and future plans related to B. humidicola). Soil samples were taken from B. humidicola paddocks.

Table 4 presents average areas of B. humidicola per farm and expansion intentions. Substantial areas have already been established, and these will be expanded. Areas increase with distance from the Piedmont as does total farm size. Seventy-two per cent of the farms surveyed planned to expand areas. Farmers were well aware of the characteristics of the material (Table 5). Its aggressiveness is ranked high; this allows for a low planting density of vegetative material, thus reducing costs, labour input and weed invasion. Its resistance to spittlebug was mentioned 14 times; this seems to have been the case in the Llanos up to now, but has been refuted by the experience in other countries, particularly in Brazil. Its good performance on poorly-drained soils was mentioned more frequently in the region Puerto López-Puerto Gaitán than in the area between Puerto Gaitán-Carimagua. On the other hand farmers tended to be aware of the limitations of the material: its limited nutritive value, particularly when mature.

Farmers tended to establish B. humidicola in the slightly more fertile patches of land and an increasing tendency was noted to establish it in poorly drained areas (Table 6).

Table 4. Brachiaria humidicola: existing areas and expansion intentions.

Region	Actual		Expansion	
	No.	Area (ha)	No.	Area (ha)
Pto.López-Pto.Gaitán	23	62.7	13	106.0
Pto.Gaitán-Carimagua	24	98.6	21	152.0
Total	47	81.0	34	128.0

Total area surveyed or reported in the Llanos Orientales: 7,572 ha

Information concerning areas of other pastures on farms using B. humidicola reveals that its use is associated closely with the existence of B. decumbens, while only few farms grow A. gayanus (Table 7). The percentage area per farm of B. decumbens is particularly large in the region Puerto López-Puerto Gaitán, in comparison with the Puerto Gaitán- Carimagua region. On the other hand, A. gayanus areas increase substantially in the latter region, probably indicating the influence of Carimagua Research Station, where A. gayanus was developed and tested extensively.

In both regions initial plantings of B. humidicola were of substantial size, indicating that farmers perceived it as a well- established low-cost technology of low risk (Table 8). As B. humidicola sets hardly any sexual seed, virtually all areas have been established from vegetative material. Multiplication rates of about 20 to 1 are reported, showing that in this case the lack of sexual seed is no serious limitation for area expansion.

The use of B. humidicola on Llanos farms leads to the following conclusions:

1. B. humidicola has clear limitations as a forage, but farmers have realized these and on balance have considered it a

Table 5. Brachiaria humidicola: perceived attributes[1].

	Number of cases		
	Pto.López-Pto.Gaitán	Pto.Gaitán-Carimagua	Total
Positive attributes:			
. good and rapid soil coverage	15	16	31
. drought resistance	9	6	15
. eaten by horses	5	9	14
. good weed control	8	6	14
. resistant to spittle-bug	8	4	12
. good performance on poorly-drained soils	6	1	7
Negative attributes			
. none	6	7	13
. not grazed when mature	5	10	15
. not suitable for fattening	5	3	8

1/ Multiple responses were possible

Table 6. Brachiaria humidicola: soil characteristics

	Puerto López-Puerto Gaitán		Puerto Gaitán-Carimagua		Llanos Orientales[1]
	Well-drained	Poorly drained	Well-drained	Poorly drained	Well-drained
Number of farms	15	8	19	5	-
pH	4.94	4.91	4.92	4.73	4.50
P (ppm)	4.46	5.32	1.72	6.91	1.60
K (meq/100 grs)	0.06	0.09	0.05	0.07	0.08
Ca (meq/100 grs)	0.39	0.42	0.25	0.43	0.10
Mg (meq/100 grs)	0.09	0.13	0.08	0.10	0.02
Al saturation (%)	66.80	51.62	84.15	25.87	93.20

1/ For comparison with the whole region, 18 representative soil profiles 0-20 cm (ETES Study)

Table 7. Brachiaria humidicola: importance in relation to other pastures

	B.humidicola		B.decumbens		A.gayanus	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Puerto López-Puerto Gaitán						
Average	23	62.7	20	158.2	5	2.9
Max		220.0		1000.0		30.0
Min		3.0		0.0		0.0
Puerto Gaitán-Carimagua						
Average	24	98.6	15	107.7	5	41.2
Max		500.0		600.0		450.0
Min		10.0		0.0		0.0
Total						
Average	47	81.0	35	132.4	10	22.3
Max		500.0		1000.0		450.0
Min		2.0		0.0		0.0

Table 8. Brachiaria humidicola: area of initial plantings and multiplication rates.

Region	Area of initial planting (ha)	Multiplication rates
Pto.López-Pto.Gaitán:		
Average	12.6	21.9
Max	83.0	50.0
Min	0.5	10.0
Pto.Gaitán-Carimagua:		
Average	30.5	20.4
Max	200.0	40.0
Min	1.0	8.0
Total:		
Average	21.7	21.1
Max	200.0	50.0
Min	0.5	8.0

useful contribution to their present farming system.

2. Establishment is easy, low-cost and low risk, allowing the utilization of low opportunity cost resources, such as machinery not used elsewhere in the second half of the wet season, and fixed labour not used in other activities. At the same time, very few purchased inputs are required as vegetative planting material produced on-farm is employed, and fertilizers are used to a very limited extent; when used these consist of basic slag only.

3. In the existing production systems B. humidicola, particularly when sown in the poorly-drained parts of the farm which have somewhat higher soil moisture in the dry season, plays the role of a buffer which allows the destocking of more productive pastures during the dry season. This role is gaining in importance as the total stocking rate of the farm increases with expanding areas of other improved pastures.

4. The success of B. humidicola highlights the need for materials to replace the savanna as a dry season buffer and increase the production potential of poorly-drained areas. In spite of limited specific screening efforts for this environment, several new materials show promise. Research is needed particularly on how to establish these materials and integrate them into the production systems.

3. Adoption and Impact of A. gayanus on the North Coast of Colombia

A. gayanus was released in Colombia as a grass for the acid infertile savannas of the Llanos. From 1983 onwards seed production of A. gayanus increased markedly and originated mainly from the Department of Cesar, a region considered particularly appropriate for seed production because of its latitude and climatic conditions.

A visit to the region revealed that about 60-70 tons of seed were being produced annually, that this was related to very few individual enterprises and larger farmers, that some of it was sold to seed dealers in the Llanos and some sold to Venezuela, but that the largest quantity was being used on the North Coast itself, particularly in Cesar itself.

This led to the implementation of a survey of early adopters during 1985. Customer lists were obtained from the main A. gayanus seed producers. A random sample of customers having bought less than 200 kg each was drawn and all customers having bought 200 kg or more were included. The survey questionaire included questions on general characteristics of the farming operation, management of different types of pastures and particularly A. gayanus, and future plans related to the cultivar. In addition A. gayanus plots were visited, soil samples drawn and measurements taken of profile depth as well as plant size (diameter of tussocks) and plant density (number of plants in a 5 m transect) as well as presence of legume and weeds. A total of 66 farms were surveyed and 1,103 individual 5 m transects were evaluated. Figure 1 shows the distribution of the farms surveyed in Cesar classified by the size of the A. gayanus paddocks established. Adoption clearly concentrated in the northern half of the department.

Truly random surveys of early adoption need very large sample sizes in order to include enough adopters to allow inferences to be drawn about factors determining adoption. Studies which consider only adopters thus focus on explaining the extent of use of the technology being monitored as the central variable.

Farms were therefore classified in three categories according to the area of A. gayanus existing on the farm at the time of the survey. Farm size and land use differ markedly between adoption categories (Table 9). Mean Andropogon areas increase from 8 ha in the lowest category up to 182 ha in the 50 ha + category. While A. gayanus comprises only 2% of the total farm area in the lowest category, it increases to 5% in the intermediate category and 16% in the highest one. This clearly indicates a better fit of the technology on the latter farms. Farms tend to grow crops in all three categories.

Animal production in Cesar comprises an important dual-purpose beef and milk production system and the fattening of steers. The relative importance of dual-purpose milk production is larger in the smaller farms (Table 10) which have less A. gayanus in relation to other pastures (Table 9). Nevertheless the absolute number of dual-purpose cows increases substantially in the 50 ha + category.

To depict the dynamics of the early adoption process, decision trees were constructed indicating the number of farmers continuing to plant A. gayanus once they had tested it and the average areas planted by those who continue to expand areas in subsequent years (Figure 2). This analysis was done separately for each year since the release of the material. The figures for 1985 are not included because the survey was done before the end of the planting season. Year 1 is atypical because one farmer introduced the material in the region, saw a market for its seed and continued to expand, mainly in order to increase his seed volume. In subsequent years increasing numbers of farmers tested the material, and did so with relatively important areas. These initial areas tended to increase in size over

Table 9. Land use on farms adopting A. gayanus in the Department of Cesar, Colombia.

	A. gayanus area (ha)		
	1-20	21-50	+50
Number of farms	37	18	11
Hectares of:			
. A. gayanus	8	35	182
. P. maximum+ H. rufa + D. aristatum	126	438	570
. Savannas	98	30	225
. Other pastures and fallow	112	66	114
. Crops	23	105	67
Total farm area	367	674	1158

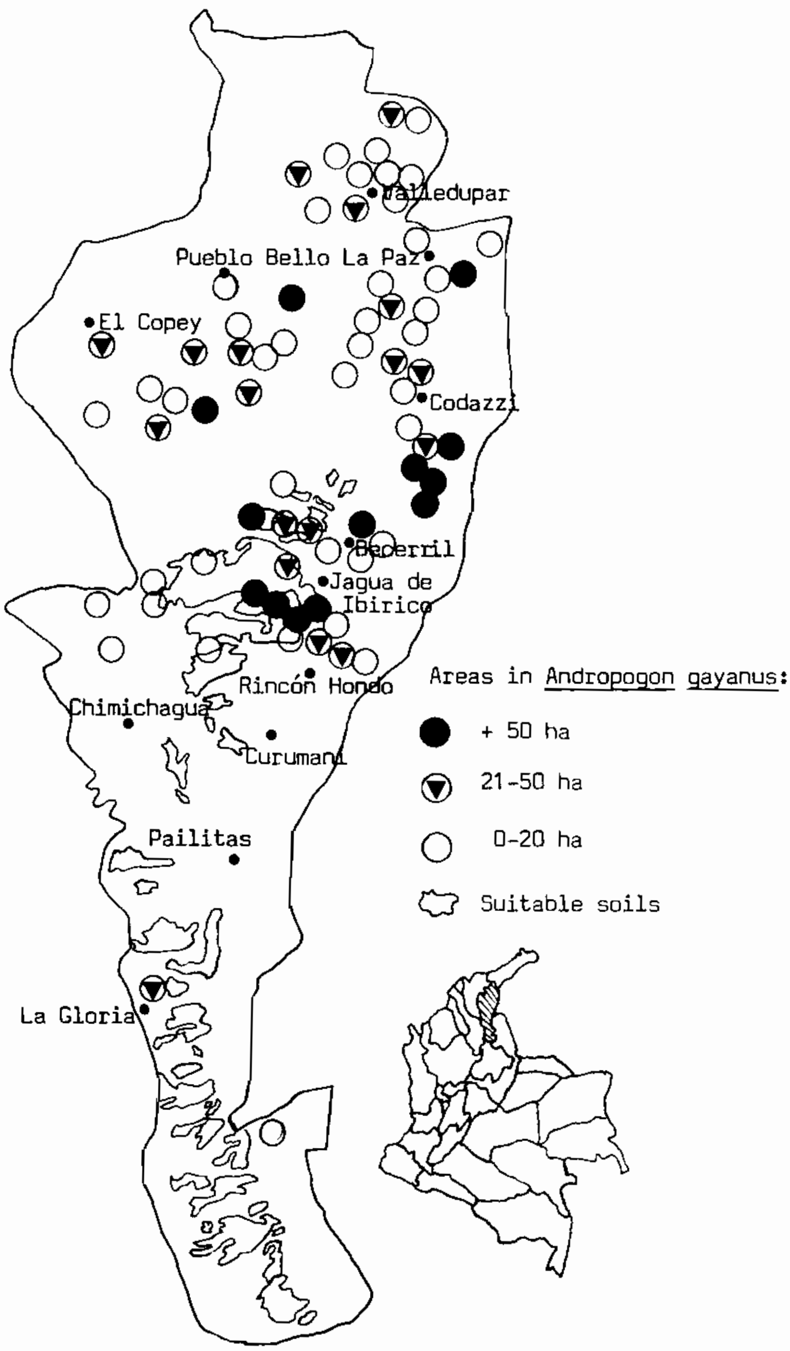
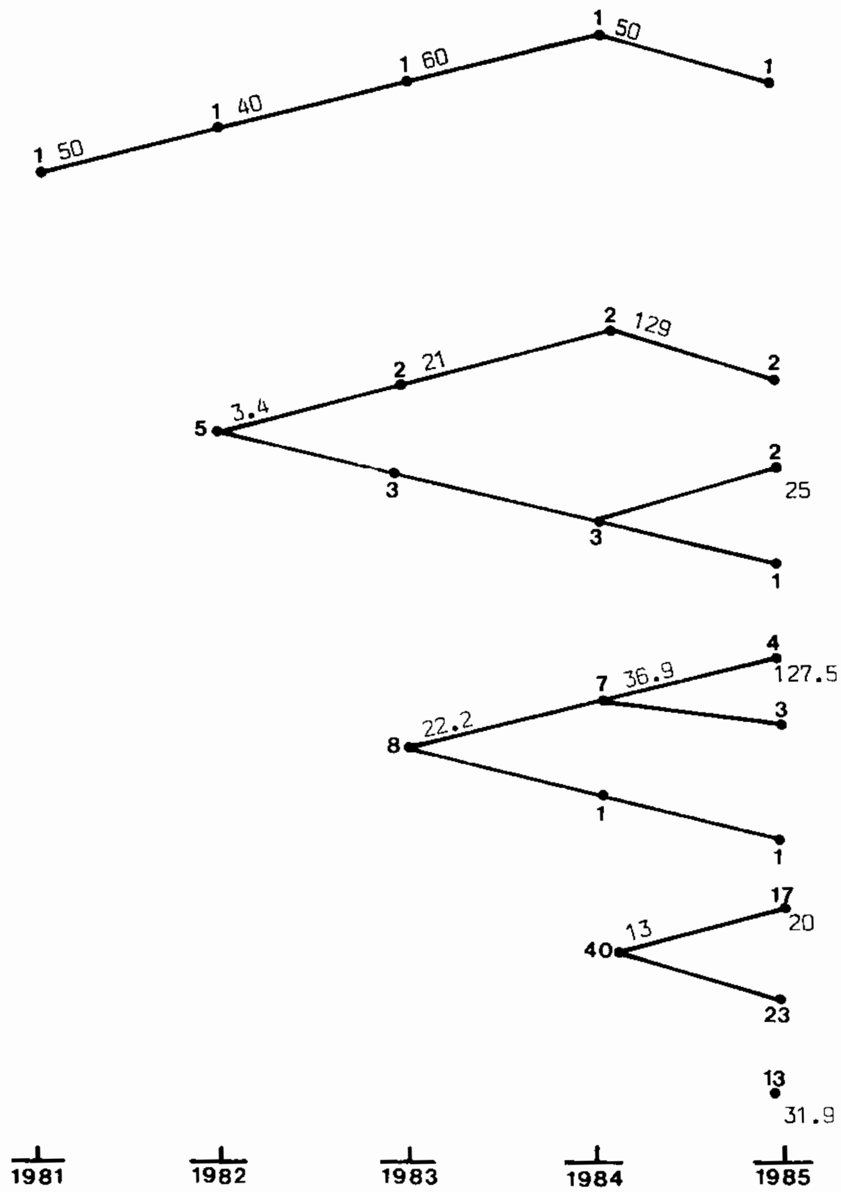


Figure 1. Location of farms surveyed in the Department of Cesar, Colombia



1/ Number of users, mean area planted (ha)

Figure 2. Adoption over time: number of adopters continuing to grow Andropogon gayanus in the Department of Cesar, Colombia[1]

Table 10. Stock numbers on farms adopting A. gayanus in the Department of Cesar, Colombia.

	A.gayanus area (ha)					
	1-20		21-50		+50	
	Dry	Wet	Dry	Wet	Dry	Wet
. Dual-purpose cows	107	112	117	127	402	409
. Steers	56	83	178	199	506	528
Total herd	348	381	607	654	1306	1423

time, reflecting increasing confidence in the technology, decreasing seed prices, and ample seed supply.

At the same time an important number of farmers discontinued testing, while continuing adopters rapidly increased areas planted.

This seems to indicate that large numbers of farmers were willing to test a new grass cultivar promoted as being adapted to poor soils. Many found it unsuited for their conditions. It must be kept in mind also that these pastures are perennial crops. Thus after a few years some farms had already planted all the land appropriate for it and therefore. stopped. Regression analysis was used in an attempt to explain the wide variability of the stands of Andropogon observed in the region. Table 11 presents the analysis undertaken for all plots surveyed except those established in 1985, where the coverage index would have been misleading. The analysis shows that:

- poor drainage has a very negative effect;
- plots planted after crops have significantly higher coverage indices;
- sandy soil texture is associated with significantly higher coverage index values;
- soil depth has a highly significant effect which is not linear; very shallow soils have a particularly negative effect on A. gayanus stands;
- Andropogon is very sensitive to low levels of salinity;
- there is a significant association between increasing aluminium levels and higher Andropogon coverage indices, thus confirming its adaptation to acid soils;
- Andropogon reacts negatively to late planting.

In spite of not including any manage-management variable such as grazing regime, stocking rate or weed control, this model explains 43% of the total variability observed, thus highlighting the importance of the characteristics of the land resources allocated to the grass.

A second model was estimated for farms with more than 10 ha of A. gayanus which basically confirmed the previous model's results but increased the multiple coefficient of determination to 54% (Table 12).

The above information was used to develop a regression model explaining the area of Andropogon per farm (Table 13). Aluminium was again shown to influence the extent of adoption as well as the area of savanna on the farm. This reflects the existence of infertile sandy areas without tree vegetation, sometimes with the presence of aluminium, which are particularly suitable for A. gayanus. Finally, the number of years in which the farmer planted Andropogon contributed significantly to the regression.

This reflects the fact that seed was limiting in the first years and that most farmers harvested seed to expand areas of Andropogon. The above mentioned factors explained 60% of the total variability observed in A. gayanus areas between farms.

Table 11. Explanatory model for *A. gayanus* coverage: all farms surveyed except 1985 plantings, Department of Cesar, Colombia, 1985

Dependent variable: Andropogon coverage index (cm/5m transect)

Variable	Mean	Range	Regression coefficient	Significance
1. Constant			-101.786	-
2. Dummy: poorly drained soil			-159.811	0.001
3. Seeding rate (kg/ha)	10.72	4-25	6.131	0.001
4. Dummy: previous land use - crops			97.952	0.001
5. Sand, %	43.39	4.3-78	2.261	0.001
6. Square root of soil depth (cms)	3.75	1- 8.36	46.309	0.001
7. Salinity (mmhos/cm)	0.47	0- 3.75	-72.620	0.003
8. Salinity squared	0.72	0-14.06	6.622	0.390
9. Aluminium (meq/100 grs soil)	0.04	0- 1.30	385.861	0.001
10. Dummy: planting after October			-105.284	0.001

Number of observations.. 982
Multiple coefficient of determination (R^2).................... 0.431

Table 12. Explanatory model for *A. gayanus* coverage: farms with areas of *A. gayanus* of more than 10 ha, Department of Cesar, Colombia, 1985[1]

Dependent variable: Andropogon coverage index (cm/5m transect)

Variable	Mean	Range	Regression coefficient	Significance
1. Constant			-96.047	-
2. Dummy: poorly drained soil			-163.608	0.001
3. Seeding rate (kg/ha)	10.75	4-25	2.433	0.238
4. Dummy: previous land use - crops			193.048	0.001
5. Square root of soil depth (cms)	3.89	1- 8.36	65.364	0.001
6. Salinity (mmhos/cm)	0.24	0- 2.35	-252.572	0.001
7. Salinity squared	0.23	0- 5.52	184.173	0.004
8. Aluminium (meq/100 grs soil)	0.07	0- 1.30	396.995	0.001
9. Sodium (meq/100 grs soil)	0.11	0- 5.90	-247.831	0.001
10. Rest period (days)	32.96	0-180	2.573	0.001

Number of observations.. 585
Multiple coefficient of determination (R^2).................... 0.543

1/ Excludes 1985 plantings

Table 13. Explanatory model of the A. gayanus area per farm, Department of Cesar, Colombia. 1985.

Dependent variable: Andropogon area per farm (ha)

Variable		Regression coefficient	Significance
1.	Constant	-0.397	-
2.	Aluminium (meq/100 grs soil)	137.077	0.025
3.	Savanna areas (ha)	-0.134	0.086
4.	Number of years planting A. gayanus squared	14.608	0.001
5.	Savanna area squared (ha)	8.655	0.101

Number of observations.. 66
Multiple coefficient of determination (R^2).................... 0.596

The strong association of soil characteristics with A. gayanus performance and extent of adoption on farms led to a classification of soils sampled into "suitable" for A. gayanus (whenever aluminium was present), "not suitable" (when salinity was detected), and "intermediate" (when neither aluminium nor salinity were encountered). For comparative purposes soil samples were drawn from "fertile" plots where pastures with higher requirements such as P. maximum and D. aristatum were grown. Even "suitable" soils with aluminium are substantially richer in phosphorous, potassium, calcium and magnesium than typical Llanos Orientales soils, and aluminium saturation is only about one fourth of its level in the Llanos (Table 14).

This contributes to an explanation of the fact that A. gayanus is never fertilized on the North Coast. This reduction in costs compared with the Llanos is one of the key elements in explaining its substantially higher rate of adoption on the North Coast than in the Llanos.

ICA supplied a map produced by the IGAC (Instituto Geográfico Agustín Codazzi) which included a mapping unit of soils with aluminium. It showed approximately 200,000 ha of these soils in Cesar and 400,000 ha on the whole North Coast (see Figure 3). The overlap with the existence of large areas of A. gayanus (more than 50 ha) was very marked in the Northern part of the department. Analysis of the rainfall patterns, particularly the length and severity of the dry season, leads to the hypothesis that A. gayanus' competitive advantage over other grasses, particularly B. decumbens, is associated with the existence of a dry season of 5 months, with frequent months of zero rainfall. This does not occur in Southern Cesar.

In terms of research effort, the study of the impact of A. gayanus, on the North Coast has to be considered a spill-over of the programs' main research effort geared at developing forage germplasm for the acid infertile lands of tropical America. To quantify its potential magnitude the following set of assumptions was used for Cesar:

Potential area for which A. gayanus is suitable....	109,000 ha
Average farm size.........	1,158 ha
Number of farms with potential	95
Average area of suitable soils per farm...........	407 ha

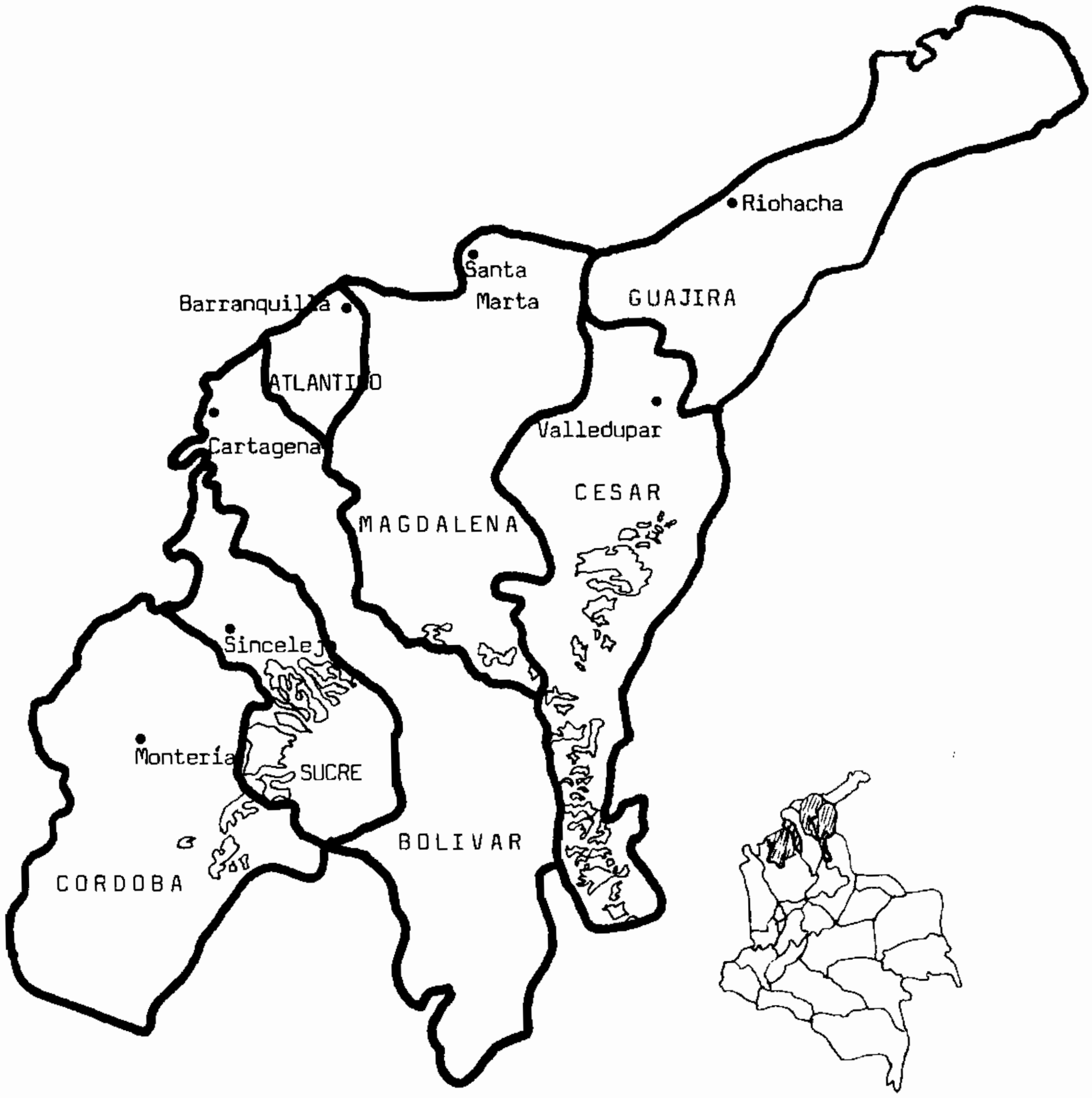


Figure 3. Areas suitable for Andropogon gayanus on the North Coast of Colombia

Table 14. Soils of farms using *A. gayanus* in the Department of Cesar, Colombia

	Cesar				Llanos Orientales
	Suitable	Intermediate	Not suitable	Fertile	
Number of samples	9	39	47	32	*
pH	5.08	5.77	6.86	6.29	4.50
P (ppm)	11.07	35.68	103.00	74.10	1.60
K (meq/100 grs)	0.16	0.29	0.53	0.43	0.08
Ca (meq/100 grs)	1.51	5.60	15.22	9.47	0.10
Mg (meq/100 grs)	0.32	1.19	2.69	2.19	0.02
Al saturation (%)	24.90	0.00	0.00	0.00	93.30

* 18 representative soil profiles 0-20 cm (ETES Study)

Adoption ceilings: % of farms..................... 70% (66 farms)

% of suitable area per farm.................... 70% (284 ha)

The major impact expected is the increase in stocking rate both in the wet and dry seasons and the increased weight gain per animal (Table 15). For comparative purposes corresponding values for straight grass and legume-grass associations in the Llanos are presented. These assumptions consider only the impact on farms similar to those with more than 50 ha of *A. gayanus*, thus ignoring the benefits achieved on all other farms using the material, farms on which the advantage of *A. gayanus* may be smaller. Establishment costs are limited to seed and minimal seed bed preparation, resulting in markedly lower investments per hectare than in the Llanos. Given the fact that machinery is available on most farms, only the variable costs of its use are imputed. Similarly, pasture maintenance represents only about one fourth of its cost in the Llanos (Table 16). Per hectare investment costs amount to US$145 in Cesar compared with between US$340 and US$404 in the Llanos. Cash flows in years 1 to 15 are higher for the Llanos alternatives (Table 17), but marginal internal rates of return are substantially higher in Cesar (78% p.a.) than for both alternatives in the Llanos (33% and 39% p.a.).

In order to asses the level of impact, farms were assumed to adopt the technology in the following sequence:

1.5% in year 1	22.0% in year 6
3.0% in year 2	16.0% in year 7
7.5% in year 3	7.5% in year 8
16.0% in year 4	3.0% in year 9
22.0% in year 5	1.5% in year 10

Within farms areas sown were assumed to evolve as follows:

4 ha in year 1
50 ha in year 2
80 ha in year 3
80 ha in year 4
70 ha in year 5

At the aggregate level four alternatives were compared (Table 18): the impact in Cesar, the impact on the North Coast based on the same parameters and areas of appropriate soils as reported by the IGAC/ICA map, the impact in the Llanos assuming the same number of adopters and the same area adopted as in Cesar, and the use of either a pure grass technology or a

Table 15. Physical impact of A. gayanus in Cesar and the Llanos Orientales, Colombia.

	Cesar		Llanos Orientales			
	A.gayanus		Grass		Legume grass association	
	Wet	Dry	Wet	Dry	Wet	Dry
Native pasture						
Stocking rate (UA/ha)	1	0	0.2	0.2	0.2	0.2
Production (kg/UA)	100	0	75	0	75	0
Established pasture						
Stocking rate (UA/ha)	1.5	1	1.5	1.1	1.8	1
Production (kg/UA)	150	45	130	25	150	25
Marginal stocking rate (UA/ha)	0.5		1.3		1.6	
Marginal production (kg/ha)	170		206		281	
Persistance (years)	15		15		15	

Table 16. Establishment and maintenance costs of A. gayanus in Cesar and the Llanos Orientales, Colombia.

	Cesar		Llanos Orientales			
	A.gayanus		Grass		Legume grass association	
	$/ha	%	$/ha	%	$/ha	%
Establishment						
Land preparation	1520	30	1682	11	1682	11
Sowing	3500	70	5840	39	6840	43
Fertilization	0	0	7400	50	7400	46
Total	5020	100	14922	100	15922	100
Maintenance						
Fertilization (every three years)	0	0	3700	100	3700	100
Weed control (every year)	1000	100	0	0	0	0
Total	1000	100	3700	100	3700	100

Table 17. Cash flow of pasture investments on the North Coast and in the Llanos Orientales, Colombia

	Cesar		Llanos Orientales			
	A. gayanus		Grass		Legume grass association	
	$/ha	US$/ha	$/ha	US$/ha	$/ha	US$/ha
Investment:						
Pastures	5020	31.12	14922	92.51	15922	98.71
Marginal investment in steers	17250	106.95	39000	241.80	48000	297.60
Others	1250	7.75	1040	6.45	1280	7.94
Total	23520	145.82	54962	340.76	65202	404.25
Net income:						
Year 1	18300	113.46	19560	121.27	26820	166.28
Year 3	18300	113.46	15860	98.33	23120	143.34
Year 15	35550	220.41	58560	363.07	74820	463.88
IRR (%)	77.79		33.25		39.22	

Table 18. Adoption impact of *A. gayanus* on the North Coast, Colombia

	Cesar	North Coast	Llanos Orientales	
	A. gayanus	A. gayanus	Grass	Legume grass association
Adoption ceiling (No. of farms)	66	121	66	66
Cummulative *A. gayanus* areas (ha):				
Year 5	1982	2244	1982	1982
Year 10	16554	26106	16554	16554
Year 15	18744	34578	18744	18744
Incremental steers needed (No):				
Year 5	991	1122	2576	3171
Year 10	8277	13053	21520	26486
Year 15	9372	17289	24367	29990

legume grass association. The same adoption level as in the Cesar would require a substantially higher number of steers to be fattened. Expressed in terms of percentage of steers existing in 1981 in each region, values of 5% for the Cesar, 1% for the North Coast, 16% for a grass technology in the Llanos and 20% for a legume-grass association technology in the Llanos are reached. This clearly indicates that while adoption will be feasible and will not affect market prices significantly on the North Coast, the converse applies to the Llanos.

Table 19 presents the evolution over time of the aggregate impact of the four strategies in terms of incremental beef production and cash flow in US$ assuming constant 1985 prices. Given the fact that zero research costs are imputed to the North Coast as a spill-over of Llanos research and no extension efforts were involved beyond those of private seed producers, and that these costs are internalized in the seed price paid by farmers, project level returns correpond to the aggregate of the farm level parameters. Net present values at a 10% discount rate were highest for the whole North Coast alternative, followed by the Llanos association alternative, the Cesar alternative and finally the Llanos grass alternative. Nevertheless, due to the different investment levels required, the order changes when the alternatives are ranked by marginal internal rates of return, with the Cesar and North Coast alternatives achieving 78% p.a. versus 39% for the association and 33% for the grass alternative in the Llanos.

It can be concluded that:

1. In spite of having been developed as a technology for very acid infertile soils, *A. gayanus* can make an impact in very specific farming system niches such as the moderately acid soils with aluminium in the North Coast.

2. As can be expected from a low external input technology, its

Table 19. Adoption impact of *A. gayanus* on the North Coast, Colombia

	Cesar	North Coast	Llanos Orientales	
	A.gayanus	A.gayanus	Grass	Legume grass association
Adoption ceiling (No. of farms)	66	121	66	66
Incremental beef production (tons liveweight)				
Year 5	336	381	408	557
Year 10	2814	4438	3410	4651
Year 15	3186	5878	3861	5267
Average	1707	2945	2068	2821
Cash flow ('000 US$)				
Year 5	-81	-106	-318	-362
Year 10	1250	1625	812	1312
Year 15	2125	3875	2125	3000
Net present value (10%)	6250	11250	5062	7500
IRR (%)	78	78	33	39

performance depends markedly on the resource endowment (particularly soils and climate) existing on the farm. Where this is very variable across farms as in Cesar, adoption will not be uniform but very selective.

3. Rapid initial adoption in Cesar is explained by the low opportunity cost of the land involved, the substantial production impact achieved, the low establishment costs, ample supply of cattle on the farms, and complementarity of the *A. gayanus* pasture with other pastures grown on more fertile soils on the same farms.

4. The high marginal rates of return achieved (78% p.a.) have been a strong incentive for adoption, which has occurred without any official sector intervention, in years where cattle prices were on a downward trend and the general socioeconomic framework was not conducive to pastoral investments.

4. Andropogon gayanus in Central Brazil

a) Survey of the tropical pasture seed industry

In cooperation with CPAC/EMBRAPA and the Seed Section of the Tropical Pastures Program a survey of the main tropical pasture seed producers and dealers was undertaken to assess the extent of diffusion of *A. gayanus* in Brazil. Major findings of economic relevance were:

- The total volume of *A. gayanus* seed handled by the large-scale pasture seed sector was 175 tons in 1982, 422 tons in 1983 and 496 tons in 1984.

- Price of *A. gayanus* seed dropped rapidly in real terms, moving from US$13.63 in 1982 to US$1.58 in 1984.

- Estimates of the importance of farmer-to-farmer trade in *A. gayanus* seed varied widely. The median estimate by seed producers was that they provided 65% of the total volume sown.
- Using this information and the reported median seeding rate the present area of *A. gayanus* existing in Brazil was estimated to be about 170,000 ha.

- Main areas of adoption are Mato Grosso, Goias, and Minas Gerais, with minor areas in the Pantanal and the Northeast.

More details of this survey are presented in the report of the Seed Section.

b) Early adoption and impact of A. gayanus in the Cerrados

In 1984 EMBRAPA's Cerrados Center CPAC commissioned a study on the adoption of agricultural technology generated by the EMBRAPA system for the Cerrados region. This study was undertaken by the University of Brasilia. Based on CPAC's agroecological studies the Geoeconomic Region of Brasilia (approximately 20 million ha) was stratified into homogeneous regions, and 11 "municipios" considered representative of the main agroecological regions were sampled. Within these "municipios" 450 farmers were sampled randomly. This survey included two questions on *A. gayanus*: whether the farmer knew it and whether he was using it on his farm. Usage was defined as having any area of his farm planted to it, including very small "test" plots.

Preliminary manual tabulations showed that 85% of the respondents knew the plant and 25% claimed to "use" it. Given this indication of relatively wide adoption, a more detailed study of the adoption process and present use of the material was planned jointly by CPAC and CIAT.

Using the sampling frame work of the farms surveyed by the University of Brasilia, a random sample of 60 "users" stratified according to occurrence in the 11 "municipios" was drawn, as well as of 40 farmers knowing the cultivar and 20 not knowing it. A survey was designed covering general characteristics of the farms, detailed information on the adoption and use of A. gayanus as well as its impact on the farming system, and intentions of expanding A. gayanus areas. Farmers not using it were asked the same set of questions on characteristics of the farm and specific questions on reasons for not using the material. The survey has been completed and presently (December 1985) data are being tabulated and analyzed. Results of the survey will be used for the assessment of the economic impact of the technology.

5. Status of A. gayanus adoption throughout tropical Latin America (October 1985)

During the recent RIEPT meeting a rapid survey of diffusion and use of A. gayanus in tropical Latin America was undertaken.

Participants were asked to estimate the present area of A. gayanus in commercial use in their state or department and a figure for their whole country, disaggregated according to whether it was grown as a pure grass pasture or in association with a legume. They were also asked to forecast the areas to be sown in 1986, again in terms of pure stands and in association.

Table 20 shows that almost 300,000 ha are estimated to have been established up to 1985. The picture is clearly dominated by the extent of adoption in Brazil which contributes 93% of the total existing area. Nevertheless, important areas are also found in Colombia and Venezuela, countries with substantial areas of acid infertile savannas.

Andropogon adoption seems to be gaining momentum in Central America

Table 20. Use of A. gayanus in Latin America, 1985[1] (hectares)

	1985 Existence		1986 Planting Intentions	
	In pure stands	In legume-grass mixtures	In pure stands	In legume-grass mixtures
Bolivia	100	0	450	0
Brazil	268000	0	66000	0
Colombia	7600	300	3400	300
Costa Rica	1	1	8	5
Guatemala	0	0	1	0
Guyana	2	0	0	0
Honduras	15	0	8	0
Mexico	22	0	75	0
Nicaragua	245	0	150	0
Panama	1032	50	1085	0
Paraguay	1000	0	1500	0
Peru	120	5	220	0
Venezuela	11100	200	17900	500
Total	289237	556	90797	805

1/ Based on a survey of researchers of the RIEPT, October 1985 and Panama, with more than 1,000 ha in the latter country and initial areas in Nicaragua, Mexico, Honduras and Costa Rica. Virtually all areas established have been planted as pure grass pastures.

Planting intentions for 1986 indicate an expansion of about 31% over existing areas at a regional level. This figure nevertheless masks the marked differences in adoption stage and growth rates between Brazil and Colombia, where the material was released first with growth rates of 25% and 45% respectively, and the rest of the countries, with growth rates above 100%. Planting intentions clearly indicate the overwhelming tendency to establish A. gayanus as a pure-grass pasture.

The survey reveals that A. gayanus represents a valuable and distinct germplasm contribution to Latin Americas' tropical pasture production. Nevertheless it also highlights the fact that a tropical forage legume still remains a major challenge for the Tropical Pastures Program.

Training

During 1985 forty professionals from 18 countries were trained in production and utilization of pastures in unfertile, acid soils with the objectives of collaborating with national institutions in the formation and actualization of, their researchers and strengthening the International Tropical Pastures Evaluation Network (Table 1).

Seven of the professionals worked on MS or Ph.D. level theses, 14 received training on research in the Program's sections and 17 attended the Scientific Training Program's Intensive Multidisciplinary Phase in Research for the Production and Utilization of Tropical Pastures held from February 4 to March 29, 1985. The Specialization Phase started in March 30 and 13 of the researchers assisting remained for several months, participating in projects and in on-farm tasks related to their specialization.

The sections which dedicated the most time to training during 1985 were Pasture Quality and Productivity (52.3 man-months), Regional Trials (20.7 man-months) and Soil-Plant Nutrition (17.1 man-months), as shown in Table 1.

As shown in Table 2, the highest percentage of participants were from Colombia, Cuba and Peru followed by Mexico and Brazil.

EXTENT OF TRAINING IN TROPICAL PASTURES

Contribution to the International Tropical Pastures Evaluation Network

The strengthening of the International Tropical Pastures Evaluation Network RIEPT was an important achievement obtained through training. Eighty-one pf the RIEPT trials (52%) established up to June 1985 in the three major ecosystems of tropical America, are executed by CIAT-trained professionals (Figure 1).

Summary of training in tropical pastures

Table 3 includes the number of researchers trained in each section of the Tropical Pastures Program from 1969 until 1985. It shows that, of 518 researchers trained in this period, 75 (14%) worked on MS or Ph.D. theses tasks, 393 (76%) as Visiting Researchers and 50 (10%) received the Intensive Multidiscipli- nary Phase or Short Course. These statistics show the process of fulfilling the main objective of integral training of researchers in tropical pastures. The researchers trained in the 8 Programs of Scientific Training in Research are shown by country in Table 4. The highest percentage of researchers trained came from Brazil, Colombia and Peru, countries which possess extensive areas with unfertile, acid soils.

Table 1. Researchers trained in the Tropical Pastures Program during 1985 by categories and man/months in each section.

Section	Associate Visiting Scientists				Visiting Researchers						Fellowship		Intens. Multidisc. Course		Subtotals	
	Thesis Ph.D.		No Thesis		Thesis MS		Specializ.		Specializ. plus Intens. Multidisc. Course							
	No.	M/M*	No.	M/M	No.	M/M	No.	M/M	No.	M/M	No.	M/M	No.	M/M	No.	M/M
Germplasm	1	12.0													1	12.0
Agronomy (Carimagua)									2	9.5	1	8.3			3	17.8
Regional Trials							2	1.7	4	19.0					6	20.7
Entomology							1	4.4							1	4.4
Phytopathology									1	9.2					1	9.2
Soils, Plant Nutrition	1	8.3							1	8.8					2	17.1
Soil Microbiology	1	8.7					2	4.9							3	13.6
Quality and Productivity of Pastures					2	8.9	4	21.2	3	22.2					9	52.3
Ecophysiology			1	8.0			1	2.1							1	10.1
Pasture Development							2	5.7							2	5.7
Seed Production					1	2.2	1	9.1							2	11.3
Livestock Production Systems	1	12.0							1	4.6					2	16.6
Economics							1	2.7	1	4.8					2	7.5
Intensive Phase (Short Course)													4	7.4	4	7.4
Total	4	41.0	1	8.0	3	11.1	14	51.8	13	78.1	1	8.3	4	7.4	40	205.7

* Equivalent to man/months of training.

Table 2. Distribution by country of origin of researchers trained in the Tropical Pastures Program during 1985.

Country of Origin	No. of Researchers	Percentage
Germany	1	2.5
Bolivia	1	2.5
Brazil	3	7.5
Colombia	6	15.0
Cuba	7	17.5
Ecuador	1	2.5
United States	1	2.5
Guatemala	1	2.5
Guyana	1	2.5
Mexico	4	10.0
Nicaragua	1	2.5
Panama	1	2.5
Paraguay	2	5.0
Peru	6	15.0
United Kingdom	1	2.5
Dominican Republic	1	2.5
Republic of China	1	2.5
Total	40	

The Program of Scientific Training in Research has been targeted mainly to professionals having linkages with national entities working in tropical pastures within the scope of CIAT's Tropical Pastures Program and which collaborate with RIEPT.

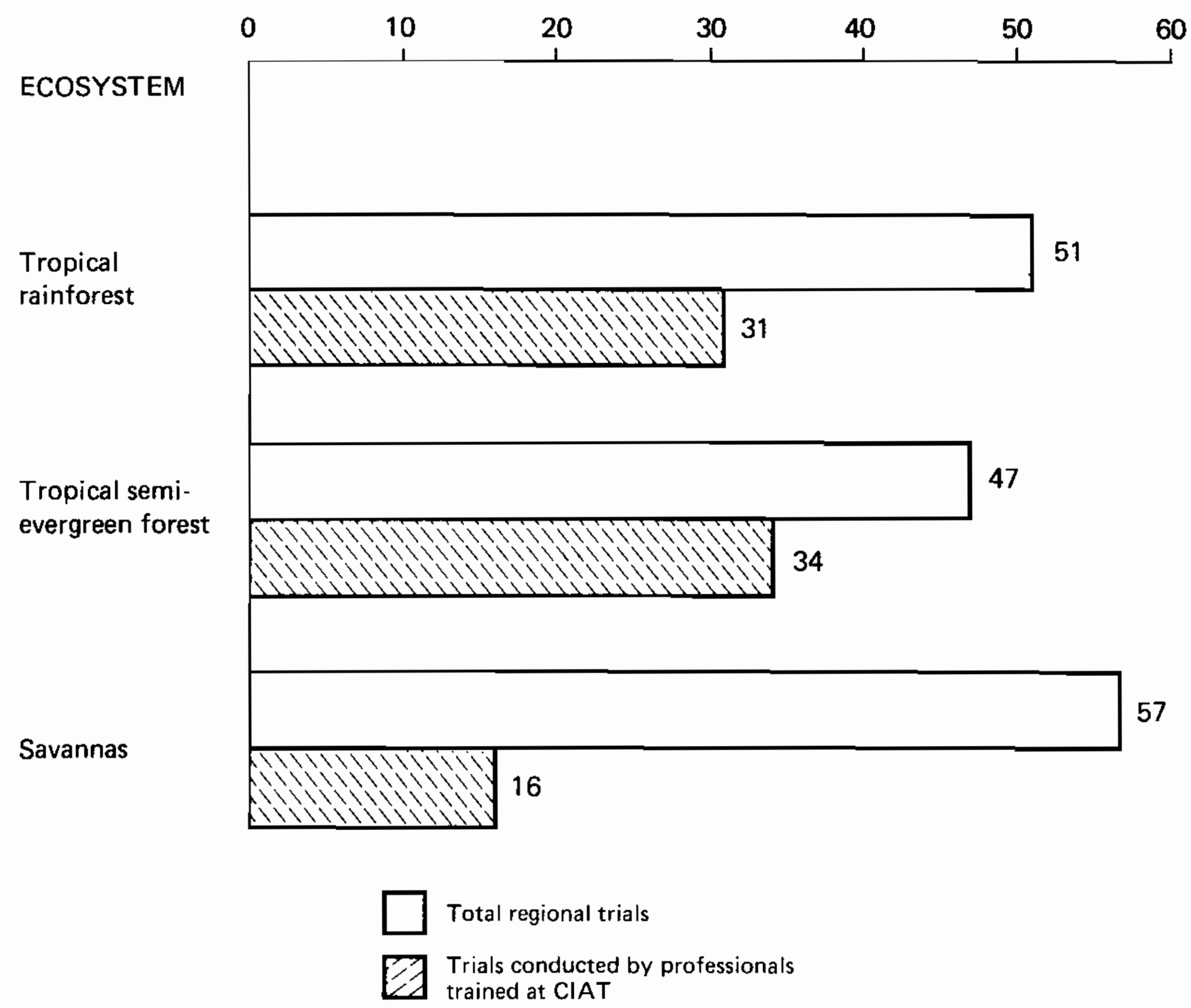


Figure 1. Total regional trials on tropical pastures established by ecosystem until June 1985 and conducted by professionals trained at CIAT.

Table 3. Researchers trained in the Tropical Pastures Program by year and categories from 1969 to 1985.

Year	Training Categories					
	Ph.D. Thesis	Visiting Researchers: MS Thesis	Visiting Researchers: Special Training in Research	Visiting Researchers: Intensive Multidisc. Course plus Res.Spec.	Intensive Multidisc. Course	Subtotals
1969			9			9
1970		1	10			11
1971			7			7
1972	2		27			29
1973		3	23			26
1974	2	1	11			14
1975	8	1	40		1	50
1976			21			21
1977	4	2	27			33
1978	3	2	27			32
1979	5	6	34			45
1980	5	2	10	21	8	46
1981	4		11	12	5	32
1982	5	3	13	15	2	38
1983	1	4	4	19	3	31
1984	3	1	5	19	27	55
1985	4	3	15	13	4	39
Subtotals	46	29	294	99	50	518
Totals (5)	75(14%)		393(76%)		50(10%)	

Table 4. Participants by country in the eight Scientific Training Programs on Research for the Production and Utilization of Tropical Pastures, conducted at CIAT from 1978 to 1985*.

Country	I	II	III	IV	V	VI	VII	VIII	Total	Percentage
Argentina	1								1	0.6
Bolivia	1	2	2	1		1	3	1	11	6.6
Brazil	7	3	5	4	5		3	1	28	17.0
Belice		2							2	1.2
Colombia	4	4	5	3	3	2		3	24	14.5
Costa Rica			1	1	1				3	1.8
Cuba	1		2				1		4	2.4
Ecuador		2	1			1		1	5	3.0
Guatemala								1	1	0.6
Holanda						1			1	0.6
Honduras			2	1	1	1			5	3.0
Haiti				1					1	0.6
Mexico				1			2	3	6	3.6
Nicaragua	2	1	2		1	3	2	1	12	7.3
Panama	1		2	3		6	2	1	15	9.1
Paraguay							1	1	2	1.2
Peru	3	4	3	2	1	3	4	4	24	14.5
Dominican Republic		1	1		4	2	1	1	10	6.0
Venezuela	1	5	2	1			1		10	6.0
Total	21	24	28	18	16	20	20	18	165	

* Does not include professionals who conducted MS or Ph.D. postgraduate level training or Special Researchers.

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