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Annual Report 1984

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INTRODUCTION

Beef and milk are high quality, nutritive commodities, basic in the diet of the population of tropical America. Their consumption and preference is high, independent of the population's income level (see Annual Reports 1979-1983).

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 extensiveness 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).

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

Contrasting with the large agricultural frontier areas (more than 300 million hectares of savanna and more than 600 million hectares of forests), 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

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.

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, from 1977 to 1981 this region was classified into large ecosystems creating the basis for development of a descentralized germplasm evaluation approach.

The map in Figure 1 classifies and locates the main ecosystems with which the Program works (Cochrane, 1982).

OBJECTIVE

The Tropical Pastures Program is essentially a strategy for the rural and pioneer 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.

The following strategies have been designed to meet this objective:

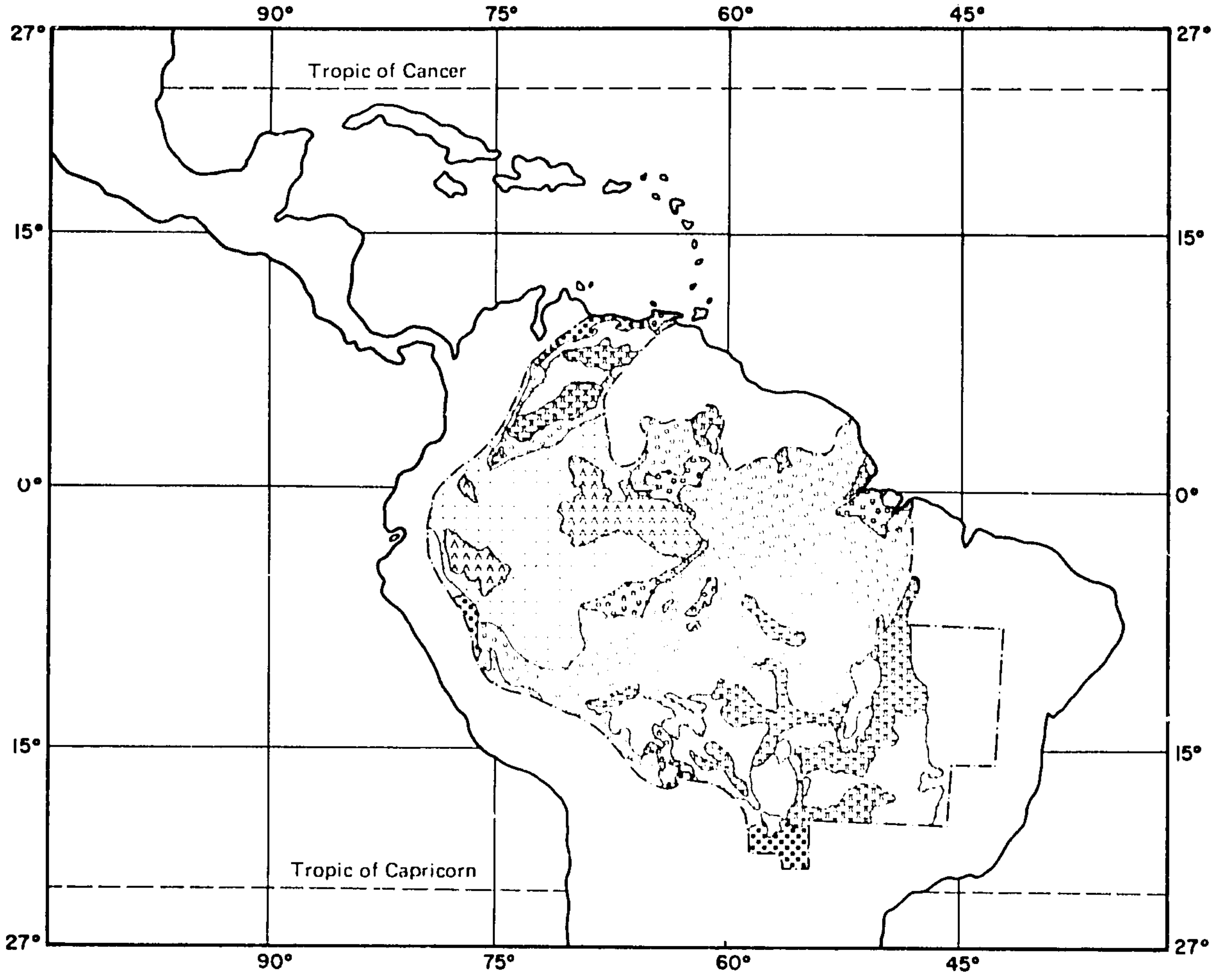
a) Selection of pasture germplasm adapted to the environmental conditions (climate and soil) and to the prevailing biotic conditions (pests and diseases).
b) Development of pastures and their management to optimize productivity and persistence.
c) Integration of new pasture technology into biologically, ecologically, and economically efficient animal production systems.

ORGANIZATION

According to the strategies described above, the Tropical Pastures Program is divided into three interdisciplinary groups:

a) Germplasm Evaluation.
b) Pasture Evaluation and Management.
c) Evaluation of Pastures in Production Systems.

The Germplasm Evaluation group focuses on the collection, selection, characterization, and development of legumes and grasses adapted to acid,



WELL-DRAINED ISOHYPERTHERMIC SAVANNAS (mostly Llanos). TWPE[a] 901-1060 mm, 6-8 months wet season, WSMT[b] > 23.5°C.

WELL-DRAINED ISOTHERMIC SAVANNAS (mostly Cerrados). TWPE 901-1060 mm, 6-8 months wet season, WSMT < 23.5°C.

POORLY DRAINED SAVANNAS. (Found in lowlands of tropical South America, in varying climatic circumstances.)

SEMI-EVERGREEN SEASONAL FOREST. TWPE 1061-1300 mm, 8-9 months wet season, WSMT > 23.5°C.

TROPICAL RAIN FOREST. TWPE > 1300 mm, > 9 months wet season, WSMT > 23.5°C.

POORLY DRAINED FOREST REGIONS.

DECIDUOUS FORESTS, CAATINGA,[c] etc.

OTHERS[c]

AREA CURRENTLY BEING ANALYZED

AREA CURRENTLY BEING STUDIED

[a] TWPE: Total Wet Season Potential Evapotranspiration.

[b] WSMT: Wet Season Mean Temperature.

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

Figure 1. Main ecosystems of tropical South America.

infertile soils and tolerant to pests and diseases.

The Pastures in Production Systems group analyzes the production systems prevailing in a specific area, the socio-economic conditions where these systems operate, and their implications for pasture technology. This group identifies the improved pastures component requirements to strategically solve and correct critical problems at the farm level. It also evaluates at the farm level the impact expected from the different alternatives of new improved-pastures technology.

The Pasture Evaluation and Management group serves as a bridge between the other two groups. Starting from characterized germplasm, provided by the Germplasm group, this group assembles pastures that respond to the requirements set by the Production Systems group. Its work focuses on the development and evaluation of pastures under different management schemes (grazing, fertilization, etc.) to optimize pasture productivity and persistence.

DESCENTRALIZED TECHNOLOGY DEVELOPMENT

The major screening sites of the Program are Carimagua (in the Eastern Plains of Colombia) in collaboration with the Instituto Colombiano Agropecuario (ICA) for the Llanos ecosystem, and the Centro de Pesquisa Agropecuária dos Cerrados (CPAC) in Brazil, in collaboration with EMBRAPA, for the Cerrados ecosystem. Furthermore, the initial stages of evaluation and seed multiplication take place at the CIAT-FES station in Quilichao. Given its proximity to CIAT headquarters, in addition to training, this station is used also for specific studies such as evaluation of nutritional value and methodology development. A new major screening site will be initiated at Pucallpa, Peru in 1985 for the selection of germplasm under the humid tropics conditions. This new effort will be conducted in collaboration with the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), and the Instituto Nacional de Investigación y Promoción Agraria (INIPA).

The experimental materials identified as promising in these major screening sites, are exposed throughout the International Tropical Pastures Evaluation Network (RIEPT) to the wide range of conditions in subecosystems within the main ecosystems of tropical America. The RIEPT is an inter-institutional cooperative effort, through which national programs evaluate new pasture germplasm, with the aim of selecting promising materials, and developing a pasture technology capable of having impact on the heterogeneous ecosystem/production system conditions of tropical America. This Network follows consecutive evaluation stages of agronomic adaptability, productivity, and grazing management, moving new pastures towards their utilization in producers' farms. The RIEPT not only is a mechanism to exchange and select germplasm, it is also a mean of exchanging technical information and methodologies for efficient pasture research.

GERMPLASM

During 1984 the activities of the germplasm section were focused on:

1) Assembling of germplasm through direct collection and through exchange of material 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 section's efforts and resources were devoted to germplasm collection activities, as the result of (a) the addition of a new principal staff member on a postdoctoral assignment at the beginning of 1984, and (b) the re-assumption of the responsibility for collection and introduction of grass germplasm in the second half of the year. This responsibility had been temporarily in the hands of the Program's Forage Breeding section.

Germplasm collection activities during 1984 took place in three continents:

- Tropical America:

a) Colombia: Two collection expeditions were carried out in the Llanos Orientales (Meta and Vichada); during a third trip, in which a visiting researcher from the Instituto Nacional de Investigaciones Agropecuarias INIA (Mexico) participated, a part of the central region of the country (principally Tolima and Caldas) was sampled. All expeditions were carried out in collaboration with CIAT's Genetic Resources Unit and aimed at legume species, with some emphasis on the *Centrosema* genus. Figure 1 shows the collection routes, and in Table 1 the results of the three trips in terms of collected germplasm are presented.

b) Venezuela: In collaboration with the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP), a collection expedition was carried out in the western region of the country (Fig. 2). Altogether 410 legume samples were collected (Table 2).

c) Brazil: In collaboration with the Centro Nacional de Recursos Genéticos of the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA-CENARGEN) and the International Board for Plant Genetic Resources (IBPGR), a collection expedition was carried out in the states of Mato Grosso and Pará (Fig. 3). This trip aimed at grasses and legumes with emphasis on *Centrosema* and *Stylosanthes*. Table 3 informs about the generic composition of the total collection of 533 samples.

- Tropical Asia:

a) China: In collaboration with the South China Academy of Tropical Crops (SCATC) the herbaceous and shrubby legume vegetation on a major portion of Hainan Island was sampled (Fig. 4).

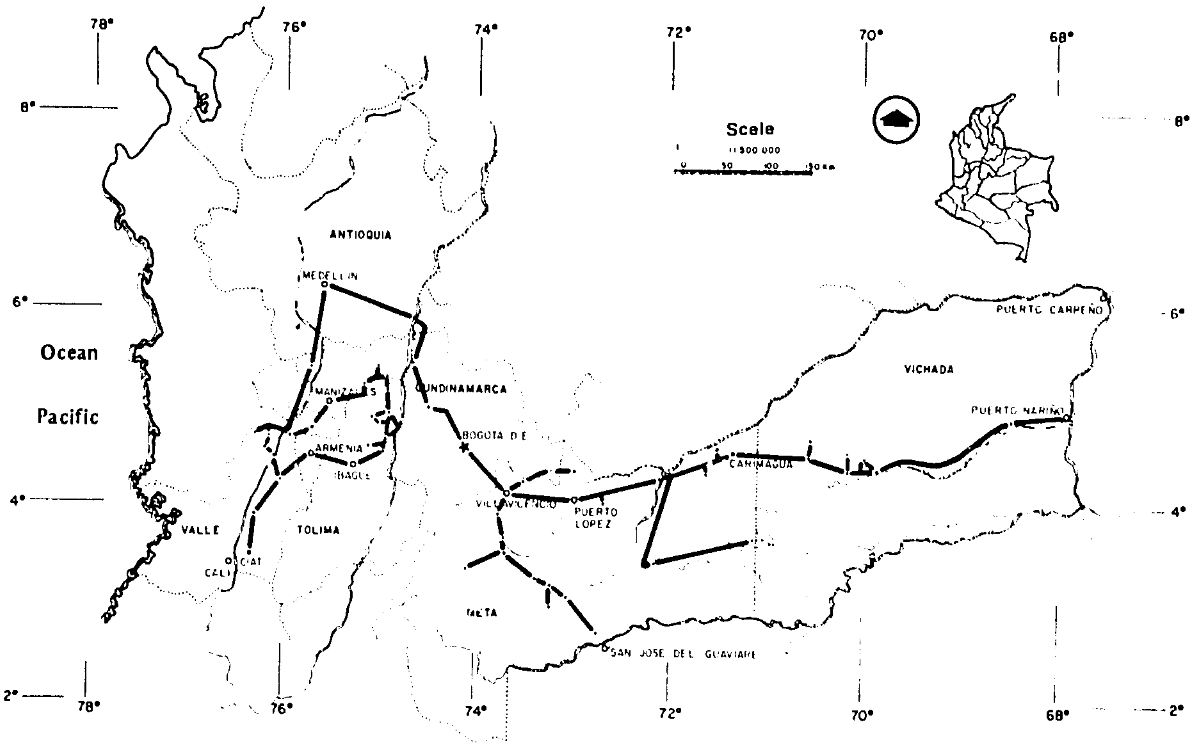


Figure 1. Routes of systematic collection of tropical legume germplasm in Colombia (January/February and April 1984).

Table 1. Summary of tropical forage germplasm collected in Colombia during 1984.

Genera	January Meta	February Meta/Vichada	April Tolima	Total
	No. of samples			
Aeschynomene	8	14	16	38
Calopogonium	3	9	17	29
Centrosema	15	40	35	90
Desmodium	20	34	39	93
Galactia	-	4	11	15
Macroptilium/*Vigna*	13	32	14	59
Stylosanthes	11	17	23	51
Zornia	8	7	9	24
Miscellaneous legumes*	36	63	39	138
Grass (unid.)	1	-	-	1
TOTAL	115	220	203	538

* *Acacia* (1), *Canavalia* (1), *Cassia* (*Chamaecrista*) (32), *Crotalaria* (7), *Clitoria* (9), *Dioclea* (36), *Dolichos* (1), *Indigofera* (3), *Mucuna* (1), *Pueraria* (2), *Rhynchosia* (15), *Sesbania* (1), *Tephrosia* (8), *Teramnus* (14), unidentified genera (7).

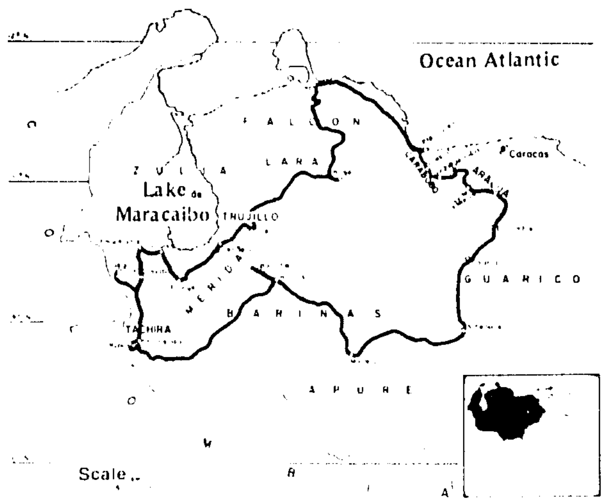


Figure 2. Route of systematic collection of tropical legume germplasm in Venezuela (March-April 1984; FONAIAP-CIAT).

Table 2. Summary of tropical forage legume germplasm collected in West Venezuela (March - April, 1984).

Genera and Species		No. of Samples
Aeschynomene		17
Calopogonium		39
Canavalia		16
Cassia (Chamaecrista)		10
Centrosema		87
brasilianum	4	
macrocarpum	17	
pascuorum	2	
plumieri	7	
pubescens	54	
sagittatum	2	
vexillatum	1	
Desmodium		57
Galactia		32
Macroptilium/Vigna		35
Rhynchosia		25
Stylosanthes		18
Teramnus		31
Zornia		4
Other genera		39
TOTAL		410

b) Thailand: In collaboration with the Thailand Institute of Scientific and Technological Research (TISTR) and IBPGR, a trip to collect native legume germplasm was carried out in the east provinces of the country (Fig. 5).

c) Indonesia: In collaboration with the Sukarami Research Institute for Food Crops, some exploratory sampling of the native legume vegetation in a portion of West Sumatra was done.

All collecting in tropical Asia aimed at legume material, with emphasis on species of Desmodium and allied genera, and Pueraria spp. The results of the collection efforts are summarized in Table 4.

- Tropical Africa:

a) Kenya: In collaboration with the International Livestock Center for Africa (ILCA) a collection trip was carried out in several of those regions of the country which were somewhat less affected by this year's drought (Fig. 6).

b) Ethiopia: Also in collaboration with ILCA, several provinces of Ethiopia were sampled (Fig. 7).

Although the collection activities in Africa aimed particularly at grass germplasm with emphasis on the Brachiaria genus, also legumes were collected. As shown in Table 5, 35% of the 1027 collected samples were legumes; the remaining were grass accessions of which more than half were samples of Brachiaria germplasm.

Introduction

With respect to the introduction of germplasm through exchange with other institutions, important contributions were received from the Empresa de Pesquisa Agropecuária de Minas Gerais EPAMIG (collections of Stylosanthes scabra and S. guianensis var. vulgaris) and the Commonwealth

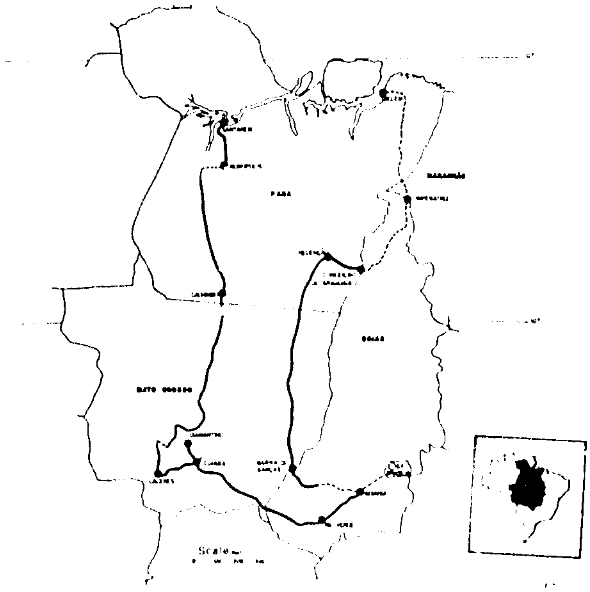


Figure 3. Route of systematic collection of tropical forage germplasm in Mato Grosso and Para, Brazil (August-September 1984; EMBRAPA-IBPGR-CIAT).

Scientific and Industrial Research Organization CSIRO, Australia (*S. scabra*). Furthermore, a collection of legume germplasm was received which was 1983 collected in Papua New Guinea by CSIRO staff during an expedition funded by CIAT.

With the additions during the year (approx. 3100 accessions), the collection of the CIAT Tropical Pastures Program increased to approximately 14.000 accessions (Table 6), the majority of which originate from regions with acid, infertile soils. The collection is maintained by CIAT's Genetic Resources Unit.

MULTIPLICATION AND MAINTENANCE

The multiplication of legume and grass germplasm continued to be one of the section's important service functions.

Table 3. Summary of tropical forage germplasm collected in Mato Grosso and Para, Brazil (August - September, 1984).

Genera	No. of Samples	Genera	No. of Samples
Aeschynomene	32	*Leucaena leucocephala* (nat.)	1
Arachis	3	*Macroptilium*	5
Bauhinia	6	*Mimosa*	3
Calopogonium	28	*Mucuna*	8
Cajanus cajan (nat.)	2	*Phaseolus*	1
Canavalia	34	*Pueraria phaseoloides* (nat.)	2
Centrosema	69	*Periandra*	16
Cratylia	12	*Rhynchosia*	8
Camptosema	7	*Sesbania*	3
Chamaecrista	8	*Stylosanthes*	100
Crotalaria	4	*Tephrosia*	3
Chaetocalyx	1	*Teramnus*	4
Clitoria	3	*Vigna*	21
Dioclea	22	*Zornia*	30
Desmodium	62	Unid. genera	14
Eriosema	2		
Galactia	7	*Panicum*	1
Indigofera	1	*Paspalum*	10
TOTAL			533

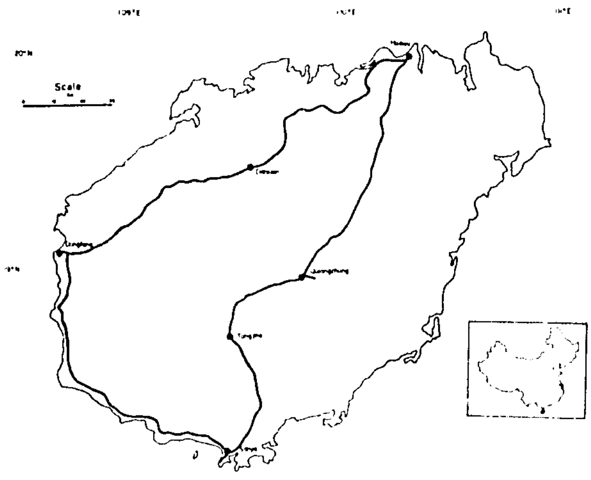


Figure 4. Route of systematic collection of tropical legume germplasm on Hainan, China (March 1984; SCATC-CIAT).

During 1984, 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 1650 accessions.

- Initial seed increase of all germplasm material under preliminary evaluation at CIAT-Quilichao: approximately 1600 accessions.

- Seed rejuvenation of the of Stylosanthes guianensis (common forms) collection for long-term storage: approximately 750 accessions.

In 1984 the responsibility for (a) maintaining germplasm stocks under appropriate cold-storage conditions, and (b) its distribution, was fully assumed by the Genetic Resources Unit of CIAT.

CHARACTERIZATION AND PRELIMINARY EVALUATION

During the characterization and preliminary evaluation phase, germplasm of priority or "key" species and new, agronomically still unknown or only little-known genera and species, is established in CIAT-Quilichao for seed increase as well as for observations of the most important plant descriptors (life 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;

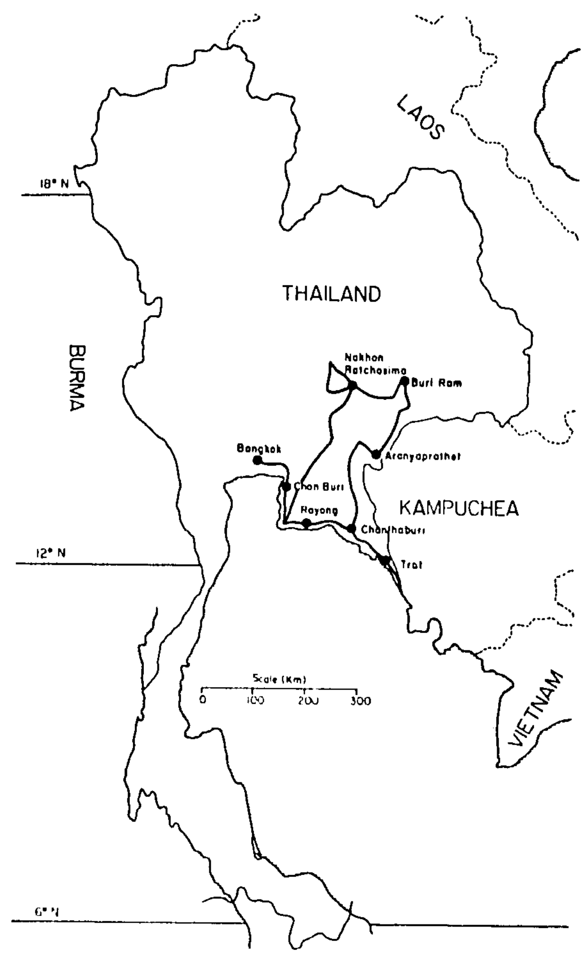


Figure 5. Route of systematic collection of tropical legume germplasm in Thailand (April 1984; TISTR-IBPGR-CIAT).

Table 4. Summary of tropical forage legume germplasm collected in Southeast Asia (March - April 1984).

Genera and Species	China Hainan	Thailand East	Indonesia W. Sumatra	Total
	------------- No. of samples -------------			
A) DESMODIUM SPP.				
D. gangeticum	4	13	2	19
D. heterocarpon	12	6	2	20
D. heterophyllum	2	6	2	10
D. laxiflorum	-	-	1	1
D. ovalifolium	-	12	1	13
D. styracifolium	-	3	-	3
D. triflorum	-	1	-	1
D. velutinum	1	10	1	12
D. sp. (unid.)	1	-	-	1
TOTAL	20	51	9	80
B) ALLIED GENERA				
Codariocalyx	2	-	-	2
Dendrolobium	3	7	-	10
Dicerma	-	1	-	1
Hegnera	-	1	-	1
Phyllodium	9	7	4	20
Tadehagi	7	7	2	16
TOTAL	21	23	6	50
C) PUERARIA SPP.				
P. phaseoloides	10	13	-	23
P. sp. (unid.)	2	1	-	3
TOTAL	12	14	-	26
D) OTHER GENERA*	39	66	26	131
GRAND TOTAL	92	154	41	287

* *Abrus*, *Aeschynomene*, *Alysicarpus*, *Atylosia*, *Crotalaria*, *Christia*, *Dunbaria*, *Flemingia*, *Galactia*, *Pseudarthria*, *Pycnospora*, *Uraria*, *Vigna*, etc.

(b) disease and insect tolerance, and (c) seed production potential. Establishment and evaluation methodology is equivalent to the Category I evaluation in the Program's major testing sites, and is based upon unreplicated, space-planted rows.

These preliminary evaluation observations assist in defining which materials should be given priority in the flow of germplasm to the Program's principal testing sites in Carimagua and Brasilia.

Table 5. Summary of tropical forage germplasm collected in Kenya (August - September, 1984) and Ethiopia (October - December, 1984).

Genera, species	Kenya	Ethiopia	Total
	------------ No. of samples	------------	
A) LEGUMES			
Alysicarpus	26	29	55
Indigofera	12	5	17
Rhynchosia	20	2	22
Sesbania	10	10	20
Stylosanthes	14	16	30
Tephrosia	27	6	33
Vigna	16	11	27
Other genera[1]	49	109	158
TOTAL	174	188	362
B) GRASSES: *Brachiaria* spp.			
B. brizantha	58	129	187
B. decumbens	17	-	17
B. dictyoneura	4	9	13
B. humidicola	2	18	20
B. jubata	31	26	57
Other *Brachiaria* spp.[2]	12	49	61
TOTAL	124	231	355
C) GRASSES: Other genera			
Cenchrus	17	14	31
Cynodon	14	-	14
Chloris	30	3	33
Panicum	23	19	42
Paspalum	20	7	27
Pennisetum	11	19	30
Setaria	24	7	31
Urochloa	11	8	19
Other genera[3]	31	52	83
TOTAL	181	129	310
GRAND TOTAL	479	548	1027

1/ *Aeschynomene*, *Cassia*, *Clitoria*, *Desmodium*, *Macrotyloma*, *Neonotonia*, *Teramnus*, *Trifolium*, *Zornia*, etc.

2/ *B. cruciformis*, *B. lachnantha*, *B. leucocrantha*, *B. longiflora*, *B. platynota*, *B. ruziziensis*, *B. serrata*, *B.* sp. (unid.).

3/ *Digitaria*, *Eragrostis*, *Hyparrhenia*, *Melinis*, *Sorghum*, *Sporobolus*, etc.

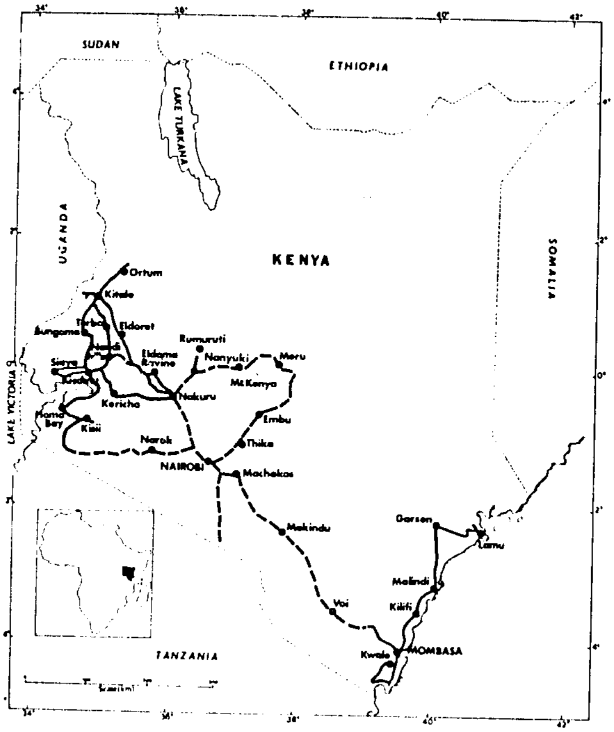


Figure 6. Routes of systematic collection of tropical forage germplasm in Kenya (August-September 1984; ILCA-CIAT).

In some cases, principally for Centrosema and Zornia germplasm, selected accessions also undergo agronomic evaluation at a Category II level (cutting trials in replicated, space-planted plots).

Preliminary Evaluation

Table 7 reports all Category I trials which existed in CIAT-Quilichao during 1984. Some key observations on these trials are:

- The Centrosema macrocarpum collection suffered this year from a severe virus attack which was possibly related to changes in the insect vector populations due to particularly high rainfall conditions throughout the year.

- New C. macrocarpum germplasm from the 1983 collection trip in the Colombian Llanos, is showing considerable variation with respect to the stoloniferous growth habit of accessions (Table 8). CIAT 5957 is also an outstanding accession regarding plant vigour, dry season performance and seed production potential.

- As pointed out last year, the priority species Stylosanthes capitata, S. macrocephala and S. guianensis var. pauciflora (the new taxon for the former "tardio" types) cannot be adequately evaluated in Quilichao; these species warrant thorough evaluation in the principal testing sites representative of the two well-drained savanna ecosystems (Carimagua and Brasilia).

- The promising 2-leaflet Zornia species from the humid coastal strip of east Brazil ("Zornia sp. type CIAT 7847") has now been identified as Z. glabra.

- Practically the entire collection of Desmodium heterocarpon is sus-

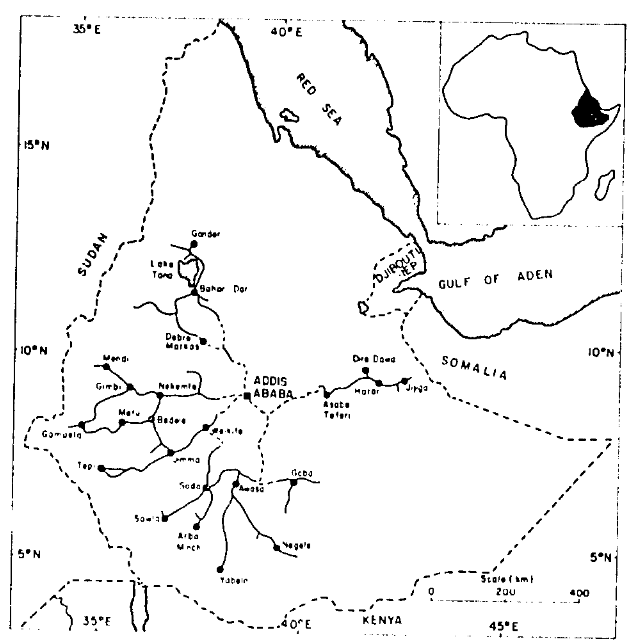


Figure 7. Routes of systematic collection of tropical forage germplasm in Ethiopia (October-December, 1984; ILCA-CIAT).

Table 6. Introduction of tropical forage germplasm through direct collection and exchange with other institutions during 1984 (No. of accessions).

Genera	Collections: Colombia	Venezuela	Brazil	SE Asia	Kenya	Ethiopia	Introductions through Exchange[1]	Total 1984	Total Collection Dec.31 1984
Aeschynomene	38	17	32	11	4	1	15	118	641
Calopogonium	29	39	28	3	-	-	7	106	324
Centrosema	90	87	69	2	-	-	44	292	1296
Desmodium	93	57	62	80	2	1	55	350	1635
Galactia	15	32	7	5	-	-	7	66	451
Macroptilium/*Vigna*	59	35	26	11	16	11	34	192	954
Stylosanthes	51	18	100	-	14	16	332	531	2961
Zornia	24	4	30	1	6	4	15	84	879
Miscellaneous legumes	138	121	168	173	132	155	100	987	3196
Grasses	1	-	11	1	305	360	11	689	1823
Total	538	410	533	287	479	548	620	3415	14160

1/ Including 188 accessions from occasional collections.

ceptible to little-leaf mycoplasma. Resistant accessions were identified as corresponding to the closely related species *D. strigillosum* which warrants further evaluation.

- A large collection of *Stylosanthes scabra* has been established in the field with the objective to adequately describe the variation in the species and to eventually select productive accessions that are tolerant to diseases and insects.

Agronomic Evaluation

Table 9 shows the agronomic evaluation experiments conducted during 1984 in CIAT-Quilichao. None of the trials has yet been concluded. *Zornia glabra* and *Centrosema macrocarpum* continue to be amongst the most promising species under Quilichao conditions.

Preliminary information on the performance of selected *Z. glabra* accessions is presented in Table 10. There is not very much variation among accessions to be observed, neither regarding dry matter production nor nutritive value. However, accessions CIAT 8278, 8279, and 8283 slightly outyielded the control accession CIAT 7847 throughout the trial. With respect to the nutritive value, the high crude protein and P content in leaves is noteworthy.

Some preliminary results for *Centrosema macrocarpum* are presented in Table 11. The new accessions tested are considerably more productive than the control variety CIAT 5065. Also regarding stoloniferous growth habit there are considerable differences between accessions, CIAT 5713 being outstanding. No major differences between accessions can be detected in the nutritive value

Table 7. Multiplication and preliminary evaluation of germplasm in CIAT-Quilichao at Category I level during 1984.

	No. of Accessions
A. KNOWN AND PRIORITY LEGUME SPECIES	
Centrosema macrocarpum	153
Stylosanthes guianensis (common)*	759
Stylosanthes guianensis var. pauciflora	170
Stylosanthes capitata	60
Stylosanthes macrocephala	55
Zornia spp.	68
TOTAL	1265
B. "NEW" LEGUME SPECIES	
Desmodium heterocarpon	73
Desmodium spp. and allied genera from SE Asia	80
Stylosanthes scabra	575
Stylosanthes viscosa	60
TOTAL	788
C. KNOWN AND PRIORITY GRASS SPECIES	
Andropogon gayanus	63
Brachiaria spp.	72
Panicum maximum	154
TOTAL	289
GRAND TOTAL	2342

* For seed rejuvenation.

components; the overall high level of crude protein content, however, is noteworthy.

FUTURE PLANS

Whereas field work will continue in a routinary way, a continuing involvement in germplasm collection activities in east Africa (Ethiopia, Rwanda, Burundi, Tanzania, and Zimbabwe), southeast Asia (Indonesia) and South America (Venezuela) is intended for 1985. All trips will be planned and eventually executed in collaboration with the respective national institutions.

Table 8. Stoloniferous growth habit of 34 accessions of *Centrosema macrocarpum* after 18 months of Category I evaluation in CIAT - Quilichao.

Accession No.	No. of rooted stolon nodes/m^2	Accession No.	No. of rooted stolon nodes/m^2
5065 (control)	18	5945	0
5713 (control)	208	5946	0
		5947	88
5452	144	5948	56
5613	216	5949	24
5645	0	5950	40
5733	328	5951	0
5887	40	5952	0
5900	0	5953	0
5901	0	5954	72
5911	0	5955	64
5940	272	5956	40
5941	96	5957	344
5942	0	5959	56
5943	16	5960	88
5944	0	5961	24

Table 9. Agronomic evaluation of selected legume germplasm in CIAT-Quilichao at Category II level during 1984.

		No. of Accessions
A. KNOWN AND PRIORITY SPECIES		
Centrosema brasilianum		130
Centrosema macrocarpum		20
Desmodium ovalifolium		85
Zornia glabra		15
	TOTAL	250
B. "NEW SPECIES"		
Desmodium heterocarpon and *D. strigillosum*		9
Dioclea guianensis		6
Stylosanthes viscosa		14
	TOTAL	29
GRAND TOTAL		279

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

Accession No.	Dry Matter (g/plant)[1]	Concentration in leaves (%)[2] N x 6.25 (Crude protein)	P	Ca
8278	43.9 a[3]	26.5	0.34	0.75
8279	42.1 ab	24.5	0.31	0.77
8283	38.4 abc	25.8	0.34	0.86
7847	38.0 abc	26.3	0.38	0.86
280	37.6 abc	25.4	0.36	0.63
8307	36.1 bcd	22.5	0.30	0.92
8346	35.9 bcd	23.7	0.34	0.71
281	35.4 bcd	25.7	0.40	0.69
8297	33.1 cd	25.8	0.35	0.77
8308	32.7 cde	25.5	0.39	0.77
278	31.5 cde	25.5	0.38	0.67
255	31.2 cde	27.0	0.38	0.91
8273	30.2 de	26.9	0.38	0.90
8343	30.2 de	23.2	0.36	0.70
283	25.9 e	27.0	0.40	0.77

1/ Mean of 8 cuts (3-month regrowth each). 2/ Mean of 4 cuts (3-month regrowth). 3/ Means followed by the same letter do not differ significantly at P = 5%.

Table 11. Evaluation of 12 selected *Centrosema macrocarpum* ectoypes during 18 months in CIAT - Quilichao: Cumulative dry matter yields, stoloniferous growth habit, and concentration of N x 6.25, P and Ca in leaves.

Accession No.	Dry Matter[1] (g/m^2)	No. of rooted stolon nodes/m^2 2/	Concentration in leaves (%)[3] N x 6.25 (Crude protein)	P	Ca
5730	1407 a[4]	80 bcd	27.9	0.22	0.75
5616	1312 ab	100 ab	24.3	0.21	0.86
5740	1290 abc	60 cde	27.4	0.23	0.75
5713	1211 abcd	120 a	25.9	0.22	0.94
5735	1198 abcd	100 ab	26.8	0.22	0.86
5620	1158 bcde	95 abc	26.4	0.22	0.70
5685	1134 bcde	80 bcd	24.2	0.23	0.80
5887	1107 bcde	32 e	28.0	0.21	0.85
5737	1061 cde	76 bcd	27.2	0.20	0.88
5645	992 de	100 ab	26.3	0.23	0.87
5452	983 de	108 ab	26.5	0.21	0.98
5065	952 e	52 de	28.7	0.25	0.65

1/ Sum of 6 cuts (3-month regrowth each). 2/ Mean of 6 cuts. 3/ Mean of 5 cuts. 4/ Means followed by the same letter do not differ significantly at P = 5%.

PLANT BREEDING

INTRODUCTION

The Plant Breeding Section was relieved of responsibilities for the management of forage grass germplasm when these activities were returned to the Germplasm Section. The Plant Breeding Section continues to be responsible for plant breeding and genetic studies within the Program, currently with a major breeding project in Stylosanthes guianensis and a more modest project in Andropogon gayanus. Steps are being taken to initiate "pre-breeding" activities in the Centrosema pubescens-C. macrocarpum-Centrosema sp. group by year's end.

Breeding and Genetics

Selection in Andropogon gayanus. A selection project aimed at producing a short statured A. gayanus synthetic was initiated in 1983 (see Ann. Rep. 1983) with the objectives of (1) improving compatibility with well adapted but less vigorous legumes (e.g. Stylosanthes capitata and S. macrocephala), and (2) improving ease of management under grazing.

A replicated "polycross" nursery was established originally with 19 clones selected from A. gayanus germplasm introduction plots. Two clones were eliminated early on due to excessive plant height. Plant height data were taken on the remaining 17 clones on two dates (Table 1) and one additional clone was eliminated. Harvest of open-pollinated seed has begun on the remaining 16 clones. It is anticipated that the resulting open-pollinated, "polycross" progenies will be under evaluation in Quilichao and Carimagua in 1985.

Table 1. Mean plant height (cm)[A] of 17 Andropogon gayanus clones on two dates.

Clone	16 July 1984	02 October/84
1	168.3 (7)[B]	146.8 (10)
3	147.3 (16)	157.0 (5)
4	157.1 (14)	142.0 (15)
5	180.1 (3)	160.3 (3)
6	166.9 (9)	139.5 (16)
7	176.3 (4)	164.4 (2)
8	158.5 (11)	149.6 (9)
9	93.5 (17)	93.5 (17)
10	167.4 (8)	158.1 (4)
11	157.3 (13)	146.6 (11)
12	162.5 (10)	144.3 (14)
13	156.0 (15)	150.9 (8)
14	176.2 (5)	155.6 (6)
15	185.8 (1)	183.2 (1)
17	170.6 (6)	145.2 (13)
18	185.6 (2)	153.9 (7)
19	158.0 (12)	146.2 (12)
Mean	163.8	150.5
LSD.05	9.06	7.10
Genetic correlation between 2 dates.....	r_g = 0.85	

A = Mean over 20 or 40 single-plant replicates on 16 July or 02 October, respectively.

B = Rank (tallest to shortest) in parentheses.

Stylosanthes guianensis Breeding Project

The major activity in 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 levels of seed yield (see Ann. Reps. 1981-1983).

The *S. guianensis* breeding project made significant progress in 1984 as the initial diallel set of crosses are being advanced to the F_4 generation by pedigree and bulk advance procedures. A large scale "natural selection under grazing" trial was successfully established at Carimagua. Seventy new crosses are being advanced to the F_3 generation, and F_2 seed is being produced on some 270 additional crosses in the glasshouse. Improved breeding procedures are being tested, refined, and incorporated into the main breeding project.

Initial diallel crosses

Pedigree advance. A total of 454 F_3 individuals from crosses selected on the basis of F_2 family performance at Carimagua last year (see Ann. Rep. 1983) were space planted at Quilichao this year. These F_3's derive predominantly from five crosses but one or more derive from a total of 33 of the 45 original crosses. It is now anticipated that at least 300 F_4 families can be included in a direct seeded, replicated evaluation trial at Carimagua in 1985.

Bulk advance. 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 (see Ann. Rep. 1983). On each of 12 dates between 19 September 1983 and 5 March 1984, seed was "once-over" harvested from one of twelve 8 x 10 m plots planted to a balanced bulk of diallel F_2 seed. Bulk F_3 seed yield was low: on only three of the 12 harvest dates was as much seed recovered as had been planted (Table 2). The resulting 12 bulk progenies were planted at Carimagua in April 1984, for a second cycle of bulk advance. A single plot (size depending on seed available) was planted per progeny. The 12 progenies are being harvested in the same order as last year between 1 October 1984 and 4 March 1985.

Mean flowering prolificacy of each progeny was scored in September. Prolificacy was found to be highly related to first generation harvest date (Figure 1), indicating that the first generation bulk harvest had effectively altered maturity.

Results of the first bulk seed harvests this year are encouraging. The first plot, harvested on 1 October, yielded 21 times more seed than the first harvested plot last year and two times more seed than the highest yielding of last year's harvests. The

Table 2. Seed yields from bulk harvests of a heterogeneous *Stylosanthes guianensis* population[A] on 12 harvest dates.

Harvest	Date	Seed Yield kg/ha	Seed Yield As proportion seed planted
1	19 Sep.83	0.43	0.52
2	17 Oct.83	4.38	5.34
3	31 Oct.83	3.48	4.24
4	14 Nov.83	0.08	0.10
5	28 Nov.83	0.13	0.16
6	12 Dec.83	0.12	0.15
7	26 Dec.83	0.15	0.18
8	09 Jan.84	0.12	0.15
9	23 Jan.84	0.06	0.07
10	06 Feb.84	0.36	0.44
11	20 Feb.84	0.26	0.32
12	05 Mar.84	1.33	1.62

A = A balanced blend of F_2 seed from the 45 crosses of a 10-parent diallel was planted at the rate of 0.82 kg/ha on 5 April, 1983.

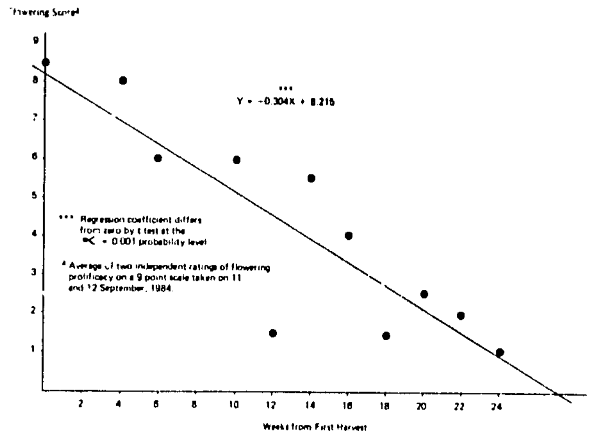


Figure 1. Relation between first generation harvest date and second generation flowering score of heterogeneous Stylosanthes guianensis bulk populations.

second (15 October) and third (29 October) harvests yielded 4.5 and 1.9 times, respectively, more than the highest yielding of last year's harvests. This result is probably attributable to a greater concentration in time of seed maturity and the elimination, in the first cycle, of a high proportion of partially sterile genotypes.

A separate experiment was planted at Quilichao this year to evaluate critically the effect of the first generation of bulk advance on flowering maturity. Twenty random individuals from each of the 12 harvest date progenies were transplanted to the field on 17 April 1984. Date of first flower was recorded on each plant. Although individual progenies remain heterogeneous, mean flowering date is strongly associated with bulk harvest date (Figure 2). Seed harvested from these plants will originate the first lines derived from the bulk advance scheme. These will be included along with pedigree-derived lines in replicated evaluation trials in Carimagua in 1985.

Natural selection. A four hectare grazing trial was established during 1984 to study the effects of natural selection on an initial, highly heterogeneous S. guianensis population formed by blending F_2 seed from most of the diallel crosses. The S. guianensis seed was planted at the rate of approximately 1 kg/ha either in prepared rows in native savanna (2 ha) or in rows in association with A. gayanus (2 ha). Establishment was highly successful and at approximately 4 weeks after planting 10.6 ± 1.3 or 8.4 ± 0.9 S. guianensis plants/m^2 were present in the association with native savanna or A. gayanus, respectively. Each association will be subjected to grazing at three different stocking rates thus generating six association-by-stocking rate environments. surviving plants will be sampled in each of these environments at yearly intervals so as to be able to follow the course of natural selection over time.

New Crosses. Seventy new crosses were established in the field as replicated F_2 rows at Quilichao. Approximately 90 F_2 individuals were transplanted per cross in two 22.5 m rows. Bulk F_3

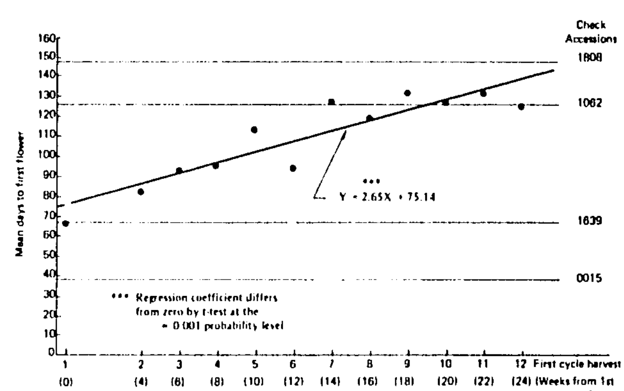


Figure 2. Relation between first cycle harvest date and mean flowering date of second generation bulk Stylosanthes guianensis progenies.

seed is being harvested on several dates for each cross generating a maximum of four different F_3 bulks per cross. These F_3 bulks will be established in replicated, direct-seeded evaluation trials at Carimagua in 1985.

An additional 270 crosses are presently in the form of F_1 plants in the glasshouse. As many as possible of these will be advanced to F_2 field plots in 1985.

Germplasm Evaluation. In collaboration with the Plant Pathology Section a trial of 50 standard and newer CIAT germplasm accessions are under observation at Carimagua. Of particular importance is to detect as soon as possible any change in the race structure of the anthracnose pathogen. It is encouraging to note that accessions selected four and five years ago continue to maintain high levels of resistance.

Other Studies

Estimation of Outcrossing Rate in *S. guianensis*. In 1983 we reported a substantial rate of outcrossing (13%) in *S. guianensis* (see Ann. Rep. 1983). A second and independent estimate of outcrossing rate in *S. guianensis* was obtained in 1984 from observations of the proportion of yellow-flowered individuals within the progeny of white-flowered plants which had been grown in 1983 surrounded either by CIAT 0015 (cv. Graham) or by an F_3 bulk of the cross CIAT 0015 x CIAT 10136. In this case, rate of outcrossing was markedly affected by the genotype of the surrounding yellow-flowered plants (Table 3). The

Table 3. Percent identifiable yellow-flowered outcrosses as affected by source of pollen carrying "yellow" allele.

SOURCE OF POLLEN					
F_3 Bulk[a]			CIAT 0015		
Progeny	Percent Outcrosses	(Number Observed)	Progeny	Percent Outcrosses	(Number Observed)
1	0.02	(90)	17	0.17	(6)
2	0.00	(89)	18	0.27	(15)
3	0.10	(90)	19	0.07	(89)
4	0.06	(86)	20	0.06	(87)
5	0.07	(15)	21	0.08	(89)
6	0.05	(88)	22	0.02	(90)
7	0.03	(89)	23	-	(0)
8	0.07	(14)	24	0.30	(90)
9	0.00	(90)	25	0.20	(15)
10	0.20	(15)	26	0.29	(89)
11	0.04	(90)	27	0.33	(15)
12	0.01	(86)	29	0.22	(88)
13	0.10	(86)	29	0.17	(88)
14	0.20	(15)	30	0.13	(15)
15	0.07	(90)	31	0.11	(83)
16	0.13	(15)	32	0.13	(15)
Pooled	0.05 $\pm$ .007	(1047)	Pooled	0.15 $\pm$ .012	(874)

a = F_3 individuals of cross CIAT 0015 x CIAT 10136.

low rate of outcrossing to the F_3 bulk is probably attributable to partial pollen sterility in this material.

A recurrent selection scheme, based on natural outcrossing, is currently being implemented (Table 4).

A survey of potential insect pollinators of S. guianensis at Quilichao and Carimagua has been initiated. Honey bees (Apis mellifera) are commonly observed working S. guianensis flowers at both locations, as are several species of smaller, wild bees.

Inheritance of Anthracnose Resistance

A small glasshouse experiment was performed to investigate the inheritance of anthracnose resistance of the most highly resistant accession identified in field trials in Colombia. As this accession (CIAT 10136) has been used heavily in crosses, it was considered imperative to determine whether or not resistance is determined by a single gene. Populations of F_2 individuals from two different crosses were each inoculated with two anthracnose isolates. In no case do the results give any evidence of single gene segregation. Distributions of individual F_2 reaction scores were essentially continuous and strongly skewed towards resistance (Figure 3).

Tabla 4. Generalized plan for a systematic recurrent population improvement scheme in Stylosanthes guianensis

Year 1	Plant S_1 (F_2) progenies seggregating 3:1 for yellow:white flower color in replicated evaluation trial. Harvest bulk S_2 seed from each of the selected progenies.
Year 2	Plant space planted crossing block with a balanced blend of bulk S_2 seed harvested from progenies selected in the first year evaluation trial. Harvest open-pollinated seed from selected white flowered individuals.
Year 3	Plant replicated trial of single-plant progenies obtained from open-pollinated seed harvested in crossing block. These progenies will be predominantly white-flowered, S_3 families, which contain a low proportion of outcrosses. Select among these progenies and harvest seed from individual yellow-flowered (outcrossed, S_0) individuals within selected progenies. This seed represents S_1 progenies with which a new cycle is initiated in year 4.

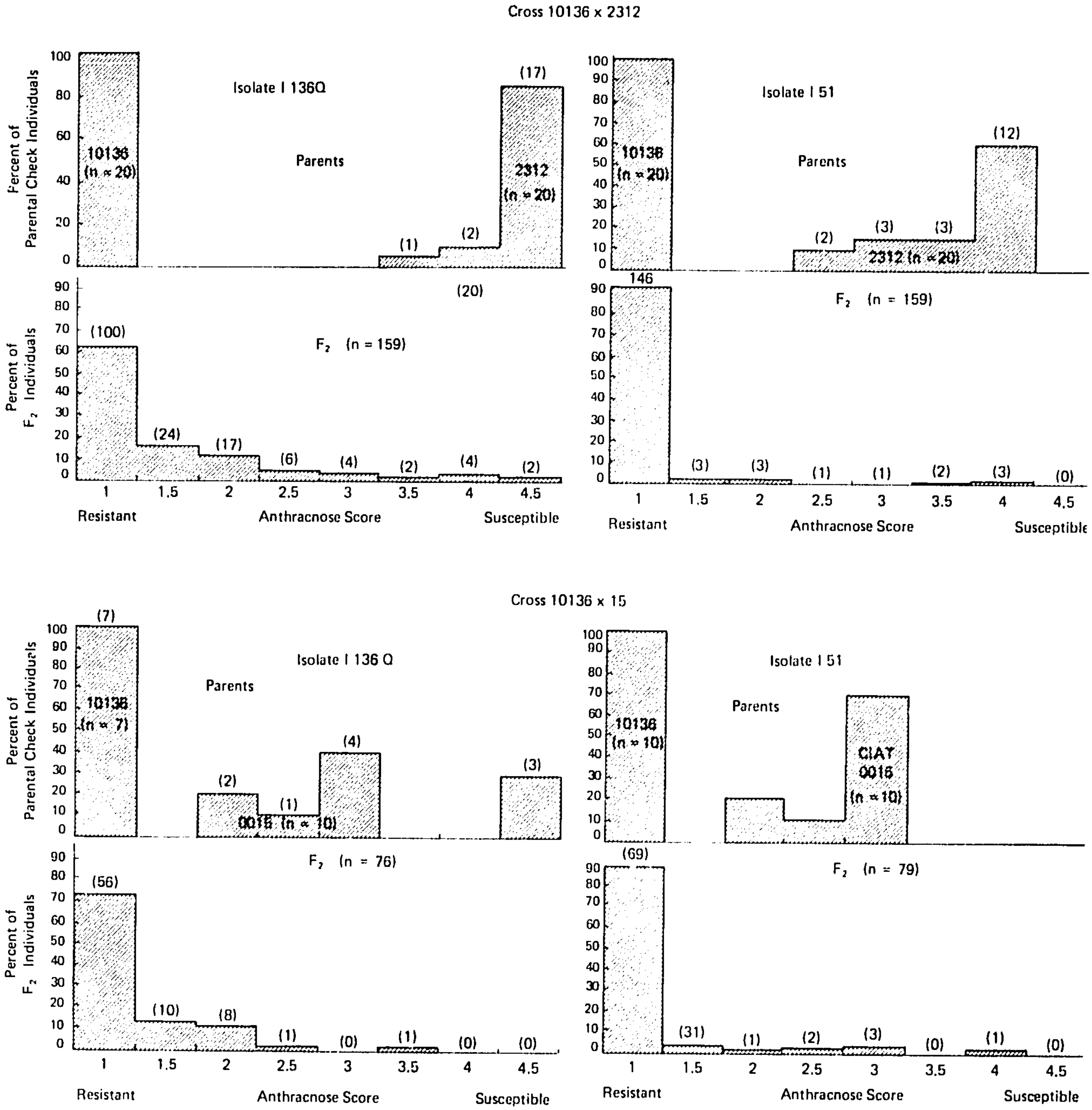


Figure 3. Reaction to two *Collectotrichum gloeosporioides* isolates of artificially inoculated parental and F_2 *Stylosanthes guianensis* seedlings of two crosses.

AGRONOMY (Carimagua)

In the continuing search for superior germplasm for the Llanos ecosystem, the main emphasis in 1984 was on selection within key species of legumes and grasses. The number of forage species introductions established since 1982 and currently under observation totals 1420 accessions, including 974 legumes and 446 grasses.

New grass germplasm under evaluation includes 153 accessions of Panicum maximum introduced by CIAT from collections existing in Australia, Cuba, Ecuador, Kenya and Puerto Rico. Recently, a portion (239 accessions) of the ORSTOM collection was added.

Regarding legumes, a new line of investigation was initiated with browse species from Southeast Asia, including species of the genus Desmodium (e.g. D. velutinum) and closely related genera (e.g. Phyllodium and Tadehagi). Several of these accessions showed good adaptation to Llanos soils and rapid recovery after defoliation. There have been no major problems with pests and diseases to date. Tadehagi sp., however, exhibits symptoms of nutrient deficiency.

The majority of accessions currently under evaluation are ecotypes and variants of key species, for which well defined selection criteria exist. Intra-species variability was evident in all of the species studied. In dealing with such a large number of largely unknown introductions, classification had to be the first objective. For this purpose cluster analysis proved to be of great value. It has the ability to integrate data to enable the user to describe desirable and undesirable agronomic characters of varietal groups and the degree of variation within groups. In essence, it helps to reduce a large number of introductions to a manageable few for further evaluation.

PRELIMINARY EVALUATION OF GRASS GERMPLASM (Categories I and II)

Panicum maximum

The 153 accessions of P. maximum were assigned to four agromorphological groups, using existing botanical classification:

1. Panicum maximum var. typica
   a) "Giant" guinea grasses, e.g., Coloniao
   b) "Medium" guinea grasses, e.g., cv. Makueni, cv. Likoni

2. P. maximum var. trichoglume "Green panic"

3. P. maximum var. coloratum "Purple top" guinea grass

The parameters used in the evaluation process were: (1) Dry Matter (DM) yield determined at 6-week intervals; (2) vigour and recovery after defoliation; (3) adaptability, nutritional disorders; (4) leaf: stem ratio; (5) seed yield; (6) resistance to spittlebug and Cercospora.

The accessions in this experiment were sorted into six rather large cluster groups with up to 26-28 accessions per cluster. This indicates considerable similarity among entries in the same cluster. Since these introductions were obtained from various institutions, a possible explanation is that a certain number of introductions are essentially the same, but present under different introduction numbers. Nevertheless, the collection is a very good representative sample of the great variability that exists in Panicum maximum.

For example, cluster group 1 contains 26 moderately productive accessions, but includes some "medium" guinea grass types (CIAT 6180, 683) and one P. maximum var. coloratum accession (CIAT 6179) that show promise. These lines exhibit good adaptation to the Carimagua Oxisol and to date are resistant to spittlebug. Their moderate DM yields are compensated to some extent by high leaf:stem ratios.

Cluster group 3 contains two "medium" guinea grass accessions, both of which are leafy, resistant to spittlebug, and produce good seed yields. These accessions are 6171 and 6172. The control variety CIAT 673 was in the next and even higher yielding group. The highest yields were recorded for the "giant" guinea grasses. Several accessions of these, however, were susceptible to Cercospora or exhibited symptoms of nutrient deficiency. In general, they are considered non-adapted to the Carimagua environment. Selected accessions of "medium" guinea grass have a more favourable leaf:stem ratio and were less susceptible to spittlebug and Cercospora.

Brachiaria spp.

Nineteen new accessions are currently being evaluated in small plots. This collection includes accessions of B. brizantha, B. ruziziensis, B. humidicola and B. decumbens. At this early stage of evaluation, accessions 6681, 6384, 6385 and 6386 are showing promise. CIAT 6384 and 6385 are high yielding accessions and CIAT 6386 and 6681 are leafy types with a high leaf:stem ratio.

PRELIMINARY EVALUATION OF LEGUME GERMPLASM (Categories I and II)

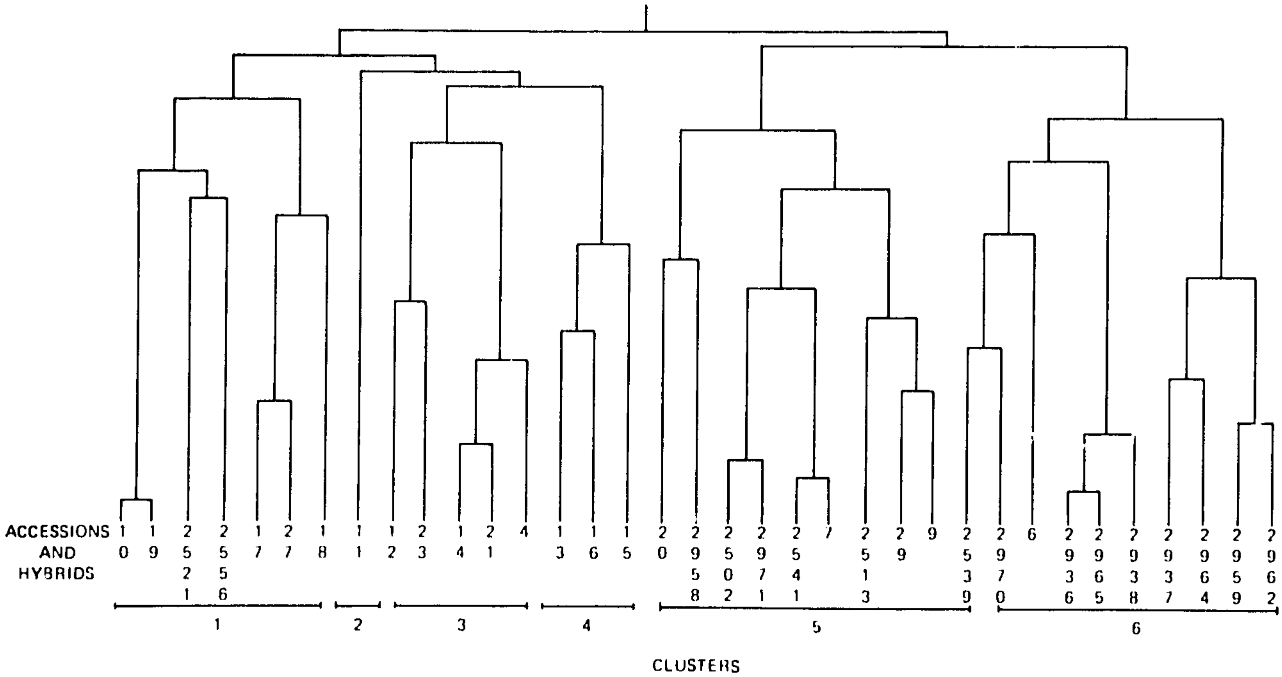
Stylosanthes capitata

The considerable natural variability which exists in this species was further increased by plant breeding. Selections made from the F_6 generation during 1982-83 are presently being compared in small-plot experiments with several new accessions as well as with cv. Capica and its components. The preliminary results of these cutting trials show higher dry matter and seed production of several hybrids compared with the accessions. Figure 1 shows the high frequency of the hybrids in the high yielding clusters 2, 3 and 4.

Previous experience at grazing S. capitata (including cv. Capica) in association with Andropogon gayanus has shown that persistence of the legume due to lack of its competitiveness is the main limiting character of the species. Screening of the best hybrids and accessions, including cv. Capica and its components, for survival of mother plants under grazing, is in progress. A second factor influencing legume persistence is seedling vigor under competition. Screening for this character is being initiated at greenhouse level.

Stylosanthes viscosa

A high percentage of 123 accessions in a small plot trial was affected by anthracnose and stemborer. Some moderately affected accessions recovered during the dry season. Nevertheless, in the second year, no more than 7



Cluster 1: Medium yield (206-280 g/plant)
Cluster 2: Highest yield (439 g/plant)
Cluster 3: Medium to high yield (303-335 g/plant)
Cluster 4: High yield (352-368 g/plant)
Cluster 5: Low to medium yield (79-168 g/plant)
Cluster 6: Lowest yield (24-73 g/plant)

Figure 1. Classification of Stylosanthes capitata accessions and hybrids by cluster analysis. Hybrids are identified by one -or two- digit numbers.

accessions showed potential for the Llanos ecosystem.

These are: CIAT 1527, 2116, 2316, 2374, 2479, 2524, and 2882.

Desmodium heterophyllum

Of the small collection of 16 accessions under observation, CIAT 349 (cv. Johnstone) is the most vigorous; CIAT 13199 is a similar productive type. However, the species has to be considered as not adapted to the extremely low fertility of the Carimagua Oxisol.

Desmodium heterocarpon

Agronomic assessment of 60 accessions of D. heterocarpon was started two years ago. The majority of accessions were affected by nematodes and/or little leaf mycoplasma, and by the end of the second season the collection was decimated. Disease resistant material proved to be D. strigillosum, represented by the accessions CIAT 13149, 13153, 13155, 13156, 13158, and 13159.

Desmodium ovalifolium

Considerable variability was observed in persistence and survival in a cutting trial among 60 accessions of Desmodium ovalifolium established at the end of 1983. This experiment included new accessions as well as some of the old introductions which have persisted under grazing for four years in another experiment. The list of the ten most productive accessions includes CIAT 3776, 3780, 3794 and 7 new accessions. The top yielder was CIAT 3776 (Table 1).

Table 1. Dry matter yields (kg/ha) of ten D. ovalifolium accessions in the wet season, 1984. Carimagua, Llanos Orientales.

CIAT No.	DM kg/ha
3776	4954
13131	4705
13089	4416
13306	4200
3794	4185
3780	4163
13080	4020
13092	3996
13088	3893
13135	3862

Pueraria phaseoloides

Seventy-eight accessions are under observation. Analysis of yield data indicated great similarity among accessions represented by the "typical" form of commercial P. phaseoloides CIAT 9900. However, superior pasture types have been identified which are quite distinct from this "typical" form. Stoloniferous habit of growth, early flowering and drought tolerance are the main criteria of selection.

Accessions CIAT 17283 and 17292 accessions are showing high vigour, good ground cover and stoloniferous rooting. CIAT 744 and 7182 accessions are similar to the common type of tropical kudzu and these, along with the commercial line CIAT 9900, performed best during the first year. Accession CIAT 4600 is a good seed producer but its DM yields are rather low.

Aeschynomene spp.

Some 217 accessions representing 15 species of this legume were established at a flooded savanna site. Very few accessions survived attacks of pests and diseases; however, the few remaining showed good adaptation to wet conditions. The area was completely inundated for lengthy periods during the year. The experiment is continuing.

Centrosema brasilianum

Sixty-two accessions of C. brasilianum were evaluated during the year. Based on their performance in previous evaluation trials, CIAT 5234 and 5178 were included as controls. The new accessions and two controls were sorted into six cluster groups on the basis of their DM yields.

Cluster 6 with a mean yield of 5953 kg/ha was superior and contained four accessions:

	CIAT No.		DM kg/ha
Cluster 6	5470		6397 a
	5886		5837 a
	5821		5817 a
	5825		5760 a
		Cluster mean:	5953
Cluster 1	5234 (control 1)		3215
		Cluster mean:	3203
Cluster 4	5178 (control 2)		4878
		Cluster mean:	4922

Rhizoctonia foliar blight continues to be the major problem affecting this species during the wet season.

Centrosema macrocarpum

Evaluation of a wide range of variants and ecotypes of this legume was carried out in the first, second and third year following establishment. Previous experiences with this legume species under cutting and grazing regimes indicated that accession CIAT 5065 and similar erect types persist poorly under frequent defoliation or heavy grazing. The better persistence/survival of stoloniferous species of Centrosema has also been recorded. Therefore, the new collection was examined for stolon root density. A small number of accessions combined both desirable characteristics (Table 2).

In one experiment, 52 accessions of C. macrocarpum were compared for yield and stolon root density. The strongly stoloniferous Centrosema sp. CIAT 5278 was used as a control. Results show that a few accessions of C. macrocarpum possess both characters, i.e., high DM yield and strong stoloniferous habit of growth. In cluster 2 there are accessions with higher stolon density than CIAT 5278 (Table 3).

ADVANCED TESTING UNDER GRAZING (Category III)

Centrosema macrocarpum - Andropogon gayanus

In a grazed association of C. macrocarpum - A. gayanus, stocking rates of 1.5 and 3 animals/ha were used. Legume DM yields and content (%) in the pasture showed no significant differences during the first wet season. In the second season from February onwards, however, legume yields and percentages were significantly ($P < 0.05$) higher in the low stocking rate treatment (Fig.2). Grass yields were significantly better in the high stocking rate treatment (Table 4).

Table 2. Accessions of Centrosema macrocarpum and Centrosema sp. (control) sorted into six cluster groups on the basis of DM yield and number of stolon rooted sites per unit area.

Cluster Group	No. of Accessions	DM Yield (kg/ha) Range	Stolon Rooted Sites (SRS); 0.25 m^2; Range	DM yield (kg/ha) of accession with max. SRS
4	1	10125- (5739)*	3.6	-
3	7	7109-8027 (5732) n.s.	2.0-14.0 (5418)*	7577
1	7	6086-6846 (5904) n.s.	0.0-11.7 (5733)	6386, Control (1) CIAT 5065 SRS 0.0, DM 6498 kg/ha
2	7	4891-5840 (5460) n.s.	0.3-13.3 (5713)	5324, Control (2) CIAT 5278 SRS 10.7, DM 5687 kg/ha
5	3	3095-5743+(5395)	0.0- 8.2 (5395)	5743
6	6	3799-4519 (5887)	0.0-10.0 (5736)	4505

* CIAT accession numbers in parentheses.
\+ Denotes significant difference ($P < 0.05$).
n.s. Denotes non-significant.

S. guianensis var. pauciflora
CIAT 10136 - A. gayanus

This experiment was under grazing from the beginning of February 1984. In this relatively short period, some loss of legume content was recorded. Legume percentages at the beginning and end of wet season were:

Stocking Rate an/ha	% Legume Beginning wet season	End wet season
1.0	40.8	20.7
1.7	55.7	23.9
2.4	39.0	20.8

Samples of the forage ingested by oesophageal fistulated animals indicated a very low intake and percentage of S. guianensis during the dry period from February to April. Of the total of 1.60% legume in the sample, 1.47% was leaf and 0.13% stem. A possible explanation of the decline in legume content is interspecific competition.

Desmodium ovalifolium - grass associations

Recovery was observed in most areas of D. ovalifolium under grazing during the current wet season. Even the accessions most affected by diseases, e.g. CIAT 3652 and 350 recovered well in several old experiments. In one of the grazing tests which includes 5 accessions of D. ovalifolium in association with Brachiaria dictyoneura, the best line was CIAT 3784. Percentage legume content in this association was 19%.

Monitoring DM yields and legume contents of various D. ovalifolium-grass associations continued. Some of these areas have been under grazing for 4 years. DM yields at the end of the wet season in the grazing experiment of eight D. ovalifolium accessions with five Brachiaria spp.

Table 3. Density of stolon rooted sites (SRS) of Centrosema macrocarpum accessions.

Cluster 1		Cluster 2		Cluster 3	
CIAT #	SRS/0.25 m^2	CIAT #	SRS/0.25 m^2	CIAT #	SRS/0.25 m^2
5733	11.67 a*	5713	13.33 a	5418	14.00 a
5275	5.40 ab	5735	12.75 a	5645	8.20 ab
5798	5.20 ab	5620	12.67 a	5901	5.40 ab
5888	5.00 ab	5460	11.40 a	5730	5.20 ab
5904	5.00 ab	5278 (control)	10.67 a	5732	5.00 ab
5563	0.00 b	5396	0.60 b	5864	4.50 ab
5065 (control)	0.00 b	5616	0.33 b	5740	2.00 b

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

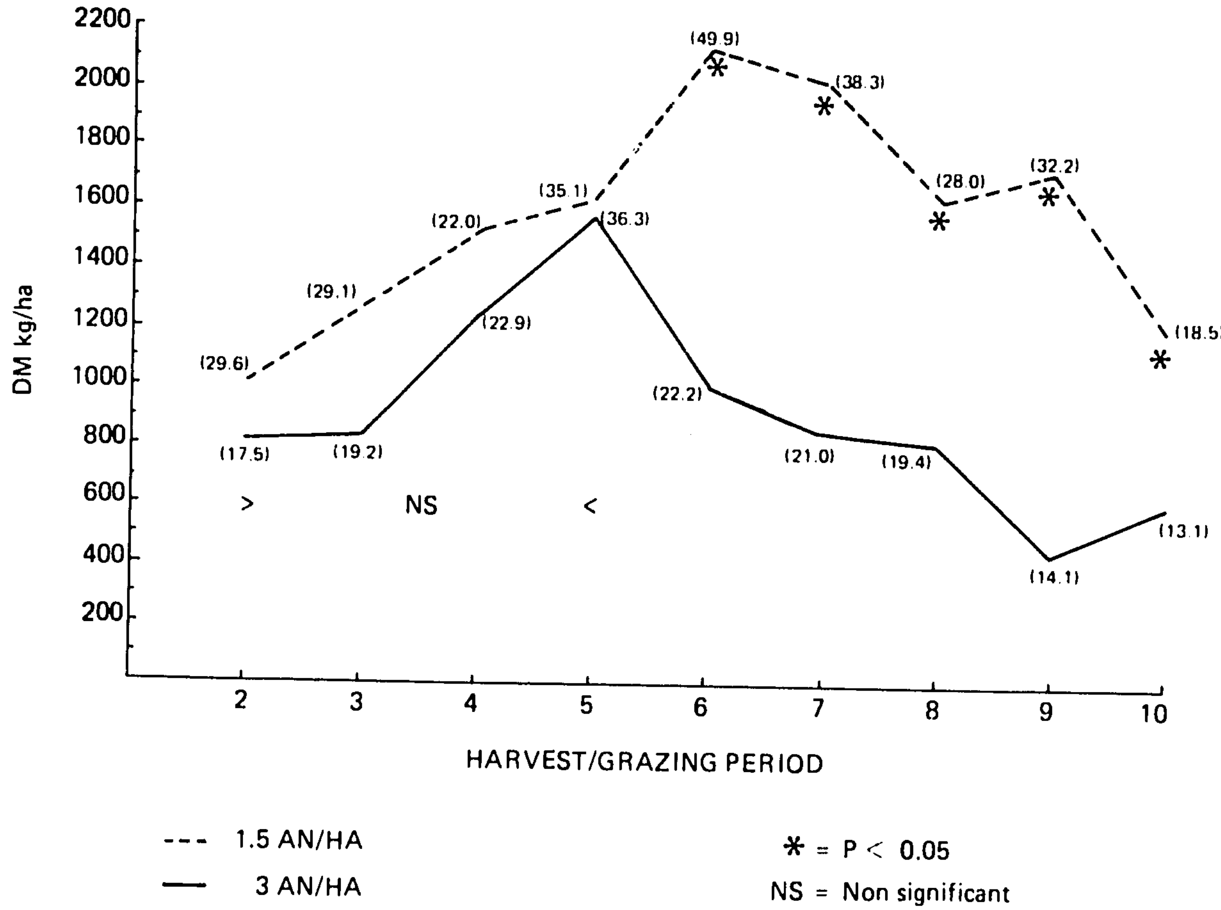


Figure 2. Presentation yield (kg/ha) of Centrosema macrocarpum CIAT 5065 grown in association with Andropogon gayanus Carimagua 1, grazed at two stocking rates. Carimagua, Llanos Orientales. (Values in parenthesis are legume contents (W%) in the mixture).

Table 4. Mean yield of dry matter (kg/ha/year) and legume content (W%) of A. gayanus/C. macrocarpum pastures grazed at 2 stocking rates. Carimagua, Llanos Orientales.

Stocking rate	Grass	Legume	% Legume	(Grass + Legume)
	------- kg/ha	------		----- kg/ha ----
High - 3 an/ha	9,621 a	2,499 b	20.6 b	12,120 a
Low - 1.5 an/ha	8,101 b	4,488 a	36.0 a	12,589 a

are as shown in Table 5. In this experiment, accession 350 was one of

Table 5. Presentation yields of eight Desmodium ovalifolium accessions, each in association with five Brachiaria spp. in the wet season of the fourth year under grazing. Carimagua, Llanos Orientales.

Accession No.	Individual DM	Total DM (x Grass + Legume)
D.ovalifolium:	----- kg/ha ------	
3793	3693a	4760a
3794	2734ab	4155abc
3784	2421b	4333ab
3788	2243bc	4135abc
350	1269cd	3399bcd
3652	732d	3118cd
13400	1269d	2899d
3780	480d	2560d
Brachiaria spp.:		
B.humidicola 679	3061a	
B.brizantha 665	1970b	
B.brizantha 664	1613bc	
B.brizantha 6298	1592bc	
B.dictyoneura 6133	1324c	

Means followed by different subscripts differ significantly ($P < 0.05$).

the most affected by stem gall nematode and was also affected by Synchytrium. In the second year, legume content of D. ovalifolium CIAT 350/Brachiaria spp. was nil. In the 4th year, legume percentage increased to 37.3%. In this experiment, B. humidicola continued to be the highest yielder.

In another grazing experiment, 6 legumes including two accessions of D. ovalifolium, CIAT 3784 and 3666, are being evaluated in associations with A. gayanus, Melinis minutiflora and native savanna. In the fourth year, D. ovalifolium is the dominant legume in association with native savanna and a good grass-legume balance is being maintained with M. minutiflora and A. gayanus. S. guianensis var. pauciflora CIAT 1283 disappeared from all three associations and only very low percentages of S. macrocephala CIAT 1643 and S. leiocarpa CIAT 1087 remained (Table 6).

Arachis pintoi CIAT 17434 - Brachiaria spp.

A. pintoi continued to show excellent promise in association with four Brachiaria spp. under grazing. It was particularly successful with B. humidicola and B. dictyoneura. It is well accepted by cattle but not grazed exclusively in associations with Brachiaria spp.

A. pintoi was successful under heavy grazing (av. 2.4 AU/ha) employed over 594 grazing days. The rotational system of 7 days grazing and 21 days deferrment permitted increases of legume content in all Brachiaria spp. - A. pintoi mixtures. Stoloniferous rooting, reserves of geocarpic seed in

Table 6. Percentage legume content in various mixtures in the 4th year under grazing. Carimagua, Llanos Orientales.

Association Grass	Legume	CIAT No.	% Legume
Savanna	D.ovalifolium	3784	75.7 a
Savanna	D.ovalifolium	3666	52.6 b
A.gayanus	D.ovalifolium	3784	33.0 c
Melinis m.	D.ovalifolium	3666	31.1 c
Savanna	S.capitata	1441	17.9 d
A.gayanus	D.ovalifolium	3666	17.3 de
Melinis m.	D.ovalifolium	3784	14.2 def
A.gayanus	S.capitata	1441	10.3 def
A.gayanus	S.macrocephala	1643	3.6 def
Savanna	S.leiocarpa	1087	3.5 def
Savanna	S.macrocephala	1643	2.7 ef

Means followed by different subscripts differ significantly ($P < 0.05$).

the soil, and hidden and inaccessible leaf buds protect this palatable legume from effects of overgrazing. A. pintoi is a prolific seeder. Soil seed reserves in grazed B. humidicola and B. dictyoneura swards averaged 670 and 618 kernels/m^2 or 48 g/m^2 and 57 g/m^2, respectively. Legume growth rates showed a dry season low and a wet season (July-October) peak. The legume content of the B. humidicola - A. pintoi mixture ranged from 8.3% in the dry season to the highest level of 44.5% in the second wet season (Table 7). For the B. dictyoneura - A. pintoi association, the range was from 9.5% to 25.7%. Total (grass and legume) DM yields ranged from 20.5 t/ha to 25.4 t/ha/yr. A. pintoi yielded 5.2 t/ha to 9.6 t/ha/yr. when harvested at 4-week intervals (Table 8). Crude protein (CP) content of A. pintoi averaged 14.8% in the first year and 16.6% for the second grazing period of 229 days.

The range of P content in the dry matter (0.18% - 0.20%) was adequate, K (1.28% - 1.42%) and Ca (1.92% - 2.00%) contents were above the requirements of beef cattle. The average in vitro digestibility of A. pintoi associated with the Brachiaria spp. was 60.4%. Mean percentages of CP in the associated Brachiaria spp. ranged from 6.7% to 7.3%. Cumulative liveweight gains were 643 kg/ha/yr. Average daily liveweight gain for the 594 day

Table 7. Changes in the legume content (W%) of four Arachis pintoi - Brachiaria spp. associations in the 1st and 2nd year under grazing. Carimagua, Llanos Orientales.

	Range of Legume Content (W%)	
	1st Year	2nd Year
A. pintoi - B. humidicola CIAT 679	5.2 - 25.1	8.3 - 44.5
A. pintoi - B. dictyoneura CIAT 6133	5.6 - 29.2	9.5 - 25.7
A. pintoi - B. brizantha CIAT 664	4.1 - 24.7	4.6 - 72.0
A. pintoi - B. ruziziensis CIAT 6291	11.4 - 40.0	16.1 - 69.0

Table 8. Dry matter yields (t/ha/yr) of four Brachiaria spp. - A. pintoi associations harvested at 4-week intervals.

	Grass	Legume	Total (Grass + Legume)	(%) Legume
B. dictyoneura-A. pintoi	20.14 a*	5.24 a	25.38 a	20.04
B. brizantha-A. pintoi	15.95 ab	5.23 a	21.56 a	24.30
B. humidicola-A. pintoi	15.74 ab	5.82 a	21.18 a	26.15
B. ruziziensis-A. pintoi	10.85 b	9.64 a	20.49 a	44.76

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

grazing period was 515 g/head.
The high potential of A. pintoi, a new addition to the limited range of tropical legume species adapted to Oxisols, that is also compatible with the productive, stoloniferous B. humidicola and B. dictyoneura, is indicated (Fig. 3).

Figure 3. Arachis pintoi stoloniferous legume compatible with Brachiaria spp. under heavy grazing.

AGRONOMY (Cerrados)

The objective of the collaborative project CIAT-EMBRAPA-IICA at CPAC is to select germplasm that is adapted to the soil-climate environment and resistant to pests and diseases prevailing in the Cerrados of Brazil. 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)

One-thousand three hundred and eighty-one legume accessions have been hitherto evaluated at CPAC. Observations continue to be made on phenology, plant vigour, resistance to pests and diseases, flowering and seed production. Six 'key' species are now identified namely Stylosanthes guianensis, S. capitata, S. macrocephala, S. viscosa, Centrosema macrocarpum and C. brasilianum. Zornia brasiliensis is no longer regarded as a 'key' species because of problems of low acceptability.

Stylosanthes guianensis

Most selected accessions belong to the "tardío" group now classified as S. guianensis var. pauciflora. Seventeen accessions have been selected and are under seed multiplication. These are CIAT 1286, 1317, 1808, 2078, 2146, 2191, 2203, 2244, 2245, 2315, 2326, 2328, 2540, 2750, 2973, 2976 and 2982. Accession CIAT 2243 has already been released as cv. Bandeirante. Four accessions selected earlier, CIAT 1095, 2046, 2981 and 2993, have been eliminated because of disease problems. Two other botanical varieties of the species showing promise have been identified as S. guianensis var. microcephala and S. guianensis sp. guianensis var. vulgaris. Accessions CIAT 2091, 2950, 2951 and 2953 have been selected based on vigour and anthracnose resistance.

Seven of the selected accessions from the "tardío" group together with a control (cv. Bandeirante) and one accession (CIAT 2953) of S. guianensis var. vulgaris have been sown in replicated 9 m^2 plots with Andropogon gayanus cv. Planaltina and Brachiaria brizantha cv. Marandu. These plots will be "mob" grazed with cattle in 1984-85 in order to select more acces- sions for detailed evaluation in Category III. With the exception of accession CIAT 2078, establishment of the legumes has been satisfactory.

Stylosanthes capitata

Four accessions have been selected, CIAT 1019, 1097, 2853 and 2935. The first two accessions are in advanced testing in Category IV and only slight anthracnose was observed on the accessions this season. Seed is being multiplied along with that of CIAT 10280 (cv. Capica).

In January 1983 an experiment was established to determine the effects of anthracnose on S. capitata cv. Capica and the five component accessions

Table 1. Evaluation of *S. capitata* cv. Capica in second season at CPAC, Brazil.

Accession (CIAT)	1st Flowering (1984)	DM Yield[1] (kg/ha)	Anthracnose Rating[2] (1.0-5.0)	Pure Seed Yield (kg/ha)	Pure Seed Unit Wt. (mg/100)
cv. Capica	6 April	4117	1.2	132	267
1315	6 April	4900	1.2	63	287
1318	6 April	3350	1.2	98	280
1342	6 April	3950	1.3	131	284
1693	6 April	4233	1.7	65	262
1728	6 April	3483	1.7	130	256
(mean of 5 components)		(3983)	(1.4)	(97)	(274)
1019	14 Feb.	4017	1.3	90	269
Significance	-	N.S.	-	***	N.S.

1. Sum of three harvests.
2. Recorded May 1984; see Plant Pathology Section.

(CIAT 1315, 1318, 1342, 1693 and 1728) of the blend. CIAT 1019 was also included and a border of the highly anthracnose-susceptible CIAT 1405 established around the experiment. Data for the second season (1983-84) are shown in Table 1. All components of cv. Capica flowered at the same time in early April, almost two months later than CIAT 1019. There were no significant differences in dry matter yield between cv. Capica and the components of the blend. Slight to moderate anthracnose levels were present in the border of CIAT 1405, and only slight levels were recorded on cv. Capica and the other accessions. In previous years anthracnose has destroyed pure stands of CIAT 1405 in the first season. It would appear that there have been changes in the anthracnose race populations at CPAC since 1980. This may have been influenced by climatic factors and an increase in the sowing of resistant accessions. Significant differences in seed yields were recorded, but seed size did not vary markedly between accessions.

Stylosanthes macrocephala

Six accessions are being multiplied. These are CIAT 1281, 2039, 2053, 2133, 10007 and 10009. Accessions CIAT 2280, 2732 and 2756 are no longer regarded as promising. CIAT 1281 has already been released as cv. Pioneiro whilst CIAT 2039 and 2053 are in advanced stages of testing under grazing. CIAT 2133 is later flowering than the other accessions and retains green leaf longer into the dry season. Accessions continue to show good anthracnose resistance.

Stylosanthes viscosa

Four accessions have been selected as promising, CIAT 1094, 2368, 2903 and 2923. Accessions CIAT 2872, 2879, 2914 and 2919 have been eliminated because of poor vigour, plant death or anthracnose. Multiplication of seed is most advanced for CIAT 1094.

Centrosema macrocarpum

Although the species shows excellent vegetative vigour and good disease resistance, problems of flowering and seed production at CPAC continue to limit the potential of existing introductions. On the other hand, crosses between *C. pubescens* and *C. macrocarpum* (CIAT 5062, 5065 or 5276) show promise in this respect and a number of hybrids multiplied for seed in 1983-84, will be evaluated in Category III under grazing.

Centrosema brasilianum

Among accessions there has been an increase in the incidence of *Rhizoctonia* foliar blight and CIAT 5487, 5825 and 5826 are no longer classed as promising. Accessions CIAT 5234, 5523 and 5824 continue to show promise and two new accessions CIAT 5518 and 5588 are being multiplied. Selected accessions are producing large quantities of seed with CIAT 5824 flowering later than the other lines. Some of these accessions have been under grazing in Category III for the first time in 1984-85.

New Germplasm

Considerable emphasis in the coming wet season will be placed on new accessions from the genera *Pueraria*, *Desmodium* and *Zornia*. Forty-seven accessions of *Pueraria phaseoloides*, will be sown along with 78 accessions of *Desmodium ovalifolium*, 10 accessions of *D. heterocarpon*, *D. velutinum* and *D. strigillosum* and 22 accessions of *Zornia glabra*. In addition, more germplasm of *Stylosanthes guianensis*, *S. capitata*, *S. macrocephala* and *Centrosema brasilianum* will be introduced.

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

In the past problems have been encountered on soils such as the red-yellow latosol with grasses of African origin. It has been suggested that genera of American origin such as *Paspalum* might be better adapted to these soil types. Preliminary studies have commenced at CPAC with a small number of species of *Paspalum* and those of other genera. As more material is collected these investigations will expand.

Two species, *Paspalum conspersum* and *P. guenoarum* have already shown good adaptation to the red-yellow latosol. They are more vigorous than *Andropogon gayanus* cv. Planaltina, appear to be resistant to spittlebug, flower and produce seed. Multiplication of two of the lines will commence this season. In 1983-84, 24 other accessions of *Brachiaria dictyoneura*, *B. radicans*, *Setaria vulpiseta*, *Axonopus jesuiticus*, *Paspalum* species, *P. maritimum*, *P. mandiocanum*, *P. plicatulum*, *P. conspersum*, *P. guenoarum*, *P. virgatum* and *P. densum* were established vegetatively on the red-yellow latosol. These will be evaluated against *A. gayanus* cv. Planaltina.

AGRONOMIC EVALUATION OF GERMPLASM UNDER GRAZING - (Category III)

Promising germplasm from Categories I and II is evaluated in small, individually grazed plots in Category III to determine legume persistence. In the current experiment seven replicated *Andropogon*-legume associations are being grazed at two stocking rates, which are obtained by varying plot size (320 and 430 m^2). Each plot is grazed for 2 days every 3 weeks in the wet season and 4 days every 6 weeks in the dry season. In 1984-85 this trial will enter its fourth and last season.

Available dry matter yields and botanical composition of the treatments are presented in Table 2. The legume contents of all S. macrocephala accessions have decreased since grazing began. However, accessions CIAT 2039 and 2053 continue to be the most vigorous lines and are more productive than cv. Pioneiro. No anthracnose problems have been observed in the accessions. Grazing of the Z. brasiliensis accessions has been terminated because of the refusal of animals to consume plants at any point in time. Stocking rate effects have increased with time and yields of dry matter on offer are lower at the high stocking rate but legume contents are higher.

During 1983-84 a new Category III trial was established employing the same design as in the previous trial. Two legumes of the S. guianensis var. pauciflora group, cv. Bandeirante and CIAT 2245, were associated with three grasses, Andropogon gayanus cv. Planaltina, Brachiaria brizantha cv. Marandu and the new selection Panicum maximum CIAT 6116. The legume accessions and the grasses (A. gayanus and P. maximum) have established well. However, the plant population of B. brizantha is low and variable. Plants were not defoliated in the first season to allow seeding to take place.

Table 2. Available dry matter yield and botanical composition of grass-legume associations in Category III at CPAC, Brazil.

	Available Dry Matter (kg/ha)			
Accession	3.11.82	30.5.83	7.11.83	24.5.84
Stylosanthes macrocephala				
cv. Pioneiro[1]	1197(21)[2]	3643(11)	1343[3]	2574(5)
CIAT 10138[1]	1288(18)	2652(15)	1063	2407(3)
CIAT 2039	1539(71)	2943(51)	1004	1963(22)
CIAT 2053	1184(68)	3081(54)	728	2475(25)
Zornia latifolia				
CIAT 728[1]	1350(69)	2280(30)	839	2457(2)
Zornia brasiliensis				
CIAT 7485	1549(59)	4514(98)	-	-
CIAT 8025	1416(27)	3471(44)	-	-
Low stocking rate	1389(52)	3974(45)	1178	2764(4)
High stocking rate	1332(41)	2478(64)	813	1906(19)

1. Controls.
2. % Legume on a dry matter basis.
3. In sampling on 7.11.83 legumes present but were below cutting height of 10 cm.

Hopefully, the population of cv. Marandu will increase this season by recruitment from seed on the soil surface.

In 1984-85, a further Category III will be established with new selections from the genus Centrosema.

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. In 1981-82, a trial was established to evaluate pastures of *Andropogon gayanus* cv. Planaltina in association with *Stylosanthes guianensis* cv. Bandeirante, *S. macrocephala* cv. Pioneiro, *S. capitata* CIAT 1019 and 1097. Subsequently, a further trial was established with *Brachiaria brizantha* cv. Marandu and *S. macrocephala* CIAT 2039. Grazing in the latter trial began in May 1984. All paddocks are grazed continuously at three stocking rates, variable by season of the year. Animals are changed annually at the start of the dry season.

The results for the *Andropogon*-legume associations for the first ten months of the first grazing year (1983-84) are presented in Table 3. Liveweight gain results are divided on a dry and wet season basis, each of five months duration. The rains commenced at the end of September 1983 and October is regarded as the first month of the wet season. In almost all treatments animals gained some weight during the dry season, with the *Andropogon*-cv. Bandeirante association giving twice the daily gains of the other associations, when results are compared across stocking rates. A strong negative relationship between animal gains and stocking rate was also observed for the period reported. These results are in accordance with observations made concurrently on the pasture and on diet selection by oesophageal-fistulated steers. The *Andropogon*-cv. Bandeirante association contained between 29 and 52 per cent legume in the dry season compared with 8 to 20 per cent for the other associations. In the *Andropogon*-cv. Bandeirante associations steers consumed markedly more legume (up to 20 per cent) than in the other treatments (1 per cent). As anticipated, animal performance improved considerably in the wet season, but differences due to associations and stocking rate effects were less pronounced than in the dry season.

MULTIPLICATION OF SEED

Fifty-three promising legumes and grasses are currently under multiplication at CPAC in areas of varying size. There are 22 accessions of *Stylosanthes guianensis*, 5 accessions of *S. capitata*, 6 accessions of *S. macrocephala*, 4 accessions of *S. viscosa*, 5 accessions of *Centrosema brasilianum*, 7 hybrids from *C. pubescens* x *C. macrocarpum* and 1 accession each of *Zornia glabra*, *Rhynchosia* sp., *Panicum maximum* and *Brachiaria brizantha*. Much effort has been put into multiplication of the new cultivars Bandeirante, Pioneiro and Marandu in order to supply genetic seed to the Basic Seeds Unit of EMBRAPA.

PROBLEMS OF SEED PRODUCTION IN CULTIVAR BANDEIRANTE

Relatively low seed yields have been recorded over the years in *Stylosanthes guianensis* cv. Bandeirante. Flowering and seed maturation occur during the dry season when moisture is limiting and as a consequence supplementary irrigation could be a means for improving yields in the cultivar.

In 1981-82 an experiment was esta-

Table 3. Animal performance from *Andropogon*-legume pastures during the dry season (May to September 1983 inclusive) and the wet season (October 1983 to February 1984 inclusive) at CPAC, Brazil.

Pasture	Dry Season Stocking Rate (AU/ha)[1]			
	0.77	1.05	1.33	X
	kg gain/animal/day			
Andropogon + *S. capitata* CIAT 1019	0.152	0.036	-0.009	0.060
Andropogon + *S. capitata* CIAT 1097	0.134	0.055	0.054	0.081
Andropogon + *S. guianensis* cv. Bandeirante	0.202	0.175	0.098	0.158
Andropogon + *S. macrocephala* cv. Pioneiro	0.082	0.104	0.043	0.076
X	0.143	0.093	0.047	

	Wet Season Stocking Rate (AU/ha)[1]			
Pasture	1.03	1.38	1.62	X
	kg (gain/animal/day)			
Andropogon + *S. capitata* CIAT 1019	0.664	0.716	0.328	0.569
Andropogon + *S. capitata* CIAT 1097	0.725	0.648	0.621	0.665
Andropogon + *S. guianensis* cv. Bandeirante	0.651	0.637	0.362	0.550
Andropogon + *S. macrocephala* cv. Pioneiro	0.662	0.712	0.685	0.686
X	0.676	0.678	0.499	

1/ 1 AU = 400 kg liveweight.

blished to examine the effects on seed production of irrigation up to peak flowering (mid-July) or irrigation up to harvest time (early September). In 1982-83, pure seed yields in plots irrigated up to mid-July were increased by 41 per cent over unirrigated plots, but absolute yields were still low at 34 kg/ha. Results for 1983-84 (Table 4) indicated that irrigation to peak flowering in mid-july continued to be the best treatment. Pure seed yield in this treatment was 55 per cent higher than that in unirrigated plots. The yield of 79 kg/ha was the highest ever obtained in the cultivar at CPAC. The increase in yield appears to be a function of increased inflorescence number rather than any marked increase in number of seeds per inflorescence. There is also evidence from the seed multiplication plots to suggest that seed production in some other accessions of S. guianensis var. pauciflora may be inherently higher than in cv. Bandeirante. For example, 2 accessions CIAT 2244 and 2245 (already in

Table 4. Effects of supplementary irrigation on seed production in S. guianensis cv. Bandeirante at CPAC, Brazil.

Treatment	Pure Seed Yield (kg/ha)	Inflorescens (No./m^2)	Seeds (No./infl.)
No irrigation	51	20,480	1.4
Irrigation to peak flowering	79	27,008	2.0
Irrigation to harvest time	64	20,128	2.0

Category III evaluation) produced almost three times as much seed as cv. Bandeirante over a three year period (Table 5). The yield of 200 kg/ha in CIAT 2245 compares favourably with that of accessions of S. capitata and S. macrocephala. In the establishment year accessions CIAT 2244 and 2245 were planted much later than cv. Bandeirante. It is now believed that seed yields in these accessions could be increased still further by earlier sowing.

Table 5. Production of seed in three of accessions of S. guianensis var. pauciflora at CPAC, Brazil.

Accession	1981-1982 (Estab. year)	1982-1983	1983-1984	Mean
	- Pure Seed Yield (kg/ha)-			
CIAT 2244	13	103	188	101
CIAT 2245	12	60	200	91
cv. Bandeirante	35	56	16	36

PASTURE PROJECT IN PANAMA (IDIAP/RUTGERS/CIAT)

The objectives of the Tropical Pastures Program in Panama are realized within an agreement between Rutgers University (New Jersey) and the Instituto Panameño de Investigación Agropecuaria (IDIAP). These can be summarized as follows: (a) selection of promising forage germplasm for ecosystems of economic importance in the country, (b) agronomic studies of adapted species, mainly in relation to their response to low levels of fertilization, (c) seed multiplication of promising species, and (d) weed control and evaluation of the potential animal productivity with promising species selected for their adaptation to acid soils with low fertility.

GERMPLASM

Regional Trials Type A (RTA)

Using Regional Trial A methodology, a large number of grasses and legumes have been evaluated at Los Santos (premontane forest), Calabacito (humid tropical forest -derived savanna subecosystem), and Sona (very humid tropical forest). Although these sites do not cover all ecosystems found in Panama, they are representative of a large percentage of the area where dual-purpose agriculture predominates. Calabacito and Sona are characterized by acid soils, high Al saturation, and low P levels (Ultisols); while Incentisols predominate in Los Santos with neutral pH, low or no Al in the organic horizon, low P content, and high levels of Ca and Mg. At this site the most important production constraint affecting plant growth is the annual 6-month dry period, approximately from December to June.

Tables 1 and 2 show the number of ecotypes established at each site. A large number of species are being evaluated in the three localities, however, at Los Santos the germplasm includes species tolerant to drought, as is the case of the genus Cenchrus. Moreover, native or natural forage ecotypes have been included to compare the degree of adaptation and productivity of introduced germplasm with that commonly found or used in the areas.

Outstanding adapted germplasm has been identified through periodic evaluations of resistance to pests and diseases and dry matter (DM) production during a complete dry season-rainy season cycle. Table 3 presents a detailed summary of the three respective sites.

The following materials have been found outstanding in the various ecosystems: (a) A. gayanus and Brachiaria spp. ecotypes; (b) the genus Centrosema, particularly C. macrocarpum, and (c) the genus Stylosanthes, particularly S. guianensis (common) and S. guianensis var. pauciflora. Commonly observed

Table 1. Germplasm of forage legumes included in Regional Trials A in different sites of Panama (1983-1984).

LEGUMES	Accession CIAT No.	Evaluation Site		
		Sona	Calabacito	Los Santos
Aeschynomene histrix	9690, 9666	+	-	-
Alysicarpus vaginalis	Native	-	+	+
Calopogonium mucunoides	Native	+	-	+
Carnavalia sp.	Native	-	-	+
Centrosema brasilianum	5234	+	+	+
Centrosema brasilianum	5247	+	+	+
Centrosema brasilianum	494	+	-	-
Centrosema macrocarpum	5062	-	+	+
Centrosema macrocarpum	5434	+	+	+
Centrosema macrocarpum	5065	+	+	+
Centrosema macrocarpum	5478	-	-	+
Centrosema pubescens	5126	-	+	+
Centrosema pubescens	438	+	-	-
Centrosema sp.	Native	-	+	+
Centrosema sp.	5112, 5278	+	+	+
Centrosema pascuorum	5190, 5192	-	-	+
Desmodium canum	13032, Native	+	+	+
Desmodium barbatum	Native	+	-	+
Desmodium ovalifolium	3784	+	+	+
Desmodium heterophyllum	349	+	-	-
Desmodium ovalifolium	350	+	-	-
Codariocalyx gyroides	3001	+	-	-
Galactia striata	964	-	+	+
Neonotonia wightii	204, 206	-	-	+
Macroptilium atropurpureum	506	+	-	+
Pueraria phaseoloides	9900	+	+	+
Stylosanthes capitata	1019, 10280	+	+	+
S. capitata	1441, 2044	-	+	+
S. capitata	1315,1693,1728	+	-	-
Stylosanthes macrocephala	1643, 2133	-	+	+
Stylosanthes guianensis	136, 184	+	+	+
Stylosanthes guianensis var. pauciflora	1280,1283	+	+	+
Stylosanthes guianensis var. pauciflora	10136	-	+	+
Stylosanthes hamata	118, 147	-	-	+
Stylosanthes humilis	Native	+	+	+
Stylosanthes scabra	1047	-	+	+
Stylosanthes leiocarpa	1087	-	+	-
Stylosanthes sympodialis	1044	-	-	+
Zornia glabra	7847	+	+	-
Zornia latifolia	728	+	-	-
Zornia sp.	Native	+	-	-

\+ = Established in the site.
\- = Was not included.

Table 2. Germplasm of forage grasses included in Regional Trials A in different sites of Panama (198301984).

GRASSES	Accession CIAT No. or cultivar	Evaluation site		
		Sona	Calabacito	Los Santos
Andropogon gayanus	621, 6200	+	+	+
Brachiaria decumbens	606	+	+	+
Brachiaria dictyoneura	6133	+	+	+
Brachiaria humidicola	679	+	+	+
Brachiaria radicans	Local	+	+	-
Brachiaria ruziziensis	Local	+	-	-
Cenchrus ciliaris	678, Molopo, Nunbank, Gayndah, Nueces	-	-	+
Cynodon plectostachyus	Local	+	-	-
Dichanthium aristatum	Local	+	-	+
Digitaria swazilandensis	Local	+	+	+
Digitaria decumbens (Pangola)	Local	-	+	+
Digitaria decumbens (Transvaala) Local		-	-	+
Hyparrhenia rufa	Local	+	+	+
Panicum maximum	604, Indiana, Guinea	-	-	+
Pennisetum orientale	Cowboy	-	-	+

\+ = Established in the site.
\- = Was not included.

pests in these trials are leaf chewing and sucking insects. Anthracnose in Stylosanthes and Rhizoctonia in Centrosema, Galactia, and Phaseolus spp. have been the diseases of major incidence, causing most damage in the different sites.

Overall, the productivity of native species has been low compared to that of introduced species. For example, native S. humilis is an annual species which practically disappears during the dry period. Although it persists well by the production of abundant seed which germinates easily with the first rains and invades neighboring plots, its production in terms of DM is insignificant.

Naturalized grass species or those species currently in commercial use which were included in the trials have shown a tendency towards decreased productivity after each cut. It is evident that many of these species, mainly grasses, need high fertilizer inputs to maintain adequate yields through time.

These trials have confirmed the wide adaptation range in different ecosystems of Hyparrhenia rufa (Faragua), the natural grass predominating in Panama. However, Faragua tends to be less vigorous in sites such as Calabacito, characterized by low pH and high Al saturation. On the other hand, its DM production (4 t/ha) has been lower than that of

Table 3 Germplasm selected as promising in the different ecosystems where Regional Trials A were established.

Species	Accession CIAT No.	Evaluation site		
		Calabacito	Los Santos	Sona
GRASSES				
A. gayanus	621, 6200	Excellent	Good	Excellent
B. dictyoneura	6133	Excellent	Excellent	Excellent
B. humidicola	679	Good	Good	Excellent
B. decumbens	606	Good	Excellent	Good
C. ciliaris	"Numbank"	-	Excellent	-
C. ciliaris	"Molopo"	-	Excellent	-
LEGUMES				
C. sp.	5112, 5278	Good	Good	Average
C. macrocarpum	5434	Excellent	Good	Good
C. macrocarpum	5062, 5065	Good	Good	Good
P. phaseoloides	9900	Excellent	Good	Excellent
S. capitata	10280	Good	Bad	Good
S. macrocephala	2133, 1643	Good	Bad	-
S. guianensis	184, 136	Excellent	Excellent	Good
S. guianensis var. pauciflora	1280, 1283	Good	Good	Good
S. guianensis	1175		-	Excellent
G. striata	964	Bad	Excellent	-

A. gayanus CIAT 621 (14 t/ha) and CIAT 6200 (9 t/ha) during the period of maximum precipitation. Although Faragua's main disadvantage is its minimal production during the dry season once its reproductive cycle has been accomplished, it is worth mentioning its persistence through seed production and its resistance to fire and tolerance to pests and diseases.

REGIONAL TRIALS B (RTB)

During August, a Trial B was established in the locality of El Ejido (Los Santos) on an Alfisol with germplasm selected for its promising performance in a Trial A located in the same area. A total of 12 legumes and 15 grasses were established including commercial species common in the area (Cynodon sp. [Estrella], Bothriocholoa sp. [Pangola de pobre], Digitaria swazilandensis [Swazi], Panicum maximum [Guinea and Indiana], and H. rufa [Faragua]), and some introduced grasses (Cenchrus ciliaris [Molopo and Numbank], A. gayanus [CIAT 621 and 6200], B. decumbens [CIAT 606] and B. dictyoneura [CIAT 6133]).

Legumes included in the trial were: C. macrocarpum CIAT 5062 and 5434, C. brasilianum CIAT 5234, C. pubescens CIAT 5189, Centrosema sp. 5278, P. phaseoloides CIAT (9900, S. guianensis CIAT 136 and 184, S. hamata CIAT 147, S. scabra CIAT 1047, S. sympodialis CIAT 1044 and Galactia striata CIAT 964). All species were established well, although the grasses Faragua and Swazi and the legumes P. phaseoloides CIAT 9900, C. macrocarpum 5434, and Stylosanthes spp. CIAT 147, 184, 136, and 1044 were outstanding for their vigour during establishment. CIAT 1044 has shown susceptibility to inflorescence blight caused by *Rhizopus* spp. Overall, this year has been wetter than the past year during the evaluation of the RTAs. This factor probably contributed to higher disease incidence.

Brachiaria ecotypes

A total of 23 *Brachiaria* spp. ecotypes were established in three localities in Panama (Calabacito, Gualaca and Finca Chiriqui) to evaluate their degree of adaptation in terms of seasonal production of DM, tolerance to diseases and resistance to spittlebug, which is a pest of high incidence in forage grasses in Panama. The species included in the trial were: 1) *B. decumbens* (6 ecotypes), 2) *B. humidicola* (6 ecotypes), 3) *B. ruziziensis* (3 ecotypes), 4) *B. eminii* (2 ecotypes), 5) *B. dictyoneura* (2 ecotypes), 6) *B. brizantha* (1 ecotype).

Dry matter production will be determined by cuts every 8 weeks during the rainy season, and the pest and disease incidences will be determined by counting the number of nymphs/m^2 (in the case of spittlebug) and by visual rating of damage (in the case of diseases). Ecotypes superior to those presently in commercial use in terms of spittlebug resistance and other agronomic characteristics are expected to be selected during the next 18 months.

Leucaena ecotypes

In collaboration with the Instituto Nacional de Agricultura (INA) located in Divisa (Provincias Centrales), 16 *Leucaena* ecotypes were established during July, 1984 (Table 4). The germplasm includes three hybrids and four ecotypes of *L. diversifolia*; this latter species has shown higher levels

Table 4. *Leucaena* ecotypes established to evaluate production of edible dry matter and mimosine content in INA (Divisa), Panama, 1984.

CIAT No.	Species/selection or cultivar
17461	*L. diversifolia*/30
17388	*L. diversifolia*/31
17485	*L. diversifolia*/26 (78-49)
17503	*L. diversifolia*/25 (78-3)
17467	*L. leucocephala*/32
17495	*L. leucocephala*/11 (78-15)
17498	*L. leucocephala*/K 29
17488	*L. leucocephala*/K 132
17502	*L. leucocephala*/cv. Cunningham
17475	*L. leucocephala*/18-92-15 hybr.
17477	*L. leucocephala*/23-1/12-12
17491	*L. leucocephala*
17489	*L. pulverulenta*/hybrid K 340
17490	*L. pulverulenta*/hybrid AJO 3279
17487	*L. shannoni* /78-70
17478	*L.* sp. /30/4-11

of tolerance to soil acidity in experiments carried out by CIAT in Colombia. Yield variability of these ecotypes will be studied by means of cuts every 8 weeks to a height of 50 cm and edible dry matter production and mimosine content of the most outstanding ecotypes will be evaluated during at least two years.

AGRONOMY

The effect of P, Mg, K, and S fertilization on *A. gayanus* CIAT 621 and *S. capitata* cv. Capica, alone and in association, have been evaluated during the establishment phase of a trial conducted on an Ultisol in the Experimental Station in Calabacito. This soil is characterized by its high acidity, low P level, high Al saturation, and intermediate K and Mg values (0.2 and 0.4 meq in the first 15 cm, respectively). Other soil characteristics are shown in Table 5. Sources of the elements used were triple superphosphate for phosphorus (P), and potassium muriate, sulpomag,

Table 5. Physical-chemical parameters of a Panama Ultisol (Calabacito), November, 1984.

Depth (cm)	Sand	Loam (%)	Clay	Bases (meq/100 g) Ca	Mg	Na	K	Al	pH (H_2O)	OM (%)
0-15	16.5	39.0	44.5	5.1	0.4	-	0.2	0.8	4.8	2.9
15-26	10.7	27.6	61.7	0.8	0.1	-	-	4.4	4.8	1.6
26-43	10.9	32.1	57.0	0.2	TR	TR	-	4.8	5.1	1.1

magnesium oxide and elemental sulphur for potassium (K), magnesium (Mg), and sulphur (S), respectively. Fertilizers were applied and incorporated before planting.

Yield results of three successive cuts at 8-week frequency are shown in Table 6. S. capitata responded to successive increases of P_2O_5, although the response was significant ($P < 0.01$) only at the highest fertilization level (60 kg/ha). There was no significant response to applied K or Mg at the levels used, even though a slight yield increase was observed. The highest response was obtained with S at the 20 kg/ha level, resulting in increases of 39% in dry matter yield in the presence of intermediate P levels. The combination of all these elements produced significant ($P < 0.05$) yield increases only at the highest level of P. This is probably due to the positive interaction between this element and sulphur.

A. gayanus did not reponc significantly to any of the elements applied, even though yields tended to increase with respect to the effect of each element independently, especially in the case of phosphorus and sulphur. However, the interaction between the highest level of phosphorus and the remaining elements was highly significant ($P < 0.01$). In this case, yields were increased by 30% in comparison to the control. The performance of A. gayanus was similar when planted in association with S. capitata, but this legume shows more variability in yield when grown in association with A. gayanus. This may be due to problems in establishment and competition with the grass in the mentioned ecosystem. Only 10% of the total biomass in the association was contributed by the legume, although a yield increase was observed in the last cuts.

In the species studied, the response to fertilizer application was not only shown in terms of total biomass produced but also with respect to vigour and speed of establishment. The greater development capacity of fertilzied plots was evident, mainly in those plots where P and S were applied. This factor may be important for achieving rapid soil coverage and better weed control by competition.

SEED PRODUCTION

Seed production activities have developed in order to multiply experimental lines and increase, at a semi-commercial scale, seed of promising species or seed presently used by producers (basic seed). In parallel to multiplication activities, harvesting practices have been observed with the aim of improving the technology for production of forage seed.

Table 7 presents information on sites, areas harvested and some observations

Table 6. Response during the establishment period of *A. gayanus* CIAT 621 and *S. capitata* cv. Capica alone and in association at different levels of applied P, K, Mg, and S, in a Panama Ultisol (Calabacito).

	Treatments (kg/ha)				Yield (kg DM/ha)*		
	P_2O_5	K_2O	MgO	S	*S. capitata*	*A. gayanus*	*A. gayanus* *S. capitata*
1.	0	0	0	0	1.052.4	2.840.9	1.761.9 211.5
2.	0	50	20	20	1.278.6	2.828.5	1.876.9 239.5
3.	15	0	0	0	1.363.6	2.968.6	2.319.0 248.4
4.	15	50	20	20	1.488.3	2.740.0	2.122.8 337.7
6.	30	50	20	20	1.629.7	3.173.0	2.396.0 355.8
7.	30	0	20	20	1.374.9	3.328.5	2.309.9 228.2
8.	30	0	0	20	2.134.3	3.518.3	2.789.4 328.4
9.	30	0	20	0	1.534.3	3.115.0	2.280.2 324.9
10.	30	50	0	0	1.351.9	3.504.1	2.494.6 341.8
11.	60	0	0	0	1.743.5	3.343.4	2.291.1 210.7
12.	60	50	20	20	1.862.8	4.052.3	3.322.7 299.4
DMS ($P < .05$)					862.8	842.3	1.014.2
DMS ($P < .01$)					465.0	1.149.9	1.367.2

* Mean of 3 cuts done at 8-week intervals.

related to seed production. With the exception of *C. macrocarpum* CIAT 5065, all species flowered and formed seed during the period 1983-1984. This species started flowering at the end of November 1983, but reverted to vegetative stage due to sporadic rainfall during this month. It seems that *C. macrocarpum* requires some drought stress to produce seed, once flowering has been induced. The rest of the legumes flowered abundantly under the prevailing conditions, but seed yield was reduced significantly by pod anthracnose in *P. phaseoloides* and by budworm, *Stegasta bosqueella*, in *S. guianensis*. *S. capitata* yields were high, compared to those obtained in other production sites, mainly in Colombia. During the second growth cycle, however, the crop had notably lost vigour and was invaded by weeds. This implies that a second harvest has little value. The biggest difference between the two flowering cycles was the high precipitation during the second cycle (> 4.500 mm), much higher than the mean, which probably influenced the behavior of *S. capitata*. On the other hand, a large percentage of *S. guianensis* CIAT 136 died after the first harvest (cutting

Table 7. Yield and production parameters of forage seed in Panama during the period 1983-1984.

Species	Area harvested (ha)	Place of harvest	Initiation of Flowering	Initiation of Harvesting	Yield (kg/ha)*	Total harvested (kg)*
LEGUMES						
Stylosanthes guianensis CIAT 136	0.15	Gualaca	7-11-83	30-1-84	30.00	4.50
Stylosanthes capitata cv. Capica	0.33	Gualaca	29-9-83	10-1-84	589.0	194.50
Pueraria phaseoloides CIAT 9900	1.00	Gualaca	10-12-83	Feb.-Mar.'84	22.50	22.50
Centrosema macrocarpum CIAT 5065	0.40	Gualaca	28-11-83	-	-	-
GRAMINEAS						
Andropogon gayanus CIAT 621	2.0	Gualaca	29-9-83	23-11-84	431.00	862.00
		Calabacito	25-9-83	-	-	860.00
Brachiaria humidicola Commercial	5.0	Chiriqui	14-6-83	20-7-84	75.0**	375.5
Brachiaria decumbens Commercial	2.5	Gualaca	16-20 May		191.47	479.68

* Crude seed.
** Yield using a combine, other yields correspond to manual harvest.

height between 20-25 cm) but regenerated normally from seed and later showed good density and plant development.

All grasses flowered abundantly in the different sites of the Province of Chiriqui. The most abundant flowering and fructification of Brachiaria species occurred during May-June, when precipitation was high. However, these plants continued flowering at least through October, enabling more than one harvest per year.

A. gayanus yields were acceptable, but the plant lost vigour during the second growth cycle, primarily because of excessive humidity resulting from high precipitation. On the other hand, B. decumbens showed a higher yield potential even though the harvest was carried out during the rainy season. There is however a high index of infertile and immature seed (Table 8). Seed yield is only 13.5% of that expressed as crude seed and only 0.9% of the potential yield. There is no doubt a broad field of investigation in this species, mainly with regard to efficient harvesting management, plant management and nutritional factors which increase the formation of caryopses.

As shown in Table 9, seed harvested has been used mainly by private producers and IDIAP. Since Panama does not have an organized forage seed industry, it is IDIAP's responsibility to supply the commercial demand for seed. This situation may change in the future, but will continue to exist for quite a while and must adjust to the Institute's research policies and needs.

WEED CONTROL

During the establishment period, activities have been oriented toward weed control, including shrubs found in pastures. The first experiment was established at Gualaca Experiment Station to observe the degree of control and selectivity of seven pre- and post-emergent herbicides on the establishment of the forage legume P. phaseoloides (Kudzu). Table 10 shows the treatments, combinations and doses used. Observations made 48 days after treatment applications showed that the best pre-emergent herbicide in terms of control and selectivity was Oxyfluorfen at a dose of 0.50 kg ai/ha. At a dose of 1.12 kg ai/ha, similar control was obtained but phytotoxicity increased to 31%. The second herbicide in order of effectiveness and selectivity was Alachlor at a dose of 2.24 kg ai/ha, although its residual control decreased after 48 days. Linuron performed well but was highly phytotoxic to the legume at a dose of 2.0 kg ai/ha. A similar result was obtained with the mixture of Linuron and Alachlor.

None of the post-emergent herbicides was outstanding in terms of both control and selectivity. However, the high degree of selectivity of Fluazifop-butyl at both doses must be mentioned. The poor control shown by the product was due to the fact that a high percentage of the weed complex constituted broad leaf species dominated by Liendrepuerco (Borreria alata) and Cocli (Croton trinitatis). This product is recommended mainly for control of grass weeds. In the same way, the control achieved with the pre- plus post-emergent herbicide treatment was due mainly to the action of the pre-emergent although Acifluorfen inhibited growth of broad-leaf weeds and in some cases caused severe deformation of the growing points and death.

Shrubby weeds constitute a serious problem in the management of pastures in Panama for two main reasons: (a) their resistence to conventional weed control methods, and (b) strong competition with the desirable species. Some of them are toxic

Table 8. Maturity and yield of *B. decumbens*, Gualaca, 1984.

Initiation of flowering	Sampling date	No. of flowering stems/m^2	Potential yield of crude seed	Yield of harvested Seed - kg/ha	
				Crude	Processed
			---------------- (kg/ha)	------------	
16-20 May	18 June	455	2.820	191.68*	25.84**
	2 July	311	3.441	-	-
	10 July	312	2.717	-	-

* Harvested between June 18 and July 4, 1984.
** Purity undetermined.

Table 9. Distribution of forage seed harvested in Panama during 1983-1984.

Applier	No.	Purpose	Amount of seed (kg)		
			Grass	Legume	Total
Private producers	14	Commercial planting	204.7	5.0	209.7
Institutions (including IDIAP)	3	Forage evaluation	140.3	3.0	143.3

and/or possess horns or spines which can injure cattle. During the rainy period (1984), an experiment was established at Gualaca Experiment Station to evaluate the degree of control of "Chumico" (*Curatella americana*), "Protobelillo" (*Casearia javitensis*) and "Guayabo" (*Psidium* sp.) shrubs with Pichloran + 2,4-D amine dissolved in water and diesel oil. The herbicides were applied to the stump or to the stem base in several doses as described in Table 11. Although Pichloran + 2,4-D amine does not dissolve in organic media, for example diesel oil, through the use of a surfactant at 2.0% it was possible to obtain an emulsion with a certain degree of stability, especially if maintained under frequent agitation compatible with methods of commercial herbicide application.

Results showed regrowth of "Chumico" up to 60 days after application of all treatments at the stolon. Only when the herbicide was applied at 2.0% with diesel oil was the percentage of regrowth reduced to 40%. In contrast, application at the base produced increasing defoliation, especially when diesel oil was used as the solvent. During this same period, treatment with herbicide at 2.0% in diesel oil prevented regrowth of the stolon in "Guayabo" and reduced regrowth of "Portobelillo". This experiment will be evaluated for 150 days to obtain a more confident appraisal of the effect of various treatments.

Table 10. Weed control during the establishment of Kudzu (*P. phaseoloides*) through the use of pre- and post-emergent herbicides, Gualaca, 1984.

A. Pre-emergent

Treatment	Dose (kg ia/ha)	% of Weed control (No. days after)		% of Kudzu damage (No. of days after)	
		21	48	21	48
Oxyfluorfen	0.50	92.0	65.0	9.0	1.0
Oxyfluorfen	1.12	97.0	87.0	21.0	31.0
Oryzalin	1.40	70.0	47.0	21.0	26.0
Oryzalin	2.80	73.0	57.0	85.0	71.0
Alachlor	2.24	69.0	35.0	16.0	12.0
Alachlor	4.48	79.0	55.0	22.0	26.0
Linuron	1.0	53.0	32.0	37.0	26.0
Linuron	2.0	82.0	81.0	93.0	100.0
Linuron + Alachlor	1.5 + 1.0	82.0	67.0	92.0	95.0

B. Post-emergent*

Treatment	Dose (kg ia/ha)	% of Weed control (No. days after)		% of Kudzu damage (No. days after)	
		16	40	16	40
Pendimentamine	1.30	38.0	14.0	51.0	17.0
Pendimentamine	2.60	48.0	10.0	78.0	17.0
Acifluorfen	0.30	11.0	10.0	3.0	2.0
Acifluorfen	0.60	27.0	13.0	6.0	1.0
Fluazifop-Butyl	0.50	0	0	0	0
Fluazifop-Butyl	1.0	0	0	C	0

C. Pre- and Post-emergent*

Treatment	Dose (kg ia/ha)	% of weed control (No.days after)				% of kudzu damage (No. days after)			
		Pre		Post		Pre		Post	
		21	48	16	40	21	48	16	40
Alachlor + Acifluorfen	2.24+0.30	76.0	57.0	24.0	8.0	6.0	11.0	2.0	1.0
Oxyfluorfen + Fluazifop-Butyl	0.50+0.50	88.0	56.0	19.0	0	12.0	33.0	0	0
Oryzalin + Fluazifop-Butyl	1.40+0.50	62.0	55.0	0	0	56.0	75.0	0	0
Mechanical control		100.0				0			
Absolute control		0				0			

* Post-emergent products applied 35 days after emergence.

Table 11. Control of "Chumico" (Curatella americana), "Portobelillo" (Casearia javitensis) and "Guayabo" (Psidium sp.) shrubby weeds with herbicides.

Treatments	% of regrowth (days after)					
	Chumico		Guayabo		Portobelillo	
	30 d	60 d	30 d	60 d	30 d	60 d
A. Applied to the stolon						
1. Picloran + 2,4-D** 1.0% in water	50	100	20	60	0	40
2. Picloran + 2,4-D 1.5% in water	20	100	0	80	0	60
3. Picloran + 2,4-D 2.0% in water	80	100	20	80	0	40
4. Picloran + 2,4-D 1.0% in diesel*	80	100	60	00	0	60
5. Picloran + 2,4-D 1.5% in diesel	20	100	25	25	0	0
6. Picloran + 2,4-D 2.0% in diesel	20	40	0	0	0	25
B. Aplied to the Base						
1. Picloran + 2,4-D 1.0% in water	13	11	6	5	6	6
2. Picloran + 2,4-D 1.5% in water	4	6	10	6	1	7
3. Picloran + 2,4-D 2.0% in water	5	8	10	15	20	22
4. Picloran + 2,4-D 1.0% in diesel	56	61	22	35	17	48
5. Picloran + 2,4-D 1.5% in diesel	68	77	14	23	11	47
6. Picloran + 2,4-D 2.0% in diesel	65	63	23	21	71	73

* Mixture obtained by using a surfactant at 2.0%.
** 2,4-D amine.

PASTURE MANAGEMENT AND PRODUCTIVITY

Among the grazing experiments in progress to evaluate germplasm persistence in pastures under different managements, the most advanced is the RTC being carried out in collaboration with the Agronomy Faculty (Chiriqui). The total area established is 2.6 ha and the treatments are: a) 5 associations -A. gayanus CIAT 621 and H. rufa (local) in association with S. capitata cv. Capica and C. macrocarpum CIAT 5065; and B. humidicola in association with P. phaseoloides (Kudzu); and b) three stocking rates 1.25, 2.0, and 2.5 AU/ha in a rotational system of 7 occupation days and 35 rest days. The experiment will be under grazing during the next rainy season.

Advances have been achieved in the establishment of another RTC at the Gualaca Station. The species selected for this trial were A. gayanus CIAT 621 and H. rufa in association with S. guianensis CIAT 136, Centrosema sp. CIAT 5277, and S. capitata cv. Capica, in a total area of 3.13 ha. The grazing system will consist of 7 occupation days and 35 rest days. In addition, a RTD has been designed with A. gayanus CIAT 621, H. rufa, and B. humidicola, alone or in association, to determine mineral production in a total area of 24 ha and under rotational grazing. Both experiments are well underway in their establishment in more than 50%.

SMITHSONIAN RESEARCH INSTITUTE (SRI)

Due to serious erosion problems in the valley of the Panama Canal, SRI has initiated research to find management alternatives to prevent ecosystem destruction in this valuable area of Panama. An important alternative is selection of forage germplasm with high yield potential, desirable qualities for erosion control, and attractive to the wild fauna. Species offered to SRI were selected for multiplication and evaluation (Table 12). Plots have now been established and their performance will be evaluated during one year. These species have potential as alternatives to traditional grass pastures, now deteriorating in persistence and yield.

TRAINING

The First Course on Collection, Preliminary Evaluation of Germplasm, and Seed Production was carried out in Santiago (Veraguas) from November 27 to December 13, 1984. The course was financed by FAO and organized by GREDPAC (Grupo Regional de Pastos de Centroamérica and El Caribe) and IDIAP. Five scientists from CIAT's Tropical Pastures Program, four technicians from IDIAP and one from RENARE, participated as instructors.

A total of 16 technicians from various national research institutes assisted as follows: Mexico (1), Costa Rica (2), Honduras (3), El Salvador (2), Panama (8-6 from IDIAP and 2 from the University of Panama). The course included both theory and field training; to this end, the pasture evaluation and seed production experiments, established in the central provinces during the last year, proved very useful. The course was very successful in training participants on pasture evaluation methodologies and in motivating technicians to learn about the different disciplines and subjects treated. Favorable comments were made at the end of the course and interest to continue such courses in coming years was evident.

Table 12. Germplasm established by the Smithsonian Research Institute (SRI) in the Las Pavas area (ancient Canal Zone). Establishment June-July, 1984.

SPECIES

1. For seed source and/or green fertilizer:
   Brachiaria humidicola "Commercial" - 1.0 ha
   Brachiaria decumbens "Commercial" - 1.0 ha
   Pueraria phaseoloides "Commercial" - 2.0 ha

2. For evaluation of adaptation and production 5 x 10 m plots, 2 repetitions)
   Brachiaria humidicola CIAT 6707, 682
   Brachiaria decumbens CIAT 6132, 6131, 6009, 6012
   Brachiaria ruziziensis CIAT /291, 654
   Brachiaria dictyoneura CIAT 6133, 6369
   Brachiaria eminii CIAT 6241
   Brachiaria radicans "Commercial"
   Digitaria swazilandensis "Commercial"

   Desmodium ovalifolium CIAT 350
   Centrosema macrocarpum CIAT 5478A
   Centrosema pubescens CIAT 438
   Centrosema sp. CIAT 5112, 438
   Stylosanthes capitata "Capica"
   Stylosanthes guianensis CIAT 136

INTERNATIONAL TROPICAL PASTURES EVALUATION NETWORK

INTRODUCTION

The main objective of the Regional Trials Section is to evaluate new forage germplasm in the main ecosystems of tropical America, under the combined effort of national research institutions and CIAT's Tropical Pastures Program. This joint effort constitutes the International Tropical Pastures Evaluation Network (RIEPT) which operates under a systematic evaluation program made up of four stages: Regional Trials A, B, C, and D (RTA, RTB, RTC, and RTD), which allow for the introduction, agronomic evaluation and evaluation under grazing of the most promising germplasm. The first two stages (RTA and RTB), are essentially agronomic, where germplasm is selected basically according to its tolerance to climate, soil, pest, and disease conditions. Regional Trials A evaluate survival of a great number of entries (80-150) in a few representative sites, within the five major ecosystems: well-drained isohyperthermic savanna ("Llanos"), well-drained isothermic savanna ("Cerrados"), poorly-drained savanna, semi-evergreen seasonal forest, and tropical rain forest. Regional Trials B evaluate seasonal productivity under cutting of the best entries selected in the previous stage, in the greatest number of sites possible within each ecosystem. Regional Trials C and D study the effect under grazing in order to evaluate characteristics such as stability and persistence of pasture components (grasses + legumes) in RTC; and beef, milk, and/or calf production under different grazing management systems (RTD).

ADVANCES OF THE INTERNATIONAL TROPICAL PASTURES EVALUATION NETWORK

Meeting of RIEPT's Advisory Committee

With the object of discussing the criteria to estimate animal productivity (beef, milk, and/or calves) from grazing tropical pastures, a meeting was held in Lima, Peru with the participation of special guests and RIEPT's Advisory Committee, with the support of CIID (Centro Internacional de Investigaciones para el Desarrollo), INIPA (Instituto Nacional de Investigación y Promoción Agropecuaria), and IVITA (Instituto Veterinario de Investigaciones Tropicales y de Altura). This meeting was attended by 40 representatives from national and international institutions from 16 countries (Table 1). During the meeting, RTD were defined to evaluate and compare new pastures in terms of animal productivity and persistence of the planted species. However, it was recognized that the specific objectives mentioned can vary from trials that emphasize the characterization of productivity and persistence potentials of new pastures, to those trials seeking a direct solution to the problems of pasture management and utilization within the context of production systems. Four major alternatives (RTD) were identified; these will be published during this year in the meeting's proceedings and later

Table 1. Participants at the Workshop on "Methodologies for Pasture Evaluation under Grazing (RTD). Lima, Peru, October 1-5, 1985.

Country	Institution	Participants
ARGENTINA	INTA	Sonia Chifflet de Verde
AUSTRALIA	CSIRO	R.M. Jones
BELIZE	Min. of Natural Resources	H.A. Parham
BRAZIL	EMBRAPA/CPAC	C.M.C. da Rocha
	EMBRAPA/CNPGL	L.C.S. Valle
	EMBRAPA/CNPGC	A.H. Zimmer
	EMBRAPA/CPATU	E.A. Serrão
	CEPLAC/CEPEC	J.Marques Pereira
	CIAT/EMBRAPA/IICA	D.Thomas
COLOMBIA	ICA	P.E. Mendoza
	CIID	H.H. Li Pun
	CIAT	J.M.Toledo, J.M. Spain, C.Seré, R.Vera, E.A.Pizarro, A.Ramírez, C.Lascano, C.Sackville-Hamilton M.C.Amézquita
COSTA RICA	CATIE	V.M. Mares
CUBA	Min. de Agricultura	J.J. Paretas
CHILE	Universidad Católica	G.Pichard
	CIAT/CIID	O.Paladines
ECUADOR	IICA	H. Caballero
	INIAP	J. Costales
GUATEMALA	IICA	G.Cubillos
MEXICO	INIA/SARH	A.Ramos, F.Meléndez
PANAMA	IDIAP	C.M. Ortega
	IDIAP/Rutgers	P.Argel
PERU	NCSU/INIPA	D.E.Bandy
	PEPP/INIPA/NCSU	K.Reátegui
	INIPA	M.Arca
	IVITA	C.A.Reyes, H.Huamán, A.Riesco
REP.DOMIN.	CENIP/Sec. Agricultura	Y. Soto de Rosa
TRINIDAD	CARDI	P.Onyemauche Osuji
USA	Texas A&M University	M. Riewe

distributed to members and collaborators of the RIEPT.

Regional Trials by Ecosystems

Today, the RIEPT has partial information from 146 regional trials within the five main ecosystems of tropical America mentioned previously, grouped as follows: 31 RTA, 96 RTB, 9 RTC, and 10 RTD. Of these, a total of 114 regional trials (80%) report data. Figure 1 presents the geographic distribution of regional trials currently established, and the evolution of regional trials in tropical America from 1978 to 1984. Tables 2, 3, 4, and 5 show the country and locality where these regional trials are carried out, the collaborating institution, and the person or persons responsible for these trials.

Cooperation improved significantly during 1984, the most outstanding cases being:

México: The number of regional trials in the southern part of the country has increased substantially, including establishment of agronomic trials (RTB), initial programming of grazing trials (RTC-RTD), and fertilization trials with B. decumbens CIAT 606 and A. gayanus CIAT 621.

Panama: Its development is very similar to that of Mexico. Various RTA, RTB, RTC, and RTD are being conducted, covering two main ecosystems in the country, under the guidance of IDIAP-Rutgers University, University of Panama, CIID, and CIAT.

Brazil: With the support and coordination of EMBRAPA-CPAC, various regional trials have been established in the Brazilian cerrado, from 3° 15'N to 22° 01'S latitude and between 15 and 850 masl in the Ultisols and Oxisols.

Colombia: The integration during 1984 of ICA's (Instituto Colombiano Agropecuario) Pastures Program to the RIEPT has been, without doubt, an important event worth mentioning. Only two ICA-CIAT regional trials had been established by 1983; today 15 trials have been established in the forest and savanna ecosystems, covering soils of low and medium fertility. In turn, the Federación de Cafeteros (CENICAFE), with headquarters in Chinchiná, Caldas, coordinates a series of agronomic trials (RTB) in the coffee-growing area of the country and will soon initiate evaluation of pastures with animals (RDT).

Well-drained Isohyperthermic savannas "Llanos"

Regional Trials A within the well-drained isohyperthermic savanna ecosystem have been established recently; it is therefore considered premature to report results during the present year.

Average seasonal production figures for each accession (summarized in Table 6) were calculated using data from the new RTB's in this ecosystem (see Table 3). A. gayanus 6200 presented high yields, higher than all Brachiaria species, of which the best were B. humidicola 6705, B.dictyoneura 6133 and B. brizantha 664, especially during the dry period. Among legumes, the productivity of Centrosema sp. 5112 is outstanding during the dry period, followed by D. ovalifolium 350 and Centrosema sp. 5278. During the rainy season "Capica's" components (Stylosanthes capitata 1315, 1318, 1342, 1693, and 1728) were outstanding. Recent establishment of these trials do not allow for more conclusions than those already presented.

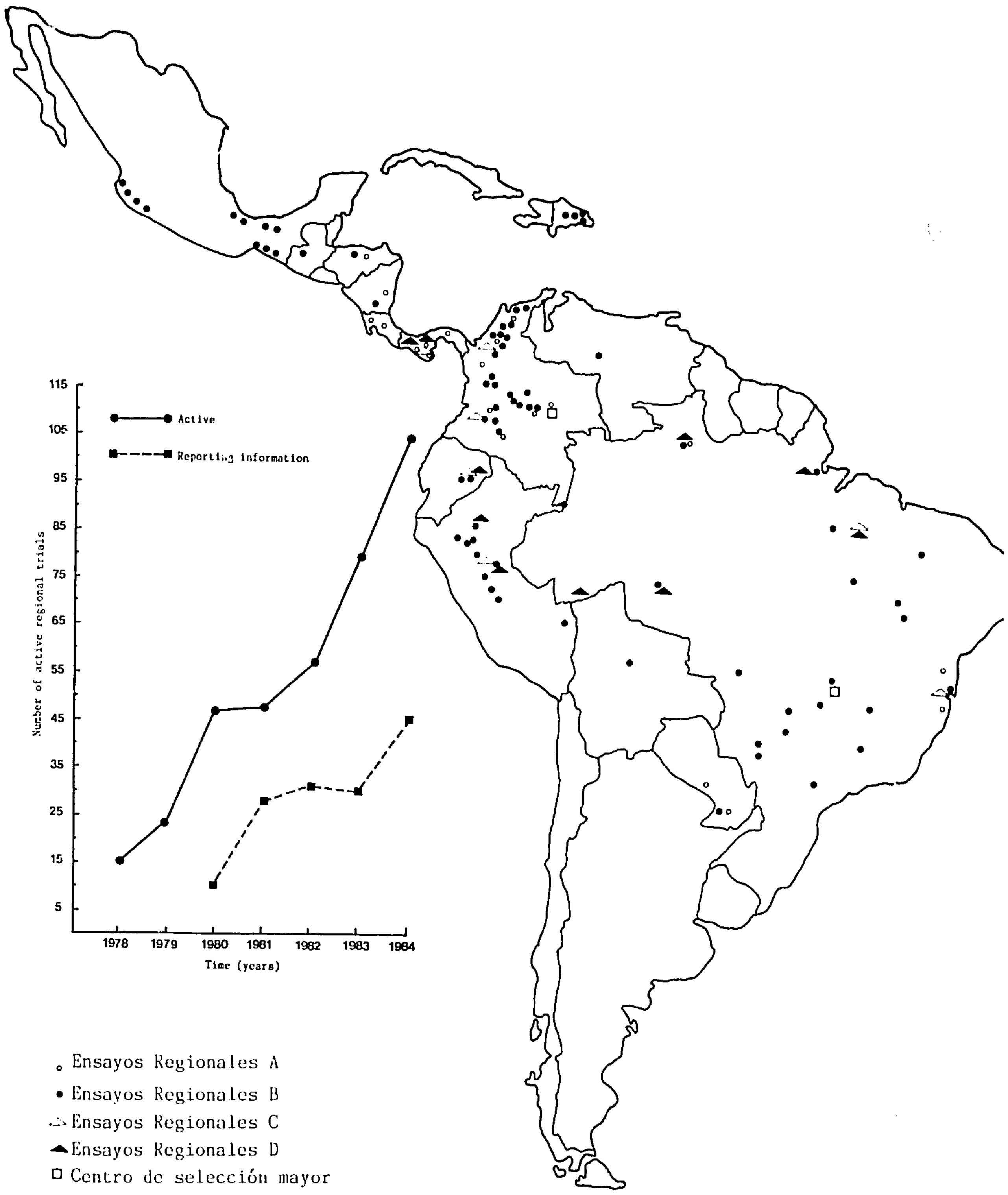


Figure 1. International Tropical Pastures Evaluation Network (RIEPT), 1984 and evolution of the number of active regional trials and information reported during 1978-1984.

Table 2. Regional Trials A in tropical America.

Country	Location	Institution/Collaborator	Eco-system*	Planting Date
BRAZIL	Boa Vista II	EMBRAPA-UEPAT Boa Vista/ V. Gianluppi	WDIS	V-83
	Itabela II	CEPLAC/M. Moreno, J. Marques Pereira	TRF	III-83
	Itajú	CEPLAC/M. Moreno	TRF	1984
COLOMBIA	Carimagua	CIAT/B. Grof, Regional Trials	WDIS	XII-83
	Macagual II	ICA/A. Acosta	TRF	IV-83
	Tulenapa	ICA/Alberto Mila	TRF	IV-84
	Palmira	ICA/Freddy Ospina	SESF	VI-84
	Turipaná	ICA/Roberto Cabrales	SESF	V-84
	Motilonia	ICA/Justo Barros	WDIS	V-84
	Las Leonas	CIAT/Regional Trials	WDIS	VIII-84
COSTA RICA	Turrialba	CATIE/R. Borel	TRF	III-83
	Guápiles	MAG/J. Alpízar	TRF	1983
HONDURAS	La Ceiba	CURLA/G. Valle	SESF	VII-83
NICARAGUA	Pto. Cabezas	MIDINRA/F. Alguera, O. Miranda	TRF	VI-83
PANAMA	Calabacito	IDIAP/H. Aranda	TRF	VII-83
	El Chepo	IDIAP/F.Garibaldo	TRF	IX-83
	Los Santos	IDIAP/O.Duque	SESF	IX-83
	Soná	IDIAP/L.Tasón	SESF	IX-83
PARAGUAY	Caapucú	PRONIEGA/R. Samudio, P. Valinotti	WDS	IX-82
	Eusebio Ayala	PRONIEGA/O. A. Molas, P. Valinotti	PDS	XII-83

*WDIS = Well-drained isohyperthermic savanna; WDS = Well-drained savanna; PDS = Poor-drained savanna; TRF = Tropical Rainy Forest; SESF = Semi-evergreen seasonal forest.

Evaluation of damage caused by diseases by genera, show the most important to be: anthracnose for Stylosanthes; Sphaceloma scab and Drechslera leaf spot for Zornia; Cercospora leaf spot and Rhizoctonia leaf blight for Centrosema; and nematodes for Desmodium. In the case of pests, results show significant damage caused by sucking insects for the genera Stylosanthes, Zornia,

Table 3. Regional Trials B in tropical America.

Country	Location	Institution/Collaborator	Eco-system	Planting Date
BOLIVIA	Peroto	IBTA/R. Baptista	WDTS	1984
BRAZIL	Terezina	EMBRAPA-UEPAE Terezina/ J.C.Pimentel, G.M. Ramos	WDTS	1983
	Amarante	EMBRAPA-UEPAE Terezina/ G. Moreira Ramos	WDTS	I-84
	Barrolândia II	CEPLAC/J. Marques Pereira	TRF	III-83
	Barreiras I	EPABA/L. A. Borges de Alencar	WDIS	XI-82
	Boa Vista	EMBRAPA-UEPAT Boa Vista/ V. Gianluppi	WDIS	V-83
	Capinópolis	CEPET-UFV/C.P.Zago, M.E.da Cruz	WDTS	XII-83
	Macapá	EMBRAPA-UEPAE Macapá/ A. P. Souza Filho	WDIS	II-84
	Planaltina	EMBRAPA-CPAC/C.M. Da Rocha, D.Thomas, A.O.Barcellos	WDTS	I-83
	São Carlos	EMBRAPA-UEPAE São Carlos/ L.A. Correa	WDTS	XII-83
	Barreiras II	EPABA/L.A. Borges de Alencar	WDIS	XII-84
	Jaciara	EMPA/G. S. Lobo	PDS	XI-83
	Felixlândia	EPAMIG/N. M. Sousa Costa	WDTS	I-84
	Vilhena	EMBRAPA-UEPAE Porto Velho/ C.A. Gonçalves	WDTS	XII-84
	Campo Grande	EMBRAPA-CNPGC/M.I.Penteado, L.Jank	WDTS	XI-83
	Goiânia	EMGOPA/J. M. Sobrinho	WDTS	I-84
	Araguaina	EMGOPA/A. Braga	WDIS	XII-84
COLOMBIA	Bonanza	CIAT/Regional Trials	WDIS	IV-83
	Guadalupe	CIAT/Regional Trials	WDIS	IV-83
	Menegua	CIAT/Regional Trials	WDIS	IV-83
	Pachaquiaro	CIAT/Regional Trials	WDIS	IV-83
	Villavicencio	CIAT-SEMILLANO/Regional Trials	WDIS	IX-83
	Amalfi	Sec.Agric.Ant./L.A. Giraldo	SESF	IV-84
	Quilichao II	CIAT/Regional Trials	SESF	XI-82
	Leticia	CIAT-Bat.Mixto/Regional Trials	TRF	XII-82
	Macagual	CIAT-ICA-Univ.Amazonia/ A.Acosta, R.Angulo, G.Collazos	TRF	IV-83
	Palmira	ICA-CIAT/Regional Trials	SESF	VI-84
	Tulenapa	ICA/Alberto Mila	TRF	IV-84
	Mutatá	ICA/H.Restrepo	TRF	IV-84
	Turipaná	ICA/R. Cabrales	SESF	V-84
	San Marcos	ICA/R. Cabrales	WDIS	V-84
	El Nus	ICA/F. Baez	TRF	IV-84
	La Libertad	ICA/P. Cuesta	TRF	IV-84
	Motilonia	ICA/J. Barros	WDIS	V-84
	Chiriguaná	ICA/J. Barros	WDIS	V-84

Table 3. (Cont'd).

Country	Location	Institution/Collaborator	Eco-system	Planting Date
	Florencia (Magangué)	CIAT/R. Botero, R. Posada	WDIS	V-84
	Supía	CENICAFE/F. Machado	SESF	V-83
	Paraguaicito	CENICAFE/S. Suárez	SESF	V-83
	Gigante	CENICAFE/S. Suárez	SESF	VI-83
	Venecia	CENICAFE/S. Suárez	SESF	1984
DOMINICAN REPUBLIC	Pedro Brand	CENIP/M. Germán, Y. Soto	TRF	VIII-83
	Sabana de la Mar	CENIP/M. Germán, Y. Soto	TRF	VIII-83
	Miches-Seybo	CENIP/M. Germán, Y. Soto	TRF	IX-83
	Centro Palmilla	CENIP/M. Germán, Y. Soto	TRF	IX-83
ECUADOR	El Napo II	INIAP/K. Muñoz	TRF	1983
	Coca	INIAP/K. Muñoz	TRF	1983
GUATEMALA	Alta Veracruz	Centro Universitario/O. Pineda	TRF	VIII-84
HONDURAS	La Esperanza	Sec.Rec.Nat./L. Acosta	SESF	VI-84
	La Ceiba	CURLA/G. Valle	TRF	1983
MEXICO	Huimanguillo	INIA/A. Izquierdo T.	WDS	IX-83
	Isla Veracruz	INIA/J.J. Pérez	WDIS	IX-83
	Jalapa	INIA/A. Ramos	WDS	IX-83
	Jericó	INIA/A. Ramos	SESF	IX-83
	Loma Bonita	INIA/A. Ramos	SESF	IX-83
	Ocuilapa	INIA/A. Ramos	SESF	IX-83
	Pto. Vallarta	INIA/Guzmán-Monjaraz	SESF	VII-84
	Tomatlán	INIA/A. Peralta	WDIS	VII-84
	La Huerta	INIA/Guzmán-Monjaraz	WDIS	VII-84
	Purificación	INIA/Guzmán-Monjaraz	WDIS	VII-84
	Niltepec	INIA/A. Córdova	WDIS	IX-83
NICARAGUA	Pto.Cabezas	MIDINRA-DGTA	TRF	1983
PARAGUAY	Caapucú	PRONIEGA/P. Valinotti	WDIS	III-83
PERU	Alto Mayo-Calzada	INIPA/E. Palacios	SESF	X-81
	La Morada	INIPA-NCSU-UNAS/K.Reátegui, E.Cárdenas	TRF	1983
	Pucallpa II	IVITA/H. Ordóñez	SESF	I-83
	Palcazu Pichis	NCSU/R.Schaus, P.A.Sánchez, K.Reátegui	TRF	1983
	Pto.Maldonado	NCSU-INIPA/R.Schaus, P.A.Sánchez, K.Reátegui	TRF	X-82
	Pumahuasi	NCSU-INIPA-PEAH/K.Reátegui, H.Ivazetta	TRF	1983
	Tingo María	NCSU-INIPA/W.López	TRF	1983

Table 3. (Cont'd).

Country	Location	Institution/Collaborator	Eco-sys-tem	Planting Date
	Tarapoto COPERHOLTA II	INIPA-CIPA X/W. López	SESF	XII-82
	Tarapoto ESEP II	INIPA-CIPA X/G. Silva	SESF	I-82
	Yurimaguas II	NCSU-INIPA/R. Schaus, K. Reátegui	TRF	IX-83
VENEZUELA	Calabozo	Univ.Central Venezuela/ P.J. Arias	WDIS	V-83

Table 4. Regional Trials C in tropical America.

Country	Location	Institution/Collaborator	Ecosys-tem	Planting Date
BRAZIL	Barrolândia	CEPLAC-CEPEC/J. Ribeiro, J.M. Pereira, J.M. Spain, M. Moreno	TRF	XII-83
	Paragominas	EMBRAPA-CPATU/Jonás de Vastos, E.A.Serrão	SESF	II-84
COLOMBIA	Quilichao II	CIAT/E.A. Pizarro, C.Lascano	SESF	XI-83
	Caucasia	CIAT-Univ.Antioquia/L.F.Ramirez	SESF	XI-84
ECUADOR	El Napo	INIAP/K. Muñoz	TRF	VIII-83
PERU	Pucallpa	IVITA/H. Huamán	SESF	X-83
PANAMA	Soná	IDIAP/C.M. Ortega V.	SESF	IX-83

Table 5. Regional Trials D in tropical America.

Country	Location	Institution/Collaborator	Ecosystem	Planting Date
BRAZIL	Boa Vista	EMBRAPA-UEPAT Boa Vista/ V.Gianluppi, J.D.Santos	WDIS	V-82
	Macapá	EMBRAPA-UEPAT Macapá/E.A.Serrao, A.P.Souza Filho	WDIS	1982
	Paragominas	EMBRAPA-CPATU/M.B.Dias Filho, E.A.Serrao, J.de Vastos	SESF	1982
	Rio Branco	EMBRAPA-UEPAE Rio Branco/ José Pagani	SESF	1984
	Porto Velho	EMBRAPA-UEPAE Porto Velho/ Carlos A. Goncalves	SESF	1984
ECUADOR	El Napo	INIAP/K. Muñoz	TRF	VI-82
PANAMA	Calabacito	IDIAP-CIAT/C.Ortega,P.Argel	SESF	1984 (partial)
	Gualaca	IDIAP-CIAT/C.Ortega,P.Argel	TRF	IX-83
PERU	Pucallpa I	IVITA/A.Riesco,C.Reyes, H.Huamán	SESF	II-83
	Yurimaguas	INIPA/M.Ara, R.Schaus, K.Reátegui	TRF	1981

Centrosema, and Brachiaria; next in importance were chewing insects attacking Centrosema, Desmodium, Pueraria, and Brachiaria, and budworms feeding on Stylosanthes.

Well-drained isothermic savanna ("Cerrados")

Preliminary observations of 12 Regional Trials B established during 1983/1984 indicate that "key" species selected at CPAC are showing wide adaptation to cerrados conditions. The general performance of Stylosanthes accessions is: S. guianensis var. pauciflora, S.capitata = S. macrocephala, S. viscosa. Several accessions of S. guianensis var. pauciflora and S. guianensis var. vulgaris are excellent at some sites.

Of particular interest is the good adaptation of the two cultivars Bandeirante and Pioneiro, which can now be recommended with more confidence for areas outside the "central core" of the cerrados. The performance of the few Centrosema species was variable with poor vegetative vigour and flowering problems at many sites. However, no conclusions can be made on the potential of the genus for the cerrados based on such a narrow range of germplasm. More accessions need to be tested. Few disease and insect problems were encountered at this early state. Severe anthracnose was noted only on S. capitata at Amarante in Piauí where native plants of the species are common around the trial.

Table 6. Average seasonal production of DM for tropical forage grasses and legumes in the well-drained isohyperthermic savanna ecosystem.

Species	CIAT No.	Minimum Precipitation Period	Maximum Precipitation Period
		------- kg DM/ha/12 weeks --------	
GRASSES**			
Andropogon gayanus	6200	3034	1618
Brachiaria brizantha	6294	1421	1194
B.brizantha	664	1309	1033
B.decumbens	606	-	1259
B.decumbens	6700	1044	993
B.dictyoneura	6133	1399	1495
B.dictyoneura	6369	1026	1096
B.humidicola	6705	1384	1634
B.humidicola	6707	924	1686
B.ruziziensis	6419	686	915
LEGUMES***			
Aeschynomene histrix	9690	171	1315
Centrosema brasilianum	5234	406	382
C.macrocarpum	5062	540	1259
C.macrocarpum	5065	815	697
C.pubescens	5050	0	-
C.pubescens	5126	0	-
Centrosema sp.	5112	2585	-
Centrosema sp.	5278	1103	1470
Desmodium incanum	13032	-	217
D.ovalifolium	350	1644	-
D.ovalifolium	3784	794	764
Pueraria phaseoloides	9900	573	1130
Stylosanthes capitata	1019	86	1576
S.capitata	1315*	150	2799
S.capitata	1318*	153	2274
S.capitata	1342*	114	2153
S.capitata	1405	161	2282
S.capitata	1441	571	1369
S.capitata	1693*	196	2629
S.capitata	1728*	164	2556
S.capitata	1943	221	2123
S.capitata	2013	274	2906
S.capitata	2044	503	1111
S.capitata cv. Capica	10280	-	1293
S.guianensis var.pauciflora	1280	621	2316
S.macrocephala	1643	595	951
Zornia latifolia	9199	46	1311

* Components of cv. Capica.- ** Minimum precipitation period includes 3 locations with common ecotypes; maximum precipitation period includes 5 locations.- *** Minimum precipitation period includes 7 locations; maximum precipitation period includes 9 locations.

At one site, Capinópolis in Minas Gerais where natural soil fertility is high, spectacular growth of almost all accessions was observed. This confirms observations made at CPAC that accessions selected for low fertility conditions are also capable of responding dramatically to improvements in environment.

Poorly-drained savannas

A RTA established in Eusebio Ayala, Paraguay on acid soils (pH = 5.3) and carried out by technical personnel from PRONIEGA, indicates (Table 7) that total grasses planted were still present one year after establishment while 84% of the legumes had disappeared. It is important to note that Centrosema macrocarpum 5065, Centrosema sp. 5278; C. brasilianum 5234; and P. phaseoloides 9900 performed well.

Table 8 shows results of a RTB under "bank" (bank = non-floodable areas within poorly-drained savannas) conditions in Orocué, Colombia. It can be observed that average dry matter production was drastically reduced during the first and second years, for grasses as well as for legumes during periods of maximum and minimum precipitation. Out of 5 grasses and 32 legumes planted during the dry season, only the grasses Brachiaria dictyoneura 6133 and Brachiaria humidicola 679 surpassed initial production. Among legumes, Desmodium ovalifolium 350 sustained production from one year to the next throughout the four seasons studied, while Codariocalyx gyroides 3001 and P. phaseoloides 9900 only sustained production until the dry season. The first evaluation period after establishment was year 1 (minimum precipitation) and the last (2 years later) was year 2 (maximum precipitation).

Table 7. Grass and legume ecotypes with an average degree of adaptation*, equal or superior to "good" in the poorly-drained savanna ecosystem at Eusabio Ayala, Paraguay.

Species	CIAT No.	Coverage (%)
GRASSES		
Andropogon gayanus	621	99
Andropogon gayanus	6200	99
Brachiaria brizantha	664	99
Brachiaria decumbens	606	93
Brachiaria dictyoneura	6133	99
Brachiaria humidicola	679	99
Brachiaria ruziziensis	6291	88
Setaria anceps cv. Kazungula	--	90
LEGUMES**		
Centrosema brasilianum	5234	38
Centrosema macrocarpum	5065	75
Centrosema sp.	5278	50
Pueraria phaseoloides	9900	53

* Grade average calculated in October 11, 1984.

**Legumes tested: D. ovalifolium 3784, D. incanum 13032, D. heterophyllum 349, S. capitata 1019-1441-2044-10280, S. guianensis 136, S. guianensis var. pauciflora 1280, S. macrocephala 1582-1643, S. scabra 1009-1047, S. leiocarpa 1087-2115, C. macrocarpum 5062, C. pubescens 5126-5189, C. pascuorum 5545, Centrosema sp. 5112, Zornia glabra 7847.

Table 8. Average production (kg DM/ha at 12 weeks) of grasses and legumes in the poorly drained savanna ecosystem under "bank" conditions in Orocué, Colombia.

Species	CIAT No.	Maximum precipitation period			Minimum precipitation period		
		Year 1	Year 2	Dif.	Year 1	Year 2	Dif.
GRASSES							
Andropogon gayanus	621	3462	673	-2789	600	0	-600
Brachiaria decumbens	606	1897	361	-1536	240	156	-184
Brachiaria decumbens	6131	-	D	-	450	-	-
Brachiaria dictyoneura	6133	2725	959	-1766	430	859	+429
Brachiaria humidicola	679	4340	1820	-2520	293	900	+566
LEGUMES							
Centrosema arenarium	5236	891	D	-	383	155	-230
Centrosema brasilianum	5055	1025	248	- 777	370	70	-300
Centrosema brasilianum	5184	2219	309	-1910	443	-	-
Centrosema brasilianum	5234	1853	200	-1653	396	80	-316
Centrosema brasilianum	5247	683	D	-	230	-	-
Centrosema macrocarpum	5065	2105	133	-1972	282	70	-212
Centrosema pubescens	5050	266	185	- 81	166	60	-106
Centrosema pubescens	5053	326	120	- 206	148	-	-
Centrosema pubescens	5126	126	170	+ 44	100	20	- 80
Centrosema sp.	5112	2544	685	-1859	310	120	-190
Codariocalyx gyroides	3001	3581	742	-2838	146	836	+690
Desmodium ovalifolium	350	3796	2340	-1456	256	1009	+753
Pueraria phaseoloides	9900	3378	926	-2452	240	515	+275
Stylosanthes capitata	1019	1358	270	-1088	120	280	+160
Stylosanthes capitata	1315*	2046	547	-1499	140	-	-
Stylosanthes capitata	1318*	3486	817	-2669	133	-	-
Stylosanthes capitata	1342*	2010	640	-1370	96	130	+ 34
Stylosanthes capitata	1405	2260	576	-1684	273	-	-
Stylosanthes capitata	1441	2252	606	-1646	156	260	+106
Stylosanthes capitata	1693*	2944	690	-2254	143	-	-
Stylosanthes capitata	1728*	2009	765	-1244	83	120	+ 37
Stylosanthes capitata	2044	1844	496	-1348	115	115	0
Stylosanthes capitata	2310	1120	626	- 494	326	350	+ 24
Stylosanthes guianensis	1283	1617	511	-1106	800	-	-
Stylosanthes macrocephala	1281	1627	170	-1457	150	40	-110
Stylosanthes macrocephala	1643	1627	D	-	93	-	-
Stylosanthes macrocephala	2039	1597	D	-	73	150	+ 77
Stylosanthes macrocephala	2061	1976	150	-1826	45	-	-
Stylosanthes macrocephala	2093	753	D	-	65	-	-
Stylosanthes macrocephala	2133	949	140	- 809	225	-	-
Stylosanthes leiocarpa	1087	2080	D	-	206	-	-
Zornia brasiliensis	7485	1255	D	-	270	120	-150

* Components of cv. Capica, S. capitata CIAT 10280.
D= Disappeared during the second year.

Tropical Forest Ecosystems

Of the new RTAs established with more than 18 months in the field are those located in Macagual (Colombia) and Turrialba (Costa Rica). Table 9 shows grass and legume ecotypes in Macagual with a degree of adaptation equal or superior to "good" after the fourth evaluation. It can be observed that 64% of the grasses and 34% of the legumes established have shown good adaptation. On the contrary, results of a RTA in Turrialba (Costa Rica), under lower Al saturation conditions and medium-fertility soils, show the percentage of promising material to be relatively high, especially with respect to legumes (Table 10).

Table 9. Grass and legume ecotypes with a degree of adaptation equal or superior to "good" after the fourth evaluation in a tropical rainy forest ecosystem. Regional Trial A, Macagual, Colombia.

Species	CIAT No.
GRASSES*	
Andropogon gayanus	6225-6265
Brachiaria decumbens	6693-6699-6700
Brachiaria dictyoneura	6369
Brachiaria humidicola	6705
LEGUMES**	
Centrosema macrocarpum	5062-5434-5629
Centrosema pubescens	5172-5189
Centrosema schiedeanum	5066-5201
Centrosema sp.	5277
Desmodium heterocarpon	3787
Stylosanthes viscosa	2171-2405

* Other grasses: *A. gayanus* 6221, *B. ruziziensis* 6413, *B. brizantha* 6684-6686.

** Other legumes: *C. rotundifolium* 5283, *C. macrocarpum* 5427-5452, *C. brasilianum* 5247, *C. pascuorum* 5545, *D. ovalifolium* 3780, *S. guianensis* 015-145-191-1028, *S. capitata* 1693-1728, *S. humilis* 1304-2420, *S. hamata* 2770, *Clitoria* sp. native, *Zornia glabra* 280-7847-8279, *Z. brasiliensis* 7485, *Phaseolus* sp. native.

Table 10. Tropical forage grass and legumes ecotypes with an average degree of adaptation equal or superior to "good" in a tropical rain forest ecosystem in Regional Trials A at Turrialba, Costa Rica

Species	CIAT No.
GRASSES*	
Andropogon gayanus	621
Brachiaria decumbens	606
Brachiaria ruziziensis	local
Cynodon dactylon	local
Cynodon plectostachyus	local
Digitaria decumbens	local
Digitaria sp.	local
Panicum maximum	604
Paspalum fasciculatum	local
LEGUMES**	
Canavalia ensiformis	local
Centrosema brasilianum	5234
Centrosema macrocarpum	5065
Centrosema pubescens	438
Centrosema pubescens	5126-5189
Centrosema sp.	5112
Codariocalyx gyroides	3001
Desmodium heterocarpon	365
Lablab purpureus	local
Leucaena leucocephala	871
Pueraria phaseoloides	Commercial
Stylosanthes guianensis	136
Stylosanthes hamata	147
Vigna adenantha	4016
Zornia brasiliensis	7485
Zornia latifolia	9199

* Grasses evaluated: *P. plicatulum* 600, *B. dictyoneura* 6133.

** Legumes evaluated: *D. heterophyllum* 349, *D. ovalifolium* 350, *Z. latifolia* 728, *S. capitata* 1019-1078, *Stylosanthes leiocarpa* 1087, *S. macrocephala* 1281, *S. guianensis* var. *pauciflora* 1283, *Desmodium* sp. 3019, *Z. latifolia* 9179, *Zornia* sp. 9648, *A. histrix* 9666, *A. paniculata* 9665.

Based on close to 30 RTBs in Tropical Forests having reported results for more than two years, the capacity to survive and sustain production from one year to the next, even under a highly extractive system such as management with cutting, was evaluated. The "production stability index" was calculated for this evaluation.

Table 11 shows that A. gayanus 621 and B. humidicola 679 are the most stable grasses in as far as production throughout time, while B. decumbens 606, probably due to its susceptibility to spittlebug, and P. maximum 604, due to its greater nutritional requirements, had PSI values below 1.

Among legumes, S. guianensis 184, Zornia latifolia 728 and D. ovalifolium 350 were outstanding for their high productivity and stability. C. pubescens 438 and "common" showed average productivity and a PSI greater than 1.2. In a similar way, D. heterophyllum 349 presented average yields, with PSI values however, close to 2.

Table 11. Average production and production stability index* of tropical forage grass and legume ecotypes in the tropical forest ecosystem.

Species	CIAT No.	Maximum precipitation period 12 weeks kg DM/ha ± SD	PSI**	Minimum precipitation period 12 weeks kg DM/ha ± SD	PSI**
GRASSES					
A. gayanus	621	6692 ± 4484	1.4 a	4652 ± 4020	1.2 a
B. decumbens	606	5272 ± 4613	0.7 b	4886 ± 4368	0.7 b
B. humidicola	679	5914 ± 3725	1.5 a	4650 ± 3710	-
P. maximum	604	4660 ± 4636	0.5 b	1152 ± 771	-
LEGUMES					
A. histrix	9690	2459 ± 1930	6.5 a	2540 ± 4043	0.5 c
C. mucunoides	(common)	1256 ± 1120	1.2 b	-	-
C. pubescens	438	1627 ± 1613	1.2 b	1450 ± 1386	1.2 bc
C. pubescens	(common)	1037 ± 721	1.5 b	1027 ± 871	1.7 ab
C. gyroides	3001	2063 ± 1639	2.4 b	2050 ± 2267	0.9 bc
D. heterophyllum	349	1318 ± 1227	1.9 b	1108 ± 1456	2.0 a
D. ovalifolium	350	2448 ± 1862	1.4 b	2283 ± 2079	1.3 bc
P. phaseoloides	9900	1937 ± 1479	1.0 b	1849 ± 1618	1.1 bc
S. capitata	1405	2148 ± 1973	3.3 b	1198 ± 1879	0.6 c
S. capitata	1097	2131 ± 2048	2.3 b	961 ± 441	-
S. guianensis	136	2802 ± 2397	1.2 b	2836 ± 2495	0.7 c
S. guianensis	184	3172 ± 2917	1.9 b	1108 ± 1456	2.0 a
Z. latifolia	728	2940 ± 2313	1.6 b	2152 ± 2059	1.1 bc

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

** Means with same letter are not significantly different ($P < 0.05$).

An analysis was carried out to evaluate the degree of adaptation of ecotypes common in the different localities. The method used was that suggested by Eberhart and Russell, whose references, modification, and steps followed are described in the Tropical Pastures Program Annual Report of 1981 (pp. 57-66).

Table 12 shows values of slope "b" representing the degree of adaptation of ecotypes in different environments within the ecosystem; and values of intercept "a" representing average productivity of the ecotype for the ecosystem. A higher productivity is observed for grasses most of them having similar values; however, A. gayanus 621 and B. humidicola 679 have lower "b" values than B. decumbens 606 and P. maximum 604, indicating greater adaptability coverage for the first two.

The most productive legumes were: S. guianensis CIAT 136 and 184, and A. histrix 9690, during both evaluation periods, with yields higher than 3000 kg DM/ha 12 weeks after regrowth, while the rest ranged from 1000 to 2500 kg DM/ha 12 weeks after regrowth. The same table also shows adaptability indexes "b" for both evaluation periods. With the exception of A. histrix CIAT 9690, all other legumes showed significant values. These "b" values, as in previous analyses (see Annual Report 1983) tend to be greater when the ecotype's yield is higher. For example, S. guianensis CIAT 136 and 184 are the ecotypes with higher "b" values for both evaluation periods. Instead, C. pubescens "common" and D. heterophyllum 349 have low "b" values.

Figure 2 shows S. guianensis CIAT 136 and 184 to be the ecotypes showing a marked response to environmental changes during the maximum and minimum precipitation periods. Z. latifolia CIAT 728 performed similarly to S. capitata 136 and 184 during the period of maximum precipitation, but reduced its degree of adaptation during the period of minimum precipitation. P. phaseoloides CIAT 9900, D. ovalifolium CIAT 350, C. pubescens CIAT 438, and S. capitata 1405 presented yields lower than the average for the ecosystem and less sensibility to environmental changes, both during maximum and minimum precipitation periods.

Future Activities

A new list of RTAs and RTBs has been officialized by the Program for the end of 1984, including shrubby legumes. This will allow the RIEPT to increase the number of regional trials and evaluate the range of germplasm adaptation.

The III General Meeting of the RIEPT and a workshop of the Advisory Committee are planned for October, 1985, to define the bases for methodological trials to support the RIEPT. These trials will evaluate fertility adjustment, seed production, soil microbiology, pests and diseases.

Table 12. Production and adaptability index of tropical forage grass and legume ecotypes in the forest ecosystem.

Species	CIAT No.	Maximum precip. Period (Year 1) a DM kg/ha	b	Minimum precip. Period (Year 2) a DM kg/ha	b
LEGUMES					
A. histrix	9690	2511	0.69	3024	0.23
C. mucunoides	(common)	937	0.58	--	--
C. pubescens	(common)	1288	0.37	1074	0.45
C. pubescens	438	1843	0.93	1581	0.61
C. gyroides	3001	2185	0.75	2423	1.45
D. heterophyllum	349	1304	0.40	1132	0.72
D. ovalifolium	350	2464	1.14	2377	0.88
P. phaseoloides	9900	2130	0.79	2029	0.91
S. capitata	1097	2108	1.06	--	--
S. capitata	1405	1970	0.93	1447	0.70
S. guianensis	136	3042	1.49	3139	1.27
S. guianensis	184	3039	1.65	3438	1.89
Z. latifolia	728	3006	1.57	2221	1.02
OVERALL AVERAGE FOR ECOSYSTEM	2182			2191	
GRASSES					
A. gayanus	621	6749	0.71	5287	0.94
B. decumbens	606	5841	1.36	5806	1.05
B. humidicola	679	5502	0.59	4650	0.77
P. maximum	604	5516	0.90	--	--
OVERALL AVERAGE FOR ECOSYSTEM	6054			5345	

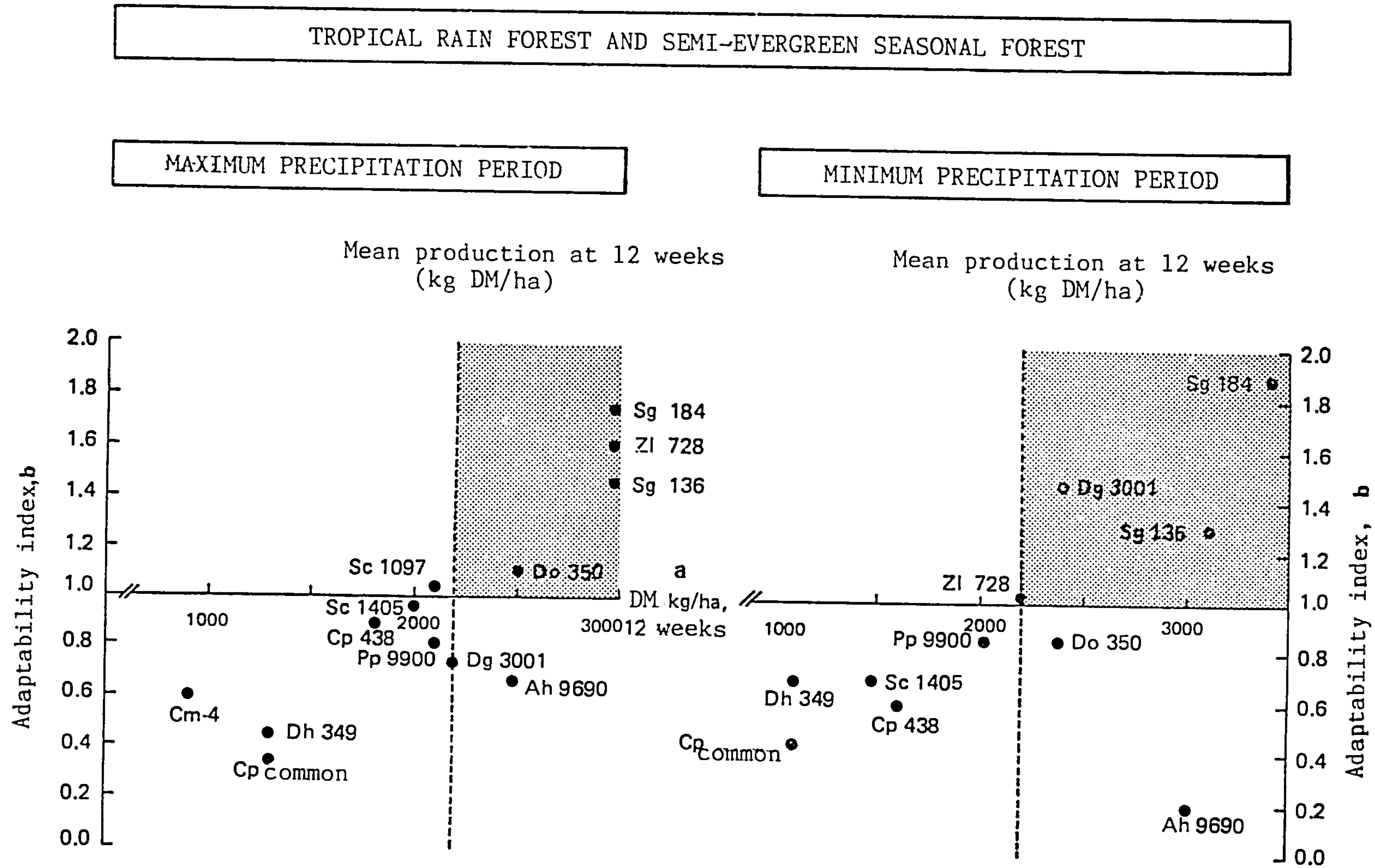


Figura 2. Classification of legumes by degree of adaptability (b) and potential productivity (a). Shadowed areas present ecotypes having productivity rates superior to the mean for the ecosystem.

ENTOMOLOGY

The Entomology Section has continued studies on key pests both in major selection sites and in regional trials.

Reported in this section are results on pest incidence on legumes and a series of considerations on spittlebug incidence on grasses. Also, a report is presented on studies being carried out with the budworm on S. guianensis and with ants on grasses in the Colombian Llanos.

PEST EVALUATION --LEGUMES

During 1984 evaluations were continued on damage caused by insects to the different grass species introduced in Carimagua during 1982 and 1983.

During 1984, 515 legume accessions were evaluated. Table 1 shows each of these species and its most important pest, as well as the accessions considered promising. Overall, it was found that for the different legumes evaluated, certain groups of insects were predominant, though they currently do not cause economic damage as is the case of Homoptera. However, their presence makes them potential pests which must be considered in the future.

PEST EVALUATION --GRASSES

Given the importance of the pest spittlebug, the Entomology Section has concentrated most of its efforts on studies of this insect.

Methodological studies with Spittlebug

Using two evaluation stages, a system was defined to select grass germplasm for the genus Brachiaria spp., in terms of spittlebug incidence. Table 2 shows the performance of the species when infestation pressures varied from 5 to 16 adult insects/plant. In contrast with results obtained for B. dictyoneura, out of 11 initial B. decumbens ecotypes, only one showed desirable characteristics to be included in stage II. Of the 7 initial ecotypes of each B. humidicola and B. ruziziensis, only two of the first species and one of the second advanced to stage II.

All ecotypes included in the trial were quantitatively evaluated in terms of damage and degree of recovery 20 and 35 days after the respective infestation during stage I. As a result, 17 ecotypes were selected for stage II. B. dictyoneura 6369 and B. humidicola 6707 (resistant) and B. brizantha 6016 (tolerant) were the most outstanding accessions (Table 3) in stage II under three times higher infestation pressure.

Multilocational studies with Spittlebug

Of the total Brachiaria germplasm collection (70 accessions), 48 were planted in Leticia, Tumaco, Florencia, Villavicencio, and Antioquia to observe their adaptability, agronomic performance, and susceptibility and/or

Table 1. Evaluation of Introduction Nursery of 1982 and 1983 (La Pista, Carimagua, 1984).

Legume	Main pest	Accesions evaluated (No.)	Promising accessions
C. brasilianum	Sucking [1]	96	5556, 5604, 5614, 5682, 5692, 5725, 5486, 5492, 5703, 5812, 5884
C. macrocarpum	Chewing [2]	54	5563, 5573, 5616, 5635, 5639, 5738
Centrosema spp.	Sucking [1] Chewing [2]	40	C.P.B. 5434, 5662, 5611, 219.81
S. capitata	Borer [3] Budworm [4]	348	1441, 2620, 2680, 2814, 2815, 2838, 2842, 2943, 2946, 2962, 2967, AJ-IA, AJ-IB
S. macrocephala	Borer Budworm	30	1643, 10003, 10010, 10015
D. heterophyllum	Chewing	16	3779, 3792, 13185, 13199, 13202
P. phaseoloides	Chewing	81	4600, 17279, 17280, 17281, 17282, 17287, 17390

1/ Order Hemiptera and Homoptera. 2/ Order Coleoptera (Family Crysomelidae).
3/ Order Lepidoptera (*Caloptilia* spp.). 4/ Order Lepidoptera (*Stegasta bosquella*).

Table 2. Number of ecotypes of the different grass species evaluated during two stages in studies of spittlebug incidence (CIAT, Colombia, 1984).

Species	No. of ecotypes Stage I	Stage II	Observations
B. brizantha	13	9	
B. decumbens	11	1	
B. humidicola	7	2	6707 without damage
B. ruziziensis	7	1	6419 total damage
B. dictyoneura	2	2	
B. eminii	2	0	
B. sp.	2	1	
B. radicans	1	0	
B. hibrida	1	0	
B. soluta	1	1	

Stage I = Infestation of 5 adult insects per plant.
Stage II = Infestation of 16 adult insects per plant.

Table 3. Performance of each one of the ecotypes selected for stage II, estimating damage vs. recovery at 20 and 35 days, respectively (CIAT, Colombia, 1984).

Especie	Daño	Recovery in Stage II									
		Excellent		Good		Moderate		Bad		Dead	
		20	35	20	35	20	35	20	35	20	35
B. brizantha	3					6297	6297				
	3							6424	6424		
	3							6688	6688		
	3									6687	6687
	3									6686	6686
	4									6682	6682
	4			6016 **	6016 **						
	4							6690			6690
	4							6683	6683		
B. humidicola	2		6707 *	6707 *							
	4					6709	6709				
B. dictyoneura	2	6369 *	6369 *								
	3							6133	6133		
B. decumbens	4									6693	6693
B. ruziziensis	4				6413	6413					
B. soluta	5									6409	6409
_B._ sp.	3				6058	6058					

* Ecotypes which showed the best performance in the two stages of the trial.
** Ecotypes catalogued as tolerant.

resistance to the attack of different spittlebug species. Of the accessions planted, only 27 were adapted and were common (Table 4) in Macagual (Florencia), San José del Nus (Antioquia), and La Libertad (Villavicencio). In Macagual, the Brachiaria spp. are in their second year of evaluation. During the first year, forage production ranged between 2 and 8 t DM/ha, with B. eminii and B. humidicola being the highest yielding species and B. ruziziensis the lowest yielding species (Table 5). During the second year, however, forage production decreased but B. humidicola and B. ruziziensis continued to be the most and the least productive, respectively. At San José del Nus, Brachiaria spp. are in their first year of evaluation (Table 5); a high forage production was observed, particularly for B. brizantha. At La Libertad, the Brachiaria spp., during their first year of evaluation, produced between 0.9 and 3.0 DM/ha, which is low compared with first year yields in Macagual and San José del Nus.

Table 4. Adapted common Brachiaria spp. accessions in three localities of Colombia (San José del Nus, Macagual, and Villavicencio).

B. brizantha	664,665,667,6021, 6294 y 6297
B. decumbens	606,6009,6023,6240 6132 y 6370
B. ruziziensis	654,655,656,660 y 6291
B. humidicola	675,679,682 y 6013
B. dictyoneura	6133 y 6369
B. eminii	6134 y 6241
B. sp.	6008
B. sp. (hybrid)	6298

A very small population of spittlebug nymphs and adults has been observed during the first year of evaluation (Figure 1). The largest populations were found associated with B. decumbens, B. humidicola, and B. ruziziensis. On the other hand, different species of the insect were found, depending on the location. In San José del Nus, Zulia colombiana and Aeneolamia sp. were identified; in Macagual, Zulia pubescens; and in Villavicencio, Aeneolamia varia. This insect population did not cause damage in San José del Nus, while in Macagual and Villavicencio it caused moderate damage to B. decumbens, B. eminii, sp. and the hybrid (Table 6).

Spittlebug studies with B. humidicola

A trial was carried out in Santander de Quilichao where levels of nymph and adult infestations of Zulia colombiana on B. humidicola 679 were evaluated.

At levels of infestation of 30, 60, and 120 adults/m^2, compared with the control (0 adults), no damage or difference in forage production or nutrient content of the vegetable tissue of either of two cuttings was observed (Table 7). This was similar to that found with infestation levels of 30, 60, and 120 nymphs/m^2, in relation to the control (0 nymphs/m^2) (Table 8). These results suggest that B. humidicola can resist higher nymph and/or adult infestation pressures than those used in this study.

Effect of plant height on spittlebug incidence with and without grazing

During 1984, an experiment was established in Carimagua to evaluate spittlebug (A. reducta) populations under conditions of controlled height (20, 40, and 60 cm) in three species of Brachiaria. Throughout the year it was observed that higher spittlebug populations were found when the height of the grass was 60 cm (Figure 2). On the other hand, the highest spittlebug

Table 5. Average production of *Brachiaria* spp. accessions in three localities of Colombia.

Species	Accessions	Macagual '83	Macagual '84	El Nus '84	La Libertad '84
		MS t/ha			
B. brizantha	664	3.0	1.2	10.0	2.2
	665	4.3	1.9	15.6	2.2
	667	5.7	2.0	12.5	2.2
	6021	1.9	2.1	14.0	3.0
	6294	6.3	1.7	12.6	0.8
	6297	6.7	1.7	12.4	1.4
B. decumbens	606	2.1	2.3	15.3	1.8
	6009	2.2	1.1	10.8	1.5
	6012	7.6	1.5	11.3	1.6
	6130	5.2	1.0	7.0	1.5
	6132	2.1	1.0	7.1	0.7
	6370	2.0	1.7	11.6	1.9
B. dictyoneura	6133	5.6	2.2	9.5	2.7
	6369	4.6	1.7	8.1	2.4
B. eminii	6134	6.3	1.3	7.8	1.5
	6241	7.9	0.7	9.9	0.8
B. humidicola	675	5.8	2.2	8.4	2.0
	679	5.2	1.6	10.3	
	682	5.7	1.4	8.8	2.6
	6013	6.1	1.7	8.9	2.3
B. ruziziensis	654	2.4	0.9	6.5	1.2
	655	7.3	1.0	9.6	1.3
	656	2.4	1.1	6.7	1.3
	660	2.6	0.8	9.1	0.9
	6291	6.7	1.0	7.9	1.1
Brachiaria sp.	6008	4.3	1.1	12.2	1.3
B. sp. (hybrid)	6298	3.5	0.9	11.5	1.4

Table 6. Average nymph and adult spittlebug populations and their damage to *Brachiaria* accessions in three localities of Colombia for the first year of evaluation (rainy season).

Species	Ecotipe	San José del Nus (Antioquia)			Macagual (Florencia)			La Libertad (Villavic.)		
		Adults (20 samples)	Nymphs (per m^2)	Damage (1 to 5)	Adults	Nymphs	Damage	Adults	Nymphs	Damage
B. brizantha	664	0.2	0.4	1.0	0.2	6.0	1.7	5.2	25.0	2.1
	665	0.2	0.0	1.0	0.2	1.8	1.0	1.7	9.7	1.5
	667	0.1	0.5	1.0	0	6.2	1.3	1.3	2.2	1.5
	6021	0	0.2	1.0	0	0.5	0.3	2.0	14.5	1.7
	6294	0.1	0	1.0	0	0	1.0	0.7	0.2	1.0
	6297	0	0	1.0	0	0.5	1.3	0.2	0.2	1.0
B. decumbens	606	0.1	0	1.0	0	0.5	1.7	1.3	2.8	1.7
	6009	0.2	0.9	1.0	0	2.7	1.3	1.5	22.7	2.2
	6012	0	0.4	1.0	0.3	6.5	2.3	0.7	4.7	1.7
	6130	0.2	0.5	1.0	0	1.7	1.7	1.0	4.2	2.5
	6132	0.1	0.3	1.0	0	3.5	1.3	0.3	12.2	1.8
	6370	0.2	0.8	1.0	0.2	1.5	1.3	1.8	21.2	1.8
B. dictyoneura	6133	0.1	0.2	1.0	0.2	1.3	1.0	0.7	16.3	1.0
	6369	0.1	0	1.1	1.2	5.5	1.3	4.2	4.3	1.0
B. eminii	6134	0.3	0.7	1.0	0.2	3.2	1.3	0.7	7.5	2.3
	6241	0.1	0	1.0	0.2	4.2	2.0	0.7	1.0	1.7
B. humidicola	675	0.2	0.1	1.0	1.2	14.2	1.0	0.5	9.0	1.0
	679	0.2	0	1.0	1.5	7.5	1.3	1.2	12.5	1.0
	682	0.3	0	1.0	1.0	6.0	1.0	1.7	9.1	1.0
	6013	0.2	0	1.0	1.8	6.3	1.3	1.0	16.3	1.0
B. ruiziziensis	654	0.6	0.9	1.0	0.5	4.5	1.3	3.0	12.0	1.8
	655	0.2	0.3	1.0	0.7	2.7	1.3	1.8	4.8	2.0
	656	0.1	0.4	1.0	0	16.2	1.7	1.2	11.2	1.1
	660	0.2	0	1.0	0.2	4.2	1.3	0.5	8.2	1.7
	6291	0.1	1.1	1.0	0.3	4.2	1.7	1.3	16.3	2.5
B. sp.	6008	0.2	0.7	1.0	0	0.2	1.7	0.5	8.3	2.0
B. sp. (hybrid)	6298	0	1.3	1.0	1.0	1.7	1.3	0.7	5.2	1.7

Table 7. Effects of different infestation levels of adults of *Zulia colombiana* on *B. humidicola* 679 forage production and nutritional content (Santander de Quilichao, 1984).

Parameter	0 Adults		30 Adults		60 Adults		120 Adultos	
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Corte 1	Corte 2
M.S. (g/m^2)	91	74	100	58	64	40	84	41
N (%)	1.2	1.4	1.2	1.2	1.3	1.3	1.2	1.2
P (p.p.m.)	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2
K (meq/100 g)	0.8	1.1	1.1	0.9	0.6	0.6	1.1	0.9
S (%)	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.1

Cut 1: 21 days after infestation.
Cut 2: 45 days after infestation (two weeks after the first cut).

Table 8. Effects of different infestation levels of nymphs of *Zulia colombiana* on *B. humidicola* 679 forage production and nutritional content (Santander de Quilichao, 1984).

Parameter	0 Nymphs		30 Nymphs		60 Nymphs		120 Nymphs	
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2	Cut 1	Cut 2
M.S. (g/m^2)	108	34	90	61	112	60	95	73
N (%)	1.2	1.2	1.6	1.2	1.6	1.4	1.4	1.4
P (p.p.m.)	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
K (meq/100 g/)	0.8	0.8	1.0	0.9	1.0	0.9	1.1	1.0
S (%)	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.2

Cut 1: 21 days after infestation.
Cut 2: 45 days after infestation (two weeks after first cutting).

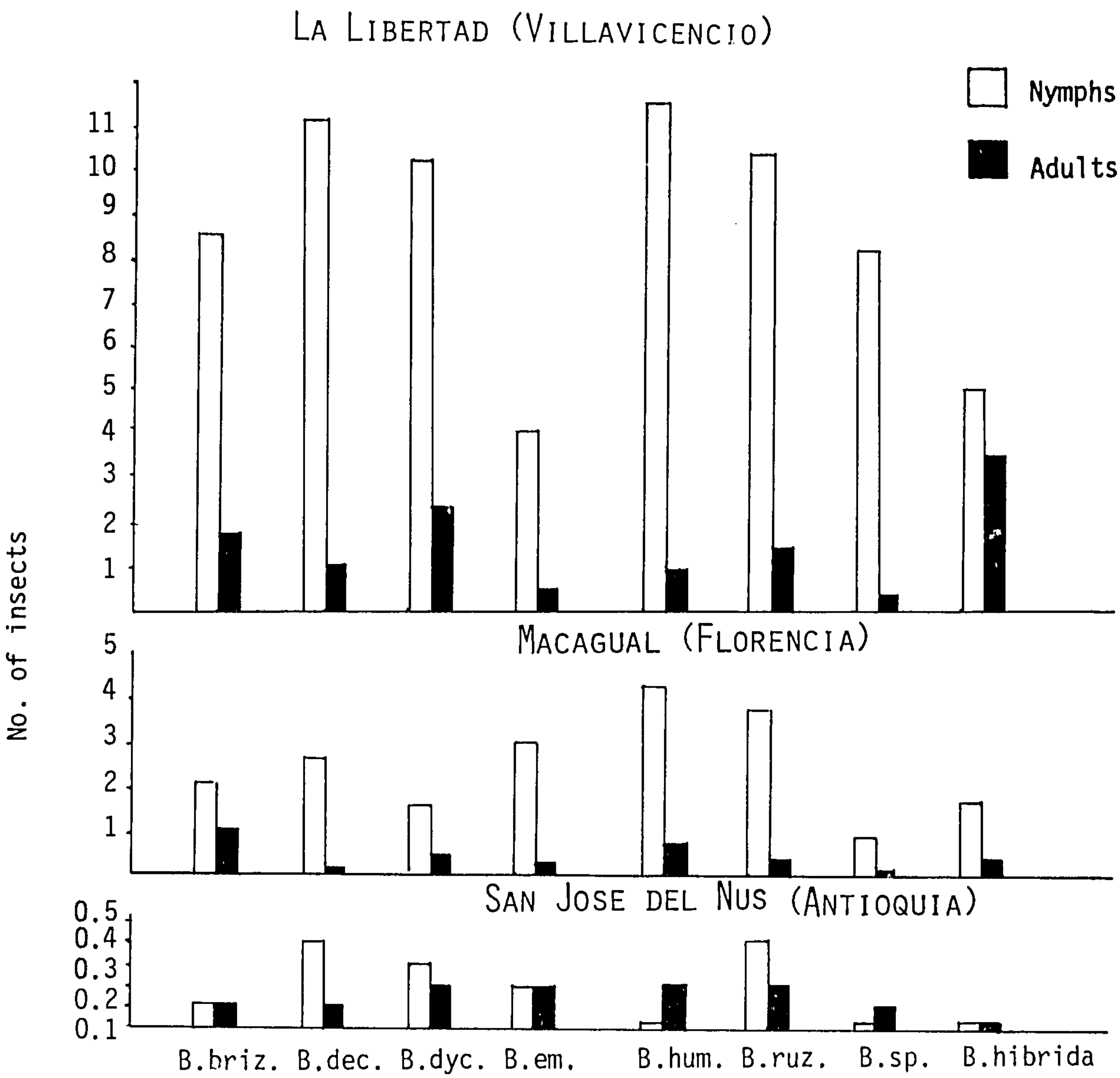


Figure 1. Average nymph and adult spittlebug populations in the different Brachiaria species evaluated at La Libertad, Macagual, and San José del Nus.

population (at a height of 60 cm) was found in B. dictyoneura 6133 (6.7 nymphs/m^2) and the lowest population in B. humidicola 679.

The information obtained in the trial evaluating cutting height in Carimagua, suggests that the ecosystem, type of soil, insect species, grass species, and management interact to regulate spittlebug populations, although contradicting observations made in Brazil.

Taking advantage of one of the trials done by the Pasture Productivity and Management Section, the incidence of the spittlebug A. reducta on

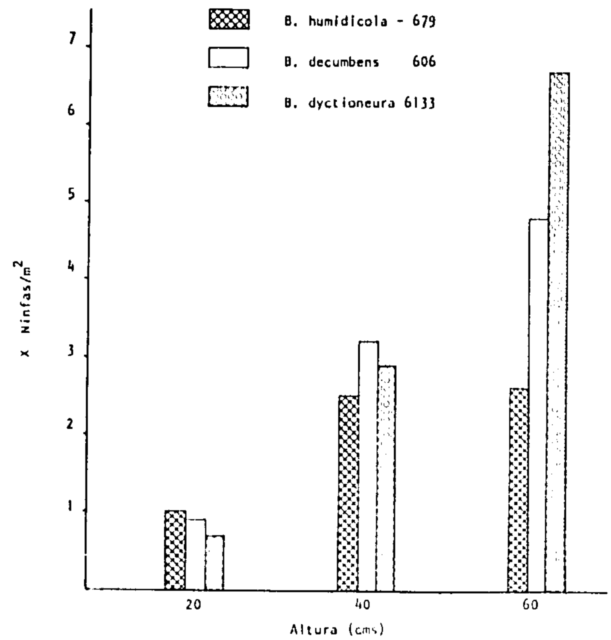


Figure 2. Spittlebug population in B. decumbens, B. humidicola and B. dictyoneura at different cutting heights (Carimagua, 1984).

Table 9. Effect of grazing system and stocking rate on the height of B. decumbens in association with D. ovalifolium (Carimagua 1984).

Grazing system	Stocking Rate[1] High	Medium	Low	X
	-------- height, cm			-------
Continuous	12.9	23.9	42.1	26.3
Alternate[2]	20.4	24.6	36.4	27.13
Rota-tional[3]	25.4	29.8	40.7	31.96
X	19.56	26.1	39.73	

1/ 3.45,2.30, and 1.15 A ha^{-1}: high, medium, and low stocking rates, respectively.
2/ 14/14 occupation/rest days.
3/ 14/42 occupation/rest days.

B. decumbens in association with D. ovalifolium 350 was studied in Carimagua under three grazing systems (continuous, alternate 14/14, and rotational 14/42), three stocking rates (3.45, 2.30, and 1.15 animals ha^{-1}), and two replications. In each treatment, the number of spittlebug nymphs and adults per m^2 was counted and grass height was measured to correlate these variables with each pasture management system.

The analysis of variance showed simple significant effects ($P < .05$) of grazing systems and stocking rate on the number of nymphs and adults and one interaction ($P < .05$) of grazing system x stocking rate for grass height, which was higher in rotational grazing with low stocking rate (Table 9) When changing from continuous grazing to alternate or rotational grazing, or when using lower stocking rates, a significant increase was produced ($P < .05$) in the number of nymphs and adults (Table 10).

In another study under grazing in Carimagua, the spittlebug population was evaluated in association of Brachiaria spp. with Arachis pintoi. Results to date indicate that B. humidicola 679 presents the smallest spittlebug population (an average of 3.1 nymphs/m^2), with grass height varying between 15 and 25 cm during this year of evaluation (Table 11). In contrast, the grasses presenting larger populations of this pest were B. brizantha 664 (an average of 7.2 nymphs/m^2) with a grass height which ranged between 15 and 35 cm, and B. ruziziensis 6291 (an average of 6.8 nymphs/m^2 with a grass hieght between 20 and 40 cm. A population of 5.2 nymphs/m^2 with a height between 20 and 30 cm was found in B. dictyoneura 6133.

Spittlebug evaluation continued during 1984 with B. decumbens in association

Table 10. Spittlebug incidence on *B. decumbens* + *D. ovalifolium* under different managements (Carimagua, 1984).

Grazing system	Stocking rate			
	High	Medium	Low	Average
	No. of Nymphs/m^2			
Continuous	2.09	2.67	3.81	2.86a
Alternate	2.70	3.28	4.82	3.60b
Rotational	2.70	3.83	5.15	3.89b
X	1.66a	1.88b	2.14c	
	No. of Adults/m^2			
Continuous	1.52	1.60	2.09	1.74a
Alternate	1.87	2.08	2.22	2.06b
Rotational	1.60	1.97	2.12	1.90c
X	1.66a	1.88b	2.14c	

a, b, c Means followed by different letters are significantly different ($P < 0.05$).

Table 11. Spittlebug population in *Brachiaria* spp. in association with *Arachis pintoi* CIAT 17434 - Carimagua, 1984.

Specie	Nymphs/m^2		Height (cm)
	Medium	Range	Range
B. humidicola 679	3.1	0.5-10.3	15-25
B. dictyoneura 6133	5.2	0.8-13.2	15-30
B. ruziziensis 6291	6.8	0.8-16.6	20-40
B. brizantha 664	7.2	0.8-17.7	15-35

with P. phaseoloides at Los Triángulos (La Torre, in Carimagua). This lot has presented spittlebug problems in past years. Results (Figure 3) indicate that the largest pest population coincided with the months of highest precipitation, July-August, 1983. However, in 1984, insect population was low during all the months, possibly due to the low percentage of grass in the different paddocks. No differences were observed in pest incidence under the different grazing management systems used. Based on the previous results, it is suggested that the spittlebug A. reducta could be regulated by using a continuous grazing system with relatively high stocking rates which would keep the grass low.

STUDIES ON THE STYLOSANTHES GUIANENSIS BUDWORM

Due to variable flowering periods of progenies of S. guianensis generated in the breeding program, ideal conditions exist to keep populations of Stegasta bosquella (budworm) for a long time, since the insect attacks inflorescences at different developmental stages (from seeds in formation to completely mature seeds).

At Santander de Quilichao, the population of Stegasta bosquella has been evaluated in various trials with progenies of S. guianensis. Due to the lack of uniformity in days to flowering, plants with the same flowering date and inflorescences with at least one seed formed were used for this evaluation.

Plant resistance to insect attack is being evaluated in relation to inflorescences attacked (percent damage) and damaged seed (percent of damage intensity). The percentage of infestation (larvae present at inflorescence) is not considered a good index for measuring damage since larvae may or may not remain in the perforated inflorescence. In the

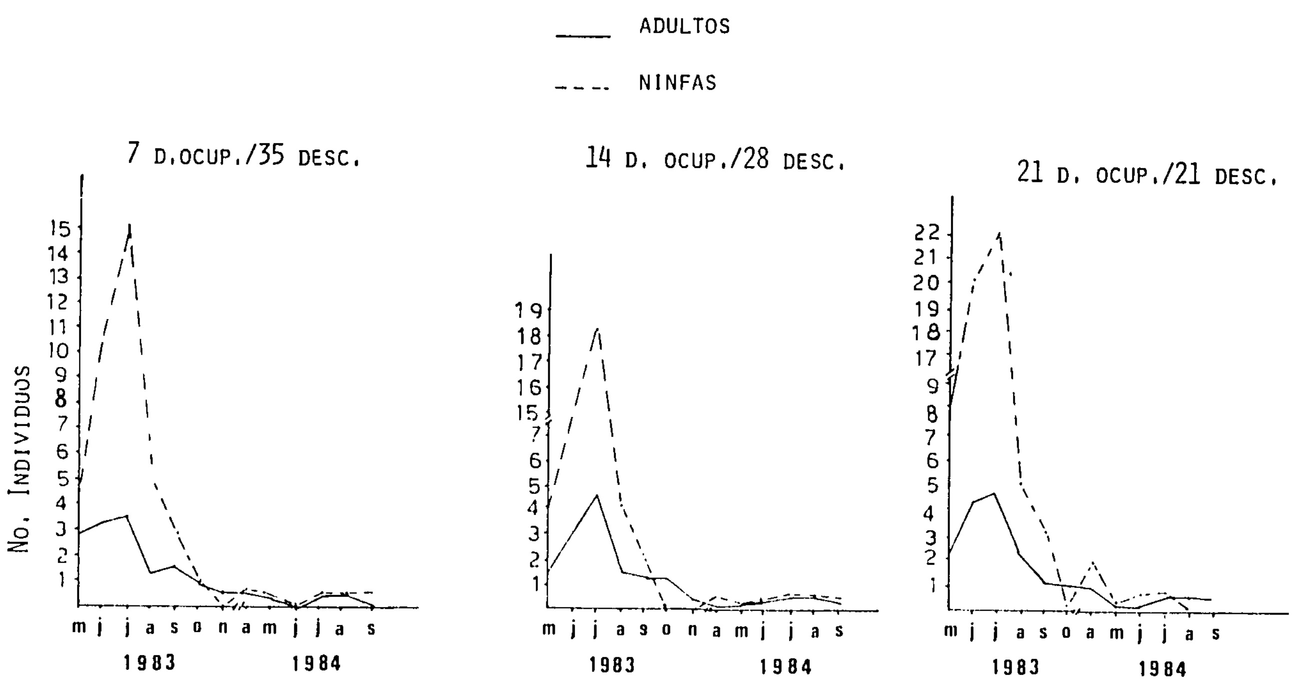


Figure 3. Effect of grazing management system on the spittlebug Aeneolamia reducta population in B. decumbens + P. phaseoloides (Carimagua).

trials evaluated, much variability has been found in the number of inflorescences in F_3 progenies of S. guianensis in open pollination, since plants with many (564) or few (64) inflorescences were found; the average was 0.3 to 2.2 seeds/inflorescence and damage ranged from 25% to 90% (Table 12). The broad variability in reaction to budworm attack and production of inflorescences presented by the lines obtained to date is evidenced by these preliminary results.

STUDY OF ANTS

The trial on the effect of soil preparation and burning on the behaviour of ant populations in the Eastern Plains of Colombia was concluded.

With this trial, an attempt was made to define the effect of this practice on ant incidence, both in areas burnt and in neighbouring areas with improved pastures established at the starting the different treatments.

The first phase of the study included conventional preparation of the soil at the same time as bordering areas were being burnt (August, 1982). One month later the second burning was done which coincided with planting or establishment of improved pastures in prepared areas. After this second burning, ant nests were counted in the burnt areas, in those prepared and planted, and in areas which were not burnt. In those areas which were burnt, ant population increased considerably in subsequent months, the larger population being present in areas burnt at the time of planting (September) (Figure 4). The higher population peaks occurred in December and February in burnt areas. A marked decrease occurred in December and February in burnt areas. A marked decrease occurred during the following months through June and during this month the population tended to be constant until the second phase of the study was initiated. In savanna areas the smallest ant populations were always found in areas which were not burnt.

For the second phase of the study, treatments were carried out during two different periods: the first burning took place at the end of wet season and the second at the end of dry season. Bordering areas which were not improved were raked in a parallel manner. Improved areas were also evaluated to see the effect of ants on pastures already established since 1982.

For the savanna, it was found that the larger populations were present in those areas burnt at the end of the rainy season, intermediate populations were present in areas burnt at the end of the dry period, and the smallest populations concentrated in areas which received no burning treatment (Figure 4).

During phases 1 and 2, burning caused no effect on bordering areas with improved pastures or on areas which were raked.

Table 12. Evaluation of the budworm, *Stegasta bosquella*, in F_3 progenies of *S. guianensis* under open pollination (Santander de Quilichao, 1984).

Plant identification	X infl./ plant	X seed./ infl.	% Damage	% damage intensity	% in-festation
23	564.3	0.3	66.7	50.0	33.3
17	527.2	0.3	86.7	88.9	33.3
3	444.2	1.6	58.3	54.5	31.7
20	417.5	2.2	71.7	52.3	30.0
11	399.4	1.0	83.3	75.4	28.3
28	365.8	1.6	53.3	56.7	23.3
2	349.2	1.8	66.7	50.5	36.7
6	332.7	1.8	56.7	56.6	26.7
24	323.5	1.8	30.0	60.4	28.3
26	319.9	1.6	66.0	60.0	28.3
30	304.2	0.2	76.7	85.7	23.3
22	304.0	1.5	70.0	57.8	25.0
19	300.6	1.9	25.0	56 1	20.0
9	296.1	1.4	58.3	63.1	28.3
7	267.1	1.1	65.0	60.6	23.3
18	264.2	0.6	90.0	64.7	40.0
31	256.1	1.5	75.0	55.9	30.0
1	244.1	0.8	51.7	53.2	28.3
29	240.7	1.3	43.3	65.4	31.7
16	216.0	0.3	76.7	70.0	36.7
15	206.5	1.1	60.0	49.3	45.0
25	195.5	0.4	83.3	75.0	36.7
12	189.2	0.8	65.0	68.0	21.7
4	189.2	1.2	66.7	58.7	23.3
21	178.5	1.6	28.3	67.0	23.3
8	168.7	0.5	80.0	40.0	43.3
27	167.0	0.4	46.7	58.3	26.7
14	144.8	0.5	80.0	64.3	43.3
13	127.6	1.5	28.3	63.7	28.3
32	87.9	0.4	56.7	45.4	46.7
10	64.0	0.2	71.4	43.3	43.3

Note: % damage refers to inflorescences with damage.
% damage intensity refers to damaged seed.
% damage intensity = 2.29 x % damage - 0.02 (% damage).

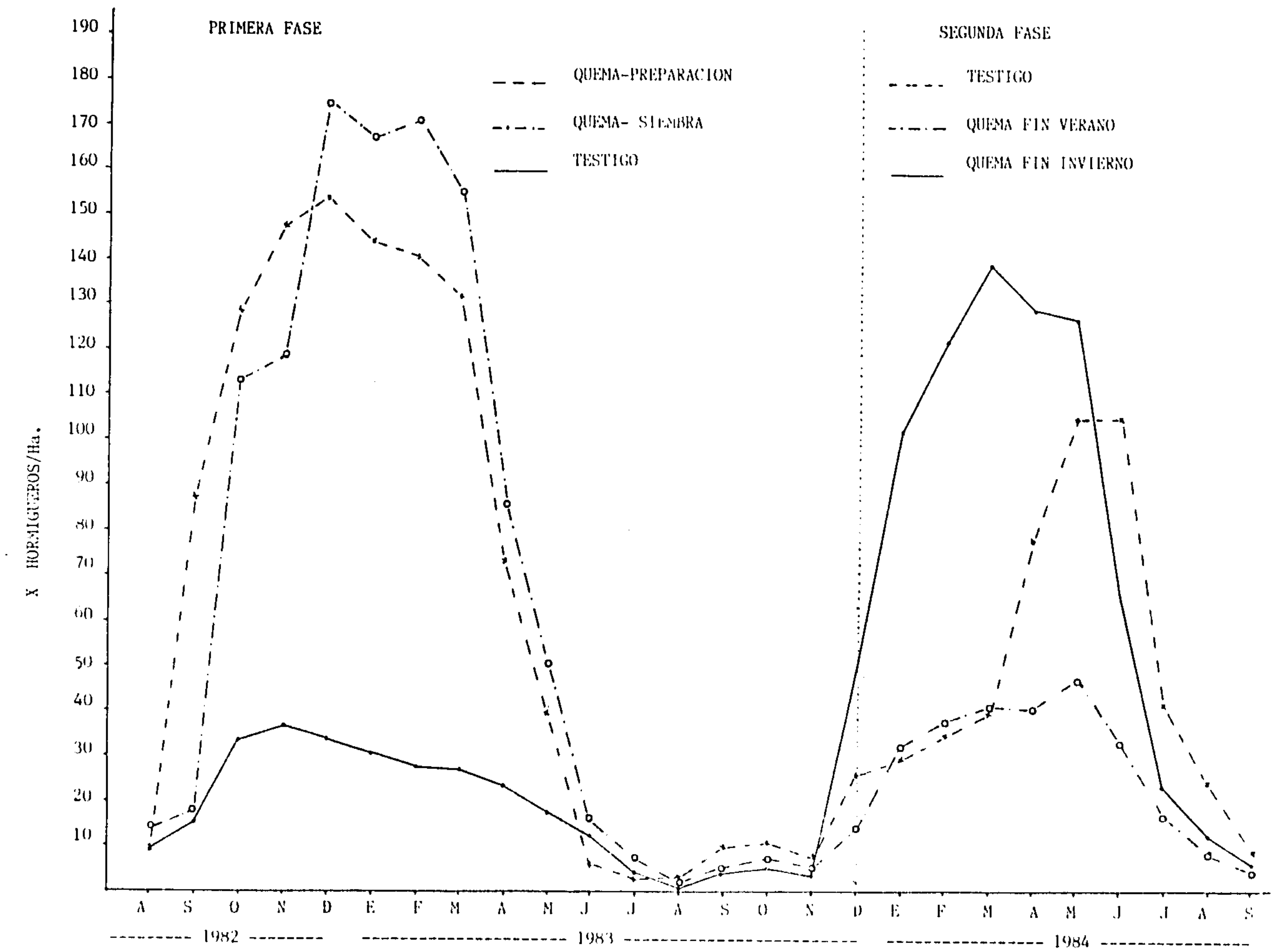


Figure 4. Ant population fluctuation in burnt savanna areas (Carimagua, 1982-1984).

PLANT PATHOLOGY

PART 1. DISEASES CAUSED BY FUNGI, BACTERIA AND VIRUSES

During 1984, the Plant Pathology section continued with (a) the evaluation of germplasm for reaction to diseases in major ecosystems of tropical America, (b) the identification and assessment of diseases of germplasm under pasture evaluation, and (c) the development and evaluation of control measures for the most important diseases of promising pasture species. In addition, considerable emphasis was placed on grass diseases for the first time with detailed surveys in Kenya, Zimbabwe, Nigeria, Ivory Coast and Ethiopia in close collaboration with current germplasm collecting activities.

GENERAL STUDIES

Disease Surveys in Tropical America

Several new diseases were detected in 1984. In the well-drained isohyperthermic savannas (llanos), *Macrophomina phaseolina*, the causal agent of charcoal rot, caused severe chlorosis, wilting and death of 47.4%, 52.5% and 24.9%, respectively of accessions CIAT 1927, 2031 and 10136 of *S. guianensis* var. *pauciflora* in one planting in Carimagua.

The fungus has been previously recorded as an occasional and minor pathogen of *S. capitata*. It is thought that the unusual dry season from November 1983 to April 1984 and use of vegetative material which did not develop sufficiently strong root systems contributed to the severe disease development in this planting. Observations will continue during the coming dry season.

Pseudocercospora sp. was recorded on several accessions of *S. capitata* in Carimagua causing diffuse chlorotic lesions on lower mature leaves. It is currently viewed as a minor pathogen.

On *Centrosema* spp., in particular *C. macrocarpum*, an aphid-transmitted poty-virus was found for the first time causing severe chlorosis, mosaic, leaf deformation and stunting of many accessions of this promising legume. Although Centrosema Mosaic Virus (CSMV) incidence and severity was greatest in germplasm evaluation plots in CIAT- Palmira and Quilichao, it was also detected in Carimagua in 58.4% of accessions (Table 1). All accessions at the three sites have been evaluated for the presence of CSMV using the Elisa technique in close collaboration with Bean Virology. In addition, Elisa has also been used to screen other *Centrosema* spp. and other legumes. Among the former, all accessions of *C. pubescens*, one each of *C. pascuorum*, *C. schottii* and *C. acutifolium* and three accessions of *Centrosema* sp. were positive; among the latter, accessions of *Macroptilium*, *Dioclea*, *Galactia*, *Zornia*, *Crotalaria*, *Uraria*, *Desmodium* spp., several cultivars of *Glycine max* and two cultivars (among thirty) of *Phaseolus vulgaris* were positive; accessions of *Acacia*, *Vigna* and

Table 1. Incidence of Centrosema Mosaic Virus in accessions of Centrosema macrocarpum in various sites in Colombia.

Site	Accessions surveyed[1] No.	Accessions with virus[2] %
Palmira	22	95.5
Quilichao	86	87.2
Carimagua	196	58.4

1/ Including all replications of each accession.
2/ Confirmed by Elisa.

Stylosanthes spp. were negative. At present, 14 accessions of C. macrocarpum (7-82, 5275, 5277, 5392, 5395, 5794, 5835, 5836, 5913, 5940, 5941, 5944, 5946, 5951) remain virus-free at all three sites.

Studies are presently in progress with Bean Virology to assess the importance of this problem in C. macrocarpum. Screening under controlled conditions is planned as well as determination of seed infection.

Minor leaf spotting caused by a species of Cylindrocladium was recorded on several accessions of C. macrocarpum in Carimagua, also.

Among grass germplasm, Rhizoctonia foliar blight was recorded on several accessions of Brachiaria spp. during the wettest period of the year in Carimagua. It was also observed on B. dictyoneura at one site in the humid tropics. In both ecosystems, rapid recovery of affected plants was observed.

In the well-drained isothermic savannas (Cerrados) two new leafspots were recorded on Centrosema spp. The Phomopsis state of Diaporthe phaseolorum, a common pathogen of soybean in the Cerrados, caused widespread moderate lesions on C. pubescens x C. macrocarpum hybrids. In addition, Pseudocercospora bradburyae was recorded for the first time on several accessions of C. brasilianum at CPAC. During surveys of native Stylosanthes populations, the host range of the rust Puccinia stylosanthis was extended to include S. guianensis var. pauciflora with findings in northern Minas Gerais. Further work will be carried out on this rust in 1985. A Cladosporium sp. was also observed on inflorescences of S. guianensis var. vulgaris in Minas Gerais.

Cladosporium Inflorescence Blight was recorded at several sites in the humid tropics on Brachiaria brizantha and B. humidicola. This fungus could cause problems for seed production in this ecosystem. Pseudocercospora leaf spot was observed on Zornia brasiliensis in Paragominas and Itabela, Brazil, as a minor pathogen.

The present status of these diseases is given in Table 2.

Surveys of Grass Diseases in Africa

Recent emphasis on collection of germplasm of promising tropical pasture grasses, especially Brachiaria spp., in Africa necessitated a survey trip to Kenya, Zimbabwe, Ethiopia, Ivory Coast and Nigeria to obtain information on diseases in native populations and assessment of their quarantine risk. A summary of diseases found is given in Table 3. Four different disease types were found on Andropogon spp.: rusts caused by Puccinia agrophila and less commonly Uredo andropogonis-gayani; Cercospora leaf spot -C.fusimaculans; Phyllachora leaf spot - P.ischaemi; and Tangle Top caused by Myriogenospora sp. Only the last disease has been recorded in tropical America. The most widespread and

Table 2. Status of new diseases detected in tropical pasture plants in tropical America during 1984.

Host	Disease	Distribution[3]	Status
Stylosanthes guianensis	Rust[1]	WDS	Potentially Important
	Cladosporium Inflorescence Disease	WDS	Minor
	Charcoal Rot[2]	WDIS	Secondary
Stylosanthes capitata	Pseudocercospora Leaf Spot	WDIS	Minor
Centrosema macrocarpum	Centrosema Mosaic Virus	WDIS	Potentially Important
	Cylindrocladium Leaf Spot	WDIS	Minor
Centrosema brasilianum	Pseudocercospora Leaf Spot	WDS	Secondary
Centrosema hybrids	Phomopsis Leaf Spot	WDS	Minor
Zornia brasiliensis	Pseudocercospora Leaf Spot	HT	Minor
Brachiaria spp.	Rhizoctonia Foliar Blight	WDIS HT	Secondary Secondary
	Cladosporium Inflorescence Disease	HT	Secondary

1/ Puccinia stylosanthis.
2/ Macrophomina phaseolina.
3/ WDS = Well-drained isothermic savannas; WDIS = Well-drained isohyperthermic savannas; HT = Humid tropics.

damaging disease was rust (P. agrophila). Quarantine will be strictly maintained to prevent its introduction into Latin America.

Among Brachiaria spp., the most common diseases were leaf spots Phyllachora and Cercospora, two Uromyces rusts and the Fusarium - Ergot Inflorescence Complex (Table 3). Although none of these diseases have been recorded in tropical America, only the latter two are considered of quarantine risk. Appropriate precautions will be taken with all seed from Africa.

The most significant finding was the widespread occurrence of spittlebug in native grass populations, including Brachiaria spp., in Kenya, Ethiopia, Nigeria and Zimbabwe. Although widespread, its frequency within individual populations was only occasional and at no site was it regarded as a pest. The natural diversity in native grass populations as well as contributing natural biocontrols are probably largely responsible for the non-pest status of spittlebug in native grass populations in Africa.

Six different diseases were recorded on P. maximum in the Ivory Coast, Nigeria, Kenya and Ethiopia; three of these - smut, Cercospora leaf spot and Fusarium Pink - ear are well-known in tropical America (Table 3). Of the

Table 3. Survey of diseases of tropical pasture grasses in Africa during September - October, 1984.

Host	Diseases Found	Country	Severity	Frequency	Quarantine Risk
Andropogon gayanus	Rust - *Puccinia agrophila*	N, Z	Moderate - Severe	Common	+
	Rust - *Uredo andropogonis-gayani*	N	Slight	Rare	-
	Cercospora Leaf Spot- *C. fusimaculans*	N, Z	Slight - Moderate	Common	-
	Tangle Top - *Myriogenospora* sp.*	N	Moderate	Occasional	-
	Phyllachora Leaf Spot - *P. ischaemi*	Z	Moderate	Rare	-
A. tectorum	Rust - *P. agrophila*	N	Moderate - Severe	Common	+
	Cercospora Leaf Spot- *C. fusimaculans*	N	Slight - Moderate	Common	-
	Tangle Top - *Myriogenospora* sp.	N	Moderate	Occasional	-
Brachiaria brizantha	Phyllachora Leaf Spot- *P. bonariensis*	K, Z, E	Moderate - Severe	Common	-
	Cercospora Leaf Spot- *C. fusimaculans*	K, Z, E	Moderate	Common	-
	Rusts - *Uromyces leptodermus*	K, Z, E	Moderate	Occasional	+
	U. setariae-italicae				
	Fusarium-Ergot Complex	K	Moderate	Common	+
	F. heterosporum-Claviceps sulcata				
	False-smut-*Ustilaginoides virens**	K	Moderate	Rare	+
	Anthracnose - *Colletotrichum* sp.	K	Moderate	Rare	-
	Virus	K	Moderate	Rare	-
B. bovonei	Phyllachora Leaf Spot-*P.bonariensis*	Z	Slight - Moderate	Common	-
	Cercospora Leaf Spot-*C.fusimaculans*	Z	Slight - Moderate	Occasional	-
	Rust - *U. leptodermus*	Z	Moderate	Rare	+
	Anthracnose - *Colletotrichum* sp.	Z	Slight	Occasional	-
B. decumbens	Phyllachora Leaf Spot-*P. bonariensis*	K	Moderate	Occasional	-
	Rust - *U. leptodermus*	K	Moderate	Common	+
	Fusarium-Ergot Inflorescence Complex	K	Moderate	Occasional	+
	F. heterosporum - C. sulcata				
	Anthracnose - *Colletotrichum* sp.	K, E	Moderate	Occasional	-
	Cercospora Leaf Spot-*C.fusimaculans*	K	Moderate	Rare	-
	Spittlebug	K	Moderate	Occasional	-
	Spidermite	K	Severe	Occasional	-

Table 3. (Cont'd.)

Host	Diseases Found	Country	Severity	Frequency	Quarantine Risk
B. dictyoneura	Phyllachora Leaf Spot-P. bonariensis	Z	Slight	Occasional	-
	Rust - U. leptodermus	Z	Moderate	Occasional	+
	Cercospora Leaf Spot-C. fusimaculans	Z	Slight	Occasional	-
B. humidicola	Rust - U. leptodermus	K, Z, E	Severe	Common	+
	Cercospora Leaf Spot-C. fusimaculans	K, Z, E	Slight	Occasional	-
	Fusarium-Ergot Complex F. heterosporum-C. sulcata	K, E	Moderate	Occasional	+
	Phyllachora Leaf Spot-P. bonariensis	E	Slight - Moderate	Rare	-
	False-smut - U. virens*	E	Moderate	Rare	+
B. jubata	Cercospora Leaf Spot-C. fusimaculans	K, Z, E	Moderate - Severe	Occasional	-
	Phyllachora Leaf Spot-P. bonariensis	K, Z, E	Moderate - Severe	Occasional	-
	Rust - U. setariae - italicae	K, Z, E	Moderate	Occasional	+
	Fusarium - Ergot Complex F. heterosporum - C. sulcata	K	Moderate	Occasional	+
	Spittlebug	K	Moderate	Occasional	-
B. leucocrantha	Phyllachora Leaf Spot-P. bonariensis	K	Moderate	Rare	-
B. platinota	Cercospora Leaf Spot-C. fusimaculans	K, Z, E	Moderate	Occasional	-
B. ruziziensis	Spittlebug	K	Severe	Common	-
	Spidermite	K	Moderate	Occasional	-
Panicum. maximum	Smut - Tilletia ayersii*	IC**,N,E	Moderate - Severe	Common	-
	Fusarium Pink Ear -F. heterosporum*	IC**,E	Moderate	Occasional	-
	Cercospora Leaf Spot-C. fusimaculans*	IC**,N	Moderate	Occasional	-
	Rust - To be confirmed	IC**,K	Moderate	Occasional	+
	Virus - Panicum maximum Mosaic Virus	IC**	Moderate - Severe	Occasional	-
	Phyllachora Leaf Spot - P. sp.	K, N	Moderate	Occasional	-
	Spittlebug	K	Slight	Rare	-

N = Nigeria; Z = Zimbabwe; K = Kenya; E = Ethiopia; IC = Ivory Coast.
* Present in Latin America.
** ORSTOM P. maximum collection located near Abidjan, Ivory Coast.

others, only the rust offers some quarantine risk. The lack of serious diseases in the ORSTOM collection, half of which CIAT recently received, was confirmed.

No diseases of extreme quarantine risk were found on any native Andropogon or Brachiaria spp. populations. At least now all these diseases can be readily recognized in quarantine and appropriate treatments have already been taken and will be further taken on receipt of seed to prevent introduction of these diseases into tropical America.

Anthracnose of Stylosanthes spp.

a) Studies on pathogenic variation of C. gloeosporioides isolates. During the past year further work was done on pathogenic variation among isolates of Colletotrichum gloeosporioides from Stylosanthes spp. Preparation of a set of host differentials for S. guianensis facilitated further detailed work on 413 pathogenic isolates from various sites in Peru, Colombia and Brazil (Table 4).

With one exception only, a greater percentage of isolates from var. guianensis hosts ("common") were pathogenic to var. guianensis only than to var. pauciflora ("tardios") or both (Table 4). Within a small sample of nine isolates from commons from Pucallpa, Peru, however, 88.8% of isolates were pathogenic to both commons and "tardios". Clearly more isolates from Pucallpa must be tested. Isolates from "tardio" hosts from Colombia and Brazil show different population structures. Ninety-six percent of isolates from CPAC, Santa Rita and Diamantina, Brazil were pathogenic only to "tardios" while in Colombia, the majority of "tardio" isolates were pathogenic to both "tardios" and commons. Possibly because these regions of Brazil lie within the center of diversity of the "tardio" group, specialized isolates to this group are more common there. "Tardios" are not native to Colombia.

Of great interest was the finding of isolates pathogenic to "tardios" collected from native populations of commons in the Tarapoto region of Peru. As introduction from outside of pathogenic "tardio" isolates would have been impossible in this isolated region, it is clear that within native populations of common-associated C. gloeosporioides there exist genes for virulence to "tardios". This also helps to explain the existence of isolates pathogenic to "tardios" in Carimagua and Quilichao, Colombia and Pucallpa, Peru where also "tardios" are not native.

Considerable numbers of pathogenic types (potential races) were found in each group of isolates. This further confirms the large range in pathogenic variability among isolates of C. gloeosporioides from the S. guianensis complex.

b) Further studies on Lago Calima populations. A more extensive collection of Lago Calima germplasm was made from a native population in June, 1984. Among the 113 plants collected, variation was found for anthracnose reaction, growth habit, stem hairiness (Table 5), stem, flower and seed colour, and colour and form of leaflets. Variation among cultural characters of the 163 associated C. gloeosporioides isolates was also considerable with three asexual and two sexual types being distinguished (Table 6). As expected, sexual isolates comprised only 6.8% of the population; yet their presence indicates potential for increased variability in the population. Detailed studies are planned on these two co-evolved populations during 1985 in order to obtain further information concerning natural anthracnose controls in native populations.

Table 4. Population structure of 413 pathogenic isolates of Colletotrichum gloeosporioides associated with Stylosanthes guianensis in various countries.

Country	Source of Isolate	Host	Isolates No.	% Isolates Pathogenic to Commons	Tardios	Both	Pathogenic Types No.
Colombia	Carimagua Quilichao	Common	184	71.2	0.5	28.3	24
	Carimagua	Tardio	69	5.9	26.5	67.6	16
Brazil	CPAC Pará Bahía	Common	20	90.0	0	10.0	7
	CPAC St. Rita Diamantina	Tardío*	83	1.2	96.4	2.4	7
Peru	Tarapoto	Common*	23	56.5	0	43.5	22
		Common	16	87.5	0	12.5	11
	Pucallpa	Common	9	11.2	0	88.8	8
	Yurimaguas	Common	9	100	0	0	7

* Collections from native populations.

c) Oestrogenic activity of anthracnose-affected Stylosanthes guianensis common. Previous studies had shown that certain foliar pathogens of legumes cause considerable increases in the concentration of oestrogenic compounds in the foliage which can effect the reproductive performance of female animals. In 1980, Zornia latifolia CIAT 728 affected with Sphaceloma scab was found to contain considerable quantities of oestrogenic compunds which affected significantly uteri weights of immature female mice. A similar mouse bioassay was done with diets prepared from anthracnose-affected and healthy leaves of S. guianensis common CIAT 136. Uteri weights of mice on the commercial diet and that ammended with the oestrogen diethylstilbestrol (DES) were greater than those of mice on the healthy and anthracnosed S. guianensis diets (Table 7). There was no evidence of oestrogenic activity in these diets.

Table 5. Variation in morphological characters among 113 Stylosanthes guianensis common plants from a native population at Lago Calima.

Character	Plant (%)
Growth Habit	
Erect	16.8
Semi-erect	40.7
Semi-prostrate	21.2
Prostrate	21.3
Stem Hairiness	
Very hairy	18.3
Mod. hairy	41.3
Few hairs	30.8
Glabrous	9.6
Native Anthracnose Level	
0	0
1	6.2
2	29.2
3	58.4
4	6.2

Other characters evaluated: stem colour, colour and form of leaflets, flower colour, seed colour.

Table 6. Variation in cultural characters among 163 native isolates of Colletotrichum gloeosporioides collected from 113 Stylosanthes guianensis common plants from a native population at Lago Calima.

Characters	Isolates (%)
Sexuality	
Sexual	6.8
Asexual	93.2
Culture Type	
Type 1 - Sparse mycelium Abundant acervuli and spore masses: general	54.0
Type 2 - Abundant mycelium; Mod. Acervuli and spore masses: Central	19.6
Intermediate types	14.1
Type 3 - Abundant mycelium; no acervuli; spores borne on mycelium	5.5
Type 4 - Dark sexual	3.7
Type 5 - Light sexual	3.1

Rhizoctonia Foliar Blight of S. guianensis and C. brasilianum

Rhizoctonia foliar blight has been observed as an occasional but severe disease of S. guianensis at several sites in the humid tropics ecosystem during the past two years. In Pucallpa and Yurimaguas, Peru and Paragominas, Itabela and Barrolandia, Brazil, R. solani caused leaf-blighting and terminal dieback of several accessions including "tardíos" CIAT 1280, 1283, 2031 and 10136 during the wettest months. In all cases, however, plants recovered rapidly.

In order to assess the importance of this disease on S. guianensis in the humid tropics basic studies were begun in 1983. Seven isolates of R. solani from S. guianensis and C. brasilianum were compared with respect to cultural and morphological characters and virulence. Considerable variation was found in growth rate; mycelium colour, texture and form; production and type of sclerotia and virulence on accessions of S. guianensis and C. brasilianum, both within and among isolates from the two hosts (Table 8). Although isolates from S. guianensis were more pathogenic than isolates from C. brasilianum on the former host, there was considerable variation among isolates of C. brasilianum on the same host. All isolates classified to date belong to Anastomosis group 1, consistent with their status as foliar pathogens.

Preliminary studies were also made on isozyme variation among twelve R. solani isolates by starch gel electrophoresis in collaboration with Dr. Helen Stace, CSIRO Division of Tropical Crops and Pastures, Queensland, Australia. Very clear repeatable results were obtained in MDH in which 8 different genotypes were distinguished. PGM indicated 10 genotypes; GDH at least 3; 6 PGD at least 2; and ACP at least 3. Previous studies with isolates classified in anastomosis group one have shown many different isozyme genotypes.

Preliminary studies with starch-gel electrophoresis were most promising and suggest the potential for further classifying strains of R. solani virulent on tropical pasture legumes.

Further Studies on Bacterial Wilt of Zornia glabra

The pathogenicity of isolates of Corynebacterium flaccumfaciens from Z.

Table 7. Response of immature female mice to diets containing *Stylosanthes guianensis* CIAT 136 with and without anthracnose.

Diet	Diet intake in 24 hrs.(g)	Final Mouse Wt. (g.)	Uterus Wt. (g.)
Commercial*	2.74	13.7	85.6 ab
Commercial + DES**	2.70	12.1	105.0 a
Commercial + Healthy *S. guianensis*	2.98	12.8	65.8 bc
Commercial + Anthracnosed *S. guianensis*	3.88	13.9	47.6 c

* Restricted Feeding.
** Diethylstilbestrol.

glabra to several lines of *Phaseolus vulgaris* was confirmed in glasshouse (Table 9) and field trials (Table 10). In the field, these isolates caused chlorosis, necrosis, atrophy, wilting and death of plants with associated dry matter losses of 75.4-81.4% in *Z. glabra* CIAT 7847 and 37.1-41.2% in various lines of *P. vulgaris* (Figure 1). Seed infection levels of 52.5% and 88.8% were found for seed of beans and *Z. glabra* CIAT 7847, respectively. The correlation coefficient between bacterial seed infection and germination was negative and highly significant (r = -0.87, Figure 2).

STUDIES IN THE WELL-DRAINED ISOHYPERTHERMIC SAVANNAS - LLANOS

Diseases of *Stylosanthes* spp.

Anthracnose. Studies on the use of accession mixtures of *S. guianensis* to control anthracnose continued during 1984 with an experiment in Carimagua to determine the effect of mixtures of different proportions of three accessions of *S. guianensis* "tardio" - resistant CIAT 10136 and 2031 and susceptible CIAT 1927 - on anthracnose development, plant yield and survival and pathogenic variation within populations of associated isolates of *C. gloeosporioides*. Significant differences were found in anthracnose levels in treatments with different proportions of susceptible CIAT 1927 from 0 to 80%. Differences between 80 and 100% were not significant (Figure 3). At the same time, all mixtures of 50% CIAT 1927 with different proportions of CIAT 2031 and 10136 had similar levels of anthracnose as did pure stands and mixtures of the two resistant accessions CIAT 2031 and 10136.

Preliminary evaluation of 58 pathogenic isolates collected from different mixtures of the three *S. guianensis* var. *pauciflora* accessions clearly showed that greater variation in pathogenicity was associated with isolates collected from mixtures than from pure stands (Table 11). In total, ten pathogen groups were detected: five, six, and five of these, respectively, were found in the mixtures 20% CIAT 1927 and 40% of each of CIAT 2031 and 10136; 40% CIAT 1927 and 30% of each of CIAT 2031 and 10136; and 80% CIAT 1927 and 10% of each of CIAT 2031 and 10136. In comparison, zero, one and three pathogen groups only were

Table 8. Cultural characters of isolates of *Rhizoctonia solani* from *Stylosanthes guianensis* and *Centrosema brasilianum*.

Character	Isolates from *S. guianensis* 1283	1177	5178	5247	Isolates from *C. brasilianum* 5369	5565	5583
Growth rate cm/24h at 24°C	2.65	2.40	2.95	1.98	3.09	1.16	2.63
Colour of Mycelium	Brown	Dark Brown	Light Brown	White	Light Brown	White	Dark Brown
Presence of Zonation	++	++	+	++	+	-	++
Texture of Mycelium	Velvety	Compact	Velvety	Cottony	Velvety	Woolly	Compact
Presence of Aerial Mycelium	+	-	+	++	+	+	-
Production of Sclerotia	+	+++	-	++	++	-	++
Anastomosis Group	?	AG-1	?	?	AG-1	?	AG-1
Pathogenicity to *S.guianensis*	++	+++	+	+	++	-	
Pathogenicity to *C.brasilianum*	++	++	+	++	+++	+	++

Table 9. Reaction of seven varieties of *P. vulgaris* and three accessions of *Zornia* spp. to four isolates of *Corynebacterium flaccumfaciens* in the glasshouse.

Species	Line	*Zornia glabra* CIAT 7847			*P. vulgaris*	
		I 603	I 607	I 614	I 615	Testigo
Phaseolus vulgaris	P.I. 136677	4.00 a	3.33 abc	3.66 ab	2.66 bcde	2.33 cdef
P. vulgaris	Bat. 41	1.33 fghi	3.33 abc	2.00 defg	3.66 ab	1.00 ghij
P. vulgaris	Porrillo sintético	1.66 efg	3.66 ab	3.33 abc	2.66 bcde	2.00 defg
P. vulgaris	ICA Guali	3.66 ab	2.66 bcde	2.00 defg	2.33 cdef	1.66 efgh
P. vulgaris	PI 204600	2.66 ab	2.66 bcde	2.00 defg	2.33 cdef	1.66 efgh
P. vulgaris	ICA Pijao	3.00 abcd	3.00 abcd	2.66 bcde	2.00 defg	1.00 ghij
P. vulgaris	PI 165078	2.66 bcde	3.00 abcd	1.33 fghi	2.33 cdef	1.00 ghij
Zornia glabra	CIAT 7847	1.00 ghij	1.66 efgh	1.33 fghi	0.66 hij	0.33 ij
Z. brasiliensis	CIAT 7485	0.33 ij	1.00 ghij	0.66 hij	0.66 hij	0.00 j
Z. latifolia	CIAT 728	1.33 fghi	0.66 hij	0.00 j	0.00 j	0.33 ij
	MEAN	2.13 b	2.53 a	1.93 b	2.03 b	1.05 c

Values followed by the same letters are not significantly different ($P < 0.05$).

Table 10. Reaction of three bean varieties and Z. glabra to Corynebacterium flaccumfaciens in the field.

Species	Line	I 603	Mixture of I603 I 607, I 614	Control
Phaseolus vulgaris	PI 136677	3.22 bc	3.45 bc	1.17 f
P. vulgaris	PI 204600	2.72 d	2.97 cd	1.82 e
P. vulgaris	Porrillo sintētico	1.20 f	1.90 e	0.45 g
Zornia glabra	CIAT 7847	4.10 a	3.62 b	1.87 e
	MEAN	2.81 a	2.98 a	1.33 b

Values followed by the same letters are not significantly different ($P < 0.05$).

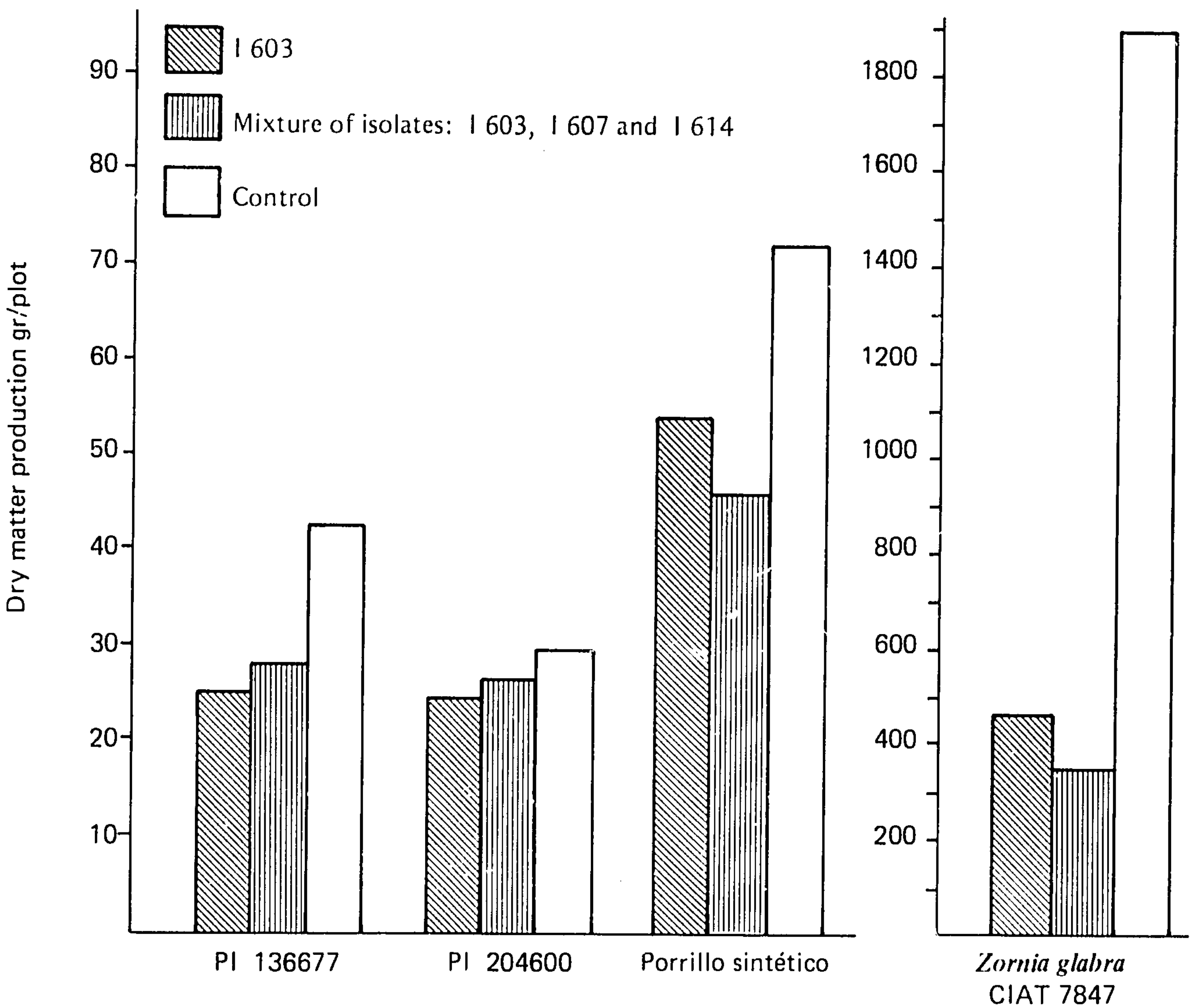


Figure 1. Effect of three isolates of Corynebacterium flaccumfaciens on dry matter production of Z. glabra CIAT 7847 and three lines of Phaseolus vulgaris.

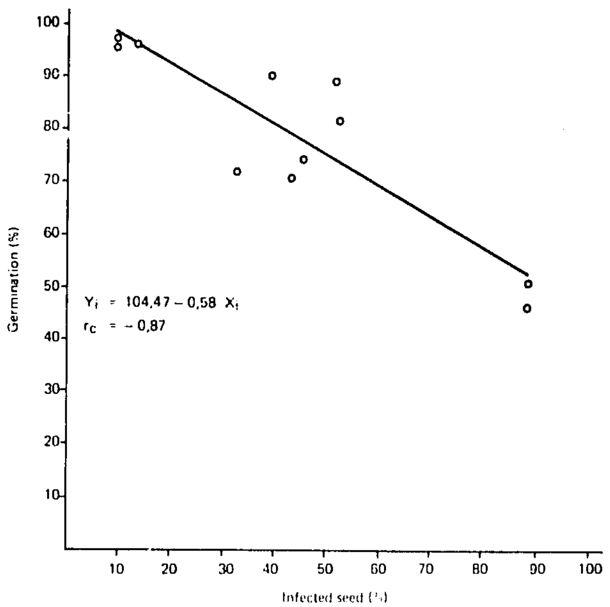


Figure 2. Corynebacterium flaccumfaciens and its effect on germination of seeds of bean and Z. glabra CIAT 7847.

detected in pure stands of CIAT 2031, CIAT 10136 and CIAT 1927, respectively. Results to date support the hypothesis that the pathogen population associated with mixtures is more diverse than that associated with pure stands and is thus exposed to less pressure to change.

During the past three years in Carimagua, symptoms of chlorosis and wilting have commonly been observed in S. guianensis "tardio" accessions affected with anthracnose. Production of toxins by C. gloeosporioides was postulated. Four accessions of S. guianensis - three "tardios" CIAT 1927, 2031 and 2243 and one common CIAT 136 - were exposed to different percentages of crude toxin produced by a pathogenic isolate of C. gloeosporioides. All accessions were considerably affected (chlorosis and necrosis) by 20% or greater crude toxin within 72 hours (Figure 4); CIAT 2243 being the most affected. This helps to explain the symptoms observed in the field on this and other "tardio" accessions.

Previous in vitro and in vivo studies in the laboratory and glasshouse with antagonistic phylloplane bacteria collected from S. guianensis in Pucallpa, Peru had demonstrated their ability to affect the infection process by C. gloeosporioides and subsequent anthracnose development on S. guianensis CIAT 136 and 184. The effect of these bacteria on anthracnose development in CIAT 136 and 184 in Quilichao, and Carimagua was assessed during June to November 1984. In general, there were no significant differences in anthracnose development among treatments in Quilichao, with the exception of I2 on CIAT 184. In Carimagua, however, all bacterial treatments were significanly less affected by anthracnose than the control and those plants treated with the mixture of bacteria were least affected. It appears that these antagonistic bacteria have the potential for controlling anthracnose in other ecosystems, at least in the short-term.

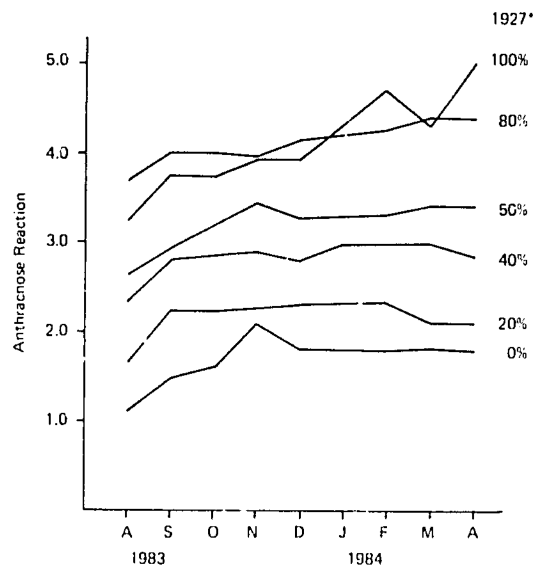


Figure 3. Development of anthracnose in mixtures of different proportions of Stylosanthes guianensis var. pauciflora CIAT 1927 in Carimagua, 1983-1984.

* Components were equal % CIAT 2031 and 10136.

Table 11. Effect of different mixtures of three accessions of *Stylosanthes guianensis* var. *pauciflora* on variation within the associated pathogen population.

Mixture Components (%)			% Isolates[1] Tardios & Commons	Pathogenic to		Pathogen Groups[2] No.
1927	2031	10136		Tardios	Commons	
0	100	0	0	0	0	0
0	0	100	0	0	100	1
100	0	0	71.4	14.3	14.3	3
0	50	50	50.0	0	50.0	2
20	40	40	66.7	0	33.3	5
40	30	30	62.5	25.0	12.5	6
80	10	10	80.0	0	20.0	5
50	25	25	66.7	0	33.3	2
50	50	0	33.3	0	66.7	4
50	0	50	100.0	0	0	2

1/ Number of isolates collected = 73
Number of isolates pathogenic = 58

2/ Total number of different pathogen groups = 10.

Diseases of Desmodium spp.

False-rust. A collection of 60 accessions of *D. ovalifolium* has been under evaluation for reaction to various diseases during 1984. By September, only 10.6% of accessions remained unaffected: CIAT 13085, 13089, 13091, 13093, 13098, 13103 and 13306 (Table 12). The majority, however, were only slightly to moderately affected. When the methodology presently under evaluation to assess losses is developed, it is hoped that these accessions may show small enough losses to be of value. A screening methodology has been developed and the complete collection is being evaluated under controlled conditions.

Collections of *D. heterocarpon* in both Carimagua and Quilichao were affected by various diseases during 1984 including little leaf mycoplasma. A considerable percentage of the collections in both sites were moderately to severely affected (Table 13). Six accessions which later were identified

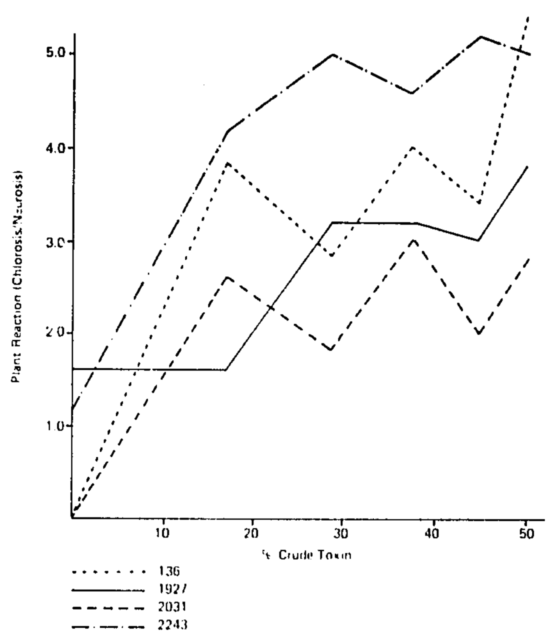


Figure 4. Effect of toxins produced by a pathogenic isolate of *Colletotrichum gloeosporioides* on three accessions of *Stylosanthes guianensis* var. *pauciflora* and one accession of "common".

Table 12. Evaluation of *Synchytrium desmodii* in 66 accessions of *Desmodium ovalifolium* in Carimagua during 1984.

% Accessions			
Severely Affected	Moderately Affected	Slightly Affected	Not* Affected
30.3	33.3	25.8	10.6

* Accessions unaffected September 1984: 13085, 13089, 13091, 13093, 13098, 13103, 13306.

as *D. strigillosum*: 13149, 13153, 13155, 13156, 13158 and 13159 were only very slightly or not affected at both sites. Most of these accessions were also high yielding and resistant to other pests and diseases.

Diseases of *Zornia* spp.

Sphaceloma scab. Resistant and susceptible lines to Sphaceloma scab selected from the variable *Z. latifolia* CIAT 728 population under glasshouse screening and field evaluation in Quilichao during 1981 to 1983, were planted in Carimagua in May, 1984. In general, their reactions to Sphaceloma scab in Carimagua was similar to that recorded in Quilichao (Table 14). Sphaceloma scab levels were slightly greater in the most resistant selections FP 1 and FP 3 and considerably greater in the moderately resistant FP 2. It appears that scab pressure is greater under Carimagua conditions. Evaluations will continue during 1985 with the aims of selecting a sufficiently resistant line of CIAT 728.

Diseases of *Centrosema* spp.

Rhizoctonia Foliar Blight. Evaluations continued during 1984 in collections of *C. brasilianum* accessions at Carimagua. Rhizoctonia foliar blight (RFB) was the most common and serious disease affecting the whole collection of 60 accessions moderately to severely during June to August (Table 15). The least affected accessions were 5178, 5365, 5514, 5657 and 5810. It is expected that this collection will be only slightly affected in 1985. Past experience with RFB in *C. brasilianum* in Carimagua has clearly show that disease severity is always greatest in the first full wet season while in the second year RFB is only a minor disease. For example: in 1982, a

Table 13. Reaction of accessions of *Desmodium heterocarpon* and other species to little leaf mycoplasma in Quilichao[1] and Carimagua[2] during 1984.

Site	Reaction to Little Leaf				
	0/1	2	3	4	Not Eval.[3]
Quilichao	18.3	32.8	42.5	2.7	2.7
Carimagua	6.1	16.7	32.9	10.8	32.5

1/ 73 accessions
2/ 89 accessions
3/ Not evaluated due to dead or missing plants.

Table 14. Reaction of selected progenies of Zornia latifolia CIAT 728 to Sphaceloma scab in Quilichao during 1981-1983 and in Carimagua June to November, 1984.

Selection	Reaction to Sphaceloma scab Quilichao 1982-1983	Carimagua 1984
728	3.2	2.8
FP 1	0.9	1.5
FP 2	1.9	2.8
FP 3	0.7	1.3
FP 4	3.9	3.8
FP 5	1.6	1.8

0 = No disease; 5 = Plant death.

collection of 40 accessions of C. brasilianum was moderately to severely affected while in 1983, the same collection was much less affected with only 12.6% of accessions being moderately affected (Table 15). Although results could be confounded with climatic factors, it appears that natural antagonists are most probably important in the diminishing problem with RFB over time.

Small plot evaluations of RFB in C. brasilianum using natural inoculum are still regarded as inaccurate in assessing the reaction of individual accessions. These vary tremendously among replications. In the case of the August 1984 evaluation, none of the correlation coefficients among the four replications were significant. The fact that this was not site specific was clearly shown by similar, not significant correlations among replications at two evaluation dates of 130 accessions of C. brasilianum in Quilichao.

It is clear that an improved screening methodology for RFB of C. brasilianum must be developed. Studies are in progress evaluating reactions of the whole collection to RFB under controlled conditions. Another alternative would be to artificially inoculate field screening plots to uniformize inoculum.

Studies on the effect of RFB on C. brasilianum CIAT 5234 with and without A. gayanus association and with and without grazing were begun in

Table 15. Evaluation of Rhizoctonia Foliar Blight (RFB) of Centrosema brasilianum in Carimagua during 1982 to 1984.

Collection	Accessions No.	Eval. Date	Reaction to RFB[1] 1.0	2.0	3.0	4.0	5.0
			% Accessions				
1982	40	Sep.-82	0.8	40.3	43.7	15.1	0
		Aug.-83	25.2	62.2	12.6	0	0
1983	60	Aug.-84	0	0	26.7[2]	51.7	21.6

1/ 1.0 = 0 - 1.0; 2.0 = 1.1-2.0; 3.0 = 2.1-3.0; 4.0 = 3.1-4.0; 5.0 = 4.1-5.0.
2/ Least affected accessions: 5178, 5365, 5514, 5657 and 5810.

Carimagua during 1984. From June to November, in all treatments under grazing RFB levels were slightly higher than in treatments without grazing (Table 16). RFB was generally lowest in the fungicide treatments, however, at the same time there was a tendency for lower RFB under grazing in association with A. gayanus and without fungicide. This experiment is only in its first year. The significance of these tendencies and the effect of RFB on dry matter production will become clearer during the coming year.

STUDIES IN THE WELL-DRAINED ISOTHERMIC SAVANNAS - CERRADOS

Survey of Diseases

During April-May, 1984, the first extensive survey of diseases was made throughout the Cerrados in eight regional trials established in 1983. In general, there were few disease problems at this early stage. Diseases detected included:

Table 16. Effect of Rhizoctonia Foliar Blight on Centrosema brasilianum CIAT 5234 with and without Andropogon gayanus association and with and without grazing in Carimagua, June to November 1984.

Treatment	Evaluation of RFB	
	+ Grazing	- Grazing
+ A. gayanus + Fungicide	1.8	1.5
+ A. gayanus - Fungicide	2.2	2.5
- A. gayanus + Fungicide	2.2	1.5
- A. gayanus - Fungicide	3.2	2.8

0 = No disease; 5 = Plant death.

anthracnose and inflorescence dieback on Stylosanthes spp.; Phomopsis and Cercospora leaf spots, Rhizoctonia foliar blight and virus on Centrosema spp. and stem complex on Zornia spp. Of note, was severe anthracnose on accessions of S. capitata at Amarante, Piaui, where anthracnosed native S. capitata was common around the trial site. Anthracnose was not a problem on S. capitata at any other site and nor was native S. capitata found at any other site. Dieback of inflorescences of S. macrocephala was noted for the first time at Vilhena and Cuiaba, however the causal pathogen was not identified. All diseases on Centrosema spp. caused minor damage, only. Desmodium ovalifolium was disease-free at all sites.

Diseases of Stylosanthes spp.

Anthracnose. A collaborative experiment was planted in 1983 to evaluate the performance of S. capitata cv. "Capica" and its components at CPAC under some anthracnose pressure. During 1983, anthracnose was detected only and even the border rows of S. capitata CIAT 1405, previously found to be highly susceptible to anthracnose at CPAC, were only slightly affected.

During January to May, 1984 however, slight to moderate levels of anthracnose were recorded in CIAT 1405 and slight anthracnose in cv. "Capica", its components and CIAT 1019 (Table 17), cv. "Capica" and its components CIAT 1315, 1693 and 1728 were more vigorous than CIAT 1318, 1342 and 1019. By August-September 1984, anthracnose levels were again very slight only.

The apparent resistance of S. capitata to anthracnose at CPAC during 1983 and 1984 is contrary to its considerable susceptibility during 1979 to 1981, and is even more difficult to explain when virulent isolates to cv.

Table 17. Evaluation of anthracnose and general vigour of *S. capitata* cv. CAPICA; its components; and CIAT 1019. May 1984 in CPAC, Brazil.

Accession CIAT No.	EVALUATIONS							
	REPLICATION I		REPLICATION II		REPLICATION III		MEAN	
	Anthracnose	Vigour	Anthracnose	Vigour	Anthracnose	Vigour	Anthracnose	Vigour
10280	1.0	E	1.5	E	1.0	E	1.2	E
1315	1.0	E	1.0	E	1.5	E	1.2	E
1318	1.5	B	1.0	B	1.0	B	1.2	B
1342	1.0	E	1.5	B	1.5	B	1.3	B
1693	2.0	E	1.5	E	1.5	E	1.7	E
1728	1.5	E	1.5	E	2.0	B	1.7	E
1019	1.0	R	1.5	E	1.5	B	1.3	B

"Capica", its components and other accessions of S. capitata have been isolated at CPAC during 1983 to 1984. One must question whether anthracnose development on S. capitata is a cyclical phenomenon in the Cerrados with prevailing climatic conditions playing a significant role? Detailed climatic data is presently being studied. A reassessment of S. capitata in the Cerrados may be necessary.

Studies continued on the pathogenic variation among isolates of C. gloeosporioides from S. capitata collected from various sites in the cerrados of Brazil including CPAC, Acauã, Santa Rita and Boa Vista. Of 89 isolates evaluated in 1984, the majority of pathogenic isolates (34) were virulent on cv. "Capica" and its five components (Table 18). Thirteen remaining isolates were separated into 9 pathogenic groups according to their differential reactions on the five components. The most common groups were (a) pathogenic to all components except CIAT 1315, (b) pathogenic to all components except CIAT 1728; and (c) pathogenic to all components except CIAT 1318.

Apart from CPAC, most isolates included in the study were collected in Boa Vista where S. capitata is an introduced legume. Among pathogenic isolates from Boa Vista, three pathogenic groups were distinguished (Table 19) all of which were present at CPAC. It is thought that these isolates were introduced from CPAC.

It was also of interest to note that the most virulent isolates among the 89 evaluated were collected in Acauã, a region of native S. capitata and close to the suspected center of origin of the species.

Isolates of C. gloeosporioides from S. macrocephala were also collected from Boa Vista in 1983. These were compared with isolates from S. capitata on both hosts in a cross-inoculation study. Two of seven isolates from S. macrocephala were pathogenic, I 1045 to both S. capitata and S. macrocephala and I 1094 to S. capitata only (Table 20). Of great interest also was the virulence of five of seven pathogenic isolates from S. capitata on three accessions of S. macrocephala (Table 20).

Table 18. Pathogenic variation among 89 isolates of Colletotrichum gloeosporioides collected from Stylosanthes capitata from four sites* in Brazil on cv. Capica and its components.

	Reaction Type					Isolate
CAPICA	1315	1318	1342	1693	1728	%
-	-	-	-	-	-	47.2
+	+	+	+	+	+	30.3
+	-	+	+	+	+	5.6
+	+	+	+	+	-	4.5
+	+	-	+	+	+	4.5
+	+	+	-	+	+	1.1
+	-	+	+	+	-	1.1
-	-	-	+	+	+	1.1
-	-	+	-	+	-	1.1
-	-	+	-	-	-	2.2
-	-	-	+	-	-	1.1

* CPAC (56), Acauã (2), Sta. Rita (11), Boa Vista (20).

Table 19. Pathogenic variation among 20 isolates of Colletotrichum gloeosporioides collected from Stylosanthes capitata from Boa Vista, Brazil on cv. Capica and its components.

	Reaction Type					Isolate
CAPICA	1315	1318	1342	1693	1728	%
–	–	–	–	–	–	65.0
+	+	+	+	+	+	25.0
+	–	+	+	+	+	5.0
+	+	–	+	+	+	5.0

Table 20. Pathogenic variation among isolates[1] of Colletotrichum gloeosporioides collected from S. capitata and S. macrocephala from Boa Vista, Brazil.

Acces-	Isolates from S. capitata							Isol.from S. macrocephala	
sions	902A	720B	1097B	1019B	1019C	1097A	1019A	1045	1094
S. capitata									
CAPICA	+	+	+	+	+	+	+	+	+
1315	+	+	+	+	+	–	+	+	+
1318	+	+	+	+	+	+	–	+	–
1342	+	+	+	+	+	+	+	+	–
1693	+	+	+	+	+	+	+	+	–
1728	+	+	+	+	+	+	+	+	–
1019	+	+	+	+	+	+	+	+	+
2252	+	+	+	+	+	+	+	–	+
S. macrocephala									
1281	+	+	–	+	+	–	–	+	–
1582	+	+	+	+	+	–	–	+	–
1643	+	+	+	+	+	–	–	+	–

1/ Thirteen isolates from S. capitata and five from S. macrocephala were not pathogenic.

For the first time, isolates of C. gloeosporioides strongly pathogenic to S. macrocephala have been found and the ability of isolates from both related species to affect each other has been proved. Yet, at the same time, most accessions of S. macrocephala remain unaffected by anthracnose at most sites in the Cerrados. Further work on anthracnose in S. macrocephala is planned for 1985.

The Multilocational S. capitata Screening Trial continued into its third year at Acauã, Minas Gerais with the continuing excellent collaboration of EPAMIG. Anthracnose has increased considerably since 1982, however, as yet only 60% of the accessions can be eliminated due to their susceptibility. The most susceptible accessions were those native to Minas Gerais. The least anthracnosed and most vigorous and productive accessions in 1984 were CIAT 2251, 2252, 2253 and 2254 from Ceara; CIAT 2138, 2044 and 2221 from Bahia and CIAT 1356 and 1899 from Venezuela (Table 21). CIAT 2251, 2252, 2253, 2254, 2138, 2044 and 2221 were also among the most promising accessions in 1983. Unfortunately due to the rigorous cutting regime, several plots of 2252, 2253 and 2254 were permanently damaged during 1984. Obviously, a different cutting methodology should be developed and utilized for accessions of this growth habit to more realistically assess their potential.

STUDIES IN THE HUMID TROPICS

Diseases of Stylosanthes spp.

Anthracnose. The Multilocational S. guianensis Screening Trials continued at Pucallpa, Tarapoto, and Yurimaguas, Peru during 1984. New trials were established at Moyobamba and Pto. Bermudez, Peru. At Pucallpa, Peru, 14 accessions showed good to excellent adaptation and very slight to slight anthracnose levels

Table 21. Multilocational S. capitata screening trials. Most promising accessions of Stylosanthes capitata in Acauã, Minas Gerais, Brazil during June 1982 to May 1984.

CIAT No.	Origin	Anthracnose Evaluation[1]	General Adaptation[2] 1984	Mean Dry Matter Production		
				Wet.[3]	Dry[4]	Mean[5]
				---------	(g/plot)	-------
2251[8]	Ceará[6]	1.3	E	529.1	62.5	354.1
2253[7,8]	Ceará	1.3	B	427.4	39.0	281.8
2254[7,8]	Ceará	1.3	M	385.4	50.0	259.6
2138[8]	Bahía	1.5	R	371.3	45.1	249.0
1356	Venezuela	1.5	E	371.6	38.3	246.6
2044[8]	Bahía	1.5	B	368.3	37.3	244.2
1899	Venezuela	1.5	R	368.3	30.2	241.5
2221[8]	Sel. 2044	1.5	E	354.2	40.3	226.5

1. 1 = No disease, 5 = Plant death
2. E = Excellent, B = Good, R = Average, M = Bad
3. Mean of five harvests.
4. Mean of three harvests.
5. Mean of eight harvests.
6. All accessions from Brazil except 1356 and 1899.
7. Accessions damaged by too rigorous cutting during 1984.
8. Also most promising 1983.

(Table 22). The best accessions were commons CIAT 21, 1248 and 1165 and "tardio" CIAT 1283. Although CIAT 136 and 184 were among the 14 better accessions, the above four accessions were more promising during 1984. Other diseases detected were Rhizoctonia Foliar Blight which affected seven accessions including CIAT 1283, 1165, 1280 and 10136 during the wettest months. It was noted that the "tardios" were generally more affected than the commons. Minor Cercospora leaf spot was detected on seven accessions including CIAT 64, 136, 1164 and 1248.

At Tarapoto, Peru, nine accessions were more vigorous than the other 22 during 1984. However among these higher levels of anthracnose were recorded than in Pucallpa (Table 23). Three accessions CIAT 128, 184 and 1165 were superior, being better than the control CIAT 136 (Table 23). No

Table 22. Reaction to anthracnose and general adaptation of accessions of *Stylosanthes guianensis* common in Pucallpa, Peru during September 1982 to September 1984.

Accession No.	Mean Reaction to Anthracnose	General Adaptation
21	1.41	E
1283	1.53*	E
1248	1.60	E
1165	1.69*	E
184	1.49	B/E
1113	1.59	B/E
64	1.65	B/E
1177	1.75	B/E
1280	1.00*	B
10136	1.45*	B
68	1.57	B
136	1.69	B
1164	2.01	B
1017	2.08	B

* Susceptible to *Rhizoctonia solani* during the wettest months.
Reaction to anthracnose: 0 = No disease, 5 = Plant death.
General adaptation: E = Excellent, B = Good.

Table 23. Reaction to anthracnose and general adaptation of accessions of *Stylosanthes guianensis* common in Tarapoto, Peru during January 1983 to September, 1984.

Accession No.	Mean Reaction to Anthracnose	General Adaptation
184	1.3	B/E
128	2.0	B/E
1165	3.3	B/E
136	1.0	B
64	1.2	B
21	1.7	B
1160	1.9	B
1017	2.3	B
1164	2.3	B

Reaction to anthracnose: 0 = No disease, 5 plant death.
General adaptation: E = Excellent, B = Good.

At Yurimaguas, the lowest levels of anthracnose were recorded with no accessions rating more than slightly (A = 2.0). Rhizoctonia foliar blight was severe on CIAT 73, 1031, 1177 and 1919 during the wettest months and Cercospora leaf spot was detected on CIAT 1031 and 1091. Most accessions were vigorous, productive, and only slightly anthracnosed. Further evaluation will be necessary to select the most promising accessions.

Comparison of promising accessions in Pucallpa and Tarapoto, Peru clearly showed that seven accessions were common to both sites: CIAT 21, 1165, 184, 64, 136, 1164 and 1017 (Table 24) which supports wide adaptation of these accessions. Further trials are planned next year including these most promising accessions.

Previous observations on establishing plots of *S. guianensis* CIAT 136 after pre-application of Tourdon had occasionally found greater levels of anthracnose than in plots establishing

Table 24. Reaction to anthracnose and general adaptation of accessions of *Stylosanthes guianensis* common in Pucallpa and Tarapoto, Peru during September, 1982 to September 1984.

Accession No.	Mean Reaction to Anthracnose		General Adaptation	
	Pucallpa	Tarapoto	Pucallpa	Tarapoto
21	1.4	1.7	E	B
1283	1.5		E	
1248	1.6		E	
1165	1.7	3.3	E	B/E
184	1.5	1.3	B/E	B/E
1113	1.6		B/E	
64	1.7	1.2	B/E	B
1177	1.8	2.7	B/E	B/R
1280	1.0		B	
10136	1.5		B	
68	1.5	2.9	B	R
136	1.7	1.0	B	B
1164	2.0	2.3	B	B
1017	2.1	2.3	B	B
1160		1.9		B

Reaction to anthracnose: 0 = No disease; 5 Plant death.
General adaptation: E = Excellent, B = Good, R = Average.

without Tourdon. The effect of pre-application of Tourdon and planting date on the severity of anthracnose during the establishment period of *S. guianensis* CIAT 136 was evaluated in Pucallpa, Peru from December 1983 to June 1984. No significant differences were found between anthracnose levels in treatments established with and without Tourdon pre-application. However, plantings made from March to May had higher levels of anthracnose than those made from November to February. The situation is complex but possibly there was more inoculum present later in the wet season to affect young plants and/or environmental conditions were not as favourable for establishment of latent infections later in the wet season. The results strongly support planting early in the wet season.

Studies on the effect of diurnal temperature fluctuations on development of anthracnose latent infections in *S. guianensis* have clearly shown that fluctuations of 18°C cause significantly greater development of latent infections. During 1982 to 1984, anthracnose development in a collection of 28 accessions of *S. guianensis* was assessed monthly. Comparison of fluctuations in anthracnose with fluctuations in diurnal temperatures (°C) expressed as monthly means and monthly precipitation (mm) suggest a close relationship between fluctuations in anthracnose ratings and diurnal temperatures (Figure 5).

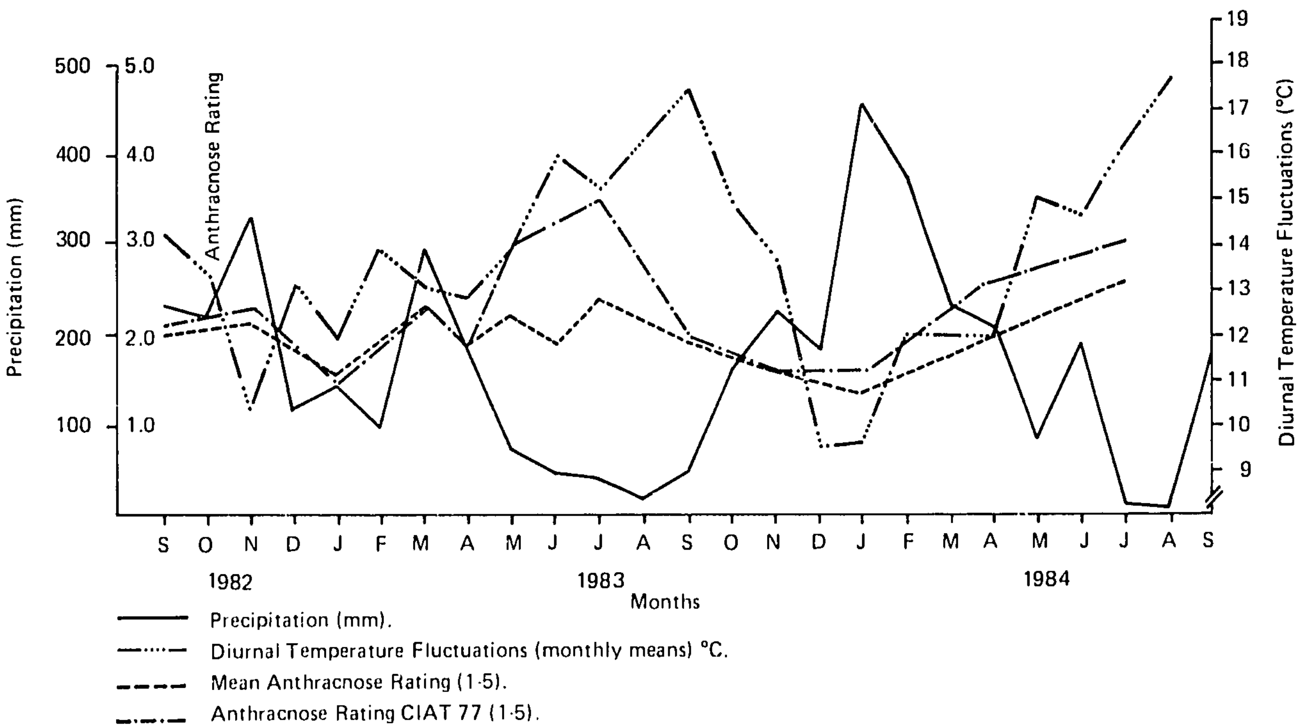


Figure 5. Diurnal temperature fluctuations, precipitation and mean anthracnose rating of 28 accessions of Stylosanthes guianensis from September 1982 to September 1984 in Pucallpa, Peru.

PART II. DISEASE CAUSED BY NEMATODES

1. Studies on stem gall nematode - Pterotylenchus cecidogenus

Until December 1981, D. ovalifolium was under pre-release evaluation in Carimagua. At that time, however, galls were detected on stems. Other symptoms included chlorosis, dieback and eventual plant death. This was caused by a new genus of nematodes Pterotylenchus cecidogenus, or stem gall nematode. The major objectives for work on this nematode problem are listed in Table 25. This year techniques have been developed and trials established for evaluation in 1985.

Table 25. Objectives for work on stem gall nematode of Desmodium ovalifolium.

a) To develop reliable and efficient screening methods to evaluate resistance and tolerance of D. ovalifolium under glasshouse and field conditions.

b) To evaluate the relationship between animal trampling and resistance.

c) To find the native hosts and distribution of the nematode in the the Llanos of Colombia.

d) To determine the host range of the nematode among Desmodium spp. and other promising tropical pasture legumes.

e) To study the seed transmission aspect of the nematode.

Preliminary Assessment of D. ovalifolium and Development of a Resistance Screening Trial in the Field. We are looking for an ideal accession for use in stem gall nematode infested pastures which will not allow rapid multiplication of the nematode (ie. resistant), which will not be severely damaged by the nematode (ie. tolerant) and which will have high yield potential and suitable agronomic characters.

In order to assess resistance in the field, a small plot trial of 60 accessions established in 1983 was evaluated to eliminate those accessions which obviously did not have useful resistance. This was done in January, 1984 by examining 4 areas of approximately 30 cm in diameter in each plot (Table 26). If well-developed galls were found in more than one of these areas per plot then that accession was not included in the field screening experiment. Accessions not in that planting were also included along with CIAT 350 as the control. That planting has been assessed at various times during the

Table 26. Assessment of Desmodium ovalifolium inoculated with Pterotylenchus cecidogenus.

Accession No.	Gall[a] rating May 84	Growth[b] rating Oct.84	Accession No.	Gall rating May 84	Growth rating Oct.84	Accession No.	Gall rating May 84	Growth rating Oct.84
3666*	2.00	2.00	13099*	2.67	1.33	13122	2.67	2.33
3776*	1.00	2.67	13100	3.67	2.00	13123*	0.00	2.33
3780	1.75	3.25	13101	1.67	2.00	13124	3.00	3.00
3793*	0.75	3.25	13102	3.00	3.00	13125	3.33	2.00
3794*	0.50	3.00	13103	3.00	3.00	13126	3.00	2.00
13030	3.67	1.00	13104	1.00	4.00	13127	1.33	2.67
13081	1.67	1.67	13105	3.67	3.33	13128	3.67	3.00
13082	3.00	2.33	13106	2.33	3.00	13128A*	3.00	2.25
13083	4.00	1.67	13107	2.33	3.33	13129*	0.00	4.33
13085	3.00	2.50	13108	2.67	2.00	13130	2.67	2.67
13086	2.33	3.00	13109	2.00	2.33	13131*	1.33	5.00
13087	1.75	3.25	13110	3.00	1.00	13132	3.00	2.67
13088*	1.33	5.00	13111	3.00	2.67	13133	2.33	3.00
13089*	0.33	2.33	13112	2.00	1.33	13134*	0.00	1.00
13090	3.00	1.33	13113	4.00	1.25	13135	2.67	3.67
13091	2.33	2.67	13114*	1.75	2.67	13136*	2.00	3.00
13092*	1.00	3.33	13115*	2.67	2.67	13137	3.33	1.33
13093	3.33	3.00	13116	2.67	3.00	13138	1.33	0.67
13094	3.33	3.00	13117	2.67	3.00	13139*	0.67	2.00
13095	3.00	3.00	13118	3.67	2.67	13140	0.33	1.33
13096	1.67	2.67	13119*	0.67	2.67	13302	3.67	2.00
13097	2.67	4.00	13120	3.67	1.33	13306	1.00	2.00
13098	2.67	4.67	13121*	1.67	3.50			

a/ Mean number of sites (out of 4) per plot with large galls.
b/ On scale of 0-5.
* Included in field screening based on gall rating in January 1984.

year for gall development and plant growth to ensure that no promising accessions have been missed. It appears that CIAT 13104 may also be useful and should be included in the field screening. Two accessions - CIAT 13123 and CIAT 13129 - as yet remain free of galls and are also vigorous. The growth of these, with and without nematodes, will be examined in more detail under controlled conditions. Accession CIAT 13134 has not yet developed galls but in October, its growth rating was poor.

The field resistance screening trial was re-inoculated in September as rain washed away the first inoculum. The trial will be assessed in 1985.

Development of a Resistance Screening Technique for the Glasshouse. The search for a suitable screening method involved finding an assay which was simple to use and which would show differences between resistant and susceptible plants in as short a time as possible. There were many variables involved and these were compared in various combinations using CIAT 350. These included evaluation of inoculum carriers, post-inoculation conditions, wounding and plant age.

The present screening method is as follows: seeds are pregerminated for one week in Petri dishes and then sown, one per pot, in sterile Quilichao soil with the appropriate Rhizobium strain. Ten replicates are used with CIAT 350 as the control. After 2 weeks, 0.5 ml of a nematode suspension containing 70 juveniles and females of P. cecidogenus extracted from galls is dropped onto each plant. This is repeated twice at 3 to 5 day intervals. The plants are covered with beakers until one week after the final inoculation to prevent drying of the nematodes. Two to three weeks after the final inoculation nematodes are extracted from each plant. These numbers are compared with those in CIAT 350.

When the D. ovalifolium collection has been screened for resistance, the same method will be used to assess the nematode's host range within weed species in Carimagua and other promising tropical legumes. To date, we have identified D. barbatum as a native host. This is an important finding as D. barbatum is found throughout the Llanos and emphasizes the danger of moving infested material within that area into possible stem gall nematode free areas. The natural distribution of the nematode in undisturbed savanna in the Llanos should be determined. As stem gall nematode has been found on D. ovalifolium at Porto Velho, surveys should also extend to Brazil.

Effect of Animal Trampling on Reproduction of the Nematode. Previous field observations have led to the suggestion that trampling by grazing animals may cause wounds which allow greater penetration of plants by nematodes, thus increasing susceptibility. A field trial has been sown to assess this aspect as well as plant growth habit, gall production and resistance in the relationship between D. ovalifolium and P. cecidogenus. Nematode populations and plant growth will be measured.

Effect of P. cecidogenus on D. ovalifolium. To assess the severity of damage caused by the stem gall nematode, its effect on various aspects of the D. ovalifolium CIAT 350 growth was studied.

1) Germination - No effect of nematodes on germination was found in pots with up to 800 nematodes/50 seeds or in Petri dishes with up to 500 nematodes/50 seeds.

2) Seedling survival.- Fifty-seven days after inoculation with a range of nematode densities, the number of live plants in each treatment and the number of plants in each treatment which had developed galls was noted (Figure 6). Even at the lowest inoculum density only about half of the seedlings survived. This was clearly related to gall formation. The production of gall tissue would reduce the quantity of assimilates available for plant growth by acting as a 'metabolic sink'. This has been observed in other host-nematode relationships. Death could also have been due to tissue breakdown and, therefore, to loss of vascular function or to the effects of secondary fungal infections.

In this trial, the number of visible green leaves on each plant was also counted at various times (Figure 7). After the first sampling at day 13, leaf number was significantly negatively correlated with inoculum density. Another observation was a rapid increase in the number of leaves on plants which developed galls. These leaves died shortly afterwards.

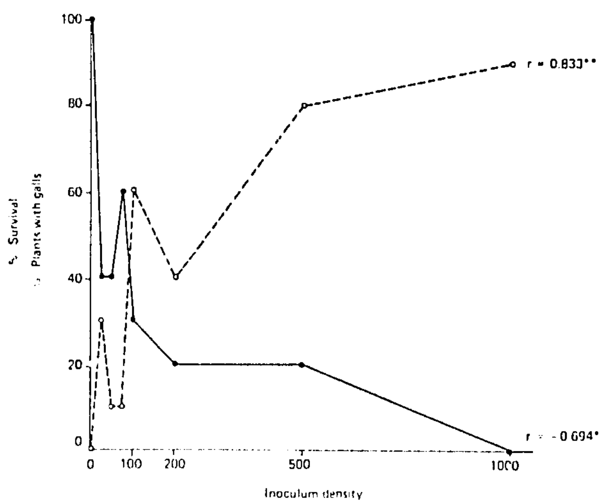


Figure 6. Seedling survival (●) and number of galled plants (O) of D. ovalifolium CIAT 350, 57 days after inoculation with different numbers of P. cecidogenus.

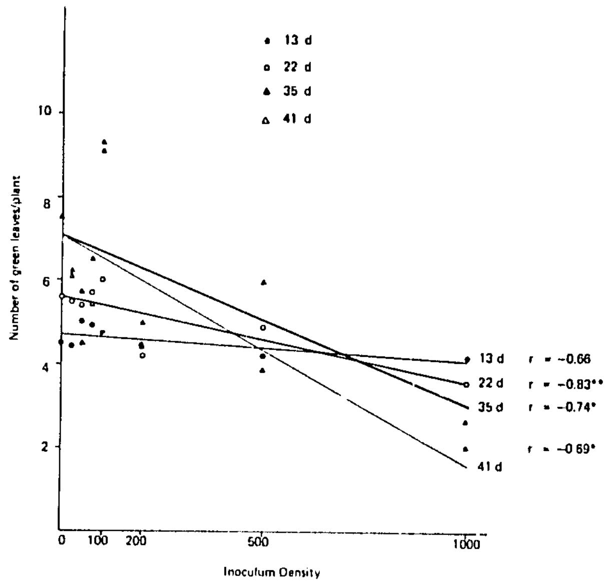


Figure 7. Number of green leaves present at four times after inoculation with different numbers of P. cecidogenus. Straight lines (with corresponding sampling times) are calculated regression lines.

It would be interesting to determine just how much these leaves contribute to or detract from the plant's nutrient store. Quite apart from the drain on the plant's resources caused by the galls, production of excess leaves which eventually die must use a very large proportion of the plant's assimilates. Clearly, the stem gall nematode can have a dramatic effect on the establishment of D. ovalifolium seedlings.

3) Plant growth.- The effect of P. cecidogenus on plant growth of D. ovalifolium was studied by inoculating plants in pots once with 0 or 70 nematodes. After 40 days, root and shoot lengths, root and shoot dry weights and number of leaves were recorded (Table 27). After 40 days, plants were severely affected in stem height, root length, shoot dry weight and leaf number.

Table 27. Effect of Pterotylenchus cecidogenus on growth of Desmodium ovalifolium 350, 40 days after inoculation.

Treatment	Stem length (cm)	Root length (cm)	No. leaves	Root dry weight (mg)	Shoot dry weight (mg)	Shoot: root ratio
C[a]	1.8	54.5	8	7	30	4.46
I	1.3**[b]	32.5*	5*	5	18*	3.20

a/ C = control; I = inoculated.
b/ * = P 0.05; ** = P 0.01.

Effect of Wounding and Plant Age on Penetration and Reproduction the Nematode. a) Wounding.- Previous observations on nematode infested pastures have led to the suggestion that animal trampling causes wounds which facilitate entry by nematodes. To test this theory, 10 plants were wounded by cutting the stem cuticle 6 times with a scalpel blade. These and 10 unwounded plants were inoculated with 200 nematodes. After 14 days, nematodes were extracted. No significant difference was found between treatments with the mean penetration being 4.7%.

b) Plant age.- Many nematodes are capable of entering only younger tissues. To determine whether this is the case with P. cecidogenus, plants of 0, 1, 2, 4 or 8 weeks of age were inoculated. Seven days after inoculation there was so much variation in nematode numbers that no significant relation between age and penetration was found (Figure 8). After 45 days, however, this relationship was significant. This later sampling time shows the combined effects of penetration and reproduction. How much was due to each cannot be determined from this trial but it is likely that reproduction would increase with age and, therefore, plant size and amount of available nutrients. This trial does

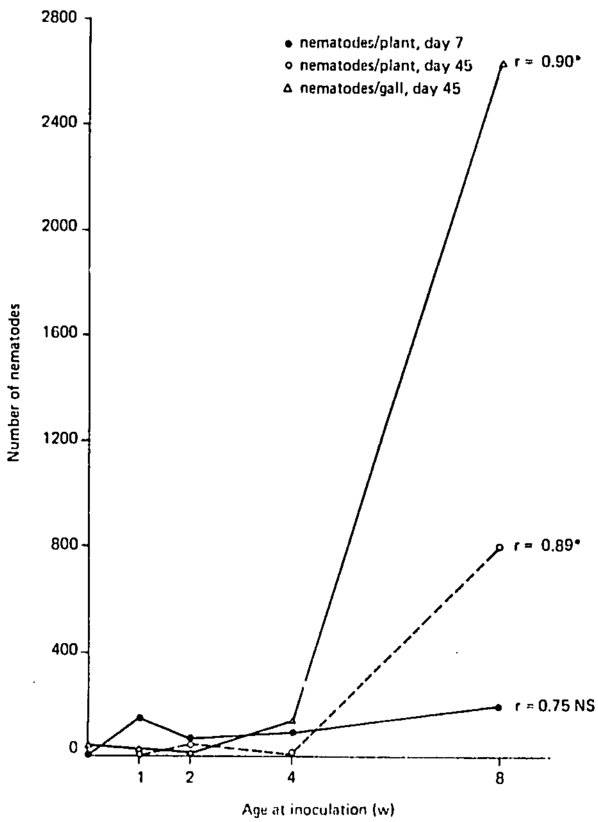


Figure 8. Number of P. cecidogenus/ plant 7 (•) and 45 days (o) and number/gall 45 days (Δ) after inoculation of D. ovalifolium CIAT 350 plants of different ages.

show that infection was not limited to the early seedling stage and that wounding was not required for infection.

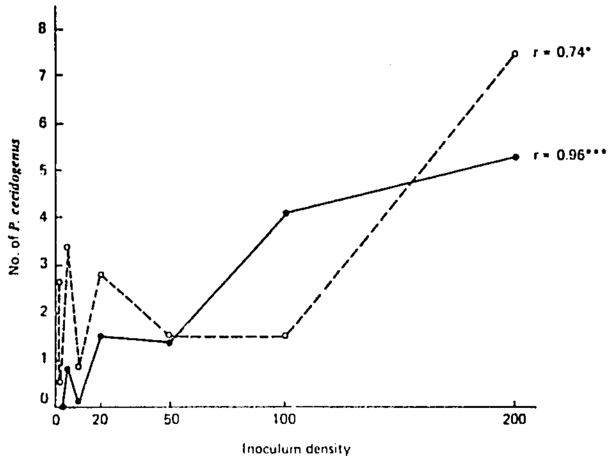


Figure 9. Penetration and reproduction of P. cecidogenus on D. ovalifolium CIAT 350 following inoculation with different inoculum densities and measured 7(●) and 52 days(x10^2) (○) respectively after inoculation.

Rate of Multiplication of the Nematode. To determine reproduction rate of P. cecidogenus, seedlings of D. ovalifolium CIAT 350 were inoculated with various inoculum densities. After 7 and 52 days nematodes were extracted from plants. The number of nematodes/plant at each sampling time was significantly correlated with inoculum density (Figure 9). At each inoculum density, the number of nematodes/plant 52 days after inoculation (slope = 2.36) was about 100 times that 7 days after inoculation (slope = 0.027). This rapid increase in population indicates the great need for plant resistance.

Life Cycle and Biology. Although, the life cycle of P. cecidogenus has not yet been studied in detail, preliminary findings indicate four juvenile stages, including one in the egg, and the female. The total life cycle from egg to egg took approximately 2 weeks under laboratory conditions.

To study the biology of the nematode in relationship with the plant and environmental conditions, various possible infection routes have been studied. First, various sites on older plant stems were inoculated. The trial showed that P. cecidogenus can move from established galls to infect other sites. We will be looking at this in more detail, including effects of environment. Second, plants were sown in trays at various intervals from fresh galls placed in the centre. No plants were touching the galls. After 4 months no plants had developed galls.

Clearly, there was very little movement through the soil by the nematode. It was found that the two processes, (a) movement into soil and (b) movement out of soil to infect, actually took place. (a) Galls were placed on top of measuring cylinders full of Carimagua soil and kept wet for one week. At that time, nematodes were found down to 6". However, much less than 1% of the inoculum had moved into the soil. (b) In our inoculation method, nematodes are placed on the soil. Infection occurs readily. Third, infection occurred by contact between galls and non-galled plants. Fourth, it has already been found that nematodes were associated with the seed pods although not within the seeds. When seed is produced on D. ovalifolium in Carimagua this aspect will be looked at in more detail.

It appears that the stem gall nematode is able to survive at least some desiccation which would be necessary for survival in seed pods and in galls of dead plants during the dry season. After the dry season, nematodes probably emerge from galls in response to rain. In order to gain some information on the dynamics of the nematode within the plant, 12 galled plants were collected in Carimagua in July and September. Starting at the plant base, the plant was cut into 5 cm lengths and nematodes extracted from stem sections at equal distance from the stem base. When looking at

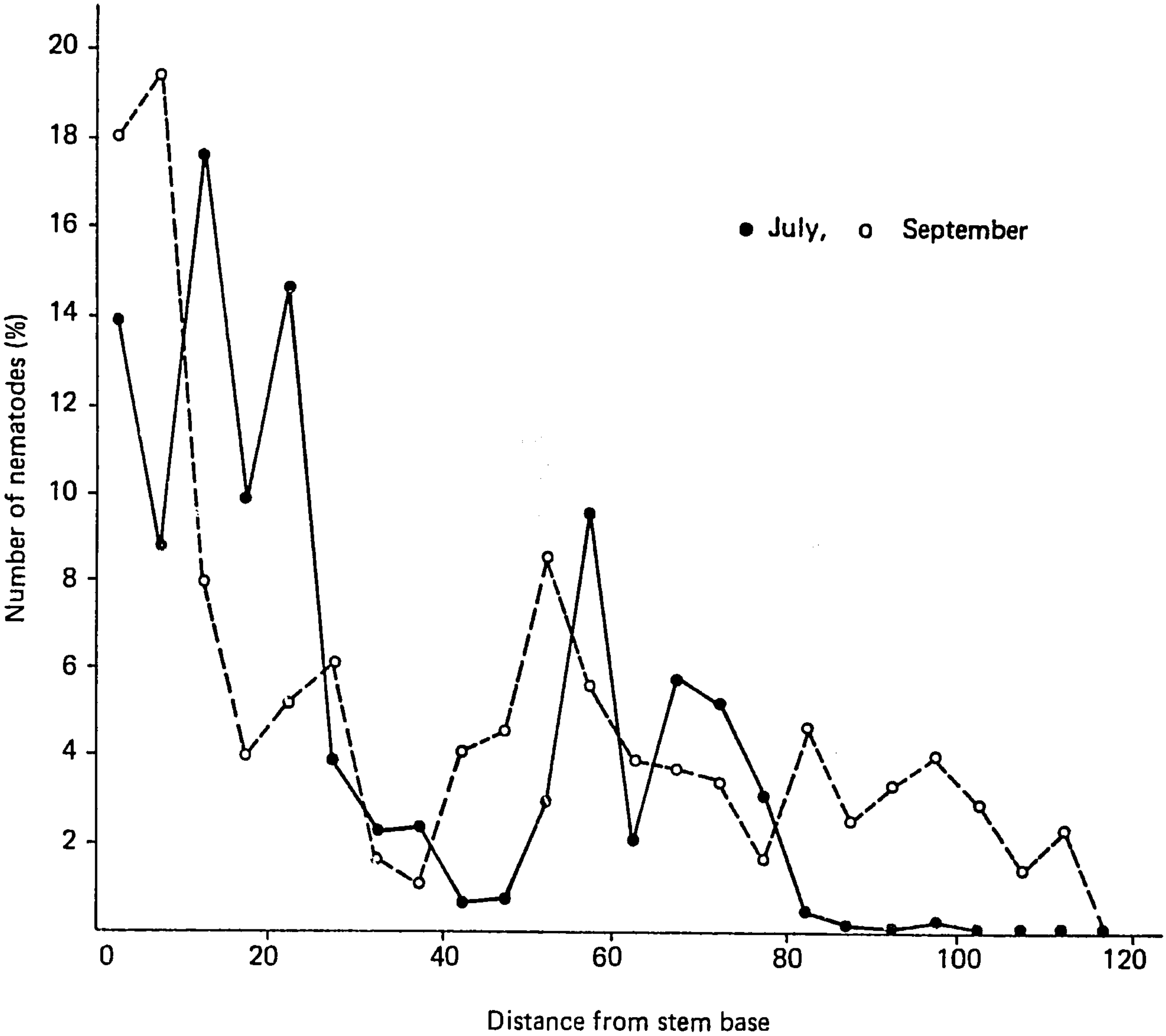


Figure 10. Number of nematodes in each 5 cm stem section as % of total in plant vs. distance from stem base. Each value represents the midpoint of the section.

the number of nematodes per 5 cm stem section (as % of the total number in the plant) vs. distance from stem base, the vast majority of nematodes were at the base (Figure 10). This was not unexpected as this was the oldest part of the plant and therefore the first to be attacked and had had the longest time for reproduction of the nematode. Further along the stem the number of nematodes decreased at both sampling times, and then, at about 50 cm from the base, the number increased. In July this number again declined at 80 cm from the base but in September the decline did not occur until 35 cm further. It is probable that these plants germinated during the wet season of 1983 and were infested by nematodes shortly afterwards. These nematodes continued to move up the plant establishing feeding sites and galls while it was growing vigorously. With the onset of the dry season, conditions were not so suitable for movement of the nematode. With the next wet season, nematodes moved to the most actively growing part of the plant, i.e. toward the apices, to establish new feeding sites. This has continued throughout the wet season so that there were more nematodes higher up the plant in September than in July. This hypothesis should be examined in more detail to determine what conditions favour "within plant" infestation and, therefore, at which times of the year this occurs.

P. cecidogenus seems to survive very well in the field in the absence of host plants. An established trial at Carimagua showed that even after burning a previously infested pasture, newly germinated plants became galled. This inoculum was very likely from buried seed pods.

2. Screening of the D. ovalifolium collection to Meloidogyne spp.

Screening of the D. ovalifolium collection to a few species and races of Meloidogyne has now been completed by the International Meloidogyne Project at the N.C.S.U. Fifty-six accessions were tested for resistance and tolerance to races 1 and 3 of M. incognita, race 1 of M. arenaria, M. javanica and M. hapla (Table 28). Of these, 13 accessions possessed at least some resistance and tolerance to all nematodes tested. These are:

13081	13105	13128
13082	13111	13132
13087	13113	13289
13098	13125	13302
13099		

All accessions had some resistance and tolerance to M. hapla. An additional three accessions, 13083, 13092 and 13095, were not tested with M. incognita race 1 but had some resistance and tolerance to the others.

Table 28. New Desmodium ovalifolium accessions with resistance and tolerance to Meloidogyne spp.

	Complete Resistance and Tolerance	Some Resistance and Tolerance
M. incognita Race 1	8	34
M. incognita Race 3	4	47
M. arenaria Race 1	0	38
M. javanica	0	23
M. hapla	26	55

There is a need to determine which species and races of Meloidogyne that are present and to screen for resistance and tolerance to these if that has not already been done. One population of Meloidogyne in Carimagua was tentatively identified as M. javanica. However, it should not be assumed that this is the only one present. It is very common to find more than one species or race in an area and very often there are mixtures. All of our promising legumes, and probably the grasses as well, are hosts to one or more Meloidogyne species. The use of grasses for control of this nematode on various legumes in the field should also be investigated. This is being done at Tarapoto but the results may not be the same under Carimagua conditions with the local nematode population.

3. Reaction of the D. heterocarpon collection to Meloidogyne sp.

This year a severe Meloidogyne infestation was found in the D. heterocarpon germplasm collection at Carimagua and Quilichao. A sample has been sent to NCSU for identification and screening of the best D. ovalifolium accessions. At Carimagua, the collection was examined for number of galls and for possible above ground symptoms. There were 16 ungalled accessions (Table 29). Symptoms included chlorosis and necrosis. Correlations between gall rating and symptom rating; gall rating and % coverage and between symptom rating and % coverage were all highly significant suggesting that nematode damage was causing those symptoms and reduction in coverage. In future evaluations, the nematode population should be assessed directly and not on the basis of symptoms alone.

4. Survey of Plant Parasitic Nematodes in Pastures

A survey of plant parasitic nematode genera in soil and roots of various legume-grass associations was made at Quilichao (Table 30). Tolerance limits for damage by these nematode genera on these plant species is probably unknown and Tylenchus and Aphelenchus may or may not be parasitic. It seems likely, however, that populations of Pratylenchus and Helicotylenchus may be high enough to cause yield reductions in at least some of these associations and this should be determined.

Table 29. Evaluation of Meloidogyne sp. on D. heterocarpon in Carimagua.

Gall rating[a]	Number of Accessions	Symptom Rating[b]	% Coverage
0.00-0.50	22	1.04	79.7
0.51-1.00	5	0.60	91.0
1.01-1.50	5	1.36	45.5
1.51-2.00	5	2.05	60.6
2.01-2.50	7	1.79	35.2
2.51-3.00	4	1.88	19.7
3.01-3.50	3	2.67	32.9
3.51-4.00	2	2.30	7.5
4.01-4.50	4	3.00	24.7

a/ On scale of 0-5.
b/ On scale of 0-4.

Table 30. Number of nematodes in 100 g of soil and 20 g of roots in various pasture associations at Quilichao.

	Pratylenchus	*Helicotylenchus*	*Tylenchus*	*Aphelenchus*
D. ovalifolium-*B. dyctioneura*	149	0	0	0
A. gayanus-*Zornia* sp.	87	0	268	0
A. gayanus-*S. macrocephala*	429	0	0	0
A. gayanus-*C. macrocarpum*	12	0	69	84
A. gayanus-*D. ovalifolium*	60	200	0	127

SOIL/PLANT NUTRITION

During 1984 the Section has continued focusing the research work in five main areas: 1) evaluation of methods for nutritional diagnosis of forage germplasm; 2) integrated studies of soil fertility and microbiology on plant nutrition; 3) nutrient competition in grass-legume mixtures; 4) evaluations of nutrient cycling in pastures, and 5) use of mineral rocks as alternative sources of fertilizers.

EVALUATION OF METHODS FOR NUTRITIONAL DIAGNOSIS OF FORAGE GERMPLASM

In the past, the missing element technique has been used for the diagnosis of nutritional requirements for forage germplasm adapted to acid soils. During the establishment period the missing element technique has clearly identified P as a key element without which plants showed significant production differences as compared with the positive control, but the same forage production as the negative control. With this technique, the effect of other elements such as K, Ca, Mg and S was not detected. This is possibly due to some partial substitutions that plants make of deficient elements by others which are in sufficient quantities.

In order to avoid these possible partial substitutions, and knowing that N and P are essential for the establishment phase of grasses and legumes in these acid soils, a nutritional diagnosis technique was designed so that N and P were applied to all individual treatments. These treatments include recommended levels of different elements such as K, Ca, Mg, S and single microelements. Additional treatments such as one with major, secondary and minor elements, with and without N (positive controls), and the secondary elements alone were included for comparison against a negative control (no fertilization).

For this evaluation two acid soils with contrasting physical and chemical characteristics were used (Table 1). The fertilizer treatments and rates are described in Table 2.

Arachis pintoi, CIAT 17434, a highly promising forage legume for the Carimagua type soils was used as a test plant to evaluate this methodology. The dry matter productions obtained from vegetative planted material, two months after planting are shown in Table 3. This table includes an artificial variable called "degree of need" which is defined as the difference between the dry matter produced by a given treatment minus the negative control and expresed as a percentage of this.

The results indicate that for *A. pintoi* 17434, in addition to N-P, magnesium, sulphur and especially the interaction among them were the key elements for establishment at the Carimagua site; and Ca and Mg in the sandy soil at Guayabal (Table 3). Since the single micronutrient applications did not yield a higher dry matter production than that of N-P

Table 1. Physical-chemical characteristics of the plough layer from the Reserva-Carimagua and Guayabal. Puerto Gaitán sites.

Site	pH	M.O	P (Bray II)	Exchangeable cations				Al Saturation	Texture		
				Al	Ca	Mg	K		Sand	Silt	Clay
		%	ppm	--------meq/100g----------				%	---------- % ------------		
La Reserva	4.1	2.8	1.5	3.6	0.36	0.09	0.11	86	12	50	38
Guayabal-Pto.Gaitán	4.5	2.3	2.7	1.6	0.17	0.05	0.09	84	50	24	25

Table 2. Nutrients and rates used with a nutritional diagnosis technique, using A. pintoi 17434 as a test plant under greenhouse conditions.

Treatments	N*	P	K	Ca	Mg	S	Zn	Cu	B	Mn	Mo
	kg/ha eq.										
Negative control	0	0	0	0	0	0	0	0	0	0	0
Positive control	15	20	30	100	20	20	3	2	1	10	.4
Positive control-N	0	20	30	100	20	20	3	2	1	10	.4
N P	15	20									
N P K	15	20	30								
N P Ca	15	20		100							
N P Mg	15	20			20						
N P S	15	20				20					
N P Sec	15	20	0	100	20	20					
N P Zn	15	20					3				
N P Cu	15	20						2			
N P B	15	20							1		
N P Mn	15	20								10	
N P Mo	15	20									.4

*Applied every 15 days.

Table 3. The effect of several nutrients on the dry matter production of A. pintoi 17434 under greenhouse conditions.

Treatment	Reserva, Carimagua site		Guayabal, Pto.Gaitán site	
	Dry matter	Degree of need[a]	Dry matter	Degree of need
	g/pot	%	g/pot	%
Positive control	2.5	169	3.6	177
Posit.control -N	2.3	147	4.2	218
N P	1.7	86	3.1	138
N P K	1.5	65	3.7	182
N P Ca	1.5	58	4.0	208
N P Mg	2.1	123	3.4	159
N P S	2.1	118	2.5	95
N P Sec.	2.5	166	4.0	205
N P Zn	1.7	86	3.0	125
N P Cu	1.4	51	3.2	146
N P B	1.4	51	3.2	146
N P Mn	1.5	65	2.8	113
N P Mo	1.4	43	3.0	131
Neg.Control (C-)	.9	0	1.3	0
LSD (Dunnett .05)	.75	111	1.2	120

a/ Degree of need = $\frac{TRAT-(C-)}{C-} \times 100$

alone, this might indicate that at least for the establishment phase, micronutrient applications are not needed in these two soils.

Comparing the positive controls with and without N, it was possible to determine the relative high efficiency of native Rhizobium strians for this legume.

During 1985 similar trials will be conducted covering a wide range of adapted germplasm and soil types to determine the key nutritional elements.

THE EFFECTS OF SOURCES AND RATES OF FERTILIZATION WITH AND WITHOUT RHIZOBIUM INOCULATION IN FORAGE LEGUMES

Even thought most of the soils in the target area of the Tropical Pastures Program are classified as Oxisols and Ultisols, and are generally acid and low in fertility, they present a wide variability in texture, organic matter content, soil-water relationships, and microbial populations. Because of this natural variability, an integrated research with soil microbiology was initiated studying different soil types, fertilizer sources and nutrient rates.

The following results show the effects of two sources and two rates of fertilization, with and without Rhizobium inoculation, on the dry matter production and the number of nodules of Centrosema macrocarpum 5065 and Pueraria phaseoloides 9900 (Table 4). This study was established under greenhouse conditions in an acid low fertility soil from Carimagua.

The dry matter production and the number of nodules for the two legumes are shown in Figure 1. Both legumes, with and without Rhizobium inoculation showed less response to the slow release fertilizers in comparison with the soluble ones, independently of the rate applied. This effect is mainly related to the differential nutrient supplying rate of the two fertilizer sources. Centrosema macrocarpum 5065 with Rhizobium inoculation showed the most significant response on dry matter producton and nodule number with the soluble fertilizers. Without inoculation there was not a response to the fertilizer treatment. This seems to indicate that for C. macrocarpum 5065, the studies on fertilizer requirements must be performed in the presence of an effective Rhizobium inoculum, given the specific requirement of this legume for Rhizobium strains. In contrast, even though P. phaseoloides showed a response to Rhizobium inoculation, native Rhizobium strains seem to be quite effective showing an interaction between applied fertilizer rates. A similar response was also observed in the N content of the plant tops, in both legumes (Figure 2).

The Rhizobium inoculation of both legumes also caused a significantly higher nutrient extraction rate (Table 5). For C. macrocarpum 5065 extraction rates were affected mainly by inoculation and fertilizer solubility, but for P. phaseoloides 9900 nutrient extraction, with the exception of N, was affected only by the solubility of the applied fertilizer.

THE RESIDUAL EFFECT OF MICRONUTRIENT APPLICATIONS IN TROPICAL FORAGES

In the beginning of the rainy season 1980 a field trial was established in Carimagua with the objective of studying the residual effect of a single micronutrient application (Zn, Cu, B, and Mn). During the first year (establishment period) none of the grasses showed a response to the above mentioned micronutrients (Annual Report, 1981).

The results, four years after the initial application are showed in

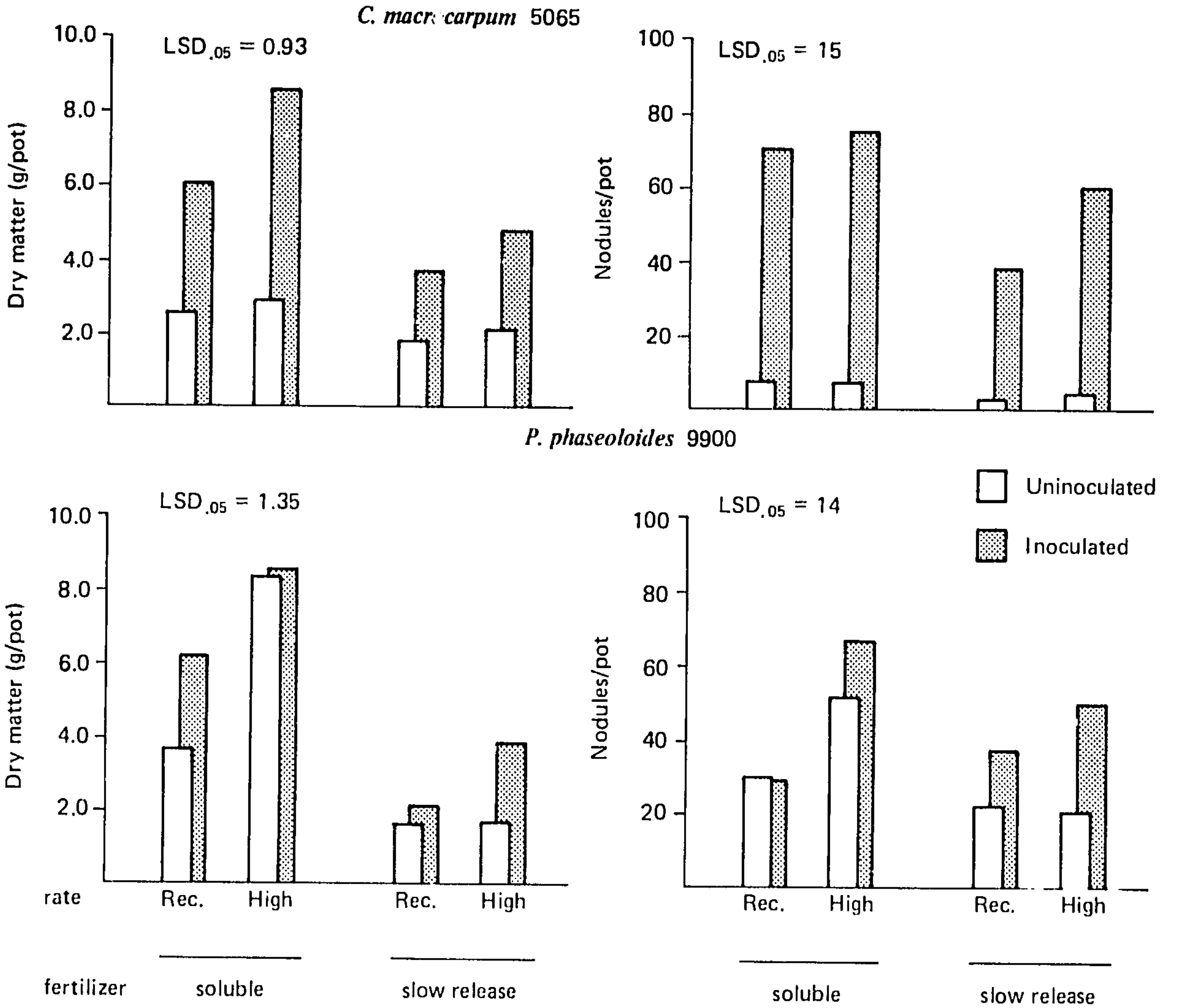


Figure 1. Effect of 2 sources and rates of fertilization with (▩) and without (☐) Rhizobium inoculation on the dry matter production and number of nodules of C. macrocarpum 5065 and P. phaseoloides 9900.

Table 4. Fertilizer sources and rates used in the integrated research studies with Soil Microbiology.

Nutrient	Fertilizer Rate (kg/ha) Recommended	High	Fertilizer Source Soluble	Low release
N	-	-	-	-
P	20	50	$NaH_2PO_4H_2O$	Huila Rock phosphate
K	30	60	K_2SO_4	K-feldspar (Tune river)
Ca	100	500	Cal agrícola	Lime
Mg*	20	40	$MgSO_47H_2O$	Mg serpentine
S	38	75	-	Sulphur flower
Zn	3	3	$ZnSO_4$	
Cu	2	2	$CuSO_4$	
B	1	1	H_3BO_3	
Mo	0.1	0.1	$Na_2Mo_2O_4H_2O$	

* In the soluble source S was not applied as it was included in the other elements used fulfilling the required rates.

Table 5. Nutrient extraction by *C. macrocarpum* 5065 and *P. phaseoloides* 9900 as affected by two sources and rates of fertilization with and without *Rhizobium* inoculation under greenhouse conditions.

Specie	Treatments			Nutrient extraction				
		Fertilization						
	Rhizobium	Source[1]	Level[2]	N	P	K	Ca	Mg
				----------		mg/pote		----------
C. macrocarpum 5015	Inoculated	Soluble	Recommended	137	6.3	54.3	63.2	16.4
			High	212	8.3	78.5	114.7	20.3
		Slow release	Recommended	106	4.7	20.3	50.3	9.6
			High	144	6.3	21.7	89.7	21.6
	Uninoculated	Soluble	Recommended	34	4.1	27.0	30.6	8.5
			High	45	5.8	36.8	63.5	12.0
		Slow release	Recommended	28	3.4	13.1	26.9	4.9
			High	27	4.8	13.2	41.0	9.3
$DMS_{0.05}$				26	1.5	7.0	16.3	1.8
P. phaseoloides 9900	Inoculated	Soluble	Recommended	166	7.4	57.4	49.4	17.1
			High	195	9.7	76.3	94.8	26.7
		Slow release	Recommended	64	3.7	12.6	24.9	5.7
			High	140	7.2	17.2	57.5	14.7
	Uninoculated	Soluble	Recommended	80	5.3	37.8	37.5	10.6
			Alto	200	11.1	82.4	107.2	30.3
		Slow release	Recommended	44	3.1	11.6	23.3	5.7
			High	46	3.6	11.1	31.9	7.8
$DMS_{0.05}$				39	2.0	12.1	18.9	6.3

1/ Soluble sources: P = $NaH_2PO_4.H_2O$; K = K_2SO_4; Ca = Lime; Mg = $MgSO_4.7H_2O$.
Slow release sources: P = rock phosphate; K = feldespar; Ca = Lime; Mg = serpentine; S = Sulphur flower.

2/ Recommended Level (kg/ha): P = 20; K = 30; Ca = 100; Mg = 20; S = 38.
High level (kg/ha): P = 50; K = 60; Ca = 500; Mg = 40; S = 75.

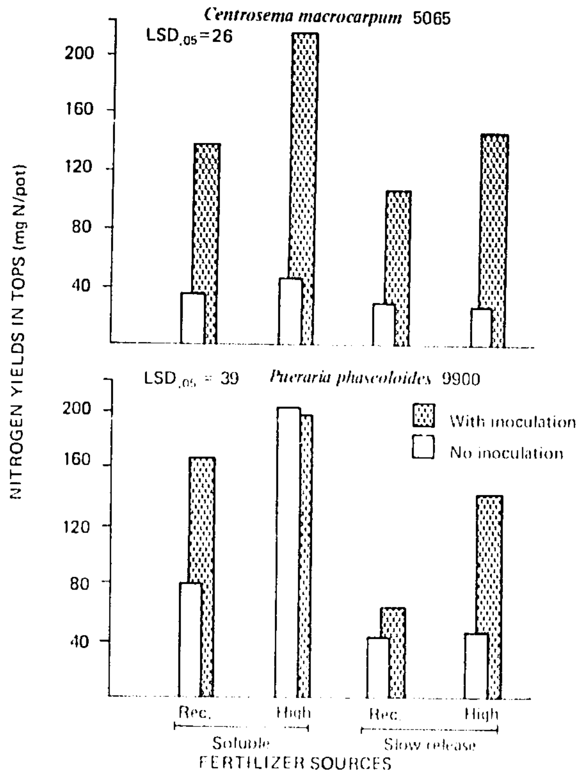


Figure 2. Effect of low and high rates of two fertilizer sources with and without Rhizobium inoculation on the nitrogen yields in tops of two tropical forage legumes.

Table 6. The accumulated dry matter production showed a small increase with the 2 kg Zn/ha rate, being Andropogon gayanus the grass with the highest increase (25%) in relation to the other grasses (10-15% increase). This result suggests that Zn begins to be required at low doses four years after its application. The dry matter production of the grasses did not showed residual effects due to the other micronutrients (Cu, B, Mn).

The results obtained at the Carimagua site cannot be generalized to all acid soils since a micronutrient response depends on the natural fertility of each soil (Annual Report, 1981).

The residual effect of a single micronutrient application was also studied with 2 forage legumes (Centrosema macrocarpum 5065 and Stylosanthes macrocephala 1643), which after the third year replaced those established originally in 1980. The lack of persistence of Stylosanthes capitata and Pueraria phaseoloides, a nematode infestation in Desmodium ovalifolium and Sphaceloma scab in Zornia latifolia were the reason why these species were replaced. Table 7 shows the residual effect of the micronutrients applied in 1980 on the dry matter production, tissue content and micronutrient extraction of the recently planted legumes.

The legumes showed a differential response to the residual fertilizer treatments. C. macrocarpum showed a considerable increase in dry matter production and tissue content to Zn at the 2 kg/ha rate. There was also an increase in dry matter production to the first rate of boron applied. Stylosanthes macrocephala showed a gradual increment in dry matter production with the residual Cu fertilization. However, this increment in production was independent of the Cu tissue content, which even without Cu fertilization was above a given critical level for forage legumes (4 ppm Cu).

These results suggest that the effect of a micronutrient application highly depends on the legumes being tested and also on the degree of interaction with each microelement.

MAINTENANCE FERTILIZER WITH POTASSIUM IN A MIXTURE OF A. GAYANUS AND S. CAPITATA

In the 1982 and 1983 Annual Report, results were presented on the initial performance of a mixture of A. gayanus 621 and S. capitata 1019, in response to 3 sources and 2 rates of P, with and without basic fertilization applied during the establishment period. After the second year of evaluation, this experiment was modified in order to study the maintenance fertilizer effects on the growth of seedlings from the first generation of S. capitata (Annual

Table 6. Effect of different fertilizer rates of micronutrients on the dry matter (DM) production in a four year period by several tropical forage grasses. Carimagua.

Micronutrient	Applied Rate	*A. gayanus* 621	*B. decumbens* 606	*B. brizantha* 665	*B. humidicola* 679
	kg/ha	(DM (t/ha/yrs)			
Zinc	0	33.9	21.8	22.5	23.0
	2.0	42.4	25.2	25.6	25.3
	4.0	30.2	23.5	21.0	23.3
	8.0	32.5	23.7	24.2	24.3
Copper	0	35.5	25.2	22.7	26.4
	1.0	31.5	22.5	23.6	24.0
	2.0	36.0	23.3	22.2	26.7
	4.0	35.2	22.8	22.1	22.9
Boron	0	33.8	23.2	24.7	23.6
	0.5	31.8	25.5	22.7	24.6
	1.0	32.5	23.4	24.7	25.3
	2.0	30.8	23.5	21.3	22.7
Manganese	0	35.3	25.3	26.0	27.3
	0.25	37.0	24.6	24.1	27.4
	0.50	34.6	21.5	21.7	25.8
	1.00	28.7	23.1	21.6	24.4

1/ With exception of the micronutrient under study, the other micronutrients were applied at the third rate described. Annual maintenance fertilization was 50 kg N/ha, 50 kg k/ha and 20 kg Mg/ha.

Table 7. The residual effect of applied micronutrients[1] on the dry matter production, tissue content and extraction in two tropical forage legumes, Carimagua, Colombia.

		C. macrocarpum 5065			S. macrocephala 1643		
			Micronutrient[3]			Micronutrient[3]	
Micronutrient	Applied Rate	Dry Matter[2]	Tissue content	Extraction	Dry Matter[2]	Tissue content	Extraction
	kg/ha	t/ha/year	ppm	g/ha	t/ha/year	ppm	g/ha
ZINC	0	0.9	29	20	5.5	50	25
	2.0	3.1	44	120	3.5	40	90
	4.0	2.2	37	80	5.3	59	270
	8.0	3.1	52	160	4.3	64	230
COPPER	0	2.3	9	200	3.3	10	210
	1.0	1.4	10	130	4.4	9	310
	2.0	1.9	10	140	5.0	10	420
	4.0	1.8	11	170	5.5	9	420
BORON	0	1.6	27	390	4.0	21	690
	0.5	3.2	26	770	4.0	26	800
	1.0	1.7	29	380	4.1	22	750
	2.0	1.6	27	390	4.4	18	540
MANGANESE	0	3.7	172	2830	3.3	158	3890
	0.05	3.6	157	5410	3.8	180	5350
	0.10	3.1	185	5460	3.6	162	4700
	0.20	1.8	152	4750	3.7	213	6100

1/ Micronutrients applied during 1980.
2/ Sum of 4 harvests.
3/ Mean of 3 harvests.

Report, 1983). During 1984, the effects of a maintenance fertilization with potassium on the growth of S. capitata seedlings (second generation) and also the performance of A. gayanus as the associated grass were further evaluated.

Without basic fertilization applied at the establishment period, the response of A. gayanus was only to the first rate of K (10 kg/ha), with no significant differences due to the residual P fertilization. On the contrary, the legume showed a low dry matter production which was associated with a lack of seedling vigor.

CONTRIBUTION OF PLANT RESIDUES TO NUTRIENT RECYCLING IN THE SYSTEM

One of the most important contribution to nutrient recycling in grazed tropical pastures is probably the plant residues which consists of fallen leaves and stems.

Keeping this in mind, the contribution of plant residues at the soil surface was evaluated in 4 tropical pastures, all previously established more than 2 years before in Carimagua. These pastures were (1) Andropogon gayanus + Pueraria phaseoloides; (2) Brachiaria decumbens + Pueraria phaseoloides; (3) Andropogon gayanus + Desmodium ovalifolium; and (4) Brachiaria humidicola + Desmodium ovalifolium.

Four permanent sampling areas (40 x 40 cm) were selected on each pasture in areas which represented as much as possible the pasture variability. The initial plant residues present on the soil surface were removed and separated into its components (leaves and stems of grasses and legumes). The same sites were then sampled every 3 weeks for the litter present without determining individual components. All samples were dried and analyzed for N, P, K, Ca, Mg and S.

The differential nutrient contribution from plant residues in the 4 associated pastures are presented in Figures 3 and 4. In general, litter accumulates during the dry season and a fast decomposition of plant residues takes place in the rainy season with a consequent nutrient release, which is available for plant growth. Significant differences in the amount of nutrients in the residues were encountered. Pastures with P. phaseoloides in the mixture showed the biggest contributions in terms of N, S, K and Mg which had an inverse correlation with the rainfall distribution. In contrast, pastures with Desmodium ovalifolium in the mixture presented a lower nutrient contribution. Associations with P. phaseoloides presented cycles of litter accumulation and decomposition inversely proportional with the rainfall.

The annual production of the plant residues in the 4 associated pastures is presented in Table 8. These results suggest that there is a considerable amount of nutrients returned to the ground and especially N and Ca, followed by K, Mg, S and finally P. If these values are compared with those in the body of a live animal and also with those extracted in the final product (meat) (Figure 5), it appears that the nutrient extraction by the animal is low.

In general, the results also suggest that during the pastures management it is important to maintain a stable biomass production in order to have a constant return of plant residues, which may partially compensate the nutrient extractions by the animals and therefore reducing the maintenance fertilization.

NATURAL ROCKS AS ALTERNTIVE SOURCES OF FERTILIZERS FOR MARGINAL ACID SOILS

The Soil/Plant Nutrition Section during this year has carried out

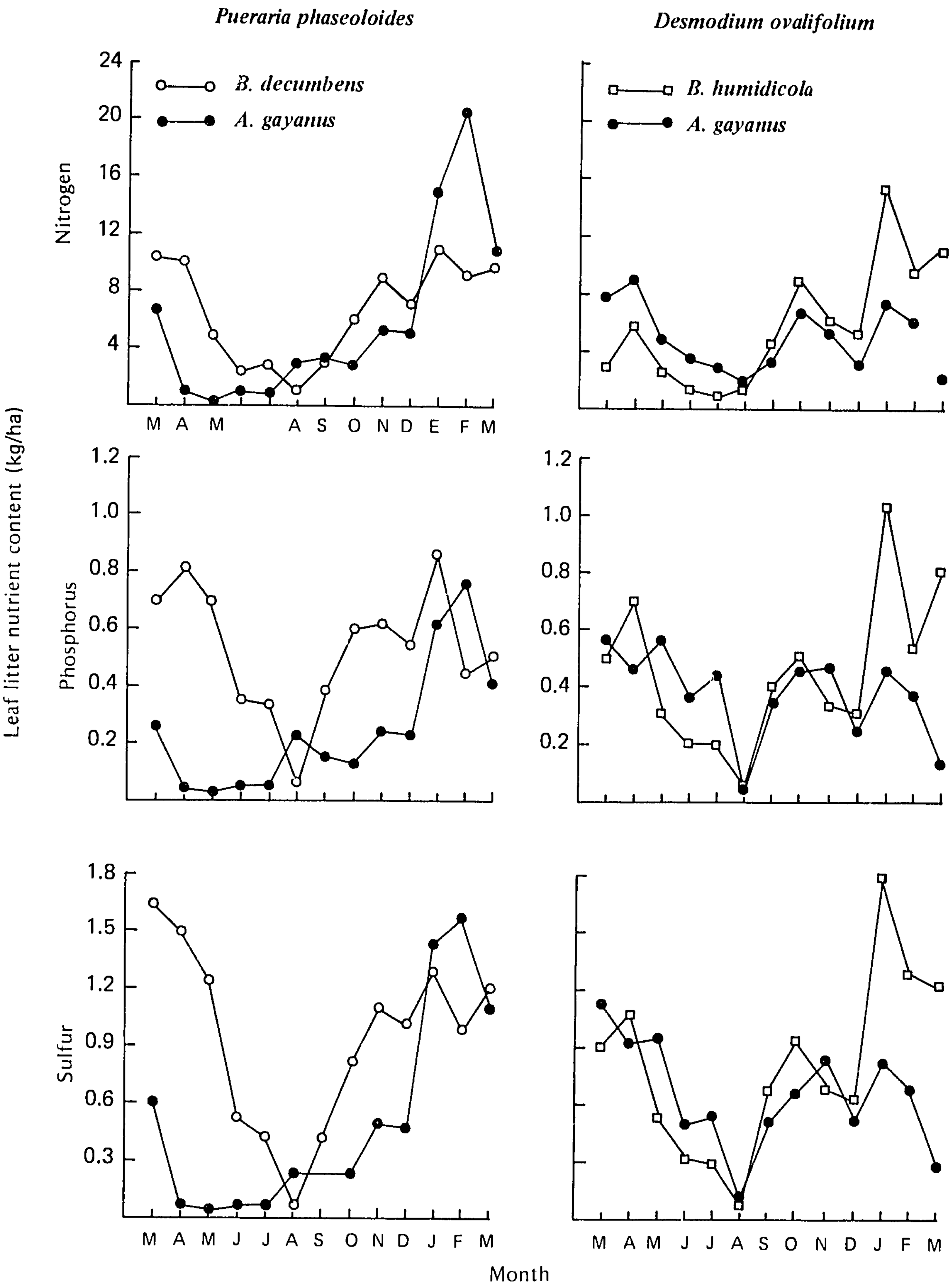


Figure 3. Contribution of N, P and S by the leaf litter (0-3 cm depth) in four different grass-legume association, under grazing condition, Carimagua.

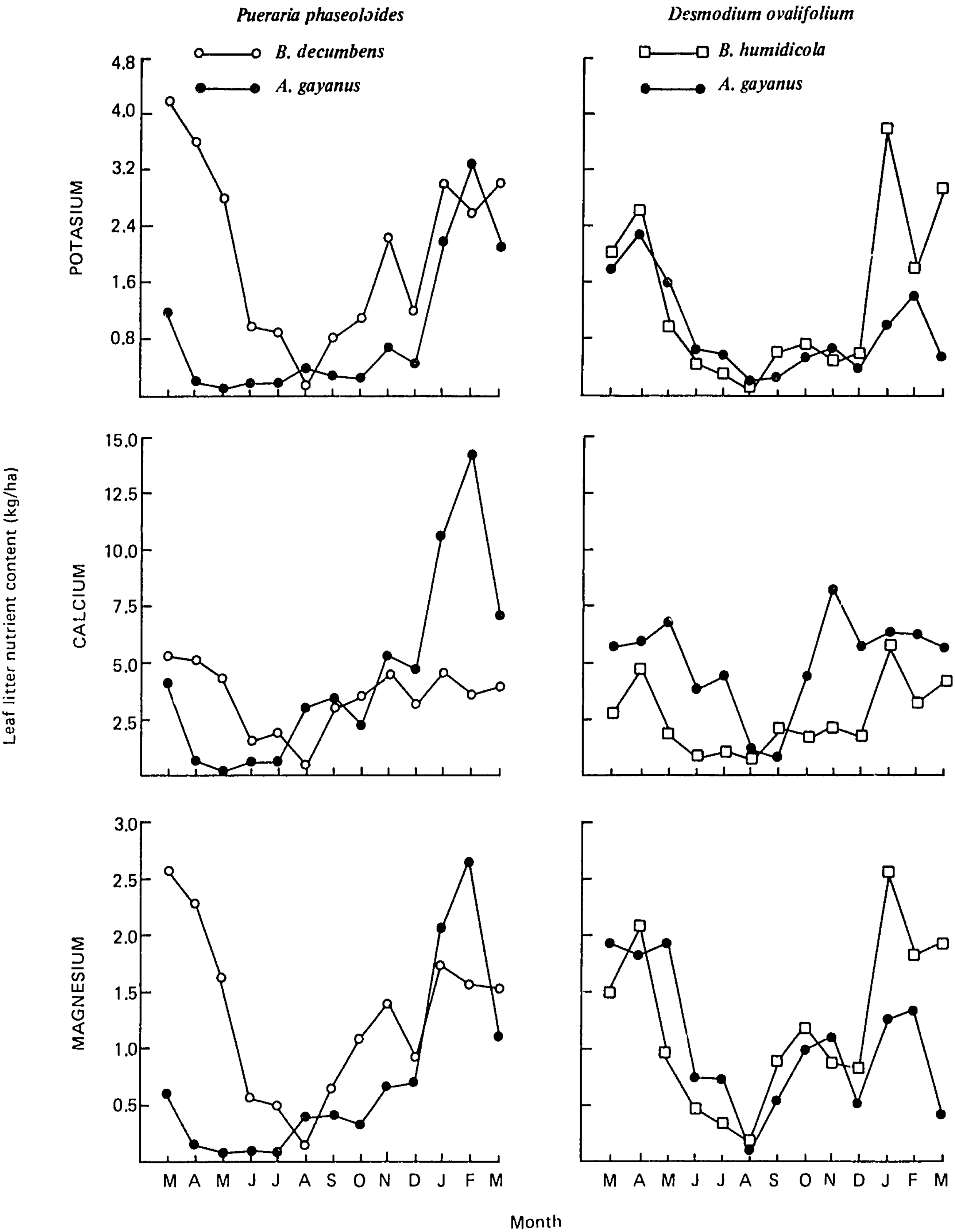


Figure 4. Contribution of K, Ca, and Mg by the leaf litter (0-3 cm depth) in four different grass-legume associations, under grazing conditions. Carimagua. First month March.

Table 8. Annual litter production and annual nutrient supply in 4 associated pastures under continuous grazing. Carimagua, Colombia.

Association	Litter production	Macronutrients					
		N	P	K	Ca	Mg	S
	kg/ha/year						
P. phaseoloides - A. gayanus	3562	77.5	3.3	12.1	59.5	9.9	6.8
P. phaseoloides - B. decumbens	7085	86.6	6.9	26.5	46.2	16.6	12.3
D. ovalifolium - A. gayanus	7537	60.3	4.9	11.8	59.8	13.5	8.3
D. ovalifolium - B. humidicola	7014	78.3	6.1	17.8	32.9	15.3	10.9

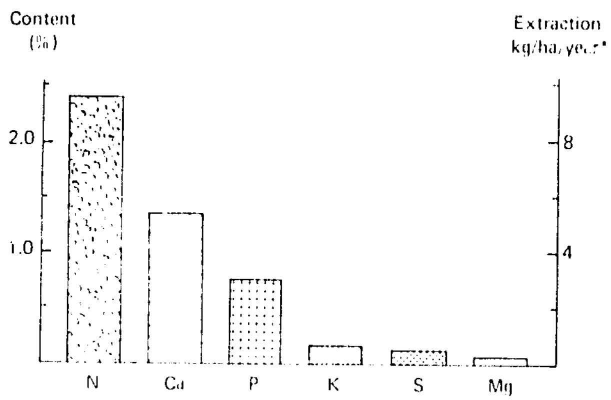


Figure 5. The tissue mineral content of live cattle and the animal removal in the beef product.

* Based in the production of 400 kg of liveweight/ha/year.

research with natural rocks relating to (1) development of analytical methods, (2) chemistry of acid soils, and (3) agronomic trials. The objective of this research has been to study the effects of mixtures of different rocks and their interactions between themselves and with the soil minerals. These studies have been also used to carry out integrated research with soil microbiology.

Simplified method for total K analysis in Potassium Feldpars

The method of fusion of potassium feldspars at 1000°C in the presence of Na_2CO_3 used in the preliminary determinations, is a precise method but implies high costs and very long times for analysis. The most important simplified way that has been adapted during this year for total potassium determination in feldspars is to disolve the rock with cold 40% HF in plastic containers during 24 hours. Afterwards, potassium is determined directly in a dilution of the product of such disolution. Table 9 shows results of the analysis of several feldspars from the Department of Huila (Colombia), where it can be seen the similarity and greater effectivity of the simplified new method in comparison with the one used

Table 9. Total K determination in K-feldspar.

K-Feldespar	Fusion (1000°C) in the presence of Na_2Ca_3	Cold attack with HF (40%)
	% K	
Moyita blanca	4.1	5.1
Ospina Pérez	4.5	5.4
Río I	8.4	8.3
Río II	7.7	7.7
Río III	12.4	12.2
Moyita amarilla I	2.8	3.5

before, as well as the quality of some of the materials collected and studied during this year.

The assessment of the different forms of potassium in soils of the Eastern Plains of Colombia

The complexity of the responses to applied potassium to the soil in a soluble or a slowly soluble way has made necessary a detailed study of the different forms of potassium in soils of the Eastern Plains of Colombia. The purpose is understanding of the dynamics that such element follows in the soil, and thus, to clarify the type of obtained responses.

Total potassium in the soil

For this determination it was used the same method as for the total potassium in K-feldspars (cold 40% HF). The obtained data (Table 10) show variability between sites and indicate the possible presence of soil minerals of the 2:1 type containing potassium.

Exchangeable potassium and potassium in the soil solution

Exchangeable potassium and potassium in the soil solution were analyzed by the 0.01 molar calcium chloride method (0.01M $CaCl_2 2H_2O$) and in a similar way as with the total potassium, the results (Table 10) vary greatly between the different sites tested.

Potassium fixation in the soil

Known amounts of soluble K were added to the soil and after some reaction time (wet fixation) or after drying (dry fixation), using as extractant magnesium acetate (0.25 M $(CH_3COO)_2Mg.4H_2O$) exchangeable K was determined. In general terms, all the studied soils fixed 50% of the soluble K added (1000 ppm K) (Table 10). This fixation indicates even more the presence of 2:1 potassium fixing minerals in the studied soils. This point above agrees with the mineralogical studies carried out by Reading University (England) and Hokkaido University (Japan), where the presence of some interstratified mica-smectite and a common occurrence of vermiculite are respectively reported.

At present, methods are being tested with the purpose of making sure of this potassium fixation, and to avoid the slightest possibility of any chemical interference affecting the carried out determinations. This fixing potassium capacity opens new possibilities in the low input technology when related to the use of slow solubility sources such as potassium feldspars in relation to soluble sources.

Several experiments were carried out in order to predict the nutrient release and the residual effects of

Table 10. Different forms of potassium in Carimagua and Guayabal soil.

Site	Total K (HF in cold)	Exch.-K $CaCl_2$ 0.01M	K in the soil Solution $CaCl_2$ 0.01M	Fixed-K* $(CH_3COO)_2 Mg4H_2O)$	Capacity of supply Exch.K/K in the soil solution
	K ppm				
Reserva	2.785	55	20	490	2.75
Alegría	959	23	21	445	1.09
Guayabal	2.690	60	25	505	2.40

* Per each 1,000 ppm of soluble K added.

rocks either alone or in mixtures, when they were previously calcinated or acidulated. Interesting and complex interactions between rock mixtures and treatments were observed in reference to P extraction from rock phosphate and K extractions from K-feldspars. Thus, the need from agronomic trials.

Agronomic studies

The evaluation of K-feldspars continued during 1984. The objective of the trials has been to observe the initial and residual effects of K-rocks in different soils. Also, to determine how the different elements of a rock mixture affect the production of grasses and legumes in pure stands and in association. Due to the brief evaluation period, only partial results are presented here.

At Carimagua, a field trial was established using K-feldspars and Mg-serpentine as fertilizer sources, including as control several treatments with soluble fertilizers (KCl, MgO). The effect of these sources and the different rates was evaluated using Brachiaria decumbens in pure stands and in association with Pueraria phaseoloides.

The dry matter productions during the first year (establishment phase) are shown in Table 11. Potassium and Mg extraction rates are shown in Tables 12 and 13, respectively. An interaction K - Mg with the slow release and the soluble sources was observed in the dry matter production of B. decumbens.

The greatest dry matter production were achieved with the highest rates of K and Mg with the slow release sources (20-40 kg of Mg and 40-80 kg of K). Similar dry matter production were obtained with the soluble fertilizers with 10 kg of Mg and 20 kg of K/ha. It is expected that with time the slow release sources will maintain or improve actual production levels.

The K and Mg extraction rates with the higher rates of soluble fertilizers were 25% higher for K and 80% higher for Mg as compared to the extractions at the higher rates of the slow release fertilizers. Consequently, it is expected that the benefit of the slow release fertilizers, applied at higher rates will be to supply adequate quantities of K and Mg over extended periods of time avoiding luxury consumption. At the same time slow release fertilizers would reduce leaching, especially K.

With the association B. decumbens and P. phaseoloides, the higher dry matter productions were obtained with lower rates of slow release fertilizers (10 kg/ha of K and Mg) than that needed in a pure stand. The response of the association to lower rates of K and Mg is possibly related to a better nutritional balance. Similar situations have been reported for other grass-legume associations (Hall, 1974).

Keeping in mind the long term effects of the slow release fertilizers, the fourthcoming evaluations will bring a better understanding on the dynamics of these elements in the soil-plant system.

Hall, R. L. 1974. Aust. J. Agric. Res. 25: 749-756.

Table 11. Dry matter produced by B. decumbens 606 when fertilized with K and Mg from soluble and slow release sources. Carimagua, Colombia.

Applied Mg	Slow release fertilizer[1] K (kg/ha)						Soluble fertilizer[2] K (kg/ha)			
	0	10	20	40	80	X	0	10	20	X
(kg/ha)	Dry matter (t/ha)[3]									
1. B. decumbens										
0	4.8	5.1	4.5	4.2	5.5	4.8	4.8	5.4	-	5.1
10	5.2	4.3	4.5	5.2	5.1	4.9	5.4	5.7	6.2	5.8
20	5.4	5.2	4.5	5.3	5.8	5.2	-	5.5	-	5.5
40	4.7	5.0	5.2	6.6	5.9	5.5	-	-	-	
X	5.0	4.9	4.7	5.3	5.6		5.1	5.5	6.2	
$DMS_{0.05}$ = 1.1 t/ha							$DMS_{0.05}$ = 1.7 t/ha			
2. B. decumbens x P. phaseolcides										
0	5.5	5.3	5.7	6.2	5.7	5.7	5.5	5.7	-	5.6
10	5.5	6.2	5.0	5.6	5.6	5.6	5.4	6.4	5.8	5.9
20	5.2	6.1	5.8	5.7	5.8	5.7	-	6.3	-	6.3
40	5.1	5.7	5.0	5.7	5.3	5.4	-	-	-	
X	5.4	5.8	5.4	5.8	5.6		5.5	6.1	5.8	
$DMS_{0.05}$ = 1.11 t/ha							$DMS_{0.05}$ = 1.1 t/ha			

1/ Serpentine, 15% Mg, K-feldspar, 8% K.
2/ MgO, 43% Mg; KCl, 50% K, used as controls.
3/ Sum of 5 cuts.

Table 12. Potassium extracted by *B. decumbens* 606 when fertilized with K and Mg from soluble and slow release sources. Carimagua.

Applied Mg (kg/ha)	Slow release fertilizer[1] K (kg/ha) 0	10	20	40	80	X	Soluble fertilizer[2] K (kg/ha) 0	10	20	X
	Ext. K kg/ha/year[3]									
1. *B. decumbens*										
0	25.9	30.0	27.0	25.6	27.9	27.3	25.9	32.2	-	29.1
10	30.2	24.9	27.0	26.3	29.1	27.5	34.3	41.0	46.8	40.7
20	37.2	31.1	26.3	32.8	37.8	33.1	-	36.1	-	36.1
40	26.6	31.5	35.0	39.5	36.5	33.8	-	-	-	
X	30.0	29.4	28.9	31.0	32.8		30.1	36.4	46.8	
$LSD_{0.05}$ = 6.8 kg/ha							$LSD_{0.05}$ = 12.3 kg/ha			
2. *B. decumbens* x *P. phaseoloides*										
0	35.7	28.1	30.0	28.4	29.2	30.6	35.7	39.3	-	37.5
10	30.6	34.6	27.9	31.8	30.6	31.1	26.3	36.9	38.4	33.9
20	27.9	31.8	31.0	34.1	37.4	32.4	-	42.0	-	42.0
40	29.0	32.3	25.1	30.9	32.7	30.0	-	-	-	
X	31.2	31.7	28.5	31.3	32.5		31.0	39.4	38.4	
$LSD_{0.05}$ = 7.4 kg/ha							$LSD_{0.05}$ = 8.8 kg/ha			

1/ Serpentine, 15% Mg, K-feldspar, 8% K.
2/ MgO, 43% Mg; KCl, 50% K, used as controls.
3/ Sum of 4 cuts.

Table 13. Magnesium extracted by B. decumbens 606 when fertilized with K and Mg from soluble and slow release sources. Carimagua.

Applied Mg	Slow release fertilizer[1] (K kg/ha)						Soluble fertilizer[2] (K kg/ha)			
	0	10	20	40	80	X	0	10	20	X
(kg/ha)	Ext. Mg kg/ha/year[3]									
1. B. decumbens										
0	8.7	7.9	7.5	6.4	8.3	7.8	8.7	12.8	-	10.8
10	9.1	6.4	7.8	14.9	8.2	9.3	14.4	16.8	19.5	16.9
20	9.7	8.9	7.9	10.9	9.2	9.5	-	23.9	-	23.9
40	8.8	8.1	10.4	11.6	11.6	10.0	-	-	-	
X	9.1	7.8	8.4	11.0	9.4		11.6	17.8	19.5	
$LSD_{0.05}$ = 2.2 kg/ha							$LSD_{0.05}$ = 6.6 kg/ha			
2. B. decumbens x P. phaseoloides										
0	7.8	8.5	9.2	9.9	8.5	8.9	7.8	9.2	-	8.5
10	9.0	11.6	7.6	8.6	8.8	9.1	18.5	18.2	18.2	18.2
20	8.6	10.1	9.5	8.9	8.9	9.4	-	23.4	-	23.4
40	9.0	10.4	8.1	10.2	9.7	9.5	-	-	-	
X	8.7	10.2	8.6	9.4	9.2		13.2	16.7	18.0	
$LSD_{0.05}$ = 2.0 kg/ha							$LSD_{0.05}$ = 3.9 kg/ha			

1/ Serpentine, 15% Mg; K-feldspar, 8% K.
2/ MgO, 43% Mg; KCl, 50% K, used as controls.
3/ Sum of 4 cuts.

SOIL MICROBIOLOGY

An understanding of the soil-plant-microorganism interactions which occur in tropical pastures is an essential part of the germplasm evaluation process. It is necessary to obtain a good basis of information on nutrient uptake by germplasm in response to fertilization and in the presence or absence of inoculated microorganisms in different soil types and in different grass-legume combinations in order to be able to select the most adapted germplasm and appropriate management packages in the different ecosystems the program is working in. Thus the Soil Microbiology and Soil Fertility and Plant Nutrition Sections are undertaking studies which are closely related to each other, since the overall objective is to optimize production through adequate plant nutrition, both at establishment and in grazed pastures.

Most of the results reported in these two chapters are specifically related to Rhizobium, mycorrhizal or fertilization responses. However, this year results of studies on interactions between these aspects of plant nutrition are also presented. This reflects the recognition of the need to study such interactions in order to improve management recommendations, and that future studies on nutrient recycling in tropical pastures will also need an integrated approach.

CHARACTERIZATION OF COLONY FORM OF RHIZOBIUM STRAINS

It has been observed that the official description (published in Bergey's Manual) of the genus Rhizobium does not include all the variability observed in the strains in the CIAT Rhizobium germplasm bank. An attempt was therefore made to categorize the collection according to some easily recognizable criteria. Colony characteristics of slow-growing, alkali-producing rhizobia grown on yeast mannitol agar at initial pH 5.5 and 6.8 were examined. Five types of growth were defined (V, W, X, Y and Z; Figure 1). Type V scarcely grows at pH 6.8, grows slowly at pH 5.5 and is relatively rare in the collection. The reverse situation (growth at pH 6.8 and not at 5.5) was not observed as a constant characteristic of any strain. Type W is typical of the description given for slow-growing, alkali-producing rhizobia in the new edition of Bergey's Manual (1984) which have been reclassified as Bradyrhizobium. However, this growth type was not very common in the strains we examined. Types X, Y and Z, which give translucent growth, form larger colonies, and often contain small-colony variants were the commonest growth types observed. Type X shows gelatinous growth, and types Y and Z aqueous or "wet" growth. Strains of type Z normally show completely different growth characteristics at the two pHs used. Small, opaque, "dry" colonies are formed on medium of initial pH 6.8, and large, translucent translucent, "wet" colonies are formed at initial pH 5.5. However, some strains of this type occasionally do show "wet" growth at pH 6.8. We

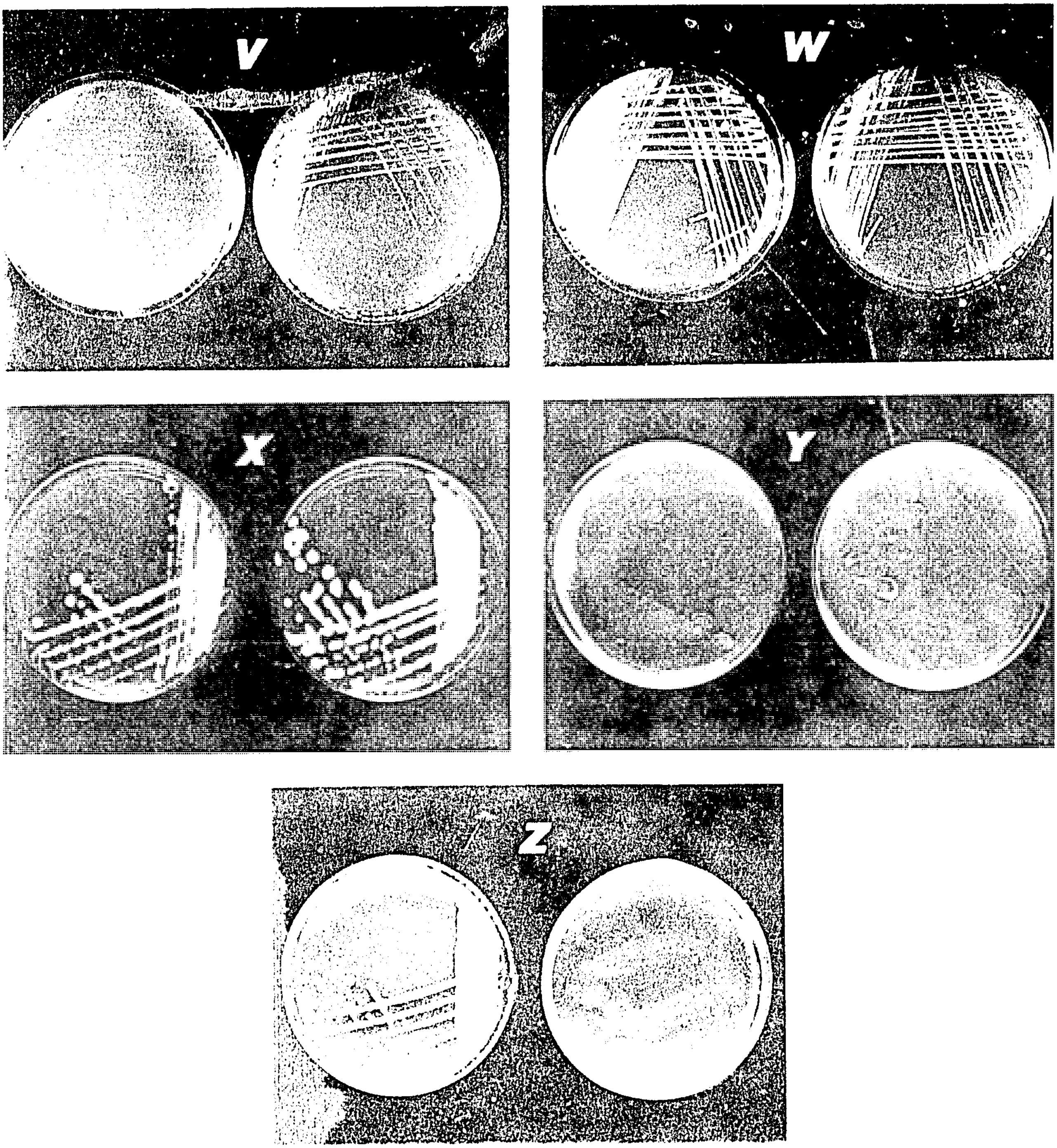


Figure 1. Colony types of five groups of slow-growing, alkali-producing rhizobia on yeast mannitol agar medium at pH 6.8 (left) and 5.5 (right).

therefore consider type Z to be a sub-group of type Y, where growth is consistently "wet" at both pHs.

These groups may be useful to microbiologists working with tropical forage legume rhizobia which have been studied far less intensively than other groups of rhizobia and may contain more genetic variability than has previously been recognized.

SEROGROUPS OF RECOMMENDED *RHIZOBIUM* STRAINS

Groups of effective strains for each genus are being typed serologically by immunodiffusion in order to avoid the possibility that genetically identical strains are being compared with each other in field trials. Table 1 shows that for each genus investigated so far, the selected strains fell into at least two serogroups. However, it can be seen that the majority of strains effective on *Centrosema* fell into one group and all three effective *Pueraria* strains (2434, 2453, 3221) fell into one group. On the other hand, these effective *Pueraria* strains are different from CIAT 79 (CB 756) which is the strain which has been widely recommended for inoculation of *Pueraria* and other legumes of the "cowpea" group. Unfortunately CB 756 has not been effective in our strain screening trials on *P. phaseoloides* in acid soil.

This study emphasizes the need to demonstrate that strains included in new screening trials are serologically different from currently recommended strains.

COMPUTERIZED *RHIZOBIUM* STRAIN CATALOG

In the computerized catalog of the complete collection of 2,850 isolates available information on colony type (V, W, X, Y and Z) and the origin of each isolate is recorded. The information can be retrieved by the users for any group of rhizobia desired. A summary of the detailed information shows the number of isolates for each genus, species, nodule collector and/or laboratory of origin, and country of origin, and is being circulated to facilitate the use of the catalog by interested scientists. In addition, all the results of the strain screening trials in soil cores and in the field since 1980 are incorporated in a catalog of "evaluated strains", including information on the effect of each strain on total N in the tops (N yield) of each legume

Table 1. Serogroups of effective *Rhizobium* strains.

Centrosema	
I	1670, 3334, 3196, 2380, 590, 2290, 3024, 2385, 2348, 3459
II	1780, 594
III	2287
IV	49, 3664
V	3111
Pueraria	
I	2434, 2453, 3221
II	79, 7, 81, 859, 3338
Desmodium	
I	3143
II	1502
III	2335
IV	2469, 2459, 2470
Stylosanthes	
I	1460
II	71

tested. Strains showing significant increases in N yield as compared with the uninoculated control (i.e. the native strains) are classed as 'B' (good) and 'E' (excellent), where 'E' represents more than a 2-fold increase in N yield. Strains classed as 'R' (moderate) and 'M' (negative) show no significant difference or a negative significant difference (i.e. 'M' strains are parasitic), respectively. Of 602 strain evaluations in different experiments and legumes, 132 (22%) were classified as 'B' or 'E'. The highest proportion of 'B' and 'E' strains occurred in trials with C. pubescens 438, C. macrocarpum 5065, Centrosema sp. 5112, D. canum 13032, D. heterophyllum 349 and P. phaseoloides 9900. Some of the other legumes tested (C. brasilianum 5234, C. macrocarpum 5062, D. heterocarpon 365, D. ovalifolium 350, 3666 and 3784, D. canum 3005, S. capitata 1315 and 1019), responded significantly to a very small proportion of the strains tested, and others (Centrosema sp. 5277, D. heterocarpon 3787, S. capitata 10280) gave no positive responses to inoculation even though growth was stimulated significantly by N fertilization. S. capitata 10280 ('Capica') showed very high variability in the strain screening trial; perhaps due to its heterogeneous composition. Each ecotype of which 'Capica' is composed should be tested separately. One effective strain for all five ecotypes would be ideal.

The lack of response of some legumes to inoculation, even though N fertilizer stimulates growth, may be due to their sensitivity to nutritional or physical limitations in the soil cores, or because their N_2-fixing potential is not as high as that of other ecotypes or species.

S. guianensis 1283 showed no significant response to inoculation or N fertilization, which indicates that it nodulates effectively with native strains in Carimagua soil.

Further screening under a range of growth conditions is required in order to obtain groups of effective strains for each promising legume which can then be used in collaborative trials with national institutes. Potential collaborators in an international network of Rhizobium screening trials for tropical forage legumes have been identified in Brazil, Venezuela, Peru and Bolivia. Central American and Caribbean countries will also be included.

The number of strains requested by national institutes has increased markedly over the last year, including a number of requests from Africa, where positive responses of S. capitata to inoculation have been reported.

The strain catalog and the most recent list of promising strains can be obtained on request from the Soil Microbiology Section. The current list of promising strains is shown in Table 2.

STUDY OF NUTRITIONAL FACTORS AFFECTING N_2 FIXATION

It is necessary to determine nutritional levels at which N_2 fixation becomes limited (i.e. "critical levels" for N_2 fixation) and whether different levels of certain nutrients affect the efficiency of native strains or the ability of the legume to respond to inoculation. In pot experiments nutrient levels often become deficient much more rapidly than in the field. Some preliminary studies have shown that higher rates of P application than those normally used in the strain screening trials in soil cores (25 kg P/ha) stimulated growth, N uptake and nodulation of 4 inoculated legumes, especially P. phaseoloides and C. macrocarpum (Figure 2, Table 3).

Table 2. Rhizobium strains with potential for use as inoculants on tropical forage legumes, selected on the basis of N yield data and other criteria.

Legume	Strain No.
Centrosema brasilianum 5234	1670*, 3334
C. macrocarpum 5062	3101*, 3111, 3196
C. macrocarpum 5065	590, 1670*, 1780*, 2290, 3101, 3174, 3196, 3334
C. sp. 5112	49, 590, 1670*, 1780*, 2290, 3101, 3694, 3714
C. sp. 5277	3714*, 3101*
C. hybrid 5931	3111, 3196, 2348, 3334*
C. pubescens 438	1670*, 49, 1780*, 590
Desmodium heterophyllum 349	2469*
D ovalifolium 350	46, 2335*, 3143
D. ovalifolium 3666	2335*, 2469*, 3418*
D. ovalifolium 3784	2335*, 2469*, 2413, 3418*
D. heterocarpon 365	3418*
D. canum 3005	1502*
D. canum 13032	1502*, 2372, 2383, 2487, 3030
Pueraria phaseoloides 9900	2434*, 2453, 3221, 643
Stylosanthes capitata	1460, 2138*, 995*, 2400, 2403, 308, 2265, 870*, 3232

* Strains currently recommended for inoculation singly or in mixture.

However, the levels of nutrients in the plant tissue, even at the higher rates of P application, were low (Table 4). It can be seen that K and Ca levels were well below the "critical levels" defined for these plants. With higher levels of these two nutrients, it is possible that even higher responses to P would be observed.

Figure 3 shows the relationship between %P in the leaf tissue of the four legumes and the acetylene reduction rates associated with the roots. Although acetylene reduction rates are not an absolute measure of N_2 fixation, it can been seen that C. macrocarpum and D. ovalifolium reduced more acetylene at lower P levels than the other two legumes. C. macrocarpum and P. phaseoloides were very responsive to higher P levels. Acetylene reduction rates shown by S. capitata were very low.

The rates observed may change in response to levels of other nutrients or other factors such as water availability.

Since mineral N is unlikely to be available to legumes growing in the field in mixed stands, it seems important to evaluate their nutrient requirements under N-limited conditions. Thus experiments carried out in soil cores where tissue nutrient levels are related to growth and N_2 fixation parameters could be a useful way to compare the nutrient requirements of different legumes.

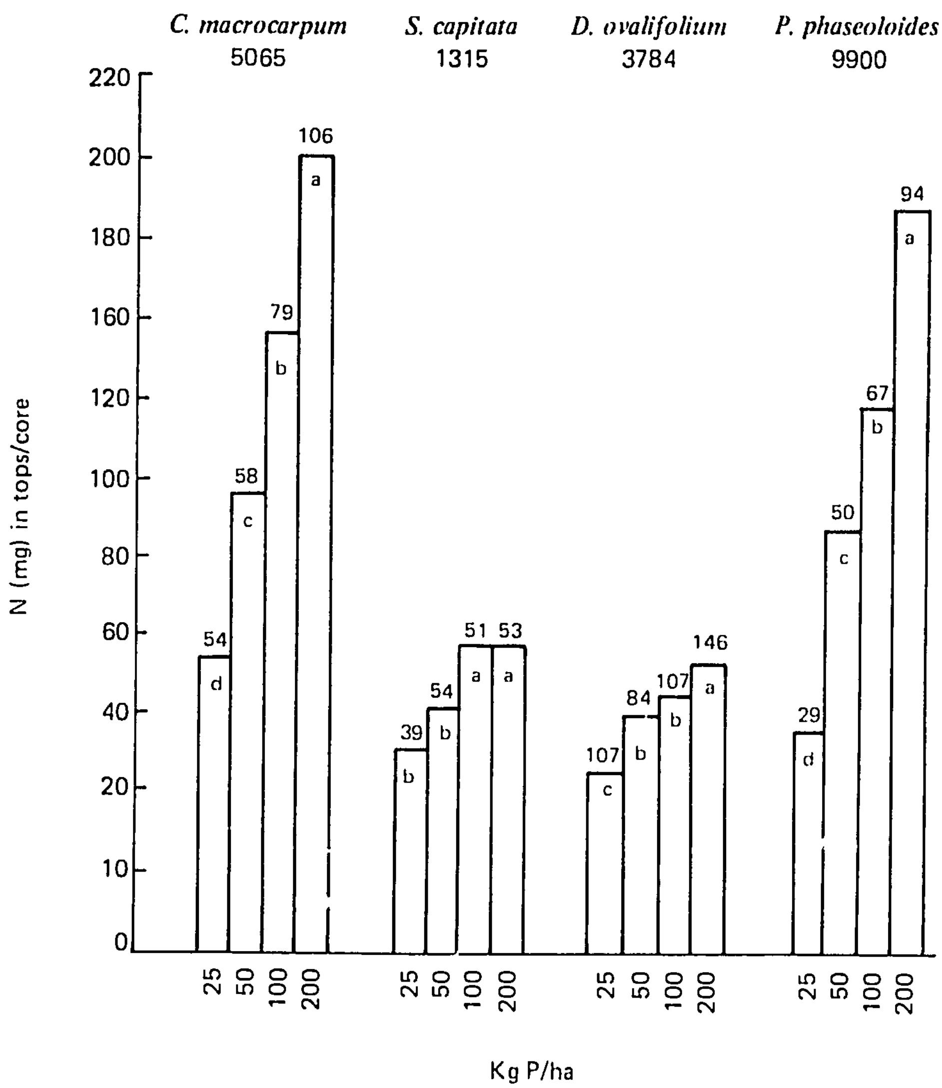


Figure 2. Effect of levels of P on N yield and number of nodules/core (numbers above bars) in cores of 2 Carimagua soils.

Table 3. Dry matter (g/core) production of four inoculated legumes grown in soil cores at 4 P levels (letters indicate significant differences within legumes only).

	kg P/ha			
	25	50	100	200
C. macrocarpum 5065	3.13 a	4.45 b	6.27 c	6.77 c
S. capitata 1315	2.07 a	2.24 ab	2.80 c	2.66 bc
D. ovalifolium 3784	2.13 a	2.59 ab	2.97 bc	3.37 c
P. phaseoloides 9900	2.34 a	4.06 b	4.47 b	5.04 c

Table 4. P, K and Ca levels in tops with applications of different P levels, 40 kg K_2O/ha and 128 kg Ca/ha levels in cores of 2 Carimagua soils (mean of Réserva and Rincon) after 12 weeks of growth.

		kg P/ha applied				
Legume	Element	25	50	100	200	'Critical level'*
C. macrocarpum 5065	%P	0.10	0.13	0.13	0.19	0.16
	%K	0.79	0.67	0.54	0.66	1.24
	%Ca	0.18	0.21	0.17	0.20	0.72
S. capitata 1315	%P	0.11	0.16	0.20	0.29	0.18
	%K	1.07	0.92	0.84	0.90	1.18
	%Ca	0.26	0.28	0.27	0.28	0.73
D. ovalifolium 3784	%P	0.10	0.14	0.14	0.17	0.10
	%K	0.83	0.81	0.69	0.67	1.03
	%Ca	0.19	0.17	0.17	0.16	0.74
P. phaseoloides 9900	%P	0.11	0.14	0.17	0.21	0.22
	%K	0.91	0.65	0.51	0.50	1.22
	%Ca	0.20	0.18	0.19	0.18	1.04

* Critical levels from Annual Report 1981.

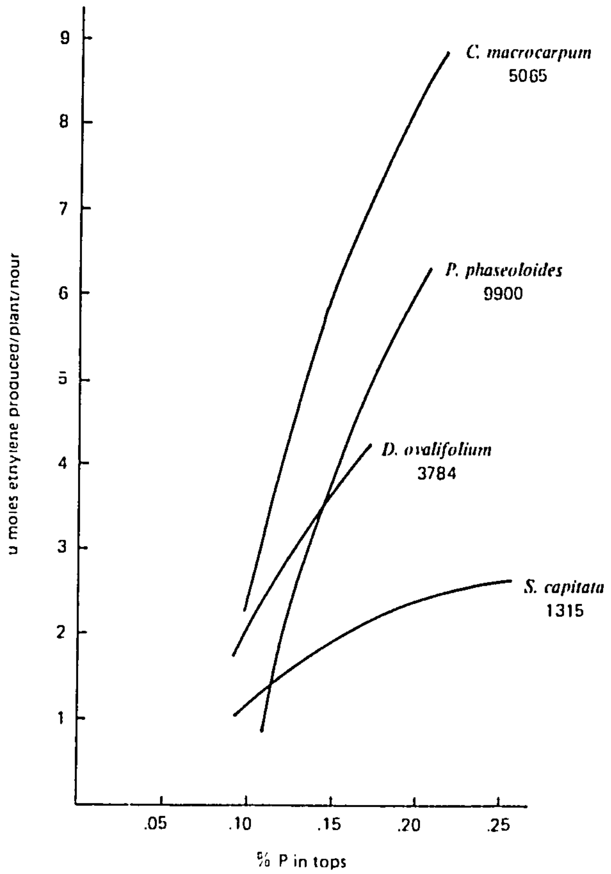


Figure 3. Acetylene reduction rates as affected b P content in tops of 4 forage legumes.

Such data could contribute to the evaluation of the N_2-fixing status of legumes in the field.

It is also important to determine whether different fertility levels affect relative strain efficiency and whether in more fertile soils the relative efficiency of native and inoculated strains changes.

EFFECT OF TILLAGE ON <u>RHIZOBIUM</u> INOCULATION RESPONSE

Results reported in previous years have shown that tillage stimulates nitrification in Carimagua soil. This may be advantageous or disadvantageous depending on whether the NO_3^- flush is taken up by plants or lost by leaching. Reduced tillage methods may may help to preserve soil organic N by reducing the size of the flush and maintaining a continuous plant cover on the soil surface. With reduced tillage establishment legumes may be more dependent on biologically fixed N_2 than with conventional tillage, if this results in more mineral N being available for legume growth. An experiment was carried out comparing inoculation response of two legumes established by conventional and reduced tillage at three sites at Carimagua. It was found that for both legumes the inoculation response was greater with reduced tillage than conventional tillage, and this effect was more marked in the soil with the highest organic N content (Table 5). However, with both tillage treatments there was an inoculation response.

It can be seen that at site 2 the inoculation response was greater than at the other sites even with conventional tillage, which is surprizing as the soil contains more N than at Site 1. However, the smaller response at Site 1 may have been due to limitation by other nutrients since leaching rates are likely to be higher in this very sandy soil.

<u>RHIZOBIUM</u> STRAIN TRIALS IN THE FIELD

Strain trials were carried out in the field at 4 sites in Colombia using reduced tillage establishment, assuming that tillage treatment is unlikely to affect differences between strains.

At Villavicencio and Puerto López the experiments were carried out in collaboration with the seed firms Gramicol and Semillano respectively, and their purpose was partially to demonstrate the importance of inoculation to the seed producers who could play an significant role in supplying inoculants to farmers who are establishing legume - based pastures. Figure 4 shows that at Puerto López

Table 5. Analysis of inoculation response as affected by land preparation during establishment (kg N/ha produced in 3 cuts) in C. macrocarpum and P. phaseoloides. (Different letters represent differences between paired treatments only).

Treatment	Inoculation Effectivity Index *			
	Analysis for individual sites			Analysis across sites
	Site 1 (448 ppm N)	Site 2 (952 ppm N)	Site 3 (1176 ppm N)	
Reduced tillage	69.8 a	37.4 a	54.3 a	53.8 a
Conventional tillage	70.6 a	47.2 a	81.3 b	66.4 b
C. macrocarpum	65.5 a	21.6 a	53.7 a	46.9 a
P. phaseoloides	74.8 a	63.0 b	82.0 b	73.3 b

$$\text{* Inoculation Effectivity Index} = \frac{\text{N yield uninoculated treatment}}{\text{N yield inoculated treatment}} \times 100$$

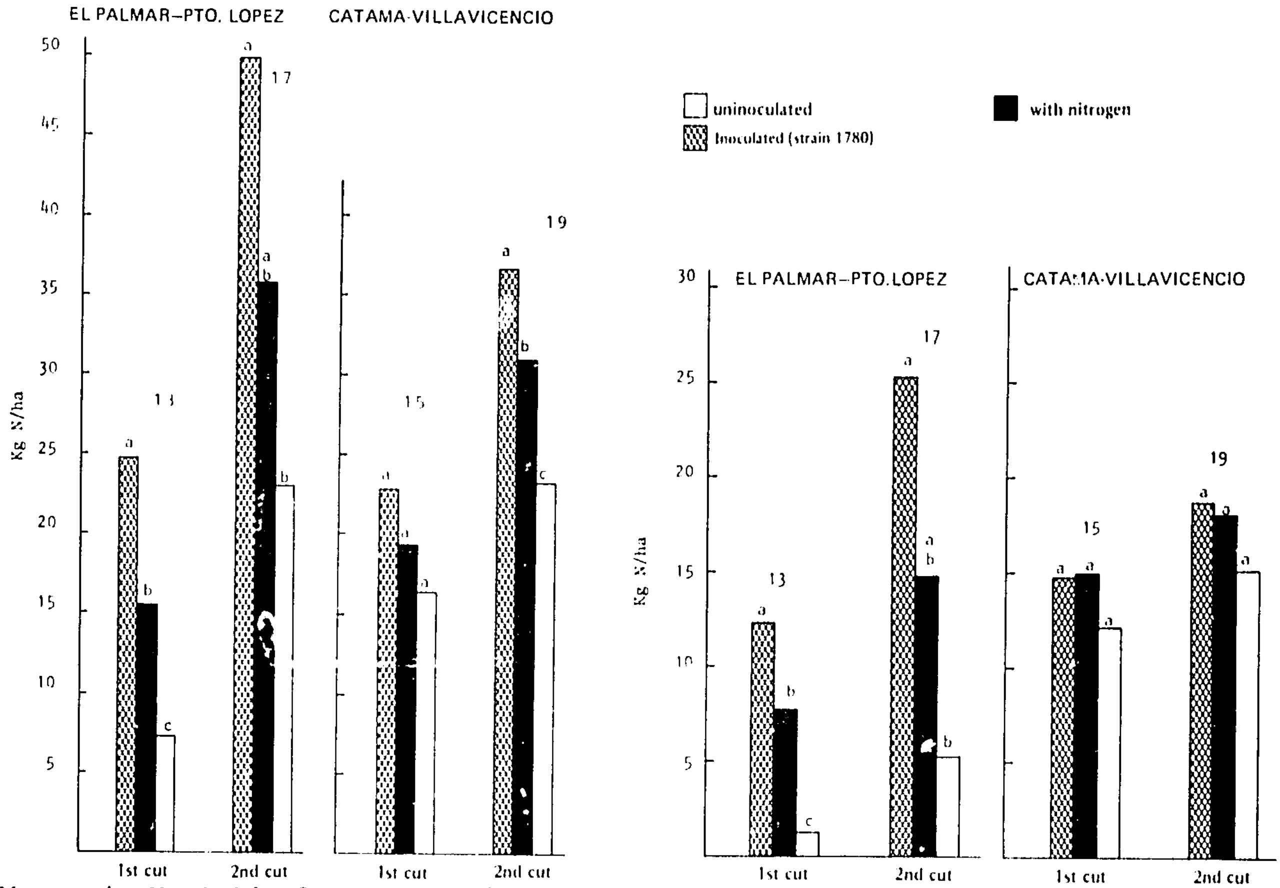


Figure 4. N yield of Pueraria phaseoloides 9900 and Centrosema macrocarpum 5065 at two sites of the Colombian Llanos, 13 and 17 or 15 and 19 weeks after sowing (MSPT-173).

(savanna ecosystem), N yield of both P. phaseoloides and C. macrocarpum was more than doubled by inoculation. At Villavicencio, where the rainfall is higher (rainforest ecosystem), the reponses to inoculation were not so great. This may have been due to a number of factors (high soil organic N, high weed infestation, cross-contamination, different native rhizobium populations) which need further investigation in areas representing degraded pastures in rainforest regions.

At Quilichao, different strains were compared when inoculated singly and in mixture. The design of the experiment was the same as that proposed for international inoculation trials to be carried out in collaboration with national institutes. The trial was set up by a group of visiting scientists from national institutes in collaboration with the Regional Trials Section. Despite the high organic N content of the Quilichao soil, marked inoculation responses and differences in strain effectivity were observed (Figure 5). The result with C. pubescens, where the mixture of strains gave an inferior response to that of any of the three strains when inoculated separately was surprizing. Further work is needed to explain this effect.

At Carimagua it can be seen that for C. macrocarpum 5065, all three strains tested gave marked inoculation responses and did not differ significantly between each other (Fig.6), whereas at Quilichao strain 1670 was more effective than the others (Fig.5). P. phaseoloides 9900 (Fig.6) also showed a marked response to inoculation with all three strains at Carimagua (approximately double the N yield of the uninoculated control). As has been observed in previous experiments, the increase in N yield due to inoculation of C. macrocarpum was more

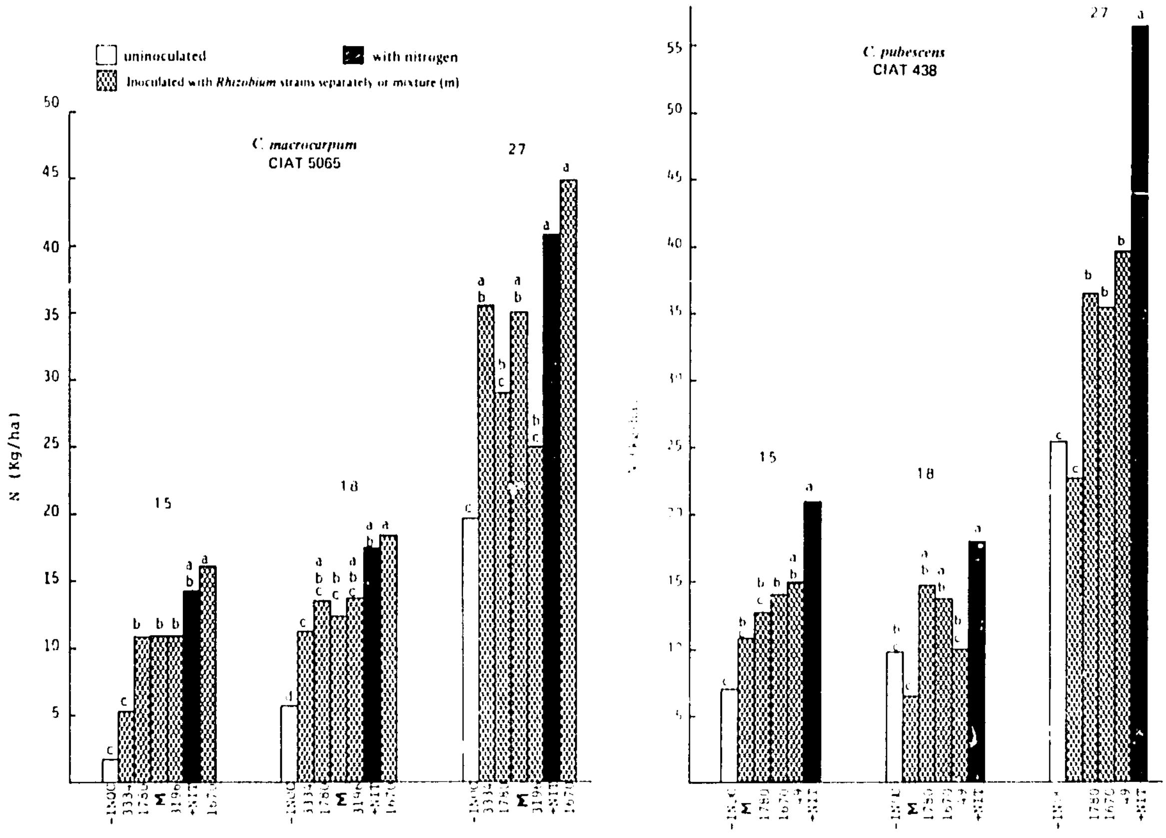


Figure 5. N yield of Centrosema macrocarpum 5065 and C. pubescens 438 in Quilichao 15, 18 and 27 weeks after planting (MSPT-169).

marked than that of P. phaseoloides due to the fact that C. macrocarpum forms virtually no nodules with native rhizobium strains in Carimagua soil. P. phaseoloides does form nodules with native strains, and therefore does not become as chlorotic as C. macrocarpum when it is not inoculated, but as can be seen clearly from Figure 6, these native strains do not fix as much N_2 as the inoculated strains.

Figure 6 also shows that although D. ovalifolium 3784 responded to N fertilization, there was only one significant response to inoculation with strain 2335 in the first cut. The inoculated plants were initially greener than the uninoculated plants. D. ovalifolium nodulates abundantly with native strains, so inoculated strains must be very competitive to be able to dominate the native population. The seeds of this legume are small which limits the number of rhizobia that can be applied per seed. Higher inoculation rates may therefore be necessary to enable the inoculated strains to become dominant in the soil.

The results of these trials carried out at different sites within Colombia provide strong evidence that production of some tropical forage legumes can be increased substantially by inoculation during establishment. Previous evidence (Annual Report 1983) has shown that the inoculation effect can persist into the second year. Clearly further screening work is needed, but these results emphasize another problem: the need for improving inoculant production and distribution to farmers.

DEVELOPMENT OF FREEZE-DRIED OIL-BASED RHIZOBIUM INOCULANTS

Traditional peat-based inoculants present several practical problems, especially in the tropics. Firstly, since they are perishable, they cannot be stored for more than six months even under refrigeration. Secondly, the identification of appropriate sources of peat or other support materials requires considerable experimentation before the factory can be set up. The quality and exportability of inoculants is improved dramatically by gamma-irradiating the peat, but this facility is expensive and not always available. Thirdly, once inoculated onto the seed, the rhizobia in peat-based inoculant die very rapidly due to dessication, so seeds should ideally be inoculated on the same day as planting.

Many attempts have been made to improve inoculation technology but most of the work has been carried out in developed countries where the limitations to using traditional inoculants are less severe. We have begun a UNDP-funded special project to test a method based on the use of freeze-dried, oil-based inoculant published by R. J. Kremer and H. L Peterson (Agron. J. 75, 139-143, 1983) under tropical conditions. This type of inoculant has several advantages. It can be prepared using the same equipment as factories producing medical or vetinerary vaccines; it is much less bulky and perishable than traditional inoculant; it can be applied at higher rates/seed and remains viable on seeds for a longer time. Preliminary results showed only 12% mortality after 3 days on seeds of Centrosema macrocarpum whereas with peat-based inoculant, mortality was 99.9% (Table 6).

The effects of different types of oil on Rhizobium survival and seed germination are being tested. It seems likely that seed firms will be interested in the potential for selling pre-inoculated seeds.

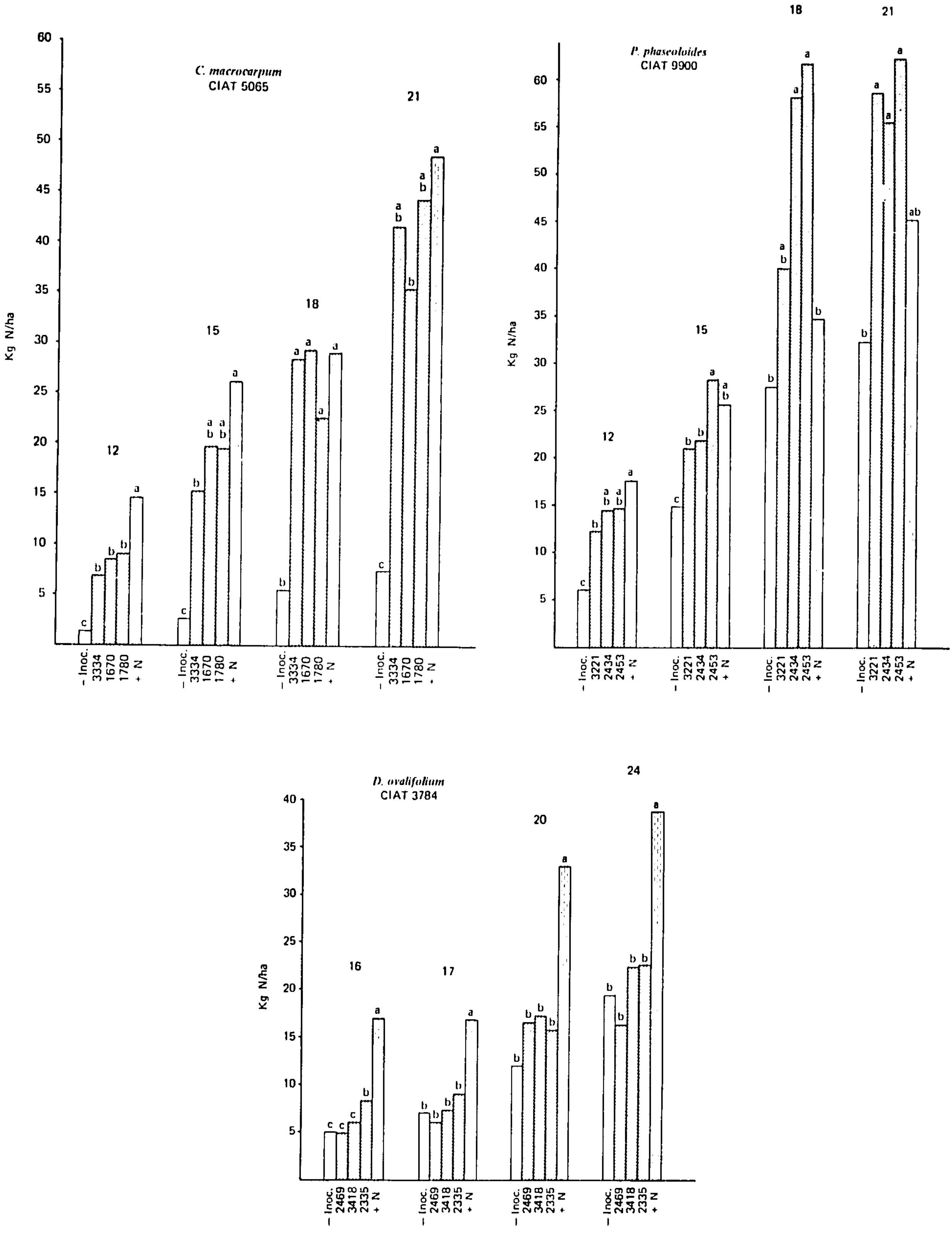


Figure 6. N yield of Centrosema macrocarpum 5065, Pueraria phaseoloides 9900 and Desmodium ovalifolium 3784 at Carimagua (Hato 4) 12, 15, 18 and 21 or 16, 17, 20 and 24 weeks after planting (MSPT-172).
□ Uninoculated; ▨ inoculated; ▦ with N fertilization.

FIELD RESPONSE TO MYCORRHIZAL INOCULATION

This experiment was established in an Oxisol at Carimagua during 1983. The objective was to see if field inoculation with VAM fungi would increase the establishment rate of seedlings, growth and mineral uptake of P. phaseoloides, S. capitata and A. gayanus and if so how long the effect of inoculation would last.

There were four treatments: (1) Nil, no addition of mycorrhizal inoculum or phosphate; (2) M, with mycorrhizal inoculum; (3) RP, with rock phosphate from Huila; and (4) RP + M, rock phosphate and mycorrhizal inoculum. Phosphorus was applied at the rate of 20 kg P/ha.

Mycorrhizal inoculation of P. phaseoloides when combined with rock phosphate continued to produce significantly greater dry matter than the rock phosphate treatment only until the 3rd cut (Figure 7). At 12 months after sowing (2nd growing season) phosphorus (20 kg P/ha) and nitrogen (50 kg N/ha) were applied to all plots to see if the mycorrhizal activity of the introduced VAM fungi would increase or not. The data of the 4th cut (15 months after sowing) did not show any effect (Figure 7). Mycorrhizal inoculation without any phosphorus application did not produce any significant increase in dry matter

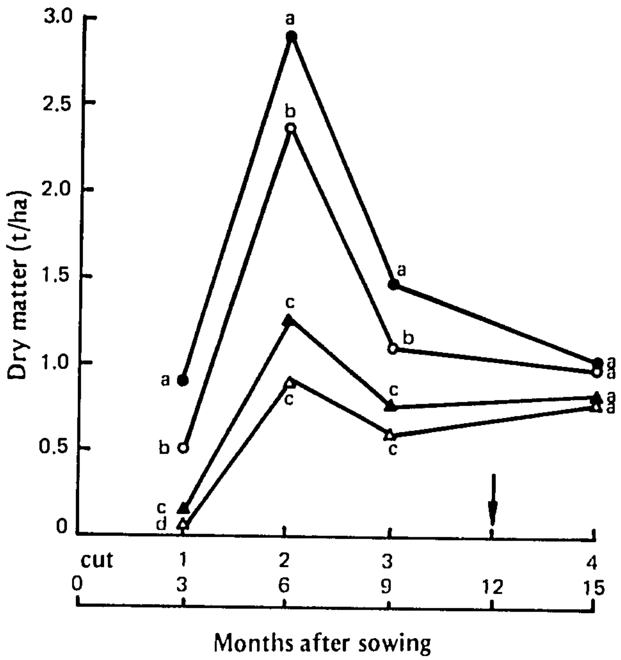


Figure 7. Dry matter production (t/ha) of Pueraria phaseoloides CIAT 9900 grown in unsterilized Oxisol under field conditions at Carimagua. Treatments: Rock phosphate plus mycorrhizal inoculum (●); rock phosphate only (○); mycorrhizal inoculum (▲); control (△). The means at each cut with different letters are significantly different ($P < 0.05$) by Duncan's multiple range test.

Table 6. Survival of Rhizobium on seed of Centrosema macrocarpum using traditional and improved inoculants (Strain CIAT 3111).

Type of Inoculant	No. of Cells/Seed Days preinoculation		% Mortality
Traditional (Peat-based)	170,000	170	99.9
Improved (Lyophilized oil-based)	250,000	220,000	12

yield over controls from the 2nd cut onwards. The total phosphorus and nitrogen uptake was increased significantly by mycorrhizal inoculation combined with rock phosphate over the rock phosphate treatment until the 3rd cut only.

Figure 8 shows that dry matter production of A. gayanus was also increased by mycorrhizal inoculation when combined with rock phosphate but this effect disappeared at the 3rd cut. Similar to Kudzu, mycorrhizal inoculation without application of any P fertilizer did not increase growth of A. gayanus over controls. Phosphorus and nitrogen uptake was increased by RP + M treatment in the 1st. cut only. In both A. gayanus and Kudzu there was a decrease in overall production in the last cut, which implies that other factors may have been limiting growth.

The fresh and dry matter production and mineral uptake of S. capitata was increased by mycorrhizal inoculation alone at the 1st. cut after three months (Table 7). Due to very poor growth no cuts were made at 6 months after sowing. At 9 months after sowing, significant increases in dry matter production were only observed with the RP + M and RP treatments. The data clearly show that mycorrhizal inoculation combined with rock phosphate can increase the production of pasture plants. The longevity of the effect depended on the plant species. This may be due to differences in the efficiency of the introduced mycorrhizal fungi, the build up of indigenous mycorrhizal population or availability of

Table 7. Dry matter (t/ha) and mineral uptake (kg/ha) of Stylosanthes capitata 1315 grown in the field at Carimagua.

Cut	Treat-ments*	Dry matter (t/ha)	Mineral uptake (kg/ha)				
			P	N	K	Ca	Mg
First	RP+M	0.67a	1.33a	24.39a	13.58a	5.05a	2.33a
	RP	0.40b	0.77b	14.96b	8.93b	2.97b	1.25b
	M	0.13c	0.15c	4.84c	2.74c	0.85c	0.40c
	Nil	0.07d	0.09d	2.73d	1.57d	0.48d	0.22d
Second	RP+M	1.42a	1.27a	25.33a	8.32a	9.00a	3.55a
	RP	1.19b	1.07a	22.10a	7.77a	7.94a	3.00a
	M	0.62c	0.56b	12.30b	4.66b	4.55b	1.97b
	Nil	0.55c	0.50b	10.41b	4.05b	3.78b	1.72b

* Treatments: RP+M, rock phosphate plus mycorrhizal inoculum; RP, rock phosphate; M, mycorrhizal inoculum; Nil, control. The mean values in each column and for each cut not followed by same letter are significantly different ($P < 0.05$) by Duncan's multiple range test.

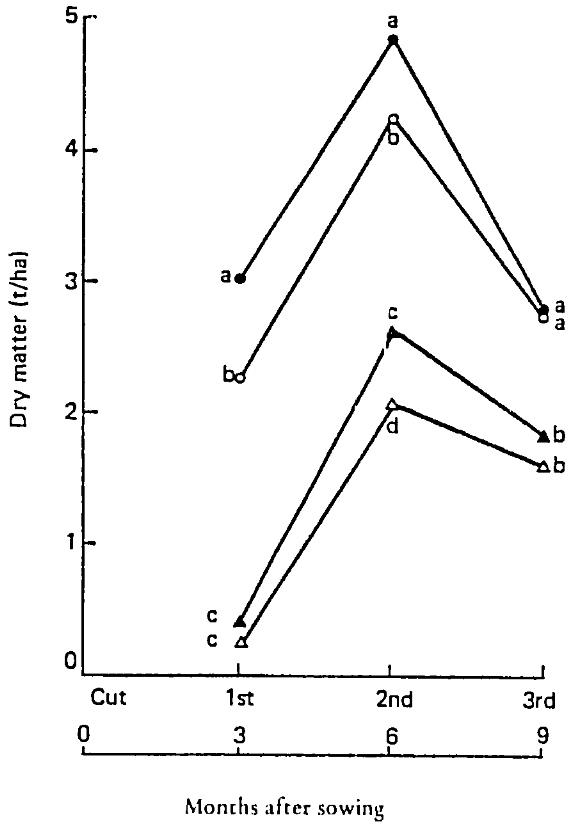


Figure 8. Dry matter production (t/ha) of Andropogon gayanus CIAT 621. For explanation see Figure 7.

nutrients for plant growth. The longevity of the response should be studied at different fertilizer levels.

INTERACTION BETWEEN TWO SOURCES OF POTASSIUM AND MYCORRHIZAL INOCULATION

This pot experiment was conducted to compare the agronomic effectiveness of K-feldspar rock and KCl as potassium fertilizers, and to see if mycorrhizal inoculation would increase the effectiveness of these fertilizers in unsterilized soil. The species used were: Centrosema, Stylosanthes, Zornia, Andropogon and Panicum. They were grown in an unsterilized Oxisol from Carimagua. There were four fertilizer treatments: (1) 0, control; (2) KCl, 30 kg K/ha; (3) KFs, K-feldspar rock, 30 kg K/ha; (4) Mix, KCl and KFs mixed in ratio 1:1 to give 30 kg K/ha.

Dry matter production of all plants (with few exceptions) was increased significantly by mycorrhizal inoculation (Table 8). However, the extent of the increase varied among species and potassium treatments. For Z. glabra, C. macrocarpum and P. maximum, the dry weight of plants, with or without inoculum, was higher with KFs than with the other potassium treatments. Exceptionally good growth of non-inoculated Zornia, Centrosema and Panicum plants given KFs indicates that KFs may have some positive secondary effects on the growth of plants (or KCl negative) or KFs may have stimulated the activity of indigenous mycorrhizal fungi. The P level applied in this experiment was very low (10 kg P/ha) which may have limited plant growth or mycorrhizal development and activity in some or all off the treatments.

Mycorrhizal inoculation increased the fertilizer effectiveness (efficiency of K uptake) of the potassium fertilizers. However, the increase in fertilizer effectiveness appeared to be dependent on plant species and fertilizer source (Table 9). The main effect of mycorrhizal inoculation on fertilizer value was highly significant in the species used, with the exception of Centrosema (Table 10).

This experiment indicates the importance of mycorrhizae in the K nutrition of the plants studied. This may be due to improvement of plant growth due to increased P availability. However, it is possible that in these tropical forage plants mycorrhizae may have a direct role in K uptake, which should be studied in further experiments.

Table 8. Shoot dry weight (g/pot) of five tropical forage plants grown in unsterilized Oxisol as monoculture and supplied with two different sources of potassium and either inoculated (M) or not inoculated (NM) with mycorrhizal fungi.

Potassium treatments* (kg K/ha)	*Z. glabra*		*C. macrocarpum*		*S. capitata*		*A. gayanus*		*P. maximum*	
	NM	M	NM	M	NM	M	NM	M	NM	M
0	3.30	8.20	5.01	8.21	2.25	3.80	3.97	6.46	6.36	7.82
30 (KCl)	2.79	9.37	5.05	9.55	2.48	8.17	5.08	9.38	9.43	11.53
30 (Mix)	4.40	7.60	6.55	10.60	2.41	5.14	5.49	8.72	10.32	15.18
30 (KFs)	8.87	10.31	9.55	10.89	3.41	5.20	5.52	9.37	13.22	16.20
LSD at 5%	1.98		2.23		1.55		1.78		3.26	
Main effect of inoculation	4.84	8.87	6.54	9.81	2.64	5.58	5.02	8.48	9.83	12.68
LSD at 1%	1.36		1.54		1.07		1.22		2.24	

* 0, control; 30 (KCl), as KCl; 30 (Mix), KCl and K-feldspars in ratio 1:1; 30 (KFs), potassium feldspar.

Table 9. Fertilizer effectiveness of KCl and K-feldspars (KFs) and a mixture of both (Mix) for five tropical forage species grown in unsterilized Oxisol as monoculture and either not inoculated (NM) or inoculated (M) with mycorrhizal fungi.

Species	Inoculation	Fertilizer effectiveness* KCl	KFs	Mix	LSD at 5%
Z. glabra	NM	43.54	80.01	- 6.19	27.20
	M	103.67	71.73	124.68	
C. macrocarpum	NM	52.01	89.75	72.82	45.18
	M	45.90	54.38	143.18	
S. capitata	NM	29.69	67.70	32.43	53.37
	M	217.24	86.62	100.38	
A. gayanus	NM	74.03	51.33	97.48	53.37
	M	161.53	119.65	91.26	
P. maximum	NM	78.82	30.18	110.30	60.26
	M	129.19	101.47	136.37	

* Fertilizer effectiveness =

$$\frac{\text{K uptake by fertilized Plants} - \text{K uptake by unfertilized Plants}}{\text{K uptake by unfertilized plants}} \times 100$$

Table 10. Main effect of mycorrhizal inoculation on the fertilizer effectiveness of KCl, K-feldspars (KFs) and a mixture of both (Mix).

Mycorrhizal Inoculation	Fertilizer effectiveness* *Z. glabra*	*C. macrocarpum*	*S. capitata*	*A. gayanus*	*P. maximum*
-Inoculation	39.18	71.52	43.27	74.28	73.10
+Inoculation	99.50	81.15	134.75	124.15	122.34
LSD at 1%	36.61	NS	54.65	43.26	48.83

NS, not significant.
* Same as in Table 9.

INTERACTION BETWEEN RHIZOBIA AND MYCORRHIZAL FUNGI IN *Stylosanthes capitata* cv. "Capica"

The objective of this experiment was to determine whether mycorrhizal inoculation would improve *Rhizobium* response of "Capica" in undisturbed soil cores. In general *Rhizobium* plus mycorrhizal inoculation increased the growth of plants more than the *Rhizobium* inoculation alone (Figure 9). However, the positive effect of *Rhizobium* plus mycorrhizal inoculation did not increase the growth of "Capica" significantly when compared to the control. It is possible that some soil nutrients e.g. N, P and K could be limiting the efficiency of *Rhizobium* or mycorrhizal fungi. An experiment with varying levels of these fertilizers will be performed to study the interaction between fertilizer levels and *Rhizobium* and mycorrhizal inoculation.

INTERACTION BETWEEN *Rhizobium* AND THREE MYCORRHIZAL FUNGI IN *Centrosema*, *Desmodium* AND *Pueraria* IN TWO SOILS

The aim of this experiment was to compare three selected *Rhizobium* strains recommended for each of the three species under test and their interaction with three VAM fungi in two soils. The *Rhizobium* strains used for each legume species were: *Centrosema*, R_1 1670, R_2 3334, R_3 1780; *Desmodium*, R_1 2469, R_2 2335, R_3 3418; *Pueraria*, R_1 2453, R_2 3221, R_3 2434. The three VAM fungi used were: M_1, *Glomus manihotis*; M_2, *Enthrophospora colombiana*; M_3, *Acaulospora longula*. The undisturbed soil cores used were from La Reserva (12% sand) and El Rincon (61% sand) in Carimagua.

Table 11 shows that all three legumes responded to inoculation in La Reserva soil, whereas in El Rincon no significant differences in dry matter yield were observed between inoculated and uninoculated treatments. The uninoculated treatments in El Rincon soil produced more than in La Reserva, even though La Reserva is a more fertile soil. On the other hand, the highest yielding treatments in La Reserva produced more than the highest yielding treatments in El Rincon. Clearly the two soils affected the activity of native and inoculated microorganisms differently.

Table 12 shows that growth, nutrient uptake and concentration were higher in La Reserva than El Rincon soil although mean nodule number did not vary between soils. The different effects of the two soils on native and inoculated microorganisms could therefore be due to an indirect effect of the nutritional status of the plants.

The mycorrhizal fungus M_1 (*Glomus manihotis*) caused the highest yield in *Pueraria* and *Desmodium* even without rhizobial inoculation (Table 11). However, *Rhizobium* alone did cause inoculation responses in these two legumes. With the most effective inoculated rhizobia M_1 was not so effective. This implies that M_1 can improve the efficiency of native rhizobia or mineral N uptake or that possibly the combination of more effective rhizobia and mycorrhizae created a nutrient or energy demand which could not be supplied under the conditions of the experiment. The greatest yield of *Centrosema macrocarpum* occurred when rhizobium and mycorrhizal inoculation were combined, possibly due to the lack of native rhizobia for nodulation of this species. Further analysis of

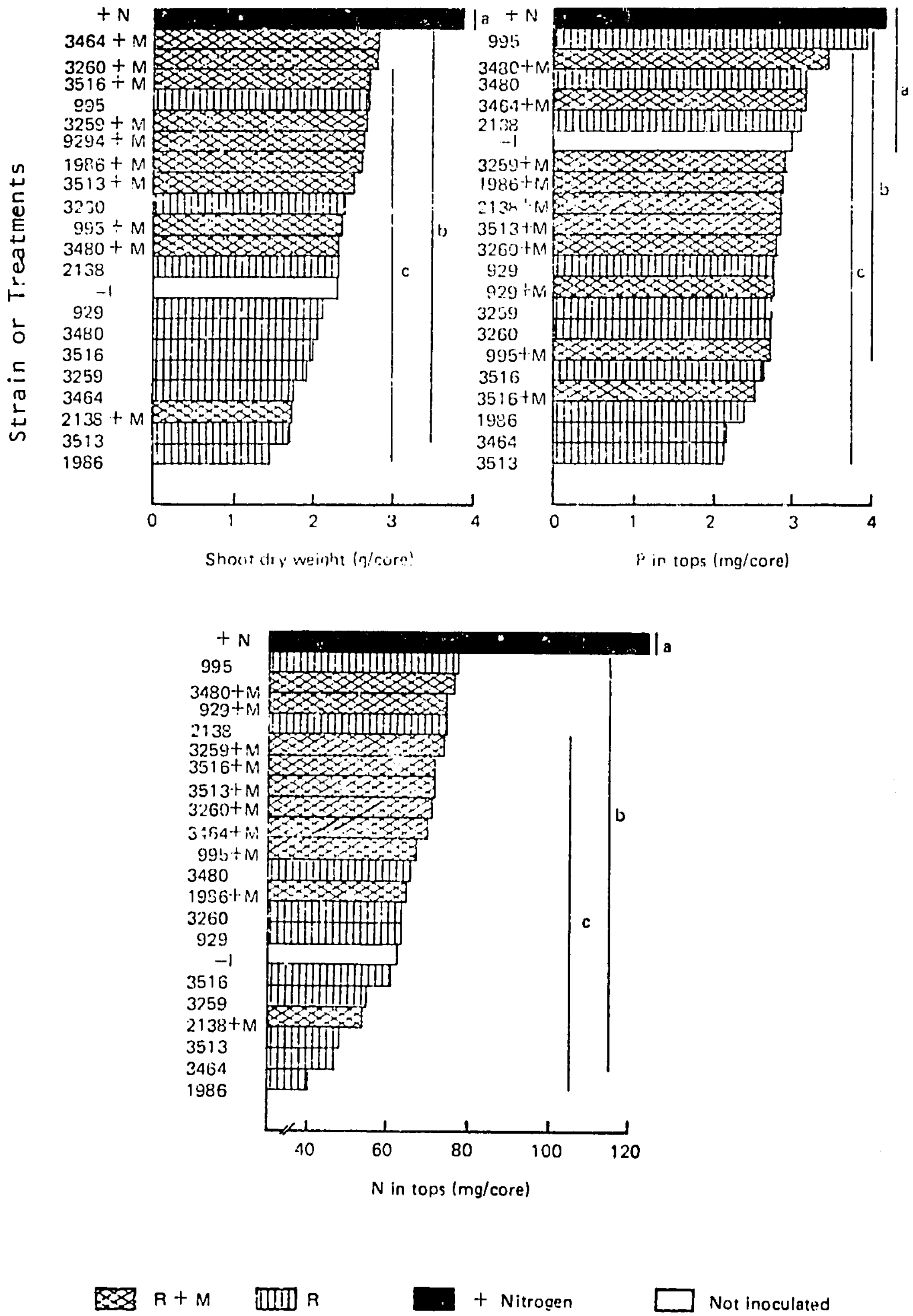


Figure 9. Shoot dry weight (g/core), P in tops (mg/core) and N in tops (mg/core) of Stylosanthes capitata "Capica" grown in undisturbed soil cores from Reserva and inoculated with Rhizobium alone or Rhizobium and mycorrhizal fungi. Means joined by the same line are not significantly different ($P < 0.05$).

Table 11. Shoot dry weight (g/core) of *Centrosema*, *Desmodium* and *Pueraria* grown in undisturbed soil cores from Reserva (A) and Rincon (B) and inoculated either with VAM fungi or *Rhizobium* or a mixture of both.

Treatments*	Centrosema		Desmodium		Pueraria	
	A	B	A	B	A	B
Control	0.67e	1.33abc	2.25f	2.02abc	1.23f	1.00ab
M_1	1.11de	1.14c	3.78a	3.01a	2.60a	1.62a
M_2	1.08de	1.02c	2.42ef	2.02abc	1.72bcdef	1.18ab
M_3	1.51cd	1.53abc	3.38abc	1.92bc	1.23f	0.69b
R_1	1.75abcd	1.49abc	2.25f	2.19abc	1.46def	0.98ab
R_1M_1	2.24ab	2.06a	3.17abcde	2.68ab	2.10bc	1.61a
R_1M_2	2.32a	1.52abc	2.79cdef	1.97abc	1.75bcdef	1.22ab
R_1M_3	2.50a	1.32abc	2.21f	2.19abc	1.59cdef	1.17ab
R_2	1.43cd	1.16c	2.58def	2.14abc	1.35ef	1.12ab
R_2M_1	2.42abc	2.02ab	3.32abcd	3.00a	1.97bcd	1.53a
R_2M_2	2.19abc	1.46abc	2.58def	2.25abc	2.14b	1.11ab
R_2M_3	2.35abc	1.19bc	3.15abcde	1.52c	1.85bcde	1.00ab
R_3	2.17abc	1.45abc	3.04abcde	1.96abc	1.95bcd	1.17ab
R_3M_1	2.19abc	1.59abc	3.69ab	2.93ab	1.85bcde	1.50a
R_3M_2	2.34a	1.36abc	2.96bcdef	2.25abc	1.58cdef	1.10ab
R_3M_3	2.00abc	1.37abc	3.40abc	1.59c	1.59cdef	1.02ab

* For explanation of treatments see the text. Means in a column not followed by the same letter are statistically different by Duncan's multiple range test ($P < 0.05$).

Table 12. Main effect of soils on the growth and mineral composition of Centrosema, Desmodium and Pueraria.

Soil	Shoot/root ratio	Total dry weight g/core	Number of nodules /core	Mineral composition			
				N	P	K	Ca
		A) Centrosema macrocarpum					
Reserva	3.0	2.52a	35a	43.99a* (2.34a)**	2.06a (0.112a)	16.06a (0.97a)	27.53a (1.511a)
Rincon	2.9	1.94b	34a	32.22b (2.22b)	1.39b (0.097b)	13.89b (0.86b)	22.15b (1.50a)
		B) Desmodium ovalifolium					
Reserva	4.5	3.56a	130a	62.04a (2.11a)	2.67a (0.09a)	21.96a (0.86a)	24.07a (0.82a)
Rincon	3.7	2.82b	118a	44.07b (1.99b)	1.67b (0.07b)	18.73b (0.74b)	17.99a (0.81a)
		C) Pueraria phaseoloides					
Reserva	-	-	-	50.79a	2.07a	-	-
Rincon	-	-	-	32.33b	1.26b	-	-

The mean and for each plant with different letters are significantly different by Duncan's multiple range test.
* Mineral uptake (mg/core).
** Concentration (%).

the data is in progress to evaluate specific interactions between rhizobial and VAM fungal strains.

MYCORRHIZAL DEPENDENCY OF TWENTY-FOUR TROPICAL FORAGE SPECIES

Mycorrhizal dependency (MD) is defined as the degree to which a plant is dependent on the mycorrhizal condition to produce its maximum yield at a given level of soil fertility. The lack of detailed information on the dependence of many plant species on mycorrhiza, tor maximum yield, was considered justification to include 24 forage species to test their MD. The species used were: Stylosanthes leiocarpa (1087), S. macrocephala (1643), S. guianensis (10136), S. capitata (2252), Desmodium ovalifolium (3784), D. canum (13032), D heterocarpon (3787), Zornia glabra (7847), Z. brasiliensis (7485), Centrosema macrocarpum (5065), C. brasilianum (5234), C. arenarium (5236), C. pascuorum (5190), C. pubescens (5189), Pueraria phaseoloides (9900), Arachis pintoi (17434), Macroptilium atropurpureum, Brachiaria humidicola (679), B. brizantha (664), B. dictyoneura (6133), B. decumbens (606) and Andropogon gayanus (621). The plants were grown in a sterilized Oxisol with 20 kg P/ha as rock phosphate from Huila.

A large variation in dependence on mycorrhiza between forage species was observed (Figure 10). The grasses B. decumbens and B. brizantha were the

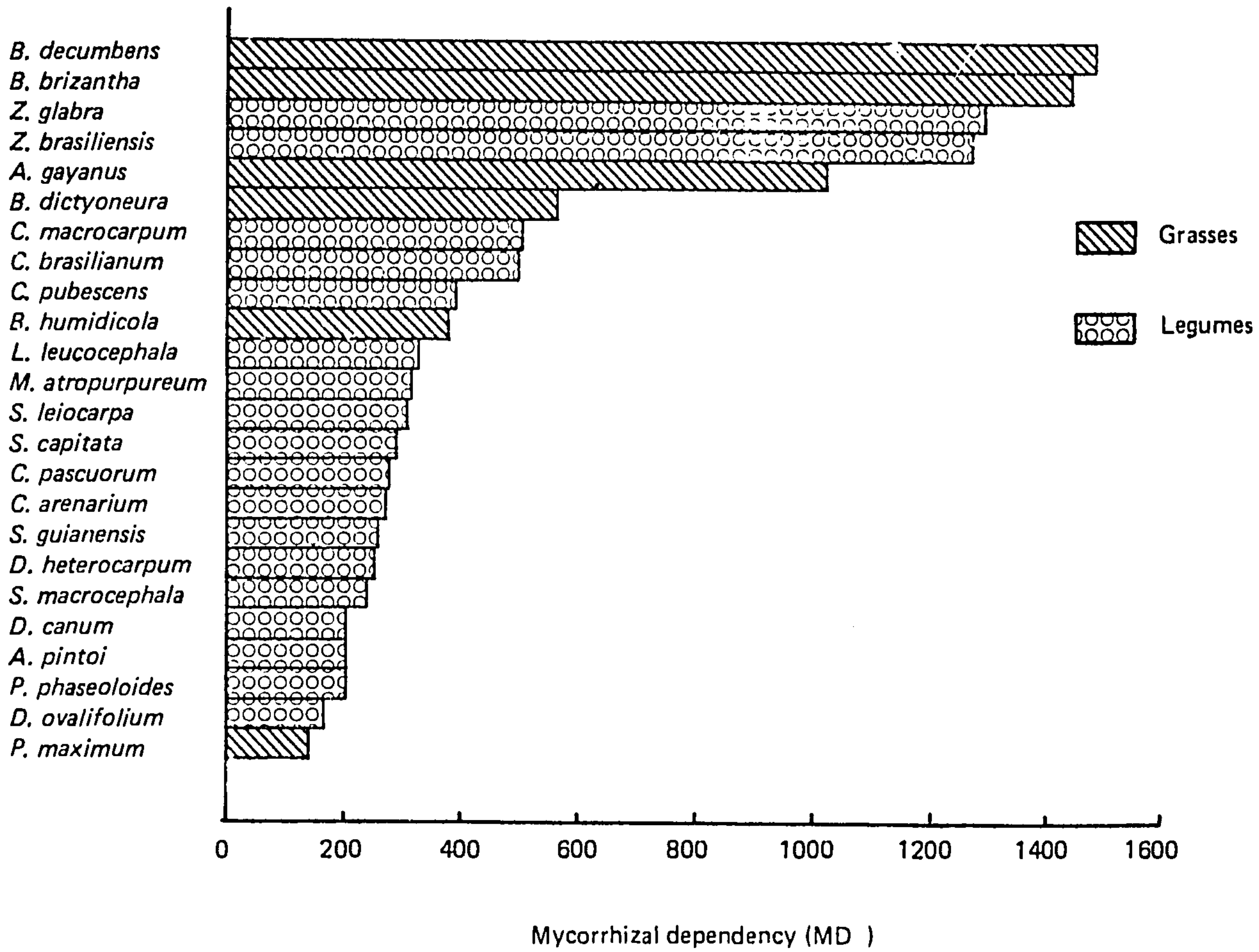


Figure 10. Mycorrhizal dependency (MD) of twenty-four tropical forage species. MD = Dry weight of mycorrhizal plants expressed as percentage of dry weight of non-mycorrhizal plants.

most dependent species (> 1400%) followed by the two Zornia species with a value of more than 1200%. Out of the six grass species tested, five species were more than 400% dependent on mycorrhiza whereas only 5 legumes out of 18 showed values higher than 400%. Twelve legume species fluctuated between 200 and 400%. P. maximum was less dependent on the mycorrhizal condition with values smaller than 150%. The shoot and root dry weight of plant species sown under non-mycorrhizal conditions and their dependence on mycorrhizal condition showed a significant negative correlation.

Generally it is believed that grasses are less dependent on mycorrhiza than legumes due to their more extensive root system. The present data (Figures 10 and 11) show that tropical grasses are equally or in some cases more dependent on mycorrhiza than legumes when grown in soils of low fertility. These data provide a basis for the selection of plants for mycorrhizal inoculum production.

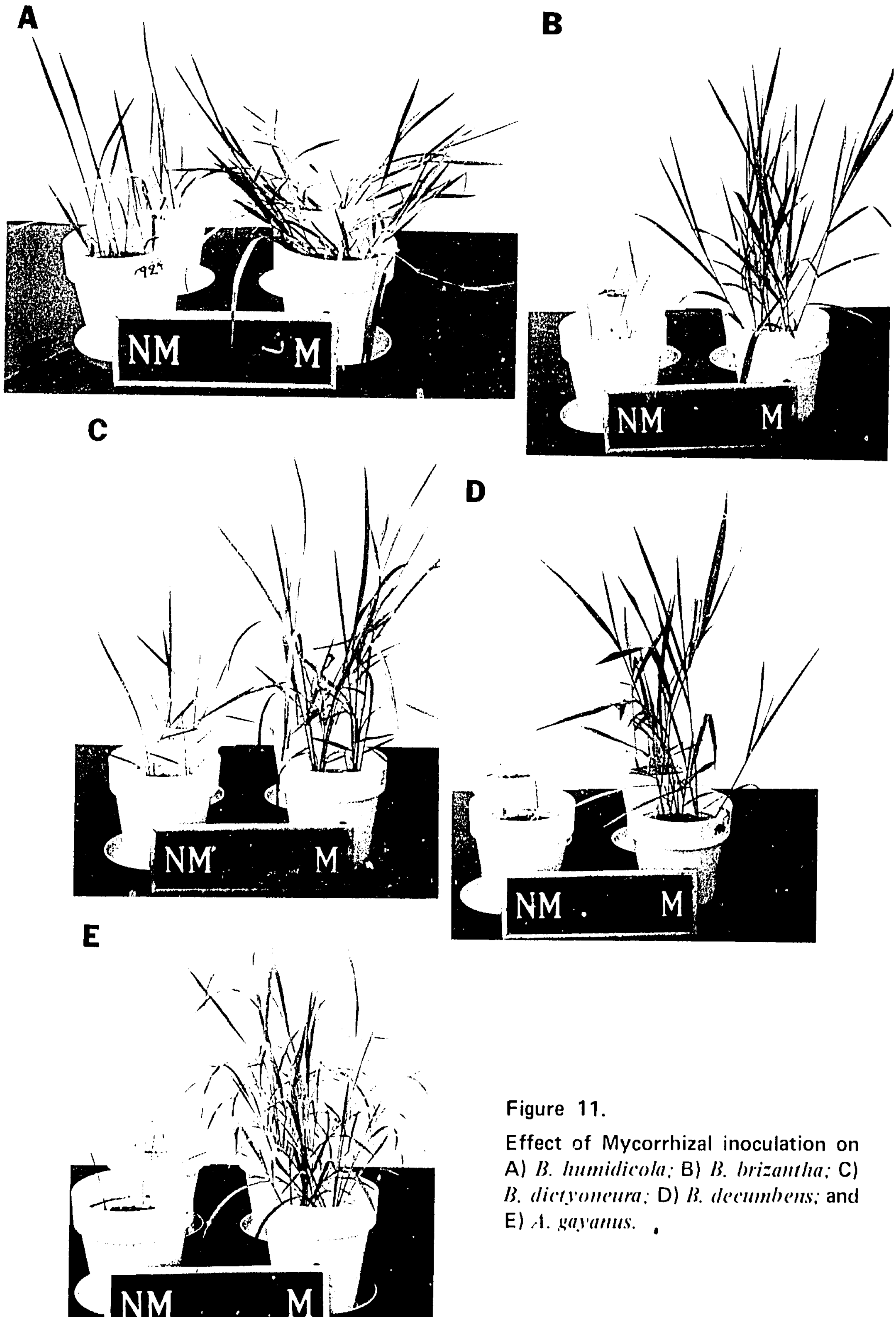


Figure 11.

Effect of Mycorrhizal inoculation on A) *B. humidicola;* B) *B. brizantha;* C) *B. dictyoneura;* D) *B. decumbens;* and E) *A. gayanus.*

PASTURE DEVELOPMENT (Carimagua)

INTRODUCTION

During 1984 the section continued in a transition phase which began three years ago resulting in a gradual increase in the range of research being conducted to include the effect of animals on the development of pastures. Of special interest is the effect of management systems on the interaction of the principal components: grazing system, stocking rates and the different species that make up the pasture under trial.

RESEARCH IN PROGRESS

Planting Patterns

This experiment was designed to determine the effect of planting pattern on the productivity, persistence and dynamics of a pasture comprising a mixture of Andropogon gayanus and five ecotypes and a cultivar (Capica) of Stylosanthes capitata. (See Annual Report 1983).

The only clear effect of planting pattern on growth of Stylosanthes capitata is seen in dry matter production. The legume is more productive in the 3:3 pattern, apparently favored by reduced interference from neighbouring grasses. There is no detectable effect of pattern on survival of 1 year-old marked plants of Stylosanthes capitata over 22 months, but there is a significant effect of ecotype (Figure 1). The ecotypes form two groups 1693, 1728 and 1315, 1318, 1342. In each ecotype the risk of mortality increases with time.

There was no effect of planting pattern on the average number of seedlings (i.e. second generation) but there was an effect on their distribution within the pattern. In the 2:2 and 3:3 patterns there are different microsites (area between the two species): grass/legume, grass/grass, legume/legume (c.f. 1:1 where there is only a grass/ legume microsite). Stylosanthes capitata seedlings were more numerous and larger in the legume/grass and legume/legume microsites, possibly because of poor distribution of seed. In Andropogon gayanus, seedling number and size were greatest in the grass/legume microsite. During the last two years a strong effect of planting pattern on the traffic of animals within the pasture has been observed. When rows of grass are dense and well developed the animal is obliged to walk on either side of each row in order to consume most of the green forage available and he prefers to walk between rows, crossing rows rather infrequently. For this reason, very pronounced paths are formed between rows of grass with the resulting loss of almost all the vegetation in the affected area. When paths coincide with the legume row the initial stand is very adversely affected.

Low density planting in zurrales

The dominance of Brachiaria humidicola, Desmodium ovalifolium and Pueraria phaseoloides continues to be

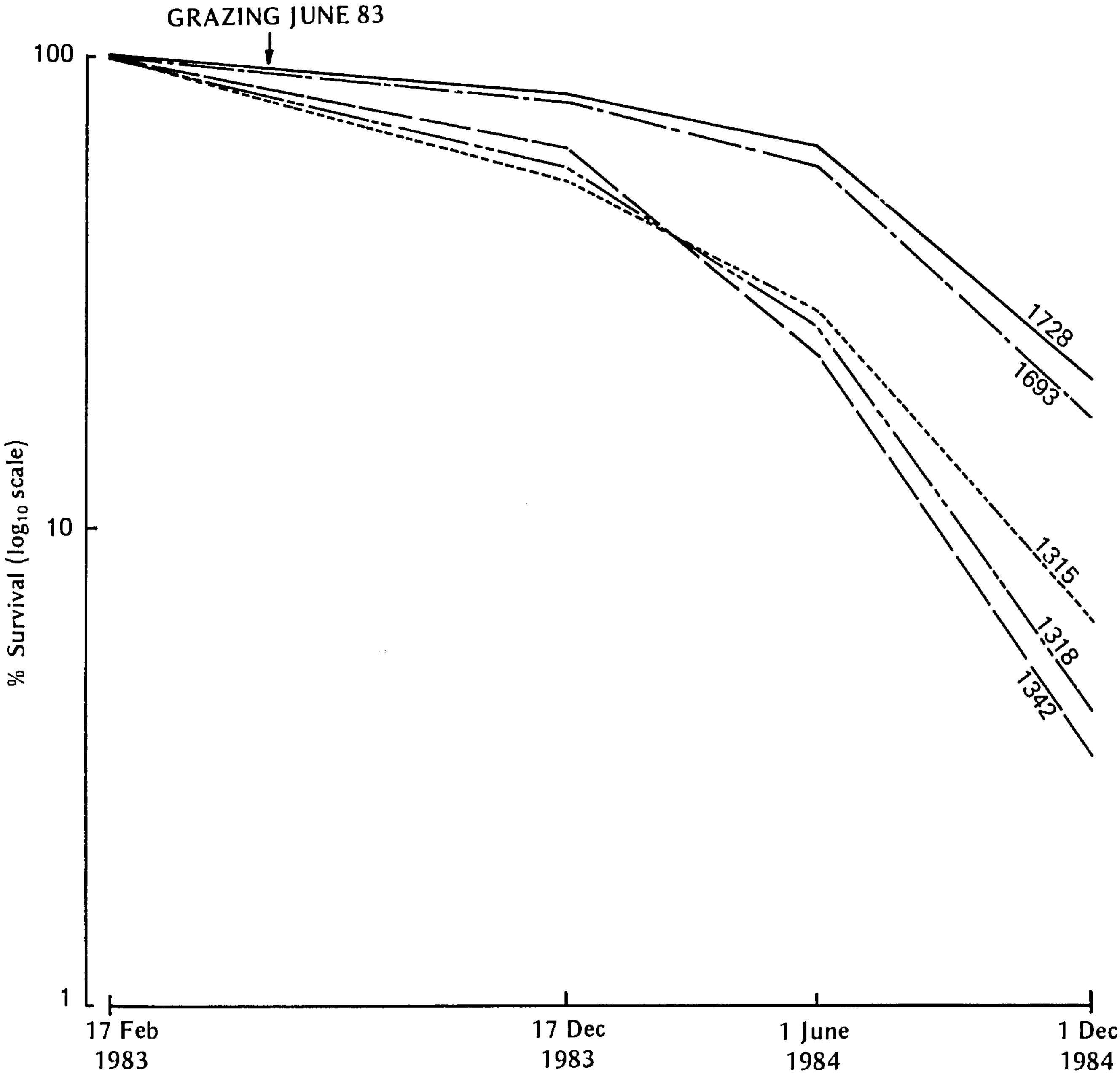


Figure 1. Survival over 22 months of marked plants of Stylosanthes capitata grown in association with Andropogon gayanus at Carimagua. The data are for five ecotypes grown separately and together as the synthetic cultivar Capica.

notable in this experiment. The grass is adapted to the entire area including the soil between zurrales, while the legumes are concentrated on the high part of the zurrales (see Annual Report 1983).

Replacement of savanna

The advance of planted species continues to follow the same trends reported last year, In the course of 1984, the process of gradually increasing the area fertilized, with an additional 20% of the total area being fertilized each year since planting (1980), was completed. Several treatments have resulted in the total displacement of savanna, with the planted species presently covering the entire area. Late in 1984, it was necessary to increase stocking rates in the treatments with B. humidicola associated with P. phaseoloides and D. ovalifolium. The present stocking rates for these associations are 2.5 and 2.0 animals/ha, respectively.

The effect of planted strip width on the rate of advance of planted species and percent coverage has been observed from the outset. The narrower the planted strip, the more interfaces between planted strips and savanna, and for that reason,the more rapid the advance of planted species. The effect of strip width on forage availability has been observed this year, especially as related to the planted grass. As in the case of species advance,the narrower the strip the more rapid the increase in total area covered by the planted grass and thus the greater the carrying capacity of the treatment. In view of this development, it was decided to adjust the grazing schedule for the animals which rotate between the sub-plots (strip widths) in each association, leaving animals for a longer time in the treatments with larger areas of introduced grass (narrow strips) in order to compensate for the greater availability of grass.

A summary of liveweight gains as affected by the different associations during four years is shown in Table 1. The marked difference in gains of animals grazing savanna associated with P. phaseoloides and those grazing in savanna with D. ovalifolium is of special interest. Both treatments started with A, gayanus but the grass failed because the management system did not permit flowering nor seed set of the grass. Animals grazing P. phaseoloides with savanna have consistently gained approximately twice the amount gained by animals grazing savanna with D. ovalifolium. This is a reflection of the very large difference in quality of the two legumes.

After almost four years of experimentation it appears that the strategy for replacing native savanna by planting introduced species in strips is a viable one which offers the advantage of low initial cost and the possibility of grazing from the outset without need for burning. The weight gains of animals grazing in this trial have been superior during all years to the gains observed in animals pasturing pure savanna and have been equal or superior to those observed in experiments in which the legume has been planted in a protein bank to supplement the savanna, burned in the traditional way. Another advantage of the system could be its flexibility which permits the owner to increase the area fertilized in a given year or defer fertilization, depending on economic conditions, availability of fertilizer, etc.

Legume Strips in Savanna

Due to the failure of A. gayanus in the experiment just described, it was possible to observe the performance of animals pasturing native savanna supplemented only with planted legumes. The liveweight gains observed and the carrying capacity of savanna supplemented with P. phaseoloides were

Table 1. The effect of association and year on mean liveweight gains in savanna replacement trial. Carimagua 1981-1984.

Treatment	Year	Stocking Rate Dry/Wet (A/ha)	Season: Dry 150 days (g/A/day)	Season: Wet 210 days (g/A/day)
B. humidicola	1981	-/1.0	-	384
+	1982	1.5/1.5	87	474
D. ovalifolium	1983	1.0/1.0	298	510
	1984	1.0/1.0	-29	340*
B. humidicola	1981	-/1.0	-	481
+	1982	1.5/1.5	274	518
P. phaseoloides	1983	1.0/2.0	443	455
	1984	2.0/2.0	129	222
A. gayanus	1981	-/1.0	-	268
+	1982	1.5/1.5	137	218
D. ovalifolium	1983	1.0/1.0	270	163
	1984	1.0/1.0	33	25
A. gayanus	1981	-/1.0	-	458
+	1982	1.5/1.5	112	437
P. phaseoloides	1983	1.0/1.0	331	474
	1984	1.0/1.0	66	360

* 197 days in 1984.

both surprisingly high. On the basis of this experience, it was decided in 1982 to initiate a new experiment in which only legumes would be planted in strips in order to supplement the native savanna. The strategy followed in the new experiment is to fertilize only the strips planted in order to maintain a stable association between legume and native species. The initial planting in 1982 was not very successful due to an undue delay in planting after burning the savanna. As a consequence, a great deal of damage was caused by ants harvesting the planted species. Thus it was necessary to replant in 1983, accompanied by a rigorous control of ants. The effort finally achieved good stands of both planted legumes. The experimental design for the trial is presented in Table 2. Grazing was initiated in May of 1984 after having slashed the savanna between planted strips in order to stimulate regrowth. There will be no further burning nor slashing during the balance of the experiment, with the exception of control blocks in which the native savanna is being managed with traditional sequential burning.

Based on experience with protein banks of S. capitata during 1982 and 1983, it was feared that animals would eat only legume until it was entirely consumed, with little tendency to consume savanna. On the other hand, the experience with P. phaseoloides had shown that animals consuming that legume are stimulated to consume savanna, even though mature. To date there have been no problems of excess consumption of either of the two legumes and treatments including S. capitata have shown excellent development under grazing. Animals are eating S. capitata but also consuming mature native savanna which has not been burned for two years.

Table 2. Experimental design: The supplementation of native savanna (without burning) with strip planted legumes.

Legume area planted and fertilized/animal (m^2)	Stocking rate (an/ha)			
	0.33	0.67	1.00	1.33
	----- % area planted to legume ------			
Native savanna				
0	0.0			
S. capitata				
750	2.5	5.0	7.5	
1500	5.0	10.0	15.0	20.0
2250		15.0	22.5	30.0
P. phaseoloides				
1500	5.0	10.0	15.0	20.0

Pueraria phaseoloides has spread from the original strips, inter-twining and mixing with the savanna as expected. There has been a surprisingly rapid advance of *S. capitata*, generally spreading by seeds in feces, but also washing from the planted strips in run-off water. New plants of *S. capitata* are relatively vigorous, even in the midst of savanna and without fertilizer. The botanical composition of several pastures with different proportions of legumes is shown in Figures 2 and 3. The liveweight gains of steers grazing in this experiment during the first 206 days are shown in Table 3.

The Effect of Stocking Rate and Grazing System on Productivity and Balance Between A. gayanus and P. phaseoloides

Observations during the last four years ha.. indicated a strong effect of grazing system on the balance between legumes and grasses in association. Two new trials were initiated in 1983 in order to measure the effects of the two factors: grazing system and stocking rate on the development of pastures formed by *A. gayanus* and *P. phaseoloides*. The field design is shown in Figure 4. The effects of grazing systems and stocking rates on availability of green forage and the proportions of legume and grass in the forage are shown in Table 4. The effect of grazing systems on the proportion of legume in the forage coincides with previous observations. The marked effect of stocking rate on forage availability also coincides with recent experience. Nonetheless, the effect of stocking rate on the proportion of legume in the association was greater than had been expected. Even more surprising was the very large effect of grazing systems on the availability of forage, which was equal to or greater than the effect of stocking rate.

Both management factors have had powerful effects on the legume/grass proportion in pastures of *A. gayanus* and *P. phaseoloides*. It would appear that legume/grass balance could be maintained in this association either with stocking rate or grazing system. Nevertheless, the maintenance of an adequate proportion of grass only with stocking rate adjustments would sacrifice production potential. These non-replicated experiments serve to illustrate in a qualitative way the effects of grazing management on the balance and productivity of this pasture.

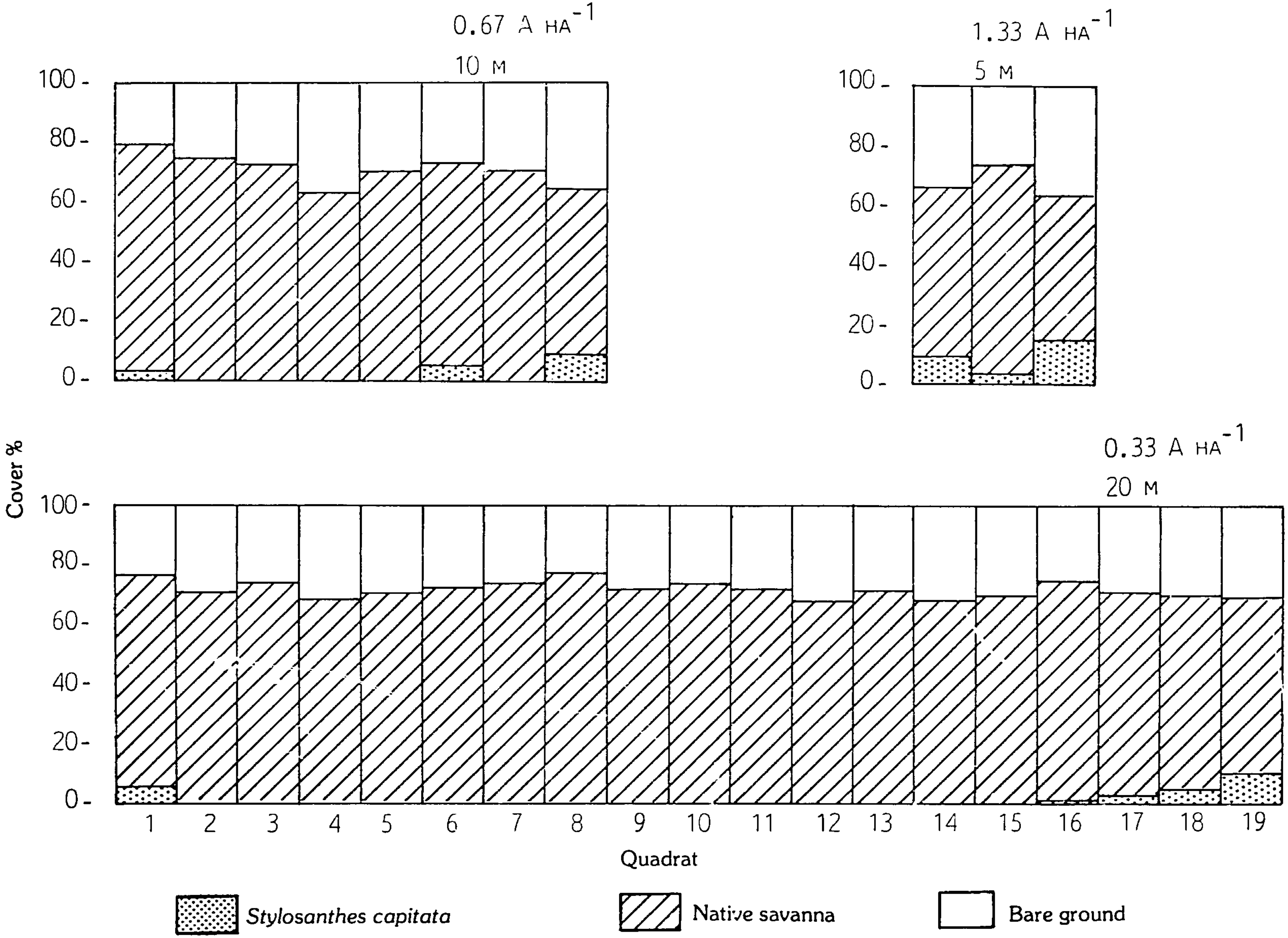


Figure 2. Percentage cover of *Stylosanthes capitata*, native savanna, and bare ground, per quadrat (1 m^2) along a transect between two strips. Ten transects were evaluated in each of three combinations of stocking rate and spacing between strips in native pastures at Yopare, Carimagua.

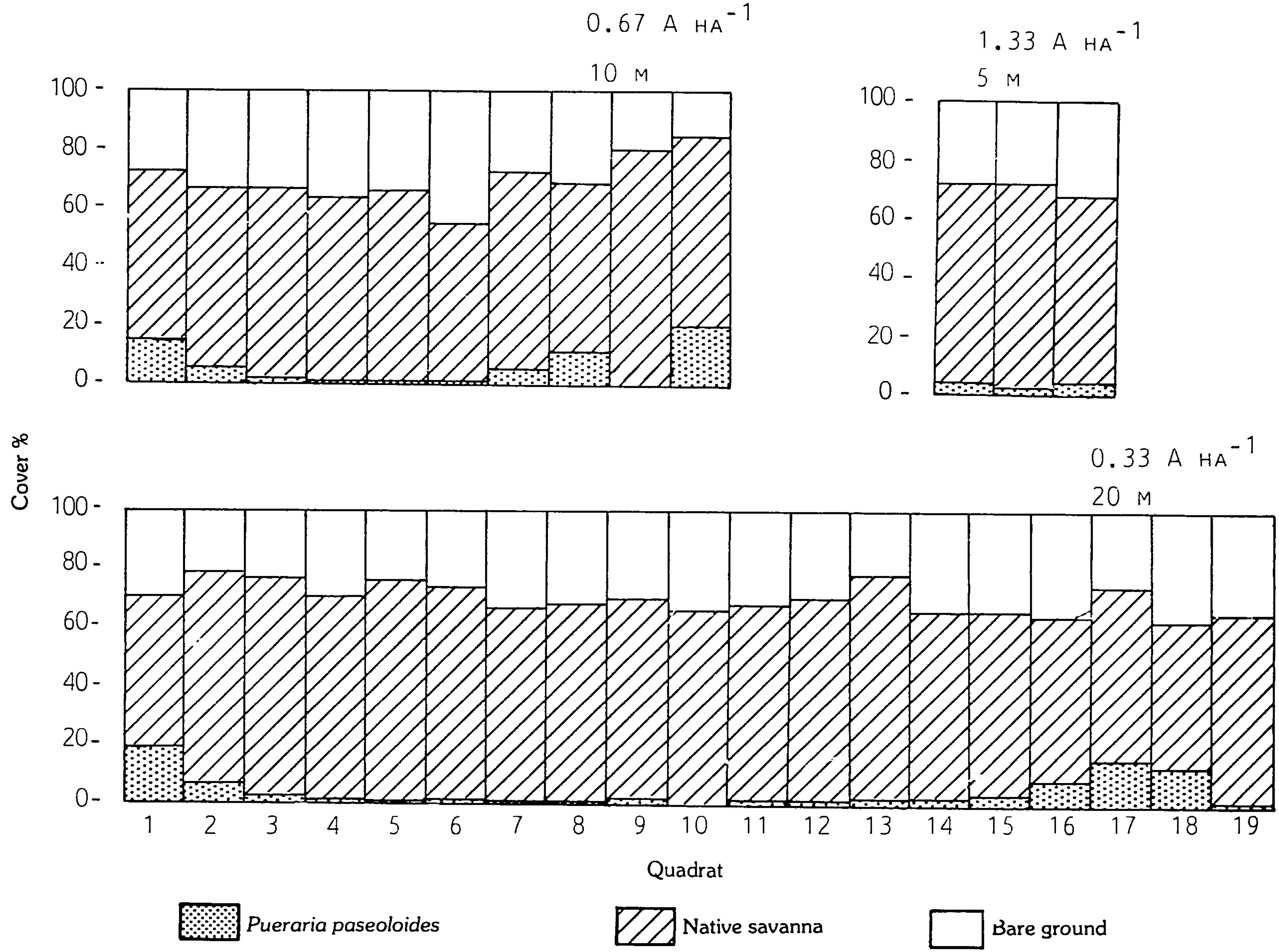


Figure 3. Percentage cover of *Pueraria phaseoloides*, native savanna, and bare ground, per quadrat (1 m²) along a transect between two strips. Ten transects were evaluated in each of three combinations of stocking rate and spacing between strips in native pastures at Yopare, Carimagua.

Table 3. The effect of stocking rate and area of legume planted $animal^{-1}$ on the productivity of animals grazing native savanna supplemented with *Stylosanthes capitata* (S.c.) and *Pueraria phaseoloides* (P.p.), in continuous grazing during 206 days, wet season, 1984. Carimagua.

Stocking rate	Parameter	Area of legume/animal (m^2)					
		Control	P.p.	---------- S.c.	----------	----------	
		0	1500	750	1500	2250	Means
0.33	kg/ha	26	25	24	27	-	26
	kg/an	78	76	74	82	-	78
	g/an/day	380	366	357	400	-	376
0.66	kg/ha		60	38	33	54	46
	kg/an		91	57	50	82	70
	g/an/day		334	277	244	399	340
1.00	kg/ha		69	38	82	62	63
	kg/an		69	38	82	62	63
	g/an/day		334	182	400	300	304
1.33	kg/ha		74	-	106	95	92
	kg/an		56	-	79	72	69
	g/an/day		269	-	386	348	334
Means	kg/ha	26	57	33	62	71	
	kg/an	78	73	56	74	72	
	g/an/día	380	360	272	357	349	

Flexible Management: A Methodology Proposed for Germplasm Evaluation in Associations under Grazing

Based on previous observations and the preliminary results of the two experiments described above, a methodology based on flexible management has been proposed for the advanced evaluation of germplasm in association and under grazing.

The proposed management consists of adjusting stocking rate when grazing pressure reaches pre-defined limits (eg. 3 and 6 kg dry weight of green forage/100 kg liveweight/day) thus maintaining the grazing pressure in the desired range. Grazing system is adjusted when the proportion of legume in the associa-

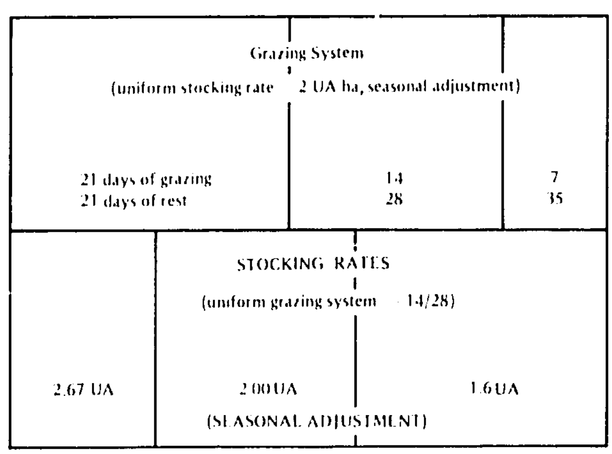


Figure 4. Field design of experiment on the effect of stocking rates and grazing systems on botanical composition, productivity and persistence of an association of *A. gayanus* and *P. phaseoloides*. Carimagua 1984.

Table 4. The effect of grazing systems and stocking rates on initial green forage availability and % legume in forage in an association of A. gayanus with P. phaseoloides. October-November grazing cycle.

Effect of grazing system (uniform stocking rate = 2.0 A.U./ha).

System Grazed/rested	Grass	Legume	Total	Legume
	------------ DM, g/m^2		------------	%
7/35	322	25	347	7
14/28	72	28	100	28
21/21	49	50	99	51

Effect of stocking rate (uniform grazing system = 14/28).

Stocking rate	Grass	Legume	Total	Legume
-- A.U./ha* --	------------ DM, g/m^2		------------	%
1.60	161	35	196	18
2.00	52	41	93	44
2.67	44	52	96	54

* 1 A.U. = 400 kg.

tion also reaches pre-established limits (eg. 15 and 50% of the available green forage). In general, it has been observed that on structurally stable soils, continuous grazing favors the legume, especially the more aggressive and/or less palatable species, while alternate or rotational grazing tends to favor the grass. The longer the rest for the pasture, the greater the advantage for the grass in the association.

The strategy for adjusting grazing systems and stocking rates to maintain balance between legume and grass and adequate forage on offer is shown schematically in Figure 5. It is hoped that the use of relatively wide ranges of botanical composition and forage on offer will result in rather infrequent adjustments.

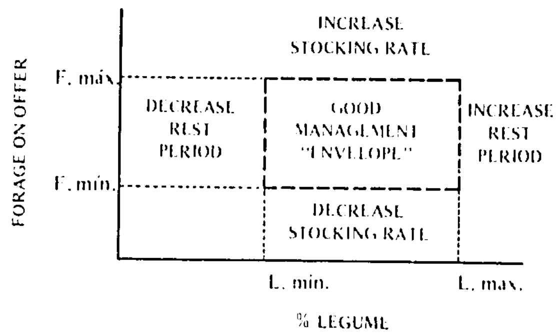


Figure 5. A schematic representation of the management required to maintain most associations of adapted tropical grasses and legumes within the good management "envelope".

The field design for an experiment being carried out at Carimagua is shown in Figure 6. In this trial, five associations are compared under flexible management. There are two replicates of completely randomized blocks. Each association will be grazed by one group of animals per replicate. The grazing animals alternate between the two divisions of each pasture. Stocking rates and grazing systems to be used at the beginning of grazing will be based on experience with the species included.

In addition to the five associations being compared in this trial, ecotypes of one of the species in each association are also included in small plots within the paddocks as shown in Figure 6. The ecotypes are associated with the other species in the association and are exposed to the same grazing management as the rest of the paddock.

It is estimated that up to 10% of the paddock could be used for these small ecotype plots without jeopardizing the results of the trial in terms of animal performance, Thus it is possible to include many promising ecotypes and greatly increase the capacity of the system to move forward more than one ecotype of the most promising species. Another experiment based on the same design was initiated in 1983 at the Gregorio Bondar Experiment Station of CEPLAC in Barrolandia, Bahía. An association of Brachiaria humidicola and P. phaseoloides is being evaluated. Grazing was initiated in March 1984.

The methodology being tested might lend itself for use in Regional Trials D in the International Network of Tropical Pasture Evaluations, especially for sites where resources are very limited but where there is

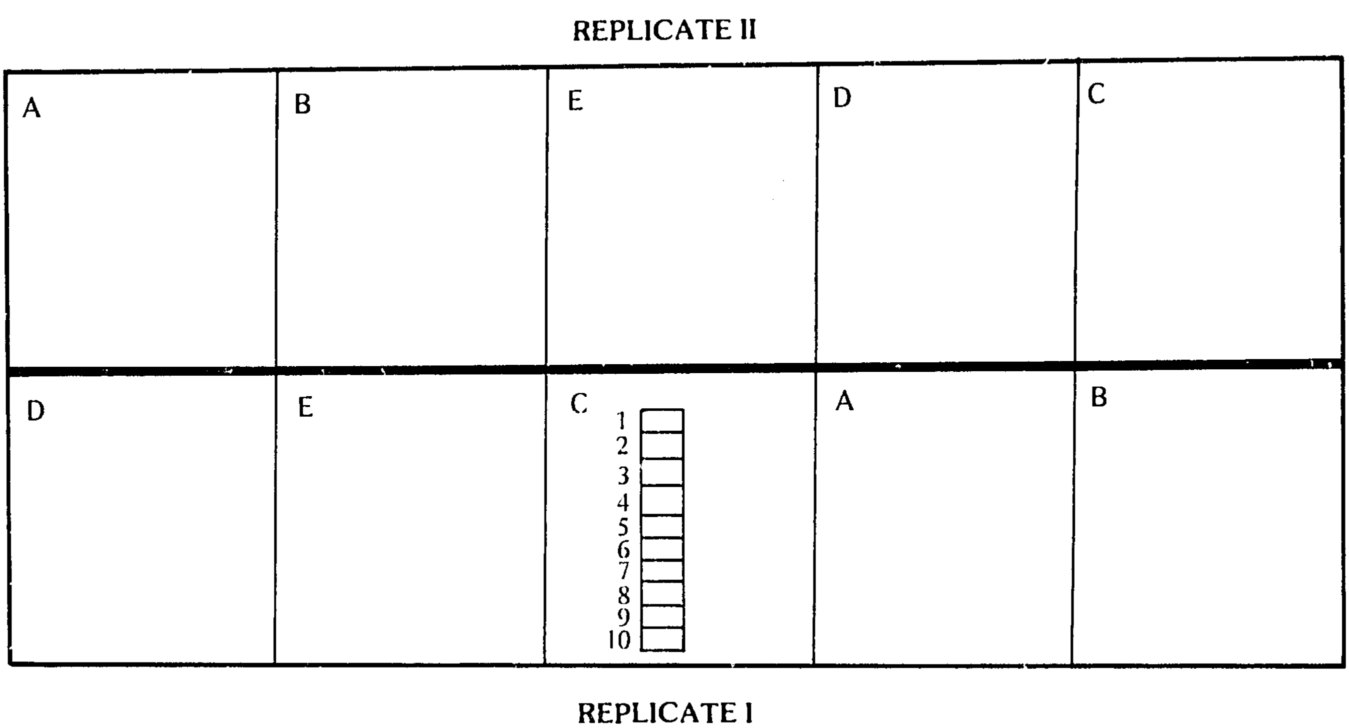


Figure 6. Field design for the evaluation on promising germplasm in associations with flexible grazing management. Each paddock is subdivided in two halves (not shown) for alternate grazing. In replicate I, association C, a plan is shown for including other ecotypes of one of the species in the association in small plots. These may be replicated within the paddock and also included in both replications of the association.

great urgency to evaluate germplasm as rapidly as possible. In addition, the design offers the possibility of evaluating additional ecotypes at minimum cost, including them in small plots within the large paddocks.

The Establishment of Pastures in Sandy Soils

Studies continue on the establishment of pastures, with emphasis on structurally less stable soils such as those sandy soils that are found on rolling terrain in large areas of tropical savannas in Latin America. Two new experiments are being conducted on sandy soils in Alegría, Carimagua, on a slope of approximately 2%.

The first trial was established in collaboration with a Japanese soil specialist assigned to the Tropical Pastures Program with a special interest in testing the use of fertilizer pellets comprised of slowly soluble sources of nutrients coated with seeds of forage species. The pellets were placed superficially in the different treatments, immediately after having coated them with seed, with the use of an appropriate adhesive. Good stands were obtained for all species in all treatments of vegetation control and tillage as shown in Tables 5, 6 and 7. A marked effect of tillage can be seen for the number of seedlings per pellet of *Centrosema* sp., *Brachiaria dictyoneura* and, to a lesser extent, *P. phaseoloides*. In addition, there is a very marked effect of tillage on all of the measured attributes of *B. dictyoneura* (height, number of plants per pellet and percentage of pellets resulting in viable seedlings).

The use of pellets opens interesting possibilities for aerial seeding or for broadcast seeding of large areas of pasture with tractor-mounted cyclone type planters.

The second experiment is designed to study the effect of tillage and chemical control of native vegetation on the establishment of four forage species planted in rows and band fertilized. Both tillage and herbicide applications had very marked effects on the growth of the planted species as shown in Table 8. When there was no tillage, chemical control of vegetation gave excellent results in terms of seedling vigor. On the other hand, when some type of tillage was used, whether chisels or off-set disc, the effect of herbicide was markedly reduced. It appears that *B. dictyoneura* is especially susceptible to competition from native savanna and responds to both chemical control and tillage. Apparently there is an additive effect when both practices are combined.

Based on this years experience, it appears that pasture establishment with only chemical control of native vegetation might be easier in sandy soils than in finer textured soils as found in the rest of Carimagua. In all of those treatments in which there was some control of vegetation, good stands of vigorous plants were obtained, in spite of severe erosion problems in those treatments with traditional tillage. There was erosion in all treatments, even the control plots with no vegetation control nor tillage, reflecting the high erodability of these soils on relatively slight slopes, under the climatic conditions which characterize the region.

Table 5. The effect of tillage and vegetation control on number of seedlings per fertilizer pellet.* Carimagua.

Species		Tillage Vegetation Control		
		Zero tillage	Chemical control	Chisel plow
		No. of seedlings		
S. capitata		3.7 ± 0.3**	3.0 ± 0.7	2.5 ± 0.8
S. macrocephala		11.6 ± 3.2	12.1 ± 2.3	11.9 ± 2.3
D. ovalifolium		7.2 ± 1.4	6.1 ± 2.2	11.7 ± 2.7
Centrosema sp.		3.3 ± 0.8	2.5 ± 0.8	13.6 ± 1.5
P. phaseoloides	Combined on same pellet	3.4 ± 0.8	3.2 ± 1.7	6.1 ± 1.7
B. dictyoneura		0.7 ± 0.4	0.6 ± 0.2	2.6 ± 0.7

* The number of seeds $pellet^{-1}$ of *S. capitata*, *S. macrocephala*, *D. ovalifolium*, *Centrosema* sp., *P. phaseoloides* and *B. dictyoneura* was 100, 100, 100, 25, 50 and 50, respectively.

** Mean ± standard deviation.

Table 6. The effect of tillage and vegetation control on plant height of forage species planted with fertilizer pellets. Carimagua.

Species		Tillage-Vegetation Control		
		Zero tillage	Chemical control	Chisel plow
		cm		
S. capitata		2.6 ± 0.3*	3.6 ± 0.4	2.9 ± 0.4
S. macrocephala		1.2 ± 0.4	1.6 ± 0.3	2.2 ± 0.1
D. ovalifolium		2.9 ± 0.4	3.9 ± 0.3	3.4 ± 0.5
Centrosema sp.		9.2 ± 1.1	10.7 ± 1.1	12.0 ± 0.9
P. phaseoloides	Combined on same pellet	5.2 ± 0.5	5.3 ± 0.6	7.0 ± 0.8
B. dictyoneura		6.5 ± 1.3	6.4 ± 1.9	15.9 ± 3.0

* Mean ± standard deviation..

Table 7. The effect of tillage and vegetation control on the percentage of fertilizer pellets producing viable seedlings. Carimagua.

Species		Tillage-Vegetation Control		
		Zero tillage	Chemical control	Chisel plow
		%		
S. capitata		91 ± 20*	89 ± 13	75 ± 20
S. macrocephala		100 ± 0	100 ± 0	97 ± 20
D. ovalifolium		89 ± 13	78 ± 51	97 ± 14
Centrosema sp.		89 ± 32	78 ± 59	100 ± 0
P. phaseoloides	Combined on same pellet	95 ± 7	81 ± 31	95 ± 9
B. dictyoneura		44 ± 73	47 ± 45	91 ± 22

Planted early September 1984; measurements taken early October 1984.

* Mean ± standard deviation..

Table 8. The effects of tillage system and herbicide on the % coverage of planted grasses and legumes and of native savanna plants, twelve weeks after planting in a sandy soil. Alegría, Carimagua.

Species	Tillage: Zero		Chisels		Chisels + offset disc		2 Passes offset disc
	Chemical control (gliphosate)						
	-	+	-	+	-	+	-
	% coverage						
A. gayanus 621	8	24	30	35	27	32	27
B. dictyoneura 6133	5	36	27	56	25	56	31
P. phaseoloides 9900	9	39	27	33	30	44	29
S. macrocephala 1281	14	30	28	31	29	35	28
Native species	65	8	34	8	30	11	15

Commercial Planting of Strips in Savanna

During the present year, the section had the opportunity to collaborate in planting an association comprised of *B. dictyoneura* and *P. phaseoloides* using a strip planting system. The objective is to eventually replace all of the savanna in the trial area by the planted species. The planting was done in one of the savannas in El Tomo, immediately after burning. The planter used consists of a chisel plow, a drill box fertilizer spreader and a small seed drill mounted on the fertilizer drill box as shown in Figure 7. The latter combination was mounted on the rear bar of the chisel plow in such a manner as to permit the preparation of land, application of fertilizer and planting in a once-over operation. Two rows of grass were planted in the middle of the 2.5 m strip and a row of legume on each edge.

The legume plays the role of pioneer, invading the savanna and creating more favorable fertility conditions for the subsequent invasion of the grass. The strategy to be used is similar to that employed in the savanna replacement trial in which the area fertilized is increased year by year. The strips were planted 12.5 m apart, leaving a strip of undisturbed savanna of 10 m.
The seedling density in the planted strip achieved at eight weeks is shown in Table 9. Planting immediately after burning the savanna was a strategy chosen in the hopes that the regrowth of the recently burned savanna would provide forage for leaf cutter ants in order to reduce the damage they normally cause to seedlings of planted species. However,

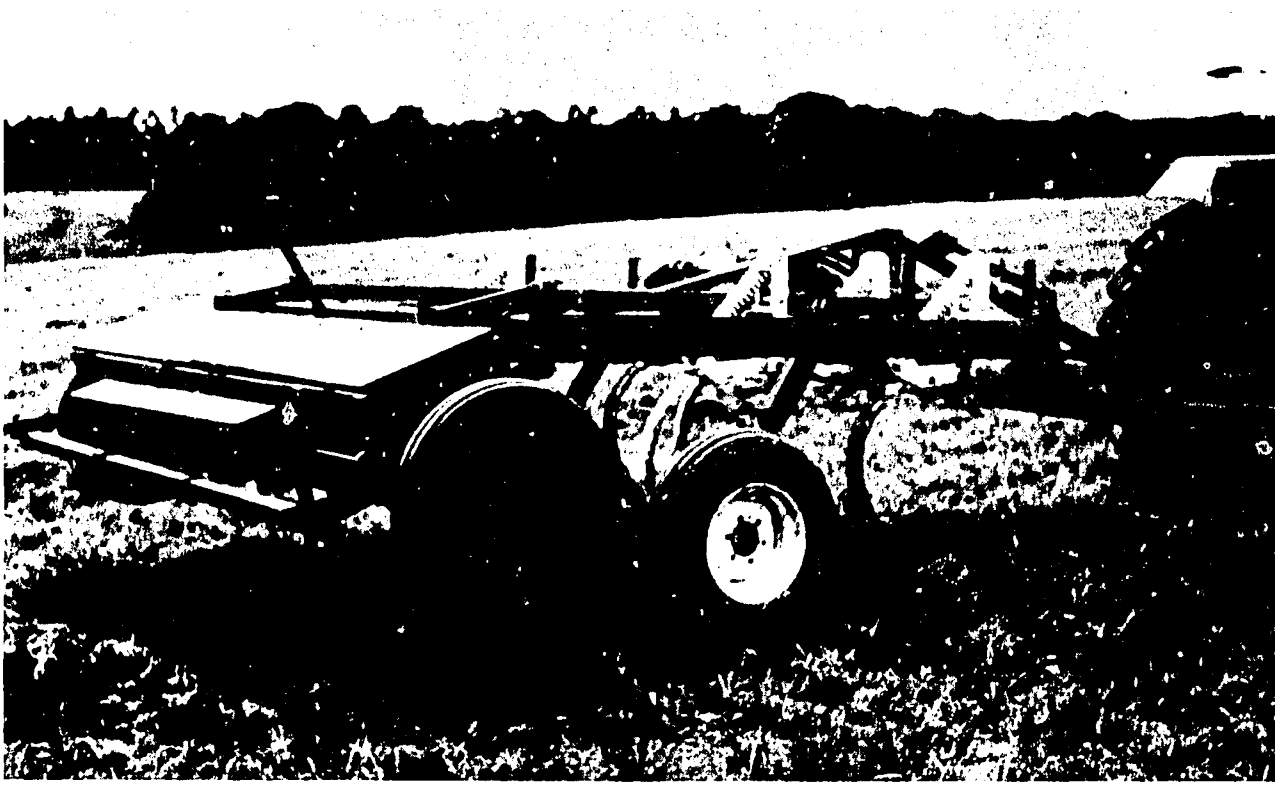


Figure 7. Combined planter consists of a chisel plow, a drill box fertilizer spreader and a small seed drill, used for strip planting on a commercial scale. Carimagua, 1984.

Table 9. Seedling density in planted strips 8 weeks after planting.

Species	Plant Density* (plants/m^2)
P. phaseoloides 9900	7.9
B. dictyoneura 6133	3.2

* Average of 30 observations.

after about 15 days, the ants began to harvest the grass, and somewhat later began to cause severe damage to the legume; this in spite of a rigorous control of the more obvious ant hills in the field of 75 hectares.

The planting system tested is quite efficient in terms of machinery time, labor and materials. The combined planter permits the sowing of approximately 1 hectare/hour. The planted strips cover approximately 20% of the total area (15 hectares planted in 75 hectares total), for a total of 15 tractor hours.

PASTURE QUALITY AND NUTRITION

Research activities during 1984 concentrated on four areas: 1) characterization of quality factors in promising germplasm, 2) relative palatability and selectivity of legumes under grazing, 3) nutritional aspects in native savanna with legume banks, and 4) methodological studies under grazing. The following is a summary of the results of experiments concluded and a progress report of on-going studies.

CHARACTERIZATION OF QUALITY FACTORS IN GERMPLASM

Characterization studies of quality factors in germplasm were carried out at the CIAT-Quilichao Substation. Results of three projects are reported: 1) factors related to *in vitro* digestibility of *Desmodium ovalifolium* 350, 2) digestibility and intake of *Zornia glabra* 7847, and 3) quality under grazing of three *Andropogon gayanus* entries.

In vitro digestibility of Desmodium ovalifolium 350

In the 1981 Annual Report it was shown that the *in vitro* system underestimates digestibility of *D. ovalifolium* 350, since *in vivo* digestibility estimates of this legume had been consistently higher than the corresponding values *in vitro*, once corrected by standards. Therefore, it was interesting to study some factors that could affect digestibility of *D. ovalifolium* 350, using *Centrosema macrocarpum* 5065 as the control.

Samples of *D. ovalifolium* 350 and *C. macrocarpum* 5065 offered to crated wethers were subject to three drying treatments: 1) oven at 100°C, 2) oven at 60°C, and 3) freeze drying. The resulting samples were incubated *in vitro* during 48 hours using a media of bacteria inoculum + buffer + macro and micromineral + a reducing solution, followed by digestion with pepsin (48 hours). Results in leaves (Table 1) showed that *in vitro* digestibility (IVDMD) of *D. ovalifolium* 350 was greater ($P < .05$) in freeze-dried samples than in those oven-dried at 100° and 60°C; these effects were not evident in samples of *C. macrocarpum* 5065.

In comparing results of *in vivo* digestibility with those of *in vitro* digestibility in the diet (Table 2), it is clear that, even when samples of *D. ovalifolium* 350 are freeze-dried, the *in vitro* values are lower than those observed with wethers *in vivo*. This unexplained difference will be investigated in the future with the idea of being able of establishing a correction factor to adjust *in vitro* values obtained with samples conventionally dried.

The effect of the drying method was evaluated also in terms of catechin equivalents (tannins); values were higher ($P < .05$) in leaves and stems of *D. ovalifolium* 350 subject to freeze drying, with no effect in the case of *C. macrocarpum* 5065, which presented a very low content of tannins (Table 3). This could indicate that as a result

Table 1. Effect of drying method on the *in vitro* digestibility (IVDMD) of the leaf of two legumes.

Legumes	Drying method		
	100°C	60°C	Freeze-drying
	% IVDMD in leaves		
D. ovalifolium 350	30.4[a]	34.3[a]	42.9[b]
C. macrocarpum 5065	58.8[a]	58.8[a]	62.5[a]

a, b Means in the same row followed by different letters are significantly different (P < .05).

Table 2. Comparison of the *in vitro* and *in vivo* digestibility estimates of the diet two legumes fed to crated wethers.

Legumes	Digestibility (diet)		
	In vitro[1] (%)	*In vivo* (%)	Difference[2]
D. ovalifolium 350	45.2	55.6 ± 2.5	-10.4
C. macrocarpum 5065	62.5	56.6 ± 2.1	+ 5.9

1/ Samples of freeze-dried forage.
2/ Difference between *in vivo* and *in vitro* estimates.

of freeze drying, absence of heat during drying, there was less reaction between condensable tannins and plant nitrogen, particularly that associated with the fiber. The acid detergent fiber (ADF) and the nitrogen associated with this fiber (N-ADF) were lower in freeze-dried leaves as compared oven-dried samples (Table 4), indicating less formation of indigestible compounds, as a result of heat damage.

Intake of Zornia glabra 7847

During 1983 it was reported that the intake of *Zornia brasiliensis* 7845 by wethers in metabolic crates was low and that in addition animals exhibited digestive problems. This fact was associated with a positive reaction of the legume to alkaloids. On the other hand, *Zornia* sp. accessions included in the alkaloid test gave negative results. To verify these findings *Z. glabra* 7847 was offered to crated wethers; results are shown in Table 5. Digestibility values as well as intake values were high, although the latter were variable between animals. During the 14-day duration of the trial no signs of digestive problems were observed in the animals, suggesting that this legume is not asociated to alkaloid problems as was the case with *Z. brasiliensis* 7485.

Quality of Andropogon gayanus clones

In experiments carried out in col-

Table 3. Effect of drying method on the catechin equivalents (tannins) content of two legumes.

Legumes	Plant Part	Drying method		
		100°C	60°C	Freeze-drying
		% tannins[1]		
D. ovalifolium 350	Leaf	13.2[a]	12.4[a]	16.4[b]
	Stem	3.0[a]	1.9[a]	5.8[b]
C. macrocarpum 5065	Leaf	0.24[a]	0.30[a]	0.28[a]
	Stem	0.05[a]	0.10[a]	0.49[a]

1/ Vaniline - HCl method.
a, b Means in the same row followed by different letters are significantly different ($P < .05$).

Table 4. Acid detergent fiber (ADF) and nitrogen in the ADF (N-ADF) in two legumes subject to different drying methods.

Legumes[1]	Fraction	Drying method		
		100°C	60°C	Freeze-drying
		%		
D. ovalifolium 350	ADF	37.7	39.6	34.3
	N-ADF	1.13	1.00	0.81
C. macrocarpum 5065	ADF	28.6	29.5	27.3
	N-ADF	0.93	0.84	0.81

1/ Leaves.

Table 5. Characterization of *Zornia glabra* 7847 offered to crated wethers.

Measurements[1]	Results
Forage on offer	
Leaves (%)	48.9 ± 4.9
Stems (%)	40.5 ± 3.3
Inflorescence (%)	10.6 ± 4.6
Trial with wethers	
Total DM on offer (g $kg^{-.75} day^{-1}$)	115.7 ± 4.5
DM digestibility (%)	60.0 ± 1.9
DM intake (g $kg^{.75} day^{-1}$)	81.1 ± 23.8

1/ Measurements carried out with six animals during 7 days after a 7-day adjustment period.

laboration with the Forage Improvement Section it was found that A. gayanus clones selected on the basis of leafiness were more consumed by crated wethers than stemy clones (Annual Report, 1982). However, it was indicated that these results had to be validated with animals under a grazing situation. Therefore, experimental plots were established in Quilichao with leafy and stemy A. gayanus clones, including the accession CIAT 621 as control, and from which the clones were selected. Each entry of A. gayanus, with two field replications, was included in an adjustment and measurement plot. Using bi-fistulated steers, digestibility and intake under grazing were measured in a 6-weeks regrowth using a similar grazing pressure for each entry.

Even though the grazing pressures actually used were not statistically different, it was observed that in one of the sampling dates (April), the pressure on the leafy clone tended to be smaller than in the other two entries (Table 6). Results of in vivo digestibility and intake (Table 7) did not indicate differences ($P > .05$) between A. gayanus entries in the two sampling periods. Complementary evaluations included in this study showed that in the two sampling dates the animals were capable of selecting high proportions of leaf from the three entries, giving selection indexes of more than 1 in all cases (Table 8). The selection of leaves was greater ($P < .05$) in the leafy clone, as compared with the other entries, ones in the first sampling period (April) and it was related to the higher proportion ($P < .05$) of leaves in this period. It is interesting to note that the leaf:stem relation in the available forage was not consistent among sampling periods, as can be seen in Table 8.

Table 6. Available forage and resulting grazing pressures in the quality evaluation of A. gayanus CIAT 621 (Control) and of two clonal selections (leafy and stemy).

Al gayanus entry[1]	Available forage[2]	Grazing pressure
	kg DM ha[1]	kg DM 100 kg $LW^{-1}day^{-1}$
Period I (April)		
CIAT 621 (Control)	2956[3]	7.7[3]
Leafy clone	2746	9.2
Stemy clone	2996	5.9
Period II (June)		
CIAT 621 (Control)	2297	5.7
Leafy clone	1889	5.2
Stemy clone	2546	5.7

1/ 6-week regrowth.
2/ Values reported are averages throughout 7 days of grazing.
3/ Means within period do not differ ($P > .05$).

Table 7. Digestibility and intake under grazing of *A. gayanus* CIAT 621 (Control) and of two clonal selections (leafy and stemy).

A. gayanus entry[1]	Dry matter digestibility[2] (%)	Dry matter intake[3] ($kg\ 100\ kg\ LW^{-1} day^{-1}$)
Period I (April)		
CIAT 621 (Control)	56.0 ± 3.0[4]	1.61 ± .19[4]
Leafy clone	49.0 ± 3.2	1.40 ± .18
Stemy clone	55.4 ± 4.4	1.66 ± .14
Period II (June)		
CIAT 621 (Control)	60.2 ± 1.6	1.80 ± .07
Leafy clone	57.0 ± .8	1.69 ± .11
Stemy clone	58.6 ± .8	1.52 ± .16

1/ 6-week regrowth.
2/ Internal marker: indigestible neutral detergent fiber.
3/ External marker: chromium oxide paper.
4/ Means within period do not differ ($P > 0.05$).

Table 8. Leaf proportion on the forage on offer and selected by esophageal-fistulated steers in *A. gayanus* CIAT 621 (Control) and in two clonal selections (leafy and stemy).

A. gayanus entry[1]	Leaves in forage (%)		
	Available[2]	Selected[2]	SI[3]
Period I (April)			
CIAT 621 (Control)	49.0[a]	84.2[a]	1.7
Leafy clone	69.3[b]	93.7[b]	1.3
Stemy clone	52.8[a]	82.7[a]	1.6
Period II (June)			
CIAT 621 (Control)	59.4[a]	89.3[a]	1.5
Leafy clone	59.4[a]	88.8[a]	1.5
Stemy clone	54.1[a]	85.0[a]	1.6

1/ 6-week regrowth.
2/ Reported values are averages throughout 7 days of grazing.
3/ Selection index = % leaf selected ÷ % available leaf.
a, b Means in the same row followed by different letters are significantly different ($P < .05$).

Results of digestibility and intake suggest that the selection of A. gayanus by leafiness would not have a major impact on animal production, at least within the range of leafiness included in the trial and under the grazing pressures used. However, it is necessary to recognize that a very leafy A. gayanus genotype with high biomass production potential could result in higher weight gains than stemy genotypes or even than the control CIAT 621 when high stocking rates are used.

To prove the above hypothesis, the experiment was modified to include measurements of liveweight in gains each entry of A. gayanus using high stocking rates in a rotational system of 7/21. Weight gain measurements will be accompanied by a detailed description of pasture attributes.

PALATABILITY AND SELECTIVITY OF LEGUMES

As in previous years, experiments on palatability and selectivity of legumes were carried out in the CIAT-Quilichao Substation in collaboration with other sections of the Program. The results of the following studies are reported: 1) relative palatability of legumes, and 2) selectivity and dynamics of legumes in association with A. gayanus.

Relative Palatability of Legumes

In collaboration with the Germplasm Section, the relative palatability of eight legumes was evaluated during the period of maximum rainfall, using a "cafeteria" system. The legumes included in the trial were:

1. Centrosema sp. (5568)
2. Zornia sp. (8279 + 8283)
3. Zornia sp. (7847)
4. Stylosanthes viscosa (1353 + 1538 + 2405)
5. Desmodium valutinum (13204 + 13213 + 13215)
6. Stylosanthes guianensis var. pauciflora (2812)
7. Tadehage sp. (13276)
8. Flamingia sp. (17403)

Measurements were carried out during 10 days, allowing the animals a 5-day period adjustment. Grazing frequency observations were done every 5 minutes from 9:00 am to 4:00 pm during the first 5 days and from 9:30 to 10:30 am and from 2:30 to 3:30 pm the remaining 5 days. A palatability index was calculated by dividing the %observed grazing frequency on each accession by the expected frequency had no preference occurred.

Results indicated that during the most sensible days (1 to 3) to detect differences, Centrosema sp. (5568) was the most palatable legume, followed by Zornia sp. (8279 + 8283) (Figure 1). During the following days (5 to 10) there was an increase in preference for Zornia sp. (7847), while preference for S. viscosa (1353 + 1538 + 2405), D. velutinum (13204 + 13213 +13215), S. guianensis (2812), and Tadehage (13276) was low and relatively constant throughout the experiment. In addition, palatability of Flamingia sp. (17403) was extremely low throughout the evaluation period. It was interesting to observe that during the first 3 days of the trial, animals had a higher preference for Zornia sp. (8279 + 8283) in relation to Zornia sp. (7847) (Figure 2), and not related to the initial forage availability of these legumes (Table 9).

As a result of this experiment, it is evident that among the legumes evaluated:

1. Centrosema sp. (5568) was highly palatable.
2. Zornia sp. (8279 + 8283) and Zornia sp. (7847) were of medium palatability, with differences between accessions.

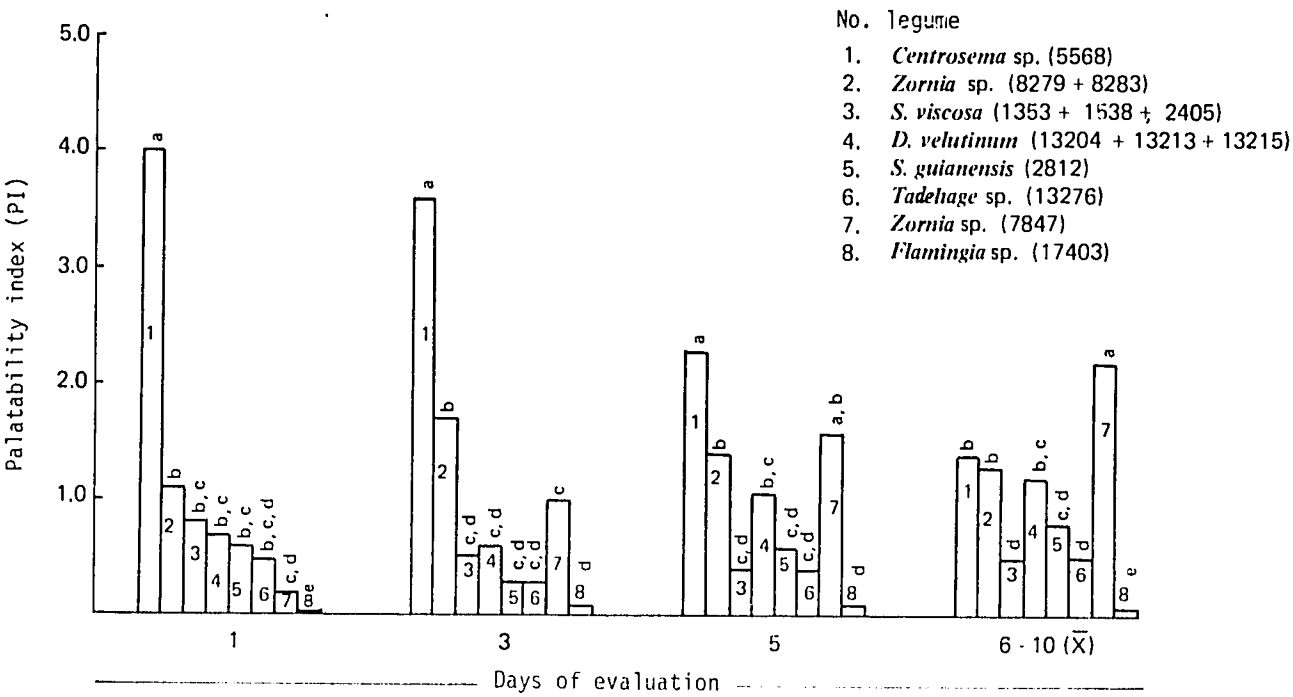


Figure 1. Relative palatability of eight legumes under grazing in "cafeteria" trial (PI = % observed eating ÷ % expected eating). [Bars with different letters are significantly different (P < .05)].

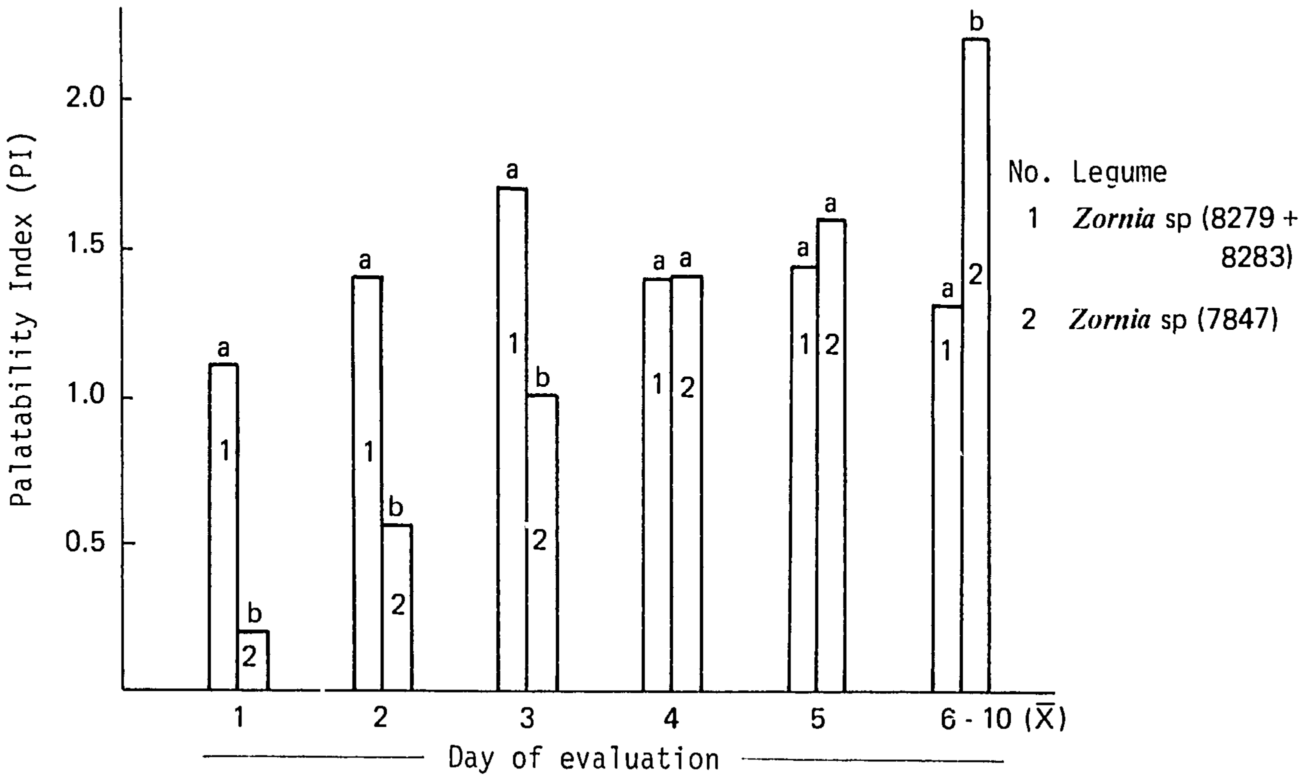


Figure 2. Relative palatability of two Zornia accessions under grazing in a "cafeteria" trial (PI = % observed eating ÷ % expected eating). [Bars with different letters are significantly different (P < .05)].

Table 9. Initial forage availability of legumes evaluated in "cafeteria" trial.

Legume (CIAT No.)	Available forage ($g.m^{-2}$)		
	REP 1	REP 2	Average
Centrosema sp. (5568)	270	260	265
Zornia sp. (8279 + 8283)	320	320	320
Zornia sp. (7847)	440	460	450
S. viscosa (1353 + 1538 + 2405)	460	547	504
D. velutinum (13204 + 13213 + 13215)	457	330	394
S. guianensis (2812)	380	340	360
Tadehage sp. (13276)	420	470	445
Flamingia sp. (17403)	490	730	610

3. D. velutinum (13204 + 13213 + 13215), S. guianensis var. pauciflora (2812), S. viscosa (1353 + 1538 + 2405), and Tadehage sp. (13276) had a low degree of palatability.
4. Flamingia sp. (17403) was completely rejected.

This trial will be repeated during a period of low rainfall since relative palatability of the species studied could be affected by environmental factors.

Botanical Composition and Selectivity in Associations

A grazing trial was established in small plots in the CIAT-Quilichao Substation to evaluate stocking rate effects on the botanical composition and selectivity of legumes in association with A. gayanus. With the stocking rates used considerable differences in forage availability have been observed during the period of minimum as well maximum rainfall in each of the six associations evaluated (Table 10). Similarly, the stocking rates have affected legume persistence but in different directions. The high stocking rate has had an adverse effect on S. guianensis var. pauciflora 1283, Z. brasiliensis 7485, and C. macrocarpum 5065 but has been beneficial to S. macrocephala 1643 (Figure 3). On the other hand, the low stocking rate negatively affected Z. glabra 7847 but favored D. ovalifolium 3784 (Figure 3).

A more detailed analysis of botanical composition over time is presented in Figure 4 for three legumes. It is obvious that Z. glabra 7847, independent of the stocking rate, is very susceptible to drought, in contrasts with the greater tolerance of S. guianensis var. pauciflora 1283. Recovery of S. macrocephala 1643 was evident during the period of maximum rainfall and most likely be the result of seedlings from seed reserves in the soil, as indicated by seed counts at three soil depths (Figure 5). The amount of S. macrocephala 1643 seed in the soil was low at all three depths, in spite of its well-known high seed production potential. Other legumes such as S. guianensis var. pauciflora 1283 and Zornia sp. 7847 seem to depend less on soil seed reserves as a mechanism of persistence.

In general, legume selection, measured with esophageal-fistulated steers, was low, and related to availability and stocking rate, particularly in the case of C. macrocarpum 5065, Z. glabra

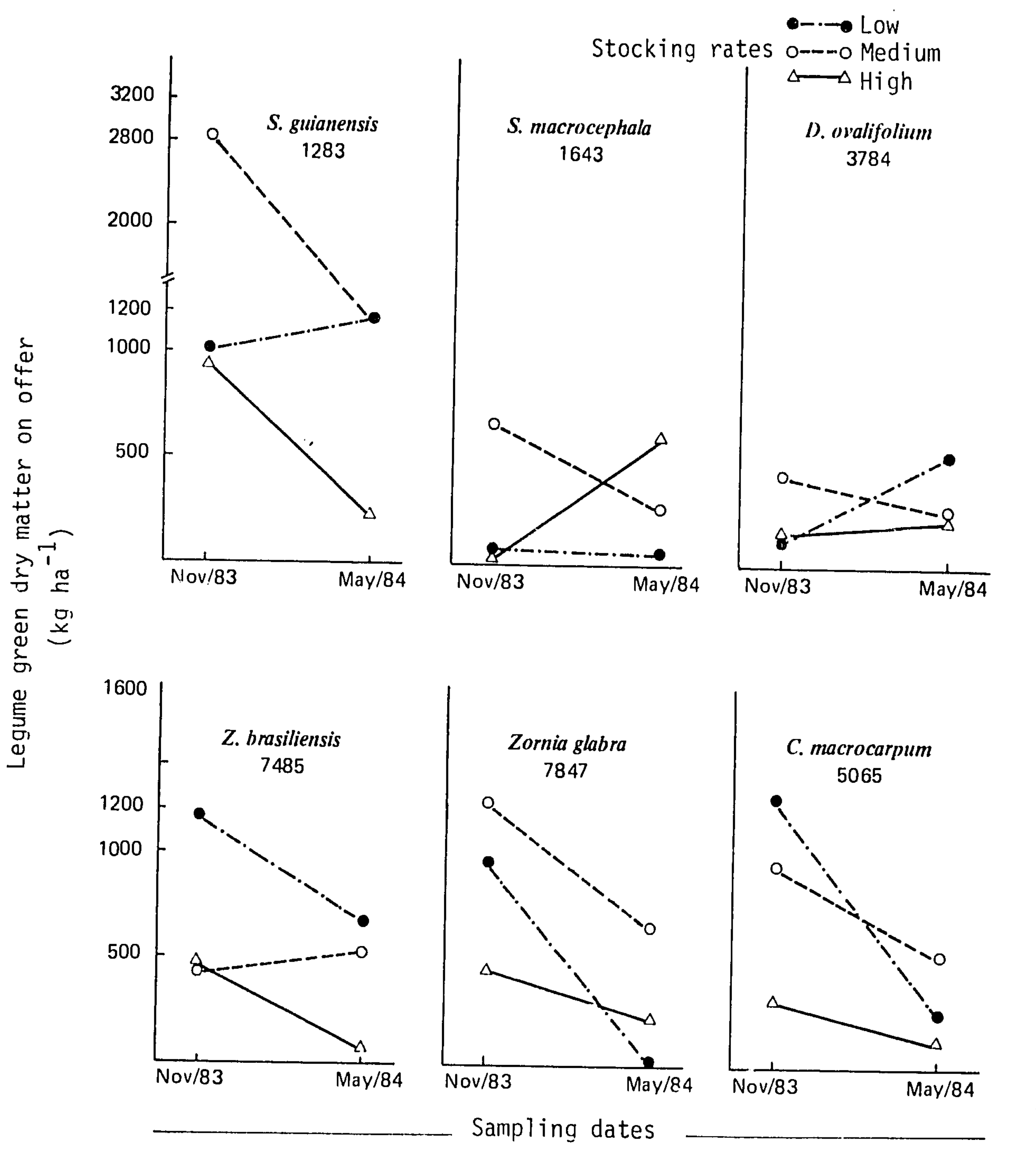


Figure 3. Changes in availability of six legumes associated with A. gayanus under three grazing pressures during the period of maximum rainfall (Quilichao).

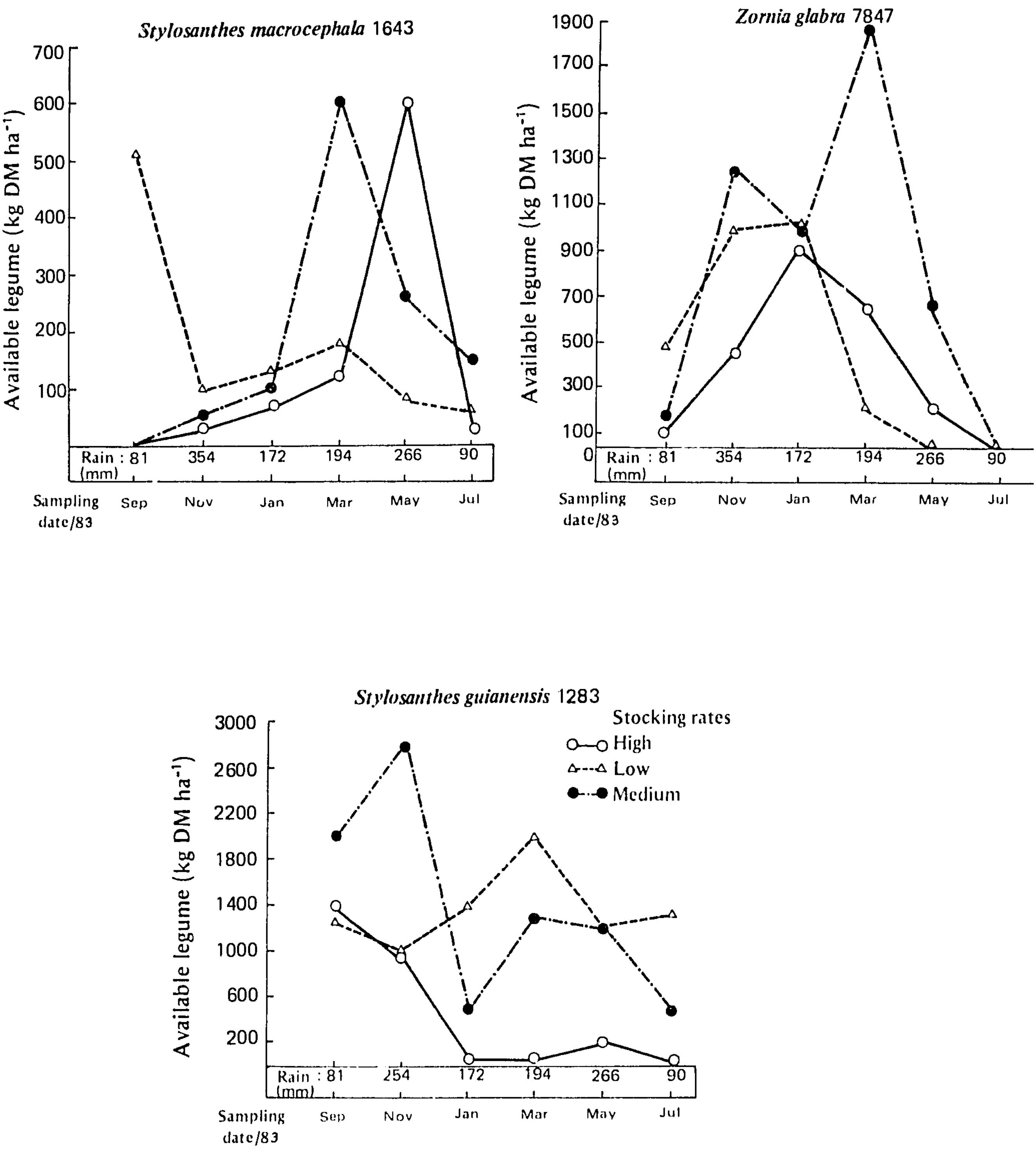


Figure 4. Changes over time of three legumes associated with A. gayanus under three stocking rates (Quilichao).

Table 10. Effect of high (H), medium (M), and low (L) stocking rates (S) in the availability of green dry matter (GDM) of A. gayanus in association with six legumes during two seasons of the year.

A. gayanus associated with	Season (rainfall)					
	(Minimum)[1]			(Maximum)[2]		
	HS	MS	LS	HS	MS	LS
	($t\ GDM\ ha^{-1}$)					
S. guianensis 1283	0.5	1.2	2.0	3.3	3.7	4.8
S. macrocephala 1643	0.9	1.7	1.6	1.4	4.4	5.3
Z. brasiliensis 7483	0.8	0.8	2.0	2.4	3.9	5.3
Z. glabra 7487	1.2	1.7	3.1	2.3	3.9	5.2
C. macrocarpum 5065	0.9	2.0	2.3	2.5	4.6	5.6
D. ovalifolium 3784	0.9	1.1	1.9	2.5	3.5	5.3
Average	0.9	1.4	2.2	2.4	4.0	5.3

1/ Values are means of two evaluations.
2/ Values are means of four evaluations.

7847, and D. ovalifolium 3784 (Figure 6). The relative low selectivity of S. macrocephala 1643 and high selectivity of Z. brasiliensis 7485 were unexpected, on the basis of results from Carimagua and Brazilia.

The information generated in this experiment is considered very valuable, since it clearly shows the high degree of interactions that exists between stocking rate and associations in terms of legume persistence. The understanding of these interactions is important to formulate adequate grazing management strategies for larger trials, where animal production is to be measured. It is expected that this type of information will be generated in Regional Trials C (RTC), which could also include different grazing frequencies as an important factor of grazing management.

NUTRITIONAL FACTORS IN SAVANNA WITH LEGUME BANKS

During some time, the Tropical Pastures Program has been evaluating in Carimagua the effect of legume banks as a complement to native savanna managed with burning. Results obtained with P. phaseoloides or S. capitata banks indicate weight gains of 110-120 kg AU^{-1} $year^{-1}$, representing approximately a 25-30% increase over non-supplemented savanna.

To better understand the native savanna + legume banks system, detailed measurements were done during 1983 in an experiment where savanna was complemented with S. capitata (2000 m^2 per animal), with two stocking rates (0.25 and 0.50 AU ha^{-1}), and where animals had free access to the legume banks. The main variables measured every two months were: 1) botanical composition of the diet using the ^{12}C to ^{13}C ratio in feces, and 2) quality of the diet selected in savanna and in

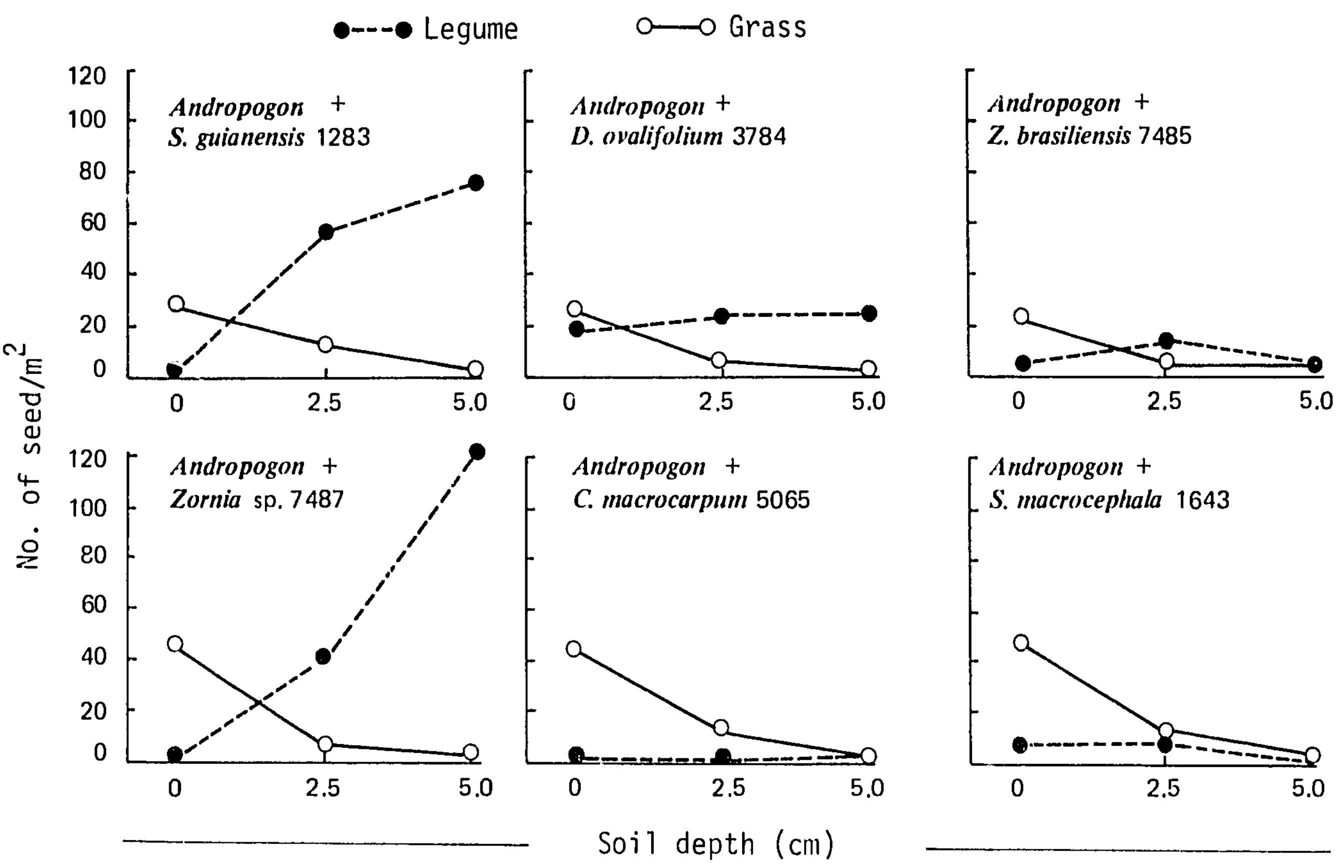


Figure 5. Soil seed availability (No./m^2) of A. gayanus and six legumes in association, at three soil depths (Quilichao).

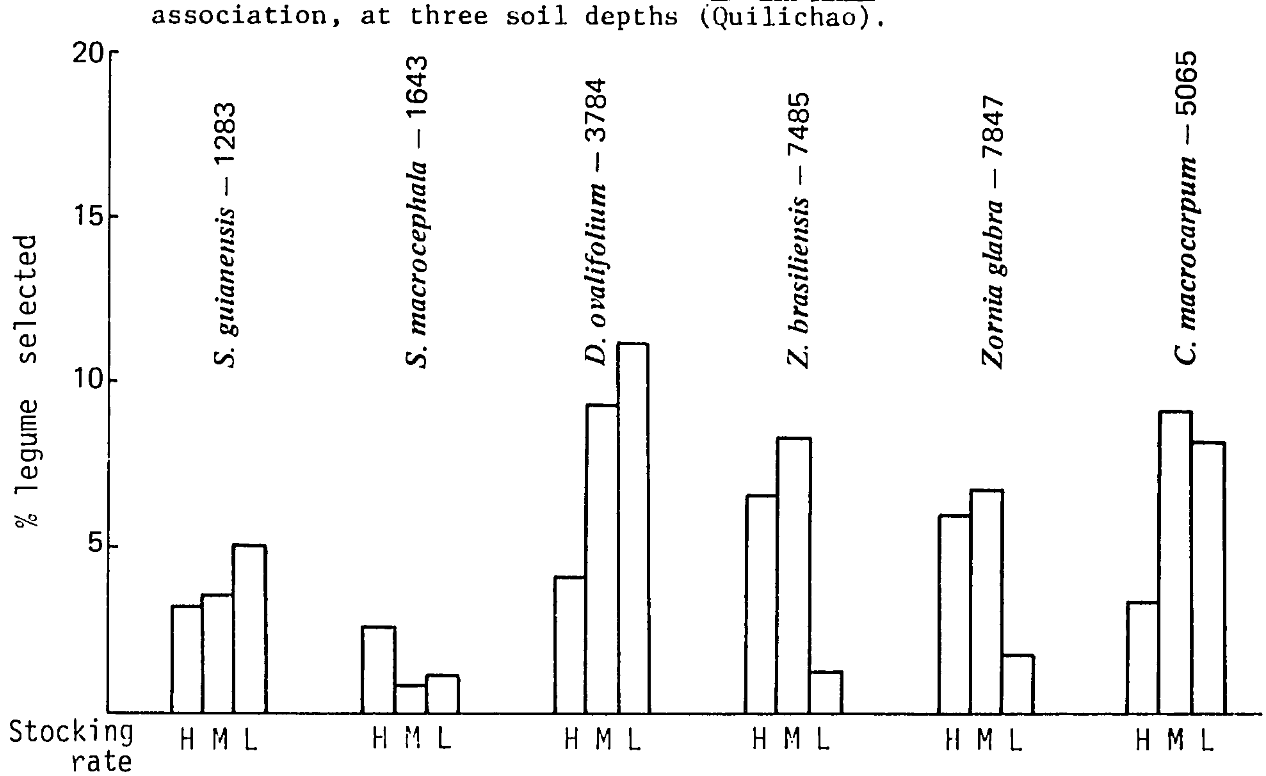


Figure 6. Proportion of legumes selected by esophageal-fistulated steers in six associations with A. gayanus under three stocking rates. Average of six evaluations (Quilichao).

the bank, in terms of protein content. In addition, digestibility and dry matter intake, were estimated using internal (indigestible neutral fiber) and external (chromium oxide paper) markers and by measuring grazing time in savanna and in banks.

Results of legume proportion and protein content in the diet selected in savanna as well as in S. capitata banks, are presented in Figure 7. The legume in the diet was not affected by stocking rate but was affected by sampling time. In July there was a considerable decrease in legume availability in the bank (see CIAT Report 1983), which resulted in less legume of in the diet during subsequent months (September to November).

As expected, the protein level in the diet selected in the bank was higher than in savanna in all sampling dates with no differences due to stocking rate (Figure 7). The lower protein values in the diet selected from the bank July and subsequent months were associated with low legume availability. It is interesting to observe in Figure 7 that protein levels in the diet selected in the native savanna were higher than the critical level throughout the year, with the highest values being after burning at the end of the dry season (March) and at the beginning of rains (April-May), and the lowest values starting in July and following months.

Data on protein and metabolizable energy intake are presented in Figure 8. Protein intake varied with stocking rate as well as sampling period; values were higher ($P < .05$) for the low stocking rate and during the dry period and at the beginning of the wet season. The highest protein intake levels (January to May) were associated with high legume selection in banks and with high protein levels in the diet selected in savanna (Figure 7). Considering ARC* (1980) protein requirements for a 200 kg LW steer, it is evident that during great part of the year there was protein in excess of that required for weight gains of 500 g AU^{-1} day^{-1}, particularly when the legume in the bank was not a limiting factor.

Differences were also detected in terms of metabolizable energy intake (Figure 8) due to stocking rate and sampling time; greater intake ($P < .05$) was observed in the low stocking rate and in the dry season.

These high levels of energy intake during the dry season were related to a relatively high consumption of S. capitata (Figure 7) and of total dry matter (2.3% of LW during dry season vs. 1.7% of LW during the rainy season). The comparison between energy values consumed and required (ARC, 1980) clearly show that, during a large part of the year there was an energy deficiency, contrary to what was observed with protein.

The results of this study suggest that in a system of native savanna managed with burning and supplemented with legume banks there is an excess of protein and an energy deficiency which limits animal productivity, in this case to approximately 300 g AU^{-1} day^{-1}. However, it is necessary to take into account that these results were obtained under a process of degradation of the S. capitata bank. It is possible that if this legume had persisted, the energy:protein rates would not have been so unbalanced and greater weight gains would therefore have been obtained, especially considering that S. capitata presents a high consumption rate and provides relatively high levels of energy in comparison to other legumes such as Kudzu (see Annual Report, 1983).

The use of a bank of improved grass associated with a legume to complement native savanna managed with burning in the Colombian llanos is thought to be a better alternative than a pure

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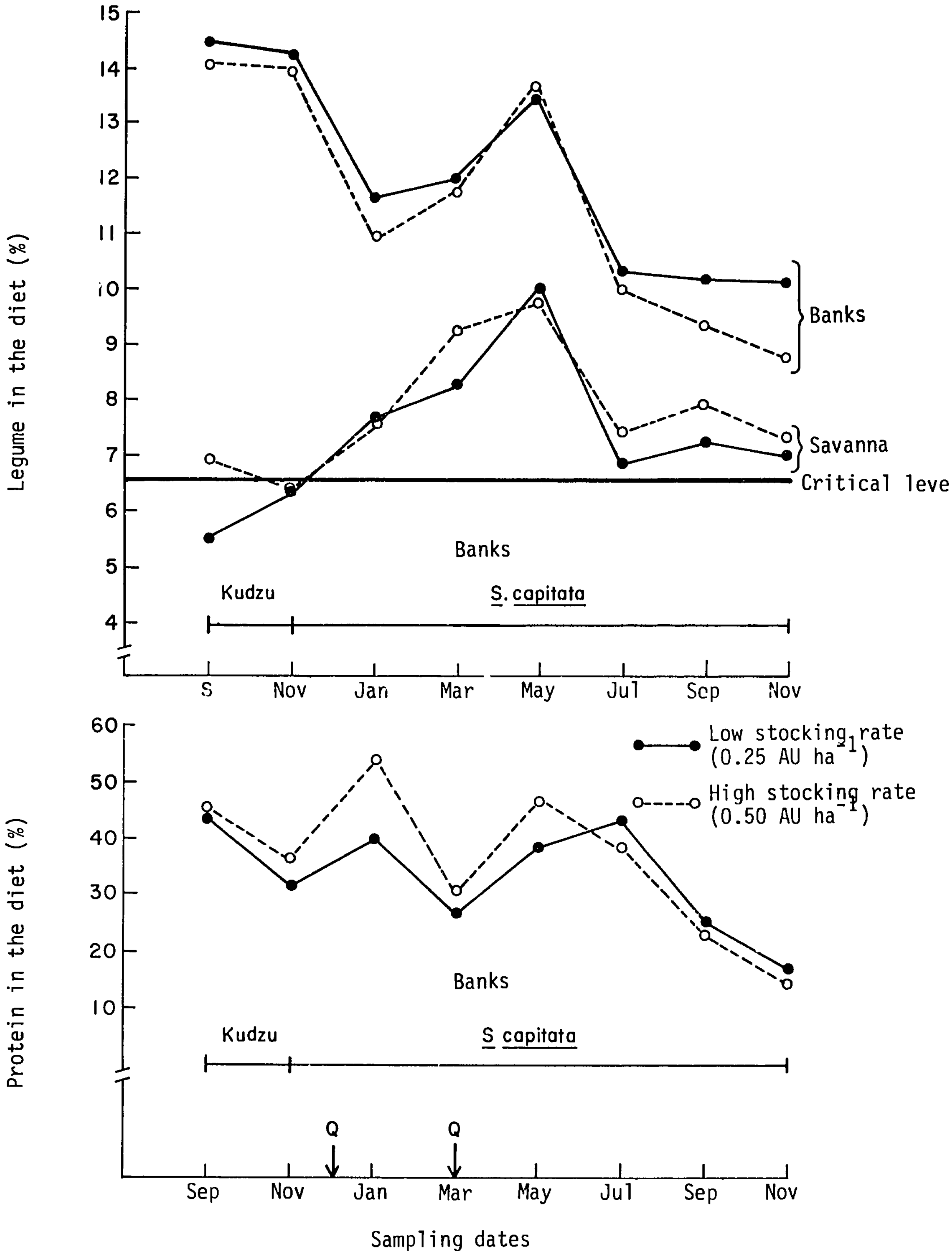

Figure 7. Protein and legume content in the diet of animals grazing savanna managed with burning (B) and legume banks (Carimagua).

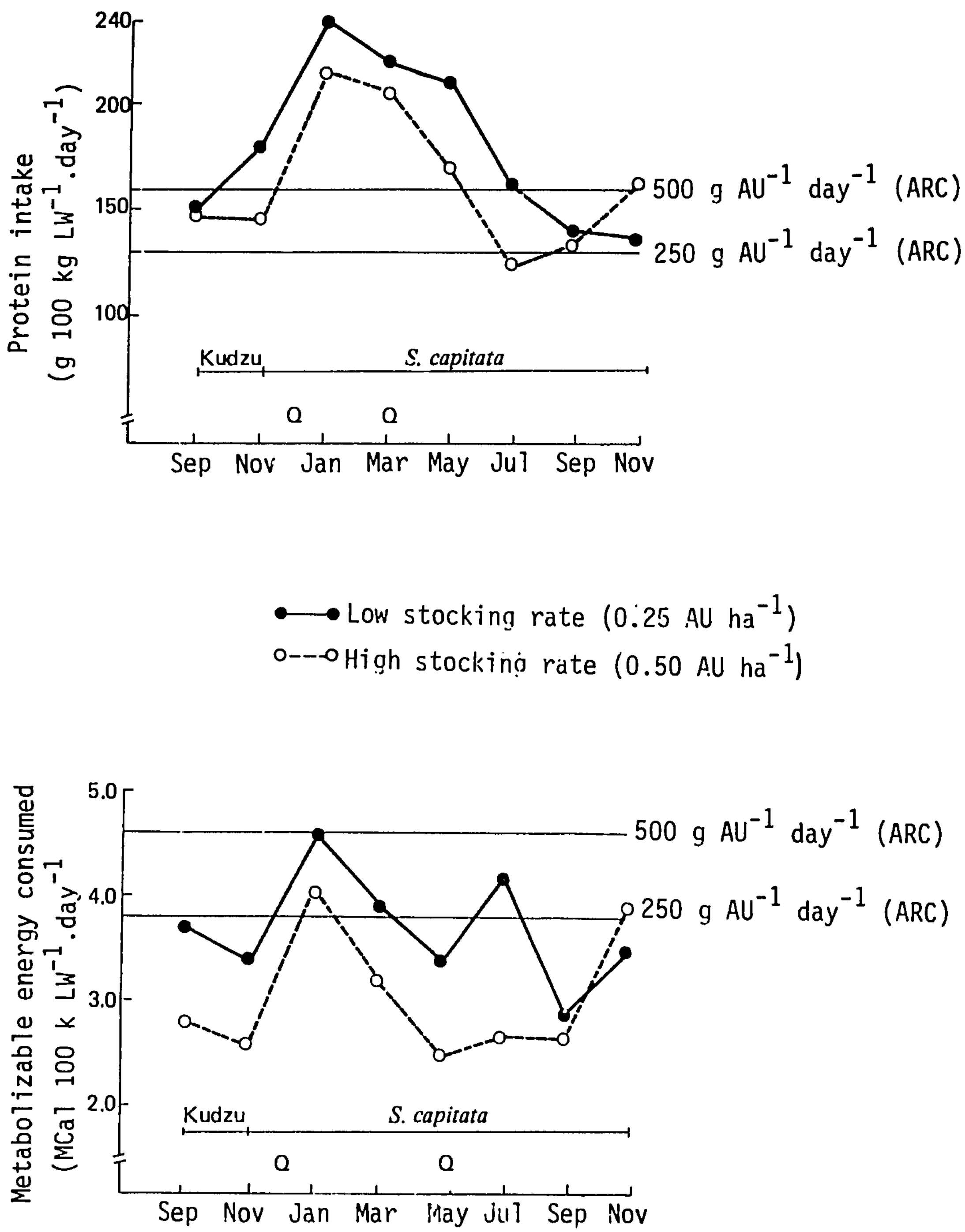

Figure 8. Protein and metabilizable energy intake in savanna managed with burning (B) + legume banks (Carimagua).

legume bank. To test this hypothesis, banks (2000 m^2 per animal) of A. gayanus + Kudzu were planted this year. These banks will be managed with two stocking rates (0.25 and 0.50 AU ha^{-1}) and with controlled access as a function of availability and botanical composition.

METHODOLOGICAL STUDIES

As part of the activities to support the International Network for the Evaluation of Tropical Pastures (RIEPT), the Tropical Pastures Program is conducting a series of methodo-ological studies in the Quilichao Sub-station as well as in the Carimagua Station, funded by the International Development Research Centre (IDRC) of Canada. The fundamental objective of these studies is the development of simple and unbiassed methods for evaluating forage germplasm under grazing.

The objective of the methodological experiments carried out in Carimagua is to evaluate the effect of individual and common grazing on the persistence of legumes in association with grasses in small plots. The trial includes the following treatments with two replications:

1. Associating grasses of contrasting growth habit (A. gayanus and M. minutiflora).
2. Legumes with different growth habit and relative palatability (S. capitata cv. Capica, S. guianensis var. pauciflora 1283, S. macrocephala 1643, C. brasilianum 5234, and C. macrocarpum 5065) sown individually with each of the grasses (individual grazing) and in combinations of 2, 3, or 5 (common grazing), referred to as plot type.
3. Two contrasting stocking rates (high and low) in a rotational grazing system (3.5 days of occupation and 31.5 days of rest).

The trial was sown on May, 1983, and will last three years. Grazing started in November, 1983, and to date, two evaluations have been carried out (January-February and June-July, 1984). The following is a summary of initial results, which already show some interesting tendencies.

The effect of the associating grass on legume availability is presented in Figures 9 and 10. The Stylosanthes (Figure 9) as well as the Centrosema (Figure 10) species have proved to be more persistent on the average with A. gayanus than with M. minutiflora, suggesting differences in competition between grasses, possibly since the establishment phase. Of the Stylosanthes species associated with A. gayanus, S. capitata cv. Capica presented the greatest reduction in availability between one sampling and another, while S. guianensis 1283 var. pauciflora has remained relatively stable and S. macrocephala 1643 has increased. On the other hand, C. brasilianum 5234 has been more persistent in association with A. gayanus than C. macrocarpum 5065.

Availability of the three Stylosanthes species in relation to stocking rate is shown in Figure 11. During the second sampling a stocking rate x legume interaction was observed in the two grasses. While S. capitata cv. Capica and S.guianensis var.pauciflora 1283 were affected by the high stocking rate, S. macrocephala 1643 has been favored when in association with A. gayanus. In the case of M. minutiflora, the low stocking rate has favored S. guianensis var. pauciflora 1283, in comparison to S. capitata cv. Capica.

The legume availability as a function of plot type, that is, legumes sown in plots with only one species (individual grazing) or in plots with combinations of 3 or 5 species (common grazing), are presented in Figure 12

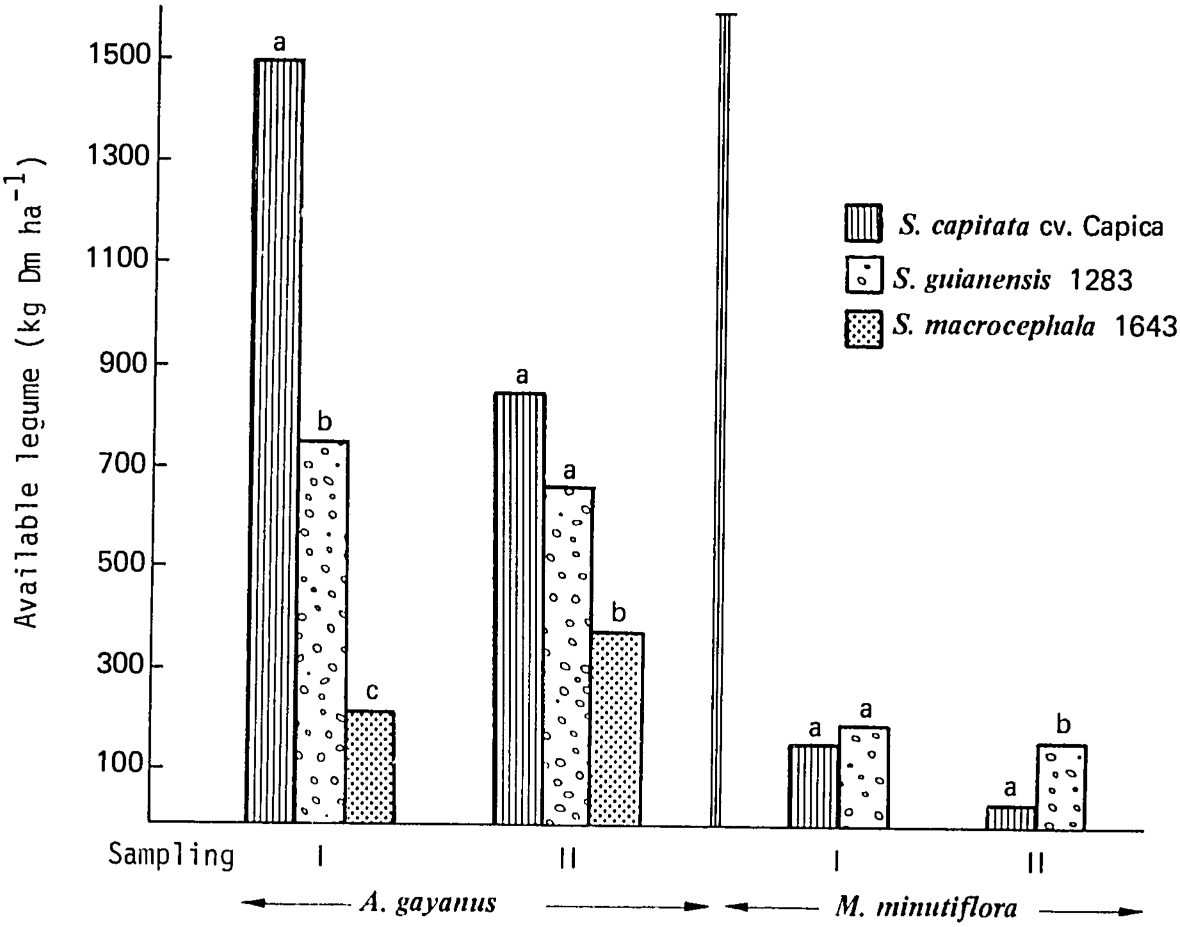

Figure 9. Availability under grazing of Stylosanthes (capitata cv. Capica guianensis 1283, and macrocephala 1643) in association with two grasses (Carimagua).

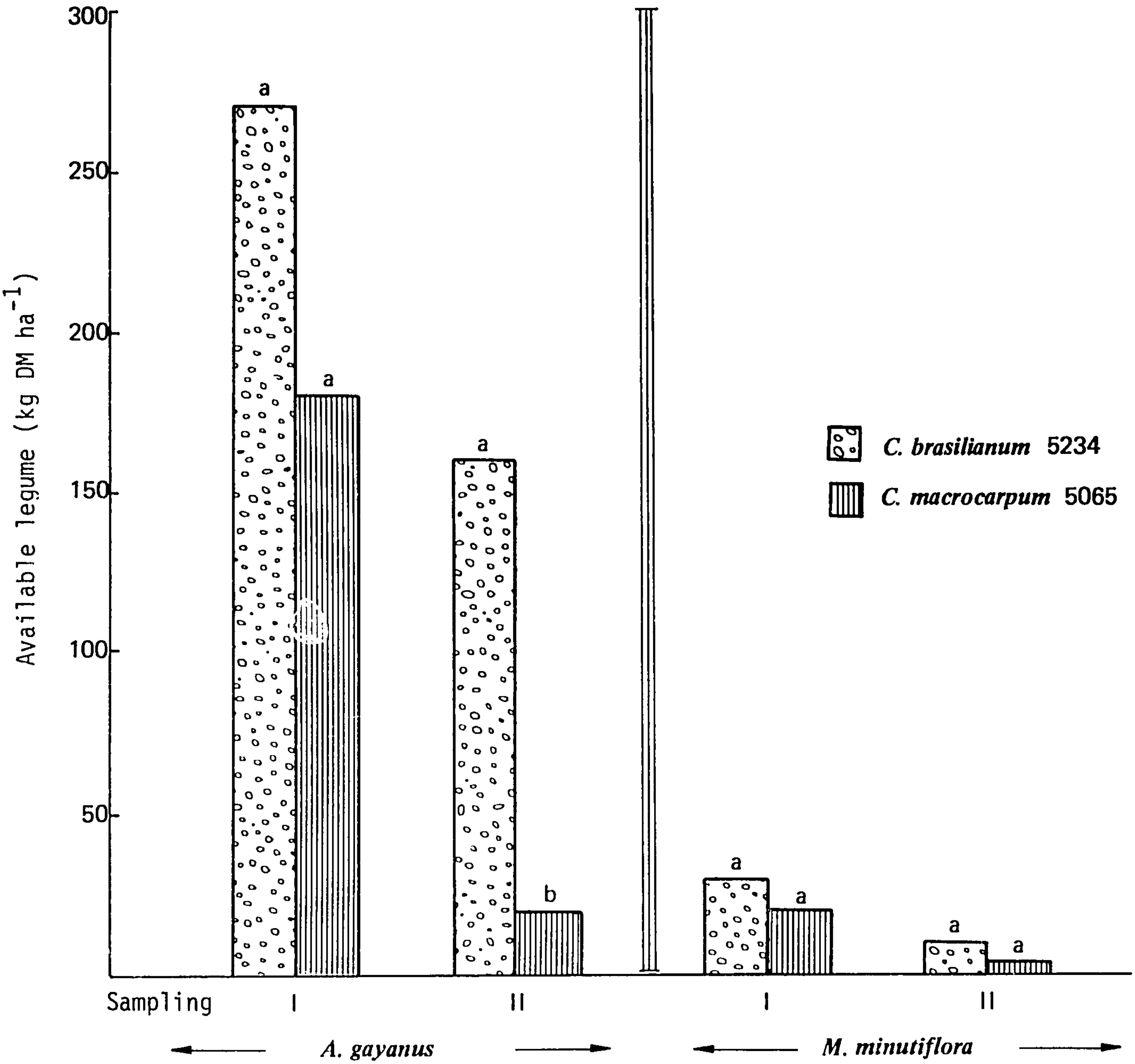

Figure 10. Availability under grazing of Centrosema (brasilianum 5234 and macrocarpum 5065) in association with two grasses (Carimagua).

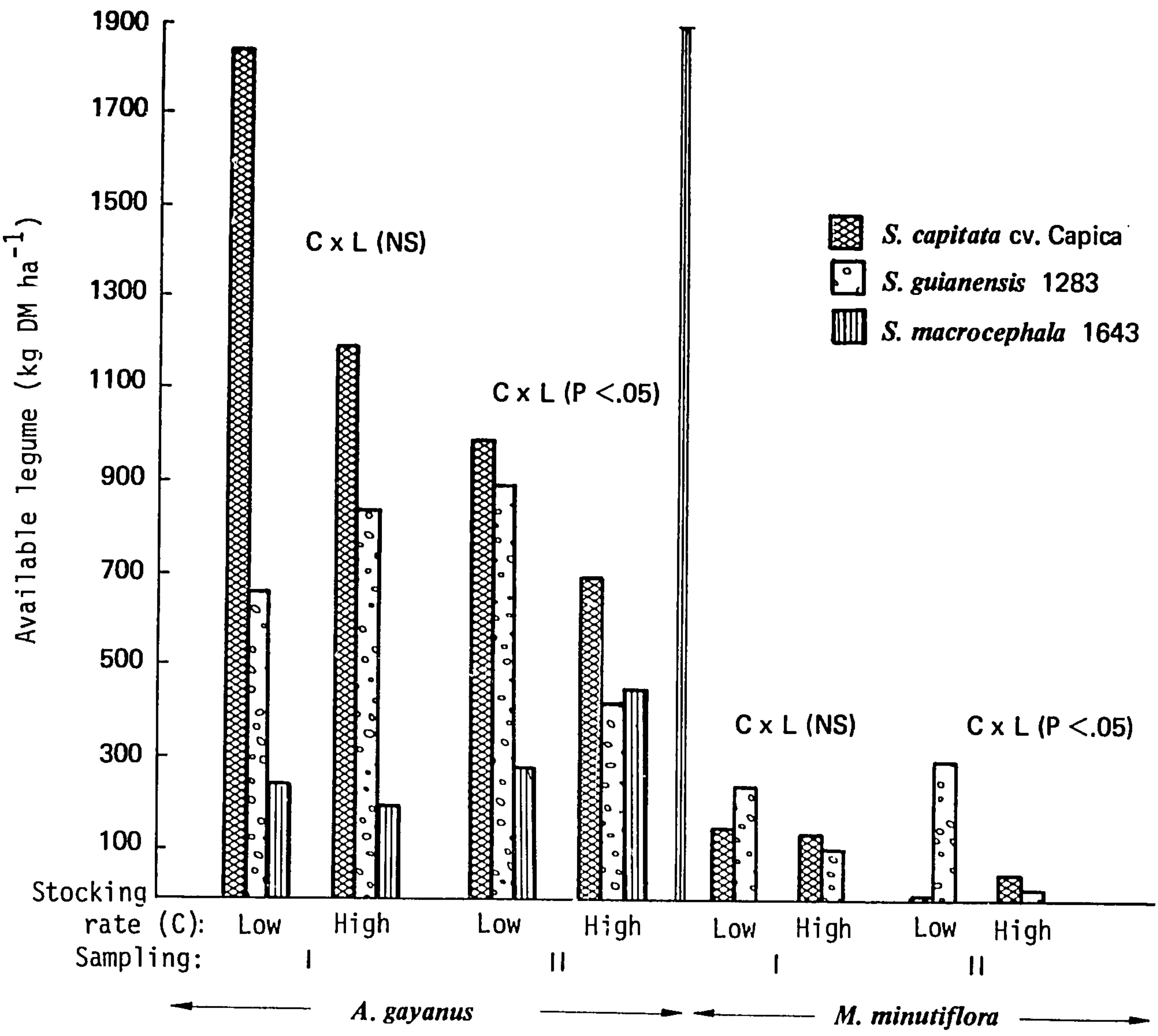

Figure 11. Effect of stocking rate on the availability of Stylosanthes (capitata cv. Capica, guianensis 1283, and macrocephala 1643) (L) in association with two grasses (Carimagua).

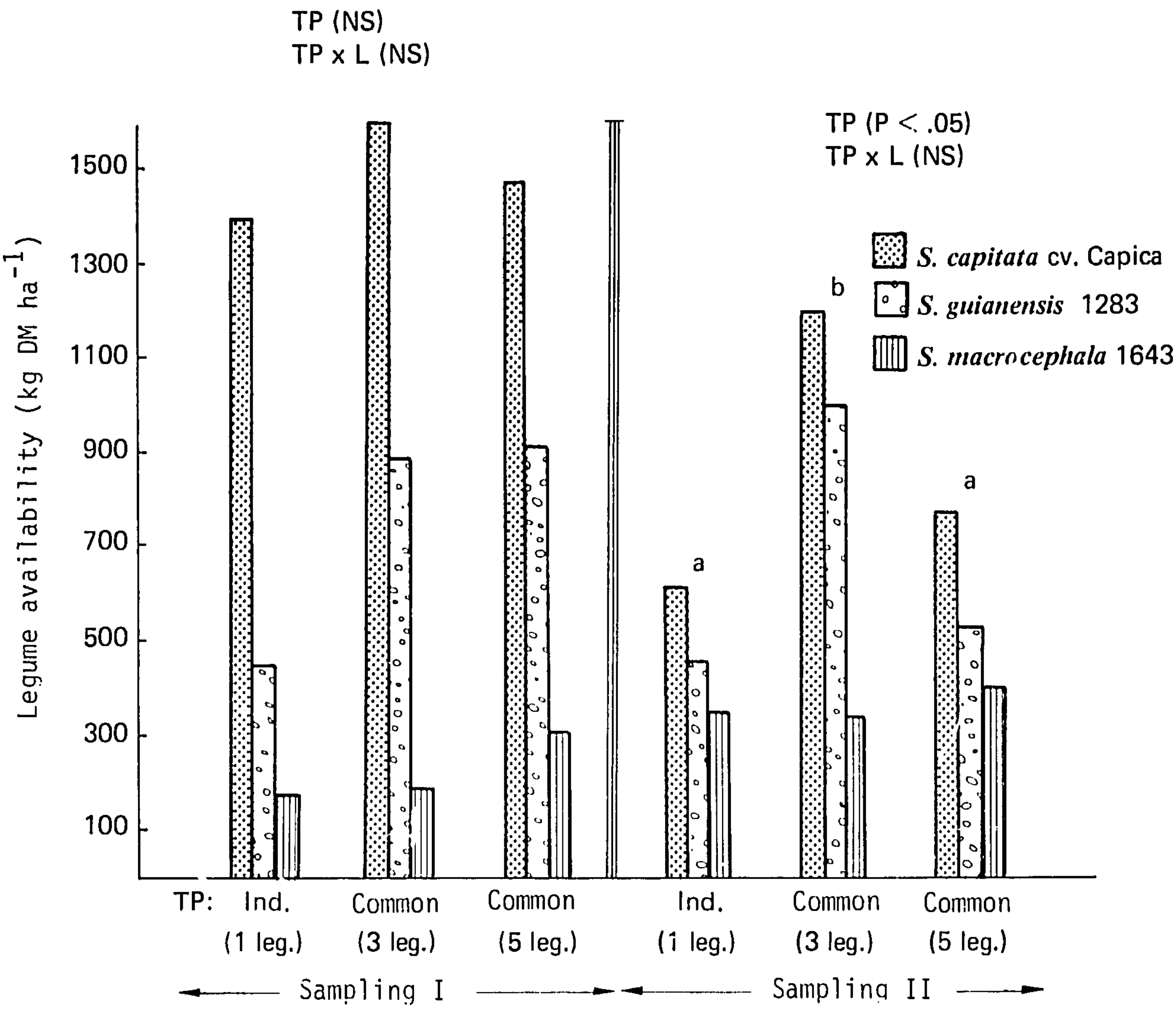

Figure 12. Effect of individual or common grazing (TP) on the availability of Stylosanthes (capitata cv. Capica, guianensis 1283, and macrocephala 1643) in association with A. gayanus.

for the three Stylosanthes spp. associated with A. gayanus. No significant effect of plot type on availability of the three Stylosanthes was observed in the first sampling. However, during the second sampling there was more legume availability in plots with three legumes than in plots where the legume was sown alone or in combination with five legumes. The effect of plot type has been particularly evident with S. capitata cv. Capica and S. guianensis 1283 var. pauciflora, but not with S. macrocephala 1643. On the other hand, the effect of plot type on the availability of the three Stylosanthes entries has been different at both stocking rates, with greater differences existing between plot types at the low stocking rate than at the high stocking rate (Figure 13).

Results obtained up to now, although preliminary, indicate that the effect of individual or common grazing on persistence of contrasting legumes varies as a function of the stocking rate used.

Given the nature of this study, it has been considered important to include a series of evaluations on plant numbers over time in order to better understand the mechanisms of persistence of contrasting legumes. In these measurements and in the general interpretation of the data from this trial and others, there will be great participation of the newly crated Ecophysiology section.

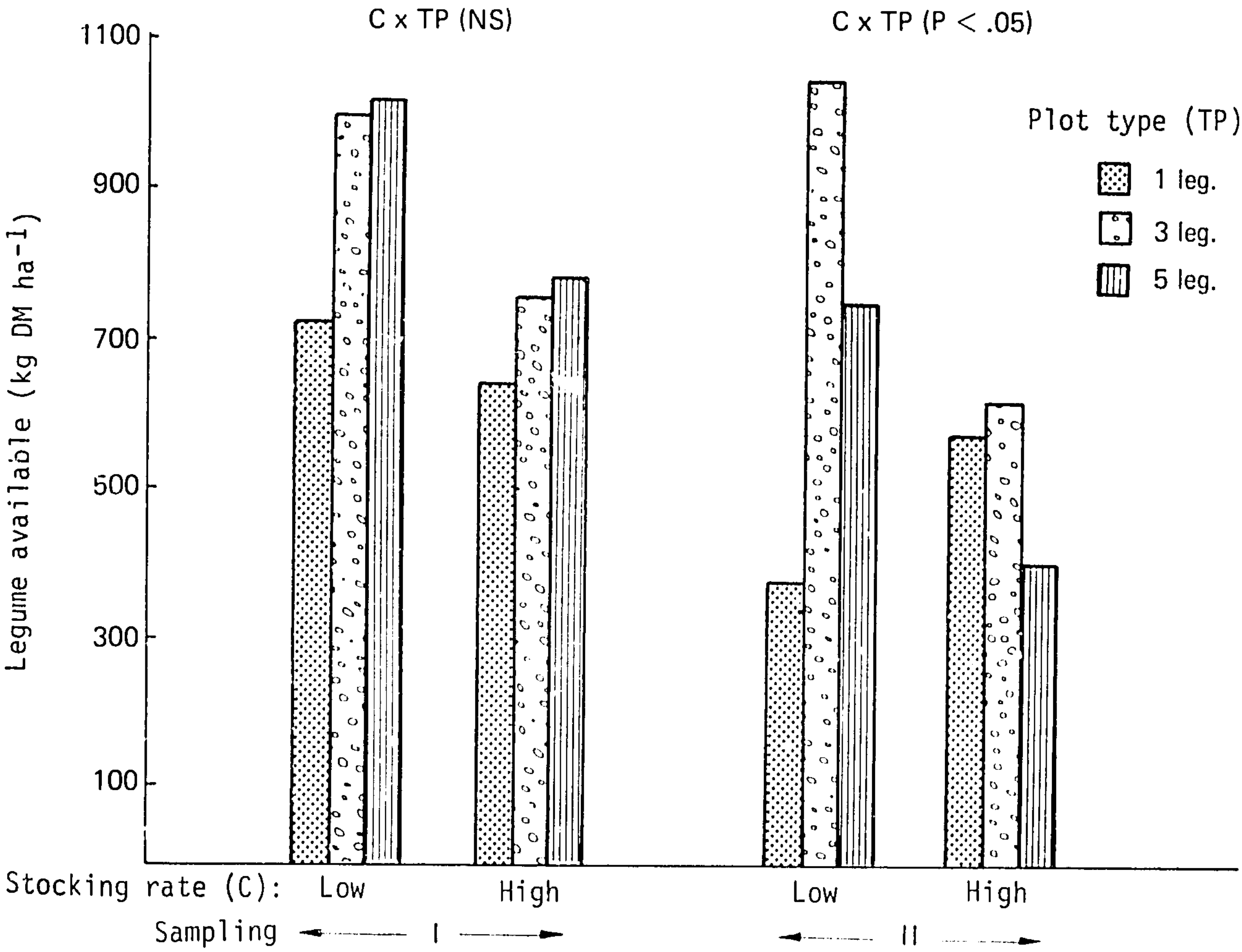

Figure 13. Effect of stocking rate on the availability of Stylosanthes (capitata cv. Capica, guianensis 1283, and macrocephala 1643) in association with A. gayanus in three plot types (PT), (Carimagua).

PASTURE PRODUCTIVITY AND MANAGEMENT

During 1984 the activities of the section continued to center around grazing trials at the Carimagua station designed to evaluate animal production potential and adequate pasture management systems to insure persistence of adapted species in the well-drained isohyperthermic savannas.

The following are the grazing trials established in Carimagua and results of which will be reported in this section:

1. Brachiaria decumbens alone and in association with Pueraria phaseoloides 9900 (Kudzu) in blocks and strips under continuous grazing.
2. B. decumbens + Desmodium ovalifolium 350 under continuous, alternate, and rotational grazing systems with three stocking rates.
3. Andropogon gayanus + Centrosema + Stylosanthes capitata under continuous and rotational grazing.
4. Native savanna + P.phaseoloides (Kudzu) banks under continuous grazing with two stocking rates.

TRIAL WITH B. DECUMBENS ALONE AND IN ASSOCIATION WITH P. PHASEOLOIDES (KUDZU)

This trial, where productivity of B. decumbens alone is compared with B. decumbens + Kudzu blocks for complementary grazing (30% of the area), and with B. decumbens + Kudzu introduced in strips, entered its sixth year of continuous grazing under variable stocking rates by season of the year (1 and 2 AU ha^{-1} during dry and wet season, respectively). The weight gain results obtained this year, were again higher in treatments with Kudzu (Table 1). The superiority of the association of B. decumbens with Kudzu over B. decumbens alone, has been consistent throughout the years but with a tendency for the differences to become greater on the fifth year, as can be seen in Figure 1.

Evaluations done in these pastures by the Pasture Quality and Nutrition Section clearly show that the level of protein in the forage on offer (leaf) as well as in forage selected by esophageal-fistulated steers, has been higher ($P < .05$) in the association in comparison to the grass in pure stand (Figure 2). Energy intake estimates have been different between seasons of the year but not between pastures (Figure 3). In contrast, protein intake has shown a tendency to be higher ($P < .10$) in the association that in the pure grass stand (Figure 4). These differences in protein content in the forage on offer and forage consumed are a clear indication of the nitrogen contribution of the legume to the grass as well as to the grazing animal. In contrast, the lower weight gains associated with reduced protein levels in B. decumbens alone indicate a degradation process of this pasture, due to nitrogen deficiency.

TRIAL WITH B. DECUMBENS AND D. OVALIFOLIUM

A grazing trial was established during

Table 1. Liveweight gain of steers on B. decumbens alone and with P. phaseoloides (Kudzu) in banks and strips[1], under continuous grazing (Carimagua, 1984).

Treatment	Stocking rate[2]	Season: Dry 124 days	Season: Wet 241 days	Total year 365 days
	AU ha^{-1}	g AU^{-1} day^{-1}		kg AU^{-1}
Grass alone	1.0/2.0	349 a	361 a	130.3 a
Grass + P. phaseoloides banks	1.0/2.0	622 b	454 b	186.5 b
Grass + P. phaseoloides strips	1.0/2.0	647 b	473 b	194.2 b
Average		539	429	170.3

1/ Sixth year of grazing (1984).
2/ Dry/wet seasons, respectively.
a, b Different means (P <.05).

1982 with B. decumbens + D. ovalifolium 350 to evaluate animal productivity and persistence of the association's components under three grazing treatments (continuous, alternate, and rotational) and three stocking rates (1.15, 2.30, and 3.45 AU ha^{-1}). Details of the experimental design are found in 1983's Annual Report. Results of weight gain during the first year indicated a significant interaction (P < .05) between the grazing system and the stocking rate, as indicated by higher gains in alternate or rotational grazing at the high stocking rate but lower gains under these systems at the lower stocking rates.

In 1983 the proportion of legumes in the different treatments decreased considerably, not only due to management or grazing effects, but also due to a continuous attack of Synchytrium desmodii and of the stem nematode. During 1984, the legume recovered, persumably due to germination from seed reserved in the soil. Something similar has occurred in other fields in Carimagua with D. ovalifolium 350.

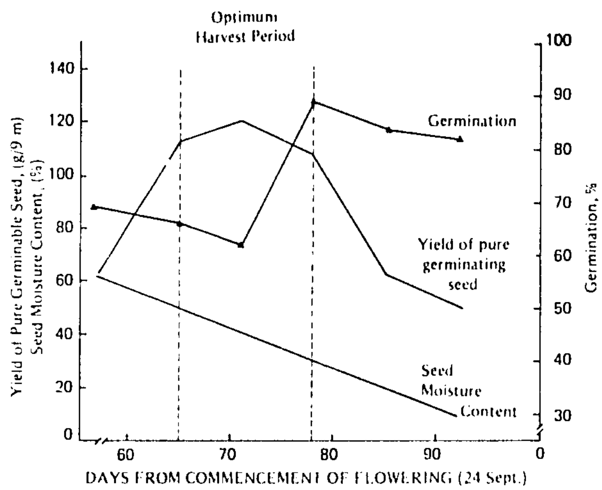

Figure 1. Mean annual weight gain of steers on B. decumbens alone (.___.) and in association with Pueraria phaseoloides (---) (Carimagua).

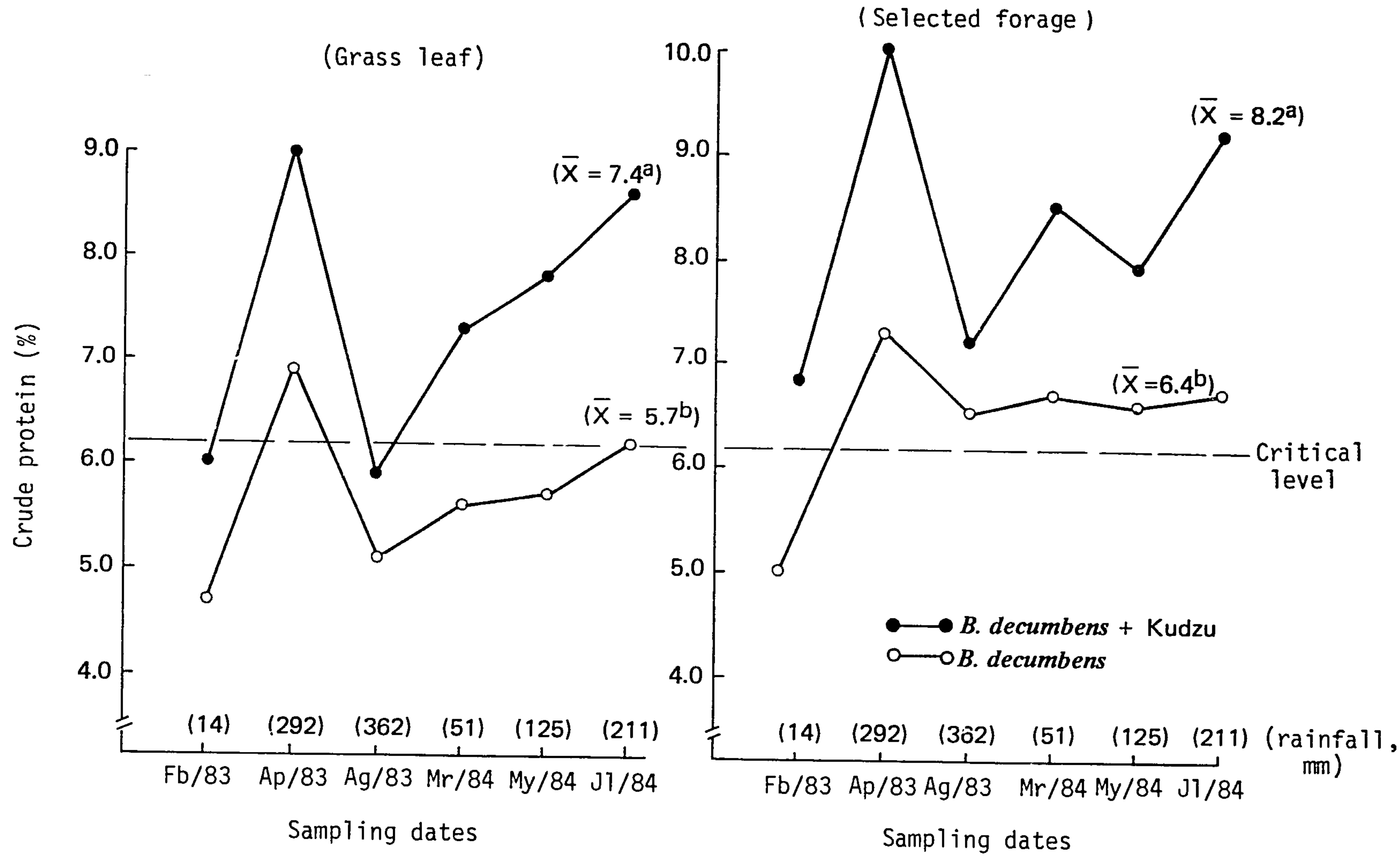

Figure 2. Crude protein content of grass leaf on offer and of selected forage in pastures planted to B. decumbens alone and in association with Kudzu (Carimagua). [a, b, different means ($P < .05$)].

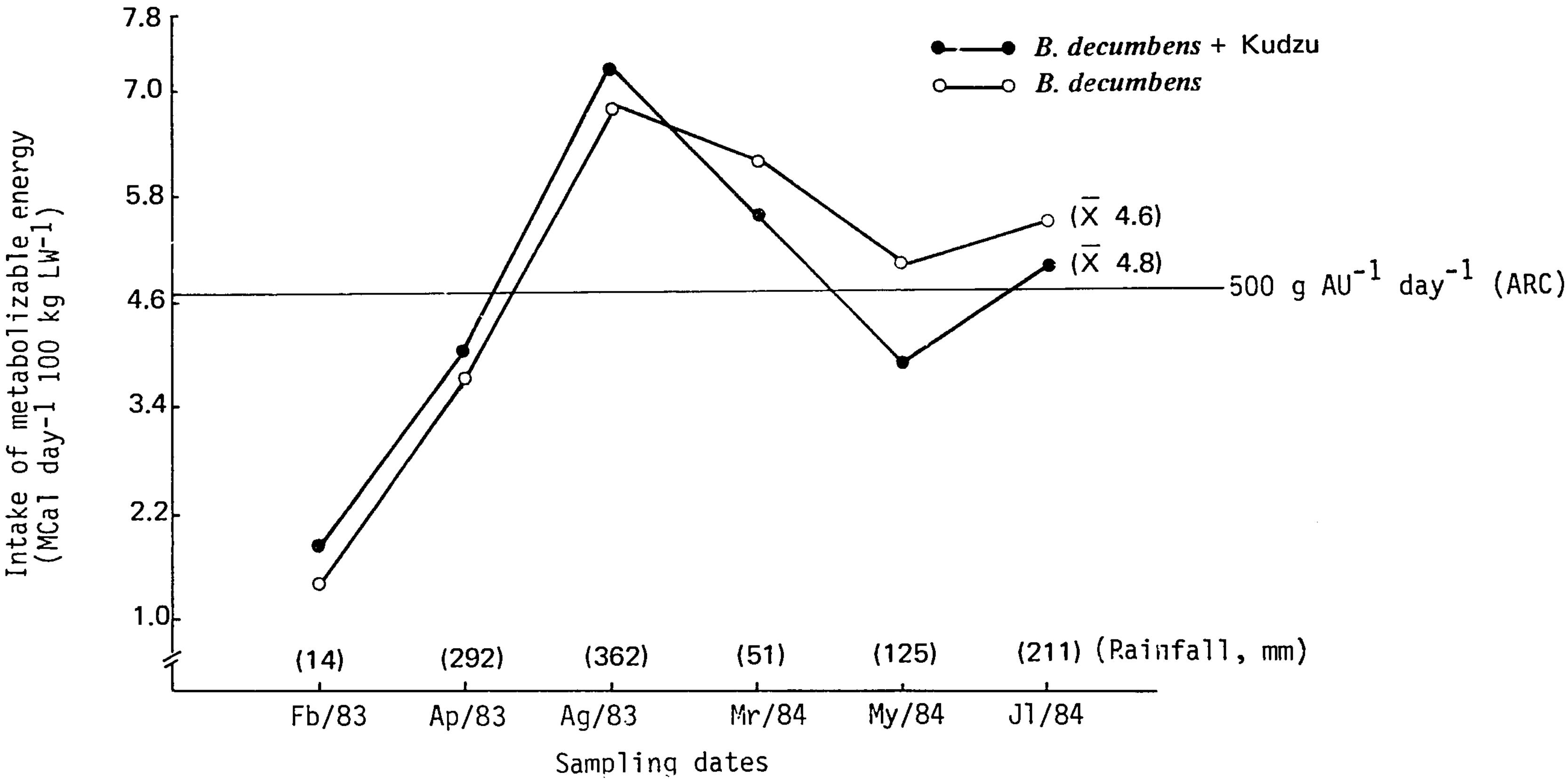

Figure 3. Intake of metabolizable energy in pastures of B. decumbens alone and associated with Kudzu (Carimagua).

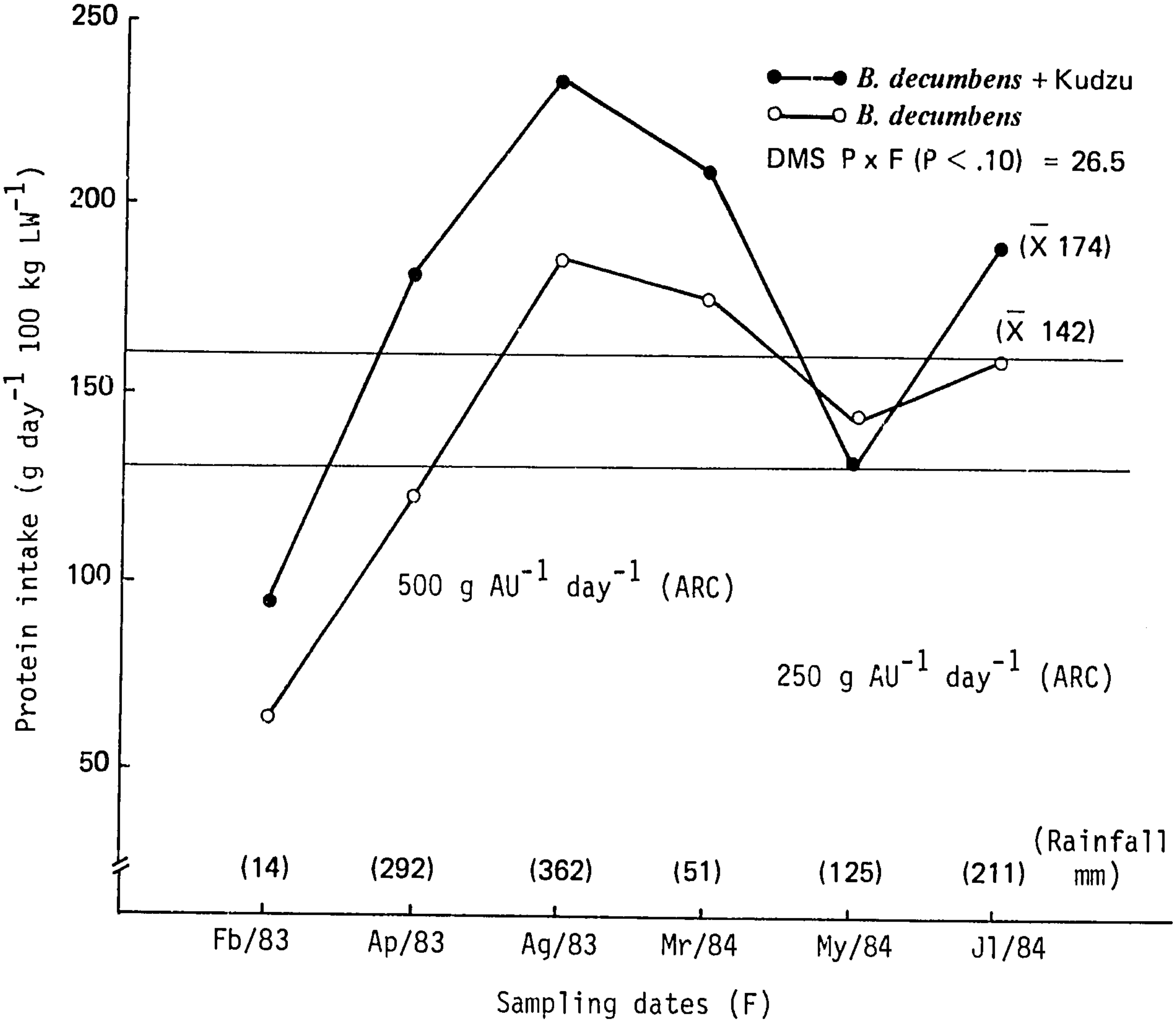

Figure 4. Protein intake in pastures of B. decumbens alone and in association with Kudzu (Carimagua).

In contrast, the availability of B. decumbens decreased as a result of a strong attack of spittlebug which caused different degrees of damage depending on the management system (see Entomology Section).

Results on gain weight this year show a marked stocking rate effect and to a lesser extent a grazing system effect (Table 2). Contrary to what was observed during 1983, there was no stocking rate by grazing system interaction.

Susceptibility of D. ovalifolium 350 to nematodes and of B. decumbens to spittlebug have determined that this trial not be continued in the future.

TRIAL WITH A. GAYANUS ALONE AND IN ASSOCIATION

A grazing trial with A. gayanus alone and in association with two S. capitata ecotypes (1019 and 1315) was established in 1979. Results were reported until 1982, when the experiment was terminated. In 1983 Centrosema macrocarpum (5065) and Centrosema brasilianum (5234) were introduced in strips in pastures of S. capitata 1019 and 1315, respectively. Continuous and rotational grazing systems were included as management variables (7 occupation and 21 rest days) using the

Table 2. Liveweight gain of steers on B. decumbens + D. ovalifolium 350 under different grazing systems and stocking rates (1983-1984).

Grazing system	Stocking rate (AU ha^{-1}) 1.15	2.30*	2.30	3.45	Mean
	kg AU^{-1} $year^{-1}$				
Continuous	171	113	139	93	129
Alternate	136	147	141	86	127
Rotational	144	102	96	56	100
Average	150	120	125	78	

* Without S maintenance.

same stocking rate (2 AU ha^{-1}) in both systems.

As part of the process for introducing strips of Centrosema the A. gayanus was mowed, resulting in a dense and vigorous population of S. capitata. Therefore, the associations under evaluation are now mixtures of Centrosema spp. (macrocarpum or brasilianum) with S. capitata.

Experimental grazing was started in April, 1984, and wet-season results are presented in Table 3. Differences in liveweight gain between pastures have only been observed under the rotational grazing, with gains being higher ($P < .05$) in the two associations as compared with A. gayanus alone. On the other hand, measurements of available forage and botanical composition have shown very large differences due to grazing systems (Table 4). The rotational system with 2 AU ha^{-1} produced almost twice the amount forage on offer, particularly grass, in comparison with the continuous system. Although the legume proportion decreased in both systems, it seemed more affected under rotational grazing.

The effect of grazing system on forage availability was expected, but not in the magnitude observed in this trial. This observation has important methodological implications for grazing trials in small plots (Category III or RTC) where rotational grazing is generally used with a range of stocking rates later imposed in larger grazing trials (Category IV or RTD) under continuous grazing.

NATIVE SAVANNA WITH P. PHASEOLOIDES (KUDZU) BANKS

A previous experiment with native savanna + P. phaseoloides (Kudzu) banks, using two stocking rates (0.25 and 0.50 AU ha^{-1}) and 2000 m^2 of bank per animal was modified in 1984 to include higher stocking rates (0.375 and 0.750 AU ha^{-1}), and consequently less bank area per animal (1333 m^2). The savanna was burnt at the end of the wet and dry seasons, as in previous years, and the animals had controlled access to the bank depending on the availability of the legume.

Results on weight gain presented in Table 5 show, as in previous years, positive weight gains during the dry season, these being higher ($P < .05$) at the low stocking rate. Weight gains during the wet season were not significatively affected by stocking

Table 3. Liveweight gain of steers on *A. gayanus* alone and in association with legumes under two grazing systems. Wet season* (Carimagua, 1984).

Treatment	Stocking rate	Grazing system	
		Continuous	Rotational
	AU ha^{-1}	g AU^{-1} day^{-1}	
A. gayanus alone	2.0	423 a	229 a
A. gayanus + *C. macrocarpum* 5065 (+ *S. capitata*)	2.0	571 a	600 b
A. gayanus + *C. brasilianum* 5234 (+ *S. capitata*)	2.0	507 a	571 b

* 175 days.
a, b Values with different letters are significantly different ($P < .05$).

Table 4. Available forage and proportion of legumes (%) in pastures of *A. gayanus* alone and in association with legumes under continuous and rotational grazing with 2 AU ha^{-1} (Carimagua).

Pasture	Grazing system	Available forage (% legume)	
		Beginning of rainy season May 84	Middle of rainy season August 84
		kg $DM.ha^{-1}$	
A. gayanus	Continuous	4223	4514
	Rotational	4378	8460
A. gayanus + *C. macrocarpum* 5065 (+ *S. capitata*)	Continuous	3200 (24)	5536 (14)
	Rotational	3383 (28)	8443 (9)
A. gayanus + *C. brasilianum* 5234 (+ *S. capitata*)	Continuous	2922 (31)	4468 (17)
	Rotational	2988 (31)	5974 (13)

Table 5. Weight gain of steers on burnt savanna with complementary grazing on Kudzu banks at different stocking rates and controlled access (Carimagua, 1984).

Stocking rate	Dry season 124 days	Wet season 241 days	Total year 365 days	
$AU\ ha^{-1}$	-------- $g\ AU^{-1}\ day^{-1}$	-------	$g\ AU^{-1}\ day^{-1}$	$kg\ AU^{-1}$
0.375	460 a	280	341	124.5
0.750	293 b	285	288	105.1

1/ Open: January 13 to March 6 (53 days); May 4 to June 17 (44 days); August 27 to October 8 (42 days). Total: 139 days.

a, b Values with different letter are significant ($P < .05$).

rates coinciding with results from previous years. Controlled access to the legume bank determined a relatively constant offer of Kudzu during different periods of the year (Figure 5).

Weight gains obtained in previous years under low (301 $g\ AU^{-1}.day^{-1}$) and high (268 $g\ AU^{-1}.day^{-1}$) stocking rates have been similar to those obtained this year (341 and 288 $g\ AU^{-1}.day^{-1}$, low and high rates, respectively) using higher rates, less bank area per animal, and controlled access to the bank. It is possible that this management system may have resulted in a higher grazing pressure on the native savanna and, consequently, in better quality of the forage on offer throughout the year.

Results of this experiment indicate that there are still many unanswered questions on the effect that grazing pressure could have on the quality of native savanna managed with burning (see Pasture Quality and Nutrition Section). Future research activities in the area of Pasture Quality and Productivity will include a detailed evaluation of nutritional aspects of burnt savanna under various stocking rates. This type of study will be valuable to better define savanna constraints in terms of quantity as well as quality of forage on offer.

NEW GRAZING TRIALS

New grazing trials were established in Carimagua during 1984 to evaluate management systems and animal productivity with Category IV germplasm. The pastures established in two different sites were:

1. A. gayanus + Stylosanthes macrocephala 1643

2. A. gayanus + Centrosema sp. 5247 and 5568

Each of the pastures in each replication will be managed with three variable stocking rates (3.0/1.5, 2.0/1.0, and 1.5/0.75 $AUha^{-1}$, wet/dry) by season of the year under continuous grazing and with rotational grazing at the highest stocking rate (3.0/1.5 $AU\ ha^{-1}$). Thus, the experiment will include four management treatments and two replications. Quantity and quality of forage on offer and of forage selected during different

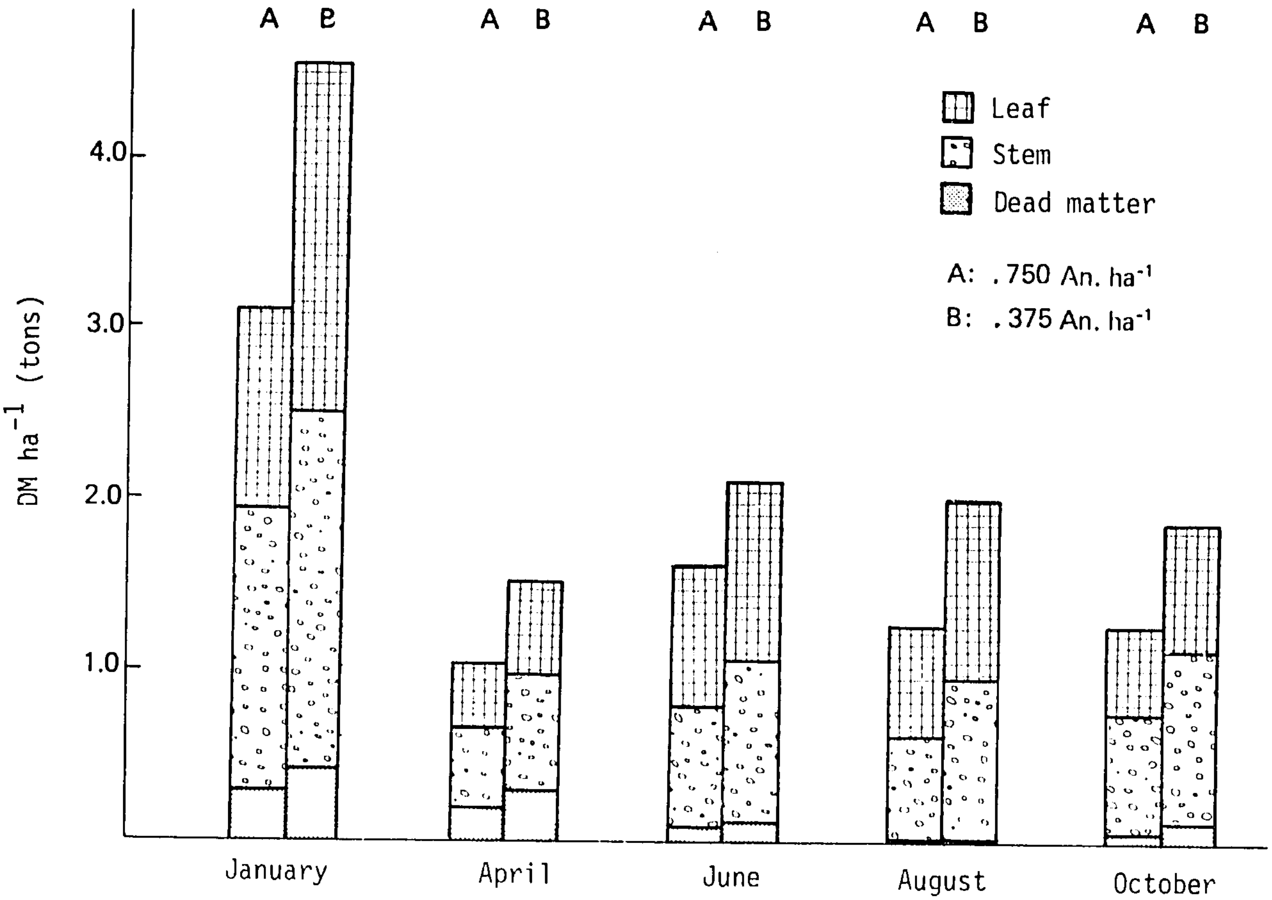

Figure 5. Effect of stocking rate on forage availability and composition of P. phaseoloides as legume bank supplementing savanna pastures (Carimagua, 1984).

seasons of the year will be evaluated. In addition, with the participation of the recently created Ecophysiology Section, plant population dynamics under different treatments will be studied in detail, once pastures are in equilibrium. It is hoped that these measurements help to explain not only responses in terms of animal production, but also mechanisms of persistence of the components in association.

SEED PRODUCTION

INTRODUCTION

The Section continued with its traditional activity of seed multiplication but also achieved a significant increase in activities of applied research and training.

APPLIED RESEARCH

1) Time, density and fertilization for the establishment of *S. capitata* cv. Capica in Carimagua.

A comparison of the effect of different dates of planting showed a significantly ($P < 0.05$) higher seed yield for the early (April) planting, and a progressive decline with later plantings (Table 1). While later plantings showed a response to the application of K and Mg, this effect was not evident for the planting in April. Also a comparison of three planting densities in April (1.5, 4.5 and 13.5 kg/ha of seed in pod) were made in a factorial experiment with two fertilizer levels and two planting systems (rows vs. broadcast). Planting density of 4.5 and 13.5 kg/ha gave similar but higher seed yields than 1.5 kg/ha. As an average of the 3 densities, (a) the addition of 50 kg/ha MgO and 60 kg/ha of KCl to a basal dressing of 300 kg/ha of basic slag (Calfos) did not result in an increase in seed yield, and (b) planting in rows was no different to broadcast in terms of seed yield.

2) Harvest methods of *S. capitata*

A wide range of harvest methods were compared in a high yielding crop of uniform maturity of cv. Capica at Carimagua. Methods ranged from totally manual to totally mechanical but including various combinations and alternatives. Results are summarized in Table 2.

Under conditions of the experiment, the combine harvestor registered the highest seed yield. In terms of pure seed yield, all other methods gave equivalent results, but with a 56% relative efficiency of recovery compared to the combine. In terms of pure germinating seed, the mower cutting/manual threshing method was 83% as efficient relative to the

Table 1. Effect of planting time and fertilizer level upon seed yield of *Stylosanthes capitata* cv. Capica in Carimagua.

Planting Time	Seed Yield ($kg.ha^{-1}$)		
	Basic fertil.[1]	Complete fertil.[2]	Average
April	431	425	428a
May	188	206	197b
June	49	82	65d
July	114	238	176b
August	86	140	113c
September	33	85	59d
(Average)	150a	196b	

1/ 300 kg/ha basic slag at planting.
2/ Basic plus 50 kg/ha MgO and 60 kg/ha KCl.
Means with different superscripts differ significantly ($P < 0.05$).

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Table 2. Seed yield and relative efficiency of recovery for alternative harvest methods in *Stylosanthes capitata*.

Harvest Method	Seed Yield		Relative Effic. of Recovery[3]	
	Pure Seed	Pure Germinating Seed	Pure Seed	Pure Germinating Seed
	-------- kg/450 m^2 -------		------------ % ------------	
Manual cut and manual thresh on same day	15.2 b	8.8 b	56	69
Manual cut and manual thresh after five days in field	13.5 b	10.5 b	56	69
Combine harvestor, one direct pass	27.3 a	14.2 a	100[1]	100[2]
Manual cut and heaped then threshed by combine after five days in field	14.1 b	9.9 b	56	69
Cut with tractor mounted mower, heaped by hand, then manual threshed after five days in field	17.9 b	11.8 ab	56	83

1/ Equivalent to 607 kg/ha of pure seed.
2/ Equivalent to 316 kg/ha of pure germinating seed.
3/ Seed yields which were statistically equivalent, were averaged in this calculation.
Means with different superscripts differ significantly ($P < 0.05$).

combine while the manual harvesting and manual cutting/combine threshing methods were comparable with a 69% relative efficiency of recovery compared to the combine.

A re-threshing, either manually or by the combine, gave the same effect, providing the equivalent of 49 kg/ha pure seed.

Seed harvested and threshed on the same day (by hand or by combine) showed lower germination (55%) compared to other methods where threshing was conducted 5 days later (71%).

3) Seed yield and maturity in the components of *S. capitata* cv. Capica

A comparison was made of the time of field maturity, yield of pure seed, germination, and yield of pure germinating seed in the five component accessions of cv. Capica. Results are summarized in Table 3.

The maximum range of field maturity was eight days (between CIAT Nos. 1315 and 1728). In terms of pure seed yield, CIAT Nos. 1693 and 1728 were significantly ($P < 0.05$) higher than CIAT Nos. 1315, 1318 and 1342. In germination, CIAT Nos. 1318 and 1342 were significantly ($P < 0.05$) higher

Table 3. Time of harvest maturity, germination and seed yield in the component accessions of Stylosanthes capitata cv. Capica.

Accession CIAT No.	Harvest Maturity No. of days	Seed Germination %	Seed Yield kg/ha Pure Seed[1]	PGS[2]
1315	228	67 b	328 b	220
1318	231	70 a	350 b	245
1342	231	72 a	348 b	251
1693	233	59 b	649 a	383
1728	236	60 b	627 a	376

1/ Second year crop, samples 3 m^2 in each of 4 replications.
2/ Pure Germinating Seed.
Means with different superscripts differ significantly ($P < 0.05$).

than the others. This resulted in higher yield of pure germinating seed of CIAT Nos. 1693 and 1728.

4) Field maturity of S. macrocephala seed crop

A crop of S. macrocephala CIAT 1643 in Carimagua was sampled progressively during a month when mature seeds were present. Measurement of seed yield, germination and seed moisture content are summarized in Figure 1.

The optimum harvest period was defined as the period of maximum yield of pure germinating seed. This occurred for a period of 13 days, from 65-78 days after commencement of flowering (September 24), indicating an ample period for harvesting. During this period seed moisture content was decreasing between the range of 47% to 28% while germination was increasing from 64% to 89%.

Under planthouse conditions, individual seeds (actually the upper articulation) were observed to reach apparent maturity in an average of 34 days after anthesis.

5) Seed yield of S. guianensis var. pauciflora

Large multiplication areas in a replicated design at Quilichao offered the first opportunity to estimate seed yields of five different accessions. Harvesting was conducted by manual cutting followed by mechanical threshing. Yields of seed in pod are presented in Table 4 indicating a wide range of seed yields from 13-164 kg/ha between accessions, with CIAT 2127 showing the highest yield.

6) Seed quality indices and field emergence in Andropogon gayanus

Investigation into laboratory procedures to measure seed quality components in A. gayanus have continued. An exploratory field trial was conducted to compare the interrelation between two contrasting composite seed quality indices (pure germinating seed or PGS, %; and germinable units or GU, '000/kg) and field emergence in six random seed lots.

PGS and GU values as measured in the

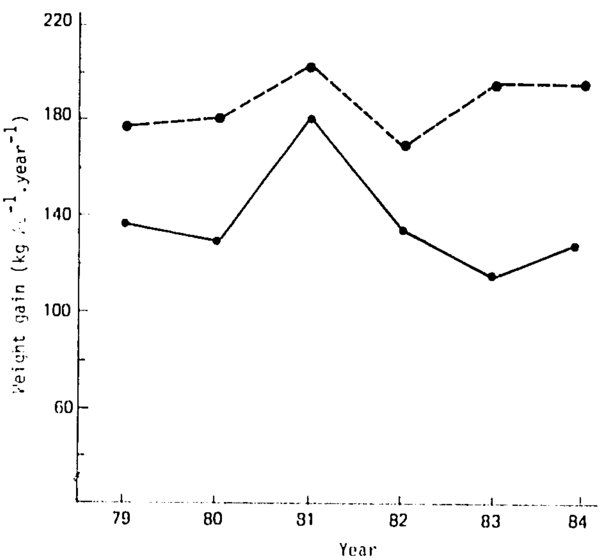


Figure 1. Dynamics of standing pure seed yield, germination and seed moisture content of Stylosanthes macrocephala CIAT 1643 during crop maturity.

Table 4. Yield of seed in pod of five accessions of *Stylosanthes guianensis* var. *pauciflora* in Quilichao 1983-84.

Accession No.	Dates of: Peak flower.	Dates of: Harvest matur.	Seed in Pod* kg/ha
2127	28 Nov.83	4 Jan.84	164 a
10136	3 Oct.83	14 Nov.83	84 b
2031	3 Oct.83	2 Nov.83	72 b
2362	26 Nov.83	29 Nov.83	22 c
1280	3 Dec.83	11 Jan.84	13 c

* Average of 3 replications, each of 250 m^2.
Means with different superscripts differ significantly ($P < 0.05$).

laboratory and seedling densities as measured in a replicated field experiment, are presented in Table 5.

The ranking of seed lots for their composite seed quality was similar for both PGS and GU. Laboratory data indicated seed lot 3 was the highest while lots 1 and 5 were the lowest and lot 4 intermediate. In the field, the highest emergence was recorded with lots 3 and 4, the lowest with lots 1 and 5. The correlation coefficients between each of PGS and GU with field emergence, as an average of all seed lots and planting densities, were comparable (r^2 = 0.39 and 0.36, respectively) indicating similar average predictive values. Seed lot 4 performed better than expected in the field and must contain some seed vigor character not recorded by measurements of either PGS or GU. These experiments will be continued.

TRAINING

A significantly increased effort was made during 1984 towards training activities in seed production and seed technology.

The first intensive short course on Seed Production of Tropical Pasture Pasture Species was held at CIAT from 29 October to 16 November 1984. The course was conducted in Spanish as a joint effort between the Tropical Pastures Program and the Seed Unit and was attended by 27 participants from 10 countries in Central and South America. In both lecture, practical and discussion phases, emphasis was placed on; production technology; interrelations with animal and crop production; the range of relevant species and cultivars of grasses and legumes; and the relevant roles of official and private sector in the development of supplies of seed for experimental purposes, basic seed and commercial seed.

A Workshop on Testing Seeds of Tropical Pasture Species was held at CIAT from 19-30 November. This event was organized and funded jointly by ISTA (International Seed Testing Association), the Tropical Pastures Program and the Seed Unit of CIAT. The Workshop provided an opportunity for the 20 participants from 11 countries to improve their knowledge of seed analysis of tropical grasses and legumes in general, with an emphasis upon the ISTA rules. In addition the participants exchanged experiences and

Table 5. Composite seed quality index and field emergence values for six seed lots of *Andropogon gayanus*.

Seed Lot	Composite Seed Quality Index: PGS[1] %	GU[2] '000/kg	Field Lot Emergence: Seedling Density[3] No./2 linear m
1	3.1 c	10.5 c	15 d
2	6.9 b	22.7 b	27 c
3	20.7 a	55.1 a	88 a
4	6.7 b	19.8 b	97 a
5	4.2 bc	14.0 bc	6 d
6	4.1 bc	22.8 b	38 b

1/ Pure Germinating Seed.
2/ Germinable Units.
3/ Average of three planting densities.
Means with different superscripts differ significantly ($P < 0.05$).

via working groups provided recommendations to ISTA for future emphasis.

TECHNICAL COLLABORATION WITH NATIONAL INSTITUTIONS

Visits were made to national institutions in Bolivia, Brazil, Peru and Panama to maintain an awareness of their activities in pasture evaluation and seed multiplication and research activities. Emphasis was made on (a) the progressive definition of limitations to the national seed supply; and (b) providing technical assistance to seed multiplication (for both experimental purposes and basic seed) and associated research efforts. These activities are part of a deliberate program policy of fostering a greater contribution by National Institutions to the supply of seed for experimental and developmental purposes. As the overall rhythm and volume of total pasture evaluation activities increases at many locations, it becomes imperative that National Institutions respond to the seed supply implications of the evaluation sequences and the process of release of new cultivars by an increased emphasis upon seed multiplication and supportive research.

SEED MULTIPLICATION AND DISTRIBUTION

Activities continued in seed multiplication and distribution. Field activities are concentrated at Quilichao and Carimagua while planthouse, seed conditioning, storage and distribution activities are conducted at Palmira.

A total of 116 accessions are under seed multiplication, 94 legumes and 22 grasses. During 1984, 7.6 ha of new multiplication areas were established to provide a total of 30 ha under seed multiplication.

Volumes of seed produced of accessions of legumes and grasses are presented in Tables 6 and 7. Approximately 1.5 t of seed of all legume accessions and 1.0 t of seed of all grass accessions were produced.

The demanding activity of seed distribution involved responding to 250 composite seed requests and the distribution of a total volume of approximately 2.0 t of composite grass and legume accessions (Table 8).

It is noteworthy that approximately 98% of requests and of actual seeds forwarded were in relation to activities in germplasm and pasture evaluations. It is of concern that few national institutions are placing a concurrent emphasis upon local seed multiplication to meet expanding demand.

Table 6. Summary of activities in seed multiplication of legume species and accessions between October 1983 and 1984.

Species	No. of Accessions	Area (ha) New	Area (ha) Total	Seed Produced (kg)
Arachis pintoi	1	0.20	0.40	1.43
C. brasilianum	3		0.32	2.25
C. (hybrids)	6		0.03	9.75
C. macrocarpum	7	0.50	0.97	138.25
C. pubescens	2		0.28	47.00
C. schiedeanum	3		0.01	0.84
C. spp.	5	0.70	1.05	84.62
D. heterocarpum	1	0.05	0.06	10.90
D. heterophyllum	2	0.11	0.23	4.06
D. incanum	1		0.24	6.83
D. ovalifolium	7	0.40	0.80	69.93
Galactia sp.	1		0.01	1.75
G. striata	1		0.02	0.92
S. capitata	9	1.05	7.19	858.56
S. guianensis	28	0.95	2.03	81.41
S. hamata	1		0.01	0.02
S. macrocephala	5	1.35	2.85	115.45
S. viscosa	4		0.01	0.53
Z. brasiliensis	1		0.03	2.35
Z. latifolia	1		0.33	34.00
Zornia sp.	2	0.40	0.43	0.49
L. leucocephala	3		0.01	15.62
	94	5.71	17.31	1.486.96

Table 7. Summary of activities in seed multiplication of grass species and accessions between October 1983-1984.

Species	No. of Accessions	Area (ha) New	Area (ha) Total	Seed Produced (kg)
Andropogon gayanus	4	0.1	3.83	870.94
Brachiaria brizantha	4	1.3	1.57	2.06
Brachiaria decumbens	2	0.2	1.30	42.85
Brachiaria dictyoneura	1	0.3	5.50	120.50
Brachiaria humidicola	1		0.10	1.50
Brachiaria ruziziensis	3		0.05	0.71
Panicum maximum	5		0.40	25.86
	20	1.9	12.75	1.064.42

Table 8. Distribution of seed of grass and legume accessions, October 1983-1984.

Request Basis and Source	Number of Requests	Volume of Seeds (kg)		
		Grass	Legumes	Total
Germplasm or Pasture Evaluations				
TPP Members	116	1.049	302	1.351
Regional Trials	48	45	45	90
National Institutions	60	321	161	482
Other CIAT Programs	11	23	9	32
Individuals	11	1	3	4
TOTAL	246	1.439	520	1.959
Seed Multiplication				
CIAT-Seed Unit	4	0	5	5
National Institutions	-	-	-	-
TOTAL	250	1.439	525	1.964

CATTLE PRODUCTION SYSTEMS

During 1984 the experiments reported in previous years have been continued; the objective has been the evaluation of various strategic uses of improved pastures as a supplement to native savanna in an attempt to improve reproductive performance in heifers and breeding cows. These experiments are under way at Carimagua and on collaborating farms in the Llanos Orientales of Colombia. The efforts aimed at studying alternative ways of integrating native forage resources with small areas of improved pastures were supplemented by the initiation during the year of a project concerned with mathematical modelling and simulation; these various activities are outlined below.

Evaluation of Breeding Systems with Improved Pastures

This experiment, details of which appear in the Annual Report 1983, involves the comparison of five production systems for breeding cows; salient features are listed in Table 1. The experiment was begun in April 1982. A preliminary analysis was attempted using results obtained over the two years from October 1982; weight gain and reproductive data for the first six months of the experiment were discarded, to avoid residual effects.

Results concerning calving rates and peri- and neonatal mortality are shown in Table 2, for all treatments. No significant differences could be detected ($P > 0.05$) in the proportion of cows that were pregnant and those that were not, using the chi-square test, but the difference in mortality between the intensively managed and the low management input treatments was significant ($P \leq 0.01$). In similar manner, the average calving percentage over the two replications of the control treatment is compared with that obtained under intensive management in Table 3. As before, no significant difference was found in calving percentage ($P > 0.05$), but there was an indication of a significant difference in mortality when the control treatment was compared with the sum of both intensive management treatments ($P < 0.10$). These preliminary results suggest that, for the period under consideration, the strategic use of small areas of improved pasture (900 and 1800 m^2/AU) was capable of maintaining the production levels obtained in native savanna (the control treatment) in spite of a higher stocking rate in these treatments (4 vs. 5 ha/AU). A high incidence of abortion was a feature of both systems of low management input (Table 4); this can certainly be attributed to the mineral deficiencies which have been detected in the animals concerned (Annual Report 1983). Mineral effects also had an influence on peri- and neonatal mortality (Table 5). On the other hand, no significant differences were found ($P > 0.05$) for calf birth weight (overall average 27 $\pm$ 4 kg), whilst very small differences were detected for weaning weight (Table 6). In terms of cow liveweights, there was

Table 1. Description of systems.

System	Description
1 Control	Savanna, 5 ha/AU; continuous mating; complete mineral supplement.
2 Minimum management	Savanna + 900 m^2 of sown pastures (SP)/AU; stocking rate of whole system: 4 ha/AU; continuous mating; continuous access to SP; common (NaCl) salt only.
3 Minimum management	As (2) but with 1800 m^2 SP/AU.
4 Intensive management	Savanna + 900 m^2 SP/AU; 4 ha/AU; 90 d mating season; controlled and selected access to SP; complete mineral supplement.
5 Intensive management	As (4) but with 1800 m^2 SP/AU.

Table 2. Reproductive performance in replicate number 1. October 26, 1982 to October 25, 1984..

Treatment	Observed calving rate	Peri- and neonatal mortality*	Corrected calving rate
	%		
1 Control	57.3	9.1	52.1
2 Minimum	60.4	19.7	48.5
3 management	53.8	22.0	42.0
4 Intensive	50.0	7.6	46.1
5 management	53.3	1.8	52.3

* Up to 30 d of age.

a tendency for animals in the intensively-managed systems to achieve a slightly higher weight ($P < 0.05$) during the critical periods of conception and parturition, especially for those cows which had controlled access to improved pastures.

Reproductive performance in the intensively-managed treatments would appear to have been detrimentally affected by an excessively short mating season; this will be modified by the addition of a second period of controlled mating of 45 days duration following weaning, particularly in situations where a high proportion of cows are cycling and amenable to conception. In addition, the low management input treatments will be modified; it is clear from an inspection of the mineral nutrition and reproduction results that, contrary to the initial hypothesis,

Table 3. Weighted mean reproductive performance, over two replicates.

Treatment	Observed calving rate	Peri- and neo-natal mortality*	Corrected calving rate
	----------	% ----------	
1 Control	54.2	10.3	48.6
4 Intensive	47.9	5.4	45.3
5 management	47.3	3.4	45.7

* Up to 30 d of age.

small areas of improved pastures are not capable of satisfying the breeding animal's mineral requirement; on the contrary, a higher level of supplementation is required.

Reproductive Performance on Brachiaria decumbens

This experiment, whose object is the evaluation of the reproductive performance of a herd maintained exclusively on improved pasture, can be considered the positive control of the systems experiment discussed above.

The first years' calving and weaning percentages are shown in Table 7. Of particular interest is the fact that two of the four unweaned calves which died were suffering apparently from symptoms of photosensitization. It is doubtful if it is possible to evaluate the reproductive potential of cows in pastures of B. decumbens with any certainty, in view of the potential for the reoccurrence of this situation. However, the performance of the surviving calves was satisfactory (Table 8). Reconception among lactating cows was high, 78%, and this contrasts sharply with the situation normally observed in the savanna; the difference can probably be attributed to the high liveweights of these animals (Table 9).

The finding that young calves born throughout this experiment had high serum titre levels of gamma-glutamyl-transferase (GGT) was noted in the Annual Report 1983. This phenomenon was investigated in detail during the current year. It is an apparently normal condition (Figure 1) even in savanna, and blood concentrations of GGT decrease rapidly with age. However, in view of the mortalities noted above, the occurrence of photosensitization in nursing calves on pastures of B. decumbens cannot be ruled out.

Improved Pasture Peformance at the Farm Level

Associations of improved grasses and legumes are being evaluated on cooperating farms in the Llanos Orientales of Colombia, as noted in the previous Annual Report. On two of these farms, this evaluation involves the comparison of the growth and reproductive performance of heifers on savanna, under standard conditions of management (the control treatment) with similar animals kept permanently on improved pastures or with seasonal access to these. Liveweights of heifers from farm 07 at the end of the first three years of data recording are presented in Table 10, whilst heifer calving percentages and subsequent reconception rates (to July 1984 only) are shown in Table 11. To date, no differences have been found ($P > 0.05$) in the proportions of heifers which produced a calf and those that did not, when at least some access to improved pasture was available subsequent to weaning; however, the differences in reconception rates were significant ($P < 0.025$) for the last three treatments in Table 11.

Similar results were obtained on farm 15. Liveweights and age at first conception (Table 12) highlight the

Table 4. Abortions, as fraction of conceptions.

Treatment	Replicate 1	Replicates 1+2
1 Control	2/47 (3.5%)	3/100 (3%)
2 Minimum	9/70 (12.9%)	-
3 management	11/61 (18.0%)	-
4 Intensive	0/52 (0%)	0/92 (0%)
5 management	3/59 (5.1%)	6/95 (6.3%)

Table 5. Mortality in suckling calves.

	Perinatal (< 24 h)	Neonatal (1-30 d)	Rest (31-270 d)
Total number	28	16	2
Percentage	58.1	37.2	4.7
No. in minimum management	17	6	0

Table 6. Age and uncorrected* weaning weights.

Treatment	Replicate 1		Replicate 2	
	Wgt., kg	Age, d	Wgt., kg	Age, d
1 Control	164[b]	266	124[a]	270
2 Minimum	167[b]	276	-	-
3 management	143[a]	267	-	-
4 Intensive	166[b]	268	125[a]	264
5 management	173[b]	258	118[a]	267
Se	26.6	36	22.7	31
P	.05		.05	

* Uncorrected for age or sex.

Table 7. Reproductive performance of heifers on B. decumbens.

	%	No.
Conception rate	94	33*
Calving rate	88	33*
Weaning rate	76	33*
Calf mortality	14	29**

* Number of heifers.
** Total number of calves born.

very limited production potential of savanna: first gestation commences at three years of age or more, at which age heifers on pastures of A. gayanus/S. capitata have produced their first calf. On the other hand, the potential of B. humidicola pasture to generate weight gains, in the absence of an associated legume, is not superior to that of native savanna (Figure 2).

Mineral supplementation with commercial mixtures is practiced on both farms, although in a somewhat irregular fashion. The composition of the mixtures used was determined from samples taken from salt tubs when the farms were visited for data collection (Table 13). It would appear that, in view of the results presented on liveweights (Tables 10 and 12) and calving percentages (Table 11), the mineral mixtures used have not limited animal performance to date; a comparison of heifers on savanna with those grazing A. gayanus/S. capitata would seem to indicate that, at these levels of mineral supplementation, the determining factor in reproductive performance is the availability of sufficient forage of good quality.

Photosensitization in Brachiaria decumbens

In 1983 a factorial experiment was designed with the object of evaluating the effect of the presence or absence of the fungus Pithomyces chartarum, and the application of zinc to the soil (0 vs. 5 kg Zn/ha), on the incidence of hepatotoxaemic photosensitization. However, the fungus proved to be present in all treatments, due to natural infection, and the zinc applied did not substantially modify the concentration of the element in the forage. At the start of the rainy season in 1984, and before changes could be made to the design of the experiment, a severe outbreak of photosensitization occurred which resulted in high levels of morbidity and mortality (Table 14), with no significant differences between treatments ($P > 0.05$). Figure 3 illustrates the relationship between daily weight gain and blood concentrations of gamma-glutamyl-transferase (GGT). Particularly note-worthy was the high daily weight loss of animals which subsequently exhibited clinical symptoms (1.2 kg/d), whilst blood concentrations of GGT increased rapidly in the 15 to 20 days which preceded the apparition of these symptoms.

For the first time at Carimagua the syndrome was reported in a pasture association of B. decumbens and strips of Pueraria phaseoloides; three out of a group of 32 rising 12 to 18 month-old heifers died. Again for the first time, a greater concentration of spores of P. chartarum was found in the legume than in the grass, in this paddock.

The Prototype Family Farm

A change in orientation has meant that this year was one of transition for the Family Farm. The unit has evolved into a dual-purpose system. Seventeen Zebu x Brown Swiss heifers from the piedmont area of the Llanos were added to the herd, and an additional 20 hectares of A. gayanus cv. Carimagua were sown, in association with P.

Table 8. Weights of sucklers on *B. decumbens*.

	Total	Females	Males
Birth weight, kg	31± 4	29± 4	33± 4
Weaning weight*, kg	186± 27	177±25	196± 27
Daily wgt. gain, g/day	625±105	627±94	679±115

* Uncorrected; mean weaning age: 238 d.

Table 9. Unadjusted cow liveweights.

Date	Dry Pregnant		Dry Empty		Lactating Empty		Lactating Pregnant	
	n	Weight	n	Weight	n	Weight	n	Weight
21-XII-83	3	478±40	2	440± 8	11	382±31	16	382±47
24-1-84	3	471±52	2	440± 9	11	362±33	16	361±46
24-III-84	4	446±79	1	437	8	358±42	19	354±45
25-IV-84	16	401±55	4	374±58	5	382±33	7	328±25
14-VII-84	8	431±59	9	426±39	14	371±49	2	376±73

phaseoloides. As in previous years, reproductive performance was good by Llanos standards (a calving percentage of 73.5). The new heifers and the original Zebu cows managed an average milk yield of 1.5 to 2 kg per cow per day for the first eight months of lactation, some of which extended into the dry season; there was a tendency for milk yield to increase right up until the end of this period.

SIMULATION

This year has seen the initiation of a project concerned with the simulation of beef cattle production in the Llanos Orientales. The objective is the development of a computer-based

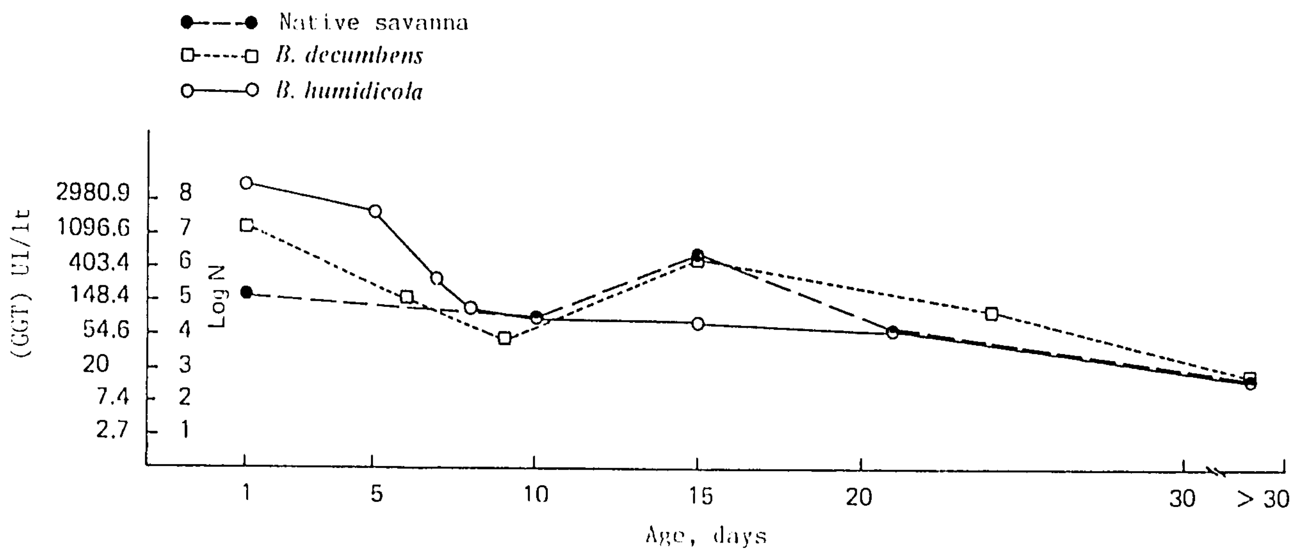


Figure 1. Concentration of gamma-glutamyl-transferase (GGT) in the serum of suckling calves.

Table 10. Performance of heifers on A. gayanus/S. capitata (AS) and savanna, in relation to farm 07. Data up to July 1984.

Treatment	No. of animals	Weight, kg			Age, months		
		Initial	1st. Conception	Current	Initial	1st. Conception	Current
Savanna	19	157	-	225*	9	-	37*
Savanna + AS up to weaning	18	161	-	243*	9	-	37*
Savanna + AS up to mating	36	145	306b	279	9	32b	49
Savanna (50%) + AS (50%)	19	151	325a	309	10	29a	49
AS	38	152	336a	343	10	28a	50

* Data up to November 1983.
Columns with different superscripts differ significantly ($P < 0.05$).

Table 11. Rates of conception, calving and reconception in heifers on *A. gayanus*/*S. capitata* (AS) and savanna, in relation to management system, farm 07. Data up to July 1984.

Treatment	Number of animals (n)	1st.Conception n	1st.Conception %	1st.Calving n	1st.Calving %	Reconception n	Reconception %
Savanna	19*	-		-		-	
Savanna + AS up to weaning	18*	-		-		-	
Savanna + AS up to mating	36	34	95	31	87	-	
Savanna (50% + AS (50%)	19	18	95	18	95	3	16
AS	38	37	97	33	87	20	54

* Data up to November 1983.

Table 12. Liveweight of heifers on different pastures. Data up to July 1984 for farm 15.

Pasture	1st. Conception n	1st. Conception Wgt.,kg	1st. Conception Age,months	1st. Calving n	1st. Calving Wgt.,kg	1st. Calving Age,months
Savanna	7	247b	35.0b	-	-	-
B. humidicola + *D. ovalifolium*	22	246b	34.7b	11	272b	38.0a
A. gayanus + *S. capitata*	88	296a	27.3a	58	361a	36.2a

* *D. ovalifolium* practically absent in last 18 months.

Columns with different superscripts differ significantly ($P < 0.05$).

Table 13. Composition of mineral supplements offered on two farms.

Element	Farm No.07 n	Farm No.07 X	Farm No.07 S	Farm No.15 n	Farm No.15 X	Farm No.15 S
P, %	4	11.0	2.4	7	7.6	4.5
Ca, %	4	15.7	0.7	7	9.2	3.6
Na, %	3	16.1	1.3	3	32.1	6.7
K, %	4	0.34	0.22	6	0.28	0.07
Mg, %	4	0.46	0.16	5	0.16	0.12
S, %	4	1.04	0.77	6	0.63	0.31
Fe, ppm	4	4880	760	5	2696	1441
Mn, ppm	4	175	22	5	100	72
Zn, ppm	4	237	251	5	68	47
Cu, ppm	4	23.0	5.5	5	20.3	2.6

model that will allow the physical and economic assessment of diverse strategies involving the incorporation of improved pastures into the existing farming systems. Experimentation with the model may then be expected to lead to the identification of a set of feasible alternatives. An important by-product of the model-building process is the identification of areas where information is lacking and the assessment of the relative importance of these through sensitivity analysis. The results of the project may thus have implications for the direction of further research in the section, and there may be implications also for the simulation of beef production in other savanna environments, when the flexibility of the model is considered.

The building of a sufficiently detailed model of the beef cattle enterprise represents a large investment of resources. Much time can be saved through the modification of an extant model for the simulation of herd dynamics, intake and growth. To this end, beef production models originating from Texas A&M University, the International Livestock Centre for Africa, and Reading University have been investigated for their suitability. Of these, the Reading

Table 14. Photosensitization: Morbidity and Mortality in 1984.

Treatment	Morbidity n	Morbidity %	Mortality n	Mortality %
1. *P. chartarum* + Zn	4	18.2	3	13.6
2. *P. chartarum*	5	22.7	5	22.7
3. Zn	4	18.2	3	13.6
4. Control	7	31.8	6	27.3
Total	20	22.7	17	19.3

University model is the most promising owing to its flexibility and the fact that animals are treated on an individual basis. Modifications are being made to some of the relationships to adapt it for conditions in the Llanos and wholly *Bos indicus* cattle. Data from Carimagua concerning beef production on native savanna, and from fincas with homogeneous pasture resources in the ETES project in

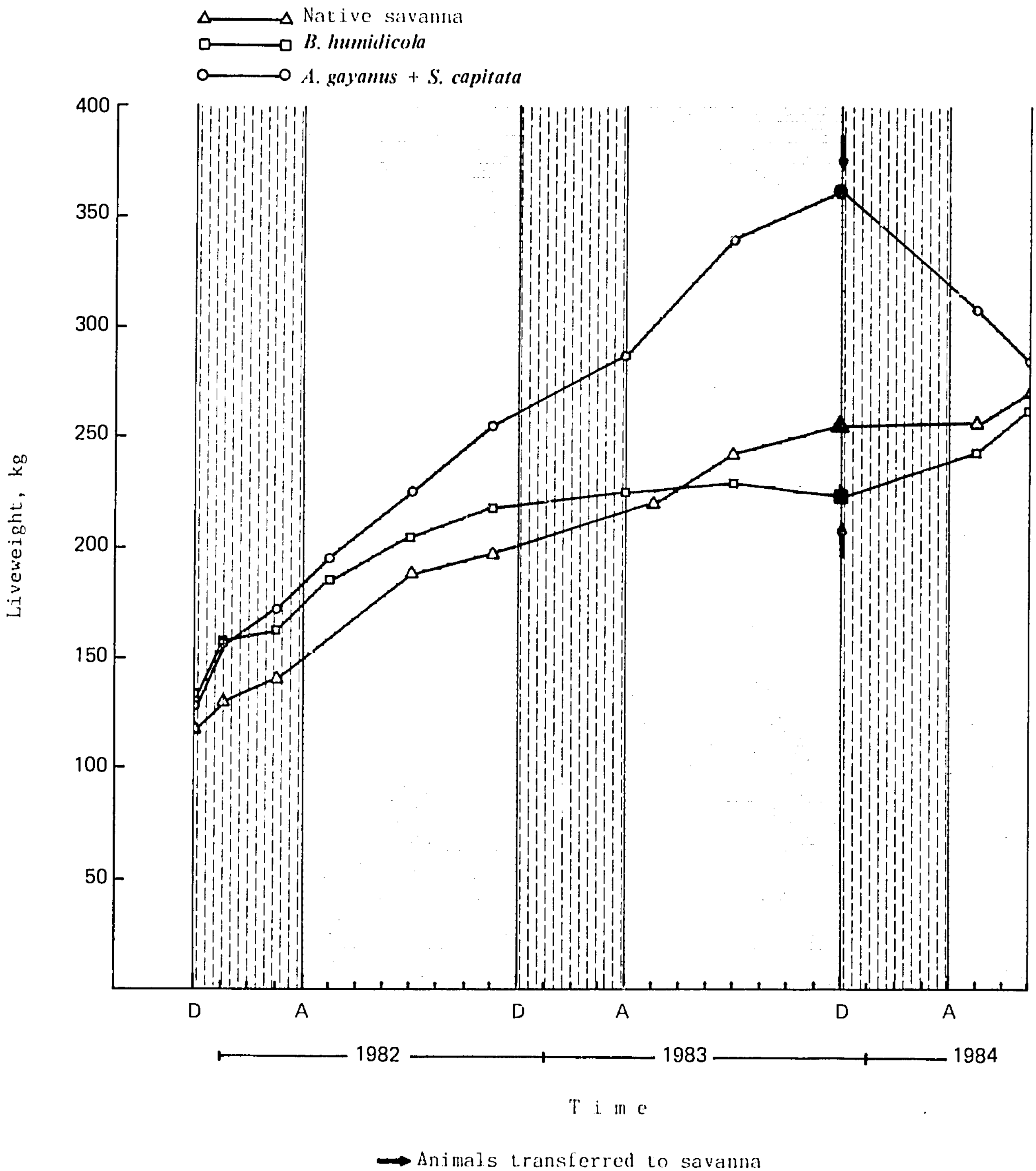


Figure 2. Liveweight of heifers on different pastures. Farm 15.

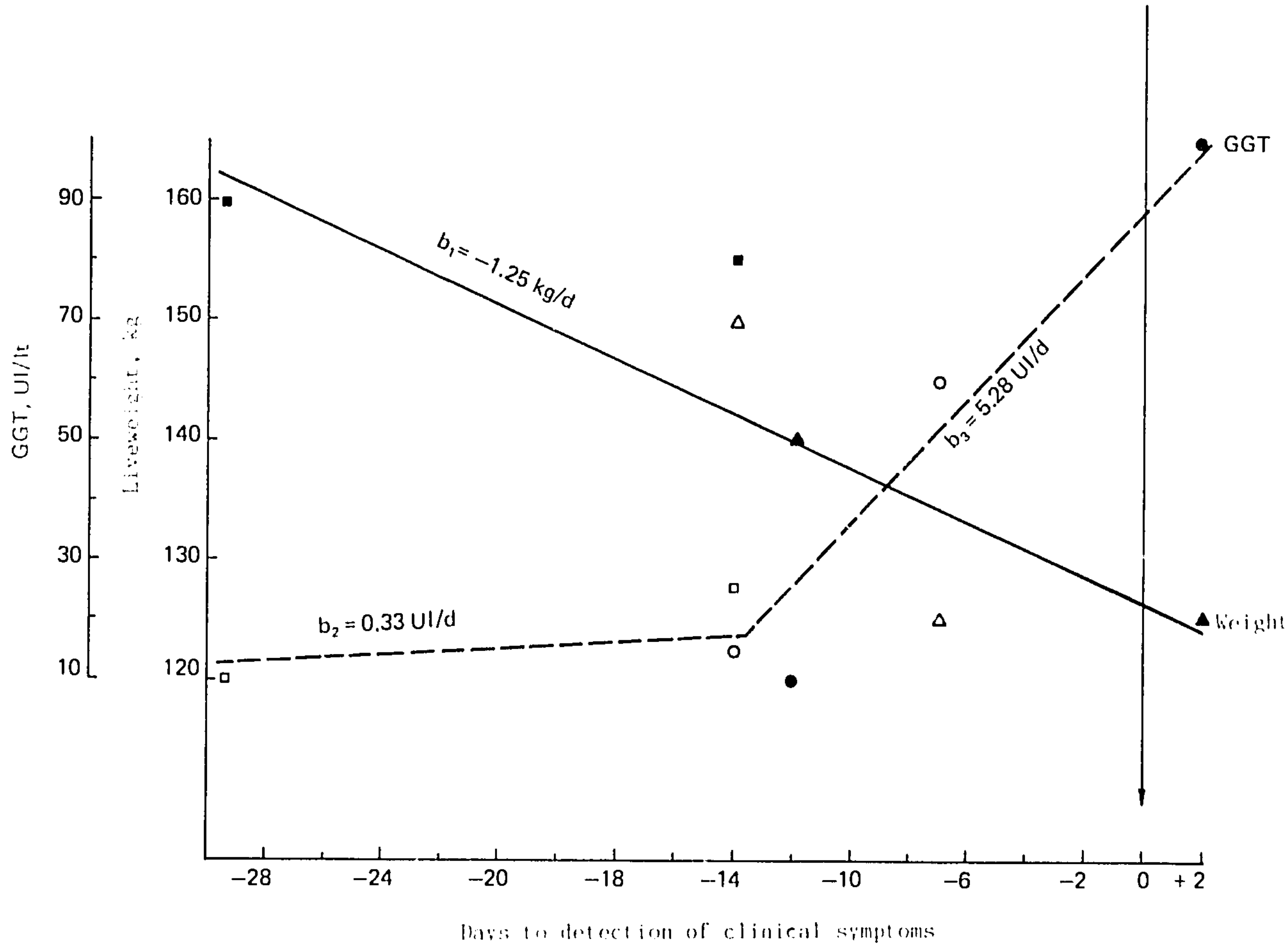


Figure 3. Changes in liveweight and in serum concentration of gamma-glutamyl-transferase (GGT) prior to detection of clinical symptoms.

Panama, are being used to reset salient parameters and to validate the model for these parts of the tropics.

Effort is also being directed towards the forage component, where interactions between animal and pasture have to be taken into account. No suitable models with flexibility enough to handle multiple species situations, in conjunction with animal preference factors, are extant. An adaption of a predator-prey model from the sphere of ecology, modified for the grazing situation, was taken as a starting point. This general one-species model is being extended to the case where more than one type of forage is available to the animal, and where the animal selectively grazes between them. The preliminary analysis of data obtained at Carimagua on animal performance on savanna supplemented with banks of Stylosanthes capitata indicates that preference is dependent on the relative levels of availability of the pertinent species, among other things. It is envisaged that this forage model will incorporate the important feedbacks between animal and pasture, thus serving at the interface between these two components.

Data collation to date has been concerned with the uncovering of information relating to animal production on native savanna, native savanna growth rates in the absence of grazing, quality of native savanna, and preliminary data collection on the important species of improved pasture. This is to continue, so that forage growth and preference functions can be defined.

ECONOMICS

Activities of the Economics Section during 1984 at the aggregate level included the study of the meat consumption patterns in Colombia and the monitoring of prices of products and inputs of relevance for pasture establishment throughout the Latin American tropics. At the farm level, the analysis of two years' data from the monitoring of dual purpose (beef and milk) farms in the Central Provinces of Panama was completed, an ex-ante assessment of the viability of growing aluminium-tolerant sorghum in combination with pasture establishment was undertaken and the analysis of the survey of early adopters of the grass Andropogon gayanus in Colombia was completed.

Consumption patterns of meat in Colombia

As was reported last year, the section is involved in a joint project with FAO/RLAC to look into the consumption of different meat and the substitution among them. As part of this project the Colombian institutions DANE/DRI made available a nutrition survey of 9000 households, representative of the whole country, undertaken in 1981. A summary of results of the econometric analysis of this survey is reported here.

The breakdown of food expenditure by type of food and region (Table 1) shows that beef is the most important item in all regions, followed by dairy products in four of the five regions defined in the study. In the Central region sugar, an important energy source, involves a higher expenditure share than dairy products. Other important food expenditure categories are rice, potatoes, vegetables and fruits. The 10 listed items correspond to 70% of the total food expenditure in all regions.

Expenditure on beef and dairy products are higher in urban than in rural areas. The lowest income quintile spends 23% of its total food expenditure on beef and dairy products in urban areas, while in rural areas the corresponding figure is only 19.3% (Table 2). The importance of sugar (including "panela", a locally produced form of brown sugar) in both rural and urban low income strata, is noteworthy.

Price and income elasticities were estimated for selected products. Independent estimates were made for each income quintile. Table 3 presents such estimates for the main sources of animal protein. All coefficients have the correct signs and most of them are significant at the 1% probability level. The least reliable estimates are those for fish, probably due to the comparative infrequency of fish consumption found in the survey.

A consistent tendency can be observed for income elasticities to drop with rising incomes. Income elasticities are particularly high for beef and dairy products, when compared with those for pork, poultry and eggs.

Table 1. Expenditure share (percentage) of main food types by geographic region, Colombia, 1981.

Type of food	Region				
	Atlántica[1]	Oriental[2]	Bogotá D.E.	Central[3]	Pacífico[4]
Beef[5]	17.3	14.5	15.1	19.6	15.5
Dairy products	11.4	10.2	11.4	9.4	8.3
Rice	8.7	4.6	4.5	5.3	7.2
Bean	1.4	1.4	1.6	3.4	1.9
Cassava	3.1	2.6	0.8	2.0	1.4
Sugar	5.0	9.1	7.2	12.4	8.2
Vegetables	8.7	7.5	9.4	5.2	5.6
Fruits	6.7	6.3	10.2	4.7	6.9
Fats	6.1	5.0	5.4	6.6	6.4
Potatoes	1.6	8.6	5.3	3.7	7.0
Total	70.0	69.8	70.9	72.3	68.4

1/ Includes the departments of Cordoba, Sucre, Magdalena, Atlantico, Bolivar, Cesar y Guajira.- 2/ Includes the departments of Norte de Santander, Santander del Sur, Cundinamarca y Meta.- 3/ Includes the departments of Antioquia, Caldas, Huila, Quindio, Risaralda y Tolima.- 4/ Includes the departments of Choco, Nariño, Cauca y Valle del Cauca.- 5/ Includes all cuts of beef and offal.

Table 2. Expenditure share (percentage) of main food types by income quintile and area, Colombia, 1984.

Type of food	Urban Area			Rural Area		
	Lowest quintile	Highest quintile	Urban average	Lowest quintile	Highest quintile	Rural average
Beef	14.2	16.6	17.7	11.6	15.1	14.3
Dairy products	8.7	11.3	10.5	7.7	10.4	9.1
Rice	9.7	4.2	5.7	9.4	5.6	7.2
Bean	2.7	1.6	2.0	1.8	2.7	2.2
Cassava	2.0	1.0	1.4	4.8	2.7	3.7
Sugar	12.0	6.8	8.0	12.2	9.5	10.4
Vegetables	6.7	7.5	7.6	5.1	7.2	6.0
Fruits	3.4	10.5	7.5	3.3	6.3	4.8
Fats	6.9	5.5	6.1	5.3	6.0	5.6
Potatoes	6.5	3.2	4.3	8.8	4.7	6.7
Total	72.8	68.2	70.8	70.0	70.2	70.0

Table 3. Price and income elasticities of the main sources of animal protein by income quintile, Colombia, 1981.

Source	Income Quintile: 1 (low) In-come	1 (low) Price	2 In-come	2 Price	3 (medium) In-come	3 (medium) Price	4 In-come	4 Price	5 (high) In-come	5 (high) Price
Beef	1.87	-0.93	0.91	-0.94	1.11	-0.39*	1.09	-0.95	0.30	-0.92
Pork	0.32	-0.50	0.24	-0.55	0.28*	-0.54	0.90	-0.57	0.40	-0.63
Poultry	0.63	-0.46	0.35*	-0.56	0.68*	-0.57	1.18	-0.58	0.54	-0.65
Fish	1.32*	-0.66	1.15*	-0.69	0.99*	-0.71	0.36*	-0.75	0.50	-0.78
Eggs	0.89	-0.79	0.87	-0.82	0.34*	-0.85	0.52	-0.68	0.26*	-0.85
Dairy products	1.21	-0.93	1.37	-0.96	1.15	-0.90	1.10	-0.75	0.41	-0.61

* NS = $\alpha > 0.01$

Using more disaggregated information on consumption of individual cuts, cross- price elasticities were estimated between selected cuts of beef, pork and poultry. Due to the overriding importance of beef in relation to pork and poultry, the latter two exhibit strong collinearity. Therefore a weighted price of these two products was used to explain demand for beef. Results (Table 4) show high own-price elasticities for all three meats as well as high cross-price elasticities of the price of beef in relation to the consumption of pork and poultry. On the other hand, the effect of the latter prices on beef demand is substantially lower, confirming the importance of beef as a leader within this market, justifying the importance attached by governments to controlling beef prices, in this way prices of pork and poultry are controlled indirectly.

This type of information is a key element in the assessment of the impact of technological changes in pastoral agriculture and future distribution among individual groups of society.

Monitoring of livestock input and output prices in the Latin American tropics

This activity, in support of the RIEPT, was continued through 1984. The first document with information on the years 1982 and 1983 was published. At the preparation deadline for this report 28 questionaires from 12 countries had been returned with information pertaining to 1984.

To assess the competitiveness of the improved pasture technology the cost of an input basket needed to establish one hectare of improve pasture is calculated in terms of kg of beef liveweight. In 1984 the average cost across locations was US$109, equivalent to 123 kg of beef liveweight (Table 5). Fertilizers continued to be the major cost item. Nevertheless a great variability can be observed in the cost structure as well as in the total cost, which ranged from US$61 to US$228 per hectare. This range is even wider when expressed in terms of kg liveweight. Comparing these figures to those of 1983, the cost in terms of kg liveweight has remained

Table 4. Own price and cross price elasticities of meats in Colombia, 1981.

Elasticities	Beef (Choice) (quantity)	Pork (Lean) (quantity)	Chicken (quantity)
Own price	-1.35 (-22.2)	-1.24 (-38.9)	-1.34 (-28.3)
Cross price	1.00[a] (0.87)	2.41[b] (2.43)	2.31[b] (2.44)

a/ Weighted average of prices other than beef.
b/ Price of choice beef.
( ) Figures in parenthesis correspond to "t" values.

approximately constant and the ranking of individual locations has remained the same (Table 6). Nevertheless there have been important changes in the cost of the input basket in some countries such as the Dominican Republic.

The 1984 survey included questions on the sown pasture technology prevailing in the regions. Table 7 presents the most interesting information. In 16 out of 28 locations sown pastures are established without the application of fertilizers. It must be taken into account when interpreting this information that 17 of the 28 locations included in this analysis correspond to forest ecosystems, in which pastures are established jointly with crops using the fertility made available by burning the forest vegetation.

When fertilizers are applied, it is noteworthy that nitrogen and compound fertilizers are used in addition to phosphatic compounds.

Among the species sown, those with the highest frequencies are Brachiaria decumbens, Panicum maximum and Hyparrhenia rufa. At 27 out of 28 locations weed control is undertaken regularly, usually by hand, followed by a combined application of herbicides and manual weeding. This confirms the importance of weeds, particularly in humid forest ecosystems where the forage species utilized are not adapted and lack the aggresiveness to persist and dominate in the pasture. The importance of pasture establishment with vegetative material is quite remarkable; it is probably due to the lack of access to seed of good quality and the lower risk involved in vegetative planting. It is important to understand the reasons for the practices presently used, in attempting to design improved technologies

Monitoring of dual-purpose farms in the Central Provinces of Panama

The analysis of the information from two years of monitoring was completed. Based on this information, constraints in the production system were identified and potential strategies were defined for future research.

The information presented corresponds to six farms for the period June 1981-May 1982 and five farms for the period June 1982-May 1983. Therefore means for the two periods are not strictly comparable.

Reproductive parameters (Table 8) are substantially higher than in extensive cow-calf systems. Cow weights hover around 350 kg and consequently calving rates of 65% and 75% are achieved;

Table 5. Cost of principal inputs for pasture establishment (1 ha, US$, 1984)[1].

Country and Region	Fertilizers	Labour	Fencing wire	Fuel	Total cost	kg beef to cover costs: kg	kg beef to cover costs: Index	Source of phosphorous[2]
BRAZIL								
Boa Vista	93.604	10.400	6.224	17.003	127.231	223.235	185.33	1
Brasilia	66.546	9.710	4.930	20.251	101.437	90.076	74.78	1
Campo Grande	48.048	10.010	6.162	20.205	84.426	140.569	116.70	1
Sete Lagoas	47.302	7.676	5.756	16.965	77.699	154.696	128.4	1
COLOMBIA								
Amalfi	56.423	18.029	27.404	9.614	111.469	115.928	96.24	1
Caucasia	54.333	17.747	19.792	7.871	99.743	96.181	79.85	1
Florencia	21.346	20.833	23.122	8.803	74.104	79.452	65.96	2
Medellín	51.852	16.204	25.333	7.700	101.089	103.977	86.32	1
Mocoa	44.444	20.062	23.990	7.770	96.266	109.439	90.86	2
Villavicencio	21.111	23.148	15.635	7.612	67.507	70.104	58.20	2
DOMINICAN REPUBLIC								
Higuey	130.000	29.167	39.330	29.484	227.981	175.370	145.59	1
Santo Domingo	130.000	29.167	39.330	29.484	227.981	135.703	112.66	1
MEXICO								
Arriaga	23.721	18.919	14.789	8.173	65.602	55.672	46.22	1
Huimanguillo	35.525	20.656	20.484	11.824	88.490	58.688	47.06	1
Iguala	20.942	17.500	15.675	7.560	61.677	41.118	34.14	1
Isla	24.716	28.773	9.082	8.173	70.744	62.322	52.5	1
Niltepec	25.978	16.760	17.514	8.447	68.698	61.485	51.04	1
PANAMA								
Panamá	70.000	25.000	19.950	22.680	137.630	156.398	129.84	1
PARAGUAY								
Asunción	114.667	25.0	16.61	31.48	187.76	260.04	215.89	1
Depto. Central	116.667	17.361	10.364	28.665	173.056	218.597	181.47	1
Average					112.530	120.450	100.00	1

1/ Excludes seed and land costs. Fence with 3 strands of barbed wire, 57 m of fencing per hectare. Five man-days per hectare assumed for establishment. Land preparation: 2 disk harrowings and conventional seeding with 78 HP tractor.

2/ Sources and levels of phosphorous assumed: (1) triple superphosphate (200 kg/ha); (2) Rock phosphate (300 kg/ha).

Table 6. Cost of an input basket for pasture establishment (1 hectare) and sources of changes in its cost, 1983-1984.

Country and Region	Cost of the input basket (in terms of kg beef l.w.) 1983	1984	Sources of Variation of its cost[1] Cattle	Fertilizer	Fencing wire	Labour	Fuel
BRAZIL							
Boa Vista	204.59	223.25	↑	↑	↑	↑	↓
Brasilia	81.26	38.30	↑	↓	↑	↑	↓
COLOMBIA							
Caucasia	62.79	96.18	↓	↑	↑	↓	↓
Florencia	70.05	79.45	↓	↓	↑	↓	↓
Villavicencio	87.35	70.10	↓	↓	↓	↓	↓
MEXICO							
Arriaga	57.40	55.70	↑	↑	-	↑	↑
Isla	68.58	62.32	↑	↑	↓	↑	↑
Niltepec	95.30	61.50	↑	-	↓	↑	↑
PANAMA							
David	141.60	156.40	-	-	↑	↑	↑
PARAGUAY							
Asunción	295.80	260.04	↓	↓	↓	↓	↑
DOMINICAN REPUBLIC							
Higuey	101.60	175.40	-	↑	↑	↑	↑
Santo Domingo	109.70	135.70	↑	↑	↑	↑	↑

1/ Changes in prices of inputs in US$ terms at the official exchange rates.

SYMBOLS:
↑ = cost increased
↓ = cost decreased
- = cost remained constant

the cyclical patterns observed in savanna ecosystems with calving rates of about 50% are not present here. This is due to the fact that in this system the farmer gives the best forage resources available to cows which produce milk, an important income source. Farms have forage resources of higher quality than the native savannas, and these are more heterogeneous due to topography and soils. This heterogeneity is brought about by means of a large number of subdivisions to allocate forages of different quality to different categories of animals. This explains the presence of farms with heavy cows, comparatively aged heifers at first calving, and low weaning weights. The role of dual-purpose systems in

Table 7. Frequency of use of various pasture management practices at locations where trials of the International Tropical Pastures Network were conducted in 1984.

Pasture management practice	Forest: Seasonal (9)[a]	Forest: Humid (8)	Savanna: Hiperthermic (7)	Savanna: Thermic (1)	Savanna: Poorly drined (3)	TOTAL (28)
Use of fertilizers:						
Yes	6	2[b]	2	1	0	11
No	3	6	4	0	3	16
Type of fertilizer used:						
P_2O_5	3	2	2	1	0	9
N	3	0	0	0	0	3
N-P-K	2	1	0	0	0	3
Weed control:						
Yes	9	8	6	1	3	27
No	0	0	1	0	0	1
Type of weed control used:						
Chemical	1	0	0	0	0	1
Manual	4	6	4	1	2	17
Manual + Chemical	4	2	0	0	1	7
Mechanical	0	0	2	0	0	2
Planting technique:						
Sexual	1	3	4	1	3	12
Vegetative	8	5	3	0	0	16
Main species:						
B. decumbens	1	4		1	2	8
P. maximum	4		3		1	8
H. rufa	1	2	1			4
D. decumbens	2					2
B. humidicola			1			1
P. purpureum		1				1
A. micay	1					1
C. pleistostochyus			1			1
S. anceps			1			1
S. sericea		1				1

a/ Figures in brackets indicate the number of locations surveyed in each ecosystem.
b/ In this ecosystem the survey of one location did not include information on fertilizer.

Table 8. ETES-Panama: parameters of reproductive performance 1981-May 1983).

Coefficients	Farm No. 01	02	03	04	05	06	Average
Calving rate (%)							
Year 1	70.0	73.2	79.1	63.3	57.7	98.9	73.1
Year 2	69.3	29.0	67.6	71.1	-	73.5	64.4
Adult mortality (%)							
Year 1	0.0	0.0	6.9	5.2	0.0	0.0	3.3
Year 2	0.0	9.9	5.4	0.0	-	0.0	3.5
Calf mortality (%)							
Year 1	11.8	0.0	25.3	58.8	3.3	2.7	19.5
Year 2	21.4	7.2	5.4	12.1	-	0.0	7.6
Age at first calving (months)							
Year 1	30.1	34.7	42.4	41.4	38.8	30.6	37.5
Year 2	-	32.0	44.4	40.3	-	36.0	41.0
Cow weight (kg)							
Year 1	392.0	341.0	310.0	343.0	327.0	372.0	337.0
Year 2	377.0	338.0	367.0	324.0	-	340.0	350.0
Weaner weight (kg)							
Year 1	98.0	145.0	133.0	89.0	165.0	163.0	132.0
Year 2	105.0	148.0	135.0	96.0	-	144.0	125.0

increasing calving rates over those which predominate in cow-calf operations is thus confirmed. A low calving rate is the major constraint to the growth of stock numbers and consequently to the utilization of new land and new technology.

Milk production coefficients (Table 9) reflect the high flexibility of dual-purpose systems in being able to adjust to fluctuating availability of forages and labour as well as to changing price ratios. For example, lactation length varies widely. The lowest value (Farm 03) corresponds to a large herd where cows are milked during the first months only and then left to rear the calf. Farm 02 presents a completely different situation. It is a small farm on very dry land which therefore has serious forage limitations in the dry season. Calving rates are low and the owner has to milk all lactating cows. Farm 04 changed drastically from the first to the second year of monitoring. During the first year milking had to be stopped in the dry season due to lack of forage. In the second year, with newly established lowland pasture in production, milking was possible throughout the dry season.

Production per cow milked varied from 400 to 1600 kg, which again reflects very different situations. Farm 03 achieves high levels by milking a limited number of cows during the first part of their lactation only. Farm 01 achieves somewhat lower levels while milking all its cows over

Table 9. ETES-Panama: Beef and milk production (June 1981 - May 1983).

Parameters		Farm No. 01	02	03	04	05	06	Average
Milk production								
Days of lactation of cows being milked:	(Year 1)[1]	177	202	144	120	147	120	152
	(Year 2)	223	304	172	268	-	297	272
Production per cow in milk/year (kg):	(Year 1)	1247	890	1484	783	584	662	1156
	(Year 2)	1379	716	1606	1000	-	412	1019
Production per cow in the herd/yr.(kg):	(Year 1)	751	560	578	344	418	425	509
	(Year 2)	955	548	620	574	-	245	567
Production per ha/year (kg):	(Year 1)	608	259	260	326	208	220	276
	(Year 2)	669	281	216	337	-	178	336
Beef production per								
AU/year (kg):	(Year 1)	63	55	45	25	55	50	46
	(Year 2)	18	28	85	63	-	39	47
ha/year (kg):	(Year 1)	100	67	57	53	61	65	62
	(Year 2)	32	34	85	126	-	54	66
Equivalent production per[2]								
AU/year (kg):	(Year 1)	102	77	67	40	74	66	67
	(Year 2)	55	51	107	80	-	51	69
ha/year (kg):	(Year 1)	161	92	83	85	81	87	89
	(Year 2)	98	62	106	159	-	71	99
Stocking rate[3]	(Year 1)	1.8	1.2	1.2	2.1	1.1	1.3	1.3
	(Year 2)	1.8	1.2	1.0	2.0	-	1.4	1.3
Enf of dry season adjusted stocking rate[4]	(Year 1)	1.56	1.03	0.82	1.40	1.10	1.10	1.0
	(Year 2)	1.28	0.81	0.80	1.48	-	1.20	1.0

1/ Year 1 = June 1981-May 1982; Year 2 = June 1982-May 1983.- 2/ Equivalent production: 10 litres of milk = 1 kg beef.- 3/ Only cattle; 1 cow = 1 AU, 1 calf = 0.6 AU, etc. 4/ 1 AU = 350 kg of beef liveweight.

their entire lactation. Cows are of good quality, they have access to palatable forage, and little milk is left to the calves.

Milk production per cow in the herd and per hectare have increased in the second year in spite of that year being particularly dry. On the other hand, beef production dropped in three of the five farms. The marked increase in the productivity parameters of Farm 04 was due to the fact that important lowland areas had to be taken out of production to establish new pastures. In the second year these pastures were fully productive. Farm 03, the largest, emphasized beef production somewhat more in the second year by returning to their owners those milking cows which belonged to third parties.

The above has served to illustrate the flexibility of the system and the numerous potential causes for the same parameter levels being observed, clearly factors which make diagnosis difficult. It is necessary to know farmers' objectives to understand why the system is operated in one way and not in another. In broad terms, during the second drier year, milk production remained constant, and reduced forage production was reflected more clearly in reduced beef production, particularly in the lower weight of young stock. This illustrates another facet of the system's flexibility, that is its ability to adjust to fluctuations in forage production between years. This is is reflected in changes to the cattle inventory, particularly in Farms 01 and 02 (Table 10), and in livestock sales, which dropped markedly on several farms, while on average milk sales were increased. While in the first year the values of milk sales corresponded to 60% of the value of livestock sales, in the second year they reached 86%.

The cost structure is amazingly similar in the two years (Table 11). A large proportion of the costs are fixed, i.e. independent of the output level. The category which presents the largest change is the renting of pastures. On average farmers spent twice the amount of the previous year, reflecting the forage scarcity in the drought. Important features of the cost structure of these farms are the high values for labour costs (items "herd handling" and "weed control") and pasture rental as well as the low level of purchased inputs (including pasture maintenance, animal health, supplementation, and sundries). The technology presently used generates important value added at the regional level in spite of not very high productivity parameters. Net income, representing returns to production factors owned by the farmer (land and family labour), dropped from US$5,500 to US$4,500 on average in the second year (Table 12). Imputing a 3% interest on average capital, a return to family labour of US$20 per man-day was achieved in the first year, dropping to US$13.5 in the second year. For total labour employed, the corresponding figures were US$10 in the first year and US$5 in the second. The latter is equivalent to the average wage in the region.

Returns to farm capital dropped from 8% to 6% in the second year, values below the opportunity cost in terms of rates paid by banks. It must nevertheless be taken into account that dual- purpose farming is a low risk investment and land is expected to appreciate in value.

In an attempt to improve our understanding of this system a series of econometric models were developed to explain milk production per cow. A series of independent variables were examined:

- cow weight and breed type were not significant, probably due to the fact that in this farming system cows are allocated the best forage available and their weight, therefore, is above critical levels. Classification by breed type was achieved through a dummy variable which separated European types (Holstein and Brown Swiss) from Zebu types. Age was also examined by means of a dummy variable.

- weaning weight exhibited a low correlation with milk produced.

Table 10. ETES-Panama: Structure of gross income (June 1981 - May 1983) (US$).

Indicators	Farm No. 01	02	03	04	05	06	Average
GROSS INCOME							
Sale of milk							
Year 1	3714	4004	9081	2798	2943	2904	4241
Year 2	3884	3995	8724	4106	-	2327	4607
Sale of beef							
Year 1	1310	4220	17314	4804	7810	7281	7123
Year 2	2467	6074	13502	4114	-	730	5377
Changes in inventory							
Year 1	1537	-1853	-7284	-3309	-4616	-1404	-2820
Year 2	-2955	-4441	-7740	2177	-	4128	-1766
TOTAL							
Year 1	6561	6371	19119	4293	6137	8781	8544
Year 2	3396	5629	14486	10397	-	7185	8218

Table 11. ETES-Panama: Structure of expenses (June 1981 - May 1983) (US$).

Item		Farm No. 01	02	03	04	05	06	Average
Labour for cattle handling:	Year 1	37	407	4479	1601	778	0	1217
	Year 2	136	527	3963	1788	-	0	1283
Weed control:	Year 1	238	491	213	244	55	30	295
	Year 2	499	618	459	112	-	177	373
Rent of pastures:	Year 1	359	312	30	0	80	150	155
	Year 2	307	620	45	500	-	0	294
Pasture maintenance:	Year 1	0	518	1095	464	0	56	355
	Year 2	0	364	902	756	-	0	404
Animal health and supplementation:	Year 1	109	186	709	215	576	465	377
	year 2	176	317	610	262	-	341	341
Others:	Year 1	399	383	2440	111	333	638	718
	Year 2	239	731	2128	380	-	1480	992
TOTAL	Year 1	1142	2297	8966	2635	2322	1340	3117
	Year 2	1357	3177	8107	3798	-	1998	3687

Table 12. ETES-Panama: Returns to capital and labour (June 1981 - May 1983) (US$).

		Farm No. 01	02	03	04	05	06	Average
Gross income	(Year 1)	6561	6371	19119	5293	6137	8781	8544
	(Year 2)	3396	5629	14486	10397	0	7185	8218
Expenses	(Year 1)	1142	2297	8966	2635	2322	1340	3117
	(Year 2)	1357	3177	8107	3798	-	1998	3687
Net income	(Year 1)	5419	4074	10153	1658	3815	7441	5472
	(Year 2)	2039	2452	6379	6599	-	5187	4531
Return to labour (US$/man-day)[1]								
a) Family labour	(Year 1)	25.3	13.6	121.6	2.0	39.5	12.6	20.6
	(Year 2)	6.5	5.9	47.2	61.1	-	7.8	13.5
b) Total	(Year 1)	18.0	8.4	9.5	4.8	10.6	12.6	10.1
	(Year 2)	3.3	2.7	2.4	9.4	-	6.9	4.8
Return to capital (%)[2]								
	(Year 1)	15.6	7.0	6.9	2.5	7.2	11.0	7.6
	(Year 2)	3.9	3.4	4.5	12.6	-	5.8	5.8

1/ Imputing an interest rate of 3% on average total capital.
2/ Imputing a wage of US$5 per day to unpaid family labour.

Probably weaning weights are more dependent on management decisions than on biological relationships in this system.

- calving date: a dummy variable to separate calvings in the dry season from those in the wet season. It was not significant.

Two econometric models were finally selected, detailed in Table 13. Model 1 attempts to explain production of milk per cow per day as a function of a set of variables which is independent of the genetic potential of the cow. In the second model an estimate for the potential production of the cow is included. This is the daily production of the cow during the first month of the ongoing lactation. Other variables which are common to both models are:

- lactation month; this presents a significant and constant effect in both models, indicating a reduction of the daily production of milk per day of about 0.13 kg per month of lactation.
- area of lowland pastures per cow (ha); the lowlands represent the forage resource of the highest quality in this system and are allocated preferentially to the cows. The regression coefficient is positive and significant and is reduced to half its value when the production potential of the cow is included. This clearly indicates an interaction between the potential of the cow and the impact of improvement of forage resources.
- proportion of the total herd being milked; this parameter was included to reflect the fact that

Table 13. Regression models explaining daily milk yield on dual-purpose farms. Central Provinces, Panama.

	Independent variable: kg milked per cow per day	
	Model 1	Model 2
Intercept	3.766***	2.787***
Independent variables:		
. Month of lactation	-0.129***	-0.137***
. Area in lowlands pastures per cow (ha)	1.065***	0.598***
. Daily production in the first month of lactation (kg)	-	0.324***
. Proportion of total cows milked	-1.333***	-1.204***
. Year dummy variable (1981=0, 1982=1)	0.346***	0.442***
R^2	0.393***	0.467***
N	1098	1098

Significance: $\alpha \leqslant 0.0001$ ***

farmers with small herds tend to milk all cows, while larger farmers milk only part of the herd. This allows the latter to select cows and therefore obtain higher production levels per cow milked. The regression coefficient is negative and significant. It indicates that an increase of 10 percentage points of the proportion of cows milked is associated with a decrease in the production of milk per cow per day of between 0.12 and 0.13 kg.

- year; this dummy variable was significant and showed that during the second year the daily production per cow was between 0.35 and 0.45 kg above the one of the first year. This is interpreted as another indicator of the flexibility of the system. During a dry year, when it is difficult to sell cattle, farmers attempt to maintain their income (and particularly their cash flow) by milking cows more intensively and sacrificing the physical condition of their cattle.

All the coefficients of this model are highly significant and explain almost 50% of total variability of daily milk production per cow. This is considered satisfactory, taking into account the facts that forage resources are characterized very superficially in the model, variables of pasture management are not included, and there is very limited information on the milk production potential of the cow.

It is difficult to understand why some farms, for example farm 03 which has cows of good milk production potential and is located close to the market, do not expand the proportion of cows they milk. Farmers frequently state that milk production must cover the cash operating costs of the farm, reflecting the need for a certain cash flow; this is difficult to obtain on farms producing only beef.

Regressing the annual sales of milk per farm on the cash expenses of the farm resulted in an R^2 of 0.83, tending to support the above hypothesis. Under the prevailing price ratios the marginal return to investing in dual-purpose cows or in a steer fattening enterprise is similar if additional labour has to be hired for milking. For cash flow reasons milking is undertaken only to the degree made possible with otherwise necessary labour. This is associated with the fact that, on average, farms have cattle with more potential to increase weight than to increase milk production, given the difficulty in selecting dairy genotypes under conditions of fluctuating forage supply in terms of both quantity and quality.

Improvement of the forage base would have a direct impact on milk production but would also make a higher selection pressure for milk production possible. Individual farms can speed up this process through the purchase of animals of higher milk production potential, but at the national or regional level this will have to be achieved through selection, introduction of improved genes and better feeding - a lengthy process.

Based on this analysis, an attempt was made to design options aimed at increasing the system's productivity by introducing improved pasture technology. A series of constraints beyond the farm gate were identified which affect the adoption of such technologies. The main ones are as follows:

1. Critical inputs for pasture improvement, such as simple sources of phosphatic fertilizers, are either not available on the market or are highly-priced.
2. The high costs of agricultural machinery and fuels on small plot sizes lead to high costs of pasture establishment.
3. Prices of livestock products (beef and milk) receive less protection than crop prices, a fact reflecting the existence of an ample supply of land with limited crop potential and with no alternative but to be used for livestock production.

In spite of the above it is considered that in the medium term Panama will have to intensify the use of these lands. Some potential strategies for this purpose are presented in Table 14, classified according to region, size of farm, and land endowment. These alternatives are based on the assumption that in regions with marked dry seasons the main constraint is the quantity of forage produced or forage available during that period. On the other hand, increments in forage quality are needed to increase the milk production levels, which can frequently be achieved through the introduction of legumes. In small farms with high stocking rates, the transition from the previous situation to one with substantial areas of improved pastures is critical due to the marked shortage of forage during this transition period.

The technological alternatives presented attempt to meet these requirements of the production system, thus reducing the number of options which have to be tested at the experimental level.

Potential role of sorghum in livestock systems in the Llanos Orientales of Colombia

Taking account of advances in the research on the adaptation of sorghum to acid soils with high aluminium saturation, an ex-ante analysis was undertaken of the potential role of this crop in the existing predominantly cattle-orientated farming systems. The analysis was undertaken specifically for the Colombian Llanos Orientales but most of the conclusions are considered of more general validity.

The analysis started from the hypothe-

Table 14. Production systems and demand for pasture technology in Panama.

			Size		System	Technology
FARMS	With lowlands		Variable		Dual-purpose and/or fattening	Improved use of the lowlands: weed control, fertilization, pasture management, type of cattle.
	Without lowlands	Without marked dry season	Medium size farms (50-100 ha) Large farms (> 100 ha)		Cow-calf, fattening operations based on *H. rufa* pastures. Limited milking of dual-purpose	Legume grass associations increasing productivity per animal; forages of high palatability in the rainy season
		with marked dry season	Medium sized farms (50-100ha)	Ample supply of arable lands	Crops and dual-purpose	Use of crop stubble in the dry season. Supplementation of stubble with legumes. High carrying capacity grasses for wet season production (Legume grass associations).
				Limited supply of arable lands	Dual-purpose	Protein and energy banks for dry season, e.g. super cane + *Leucaena*. Improvement of hilly country country with introduction of legumes and/or grasses

sis mooted by plant breeders, of being able to produce two metric tons of sorghum grain per hectare on soils with 60% aluminium saturation. Two options were considered:

- Sorghum as an annual cash crop to be grown year after year.
- Sorghum as a crop associated with the establishment of improved pastures.

With respect to the first alternative, comparative analyses undertaken to assess the competitive position of the crop with the same crop grown on more fertile soils closer to the markets indicated that relatively high yields of at least 3 t/ha would have to be achieved for production from marginal soil to be competitive in the market. These results are due to:

- wide-spread existence of more fertile and better located soils for the production of sorghum in Colombia which are presently under cattle.
- high machinery costs, which are basically independent of the yield levels achieved per hectare.
- Significant transportation costs.

The attractiveness of this technology would be greater in countries with:

- limited areas of fertile soils with cropping potential not being utilized.
- important areas of acid soils close to urban centers or with low transport costs.
- lower machinery costs.

It was assumed that land preparation for associated establishment of pastures and crops was the same as for the establishment of improved pastures. On the other hand, it was assumed that sorghum required liming to decrease the aluminium saturation from 80% to 60%. At the same time it was assumed that nitrogen and potassium fertilizer was needed and that the phosphorous required for pastures was sufficient for yields of 2 t/ha of sorghum. The marginal investment due to the inclusion of sorghum was US$213 per hectare (Table 15). Of these costs almost 15% are related to harvesting, which indicates that there is no great risk, since if there is a low yield the crop does not have to be harvested but can be used for immediate grazing by cattle. The combination of an annual crop with the establishment of sown pasture, a traditional practice in humid forest regions and temperate countries, would have a series of additional advantages:

- it would reduce the pressure on ranchers to graze sown pastures at a very early stage.
- sorghum stubble supplies a large volume of forage (above 4 t/ha of DM) at the beginning of the dry season.
- a high volume of forage is introduced into the system at a time when it would be very useful for cow-calf operations to increase the weight of cows beyond levels critical for their reproductive efficiency. Once this increase has been achieved small areas of improved pastures would be sufficient to maintain this weight and hence reproductive efficiency.
- it gives access to short-term credit for crops which frequently require less bank guarantees than long-term credit for pasture improvement. This is particularly important in frontier regions with land settling problems and therefore lack of solid bank-acceptable guarantees.

To assess the possible impact in terms of cash-flow and profitability of sorghum grown in association with pastures, a budget was prepared for a farm of 3000 hectares with the establishment of 154 hectares of improved pastures to be used strategically with the breeding herd. Historical information was used for the process of pasture establishment during the first years, to which the cash flow of the sorghum crop established along with the pasture on the whole improved area was added, assuming yields of 2 ton/ha of sorghum. The results (Figure 1) showed a substantial improvement in the cash flow in the first years giving a positive balance in the second year.

Table 15. Comparative budget for establishing an improved pasture with and without a sorghum crop (US$/ha).

	Improved Pasture	Sorghum + Pasture	Incremental investment for sorghum
Land preparation			
a) Machinery			
(8.5 hr x US$11/hr)	93.5	93.5	0.0
b) Labour			
(10 man-days at US$5/man-day)	50.0	50.0	0.0
Inputs			
a) Seed			
-Sorghum (8 kg a US$0.80/kg)	-	6.4	6.4
-A. gayanus (5 kg a US$6.oo/kg)	30.0	30.0	0.0
-S. capitata (2 kg a US$7.oo/kg)	14.0	14.0	0.0
b) Fertilizer			
Lime (1440 kg x US$0.03/kg)	-	43.2	43.2
N (46 kg x US$0.65/kg)	-	29.9	29.9
P_2O_5 (50 kg x US$0.38/kg)	19.0	19.0	0.0
K_2O (22 kg x US$0.40/kg)	8.8	-	-
(40 kg x US$0.40/kg)	-	16.0	7.2
c) Weed control	-	-	-
d) Pest and disease control			
(1.0 litre x US$4.7/litre)	-	4.7	4.7
Harvest			
(1 hour of combine harvester at US$40.oo/ha)	-	40.0	40.0
Technical assistance and management	-	23.0	23.0
Bagging (US$0.5/unit of 60 kg)	-	17.0	17.0
Transport (US$5.oo/t x 100 km)	-	30.0	30.0
Interest	13.0	25.0	12.0
Total	228.3	441.7	213.4

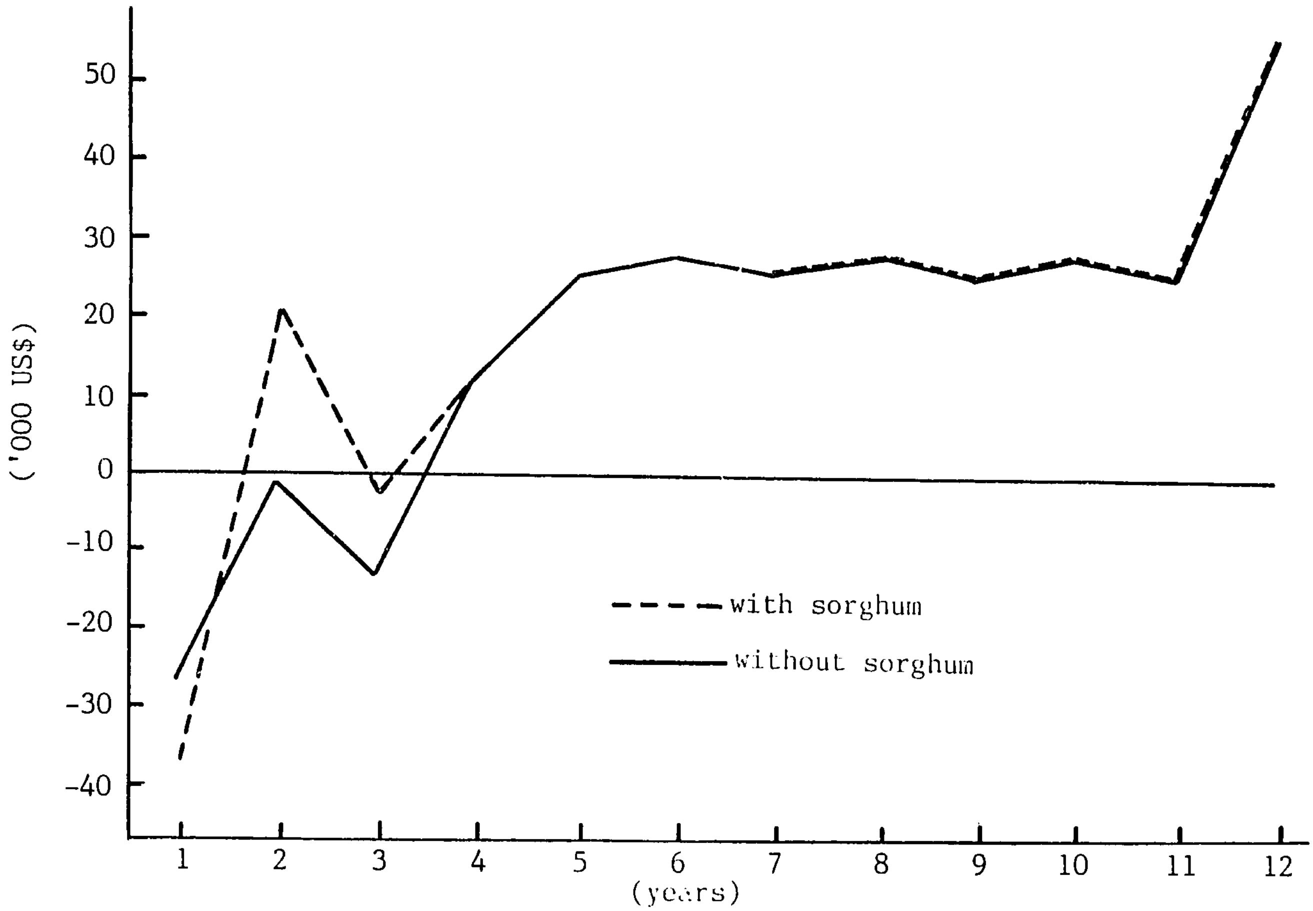


Figure 1. Marginal cash flow for the establishment of improved pasture with and without sorghum*. Case of a farm with 154 ha of improved pasture.

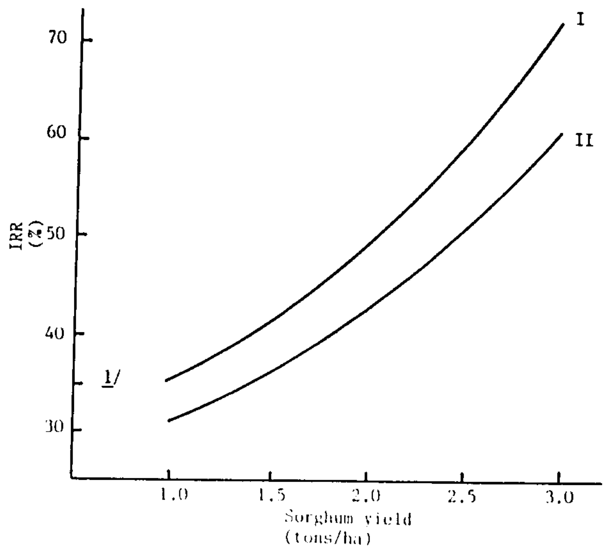
In terms of the marginal internal rate of return the effect of this improvement to the cash flow in the first years is very marked as shown in Figure 2. The additional benefits of the forage contributed by the sorghum stubble are not included in this analysis. A sensitivity analysis was undertaken assuming that all the nitrogen and potassium needed for the crop could come from the mineralization of the soil (Alternative I, Figure 2); this yielded even higher marginal internal rates of return.

It can be concluded from these analyses that the inclusion of crops may facilitate substantially the process of adoption of improved pastures. Nevertheless questions remain concerning the performance of sorghum and pastures in these integrated systems.

Adoption of Andropogon gayanus in Colombia

In 1983 the Sections of Economics, Systems and Seed Production jointly undertook a survey of early adopters of *Andropogon gayanus* in Colombia. 57 producers with a total area of 5000 hectares of *Andropogon gayanus* cultivar Carimagua 1 were surveyed. Farms were located in the Ilanos Orientales, the Middle Magdalena (including certain areas of the Valle and Cauca departments) and the North Coast.

To understand the perception that farmers have of the role of *Andropogon*



1/ Marginal internal rate of return of pasture establishment without sorghum.

I : Marginal IRR of establishing pasture associated with sorghum assuming that soil mineralization will supply the requirements of N and K.

II: Marginal IRR of establishing pasture associated with sorghum without a nutrient contribution from soil mineralization.

Figure 2. Marginal internal rates of return of pasture establishment with sorghum.

gayanus, farmers were asked about the advantages they expected when making the decision to introduce this material on their farm (Table 16).

These expectations clearly reflect regional-specific problems; adopters on the North Coast principally expected increased forage production in the dry season; in the Middle Magdalena (which has a less marked dry season) adaptation to poor soils was more important; in the Llanos Orientales the profile of expected advantages was less specific. It is amazing that farmers hardly mentioned compatibility with legumes. This shows the lack of understanding amongst farmers of the role of legumes.

Soil samples were collected from the plots where Andropogon gayanus was growing (Table 17). Essentially, Andropogon is being used in very poor soils both in the Llanos and the Middle Magdalena while on the North Coast it is used on substantially better soils. Certain trends can be detected when this information is analyzed by year of initial planting. On the North Coast Andropogon gayanus was initially sown on soils of a higher aluminium saturation and over time it expanded to better soils. In the Llanos Orientales the first plantings were made on better soils, frequently in the Piedmont, but overtime farmers realized that its role was clearly associated with the poor soils of the well-drained savanna requiring fertilizer application.

This change of environment was associated with a reduction in the average area, probably due to an increased awareness of the need to establish the grass with fertilizer and the reduced attractiveness of establishing pastures in regions more distant from the market.

Since the release of Andropogon gayanus, farmers are experimenting with the material by adjusting the management to their local conditions (Table 18). Seeding densities are substantially higher in the North Coast and in the Middle Magdalena than in the Llanos. This reflects the greater weed problem in these regions during the establishment phase. The establishment technique reflects the fertility of the soil: 90% of establishment with fertilizer takes place in the Llanos, 43% in the Middle Magdalena and 0% in the North Coast. Commercial plantings are relatively large (between 30 and 50 hectares) and were frequently used to harvest seed (Table 19). The yields reported were

Table 16. Expected benefits of the use of *A. gayanus* (frequency of cases).

Region	Dry season forage	Carrying capacity	Adaptation to poor soils	Diversification of pasture species	Persistence	Compatibility with legumes	Tolerance to pests	Other
Eastern Plains	3	4	2	3	-	-	2	3
Middle Magdalena	8	4	10	3	-	1	-	1
North Coast	19	5	1	-	1	-	-	2
TOTAL	29	13	13	6	1	1	2	6
Percentage	41	18	18	9	1	1	3	9

Table 17. Soil fertility of *A. gayanus* plots on surveyed farms.

Region	Texture (%)			M.O.	pH	P	Milliequivalents/100 g				% Al
	Sand	Clay	Loam	(%)		(ppm)	Ca	Mg	K	Al	sat.
Eastern Plains	43.9	33.5	27.7	1.9	4.6	3.0*	0.30	0.10	0.09	1.77	78
Middle Magdalena	37.2	39.7	22.9	2.8	4.6	3.6	0.42	0.28	0.13	2.23	73
North Coast	42.5	30.2	27.3	3.9	5.6	21.0	0.36	0.49	0.30	0.27	19

* Excluding one farm with 30 ppm P.

Table 18. Characteristics of the first commercial planting.

Region	Plot size (ha)	Seedling rate (kg/ha)	Planting methods (%)			
			With fertiliz.		Without fertiliz.	
			Broad-cast	In fur-rows	Broad-cast	In fur-rows
Eastern Plains	51.3	6.2	72	18	0	10
Middle Magdalena	28.1	16.5	36	7	57	0
North Coast	34.8	18.5	0	0	100	0
Total	35.8	15.2	28	7	64	1

lower on the North Coast than in other regions. Nevertheless, it must be taken into account that these figures refer to seed without cleaning.

Seed harvesting delayed the first grazing (6 months on average), which made subsequent management difficult due to the height of the pasture under these conditions. This may have also affected the harvest of the seed.

Information on carrying capacity of Andropogon gayanus (2.6 - 3.2 animals per hectare in the wet season) correlates well with the type of soil in which it was planted, being highest on the North Coast. All regions report reductions of 50% of carrying capacity during the dry season.

The assessment of Andropogon gayanus by farmers once it has been established on their farm (Table 20) shows that the most appreciated attributes are its productivity (carrying capacity and speed of regrowth) and its resistance to drought. The disadvantages listed by farmers include the bunchy growth habit and the woody inflorescenses when not managed appropriately.

Sixty-eight percent of the farmers surveyed were planning to expand the area of Andropogon gayanus in 1984; this percentage varies from 33% in the Llanos to 78% on the North Coast.

This seems to indicate a very dynamic situation, particularly on the North Coast which seems to be developing into the region specializing in seed production, to the extent of selling seed to other regions.

In general the study indicated that the use of Andropogon gayanus at the commercial level in Colombia is determined by adaptation to poor soils, dry season performance and resistance to pests, particularly spittlebug. Up to now no significant use of this grass in association with legumes can be observed, in spite of the fact that this was the main objective of the researchers who developed this grass.

Table 19. Initial management of *A. gayanus* pastures, Colombia.

Region	Seed Production		Utilization (months from seeding to)		Carrying capacity (head/ha)	
	Area harvested (ha)	Yield (kg/ha)	First grazing	Normal grazing	Wet season	Dry season
Eastern Plains	35	100	6.36	6.81	2.58	1.25
Middle Magdalena	17	100	6.28	7.50	2.83	1.37
North Coast	18	60	5.76	7.84	3.16	1.58
Total	21	83	6.07	7.49	2.91	1.38

Table 20. Initial management of *A. gayanus* pastures, Colombia.

Region	Positive characteristics							Negative characteristics						
	Seed production	Palatability	Carrying capacity	Drought tolerance	Tolerance to pests	Rapid regrowth	Other	Woody	Pests	Bunch-type grass	Dies under cutting regimes	Slow establishment	Sensitive to water logging	Other
Eastern Plains	-	-	4	2	3	5	4	2	1	6	1	-	1	2
Middle Magdalena	4	5	12	5	1	1	7	4	2	6	2	1	-	3
North Coast	2	2	22	14	-	1	7	1	2	2	-	3	1	4
TOTAL	6	7	38	21	4	7	18	7	5	14	3	4	2	9
Percentage	6	7	37	21	4	7	18	16	12	33	7	7	4	21

TRAINING

INTRODUCTION

During 1984 collaboration continued with national institutions for training of researchers in the different scientific disciplines related to pasture production and utilization in the acid, infertile soils of the tropics. To this end, an Intensive Multidisciplinary Phase was carried out between February 1st and April 13, with the participation of 20 researchers. This phase undertook aspects related with the introduction, evaluation, management, and productivity of the main tropical forage grasses and legumes. Afterwards, participants were offered the opportunity to stay and take part of a Specialization Phase, varying in time length and related to a specific section of the Tropical Pastures Program. In turn, the section where the researcher carried out this second phase was related with the activities developed by him in his country and included specialization on soils-plant nutrition, pasture quality, regional trials, and production systems.

It is worth pointing out for the first time an intensive short course was offered on Production of Tropical Pastures Seed from October 29 to November 16 with the participation of 26 researchers from ten countries.

MAIN OBJECTIVES ACHIEVED IN TRAINING

Contribution to the RIEPT

One of the training objectives is to strengthen the Red Internacional de Evaluación de Pastos Tropicales (RIEPT --International Network for the Evaluation of Tropical Pastures). Out of 154 trials established through December 82, 53% are conducted by researchers trained at CIAT (Figure 1).

Intensive course on production of tropical pastures seed

During this event, it was possible for the first time to congregate researchers and official and private producers of forage species seed. In a joint effort, participants analyzed factors affecting the multiplication, quality, liberation process, and commercialization of seed of new cultivars.

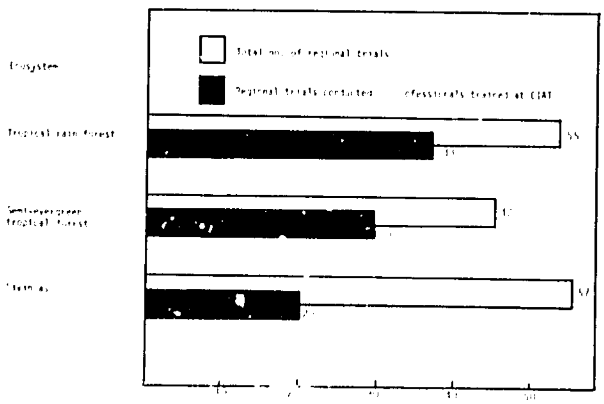


Figure 1. Total regional tropical pastures trials established by ecosystem through December, 1984 and conducted by professionals trained at CIAT.

Researchers by countries and categories trained at CIAT during 1984

Table 1 includes the number of researchers trained by country during 1984. The highest percentage corresponds to Peru, Brazil, Bolivia, and Colombia, countries which posses the largest area of acid and infertile soils.

As shown in Table 2, the sections which dedicated more time to training were: Seed Production (48.7 man months), Pasture Quality and Nutrition (43.6 man months), and Animal Production Systems (31.8 man months). Of the visiting researchers trained, 33 remained in the Intensive Phase, 18 stayed as Visiting Researchers in the Specialization Phase, and 7 as Visiting Researchers working on their M.S. and Ph.D. thesis.

Table 1. Number and origin of the researchers trained in the Tropical Pastures Program during 1984.

Country of Origin	No. of Researchers	Percentage
Argentina	1	1.7
Bolivia	8	14.0
Brazil	8	14.0
Colombia	10	17.2
Costa Rica	1	1.7
Cuba	1	1.7
Dominican Republic	1	1.7
Ecuador	1	1.7
Honduras	1	1.7
Mexico	3	5.2
Nicaragua	2	3.5
Panama	3	5.2
Paraguay	1	1.7
Peru	11	19.3
Republic of China	1	1.7
Venezuela	3	5.2
West Germany	2	3.5

CONFERENCES

The "Meeting on Evaluation Methodologies for Regional Trials D", was held in Lima, Peru, from October 29 to November 5. This meeting had the participation of 40 tropical pastures researchers coming from all countries in Latin America which participate in the RIEPT.

SUMMARY OF TROPICAL PASTURES TRAINING, 1969-1984

Figure 2 shows that from a total of 477 researchers received training from 1969 to 1984, most participated as Visiting Researchers and that the proportion of researchers in Intensive Phases or Short Courses is smaller. This is in accordance with the objective that training should be continuous and that researchers should participate in achievements and results obtained throughout the complete cycle of the experiments. As can be seen in Figure 3, there is a fluctuating tendency to increase the number of professionals trained by the Program.

Table 2. Professionals trained in the Tropical Pastures Program during 1984, by category and man months in each section of the Program.

Program Section	Visiting research associates Ph.D.	Thesis	Visiting researchers M.S.	Thesis	Specialization		Intensive multi-disciplinary phase		Total	
	No.	M/M[1]	No.	M/M	No.	M/M	No.	M/M	No.	M/M
Germplasm	1	10.73			1	4.36			2	15.09
Seed Production			1	12.16	4	18.63	26	17.90	31	48.69
Soil Microbiology			1	5.20			1	4.70	2	9.90
Pasture Quality and Nutrition			1	12.16	4	31.40			5	43.56
Animal Production Systems	1	6.26			3	16.00	2	9.53	6	31.79
Pasture Productivity and Management	1	4.86					2	8.39	3	13.25
Soil-Plant Nutrition	1	12.16					2	14.03	3	26.19
Regional Trials					4	14.00			4	18.00
Plant Pathology					2	6.70			2	6.70
Total	4	34.01	3	19.52	18	95.09	33	54.55	58	213.17

1/ M/M = equivalent to man months in training.

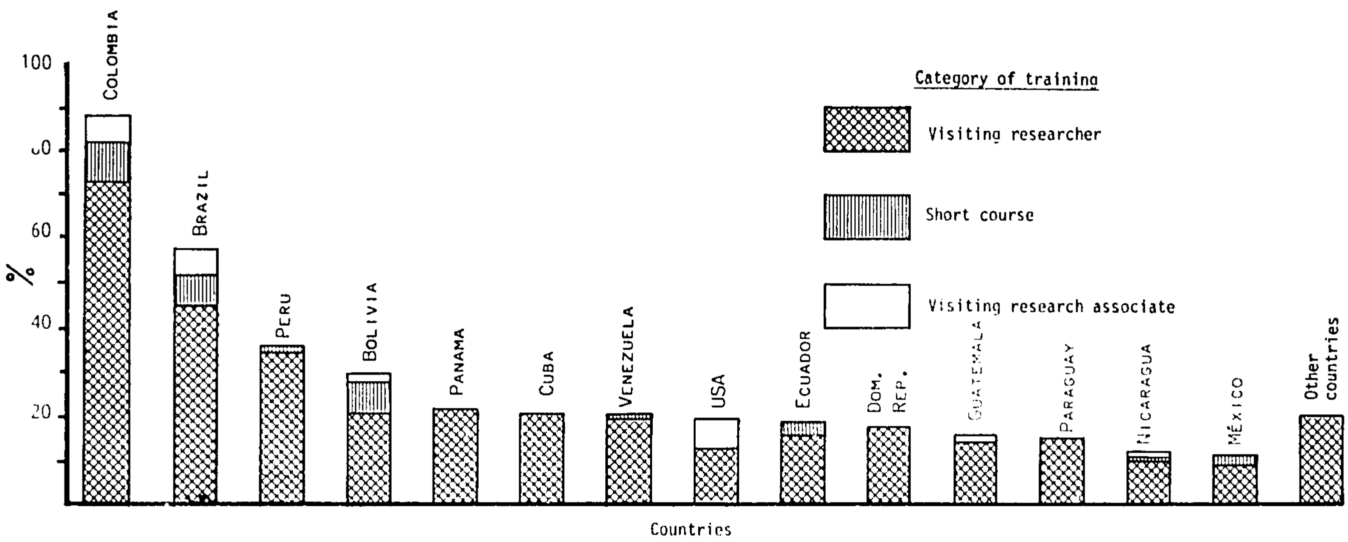


Figure 2. Distribution by country and category of researchers trained in the Tropical Pastures Program, 1970-1984.

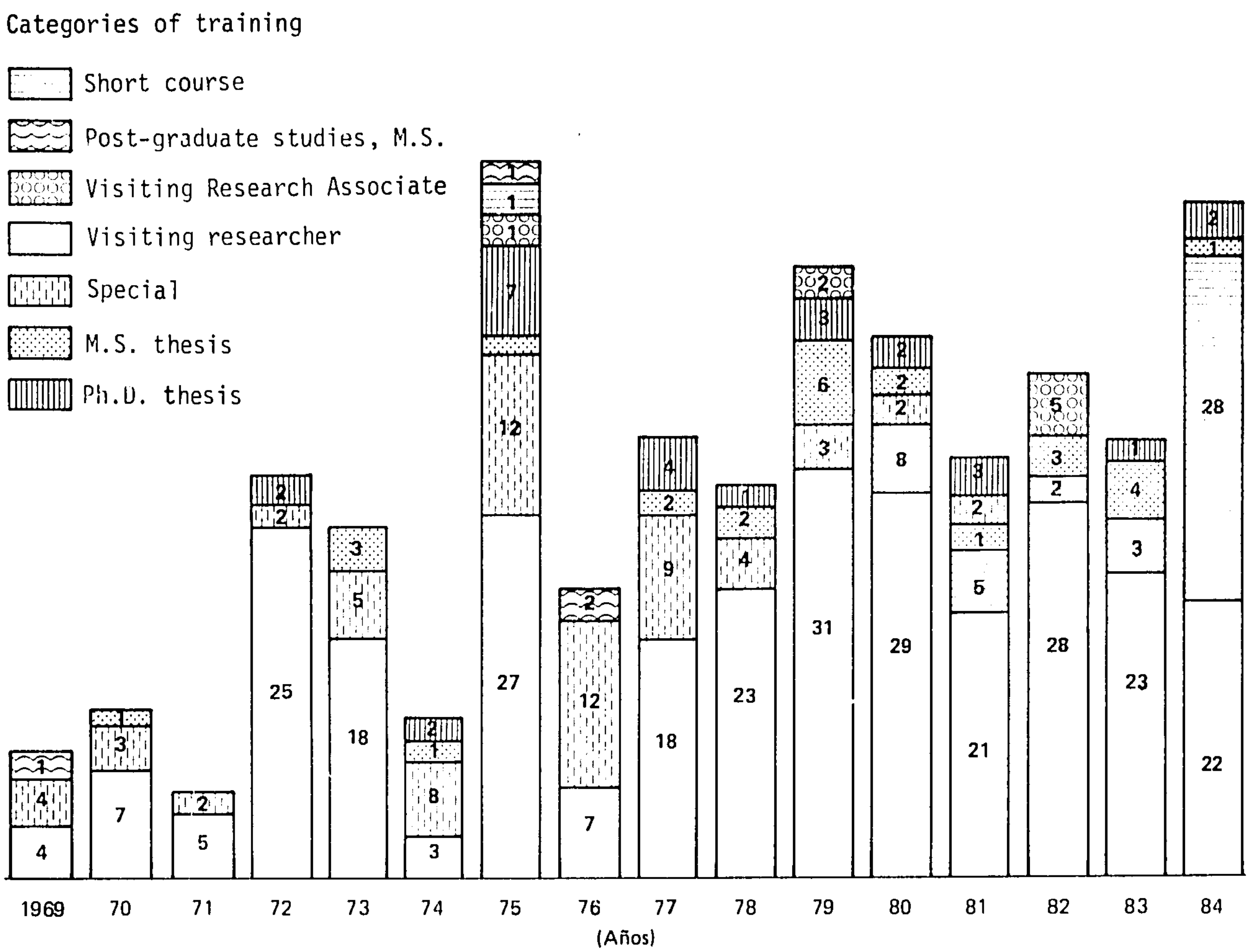


Figure 3. Researchers trained in the Tropical Pastures Program by category, 1969-1984.

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