Annual Report 1988

Tropical Pastures

Working Document No. 58, 1989

CIAT Centro Internacional de Agricultura tropical

INDEX

1. Introduction

During 1988 the Program started preparing for the forthcoming strategic planning exercise in 1989. Several members of the Program participated in different task forces and in "think tanks" that sought to define the general CIAT position. Concurrently with these preparations, the achievements of the Program were analysed, and strategies were formulated to meet the changing needs of the 1990's.

Several questions regarding the future strategies of the Program were discussed:

Basic (upstream) research

1. The Program has acquired more than twenty thousand entries of germplasm, concentrating on grasses and legumes to improve pastures for ruminant production in the marginal and frontier lands of the humid and sub-humid lowlands of the tropics with acid soils. This major collection effort has already yielded several improved cultivars, and it also provides the base for future breeding work.

The question now is, what should be the direction of germplasm development from now on?

- It is visualized that future collection and acquisitions of germplasm should be more strategically focussed to broaden the genetic variability of key species, or to obtain new collections of particular types forage plants deemed important (grasses, shrubs, tree legumes, etc.).

2. During the 1980's, a priority area of work has been the development of major screening sites in cooperation with national pasture programs. Several key species have been identified and promising materials have been selected for further evaluation throughout the Red Internacional de Evaluación of Pastos Tropicales (RIEPT). This major continental screening effort has yielded several new cultivars of grasses and legumes which use more efficiently the limited natural resources available in the infertile acid soils of the target areas in which there are only limited opportunities to use purchased inputs.

The RIEPT has become a decentralized massive screening project, and has successfully established a quick flow of germplasm from evaluation in agronomic trials, to trials where germplasm is evaluated under grazing. In this manner, it has been particularly successful in catalyzing and facilitating the pasture research work throughout target area. However, there is an important question for the future:

- How specific should the screening evaluation be during the next decade? Should the Program continue to use the broad approach of a wide range of germplasm as in the past, or should a more specialized and focussed approach be adopted? The latter would require a clear definition of the objectives needed to solve farmers' problems, which could then be applied to segregating materials from breeding work; or used to evaluate new species that might be regarded as promising in the future.

3. During the 1980's the major plant breeding effort of the Program has been the improvement of Stylosanthes guianensis, a legume that is regarded as very valuable for the infertile acid soil regions of the lowland parts of the continent. This project has been directed towards increasing both anthracnose resistance and seed production potential.

Important pre-breeding projects have also been conducted. Among these were the investigation of cross compatibility among Centrosema species; the estimation of heritability of several traits in Andropogon gayanus; and studies of reproductive behavior in Brachiaria. These activities provide a base for future expansion of the program in forage plant improvement.

Important questions for the future are:

- How should plant breeding resources be allotted among the numerous potential candidate species?

- What are relevant and achievable breeding objectives for those species chosen?

- What will be the role of the newer biotechnologies in facilitating the achievement of the objectives of pasture plant improvement?

4. During the 1980's, striking changes in the productivity of the savanna lands have been obtained with pastures based on plants that are adapted to low fertility, acid soils and high levels of aluminum and using minimum inputs. Similar adaptation is regarded as critical for the survival and efficient production of the new generation of pasture plants currently undergoing evaluation. Efficient fixation of nitrogen by the legumes in the association is also a key factor both for improving the quality of the feed for grazing animals and for stable pasture production.

It is recognized, however, that improved plants, well adapted to the environment, are not the only criteria. Other factors, such as their interaction with the environment (effect of soil texture, the availability of water, and biotic pressures), and the influence of pasture management (grazing system and maintenance fertilizer) will also determine the performance of the new technology on a broader scale. The nature of these interactions are not understood well enough to allow pasture managers (researchers, farmers) to select the combination of grasses and legumes for a particular environment and/or to apply management appropriate to optimize the productivity and sustainability of the new pastures.

The major questions are:

- how much resources and research effort should the Program allocate to the study of these interactions in the pasture complex?
- how should the research be organized best to develop the techniques and methodologies?
- how will be the resulting knowledge best transferred to the RIEPT?

5. On-farm research has been successfully initiated during the second part of this decade. In cooperation with the respective national programs, the Tropical

Pastures Program has collaborated in the following on-farm research activities:

- in the extensive systems of the Colombian Llanos (Altillanura) in cooperation with ICA;
- in Silvania (near Brasilia) in Brazil, a dual purpose crop pasture systems in cooperation with CPAC/EMBRAPA;
- in the mixed dual-purpose farming systems of the Pucallpa area in the Peruvian jungle in cooperation with INIAA and IVITA;
- with small farmers on steep farms at elevations of 1000 to 1500 meters in the northern Cauca area of Colombia in multi-institutional projects in cooperation with ICA, CVC and Fondo Ganadero del Valle;
- in the predominantly cattle production systems of the Caquetá area of the Colombian Amazon in cooperation with ICA and Fondo Ganadero del Valle.

The direct involvement of the Program in on-farm research has been particularly important in developing a better understanding of the problems of conducting pasture research in farmers fields and of linking research and development in contrasting socio-economic, ecological and institutional situations.

The questions for the 1990's are:

- how far downstream should the Program go in the area of on-farm research?
- how much effort and resources should the program allocate to the important activity of developing on-farm methodologies?
- How to catalize the orientation of pasture research throughout the RIEPT into on-farm research and more towards problem-solving?
- will the participation of farmers serve to establish better links between research and the development process?

6. It is clear that without parallel development of appropriate supplies of seed to feed the research and development process, the efficiency and effectiveness of the effort is badly diminished. When the new technology is based on plants of which the seed cannot be imported from elsewhere, the problem is compounded. Seed multiplication should be an integral part of any pasture research program that deals with new germplasm.

Important questions for the program and the RIEPT are:

- how can the research process be organized better so that the parallel activities of research on seed technology and the multiplication of experimental and basic seed are incorporated?
- how can the commercial production of seed be catalyzed when the plants are often unknown and thus there is limited initial demand?

7. The role of legumes both in improving animal production and in enhancing pasture stability on infertile acid soils has been demonstrated by the Program. In addition, there is evidence from research in the RIEPT, and elsewhere in the tropics, that documents the important contribution of legumes in pastures. However there has been only limited adoption of the concept of a mixed legume/grass association, in the tropics.

The Program believes that the poor adoption of legume/grass pastures is due to a number of factors, which led to difficulties in managing legume/grass associations and lack of persistence of the legume component. These are:

- the legumes used in the past, principally commercial cultivars from Australia, were poorly adapted to infertile acid soils.

- the legumes did not compete with the aggressive root systems and stoloniferous habit of the grasses,
- the legumes have the C3 pathway of photosynthesis, which leads to lower growth rates compared with the C4 gasses.

In contrast, on-farm research on the Colombian Llanos has shown the persistence of at least 9 years of the new generation of adapted legumes under farmers' conditions. The Program believes that environmental adaptation is a key factor in the maintenance of legumes in pasture associations.

The main questions confronting the Program are:

- how can the credibility of legume-based pastures in the target area be developed and established?
- how can the economic and ecological soundness of legume/grass pastures be demonstrated?

8. Well-managed pastures of adapted legume/grass species contribute to soil improvement through nutrient recycling, nitrogen fixation, higher amounts of organic matter, and better soil structure. The Program believes the basic components are available for the development of legume/grass associations, which could greatly contribute to soil improvement in the marginal and frontier areas of the tropical lowlands with acid soils. Many of these areas are now used predominantly for grazing by ruminants. However, farming systems in these areas are expected to intensify the use of land, capital and labor during the 1990's, which will lead to the integration of pastures with crops in ley farming systems and/or with trees in silvo-pastoral systems.

The question for the Program is:

- what research is needed to study the options and management alternatives?
- how can the soil improvement capacity of the new pasture technology be maximized?
- how can this contribute to the sustainability of integrated production systems in the savannas and humid forest of the Program's mandate area?

9. Within the decentralized sub-networks of the RIEPT, 1988 was particularly important. The first meeting of the Central American and Caribbean sub-network was held at Veracruz, Mexico, in November, 1988, during which more than 200 papers were presented. Central American pasture research is very active, both in small plots evaluation of germ- plasm and in an increasing number of grazing trials, and in seed production projects. The full advisory committee of RIEPT (including a representative from each sub-network) also met in Veracruz to discuss the topic of research approaches and techniques for pasture establishment and reclamation.

Also, during 1988, the first steps were taken towards the development a multi-institutional network, modelled on the RIEPT, to catalyze pasture and forage research and the development of the sub-Sahiel region of western Africa. Formal contacts were established with CIAT's sister Center, the International Livestock Center for Africa (ILCA) and with the French Institut d'Elevage et de Medecine Veterinaire des Pays Tropicaux (IEMVT), as well as visits to national pasture research programs in western Africa. The TPP has a demonstrated a comparative advantage in germplasm development for pasture and forage improvement in acid soils. This comparative advantage will contribute to improved productivity and diminished ecological damage of the over-grazed savannas of lowland west Africa.

Important questions for RIEPT are:

- how can the dynamic activity, complementarity and relevance be maintained between the Tropical Pastures Program and the evolving national research programs?
- How can development institutions be incorporated with the research institutions of national programs in such a way as to maximize the linkage between them?
- how can the comparative advantages of the RIEPT be used more efficiently to capture economies of scale in the process of pasture research and development?
- How can the latter be applied to a micro region, a country, and a sub-network?
- What will be the balance of the Program contribution in the WAFNET development?

These questions will be further clarified during the following year in which the Program and CIAT will consolidate the strategic planning for the decade of the 90's.

2. Germplasm

During 1988 the activities of the Germplasm section comprised the following: (1) collection of legume germplasm in Southeast Asia; (2) multiplication and maintenance of germplasm of particular interest to the Tropical Pastures Program; and (3) characterization and preliminary evaluation of germplasm.

COLLECTION OF LEGUME GERMPLASM IN SOUTHEAST ASIA

Southeast Asia is, in comparison with tropical America, a minor yet very important center of diversity of tropical legumes. Collection activities of the CIAT Tropical Pastures Program in the region, in cooperation with national institutions, began in 1979. In 1988 two collection trips were carried out, both with financial support from the International Board for Plant Genetic Resources (IBPGR). One trip was conducted in China, in collaboration with the South China Academy of Tropical Crops (SCATC), Hainan, and another in Thailand in cooperation with the Thailand Institute of Scientific and Technological Research (TISTR).

China

The collection trip was done along a northeast-to-southwest transect in the southern part of the Guangdong province, and on Hainan island (since April 1988 not anymore part of Guangdong but a separate province) (Figure 1). A total of 213 samples were collected (Table 1). It is noteworthy that of these only 28 samples (= 13%) originate from continental China (Guangdong). This reflects definitely a considerable genetic erosion on the mainland, where intensive land use has progressively destroyed the native habitats of the legume species of interest. Land use in Hainan is considerably less intensive, and the somewhat protected niches where the legumes of interest can be found (forest edges, scrub vegetation in borders of crop fields, fallow and wasteland vegetation, etc.), are still abundant. Although the magnitude of the variation in the collected material can only be assessed in comparative plant introduction trials, the diversity of collection sites and, frequently, plant morphology suggests that the collected Chinese germplasm contributes significantly to a wide genetic diversity now available to scientists.

Thailand

The collection trip in Thailand covered a major portion of the central-west and northern provinces (Figure 2). The principal target germplasm were also in this trip species of Desmodium and allied genera, and Pueraria spp. A total of 369 samples were collected (Table 1). Highlights are: the large proportion of Desmodium spp. (almost one-third of the collected samples); the finding of D. ovalifolium at unexpectedly high latitudes (beyond 20^{o} N) and altitudes

Figure 1. Routes of systematic collection of tropical forage legume germplasm in China, February 1988 (SCATC-CIAT-IBPGR).

Table 1. Summary of tropical forage legume germplasm collected in tropical China and Thailand, February-March 1988 (SCATC-CIAT-IBPGR and TISTR-CIAT-IBPGR, respectively).

Species	China	Thailand	Total
	---------	No. of samples	---------
Desmodium gangeticum	9	38	47
Desmodium heterocarpon	30	23	53
Desmodium heterophyllum	4	-	4
Desmodium ovalifolium	-	5	5
Desmodium renifolium	-	2	2
Desmodium strigillosum	-	1	1
Desmodium styracifolium	-	3	3
Desmodium triflorum	-	3	3
Desmodium velutinum	12	24	36
Desmodium spp. (unidentified)	1	20	21
Codariocalyx gyroides	-	3	3
Codariocalyx motorius	-	8	8
Dendrolobium spp.	6	9	15
Phyllodium spp.	15	23	38
Tadehagi spp.	21	4	25
Pueraria montana	13	1	14
Pueraria phaseoloides	20	26	46
Pueraria spp. (unidentified)	4	12	16
Flemingia macrophylla	11	20	31
Flemingia aff. *macrophylla*	-	5	5
Flemingia lineata, *F. strobilifera*	-	19	19
Uraria lagopodoides	4	14	18
Other genera (with lower forage potential)	63	106	169
Total	213	369	582

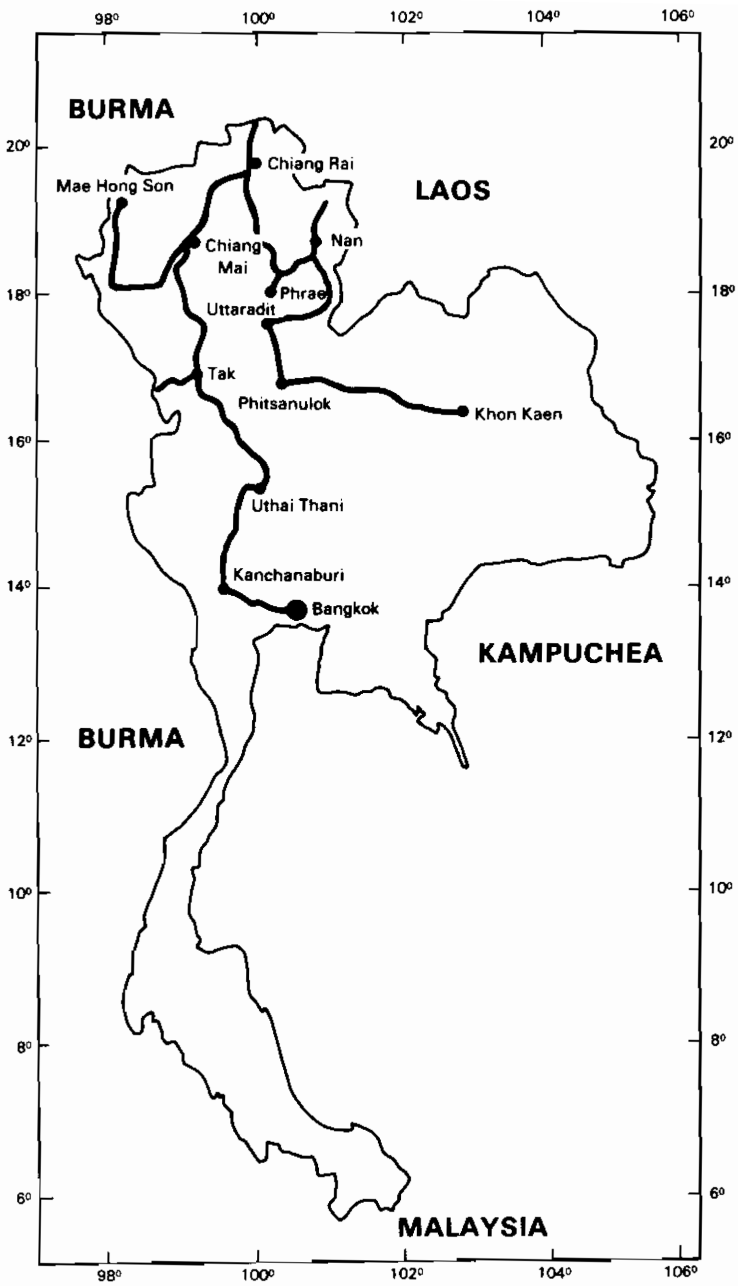


Figure 2. Routes of systematic collection of tropical forage legume germplasm in Thailand, February/March 1988 (TISTR-CIAT-IBPGR).

(as high as 900 m.a.s.l.); the finding of Codariocalyx gyroides and C. motorius not previously collected in Thailand; and the finding of several unidentified Pueraria species which were not yet presented in the CIAT collection.

In the process of seed increase for subsequent evaluation of germplasm collected during these two trips, Desmodium velutinum and Flemingia macrophylla are receiving special attention. Both species have been identified as particularly promising in association with native savanna in the Llanos ecosystem (see Agronomy Llanos report).

MULTIPLICATION AND MAINTENANCE

As in previous years, the multiplication of legume and grass germplasm of particular interest to the Tropical Pastures Program was also in 1988 an important service function of the Germplasm section. The seed multiplication activities consisted essentially of:

- Germplasm multiplication from potted plants in the Palmira greenhouse and/or from single plants of small, space-planted plots in specific germplasm multiplication areas at CIAT-Palmira and CIAT-Quilichao: approximately 1350 accessions.

- Initial seed increase of all germplasm under preliminary evaluation at CIAT-Quilichao: approximately 2050 accessions including the grass collections of Brachiaria spp. and Panicum maximum.

Multiplied seed is handed over to the CIAT Genetic Resources Unit which is responsible of maintaining germplasm stocks under appropriate cold-storage conditions, and of germplasm distribution.

CHARACTERIZATION AND PRELIMINARY EVALUATION

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

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

In some cases this characterization phase is combined with agronomic evaluation at the Category II level including determination of dry-matter yield under cutting.

In Table 2 the species and number of legume accessions which during the period November 1987-1988 were under preliminary evaluation in CIAT-Quilichao, are presented. Whereas some of the highlights of the older trials were already presented in a preliminary form in the 1987 Annual Report (e.g., C. tetragonolobum and C. macrocarpum), the following are 1988 highlights for the more recent trials:

Table 2. Preliminary evaluation of legume germplasm in CIAT-Quilichao during 1988.

Species	No. of accessions	Species	No. of accessions
Centrosema tetragonolobum	12[a]	*Flemingia* spp.	32[a]
Centrosema pubescens	575[a]	*Flemingia macrophylla*	29[c]
Centrosema grazielae and *C. schiedeanum*	72[a]	*Desmodium velutinum*	72[b]
Centrosema macrocarpum	72[b]	*Desmodium strigillosum*	11[c]
Centrosema pubescens	66[b]	*Desmodium velutinum*	44[c]
Centrosema brasilianum	109[c]		
		Codariocalyx gyroides	26[c]
Stylosanthes capitata	45[c]		
Stylosanthes guianensis		*Cratylia floribunda*	11[c]
var. *pauciflora*	51[c]		
Stylosanthes macrocephala	16[c]	*Dioclea guianensis* and	
		D. virgata	143[b]

a. Trial established in 1986.

b. Trial established in 1987.

c. Trial established in 1988.

Centrosema pubescens

The preliminary evaluation of a 575-accession collection of *C. pubescens* aimed at the identification of productive, disease-tolerant accessions with a high seed-production potential. Not all collected information has, as yet, been analyzed. However, the frequency distribution graphs for dry-matter and seed yields presented in Figures 3 and 4, respectively, show considerable variation for either attributes. It is noteworthy that a large proportion of the collection proved in both respects superior to the control accessions CIAT 413 (Australian commercial centro) and CIAT 438 (*Centrosema* hybrid).

A preliminary selection of 66 outstanding accessions was made in this *C. pubescens* collection. Plants were established in a space-planted accession-comparison trial, with 4 replicates for DM yield and 2 replicates for seed production. In Figure 5 the classification of these selected 66 accessions into nine DM yield groups is presented. It shows a wide variation and suggests that a very large proportion of these selections significantly outyields the two control accessions CIAT 413 and 438. The same is true for the seed yields (Figure 6).

Although the latter trial has not yet concluded, it appears that the CIAT collection of *C. pubescens* provides valuable germplasm with good adaptation to acid, low-fertility soils.

Centrosema brasilianum

A large proportion of the CIAT *Centrosema brasilianum* collection (109 accessions) was established in the first semester 1988. Although any definite conclusions would be premature, the susceptibility of most accessions to *Rhizoctonia* Foliar Blight (RFB) is already evident. Accessions which presently stand out because of apparent RFB-tolerance, are CIAT 5657 and 5671 from Anzoátegui and Sucre, Venezuela, respectively; CIAT 15527 (BRA-010855) from Marajó island, Pará, Brazil; and CIAT 15387, 15391, 15819, 15820, 15821, 15823, 15891, and 15902 from Bolívar, Venezuela.

Stylosanthes spp.

The main purpose of establishing germplasm of *Stylosanthes capitata*, *S. guianensis* var. *pauciflora*, and *S. macrocephala* in CIAT-Quilichao is initial seed increase. All three species show considerable variation in growth habit, plant vigor, flowering and seed-setting. A particularly vigorous, prostrate *S. capitata* line is CIAT 11628.

Flemingia macrophylla

A collection of 22 accessions of *F. macrophylla*, 7 accessions of *F. lineata* and 3 accessions of *F. strobilifera* was evaluated first for seed production (during approximately one year including the period of vegetative growth before flowering), and subsequently during 6 months, after an equalizing cut, for DM production. The cluster analysis performed produced four significantly different groups (Table 3). Of these, group 2 comprises 5 vigorous and, in terms of DM as well as seed yields, productive accessions. It is noteworthy that all *F. lineata* and *F. strobilifera* accessions are in the nonproductive group 3. In contrast with these two species, *F. macrophylla* appears to be particularly well adapted to acid soils.

Desmodium velutinum and *Dioclea* spp.

The trials with these species will be concluded soon. Germplasm in both experiments are showing very wide

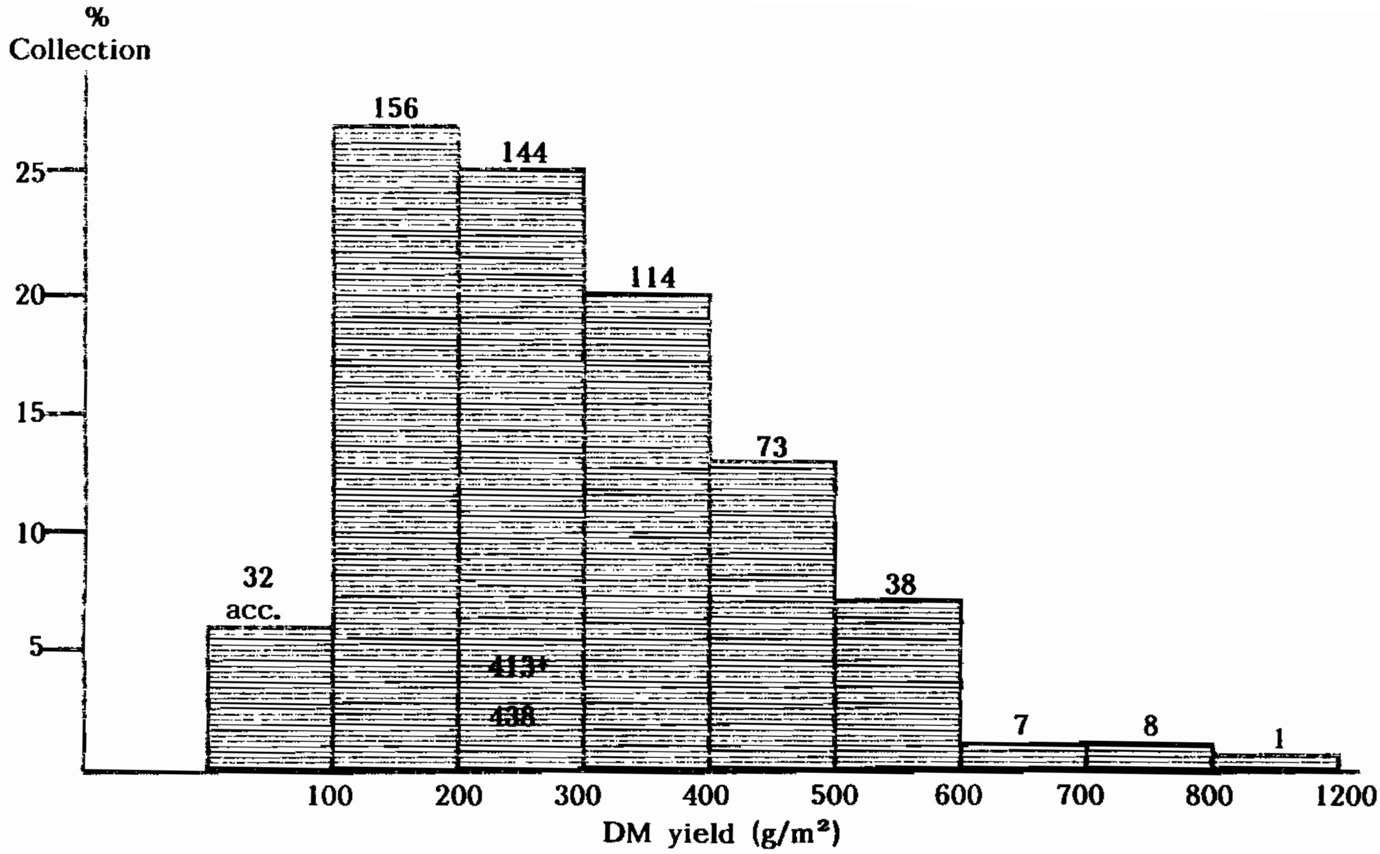


Figure 3. Classification of a Centrosema pubescens collection (575 accessions) into nine groups of dry-matter yields. (Sum of two non-consecutive cuts of 3-month old regrowth; Quilichao 1987/88.)

* Control accessions: Australian commercial centro (CIAT 413) and Centrosema hybrid CIAT 438.

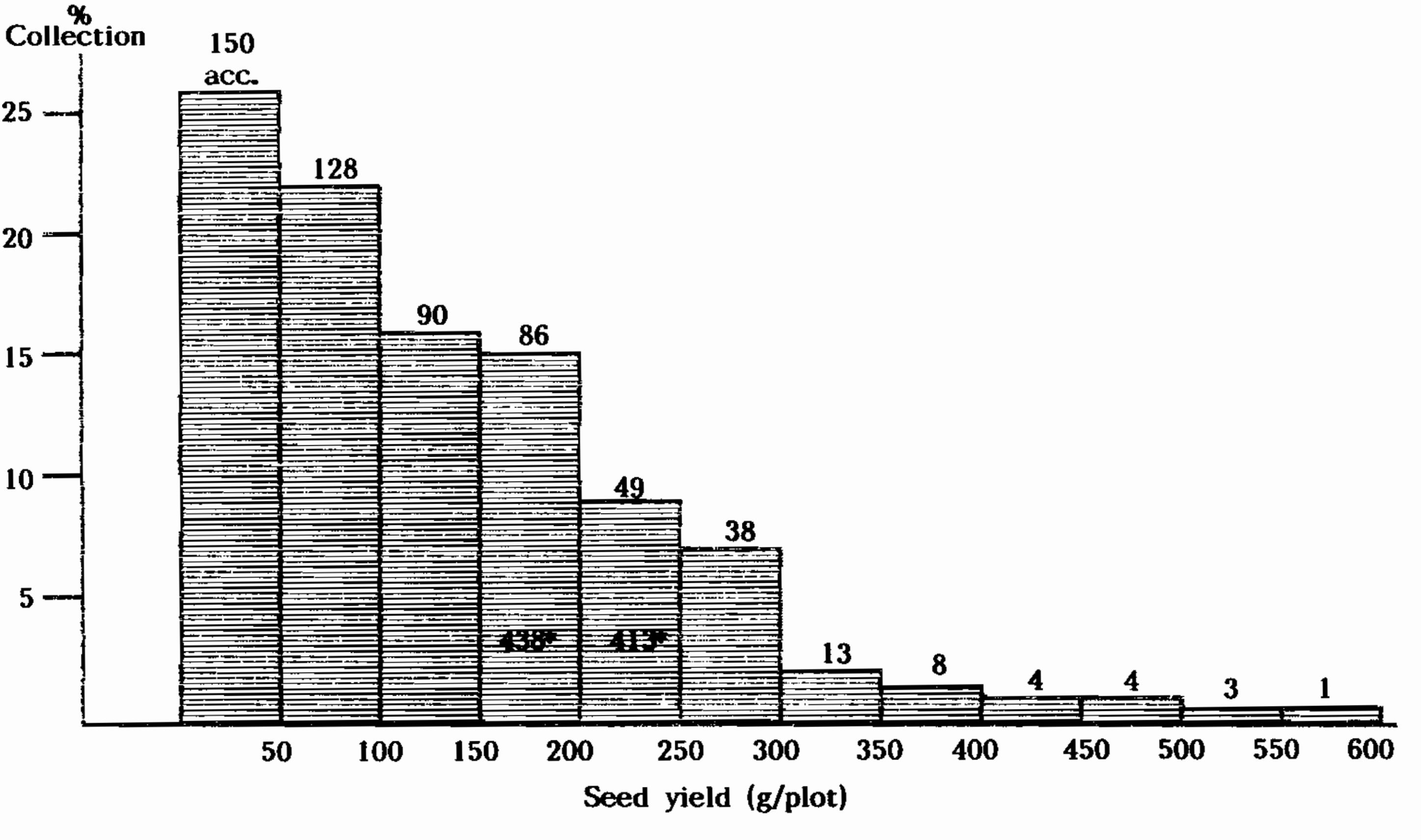


Figure 4. Classification of a Centrosema pubescens collection (575 accessions) into 12 seed-yield groups. (Cumulative yields of 8 plants during a 6-month period with 2 passes/week; Quilichao 1987/88.)

* Control accessions: Australian commercial centro (CIAT 413) and Centrosema hybrid CIAT 438.

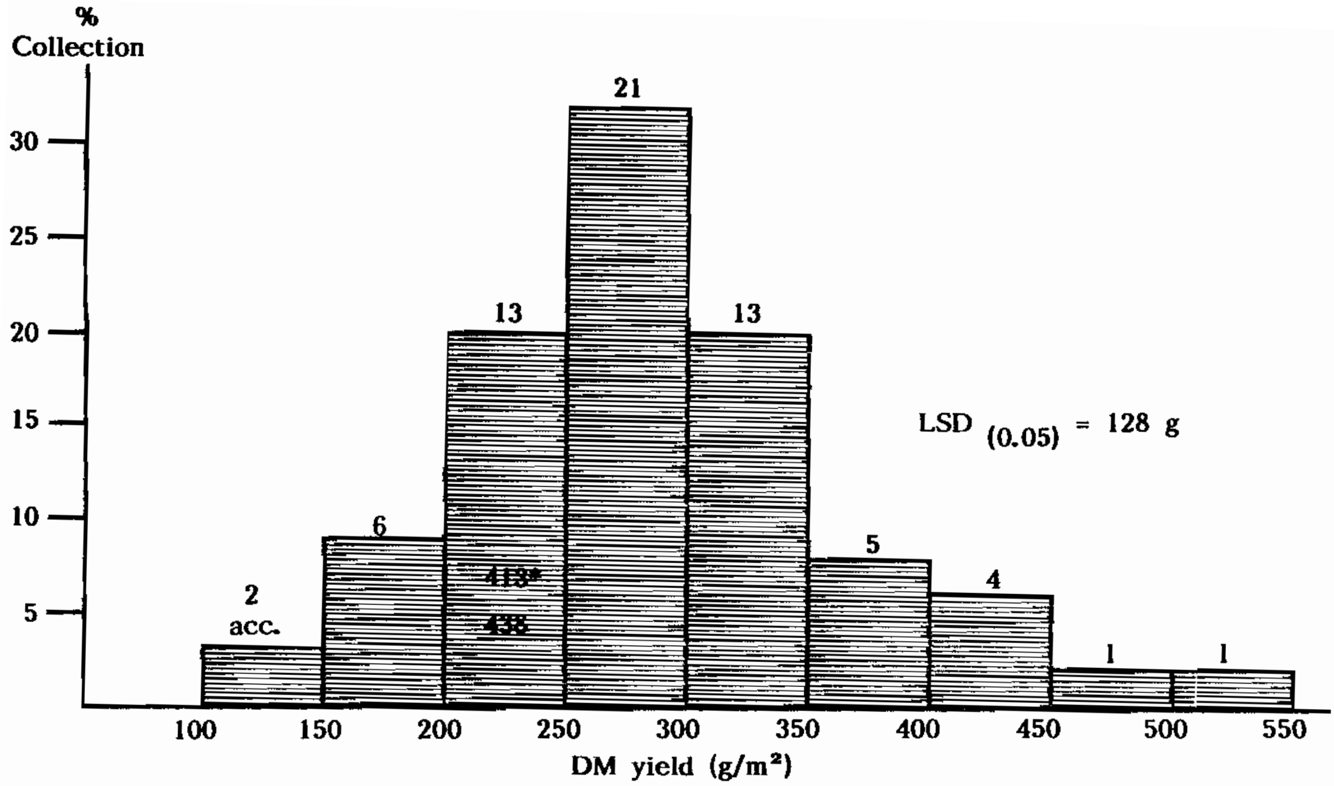


Figure 5. Classification of 66 selected _Centrosema pubescens_ accessions into nine groups of dry-matter yields. (Sum of three consecutive cuts of 3-month old regrowth; Quilichao 1987/88.)

* Control accessions: Australian commercial centro (CIAT 413) and _Centrosema_ hybrid CIAT 438.

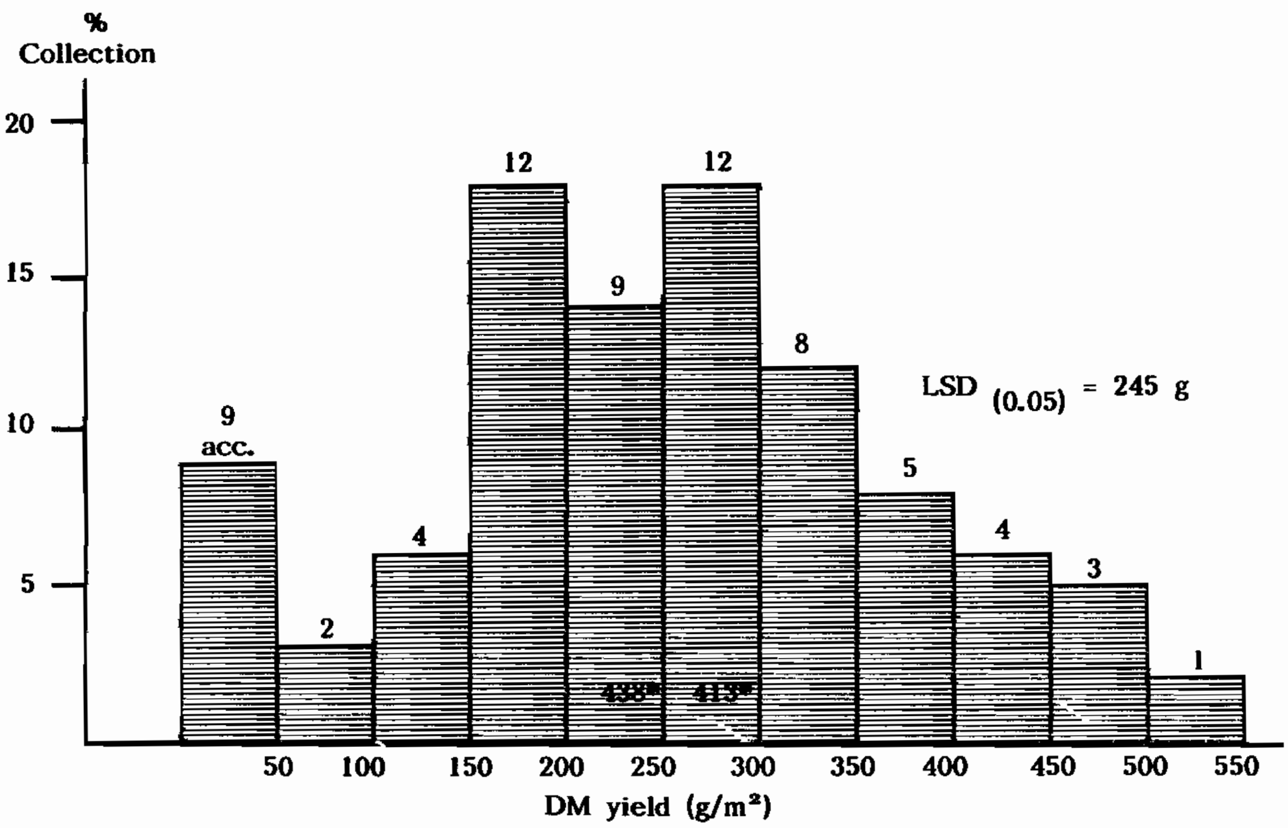


Figure 6. Classification of 66 selected Centrosema pubescens accessions into 11 seed-yield groups. (Cumulative yields of 8 plants during a 6-month period with 2 passes/week; Quilichao 1987/88.)

* Control accessions: Australian commercial centro (CIAT 413) and Centrosema hybrid CIAT 438.

Table 3. Classification of a Flemingia spp. (principally F. macrophylla) collection of 32 accessions into four cluster groups, based on DM production and seed yield (Quilichao 1987-88).

Dendrogram	Cluster group	Accessions No.	Accessions %	DM production (g/plant)[1] Mean	DM production (g/plant)[1] Range	Seed yield (g/plot)[2] Mean	Seed yield (g/plot)[2] Range	Observations
	1	8	25	198	179-219	9.4	0.0-30.6	
	2	5	16	265	240-279	18.9	4.2-67.1	CIAT 7184, 17404, 17405, 17411, 17412
	3	12	38	5	0-20	1.0	0.0-12.1	F. lineata (7 acc.) F. strobilifera (3 acc.) F. macrophylla (2 acc.)
	4	7	22	81	58-111	12.9	0.1-79.4	

1. DM accumulated during 6 months growth.
2. Cumulative yield of 2 weekly passes during 6 months.

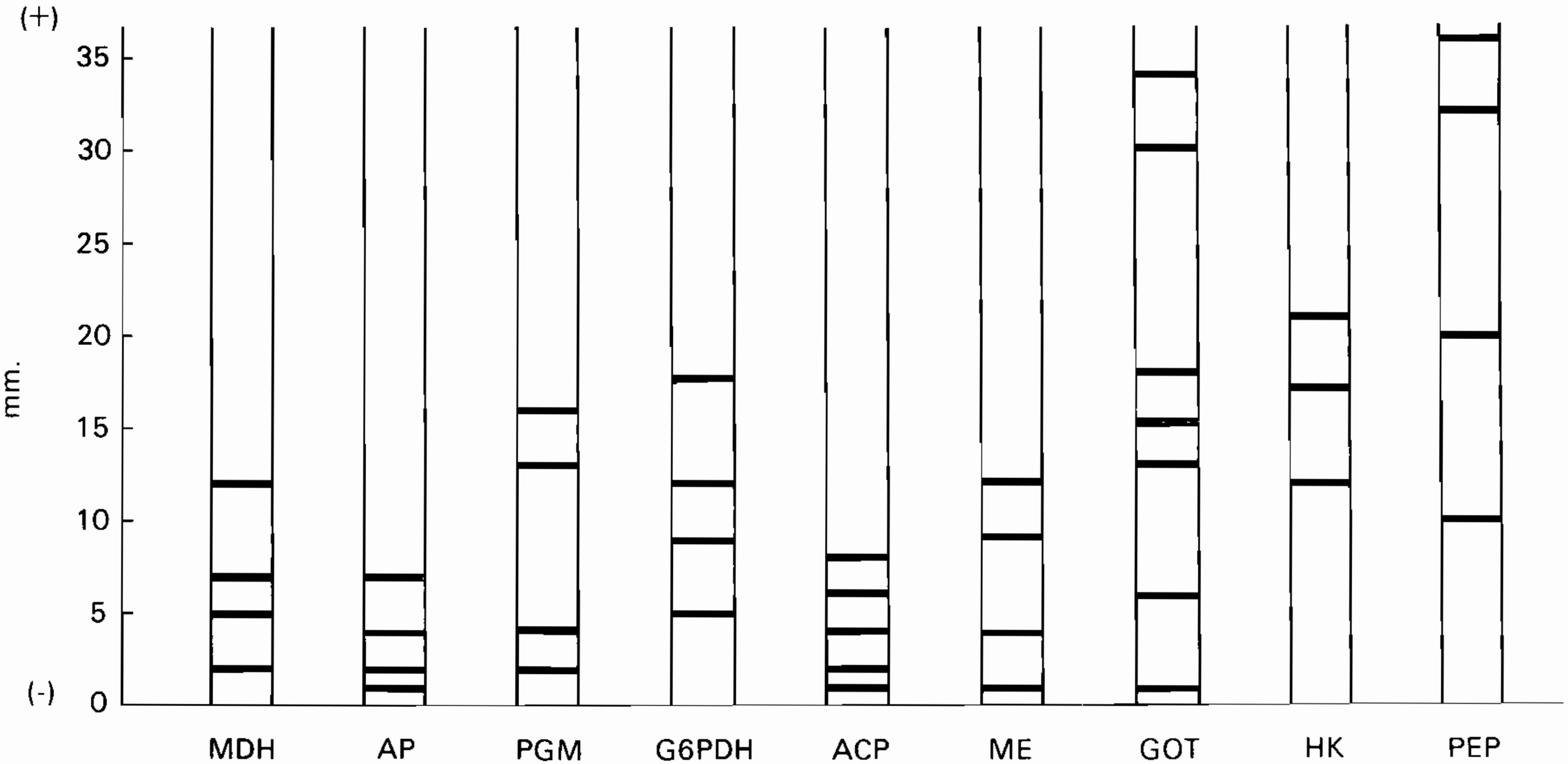


Figure 1. **Diagramatic representation of the combined major isozyme bands of six different *Rhizoctonia* species.**

Table 3. Reaction of promising accessions of Centrosema brasilianum to four isolates of Rhizoctonia species from Carimagua, Colombia

Accession	R. solani 139	R. solani 199	R. solani x̄	Binucleate Rhizoctonia species 162	Binucleate Rhizoctonia species 191	Binucleate Rhizoctonia species x̄
5234 [1]	3.7	4.4	4.1	1.6	2.5	2.1
5178	3.9	5.0	4.5	2.8	4.6	3.7
5486	4.3	5.0	4.7	3.0	3.5	3.3
5657	4.0	4.9	4.5	3.4	3.8	3.6
5671	3.9	4.9	4.4	2.6	3.6	3.1
5725	4.3	5.0	4.7	4.2	4.6	4.4
5810	4.7	5.0	4.9	3.2	3.8	3.5
5828	4.5	5.0	4.8	3.1	4.6	3.9
15387	4.4	4.8	4.6	2.3	3.1	2.7
15521	3.9	4.7	4.3	2.3	3.5	2.9
15526	3.9	4.8	4.4	3.6	4.0	3.8

Rating scale: 0 = no disease; 5 = leaf death

1/ Control

oryzae and Waitea circinata was confirmed by banding patterns obtained with these three isozymes (Figures 2 to 4). The existence of intra-specific variation was also obvious.

Intra-specific variation within several Rhizoctonia species for banding patterns of nine isozymes in three systems is presented in Figures 5 to 7. With few exceptions, intra-specific variation within Rhizoctonia species was found for all isozymes, however one or two predominant banding patterns were always distinguished (Figures 5 to 7). Intraspecific variation in R. solani was considerable for GOT and PEP (Figure 5); in BNR for ME, GOT, HK and PEP (Figure 6); while less intra-specific variation was encountered for MNR (Figure 7).

These findings suggest the occurrence of subspecific groups within the presently broadly defined species concept of Rhizoctonia. Whether correlations

Table 4. Reaction of nine accessions of Centrosema tetragonolobum to eight isolates of Rhizoctonia species from Carimagua, Colombia

Accession No.	Isolates of R solani 043	139	199	x̄	Isolates of Binucleate Rhizoctonia species 162	178	191	193	198	x̄
1587	5.0	3.9	4.9	4.6	3.2	1.5	3.9	3.7	4.0	3.3
15089	4.1	4.5	4.8	4.5	2.3	3.4	4.2	2.5	4.7	3.4
15440	4.6	3.2	5.0	4.3	2.3	3.5	3.9	2.6	5.0	3.5
15441	4.8	3.7	4.9	4.5	2.3	4.3	4.2	2.7	4.3	3.6
15443	4.9	-	-	(4.9)	-	1.7	-	2.5	3.3	2.5
15444	5.0	-	-	(5.0)	-	3.0	-	2.0	3.2	2.7
15836	4.9	-	-	(4.9)	-	3.7	-	4.0	3.8	3.8
15839	5.0	-	-	(5.0)	-	4.2	-	4.5	4.1	4.3
15840	5.0	-	-	(5.0)	-	1.9	-	2.7	3.3	2.6

Rating scale: 0 = no disease; 5 = leaf death

Figure 2.

Interspecific variation among *Rhizoctonia* species for isozyme/system Alkaline Phosphatase (AP)/Histidine

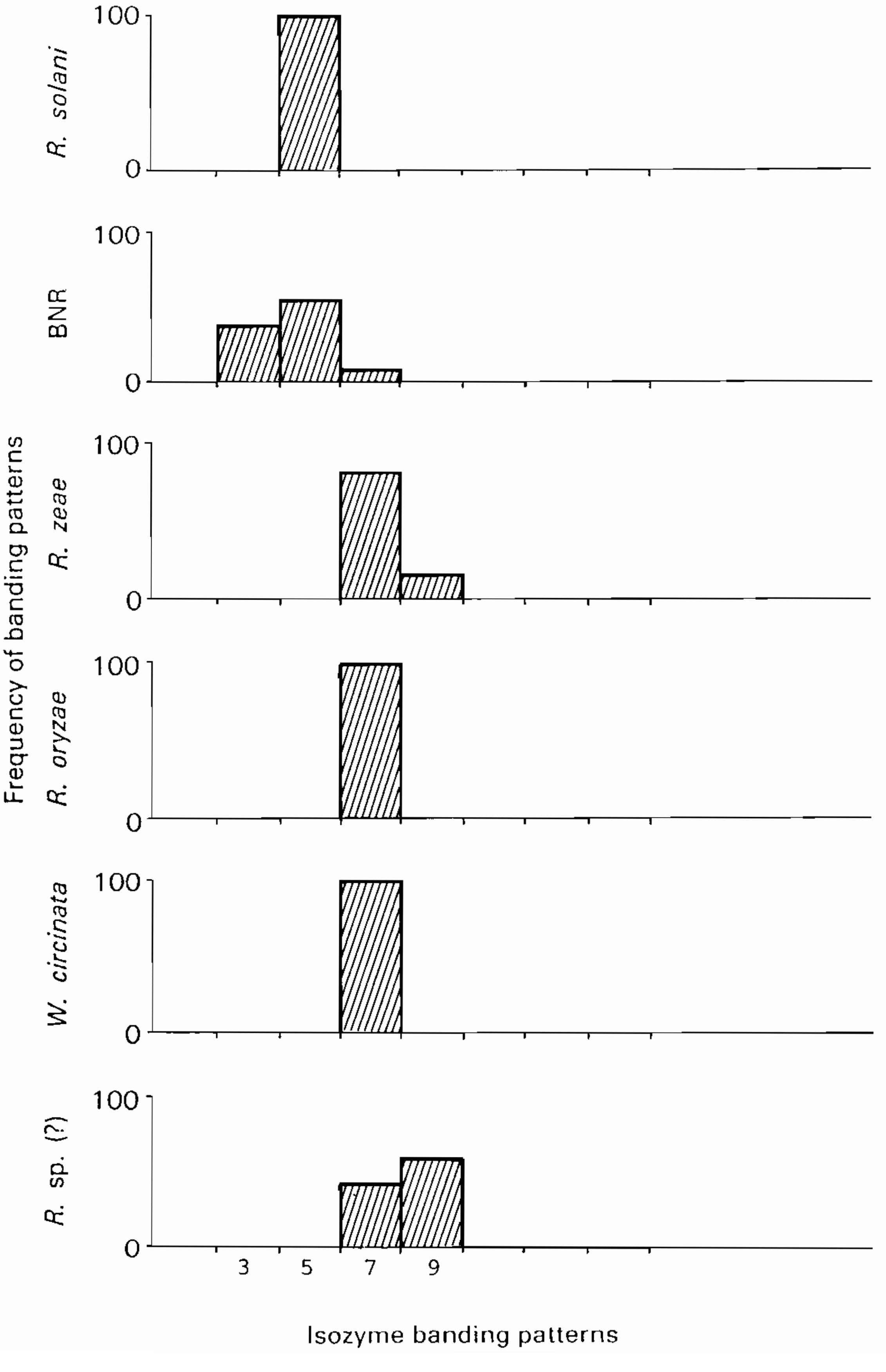


Figure 3.

Interspecific variation among *Rhizoctonia* species for isozyme/system Acid Phosphatase (ACP)/Citrate

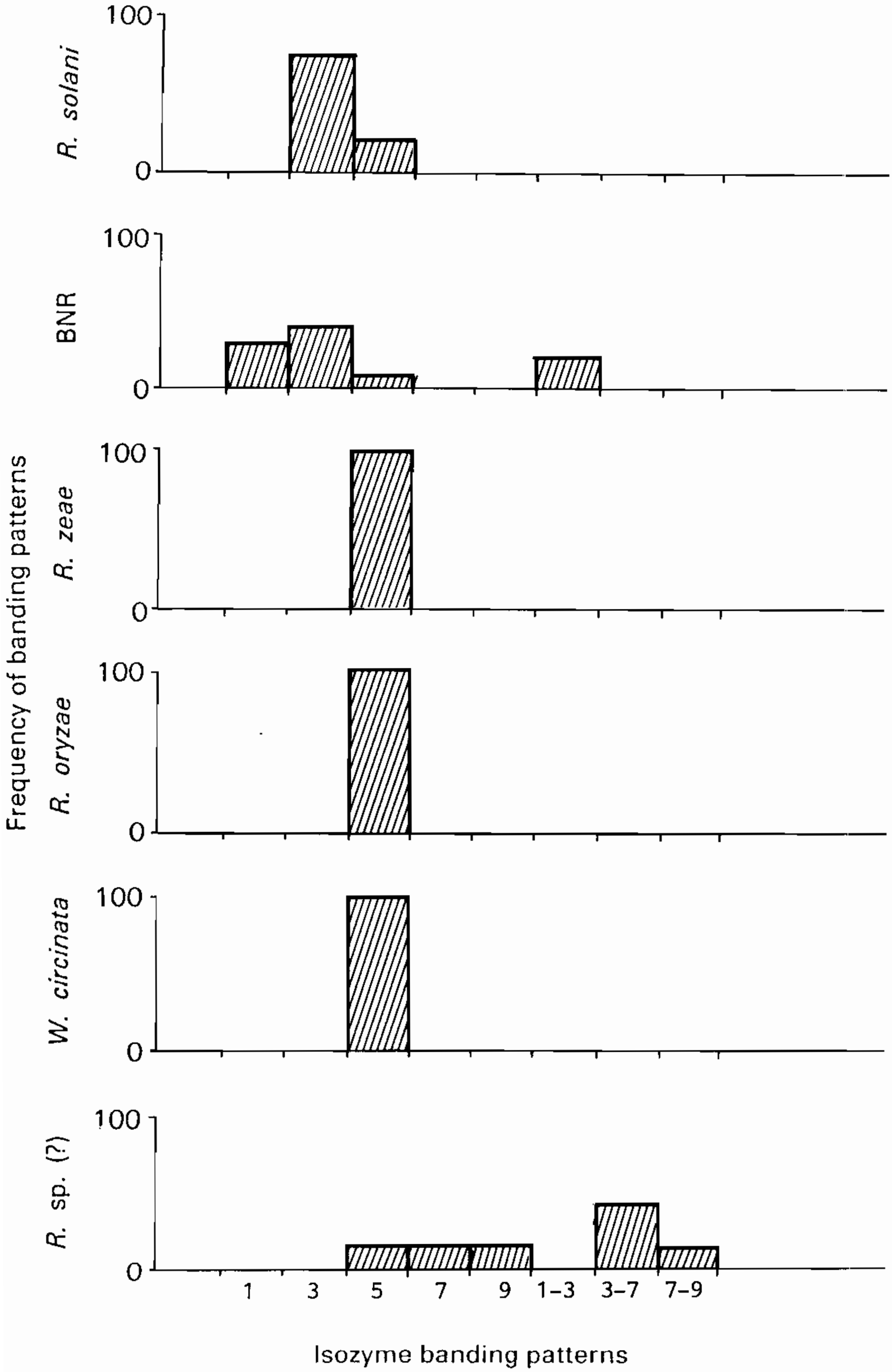


Figure 4.

Interespecific variation among *Rhizoctonia* species for isozyme/system Glutamate-oxaloacetate transaminase (GOT)/Lithium

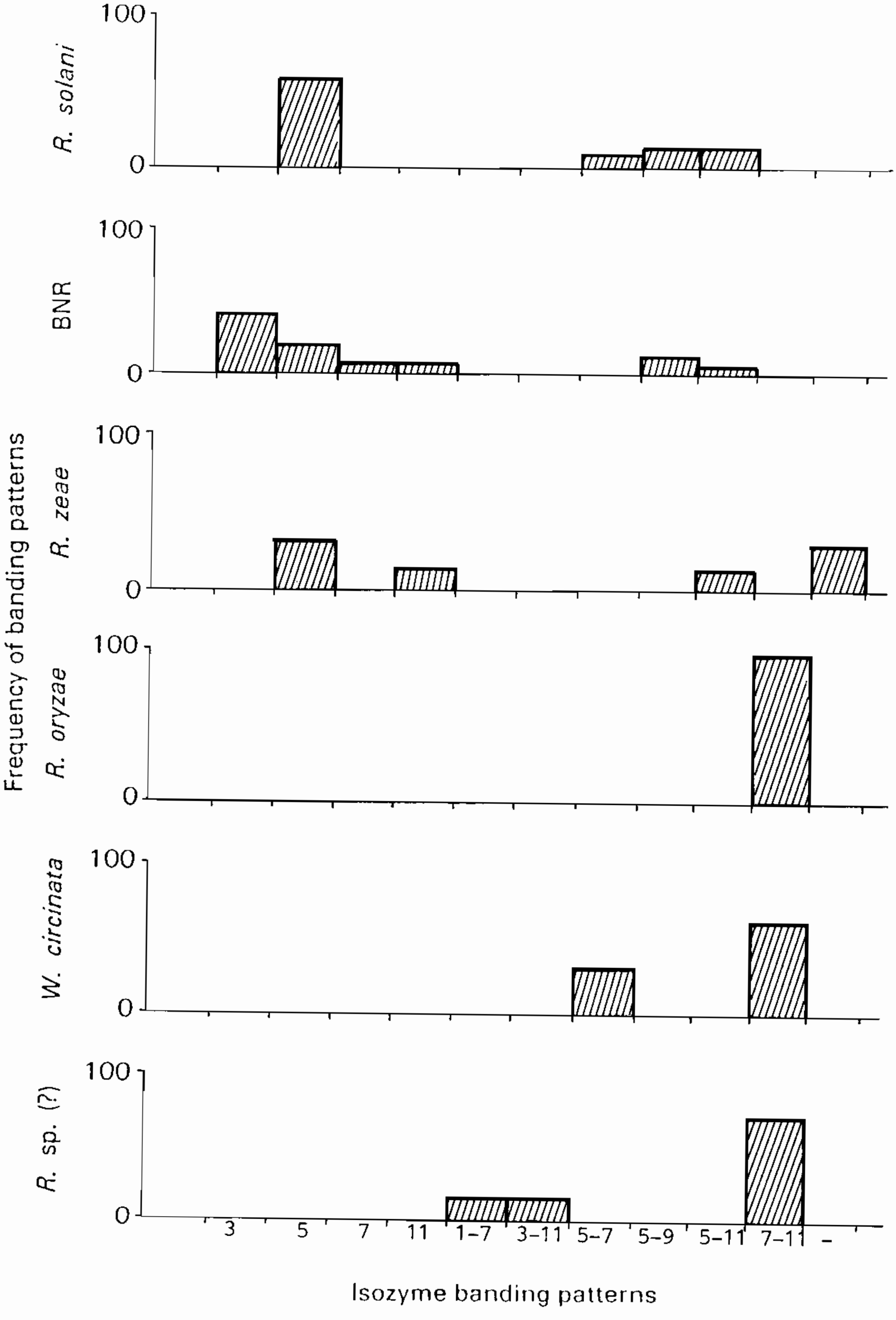
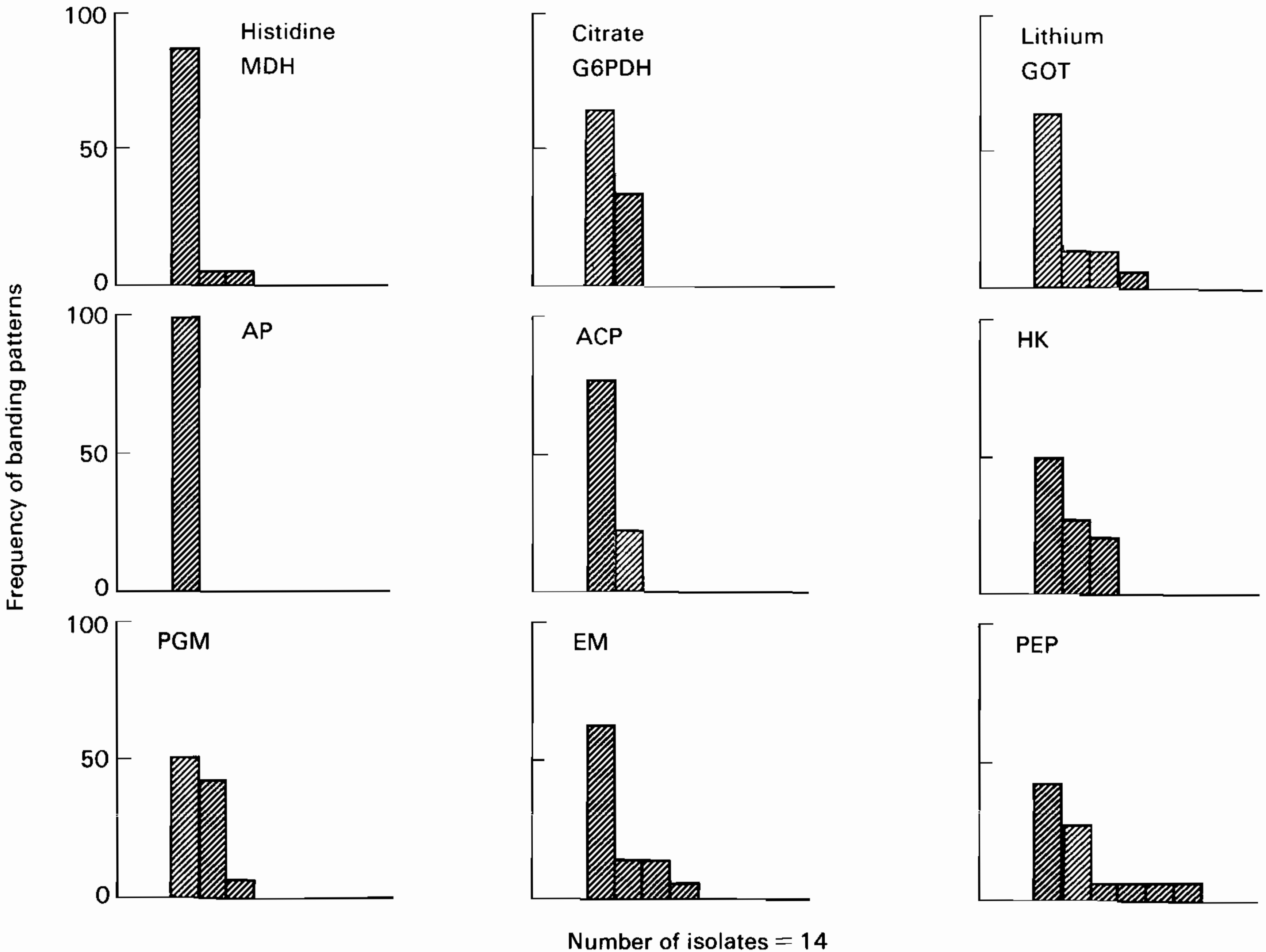


Figure 5. **Intraspecific variation in *Rhizoctonia solani* for banding patterns of nine isozymes in three systems.**



variation. In the *D. velutinum* trial accessions CIAT 13218, 23134, and 23275 outperform the remaining 69 lines in terms of soil adaptation, disease resistance, DM and seed yield. A provisional list of outstanding *Dioclea guianensis* and *D. virgata* germplasm comprises, on a preliminary basis, almost one-third of the total of 143 accessions under evaluation.

Grasses

As in the 2-3 previous years, both the *Panicum maximum* and the *Brachiaria* spp. collections (approximately 440 and 500 accessions, respectively) which are in the field in CIAT-Quilichao, are still primarily used for initial seed increase and as a source of vegetative material. It is intended to initiate characterization and preliminary evaluation in 1989. In addition to these large-sized collections, a *Hyparrhenia* spp. gene-pool is being built up and maintained in Quilichao. Presently it comprises approximately 50 accessions.

3. Plant Breeding

INTRODUCTION AND HIGHLIGHTS OF THE YEAR

The basic objective of the Section remains that of producing genetically improved lines in a limited number of key species while generating information on the genetics and breeding of largely unknown tropical forage species. The principal breeding project remains that which seeks to enhance disease and insect resistance in *Stylosanthes guianensis*. A more modest breeding project aims to alter the plant architecture of *Andropogon gayanus* to improve compatibility with legumes. A number of complementary studies in these and other species seek to provide information of use to current and future breeding activities.

The *S. guianensis* breeding project has produced lines with disease and insect resistance as high as the best germplasm accession and with greater forage yield and two to three times higher seed yield.

A non-nitrogen-fixing seedling mutant induced by gamma radiation has been shown to be inherited monogenically. It will thus be useful as a genetic marker and will permit a substantial improvement in the efficiency of the recurrent selection scheme practiced in *S. guianensis*.

Additional evidence for a large genetic component in *A. gayanus* seed yield and quality and seedling vigor has been accumulated.

Exploratory work in interspecific hybridization in Brachiaria is yielding positive results, including the first putative interspecific hybrid seedlings.

BREEDING PROJECTS

Stylosanthes guianensis Diallel crosses

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

Pedigree. Critical seed yield data for five selected *S. guianensis* var. pauciflora F4-derived lines were obtained from two separate experiments during 1988. The first experiment compared single-plant seed yield of five hybrid-derived lines with the standard *S. guianensis* var. pauciflora accessions CIAT 10136 and CIAT 2031. Yields were approximately twice as high for the best pedigree selected lines as for CIAT 10136 (Table 1). This result was confirmed in a trial conducted at Carimagua where five pedigree-derived lines were compared with the same two standard check accessions. In order to assess the degree of reduction in seed yield owing to Stegasta bud worm damage, a plus or minus insecticide treatment (Azodrin, applied every two weeks from initiation of flowering to seed harvest) was imposed on main plots in a split-plot design. Several of the selected lines again

Table 1. Seed yield (in Quilichao) of natural selection progenies, pedigree selected lines, or check accessions.

Population	Seed yield	
	Mean	Maximum
	---------- g/plant[A] ----------	
Natural selection		
Low stocking rate	5.8(±0.6)	31.5(±5.8)
Medium stocking rate	6.1(±0.6)	27.9(±5.7)
High stocking rate	6.9(±0.7)	28.6(±6.2)
Pedigree-selected lines		
FM-01-86/41	11.2(±2.3)	
FM-01-86/44	13.2(±3.5)	
Check accessions		
CIAT 2031	10.3(±2.5)	
CIAT 10136	5.6(±1.2)	

A/1 g/plant equivalent to 2.5 kg/ha (2,500 plants/ha).

Table 2. Mean seed yield of five pedigree-selected *Stylosanthes guianensis* var. *pauciflora* lines and two check accessions with, or without insecticide at Carimagua.

Entry	Insecticide (Azodrin) protection	
	With	Without
	-------------kg/ha-------------	
Pedigree-selected lines		
FM-01-86/41	159.6 b	21.3 a
FM-01-86/09	89.0 c	10.7 a
FM-01-86/44	82.2 cd	18.5 a
FM-01-86/29	62.1 de	16.7 a
FM-01-86/28	44.9 e	14.5 a
Check accessions		
CIAT 2031	244.4 a	9.0 a
CIAT 10136	48.2 e	18.1 a

yielded two to three times as much as CIAT 10136 when protected with insecticide (Table 2). However, where Stegasta attack was not controlled, seed yields were low for all lines and differences among lines were not detected (Table 2). This result suggests that while relatively high seed yield potential has been combined with high anthracnose and stemborer resistance, no progress in improving Stegasta resistance has apparently been achieved. We attribute this lack of progress in improving Stegasta resistance to deficiencies in the current methodology of assessing Stegasta damage wherein no control over natural populations of the insect is attempted. It seems that either fluctuations in the natural insect populations are masking genetic differences in Stegasta resistance or the present *S. guianensis* breeding populations do not contain useful genetic variability for Stegasta resistance.

A trial is planned for next year to evaluate several *S. guianensis* var. *pauciflora* lines under grazing.

Seed of six pedigree-derived *S. guianensis* var. *vulgaris* lines was multiplied in Quilichao during the year (Table 3) so that these materials can be distributed for wider testing in regional trials.

NATURAL SELECTION UNDER GRAZING

One hundred seedlings obtained from seed harvested from surviving plants in each of the three stocking rate paddocks established at Carimagua in 1984 were grown during 1987 to produce progenies for comparison with standard germplasm accessions and pedigree-derived lines. Single-plant seed yields ranged widely, some plants producing approx. three times as much seed as the best pedigree-derived lines or the better of the anthracnose resistant germplasm accessions (Table 1). One hundred fifty of the three hundred progenies were planted at Carimagua during 1988 where anthracnose/stemborer resistance will be compared with the best pedigree-derived lines and standard check germplasm accessions. A bulk of these progenies will be included in the small-plot grazing trial planned for next year to compare the results of natural selection with the best pedigree- derived lines.

BULK ADVANCE

Six bulk populations were advanced another generation. Seed yields (Table 3) show no evidence of increasing over cycles beyond the first cycle of bulk selection.

Recurrent selection. Improvement of var. *vulgaris* and var. *pauciflora* populations continues. Approximately 25 var. *pauciflora* selections will be tested for seed yield next year and recombined for a further cycle of selection.

Table 3. Seed yield of six *Stylosanthes guianensis* var. *vulgaris* selections, CIAT Quilichao

Accession	Seed yield (kg/ha[A])
11369	88.84
11364	86.57
11368	77.48
11376	74.38
11370	62.60
11373	44.01

[A] Converted from yield of $242 m^2$ plot.
Accessions do not differ (P=0.05).

Andropogon gayanus

Short stature population. Two hundred clones selected as single plants from polycross progenies in 1987 were propagated vegetatively for further evaluation at both Quilichao and Carimagua and for recombination during 1988.

Late flowering population. Open-pollinated (polycross) progenies were obtained from 22 late flowering clones selected by the Agronomy Section from CIAT 621 at Carimagua. These progenies are under evaluation at Quilichao and Carimagua to compare their agronomic attributes with the original source population, CIAT 621.

OTHER STUDIES

S. guianensis

Results of detailed characterization of two non-nitrogen-fixing induced mutant lines (172 and 173) indicates that the lines are not distinguishable phenotypically and that they may contain the same mutant. The mutant non-nitrogen-fixing phenotype is observed regardless of the Rhizobium strain used (data not shown), indicating that the mutant(s) is not Rhizobium strain specific. The mutant lines differ little if at all in dry matter yield nor in nitrogen content from the original source accession where nitrogen is not limiting in the growing medium (Tables 5 and 6). The mutant(s) is qualitative and, in crosses with the original source accession, segregates as a single, partially lethal recessive (Table 7). It is not yet clear at which stage (pollen or ovule abortion on the F_1 plant, abortion during development of the homozygous recessive F_2 embryo, or germination failure of the homozygous recessive F_2 seed) the lethality is occurring which gives rise to the slight deficiency in homozygous mutant genotypes in the F_2. In any case, the mutant will be extremely useful as a seedling marker, greatly improving the efficiency of the recurrent selection projects in S. guianensis. The mutant is now being incorporated into the breeding populations.

A. gayanus

Seed quality and seedling vigor. Data are now available on caryopsis content, caryopsis weight, germination, and seedling vigor of seed from three harvests of five random clones in each of three A. gayanus accessions (Table 8).

These data clearly show a season effect on all important variables, with generally poorer quality seed produced at mid year (August) than in January. This effect is likely due to the greater synchronization of flowering with the shortening daylength at year's end. However, genetic variation for seed quality attributes and seedling vigor predominate. At all harvests the range among genotypes is greater than the difference between seasons. No effect of nitrogen fertilization was detected for any attribute while genetic effects (among and within accessions) are generally significant (Table 9).

Centrosema spp.

A project was initiated during 1988 to assess the potential for improving Rhizoctonia resistance in Centrosema brasilianum through interspecific hybridization with C. tetragonologum. Several F_2 populations were established as spaced plants at Quilichao (Table 10) to produce seed of F_3 progenies which will be evaluated with artificial inoculation in the field at Carimagua during 1989. We hope to assess resistance of these progenies also under controlled conditions in the glasshouse.

Table 4. Seed yield, by cycle, of Stylosanthes guianensis bulk advance populations.

Population	Approx. harvest date	First	Second	Third	Fourth	Fifth
		kg/ha				
1	01 Oct.	0.43	9.07	2.11	-[A]	2.10
2	15 Oct.	4.38	19.69	6.43	-	4.02
3	29 Oct.	3.48	8.28	9.07	-	10.98
4	12 Nov.	0.08	0.60			
5	26 Nov.	0.13	0.06			
6	10 Dec.	0.12	0.04			
				1.05	0.49	-
7	24 Dec.	0.15	0.09			
8	07 Jan.	0.12	1.27			
9	21 Jan.	0.36	0.19			
10	04 Feb.	0.36	6.02	4.04	0.37	7.47
11	18 Feb.	0.26	10.11	5.42	2.43	8.22
12	04 Mar.	1.33	5.38	11.13	7.24	13.78

[A] Establishment failure. No seed harvested

Table 5. Mean dry matter yield of non-nitrogen-fixing mutant or normal Stylosanthes guianensis lines grown in six-inch pots in unsterilized, nitrogen-deficient soil with, or without added fertilizer nitrogen, second harvest.

Line	Nitrogen fertilizer With	Nitrogen fertilizer Without
	g/plant	
CIAT 0015	5.53^{a}	5.28^{a}
172-02	4.80^{b}	1.33^{b}
172-03	5.47^{a}	1.22^{b}
172-09	5.41^{a}	1.34^{b}
172-14	5.21^{ab}	1.17^{b}
173-02	4.79^{b}	1.28^{b}
173-04	5.08^{ab}	1.32^{b}
173-06	5.52^{a}	1.25^{b}

* Means within columns followed by the same letter do not differ by t-test ($P<0.05$).

Table 6. Mean nitrogen content of non-nitrogen-fixing mutant or normal Stylosanthes guianensis lines grown in six-inch pots in unsterilized, nitrogen-deficient soil with, or without added fertilizer nitrogen, second harvest.

Line	Nitrogen fertilizer With	Nitrogen fertilizer Without
	% N	
CIAT 0015	4.02^{a}	2.51^{a}
172-02	3.99^{ab}	1.30^{b}
172-03	3.86^{abc}	1.34^{b}
172-09	3.77^{c}	1.28^{b}
172-14	3.80^{bc}	1.33^{b}
173-02	4.03^{a}	1.30^{b}
173-04	3.87^{abc}	1.32^{b}
173-06	3.81^{bc}	1.26^{b}

* Means within columns followed by the same letter do not differ by t-test ($P<0.05$).

Table 7. Observed ratios of normal: mutant (chlorotic) seedlings in the F_2 populations of five mutant x normal *Stylosanthes guianensis* hybrids.

Cross	F_2 ratio	Chi-square (1 d.f.)
1	4.88:1 (100)[A]	3.41
2	3.60:1 (92)	0.52
3	4.88:1 (100)	3.41
4	4.56:1 (100)	2.61
5	6.14:1 (100)	6.45*
Pooled	4.72:1 (492)	14.84**

[A] Number of F_2 individuals in parentheses.

*, ** Observed F_2 ratio deviates from hypothesized (3:1) ratio at $P<0.05$ or $P<0.01$, respectively.

Table 8. Crude seed yield, caryopsis content, and 100-caryopsis weight of *Andropogon gayanus* seed on three harvest dates.

Harvest date	Crude seed yield content (range, clones)	Caryopsis weight (range, clones)	100-caryopsis (range, clones)
	(g/plant)	(%)	(mg)
January, 1987	31.6 (7.1 - 55.3)	24.0 (0.7 - 40.9)	107.9 (60.0 - 161.3)
August, 1987	14.8 (5.6 - 35.0)	13.7 (4.2 - 37.6)	78.2 (46.4 - 112.3)
January, 1988	27.1 (14.0 - 39.9)	21.0 (13.2 - 30.5)	102.4 (72.5 - 140.0)

Table 9. F-values for the effect of nitrogen fertilizer, accession, or genotype within accession from the analysis of variance of crude seed uield, caryopsis content, percent germination, or seedling weight of *Andropogon gayanus* on three harvest dates.

Source of variation	Harvest date: January, 1987	August, 1987	January, 1988
	Crude seed yield (g/plant)		
N fertilizer	0.70	1.16	4.28
Accession	3.71*	1.20	1.46*
Genot. (Acc.)	9.82***	10.18***	14.99***
	Caryopsis content		
N fertilizer	0.41	1.81	0.02
Accession	2.07	9.23***	3.64*
Genot. (Acc.)	9.09***	4.76***	1.83
	Percent germination		
N fertilizer	7.58*	1.83	0.56
Accession	35.93***	16.81***	50.06***
Genot. (Acc.)	11.84***	6.83***	9.19***
	Seedling weight (g/plant)		
N fertilizer	0.14	2.54	0.18
Accession	29.94***	5.56**	3.57*
Genot. (Acc.)	10.00***	7.09***	3.40***

*, **, *** Effect significant at P<0.05, P 0.01, or P<0.001, respectively.

Table 10. Number of F_2 and parental individuals of five *C. brasilianum* x *Centrosema tetragonolobum* hybrids transplanted to the field (Quilichao) on 09 Sep. 1988.

Entry (cross or check)	Number of plants
5234 x 15444	240
5234 x 15444	443
5234 x 15444	135
5234 x 15444	69
5234 x 15443	3
Total F_2	890
Parental accessions:	
CIAT 5234 (*C. brasilianum*)	37
CIAT 15443 (*C. tetragonolobum*)	37
CIAT 15444 (*C. tetragonolobum*)	36

Brachiaria spp.

Mode of reproduction of a major portion of the collection of *Brachiaria* spp. germplasm accessions was assessed for mode of reproduction by embryo sac analysis by Dr. C. do Valle (EMBRAPA/CNPGC, Campo Grande, MS, Brazil) during her appointment as CIAT Visiting Fellow early in 1988. Dr. do Valle also reintroduced to CIAT several lines of tetraploid *Brachiaria ruziziensis* which will serve as a source of sexuality in any future breeding work involving the tetraploid apomictic species *B. brizantha* and *B. decumbens*. Experimental crosses are already being made and a number of putative hybrid seeds and seedlings have been produced in the growth chamber, glasshouse, and field (Tables 11 and 12). The *B. ruziziensis* material appears highly self-incompatible as selfed seed set is only approx. one-tenth that of (interspecific) hybrid seed set (Table 11). Thus, production of hybrid seed on unemasculated inflorescences in the field ought to be the most efficient means of obtaining large numbers of hybrids (Tables 11 and 12). Confirmation of the hybrid nature of the seedlings obtained to date must await electrophoretic isozyme analysis.

Table 11. Summary of interspecific hybridizations[A] in the genus *Brachiaria*[B].

Venue	% set: Crosses	% set: Selfs	Number of hybrid seeds obtained
High humidity growth chamber	4.9	1.7	228
Glasshouse	25.6	0.4	318
Field (Quilichao)	21.7	-	899
Pooled	14.7	1.5	1445

[A] Crosses using tetraploid, sexual *Brachiaria ruziziensis* as female and *Brachiaria decumbens* or *Brachiaria brizantha* as male.

[B] Information to 25 October 1988.

Table 12. Number of putative interspecific *Brachiaria* hybrid seedlings obtained to date (25 Oct. 1988).

Female	x	Male	Source	Number
4x *B. ruziziensis*	x	*B. brizantha* (6387)	O.P., field	45
4x *B. ruziziensis*	x	*B. brizantha* (6384)	Glasshouse	5
4x *B. ruziziensis*	x	*B. decumbens* (0606)	Glasshouse	3

4. Plant Pathology

INTRODUCTION

The section continued this year with the following aims:

1. Detection and identification of diseases of tropical pasture germplasm at major screening sites (Carimagua - Llanos, Brasilia - Cerrados, Pucallpa - Humid Tropics and Costa Rica - Moderately acid soils).

2. Assessment of the potential importance of detected diseases involving development and implementation of appropriate screening methodologies in the glasshouse and methodologies for assessment of the importance of diseases under grazing.

3. Development of control strategies for the most promising tropical pasture germplasm relevant to the perennial pasture ecosystem.

Research was concentrated on diseases of Centrosema due to current program emphasis. Work was also continued on anthracnose of Stylosanthes, Synchytrium wart disease and stem gall nematode of Desmodium ovalifolium, diseases of Arachis pintoi, and seed pathology. Rust (Uromyces setariae-italicae) was recognized as a potentially damaging disease of Brachiaria species.

DISEASES OF STYLOSANTHES

a) Anthracnose of Stylosanthes

The effect of association with Andropogon gayanus on reaction to anthracnose and productivity of Stylosanthes guianensis was evaluated in a third experiment in Carimagua. Previous experiments had shown that association of A. gayanus with moderately anthracnose susceptible accessions of S. guianensis resulted in increased anthracnose development in comparison to S. guianensis in pure stand (CIAT 1983 and 1984).

During the second year of the current experiment investigating the effect of A. gayanus barriers and mulch and plot size on severity of anthracnose in S. guianensis CIAT 136 and 1283, anthracnose developed more rapidly and severely without A. gayanus barriers and mulch than with them in both CIAT 136 and 1283 as in previous experiments. The overall productivity of both accessions was greater with A. gayanus mulch and barriers irrespective of whether plots were large (10 x 10 m) or small (5 x 5 m) (Table 1). In addition, in association with A. gayanus barriers yields were significantly lower at the edges of both small and large plots than in the center confirming the negative effect of close association of A. gayanus on growth and productivity of S. guianensis observed in previous experiments.

Table 1. Effect of aerial barriers and mulch of A. gayanus on yield[1] of Stylosanthes guianensis in Carimagua

Treatment	+ A. gayanus		- A. gayanus	
	Small[2] (gm/m^2)	Large[3] (gm/m^2)	Small[2] (gm/m^2)	Large[3] (gm/m^2)
136 + Mulch	218.5 [4]/170.8 [5]	287.8/268.7	189.9/169.5	171.1/164.7
136 - Mulch	216.0/110.2	215.2/113.8	68.6/ 59.3	88.8/ 74.5
1283 + Mulch	193.0/159.9	216.7/142.7	103.4/93.1	113.9/105.9
1283 - Mulch	195.2/128.8	114.3/116.7	77.1/70.0	97.6/ 90.9

1/ Mean of three harvests: Aug and Dec, 1987, and Aug 1988.
2/ Plots 5 x 5 m
3/ Plots 10 x 10 m
4/ Samples from center of plot.
5/ Samples from edge of plot.

An AIDAB funded special project was begun this year in collaboration with CSIRO, DPI and the University of Queensland, Australia and Queens University, Belfast on "Characterization and comparison of isolates of Colletotrichum gloeosporioides causing anthracnose of Stylosanthes from Australia, South east Asian/-Pacific region and tropical America". The objectives of this project are: (a) to develop standardized international inoculation and evaluation methodologies; (b) to develop international differential sets to facilitate inter-regional comparisons; and (c) to characterize and compare isolates from the above regions using traditional methodologies, starch gel electrophoresis of isozymes and reduced fragment length polymorphisms (rflp's). This project represents the first formal international collaboration between institutions working on anthracnose of Stylosanthes, the most widespread and important disease of tropical pasture legumes.

The present status of anthracnose of Stylosanthes species throughout major ecosystem of tropical American can be summarized as follows:

i) Llanos ecosystem: S. capitata is an exotic species resistant to all known races of C. gloeosporioides in this ecosystem (11 years of evaluation). S. guianensis advanced breeding lines continue to show high resistance.

ii) Cerrados ecosystem: a recent anthracnose epidemic in known susceptible but otherwise promising S. capitata CIAT 1097 has lead to reappraisal of germplasm and hybrids and the possibility of an S. capitata mixture is being considered. Selected S. guianensis accessions show field resistance to local races of C. gloeosporioides however the major problem continues to be seed production. Extensive evaluation of pathogenic variation in C. gloeosporioides in regions where Stylosanthes has potential is urgently needed.

iii) Humid tropics ecosystem: prevailing environmental conditions and natural biocontrols confer reduced anthracnose cycling and build-up however it is not known whether this is a permanent or temporary phenomenon. Continued monitoring of pathogenic variation in C. gloeosporioides throughout the humid tropics and further studies on the natural biocontrol system are strongly recommended.

iv) Moderately acid soils ecosystem: present levels of anthracnose at the three screening sites are low and S. guianensis appears very promising. Attempts are being made to build up anthracnose inoculum for more reliable screening.

DISEASES OF CENTROSEMA

Investigations continued on Rhizoctonia foliar blight, Cylindrocladium leaf spot, Bacteriosis and Centrosema Mosaic Virus, and assessments continued of their importance multi-locationally and under grazing.

a) Rhizoctonia foliar blight (RFB)

i) Characterization of the collection of Rhizoctonia spp isolates. RFB caused by Rhizoctonia solani and other related fungi is the most serious disease of Centrosema species, especially C. brasilianum. The major task of characterizing the variation among Rhizoctonia isolates from the humid tropics and Llanos ecosystems was completed. Two hundred and eighty-eight isolates were classified into a four species complex including R. solani (42.4%), binucleate Rhizoctonia sp. (BNR) (42.0%), multinucleate Rhizoctonia sp. (MNR) (2.5%) and R. zeae (1.0%) (Table 2). R. solani was divided into AG-1 and AG-4 with the former highly pathogenic group predominating. Within AG-1, Peruvian isolates were readily distinguished from Colombian isolates (Table 2). R.solani AG-4 and BNR were moderately pathogenic to Centrosema species while MNR and R. zeae were of low pathogenicity.

The group MNR is the common indigenous species of Rhizoctonia in the Colombian Llanos or savanna ecosystem. The group of highly pathogenic R. solani AG-1 is rare. It appears that C. brasilianum selects out and multiplies the highly pathogenic types at the expense of the indigenous isolates.

ii) Glasshouse screening. The essential task of characterizing variation within the Rhizoctonia complex causing RFB in the humid tropics and Llanos ecosystems is now well advanced and screening can be done with more confidence. Using the previously developed glasshouse screening methodology (CIAT 1987), the germplasm collection of C.brasilianum is being evaluated for reaction to six selected isolates of Rhizoctonia species. To date, no germplasm with high resistance to RFB has been identified. Reaction of ten promising accessions of C. brasilianum and control CIAT 5234 to four isolates is given in Table 3. CIAT 5234 and 15521 were the most resistant accessions however were severely damaged by two isolates of R. solani.

Centrosema tetragonolobum has been described as a more resistant species to RFB than C.brasilianum. Using the same and additional isolates, nine accessions of C. tetragonolobum were highly susceptible to R. solani and moderately to highly susceptible to BNR isolates (Table 4). CIAT 15443, 15444 and 15840 were least affected by BNR isolates.

Table 2. Characteristics of 288 isolates of Rhizoctonia species causing foliar blight of Centrosema species in tropical America

Species	Isolates (%)	Cultural characteristics	Pathogenicity to Centrosema
R. solani AG-1	42.4	Colombia: white/yellowish cottony mycelium, sclerotia > 1.0 mm diam.	High
		Peru: medium to dark brown irregular mycelium; sclerotia < 1.0 mm diam.	High
R. solani AG-4	14.1	Light brown felty mycelium: sclerotia < 1.0 mm diam.	Moderate
Rhizoctonia sp. (binucleate)	42.0	Light brown felty/cottony mycelium; sclerotia < 1.0 mm diam.	Moderate
Rhizoctonia sp. (multinucleate)	2.5	Light orange/pink cottony mycelium; no sclerotia	Low
R. zeae	1.0	Orange/pink felty mycelium; sclerotia < 1.0 mm diam.	Low

Field trials with representative collections of both species are in progress in Quilichao and will be planted in Carimagua next year to confirm glasshouse results.

A comparative evaluation of the mean reaction of several species and accessions of Centrosema to more than 200 isolates of Rhizoctonia species confirmed the higher susceptibility of C. brasilianum CIAT 5178 ($\bar{x}$ RFB=2.51) to RFB than CIAT 5671 ($\bar{x}$ RFB=2.32) and CIAT 5234 ($\bar{x}$ RFB=1.97).

iii) Inter- and intra-specific comparisons with isozymes in starch gel electrophoresis. One of the major problems in working with the Rhizoctonia species complex causing RFB of Centrosema species is the difficulty of classifying variation within and between species. In an attempt to obtain more useful parameters to distinguish isolates, starch gel electrophoresis was evaluated as a potential tool.

Nine isozymes distributed in three systems were used to distinguish species and isolates of the Rhizoctonia complex (Table 5). Figure 1 presents a global view of the numbers and distributions of bands obtained for each isozyme. Several loci were obtained for most isozymes.

Interspecific variation among Rhizoctonia species for the isozymes/systems alkaline phosphatase (AP)/Histidine, acid phosphatase ACP/Citrate and Glutamate-oxaloacetate transaminase (GOT)/-Lithium are shown in Figures 2 to 4. R. solani, BNR and indigenous multinucleate Rhizoctonia sp (MNR) were readily distinguished with AP, ACP and GOT, the most common banding pattern being specific to each species for each isozyme. The close relationship between R.

Figure 6. **Intraspecific variation in binucleate *Rhizoctonia* (BNR) for banding patterns of nine isozymes in three systems.**

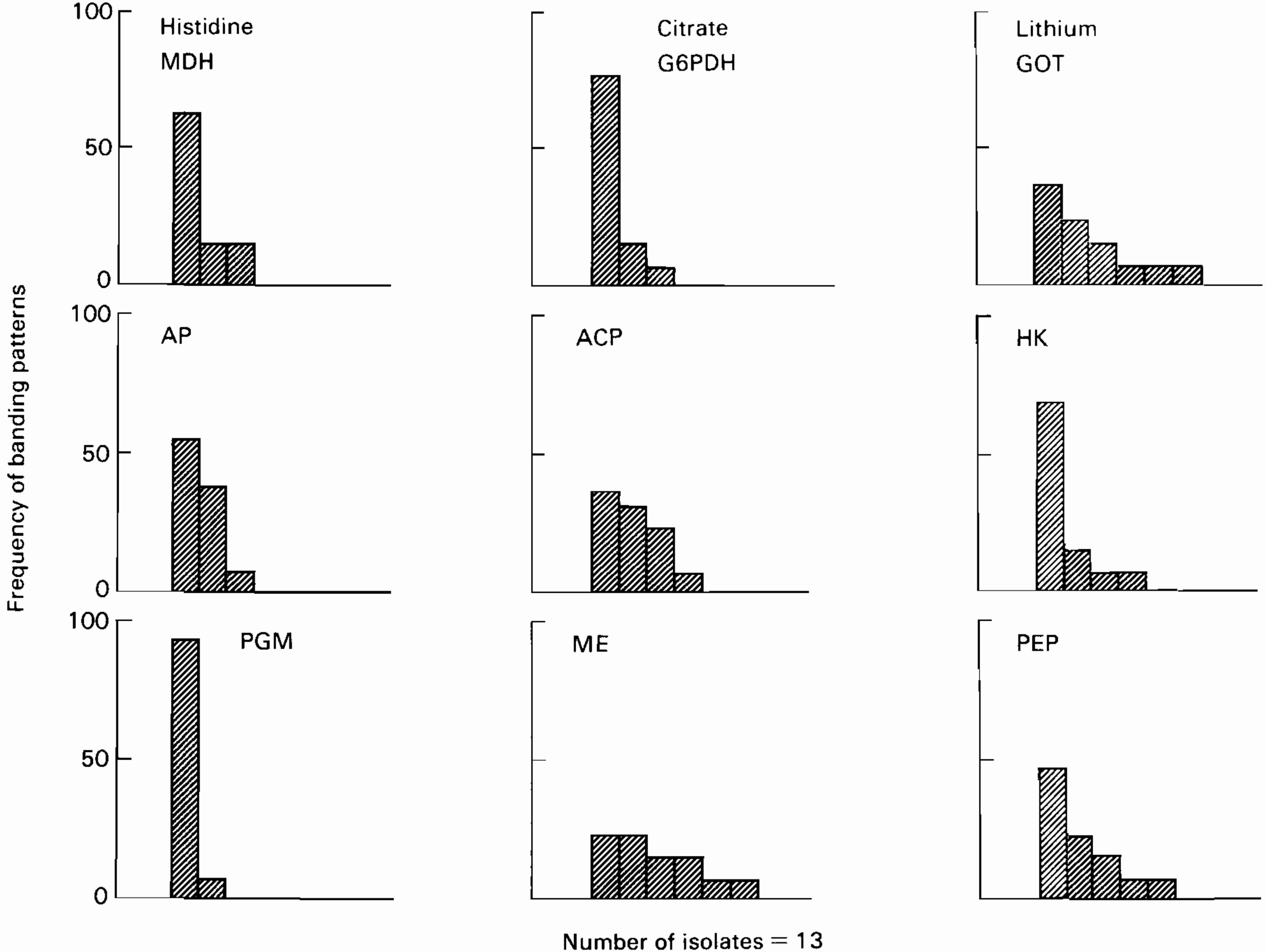


Figure 7. **Intraspecific variation in *Rhizoctonia* sp. (?) for banding patterns of nine isozymes in three systems.**

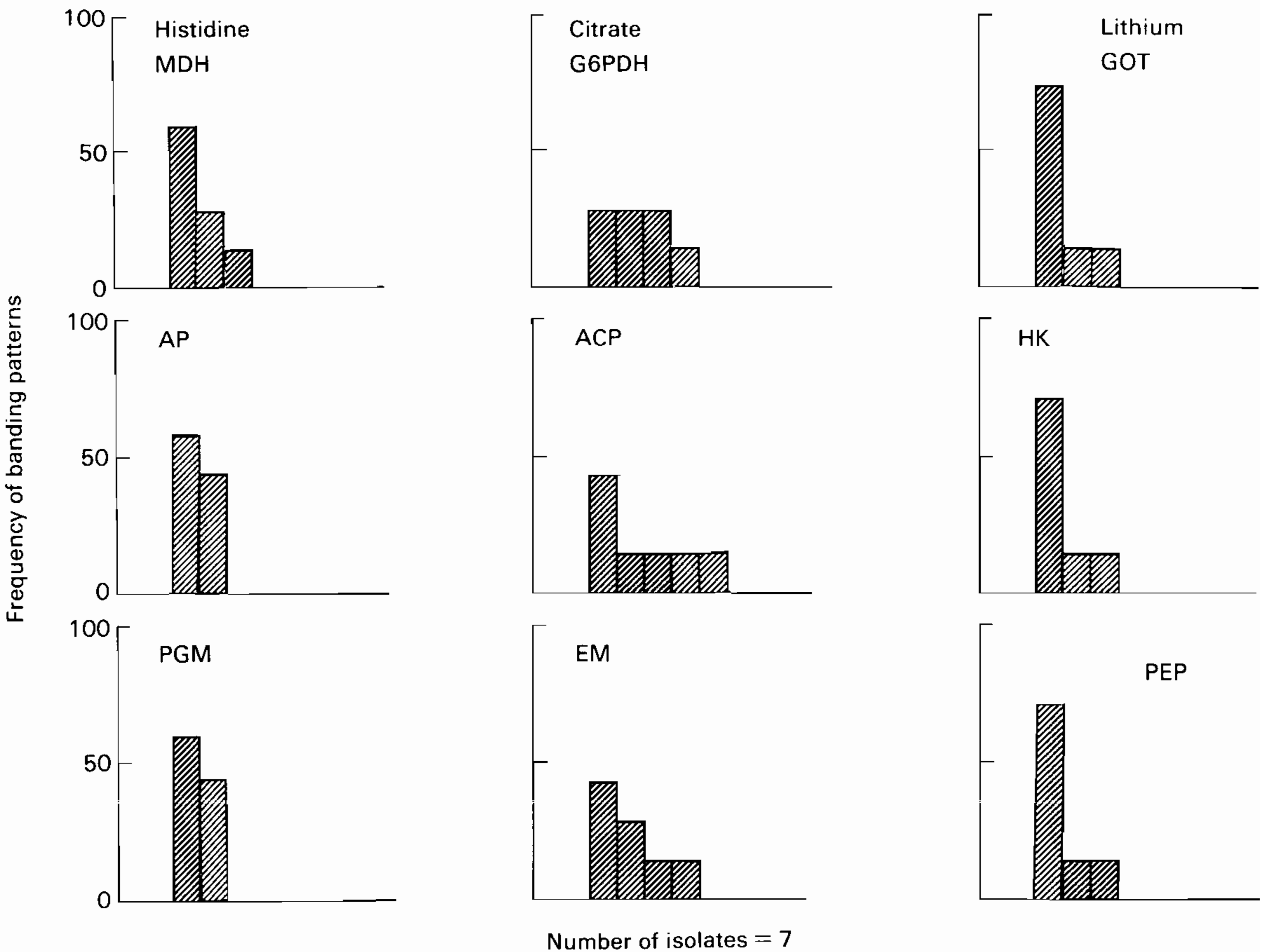


Table 5. Isozymes from Rhizoctonia analyzed in three different buffer systems

System	Isozyme	Abbreviation	E.C. number
Histidine	Malate dehydrogenase	MDH	1.1.1.37
	Alkaline phosphatase	AP	3.1.3.1.
	Phosphoglucomutase	PGM	2.7.5.1.
Citrate	Glucose-6-phosphate dehydrogenase	G6PDH	1.1.1.49.
	Acid phosphatase	ACP	3.1.3.2.
	Malic enzyme	EM	1.1.1.40.
Lithium	Glutamate-oxaloacetate transaminase	GOT	2.6.1.1.
	Hexokinase	HK	2.7.1.1.
	Peptidase	PEP	3.4.11.

exist between subspecific groups defined by banding patterns and other characteristics such as host and geographical origin and pathogenicity is presently being determined.

iv) Evaluation of field methodologies for improving screening for resistance to RFB among Centrosema species under field conditions.

Confident evaluation of resistance to RFB under field conditions is limited by lack of uniformity in disease incidence and development.

In close collaboration with the Plant Breeding section, several methodological experiments were initiated in Carimagua in 1987 and continued during 1988 with the aim of developing a reliable field screening methodology. Comparison of various inoculation and planting methods on RFB development in C.brasilianum CIAT 5234 failed to create an epidemic and to find any significant differences between treatments in 1987. Weekly inoculations were begun in June, 1988 to increase RFB. Due to application of more inoculum on the widely spaced rows than on the closely spaced rows, RFB levels were significantly higher in the former until August, 1988 (Table 6). In September, however, the inoculum methodology was modified to a more uniform application and significantly greater levels of RFB developed in the closely spaced treatment (Table 6).

The effect of inoculation time and frequency and defoliation frequency on incidence and severity of RFB in C. brasilianum CIAT 5234 and 5178 was also evaluated during 1987 and 1988. Although only low levels of RFB developed during 1987, significantly higher levels developed in the no defoliation and eight-week defoliation frequency treatments in comparison to two- and four-week frequency treatments (Table 7). As has been previously observed, CIAT 5178 was more susceptible than CIAT 5234 (Table 7).

RFB levels were increased during 1988 with weekly inoculations however, defoliation treatments

Table 6. Comparison of various planting methods for Rhizoctonia foliar blight of Centrosema brasilianum CIAT 5234 in 1988

Treatment	Mean RFB			
	Jun	Jul	Aug	Sep
Rows 2.5 m spacing	1.11 b	3.94 a	3.79 a	2.49 b
Rows 0.625 m spacing	1.56 a[1]	3.40 b	3.07 b[2]	2.74 a

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

1/ Artificial inoculation each 2 weeks

2/ Artificial inoculation modified

continued. Higher levels of RFB developed in the no defoliation treatment in comparison to other treatments and CIAT 5178 was again significantly more susceptible than CIAT 5234 (Table 7).

The following methodology is recommended for evaluation of reaction to RFB under field conditions: planting in closely spaced rows, no defoliation and frequent inoculation with pathogenic inoculum. This methodology will be used in future screening for resistance to RFB in the field.

v) Evaluation of Rhizoctonia foliar blight and other diseases of nine promising accessions of C. brasilianum under grazing.

In close collaboration with the Llanos Agronomy section, reaction to RFB and various other diseases of promising of C. brasilianum under grazing was carried out in Carimagua during 1988. RFB was the most serious disease with CIAT 5671 being the most susceptible accession (Table 8). The vigour of all accessions was generally poor with CIAT 5828 and 5486 being the most vigorous. Low levels of RFB in CIAT 5178 were confounded with its extremely low vigour (Table 8). Other minor diseases detected were Cylindrocladium leaf spot and Asteridella sooty mold. None of the accessions were considered promising under grazing. All accessions were significantly more vigorous in association with Brachiaria dictyoneura than with Andropogon gayanus and higher levels of RFB were generally encountered in C. brasilianum in the A. gayanus association (Table 8).

Table 7. Effect of defoliation frequency on severity of RFB in Centrosema brasilianum CIAT 5234 and 5178 during 1987 and 1988.

Accesion CIAT No.	1977		1978	
	(1)	(2)	(1)	(2)
5178	0	1.12 a	0	3.17 a
5234	0	0.78 b	0	2.40 bc
5178	8	0.55 c	8	3.12 a
5234	8	0.55 c	8	2.24 cd
5234	4	0.46 d	2	2.18 cd
5234	2	0.46 d	4	2.11 d
5178	4	0.39 d	4	3.05 a
5178	2	0.38 d	2	2.59 b
5178		0.61 a		2.98 a
5234		0.56 b		2.23 b
	0	0.95 a		2.78 a
	8	0.55 bc		2.68 ab
	4	0.42 c		2.58 b
	2	0.42 c		2.39 c

Rating scale: 0 = no diseases;
5 = plant death.

(1) Defoliation frequency weeks

(2) Mean RFB severity

Table 8. Evaluation of reaction to Rhizoctonia foliar blight (RFB), Cylindrocladium leaf spot (CYL), Asteridella sooty mold (AST) and vigour of nine accessions of *Centrosema brasilianum* in association with *Andropogon gayanus* and *Brachiaria dictyoneura* (DT-04-87)

Accession	Mean reaction to			
	RFB	CYL	AST	Vigour
5671	2.3 a	1.1 a	0.1 d	3.1 b
5828	2.0 ab	0.5 cd	1.2 a	2.1 c
5486	2.0 ab	0.3 d	0.7 bc	2.4 c
5234	1.9 ab	1.1 ab	0.2 d	3.0 b
5667	1.5 ab	1.2 a	0 d	3.8 a
5657	1.3 ab	0.6 bcd	0.1 d	3.4 ab
5725	1.2 ab	0.7 abcd	1.1 ab	3.0 b
5178	1.1 b	1.0 abc	0 d	3.8 a
5810	1.2 b	0.7 abcd	0.3 cd	3.4 ab
Association:				
A. gayanus	1.75 a	0.73 a	0.28 b	3.32 a
B. dictyoneura	1.46 a	0.82 a	0.53 a	2.87 b

Rating scale diseases: 0 = no disease; 5 = plant death.
Rating scale vigour: 1 = excellent; 4 = poor.

b) Cylindrocladium leaf spot (CYL)

Centrosema species including 29 accessions of *C. acutifolium* were evaluated for reaction to *Cylindrocladium colhounii* the causal agent of CYL (Table 9). Three accessions of *C. acutifolium* and *C. pubescens* CIAT 438 were most susceptible. The moderate to high susceptibility of accessions of *C. acutifolium*, *C. pubescens* and *C. macrocarpum* is confirmed by field evaluations in the Llanos and moderately acid soil ecosystems. In general, the most susceptible accessions of *C. acutifolium* originated from Mato Grosso, Brazil and Vichada, Colombia (CIAT 15291, 15281 and 5277) while the most resistant were from Goias and Minas Gerais, Brazil (CIAT 5597, 15353) (Table 10). Potential for breeding for resistance to CYL exists in the *C. acutifolium* collection.

Table 9. Preliminary evaluation of *Centrosema* species for reaction to Cylindrocladium leaf spot.

Species	Acces-sion No.	Reaction to CYL	
		Mean	Range
C. tetragonolobum	10	0.1	(0-0.8)
C. brasilianum	1	0.3	
C. macrocarpum	1	2.1	
C. acutifolium	26	3.2	(2.6-3.8)
C. acutifolium	3*	4.0	(3.9-4.1)
C. pubescens	1	4.1	

0 = no disease; 5 = leaf death

* CIAT 15291, 15281 and 5277

Table 10. Reaction of accessions of *Centrosema acutifolium* to *Cylindrocladium* leaf spot

Origin	Accession No.	Reaction to CYL: Mean	Range
Mato Grosso, B	13	3.58	4.17-3.00
Vichada, C	5	3.47	3.94-2.89
Amazonas, V	3	3.19	3.39-3.06
Goias, B	6	3.12	3.39-2.72
Minas Gerais, B	1	2.70	-

0 = no disease, 5 = leaf death.
B = Brazil, C = Colombia, V = Venezuela.

c) Dieback syndrome of *C. acutifolium* cv. Vichada

An unusual dieback syndrome of *C. acutifolium* cv. Vichada was first detected in seed production plots in 1986. It has since been detected in the Llanos including Carimagua, Tolima, Valledupar, Pance and Quilichao, Colombia but as yet not in other countries. Various fungi, including species of *Fusarium*, *Curvularia* and *Phoma*, and bacteria were isolated from affected plants however were non-pathogenic in inoculation tests. Two plants affected by root-knot nematode *Meloidogyne arenaria* were found.

The frequent occurrence of dieback in cv. Vichada in seed production plots with support and its absence in pastures prompted a survey in Quilichao and Carimagua. Of 86 and 173 affected plants in Quilichao and Carimagua, respectively, 96.5% in Quilichao and 99.4% in Carimagua were on supports in seed production plots (Table 11). A sample of affected plants from Quilichao, Carimagua and Pance were further evaluated. More than 50% showed evidence of insect damage and/or mechanical damage at the collar or upper roots (Table 12). *Fusarium* species were commonly isolated from damaged plants.

Table 11. Effect of support on occurrence of dieback syndrome in *C. acutifolium* cv. Vichada in Quilichao and Carimagua

	Quilichao	Carimagua
No. of affected plants	86	173
Percentage plants:		
- with support	96.5	99.4
- without support	3.5	0.6

Table 12. Evaluation of sampled plants of *C. acutifolium* cv. Vichada with dieback syndrome

	Quilichao	Carimagua	Pance
No. of affected plants sampled	29	36	20
Percentage insect damage[1]	38	33	40
Percentage mechanical damage[2]	17	19	20

1/ Stemborer damage
2/ Damage from machete and/or hoe

The effect of various Fusarium species isolated from damaged or wounded plants on cv. Vichada with and without wounding at the collar or roots was evaluated in the glasshouse. Fusarium species from Valledupar, Pance and Carimagua were used. Fusarium sp Carimagua 2 and Carimagua 3 were more pathogenic to cv Vichada with wounding than without wounding, however no relationship was found with other Fusarium species (Table 13).

Table 13. Effect of Fusarium species and wounding on development of dieback syndrome in C. acutifolium cv. Vichada

Origen of Fusarium species	Mean severity dieback -Wounding	+Wounding collar	+Wounding roots
Valledupar	0.3	0.5	0
Pance	1.8	0.3	0
Carimagua 1*	1.0	0.3	1.0
Carimagua 2*	2.5	1.3	5.0
Carimagua 3*	0.8	1.7	0.5
Control	0	0	0

Rating scale: 0 = no disease,
5 = plant death.

* Different unidentified Fusarium species from Carimagua.

It is probable that C. acutifolium cv. Vichada is more susceptible to biotic and abiotic factors and their interactions which affect its crown and roots when it is supported during seed production than when it is growing in a pasture. The dieback syndrome which results may therefore be caused by different factors and or different interactions of factors which are site-specific. Further work is recommended on this problem.

d) Relative adaptation of Centrosema species across seven sites in Carimagua from 1985 to 1988

Although the Llanos is classified as a single ecosystem, considerable variation occurs with respect to soil and climatic characteristics. In order to evaluate the relative adaptation of eight accessions of four Centrosema species across the micro-ecosystems of Carimagua, seven different sites were chosen: Alegria, Yopare, Torre, Pista 1, Pista 2, Agronomia and Acuario, with a range of soil types, particularly. Alegria soil has 60% sand while Agronomia has 5% sand (CIAT 1987). Reaction to RFB, CYL, Cercospora leaf spot (CER), Bacteriosis (B) and sucking insects as well as vigour were evaluated. Dry matter production was measured in 1987 and 1988.

C. acutifolium CIAT 5568 and four accessions of C. brasilianum CIAT 5234, 5178, 5184 and 5514 were more affected by RFB than other species (Table 14). However, RFB of CIAT 5568 is also complexed with Phoma/Phomopsis leaf spot. RFB was more severe at Pista 2, Yopare, Torre and Acuario than at Agronomia (Table 14). C. pubescens CIAT 438, C.macrocarpum CIAT 5062 and C. acutifolium CIAT 5278 were significantly more affected by CYL and CER than other species (Table 15). Less leaf spotting was encountered at Agronomia (as for RFB) than at other sites. Bacteriosis was low at all sites; none was detected at Alegria. CIAT 5278 was most affected. All four C. brasilianum accessions were more severely affected by sucking insects than other species (Table 16). The Acuario site supported significantly higher sucking insect damage than other sites possibly due to the concentration of Centrosema seed production at this site while Alegria, the most isolated site, showed least

Table 14. Mean severity of Rhizoctonia foliar blight on *Centrosema* species across seven sites in Carimagua from 1985 to 1988

Site		Mean RFB
Pista 2		1.04 a
Yopare		0.97 a
Torre		0.98 a
Acuario		0.89 a
Pista 1		0.70 b
Alegria		0.58 b
Agronomia		0.37 c
Species	Accesion No.	Mean RFB
C. acutifolium	5568*	1.29 a
C. brasilianum	5234	1.16 b
C. brasilianum	5178	1.04 b
C. brasilianum	5178	1.07 b
C. brasilianum	5514	0.91 c
C. pubescens	438	0.38 d
C. acutifolium	5278	0.33 d
C. macrocarpum	5062	0.12 e

Rating scale: 0 = no disease,
5 = plant death

* Associated with *Phoma/Phomopsis* complex

sucking insect damage. *C. acutifolium* CIAT 5278 was the most vigorous and productive accession over all sites (Tables 17 and 18). *C. macrocarpum* CIAT 5062 and *C.acutifolium* CIAT 5568 were the next productive while *C. pubescens* CIAT 438 was the least productive. Dry matter productivity on a site basis was variable although Pista 1 was always one of the most productive sites (Table 19). The Agronomia site was among the most productivity at the first harvest however was affected by herbicides and deer for subsequent harvests.

Results from this multilocational trial across micro-ecosystems in Carimagua have shown clearly that *C. acutifolium* CIAT 5278 (considered a genetic duplicate of cv. Vichada) is the most widely adapted, vigorous and productive accession within the eight accessions evaluated. This trial also confirmed the susceptibility of *C. brasilianum* to RFB and sucking insects and the more common association of CER and CYL with *C. pubescens*, *C. macrocarpum* and some *C. acutifolium* germplasm. Results suggest that information obtained from screening in one well-selected site in Carimagua can be readily extrapolated to a range of Llanos micro-ecosystems with respect to the relative adaptation of *Centrosema* species.

Table 15. Mean severity of Cercospora and Cylindrocladium leaf spots on *Centrosema* species across seven sites in Carimagua from 1985 to 1988

Site		Mean leaf spot
Pista 1		0.85 a
Acuario		0.81 a
Pista 2		0.77 ab
Yopare		0.77 ab
Torre		0.70 bc
Alegria		0.66 c
Agronomia		0.56 d
Species	Accession No.	Mean leaf spot
C. pubescens	438	1.65 a
C. macrocarpum	5062	1.40 b
C. acutifolium	5278	1.07 c
C. brasilianum	5184	0.46 d
C. brasilianum	5234	0.39 de
C. acutifolium	5568	0.37 def
C. brasilianum	5178	0.27 ef
C. brasilianum	5514	0.26 f

Rating scale: 0 = no disease
5 = plant death

Figure 8.

Effect of stocking rate and grazing system on severity and incidence of bacteriosis in *Centrosema acutifolium* CIAT 5277.

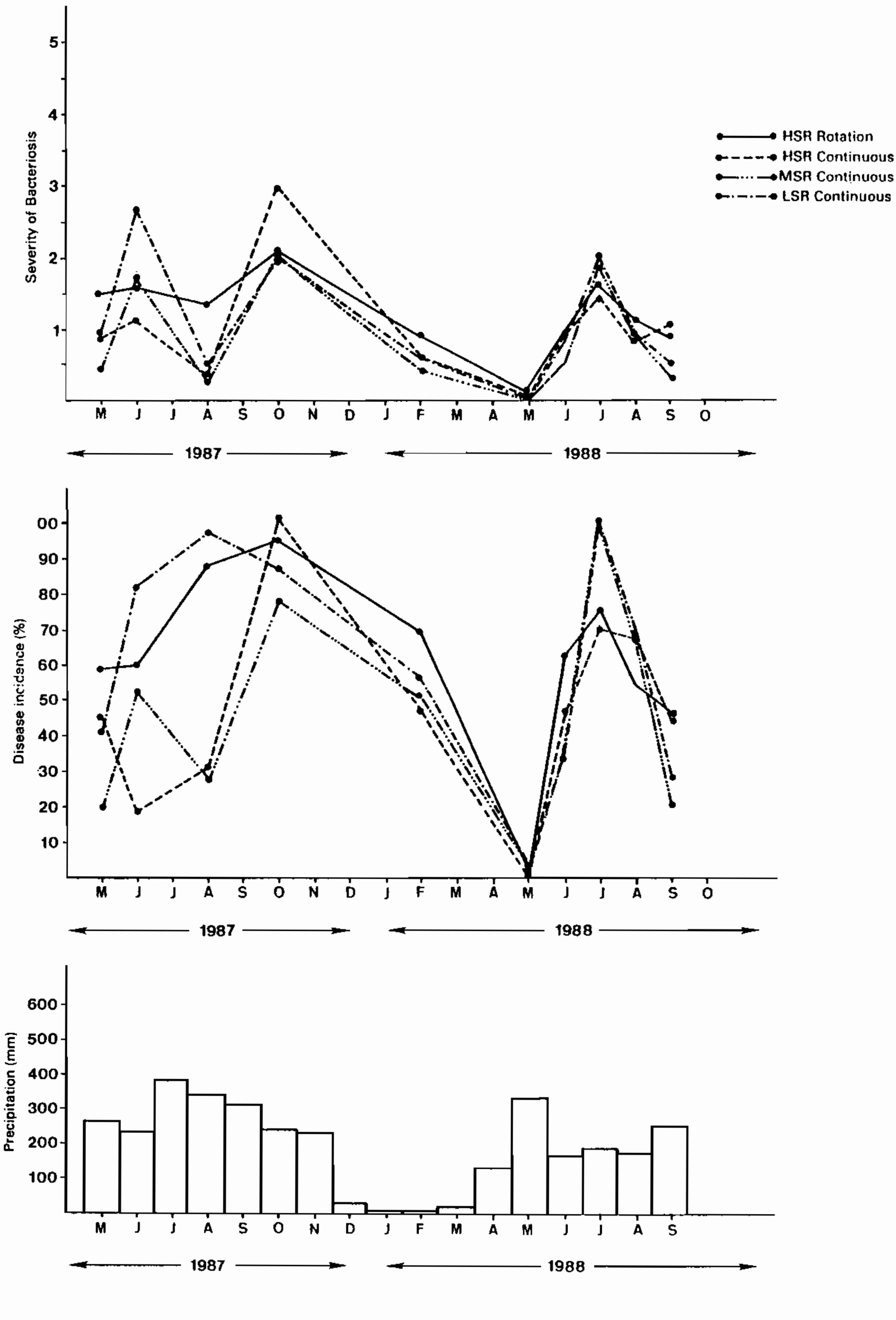


Figure 9.

Effect of stocking rate and grazing system on severity and incidence of Cylindrocladium leaf spot in *Centrosema acutifolium* CIAT 5277.

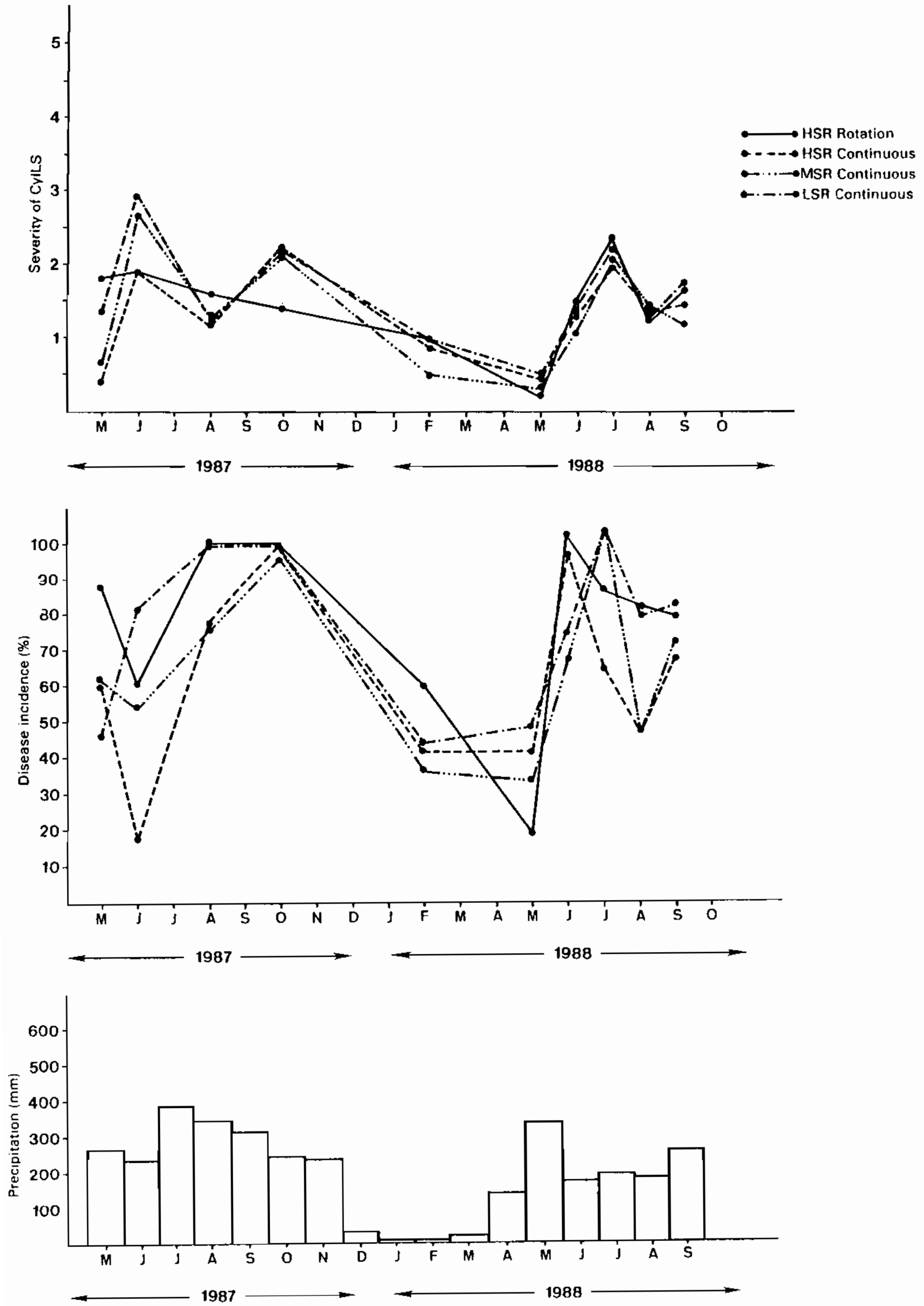


Table 16. Mean sucking insect damage on Centrosema species across seven sites in Carimagua from 1985 to 1988

Site		Mean sucking insect damage
Acuario		1.36 a
Agronomia		1.14 b
Pista 1		1.03 bc
Pista 2		1.03 c
Torre		0.90 d
Yopare		0.75 e
Alegria		0.63 f
Species	Accession No.	Mean sucking insect damage
C. brasilianum	5514	1.66 a
C. brasilianum	5234	1.53 a
C. brasilianum	5184	1.38 b
C. brasilianum	5178	1.31 b
C. acutifolium	5278	0.64 c
C. pubescens	438	0.56 cd
C. macrocarpum	5062	0.44 de
C. acutifolium	5568	0.31 e

Rating scale: 0 = no disease
5 = severe damage

Table 17. Mean vigour of eight accessions of four Centrosema species across seven sites in Carimagua from 1985 to 1988

Species	Accession No.	Mean vigour
C. acutifolium	5278	1.75 a
C. macrocarpum	5062	2.23 b
C. brasilianum	5184	2.33 bc
C. brasilianum	5178	2.43 cd
C. acutifolium	5568	2.54 d
C. brasilianum	5514	2.92 e
C. brasilianum	5234	3.06 f
C. pubescens	438	3.11 f

Rating scale: 1 = excellent, 4 = poor
* Affected by herbicide and deer.

e) Evaluation of diseases of C. acutifolium under grazing

Emphasis continued this year on evaluation of the incidence and severity of diseases of C. acutifolium under grazing in two separate grazing trials in collaboration with the Animal Management and Productivity Section. Spot evaluations of disease incidence and severity were made along transect lines.

i) Evaluation of diseases in cv. Vichada and CIAT 5568 in association with A. bicornis under rotational grazing at high stocking rate and under continuous grazing at low, medium and high stocking rates.

CYL and B were the most frequently detected diseases in cv. Vichada. With the exception of the evaluations of October, 1987, the incidence and severity of B were lower under the continuous grazing high stocking rate treatment than under other treatments (Figure 8). Similarly, the incidence of CYL was lower under continuous grazing high and medium stocking rates than other treatments with the exception of the May 1988 evaluation (Figure 9). The severity of CYL in cv. Vichada was variable: during early to mid wet season in 1987 and 1988 continuous grazing high stocking rate showed lowest CYL however during the late wet season in 1987, lower CYL was recorded in rotational grazing high stocking rate (Figure 9). Although a less serious disease in CIAT 5568 than cv. Vichada lower incidence and severity of CYL were also favoured by continuous grazing high stocking rate (Figure 11).

The effect of stocking rate and grazing system on the RFB Phoma/ Phomopsis complex in C.acutifolium CIAT 5568 was particularly obvious

Table 18. Dry matter production of *Centrosema* species across seven sites in Carimagua during 1987 and 1988

Site		Dry matter production (gm/m^2)		
		September 1987	December 1987	August 1988
Pista 1		1080.1 a	256.8 b	635.9 ab
Torre		1069.2 a	18.1 e	703.0 a
Agronomia		1026.6 a	31.5 e*	NH *
Alegria		884.6 a	187.9 c	335.7 c
Acuario		521.0 b	64.7 d	278.6 c
Pista 2		448.0 b	320.4 a	527.6 b
Yopare		375.1 b	357.0 a	531.4 b
Species:	Accession No.			
C. acutifolium	5278	1673.5 a	473.6 a	1261.0 a
C. macrocarpum	5062	951.1 b	350.8 b	589.0 b
C. acutifolium	5568	919.2 b	171.1 c	612.5 b
C. brasilianum	5184	748.1 bc	106.1 d	432.4 bc
C. brasilianum	5178	573.7 c	122.0 cd	315.4 c
C. brasilianum	5514	549.9 c	88.3 e	398.3 c
C. brasilianum	5234	516.3 ce	76.1 e	295.0 c
C. pubescens	438	246.9 d	3.8 f	112.8 d

* Affected by herbicide and deer (NH = no harvest)

Table 19. Effect of Rhizoctonia foliar blight-Phoma/Phomopsis complex and Cylindrocladium leaf spot on *Centrosema acutifolium* CIAT 5568 from May 87 to August 88.

Treatment	Mean disease rating		Loss (%)
	RFB/P/P	CYL	
- Fungicide	2.54 a	0.71 a	12.8
- Fungicide	1.43 b	0.38 b	

Effect of Bacteriosis and Cylindrocladium leaf spot on *Centrosema acutifolium* CIAT 5277 from May 87 to August 88

Treatment	Mean disease rating		Loss (%)
	RFB/P/P	CYL	
+ Fungicide	2.05 a	2.83 a	29.8
- Fungicide	1.24 b	2.32 b	

(Figure 10). Both incidence and severity of the complex was always lower under continuous grazing than under rotational grazing and generally the lowest levels were recorded under continuous grazing high stocking rate (Figure 10).

As was observed in 1987, higher stocking rate under continuous grazing favors lower levels of diseases in both C. acutifolium accessions.

Losses due to the combination of diseases on cv. Vichada and CIAT 5568 are also being monitored. Using a sequence of fungicides to control CYL, B, and RFB - Phoma/Phomopsis, dry matter production and disease severity were recorded from May 1987 to August 1988 (Table 19). Although fungicides significantly reduced the severity of diseases affecting CIAT 5568, dry matter losses were low (Table 19). Apparently, these diseases are not greatly affecting production of this accession. Fungicides significantly reduced B and to a lesser extent CYL with resulting dry matter loss values of 29.8% in cv. Vichada (Table 19). As the combination of fungicides does not appear to be controlling CYL, most of this loss is attributable to B which at moderate levels is capable of causing 30% dry matter loss. Further long-term assessment is needed to determine whether such dry matter losses will affect pasture persistence.

ii) Evaluation of diseases of C. acutifolium cv. Vichada in association with B. decumbens under two rotational grazing treatments.

In May 1987, rotational grazing treatments 7/7 and 21/21 were imposed on this experiment. In June 1988, they were changed to 14/14 and 28/28, respectively. B, CYL, RFB, sucking insect damage and Asteridella sooty mold were evaluated. Although no significant differences were encountered between treatments, for every biotic paramater, high mean severity was encountered in the longer rotation in comparison to the shorter rotation (Table 20). In addition, mean incidence and severity of bacteriosis (Figure 12) and Cylindrocladium leaf spot (Figure 13) were lower at almost all evaluations in the shorter than the longer rotation.

Table 20. Effect of rotation on levels of bacteriosis, Cylindrocladium leaf spot, Rhizoctonia foliar blight and sucking insect damage in Centrosema acutifolium CIAT 5277 in Carimagua from May 1987 to September 1988

	Mean severity	
Parameter	Rotation 21/21, 28/28	Rotation 7/7, 14/14
-Bacteriosis	1.25 a	0.82 a
-Cylindrocladium leaf spot	1.27 a	0.88 a
-Rhizoctonia foliar blight	1.01 a	0.84 a
-Sucking insect damage	1.38 a	1.14 a
-Asteriella sooty mold	0.05 a	0 a

Figure 10

Effect of stocking rate and grazing system on severiy and incidence of Rhizoctonia foliar blight in *Centrosema acutifolium* CIAT 5568.

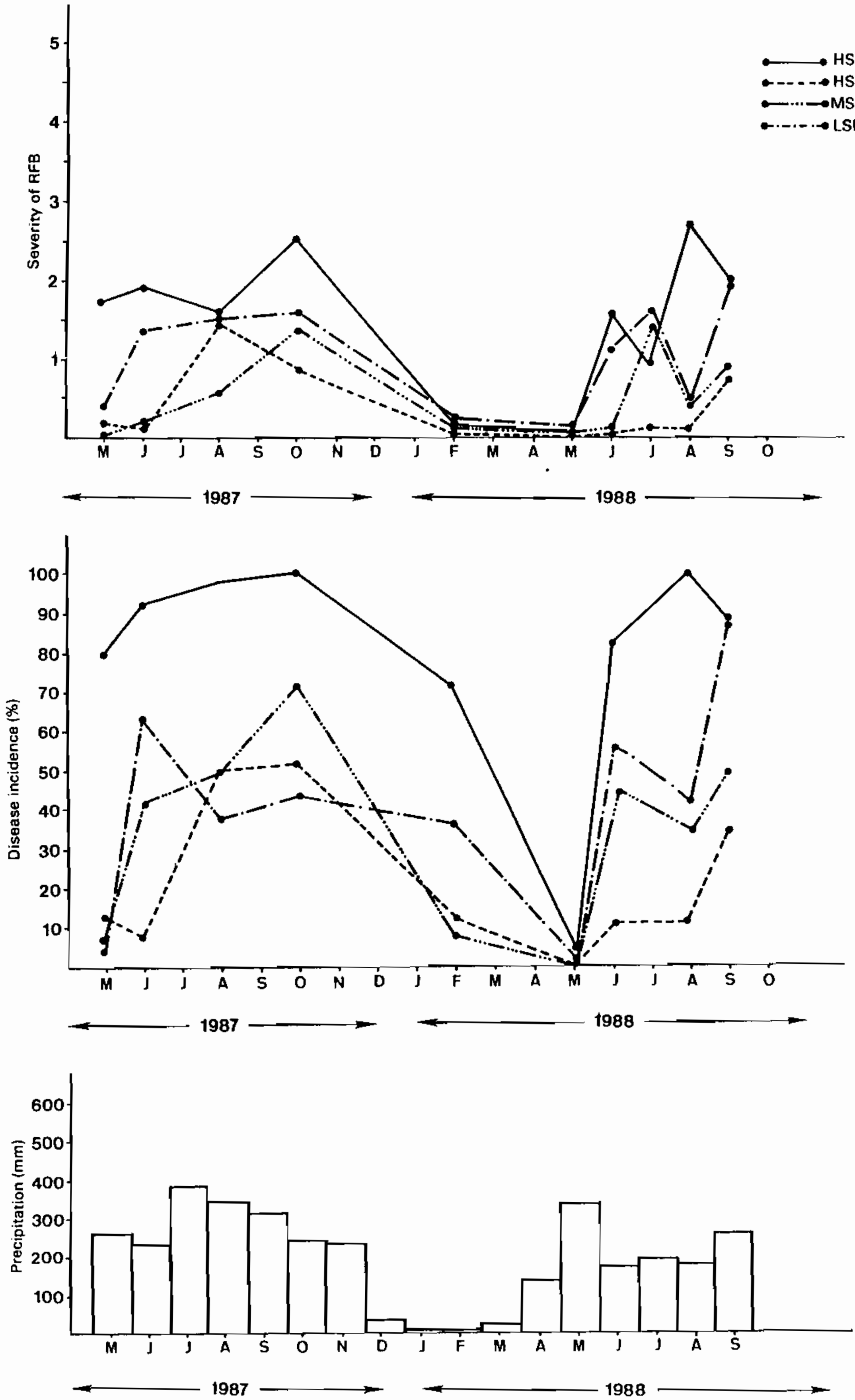


Figure 11.

Effect of stocking rate and grazing system on severity and incidence of Cylindrocladium leaf spot in *Centrosema acutifolium* CIAT 5568.

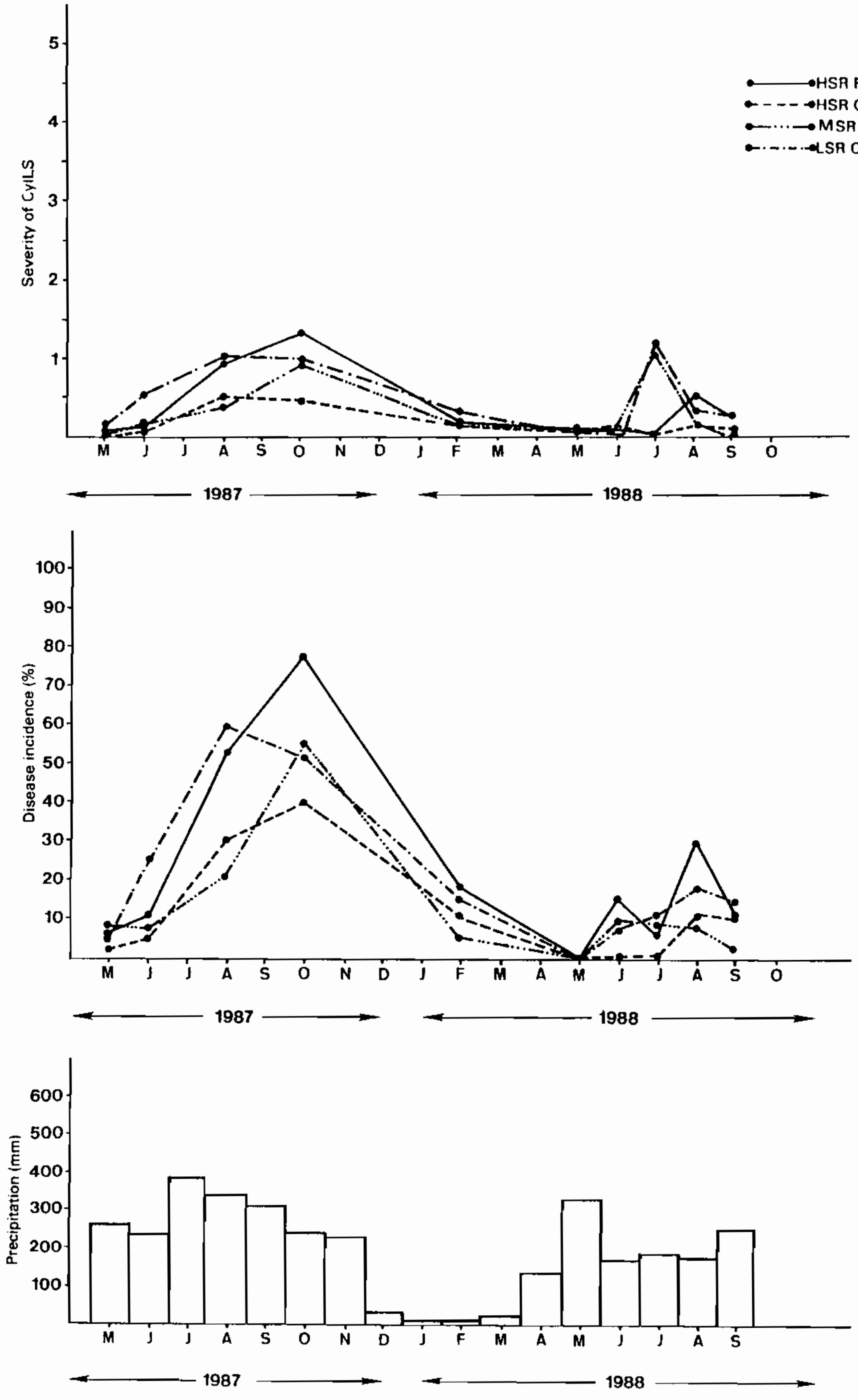


Figure 12. **Effect of grazing rotation on incidente and severity of bacteriosis in *Centrosema acutifolium* cv. Vichada.**

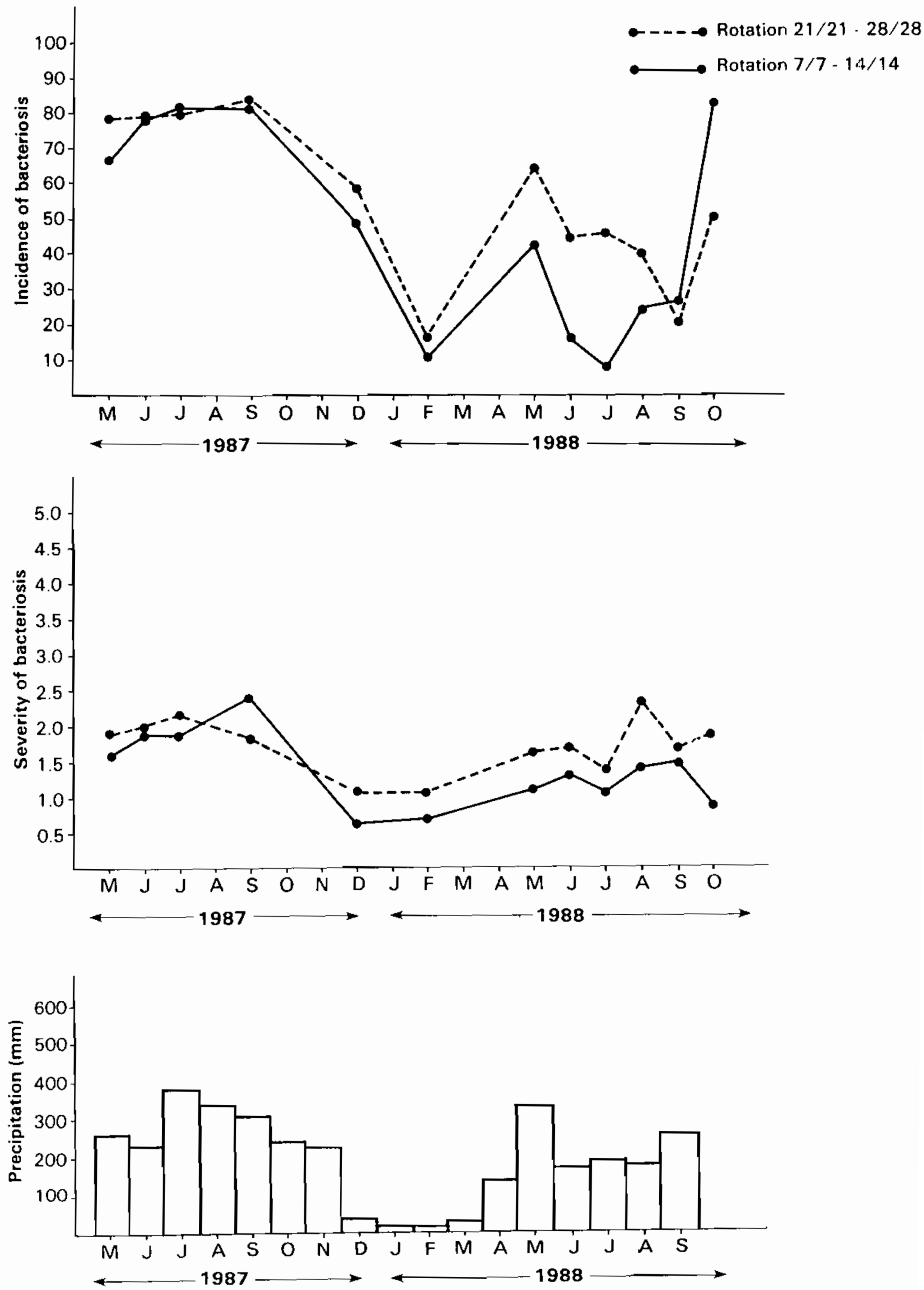
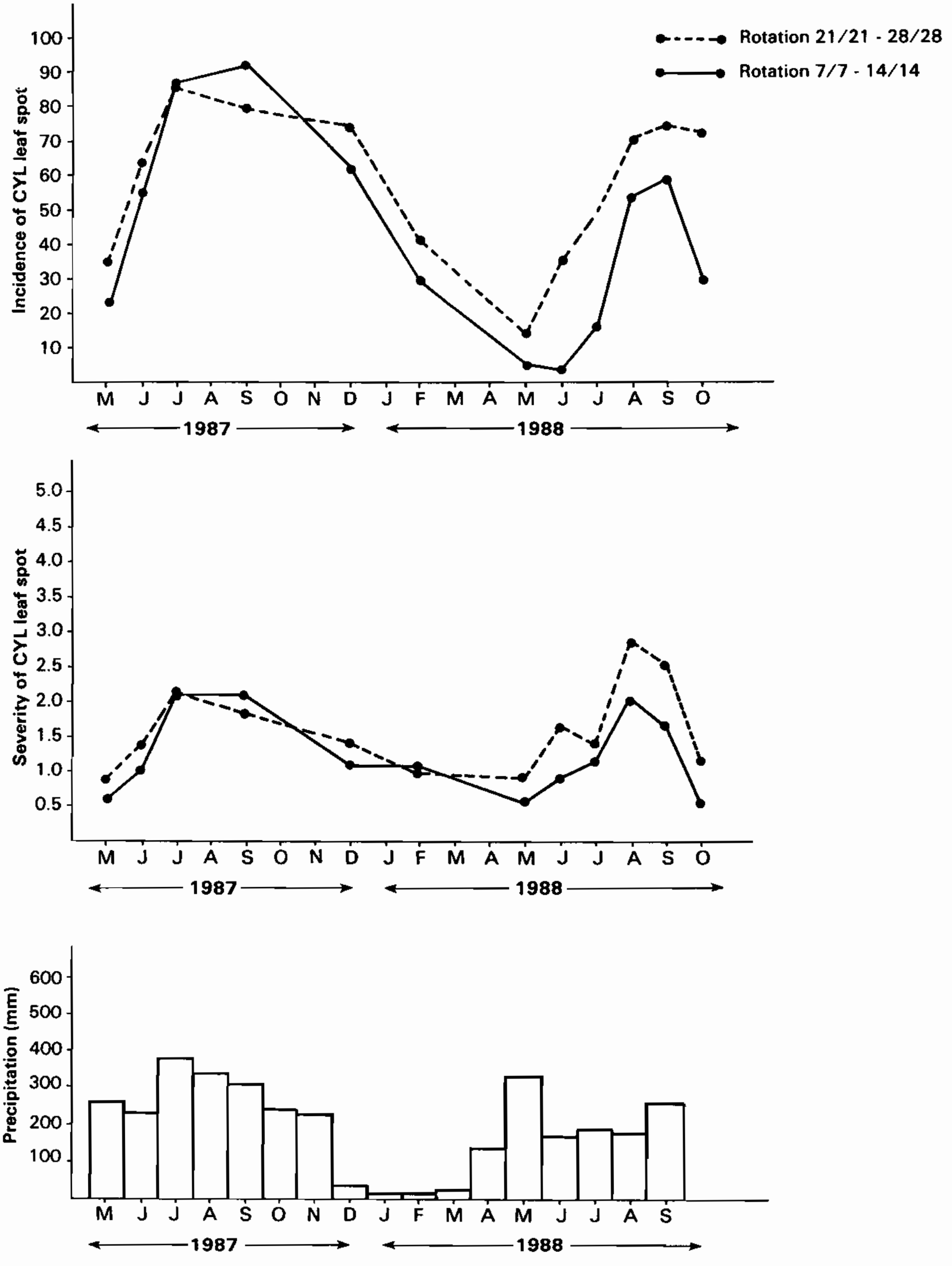


Figure 13.

Effect of grazing rotation on incidence and severity of Cylindrocladium leaf spaot in *Centrosema acutifolium* cv. Vichada.



f) Present status of diseases of Centrosema species throughout major ecosystems of tropical America can be summarized as follows:

i) Rhizoctonia foliar blight: RFB is widely distributed throughout major ecosystems of tropical America however it is most serious in more humid areas (above 2000 mm annual precipitation). It affects at least ten Centrosema species however C. brasilianum is most susceptible.

RFB causes losses of up to 50% dry matter and reduced seedling survival in the Llanos. A complex of at least four Rhizoctonia species causes RFB with R. solani AG-1 being most pathogenic (42.4% of isolates).

Electrophoretic studies have provided valuable additional information on inter- and intra-specific relationships suggesting sub-groups within R. solani and BNR.

Reliable glasshouse screening methodologies did not identify resistance to RFB in C. brasilianum or C. tetragonolobum. It is recommended that C. brasilianum should be restricted to dryer regions (less than 1500 mm). High levels of resistance encountered in C. macrocarpum and C. acutifolium could be used in a wide crossing program.

ii) Cylindrocladium leaf spot: CYL is distributed throughout the Llanos and moderately acid soils ecosystems principally affecting C. acutifolium, C. pubescens and C. macrocarpum. CYL causes chlorosis and defoliation of mainly mature leaves. Germplasm from Vichada, Colombia and Mato Grosso, Brazil is most susceptible while that from Amazonas, Venezuela, Goias and Minas Gerais, Brazil is most resistant.

iii) Bacteriosis: Bacteriosis is distributed through the Llanos and moderately acid soils ecosystems principally affecting C. acutifolium. It is the most damaging disease of cv. Vichada in the Llanos wet season particularly affecting young growth. Germplasm from Mato Grosso, Brazil, Vichada, Colombia and Amazonas, Venezuela is highly susceptible while that from Goias and Minas Gerais, Brazil is highly resistant.

The cross of C. acutifolium cv. Vichada with CIAT 5568 is recommended as a potential source of resistance to RFB-Phoma/Phomopsis complex, B and CYL.

iv) Centrosema Mosaic Virus: (CenMV) CenMV is a problem to initial germplasm evaluation and seed multiplication in Quilichao however it has not been detected in Centrosema pastures in Carimagua or in major germplasm screening sites in Pucallpa, Peru, Brasilia or Guapiles, Atenas or San Isidro in Costa Rica. A strong recommendation to move out of Quilichao continues. As the transmission rate of CenMV is low (0.5 - 2.0% Niessen, pers. comm.), seed could be readily cleaned-up without sacrificing intra-accession variability.

DISEASES OF DESMODIUM

a) Synchytrium wart or false rust disease

Evaluation of the effect of Synchytrium desmodii on adult plant yield and performance was continued during 1988 with a comparison of the most stem gall resistant accessions of Desmodium ovalifolium CIAT 13089, 13092, 13129, 3776, 3794 and control

350. Under both flooded and non-flooded conditions, CIAT 13089 produced the greatest cover percentage, was the most vigorous and had less Synchytrium. CIAT 13089 significantly out-performed all other accessions under flooded conditions and was significantly better than CIAT 3776 and 3794 under non-flooded conditions (Table 21). CIAT 13089 also out-yielded all other accessions with and without flooding at two sites in Carimagua and significantly so at site 2 (Table 22). The poor dry matter yields of CIAT 350 under flooding at both sites suggests that this accession is less tolerant of flooding than the others.

One of the major problems to date with Synchytrium wart disease has been the inability to obtain standardized inoculum for seedling screening. Field derived-inoculum is not uniform enough. This year we found that Synchytrium desmodii will grow on Desmodium tissue culture medium. To date, sporangia and zoospores have been obtained from the cultures however infection of seedlings has not yet been achieved. Further work should concentrate on conditions necessary for production of infective zoospores.

Table 21. Effect of Synchytrium desmodii on various accessions of Desmodium ovalifolium in Carimagua from May 1987 to September 1988

Accession	Cover (%)	Vigour	Reaction to Synchytrium
+ Flooding:			
13089	72.3 a	2.9 a	0.8 c
13092	58.7 b	2.4 b	1.5 bc
3776	52.8 bc	2.0 c	1.8 ab
350	50.9 bc	1.9 c	2.1 ab
13129	49.0 bc	2.1 bc	2.5 a
3794	38.8 c	1./ c	2.1 ab
- Flooding:			
13089	82.6 a	3.2 a	0.3 c
13092	71.3 ab	2.7 ab	1.2 ab
350	70.5 ab	2.8 ab	0.7 bc
13129	70.0 ab	2.8 ab	1.3 ab
3776	67.1 b	2.4 b	1.8 a
3794	61.0 b	2.5 b	1.3 ab

- r Syn/cover = - 0.17
- r Syn/vig = - 0.41
- Vigour: 1 = poor, 4 = excellent
- Reaction to Synchytrium: 0 = no diseases; 5 = plant death

Table 22. Effect of Synchytrium desmodii on yield of Desmodium ovalifolium in Carimagua. Harvest August 1988

Accession	Site 1 (gm/m^2)		Site 2 (gm/m^2)	
	+ Flooding	- Flooding	+ Flooding	- Flooding
13089	335.1 a	421.3 a	435.0 a	531.2 a
13129	149.a b	332.0 a	200.5 bc	407.3 b
13092	102.4 b	380.6 a	278.9 b	408.2 b
3776	85.8 c	254.2 a	131.0 cd	351.4 bc
3794	81.7 c	239.4 a	80.3 d	290.4 c
350	78.2 c	316.6 a	135.6 cd	374.0 bc

b) Stem gall nematode

Work continued on the evaluation of resistance to stem gall nematode (Pterotylenchus cecidogenus) of unscreened D. ovalifolium germplasm. Twenty accessions were evaluated with CIAT 350 and selected resistant CIAT 13089 as controls. Several accessions were as resistant as CIAT 13089: CIAT 13131, 13370, 13649, 13651, 13652 and 13655 (Table 23). These are worth evaluating further for agronomic characteristics (Table 23).

Table 23. Reaction of accessions of D. ovalifolium to stem gall nematode Pterotylenchus cecidogenus

Accession No.	Presence of galls	x of nematodes
13090	+	180.8
13657	+	172.5
13134	+	139.5
350*	+	138.6
13656	+	125.4
3674	+	121.9
13647	+	119.1
13654	-	110.9
13646	+	104.6
13653	+	100.1
13648	+	99.9
13099	+	97.6
13096	+	88.6
13098	+	83.4
13650	+	51.6
13089**	-	0
13131	-	0
13370	-	0
13649	-	0
13651	-	0
13652	-	0
13655	-	0

* Control
** Most resistant accession of previous screenings

Stem gall nematode was detected for the first time on accessions of Desmodium strigillosum CIAT 13155, 13158 and D. velutinum CIAT 13204, 13213 and 13215 in a grazing trial associated with savanna in Carimagua. As both legumes have promise for the Llanos ecosystem, screening of germplasm collections to identify resistant accessions is in progress.

In an attempt at localizing future collecting areas for D. ovalifolium, disease evaluation information for its three key disease problems: Synchytrium wart or false rust, stem gall nematode and nine species and races of Meloidogyne was superimposed on collection locations. For stem gall nematode, native to the Colombian Llanos and not recorded in South-east Asia, random location of resistant and susceptible accessions was found (Figure 14). For Synchytrium wart disease, native to parts of South-east Asia but not recorded in the literature on D. ovalifolium in Thailand, clusters of resistant and susceptible accessions were found particularly in southern Thailand (Figure 15). This may indicate some host-pathogen co-evolution. And, for root knot nematode, a world-wide pathogen of tropical legumes and reported widely in South-east Asia, clearly defined clusters of resistant germplasm were identified in Malaysia, Southern Thailand and near the Thailand - Laos border (Figure 16). Future needs for germplasm resistant to Synchytrium and root knot nematode should be concentrated in areas defined by these clusters of resistant germplasm.

c) Present status of diseases of Desmodium species throughout major ecosystems of tropical America can be summarized as follows:

D. ovalifolium CIAT 13089 has continued to show high resistance to stem gall nematode and high "tolerance" to Synchytrium wart disease in various trials in Carimagua. Several new

Figure 14. Location of collection sites and most resistant and susceptible accessions of Desmodium ovalifolium to stem gall nematode.

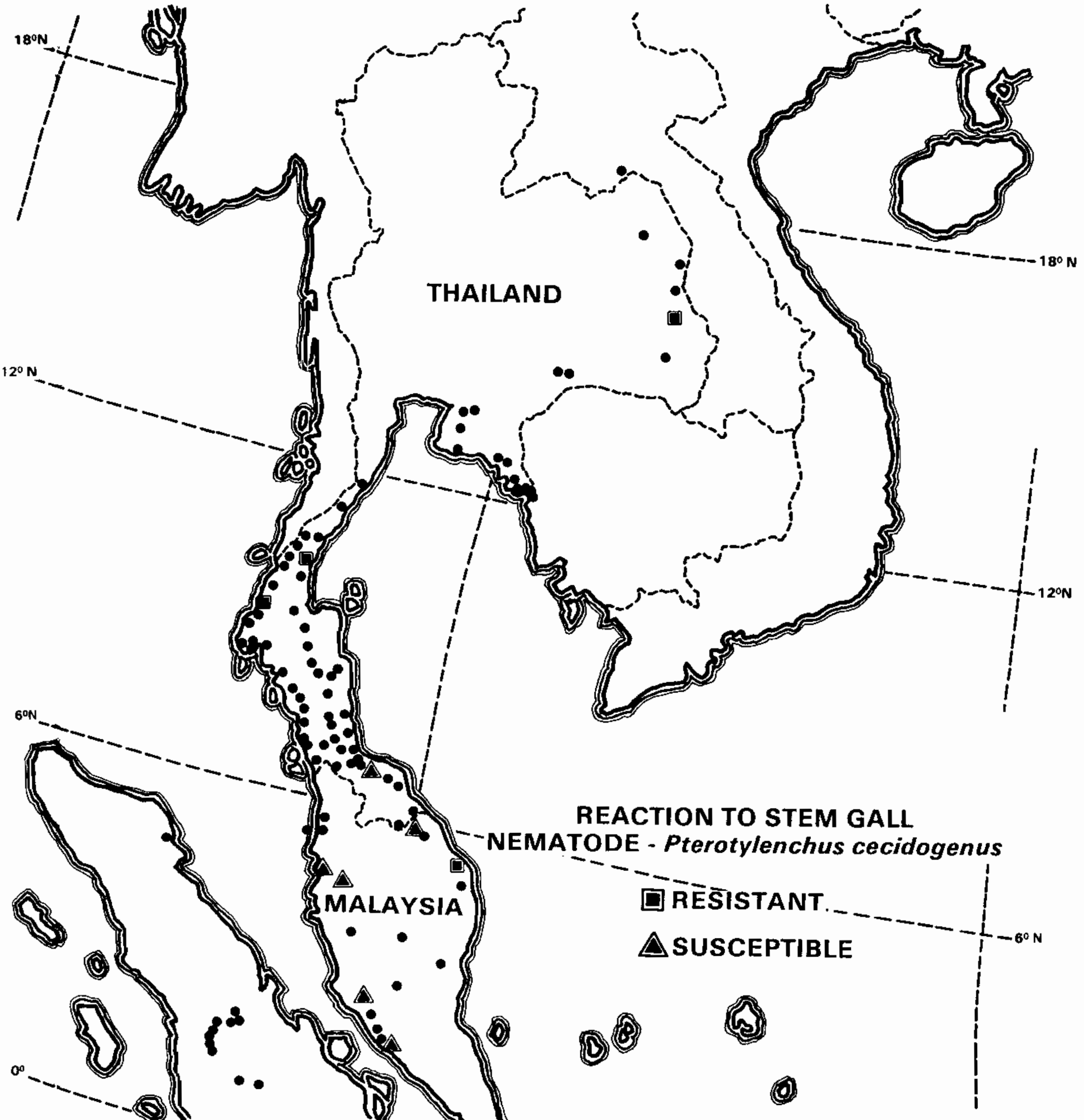
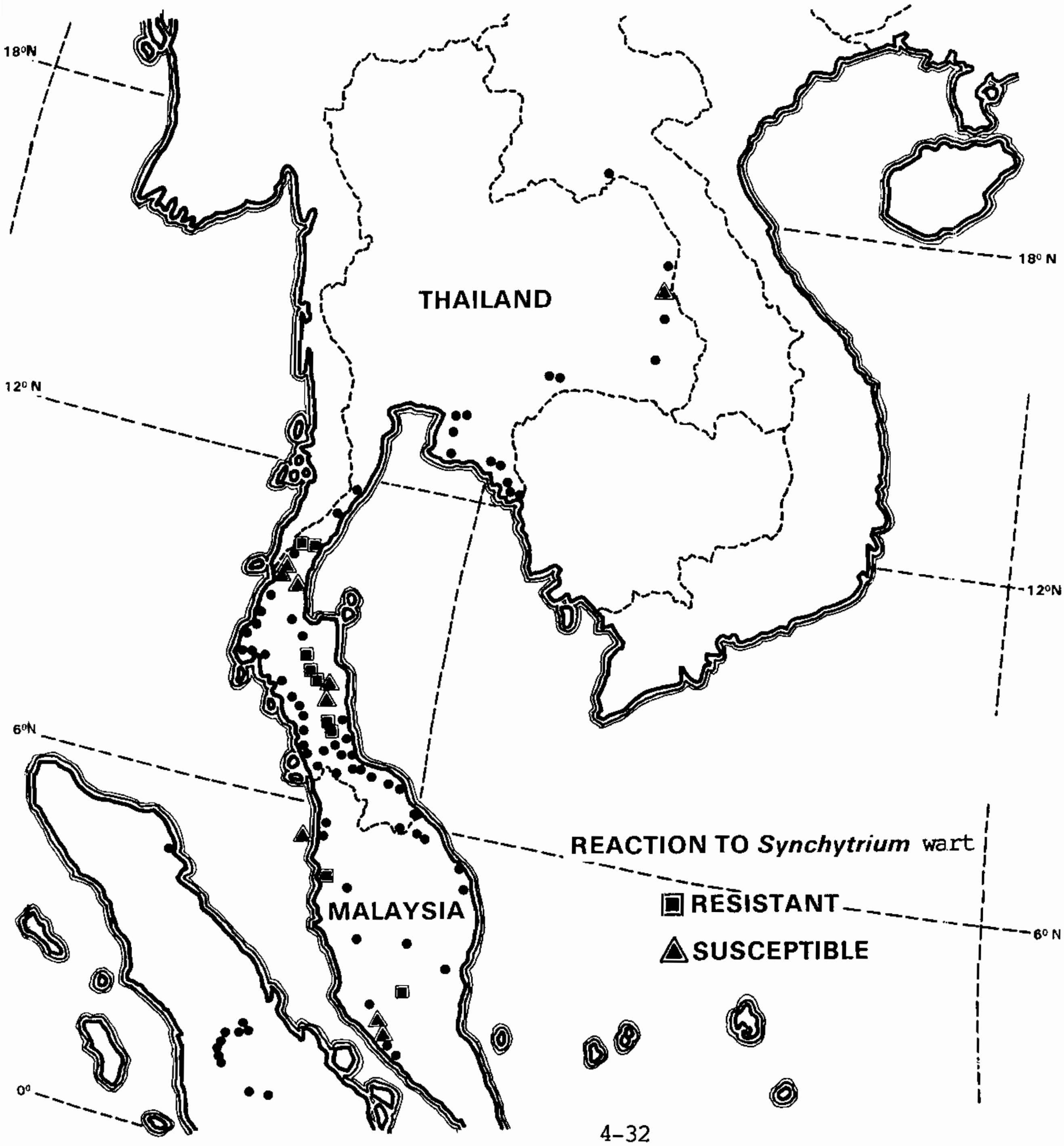


Figure 15. Location of collection sites and most resistant and susceptible accessions of Desmodium ovalifolium to Synchytrium wart disease.



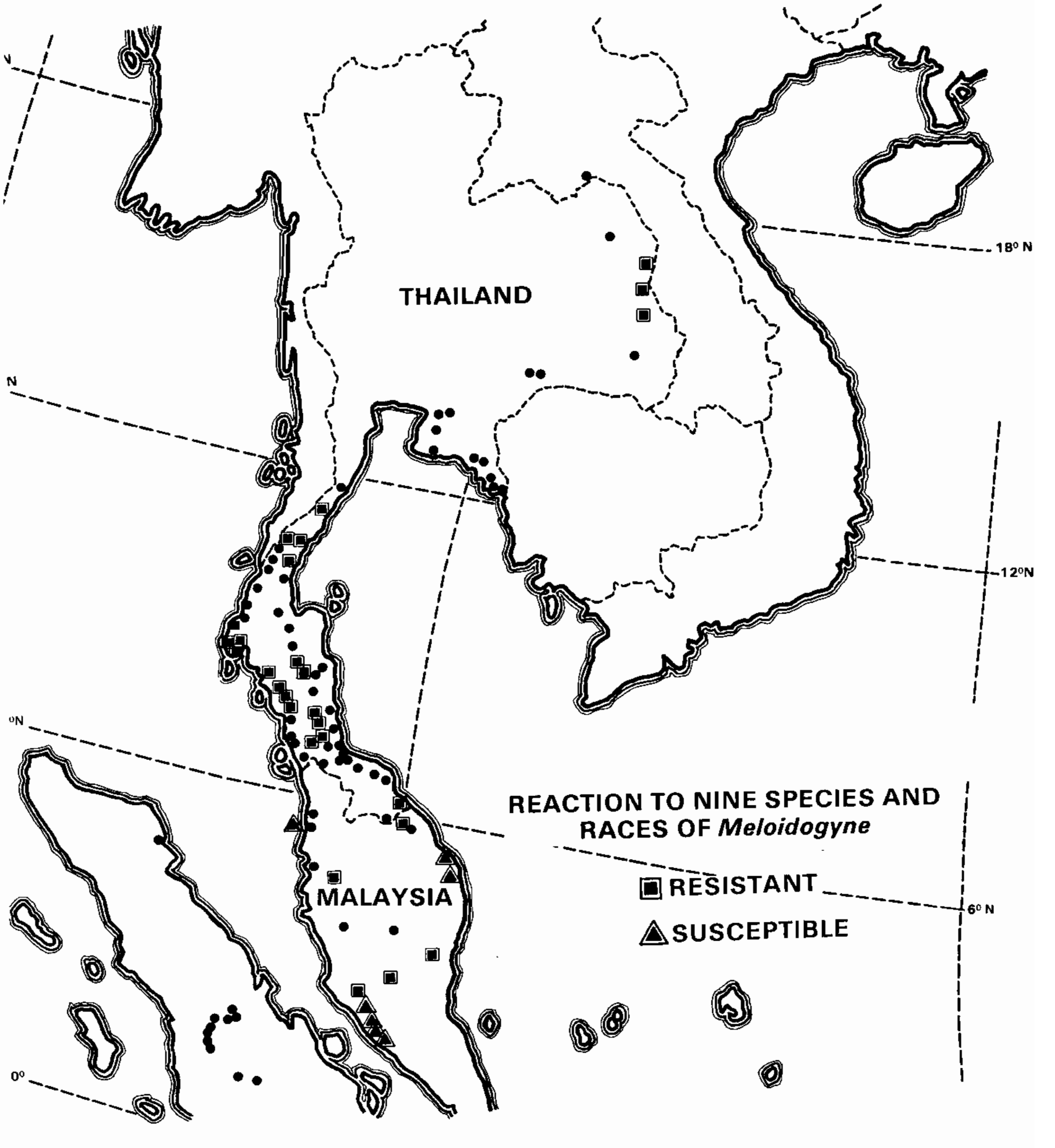


Figure 16. Location of collection sites and most resistant and susceptible accessions of Desmodium ovalifolium to nine species and races of Meloidogyne.

accessions show high resistance to the former pathogen and will be evaluated for reaction to Synchytrium wart disease.

DISEASES OF *Arachis pintoi*

a) Sphaceloma scab

Scab caused by *Sphaceloma arachidis* was detected on *A.pintoi* in the Cauca Valley in 1987. Field evaluations to date suggest that it does not greatly affect dry matter production of CIAT 17434, the most promising accession. CIAT 18752 and 18746 were resistant in a field screening. All attempts to culture *S. arachidis* have not been successful to date. This must be accomplished before detailed evaluation of the germplasm collection can be achieved.

Other potentially important diseases of *A. pintoi* include Pepper spot caused by *Leptosphaerulina arachidicola* and a potyvirus causing mottle/mosaic.

DISEASES OF BRACHIARIA SPECIES

The rust *Uromyces setariae-italicae* Yosh, first reported in Latin America in 1981 (on *B. humidicola* and *P. maximum* in Brazil), caused considerable damage to *B. humidicola* in Napo and Puyo, Ecuador; Quilichao, Colombia and to a lesser extent in Carimagua, Colombia. The rust produces pustules on both sides of the upper leaf blades of *B.humidicola* resulting in leaf death. This rust has been reported on 22 different *Brachiaria* species including *B. brizantha*, *B. dictyoneura*, *B. eminii*, *B. humidicola* and *B. mutica* and from Brazil, Colombia, Cuba and Peru as well as being wide-spread in Africa. This rust is the first potentially important disease encountered in tropical pasture grass germplasm in Latin America. Several trials will be carried out in Carimagua next year to evaluate promising spittlebug resistant lines and other *Brachiaria* species. It is strongly recommended that *Brachiaria* germplasm be evaluated *in situ* as well as in tropical America in order to collect basic information on its reaction to the large range of pathogenic fungi encountered in East Africa.

SEED PATHOLOGY RESEARCH

a) Effect of methods of seed production and application of fungicide treatments on *Pseudomonas fluorescens* Biotype II associated with seed of *Centrosema acutifolium* cv. Vichada.

Pseudomonas fluorescens Biotype II, the causal agent of bacteriosis is seed-borne in *C. acutifolium* cv. Vichada. All harvested seed is screened for the presence of this bacterial pathogen and treated accordingly. An investigation was therefore made of the effect of field chemical treatments applied during the seed production period on levels of bacteriosis in plants and seed.

All chemical treatments significantly reduced bacteriosis in plants (Table 24). Most bacteriosis was recorded in both King grass support systems probably because the sprouting grass provided a more conducive microclimate for disease development. All chemical treatments increased pod, seed and dry matter production (Table 25). Bravo plus Orthocide was the best treatment.

All chemical treatments reduced percentage seed infection with fluorescent *Pseudomonas* species including *P. fluorescens* Biotype II however the reduction was significant only for the Bravo + Kocide treatment (Table 26). No *P. fluorescens* Biotype II was isolated from seeds harvested from plants treated with Bravo + Orthocide and Kocide + Orthocide (Table 26). Strategic application of chemicals to control bacteriosis during the seed production period increased seed yield and decreased seed infection by *P. fluorescens* Biotype II.

Table 24. Effect of six fungicide treatments and five production methods on bacteriosis of *Centrosema acutifolium* cv. Vichada.

Treatments	Mean bacteriosis
Fungicides:	
Control	2.0 a*
Bravo 500+Kocide 101	1.4 b
Kocide 101	1.4 b
Kocide 101+Orthocide 50%	1.4 b
Bravo 500	1.4 b
Bravo 500+Orthocide 50%	1.4 b
Orthocide 50%	1.3 b
Production methods:	
B-King grass inverted 1.8m	1.6 a
A-King grass 1.8m	1.5 b
D-Conventional support 2.5m	1.5 bc
E-No support	1.4 c
C-Conventional support 1.8m	1.4 c

Rating scale: 0 = no disease
5 = plant death

Table 25. Effect of six fungicide treatments on bacteriosis of *C. acutifolium* cv. Vichada with respect to seed and forage yield

Treatments	Production variables		
	Podds (No. x 10^3/ha)	Seed (kg/ha)	Dry matter produc (t/ha)
Bravo+ Orthocide	162.6a	29.4a	2.1a
Bravo+Kocide	136.0ab	23.7ab	1.8ab
Kocide+Orthoc.	99.7abc	18.6abc	1.6ab
Orthocide	93.7bc	17.8bc	1.8ab
Kocide	93.5bc	16.1bc	2.0a
Bravo	97.2abc	15.2bc	1.9ab
Control	58.0c	10.4c	1.3b

Table 26. Effect of six fungicide treatments on the level of seed-borne infection of fluorescent *Pseudomonas* spp in *Centrosema acutifolium* cv. Vichada.

Treatment	Percentage Seed infection	
	Fluorescent Pseudomonas spp.	*Pseudomonas fluorescens* Biotype II
Bravo+Kocide	1.7 b	0.5 a
Kocide	2.3 ab	0.1 a
Bravo+Orthocide	2.6 ab	0 a
Bravo	2.8 ab	1.1 a
Orthocide	3.9 ab	1.2 a
Kocide+Orthocide	5.1 ab	0 a
Control	8.3 a	2.6 a

b) Effect of various seed treatments on the presence of smuts *Tilletia ayersii* and *Ustilago* sp. in seed of *Panicum maximum* harvested from plants derived from treated seed.

P. maximum smuts (particularly *T. ayersii*) are widespread throughout the tropis greatly reducing seed production. Of 64 accessions of *P. maximum* surveyed for smuts *T. ayersii* and *Ustilago* sp, more than half were affected by at least one smut at levels ranging from 1 to 44% seed infection (mean 18 to 23%) (Table 27). Seed treatments with Carboxin and Benomyl were successful in eliminating smut from seed harvested from plants derived from treated seed (Table 28). Hot water was effective for *Ustilago* sp. but less so for *T. ayersii*.

c) Survival of *Bradyrhizobium* in contact with chemical protectants on seed of *Centrosema acutifolium*.

Centrosema acutifolium cv. Vichada is affected by various seed-borne

Table 27. Infection of seed of 64 accessions of Panicum maximum with smuts - Tilletia ayersii and Ustilago sp

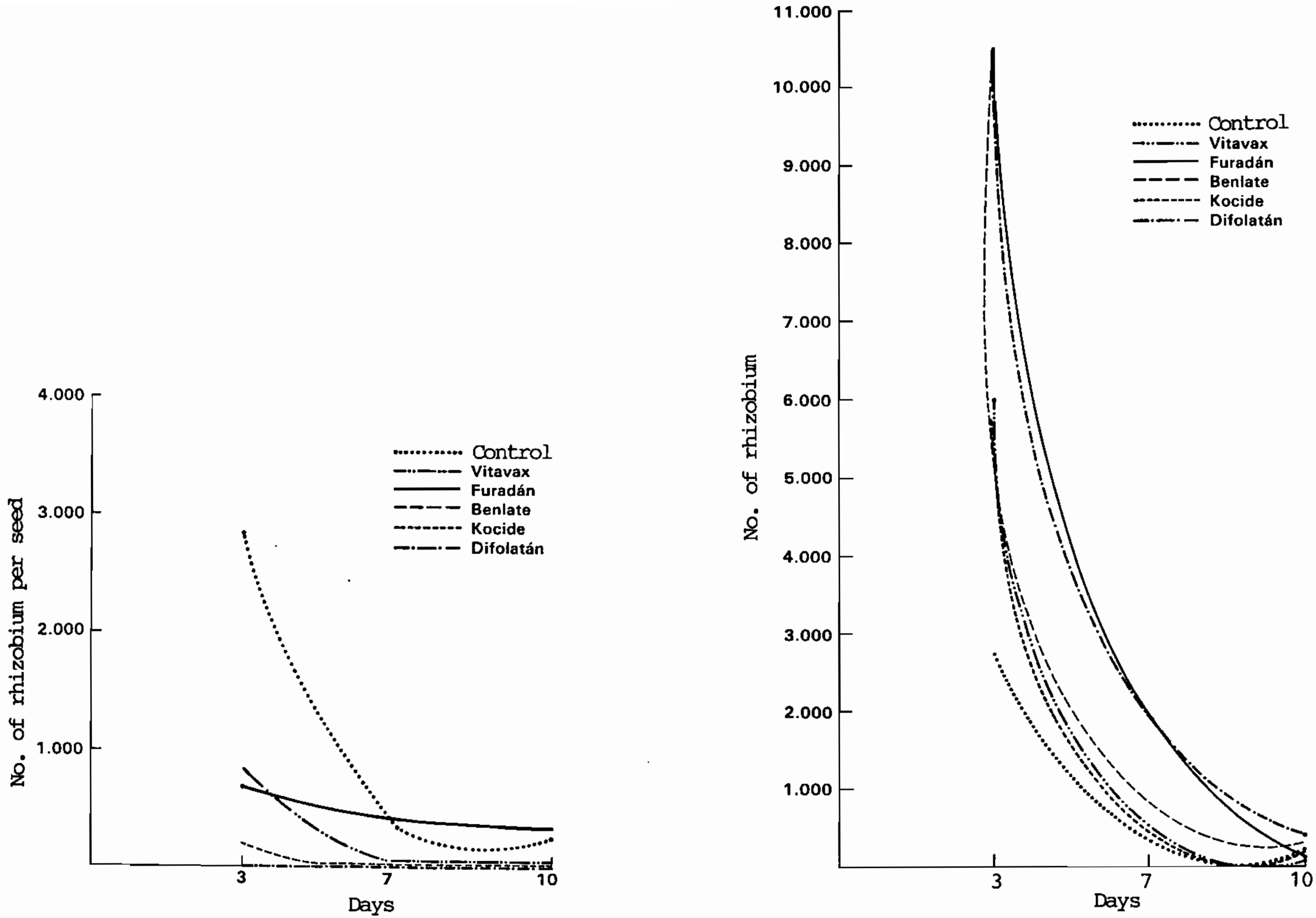
	Percentage Seed infected by		
	T. ayersii	Ustilago sp.	T. ayersii+ Ustilago sp.
No. of accessions	34	15	3
Mean % infection	18.5	18.8	23.2
Range	1-44	3-36	21-25

pathogens eg. P. fluorescens Biotype II which are managed by chemical protectants. In collaboration with the soil Microbiology Section, we determined whether these protectants affect survival of Bradyrhizobium. Recommended rates of benomyl, carboxin, captafol, copper oxide and carbofuran were applied to seed of cv. Vichada for one week. The seed was then washed or not washed prior to pelleting with Bradyrhizobium. After 3 days, high levels of Bradyrhizobium were measured on treated seed washed before pelleting but not on unwashed seed (Figure 17). Chemical treatments may therefore be used successfully on pelleted seed provided residual chemical is washed off and seed is sown within a few days of pelleting.

Table 28. Effect of various treatments on seed infection of 6 Panicum maximum accessions with smuts.

Accession	Smut	Seed infection (%)	Seed infection after treatment with		
			Carboxin	Benomyl	Hot water
6500	Ustilago	23.3	-	-	-
6790	Ustilago	24.3	-	-	-
6829	Ustilago	18.5	-	-	-
6971	Tilletia	17.3	-	-	-
6972	Tilletia	11.8	-	-	-
16021	Tilletia + Ustilago	21.8	-	-	-

Application rates: Carboxin 0.2 gr i.a./100 gr seed.
Benomyl 0.5 gr i.a./100 gr seed.



a) Time after pelleting

b) Time after pelleting

Figure 17. Effect of various chemical protectants on survival of <u>Bradyrhizobium</u> without (a) and with (b) washing of seed before pelleting.

5. Entomology

INTRODUCTION

During 1988, the Entomology section concentrated its efforts on the screening of the Brachiaria and Panicum germplasm collections for host plant resistance to spittlebug (Aeneolamia reducta and Zulia colombiana). The development of an efficient, standardized glasshouse screening technique has resulted in the screening of approximately 400 accessions during 1988. The entire Brachiaria and Panicum collections will be screeened by the end of 1989. Potentially valuable sources of antibiosis in accessions of Brachiaria have been identified. These accessions will be further evaluated to determine mechanisms of resistance. In conjunction with the Plant Breeding section, sexual parental material consisting of induced tetraploids of Brachiaria ruziziensis will be characterized for resistance to spittlebug prior to initiation of breeding for resistance and other traits (see Plant Breeding section).

Field screening of Brachiaria for resistance to spittlebug was particularly rigorous this year due to high spittlebug pressure at the Carimagua station. Promising accessions have been identified and are being propagated for evaluation under grazing (see Agronomy section).

Surveys of leaf-cutter ants (Atta laevigata and Acromyrmex landolti) have shown a high degree of variability of nest density in native savanna and in improved pastures at Carimagua. Part of this variability is explaned by soil moisture. Additional chemical factors in the soil may also determine ant nest distribution. The survey also indicated a possible repressive effect of Brachiaria grasses, particularly Brachiaria humidicola, on populations of A. landolti.

SPITTLEBUG

The systematic screening of the Brachiaria collection for resistance to spittlebug has proceeded in the field and in the glasshouse. In collaboration with the Agronomy section, promising accessions have been identified from the field screen at Carimagua that are well adapted to edaphic conditions and are resistant to spittlebug. In the glasshouse, accessions have been selected based on their antibiotic effect on spittlebug nymphs. These accessions will be further studied to elucidate mechanisms of resistance in order to facilitate gene transfer.

Field evaluation of Brachiaria

Natural spittlebug populations were high in the Colombian llanos during 1988 and this resuted in an unusually vigorous screen for resistance to A. reducta in the 265 accessions of Brachiaria spp. planted in Carimagua in June, 1987. The technique of planting within an old field of B. decumbens was particularly successful in establishing a very high spittlebug population in the collection early in the rainy season of 1988. Proliferation of superficial roots under litter was increased and conditions of relative humidity and shade that favor spittlebug survival were created by maintaining *B. decumbens* at a height of 15 cm or more and by allowing accumulation of litter at the soil surface. The first peak of adult spittlebugs was observed in early May (Figure 1). A second large peak occurred in late June and early July. During June, populations of nymphs in the collection were high. In some susceptible accessions of *B. ruziziensis* nymph densities exceeded 200 nymphs/m^2. A third peak of adults expected to occur in mid to late August failed to appear. This may have been a result of a relatively dry period during June that reduced nymph populations.

Spittlebug populations in the field trial greatly exceeded those in adjacent fields of *B. decumbens* under grazing (200 and 10 nymphs/m^2 respectively in June, 1988). The high populations resulted in severe damage early in the season to a majority of accessions. The susceptible control, *B. decumbens* CIAT 606, was completely blighted and judged to be dead by June, 1988. Selection of promising accessions was made in July, 1988, over one year before the anticipated termination of the trial. One of the most promising accessions, *B. brizantha* CIAT 16338, has shown excellent edaphic adaptation, field resistance to spittlebug, as well as an antibiotic response to spittlebug in the glasshouse.

Field trials for spittlebug resistance are more rapid and more reliable if established in old fields of a spittlebug susceptible grass such as *B. decumbens* and managed to maintain conditions that favor spittlebug. Six outstanding accessions from the field trial have been identified and will be evaluated for performance under grazing (see Agronomy section for list of accessions).

Glasshouse evaluation of host plant resistance in Brachiaria and Panicum

1. Screening methodology

Glasshouse evaluation of host plant resistance to spittlebug has continued (CIAT 1987 Annual Report). In the glasshouse, damage at 30 days aafter infestation with nymphs ranged from slight (0 to 20% foliar area blighted) to severe (60 to 80%) and in some cases plant death. Emergence of adults (survival) ranged from 10 to 90%. Accessions with high spittlebug survival and a low damage rating were considered tolerant, those with low nymphal survival or prolonged nymphal development time were considered antibiotic, and those with a high damage rating, regardless of spittlebug survival were considered susceptible.

Due to the large number of accessions of *Brachiaria* to be evaluated, groups of 50 accessions, each with a set of controls, were screened sequentially. To control for variability between groups due to variation in plant age and environmental conditions, a standardized index for each evaluation parameter was developed to allow for comparisons between groups. Figure 2 shows the index for nymphal survival for one group of accessions. The index is calculated as follows:

$$\frac{(X_s - X_r) - (X_s - X_i)}{(X_s - X_r)}$$

where X is nymphal survival on the susceptible control *B. decumbens* cv.

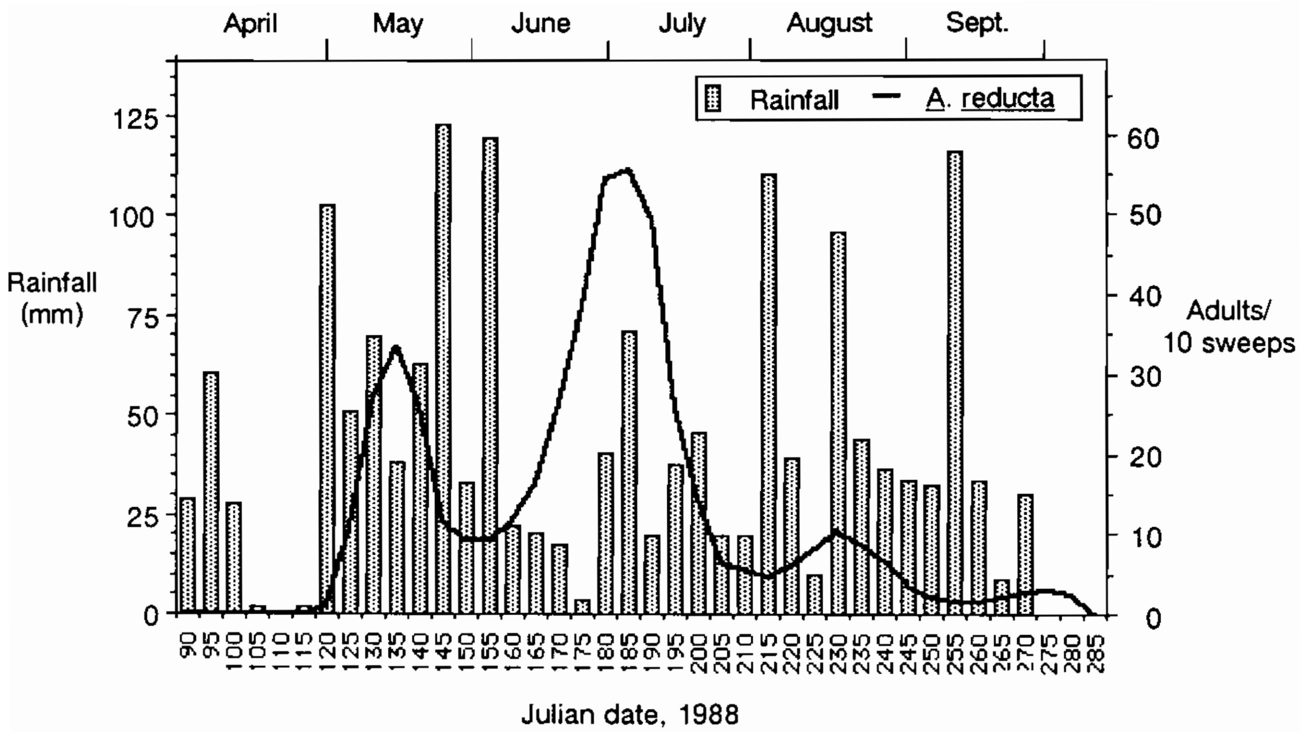


Figure 1. Rainfall and daily counts of adult spittlebugs (Aeneolamia reducta) at Carimagua, 1988.

Basilisk, X_r is nymphal survival on the resistant control B. brizantha cv. Marandú, and X_i is nymphal survival on the test accession. Similar indices are calculated for nymphal development time and damage at 30 days after infestation. A data base is being prepared for all Brachiaria accessions including these data as well as data from the field screen.

Glasshouse evaluation can identify potentially useful levels of resistance for breeding in otherwise unsuitable accessions. In contrast to field trials, glasshouse screening can differentiate between tolerance and antibiosis. In the past, accessions have been selected on the abasis of tolerance. The glasshouse technique described here allows selection of accessions that possess antibiosis, a potentially more useful type of resistance.

Figure 2 presents survivorship scores for nymphs reared on one cohort of Brachiaria accessions. The resistant control is B. brizantha cv. Marandú (CIAT 6294), and the susceptible control is B. decumbens cv. Basilisk (CIAT 606). Note also the high survival of nymphs reared on B. dictyoneura cv. Llanero (CIAT 6133), the tolerant control. B. brizantha accessions CIAT 16767, 16777, and 26156 have been selected for further study based on their antibiotic effect on spittlebug nymphs. Fewer nymphs survived to adult on B. jubata CIAT 16531 compared with the resistant control.

Figure 3 shows scores for duration of nymphal stadia reared on the same cohort of Brachiaria. Six accessions are identified as prolonging development (B. brizantha CIAT 16123, 16849, 16960, 16962, 16964, and 26124).

To date, over 350 accessions of Brachiaria have been evaluated in the glasshouse for resistance to A. reducta and/or Z. colombiana. In the glasshouse, responses of the two spittlebug species to controls were comparable. Nymphs reared on antibiotic accessions (B. brizantha cv. Marandú, B. jubata CIAT 16531, and B. brizantha CIAT 16338) experienced higher mortality than nymphs reared on the susceptible B. decumbens cv. Basilisk and the tolerant B. dictyoneura cv. Llanero. Similar results have also been obtained with Zulia entreriana in Campo Grande, Brazil (J. R. Valerio, pers. comm.). Screening of Brachiaria is now done with A. reducta since it is the predominant species in major cattle-producing areas of Colombia and it has a shorter life cycle than Z. colombiana, thereby speeding up glasshouse evaluation.

During August, 1988, two Brazilian entomologists, José Raul Valério (CNPGC, Campo Grande), and Antonio Brito de Silva (CPATU, Belém) participated in a month long intensive training program at CIAT Palmira and Carimagua in spittlebug rearing and resistance evaluation techniques. As a result, they are initiating Brachiaria screening at their respective institutions. This will provide a basis of comparison of results between contrasting sites and with different species of spittlebug. Preliminary results at Campo Grande indicate that response of Zulia entreriana to a range of Brachiaria accessions is similar to that of Z. colombiana and A. reducta.

Panicum maximum

Sixty accessions of Panicum maximum have been evaluated in the glasshouse for resistance to A. reducta using the methodology developed for Brachiaria. Nymphal survival was low on two accessions, CIAT 6177 and CIAT 6172. Development time of those nymphs surviving to adult was similar to that of nymphs reared on the

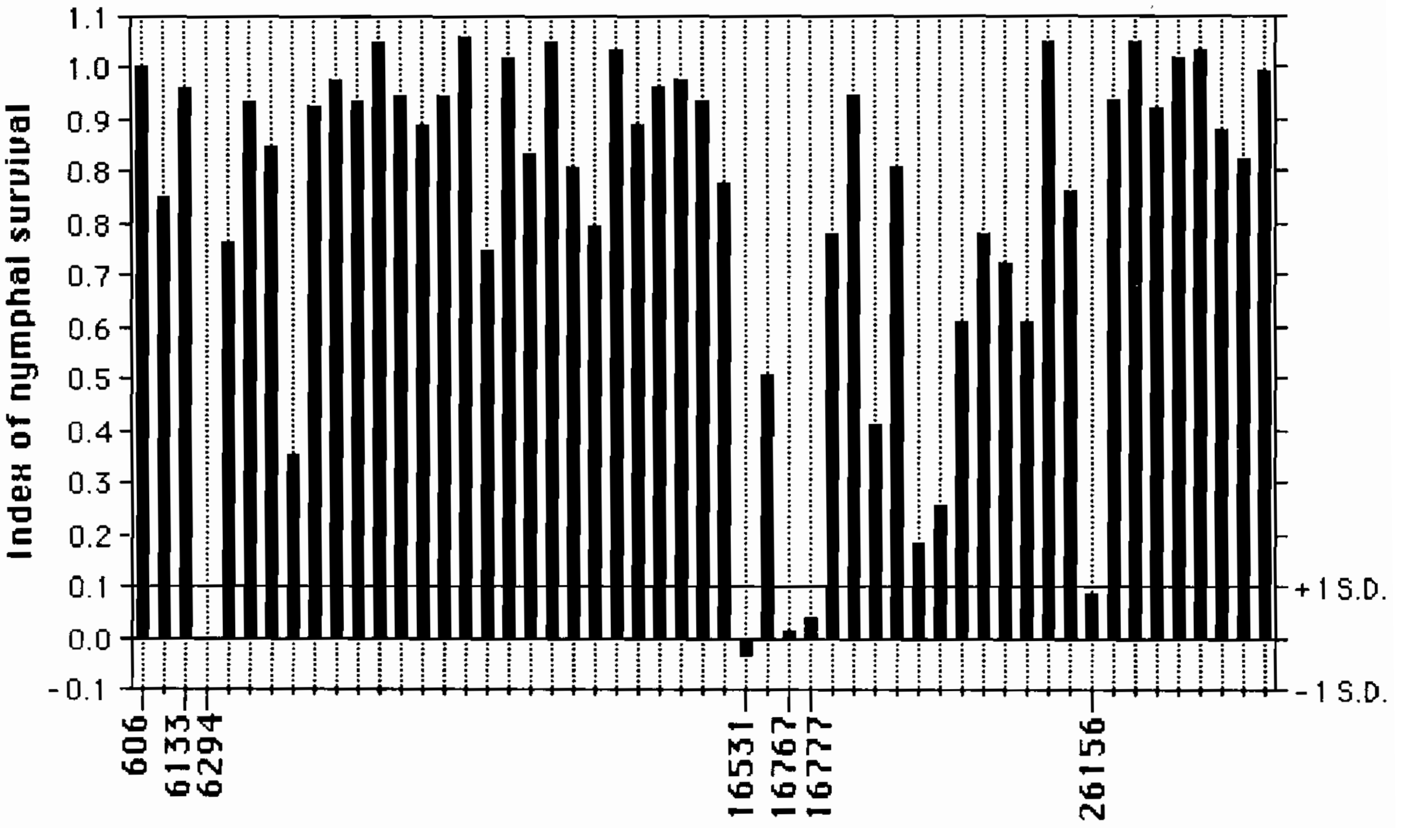


Figure 2. Survival index of spittlebug nymphs reared on 50 accessions of Brachiaria in the glasshouse. S.D. = standard deviation of nymphal survival on the resistant control, B. brizantha cv. Marandú (CIAT 6294).

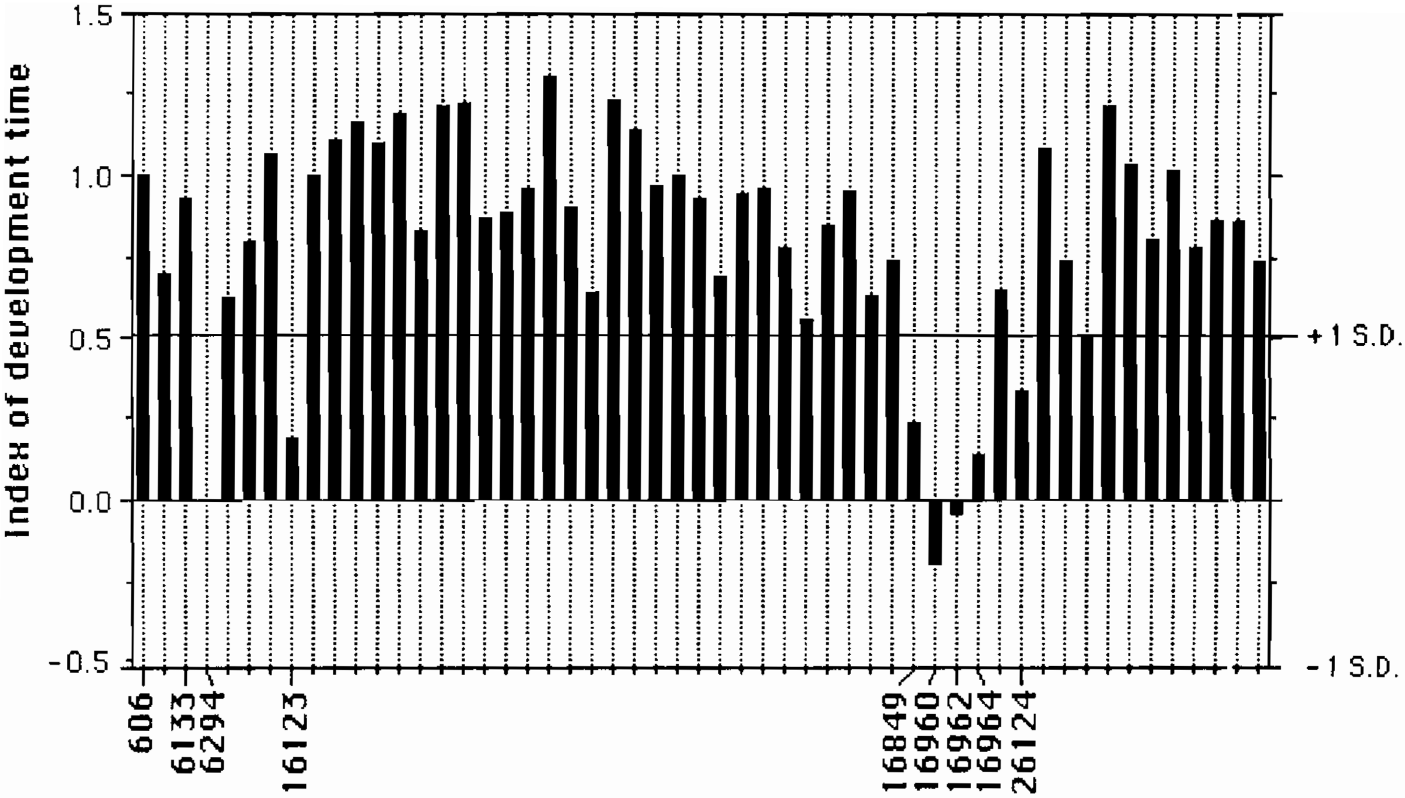


Figure 3. Development rate index for spittlebug nymphs reared on 50 accessions of Brachiaria in the glasshouse. S.D. = standard deviation of nymphal development time on the resistant control, B. brizantha cv. Marandú (CIAT 6294).

susceptible control B. decumbens cv. Basilisk (CIAT 606). Development time of nymphs reared on these antibiotic accessions was not delayed as we have consistently found with nymphs reared on the resistant control B. brizantha cv. Marandú (Figure 4). This finding suggests that the mechanism of antibiotic resistance in P. maximum CIAT 6177 and 6172 is distinct from the mechanism operating in cv. Marandú. One of these, CIAT 6177, has also been selected from field trials in Carimagua for edaphic adaptation and productivity (see Agronomy section).

Mechanism of resistance to spittlebug in B. jubata

Further investigation into the high level of resistance to spittlebug nymphs observed in B. jubata CIAT 16531 indicates that this accession may possess factors that interfere with emergence of adults from fifth instar nymphs. The hormone responsible for moulting in insects, ecdysone, was isolated in 1954. The chemical structure was later determined, after large scale extraction and isolation from silkworm pupae. Subsequently, 20-hydroxyecdysone (identical to the insect hormone) and many biologically active ecdysone analogues have been identified from many plants in much higher concentrations than found in insects.

The symptoms that have been observed in Z. colombiana and A. reducta reared on B. jubata CIAT 16531 agree with reports of symptoms of other insects fed on diets containing phytoecdysteroids (ecdysone or a steroidal ecdysone analogue of plant origin). Spittlebugs reared on B. jubata CIAT 16531 appear to develop normally until the last (fifth) instar. The majority of insects die during moult to the adult stage. Specifically, death occurs after initiation of apolysis (separation of the pharate adult from the nymphal cuticle) and before completion of ecdysis (emergence of the adult). Attempts to identify and extract the active component are planned.

Nymphs of A. reducta initially reared on B. dictyoneura cv. Llanero and then transferred to B. jubata CIAT 16531 after 21 days suffered mortality equivalent to that of nymphs reared on B. jubata CIAT 16531 alone (Figure 5). Nymphs transferred at 21 days from B. jubata CIAT 16531 to B. jubata CIAT 16531 survived at a lower although not significantly different rate than nymphs reared without manipulation on B. jubata CIAT 16531. Nymphs transferred from B. jubata CIAT 16531 to cv. Llanero emerged as adult as frequently as nymphs reared on Llanero. These data suggest that it is not necessary for nymphs to feed on B. jubata CIAT 16531 throughout the nymphal stadia in order for the antibiotic effect to be expressed, and that there is a specific developmental event (final moult) that is being disrupted by factors present in B. jubata CIAT 16531 that are not present in cv. Llanero.

Developmental threshold for eggs of Z. colombiana

Eggs of Z. colombiana were incubated at 10, 15, 20, 25, 30 and 35°C to determine the effect of temperature on rate of development and to determine the developmental threshold. No eclosion occurred at 10 or 35°C. Maximum rate of development occurred at 25°C (Table 1). By extrapolation, developmental threshold was determined to be 10-16°C (Figure 6).

LEAF-CUTTER ANTS

Counts of nests of the leaf-cutter Acromyrmex landolti and termite mounds (tentatively identified as Heterotermes tenui) were made at Carimagua during the dry season of 1988 (Jan - April). Nest densities varied widely in areas of native

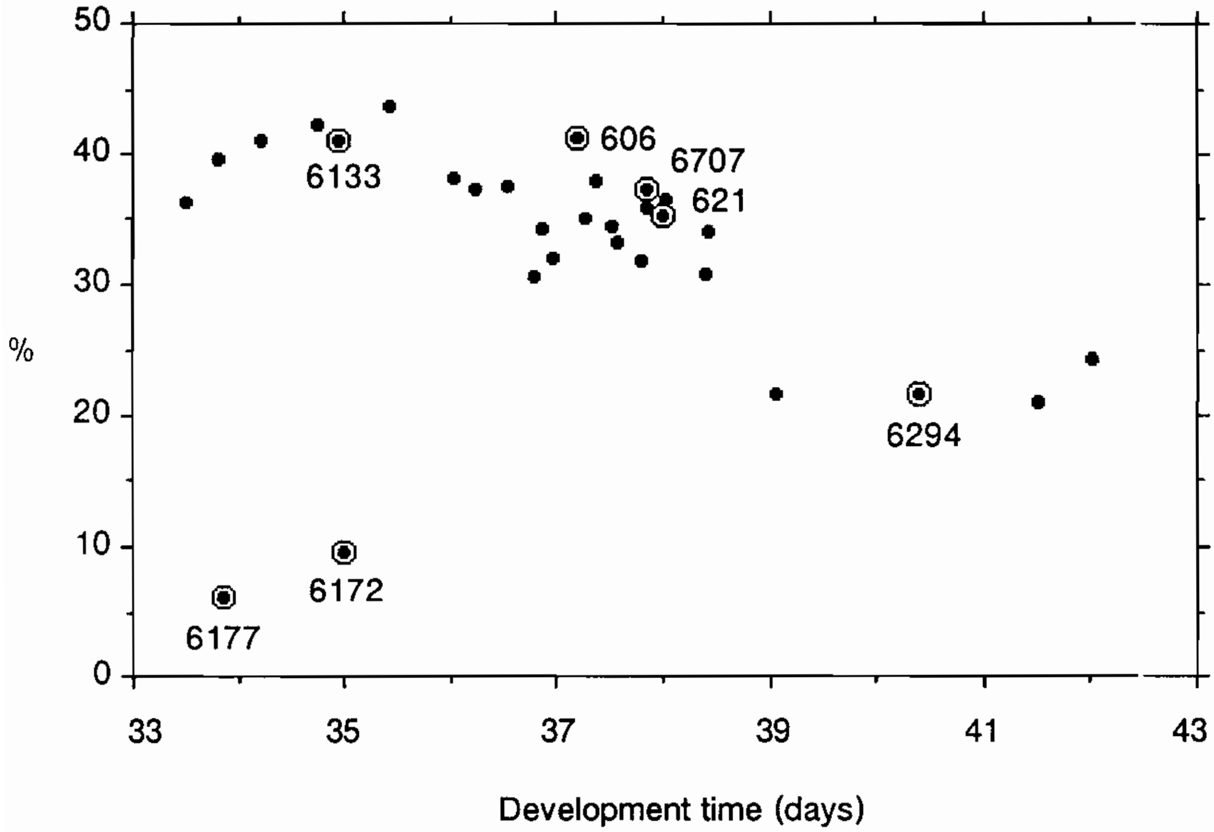
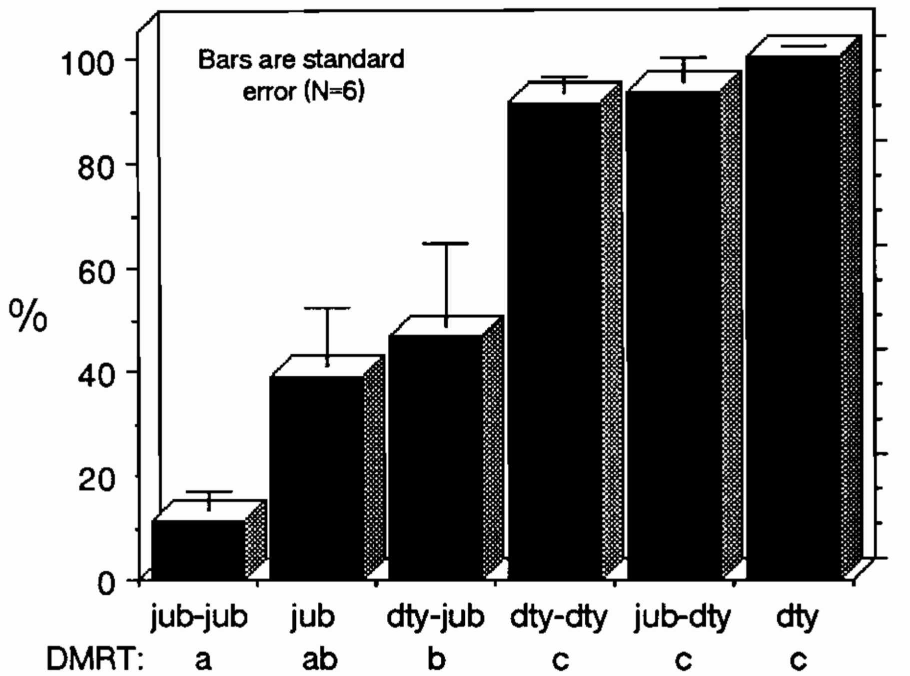


Figure 4. Percent survival vs. development time of spittlebug nymphs reared on 30 accessions of <u>Panicum maximum</u> in the glasshouse.



jub = B. jubata CIAT 16531
dty = B. dictyoneura cv. Llanero

Figure 5. Survival of spittlebug nymphs reared on B. jubata CIAT 16531 or B. dictyoneura cv. Llanero. Nymphs were allowed to feed on the same plant until adult emergence (treatments jub and dty) or transferred after 21 days. DMRT = Duncan's Multiple Range Test. Treatments with the same letter do not differ at the 5% level.

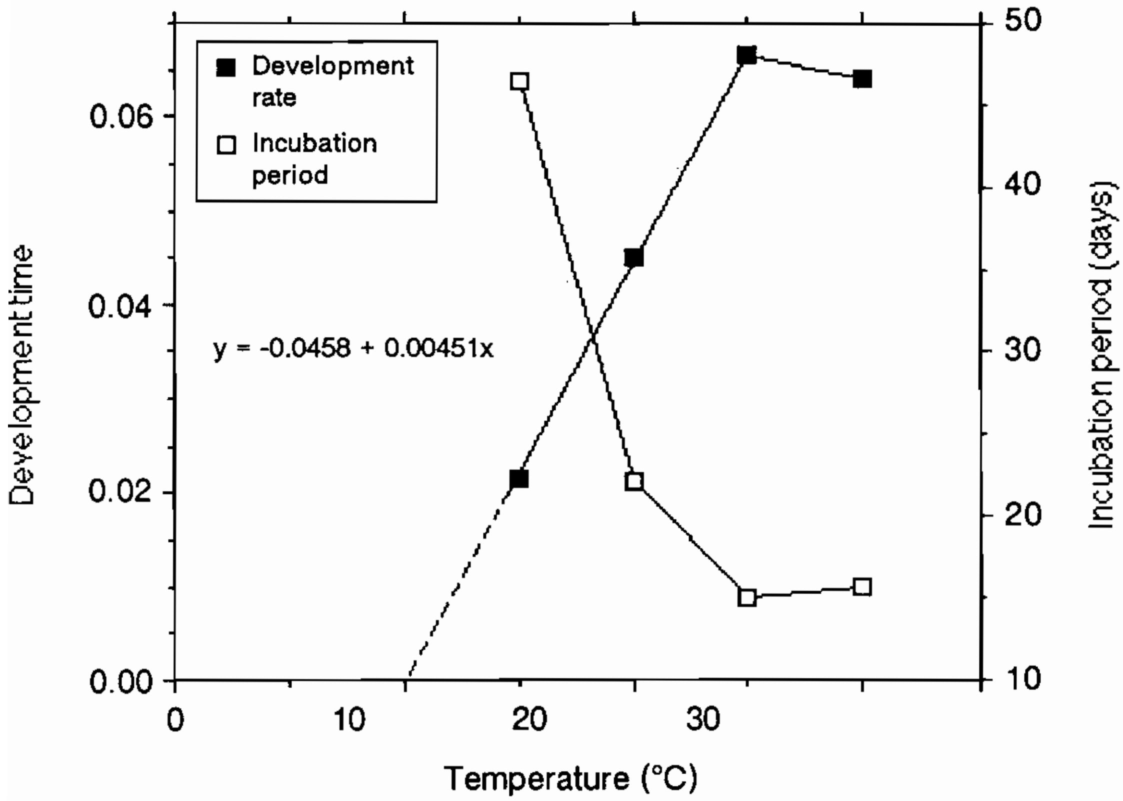


Figure 6. Determination of development threshold for eggs of
<u>Z. colombiana</u> by extrapolation.

Table 1. Rate of development and percent eclosion of eggs of Z. colombiana incubated at various temperatures.

T °C	Days to eclosion	Rate of development	Eclosion (%)
10	-	0	0
15	46.4	2.16	90
20	22.2	4.50	93
25	15.0	6.67	99
30	15.6	6.41	97
35	-	0	0

savanna not previously planted to improved forages (Figure 7). In general, Acromyrmex nest density was low in poorly drained areas where mound building by termites was evident. Similarly, variation was observed in nest density in Andropogon gayanus pastures (Figure 8). Preliminary analysis of survey data from Carimagua indicates that ant nest distribution is most highly correlated with superficial water availability. Results of the survey are currently being analyzed to further identify soil physical and chemical properties that influence ant pest distribution.

Survey results show that B. humidicola may have a repressive effect on ant populations. At one site, Altagracia, nest density of A. landolti was slightly less than 5,000 nests per hectare in January, 1988 (Figure 9). An adjacent field of B. humidicola planted at approximately the same time, however, had no active A. landolti nests. Surrounding areas of native savanna had nest densities of approximately 750 nests/ha. Another site, El Tomo, showed a similar pattern with low densities in B. humidicola and higher densities in native savanna and A. gayanus (Figure 10). These data indicate that ant populations are reduced in pastures of B. humidicola compared with a relatively natural savanna habitat, while pastures of A. gayanus can experience a large increase in leaf-cutter populations.

Possible strategies for ant control include strategic deployment of grass germplasm options based on an assessment of the area to be planted in terms of actual ant population and conditions known to influence ants (soil moisture), and a knowledge of the susceptibility to ant predation of the available germplasm.

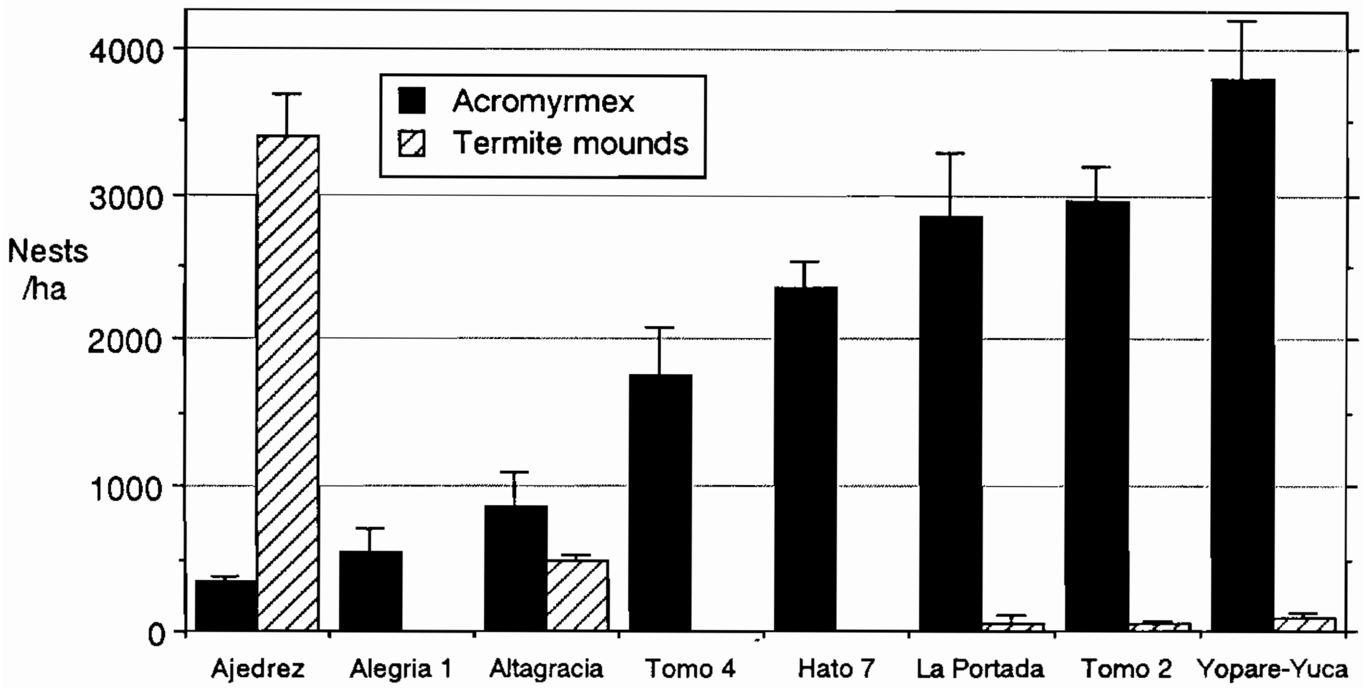


Figure 7. Densities of ant nests and termite mounds in areas of native savanna at Carimagua. 1988.

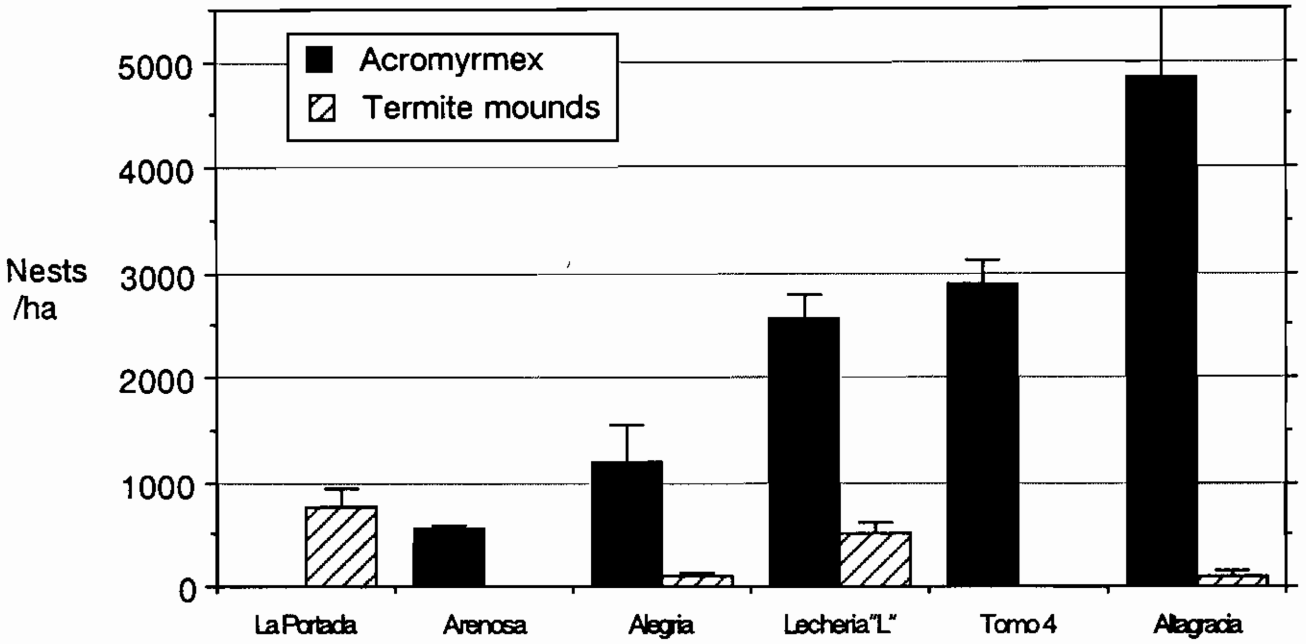


Figure 8. Densities of ant nests and termite mounds in pastures of A. gayanus at Carimagua. 1988.

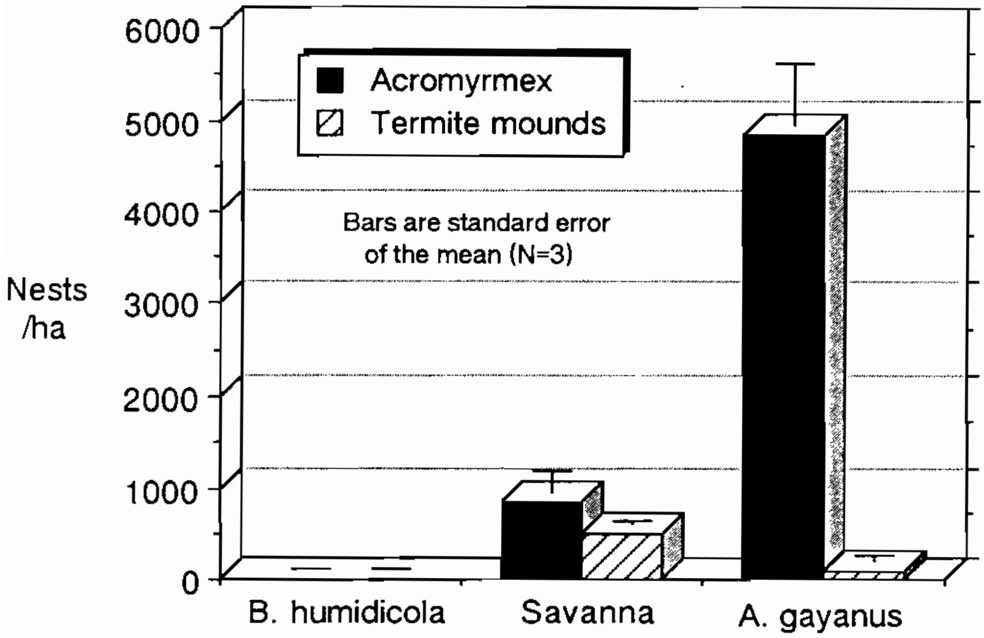


Figure 9. Densities of ant nests and termite mounds in native savanna and pastures of B. humidicola and A. gayanus at Altagracia, Carimagua.

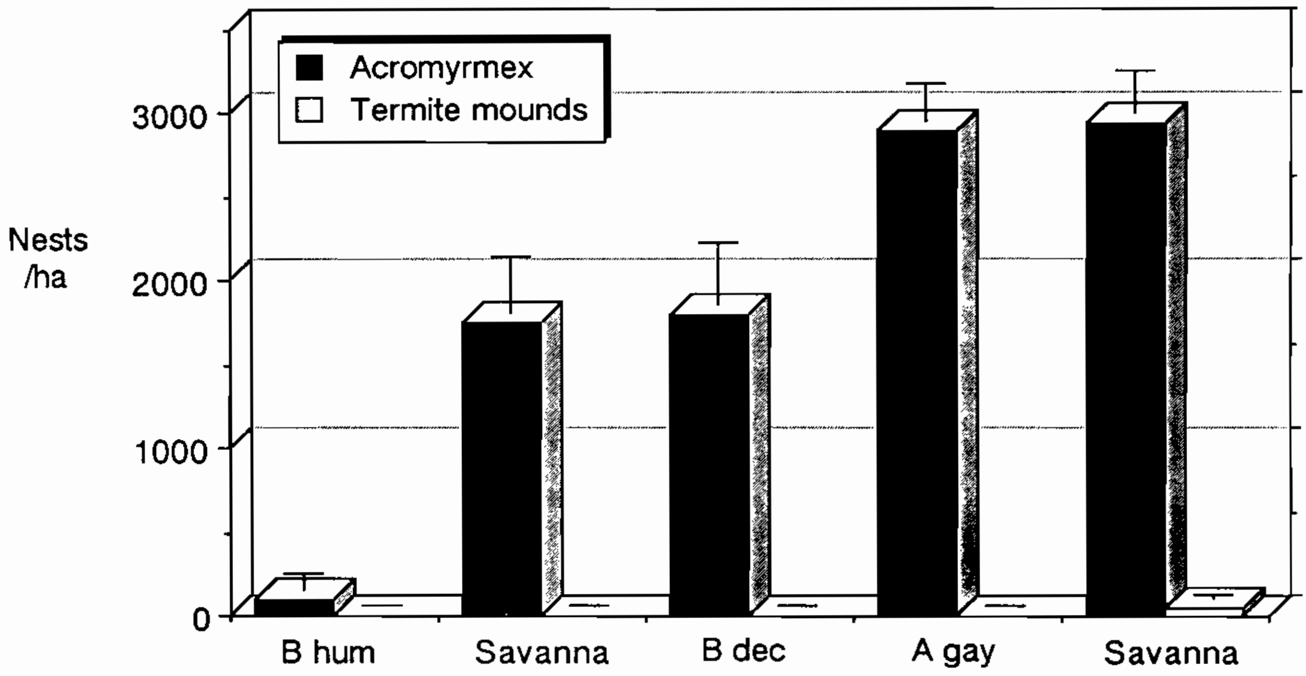


Figure 10. Densities of ant nests and termite mounds in native savanna and pastures of B. humidicola, B. decumbens, and A. gayanus at El Tomo, Carimagua.

6. Agronomy Llanos

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

PRELIMINARY EVALUATION OF GERMPLASM (CATEGORY II)

The aim of this stage of evaluation is to select accessions adapted to the climatic, edaphic and biotic factors in the environment. Accessions are grown in small plots in pure stands and subjected to periodic defoliation. Observations are made on vigour, flowering time, seed production potential, drought resistance, pest and disease incidence. Where possible, evaluation is being conducted at two sites, "Yopare" and "La Alcancía", with different soil textures and organic matter contents. Legume accessions and those of Panicum maximum were established in savanna, without removal of vegetation from inter-plot areas. Accessions of Brachiaria were established in an old paddock of B. decumbens.

Stylosanthes scabra

In May 1986, 93 potentially promising lines selected from a larger collection of over 500 accessions at Quilichao were sown at the two sites. The Australian commercial cultivars Seca and Fitzroy were included as controls. Ninety per cent of the accessions were collected in Brazil, seven per cent in Venezuela and three per cent in Colombia.

The main limitations are the fungal disease anthracnose and an insect pest stemborer. Most of the collection, including the commercial cultivars, has now died from the effects of stem-borer; the only types surviving are low-growing bush types mainly of Venezuelan origin. The productivity and chemical composition of these types are shown in Table 1. There were no differences in performance of accessions between sites. The outstanding accession, in terms of vigour and pest/disease resistance, continues to be CIAT 2808. Seed of these low-growing types is being multiplied for distribution to other locations particularly in the Venezuelan "Llanos". Accession CIAT 2808 is to be further tested under grazing in Category III.

Centrosema brasilianum

In June 1986, 18 accessions from Brazil and Venezuela were sown at the "La Alcancía" site. The main limitation to the species is the fungal disease Rhizoctonia Foliar Blight. Nine of the accessions (those with 4-digit numbers) were selected previously at Carimagua and are already under evaluation in Category III. The other nine accessions (those with 5-digit numbers) are new and were selected at Quilichao.

Table 1. Productivity and chemical analysis of selected accessions of *Stylosanthes scabra* at Carimagua.

CIAT No.	DM YIELD[1,2] (Wet) g/plant	DM YIELD[1,3] (Dry) g/plant	IVDMD[2] %	N[2] %	Ca[2] %	P[2] %
2808	225a	10a	49.51	2.10	0.33	0.12
1926	188ab	6abc	51.88	2.32	0.37	0.16
1526	166bc	9ab	52.78	1.90	0.43	0.13
1522	154bc	3bc	50.17	2.06	0.39	0.14
2818	134cd	2bc	47.65	1.93	0.36	0.13
2015	96d	8ab	47.98	2.44	0.47	0.16
1917	96d	0c	45.02	2.03	0.33	0.13
1009 (cv. Fitzroy)	13e	0c	-	-	-	-

1/ Means with the same letter are not significantly different.
2/ Sampled twice in wet season.
3/ Sampled end of dry season.

Dry-matter yields and pest/disease scores are presented in Table 2. Only accession CIAT 15521 produced significantly more dry matter than the control CIAT 5234. All of the accessions were moderately to highly susceptible to *Rhizoctonia* Foliar Blight, confirming previous greenhouse observations by the Plant Pathology Section. In addition, all accessions were severely attacked by leaf-sucking insects in the wet season, causing chlorosis over much of the leaf surface. These pest and disease problems seriously question the future of this species as a pasture plant in the Colombian "Llanos".

Pueraria phaseoloides

In June 1987 a collection of 99 accessions was established at the two sites. The accessions represented the three main botanical types var. *javanica*, var. *phaseoloides* and var. *subspicata* from dry areas in northern *Thailand*. The commercial cultivar CIAT 9900, included as a control, shows poor adaptation to low soil fertility, a low tolerance of the dry season and seed production is variable. The collection was evaluated previously at another site at Carimagua of relatively high fertility and six accessions selected on the basis of yield, disease resistance and seed production. The present evaluation sites at "Yopare" and "La Alcancía" are, in terms of inputs of fertilizer and fertility, more typical of the situation likely to exist in production systems in the "Llanos". For continuity, the performance of the six selected accessions at the new sites are described (Table 3).

At "La Alcancía", accessions CIAT 9279, 17290 and 18031 produced significantly more dry-matter than the commercial control, and were the highest yielding accessions in the collection. At "Yopare", accessions CIAT 17281, 17290, and 18031 performed significantly better than the control and were amongst the highest yielding of the 99 accessions at this site. There were significant differences between locations in the

Table 2. Performance of accessions of *C. brasilianum* under cutting in Carimagua.

CIAT No.	Total DM Yield (kg/ha)	DM Yield in Dry Season (% of Total)	Maximum values* RFB	CLS	LSI
15521	3725a	9	4.0	1.0	4.0
5725	3181ab	18	3.0	2.0	4.0
5486	3070abc	9	4.0	1.0	5.0
5234 (Control)	2933bcd	14	4.0	3.0	5.0
15387	2882bcd	8	4.0	3.0	4.0
15522	2773bcd	6	3.0	0.0	4.0
15527	2753bcd	5	4.0	2.0	5.0
15525	2718bcd	7	3.0	4.0	5.0
5828	2672bcde	5	4.0	3.0	5.0
5810	2530bcdef	8	4.0	3.0	5.0
15526	2455bcdef	4	3.0	3.0	5.0
15520	2300cdefg	2	4.0	0.0	5.0
15523	2228cdefg	9	4.0	0.0	5.0
5657	1899efgh	3	3.0	4.0	5.0
5667	1868fgh	6	4.0	4.0	5.0
15524	1811fgh	3	3.0	4.0	5.0
5178	1527gh	7	4.0	3.0	5.0
5671	1465h	1	5.0	2.0	5.0

* RFB = *Rhizoctonia* Foliar Blight; CLS = *Pseudocercospora*·Leaf Spot; LSI = Leaf-Sucking Insects
Pest and disease scores; 0 = no symptoms and 5.0 = highly suceptible.
Means with the same letter are not significantly different.

Table 3. Performance of selected accessions of *P. phaseoloides* in second year at Carimagua (first cut).

CIAT No.	DM Yield (kg/ha) "Alcancía"	"Yopare"	No. Rooted Nodes (m^2) "Alcancía"	"Yopare"
18031	1888a	789a	19a	25a
9279	1343a	157b	16a	9b
17290	1144a	513a	28a	3b
17281	725b	705a	24a	44a
8352	711b	107b	15a	4b
17325	436c	177b	12a	13b
9900 (control)	678b	142b	13a	8b

Means followed by the same letter at each site are not statistically significant.

production of dry-matter, with accessions tending to yield more dry-matter at "La Alcancía". However, none of the selected accessions showed a high density of rooted nodes, an important morphological characteristic associated with persistence in grazed pastures. At "La Alcancía", there were no differences between selected accessions and the control. At this site the accession that produced the highest number of rooted nodes (93 per m^2) was CIAT 18032. Although two accessions at "Yopare" were superior to the control in numbers of rooted nodes, all accessions produced significantly less than accession CIAT 18377 (87 per m^2). The incidence of diseases such as anthracnose and Pseudocercospora Leaf Spot was low to moderate.

Panicum maximum

The original collection numbered 436 accessions at the two sites and was subsequently reduced to 30 accessions (morphologically similar to the Austalian cultivars common and Petrie green panic) on the basis of yield of digestible dry-matter in green leaf. The rationale for using this selection criterion was described in the Annual Report for 1987. The final selection of five promising accessions with some variation in morphology has now been made (Table 4).

All selected accessions were significantly more productive than the commercial controls. There were significant differences between sites in performance, with accessions yielding more at "Yopare" than at "La Alcancía". However, the five selected accessions showed the same ranking order at both "Yopare" and "La Alcancía", and were the most productive accessions at both locations. With the exception of CIAT 16042, a fine-leaved introduction, differences in digestibility between selected accessions and the controls were small. Thus, the major improvement as a consequence of selection has been an incrase in the production of green leaf rather than digestibility per se.

The major limitation for grasses in the savannas is the incidence of spittlebugs. At Carimagua the main problem species is Aenolamia reducta. Although spittlebugs were not a problem at the experimental sites due to low populations in the surrounding savanna, the original 30 selections were screened in the glasshouse by the Entomology Section. Damage ratings for the selected accessions were low to moderate (Table 4), whilst survival of nymphs to the adult stage was severely curtailed in accessions CIAT 6799 and 6177, indicating strong antibiotic effects. No disease problems were noted in the selected lines. These accessions are now under seed multiplication for evaluation in Category III.

Brachiaria brizantha

In June 1987, 265 accessions of species of Brachiaria were planted vegetatively within an existing pasture of Brachiaria decumbens. Most of the accessions in the collection (53 per cent) were B. brizantha.

This wet season the natural incidence of spittlebugs in the surrounding pasture and the plots was exceptionally high, and it was unnecessary to infest the plots artificially. Most of the accessions and plants of B. decumbens around the plots were destroyed, so it was not difficult to identify resistant accessions. On the basis of spittlebug resistance and adaptation to edaphic conditions, six accessions including the control cultivar Marandú were selected for seed multiplication and evaluation in Category III (Table 5). There were no significant differences in yield between these selected accessions, and the

Table 4. Performance of selected accessions of *Panicum maximum* in the wet season at two sites in Carimagua.

CIAT No.	Yield of digestible DM in green leaf[1] "Yopare"	"Alcancía" (g/plant)	Mean	Mean IVDMD[2] (%)	Spittlebug[3] Damage (1-5)	Survival (%)
6799	112a	69a	91a	43.37	2.5	19
16042	82bc	57ab	70b	40.50	3.0	71
6944	67cd	62ab	65b	44.82	3.5	73
6177	35ef	50b	43c	44.07	2.0	10
6973	51de	26c	39c	45.88	3.5	94
661 cv. Common	28f	11d	19d	45.85	2.5	77
685 cv. Petrie	25f	14d	19d	45.41	4.0	86

1/ Means with the same letter within sites are not significantly different.
2/ Range for 90 accessions 36.95-53.03.
3/ Results from glasshouse trial of Dr. S. Lapointe.
Damage 1.0 = no symptoms and 5.0 = highly susceptible. Survival is % surviving to adult stage.

Table 5. Productivity of selected accessions of Brachiaria brizantha cut in the mid-wet season at Carimagua.

CIAT No.	Green DM yield* (kg/ha)	Senescent Tissue (%)	Leaf Content (%)	Comments
6297 (cv. Marandú)	2589	13	64	Broad-leaved/Semi-erect
6690	3767	8	62	Broad-leaved/Erect
16126	5128	10	58	Fine-leaved/Erect
16338	3360	11	66	Fine-leaved/Erect
16827	3651	10	62	= Marandú
16829	3270	14	57	= Marandú

* Differences not statistically significant.

proportion of leaf was in excess of 50 per cent. The accessions represented three of the five morphological types present in the total B. brizantha collection. No diseases were recorded.

GRAZING EVALUATION OF GERMPLASM (CATEGORY III)

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

Centrosema brasilianum

In June 1987 a new trial was established at "La Alcancía" with nine accessions of C. brasilianum associated with Andropogon gayanus cv. Carimagua I and Brachiaria dictyoneura cv. Llanero. The accessions were CIAT 5234 (control), CIAT 5486, 5725, 5810, 5828 (all from Brazil); CIAT 5178, 5657, 5667 and 5671 (all from Venezuela). Plot size was 500 m^2 and establishment in the 1987 wet season of all species and accessions was excellent. Grazing commenced this year at a forage allowance of 3 kg green dry-matter per 100 kg liveweight. Paddocks were grazed rotationally for 7 days in a 35 day cycle.

Since none of the legumes has

performed well under grazing results are presented across legume accessions (Figure 1). Initially, the yields of B. dictyoneura in the legume plots were significantly higher than those of A. gayanus. However, at the last sampling yields were similar. Legume yields were low and declined almost linearly with time. At the start of grazing the highest legume contents were 22 per cent, whilst presently the proportion of legume ranges from zero to 4 per cent depending on the accession. Counts of seedling recruitment were made in the early part of the wet season, and values recorded were low ranging from 0 to 8 plants per m^2. The low seedling recruitment together with a moderate incidence of Rhizoctonia Foliar Blight and the presence of leaf-sucking insects could account for the decline in legume contents in all treatments.

LEGUMES IN SAVANNA

In June 1986 a trial was established in savanna with ten legumes. Eight of these legumes (Table 6), the exceptions being the controls Centrosema acutifolium and C. brasilianum, are known to be rather poorly consumed when grown with improved grasses of high acceptability. The purpose of the trial is to determine whether these species are better consumed when associated with poor quality native grasses. Establishment was excellent and the plots were grazed individually by oesophageal-fistulated steers at the beginning, middle and end of the dry season and in the middle of the wet season.

Data for the dry season across the three grazing cycles are shown in Table 7. Of particular interest was the consumption of Desmodium velutinum, Flemingia macrophylla, Desmodium strigillosum and Tadehagi triquetrum. In all cases, these shrub legumes were selected in markedly higher proportions than they appeared in the pasture. Crude protein and digestibility contents recorded in the mid-dry season are presented in Table 8. The highest values were observed in Desmodium velutinum and Centrosema arenarium, whilst the digestibility of Flemingia macrophylla was lower than that of native pasture. Although studies elsewhere have shown that digestibility is low due to the presence of lignins in this species, it is possible that limitations in the in vitro technique result in an

Table 6. Evaluation of eight legumes of relatively low acceptability in association with savanna in Carimagua.

Centrosema arenarium	CIAT 5236
Desmodium incanum	CIAT 13032
Desmodium strigillosum	CIAT 13155/13158
Desmodium velutinum	CIAT 13204/13213/13215
Flemingia macrophylla	CIAT 17403
Stylosanthes guianensis	CIAT 2031
Tadehagi triquetrum	CIAT 13276
Zornia glabra	CIAT 8279
Centrosema acutifolium	cv. Vichada (Control)
Centrosema brasilianum	CIAT 5234 (Control)

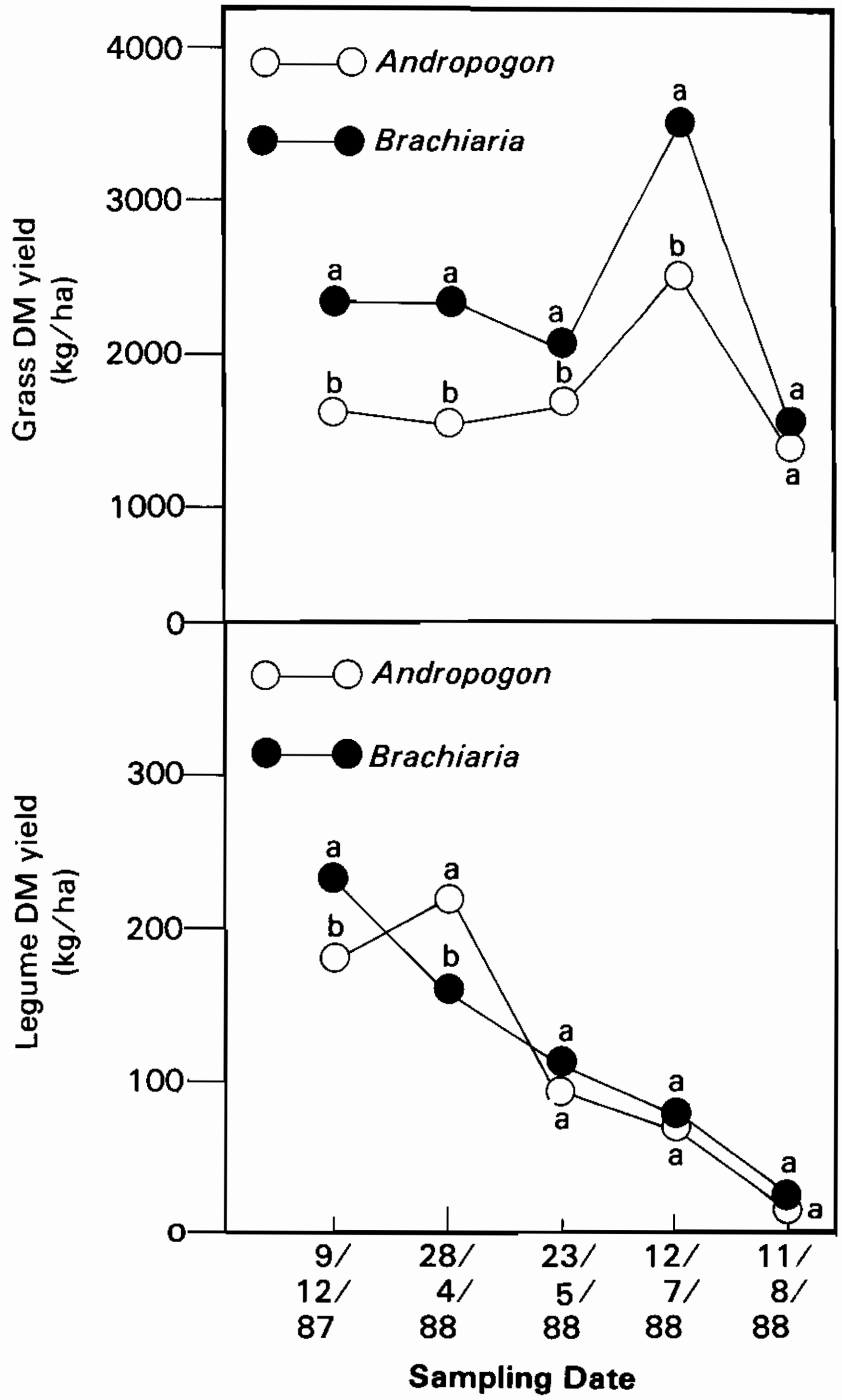


Figure 1. Grass and legume yields in associations of A. gayanus and B. dictyoneura with accessions of C. brasilianum. (Means with the same letter are not significantly different).

Table 7. Productivity and consumption during the dry season of legumes sown in savanna in Carimagua (mean of three grazing cycles).

Legume in association	Native pasture DM yield (kg/ha)	Legume DM yield (kg/ha)	Legume in Pasture (%)	Legume in Extrusa (%)	Ratio Consumption/ Availability
Desmodium velutinum	1291bc	334*ab	18bc	49	2.72
Flemingia macrophylla	1304bc	780*ab	24abc	55	2.29
Desmodium strigillosum	1446abc	426*ab	20bc	38	1.90
Tadehagi triquetrum	1679ab	284*ab	14bc	22	1.57
Centrosema arenarium	2223a	304*ab	13bc	14	1.08
Desmodium incanum	1992ab	155b	8c	4	0.50
Stylosanthes guianensis	1636ab	933ab	37abc	9	0.24
Zornia glabra	1918ab	1231a	41ab	8	0.20
Centrosema brasilianum (Control)	1406abc	346abc	22bc	25	1.14
Centrosema acutifolium (Control)	651c	826ab	55a	54	0.98

* Yields of leaf and stem tips only.
Means with the same letter are not significantly different.

Table 8. Crude protein content (CP) and dry-matter digestibility *in-vitro* (IVDMD) in the middle of the dry season of ten legumes sown in savanna in Carimagua.

Legume	CP Content (%)	IVDMD (%)
Desmodium velutinum	16.8	50.31
Centrosema arenarium	16.8	47.01
Tadehagi triquetrum	13.1	29.90
Stylosanthes guianensis	12.3	40.89
Centrosema acutifolium (Control)	11.9	41.34
Desmodium strigillosum	11.6	39.83
Desmodium incanum	11.6	31.47
Flemingia macrophylla	11.0	21.18
Centrosema brasilianum (Control)	9.8	37.55
Zornia glabra	5.4	29.35
Native pasture	3.5	27.12

underestimate of the true *in vivo* value.

In the wet season (Table 9) consumption of all legumes was less than 10 per cent except for the control *Centrosema acutifolium*. In every case the percentage legume consumed was less than the percentage legume available in the pasture. The most important pests and diseases observed in the trial in the wet season are documented in Table 10. For the first time, stem-gall nematode was observed in *Desmodium strigillosum* and *D. velutinum*. New accessions of these legumes will be screened next season at Carimagua for resistance to this pest.

Arachis pintoi

A. pintoi CIAT 17434 has shown considerable promise as a companion legume in associations containing vigorous species of *Brachiaria*. In October 1984, a trial was established

Table 9. Productivity and consumption during the wet season of legumes sown in savanna in Carimagua.

Legume	Native pasture DM Yield (kg/ha)	Legume DM Yield (kg/ha)	Legume in Pasture (%)	Legume in Extrusa (%)	Ratio Consumption Availability
Desmodium velutinum	6.766a	545*b	8c	7a	0.88
Flemingia macrophylla	9.244a	754*b	8c	6a	0.75
Desmodium strigillosum	8,804a	8,261a	49a	8a	0.16
Tadehagi triquetrum	7,401a	388*b	5c	4a	0.80
Centrosema arenarium	8,457a	222*b	3c	2a	0.67
Desmodium incanum	12,414a	430b	4c	1a	0.25
Stylosanthes guianensis	13,864a	6,197ab	30b	9a	0.30
Zornia glabra	11,958a	6,546ab	36ab	8a	0.22
Centrosema brasilianum (Control)	11,536a	960b	7	5a	0.71
Centrosema acutifolium (Control)	8,963a	6,011ab	42ab	21a	0.50

* Yields of leaf and stem tips only.
Means with the same letter are not significantly different.

Table 10. Main diseases and pests observed in legumes sown in savanna in Carimagua (September 1988).

Diseases/pests	Species	Comments/Score*
Stem-Gall Nematode	Desmodium strigillosum	All replicates (1.5-4.0)
	Desmodium velutinum	All replicates (0.5-3.0)
Anthracnose	Zornia glabra	All replicates (1.0-2.0)
	Stylosanthes guianensis	All replicates (1.0-3.0)
Rhizoctonia Foliar Blight	Centrosema brasilianum	All replicates (2.0-3.0)
Cylindrocladium	Centrosema brasilianum	One replicate only (1.5)
	Centrosema acutifolium	All replicates (2.0)

* 1.0-2.0 = light infestation; 3.0 = moderate infestation; 4.0-5.0 = heavy infestation.

in which the legume was associated with five accessions of Brachiaria namely B. humidicola CIAT 679 (control), CIAT 6705, 6709, 6369 and B. brizantha CIAT 6294. Two treatments of different forage allowances are being imposed on the associations.

Changes in the proportion of legume in the four B. humidicola associations (across forage allowance treatments) since grazing began in 1986 are presented in Figure 2. The contents of A. pintoi in the pastures containing B. humidicola CIAT 679 and CIAT 6705 declined appreciably between August 1987 and July 1988 reaching a level of less than 20 per cent legume. Over the same period a less marked and short-term decline occurred in the association with B. humidicola CIAT 6369. In each of these treatments a subsequent increase in legume proportion was noted, with contents at the final sampling ranging from over 40 to 80 per cent. On the other hand, the proportion of A. pintoi in the association with B. humidicola CIAT 6709 remained virtually constant at 100 per cent legume. No pests or diseases were recorded in the pastures.

A good grass-legume balance at the final sampling has been achieved in the associations containing B. humidicola CIAT 679 (commercial cultivar) and CIAT 6705. In contrast, A. pintoi dominated the other two associations with B. humidicola accession CIAT 6709 completely disappearing from the pasture. A. pintoi CIAT 17434 is now under evaluation in Category IV when animal performance data will be obtained.

Desmodium ovalifolium

Accession CIAT 350 has long shown promise for "Llanos" conditions as a companion legume for vigorous species of Brachiaria. However, there have been problems with a stem-nematode (Pterotylenchus cecidogenus) and the fungal disease False Rust (Synchytrium desmodii). A number of new accessions were selected for better tolerance to these pests and diseases. Five accessions together with a control CIAT 350 were sown in July 1985 in association with Brachiaria dictyoneura cv. Llanero. Two forage

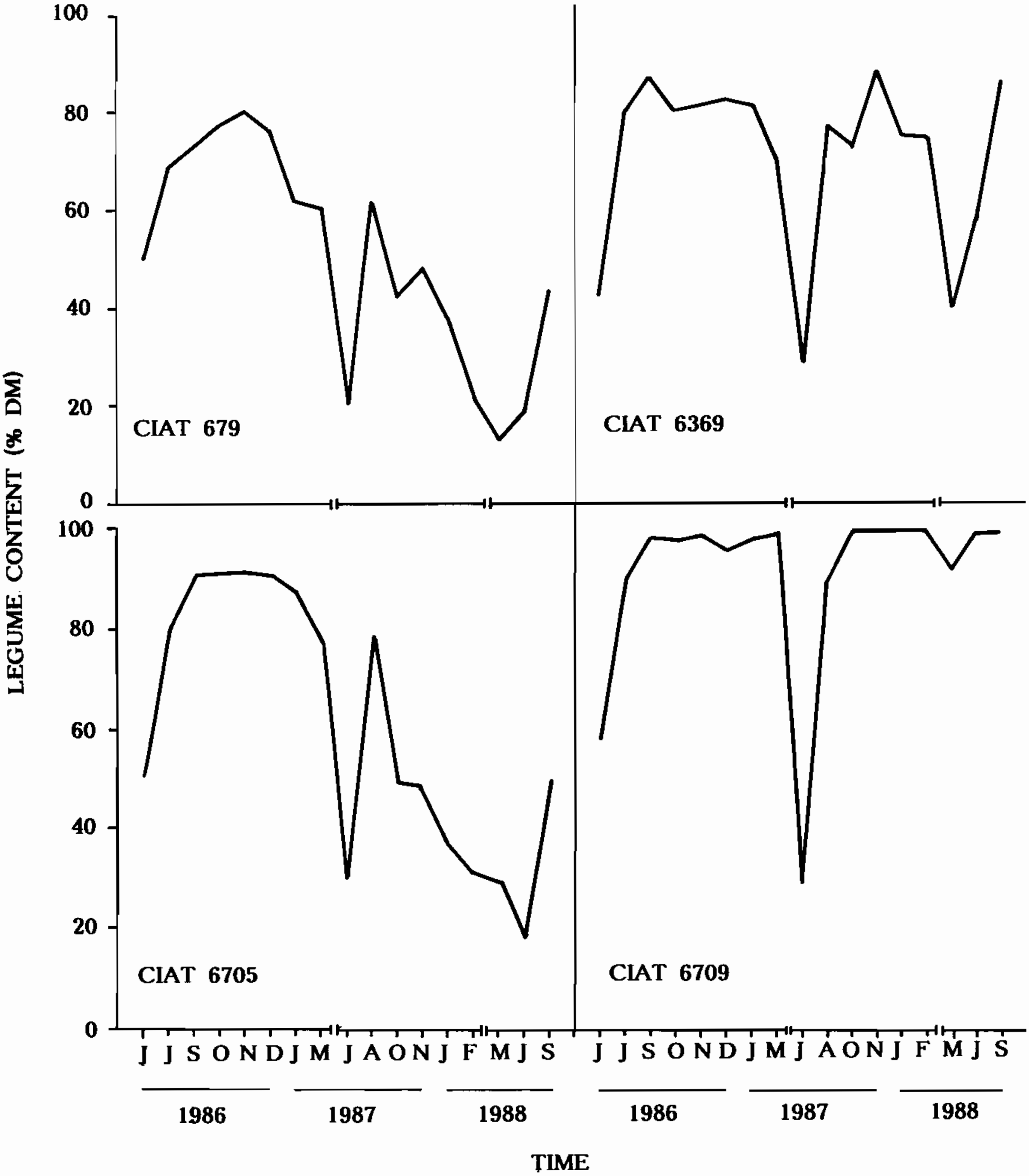


Figure 2. Changes in the proportion of Arachis pintoi CIAT 17434 in association with four accessions of Brachiaria humidicola in Carimagua (// indicates suspension of grazing in dry season).

allowance treatments were imposed by variation in the number of days the plots are grazed by animals.

The data for six *D. ovalifolium* accessions across forage allowance treatments for the three years since grazing began are shown in Figure 3. The pattern of changes in legume content over this period are similar for all accessions. Following an initial increase there has been an almost continuous decline in the proportion of legume. Four of the accessions (CIAT 350, 3776, 3794 and 13092) have disappeared, whilst the other two accessions persist at a low level i.e. 12 per cent for CIAT 13089 and 8 per cent for CIAT 13129. Despite artificial inoculation, nematode problems were again absent even in the control CIAT 350. This year, due to the low legume contents, False Rust was not a problem. Accession CIAT 13089 has been selected for further evaluation due to its low susceptibility to False Rust during the period of this trial.

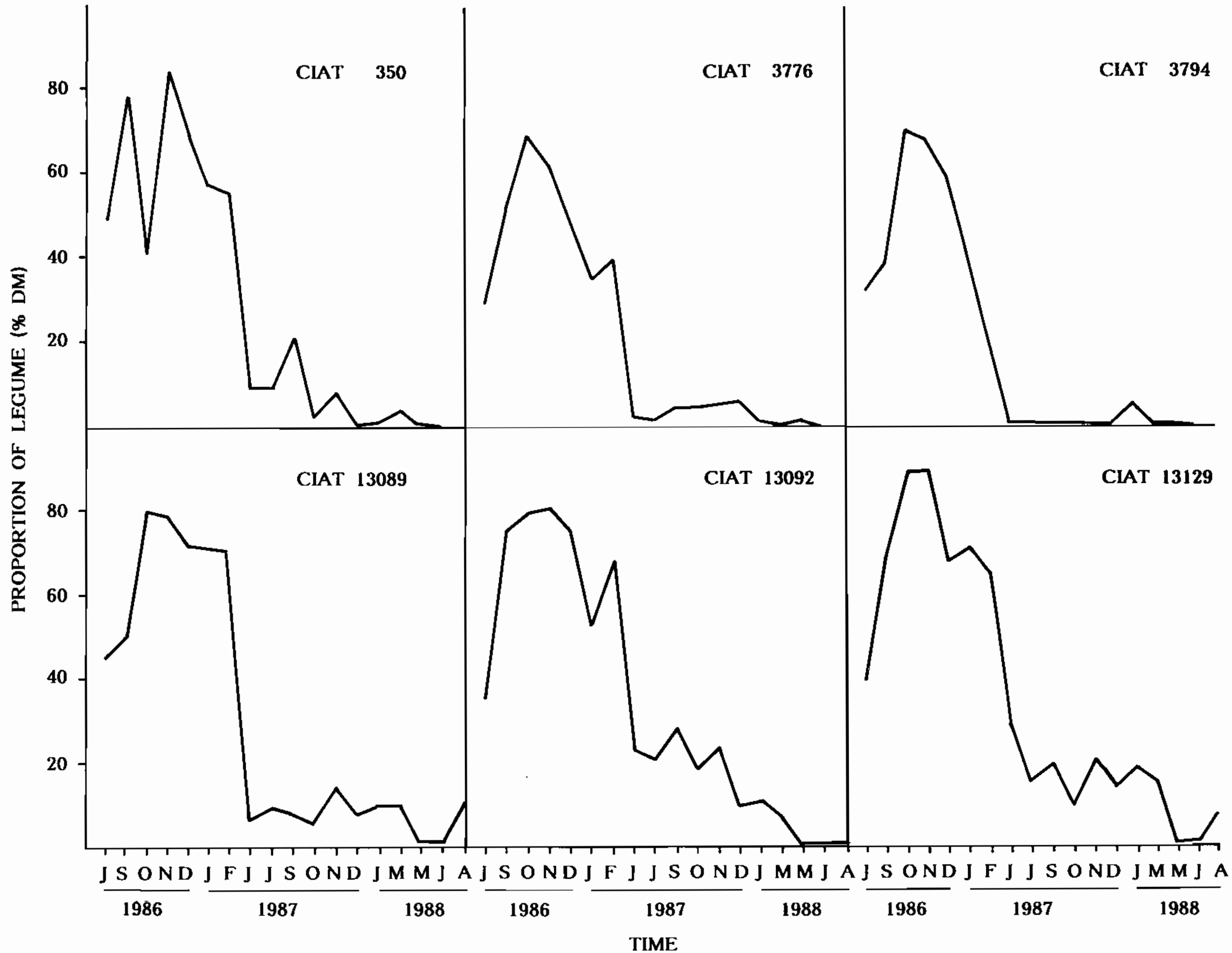


Figure 3. Changes in legume content in six associations of B. dictyoneura and D. ovalifolium under grazing at Carimagua.

7. Agronomy Cerrados

Evaluation of forage species--a CIAT/EMBRAPA/IICA Collaborative Project--with the primary objective of identifying grasses and legumes adapted to Cerrados conditions and grazing utilization has been in progress at the Cerrados Agricultural Research Center (CPAC), Planaltina since 1978. During the past decade significant progress has been made in tropical pasture development by exploiting the naturally occurring species of legumes and exotic grasses through introduction and screening for desirable forage characteristics. CPAC staff presently involved in forage germplasm evaluation are: R.P. de Andrade and M.S. Franca-Dantas.

Since the inception of the Collaborative Pastures Agronomy Program at CPAC some 2786 accessions, grasses and legumes have been evaluated.

Edaphically and environmentally adapted legumes and grasses than can grow at low levels of P and at high Al-saturation have already been identified for the Cerrados ecosystem.

During the initial phase of pasture species evaluation the emphasis was on the genus Stylosanthes. Sixty percent of the legumes evaluated at CPAC prior to 1985, were accessions of Stylosanthes.

An achievement was the identification of anthracnose resistant genotypes of S. guianensis var. pauciflora and S. macrocephala. In addition to these species, two accessions of S. capitata were selected as "key" species and included in a grazing productivity experiment.

Results of this and other grazing experiments conducted at CPAC indicate the need for a wider range of legumes with better stress and grazing tolerance. In case of Stylosanthes capitata, better anthracnose resistance is needed.

Low seed yields, lack of persistence in grazed grass-legume associations handicap S. guianensis var. pauciflora, while S. macrocephala has a short season of growth and it is not adapted to the higher rainfall regions of the northern Cerrados.

A broader range of genetic material of "key" species and new introductions of legumes and grasses have been evaluated during the past three years. A collecting mission of CIAT to East and Central Africa lead by Dr. Gerhard Keller-Grein realized new accessions of Brachiaria. Accessions of legumes and grasses evaluated during the period under review are listed in Tables 1 and 2.

Twenty-one accessions of forage species, 7 grasses and 14 legumes were selected for advanced testing.

Selections for the well-drained Cerrados:
Centrosema acutifolium (1 accession)
C. brachypodum (1)

Table 1. Legume germplasm under preliminary evaluation (Cats. I, II, III) 1985/88, at CPAC, Brazil.

Species	No.of acces-sions	Total
Arachis pintoi	6	6
Centrosema acutifolium	51	
C. arenarium	5	
C. bifidum	1	
C. brasilianum	88	
C. brachypodum	1	
C. capitatum	1	
C. macrocarpum	130	
C. pascuorum	17	
C. pubescens	9	
C. pubescens x C. macrocarpum	5	
C. rotundifolium	2	
C. sp.	3	
C. tetragonolobum	11	
C. vexillatum	1	325
Desmodium canum	1	
D. heterocarpum	3	
D. heterophyllum	20	
D. ovalifolium	70	
D. strigillosum	6	
D. velutinum	1	101
Periandra coccinea	1	1
Pueraria lobata	3	
P. phaseoloides	36	
P. sp.	8	47
Stylosanthes capitata	76	
S. guianensis var. pauciflora	64	
S. guianensis var. vulgaris	2	
S. guianensis híbrido	50	
S. macrocephala	33	225
Tadshagi sp.	1	1
Total		706

Table 2. Grass germplasm evaluated at CPAC from 1985 to 1988.

Species	No.of acces-sions	Total
Brachiaria brizantha	169	
B. decumbens	40	
B. ruziziensis	14	
B. humidicola	48	
B. jubata	35	
B. serrata	3	
B. dictyoneura	13	
B. leucorantha	2	
B. bovonei	6	
B. subulifolia	4	
B. platynota	3	
B. nigropedata	1	
B. sp.	5	343
Paspalum sp. aff. P. plicatulum	19	
P. plicatulum	1	
P. urvillei	2	
P. paucicillatum	1	
P. modestum	2	
P. oterol	1	
P. indacorum	1	
P. pumilum	1	
P. lividum	2	
P. proliferum	1	
P. notatum	2	
P. conspersum	1	
P. sp. aff. P. virgatum	1	
P. sp.	2	37
Penisetum sp.	1	1
Panicum maximum	5	5
Andropogon gayanus	2	2
Hemarthria altissima	2	2
Axonopus complanatus	1	
A. repens	1	
A. araujoi	1	3
Total		393

C. brasilianum hybrid (1)
Brachiaria brizantha (3)
B. decumbens (1)
P. maximum (1)
For the varzeas:
Arachis pintoi (2)
Desmodium ovalifolium (5)
Pueraria phaseoloides (4)
Paspalum conspersum (1)
Paspalum sp. aff. P. plicatulum (1)

Recently, pasture species evaluation was expanded in the varzea where accessions of Paspalum, Hemarthria and Axonopus have been tested, in the first instance, in a small-plot clipping experiment. Legume accessions selected from the collection of Arachis pintoi, Desmodium ovalifolium and Pueraria phaseoloides were included in a Category III type of experiment. These legumes were combined in association with Paspalum sp. aff. P. plicatulum, P. conspersum (syn. P. regnellii) and Brachiaria dictyoneura.

Two other Category III grazing experiments were initiated; one consists of 5 Brachiaria spp. each with Centrosema brasilianum, S. guianensis hybrids, S. guianensis var. vulgaris, an ecotype, locally referred to as "Mineirao" and S. capitata hybrid No. 56. Another experiment of this type contains, "Mineirao" and four accessions of C. pubescens x C. macrocarpum.

Preliminary evaluation of grasses

Since 1978 priority has been given to the evaluation of legumes at CPAC due to the major role adapted legumes can play in pasture improvement. In recent years emphasis has been given to the evaluation of species and accessions of Paspalum and Brachiaria. Species of Paspalum are particularly well-adapted to poorly drained conditions and Brachiaria spp. have great economic significance in the acid soil regions of Cerrados and cleared forest areas of Brazil.

The susceptibility of the widely growh B. decumbens, B. humidicola and B. ruziziensis to spittlebug make it necessary to concentrate on the search of resistant accessions adapted to a wide range of ecological situations.

Brachiaria spp.

Some 343 accessions representing 12 species of Brachiaria have been evaluated in a small plot experiment at CPAC. Fifty-two percent of the collection established as spaced plants were ecotypes of B. brizantha, by far, the most variable and promising species in the collection.

The collection was evaluated over two season, for dry-matter yield, and its seasonal distribution, growth habit, number of days to seed maturity, seed yield, regrowth following defoliation, and damage by spittlebug (Deois flavopicta). Cluster analysis was applied to the data matrix. The data matrix of these agronomic attributes was truncated at the seven-group level.

Dry-matter yields - overall

Annual dry matter yields for the seven clusters ranged from 10.2 to 22.4 t/ha/year and were the highest for clusters 2, 4 and 1, that is, 22.4, 22.2 and 17.1 t/ha per year, respectively (Table 3).

These 3 clusters contain 123 accessions, of which 105 (85.4%) are ecotypes of B. brizantha and they are all erect or semierect plants. In the "second best" cluster 4, 89% of all accessions displayed erect/semierect growth habit. Eleven per cent and 5% in cluster 4 and 1 are stoloniferous, respectively.

In cluster (3) containing only B. brizantha, 60% of the accessions are late flowering, that is, flowering began at the end of March or later.

Table 3. Classification of 238 accessions from 13 species of Brachiaria on the basis of five paremeters.

Herd	No. of accessions (% total)	DM Yield (t/ha/year)	Growth Habit *	Flowering**	Regrowth***	Spittlebug damage score****
1	57 (23.95%)	17.12	3(50.9%)-2(43.9%)	2(94.7%)	3(73.8%)	0(86%)
2	14 (5.88%)	12.67	2(85.8%)	2(85.8%)	4(49.8%)-3(42.7%)	0(71.4%)-1(25.5%)
3	30 (12.61%)	22.40	2(50%)-3(50%)	3(60%)-2(40%)	3(73.3%)-4(20%)	0(100%)
4	36 (15.13%)	22.22	3(52.8%)-2(36.1%)	3(88.9%)	4(69.6%)-3(19.5%) 5(11.2%)	0(97.2%)
5	25 (10.50%)	10.80	2(68%)-3(24%)	3(92%)	3(60%)-2(32%)	0(80%)-1(20%)
6	60 (25.21%)	14.03	5(100%)	3(98.3%)	3(73.8%)-4(18.4%)	0(91.6%)
7	16 (6.72%)	10.20	5(87.5%)	3(87.6%)	3(56%)-2(44%)	1(83.7%)
Total	238	X:15.63				

* Growth habit : 2 = erect, 3 = semierect, 4 = stoloniferous.
** Flowering time: 1 = early, 2 = mid-season, 3 = late.
*** Regrowth: 1-5 = minimum - maximum
**** Damage score: 0-5 = no spittlebug - major damage (dead plant)

Total dry-matter yields sorted into the remaining four clusters in declining order: 6 > 2 > 5 > 7, that is, 14.0, 12.7, 10.8 and 10.2 DM t/ha per year, respectively. These clusters contain the majority of accessions of B. decumbens, B. humidicola, and B. ruziziensis including the commercial cultivars of B. decumbens and B. humidicola. In addition to lower DM yields, accessions of these four clusters showed poor adaptive characteristics. Cluster 7 (the lowest yielding group) showed the highest incidence (94%) of spittlebug damage. Note, that only one accession of B. brizantha is located in cluster 7.

Dry-matter yields - wet season

The bulk of the dry matter yield was produced during the wet season. Highest DM yields in two wet seasons were recorded for clusters 2, 3 and 1, which produced 21, 18, and 16 t/ha, respectively. Up to 95% of the accessions were B. brizantha in the three clusters with the highest DM yields (Table 4). Furthermore, 87%, 95% and 89% of the accessions in these three clusters were unaffected by spittlebug.

Dry-matter yields - dry season

Seventy-eight accessions of B. brizantha or 61% of the 127 accessions of this species included in the experiment were sorted into clusters (3, 1, and 4) with DM yields of 5.3, 3.7, and 2.9 t/ha. Cluster 3 with the highest (5.3 t/ha) yield contains 24 accessions. Of these, 18 or 75% are B. brizantha and the remaining five are the best-yielding accessions of B. decumbens, including CIAT 16488.

In the cluster (6) with the lowest dry matter yield, 50% of the accessions are B. humidicola and the rest of the accessions are B. ruziziensis and B. decumbens. These were badly hit by spittlebug in the wet season and recovery was slow or nil during the dry season. The poor performance of B. humidicola during the dry season has already been recorded at CPAC (Tables 5 and 6).

Seed yield

Days to seed maturity (counted from January 1) ranged from 75 to 185 days (Table 7). Some of the latest flowering accessions failed to produce

Table 4. Dry-matter yield of 244 accessions of Brachiaria spp. in the wet season (4 harvests). CPAC, Planaltina.

Cluster	No.of accessions (% of total)	DM yield t/ha	B. brizantha No. and % per cluster
1	70(29.41%)	16.43	64(91.4%)
2	42(17 65%)	21.24	29(69.0%)
3	20(8.40%)	18.11	19(95.0%)
4	14(5.88%)	11.80	7(50.0%)
5	15(6.30%)	6.49	5(33.0%)
6	63(26.47%)	13.25	2(3.17%)
7	14(5.88%)	9.22	1(7.14%)

Table 5. Dry-matter yield of 244 accessions of *Brachiaria* spp. in the dry season. CPAC, Planaltina, Brasil.

Cluster	No.of accessions (% of total)	DM yield (t/ha)	*B. brizantha* No. and % per cluster
1	44 (18%)	3.69	40 (90.9%)
2	38 (16%)	1.96	28 (73.7%)
3	24 (10%)	5.34	18 (75.0%)
4	28 (11%)	2.86	20 (71.4%)
5	34 (14%)	2.74	19 (55.9%)
6	56 (23%)	1.58	1 (1.79%)
7	20 (8%)	2.26	0

Table 6. A cluster of accessions of *Brachiaria brizantha* and *B. decumbens* with the highest DM yield in two dry seasons. CPAC, Planaltina, Brasil.

Accesión CIAT No.			
B. brizantha			
16113	16119	16121	16168
16288	16307	16308	16457
16458	16467	16473	16483
16487	16459	16827	16829
16830	26110	cv. Marandú	
B. decumbens			
16488	16498	16499	16500
26181			

Table 7. Seed yield (g/plant) of accessions from 11 species of Brachiaria. Cerrados Agricultural Research Center, Planaltina, D.F., Brazil.

Species		Seed yield Range or Mean g/plant	Number of days to maturity Range or Mean
B. brizantha	(145)*	0.45 - 55.87	75 - 185
B. decumbens	(40)	0.13 - 18.65	77 - 127
B. humidicola	(34)	0.39 - 26.00	77 - 130
B. ruziziensis	(15)	11.30 - 36.19	87 - 133
B. jubata	(27)	0.60 - 36.42	83 - 174
B. serrata	(1)	38.80	139.7
B. bovonei	(3)	0.81 - 392	76 - 98.3
B. dictyoneura	(1)	2.43	89.5
B. subulifolia	(2)	0.30 - 1.65	81 - 89
B. platynota	(1)	1.00	123
B. nigropedata	(1)	0.81	82
Control B. brizantha cv. Marandu		25.3	121

* Number of accessions per species.

seed. Seed yields also showed a wide range of variability among accessions, and ranged from 4 to 155 kg/ha.

Frequency of cutting trial

In the follow-up small plot experiment, 24 accessions of Brachiaria were compared using cv. Marandu as the control. Several accessions of Brachiaria brizantha and 1 accession of B. decumbens (CIAT 16488) produced high yields of dry matter when cut at 3, 6, 9 and 12 weeks intervals and outyielded cv. Marandu. The relative growth rate and recovery after defoliation of several of these accessions were superior to that of Marandu.

Preliminary agronomic evaluation of the Brachiaria spp. collection has now been completed and three accessions of B. brizantha and one accession of B. decumbens have been selected for Cat. III type of evaluation, that is, under grazing and in association with legumes.

These selected accessions represent distinct growth forms with specific agronomic characteristics. For example, CIAT accessions 26110 is a "Marandu-type" but it has significantly better recovery during the dry season and a higher relative growth rate. It appears, that it requires better soil fertility or higher rate of fertilizer application. CIAT 16315 a less productive type of B. brizantha with excellent performance during the dry season. It is a short growth form, tolerant of drought and it is a good seed producer. CIAT 16306 is one of the tall, erect types, this accession also showed good recovery following defoliation during the dry season. The ability of these different growth forms to combine in association with legumes e.g. S. capitata and C. brasilianum is of particular interest. This aspect is being investigated in a small-scale grazing experiment on the Chapadao.

Cluster analysis of numerical data of relatively few, well-chosen, agronomic attributes sorted the Brachiaria collection into a similar agro-morphological groups of accessions with well defined characteristics. The superior adaptive characteristics of some of the accessions of B. brizantha became quite obvious.

Paspalum spp.
Paspalum is a predominantly American genus. It contains approximately 250 species most of which are good grazing grasses and several of them are adapted to wet situations. It is estimated that there are 30 million ha of hydromorphic soils in Brazil and 12 million ha of these varzea lands are situated in the Cerrados. Most of the c. 160 species of this genus occurring in Brazil are well-accepted by cattle. Several species such as P. guenoarum and P. plicatulum possess antibiosis that effectively reduced survival and fecundity of adult spittlebugs and killed numphs of the insect feeding on these species.

In a small plot, cutting experiment established in a low humid gley soil at CPAC, 8 accessions of Paspalum sp. aff. P. plicatulum were compared with seven other grasses. These accessions were selected from 43 wet-land grass species collected by Dr. J.F.M. Valls, curator of Gramineae, CENARGEN.

Two agromorphological groups of this species form were distinguished: late flowering, broad-leafed, genotypes with high yield capacity, IVDMD and nutrient values; early flowering, narrow leafed types with low yield capacity and generally low nutritive values.

The highest total annual and dry season herbage yields were produced by Paspalum sp. aff. P. plicatulum BRA accessions 009661, 003913 and 009610. These accessions produced dry matter yields ranging from 25.7 to 28.6 t/ha (Table 8). The same accessions were most productive in the dry season (Table 9).

Significant intraspecies variability was recorded in IVDMD among accessions of P. sp. aff. plicatulum. In the wet season, IVDMD values for this species ranged from 33.4% to 57.3%. BRA accessions 003913, 009661, and 009610 selected on the basis of several desirable agronomic characteristics were in the top range of IVDMD values: 55.5%, 54.91%, and 54.83%. In the dry season, IVDMD values were the highest, 51.9% and 51.7%, for two of the selected BRA accessions, 009610 and 003913, respectively (Table 10). Crude protein contents of the selections were above maintenance level in the wet season, while P content of the forage was marginal. Both values were below or at maintenance level at the end of the dry season (Table 11).

Mean yields of cleaned seed for accessions of P. sp. aff. P. plicatulum ranged from 214 to 918 kg/ha.

The species and ecotypes of Paspalum included in this experiment were free of foliar diseases and insect pests, including spittlebug. The long growth season, high DM yields, and nutrient contents of selected accessions of P. sp. aff. P. plicatulum in a seasonally flooded situation are of considerable economic significance. These accessions can provide an adequate diet for the maintenance of adult cattle by filling the "nutritional gap" regularly occurring in the well-drained savannas during the dry season.

Panicum maximum
Dr. E.M. Hutton selected three lines from hybrid progenies of sexual P. maximum for evaluation. One of these accessions, a drought tolerant type of intermediate growth habit, CPAC 3148 is showing good promise in small plot experiments and in regional trials "B" established at Lucas de Rio Verde, Canarana and Rondonopolis, MT in the 1500 to 2000 mm rainfall region.

Table 8. Dry matter yields (t/ha/year) of 15 grass accessions in a várzea at the Cerrados Agricultural Research Center, near Brasilia.

Species	BRA No.+	Dry matter yields t/ha/year
Paspalum sp. aff. *P. plicatulum*	003913	28.6 a*
P. sp. aff. *plicatulum*	009661	25.9 ab
P. sp. aff. *plicatulum*	009610	25.7 ab
P. sp. aff. *plicatulum*	009628	24.2 abc
P. sp. aff. *plicatulum*	009431	19.8 bcd
P. sp. aff. *plicatulum*	003638	19.2 bcd
Paspalum urvillei	010685	18.4 cd
P. urvillei	007323	18.3 cd
P. sp. aff. *plicatulum*	008486	17.7 cd
P. sp. aff. *plicatulum*	008486	16.9 d
Hemarthria altissima	-	16.1 d
Paspalum oteroi	003905	6.9 e
P. pauciciliatum	003891	3.5 e
P. modestum	006203	2.0 e
Axonopus complanatus	-	1.8 e

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

\+ Accession number of Centro Nacional de Recursos Genéticos, Brasilia.

Table 9. Dry-matter yield produced by 15 wet-land grasses during the dry season (May-June), Várzea, CPAC, Planaltina.

BRA	Species	DM yield kg/ha
009661	*Paspalum* sp. aff. *P. plicatulum*	2301.1 a*
003913	*P.* sp. aff. *P. plicatulum*	2259.0 a*
009610	*P.* sp. aff. *P. plicatulum*	2034.7 a
010685	*P. urvillei*	1950.4 a
007323	*P. urvillei*	1388.6 b
009407	*Paspalum* sp. aff. *P. plicatulum*	1220.2 bc
003638	*P.* sp. aff. *P. plicatulum*	1024.2 bc
008486	*P.* sp. aff. *P. plicatulum*	963.2 bcd
006203	*P. modestum*	959.3 bcd
009431	*Paspalum* sp. aff. *P. plicatulum*	889.2 cd
-	*Hemarthria altissima*	786.0 cde
009628	*Paspalum* sp. aff. *P. plicatulum*	762.4 cde
003905	*P. oteroi*	755.6 e
003891	*P. pauciciliatum*	507.8 e
-	*Axonopus complanatus*	381.9 e

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

Table 10. Seasonal changes in IVDMD values of 15 wet-land grasses. Várzea, CPAC, Planaltina.

Species and BRA accessions No.	Wet	End of Wet (IVDMD %)	End of dry
P. sp. aff. P. plicatulum			
008486	57.25 a*	49.11 abcde	43.85 bcd
003913	55.56 ab	59.98 a	51.69 a
009661	54.91 ab	55.87 ab	44.43 abcd
009610	54.83 ab	51.77 abc	51.88 a
009431	54.41 ab	50.51 abcd	46.61 abc
003638	52.51 abc	45.16 def	46.66 abc
009407	46.27 cd	41.10 ab	36.80 de
009628	33.43 e	40.12	32.23 e
P. urvillei			
007323	48.26 bcd	46.72 cde	49.02 abc
010685	42.79 d	50.61 abcd	45.73 abc
Hemarthria altissima	47.42 cd	53.10 ab	51.49 ab
P. modestum			
006203	48.87 bcd	48.89 bcde	41.86 cd
P. oteroi			
003905	47.29 cd	44.14 ef	43.45 cd
Axonopus complanatus	35.51 e	44.33 ef	42.16 cd
P. pauciliatum	42.83 d	44.65 ef	42.10 cd

* Mean values followed by a different letter are significantly (P<0.05) according to Duncan's Multiple Range Test.

Table 11. Chemical composition of selected accessions of P. sp.aff. P. plicatulum Várzea. CPAC.

P. sp. aff. plicatulum (BRA No.)	PC	P	K	Ca	Mg
Wet season					
009610	7.5	0.15	1.51	0.63	0.55
009661	7.4	0.13	0.85	0.58	0.66
003913	7.5	0.14	1.03	0.63	0.65
Final of the wet season					
009610	6.5	0.19	1.21	1.14	1.04
009661	8.6	0.17	0.93	1.16	0.98
003913	7.4	0.16	0.90	1.01	1.06
Final of the dry season					
009610	6.1	0.12	0.87	1.23	0.55
009661	5.2	0.11	1.00	1.10	0.44
003913	5.1	0.09	0.54	1.09	0.62

Preliminary evaluation of legumes

CPAC has assembled and studied a wide range of accessions of *Stylosanthes* species with emphasis on *S. guianensis* var. *pauciflora*, *S. capitata*, *S. guianensis* var. *vulgaris* and *S. macrocephala*.

One-humdred and seventy-three accessions of *Stylosanthes* have been evaluated during the period 1985-88. Anthracnose continued to be a problem in *Stylosanthes* accessions. Infestation was relatively low in the year of establishment. Twenty-seven percent of the accessions under observations were free of the disease, less than one percent of the accessions were killed and the rest was slightly or moderately affected.

Anthracnose damage was severe in the 1987/88 season, the pathogen destroyed a stand of 1.2 ha of *S. capitata* CIAT 1097. This accession showed field resistance to anthracnose in the grazing trial established in 1983.

S. guianensis var. *pauciflora*

One-hundred and twenty-seven accessions of the "tardio" group have been evaluated prior to 1985 and an additional 64 accessions were tested since, totalling 191 accessions of this species form. Selection of accessions with an early flowering habit and improved seed production continued.

Main attributes of the "tardio" group

- Most accessions are very well-adapted to the soils and climate of the region;
- excellent tolerance to drought and are not defoliated in the dry season;
- high degree of resistance to anthracnose.

Deficiencies

- Low inherent capacity to produce seed;
- lack of persistence in grass-legume associations;
- poor regeneration from self-sown seed;
- unstable resistance to anthracnose and stemborer in the northern Cerrados.

Past experience with CIAT 2243 (cv. Bandeirante) indicated that the low inherent capacity of this species form to produce commercially acceptable seed yields cannot be improved upon by agronomic manipulation, including irrigation and high rate of fertilizer application. Seed yield of this accession with irrigation until peak flowering produced 34 kg of pure seed per ha as against 24 kg/ha without irrigation.

Although seed production of six accesions of "tardios" varied considerably in 1988, only one accession (CIAT 2542) produced good seed yields. These accessions were hand harvested during the second week of September and fallen seed was collected on a plastic sheet placed under the plants. Pure seed yields were as follows:

CIAT accession	Pure seed yield kg/ha		
	from plant	fallen seed	total
2542	127.0	48.8	175.8
10417	68.3	10.4	78.7
10484	68.1	9.9	78.0
2017	33.8	9.9	43.7
2974	23.2	13.2	36.4
2983	5.6	8.6	14.2

The aim of a recently developed project is to select superior genotypes from hybrid derivatives of a series of crosses of *S. guianensis* var. *pauciflora* x *S. guianensis* var. *vulgaris* and *vulgaris* x *vulgaris*. Fifty hybrid lines, products of the breeding program conducted by Dr. J.W. Miles in Colombia, were established for evaluation in a space-planted nursery in four randomized blocks in 1986/87. The hybrids were classified on the basis of flowering date, vigor, anthracnose resistance and seed yield. Early- and mid- season lines were considered those which were in the "full seedhead stage" or at least began flowering at the end of March. Seeds of these lines reached maturity in June/July (Table 12).

There is an inverse relationship between early maturation of seeds and retention of leaves during the dry season. Several of the mid-season and late flowering (April-May) hybrids possess the desirable characteristic of retaining green leaves throughout the dry season. The agronomic value of these genotypes largely depends on their capacity to produce seed yields better than those of cv. Bandeirante, at the same time, they must have a high degree of resistance to anthracnose. Apparently, there is a certain loss of disease resistance in the hybrids. The following lines combined these desirable characteristics:

16 - 8 (CIAT 15 z 1539)
24 - 23 (CIAT 1639 x 1633)
24 - 22 (CIAT 1122 x 1539)

A late flowering F_5 hybrid, 16-4 (CIAT 1808 x 1062)[5] has excellent forage characteristics and it is somewhat earlier flowering than cv. Bandeirante (Table 13).

Anthracnose caused only minor damage in these selected materials while one of the controls S. guianensis CIAT 136 was moderately affected by anthracnose.

Styolosanthes capitata
Unquestionably, this species has the best adaptation to the poor fertility acid-soil Cerrados.

Two-hundred ninety-six have been evaluated at CPAC, and all showed good adaptation to climate and soil. In the preliminary evaluation trials Brazilian accessions CIAT 1019 and CIAT 1097 were selected on overall performance for advanced testing. Initially, these accessions have shown resistance to anthracnose and were included in the first grazing productivity (Category 4) experiment conducted from May, 1983 to 1987. A relatively high population of these two S. capitata accessions was maintained in association with A. gayanus for the duration of the experiment. A slight advantage in

Table 12. Early and mid-season flowering S. guianensis hybrids selected from the F_4 generation.

Parental lines (CIAT No.)	Breeder's No.	Type of cross	Origin
15 x 1539	6-2	vulgaris x vulgaris	Bolivia, Venezuela
15 x 1539	6-4	vulgaris x vulgaris	Bolivia, Venezuela
15 x 1539	6-6	vulgaris x vulgaris	Bolivia, Venezuela
15 x 1539	7-2	vulgaris x vulgaris	Bolivia, Venezuela
15 x 1539	7-7	vulgaris x vulgaris	Bolivia, Venezuela
15 x 1539	16-8	vulgaris x vulgaris	Bolivia, Venezuela
15 x 1539	28-23	vulgaris x vulgaris	Bolivia, Venezuela
1122 x 1539	24-22	vulgaris x vulgaris	Colombia, Venezuela
1639 x 1633	24-23	vulgaris x pauciflora	Brazil

Table 13. F_3, F_4 and F_5 progenies of S. guianensis hybrids selected for drought tolerance and retention of leaves in the dry season.

Breeder's No.	Parental accessions (CIAT No.)	Type of cross
45- 4 F3	1808 x 10136	pauciflora x pauciflora
44- 3 F3	unknown	----
1- 8 F3	10136 x 2031	pauciflora x pauciflora
5- 7 F3	10136 x 2031	pauciflora x pauciflora
16- 4 F5	1808 x 1062	pauciflora x pauciflora
47- 3 F3	10136 x 1062	pauciflora x pauciflora
2- 4 F3	unkhown	----
46- 2 F3	unknown	----
17-10 F4	15 x 1539	vulgaris x vulgaris

terms of animal liveweight gain was recorded for CIAT accession 1097.

A major limitation to S. capitata is anthracnose. However, substantial intraspecific variation and resistance occurs in this character.

CIAT 1097 (BRA 005886) included in advanced testing was severely infected by anthracnose in a 1.2 hectare seed multiplication plot in 1987/88. Because of the cyclic incidence of severe attacks of anthracnose it is imperative to carry out anthracnose screening over several seasons and inoculation with a broad spectrum of races of the pathogen. A collaborative project with Plant Pathology, CPAC was initiated in the second semester in 1988.

In a glass-house experiment 27 accessions, including susceptible controls are being tested using artificial inoculation. Resistant material will be further tested in the field (Table 14).

In addition to S. capitata CIAT 1097 which is an early flowering accession hybrid lines were selected from the plant breeding project of Dr. E.M. Hutton for evaluation. The hybrids, Nos. 56 and 111, are early and late flowering types, respectively, the difference in seed maturation is up to 8 weeks. They were found to be superior types with respect to vigor and anthracnose resistance. Both hybrids are currently under seed multiplication. Most early flowering accessions of S. capitata are defoliated when their seeds mature. Consequently, late flowering habit with retention of leaves long into the dry season is an important criterion in the selection of suitable ecotypes of this species. The following accessions were selected for late flowering and retention of leaves: CIAT 2320, CIAT 2353, and CIAT 2546.

S. guianensis var. vulgaris CIAT 2950

Attributes of Stylosanthes guianensis var. vulgaris - "Mineirao", CIAT 2950:

- Well adapted to soils and climate of the cerrados;
- resistant to anthracnose in the Central Plateau region and in Mato Grosso. However, it is susceptible to anthracnose in the northern Cerrados, in the Boa Vista, Macapa and Amapa savannas;
- excellent establishment vigor;
- compatible with Andropogon gayanus and Panicum maximum (hybrid No. CPAC 2148);

Table 14. Accessions of *Stylosanthes capitata* resistant to anthracnose. Selected at CPAC 1978-88.

No.	CPAC	BRA	CIAT
	----------------------	Accession Nos.	----------------------
1	706	005886	1097*
2	704	007251	1019*
3	2826	014401	2546
4	2829	014532	2553
5	2700	035220	16
6	2831	014281	2536
7	2836	015113	2320
8	2821	035173	2353
9	2837	014362	2543
10	2841	014397	2545
11	2839	014443	2548
12	2683	029050	10398
13	2699	035211	12
14	1925	--	Hybrid 56
15	--	--	Hybrid 111 L
16	--	--	Hybrid 111 G
17	--	--	9 G
18	1594	013935	2502
19	1608	--	2829
20	1597	014117	2521
21	2825	035548	15
22	2844	031160	1682
23	2823	001881	1328
24	650	--	1405*
25	662	--	136*
26	Lago Norte	--	--
27	Barra do Garca - MT		

* Control.

- superior drought tolerance;
- first to recover after the opening rains;
- a major deficiency of this ecotype is poor seed production.

This accession has been included in two small-scale grazing trials. In one experiment, it is being evaluated in association with five *Brachiaria* spp. representing distinct growth forms. Mineirao significantly (P < 0.01) outyielded *S. capitata* No.56, *C. brasilianum* CIAT 5234 and *S. guianensis* hybrids during the dry season following heavy grazing. "Mineirao" also performed well in association with *Andropogon gayanus* and *Panicum maximum*. It has persisted well in a protein bank and there was no loss of stand under this type of intermittent grazing.

Stylosanthes macrocephala

Promising accessions in the CIAT germplasm collection show resistance to anthracnose and stemborer at least in the Central Plateau region and in Mato Grosso. In the northern

Cerrados, stand losses-up to 75% occurred due to these problems. One-hundred and fifty accessions have been evaluated at CPAC; the promising accessions selected earlier are CIAT 2133 (BRA 008419), CIAT 10007 (BRA 0022781) and CIAT 10009 (BRA 0022837). These have been included in regional trials conducted in Mato Grosso and, CIAT 10007 has shown the best vigor also a tendency to make new growth after seed maturation.

There are distinct growth forms among the thirty-three new accessions of S. macrocephala introduced in 1985/86. For example, accession CIAT 10010 (BRA 022965) is a very prostrate type. All accessions are prolific seed producers and the majority of accessions flower in February or early March and these are completely defoliated by the on-set of the dry season. This is a major disadvantage of the species and in this respect there is no ecotypical variability among the accessions evaluated. CIAT 1430 (BRA 0028967) has shown better vigor than the control cv. Pioneiro CIAT 1281 (BRA 003697).

Centrosema spp.

C. brasilianum
At present, this is the most promising species for Cerrados conditions. CIAT 5234 (BRA 012297) persisted in association with Andropogon gayanus for three years under a heavy intermittent system of grazing. It was somewhat less successful in association with B. brizantha cv. Marandu. It has excellent drought tolerance and it is a prolific seed producer. Hand harvested small plots yielded the equivalent of 850 kg/ha cleaned seed.

A major constraint for the species on the dark-red latosol site is little leaf mycoplasma (LLM). Practically all accessions of C. brasilianum were affected to some extent by LLM. The disease has severely reduced dry matter production and in most cases prevents seed setting. This problem is affecting only a small number of plants in the new experiments established on the Chapadao. Rhizoctonia attacks the plant during the wet season but it is not a serious problem under regular grazing.

C. macrocarpum
In addition to the 58 accessions tested earlier 130 accessions were included in the recent testing program. C. macrocarpum accessions were noted for good resistance to foliar diseases. All showed excellent adaptation to climate and soil conditions. Vegetative vigor and tolerance to drought were also good. A major problem with this legume is lack of flowering and seed set at CPAC and this applies to all 188 accessions evaluated. The presence of Cercospora, anthracnose, Rhizoctonia and the Phoma/Phomopsis complex were recorded, but the incidence of diseases was low. A virus condition also affects most accessions.

Selections from a breeding program initiated by Dr. E.M. Hutton produced hybrids of C. pubescens x C. macrocarpum which show better resistance to Phoma/Phomopsis and produce high seed yields as well. Four F_8 lines have been included in a Category III type grazing evaluation trial, each hybrid was established in association with A. gayanus and Panicum maximum.

Evaluation of 188 accessions of C. macrocarpum has now been concluded. The findings indicate that, in the collection evaluated to date, no suitable ecotype exists for the Planalto region of Central Brazil.

C. acutifolium
Fifty-one accessions of this species, introduced from Colombia, Venezuela and Central Brazil have been

evaluated. In general, the species is well adapted to soil and environmental conditions. Excellent disease resistance but late flowering and poor seed production was recorded in accessions such as CIAT 5277, introduced from the Colombian Llanos. Several accessions of this species are highly susceptible to Phoma/Phomopsis.

One accession of C. acutifolium, originally selected at CNPGC, Campo Grande, showed good performance, that is, resistance to foliar disease and remained green throughout the dry season.

Flowering of this accession (CIAT 15531) and seed production occurred late in the season and it was moderate.

C. tetragonolobum and C. brasilianum hybrids

In view of the good forage potential of C. brasilianum and the related C. tetragonolobum, 88 and 11 new accessions have been evaluated, respectively in 1987/88.

Establishment yield and early vigor of 6 accessions of C. tetragonolobum, were particularly good. DM yield for these accessions ranged from 2381 to 2437 kg/ha six months after establishment. All accessions of C. tetragonolobum exhibited resistance to pests and diseases. Only one accession (CIAT 15838) of this promising species is early flowering at CPAC. However, few of the flowers produced pods and most of them were distorted and empty.

A bulked-up population of the hybrid C. brasilianum (5234 x 5224, BRA 012297) and selections from the F_2 population were planted on the Chapadao in December 1987. Selection 108 outyielded all other accessions including the control CIAT 5234, the bulk population of the hybrid, C. acutifolium CIAT 15531 and C. brachypodum CIAT 5850 (Table 15).

Desmodium ovalifolium

This vigorous, stoloniferous perennial is best adapted to regions with 2000 mm or more rainfall and with a short dry season. It lacks vigor in dry land areas of the Brazilian Cerrados where the length of dry season is more than two months. However, the species is promising in the Cerrados in low-lying areas subject to periods of flooding. At CPAC it was found to be susceptible to root-knot nematodes. Considerable variation was observed among accessions in this respect. The number of root-knot nematodes (Meloidogyne) ranged from nil to 13,725 per 5 g of roots. On the basis of tolerance to root-knot nematodes and vegetative vigor 9 accessions were selected for seed multiplication and continuing evaluation (Table 16). Four accessions are under grazing in the Category III experiment in the varzea at CPAC.

Significant ecotypical variability was observed in seed production among accessions tested in the varzea. The range was from 0,6 to 440 kg/ha. Higher seed yields were obtained from accessions in which peak flowering occurred before June (Table 17).

Currently, selected accessions are evaluated under grazing in association with B. dictyoneura and two accessions of Paspalum sp. aff. P. plicatulum.

Pueraria spp.

Some 47 accessions from 3 species have been evaluated under varzea conditions at PCAC. Four accessions have been selected and included in a grazing evaluation trial in the varzea. These selections have grown vigorously during the six months of wet season but appear to be intolerant of low temperatures (< 15°C) and made no regrowth during the cool-dry season eventhough moisture in the varzea was non-limiting. Apparently, the species

Table 15. Dry matter yields (kg/ha) of 18 accessions of *Centrosema* spp. produced during the wet season. Chapadao, CPAC, Planaltina, Brasil.

No.	Accession	Yield* (kg/ha)
108	*C. brasilianum* F3 (5234 x 5224) selection	5225.1 a
5234	*C. brasilianum*	3758.4 b
	C. brasilianum F3 (5234 x 5224) bulk	3594.7 b
2013	*C. brasilianum* F3 (5234 x 5224) selection	3183.1 bc
206	*C. brasilianum* F3 (5234 x 5224) selection	3142.8 bcd
203	*C. brasilianum* F3 (5234 x 5224) selection	2870.8 bcde
106	*C. brasilianum* F3 (5234 x 5224) selection	2847.5 bcde
309	*C. brasilianum* F3 (5234 x 5224) selection	2505.5 bcdef
104	*C. brasilianum* F3 (5234 x 5224) selection	2222.4 bcdefg
1015	*C. brasilianum* F3 (5234 x 5224) selection	2157.1 cdefg
15531	*C. acutifolium*	1843.5 defgh
15899	*C. acutifolium*	1695.5 efgh
15398	*C. brasilianum*	1657.1 efgh
15533	*C. acutifolium*	1489.7 fgh
5850	*C. brachypodum*	1401.2 fgh
15387	*C. brasilianum*	1089.8 gh
15530	*C. acutifolium*	1045.1 gh
15525	*C. brasilianum*	653.8 h

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

Cuadro 16. Número de nematodos en las raíces de accesiones de Desmodium ovalifolium, área de varzeas, CPAC, Brasil.

Desmodium ovalifolium	Nematodes Meloidogyne	Nematodes Pratylenchus
	No. per 5 g of roots	
3652	0	57
3663*	7	223
3666*	3	319
3673	0	200
3776	0	243
13081*	10	1053
13987*	128	103
13089*	25	192
13103*	3	120
13104*	7	846
13114	25	638
13117	0	228
13120	0	125
13125	0	404
13129	0	419
13131	0	374
13132*	6	256
13136	0	57

* Accessions selected for general vigor.

Table 17. Seed yield of *Desmodium ovalifolium* accessions Várzea, CPAC, Brasil.

CIAT Accession	Cleaned seed yield (kg/ha)	CIAT accession	Cleaned seed yield (kg/ha)
13130	440.00	13101	24.57
13129	252.14	13097	24.14
13081	198.14	13085	21.14
13082	144.76	13092	20.38
13131	129.71	3788	20.24
13103	119.43	13302	17.33
13137	115.81	3780	16.76
13098	109.57	3784	16.19
13083	108.14	13114	15.86
13099	98.57	13105	15.57
13124	82.86	13089	10.29
13088	69.71	13113	10.29
13117	66.67	13115	10.29
13120	64.38	3668	9.91
13132	63.00	13133	9.29
13122	61.14	3776	7.05
3781	55.62	13289	6.86
13139	55.43	13136	3.81
13110	53.43	13091	3.43
3666	49.91	13125	3.43
13087	40.57	13119	3.14
13111	37.52	13095	2.48
13128	35.00	13109	2.29
13104	33.71	3663	0.76
13126	31.05	13135	0.57
13166	29.05	3674	0.19
3673	28.19	3778	0.19
13086	25.71		

is out of its normal tropical environment on the Planalto.

The accessions currently under seed multiplication are: CIAT 17283, 17300, 7182 and 17320. These are early flowering, heavy seeders.

Arachis pintoi

Forage species evaluation activities were expanded in the varzea in 1987. Accessions of A. pintoi showed good adaptation to seasonally water-logged situations. Initially, 9 accessions and the control (CIAT 17434) had been evaluated. Four accessions, representing local selections and the control were established in association with B. dictyoneura and Paspalum sp. aff. P. plicatulum under two stocking rate treatment. Two accessions of this legume CIAT 18748 and CIAT 18750, showed superior establishment vigor and nodulation in the year of establishment. An important feature of this legume is high seed production. Seed yields in excess of 1 t/ha have been obtained in two consecutive seasons from these accessions under supplementary irrigation.

Evaluation of grass-legume associations under grazing Varzea

A small-scale grazing experiment was established in the varzea in May, 1987. This trial comprises four selected accessions of each of the following legumes A. pinto (CIAT 18748, 18749, 18750, and 17434), D. ovalifolium (CIAT 13085, 13110, 13137 and 13289), and Pueraria phaseoloides (CIAT 7182, 8042, 17300, and 17320). These legumes were planted in association with the following grasses: A. pintoi - B. dictyoneura CIAT 6133, A. pintoi, Paspalum sp. aff. P. picatulum BRA 008486; D. ovalifolium - P. sp. aff. P. plicatulum - BRA 008486, D. ovalifolium - B. dictynoeura CIAT 6133, P. phaeoloides - Paspalum conspersum (syn. P. regnellii) BRA 000159, P. phaseoloides - P. sp. aff. P. plicatulum BRA 001449.

In this situation, accessions of A. pintoi and D. ovalifolium performed best. These legumes formed productive associations with B. dictyoneura and P. sp. aff. P. plicatulum. Dry matter yield accumulated at the end of the wet season was significantly ($P < 0.05$) higher for P. sp. aff. P. plicatulum than that of B. dictyoneura. Yield difference between P. sp. aff. P. plicatulum and P. conspersum at the end of wet season was not significant but regrowth produced by P. conspersum during the rainless period off July-August was higher. Apparently, this grass has better tolerance to low night temperature (10-55°C) than the other grasses in the experiment.

Accumulated DM yield and regrowth during the rainless period was significantly higher ($P < 0.01$) for A. pintoi CIAT 18750 than for three other accessions of this species in the experiment. A. pintoi proved to be the most palatable and D. ovalifolium the least palatable species. Two accessions of A. pintoi, CIAT 18750 and 18748 which originated from the Central Plateau, were found to be more resistant to fungal diseases (Cercospora, Colletotrichum and Synchytrium) and spider mite, also they nodulated better than the control accession (CIAT 17434) introduced from the Brazilian Atlantic coast.

Legume compatibility with Brachiaria spp.

This small-scale grazing trial was established on red-yellow latosol and consists of 5 Brachiaria spp. accessions of distinct growth habit, ranging from a prostrate, decumbent type to erect and semierect growth forms, with cv. Marandu as control. A stocking rate of 1.7 an/ha was superimposed on these pastures. Grazing starter at the end of the wet season and grazing intervals of six weeks to be employed during the coming wet season. Presentation dry-matter yields were significantly ($P < 0.01$) higher for S. guianensis "Mineirao" than those of S. capitata, C. brasilianum and S. guianensis hybrids. On the basis of total (grass + legume) dry-matter yield, associations containing "Mineirao" and S. capitata were better than those of C. brasilianum and S. guianensis hybrids. As regard to compatibility of pasture components it is too early to draw conclusions.

Centrosema/Stylosanthes with A. gayanus and P. maximum

Four Centrosema hybrids and S. guianensis "Mineirao" were combined in association with Andropogon gayanus or Panicum maximum (CPAC 3148). These plots are grazed at 6-weeks intervals and high and low stocking rates are superimposed on these associations. Grazing of the experiment started in 1987/88 and legume population is satisfactory in all treatments.

Regional Trials

Seven regional trials type B have been established in the Cerrados during the 1987/88 season. These regional trials include a new set of selected species such as S. capitata hybrid, C. brasilianum CIAT 5234, accessions of C. acutifolium, Panicum maximum hybrids, Paspalum conspersum, and P. sp. aff. P. plicatulum. One regional trial was established on varzea land in Mato Grosso. The two species of Paspalum, Desmodium heterocarpon are the outstanding species for this situation. Three hybrid lines of S. guianensis were included at one site in Mato Grosso. C. brasilianum is one of the most promising species for the well-drained Cerrados. Another promising accession is C. acutifolium CIAT 15331.

The "Southern Cone" - Paraguay

The summer growing legumes such as Leucaena, C. acutifolium, C. pubescens x C. acutifolium hybrids are promising for the better soils. The Centrosema accessions were practically free of foliar diseases in this situation. C. macrocarpum, D. ovalifolium, and S. capitata were killed by frost (-3°C). This ecosystem is not well catered for by our existing germplasm collection and new introductions of subtropical species are needed for evaluation. The winter growing species Lotononis and Lespedeza are promising.

Bolivia

The CIAT germplasm is more applicable to the Santa Cruz area and a regional trial B was established at the Saavedra Experimental Station. Another collaborating institution in Bolivia, the Universidad Técnica de Beni was supplied with planting material from CPAC stock. Species adapted to water-logged situations such as Desmodium heterophyllum, D. ovalifolium, and Paspalum spp. will be tested at UTB. Fifteen hybrid lines of S. guianensis and selected accessions of Brachiaria spp. were also added to the list of new accessions.

8. Agronomy Humid Tropic

The Agronomy section the INIIA-IVITA-CIAT collaborative project continued during 1988 with its principal objective of selecting legume and grass germplasm adapted to the conditions of the humid tropics, to obtain highly productive and stable pastures. The studies are being carried out at IVITA's Experiment Station in Pucallpa, Peru, which corresponds to a tropical semi-evergreen seasonal forest ecosystem; its edaphic and climatic characteristics were reported in the 1987 Annual Repot. The materials identified as promising are reported to other national research institutions, within the International Tropical Pastures Evaluation Network (RIEPT) for their final selection under different environmental conditions within the humid tropical ecosystem.

Evaluations this year included 432 legume accessions of the following species: Arachis pintoi, Centrosema acutifolium, C. brasilianum, C. macrocarpum, Desmodium heterophyllum, D. ovalifolium, Pueraria phaseoloides, and Zornia spp. Among the grasses, 245 accessions of Brachiaria spp. and Panicum maximum were studied. Germplasm evaluations are carried out mainly in sites of degraded pastures having acid and poor Ultisols, and on one occasion in an African palm tree plantation to select materials adapted to shadow conditions.

Agronomic evaluation of legume and grass germplasm (Category II)
During this phase of evaluation, experiments were carried out in small plots to select legumes and grasses for their adaptation to prevalent environmental conditions (climate, soil, biotic factors). Studies included plant vigor during establishment, resistance to pests and diseases, dry matter yield, flowering period, and seed production.

Centrosema macrocarpum
During the third year of evaluation, most of the 132 accessions of this species continued showing excellent adaptation to the climatic and edaphic factors in this region. Dry matter yields over 4 harvests showed important variation among accessions, but were good for most of the materials, as shown in Table 1. In general, damage caused by leaf cutters was slight to moderate in some accessions, especially during the period of lower precipitation; to a lesser degree, symptoms of leaf diseases caused by Rhizoctonia or Cercospora were observed.

Rooting in nodes of trailing stems showed large variation among accessions. Large differences were also observed in seed production among accessions, recording yields that ranged from 0 to 670.2 g/plot of 100 plants, harvested during 4 months (Table 2). Ten accessions did not produce seed and 58 accessions had

Table 1. Characterization of a Centrosema macrocarpum collection (128 accessions) based on dry matter yield, at Pucallpa, Peru.

Group	No. of accessions	DM (g/m^2)*	
		Media	Range
1**	10	230	(220 - 249)
2	51	197	(184 - 216)
3	41	166	(151 - 182)
4	16	138	(124 - 149)
5	6	108	(90 - 121)
6	2	45	(28 - 61)
7	2	10	(4 - 17)

* Average of 4 harvests, with 3 months of regrowth each.
** CIAT No. 15098, 5952, 5635, 5460, 5901, 5739, 15057, 5955, 5959, 5940.

relatively low yields. Among the most productive accessions, CIAT 15014 was the most outstanding. The accessions 15047-15115-5452-5447-5432 showed the most rapid establishment (rooting nodes) as well as good seed production and seasonal dry matter yield.

Centrosema acutifolium
A collection of 19 accessions was evaluated; their performance is shown in Table 3. Overall dry matter yields were good, with slight variation among accessions. However, CIAT 52178 yielded more than the control, CIAT 5277, which was affected by a moderate attack of Rhizoctonia during the period of maximum precipitation. Most accessions did not vary significatively in terms of rooting of stoloniferous nodes. All accessions flowered and produced seeds; the latter characteristic varied considerably among accessions. The highest seed production level was obtained by the control, followed by accessions CIAT 5564, 15084, and 5112. Performance of accessions CIAT 15532 and 15248 was slightly inferior due to a high incidence of Rhizoctonia foliar blight. Slight symptoms of bacteriosis as well as attack of leaf cutters were detected affecting most of the collection.

Table 2. Characterization of a C. macrocarpum collection (132 accessions) based on seed production, at Pucallpa, Perú.

Group	No. of accessions	Seed production (Range) (g/plot*)
1**	1	670.2
2***	3	381.2 - 515.3
3****	7	229.0 - 282.9
4*****	12	103.6 - 184.4
5	11	63.3 - 93.8
6	30	31.9 - 62.6
7	58	0.9 - 30.9
8	10	0

* 10-plant plot, harvest during 4 months.
** CIAT 15014.
*** CIAT 5274, 5943, 5887.
**** CIAT 15102, 5948, 15074, 15097, 5959, 15073, 15094.
***** Outstanding accessions in this group: CIAT 5936, 5460, 15063, 15115.

Centrosema brasilianum
Dry matter and seed yields of the 22 accessions evaluated are shown in Table 4. Mean dry matter production over three harvests ranged between 71 and 163 $g/m^2/3$ months, being accessions CIAT 5657, 15387, and

Table 3. Performance of 19 *Centrosema acutifolium* accessions in Pucallpa, Perú.

CIAT No.	DM (g/m^2)*	Rooting of stoloniferous nodes ($No./m^2$)**	Seed production (g/plot)***
5278	187 a****	41 abcd	234.6
5610	159 ab	48 abcd	257.5
15086	159 ab	42 abcd	365.3
5112	152 abc	60 a	538.5
5277	142 bcd	38 bcd	654.9
15291	141 bcd	57 ab	253.6
15292	139 bcd	52 abc	180.8
15353	138 bcd	62 a	95.2
5897	133 bcd	58 ab	150.6
15084	130 bcd	34 cd	555.4
15281	127 bcd	45 abcd	453.8
5597	126 bcd	59 ab	195.3
5611	123 bcde	50 abc	395.2
15088	115 cde	53 abc	379.4
5568	107 de	44 abcd	114.6
5118	99 de	44 abcd	231.3
15534	80 ef	27 d	40.5
15248	44 f	28 d	12.5

* Average of 5 harvests, with 3-months regrowth each.
** Average of 3 evaluations.
*** 12-plant plots; harvest every 2 months.
**** Values followed by the same letter in each column are not statistically different (P less than 0.05).

15524 the most productive. Seed production varied considerably, ranging from 8.1 to 1102.1 g/plot for accessions CIAT 5490 and 5825, respectively. The control, CIAT 5234, presented intermediate values for both characteristics. One of the most susceptible accessions to *Rhizoctonia* foliar blight--the most limiting factor for this species--was CIAT 4234. Although all accessions were susceptible to the pathogen, CIAT 5657, 14387, 5729, 15524, 5696, and 5671 showed relatively low incidence of the disease and recovered well after the attack.

Arachis pintoi
CIAT 18752 was the most outstanding among the 8 accessions evaluated, for its vigor and overall adaptation. This accession tends to retain more leaves during the period of minimum precipitation than the control, CIAT 17434, and is less susceptible to *Rhizoctonia* foliar blight. However, CIAT 18752 flowers poorly in comparison to the other accessions.

Desmodium ovalifolium
During 1988, the collection of 82 accessions showed considerable differences in dry matter production, which was nonetheless high in general terms. Several accessions had poor vigor and presented chlorosis; this symptom was related to the presence of root knot nematodes. At the end of the period of maximum precipitation, nematode galls were detected in all accessions, except CIAT 13125. Degree of presence, however, varied among accessions, registering a slight infestation in

Table 4. Dry matter yield and seed production of 22 accessions of Centrosema brasilianum.

CIAT No.	DM (g/m^2)*	Seed production (g/plot)**	CIAT No.	DM (g/m^2)*	Seed production (g/plot)**
5657	163***	79.5	5729	101	597.1
15387	144	43.3	5525	100	1063.6
15524	133	498.6	5827	99	520.1
5588	125	121.5	5476	97	33.8
5656	124	155.1	5705	91	59.4
5696	115	84.4	5824	88	745.7
5698	115	318.6	5490	83	8.1
5810	115	878.4	5825	81	1102.1
5234	110	420.6	5712	80	166.4
5671	106	93.4	5514	79	93.4
5509	105	27.4	5487	71	27.4
Mean				106	324.5

* Average of 3 harvests, with 3 months of regrowth each.
** 12-plant plots, harvest during 4 months.
*** Averages of 2 replications.

most of the collection and a moderate to severe infestation in 24% of the accessions. No relation was found between degree of infestation and damage caused to the plants.

This year, the entire collection flowered, with great variation in flowering dates, which differed in as much as 111 days between the earliest and latest accessions. Accessions showed marked differences in seed production (Figure 1): 23% of the accessions did not produce seed due to flower abortions and 49% showed very low yields. The control, CIAT 350, yielded 47.7 g, while the highest yields (117.6 to 195.5 g/plot of 5 plants) were obtained by accessions CIAT 13107, 13302, and 13647.

D. ovalifolium is considered to be a poor quality legume, having low acceptability by cattle. Figure 2 shows the frequency distribution of some quality attributes of young leaves and the palatability index of the collection. Crude protein contents ranged from 14.8 to 19.1% and are, in general, rather high for the species. With values between 18 and 19%, 14 accessions were outstanding. The percentage of pepsin-soluble N indicated the proportion of N available for the animal; this parameter varied considerably among accessions (38.7-70.6%). The highest values were registered by three accessions with poor vigor, CIAT 3793, 3794, and 3780; while the most productive accessions, e.g., CIAT 13651, 13118, and 350, fell in the following group. In vitro digestibility ranged from 27.7 to 50.6% and was low for most of the collection. CIAT 13030 and 13651 had the highest values.

Great variation in animal preference was found in a study of acceptability. Palatability indexes

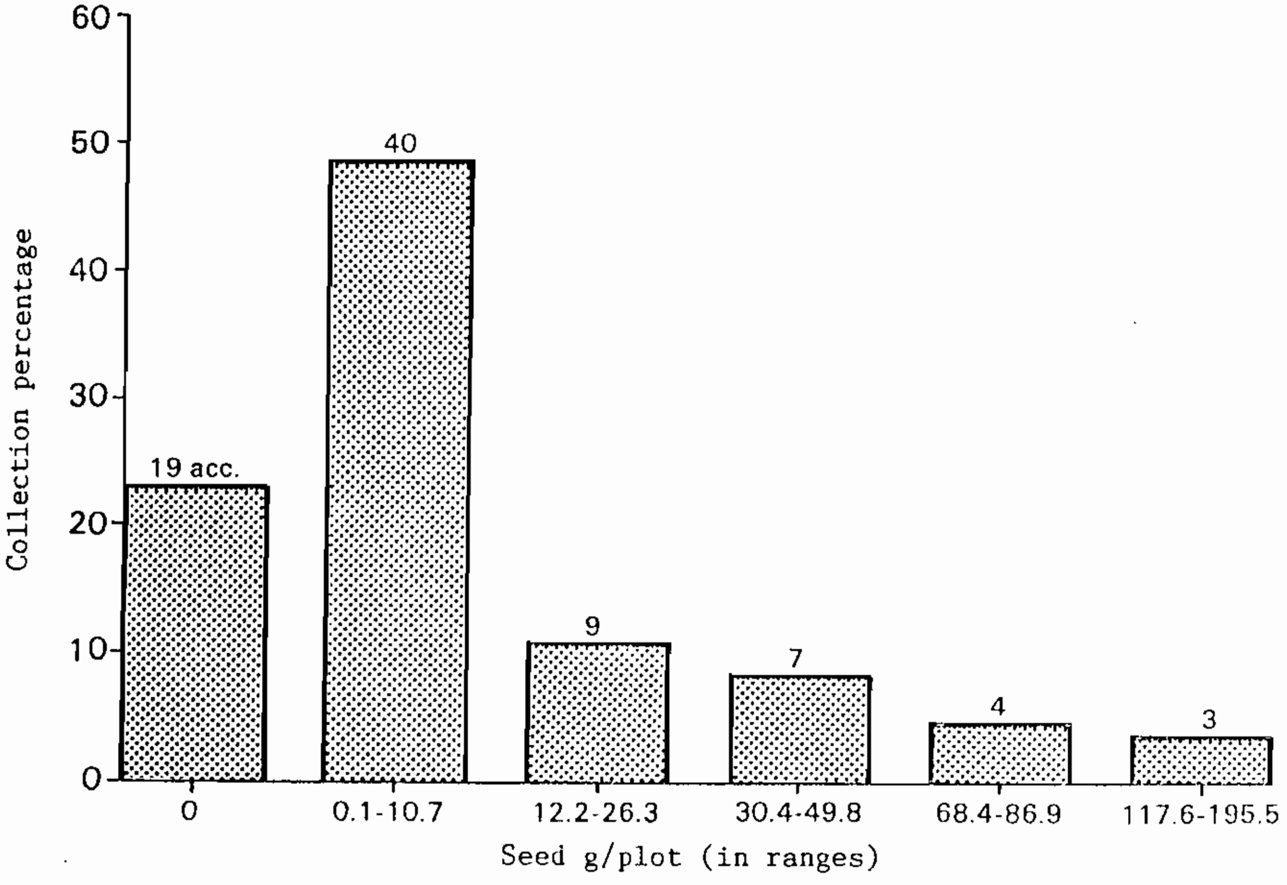


Figure 1. Distribution frequency of seeds of 82 accessions of Desmodium ovalifolium harvested during 4 months in Pucallpa, Peru.

ranged from 0.16 to 2.59 (index 1 = no preference); the best preferred accessions were CIAT 13108, 13030, 13095, and the control, CIAT 350. Accession CIAT 13030 was outstanding for its values of crude protein, IVDMD, and palatability index. Accessions CIAT 13647 and 13651 were also outstanding in at least two of the quality attributes, in addition to having high dry matter and seed yields.

Desmodium heterophyllum

Performance of this species continued being extremely poor, showing low vigor and death of some plants in several plots, primarily related to its high susceptibility to the root knot nematode. Toward the end of the period of maximum precipitation, all 20 accessions showed infestation, 15 being severely attacked. The control, CIAT 349 cv. Johnstone, showed only slight infestation.

Pueraria phaseoloides

Among the 75 accessions under evaluation, considerable variation was observed in relation to dry matter yield, this being generally lower among accessions from the Hainan island. Seed production, as was the case last year, was poor in general, in spite of the fact that flowering was satisfactory. This phenomenon is in part due to damage caused by insects to flower buds, to

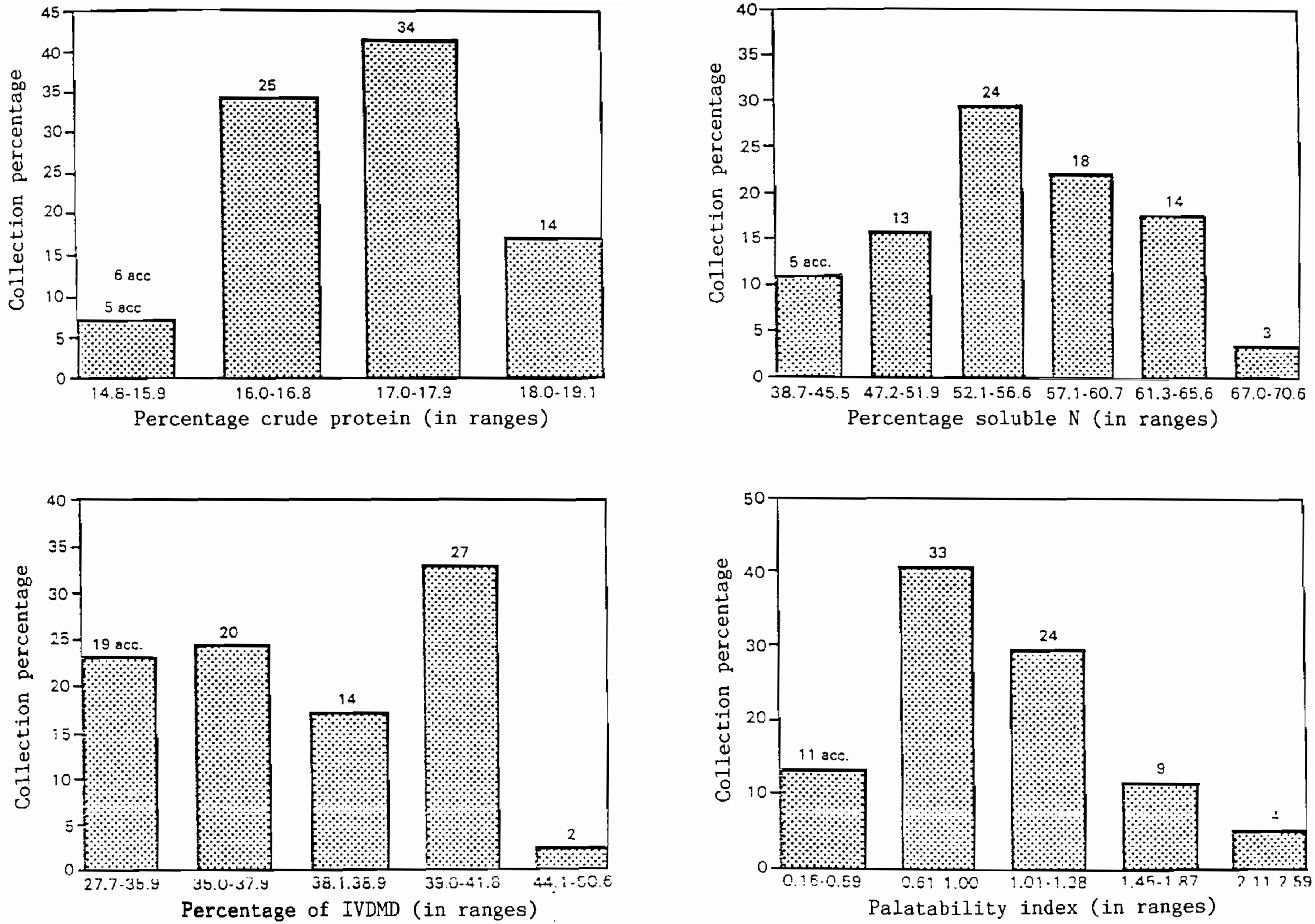


Figure 2. Distribution frequency of crude protein, soluble nitrogen in pepsin and *in vitro* dry matter digestibility of leaves, and palatability index of 82 *Desmodium ovalifolium* accessions in Pucallpa

the attack by Rhizoctonia to the legume, and, probably, to climatic factors which caused the leaves to fall.

Overgrazing of accessions of the collection varied considerably. Likewise, marked differences were found among accessions in terms of relative acceptability by cattle. In a study carried out with 3 crossed animals, high preference was recorded for accessions CIAT 17286, 17303 (var. supspicata) and the local control.

Rhizoctonia foliar blight was detected affecting most of the collection, but the level of attack was only slight; only accessions of var. supspicata showed symptoms of being more susceptible.

Brachiaria species

By April 1988, 221 accessions of 10 Brachiaria species had been established (Table 5). These had been introduced from CIAT-Palmira in the form of meristem tissue culture and were vegetatively propagated. Most of the accessions are B. brizantha, followed by B. decumbens, B. humidicola, and B. jubata.

Table 5. Collection of Brachiaria spp. established in Pucallpa Peru, during 1988.

Species	No. of accessions
B. arrecta	5
B. bovonei	2
B. brizantha	95
B. decumbens	43
B. dictyoneura	2
B. humidicola	28
B. jubata	24
B. platynota	1
B. ruziziensis	17
B. subulifolia	4
Total	221

Greater variability in morphologic characteristics was observed among B. brizantha accessions that among materials of the other species. In this species, variability is expressed in growth habit (postrated, semi-erect, or erect) and is related to plant height (less than 50 cm to over 180 cm), as well as to the size and pubescence of leaves and stems. Rooting of trailing stem nodes is almost null, except for a few accessions which have a slight rooting capacity; this is an important limiting factor for this species. Some morphologic variability was found in B. decumbens in terms of growth habit, being several accessions extremely postrated, while most have a semi-erect growth habit. Among the B. humidicola accessions, certain morphologic differences were observed in relation to their stoloniferous capacity and abundance and size of leaves. Accessions of B. ruziziensis were morphologically very similar; slight differences in size and pubescence of leaves were found among the collection of B. jubata. Overall, accessions of this species initiated flowering earlier and flowered more abundantly than the materials of the other species.

Plant vigor during establishment showed marked differences among the collection. Ground coverage, 2 months after transplanting, varied considerably, both among the species and among accessions within a species. Values fluctuated as much as 5 and 65% (Table 6).

A very desirable characteristic for the humid tropics would be the species' capacity to compete with weeds, especially during establishment. Weed incidence was measured during the first weeding, performed 2 months after transplanting. Table 7 shows the considerable differences found among the collection. This experiment will

Table 6. Classification of a collection of Brachiaria spp. (221 accessions) based on the speed of establishment expressed as ground coverage at 2 months after transplanting, in Pucallpa, Peru.

Group	% Coverage (Range)	% of the collection	Species* and No. of accessions
1	56 - 65	3.17	B.d. (3), B.h. (3), B.r. (1)
2	46 - 55	13.12	B.a. (3), B.b. (2), B.d. (17), B.h. (2), B.r. (5)
3	36 - 45	19.46	B.a. (2), B.b. (9), B.d. (14), B.h. (8), B.j. (2), B.p. (1), B.r. (7)
4	26 - 35	29.41	B.b. (38), B.d. (7), B.di. (1), B.h. (10), B.j. (5), B.r. (4)
5	16 - 25	23.53	B.b. (34), B.bo. (1), B.d. (2), B.h. (5), B.j. (9), B.s. (1)
6	5 - 15	11.31	B.b. (12), B.bo. (1), B.di. (1), B.j. (8), B.s. (3)

* B.A. = Brachiaria arrecta; B.b. = B. brizantha; B.bo. = B. bovonei; B.d. = . B. decumbens; B.di. = B. dictyoneura; B.h. = B. humidicola; B.j. = B. jubata; B.r. = B. ruziziensis; B.s. = B. subulifolia.

Performance of the controls CIAT Nos. B.b. 6780: 24; B.d. 606: 45; B.di. 6133: 33 B.h. 6369: 57.

continue for 1 1/2 years more, under a cutting regime of 9-week intervals.

Panicum maximum

The 24 accessions showed considerable morphologic differences. Performance was good during establishment and in the first harvest. However, dry matter yields decreased drastically in the following harvests, with most of the accessions presenting chlorosis and drying of leaf tips.

Germplasm evaluation in an Africa palm tree plantation

With the object of selecting germplasm for silvipastoral systems or for use as cover crop in plantations, 24 legume and 9 grass accessions were evaluated under the conditions of an African palm tree plantation.

In general, dry matter yields have decreased considerably during 1988--the second year of evaluation--, in comparison with yields obtained during the first year, as reported in the 1987 Annual Report. However, the range of the species was similar. Desmodium ovalifolium CIAT 350, which has an excellent adaptation, continued to be outstanding among the legumes. Other accessions having good adaptation and dry matter production included Centrosema macrocarpum CIAT 5735, 5713, and 5452, and C. acutifolium

Table 7. Classification of a collection of Brachiaria spp. (221 accessions) based on the incidence of weeds 2 months after transplanting, in Pucallpa, Peru.

Group	Weed (g/m^2) (Range)	% of the collection	Species* and No. of accessions
1	1 - 25	19.91	B.a. (4), B.b. (11), B.d. (15), B.h. (8), B.j. (5), B.r. (1)
2	26 - 50	35.74	B.a. (1), B.b. (22), B.d. (24), B.di. (2), B.h. (13), B.j. (11), B.p. (1), B.r. (2), B.s. (3)
3	51 - 75	21.72	B.b. (31), B.bo. (2), B.d. (3), B.h. (4), B.j. (5), B.r. (2), B.s. (1)
4	76 - 100	11.77	B.b. (17), B.d. (1), B.h. (2), B.j. (3), B.r. (3)
5	102 - 144	9.05	B.b. (14), B.h. (1), B.r. (5)
6	174 - 201	1.81	B.r. (4)

* B.a. = Brachiaria arrecta; B.b. = B. brizantha; B.bo. = B. bovonei; B.d. = B. decumbens; B.di. = B. dictyoneura; B.h. = B. humidicola; B.j. = B. jubata; B.r. = B. ruziziensis; B.s. = B. subulifolia.

Performance of the controls CIAT Nos. B.b. 6780: 71; B.d. 606: 37; B.di. 6133: 26 B.h. 6369: 44.

CIAT 5112. Among the grasses, Andropogon gayanus CIAT 621 was outstandingly superior in adaptation and productivity, followed by Brachiaria brizantha CIAT 6780 and Panicum maximum CIAT 6299.

Evaluation of grass and legume associations under grazing (Category III)

Evaluation in this phase includes the influence of grazing on the persistence and compatibility of promising grass/legume associations.

An experiment was established on March 1987 with the following associations: 1) Brachiaria dictyoneura cv. Llanero + Centrosema macrocarpum CIAT 5674-5735, 2) B. dictyoneura cv. Llanero + Desmodium ovalifolium CIAT 350, and 3) B. brizantha cv. Marandú + C. macrocarpum CIAT 5674-5735. Rotational grazing (6:30 occupation: rest days) was initiated on February 23, 1988. Two animals grazed each association under three stocking rates (2.0, 2.7 and 3.4 AU/ha) with 2 replications. In addition, two fistulated animals were used to measure the botanic composition of the diet selected on the first, third, and sixth day of grazing. Forage coverage, botanical composition, dry matter availability on offer, and residual dry matter availability after grazing were measured. Analyses of nitrogen content and in vitro dry matter digestibility were conducted for both forage on offer and selected forage. This report presents very preliminary results obtained during the first five grazing cycles, from February 23, 1988 to August 20, 1988.

Associations of B. dictyoneura with C. macrocarpum or D. ovalifolium resulted in very close mixtures and in all treatments showed greater ground coverage than the association of B. brizantha with C. macrocarpum. Among the mixtures, lower dry matter availability --showing a marked reduction over time, especially at high and medium stocking rates--was observed in the B. brizantha + C. macrocarpum association (Table 8). Forage on offer in the B. dictyoneura + C. macrocarpum association decreased significatively at the high stocking rate and slightly at the other rates. Forage decreased at the high stocking rate in the B. dictyoneura + D. ovalifolium association, while an increase was observed over the 6 months of grazing at the other two rates.

Table 9 presents information on botanic composition of the associations during the three grazing cycles. Percentage of the legume showed a marked increase in the B. dictyoneura associations with C. macrocarpum and D. ovalifolium at the 2.7 and 3.4 AU/ha stocking rates.

Legume proportion in the B. brizantha + C. macrocarpum association was lower at the three stocking rates than in the other associations and showed a slight decrease at the low rate and a marked decrease at the high rate. Weed invasion of the last association was the most severe, especially at the 2.0 and 3.4 stocking rates.

Overall, selectivity of the legume (Table 10) was greater in the B. dictyoneura + C. macrocarpum association than in the association with D. ovalifolium, which is a species known for its relatively low acceptability. The low legume selectivity in the B. brizantha + C. macrocarpum association is related to the low content of the legume in the forage on offer. No clear tendency was observed in legume selection in relation to stocking rate.

During the rainy season, C. macrocarpum presented slight symptoms of Rhizoctonia foliar blight when grown in association with B. dictyoneura, but not in association with B. brizantha, where the legume had the tendency to grow more erect and have less contact with the soil. D. ovalifolium flowered at the end of the rainy season and produced abundant seed. C. macrocarpum did not produce seed.

This trial will be evaluated during 2 1/2 years more, adjusting stocking rates depending on the availability of forage.

Table 8. Green dry matter yield (kg/ha) in the associations of *Brachiaria dictyoneura* + *Centrosema macrocarpum*, *B. dictyoneura* + *Desmodium ovalifolium*, and *B. brizantha* + *C. macrocarpum* during five consecutive rotational grazing cycles (6 days grazing/30 days rest) under three stocking rates, in Pucallpa, Peru.

Association	Stocking rate (AU/ha)	GDM (kg/ha) Grazing cycle*				
		1	2	3	4	5
B. dictyoneura cv. Llanero	2.0	2779	4410	3415	2461	2586
+ *C. macrocarpum* CIAT 5674/5735	2.7	2610	3354	4061	3020	2348
	3.4	2368	2865	2544	1866	1387
B. dictyoneura cv. Llanero	2.0	2550	4102	5169	3170	3335
+ *D. ovalifolium* CIAT 350	2.7	2111	3209	3895	2622	2593
	3.4	2297	3130	3186	3091	1737
B. brizantha cv. Marandú	2.0	2328	3063	1099	2123	1949
+ *C. macrocarpum* CIAT 5674/5735	2.7	3283	3174	3202	2893	1860
	3.4	1737	2535	2574	1593	735

* Beginning of cycle 1, 23 February 1988.

Table 9. Botanical composition (%) in the associations of *Brachiaria dictyoneura* + *Centrosema macrocarpum*, *B. dictyoneura* + *Desmodium ovalifolium*, and *B. brizantha* + *C. macrocarpum* during three consecutive rotational grazing cycles (6 days grazing/30 days rest) under three stocking rates, in Pucallpa, Peru.

Association	Component*	Grazing cycle**								
		1			2			3		
		Stocking rate (AU/ha)								
		2.0	2.7	3.4	2.0	2.7	3.4	2.0	2.7	3.4
B. dictyoneura cv. Llanero	G	58.3	58.9	62.2	67.1	54.9	73.5	60.6	46.1	37.1
+ *C. macrocarpum* CIAT 5674/5735	L	37.3	35.6	29.7	29.1	41.2	21.4	31.6	45.5	49.9
	W	4.4	5.5	8.2	3.8	3.4	5.1	7.8	8.4	13.0
B. dictyoneura cv. Llanero	G	66.3	66.2	67.4	78.5	74.0	64.1	60.6	46.1	37.1
+ *D. ovalifolium* CIAT 350	L	24.9	26.8	29.8	18.3	22.1	32.4	31.6	45.5	49.9
	W	8.8	7.0	2.8	3.2	3.9	3.5	7.8	8.4	13.1
B. brizantha cv. Marandú	G	64.7	73.8	71.9	81.4	80.3	81.1	57.1	70.4	65.5
+ *C. macrocarpum* CIAT 5674/5735	L	15.4	21.0	20.4	15.6	18.1	17.3	11.5	20.1	10.9
	W	19.9	5.2	7.7	3.0	1.6	1.6	31.4	9.5	23.6

* G = grass; L = legume; W = weeds.

** Beginning of cycles: 1, 23 February 1988; 3, 5 May 1988; and 5, 16 July 1988.

Table 10. Proportion of legume in forage on offer and selected forage in the associations of *Brachiaria dictyoneura* + *Centrosema macrocarpum*, *B. dictyoneura* + *Desmodium ovalifolium*, and *B. brizantha* + *C macrocarpum* during five consecutive rotational grazing cycles (6 days grazing/30 days rest) under three stocking rates, in Pucallpa, Peru.

Association	Stocking rate (AU/ha)	Letume (%)* Grazing cycle**				
		1	2	3	4	5
B. dictyoneura cv. Llanero	2.0	37 (30)	41 (37)	29 (46)	21 (23)	32 (18)
+ *C. macrocarpum* CIAT 5674/5735	2.7	36 (32)	38 (49)	41 (46)	42 (35)	46 (19)
	3.4	30 (37)	33 (33)	21 (23)	27 (14)	50 (21)
B. dictyoneura cv. Llanero	2.0	25 (9)	29 (17)	18 (21)	23 (8)	27 (12)
+ *D. ovalifolium* CIAT 350	2.7	27 (3)	32 (9)	22 (16)	25 (41)	37 (9)
	3.4	30 (6)	34 (9)	32 (41)	33 (20)	43 (20)
B. brizantha cv. Marandú	2.0	15 (5)	14 (17)	16 (13)	12 (12)	12 (5)
+ *C. macrocarpum* CIAT 5674/5735	2.7	21 (14)	18 (4)	18 (5)	17 (8)	20 (8)
	3.4	20 (11)	16 (14)	17 (2)	14 (5)	11 (8)

* Values in parenthesis correspond to % legume in extrusa.
** Beginning of cycle 1, 23 February 1988.

9. Agronomy Central America and The Caribbean

The procedures followed and the technical team that participated in the selection of the three localities in Costa Rica representative of the agroecologic conditions in which cattle is bred in the subhumid, seasonal, and humid tropics of the region were described in the 1987 Annual Report. This same report, include ample information on the climatic and edaphic characteristics, and a list of the forage germplasm under evaluation. The current document reports the principal research results during the year 1988.

HUMID TROPICS - TRF: Atlantic Zone

Headquarters are located in the Province of Limón at the Centro de Cría e Investigación "Los Diamantes" which belongs to the Ministerio de Agricultura y Ganadería (MAG). It is located at 10°13' latitude N and 83°47' longitude W at 250 masl. Average annual precipitation is 4260 mm and average annual temperature is 24.6°C.

The soil is classified as Typic Dystropets (Inceptisol) having a sandy loam texture and good trainage. (For details on climate and soil see the 1987 Annual Report).

GERMPLASM EVALUATION

Grasses

Panicum maximum

Part of the *Panicum* spp. collection was established in October 1987 using vegetative material at a planting distance of 1 m between plants and 2 m between rows. The size of the experimental unit was 1 x 7 m with 6 plants each with a sampling area of 4 m^2. The trial was done in a complete randomized block design with two replications. During the establishment phase, 50 kg N, 10 kg P, 20 kg K, 10 kg S, and 2 kg S/ha were applied in the form of urea, triple superphosphate, potassium chloride, flower of sulphur, and copper sulphate, respectively. Eight weeks after planting a uniform cutting was performed, followed by evaluations with at sampling intervals of 4 weeks.

A total of 52 accessions of the following species were evaluated: *P. maximum* (49), *P. coloratum* (2), and a local control of *P. maximum*. Variables studied included degree of adaptation, resistance or tolerance to pests and diseases, biomass production, leaf-stem ratio, CP content and IVDMD in the leaf and stem fractions, height of plant, basal diameter, and length and width of leaves. In addition, observations were made to determine the presence of deficiency or toxicity symptoms. Likewise, data on growth habit and flowering of the materials were recorded.

Based on results obtained during the first 11 months of evaluation and after applying the cluster analysis technique, the materials were classified into seven groups (Table 1).

Table 1. Classification of 52 accessions of Panicum spp. based on their agronomic, morphologic, and nutritive quality characteristics by means of a cluster analysis.

Cluster	Components
1	604 - 6000 - 6164 - 6179 - 6181 - 6600 - 6601 - 6798 - 6828 - 6872 - 6971 - 6974 - 6983 - 16067
2	673 - 6094 - 6095 - 6171 - 6172 - 6175 - 6215 - 6299 - 6461 - 6868 - 6890 - 6898 - 6923 - 6942 - 6945 - 6949 - 16011 - 16017 - 16028 - 16039 - 16051 - 16061 - 16062
3	6063 - 8108 - 8114 - 6115 - 8180 - 8554 - 8875
4	8536 - 6907
5	622 - 6871
6	6969 - 16020
7	Local control

Most of the germplasm under evaluation was outstanding for its excellent adaptation to the edaphic and climatic conditions of this ecosystem. Great variability between the introductions was registered in relation to the beginning of flowering; during the period studied, nine accessions (CIAT 6094, 6299, 6871, 16028, 16039, 16051, 16061, and 16062) did not flower, but most flowerd abundantly.

Accessions in cluster 2 (Table 2) were the most outstanding due to their high DM yields (3419 ± 575 kg/ha/cutting), high CP contents (17.8 ± 1.2% in leaves and 10.2 ± 1.8% in stems), and IVDMD (62.6 ± 1.6% in leaves and 59.8 ± 3.8% in stems). Furthermore, these accessions showed relatively high values for leaf:stem ratio and a high degree of tolerance to pests and diseases. Most of the accessions in this group are similar to cv. Hamil, with large leaves and relatively thick stems.

Cluster 1 groups materials with intermediate DM yields; moderate leaf: stem ratios; high CP contents and IVDMD, both in leaves and stems; moderate susceptibility to insect attack, and abundant flowering.

Accessions belonging to group 4 were outstanding for their good DM yield, intermediate PC content and IVDMD in the leaf and stem fractions, and poor to intermediate flowering (Table 2).

The entries CIAT 6969 and 16020 which are grouped in cluster 6, were outstanding mainly for their high leaf:stem ratios which varied between 4.25 and 5.5 g/g, these being the highest values in the collection. Likewise, they were very tolerant to pest and disease attacks.

Cluster 5 is characterized by its excellent production of DM, an intermediate leaf:stem ratio, intermediate to high PC content and IVDMD, and very good tolerance to pests and diseases. Group 7, made up of the local control, exhibited characteristics similar to those of cluster 5, except that the local control was severely attacked by Cercospora.

Accessions in group 3, most of them from the Pichilingue Experiment Station (Ecuador) and the Empresa de Pesquisa Agropecuaria of Goiana (Brazil), were the least productive and the most attacked by insects, although their quality in terms of CP and IVDMD is relatively high.

Most of the 52 accessions were attacked by chewing, sucking, and rasping insects. However, damage observed was not important except for CIAT accessions 6115 and 6180 which presented suffered moderate damage. Foliar blight produced by Cercospora fusimaculans affected 12 entries (CIAT 604, 6094, 6109, 6115, 6536, 6828, 6872, 6875, 6907, 6974) and the local control, being the ecotypes CIAT 604 and the local control the most susceptible. The rest of the materials were not affected by this disease.

Based on agronomic results registered during the first year of evaluation, accessions listed in Table 3 are the most outstanding until now. However, subsequent evaluations of these materials, will include more detailed phenologic studies.

Brachiaria spp.

The Brachiaria collection (290 accessions) was established in October 1987 at a planting distance of 1 m between plants and 2 m between rows. The size of the experimental unit was 1 x 7 m with 6 plants each with a sampling area of 4 m^2. The experiment was carried out in complete randomized blocks with two replications. During the establishment phase, 50 kg N, 10 kg P, 20 kg K, 10 kg S, and 2 kg S/ha were applied in the form of urea, triple superphosphate, potassium chloride, flower of sulphur, and copper sulphurate, respectively. Ten weeks after planting a uniform cutting was done, followed by evaluations at sampling intervals of 6 weeks.

Preliminary results are present for 136 accessions evaluated: B. brizantha (52), B. decumbens (26), B. humidicola (21), B. jubata (20), B. ruziziensis (8), B. arrecta (3), B. dictyoneura (2), B. subulifolia (2), B. platynota (1), and B. serrata (1). Variables under study included degree of adaptation, resistance or tolerance to pests and diseases, biomass production, leaf:stem ratio, CP content and IVDMD in the leaf and stem fractions, height of plant, coverege, number of stolons produced, and number of rooted nodes. In addition, observations were carried out to determine the presence of mineral deficiency or toxicity. Likewise, data on growth habit and flowering of the materials was recorded. The experimental period reported herein runs from 7 October, 1987 to 2 September, 1988.

Based on the average of the six samplings carried out during the experimental period, considerable variability was found among ecotypes for most of the variables measured, except for damage caused by insects. By means of a cluster analysis of the 136 Brachiaria accessions were classified in 16 groups (Table 4).

The collection was well adapted to the edaphic and climatic conditions and no major damages caused by pests or diseases were observed. However the spittlebug caused slight damage to CIAT entries 16135, 16182, 16300, 16322, 16475, 16981, and 26127; and symptoms of Cercospora attack were observed in CIAT entries 6133, 16175, 16182, 16496, 16510, 16832, and 16845. In two accessions (16110 and 16495), Rhizoctonia caused slight damage. Variability was high among ecotypes with respect to initiation and abundance of flowering.

Table 2. Agronomic, morphologic, and nutritive quality characteristics of Panicum spp. (52 accessions) grouped in seven clusters.

Variable	Cluster 1 (n = 15)* Mean	Range	C.V.**	Cluster 2 (n = 23) Mean	Range	C.V.
DM (kg/ha	2670	1629-3676	21	3419	2257-4377	16
L:S (g/g)	0.9	0.4-1.6	36	1.5	0.5-2.6	46
CP-L (%)	17.8	13.1-20.0	11	17.8	15.5-20.1	7
CP-S (%)	9.9	6.4-11.5	16	10.2	7.2-16.3	17
CP-WP (%)	13.5	10.4-16.5	13	14.5	12.1-16.4	8
IVDMD-L (%)	65.4	60.1-69.5	4	62.6	59.4-64.9	2
IVDMD-S (%)	61.5	56.5-70.7	6	59.8	53.2-68.1	6
IVDMD-WP (%)	63.2	59.3-67.9	4	61.3	56.1-66.0	4
Degree of adapt.[1]	2.6	1.2-3.2	20	3.4	2.1-4.0	15
Pests[2]	1.2	0.9-1.7	21	0.9	0.6-1.2	16
Diseases[2]	0.2	0.0-1.0	195	0.1	0.0-0.7	280
Flowering[3]	2.0	0.5-3.5	50	1.0	0.0-3.0	95
Height (cm)	78.8	43.4-101.1	20	97.2	73.0-113.1	10
Basal diameter (cm)	41.4	34.0-48.1	10	42.8	36.5-50.9	10
Leaf length (cm)	43.9	29.0-64.5	20	56.1	44.5-74.0	15
Width-L base (cm)	1.0	0.7-1.7	25	1.1	0.7-1.6	21
Width-L intermed.(cm)	1.8	1.0-3.1	28	2.5	1.3-4.0	24
Width-L apex (cm)	1.0	0.6-1.4	21	1.2	0.7-1.5	15

Table 2. (Continued.)

Variable	Cluster 3 (n = 7) Mean	Range	C.V.**	Cluster 4 (n = 2) Mean	Range	C.V.
DM (kg/ha)	1668	659-2460	35	3072	2799-3346	12
L:S (g/g)	0.7	0.5- 1.3	47	0.9	0.5-1.3	67
CP-L (%)	19.8	18.0-21.2	6	17.5	16.7-18.2	6
CP-S (%)	11.4	9.8-13.3	12	9.1	8.2-10.0	13
CP-WP (%)	14.5	13.2-16.2	8	12.7	11.5-13.8	13
IVDMD-L (%)	65.4	62.8-68.8	3	56.8	55.5-58.0	3
IVDMD-S (%)	61.8	57.9-65.4	4	49.2	45.8-52.6	10
IVDMD-WP (%)	63.2	60.1-67.3	3	52.1	49.8-54.3	6
Degree of adaptat.[1]	2.0	1.0- 2.9	27	2.4	2.3- 2.4	5
Pests[2]	1.9	1.6- 2.3	14	1.2	1.0- 1.4	23
Diseases[2]	0.2	0.1- 0.5	72	0.4	0.1- 0.7	98
Flowering[3]	3.0	1.5- 3.5	31	2.0	1.0- 3.0	75
Height (cm)	59.0	47.7-73.5	15	77.4	77.3-77.4	0
Basal diameter (cm)	43.0	31.6-55.0	18	40.0	38.0-41.7	6
Leaf length (cm)	25.5	20.0-30.0	15	44.7	41.5-48.0	10
Width-L base (cm)	0.6	0.4- 0.8	24	0.8	0.6- 0.9	26
Width-L interm.(cm)	1.1	0.8- 1.3	19	1.8	1.6- 2.0	16
Width-L apex (cm)	0.5	0.4- 0.6	15	0.9	0.8- 1.0	19

Table 2. (Continued.)

Variable	Cluster 5 (n = 2)* Mean	Range	C.V.**	Cluster 6 (n = 2) Mean	Range	C.V.	Cluster 7 (n = 1) Mean
DM* (kg/ha)	3795	3492-4098	11	2635	2517-2752	6	2294
L:S (g/g)	1.2	1.2-1.2	1	4.9	4.2-5.5	18	0.9
CP-L (%)	14.2	13.3-15.0	8	16.4	15.9-17.0	5	14.8
CP-S (%)	7.6	6.9-8.2	12	9.7	8.6-10.7	15	11.3
CP-WP (%)	11.2	10.4-11.9	9	15.3	14.5-16.0	7	12.9
IVDMD-L (%)	60.7	56.9-64.4	9	61.7	60.7-62.6	2	60.9
IVDMD-S (%)	61.0	59.3-62.6	4	62.3	61.2-63.4	2	53.6
IVDMD-WP (%)	60.8	58.1-63.5	6	61.7	61.1-62.3	1	57.0
Degree adapt.	3.5	3.0-4.0	19	2.9	2.7-3.9	11	1.7
Pests	0.9	0.8-1.0	13	0.6	0.6-0.7	11	1.0
Diseases	0.0	0.0-0.0	--	0.1	0.1-0.1	--	2.0
Flowering	0.5	0.0-1.0	141	0.5	0.0-1.0	141	1.0
Height (cm)	100.3	95.9-104.7	6	64.0	63.1-65.0	2	94.7
Basal diameter (cm)	42.6	38.9-46.2	12	43.4	42.7-47.5	9	61.0
Leaf length (cm)	60.0	55.5-64.5	11	44.5	41.5-47.5	9	61.0
Width-L base (cm)	1.2	0.8-1.6	43	0.6	0.6-0.7	11	1.5
Width-L interm. (cm)	2.4	1.7-3.0	40	1.2	1.0-1.3	18	2.7
Width-L apex (cm)	1.2	1.0-1.4	26	0.6	0.5-0.7	22	1.3

* Number of accessions in cluster.
** Coefficient of variation.

1/ 1 = poor
2 = fair
3 = good
4 = excellent

2/ 0 = unattacked plants
1 = 1-10% of plants attacked
2 = 11-25% of plants attacked
3 = 26-50% of plants attacked
4 = more than 50% of plants attacked

3/ 0 = no flowering
1 = 1-25% flowering
2 = 25-50% flowering
3 = 50-75% flowering
4 = mora than 75% flowering

Table 3. Average for yield and nutritive quality attributes of the most outstanding accessions of *Panicum maximum*[1].

Cluster	Species	Accession CIAT No.	DM[2] kg/ha	L:S g/g	CP (%) L	CP (%) S	DIVMS (%) L	DIVMS (%) S
2	*P. maximum*	6299	3748	1.49	17.5	10.5	62.3	65.0
	P. maximum	6868	3295	2.24	18.4	10.3	65.0	62.8
	P. maximum	6923	3664	2.05	17.4	9.3	65.0	68.2
	P. maximum	16011	4089	1.30	17.0	7.2	64.6	62.7
	P. maximum	16028	4350	2.10	17.2	9.6	61.6	65.0
	P. maximum	16051	4377	2.58	17.4	9.3	64.0	59.8
	P. maximum	16061	3579	2.53	17.1	9.4	61.4	56.9
	P. maximum	16062	3184	2.24	18.4	10.0	64.1	59.2
6	*P. maximum*	6969	2752	5.53	17.0	10.8	60.7	63.4
	P. maximum	16020	2517	4.25	15.9	8.7	62.7	61.3
Mean			3555	2.63	17.3	9.5	63.1	62.4
D.E. [3]			630	1.29	0.7	1.0	1.6	3.3

1/ Accessions with tolerance to pests and free of diseases.

2/ Average DM production/4 weeks in 10 harvests.

3/ Standard deviation.

Table 4. Classification of 136 accessions of Brachiaria spp. based on their agronomic, morphologic, and nutritive quality characteristics by means of a cluster analysis.

Cluster	Components
1	6294- 6387- 6780-16107-16110-16120-16128-16135-16146 16158-16161-16168-16195-16203-16208-16289-16295-16301 16303-16306-16324-16358-16359-16438-16443-16447-16449 16450-16477-16480-16504-16514-16517-16518-16522-16524 16529-16530-16532-16534-16536-16538-16539-16710-16776 16797-16823-16827-16830-16840-16894-26167
2	606- 664- 667- 679- 6133- 6369- 6705-16178-16218 16335-16445-16475-16491-16495-16496-16502-16510-16541 16551-16866-16870-16874-16876-16880-16882-16884-16886 16891-26149-26163-26181-26182-26200-26292-26303-26304 26305
3	16297-16300-16305-16318-16322-16444-16452
4	16182-16493-16494-16844-16845-16846-26141-26185-26186 26296-26300-26308
5	26112-26170-26174-26175-26347
6	16175-16507-16962
7	16500-16877-26167-26288-26301
8	16476-16523-16871
9	16126-16156-16312-16482
10	16832-16960
11	26293-26350
12	16497
13	26298
14	26294
15	16767

Cluster 3 (Table 5) includes 5% of the collection; in this group the most promising accessions had high DM yields, ranging from 4317 to 6372 kg/ha/cutting; also had high CP contents and IVDMD; and exhibited low susceptibility to pests and diseases; however the leaf:stem ratio, was, not high being close to the average for the collection (1.1 g/g). Otherwise, the number of rooted nodes from lateral stems was high, a characteristic that is important for the persistence and autopropagation of forage species.

The materials included in clusters 2 and 5 are also promising, being outstanding for their excellent DM production, high CP content and IVDMD, large number of rooted nodes, intermediate leaf:stem ratio. Additionally, these materials were less attacked by pests and diseases (Table 5). The characteristics of group 1 are similar to those group 4, except that the latter had lower IVDMD and DM production. Group 6 is constituted by the less productive entries and the poorest in terms of nutritive quality; however, they were very tolerant to insect and disease attacks.

The characteristics of cluster 7 are similar to those of cluster 8, except that the latter presents a lower IVDMD, a greater leaf:stem proportion, and less rooted nodes. Group 9 (CIAT entries 16126, 16156, 16312, and 16482) had on average the highest leaf:stem ratio values and the lowest number of rooted nodes. Group 10, formed by accessions 16832 and 16960, was characterized by their low DM yields, low to intermediate CP contents and IVDMD, abundant flowering, and absence of rooted nodes.

Ecotypes CIAT 26293 and 26350 conforming group 11 are characterized mainly by their high CP and IVDMD values in leaves and in the whole plant; however, these materials had moderate DM production values and low leaf:stem ratios. Group 12 (CIAT accession 16497) is outstanding for its high DM yield, low leaf proportion in relation to stems, intermediate CP and IVDMD values, and abundant flowering. Cluster 14 is characterized mainly for its very high CP content and IVDMD in leaves and stems; and cluster 5 for its very high leaf:stem ratio, having cluster 14 and 5 the highest values in the collection for this parameter. Group 13, which includes ecotype CIAT 26298, formed the greatest amount of stolons (stems) and rooted nodes, had intermediate CP contents IVDMD, and a leaf:stem proportion superior to the overall average (1.1 g/g).

Table 6 presents the means for yield, nutritive value, damage by pests and diseases, and number of rooted nodes of the ten <u>Brachiaria</u> evaluated.

Table 7 shows averages for yield and nutritive quality of the most outstanding accessions until now among the <u>Brachiaria</u> species. Parameters defined to date will continue to be evaluated during 1989. By the end of the second year of agronomic evaluations, phenologic studies are expected to be initiated with the most outstanding materials, including the other representative ecosystems in the region. Specially attention will be given to the performance of the material in terms of tolerance or resistance to the spittlebug.

<u>Legumes</u>

Evaluation of the 203 accessions planted to herbaceous forage legumes has been initiated. Cuttings were done at 8-weeks intervals having performed four cuttings to date. Data are presented in Table 8 only for those legumes with high to good degree of adaptation (only 10% of the germplasm planted).

Table 5. Agronomic, morphologic, and nutritive quality characteristics of <u>Brachiaria</u> spp. (136 accessions) grouped in 15 clusters.

Variable	Cluster								
	1 (n = 52)*			2 (n = 37)			3 (n = 7)		
	Average	Range	C.V.**	Average	Range	C.V.	Average	Range	C.V.
DMMS (kg/ha)	2789	952-4458	34	3186	1515-5044	28	5134	4317-6372	13
L:SH:T (g/g)	1.0	0.4-2.1	39	1.1	0.6-1.9	32	1.2	0.8-2.2	38
CP-LPC-H (%)	13.6	11.0-17.3	11	14.2	11.1-16.6	12	13.9	12.9-14.9	6
CP-SPC-T (%)	7.7	4.8-10.8	18	8.1	5.5-11.8	20	7.0	5.9-8.3	11
CP-WP (%)	10.6	7.8-13.9	11	11.3	8.6-14.4	13	10.7	9.6-11.3	6
IVDMD-L (%)	66.6	58.9-75.7	7	70.0	62.2-78.8	5	70.4	64.7-73.2	4
IVDMD-S (%)	59.8	45.6-73.4	8	61.2	48.0-71.6	9	66.1	60.6-68.1	4
IVDMD-WP (%)	62.9	53.8-74.6	7	65.7	55.4-73.7	6	68.3	62.7-70.9	4
Degree of adapt.[1]	2.4	1.0-3.8	28	2.7	2.0-3.8	18	3.6	3.3-3.8	4
Pests[2]	0.8	0.2-1.8	36	1.0	0.0-2.0	58	0.6	0.0-1.0	48
Diseases[2]	0.0	---	--	0.0	---	--	0.0	---	--
Flowering[3]	2.0	0.0-3.3	60	1.0	0.0-3.0	107	1.3	0.0-3.0	5
Height (cm)	48.7	25.4-79.2	27	40.8	19.2-70.4	25	69.9	53.3-90.4	17
Cover (%/m^2)	59.5	34.0-81.2	23	80.4	62.5-97.0	11	80.9	75.8-85.0	5
Stolons (N°/m^2)	20.4	0.0-258.0	254	323.6	20.0-702.8	48	8.4	0.0-30.8	4
Rooted nodes (N°/m^2)	5.6	0.0-104.8	300	114.4	0.0-254.0	47	0.0	---	--

Table 5. (Continued.)

Variable	Cluster 4 (n = 12) Average	Range	C.V.	Cluster 5 (n = 5) Average	Range	C.V.	Cluster 6 (n = 3) Average	Range	C.V.
DM (kg/ha)	3007	2026-4223	23	4994	4139-5695	12	255	150-310	36
L:S (g/g)	0.9	0.5-1.7	31	1.4	1.1-2.0	27	1.1	0.5-1.5	49
CP-L (%)	13.7	11.3-16.0	10	14.0	12.2-14.8	7	13.2	11.6-14.4	11
CP-S (%)	6.7	4.4-9.7	24	7.2	5.8-8.4	17	7.9	5.6-9.9	28
CP-WP (%)	10.0	7.7-12.2	15	11.0	9.1-12.5	12	10.5	7.6-12.6	25
IVDMD-L (%)	71.1	66.4-79.9	6	70.4	68.3-73.0	2	56.6	43.1-61.1	7
IVDMD-S (%)	59.8	55.9-66.3	4	68.8	64.9-77.3	7	50.1	47.1-52.7	6
IVDMD-WP (%)	65.1	60.4-70.5	5	69.9	67.1-74.8	4	52.7	51.8-53.5	2
Degree of adapt.	2.5	1.8-3.0	15	3.6	3.2-4.0	10	1.0	1.0-1.0	--
Pests	1.3	0.3-2.0	33	1.2	1.0-1.5	15	0.7	0.0-1.2	90
Diseases	0.0	---	--	0.2	0.1-0.3	39	0.0	---	--
Flowering	1.0	0.0-2.0	161	1.0	0.0-2.0	223	1.5	0.0-3.0	160
Height (cm)	36.4	22.9-44.2	18	55.7	38.7-81.2	35	18.7	17.5-20.0	7
Cover (%/m^2)	84.5	72.5-92.1	8	95.8	92.9-98.7	2	12.2	7.5-15.0	34
Stolons (N°/m^2)	595.6	480.0-776.0	15	432.4	346.8-554.0	23	4.4	0.0-12.8	173
Rooted nodes (N°/m^2)	283.2	206.0-404.8	17	128.4	44.0-292.0	75	1.2	0.0-4.0	173

Table 5. (Continued.)

Variable	Cluster 7 (n = 5) Average	Range	C.V.	Cluster 8 (n = 3) Average	Range	C.V.	Cluster 9 (n = 4) Average	Range	C.V.
DM (kg/ha)	2905	1315-4486	44	1829	1449-2482	31	3525	1964-4645	38
L:S (g/g)	1.1	0.9-1.5	21	0.8	0.7-0.9	15	1.9	0.7-3.0	49
CP-L (%)	10.7	9.4-12.2	10	11.8	9.1-13.6	20	11.2	10.3-12.0	6
CP-S (%)	5.4	3.8-8.1	32	5.0	4.4-5.8	15	6.7	5.6-7.5	12
CP-WP (%)	8.2	7.3-9.6	11	8.0	6.3-9.5	20	9.4	8.3-10.3	9
IDVMD-L (%)	70.1	62.9-77.6	8	61.3	57.2-64.6	6	58.4	56.1-60.9	4
IDVMD-S (%)	61.2	53.5-71.3	12	45.8	45.2-46.7	2	55.9	50.7-59.9	8
IDVMD-WP (%)	65.9	59.1-71.5	8	52.6	50.6-53.9	3	57.3	52.9-60.6	8
Degree of adapt.	2.6	1.5-3.5	35	1.7	1.6-2.0	12	3.0	2.4-3.7	18
Pests	1.1	0.3-1.8	50	0.8	0.4-1.0	43	0.5	0.2-1.0	69
Diseases	0.0	---	--	0.0	---	--	0.0	---	--
Flowering	0.5	0.0-1.0	173	0.5	0.0-1.0	173	1.0	0.0-2.0	71
Height (cm)	41.8	21.7-65.8	46	33.9	23.3-44.2	31	74.6	50.8-94.2	24
Cover (%/m^2)	80.3	61.7-90.8	14	72.7	59.2-80.8	16	63.0	48.0-74.2	18
Stolons (N°/m^2)	223.2	140.0-284.0	24	460.8	310.0-492.0	31	0.0	---	--
Rooted nodes (N°/m^2)	67.2	40.9-90.0	29	252.8	108.8-374.8	53	0.0	---	--

Table 5. (Continued.)

Variable	Cluster 10 (n = 2) Average	Range	C.V.	Cluster 11 (n = 2) Average	Range	C.V.	Cluster 12 (n = 1) Average
DM (kg/ha)	930	704-1155	34	3300	3137-3463	7	5514
L:S (g/g)	0.9	0.5-1.2	57	0.8	0.7-0.9	22	0.7
CP-L (%)	12.1	10.3-13.9	21	19.2	18.7-19.8	4	16.8
CP-S (%)	6.8	6.5-7.1	6	8.7	6.4-11.0	37	8.3
CP-WP (%)	9.1	8.6-9.5	7	13.2	11.3-15.2	21	11.7
IVDMD-L (%)	63.7	63.6-63.8	0	76.1	73.3-78.9	5	58.9
IVDMD-S (%)	49.0	47.9-50.2	3	66.6	59.8-73.4	14	50.1
IVDMD-PW (%)	55.5	53.4-57.6	5	70.4	67.5-73.4	6	53.6
Degree of adapt.	1.7	1.6-1.8	5	3.2	2.8-3.6	17	4.0
Pests	0.6	0.2-1.0	10	1.6	1.5-1.8	12	1.2
Diseases	0.0	---	--	0.0	---	--	0.0
Flowering	3.3	3.5-3.5	--	0.0	---	--	3.0
Heigth (cm)	43.7	39.2-48.3	15	55.4	48.3-62.5	18	69.5
Cover (%/m^2)	31.5	25.0-38.0	29	87.3	86.7-88.0	1	90.4
Stolons (N°/m^2)	0.0	---	--	164.0	130.8-196.8	28	354.0
Rooted nodes (N°/m^2)	0.0	---	--	104.0	84.8-122.8	26	46.8

Table 5. (Continued.)

Variable	Cluster 13 (n = 1) Average	Cluster 14 (n = 1) Average	Cluster 15 (n = 1) Average
DM (kg/ha)	2326	1300	1864
L:S (g/g)	1.5	1.1	5.2
CP-L (%)	10.2	19.5	13.9
CP-S (%)	4.7	11.5	9.1
CP-WP (%)	8.0	15.7	13.1
IVDMD-L (%)	77.6	80.1	66.7
IVDMD-S (%)	63.4	66.5	63.2
IVDMD-WP (%)	71.8	73.5	66.1
Degree of adapt.	1.8	1.7	2.0
Pests	1.2	1.0	0.8
Diseases	0.0	0.2	0.0
Flowering	0.0	0.0	1.3
Height (cm)	20.4	20.8	45.0
Cover (%/m^2)	80.8	77.9	55.8
Stolons (N°/m^2)	560.8	474.8	0.0
Rooted nodes (N°/m^2)	398.0	218.8	0.0

* Number of accessions in cluster.

** Coefficient of variation.

1/ 1 = poor
2 = fair
3 = good
4 = excellent

2/ 0 = unattacked plants
1 = 1-10% of plants attacked
2 = 11-25% of plants attacked
3 = 26-50% of plants attacked
4 = more than 50% of plants attacked

3/ 0 = no flowering
1 = 1.25% flowering
2 = 26-50% flowering
3 = 51-75% flowering
4 = more than 75% flowering

Table 6. Averages for yield, nutritive quality, damage by pests and diseases, and rooted nodes of the 10 *Brachiaria* spp.

Species	N°	DM** kg/ha	L:S g/g	CP leaves (%)	IVDMD leaves (%)	Damage pests	Damage diseas.	No. of rooted nodes/m^2
B. brizantha	(52)	3487±1102	1.37±0.75	13.4±1.5	66.1±4.9	1.0	0.0	20±22
B. decumbens	(26)	3249±1100	1.06±0.31	14.4±2.5	70.9±6.2	1.5	0.05	50±23
B. humidicola	(21)	2514±1090	1.08±0.37	13.4±1.7	67.9±5.6	0.5	0.02	45±19
B. jubata	(20)	1990±602	0.79±0.14	14.0±1.4	67.2±4.2	1.0	0.0	62±10
B. ruziziensis	(8)	4278±1154	1.16±0.20	14.1±2.9	71.2±1.8	1.3	0.14	41±18
B. arrecta	(3)	2811±611	0.66±0.10	13.0±1.3	68.9±2.1	1.7	0.05	79±19
B. dictyoneura	(2)	3150±477	1.50±0.35	12.8±0.9	65.8±2.7	1.0	0.08	29±6
B. subulifolia	(2)	427±392	0.88±0.53	11.0±0.9	62.4±1.8	0.0	0.0	--
B. platynota	(1)	3483	1.14	16.2	78.8	1.0	0.0	48
B. serrata	(1)	2561	1.57	16.4	72.6	1.2	0.0	31

* Number of accessions per species.

** Average DM production/6 weeks in six harvests.

Table 7. Average for yield and nutritive quality attributes of the most outstanding accessions of *Brachiaria* spp.[1]

Cluster	Species	Accession CIAT No.	DM[2] kg/ha	L:S g/g	CP (%) L	CP (%) S	IVDMD (%) L	IVDMD (%) S
1	*B. brizantha*	6294	4295	1.95	13.9	8.0	65.4	63.1
	B. brizantha	6780	4315	1.35	13.0	6.9	59.5	57.9
	B. brizantha	16146	3818	1.67	11.0	7.0	63.7	63.6
	B. brizantha	16295	3553	1.35	13.0	7.6	75.5	73.4
	B. brizantha	16301	4314	1.43	11.5	5.3	69.9	60.9
	B. brizantha	16306	4061	1.41	12.7	5.3	64.6	63.3
	B. brizantha	16449	3633	1.07	15.2	8.4	69.8	63.8
	B. brizantha	16480	4018	1.10	15.4	8.1	60.0	53.7
	B. brizantha	16877	3407	2.14	13.0	5.9	66.7	61.1
2	*B. brizantha*	16335	3793	1.88	15.9	10.3	74.4	62.7
	B. jubata	16551	4273	1.40	11.5	6.0	69.7	68.6
	B. humidicola	16866	3143	1.06	14.9	11.3	72.0	66.5
	B. humidicola	16880	3389	1.83	15.8	11.8	74.8	71.6
	B. humidicola	16884	4564	1.13	12.7	8.0	69.2	59.5
	B. platynota	26200	3483	1.14	16.2	7.3	78.8	59.1
	B. decumbens	26292	3914	1.20	14.2	6.0	77.9	64.6
3	*B. brizantha*	16297	4563	1.25	14.3	6.5	71.5	68.1
	B. brizantha	16300	6372	0.79	14.1	6.8	71.4	65.4
	B. brizantha	16305	5566	1.05	13.1	6.0	64.8	60.6
	B. brizantha	16318	5075	1.18	14.7	7.2	73.2	68.1
	B. brizantha	16322	4945	1.00	14.9	6.9	71.9	68.1
	B. brizantha	16444	5101	2.25	12.9	7.5	71.1	68.0
	B. brizantha	16452	4317	1.09	13.3	8.3	68.8	64.6
4	*B. decumbens*	16494	3639	1.01	16.0	7.6	66.4	56.8
	B. decumbens	26185	3687	1.00	14.8	6.3	75.2	61.1
	B. decumbens	26308	3405	1.67	15.2	6.1	68.6	61.3
5	*B. brizantha*	26112	4139	2.00	14.6	8.4	69.7	64.9
	B. ruziziensis	26170	5695	1.09	14.3	5.9	68.4	65.7
	B. ruziziensis	26174	5799	1.33	14.9	8.0	73.0	77.3
	B. ruziziensis	26175	5388	1.07	12.3	5.9	70.6	70.2
	B. ruziziensis	26347	4946	1.44	14.2	8.1	70.3	66.1
7	*B. decumbens*	16500	4486	1.00	12.2	3.8	62.9	55.2
Mean			4315	1.35	13.9	7.3	69.7	64.2
S.D.[3]			774	0.38	1.4	1.7	4.7	5.2

1/ Accessions with tolerance to pests and free of diseases

2/ Average DM production/4 weeks in 10 harvests.

3/ Standard deviation.

Table 8. Evaluation of adaptation and presence of pests and diseases in germplasm planted in Guápiles: TRF (November 87 - November 88).

LEGUMES	CIAT No.	Degree of Adaptation*	Level of damage by pests**			Level damage dis.**		
			0.5	1	2	0.5	1	2
A. pintoi	18744	E	--	--	S	--	Le	--
	18748	GE	--	--	S	--	Le	--
C. macrocarpum	5452	GE	--	S	--	--	--	Rh
	5733	GE	--	Ch+Ch	--	--	Rh	--
C. plumieri	5099	E	--	Ch+Ch+Tr	--	--	--	--
C. pubescens	5189	E	--	Ch+Ch	--	Rh	--	--
	5878	E	--	Ch+Ch	--	Rh	--	--
	5914	E	Ch+Ch	--	--	Rh	--	--
	5050	GE	S	S	--	--	Rh	--
C. gyroides	3001	E	--	--	--	--	Rh	--
D. virgatus	474	E	--	S	--	--	--	--
D. heterophyllum	349	E	--	--	--		--	--
D. ovalifolium	13400	E	--	--	--	--	Rh	--
	13092	GE	--	--	--	Rh	--	--
	13129	GE	--	--	--	Rh	--	--
F. macrophylla	801	E	--	S	--	--	--	--
	7184	E	--	S	--	--	--	--
	17400	E	--	S	--	--	--	--
	17403	E	--	S	--	--	Rh	--
	17407	E	--	S	--	--	Rh	--

* (better than good); G = good; E = excellent.

** 0.5 = presence; 1.0 = slight damage; 2.0 = Moderage damage; S = Suckers; S = Chewers; Tr = Trips; Le = Leptosphaerulina; Rh = Rhizoctonia.

The collection of Leucaena spp. (90 accessions, see 1987 Annual Report) is well established. It was cut at a height of 40 cm from ground level and will be evaluated in eight weeks.

SEASONAL TROPICS - TSSF: South Zone

The experimental field belongs to the agroindustrial and livestock cooperative of San Isidro "COOPEAGRI" located at 9°22' latitude N and 83°42' longitude W at 700 masl, in the Province of San José, 28 km from San Isidro de Pérez Zeledón.

Average annual precipitation is 22950 mm and average temperature is 23°C. The soils are classified as Ustoxic Palehumult (Ultisol) of clayey texture in the intermediate and low zones, and sandy loam in the upper zone (see 1987 Annual Report for details on climate and soil).

GERMPLASM EVALUATION

A summary of evaluations carried out follows:

Grasses

Of the 16 grasses planted in April 1987 only A. gayanus CIAT 621, 6053, 6766, and B. humidicola CIAT 6369 exhibited a degree of agronomic adaptation from superior to good; these accessions represent only 25% of the germplasm planted. As can be seen in Table 9 the degree of disease incidence is very low.

Legumes

Accessions with a high degree of adaptation superior to good, are shown in Table 10. The most outstanding were C. macrocarpum, D ovalifolium, and S. guianensis for their vigor, low incidence of pests/diseases, and good recovery after the eight cuttings performed to estimate DM production.

SUBHUMID TROPICS - SHT: Central Zone

The experiment field, in the Central American School of Livestock (ECAG), is located at 9°58' latitude N and 84°23' longitude W at 200 masl, in the Province of Alajuela.

Annual average precipitation is 1600 mm and average temperature is 23.7°C. The soils are classified as Inceptisol, with sandy loam texture and good drainage (for details on climate and soil see 1987 Annual Report).

GERMPLASM EVALUATION

This report presents the results of the first year of evaluation for accessions of Stylosanthes guianensis, Andropogon gayanus, and Brachiaria species.

Table 9. Evaluation of adaptation and presence of pests and diseases in germplasm planted in San Isidro: TSSF (April 87 - November 88).

Grasses	CIAT No.	Degree of Adaptation	Level of damage by diseases** 1
A. gayanus	621	E	---
	6053	E	---
	6766	E	Rh + S
B. humidicola	6369	E	---

* (better than good); E = excellent.
** 1 = Presence; Rh = Rhizoctonia; S = Smut

Table 10. Evaluation of adaptation and presence of pests and diseases in germplasm planted in San Isidro: TSSF (April 87 - November 88).

LEGUMES	CIAT No.	Degree of Adaptation*	Level damage by pests**			Level of damage by diseases**			
			0.5	1.0	2.0	0.5	1.0	1.5	2.0
A. pintoi	17434	GE	--	--	--	Rh	--	--	--
C. acutifolium	5277	GE	--	S	--	--	Rh+Cy	--	Ga
C. brasilianum	5657	GE	--	--	S	--	--	--	Rh
C. macrocarpum	5065	E	--	--	--	Cy	Rh	--	--
	5452	E	--	--	--	--	Rh	Cy	--
	5713	GE	--	--	--	Ga	Cy	Rh	--
	5733	GE	--	--	--	Ga+Cy	Rh	--	--
	5735	GE	--	--	--	Ga+Cy	--	Rh	--
	5740	GE	Tr	--	--	Ga	Rh	Cy	--
C. pubescens	5189	E	--	--	S	--	Rh+Ce	--	--
S. rotundifolia	8201	E	--	--	--	Rh	--	--	--
	8202	E	--	--	--	--	Rh	--	--
D. ovalifolium	350	E	--	--	--	--	--	--	--
	3781	GE	--	--	--	--	--	--	--
D. guianensis	7351	E	--	--	--	--	--	--	--
P. phaseoloides	9900	E	--	--	--	Rh	--	--	--
S. capitata	2044	GE	--	S	--	--	--	--	--
S. guianensis	136	E	--	--	--	--	Ce	--	--
	184	E	--	--	--	Ce	--	--	--
	21	GE	--	--	--	Ce	--	--	--
	1280	GE	--	--	--	--	Rh	--	--
S. macrocephala	2133	EG	--	S	--	--	--	--	--
	1643	GE	--	--	--	--	--	--	--
	2756	GE	--	--	--	--	--	--	--
Z. latifolia	728	GE	--	S	--	--	Dr	--	--

* (better than good); G = Good; E = Excellent.

** 0.5 = Presence; 1.0 = slight damage; 2.0 = moderate damage; S = Suckers; Rh = Rhizoctonia; Cy = Cylindrocladium; Ga = Gacteriosis; Ce = Cercospora; Dr = Dreschlera; Tr = Trips.

Legumes

S. guianensis

In June 15, 1987, 23 accessions of S. guianensis were established. This report presents data on accumulated production of 5 cuttings (13-X-87, 15-II-88, 9-V-88, 9-VI-88, and 4-VIII-88), and the chemical composition of the samples.

Accumulated production (Table 11) ranged from 3.4 to 16.0 t/DM/ha for the accessions evaluated.

Table 11. Accumulated production of 27 S. guianensis accessions.

Ecotype CIAT No.	Mean (kg DM/ha
1175	16004 a
184	15514 ab
11362	15269 ab
11374	12903 abc
11372	12242 abcd
21	11911 abcd
11375	10207 abcde
191	10135 abcde
11366	9795 abcde
136	9592 abcde
11376	9225 bcde
11364	8990 bcde
11371	8506 cde
11369	8287 cde
11367	7829 cde
2031	7712 cde
11373	7426 cde
11363	7067 cde
11365	6631 cde
64	6220 cde
15	5990 de
1280	5915 de
11368	5880 de
1283	4706 e
11370	4526 e
11370	4526 e
64A	4077 e
10136	3441 e

Standard deviation: 3465;
DM Mean = 8741 kg/ha.

The most ouststanding group in terms of production is composed by accessions CIAT 1175, 184, 11362, 11374, 11372, 21, 11375, 191, 11366, and 136, with a mean of 12.357 ± 2.495 kg/DM/ha above the mean of all accessions in almost 4 t/DM/ha.

The more adapted accessions also occupied the top positions in terms of CP content and IVDMD (Tables 12 and 13). For example, CIAT 184 is the ecotype having the best performance during the summer, greater retention of leaves, greater portion of plant with green color, low anthracnose incidence, and is second in DM production; yet its IVDMD is inferior to the mean (Table 13). Ecotype CIAT 184 also performed well in the seasonal tropics; for this reason, seed multiplication of this ecotype was initiated seed in the low sites (0.8 ha total) (see Tables 20 and 22).

Grasses

A. gayanus and Brachiaria spp.

The first evaluation of 33 accessions of A. gayanus and 11 of Brachiaria spp. was performed 108 days after planting, during the rainy period. Most of the material was successfully established, except for 1 replication of A. gayanus 6053 and 16986 and of B. decumbens 6012. About 80-90% of the A. gayanus and Brachiaria spp. ecotypes presented a high to good degree of adaptation and no problem with diseases or pests.

Among the A. gayanus entries, accessions 6368, 6216, 16974, and 16984 yielded more than 6 t/DM/ha and showed the fastest rate of establishment. Among the Brachiaria spp., B. decumbens 606 and B. brizantha 667 and 6780 yielded more than 5 t/DM/ha.

The next cutting (February 15) was done 120 days later, in the middle of the dry period. Among the Brachiaria species, all accessions of B. brizantha and B. decumbens 606 yielded

Table 12. Crude protein in 27 accessions of S. guianensis during the period of maximum precipitation (56 days of regrowth).

Ecotype CIAT No.	Mean %
11368	19.8 a
11370	19.3 a
11373	18.2 ab
136	18.1 abc
11365	17.5 bcd
11363	17.4 bcd
11367	17.3 bcde
11376	17.2 bcde
1283	17.0 bcdef
21	17.0 bcdef
11362	17.0 bcdef
1280	16.7 bcdefg
11371	16.7 bcdefg
184	16.6 bcdefgh
2031	16.3 bcdefgh
11369	16.3 cdefgh
11366	16.2 cdefgh
11372	16.0 defgh
10136	15.9 defgh
1175	15.8 defgh
11375	15.8 defgh
64	15.4 efgh
15	15.2 fgh
191	15.0 gh
64A	14.7 h

No. de observations: 54;
Range: max. 20.40 - min. 14.60
Mean: (%) 16.75;
Standard deviation: 1.33

Table 13. In vitro dry matter digestibility of the 27 accessions of S. guianensis during the period of maximum precipitation (56 days of regrowth).

Ecotype CIAT No.	Mean %
11370	66.8 a
64	65.1 ab
11367	64.4 abc
11362	64.0 abcd
11368	63.9 abcd
11371	63.9 abcd
11366	63.8 abcd
11374	61.9 abcde
11369	61.6 abcde
11364	61.0 abcde
11372	60.9 abcde
11365	60.7 abcde
11376	59.9 bcde
136	59.6 bcde
191	59.6 bcde
11375	59.5 bcde
21	59.3 bcde
11373	59.3 bcde
15	59.2 bcde
1175	59.0 bcde
64A	58.6 cdef
10136	57.9 def
11363	57.8 def
184	57.7 def
1280	57.7 def
1283	56.0 ef
2031	52.6 f

No.Observ.: 54; Range: max.67.45-min. 48.70; Mean.: (%)60.43; S.D. 3.60.

over 1 t/DM/ha. Despite the greater mean DM production of A. gayanus during this cutting, Table 14 shows that 80% of the DM produced by B. brizantha is green DM (leaves + stems); similarly, 85, 76, and 89% of the DM produced by B. humidicola, B. decumbens 606, and B. dictyoneura 6133, respectively, is also green DM. This contrast with a value of 100% for A. gayanus, with a maximum of 30% for accession 621.

Average production of total dry matter (TDM) during the summer period was 2021 ± 537 kg/ha for the A. gayanus accessions representing 17 ± 5.6% of the annual total. For the Brachiaria species, average production of TDM for the same period was 1074 ± 308 kg/ha, representing 15 ± 6.8% of the annual total.

Tables 15 and 16 present data relevant to the diameter of A. gayanus tillers

Table 14. Percentage of green leaves and green stems in the dry matter production, and stem:leaf ration of Brachiaria spp. and Andropogon gayanus in the middle of the dry period (Atenas, 15 Feb., 1988).

Accessions	CIAT No.	% Leaf	% Stem	L/S	DM (kg/ha)
Brachiaria brizantha	6780	67.6	19.2	3.5	2706.3
Brachiaria brizantha	667	57.8	32.8	1.8	1714.8
Brachiaria brizantha	664	22.4	46.2	0.5	1592.9
Brachiaria brizantha	6387	31.3	30.0	1.0	1544.2
Brachiaria decumbens	606	31.0	45.3	0.7	1369.3
Brachiaria brizantha	6294	73.7	13.8	5.3	1357.2
Brachiaria humidicola	679	64.2	19.0	3.4	706.5
Brachiaria dictyoneura	6133	65.2	23.8	2.7	588.6
Brachiaria humidicola	6705	72.8	15.6	4.7	327.2
Brachiaria brizantha	Mean	50.56	28.4		1783.08
	Min	22.4	13.8		1357.2
	Max	73.7	46.2		2706.3
	S.D.	22.6	12.62		531.88
Brachiaria humidicola	Mean	68.5	17.3		516.9
	Min	64.2	15.6		327.2
	Max	72.8	19.0		706.5
	D.E.	6.1	2.4		268.2

Accessions	CIAT No.	% Leaf	% Stem	L/S	DM (kg/ha)
Andropogon gayanus	621	4.5	25.2	0.2	3583.6
	16991	1.4	0.8	1.8	3360.1
	16978	1.0	6.2	0.2	3177.9
	6265	6.1	6.2	1.0	3063.2
	16974	1.3	1.7	0.8	3048.5
	6201	0.3	1.6	0.2	3016.4
	6214	0.2	7.7	0.0	2590.5
	16979	0.4	4.6	0.1	1871.4
	6221	0.9	22.5	0.0	1316.1
Andropogon gayanus	Mean	1.79	8.5		2780.9
	Min	0.2	0.8		1316.1
	Max	6.1	25.2		3583.6
	S.D.	2.07	9.04		737.7

Table 15. Tiller diameter of <u>Andropogon gayanus</u> nine months after planting, after a cutting on october 1987 and another on February 1988 (Atenas, 1 de may of 1988).

Ecotype CIAT No.	No. of Observations	Mean (cm)		S.D.*	Min	Max
6368	6	66.5	a	6.9	61	80
16991	6	65.0	ab	11.2	49	78
16978	6	64.2	ab	16.8	46	82
6695	6	64.2	ab	6.7	51	69
6219	6	60.5	abc	10.0	50	75
621	6	59.3	abc	5.4	55	68
16979	6	59.0	abc	3.8	55	65
6234	6	58.8	abc	9.2	50	73
16984	6	58.7	abc	9.6	48	71
6216	6	58.7	abc	12.4	43	78
6265	6	57.3	abc	13.0	42	75
16974	6	56.7	abc	6.3	46	64
6201	6	56.5	abcd	7.2	50	70
6207	6	56.2	abcd	3.9	53	62
16985	6	55.8	abcd	7.5	45	64
16975	6	54.3	abcd	8.4	45	66
6224	6	53.0	abcd	5.2	46	58
6697	6	52.7	abcd	14.4	30	66
6054	6	51.5	bcd	15.4	33	68
16983	6	51.3	bcd	19.3	14	66
6694	6	50.5	bcd	9.6	35	60
6757	6	49.2	cd	14.1	32	68
6218	6	48.5	cd	7.5	39	61
6214	6	46.7	cde	17.2	26	67
6202	6	42.5	de	16.0	20	59
6377	6	35.7	e	17.6	17	61
TOTAL	156	55.1		12.6	14	82

* S.D = Standard Deviation.

Table 16. Stem diameter of *Andropogon gayanus* nine months after planting, after cutting on October 1987 and another on February 1988 (Atenas, 1 May, 1988).

Ecotype CIAT No.	No. of Observations	Mean (mm)		S.D.	Min	Max
6200	40	4.5	a	2.2	1.2	9.4
6265	40	3.1	b	1.1	1.0	4.9
6214	40	3.0	b	1.4	0.6	5.9
6201	40	2.9	bc	1.2	0.8	5.6
6216	40	2.8	bcd	1.8	0.6	9.1
6220	40	2.7	bcde	1.2	1.0	5.0
6202	40	2.5	cdef	0.8	0.8	4.5
6694	40	2.3	defg	0.7	0.8	3.7
621	40	2.3	defg	0.9	0.5	3.9
6757	40	2.3	efgh	1.0	0.5	5.0
6207	40	2.2	efgh	1.1	0.7	4.5
6233	40	2.2	efgh	0.8	0.6	4.2
6377	40	2.2	efgh	0.8	0.6	4.0
6368	40	2.2	efgh	1.0	0.3	5.0
6054	40	2.1	fgh	1.0	0.6	4.5
6221	40	2.0	fgh	0.8	0.9	4.7
6224	40	2.0	fgh	0.7	0.8	3.2
6219	40	2.0	fghi	0.7	0.9	3.5
6759	40	2.0	fghi	1.1	0.5	4.5
6697	40	2.0	fghi	1.1	0.6	4.5
16985	40	2.0	ghi	1.0	0.5	3.5
16979	40	1.9	ghi	0.8	0.6	3.5
6218	40	1.9	ghi	0.8	0.6	3.9
6695	40	1.9	ghi	0.8	0.6	3.9
16991	40	1.8	ghi	0.8	0.5	3.6
16974	40	1.8	ghi	0.8	0.7	4.3
6234	40	1.8	ghi	0.9	0.2	4.2
16978	40	1.7	hi	0.8	0.2	3.6
16975	40	1.7	hi	0.7	0.7	3.3
16984	40	1.7	hi	0.8	0.5	3.7
16983	40	1.5	i	0.6	0.5	2.8
TOTAL	1280	2.2		1.2	0.2	9.4

and stems. The most productive accessions (Table 17) belong to the group having the greatest diameter, and some of these, such as A. gayanus 16984, 16983, and 16974, have the lowest the least average stem diameters.

The first cut (June 10) after the summer period, which was particularly dry and long, was performed 30 days after initiation of the rainy period. The superior regrowth capacity of B. dictyoneura 6133 and B. humidicola 679 was evident, the first being significantively more productive than the mean of the A. gayanus accessions and the 5 accessions of B. brizantha (Table 17).

Table 18 summarizes the production accumulated after 5 cuts. Statistical analysis shows that B. decumbens 606 and B. brizantha 667 yield similar to those ecotypes of A. gayanus better adapted to the agroecologic conditions and the management practices of the trial.

Likewise, the high levels of productivity of several of the accessions evaluated and the low incidence of pests and diseases (Table 19), indicates that new germplasm will be available in a near future for this important region.

SEED MULTIPLICATION AND PRODUCTION ACTIVITIES

From the beginning of the project in April 1987, the seed multiplication and production activities have been an important component of the project. Tables 20, 21, 22, 23, 24, and 25 summarize the main results for each locality and compares various parameters among localities.

Table 20 summarizes activities in Atenas (SHTF). Among the grasses the low yield of A. gayanus 621 stands out particularly. This can be explained by the strong and persistent winds prevalents in the region during the entire summer (November-April) which caused big seed losses. B. dictyoneura 6133 was harvested during the period of maximum precipitation and resulted in high pure seed yields (153 kg/ha) of good quality. Results for B. decumbens 606 are also very encouraging. To date, it has been harvested three times (16-IX-87, 21-VII-88, and 20-X-88) with an average production of 70 kg pure seed/ha and 7.7 t of hay during the summer period.

Among the legumes, C. acutifolium CIAT 5277 showed high incidence of bacteriosis, which seriously affected seed production and finally the crop had to be destroyed on July 25, 1988. C. pubescens 438 and C. brasilianum 5234 showed acceptable yields.

Despite the good and uniform flowering of the grasses planted in Guápiles (Table 21), seed harvesting possibilities were very low given the abundance of birds. In the case of legumes, as also observed in Table 21, D. ovalifolium had a mean yield of 360 kg pure seed/ha for the three accessions evaluated, with the lowest value for CIAT 13089 and the highest for CIAT 3788. Results for A. pintoi 17434 were extraordinary, reaching a yield of almost 2 t pure seed/ha.

In tne semi-evergreen seasonal tropical forest (Table 22), grass and legume yield, with the exception of C. acutifolium 5277, were very encouraging, both for the locality as well as among localities (Table 23). Tables 24 and 25 summarize the first phenologic studies carried out with grasses and legumes, respectively.

GERMPLASM PLANTED IN EXPERIMENTAL FIELDS IN FARMS OF SEED PRODUCERS

Table 26 shows the number of accessions under evaluation and the area destined to multiplication, which doubled previous years' figures (3.6 vs. 8.5 ha for 1987 and 1988, respectively).

Table 27 summarizes the new activities initiated during 1988 consisting in establishing evaluation fields at farm level. Approximately 5 ha have already been planted with several purposes, from grazing to seed multiplication, to the utiliza- tion of legumes as cover crop in various types of commercial plantings. This practice will undoubtedly be increased in future years.

Table 17. Production among species 30 days after the rainy period has started (Atenas, 10 June, 1988).

Species Comparison	Level of confidence minimum	Difference between means	Level of confidence maximum
B. dictyoneura - *B. humidicola*	- 535.4	794.6	2124.7
B. dictyoneura - *B. decumbens*	- 829.8	856.6	2543.1
B. dictyoneura - *A. gayanus*	80.4	1077.6	2074.8*
B. dictyoneura - *B. brizantha*	71.3	1291.7	2512.0*
B. humidicola - *B. dictyoneura*	-2124.7	- 794.6	535.4
B. humidicola - *B. decumbens*	-1268.1	62.0	1392.1
B. humidicola - *A. gayanus*	- 357.8	282.9	923.7
B. humidicola - *B. brizantha*	- 366.9	497.0	1361.0
B. decumbens - *B. dictyoneura*	-2543.1	- 856.6	829.8
B. decumbens - *B. humidicola*	-1392.1	- 62.0	1268.1
B. decumbens - *A. gayanus*	- 776.2	221.0	1218.2
B. decumbens - *B. brizantha*	- 785.3	435.0	1655.4
A. gayanus - *B. dictyoneura*	-2074.8	-1077.6	- 80.4*
A. gayanus - *B. humidicola*	- 923.7	- 282.9	357.8
A. gayanus - *B. decumbens*	-1218.2	- 221.0	776.2
A. gayanus - *B. brizantha*	- 317.0	214.1	745.1
B. brizantha - *B. dictyoneura*	-2512.0	-1291.7	- 71.3*
B. brizantha - *B. humidicola*	-1361.0	- 497.0	366.9
B. brizantha - *B. decumbens*	-1655.4	- 435.0	785.3
B. brizantha - *A. gayanus*	- 745.1	- 214.1	317.0

* Significative comparisons at the 0.05 level.

Table 18. Accumulated production of 31 accessions of Andropogon gayanus and 10 of Brachiaria spp. (Atenas, 4 August, 1988).

Accessions	CIAT No.	Mean DM kg/ha
Andropogon gayanus	6368	20561 a
Andropogon gayanus	16984	19244 ab
Andropogon gayanus	6216	17495 abc
Andropogon gayanus	6697	17231 abcd
Andropogon gayanus	16974	16861 abcd
Andropogon gayanus	16983	16676 abcde
Andropogon gayanus	6214	16342 abcdef
Andropogon gayanus	621	16143 abcdef
Andropogon gayanus	6207	15422 abcdefg
Brachiaria decumbens	606	15151 abcdefgh
Andropogon gayanus	6219	14819 abcdefgh
Andropogon gayanus	6220	14496 abcdefhgi
Andropogon gayanus	16979	14296 abcdefghij
Andropogon gayanus	6757	14270 abcdefghij
Andropogon gayanus	6224	13865 abcdefghijk
Andropogon gayanus	6265	13743 abcdefghijk
Andropogon gayanus	16985	13638 abcdefghijk
Andropogon gayanus	6218	13521 abcdefghijkl
Andropogon gayanus	6234	13512 abcdefghijkl
Andropogon gayanus	16975	13386 abcdefghijkl
Andropogon gayanus	16991	13189 abcdefghijkl
Brachiaria brizantha	667	12374 abcdefghijkl
Andropogon gayanus	16978	12295 abcdefghijklm
Andropogon gayanus	6694	12014 bcdefghijklm
Brachiaria dictyoneura	6133	12011 bcdefghijklm
Brachiaria brizantha	6780	10332 cdefghijklmn
Brachiaria brizantha	6387	9841 cdefghijklmn
Andropogon gayanus	6202	9204 cdefghijklmn
Andropogon gayanus	6201	8874 defghujklmn
Andropogon gayanus	6200	8296 efghujklmmn
Andropogon gayanus	6054	7959 fghojklmn
Andropogon gayanus	6377	7547 ghijklmn
Andropogon gayanus	6233	6858 hijklmn
Andropogon gayanus	6695	6712 hijklmn
Brachiaria humidicola	679	6165 ijklmn
Andropogon gayanus	6759	6005 ijklmn
Andropogon gayanus	6221	5915 jklmn
Brachiaria brizantha	6294	5511 klmn
Brachiaria humidicola	6705	5044 lmn
Brachiaria brizantha	664	3912 mn
Brachiaria humidicola	6369	3412 n

Table 19. Degree of adaptation and presence of pests and diseases in 33 accessions of *Andropogon gayanus* and 11 of *Brachiaria* spp. (Atenas, 4 August, 1988).

Accessions		CIAT No.	Degree of adaptation*	Pests and diseases**
Andropogon gayanus		6201	E	1TM 2FBH 1CH 1CSL
		6207	E	1TM 2FBH 1CH 1CSL
		6216	E	1TM 2FBH 1CH
		6265	E	1TM 2FBH 1CH
		6368	E	1TM 2FBH 2CH
		16978	E	2FBH 1CH 1CSL
		16984	E	2FBH 1CH
		6054	EG	1TM 2FBH 1CH 1CSL
		6214	EG	1TM 2FBH 1CH
		6218	EG	1TM 2FBH 1CH 1CSL
		6219	EG	2FBH 1CH
		6220	EG	2FBH 1CH
		6224	EG	1TM 2FBH 1CH
		6697	EG	1TM 2FBH 1CH
		6757	EG	1TM 2FBH 1CH
		16974	EG	2FBH 1CH
		16979	EG	1TM 2FBH 1CH
		16983	EG	2FBH 1CH
		16985	EG	1TM 2FBH 1CH
		16991	EG	1TM 2FBH 1CH
		621	G	1TM 2FBH 1CH
		6202	G	2FBH 1CH
		6221	G	1TM 2FBH 1CH
		6234	G	1TM 2FBH 1CH 1CSL
		6377	G	2FBH 1CH
		6694	G	1TM 2FBH 1CH 1CSL
		6695	G	1TM 2FBH 1CH
		16975	G	2FBH 1CH
		6200	I	2FBH 1CH
		6759	I	1TM 2FBH 1CH
		6233	IP	2FBH 1CH
		6053	P	1FBH
		16986	P	1TM 1FBH 1CH
Brachiaria	*decumbens*	606	EG	1CH 1SP
	brizantha	667	EG	1FBH 1CH 1SP 2CSL
	humidicola	679	EG	1CH 2SP
	dictyoneura	6133	EG	1CH 2SP
	brizantha	6294	EG	1FBH 1CH 1SP 1CSL
	humidicola	6369	EG	1CH 2SP
	brizantha	6387	EG	1FBH 1CH 2SP 1CSL
	humidicola	6705	EG	1CH 2SP
	brizantha	6780	G	1FBH 1CH 1CSL
	brizantha	664	GI	1FBH 1CH 2SP 2CSL
	decumbens	6012	P	1CH 1HE 1SP

* E = excellent; G = good; I = intermediate; P = poor; D = dissappeared

** TM = thrips-mites; FBH = flea bettle-homoptera; CH = chewers; HE = hemiptera; SP = spittlebug; CSL = creamy spot in leaf; 1 = presence; 2 = slight damage.

Table 20. Germplasm, area planted, and seed production in Atenas*.

Germplasm	CIAT No.	Area m^2	Density kg/ha	Planting date	Floral stems No./m^2	Purity %	Pure seed kg/ha
GRASSES							
A. gayanus	621	2800	11	29-V-87	--	30	7
B. brizantha	6780	7450	3	6-VII-88	--	--	--
B. decumbens***	606	2500	4	28-V-87	288	40-97**	70
B. dictyoneura	6133	2600	4	29-V-87	762	91	153
LEGUMES							
C. acutifolium	5277	2500	6	1-VI-87	--	--	0
C. brasilianum	5234	2500	6	1-VI-87	--	90	201
C. macrocarpum	5713	2500	6	1-VI-87	--	90	18
C. pubescens	438	2500	6	1-V-87	--	90	154
S. guianensis	184	3500	4	14-VIII-88	--	--	--
TOTAL AREA		28850					

* Semi-humid tropical forest
** First and second year
*** + 7750 kg hay.

Table 21. Germplasm, area planted, and seed production in Guápiles*.

Germplasm	CIAT No.	Area m^2	Density kg/ha	Planting date	Vegetative material t/ha	Pure seed kg/ha
GRASSES						
B. brizantha	664	2040	3	19-VI-87	---	0
B. brizantha	6780	2500	3	18-VI-87	---	0
B. dictyoneura	6133	2500	3	19-VI-87	---	0
B. humidicola	679	340	3	11-VI-87	---	0
B. humidicola	6705	300	3	11-VI-87	145	0
B. humidicola	6369	80	MV	30-VI-88	---	---
LEGUMES						
A. pintoi	17434	1000	8	9-VI-87	53	1965
A. pintoi	17434	2000	MV	15-IV-88	---	---
Arachis sp.	2273**	150	13	15-III-88	---	---
D. heterophyllum	349	500	3	11-VI-87	---	40
D. ovalifolium	350	2000	3	11-VI-87	50	382
D. ovalifolium	3788	610	3	9-VI-87	---	440
D. ovalifolium	13089	510	3	9-VI-87	---	256
TOTAL AREA		14530				

* Tropical rain forest
** University of Florida.

Table 22. Germplasm, area planted, and seed production in San Isidro*.

Germplasm	CIAT No.	Area m^2	Density kg/ha	Planting date	Floral stems No./m^2	Purity %	Pure seed kg/ha
GRASSES							
A. gayanus	621	1100	10	22-V-87	152	40	84
B. brizantha	6780	5000	3.5	20-VI-88	--	--	--
B. decumbens	606	950	4	20-V-87	206	67	99
B. dictyoneura	6133	950	4	21-V-87	206	63	115
	6133	600	4	15-VI-87	435	25	71
B. humidicola	679	108	VM	11-V-88	--	--	--
	6369	881	VM	27-VII-88	--	--	--
	6705	3000	VM	3-VIII-88	--	--	--
LEGUMES							
A. pintoi	17434	400	8	21-VIII-87	--	--	--
	17434	5000	VM	V-88	--	--	--
C. acutifolium	5277	970	5	21-V-87	--	90	41
C. macrocarpum	5452	5457	6	25-VI-88	--	--	--
	5620	1215	6	25-VI-88	--	--	--
	5713	3960	6	25-VI-88	--	--	--
	5957	1125	6	25-VI-88	--	--	--
D. ovalifolium	350	950	4	21-V-87	--	90	284
S. guianensis	184	4500	3	23-VI-88	--	--	--
P. phaseoloides	9900	3000	3	30-VI-88	--	--	--
TOTAL AREA		39166					

* Tropical semi-evergreen seasonal forest.

Table 23. Seed production among locations in Costa Rica*: 1987-1988.

Germplasm	CIAT No.	Atenas	Guápiles	San Isidro
		---pure seed yield (kg/ha)---		
A. gayanus	621	7	---	84
B. decumbens	606	70	0	99
B. dictyoneura	6133	153	0	93
C. acutifolium	5277	0	---	41
D. ovalifolium	350	---	382	284

* Agronomy-Central America and the Caribbean (latin speaker).

Table 24. Phenologic summary of grasses planted in Costa Rica for seed multiplication: 1987-1988.

Grasses	CIAT No.	Location*	Planting date	Maximum flowering date	Inflorescence No./m^2	Harvest	Pure seed kg/ha
A. gayanus	621	A	29-V-87	--	--	15-I-88	7
	621	SI	22-V-87	8-XII-87	152	13-I-88	84
B. brizantha	664	G	19-VI-87	--	--	--	0
	664	G	19-VI-87	VI-88	83	--	0
	6780	G	18-VI-87	31-X-87	--	--	0
	6780	G	18-VI-87	5-VIII-88	189	--	0
B. decumbens	606	A	28-V-87	---	--	16-IX-87	66
	606	A	28-V-87	29-VI-88	288	21-VII-88	72
	606	SI	21-V-87	13-VI-88	206	14-VII-88	99
B. dictyoneura	6133	A	29-V-87	26-VI-88	762	18-VII-88	153
	6133	A	29-V-87	8-VIII-88	--	--	--
	6133	G	19-VI-87	28-IX-87	--	--	0
	6133	G	19-VI-87	7-VI-88	300	--	0
	6133	SI	21-V-87	29-VI-88	206	11-VII-88	115
	6133	SI	15-VI-87	29-VI-88	435	12-VII-88	71
B. humidicola	679	G	11-VI-87	19-IX-87	--	--	0
	679	G	11-VI-87	VI-88	556	--	0
	6705	G	11-VI-87	11-XI-87	--	--	0
	6705	G	11-VI-87	VI-88	728	--	0

* A = Atenas (TShF); G = Guápiles (TRF); SI = San Isidro (TSESF).

Table 25. Phenologic summary of legumes planted in Costa Rica for seed multiplication: 1987-1988.

Legumes	CIAT No.	Location*	Planting date	Maximum flowering date	Inflorescence No./m^2	Harvest	Pure seed kg/ha
A. pintoi	17434	G	9-VI-87	29-VIII-87**	---	17-V-88	1965
C. acutifolium	5277	SI	21-V-87	30-XI-87	---	15-I-88	41
C. brasililanum	5234	A	1-VI-87	4-XI-87	---	11-I-88	201
C. macrocarpum	5713	A	1-VI-87	14-XII-87	---	16-I-88	18
C. pubescens	438	A	1-VI-87	14-X-87	---	31-XII-88	154
D. heterophyllum	349	G	11-VI-87	---	---	II/III-88	40
D. ovalifolium	350	G	11-VI-87	26-XI-87	---	11-I-88	382
	350	SI	21-V-87	17-XI-87	---	8-XII-88	284
	3788	G	9-VI-87	2-XII-87	---	21-I-88	440
	13089	G	9-VI-87	20-XII-87	---	12-II-88	256

* A = Atenas (TShF); G = Guápiles (TRF); SI = San Isidro (TSESF)

** Permanent flowering.

Table 26. Number of accessions and area for seed multiplication planted in Costa Rica: 1987-1988.

Location	Number of accessions		Area
	Grasses	Legumes	ha
Atenas	55	230	3
Guápiles	370	293	1.5
San Isidro	16	177	4
TOTAL	441	700	8.5

Table 27. Plantings carried out at the farm level: Tropical Pastures Program/ Central America and the Caribbean, 1988.

Germplasm	Ecosystem	Purpose*	Area m^2
B.d. 606 + C.m. 5452 + C.p. 438 + C.b. 5234	TShF	G	11900
B.d. 606 + C.m. 5713 + C.p. 438 + C.b. 5234	TShF	G	7650
A.g. 621	TShF	G/S	11000
B.h. 6705	TShF	G/S	2600
A.p. 17434	TSESF-Coffee	C	300
A.p. 17434	TSESF-Oil palm	C	250
A.p. 17434	TRF-Bananas	C	1060
A.p. 17434	TRF-Coconut	C	2300
D.o. 350	TRF-Pejivalle	C	1500
B.h. 6705	TSESF	S	1500
B.h. 6705	TSESF	S	1800
B.h. 6705	TSESF	S	800
B.d. 6133	TSESF	S	1500
B.d. 6133	TSESF	S	1000
B.d. 6133	TSESF	S	1800
B.d. 6133	TSESF	S	1200
B.b. 6780	TRF	G	5000
TOTAL AREA			53160

* G = Grazing; S = Seedbed; C = Cover crop.

10. Soil Microbiology

The work carried out during 1988 in the Soil Microbiology Section will be discussed under the following sub-headings:

- Rhizobium characterization
- Evaluation of legume-rhizobium-soil combinations Stylosanthes capitata - a special case.
- Use of traditional inoculation technology.
- Freeze-dried inoculants
- Legume-rhizobium evaluation network
- Non parametric nodulation evaluations N uptake and transfer
- N mineralization and immobilization

I. RHIZOBIUM CHARACTERIZATION

A simple method was developed for measuring growth rate of Bradyrhizobium strains by counting the cells in young (barely visible) 7-10 day old well-separated colonies of the strains grown on spread plates of YMA at pH 5.5. The spread plates were inoculated from a dilution series prepared from colonies of the same age. The results have shown a range of growth rates (generation time) from 6-7h for the faster growing strains, to 10-12h for the very slow-growing strains. This compares with 2-3h for fast-growing rhizobia (Rhizobium spp.). Growth rates were not markedly different on medium at initial pH 5.5 than 6.8 except for the very slow growing strains. This implies that the observed differences in colony size are due to gum production rather than faster growth at pH 5.5.

The very slow-growing strains (generation time 10-12 h) appear to be more sensitive to cold storage than normal slow-growing rhizobia and have shown low viability in inoculants stored under refrigerated conditions (e.g. CIAT 4099, 4103, 3541 and 995). When stored under non-refrigerated conditions, the inoculants are more likely to become contaminated. These strains are therefore not very suitable for use in traditional peat-based inoculants which should be stored under refrigeration. Table 1 shows the currently recommended strains which include some changes on the basis of these and other results.

Another characteristic of these very slow-growing rhizobia is that although they nodulate effectively on their own host plants, they tend to be non-infective or ineffective on Macroptilium atropurpureum cv Siratro. Siratro is a promiscuous legume which is reported to nodulate effectively with most tropical forage legume rhizobia.

Serological characterization by immunodiffusion of the strains in the B Collection has shown that the antisera are highly specific and that very little cross reaction occurs among strains. This means that it will be possible to use serological techniques for evaluation of inoculants in on-farm trials, since little cross-reaction with the native strains would be expected. This is in contrast to the position with bean

Table 1. Recommended strains for inoculation of regional trials B, C, D and other experiments of the TPP.

Legume	Recommended strain	
	CIAT No.	Origin/Synonym
Arachis pintoi	3101	*Centrosema plumieri* Sierra Nevada Santa Marta, Colombia.
Centrosema acutifolium	3101	
C. brasilianum	3101	
C. macrocarpum	3101	
C. pubescens	3101	
Cratylia floribunda	3561	*Cratylia mollis* grown in soil farm. Reserva Carimagua, Colombia.
Clitoria ternatea	4908	MAR 1315, CB 929
Desmodium heterocarpon	4099	CB 2085
D. heterophyllum	4099	
D. ovalifolium	4099	
Flemingia macrophylla	4099	
Leucaena leucocephala	1967	*L. leucocephala*
Pueraria phaseoloides	3918	UMKL 56, TAL 647
Stylosanthes capitata	995	*S. capitata*, Paraiguan, Venezuela
S. guianensis 136, 184, 1280	4969	BR 446, Semia 6154
S. guianensis 10136	4100	CB 2229
Zornia glabra (8279, 7847)	4100	
Z. latifolia	4100	

rhizobia, for which it is difficult to obtain specific antisera.

II. EVALUATION OF LEGUME-RHIZOBIUM-SOIL COMBINATIONS

Strain screening trials have been carried out with Cratylia floribunda and Flemingia macrophylla in Carimagua soil and Clitoria ternatea in Palmira soil. The strains tested on Cratylia floribunda all originated from C. mollis nodules, except for 3918 which is recommended strain for kudzu, and 4099 (recommended for Desmodium spp.) which killed the seedlings. The most effective strains were 3561 and 3564 which increased N yield 1.8 fold and nodule number 3.9 and 2.6 fold (Table 2). To test the effectiveness of native and inoculated strains in different soils, three treatments are required (uninoculated with low mineral N, inoculated with low mineral N, and uninoculated with high mineral N). A series of experiments of this type were set up to evaluate the effectiveness of strains selected in Carimagua soil in soils from other sites in Colombia using eight legumes (Table 3).

In all the soils except Villavicencio responses to inoculation in one or various parameters were observed. Possibly the responses in this soil were lower due to its exceptionally high P content (approx. 40 ppm) which may have stimulated nitrogen fixation by native strains. The most marked inoculation responses were observed in Pto. López and Florencia soil. In Mondomo soil the growth of the plants was inhibited, since although increases in nodulation and % N were observed, only in kudzu was this expressed as a significant increase in total N. This soil contained high Mn concentrations. S. guianensis only showed inoculation responses in terms of nodule number, although it responded to N fertilization, implying that the strain used (CB82) is not effective in these soils. The strain CIAT 3101 only increased the N yield of A. pintoi in Pto. López soil, although nodule number increased in most of the soils, indicating that a wider range of strains should be tested. The results suggest that more trials of this type should be carried out to permit the selection of strains adapted to the different soil types.

III. Stylosanthes capitata - A SPECIAL CASE

Previous experiments (e.g. Cadisch et al., 1989) have shown that P limits N_2 fixation by a range of legumes growing in Carimagua soil. It is also known that higher P fertilization rates in a given soil are likely to permit more marked rhizobia inoculation responses since efficient N_2 fixation requires adequate P nutrition of the plant.

An experiment was carried out in soil cores to evaluate the rhizobium inoculation response of three forage legumes at 2 P levels, and the effect of inoculation with a fluorescent pseudomonad Pp 18 was also evaluated. It was found (Table 4) that Centrosema acutifolium 5277 (cv. Vichada') and Pueraria phaseoloides 9900 showed greater rhizobium inoculation responses at high P levels, as would be expected. However Stylosanthes capitata 10280 (cv. Capica') showed a greater rhizobium inoculation response at the lower P level. At the higher P level the effect of rhizobium inoculation was negative, although not significantly so. Inoculation with the pseudomonad helped to overcome this effect (Table 5). At the low P level the rhizobium inoculation response increased from 18 to 99% in the presence of the pseudomona. The action of such bacteria is thought to be partially due to the stimulation of root growth through hormone production and partly due to P

Table 2. Strain screening trial in undisturbed soil cores from Carimagua (La Pista) for *Cratylia floribunda* no. 18516.

Treatment	mg N in tops/ core	nodules/core
+ N	117.3 a	2.6 d
3561	79.6 b	89.2 ab
3564	77.8 bc	59.6 b
3569	75.4 bcd	28.0 c
3566	75.0 bcd	94.0 a
3567	67.0 bcde	74.4 ab
3571	56.9 bcde	88.0 ab
3565	53.7 bcde	68.8 ab
3918	50.7 cde	31.0 c
3570	48.9 de	29.6 c
3562	44.2 e	25.2 c
uninoculated	43.7 e	22.8 c
3568	40.7 e	14.2 cd
3563	39.1 e	13.0 cd

Table 3. Significant responses to inoculation in total N (I), no. of nodules (N) and % N (P) of forage legumes in cores of different Colombian soils.

Legume	Soil						
	Jamundí	Quilichao	Pescador	Mondomo	Villavicencio	P. López	Florencia
Desmodium ovalifolium 13089			INP	P		NP	INP
Pueraria phaseoloides 9900			INP	IP		INP	IP
Stylosanthes guianensis 184	N	N	N				
Centrosema macrocarpum 5452	INP		IN	NP		N	INP
Centrosema acutifolium 5277	P	N		P		IP	INP
Centrosema acutifolium 5568	P		NP	N		INP	INP
Centrosema pubescens 438	NP		INP			IP	INP
Arachis pintoi 17434	N	N		N		INP	N

Table 4. Effect of P level on rhizobium inoculation response of three forage legumes in undisturbed soil cores (low and high P = 22 and 88 mg P/core respectively.

Legume	Rhizobium	low P	high P
		.... mg N/core	....
C. acutifolium	-	16.0	25.2
5277	3101	18.3 (+14)*	35.4 (+41)
P. phaseoloides	-	11.6	27.1
9900	3918	16.6 (+43)	44.4 (+54)
S. capitata	-	20.2	37.9
10280	995	32.1 (+59)	36.3 (-4)

* Percent inoculation response.
Interaction P level x inoc. significant for P.p and S.c.

Table 5. Effect of P levels and inoculation with a pseudomonad and rhizobium on N yield of *S. capitata* in undisturbed soil cores.

	low P 1/		high P 1/	
	- Pseu.	+ Pseu.	- Pseu.	+ Pseu.
	.... mg N/core		....	
- Rhiz.	20.9 cd	19.2 d	40.0 a	42.8 a
+ Rhiz.	24.6 bcd	38.2 a	30.2 abcd	39.2 a
% res to rizobio	+ 17.7	+ 98.9	- 24.5	- 8.4

1/ 22 and 88 mg P/core respectively.

solubilization. In the presence of native rhizobium strains with or without the pseudomonas a marked P response occurred, whereas in the presence of inoculated rhizobia there was almost no P response. This may be because the plant could not utilize the added P to support the additional P demand of the more effective rhizobium strains because it is obligatorily mycotrophic, and mycorrhizal infection is inhibited by P fertilization. Thus with rhizobium inoculation no additional benefit of added P over that which can be taken up by plants at low P in the presence of the pseudomonas is observed. Positive rhizobium inoculation response of S. capitata have only been observed at low P levels in clayey soils where apparently the native rhizobia nodulating this legume are less effective than in sandy soils (see previous annual reports). The interaction of P levels, rhizobium effectiveness, native mycorrhizal infection, and pseudomonad effects on root growth could be manipulated, with possible beneficial effects on the vigor of S. capitata in clayey soils, where a lack of vigor has been observed, especially when growing in competition with Andropogon gayanus. Lack of vigor of S. capitata has also been observed in rainforest ecosystems, which also may be due to lack of inoculants.

IV. USE OF TRADITIONAL INOCULATION TECHNOLOGY

Since inoculation responses have been observed in many field trials at Carimagua, it has become relevant to ask whether inoculation technology can be used successfully by the type of farmers who plant improved pastures. Four approaches have been taken to this problem:

1) On-farm trials were set-up on 4 small farms near Carimagua to compare inoculation responses observed with two main treatments: a) under the establishment conditions used by the farmers, and b) using the recommended establishment conditions. The recommended establishment conditions included fertilization with P, Ca, S, K and Mg, fixed seeding rates and spacing, compaction of the seed after sowing and hand weeding during establishment. The farmers applied no or much less fertilizer, used less seed, did not compact the seed, and did not weed. Within these two main treatments, sub treatments with and without inoculation were established using recommended inoculation methods in both cases. Much better plant growth was observed using the recommended establishment methods, presumably due to fertilization. The farmers themselves are being invited to observe and discuss the experiments, and to suggest ways to improve establishment under farm conditions. It seems that planting pastures after a crop such as sorghum could be especially appropriate for these farmers who have very limited resources for investing in fertilizer for pasture establishment and need grain for feeding farm animals. Also the availability of fertilizers in the region should be improved since the main reason given for not using them was lack of availability, not lack of cash for buying them.

A range of inoculation responses were observed at each of the sites, but these data are still being analysed. Improvements in the methodology for evaluating inoculation responses on farm could include serological determination of the proportion of nodules occupied by the inoculated strain, and inclusion of some larger farms in the Puerto López - Puerto Gaitan region. Some experimental station experiments on interactions of compaction, weed control, and fertilization are needed to complement the on-farm trials. Different methods of pre-cropping also need to be studied. Planting method (i.e. broadcast versus furrows) was not an issue on the farms studied this year since all the farmers planted in furrows using a planet junior, or by hand. However on larger farms broadcasting is much more common and the effect of this in relation to other components of the establishment technology used needs to be evaluated.

On two of the farms zinc deficiency was induced by fertilization (Table 6). Further studies on this are also needed.

2) To complement the on-farm trials, a study of traditional inoculation technology was carried out with 13 workers at Carimagua. The workers were divided into three groups depending on previous experience, and different levels of instruction were given on how to inoculate the seeds. Each worker inoculated two samples (750g) of large and small seeds. Higher numbers of rhizobia per seed were found on samples from workers whether or not they had inoculated seeds before (Table 7). Those who were shown how to inoculate by means of a demonstration achieved lower numbers than those who only received printed instructions. The negative effect of the demonstration may have been that these workers took longer to inoculate the seeds than those who saw no demonstration. The recommended method (add gum arabic to the inoculant to form a slurry and then add the seeds) was found to have certain difficulties since the packets of inoculant varied in moisture content (or moisture absorbing capacity) and therefore the mixture of a fixed quantity of gum arabic with each packet of inoculant did not result as a slurry of a given consistency. Sometimes it was necessary to add water or more gum to obtain a slurry of suitable consistency for mixing with the seeds. It also took a considerable amount of mixing to distribute the slurry well over the seed and the smaller seeds clumpled together if they were not mixed for long enough.

A further test was therefore carried out to compare the slurry method with a modified method where the gum was added directly to the seeds and mixed well, and then the inoculant was added to the seeds. With both methods a pellet of gypsum (builders plaster) was then added. Although the workers found the modified method much easier to use, and no clumping was observed, it gave slightly lower numbers per seed.

Further trials of this type are needed to define the easiest method, which can be learned from printed instructions, and which gives the highest number of rhizobia per seed. It is interesting to note that previous trials carried out in the laboratory to test the recommended method had shown it to be perfectly satisfactory, but these trials were carried out with much smaller seed samples. Only when using larger seed samples and inoculating under farm conditions did the problems with using this method become evident.

3) In collaboration with ICA, Puerto López and Tibaitatá, a special project to evaluate quality and identify problems in the use of commercial inoculants produced at the pilot plant at ICA Tibaitatá was carried out. A refrigerator also used for vaccines was used for storing the inoculants at Puerto López. Several problems with inoculant distribution and quality were identified:

a) Neither the cost of transport nor that of the gum arabic and instructions had been included in the cost of the inoculant, since ICA normally sells inoculant directly to private companies who resell it to the farmers. As a consequence (to

Table 6. Zinc deficiency and iron toxicity induced by Calfos + Sulpomag fertilization in a sandy soil. Finca "R. Janeiro" near Carimagua.

	Fert.	tissue concentrations		
		% P	ppm Fe	ppm Zn
C. acutifolium	+	0.25	1145	13.9
	-	0.12	584	20.9
P. phaseoloides	+	0.33	2631	16.1
	-	0.14	1232	21.1
critical levels		0.1 -	?	20.0
normal levels (Carimagua)		0.2	?	25-100

Table 7. Experiment to evaluate inoculation methodology with 13 workers at Carimgua.

Demonstration:	no	no	yes
Previous experience:	yes	no	no
	.... log rhizobia/seed		
	5.8 a	6.3 a	4.1 b

save money) the inoculant was sent by public transport to Puerto López, which resulted in delays for several days during which the inoculant was not kept under good conditions. To overcome this, the cost of better packing and direct delivery could be included in the price of the inoculant, or a private company could be identified for inoculant distribution. The gum arabic was sold separately by CIAT, which is also obviously not an appropriate long-term solution.

b) The packets of inoculant became compacted during transport. It is not clear whether this compaction was due to the change in air pressure from Bogotá to Puerto López, or the weight of other materials being stored on top of the packets. Also, in CIAT it has been observed that the injection hole must be opened during the inoculant maturation period (one week incubation after inoculation of the peat with the broth) because the gas phase within the packet is absorbed during this period, resulting in compaction. The effect of this compaction on survival of rhizobia in the inoculant is unknown and needs to be evaluated.

c) The paper labels and adhesive tape used to mark and seal the packets were damaged by contact with water which accumulated in the refrigerator. After sale to farmers, when inoculants were transported in polystyrene boxes with ice and sawdust as is routinely done for vaccines, water entered the packets through the injection hole and the labels were damaged. Several packets burst or were imperfectly sealed. Clearly plastic labels or another more durable packaging material with a firmer seal would be preferable.

d) Several mistakes were made by the personnel selling the inoculants (e.g. the wrong strain was delivered), possibly because one person had not been given full responsibility for this job.

e) The quality of the inoculant strain 3101 (for Centrosema and Arachis pintoi) was good, but strain 995 for S. capitata did not show good quality. This is thought to have been due to its low tolerance of refrigerated conditions (see above). Subsequent lots were not refrigerated and showed adequate quality (Table 8). The substitute strain for 995 (3541) is unfortunately also sensitive to refrigeration. A solution to this problem is needed. It is important to note that this problem had not previously been detected because in field and greenhouse experiments fresh inoculants are always used. This again demonstrates the type of feed-back from farmers, extension workers and distributors needed to design an appropriate technology. This work could not have been done without the excellent collaboration of ICA. Hopefully once an appropriate technology has been designed it will require only minor modifications in other countries.

4) Adhesives and pelleting materials

Gum arabic is imported to Latin America from Africa and rock phosphate is often not available.

Substitute adhesives (or local plantations of gum acacia trees..?) and pelleting materials are needed.
An experiment showed that molasses used as an adhesive was toxic, whereas a milk and sugar mixture was adequate (Table 9). Cassava starch showed high initial numbers but survival over time was not as good as with some of the other treatments. Adhesion was not measured in this experiment, which is obviously an important criterion for selection of adhesives. For this reason water

Table 8. Quality control of inoculants sold to farmers and no. of rhizobia/seed on the day of planting, on farms in the Eastern plains of Colombia.

Inoculant Lot No.	Strain	Rizobia/ gram	Legume	Rhizobia/ seed
8803	995	cont.[1/]	Capica	1.7×10^4
8802	3101	6.1×10^7	Vichada	7.3×10^5
8802	3101	1.3×10^8	*C. brasilianum*	3.5×10^4
8802	3101	1.7×10^8	Vichada	1.5×10^5
8801	3918	3.3×10^9	Kudzu	2.1×10^5

1/ Contaminated.

Table 9. Effect of adhesives on survival of rhizobia on stored *Centrosema acutifolium* seeds.

Adhesive	Log rhizobia/seed		% Survival (0-7 days)
	0 days	7 days	
Water	4.28 b	3.97 c	48
Molasses 80%	4.36 b	≤ 2.00 -	0.5
Sugar 25%	4.04 b	3.53 c	31
Milk + sugar	4.30 b	4.20 c	80
Gum arabic 1	4.68 b	4.74 b	100
Gum arabic 2	5.54 a	5.14 a	40
Cassava starch	4.88 b	4.34 bc	29

gave quite good results, but this would not be expected to occur if the seeds were handled normally after inoculation.

Slaked builders plaster was found to be a suitable alternative to rock phosphate as a pelleting material (Table 10).

V. FREEZE-DRIED INOCULANTS

Further studies on freeze-dried inoculants have emphasized techniques a) for improving survival in the vial, and b) for improving survival on seeds.

An experiment showed improved survival on storage of vials at different temperatures when cells were grown on agar rather than in broth and suspended in dextran or methylcellulose (Table 11). Possibly the gum produced by the cells grown on agar, and which is lost on centrifuging broth-grown cells, confers better tolerance to freeze-drying and storage. This is a basic difference between the freeze-drying method used for conservation of strain collections where the strains are grown on agar and that used for production of vaccines, where the cells are grown in fermentation tanks. The growth of the cells on agar would have implications for the production process: on the one hand agar is more costly than broth, and on the other no centrifuge is needed. Vecol is collaborating by measuring residual moisture after freeze-drying, which is an essential criterion for evaluating the freeze-drying process.

Further experiments have shown extremely low survival of freeze-dried cells when suspended in aqueous solutions and applied to Centrosema seeds. It was thought that this might at least partly be due to sensitivity of the unprotected cells to water-soluble seed coat toxins. However, no inhibition of rhizobium growth was caused by seeds placed on inoculated agar plates, which is the most commonly used method for demonstrating the presence of seed coat toxins. Further tests of the effect of materials which promote rhizobial survival on seeds are being carried out.

VI. LEGUME-RHIZOBIUM EVALUATION NETWORK

This network for the evaluation of the legume-rhizobium symbiosis in tropical forage legumes and beans has mainly been supported by UNDP funds. It now covers 14 countries and 25 institutions, 8 and 14 of which are working on forage legumes. This year experiments have been carried out at several of the sites but we have not yet received reports on the results. It is not yet possible to reach firm conclusions as to whether the same strains are effective at sites in different countries. Some strains have varied in their effectiveness between sites, but further experiments at the same sites with vigorous quality control of the inoculants used are needed if comparisons between sites are to be made. Some of the participants have not carried out quality control due to lack of materials, technical assistance etc. From the point of view of the participants it is more important to evaluate responses at their own sites than to compare their results with those of others. Some of the participants have already shown responses to inoculation at one or more sites (Panama, Cuba, Brazil, Mexico-Chiapas) whereas others have still seen no responses (Peru, Mexico-Veracruz, Colombia-Valledupar). It is important to follow through with this work in order to ensure correct interpretation of the results. Further funding is being sought.

Table 10. Effect of pelleting materials on survival of rhizobia on stored seeds of <u>Centrosema macrocarpum</u> (adhesive = gum arabic).

Pelleting material	Rhizobia/ seed (1 day)	% survival (1-6 days)
Gypsum	2.0×10^7	29
Slaked gypsum	1.1×10^7	37
Rock phosphate	7.7×10^6	25
Lime	3.8×10^6	26

Table 11. Survival of rhizobia (strain 3101) during freeze-drying and storage at three temperatures using different growth and freeze-drying media.

growth medium[1/]	freeze-drying medium	Log no. after freeze-drying	loss (logs) during freeze-drying	loss (logs) after freeze-drying during storage for 1 month		
				4°C	25°C	45°C
YMB	5% dextran[2/]	10.7	0.1	0.7	1.8	4.2
YMA	5% dextran[2/]	9.3	0.2	0.0	0.8	2.8
YMA	0.43% methyl cellulose[2]	9.6	0.0	0.1	0.4	3.4
YMA	yeast mannitol	9.6	0.2	0.0	3.2	9.6
YMA	5% peptone, 10% sucrose	9.3	0.2	0.1	1.2	9.3
YMA	13% milk, 1% glycine	9.2	0.5	0.2	2.7	9.2

1/ YMB yeast mannitol broth
YMA yeast mannitol agar

2/ Medium also includes 1% Na glutamate and 7.5% sucrose.

VII. NON-PARAMETRIC NODULATION EVALUATIONS

A method for evaluating and analysing qualitative nodulation data from field experiments has been devised in collaboration with the Biometrics Section. Previously there was no method available for this purpose. Although frequently we oberved changes in nodule color, size or distribution due to inoculation treatments in the field, we were unable to describe them adequately for lack of a suitable method. Here an example is given using nodulation data from a field experiment to evaluate inoculation methods for vegetative material of Arachis pintoi. Yield data from this experiment (Annual Report 1987) showed a large increase due to inoculation, especially when molasses was used as a sticker. Nodule numbers per plant were determined quantitatively and analysed by standard analysis of variance methods. Even though there were less nodules in the uninoculated treatments, this nodulation was still abundant and gave no statistical difference from the inoculated treatments (Table 12). The non-parametric method used for qualitative categories (color, size and distribution) is based on a modified minimum chi squared statistic, and evaluates differences in distribution of parameters among categories between treatments by comparing them with the distribution among categories over all treatments (denominated "intercept"). First the overall distributions are analysed to determine whether they vary from an even distribution (i.e. an even distribution is described by the null hypothesis which is that it does not vary significantly from 33: 33: 33 if there are 3 categories). The overall predominant color of nodules/plant confirmed the null hypothesis (i.e. 22: 49: 29 does not differ significantly from 33: 33: 33; Table 12). However, in the two uninoculated treatments there were significantly less plants with predominantly red nodules than in the overall distribution, and in both treatments using molasses as a sticker, there were significantly more plants with predominantly red nodules. Furthermore, nodule distribution over all treatments showed significantly more plants with a predominance of nodules on the tap root, but in both uninoculated treatments there were significantly less plants with a predominance of nodules on the tap root. There were no significant differences among treatments in nodule size (not shown). This example shows that qualitative changes in nodulation characteristics relate to the yield evaluations, and can be important for understanding the mechanism causing the inoculation response. In this case, molasses did not increase nodule number significantly, but nodule color did change. The results suggest that molasses increased the competitiveness of the inoculant strain used (CIAT 3101) or possibly its activity due to increased carbohydrate in the root zone. However, surprizingly, when molasses was used as a sticker for seed inoculation it had a negative effect (Table 9). Possibly, some sources of molasses contain toxic substances. Further experiments are in progress to compare molasses with sugar solution as an alternative.

VIII. N UPTAKE AND TRANSFER

An experiment using ^{15}N labelled NO_3^- and NH_4^+ was set up in collaboration with the IAEA-FAO (Vienna) to determine whether uptake of these two forms of mineral N differed between grass species, and whether it was affected by the presence of a legume. The experiment was carried out the year after establishment. By the ^{15}N dilution method kudzu was shown to fix a mean of 3.8 kg N/ha in 4 weeks

Table 12. Quantitative and qualitative nodulation characteristics in a field trial comparing inoculation methods on vegetative material of Arachis pintoi. Qualitative characteristics were analysed using a modified minimum chi squared statistic.

Treatment[1/]	no. nodules/ plant	Qualitative nodulation characteristics (frequency %)					
		color category[2/]			distribution category[3/]		
		1	2	3	1	2	3
F_1 - inoc	58.6	49	2**	49	18**	59**	23
F_1 + inoc + GA	103.7	23	54	23	3	33	64
F_1 + inoc + M	89.9	2	95*	3	8	28	64
F_1 + inoc + W	98.6	13	64	23	12	18	70
F_2 - inoc	46.8	69	3**	28	18**	59**	23
F_2 + inoc + GA	53.2	18	59	23	8	23	69
F_2 + inoc + M	71.1	3	90**	7	8	44	48
F_2 + inoc + W	49.0	13	59	28	2	18	80
Intercept		22	49	29	9**	35**	56

* Differs significantly at $P \leq 0.05$; ** differs significantly $P \leq 0.01$

1/
- F_1 F_2 source of material
- - inoc uninoculated
- GA gum arabic
- M molasses
- W water

2/
- 1 = nodules predominantly white or green.
- 2 = nodules predominantly red.
- 3 = no predominant color

3/
- 1 = no nodules on tap root.
- 2 = 1-50% nodules on tap root.
- 3 = majority of nodules on tap root.

when grown in association with 3 Brachiaria spp. (Table 13), whereas the mean difference between the N uptake of the grass-legume mixtures and that of the pure grasses was considerably greater (5.83 kg N/ha or 53% more N than that actually fixed during this time period). This substantial amount of additional N is presumably due to N transfer or higher rates of mineralization occurring in the grass-legume mixture.

The difference in N uptake of the grasses growing alone from that of the grasses grown with kudzu was smaller and not significant for any given grass, but B. decumbens grown with kudzu took up significantly more N than B. humidicola grown alone (Table 14). This confirms previous observations that B. humidicola becomes N deficient more rapidly than other Brachiaria spp. It was thought that the greater N immobilization and N deficiency observed in B. humidicola might be due to a larger quantity of N found in the roots. However, at least in this experiment, there was no significant difference between species in the amount of N in the roots, whereas there was a large difference in the amount in the stubble (Table 15). Different amounts of N in any of these three components could be an important source of N for regrowth thus causing more dilution of added ^{15}N in some species than others. Considerable dilution of ^{15}N in B. humidicola and B. decumbens did occur relative to that in B. dictyoneura (Table 16); in B. humidicola this dilution may be due in part to N_{15} from stubble. However, the added ^{15}N also appears to have been diluted in differing proportions under the three grasses due to other causes, because the ^{15}N in B. decumbens was more diluted than in B. dictyoneura even though it had less N in the roots, litter and stubble. The greater uptake of NO_3^- than NH_4^+ by all three grasses, and the lower dilution effect with NO_3^- than NH_4^+, show that even though B. humidicola was able to take up NH_4^+ more effectively than the other species in solution culture (Annual Report, 1983, pp 188-189), competi- on for NH_4^+ with microorganisms or clay fixation in the soil means that the added NH_4^+ was not so available to the grasses as NO_3^-. It would be interesting to study NO_3^- reductase activity in these grasses grown alone and in association with legumes to determine whether they take up legume derived N in the form of NO_3^- or NH_4^+, since very little NO_3^- has been detected in soil under pure grass and grass-legume mixtures (see IX).

From this study it would appear that an understanding of the relative availability of NO_3^- and NH_4^+ in the soil is the key to understanding N uptake by grasses and consequently their quality and growth rates. The immobilization of NH_4^+ in the soil under grasses can be explained ecologically as a strategy for conserving soil N, but our aim is to make efficient use of this soil N for subsequent crops, by releasing it through soil disturbance, or by use of legumes which apparently change the mineralization immobilization ratio.

IX. N MINERALIZATION AND IMMOBILIZATION

It has previously been shown that under pure established grasses very little nitrification occurs in Carimagua soil whereas under bare soil and under legumes high rates of nitrification are observed[1/].

Although changes in soil C:N ratios have not been detected, this effect in an established pasture might be due to unmeasureable changes in C:N ratios caused by recycling of litter with differing proportions of

1/ Sylvester-Bradley et al (1988). J. Soil Science, 39: 407-416.

Table 13. N_2 fixation of Pueraria phaseoloides during 4 week period of regrowth in the year after establishment using the ^{15}N dilution method (mean of NO_3^- and NH_4^+ as ^{15}N sources), and difference in N uptake of pure grasses and grass-legume mixtures.

Associated grass	N_2 fixed (^{15}N dilution)	Total N uptake difference (mixture-pure grass)
	................kg N/ha......................	
B. dictyoneura	3.47	5.35
B. decumbens	3.89	6.41
B. humidicola	4.05	5.72
mean	3.80	5.83

Table 14. N yield of 3 Brachiaria spp. with and without P. phaseoloides during a 4 week period 1 year after establishment (regrowth above 15 cm).

Species	Grass alone	Grass in mixture
	...............kg N/ha.............	
B. dictyoneura	9.24 ab	9.98 ab
B. decumbens	9.47 ab	10.28 a
B. humidicola	8.39 b	8.82 ab

Table 15. N in roots, litter and stublle in pure grass plots of 3 *Brachiaria* spp. 1 year after establishment.

Specie	Roots	Litter	Stubble (0-15 cm)	Total
	....	.... kg N/ha	....	....
B. dictyoneura	14.05 a	3.97 a	13.64 b	31.66
B. decumbens	11.83 a	3.87 a	4.85 c	20.55
B. humidicola	10.07 a	5.42 a	21.73 a	37.22

Table 16. ^{15}N atom XS of 3 pure *Brachiaria* spp. with two ^{15}N sources, and dilution relative to *B. dictyoneura*.

Specie	^{15}N source			
	NO_3^-	NH_4^+	NO_3^-	NH_4^+
	......at. % XS.....		... relative diln ... (%)	
B. dictyoneura	0.753	0.546	-	-
B. decumbens	0.657	0.406	12.8	25.6
B. humidicola	0.634	0.369	15.8	32.4

available N. However, recycling by this route is only likely to start after litter has begun to fall, i.e. it is unlikely to occur during establishment unless significant plant death is caused by some factor such as spittle bug. Thus if the effect is observed during establishment it is likely to be due to changes caused by some factor other than litter fall, e.g. root exudates with differing C:N ratios or containing toxins. Table 17 shows that NO_3- accumulation in bare soil, under A. pintoi and in the grass-legume mixture was greater than in soil under B. humidicola at 8 weeks after planting. By 16 and 20 weeks after planting the inhibitory effect of B. humidicola on NO_3- accumulation had become more marked. No effects of the treatments on NH_4+ levels can be seen. These data imply that the inhibitory effects on NO_3- accumulation observed are a direct effect of the grass roots on nitrification and not an indirect effect of recycling of litter. To identify the mechanism causing this it would be necessary to determine if the microbial biomass under B. humidicola is greater and/or more active than under A. pintoi. A large microbial biomass would imply that the inhibitory effect is due to immobilization of NH_4+, whereas a smaller one would imply that the effect is due to toxins or other factors inhibiting the activity of soil microorganisms.

In another experiment, in which N mineralization rates were studied in soil from plots in the second year after establishment, some NO_3- accumulation was detected in soil from N fertilized B. humidicola plots. However, the rates under N fertilized B. humidicola and B. dictyoneura were lower than those under N fertilized B. decumbens. The pH of the soil did not show any consistent changes related to the different species.

In another experiment a market effect of N fertilization of grasses on N uptake or loss from the soil was observed. When urea was added to soil in cores taken from plots which had either been fertilized with urea or not, a large amount of NH_4+ disappeared in the soil that had been N fertilized (Table 18). Whether this was due to volatilization or immobilization by soil microorganisms is unknown. A similar study comparing soil from under legumes with that from under grasses might throw some light on the explanation for this effect. i.e. is there a larger microbial biomass in soil from under legumes and/or are the soil microorganisms more active, and do these differences cause greater immobilization and release (i.e. faster cycling) of NH_4+?.

This year some of the UNDP/BNF Special Project funds were used for investigating how soil N mineralization affects the evaluation of enhanced nitrogen fixation by legumes through improved cultivars and/or rhizobium inoculation.

Since the use of undisturbed soil cores by the TPP in the routine evaluation of legume/rhizobium symbioses effectively eliminates high accumulation of mineral-N, much of the work was directed towards the bean program. It is very difficult to collect undisturbed cores which are large enough to adequately accommodate bean plants, and alternative soil collection, drying, grinding and rewetting processes all contribute to high levels of mineral N found in the test soil. These high levels can be reduced by the addition of mineralization inhibitors, the selection of which was studied in detail. Full results are available in a separate report compiled for the UNDP and CIAT Director General's Office.

Work of direct interest to the TPP is

Table 17. Soil mineral N levels after incubation (4 weeks) in samples from under grass, legume and a grass/legume mixture during establishment, in comparison with plant-free plots.

	NO_3^-				NH_4^+			
	WAP[1]				WAP[1]			
Treatment	4	8	16	20	4	8	16	20
	.... ppm N (dry soil)							
B. humidicola + *A. pintoi*	5.35	7.12	3.30	1.26	7.13	8.80	6.24	6.96
B. humidicola	4.23	3.44	1.62	1.20	7.02	8.52	7.17	7.20
A. pintoi	6.90	9.77	7.32	11.25	8.35	8.82	6.03	4.39
Bare soil	6.40	10.28	10.09	14.86	9.94	9.73	6.46	5.12

1/ Weeks after planting.

Table 18. Change in NH_4^+ level during 4 weeks incubation of soil from grass plots with and without N fertilization.

Grass	N fertilization –	N fertilization +
	..........ppm N_4-N............. (change)	
A. gayanus	+ 5	- 131
B. decumbens	+ 3	- 162
B. humidicola	+ 2	- 166
M. minutiflora	+ 7	- 162
Savanna	+ 8	- 117

described below under three headings 1. dynamics, 2. inhibition and 3. mechanisms of soil-N mineralization.

1) Dynamics

Both the amount of potentially mineralizable soil-N (No) and rate of release are important in determining how much inorganic N is available for crop production, over a given period. Net N mineralization was measured during a 4 week greenhouse incubation in samples of three soils each having contrasting managements. Amounts of No were estimated using a chemical extraction method as described by Gianello and Bremner (1986). Applying a first order mineralization model (Stanford and Smith, 1972), rate constants, half lives and proportions of No mineralized in 4 weeks were calculated and are presented in Table 19 along with respective No values.

In some soil samples net N mineralization did not occur, i.e. final levels of inorganic N were less than initial. The reason for this apparent net immobilization of N is not known.

No values show some interesting features. First, amounts of No are quite considerable in samples from Carimagua, being comparable with those from Quilichao, and exceeding those from Palmira. Second, there is a measurable increase in No in soils under Centrosema, grass and bare soil over that under bean cultivation. Third, enormous quantities of No have accumulated under permanent grass at Quilichao.

Derived rate constants of mineralization in soils under Centrosema and Arachis were higher than under grass or bare soil suggesting that the N accumulated under these legumes is more readily available. This is emphasized by the very short half life of the mineralization reaction under Centrosema, especially in Palmira i.e. approximately 10 days. The longest half life, found in the Quilichao soil under grass was more than 1.5 years. The range of proportions of No mineralized in 4 weeks was from 3 to 81%.

2) Inhibition of mineralization

This and previous Annual Reports (1983, p. 211; 1985, p. 224; 1986, p. 194) report suspected inhibition of nitrification in soil under Brachiaria humidicola. Figures 1 and 2 shows the effect of adding dried ground B. humidicola roots to soil on the mineralization of organic-N (values are means of 5 replicates over 4 sampling times). B. humidicola appeared to have two effects, first, to reduce net total mineralization, second, to specifically inhibit the conversion of NH_4-N to NO_3-N. In a separate experiment B. decumbens was shown to be less effective in inhibiting N mineralization than B. humidicola. Further comparative studies of the effect of different plant species on inorganic N release are planned.

3) Mechanisms

Autotrophic nitrification in soil is usually thought to be inhibited at pH

Gianello, C. and J.M. Bremner (1986) A simple chemical method of assessing potentially available organic nitrogen in soil. Commun. in Soil Sci. Plant Anal., 17(2), 195-214.

Stanford G. and Smith S.J. (1972) Nitrogen mineralization potential of soils. Soil Sci. Soc. Am. Proc., 36;465.

Adams, J.A. (1986) Nitrification and ammonification in acid forest litter and humus as affected by Peptone and Ammonium-N amendments. Soil Biol. Biochem., 18 (1), 45-51.

Table 19. Estimates of amounts of Potentially Mineralizable Nitrogen (No), Rate Constants, half Lifes and Percentages of No mineralized in 4 weeks in greenhouse incubations of Palmira, Quilichao and Carimagua soils sampled under different managements.

Soil	No[1] (kg N/ha)	Rate Constant[2] ($week^{-1}$)	1/2 life (weeks)	% of No mineralized in 4 weeks
Palmira				
Permanent grass	200	0.025	28.3	9.3
Centrosema	410	0.421	1.6	81.0
Bare Soil	360	------------net immobilization--------------		
Beans	100	ND	ND	ND
Quilichao				
Permanent grass	2.700	0.008	86.6	3.0
Centrosema	880	0.027	25.4	9.2
Bare soil	820	0.019	67.3	4.0
Beans	160	ND	ND	ND
Carimagua				
B. humidicola	720	-------------net immobilization-------------		
Arachis pintoi	580	0.103	11.7	21.0
Bare soil	900	-------------net immobilization-------------		

Notes: 1. Estimated in top 25 cm of soil depth assuming constant bulk density of 1.3 g/cm^3.

2. Average of US soils, 0.054 (Stanford and Smith, 1972).

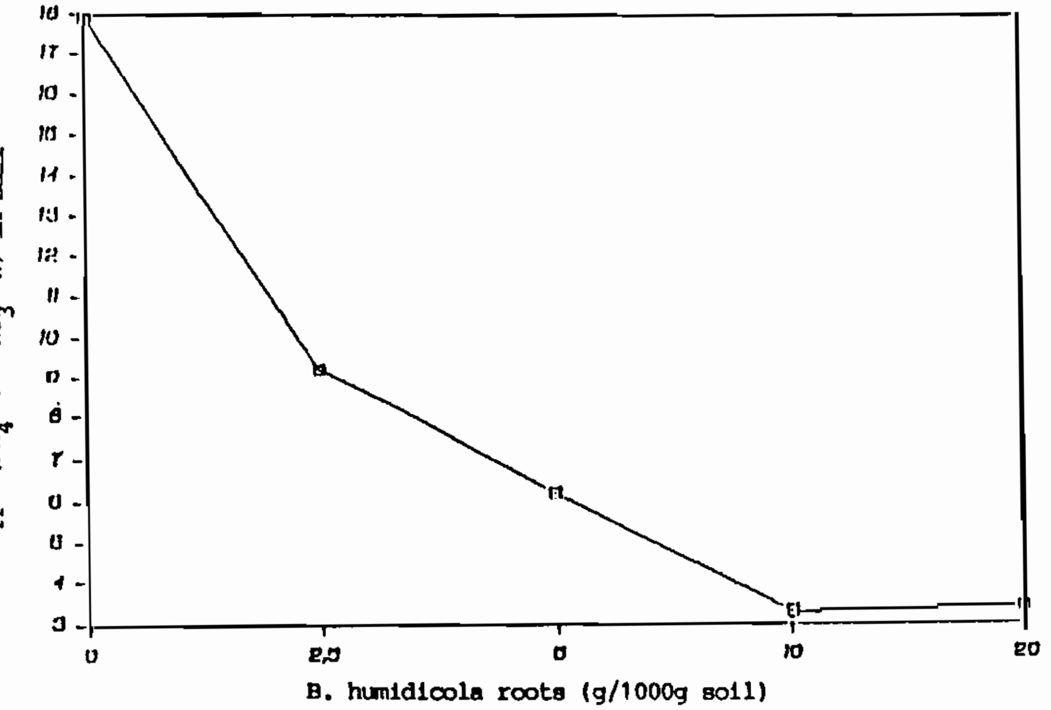


Figure 1 - Effect of adding b. humidicola roots to soil on NH_4 -N + NO_3 -N levels.

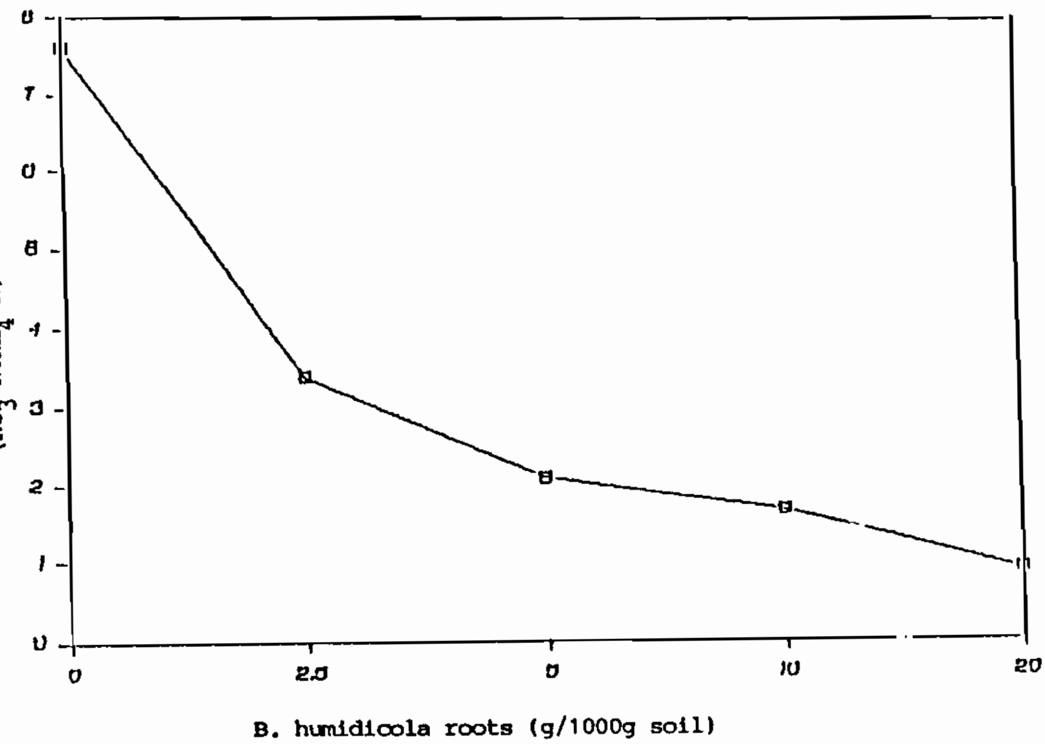


Figure 2 - Effect of adding B. humidicola roots to soil on NO_3 -N NH_4 -N levels.

values less than 5.0 (Adams, 1986). However considerable NO_3-N accumulation may be observed in strongly acid soil via heterotrophic nitrification. Heterotrophic nitrifiers can use peptone as a source of reduced N, but they cannot use NH_4, which is used by autotrophic nitrifiers. N mineralization in an incubated Carimagua soil (pH 4.8) was compared with Palmira soil (pH 7.0) with the following amendments,

I. none
II. 150 ppm N as $(NH_4)_2SO_4$
III. 150 ppm N as Peptone

Table 20 shows that $(NH_4)_2SO_4$ added to Palmira soil was rapidly converted to the NO_3-N form indicating that no inhibition of the autotrophic pathway occurred. However in Carimagua soil substantial amounts of NH_4^+ accumulated whilst no additional NO_3^- appeared relative to the control. Peptone amended Carimagua soil showed significantly less NH_4^+ but significantly more NO_3-N accumulation than the $(NH_4)_2SO_4$ treatment.

This pattern of mineralization response indicates that autotrophic nitrification is inhibited in the Carimagua soil with heterotrophic nitrification being the major pathway. Further verification of this is required on other acid soils in the Llanos.

Further studies of immobilization, mineralization and nitrification in rainforest and savanna soils under different management regimes would permit a better understanding of the role of pastures in maintaining soil fertility in these two ecosystems.

Table 20. Effect of Peptone and Ammonium-N additions on NH_4 and NO_3 levels over 30 days in Palmira and Carimagua soils. (Means of 5 replications over 3 sampling times).

Sample	Amendment	NH_4-N (ppm)	NO_3-N (ppm)
Palmira	None	8 D	40 b
	$(NH_4)_2SO_4$	36 C	74 a
	Peptone	31 C	41 b
Carimagua	None	11 D	11 c
	$(NH_4)_2SO_4$	97 A	12 c
	Peptone	72 B	31 b

Values followed by the same letter are not significantly different ($P < 0.05$) according to DMRT.

11. Soils/Plant Nutrition

During 1988, the Section has focused its research work in four main areas: 1) phosphorus fertilization efficiency in established pastures; 2) residual effect of phosphorus fertilization and recycling; 3) development of methodology to measure gains and losses in a pasture system, and 4) pasture reclamation.

PHOSPHORUS FERTILIZATION EFFICIENCY

Two small plot experiments that were established in Carimagua in 1987 continue for another year to explore the effect of rates and placement of phosphorus fertilization on the production phase of *Andropogon gayanus* with *Centrosema acutifolium* cv. Vichada, and *Brachiaria dictyoneura* cv. Llanero with *Desmodium ovalifolium* CIAT 350. In the second year, all forage from frequent cuts was returned to the plots to stimulate grazing and permit long-term monitoring of productivity. The regrowth during three overlapping periods of 42 days in the middle of the wet season were measured to represent production phase. New trends were more related to species competition and differences in primary productivity of the two sites (Table 1). Grasses were more productive in the clay loam soil. Broadcast methods gave the highest yields for *A. gayanus*. Although responses to P rates were still observed, absolute differences between rates was smaller than in the first year (Table 2).

Given the fact that pastures are grazed a year after they have been planted, it was possible to have established them with low P rates. Although establishing is slower, the pastures reached maximum productivity at the moment to initiate grazing.

RESIDUAL EFFECT OF PHOSPHORUS IN GRAZED PASTURES

A series of greenhouse and field experiments started last July to determine those soil, plant, and management factors that influence phosphorus availability in grazed pastures. The effect of soil texture was evaluated, using five acid soils of similar mineralogy that received 0, 1, 2, 4, 6, 8, 10, and 20 kg P/ha in an incubation experiment in the greenhouse. Table 3 shows some of the chemical and physical characteristics of these soils. Preliminary results have shown that P availability, as measured by the Bray II extraction method, decreased with time to reach an equilibrium. (Figure 1). The level of equilibrium was lower in the more clayey soils, suggesting that P fixation increases with increasing clay content in these soils. The practical significance of the equilibrium level on growing plants at different ages in the field will be defined next year. The effect of additional soil parameters affecting phosphorus residual effects (i.e., soil mineralogy, organic matter, etc.) will also be evaluated next year.

Table 1. Effect of planting method and placement of fertilizer on the production phase of two pasture associations grown in an Oxisol, Carimagua, Colombia.

Treatment	Dry matter (kg/ha) in site[1]					
	Alegría			Reserva		
	Grass	Legume	Weeds	Grass	Legume	Weeds
	A. gayanus + C. acutifolium					
Broadcast +	518 ns	28 b	91 ns	1000 a	23 ns	23 c
Rows 50 +	490	69 a	75	1008 a	58	22 c
Rows 50 ++	497	30 b	64	1059 a	14	41 ab
Rows 100 +	464	27 b	72	974 ab	9	27 bc
Rows 100 ++	466	18 b	79	883 b	28	53 a
	B. dictyoneura + D. ovalifolium					
Broadcast +	414 ab	186 ns	44 ns	477 c	103 a	120 ns
Rows 50 +	521 a	160	43	752 a	30 b	45
Rows 50 ++	496 ab	154	45	685 ab	30 b	37
Rows 100 +	393 b	170	43	691 ab	19	41
Rows 100 ++	415 ab	142	53	575 bc	32	89

\+ Legume and grass mixed; ++ Legume and grass separated in rows.

1/ ns = no statistical difference; means within a single column followed by the same letters are not significantly different at the P = .05 level of Duncan's Multiple Range Test.

Table 2. Effect of fertilizer rate on the production phase of two associations grown in an Oxisol, Carimagua, Colombia.

P Rates (kg/ha)	Dry matter (kg/ha) in site[1]					
	Alegría			Reserva		
	Grass	Legume	Weeds	Grass	Legume	Weeds
	A. gayanus + C. acutifolium					
5	421 b	15 c	80 ns	869 c	53 ns	59 a
10	486 a	28 bc	69	955 b	21	34 b
20	517 a	39 ab	82	1029 ab	19	23 b
40	527 a	57 a	75	1077 a	15	17 b
	B. dictyoneura + D. ovalifolium					
5	430 ns	113 b	53 a	645 ns	34 b	71 ns
10	448	155 ab	48 ab	590	43 ab	61
20	442	191 a	46 ab	649	53 a	58
40	471	191 a	35 b	660	42 ab	77

1/ ns = no statistical difference; means within a single column followed by the same letters are not significantly different at the P = .05 level of Duncan's Multiple Range Test.

Table 3. Chemical and physical characteristics of five acid soils used in an incubation study in the greenhause.

Soil Properties	Site				
	Alegría	Quilichao	Yopare	Florencia	Reserva
pH	4.8	4.5	4.5	4.5	4.5
P Bray II (ppm)	2.8	2.7	2.0	4.3	1.6
Al sat. (%)	80	65	83	51	89
Clay (%)	20	53	22	64	35
Sand (%)	49	28	45	12	17

The residual effect of phosphorus fertilization on the establishment of new populations of A. gayanus, B. dictyoneura, C. acutifolium, and S. capitata also started this year. Field experiments that have been planted in three Oxisols of Carimagua in 1985, 1986, and 1987 and included phosphorus rates of 5, 10, 20, and 40 kg P/ha were used for this purpose.

Standing vegetation was removed from plots and then planted with the pasture species in rows 50 cm apart. There was no further weed control. Residual effect of phosphorus will be compared with fresh applications of 5 and 20 kg P added in rows and broadcast, respectively. Preliminary observations have shown that A. gayanus responds strongly to fresh P additions, particulary in the more clayey soils (Reserva and Alcancía).

Responses of the legumes to the treatments are not yet apparent. However, it is interesting to observe the positive response of weeds to fresh additions of P and the low weed population in the residual treatments. The experiment will be cut at the beginning of the next year's rainy season.

PHOSPHORUS REQUIREMENTS FOR MAINTENANCE AND RECYCLING

The need for phosphorus fertilization in the maintenance of pasture productivity was evaluated using small plots planted with pure grass and several grass-legume associations already under grazing (Table 4). Pastures received 0, 5, and 10 kg P/ha. Results of the first evaluation showed no response in terms of dry matter to the P treatments in any of

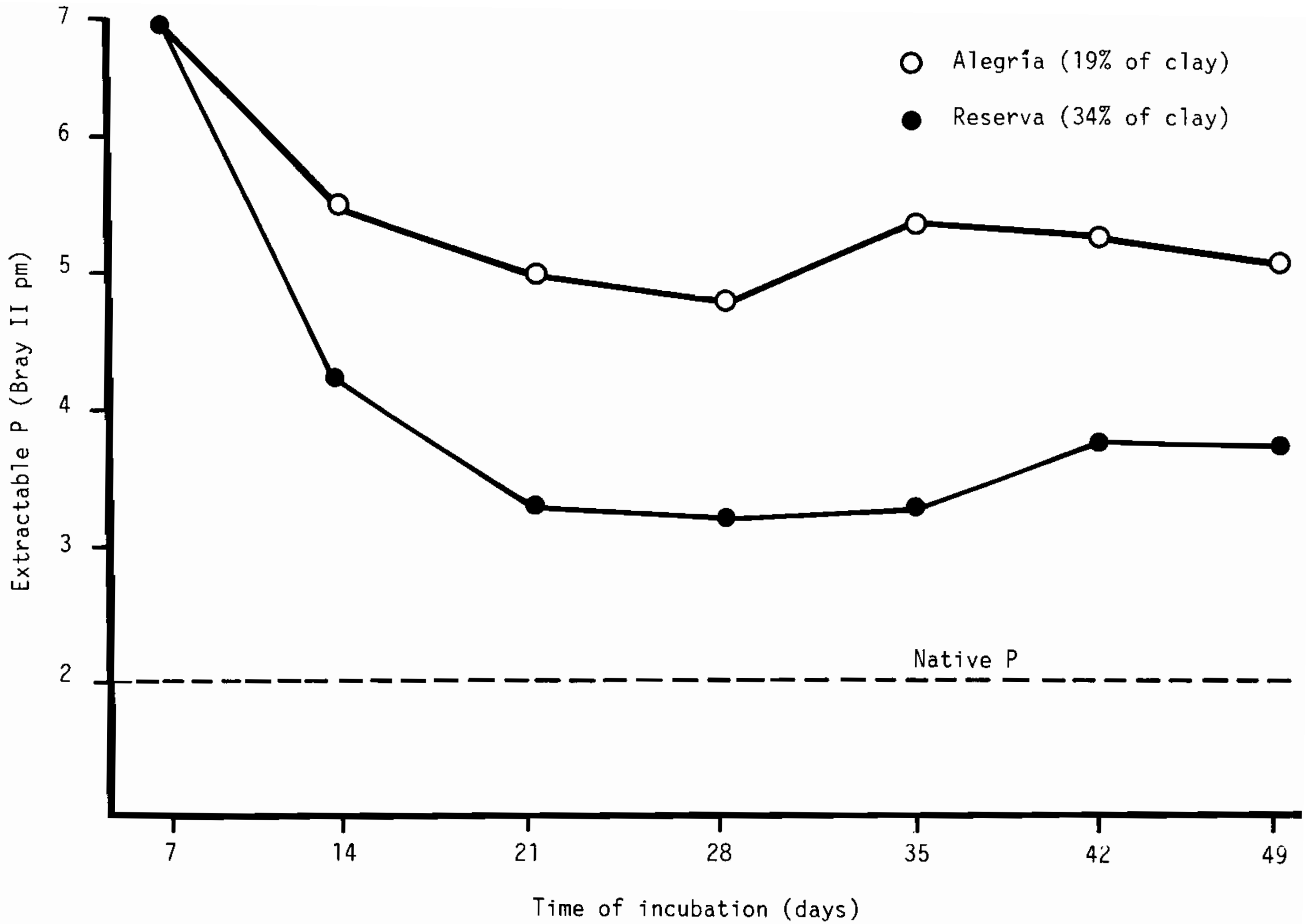


Figure 1. Changes in extractable phosphorus (Bray II) with time in two Oxisols with different clay content incubation experiment.

Table 4. Pastures selected for study response to phosphorus fertilization.

Pasture[+]	Stocking rate (an./ha)
B. dictyoneura[1] + B. brizantha[2,+]	2 and 3
B. dictyoneura + B. brizantha + C. acutifolium[3,+]	2 and 3
A. gayanus	2 and 3
A. gayanus + C. acutifolium[++]	2 and 3
B. decumbens 606++	2
B. decumbens + P. phaseoloides[++]	2

1/ cv. Llanero.
2/ cv. Marandú
3/ cv. Vichada
\+ Established in 1985.
++ Established in 1978.

the pastures studied. However, there was a consistent increase of P content in the tissue of the pasture species. This suggests that there may be another nutrient limiting the growth of pasture species. Work will continue next year to test this hypothesis. Additional work is also planned to determine optimal sized plot in which to conduct this type of work in pastures under grazing. This methodology could be a useful as a diagnostic tool, together with soil and plant analyses.

Research on phosphorus cycling will concentrate on the quality of the plant litter and animal excreta as a means of returning P to the soil. The relative importance of these two organic inputs will be evaluated in pure grass and in associations. Amounts of P returned and their relative availability will be determined. Decomposition rates of litter and excreta in different pastures will be measured. Results will be related to changes in the total phosphorus status in soil-plant system.

Field work is in progress to determine the seasonal changes of organic phosphorus in the soil of several pastures. The objective is to ascertain the supply of P by the mineralization of organic P. Greenhouse and laboratory studies will be carried out to determine the existence of plant mechanisms to decrease P fixation in soil and to increase organic phosphorus mineralization. If present, they could be exploited to minimize external P inputs.

NUTRIENT GAINS AND LOSSES IN A PASTURE SYSTEM

Work started early this year in three pastures under grazing in an Ultisol at Quilichao, Colombia, in order to evaluate: 1) litter production and nutrient return via litter; 2) atmospheric inputs via rain and dust; and 3) use of porous cups to measure changes in soil solution.

Litter production was measured by collecting dead material from fixed sampling points in each pasture before each grazing cycle. The sampling area for each of B. dictyoneura and native pastures was 0.5 x 0.5 m, and for A. gayanus + C. acutifolium pasture it was 0.5 x 2.5 m. After nine months of evaluation, results showed that litter produced in the A. gayanus + C. acutifolium and the native pasture was similar. However, nutrient returns were superior in the association, because of the legume (Table 5). The contribution of the legume's litter was even more apparent when the N and P returns from the association were compared with those of B. dictyoneura litter.

Nutrient inputs from rain and dust were measured by using nine collectors distributed throughout the pasture. After a year of evaluation, it was found that there was a large input of Ca, Mg, and K from the atmosphere in Quilichao (Table 6). This was probably because ash and dust contamination produced around the station.

There were some limitations in using porous cups to monitor changes in nutrient concentration in soil solution. Collection of enough solution from 0-30 cm was erratic and difficult to obtain (Table 7). Furthermore, N and P contents were very low and difficult to determine. Only a large concentration of Ca and Mg was observed in the soil solution. Results suggest that porous cups would be useful for studing Ca and Mg movement in the leaching of grazed pastures.

PASTURE RECLAMATION

Activities were expanded for a few new areas. Table 8 shows the soil chemical and physical properties of the new sites. In one of the pastures in Caqueta, Colombia, the effect of frequency, intensity, and type of control of the weed Homolepis aturensis on the establishment of B. decumbens 606 + A. pintoi, and B. dictyoneura 6133 + D. ovalifolium 3088 pastures was studied. The effect of phosphorus on the establishment of these pastures was also tested. According to preliminary results, the frequency of control of weeds was the most effective treatment (Figure 2). There was no significant effect of phosphorus on the esablishment of the pasture species.

Methods of controlling native species in order to introduce grasses and legumes was studied in another site (Jamundí). Results presented in Tables 9 and 10 show that the reduced tillage treatment (two diskings) was adequate for establishing the pasture species. In some instances, the addition of herbicide appeared sound. A full report of the results will be available next year.

RECLAMATION OF A DEGRADED PASTURE

A nine-year-old B. decumbens pasture under grazing on an Ultisol, Quilichao, was reclaimed by introducing a mixture of C. macrocarpum + C. ovalifolium in bands (Figure 3). Data for the first year have shown positive results for grass productivity and N content in grass tissue as a result of legume inclusion (Figure 4). As a consequence, animal performance on mixed pasture was far superior to that on pure stand (Table 11). The experiment will continue for several years to test the sustainability of the system.

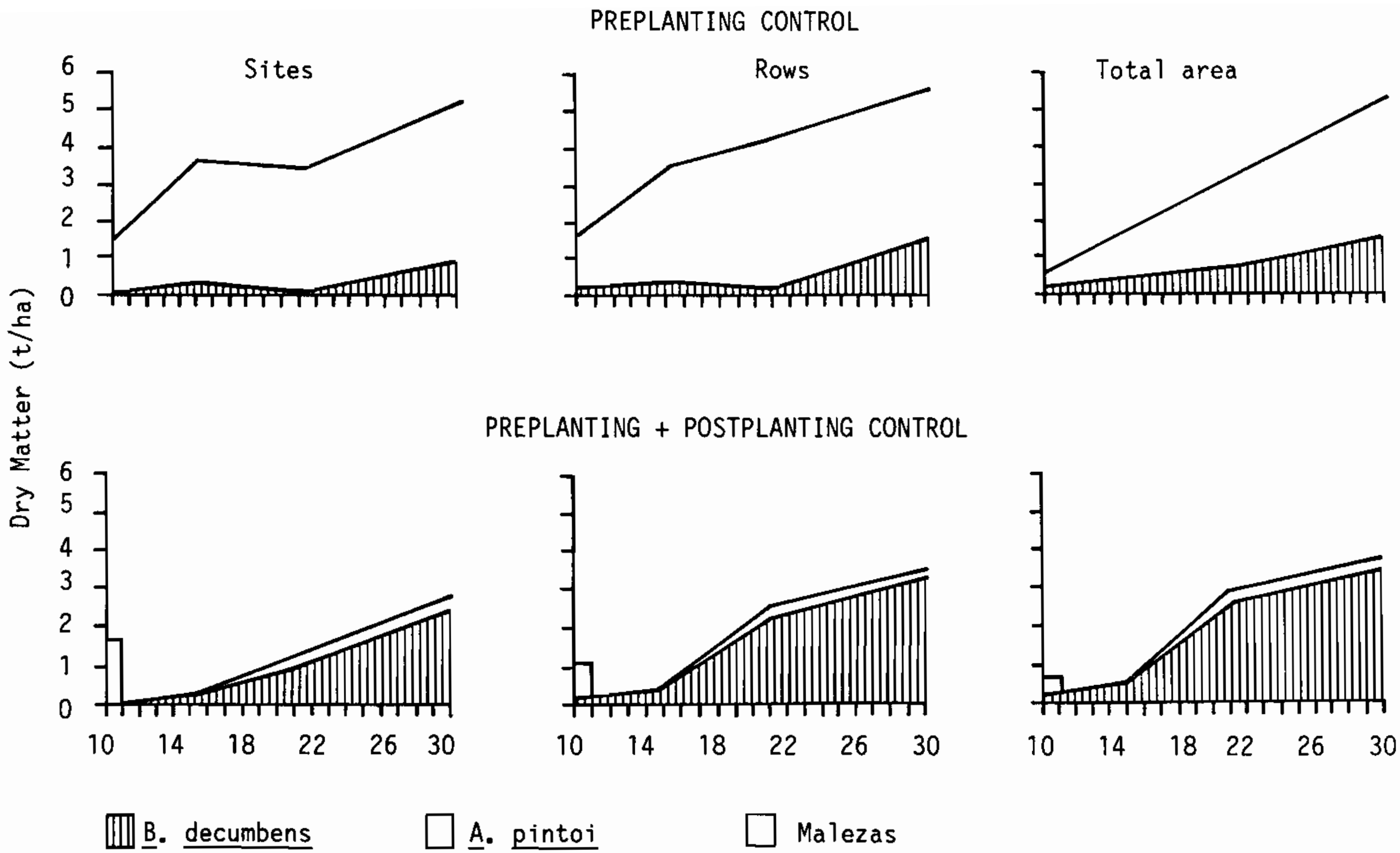


Figure 2. The effect of the frequency of chemical control of *Homolepis aturensis* on the establishment of a forage association in Caqueta, Colombia.

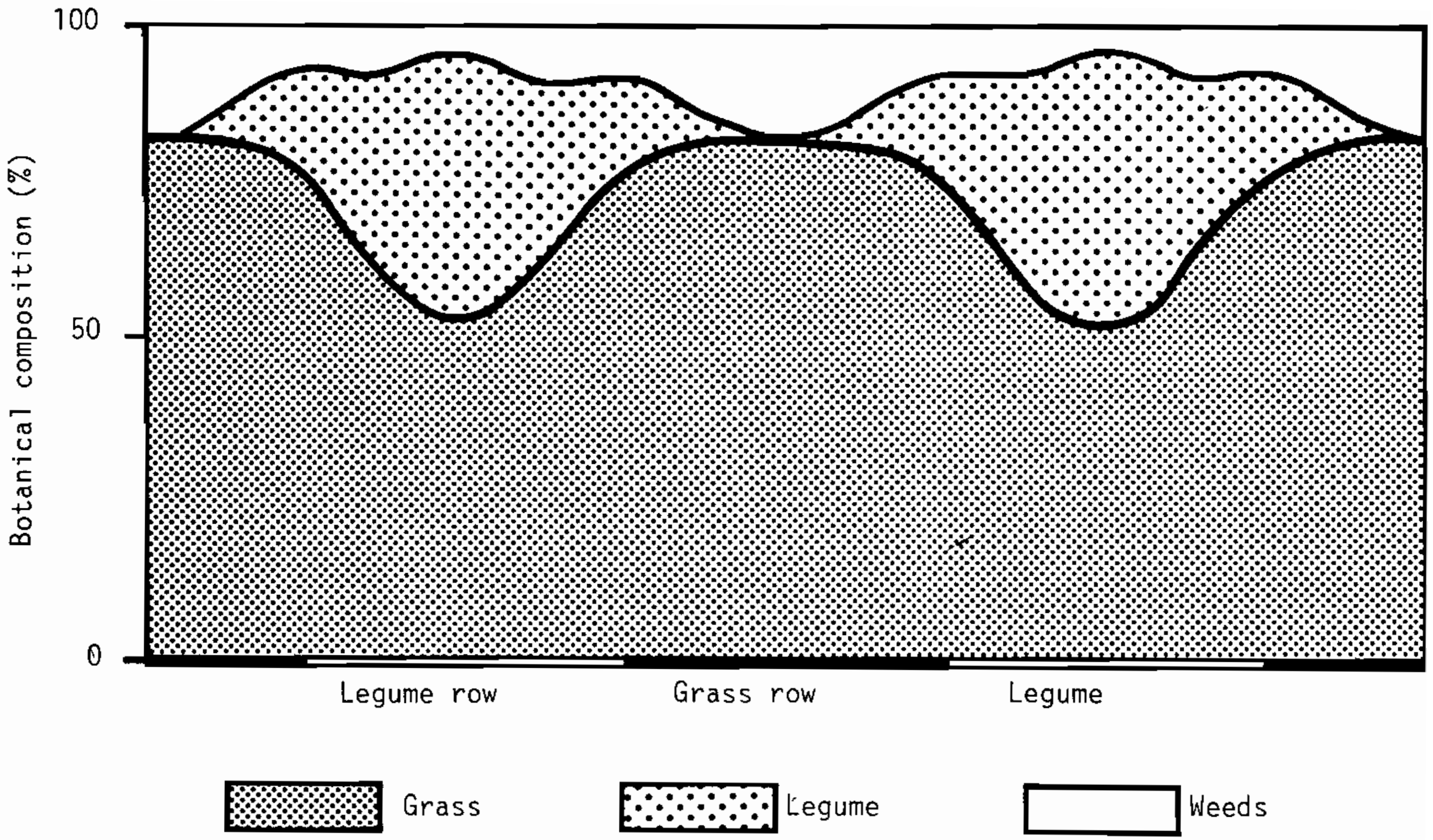


Figure 3. Spatial distribution of the pasture components in a B. decumbens and Centrosema sp., CIAT-Quilichao.

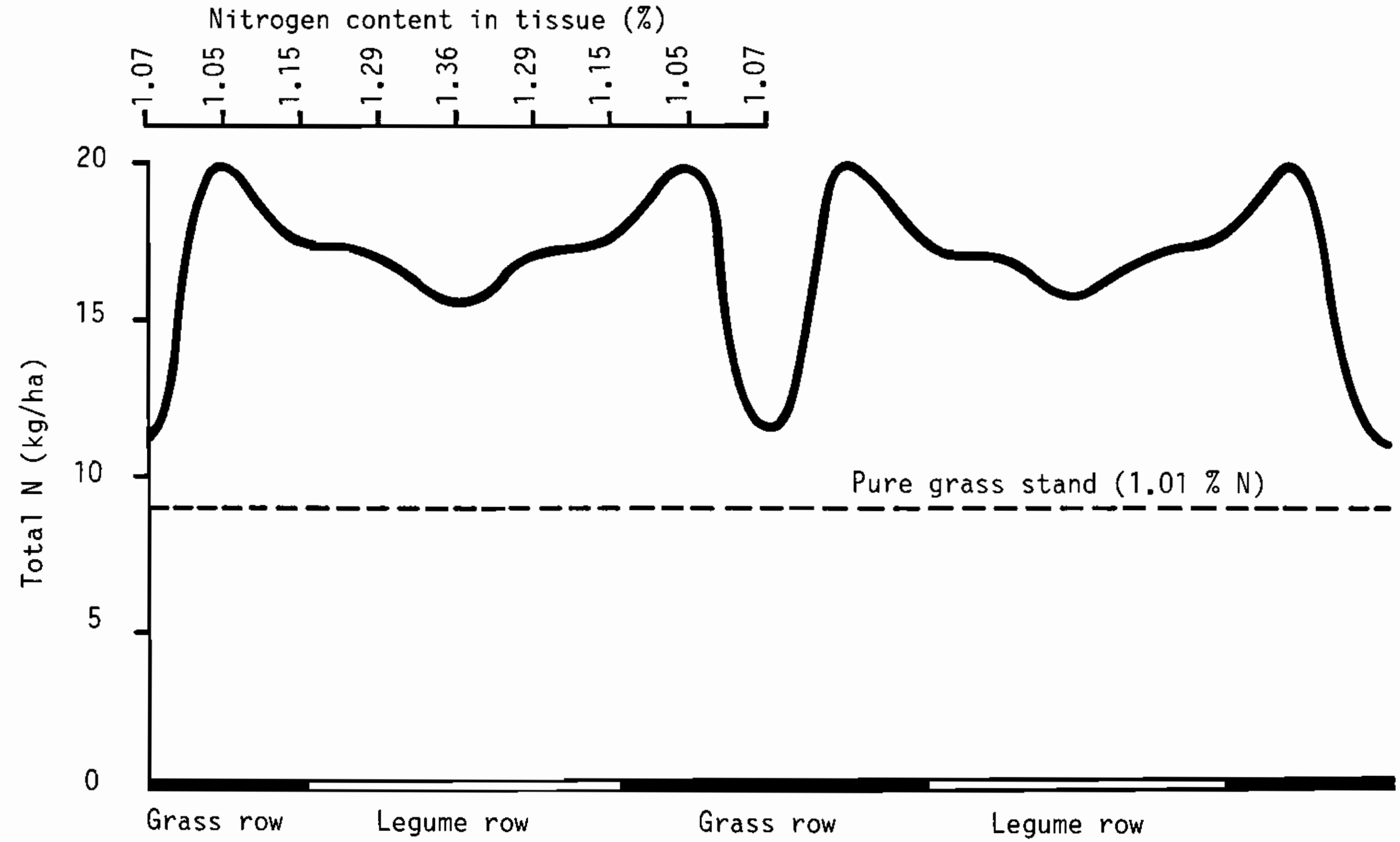


Figure 4. Spatial distribution of total N in the forage of a *B. decumbens* and *Centrosema* sp. pasture after one year of grazing. CIAT-Quilichao.

Table 5. Litter production[1] and net nutrient return in three pastures under grazing in an Ultisol, Quilichao, Colombia.

Pasture	Litter production (t/ha)	Nutrient (kg/ha)				
		N	P	K	Ca	Mg
A. gayanus 621 + *C. macrocarpum* 5713	3.7	38	1.7	6.0	24	6.3
B. dictyoneura 6133	5.4	26	1.5	3.0	23	14.2
Native pasture (*Paspalum* sp.)	3.8	27	1.7	4.0	10	6.8

1/ Evaluated at 266, 272, and 244 days.

Table 6. Nutrient inputs from rain and dust, Quilichao Experiment Station, Colombia

Nutrient	Amount (kg/ha)
P	2.1
K	15.0
Ca	51.5
Mg	9.7
S	19.9

Table 7. Efficiency of sampling collection of solution from porous cups under four vegetation treatments.

Sampling depth (cm)	Efficiency[a] (%) according to treatment with:			
	A. gayanus 621 + *C. macrocarpum* 5713	*B. dictyoneura* 6133	Native grasses	Bare soil
15	10	25	25	75
30	15	15	25	25
50	35	20	25	25
70	70	20	75	75
90	60	40	75	75

a. $$\text{Efficiency} = \frac{\text{Number collected}}{\text{Total of samplings}} \times 100$$

Table 8. Initial soil chemical and physical characteristics of the soils in the sites used for the reclamation study.

Soil properties	Soil at site (in brackets):			
	(Palehumult) Quilichao	(Humitropept) Jamundí	(Haplorthox) Montañitas	(Dystropept) Belén
pH	4.1	4.7	4.6	5.1
Mo (%)	4.1	6.7	4.9	3.2
P Bray II (ppm)	1.8	7.4	2.5	2.3
Al sat. (%)	64	65	77	72
Clay (%)	71	37	57	56
Sand (%)	4	22	24	14

Table 9. Effect of intensity of control of native vegetation on the establishment of several grasses in Jamundí, Colombia.

Treatment[a]	Dry matter (kg/ha)				
	Brachiaria decumbens 606	Brachiaria dictyoneura 6133	Brachiaria brizantha 6780	Andropogon gayanus 621	Brachiaria humidicola 679
D	1437 e	310 c	493 c	1734 c	187 d
D + Herbicide	5119 c	73 c	2841 b	5178 b	1926 c
2D	3840 d	210 c	2231 b	2118 c	2369 c
2D + Herbicide	7060 a	1284 b	3817 b	5542 b	1542 c
Plow + 2	6007 b	5368 a	8677 a	6527 b	4296 b
D + Plow + 3D	7494 a	4916 a	7961 a	8600 a	5884 a

a. D = Disking; P = Plowing
b. Means within a single column followed by the same letters are not statistically different at the P = .05 level of Duncan's Multiple Range Test.

Table 10. Effect of the intensity of control of native vegetation on the establishment of several legumes in Jamundí (Valle).

Treatment[a]	Dry matter (kg/ha)				
	Pueraria phaseoloides 9900	Desmodium ovalifolium 350	Centrosema macrocarpum 5713	Centrosema acutifolium 5277	Centrosema acutifolium 5568
D	601 e	160 c	287 a	695 b	517 c
DR + Herbicide	993 d	432 b	1535 b	1985 a	579 c
2D	675 e	153 c	517 c	2279 a	629 bc
2D + Herbicide	1288 a	327 b	1757 ab	2289 a	1387 b
Plow + 2D	1696 b	884 a	1802 ab	2419 a	2284 a
D + Plow + 3D	2360 a	888 a	2059 a	2317 a	1363 b

a. D = Disking; P = Plowing
b. Means within a single column followed by the same letters are not statistically different at the P = .05 level of Duncan's Multiple Range Test.

Table 11. Effect of introducing legume species[a] in a degraded pasture of *B. decumbens*. Results of the first year of grazing, 1987-1988.

Parameter	Pasture		
	Grass + legume	Grass	Difference (% over grass)
Mean carrying capacity (kg/ha)	830	550	51
Animal gains (g-day/an)	607	451	35
Liveweight increase (kg/ha)	642	342	88

a. *C. acutifolium* and *C. macrocarpum* mixtures.

PASTURE ESTABLISHMENT IN THE LLANOS: SEED COATED MACRO-PELLETS FOR PLANTING

The main purpose of using macro-pellets is to place the fertilizer and the seeds in the same place using smaller amounts of fertilizer and seeds in an area than with conventional establishment methods.

Until now, adequate concentrations of fertilizer in the pellet and the size of pellets have been identified.

Experiments of overseeding macro-pelleted legumes into native savanna and into an old pasture of *Brachiaria humidicola* are under way.

Overseeding macro-pelleted legumes into native savanna

Macro-pelleted Desmodium ovalifolium and *Centrosema acutifolium* were sown into savanna in July 1987. Seed bed preparations of minimum tillage and herbicide application were compared. Minimum tillage was done with a chisel plow producing bands of 50 cm width and 3 m distance. Herbicide was band sprayed in 50 cm width and 3 m distance.

Pellets were sown on the band of tillage or herbicide application in 3 m interval. Plot size was 1 ha for each legume including the two treatments of land preparation. There were two replications. Plots were rotationally grazed after two months from seeding.

As shown in Table 12, coverage of *Desmodium ovalifolium* was adequate after 1 year and 4 months, while *Centrosema acutifolium* disappeared because of too much selective grazing. Minimum tillage was slightly better than herbicide application. Percentage of growing seedlings of *Desmodium ovalifolium* (expressed in % of the total number of sowing spots) in October 1988 were 84% in minimum tillage and 74 % in herbicide application.

Overseeding macro-pelleted legumes into an old pasture of Brachiaria humidicola

Macro-pelleted *Desmodium ovalifolium* was sown in July 1988 into a *Brachiaria humidicola* pasture. Minimum tillage of bands of 50 cm width and 2 m distance was done. Thereon which pellets were sown in 2 m intervals.

Table 12. The effect of minimum tillage and application of herbicide to savanna on the % coverage of legumes planted in the form of macro-pellets in a 3 x 3 m grid in July 1987

Species	Land preparation	Coverage % 1987 Nov.	1988 Jan.	1988 May	1988 Jul.	1988 Nov.
D. ovalifolium	Minimum tillage	0.17	o.32	0.39	1.02	41.2
(CIAT 13089)	Herbicide	0.06	0.12	0.13	0.29	33.1
C. acutifolium	Minimum tillage	0.22	0.36	0.01	0.01	-
(CIAT 5277)	Herbicide	0.09	0.12	0.00	0.01	-

Two types of pellets were used. In type 1, gypsum was used as binding material while in type 2, woody peat was used. Type 2 had already shown to release the fertilizer faster than type 1.

Plot size was 0.75 ha for each type of pellet with two replications. A Brachiaria humidicola pasture without any legume-overseeding was used as control. Plots were rotationally grazed since just after seeding. As shown in Table 13, about half of the sown spots had growing legumes after three months from sowing. It was not known whether trampling by cattle damaged newly germinated legumes. Coverage of legume was not sufficient in October 1988, but could be expected to increase in the next rainy season.

So far, no difference was recognized between type 1 and type 2 pellets.

Methods of establishing macro-pelleted seed

Overseeding with macro-pellets using either minimum tillage or application of herbicide has proved to be sucessful. However, considering the higher cost of herbicide, minimum tillage

Table 13. Percentage of growing seedlings and coverage of legumes oversown in the form of macro-pellets into Brachiaria humidicola in July 1988

	Growing seedlings (% of the total number of sowing spots) August 1988	Growing seedlings (% of the total number of sowing spots) October 1988	Coverage % of total area October 1988
Type 1	67	59	2.0
Type 2	67	55	2.3

should be recommended.

The ideal method would be oversowing macro-pelleted seed into savanna without tillage and without using herbicide. In this case, the factor limiting legume establishment will be the suppression of growth of newly elongating legume roots by the roots of savanna grass. Burning, grazing and cutting of savanna grass might prevent the elongation of savanna grass roots.

The next step of macro-pellet experimentation will be oversowing legumes into savanna in combination with management of savanna in order to eliminate the root competition, without tillage and without using herbicide.

12. Pasture Reclamation Humid Tropic

After a first year of research activities of this new Section of the Tropical Pastures Program, focus continues to be on increasing the productivity of pastures invaded by weeds and dominated by native grasses of poor productivity and low nutritive value. The objectives, priorities, and research plans were presented in the 1987 Annual Report. All research activities were carried out through a Cooperative Agreement with IVITA and INIAA.

Headquarters are at IVITA's Experiment Station, 59 km from the city of Pucallpa, Peru. Located at 8°22' latitude South and 74°34' longitude West, at 270 masl, this station has an average annual rainfall of 1770 mm. Rainfall varies considerably in its weekly distribution (Figure 1); June, July, and August have been identified as the driest months. Soils in the region are acid (pH lower than 5.0) and have high levels of aluminum saturation below 40-cm depths. These Ultisols have been classified into two subgroups: the well-drained as Typic paleoudults; and the poorly-drained as Aquic paleoudults. The region falls within the tropical semi-evergreen seasonal forest ecosystem.

Various trials were established during the first year of activities trying to find possible solutions to the constraints identified in these degraded areas; results follow.

Relative importance of fertilization and effect of tillage on improved and native forage species

Under "Torourco" conditions (predominance of native grasses, i.e., Paspalum spp., Axonopus spp., Homolepis aturensis), soils generally present a slight to severe surface compaction and soil fertility is low, primarily scarce of N, P, K, Mg, and S. Hence, it is important to identify key nutrients for improved forage species, in order to increase their aggressiveness and controlling the invasion of undesirable species. Additionally, tillage disrupts the soil surface, causing greater mineralization of organic soil matter.

The trial established used a mixed factorial design: fertilization x tillage x species. Fertilization was applied using the missing element technique under two tillage treatments (with and without tillage); tillage included three off-set diskings; species planted were Brachiaria dictyoneura 6133 and Desmodium ovalifolium 13089. Measurements taken at 3, 6, and 9 months after planting included: biomass production of all species present, and invasion and identification of broad-leaf weeds and of native grasses.

Brachiaria dictyoneura CIAT 6133. Results of the first trial with B. dictyoneura 6133 appear in Table 1, showing dry matter production at 3, 6,

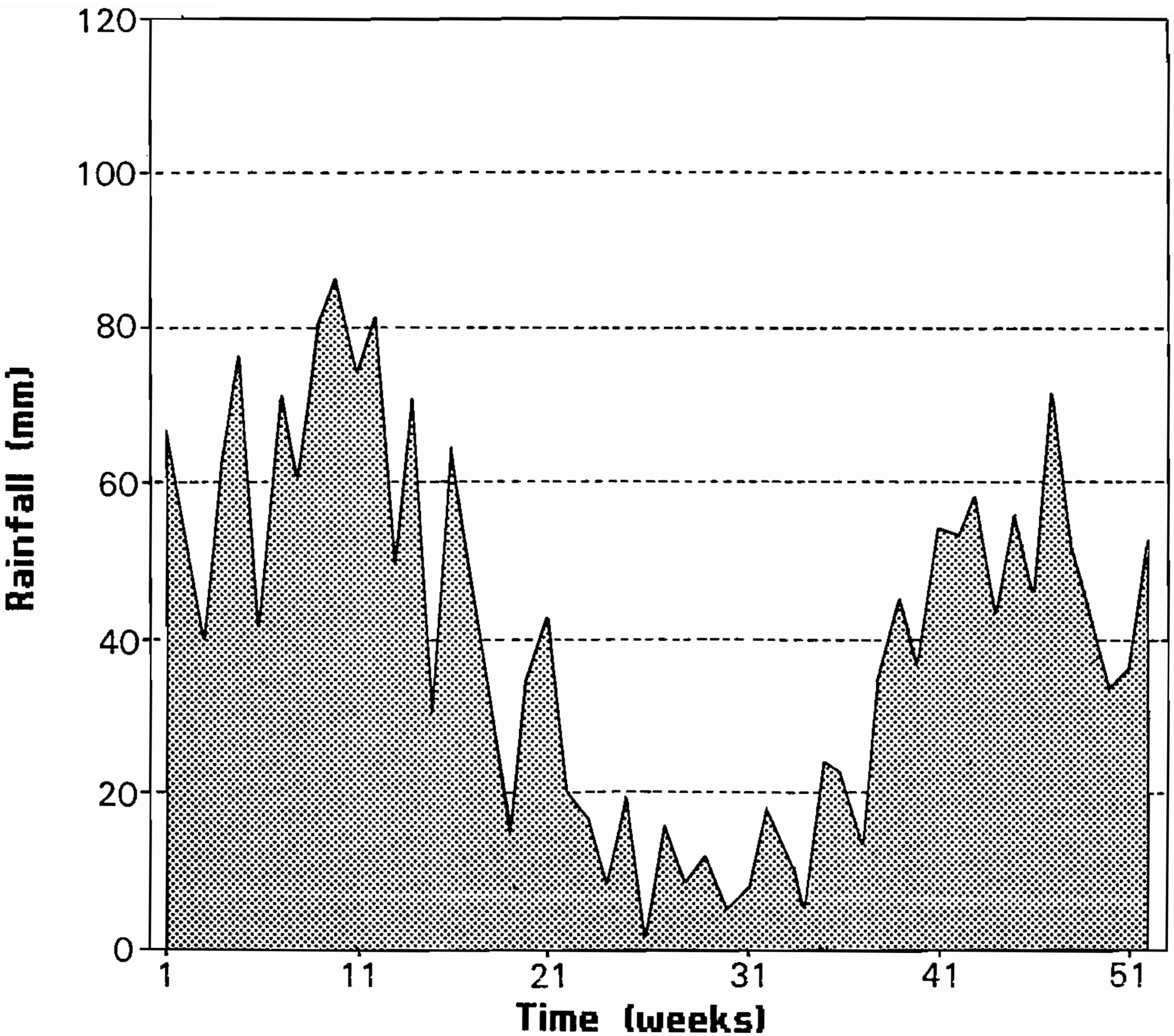


Figure 1. Average rainfall data over 10 years (1978-1987) for IVITA's Experiment Station at Pucallpa, Peru.

Table 1. Forage production and proportion of *Brachiaria dictyoneura* 6133 achieved with and without tillage and fertilization using the missing-element technique, Pucallpa, Perú.

FERTILIZATION	Without tillage			With tillage		
	3 months	6 months	9 months	3 months	6 months	9 months
	DM kg/ha (%)					
COMPLETE	1932(100)	3489(100)	795(100)	722(100)	3314(100)	653(100)
- N	1169(60)	3923(112)	611(77)	643(89)	2053(62)	506(77)
- P	789(40)	3338(85	676(85	354(49)	2062(62)	357(55)
- K	923(48)	2262(57)	358(45)	309(43)	1782(54)	318(49)
- Ca	1400(72)	3099(79)	712(77)	567(79)	2440(74)	641(98)
- Mg	1015(52)	2513(64)	457(57)	374(52)	2174(66)	526(65)
- S	554(29)	2326(59)	353(44)	266(37)	2751(83)	454(69)
CONTROL	559(31)	2027(51)	339(43)	158(22)	1152(35)	429(66)

Tillage (5 Nov., 1987) - 3 off-set diskings.
Herbicide (10 Nov., 1987) - Round-up (3 l/ha).
Fertilization (Nov. 11, 1987) - Broadcast (kg/ha): 60 N, 50 K, 100 Ca, 20 Mg, 20 S; 20 P (row).
Planting (13 Nov., 1987) - 4 kg seed/ha.
Average 4 replications.

and 9 months after planting with botanical seed, under the different fertilization treatments with and without tillage. Results, expressed in absolute terms (kg/ha) and as a relative proportion of complete fertilization (100%), indicate that without tillage, the absence of any of the nutrients studied causes--even in a differential way--a reduction in grass biomass production. During the first 3 months, the missing nutrients that caused a greater reduction were S and K, followed by Mg, N, and Ca. This response of B. dictyoneura during its first phase of establishment can be related to the low mineralization of organic matter due to soil compaction (Torourco of over 15 years) and to the low content of organic soil matter (1%). The same combined effect was observed for the control. Over time, development of the grass was superior, increasing both its aerial and root aggressiveness. Six and 9 months after planting, the key elements that continued affecting pasture productivity were S, K, and Mg, while the negative effects of the lack of N, P, and Ca had disappeared. This is possibly explained by the species' greater surface and deep-rooting capacity which allows the plant to better utilize the nutrients present in the soil and subsoil.

Using tillage to disrupt the soil, the lack of N and Ca were observed to not constitute a limiting factor in the establishment of B. dictyoneura 6133. Nevertheless, the limiting effect of S, P, and K, followed by Mg, during the first 3 months of establishment persisted. Over time, biomass production improved significatively and there was no longer a need for S. This phenomenon could be associated with a greater mineralization of organic S due to tillage. It can be concluded that fertilization for establishment requires P, K, S, and Mg, and that tillage did not contribute to cause significative changes that would justify its use under Torourco conditions.

Table 2 shows weed production and proportion. Most weeds were broad-leaved, such as Croton trinitatis, Sida rombifolia, Mimosa pudica, Cyperus rotundus, and Cassia tora. As can be observed in the table, under whatever fertilization treatment, with or without tillage, weed invasion was favored by fertilization in relation to the control. Reduction in weed population was due to the stoloniferous aggressiveness of B. dictyoneura which increased over time and eliminated weeds after 6 months of growth.

Desmodium ovalifolium CIAT 13089. The second trial consisted in establishing the legume D. ovalifolium CIAT 13089, using the same experimental design of the first trial.

Table 3 shows yield (kg/ha) and relative proportion of the forage under complete fertilization (100%), 6 and 9 months after planting.

Production was nil 3 months after planting due to the legumes' slow establishment rate. The absence of N was not a yield-reducing factor due to the positive effect of Rhizobium inoculation. The lack of K was not limiting either, contrasting with it effect on the grass B. dictyoneura 6133. Key nutrients were identified to be P, Ca, Mg, and S without tillage; these elements continued to be important up to 9 months of growth. With tillage, production increased and the lack of a specific nutrient became less limiting; nonetheless, P, Ca, and S were identified as key elements in D. ovalifolium establishment.

As was the case with B. dictyoneura 6133, weed incidence in D.

Table 2. Weed production and proportion in the *Brachiaria dictyoneura* 6133 plot, with and without tillage and fertilization ising the missing-element technique, Pucallpa, Peru.

FERTILIZATION	Without tillage			With tillage		
	3 months	6 months	9 months	3 months	6 months	9 months
	DM kg/ha (%)					
COMPLETE	610(100)	45(100)	NW*	655(100)	45(100)	NM*
- N	838(137)	30(67)	NW	653(99)	15(33)	NM
- P	612(100)	45(100)	NW	834(127)	50(111)	NM
- K	534 (87)	30(67)	NW	587(89)	15(33)	NM
- Ca	767(125)	40(89)	NW	688(105)	25(55)	NM
-Mg	643(105)	35(78)	NW	769(117)	45(100)	NM
- S	732(120)	15(33)	NW	611(93)	30(67)	NM
CONTROL	374(61)	10(22)	NW	453(69)	5(11)	NM

* NW= No weeds.

Table 3. Forage production and proportion of Desmodium ovalifolium 13089 achieved with and without tillage and fertilization using the missing-element technique. Pucallpa, Peru.

FERTILIZATION	Without tillage 3 months	Without tillage 6 months	Without tillage 9 months	With tillage 3 months	With tillage 6 months	With tillage 9 months
	DM kg/ha (%)					
COMPLETE		1731(100)	271(100)		2513(100)	371(100)
- N (Complete)		1770(102)	249(89)		2816(112)	307(83)
- P		323(19)	82(30)		1565(62)	162(44)
- K		1477(85)	268(98)		2408(96)	283(76)
- Ca		536(31)	118(44)		1797(71)	124(33)
- Mg		612(35)	179(66)		2036(81)	167(45)
- S		593(34)	113(42)		1493(63)	142(38)
CONTROL		267(15)	75(31)		1130(45)	105(28)

Tillage (5 Nov., 1987) - 3 off-set diskings.
Herbicide (5 Nov., 1987) - Round-up (3 l/ha).
Fertilization (11 Nov., 1987) - Broadcast (kg/ha): 50 K, 100 Ca, 20 Mg, 20 S;
20 P (row)
Planting (13 Nov., 1987) - 4 kg seed/ha - Rhizobium inoculation.
Average 4 replications.

ovalifolium 13089 was similar when fertilizer was applied (Table 4), showing a tendency to disappear after 9 months due to the stoloniferous aggressiveness of D. ovalifolium. With tillage, weed production was lower than without tillage. This can be explained by greater forage production by the legume when the soil was prepared, indicating a greater aggressiveness of D. ovalifolium.

Results of these two trials indicate the importance of applying certain key elements such as P, K, Ca, and S for the sound and rapid establishment of improved forage species. Yet, fertilization will promote weed invasion, indicating the need for using aggressive, stoloniferous germplasm in order to achieve natural control of the weeds. Thus, the combination of fertilization with certain nutrients and planting of aggressive, stoloniferous germplasm will enable reclamation of Torourco-type degraded areas in the humid tropics.

Optimum herbicide doses for control of native vegetation

In the establishment of grass-legume pasture associations to replace the native vegetation, selective control of the invading vegetation (broad-leaf weeds and native grasses) is very complex. Various alternatives have been identified in using herbicides: pre-emergent to destroy original vegetation and post-emergent to provide a margin of advantage to the desired species in the establishment process. The trial's experimental design included split plots with four replications, in which the main plots were the associations Andropogon gayanus 621 + S. guianensis cv. Pucallpa and B. dictyoneura 6133 + Stylosanthes guianensis cv. Pucallpa. The sub-plots were the 6 herbicide (Roundup) treatments: high (4 l/ha), recommended (3 l/ha), intermediate (2.25 l/ha), low (1.5 l/ha), minimum (0.75 l/ha), and without herbicide (control). Herbicide treatments were applied 45 days after burning of the native grasses (Torourco). Rice (var. Africano unknown was planted 15 days after application in rows 50-cm apart from each other, without tillage. Both associations were planted 60 days after planting the rice. Fertilization of the rows was equivalent to 40, 50, and 20 kg P, K, and S per hectare, respectively.

Table 5 shows average rice yields in relation to the herbicide treatment at the moment of regrowth of the original vegetation. Rice yields tended to increase with the application of the herbicide; yet, the only significative difference was found at a low dose, equivalent to 1.5 liters of herbicide per hectare, which is half of the recommended dose. Overall, rice yields were low; this is associated with the variety selected, which in spite of being adapted to acid, aluminum-toxic soils, has a low productivity.

The objective of having rice as the precursor crop was that of partially or totally reducing the cost of herbicides and fertilizers in establishing the pasture associations. The economic study of this trial will be presented in next year's annual report.

The associations were planted in the same rows, 2 months after rice planting, without application of fertilizer. Forage production was evaluated 5 months after establishment. Table 6 shows forage production as a function of the residual effect of the herbicide dose applied. In the case of A. gayanus 621 and S. guianensis cv. Pucallpa, the residual effect of the herbicide dose was evident. Biomass production of the grass and the legume was greater as the dose increased. In

Table 4. Weed production and proportion in the *Desmodium ovalifolium* 13089 plot, with and without tillage and fertilization using the missing-element technique, Pucallpa, Peru.

FERTILIZATION	Without tillage			With tillage		
	3 months	6 months	9 months	3 months	6 months	9 months
	DM kg/ha (%)					
COMPLETE		2338(100)	80(100)		1663(100)	71(100)
- N		1864(80)	83(104)		1490(89)	95(134)
- P		3165(135)	175(219)		1327(80)	169(238)
- K		1432(61)	92(115)		1791(107)	80(113)
- Ca		1632(70)	139(174)		1709(103)	159(227)
- Mg		2772(118)	109(136)		1499(90)	139(196)
- S		2204(94)	201(251)		1329(80)	124(175)
CONTROL		1048(45)	89(111)		870(52)	70(98)

Table 6. Dry matter production and proportion of *Andropogon gayanus* 621, *Brachiaria dictyoneura* 6133, *Stylosanthes guianensis* cv. Pucallpa, and of weeds, in relation to the residual effect of the herbicide dose applied. Pucallpa, Peru.

HERBICIDE DOSE	Dry matter			Dry matter		
	A. gayanus	*S. guianensis*	Weeds	*B. dictyoneura*	*S. guianensis*	Weeds
--- (l/ha) ---	(kg/ha)					
0	296(27)	214(20)	581(53)	146(12)	609(52)	416(36)
0.75	690(48)	313(22)	443(30)	137(14)	499(51)	342(35)
1.50	575(45)	363(29)	327(26)	425(41)	303(29)	313(30)
2.25	402(33)	546(44)	281(23)	266(32)	288(35)	271(33)
3.00	1446(65)	519(23)	251(11)	284(32)	276(31)	334(37)
4.00	1441(58)	702(28)	344(14)	406(38)	301(28)	352(33)

Burning Torourco: 28 October/87   Planting of rice : 29 December 1987
Herbicide : 14 December/87   Harvesting of rice: 22 June 1988
Planting of grass: 27 February 1988
Grass and weed cutting: 20 July 1988

Table 5. Average rice (var. Africano desconocido) yield as related to herbicide (Round-up) dose applied at regrowth under Torourco conditions, Pucallpa, Peru.

Herbicide dose		Grain Yield
------- 1/ha) -----		------ (kg/ha) -----
0	Nul	226 b*
0.75	Minimum	362 ab
1.50	Low	407 a
2.25	Medium	306 ab
3.00	Recommended	353 ab
4.00	High	298 ab

* Values followed by the same letter are not statistically different (5%).

Burning of Torourco: 28 October 1987
Herbicide : 14 December 1987
Planting of rice : 29 December 1987
Harvesting of rice : 22 June 1988

the same manner, percentage weed production was observed to reduce.

In the case of the other association, B. dictyoneura 6133 also showed the same tendency, but not so the legume. This reduction in legume population was possibly associated with the growth habit of the grass which increases its competition for space and nutrients due to its stoloniferous growth, thus affecting the legume. The residual effect of the herbicide was not evident in this association in terms of the proportion of weeds, which seemed to be in equilibrium throughout the trial. Weeds may disappear over time due to B. dictyoneura's aggressiveness, as happened in the fertilization and tillage experiment.

Herbicide control was expected to partially or totally eliminate undesirable invading plants. However, two important situations were observed during this trial. In the process of controlling the Torourco (native grasses, primarily Paspalum spp. and Axonopus spp.), these species disappeared and did not show up again after application of the herbicide Roundup. Second, other weeds appeared: Croton trinitatis, Sida rombifolia, Cyperus rotundus, and Mimosa pudica (Table 7).

Overall, gradual decrease in weed coverage was observed as the herbicide dose increased. Analysis of the botanical composition of the weeds, carried out during initial evaluation at pasture planting, showed the predominance of S. rombifolia and M. pudica. This proportion persisted in the A. gayanus 621 + S. guianensis cv. Pucallpa association. These weeds tended to disappear during the second evaluation carried out at rice harvest. Contrastingly, C. trinitatis showed a tendency to increase over time, presenting a greater proportion in the B. dictyoneura + S. guianensis association.

These observations indicate that, independently of the initial and residual effect of the herbicide applied, regrowth of the weeds, in terms of the type of weed and the proportion of the species, will depend on the association established, particularly on the growth habit and the degree of dormancy of the seed of the undesired species.

Fertilization and physical conditioning of the soil for pioneer crops in degraded Torourco areas

An important problem in these areas is the farmer's lack of access to capital resources, particularly in dual production systems (crop and pastures) smaller than 100 ha. This limits their possibility of applying inputs such as fertilizers, amendments, and herbicides and establishing pastures. Furthermore, mechanization opportunities are scarce and expensive. With this in mind, the integral cost of pasture reclamation needs to be reduced to an economic and biologically efficient level, in order to guarantee the adoption of new technologies. Within this framework, the use of pioneer or "financing" annual crops has been considered.

The trial carried out included planting rice (var. African unknown), maize (var. Yellow Cuban cowpea (var. Chiclayo) in an experimental design of split with four replications, where the main plot was tillage intensity (zero, minimum, reduced) and the sub-plot was fertilization (control without fertilizer; and low, intermediate, and high fertilization rates). Minimum tillage consisted of two diskings and planting in rows; and reduced tillage consisted of four diskings and planting in rows. Intermediate fertilization included

Table 7. Effect of herbicide dose on native Torourco vegetation control in establishing rice in association with forage grass and legume mixtures, Pucallpa, Peru.

HERBICIDE DOSE	A. gayanus + S. guianensis					B. dictyoneura + S. guianensis				
	WEED COVERAGE					WEED COVERAGE				
	Total	1*	2	3	4	Total	1	2	3	4
----- (l/ha) ----	(%)									
February/88 (pasture planting)										
0	85	13	54	0	17	75	5	34	8	26
0.75	80	7	54	0	18	70	2	48	7	13
1.50	60	2	42	0	16	72	6	46	8	12
2.25	45	3	38	0	4	40	8	22	2	8
3.00	42	3	24	4	12	42	1	25	8	8
4.00	30	4	13	1	11	35	3	19	6	6
June/88 (rice harvesting)										
0	79	10	31	8	30	64	31	10	15	7
0.75	82	12	23	20	17	50	25	11	2	12
1.50	72	4	52	6	10	54	32	14	1	7
2.25	76	15	47	1	12	48	19	16	5	8
3.00	74	12	48	1	13	45	22	10	0	13
4.00	66	10	48	1	7	40	22	3	4	11

* 1. Croton trinitatis
2. Sida rombifolia
3. Ciperus rotundus
4. Mimosa pudica

application of 40 kg P, 50 kg K, and 20 kg S per hectare, in addition to 60 kg N/ha gradually applied to the rice and maize crops. High and minimum fertilization were calculated as 50% more or less fertilizer, respectively, than the intermediate level. Pasture associations were planted along with the annual crops, with the following distribution: rice with B. dictyoneura 6133 and D. ovalifolium 13089, maize with B. dictyoneura 6133 and S. guianensis cv. Pucallpa, and cowpea with B. dictyoneura 6133 and Centrosema macrocarpum 5735.

Table 8 shows rice, maize, and cowpea yields in relation to tillage intensity and fertilization levels. Overall, results indicate that the three crops require only a minimum tillage of two diskings and planting in rows with an intermediate fertilization level to obtain yields equivalent to 80% of the maximum obtained with each crop. However, planting of maize with "tacarpo" (traditional method using a stick to dig the hole where the seed is to be placed) is not excluded; under this method, fertilizer is applied at the planting site to improve production levels. In fact, preparation of the soil by itself, without fertilization, does not contribute to improving yields to efficient levels. Thus, fertilization is a more important factor in these soils, which are characterized by low organic matter content and poor fertility. Fertilization and the use of more productive varieties, resistant to pests and diseases, would be the recommendation to make. This indicates the need of a variety selection process among the most promising crops in the region, such as rice, maize, and cowpea.

Forage production of the B. dictyoneura 6133 + D. ovalifolium 13089 association, established at the time rice was planted, is shown in Table 9. Results indicate that increasing tillage intensity reduced grass and legume forage production and increased weed production. Fertilization had an effect on both the association and the weeds up to the intermediate level. Weed incidence is expected to decrease, and even disappear over time, due to the aggressiveness of the species in the mixture.

These preliminary results indicate once more that increasing tillage intensity results in negative effects for these type of dual systems (crops and pastures). On the other hand, fertilization at an intermediate dose and the use of more productive, aggressive, and resistant germplasm under the edaphoclimatic conditions of the humid tropics is a more sound option.

Selection of rice varieties tolerant to soil acidity and to pests and diseases

In order to identify rice varieties having greater tolerance to soil acidity and to pests and diseases, a trial was planted with 17 rice lines, in collaboration with CIAT's Rice Program. The experimental design, fertilization, the evaluation scheme, and seed of the 17 rice lines was provided by the Rice Program. Results (Table 10) show a wide variation among rice lines and varieties, with grain production ranging from 639 to 1465 kg/ha. Plants of intermediate height seemed to be the more productive. Additionally, the more productive lines showed an intermediate to low reaction to leaf scald, a disease of mayor incidence observed during the trial. Cercospora and Pyricularia diseases were also observed, but with a low level of incidence.

Planting of the two best lines has been programmed for 1988/89, in association with B. dictyoneura 6133 + Arachis pintoi to observe

Table 8. Average grain production of rice, maize, and cowpea (grown in association with a grass/legume mixture), in relation to the intensity of tillage and fertilizer application. Pucallpa, Perú.

TILLAGE INTENSITY	Fertilization	Rendimiento en grano		
		Rice (var.African unknown)	Maize (var.Yellow Cuban)	Cowpea (var.Chiclayo)
ZERO	Control (without fert.)	46	604	201
(Tacarpo)	Low (average - 50%)	147	927	425
	Intermediate	331	1375	390
	High (average + 50%)	506	1710	384
MINIMUM	Control	58	372	325
(2 diskings and rows)	Low	442	463	354
	Intermediate	1029	569	518
	High	963	1107	692
REDUCED	Control	77	494	290
(4 diskings and rows)	Low	430	784	443
	Intermediate	1106	971	662
	High	827	1148	750

Intermediate fertilization (kg/ha: 60 N (only grasses)
40 P
50 K
20 S

Average values of 4 replications.

Table 9. Biomass production of B. dictyoneura 6133, D. ovalifolium, and weeds, in an association with rice, in relation to tillage intensity and fertilization. Pucallpa, Peru.

TILLAGE INTENSITY	Fertilization	Grain Yield (kg/ha)		
		Rice (var.African unknown)	Maize (var.Yellow Cuban)	Cowpea (var.Chiclayo)
ZERO	Control (without fert.)	379	129	129
	Low (average - 50%)	423	170	170
	Intermediate	462	199	199
	High (average + 50%)	655	303	303
MINIMUM (2 diskings and row)	Control	151	45	550
	Low	152	45	675
	Intermediate	195		
	High	240	70	974
REDUCED (4 diskings and rows)	Control	154	37	560
	Low	249	40	820
	Intermediate	315	61	1051
	High	300	79	1075

Intermediate fertilization (kg/ha): 60 N, 40 P, 50 K, 20 S.
Planting of rice and grasses : 12 November 1987
Rice harvesting and evaluation of grasses : 15 March 1988

Average values of 4 replications.

Table 10. Average grain production and comparison of reaction to leaf scald of 17 rice lines selected for their tolerance to acid soils. Pucallpa, Peru.

Rice Line	Yield (kg/ha)	Height (at grain maturity) (cm)	Reaction*	Rice Line	Yield (kg/ha)	Height (at grain maturity) (cm)	Reaction*
CT-6777-8-14-2-1E	1456	76.0	2.5	CT-6194-16-1-2-3	973	79.8	1.0
Col.1/M312A (TT)	1379	78.3	1.5	CICA 8 (TS)	928	72.3	1.5
CT-6129-17-9-5P-1	1198	75.2	1.5	CT-6196-33-10-2-8	871	82.4	2.5
P-5589-1-1-3P-4	1197	71.5	2.5	CT-6516-23-8-1-SR-2	863	71.6	5.0
CT-6777-8-14-2-1A	1168	72.5	1.5	African unkhown (LC)	806	96.0	1.5
CT-6258-52-4-3	1074	79.3	2.5	CT-6515-18-17-1-SR-1	759	90.1	2.0
CT-6196-33-4-21-2	1021	79.1	4.5	CT-6196-33-10-3-2	639	85.2	4.5
P-5589-1-1-3P-2	991	71.4	3.0				

* 0 = No disease 5 = High incidence of leaf scald

Basic fertilization (kg/a): 250 dolomitic line
60 N (Urea in 2 applications)
25 P (TSP)
50 (KCl in 2 applications)

TC = Tolerant control; SC = Susceptible control; LC = Local control.

performance of rice as a "financing" crop. Also, a collection of cowpea varieties will be evaluated for their potential productivity, as this legume is very promising in the region.

Improved pasture reclamation with weed control and seed harvest to reduce costs

Currently, large areas are found with degraded improved pastures, or pastures under degradation, based primarily on *Brachiaria* species. Invasion of broad-leaf weeds (*Cassia tora*, *Croton trinitatis*, *Sida rombifolia*, etc) due to poor management (overgrazing) and to the poor vigor of the grass, due to deficiency of N and other nutrients, are the main causes for degradation of these pastures. One of the alternatives studied was that of recovering a *B. dictyoneura* pasture established 15 years before, which had been invaded by weeds and presented poor vigor, by applying herbicides (Edonal, 2-4-D) and fertilizers (Factorial S, Mg, and K and two levels of N--50 and 100 kg/ha in the form of urea). In order to reduce reclamation costs, seed was harvested. A comparison of productivity among fertilizer treatments was also established.

Results of this trial are shown in Table 11. Application of nitrogen by itself (50 or 100 kg N/ha) did not result in forage or seed production increase. The interactive effect of N and K increased biomass and seed production. The most significative effect was the response to S application, which doubled the biomass and increased seed production four-fold, indicating an interactive effect of N and S. The most significative effect resulted from combining 20 kg S and 100 kg N/ha, which turned out in a yield of pure seed of 83 kg, in relation with the control which received only 100 kg N/ha and produced 21 kg pure seed. Definitively, calculation of the cost structure will permit recommending this strategy for reclamation of degraded *Brachiaria* sp. pastures.

The second phase of the trial consisted in introducing *Centrosema macrocarpum* 5735 in 2-m wide strips, alternated with reclaimed *B. decumbens*, for further evaluation of persistence, stability of the mixture, and animal productivity under grazing. This trial is estimated to last 3 years.

Based on results obtained during the first year, reclamation trials in farms having pastures based on native grasses and *B. dictyoneura* have been planned for 1988/89. The idea is to introduce adapted germplasm having outstanding characteristics such as aggressiveness, vigor, productivity, and sustainability. Experiment station trials will continue in order to complement initial findings and explore additional factors intervening in the process of degradation, as are soil compaction, erosion, recycling, changes in the vegetation, weeds, and germplasm.

Table 11. Effect of fertilization on pasture reclamation and seed production of a *Brachiaria decumbens* pasture established 15 years before, IVITA, Pucallpa, Peru.

S	Mg	K	Treatment	50 kg N/ha Dry Matter	50 kg N/ha Pure Seed	100 kg N/ha Dry Matter	100 kg N/ha Pure Seed
				(kg/ha)			
0	0	0	Control	2898	18	3303	21
0	0	30	K	3473	38	3856	51
0	20	0	Mg	3070	25	3896	47
0	20	30	Mg + K	3387	34	3593	51
20	0	0	S	3920	49	4178	83
20	0	30	S + K	3597	46	4114	71
20	20	0	S + Mg	3839	39	4659	58
20	20	30	S + Mg + K	3255	43	4263	57

Burning of pasture, September 1987.
Weed conrol (*Casia tora*) with Hedonal (3 liters/ha), 23 October 1987.
Fertilization with N: 50% (27 October 1987) and 50% (4 December 1987).
Dry matter evaluation: 5-8 January 1988.
Seed harvest: 19-20 December 1987.

Average data for 4 replications.

13. Pasture Development Cerrados

INTRODUCTION

The Cerrados Pasture Development Section initiated four new trials in 1987/1988. The section was also responsible for the establishment of a large grazing management trial, for which it has now assumed principle responsibility after the project leader was named Director of CPAC. Other activities included in-service training of three young professionals and collaboration with the pasture validation group working in the Silvania (GO) rural development project.

The 1987/1988 rainy season was wetter than usual with a total of 1617 mm from June 1987 through May 1988. The average monthly distribution of rainfall at CPAC during 14 years along with the monthly distribution for 1987/1988 are shown in Figure 1. The season started late with much lower precipitation for October than normal (57 mm vs. 162 mm). Most land preparation was done after November 1 and planting was done in December and early January. Late planting contributed to serious problems during the establishment phase and failure in over 50% of the new experiments. Most experiments were planted in periods of intense rainfall and poor light conditions. Runoff and erosion resulted in excessive covering of seed and even seedlings. Rainfall distribution is typically somewhat erratic in January and February, ranging from extremely intense rainy periods to frequent droughts of short duration as shown in the weekly distribution of precipitation for 1987/1988 in Figure 2. Elasmo (*Elasmopalpus lignosellus*) is often a serious problem for young grass seedlings during veranicos, (dry periods of 10-20 days), and this year caused extensive damage to *A. gayanus* and *P. maximum* plants during January. The most serious scourge of all was seed carrying and leaf-cutting ants of several species, supposed to be either *Atta* spp. or *Acromyrmex* spp. Ants were also a problem in two pasture renovation trials, selectively harvesting legume seedlings from seed reserves in the soil and from planted seed. Colleagues at CPAC say that the year was unusual for ant damage. Some blame the problem on the lack of Aldrin which was recently banned in powder formulations, a product which had been used widely, possibly somewhat indiscriminately, to control ants in years past.

ON GOING TRIALS

Pasture renovation. The section is responsible for a pasture renovation trial which was established in 1985 and grazed experimentally beginning early 1987. Five treatments in two replications have resulted in rather

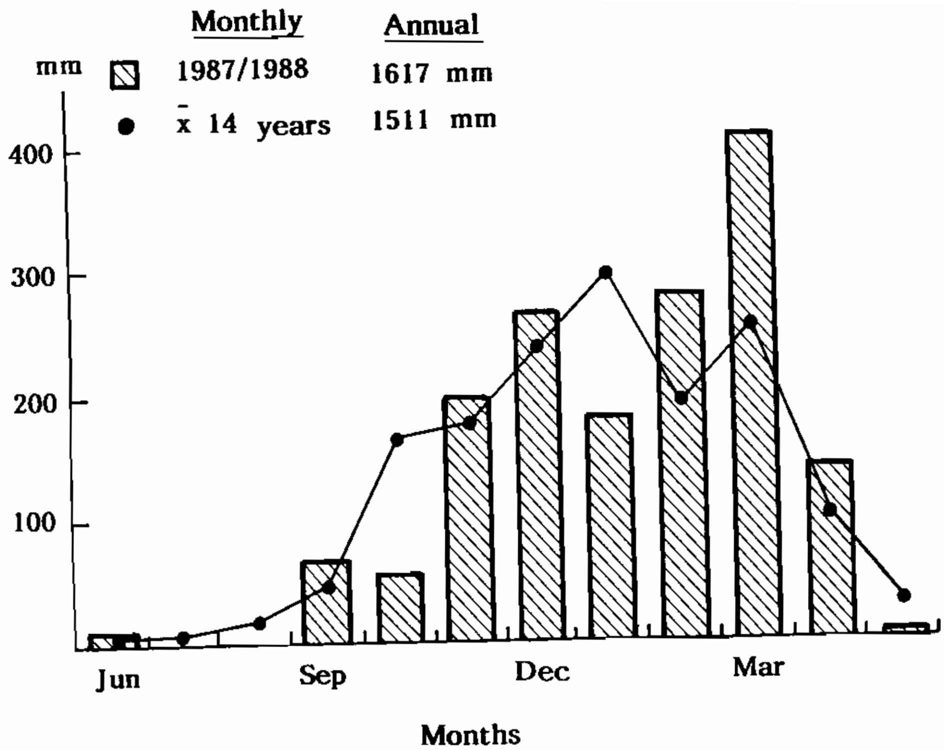


Figure 1. Monthly distribution of precipitation at CPAC, Planaltina, DF, during 1987-88 and 14 year averages. Cerrados, 1988.

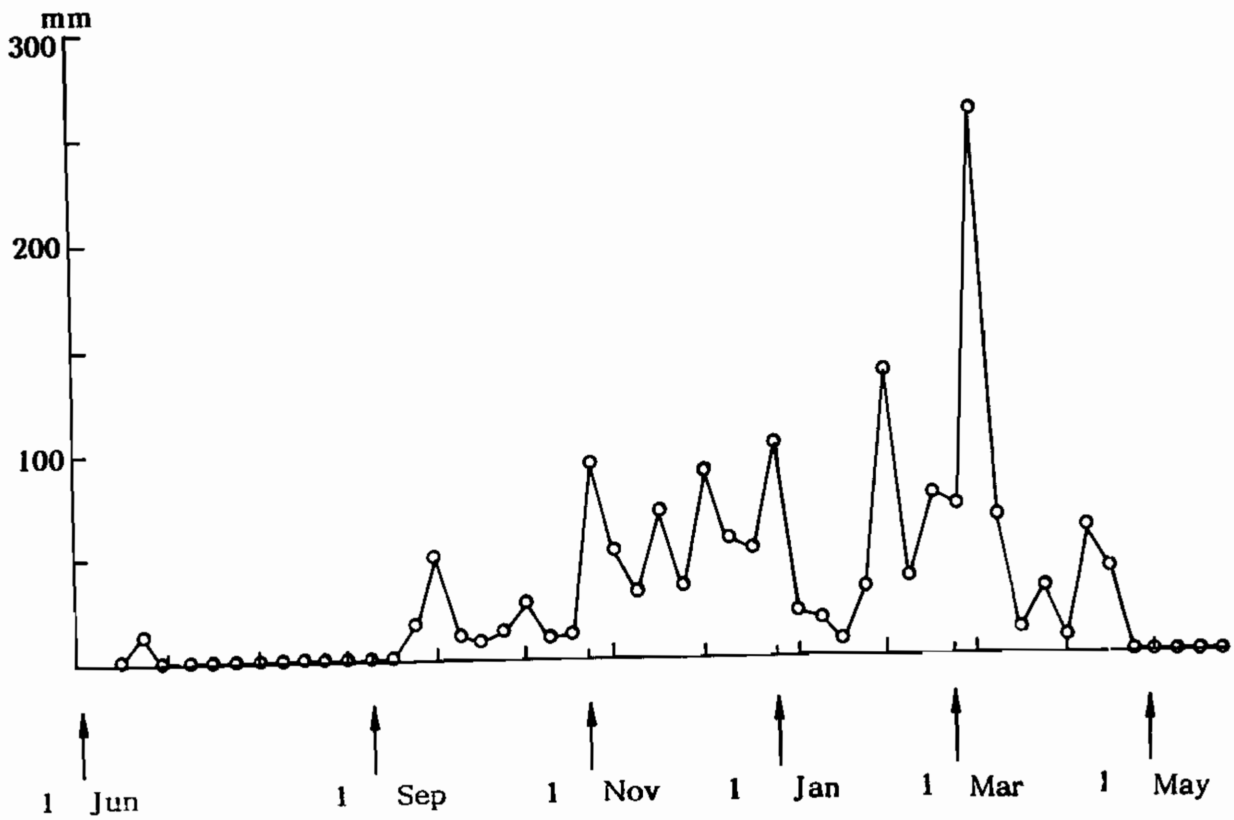


Figure 2. Weekly distribution of rainfall at CPAC, 1987-88, showing a typical "veranico" occurring in January. Cerrados, 1988.

large differences in animal performance as shown in Figure 3. A separate group of animals grazed each treatment, alternating between replications in a somewhat flexible management scheme. The treatment consisting of disking the old Brachiaria ruziziensis sod and introduction of Calopogonium mucunoides produced the highest animal gains during the experimental period. The Stylosanthes guianensis cv. Bandeirante pastures resulted in the lowest weight gains, equivalent to the control treatment. Animals selectively grazed the B. ruziziensis, with very little intake of S. guianensis. By the end of the grazing period, the pastures were strongly legume dominant.

An accidental burn in September, 1987 which affected all treatments in at least one replication gave some unexpected results. In the S. guianensis pasture that burned, there was no recovery of adult legume plants but a very large store of reserve seed in the soil gave rise to an excessive population of legume seedlings and a good stand of grass. The legume population was estimated at > 1000 plants per m^2. Within about a month of germination, ants began to selectively harvest the legume and left only a thin, irregular stand. In the replication that was not burned, the S. guianensis suffered a severe and prolonged defoliation by Sphacophylus centrus and by the end of the growing season was essentially destroyed. In the absence of fire, no new seedlings appeared in this pasture. In the paddock of C. mucunoides that was burned the legume came to a good stand from reserve seed but again, within a month after the rainy season began, ants also selectively harvested the legume seedlings and destroyed the stand. In the unburned paddock, C. mucunoides came to a good stand with no appreciable ant damage. It is important to note that the paddocks with legumes that burned were immeditely adjacent to a large A. gayanus pasture about six years old, badly degraded and heavily infested with ants. The unburned rep of the two legume treatments is adjacent to a large block of native cerrado and separated from the Andropogon pasture by paddocks of pure grass which form part of the same experiment.

NEW EXPERIMENTS, 1987/1988

Lime x P x species. Experiments were planted on clay loam (36% sand, 51% clay) and sandy loam (78% sand, 20% clay) soils. The trials consist of a factorial combination of 3 lime and 3 P levels as sub-plots and main plots are comprised of species planted separately and in association; there are three legumes: S. capitata (CIAT 1097), S. guianensis cv. Bandeirante and C. brasilianum (CIAT 5234) and A. gayanus cv. Planaltina. Both trials were planted in December and were immediately subjected to intense rain storms and then elasmo and heavy ant predation during a 20 day "veranico" in January. Stands were entirely unsatisfactory and replanting was undertaken of both grass and legumes. In the second planting, reasonably good stands of legumes were obtained but A. gayanus continued to suffer severe ant predation. In a further attempt to establish the grass, bare-rooted plants of Andropogon were used to replant the entire area. In spite of the continued use of poison bait and other insecticides, the ants destroyed a large proportion of the transplanted plants. An attempt is being made at the beginning of the 1988-1989 wet season to again establish the grass in this trial, where legume stands are finally acceptable.

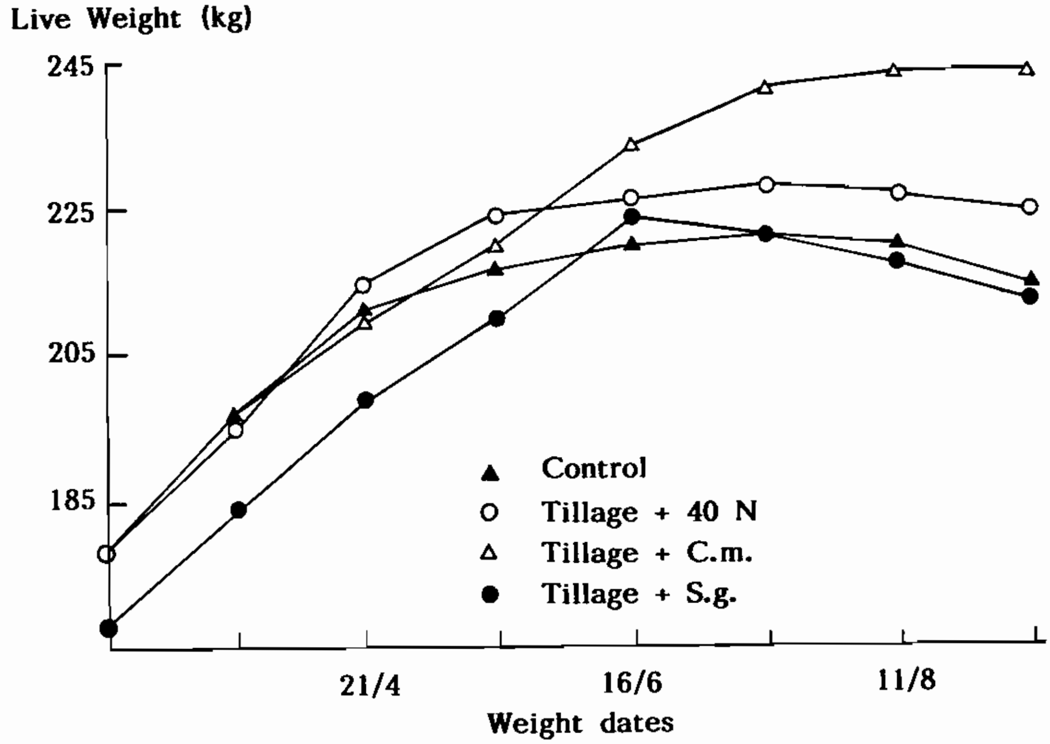


Figure 3. The effects of pasture renovation treatments on animal performance of B. ruziziensis pastures, 1987-88.

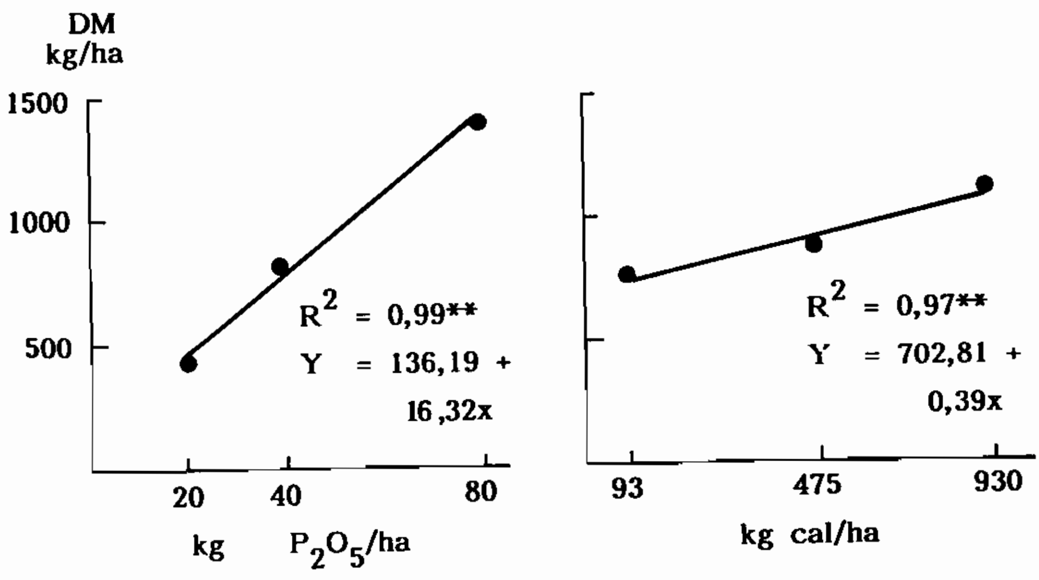


Figure 4. The effects of lime and P on dry matter production of B. brizantha cv. Marandú in the establishment year. Cerrados, 1988.

In another lime x P trial, three grasses were planted as main plots: A. gayanus, P. maximum and B. brizantha (cv. Marandú), with three levels each of lime and P. The trial was planted on the sandy loam soil, adjacent to the legume-grass x lime x P trial. Ants destroyed Andropogon and Panicum but left the Brachiaria almost untouched. Figure 4 shows the response of B. brizantha to lime and P. The strong P response is essentially linear; the much smaller response to lime was also linear. Repeated attempts were made to establish A. gayanus and P. maximum, similar to those described above, with similar results. A new attempt is being made to establish these grasses at the beginning of the rainy season.

The renovation of A. gayanus -legume pastures. These pastures were used for five years in an advanced grazing trial in which the legume component rapidly diminished in the first two years and the pastures degraded rapidly until the trial was terminated in early 1987. The paddocks of S. capitata (CIAT 1097) and S. macrocephala cv. Pioneiro were chosen for a pasture renovation trial since both legumes had demonstrated remarkable persistence after five years, even though their contribution to the pasture after the first year was minimal. The residual population produced a reasonable reserve of seed and there was an apparent stocking rate effect on seed reserves. Nine tillage x fertilizer treatments were applied to 5 x 20 m plots within each paddock. The balance of the paddock received a uniform treatment with the goal of forming new pastures which could serve for additional grazing experiments and/or demonstration purposes.

A chisel plow was used to break up the pasture sod and till the soil to a depth of 10-12 cm. The A. gayanus was stimulated by the tillage and fertilizer and was extremely competitive with new seedlings from reserve seed and seed drilled into the pasture to reinforce the seed reserves in the soil. Ants selectively harvested the new legume seedlings in the same manner as occurred in the old pasture renovation trial with C. mucunoides and S. guianensis cv. Bandeirante. As a result, pasture renovation in terms of grass was excellent, but in terms of new populations of legumes it was a total failure. Colleagues had repeatedly warned that Andropogon is extremely sensitive to tillage and can easily be destroyed, however, after the 1987 experience, a new strategy was pursued as a basis for a second round of renovation (introduction of legumes) in the same pastures.

The grass dominant pastures were grazed during 1987-1988 but spelled late in the rainy season to permit flowering and seed production of both grass and legume. In August, the paddocks were tilled with a heavy off-set disk with the objective of leaving most of the residue on the surface, cutting the tussocks of Andropogon at a rather shallow depth and hopefully killing most of the adult plants, leaving a favorable surface environment with abundant grass seed. Reserve seed of legumes was again reinforced with additional seed. With the first rains, it would appear that control of the original grass population was almost total and an excellent stand of grass is coming from seed. The following treatments are being investigated. In all cases, additional legume seed has been sown at the beginning of the rains.

1. Off-set disking in the middle of the dry season.

2. Off-set disking in the dry following a burn of all residue.
3. Off-set disking at the beginning of the wet following a burn in the dry season.
4. Off-set disking at the beginning of the wet without previous burning.

Grazing management. An advanced grazing trial focusing on management strategy was initiated in 1987. It consists of one main trial in which Andropogon gayanus is planted alone and in association with a mixture of three legumes: S. guianensis cv. Bandeirante, S. macrocephala cv. Pioneiro, S. capitata CIAT 1097. Grazing intensity will be controlled by residual forage. The treatments will be managed as follows:

1.	Continuous grazing	Associations
2.	Rotational grazing, 7/21	
3.	Rotational grazing, 14/42	
4.	Flexible management, alternate grazing beginning with 21/21	
5.	Continuous grazing	Grass alone
6.	Rotational grazing, beginning with 21/21	

The two grass only treatments will be managed as in No. 1 and No. 4.

In addition to the main trial, a satellite trial of Andropogon associated with C. brasilianum 5234 was planted in the same area. This trial will also be managed on the basis of residual forage using alternate grazing and flexible management.

The two experiments occupy a total of 35 ha located in a high, (> 1200 m elevation, the highest point in CPAC and one of the highest points in the Brazilian cerrados), well-drained "chapado", ranging from sandy loam, ($\bar{x}$ 50% sand, 37% clay), to clay loam, ($\bar{x}$ 18% sand, 67% clay). The two replications were blocked for soil texture and acceptable to excellent stands were obtained on the sandy loam replicate in contrast with almost total failure in the clay loam rep. The C. brasilianum x Andropogon experiment located on the sandy loam soil also came to an excellent stand.

Ant damage and erosion were the most serious problems and were far more severe on the clay loam than the sandy loam. It is postulated that the clay loam texture resulted in greater P fixation from the broadcast applied and incorporated phosphorus than in the sandy loam. The P fixation probably gave rise to less vigorous plant growth and plants were more susceptible to ant and elasmo damage in the seedling stage than the more vigorous plants on the sandy-loam site.

The data shown in Figure 5 were obtained by intense monitoring of seedlings resulting from late replanting in these experiments. As can be seen, 60% of the stand was destroyed in the first twenty days and none of the plants escaped some damage. The sandy loam replicate of this experiment is fenced, has water points and is ready for initiation of experimental grazing. It was grazed lightly during the dry season and presently has an abundant population of Andropogon and legumes emerging from the excellent seed crop that was set in the first year. The clay loam replicate was prepared for replanting with stubble-mulch sweeps, the first pass being made in May with sufficient moisture for good tillage and weed control; and the second pass made diagonal to the first pass in September, just prior to planting in the dry. The dry season planting is favored as a possible means of escaping some of the ant damage and encountering better growing conditions and less intense rains than were experienced with the late plantings of 1987-1988.

NEW EXPERIMENTS, 1988-1989

Time of seedbed preparation and planting. In light of experience gained during the 1987-1988 season, two new trials have been initiated for 1988-1989. One is designed to study the effects of time of seedbed preparation and time of planting. "Early" and "late" seedbed preparation correspond to May, at the end of the rains, and October, at the beginning of the rains. Planting dates include September, (in the dry), October, after the first 100 mm of rainfall, November, which is the traditional recommended planting date, and January, as representative of a late planting date. The last two planting dates are coincidental for the two seedbed preparation dates. Early results indicate excellent stands from dry season planting following early seedbed preparation. One of the advantages of early seedbed preparation is the conservation of moisture during the dry season as shown in Figure 6.

Pasture renovation via annual crops. One of the main aims of the section is to explore strategies for the renovation of degraded grass pastures via a cycle of annual crops. A suitable site was selected in an old, degraded *B. decumbens* pasture. The initial tillage was carried out in the dry season with a heavy off-set disk in an attempt to control *B. decumbens* and the plowing was done after sufficient precipitation in October. Planting of rice, corn and sorghum will be done in November, considered to be normal for most annual crops. A mixture of legumes will be planted with the crops and in control treatments without crops.

FUTURE PLANS

The experience gained in pasture research at CPAC has highlighted a number of serious problems in pasture establishment and pasture maintenance.

Pasture establishment. Perhaps the principal barrier to pasture adoption is the high cost of pasture establishment and the relatively low expected return on investment. This is due to the need for clearing (in the Cerrados), followed by tillage and rather heavy applications of fertilizer and lime. For that reason most pasture specialists have reached the conclusion that the only economically viable way to establish pastures is to do so following a cycle of annual crops to off-set the high cost of clearing and the initial fertilizer and lime application and provide residual benefits to the subsequent pasture.

One of the main components of the cost of pasture establishment is the high risk factor. This is primarily due to: a) insects, b) erosion during the establishment phase, c) problems of weeds, especially following a cycle of annual crops which results in higher fertility than in native Cerrados soil.

Even well established pastures in the Cerrados of the Planalto Central have rather low carrying capacity and production potential. This appears to be related to both germplasm and

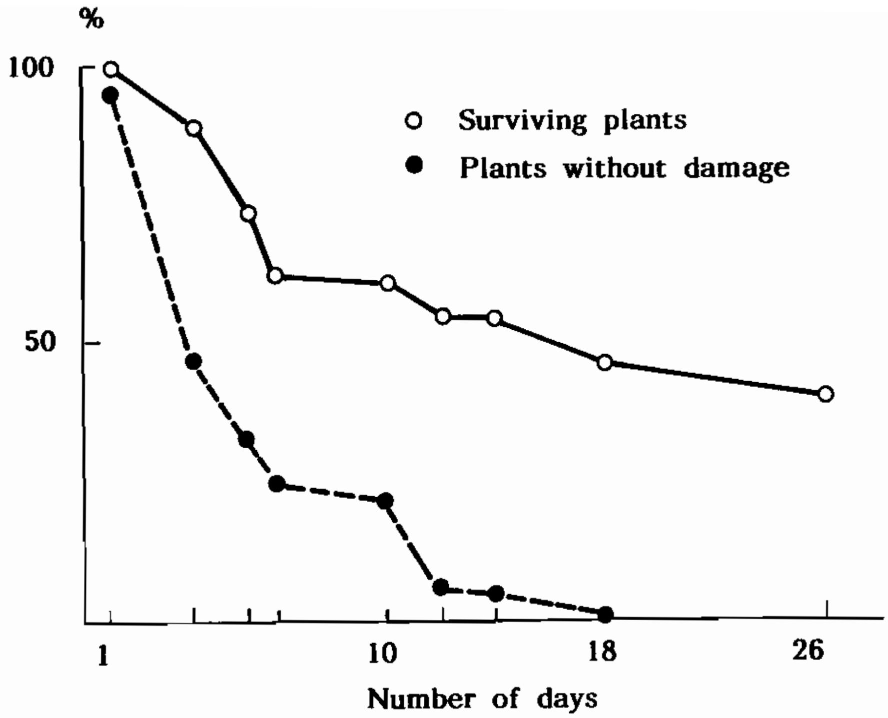


Figure 5. The fate of A. *gayanus* seedlings during a twenty-six day period in February, 1988 beginning ten days after planting. Cerrados, 1988.

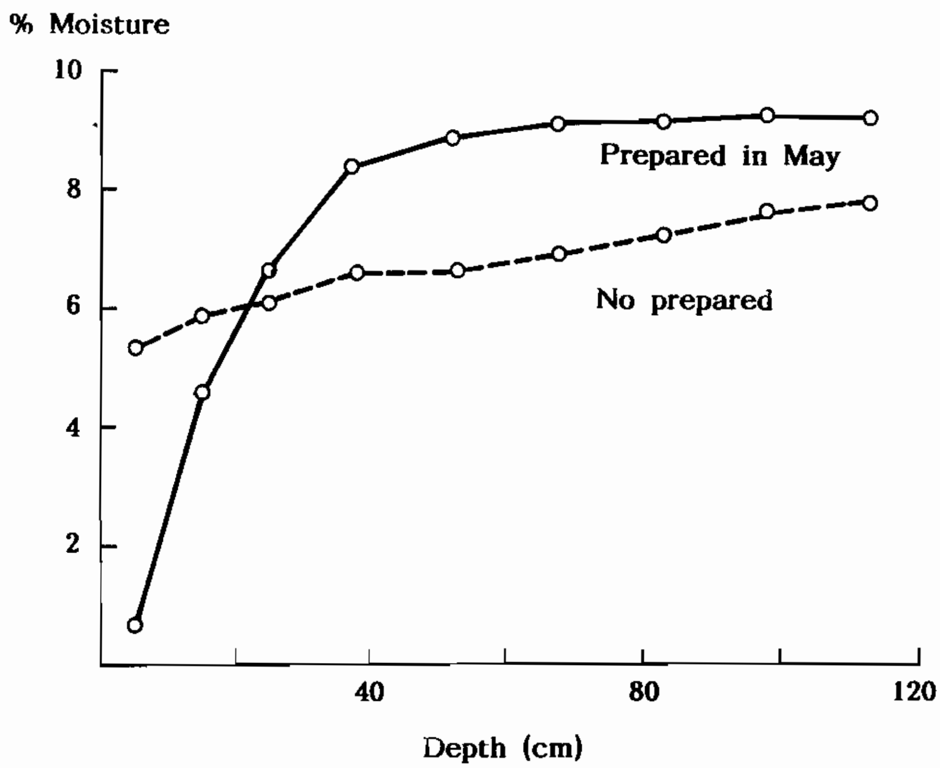


Figure 6. The effect of date of seedbed preparation on profile moisture reserves at the end of the 1988 dry season. Cerrados, 1988.

management as well as harsh climatic and edaphic conditions. The long dry season imposes a severe stress on all germplasm and the low availability of acceptable forage during the dry season results in very poor animal performance.

Maintenance. The problems encountered are largely related to: a) the rapid degradation of straight grass pastures, primarily due to declining N fertility and P deficiency on soils that have not received appreciable P fertilizer for annual crops. b) the lack of stability of legume-based pastures. This appears to be related to both germplasm deficiencies and management. It may be that a grass like *A. gayanus* is simply too competitive for most of the legumes presently available for the region; *C. brasilianum* appears to be an exception. There is no recorded experience of *A. gayanus* x *Calopogonium* at CPAC but reports from a few farmers indicate this to be a workable and productive combination. *B. decumbens* and *B. ruziziensis* have been successfully associated with *C. calopogonium* and *S. guianensis* but both grasses are very susceptible to spittlebug damage. *B. brizantha* cv. Marandu is doing well on better soils

Marandu is doing well on better soils and has also been successfully associated with *Calopogonium*.

Pasture renovation. There are millions of hectares of degraded grass pastures in the Cerrados. Nitrogen deficiency is the first limiting fertility factor leading to degradation in most cases. Phosphorus and other nutrients may also become limiting in Cerrado soils that have not been used for cropping. A major challenge facing pasture researchers is the identification of well-adapted, productive legumes and the technology necessary to introduce these legumes into degrading grass pastures. Once the association is formed, a management strategy must be followed to assure grass-legume balance and stable, persistent pastures.

Table 1 presents a summary of the principal problems faced in pasture establishment, maintenance and renovation and the strategies considered most likely to succeed in solving the problems. Some of the problems enumerated are already being addressed. The focus of the section will continue to be on the solution of the problems considered to be of highest priority.

Table 1. A summary of the principal problems faced in pasture establishment, maintenance and renovation and strategies considered most likely to provide solutions to the problems.

Principal problem	Strategies
PASTURE ESTABLISHMENT	
(a) Insects	Early planting (a, b, c, d)
(b) Erosion, sedimentation	Reduced tillage (b, d)
(c) Low seedling vigor	Fertilizer placement (c, d)
(d) High risk/cost	Integrate in crops (c, d)
	Germplasm choice (a, c, d)
PASTURE MAINTENANCE	
(a) Declining fertility: N, P, S	Include legume (a, c, d)
(b) Legume/grass instability	Grazing management (a, b, c, d)
(c) Weed invasion	Germplasm choice (a, b, c, d, e)
(d) Lack of cover/erosion	Maintenance fertilizer (a)
(e) Insects: spittlebug, ants	
PASTURE RENOVATION	
(a) Competition grass versus legume	Dry season tillage (a, b)
(b) Ant predation, legumes	Crop cycle (a, c, d)
(c) High cost	Fertilizer placement (a, c, d)
(d) Weeds	Appropriate baits (b)
	Germplasm choice (a, b, d)

14. Ecophysiology

The Ecophysiology Section has as its general objective the understanding of plant relations in grazed pastures. This may be more closely defined as to understand the factors responsible for the maintenance of satisfactory balance between grasses and legumes in mixed pastures under grazing, and how management may be used to manipulate the balance between the components. This year has been marked by the starting of studies to broaden the approach to include other aspects of management. This has been in addition to the work, described in each of the last two years, to understand how simple response functions relating growth parameters may explain the broad features of growth of grasses and legumes in association.

Modelling grass/legume associations

The experiment that was established in 1986, was continued during the year, and there are now sufficient data to commence analysis of the response functions described in previous annual reports (see TPP Annual Reports 1985, 1986, 1987). Only broad features of the behaviour of the pastures will be reported here.

- Stylosanthes capitata has almost disappeared from all the subplots in the pastures in which it was sown. It is obviously poorly-adapted to this heavier soil (ca. 10% sand), although the exact nature of the lack of adaptation will receive attention, elsewhere (see multi-location experiment later).

The problem appears to be one of population dynamics in that the original plants have died, and there has been insufficient recruitment to replace them. Moreover, growth rate of the new seedlings (and the few older plants) has been low, so that the contribution of this species to the sward is low.

- Centrosema acutifolium appears on this soil to have lower growth rates than on other, lighter soils, and hence unable to resist the effects of diseases (Rhyzoctonia) and pests especially leaf eating insects. The original plants are still largely present, but their growth rates are low, and their contribution to the pasture is small.

- Desmodium ovalifolium has suffered from considerable damage by Cinchytrium in some plots, although in others its survival and growth is satisfactory. It is clear that it is not accepted much by grazing animals, and where it is has not been affected by disease, its contribution to the swards is very satisfactory. It seems that the plots most affected by disease were grazed in the last year at the time of maximum precipitation, and hence when they were waterlogged, which may explain the ingress of the disease.

After a disappointing second year the vigor of Arachis pintoi has improved in a most spectacular fashion. In the year of establishment A. pintoi grew very well, but was severely affected by some nutrient disorder (presumed to be iron toxicity induced by waterlogging) in late 1986 when rainfall was very heavy. Subsequently, plants were heavily affected by Rhizoctonia, and during all of 1987 growth of the legume was poor. In 1988, however, substantial recovery has occurred and the pasture presents a satisfactory appearance.

It is of interest that when a stolon of an A. pintoi plant grows through a tussock of grass, the leaves that develop on that part of the stolon are larger, and darker green, which accords with other data from the piedemont under oil palm and from Australia. The physiological reasons for this are being sought in another experiment at Palmira where plants are grown in boxes of ca. 50 kg of soil with treatments of shading and with and without root competition from B. dictyoneura.

The general conclusions at this stage are that A. pintoi is obviously the best adapted legume species to conditions of soils of these tested. Population dynamics studies show that the ability of mature plants to grow and to survive are crucial to the maintenance of swards containing a high proportion of legume.

It is relevant to point out that differences in growth rate, and their consequences, were included in the original model. Nevertheless, differences in growth rate are clearly very important, and the reasons for them will be sought in other experiments. Adaptation to acid soils different soil conditions will undoubtedly be revealed in differences in growth rate and the factors responsible for poor growth of the legume components, and their dependence on soil conditions, will also be investigated.

Liveweight gains of cattle on four associations

The fistulated cattle used in this experiment graze the same association continuously in that when the animals are withdrawn from the experimental plots, they go to a bulk pasture of the same association. Moreover, they broadly graze through the same sequence of forage allowance and pasture proportions. The liveweight gains of the animals are reported in Table 1.

The effects of fire on S. capitata sown in native savanna

In the last annual report, the effect of two times of burning in the early wet season of a stand of S. capitata established in a native savanna were reported. The times were immediately following, and 3 days after a rainfall event. Broadly, survival of the S. capitata plants was good, and about 70% of the original plants

Table 1. Liveweight gains of animals grazing four associations of grass/ legumes. Data are total gains of the same animals in each association given the same but randomized, sequence of forage allowances.

Association	Liveweight gain kg/head (July to January)
A. gayanus/ S. capitata	66
A gayanus/ C. acutifolium	78
B. dictyoneura/ D. ovalifolium	33
B. dictyoneura/ A. pintoi	64

regrew during the 7 weeks following the fire (Figure 1).

However, the burning treatments in 1987 were applied following a dry season with an unusually high amount of rainfall, so that when the burning treatments were applied the S. capitata plants were green and moreover the native savanna was greener than usual, so that fire temperatures were therefore lower than would normally be expected.

A more extensive series of burning treatments were again superimposed on an exactly similar (but one year older) S. capitata stand in a native savanna.

The treatments were five times of burning:

1. End of March (completely dry)
2. Early April (more or less wet, 44 mm of rain total)
3. Early May (wet, 207 mm of rain total)
4. End May (wet, 302 mm of rain total)
5. Early June (wet 592 mm of rain total).

In addition to observations of the survival of marked plants of S. capitata, the influence of the fires on the major five components of the native savanna was followed (Table 2).

It is of interest that following a more normal dry season all the burns were much more severe than during 1987, particularly those in the dry season and early wet season (fires 1-3), because of the lower amount of green material present in the native grass fuel and hence the higher fire temperatures.

It is not clear however, why the survival of S. capitata plants for fires 4 and 5 were so much lower (17 and 4% cf. almost 70% in 1987).

There appears to be evidence of differential influence of fire on the savanna grasses depending on timing of the fire (see Table 2). Paspalum pectinatum, Panicum rudgei and Schyzachyrium hirtiflorum were unaffected by the time of burning, but the two Andropogon species were quite differently affected, A. bicornis being more affected in early wet season burns, but not much affected later, and the reverse situation for A. selloanus. Moreover, neither P. pectinatum nor P. rudgei were affected much by fire at any time that it was applied, while S. hirtiflorum was always strongly affected.

Thus one would expect that fire could strongly influence the balance between populations of the grasses, A. bicornis, S. hirtiflorum and A. selloanus, and the timing could influence the balance between the two Andropogon species.

Population dynamics of leaves within swards of Brachiaria decumbens and B. decumbens with Desmodium ovalifolium

In order to understand how senescence rate can influence the growth of the components of a pasture, it is necessary to understand how senescence rate of leaf and stem tissue reduces absolute growth rate. That is, tissue turnover is fundamental to the accumulation of biomass in a sward, and has profound effects on forecasting effective grazing management. While this approach has been shown to have relevance in the temperate regions there are no studies in the tropics. Therefore, in order to resolve methodologies, a preliminary experiment was conducted at Quilichao in an established pure grass and a grass/legume sward to obtain data of rates of leaf appearance and senescences.

Some 2000 leaves were tagged each week for 12 weeks and the rate of

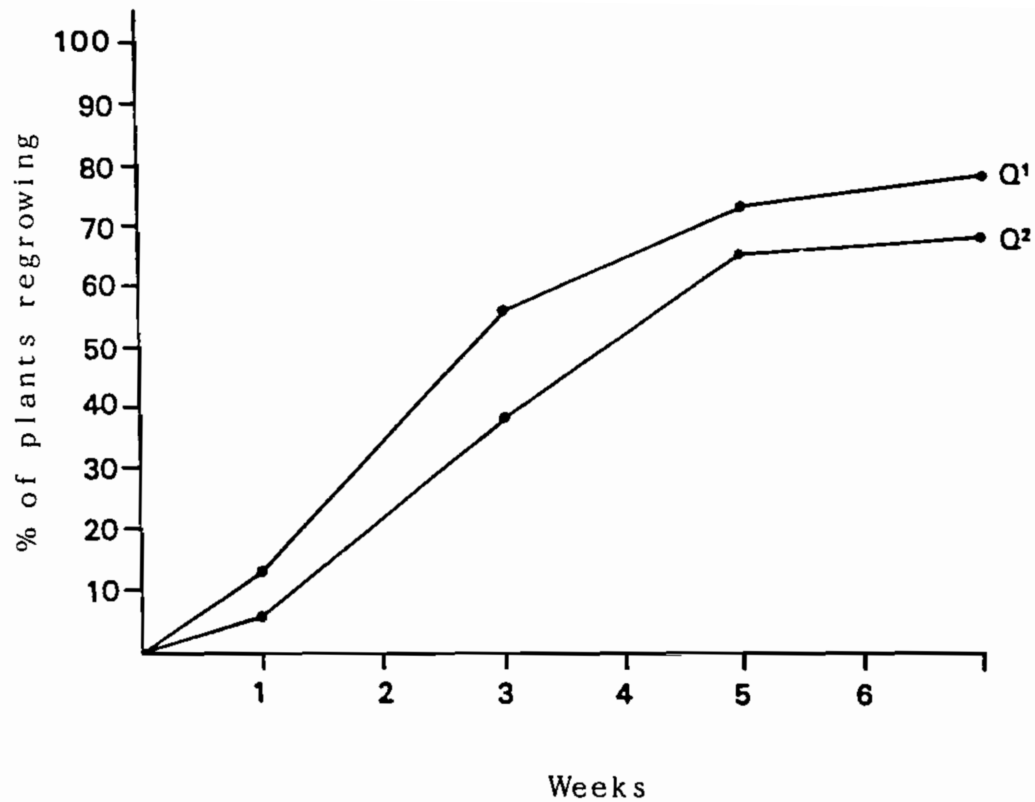


Figure 1. Plants of *Stylosanthes capitata* regrowing following burning in the early wet season 1977.

Table 2. The survival of S. capitata plants growing in a native savanna, together with the five most dominant savanna grasses, following fire at five times before and during the early part of the wet season at Carimagua.

Fire	Time	Conditions	Regrowth % S.capitata 7 weeks	Regrowth % S.capitata 16 weeks	Native Savanna Species (damage) P. pectinatum	A. bicornis	P. rudgei	S. hirtiflorum	A. selloanus
1	End March	Dry (0.0 mm)	1.38	11	-	+	-	+	-
2	Early April	± Wet (44 mm)	13	12.1	-	+	-	+	-
3	Early May	Wet (207 mm)	7.1	6.3	-	+	-	+	-
4	End May	Wet (301.5 mm)	13.6	17.1	-	-	-	+	+
5	Early June	+ Wet (591.8 mmp)	5	4.4	-	-	-	+	+

Native Savanna Species

Andropogon selloanus
Panicum rudgei
Andropogon bicornis
Paspalum pectinatum
Schyzachyrium hirtiflorum

appearance ot new leaves and new tillers was calculated. The data are summarized in Table 3.

The points of interest are that during the twelve week period about half of the tillers of B. decumbens died, and the recruitment was somewhat less. In contrast only 17% ot the stems of the legume died but there was only about 6% recruitment. The rate of leaf appearance more or less matched the rate of leaf senescence in the grass, but in the legume twice as many leaves appeared as died. Thus the legume was at an advantage in the rate of leaf appearance but not in the rate of tiller (stem) death.

The study demonstrates that rates of leaf and tiller appearance and death can be determined readily, but further observations are needed to contrast different environmental conditions between wet and dry seasons.

Digestibility of grasses as a factor in pasture quality and plant relations

Although C_4 (tropical) grasses are commonly supposed to have lower digestibility than C_3 grasses there are data to indicate that C_4 grasses can have digestibilities as high as 70%. Moreover, there is some evidence that it is possible to select within Panicum virgatum for

Table 3. Sward characteristics of a pure Brachiaria decumbens and a B. decumbens-Desmodium ovalifolium sward at Quilichao, July-August 1988.

	Grass alone	Mixture	
		Grass	Legume
	m^{-2}	m^{-2}	m^{-2}
Tillers (branches)			
Initial density	2128	1972	1085
Recruitment			
- basal tillers	839	681	63
- axiliary tillers	58	106	0
Deaths	1001	975	171
Final density	2078	1783	977
% change	-4.8%	-9.5%	-5.6%
Leaves			
Initial density	20308	18383	7336
New leaves	9043	7939	2216
Deaths	10280	9017	1259
Flowers	219	125	10
Final density	18853	17180	8282
% change	-7.0%	-6.5%	20.1%

germplasm of higher digestibility, and that this character is heritable. Obviously if higher digestibility can be found, and it is heritable, and it is not associated with unduly low dry matter yields, then the character is worth selecting/breeding for.

In an initial attempt to verify the variation that may exist for digestibility amongst germplasm of interest, samples were collected from 203 accessions of Brachiaria species growing in a nursery at Quilichao. In each case the first fully expanded leaves were selected, from small plots uniformly defoliated 4 weeks previously. The in-vitro dry matter digestibilities were determined.

The data show substantial variation, from 45 to 72%, with the largest number occurring 63 and 66% (Figure 2). It seems that there is considerable scope for selecting material within this collection for higher digestibility and for seeking to incorporate it in any program of plant improvement. The advances made in seeking sexual reproduction in some species of Brachiaria make this a realistic objective.

Further work is planned to broaden this study into other grass genera.

The comparative reaction of two forage legumes to grazing (In collaboration with Agronomy Section).

The two stoloniferous legumes Arachis pintoi and Desmodium ovalifolium form promising associations with various species of Brachiaria. The relation

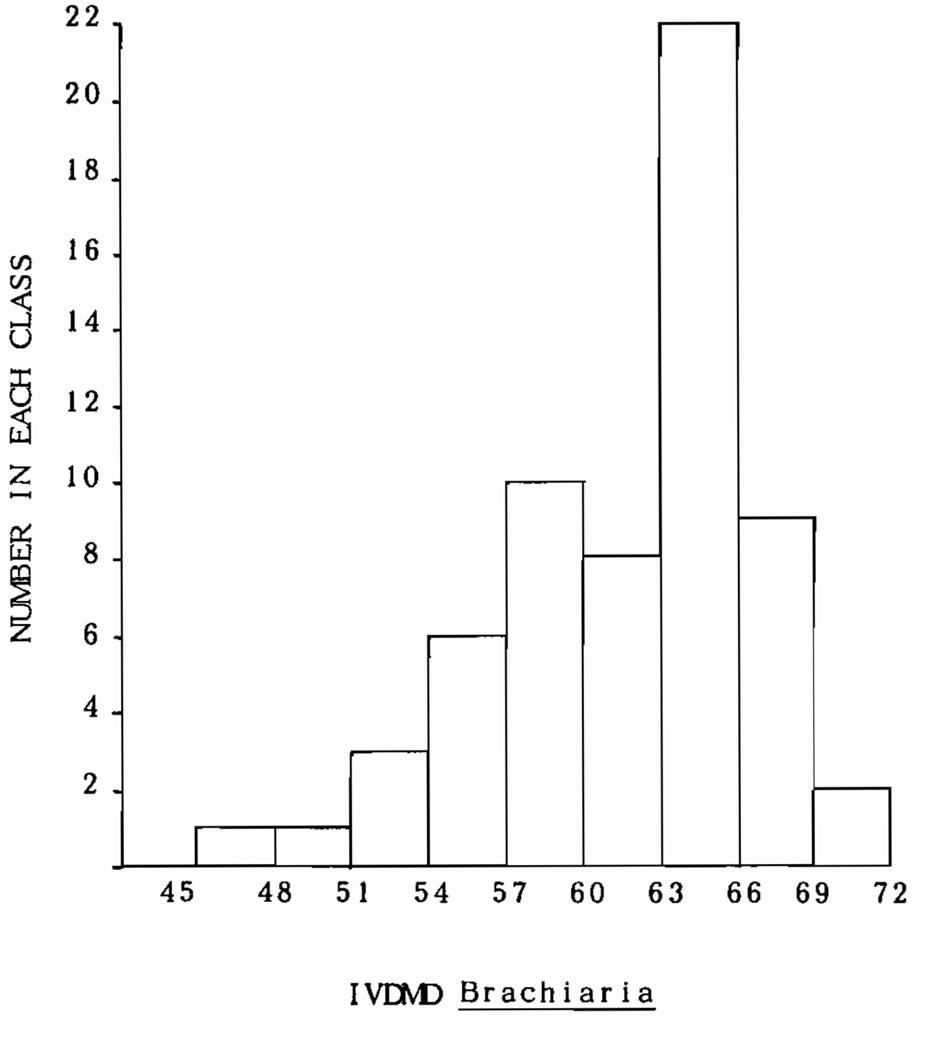


Figure 2. Histogram of frequency of digestibility of the first fully expanded leaf determined in a collection of 203 *Brachiaria* spp, grown at Quilichao.

between growth rate and the amount of residual leaf material is central to understanding how systems of grazing management influence plant relations. Because the palatability of the two legumes above differ, under constrasting treatments of forage allowance the amounts of leaf remaining after grazing varies throughout the year. Associations of these species were, therefore, monitored under rotational grazing to determine how these differences controlled growth rates during the rest period.

In the first of two experiments, Arachis pintoi CIAT 17434 was established in 1984 with B. humidicola CIAT 679, B. dictyoneura CIAT 6133, B. brizantha CIAT 664 and B. ruziziensis CIAT 6291. In the second, six accessions of Desmodium ovalifolium (CIAT 350, 3776, 3794, 13089, 13092, 13129) were sown in 1985 with Brachiaria dictyoneura CIAT 6133. Treatments were forage allowances of 3 and 6 kg dry matter/100 kg of animal liveweight, with two replicates, and plots were individually grazed for two years in a 5-week rotation. Samples were cut to ground level before the animals entered and immediately after they left and the yield of leaf and stem of each component determined.

The amount of leaf material during the regrowth stage should control the growth rate of a component unless some other factor operates to interfere with the relation. Therefore, data were pooled between associations, and mean growth rate for each rest period was regressed on the mean leaf mass for each compoenent in each of the treatments. A robust technique was used to fit the linear regressions, which identified outliers in the data.

Four features are evident from the regressions (Fig. 3 and 4):

- Within the same forage allowance treatment, common regressions fitted the data for both legume species, and all the grass species, despite the different associations, sites, and ages of the pastures.
- The slopes of the regressions (equal to net assimilation rate (NAR) of conventional growth analysis, and a measure of the photosynthetic efficiency of the leaves) for the legumes were substantially lower than for the grasses, reflecting the different photosynthetic pathways of the C_3 legumes and the C_4 grasses. The difference in photosynthetic efficiency between tropical grasses and legumes has profound consequences on the prospects for the selection and management of compatible mixtures of tropical grasses and legumes (Fisher and Thornton, 1988).
- NAR for both grasses and legumes was lower where forage allowance was higher. Biomass throughout the regrowth phase was higher in these treatments, so that it is likely that their mean leaf age would have been older. Therefore, we speculate that difference in mean leaf age was responsible for lower mean photosynthetic efficiency and hence lower NAR. Although shorter swards are more efficient, animal intake may be reduced, and absolute growth rates are lower. Thus, in order to achieve optimum performance of the pasture, a balance must be struck between animal intake and residual leaf mass.
- There were a number of outliers in the data, all of which had lower growth rates than expected. The preponderance of the outliers were for data measured in July, August, and September, which are amongst the four wettest months in

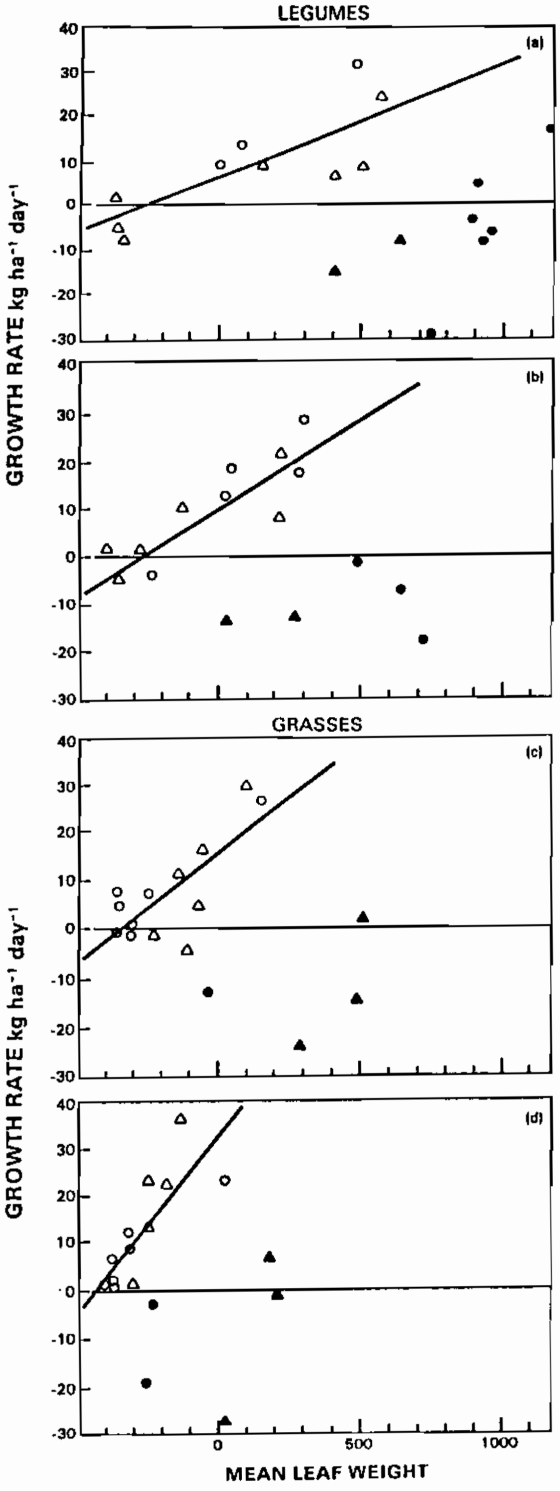


Figure 3. The relation between the growth rate and mean leaf weight of the components of two associations in Carimagua grazed at (a) and (c) high and (b) and (d) low levels of forage allowance. The data are means of the accessions. The solid symbols represent the outliers identified by the fitting routine. Triangles = B. dictyoneura/D. ovalifolium; circles = Brachiaria spp./A. pintoi.

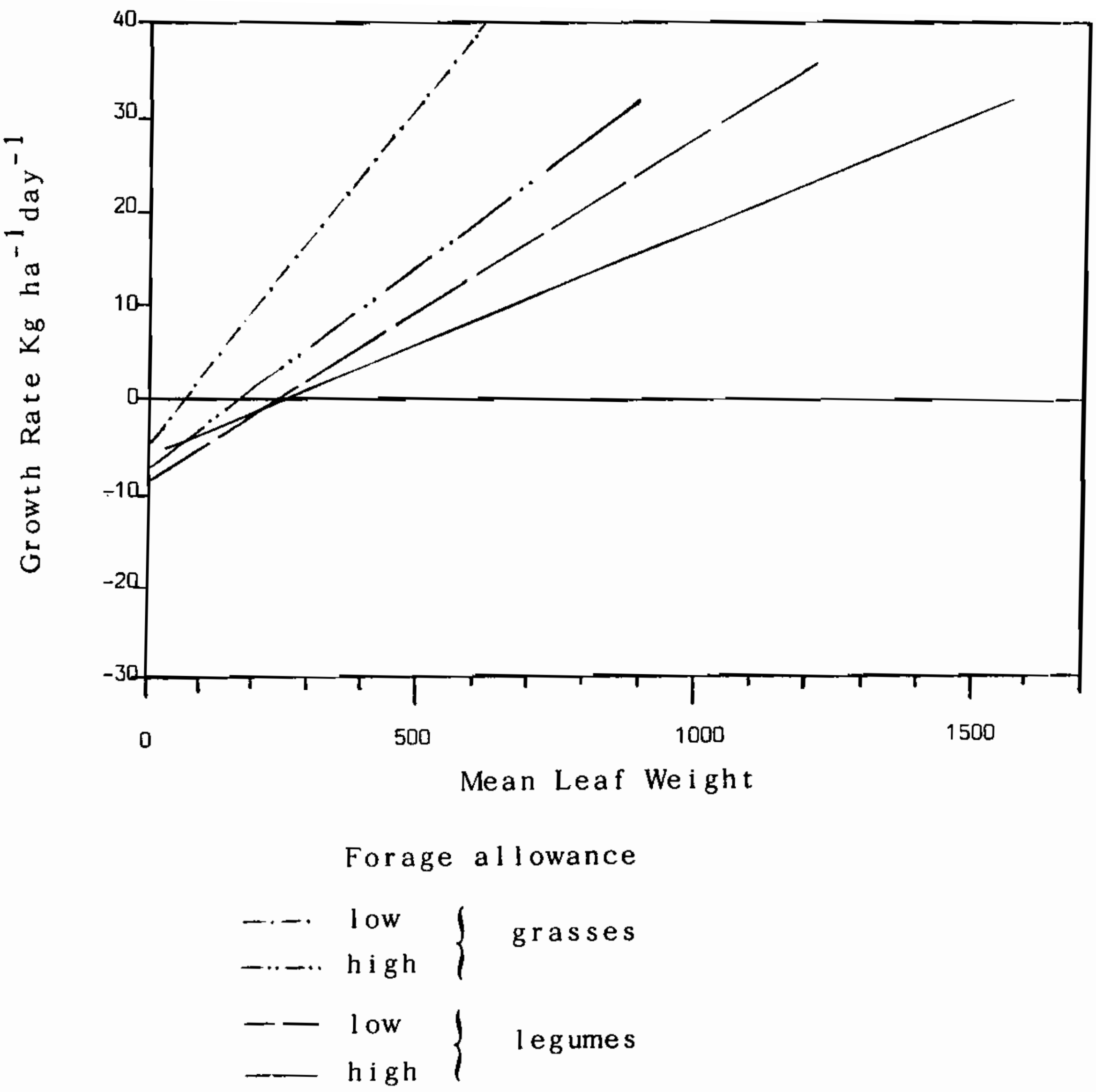


Figure 4. Growth rate as a function of mean leaf weight for contrasting grass legume associations at two levels of forage allowance.

Carimagua, and were especially wet in both 1986 and 1987 (31 and 32% above the long-term mean total of 836 mm). It is unclear whether the lower growth rates were caused by one or a combination of factors such as nutritional problems associated with waterlogged soil, low levels of radiation caused by cloudy weather, or damage of the plants by trampling during grazing when the soil was very wet.

This analysis has allowed the demonstration of the importance of residual leaf material as a primary determinant of regrowth capacity of grazed swards, although other factors may modify the relation. The legumes appear more sensitive to these other factors than the grasses.

15. Pasture Quality and Productivity

The Pasture Quality and Productivity Section has continued to evaluate grazing management strategies and to measure animal production potential in grasses alone and in association with legumes, using methodologies that could be appropriate for the RIEPT. Additionally, during 1988 the Section began work in farms in the Colombian llanos, with the objective of developing methodology to evaluate pastures at the producer level. This report summarizes the results of grazing trials in progress as well as methodological trials already concluded.

PASTURE MANAGEMENT AND PRODUCTIVITY

During 1988, 4 grazing trials continued to be evaluated in Carimagua and new grazing trials with Category IV germplasm were initiated. A grazing trial was concluded at the CIAT-Quilichao Substation, where pasture quality attributes were measured to determine their relation with animal production. In addition, a grazing trial using the flexible methodology proposed for the RIEPT was concluded.

GRAZING TRIALS IN CARIMAGUA

Grazing of Brachiaria decumbens with and without Kudzu. This grazing trial, the oldest in Carimagua, entered its 10th year of evaluation. During this year's dry season, the association resulted in 62% more weight gain than the pure grass (Table 1). However, during the rainy season there were no differences in weight gain among treatments; a severe spittlebug attack to all pastures could have contributed to these results. As a consequence of the spittlebug attack, it was necessary, since August, to reduce the stocking rate from 2 to 1 A ha^{-1} in all treatments.

An analysis of liveweight gain results obtained over 9 years in this trial demonstrated that the association yielded 42% more annual weight gain than the pure grass (123 vs 175 kg A^{-1} year^{-1}). On the other hand, the analysis, showed that the relative advantage in weight gain of the association over the monoculture during the rainy season was exponential after the 4th year of grazing.

Grazing of B. decumbens alone and in association with legumes (Centrosema acutifolium and Stylosanthes capitata). This grazing trial entered its 2nd year of evaluation and it was necessary to make changes in the grazing frequency. Due to limited grass availability in the original 7/7 day alternate system, it was changed to 14/14 during this year's rainy season. To maintain contrasting grazing systems, the 21/21 rotation was changed to 28/28 days.

During this year, greater weight gains were obtained during the dry season in the association than in the pure stand, with no differences observed between pastures during the rainy

Table 1. Seasonal weight gains in B. decumbens alone and in association with Kudzu (Carimagua, 1988-10th. year of grazing).

Pasture	Stocking rate D/W 1/ (A ha^{-1})	Season of the year Dry 2/ ($gA^{-1}day^{-1}$)	Wet 2/
B. decumbens	1/1.5	86 b	583 a
B. decumbens /Kudzú	1/1.5	139 a	498 a

1/= Stocking rate during dry and wet season.
2/= 117 and 246 days of dry and wet season, respectively.
a,b= Means within season of the year are different (P .05).

season (Table 2). To date, the grazing system has not resulted in weight gain differences, but has affected the proportion of legumes on offer (Table 3). S. capitata cv. Capica has been favored by frequent grazing (7/7 and 14/14), while C. acutifolium cv. Vichada has been favored by less frequent grazing (21/21 and 28/28), particularly in one replication of the trial. It is possible that the differences in legume proportion associated with the grazing system will be reflected in weight gains in subsequent years.

Grazing of Centrosema spp. in association with two grasses. After 3 years of grazing, it is evident that C. acutifolium cv. Vichada under flexible grazing management has been productive and persistent in association with two grasses of very contrasting growth habits, (Figure 1). However, the stability of this legume has been greater with A. gayanus than with B. dictyoneura + B. brizantha cv. Marandu. It is interesting to note that even though C. brasilianum 5234 and C. macrocarpum 5452 practically disappeared from the pastures, their persistence was greater with B. dictyoneura + B. brizantha than with A. gayanus, possibly due to greater soil nutrient competition with the latter grass.

During this year, grazing pressure treatments were replaced by stocking rates. During the dry season all pastures had 2 A ha^{-1}, while in the rainy season 3 and 2 A ha^{-1} were used for the high and low pressures, respectively. The effect of stocking rate on weight gain was not significant, so results were averaged (Table 4). During the dry season, animals in the associations of C. acutifolium cv. Vichada with the two grasses maintained their weight, contrasting with severe weight losses in the other pastures.

The advantage of C. acutifolium over C. brasilianum and C. macrocarpum in terms of weight gain, was also observed during the rainy season (Table 4). Weight gains recorded in associations with Centrosema spp. were associated with legume selectivity and crude protein level in the diet (Table 5). During both the dry and rainy seasons, esophageal-fistulated animals selected a greater proportion of C. acutifolium cv. Vichada, resulting in higher protein levels in the diet compared to the other associations. The high selectivity of Vichada by the grazing animals was related with its greater availability throughout the year in the forage on offer (Figure 1).

Grazing of native grasses with C. acutifolium. During this year, evaluation continued of the association of C. acutifolium (5568 + 5277) with native grasses in which A. bicornis predominates. Weight gain obtained this year with different grazing managements are presented in

Table 2. Seasonal weight gains in B. decumbens alone and in association with two grazing systems (Carimagua 1988-2nd year of grazing).

Pasture	Stocking rate (A ha^{-1})	Grazing system: 7/7 - 14/14 Dry[2]	7/7 - 14/14 Wet[2]	21/21 - 28/28 Dry	21/21 - 28/28 Wet
		(g A^{-1} day^{-1})			
B. decumbens	2.0	15^{b}	467^{a}	-23^{b}	475^{a}
B. decumbens/[1/] Legumes	2.0	114^{a}	500^{a}	116^{a}	389^{a}
Mean		65	484	47	432

1/ = Legumes: C. acutifolium cv. Vichada and S. capitata cv. Capica
2/ = 119 y 224 days of dry and wet season, respectively.
a,b = Means within season and grazing system are different (P .05).

Table 3. Effect of grazing system on the proportion of two legumes in association with B. decumbens[1/] (Carimagua, 1988-2nd year of grazing).

Grazing[2] system	Season of the year	Legume on offer: C. acutifolium (%)	S. capitata (%)
7/7 - 14/14	Dry	7	11
	Wet	5	15
21/21- 28/28	Dry	21	7
	Wet	24	6

1/ = Stocking rate 2 A ha^{-1}.
2/ = Alternate grazing.

Table 4. Seasonal weight gains in *Centrosema* spp. associated with two grasses (Carimagua 1988-3rd. year of grazing).

Assocciations	Season of the year: Dry	Wet
	($g\ A^{-1} day^{-1}$)	
A. gayanus		
+ *C. acutifolium* Cv.Vichada	- 86[b]	422[a]
+ *C. brasilianum* 5234	-238[c]	367[b]
+ *C. macrocarpum* 5452	-187[c]	261[c]
B. dictyoneura/B. brizantha		
+ *C. acutifolium* Cv. Vichada	33[a]	499[a]
+ *C. brasilianum* 5234	77[a]	441[a]
+ *C. macrocarpum* 5452	- 71[b]	343[b]

1/ = 114 days and 182 days of dry and wet season, respectively.
a,b,c = Means within the season of the year are different (P .05).

Table 5. Legume and crude protein proportion in the diet selected in *Centrosema* spp. associations with two grasses (Carimagua 1988).

Associations	Legume in diet (%): Dry[1/]	Wet[2/]	Protein in diet (%): Dry	Wet
A. gayanus				
+ *C. acutifolium* cv. Vichada	87	40	12.8	12.4
+ *C. brasilianum* 5234	21	1	6.1	7.9
+ *C. macrocarpum* 5452	0	0	5.2	8.0
B. dictyoneura/B. brizantha				
+ *C. acutifolium* cv. Vichada	36	8	8.4	7.4
+ *C. brasilianum* 5234	11	1	5.5	5.9
+ *C. macrocarpum* 5452	0	0	3.5	5.2

1/= January and March 1988 sampling.
2/= June, August, November, December 1988 samplings.

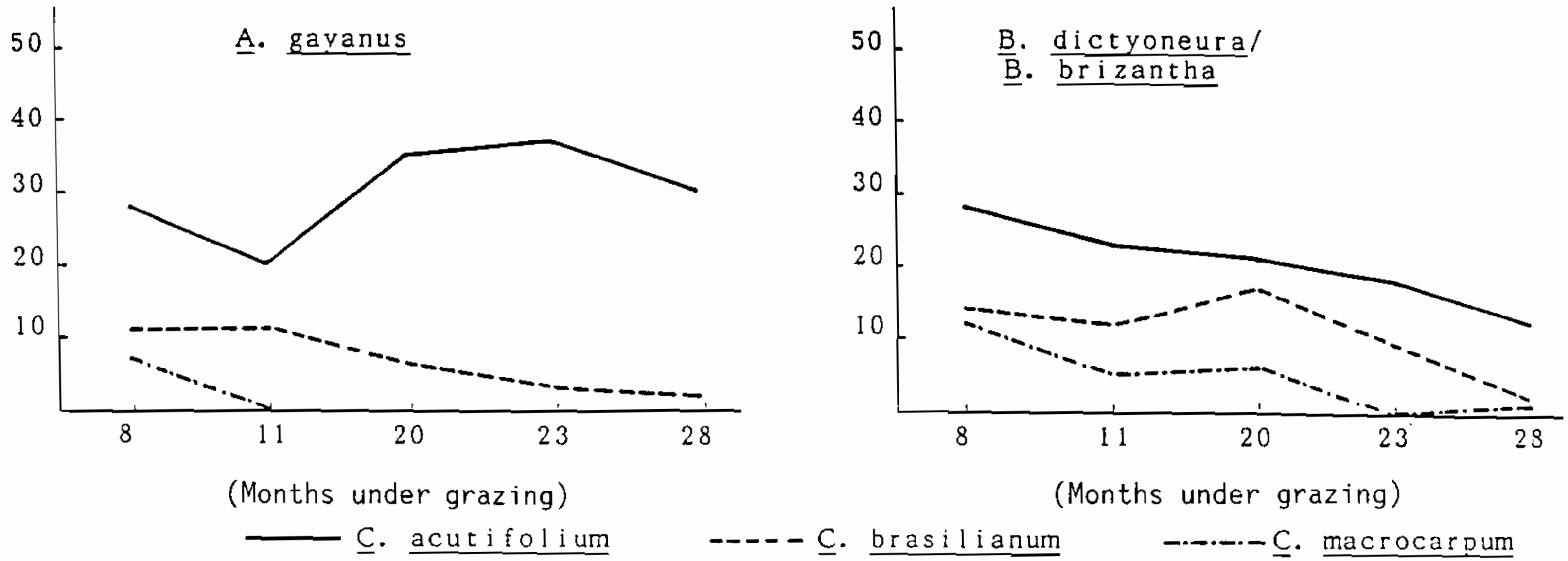


Figure 1. Legume proportion in Centrosema spp. associations with two grasses (Carimagua).

Table 6. During the dry season, the animals maintained their weight in the lower stocking rates (0.75 and 1.0 A ha^{-1}), but lost weight at the high stocking rate (1.5 A ha^{-1}), both in continuous and rotational grazing. Weight gains were good during the rainy period, with the exception of those recorded in the high stocking rate with continuous grazing.

Studies on animal selectivity showed that the esophageal-fistulated animals selected a higher proportion of legumes than that present in the pasture during the dry and rainy period (Table 7). The average selection index was 2.0 and 3.9 in the dry and rainy seasons, respectively, thus indicating a high degree of substitution of native grasses for legumes. It should be pointed out that the proportion of C. acutifolium in the pastures was high, varying between 14% in the wet season and 51% in the dry season.

The results of this study suggest that the relatively high weight gains observed are due to the animals substituting very low quality native grasses for legume, which contributes not only proteins but also energy and possibly minerals to the animal's nutrition. It is worth asking if the introduction of a legume into a better quality native savanna (for example Trachypogon) would result in the degree of substitution observed in the degraded savanna. To answer this question, a trial was established this year in Carimagua in which the legume C. acutifolium cv. Vichada was introduced in a Trachypogon/Paspalum savanna. The trial includes a constant level of legume planted per animal (1500 m^2) with three stocking rates (0.66, 1.0, and 1.33 A ha^{-1}), leaving the savanna, managed with burning and a stocking rate of 0.66 A ha^{-1} as the control. Grazing will be initiated next year at the beginning of the rainy season.

Grazing experiments with legumes in Category IV. As was reported last year, grazing trials were established in Cariamgua with Category IV legumes (D. ovalifolium 13089 and A. pintoi 17434) in association with Brachiaria spp. Grazing was begun this year in B. dictyoneura cv. Llanero pastures alone and in association with A. pintoi; however, due to a severe spittlebug attack to the grass, grazing had to be interrupted during August, and as a result no data on liveweight is available. On the other hand, at the beginning of the year grazing to reduce the grass stand was initiated in B. humidicola alone and associated with A. pintoi.

In a trial in Carimagua with B. dictyoneura associated with A. pintoi under rotational grazing, selectivity, consumption, and weight gain measurements are being made. During this year's rainy season, weight gains have averaged 580 g A^{-1} day^{-1} (2 A ha^{-1}); this has been related to a high selectivity of legumes by esophageal-fistulated animals.

Grazing of B. humidicola alone and in association with D. ovalifolium 13089 was initiated in two sites in Carimagua (Yopare - intermediate sandy soil and La L - clayey soil). First year results have indicated differences between sites in terms of forage availability and thus in the carrying capacity of the pastures (Table 8). Both in Yopare and La L, stocking rates during the dry season were the same, but due to an excess of forage in La L it was necessary to include one more animal per hectare than in Yopare. Weight gains during the dry season were greater in La L than in Yopare, the contrary occuring during the rainy season (Table 8). The inclusion of legume in the pastures has not yet resulted in greater weight gains when compared with the grass alone treatment using

Table 6. Seasonal weight gains in C. acutifolium associated with native grasses under different management (Carimagua, 1988-2nd. year of grazing).

Grazing system	Stocking rate ($A\ ha^{-1}$)	Season of the year: Dry[1/] ($g\ A^{-1} day^{-1}$)	Wet[1/]
Continuous	0.75	62^{a}	417^{a}
Continuous	1.0	14^{b}	358^{a}
Continuous	1.5	-173^{c}	258^{b}
Rotational	1.5	-67^{c}	382^{a}

1/ = 113 y 246 days od dry and wet season, respectively.
a,b,c = Means within the season are different (P .05).

Table 7. Legume selection index (LSI) in C. acutifolium associated with native grasses under different management (Carimagua 1988-2nd. year of grazing).

Grazing systems	Stocking rate ($A\ ha^{-1}$)	Season of the year: Dry[1/] (LSI)[1]	Wet[1/]
Continuous	0.75	2.3 (39)[2/]	3.4 (26)
Continuous	1.0	2.5 (25)	5.3 (14)
Continuous	1.5	1.4 (49)	4.3 (18)
Rotational	1.5	1.8 (51)	2.6 (35)

1/ = LSI = % legume in diet/% legume on offer.
2/ = Values in parenthesis are % legume in forage on offer.

Table 8. Seasonal weight gains in B. humidicola alone and associated with D. ovalifolium 13089 in two sities (Carimagua, 1988-1st year of grazing).

Pastures	Yopare			La L		
	Stocking rate[1/] (A ha^{-1})	Dry[2/] ($g\ A^{-1} day^{-1}$)	Wet[2/]	Stocking rate[1/] (A ha^{-1})	Dry ($g\ A^{-1} day^{-1}$)	Wet
B. humidicola /D. ovalifolium	2/2	54	539	2/3	208	242
B. humidicola /D. ovalifolium	3/3	-89	528	3/4	168	377
B. humidicola	3/3	-81	469	3/4	172	401

1/= Dry/Wet season.
2/= 76 and 126 days of dry and wet season, respectively.

the same stocking rate.

It is interesting to point out that the grazing management of the pastures has been different in both sites. While in Yopare the mangement strategy has been to favor the grass (alternating 21/21 - 28/28), in La L management has been to favor the legume (alternating 7/7 - 14/14).

METHODOLOGICAL DEVELOPMENT

An important objective of this Section over the years has been to develop pasture evaluation methodologies relevant to the RIEPT. This includes determining pasture attributes related to animal production, as well as validation of pasture evaluation strategies with non-traditional designs.

Quality attributes of a pasture. A grazing trial was conducted in Quilichao during 4 years with B. dictyoneura associated with D. ovalifolium 350, with the objective of defining which pasture attribute or attributes could better explain the responses observed in terms of animal production. The trial included 3 stocking rates under rotational grazing (7/21), with very frequent measurements of:

1. Amount and quality of forage on offer
2. Botanical composition of forage on offer and diet selected
3. Quality of the diet selected
4. Weight gain

This report summarizes the results obtained in the intermediate stocking rate (3.6 UA ha^{-1}) which resulted in the greatest animal production (515 kg ha^{-1} $year^{-1}$).

Daily weight gains per animal were not stable over time, as shown in Figure 2. This loss in animal production was not related with water balance (r = .14 NS), nor with the availability of green grass dry matter, which was relatively constant over time (Figure 3). However, reduction in weight gain over time was related with the loss of legume on offer and selected by esophageal fistulated steers due to a grubworm attack on the legume (Figure 4). Loss of the legume in the pasture was associated with a reduction over

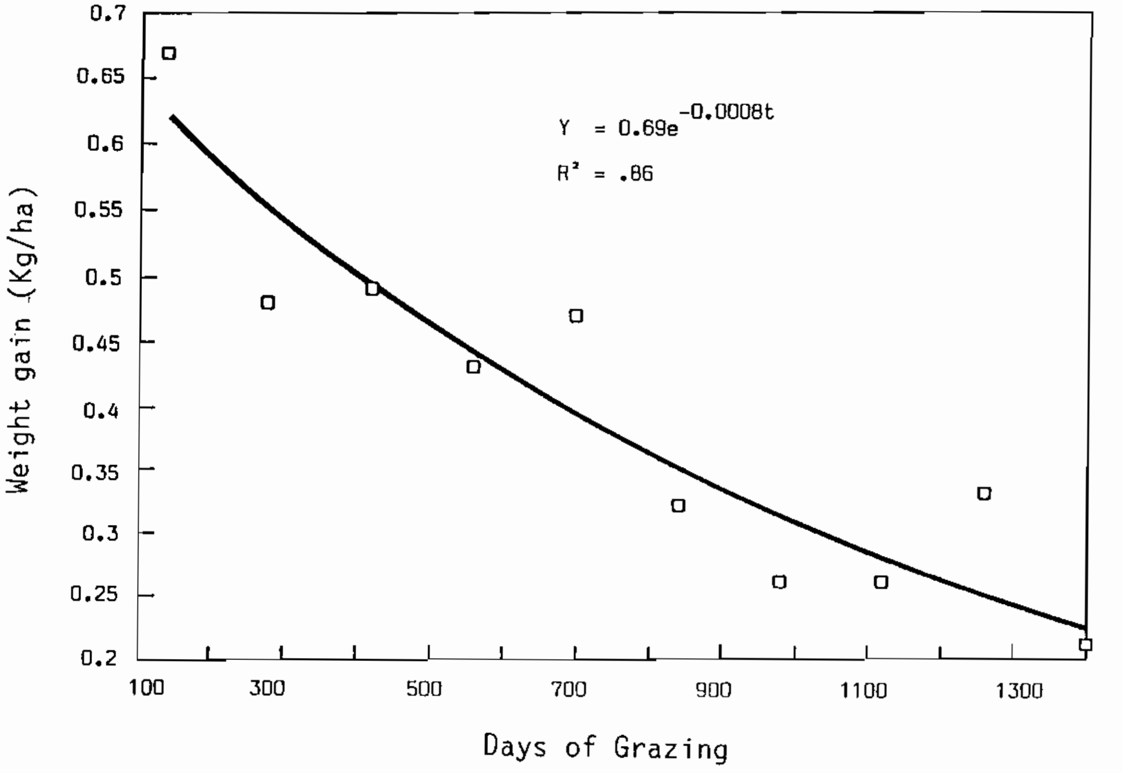


Figure 2. Weight gain over time in a B. dictyoneura/D. ovalifolium association under rotational grazing (Quilichao).

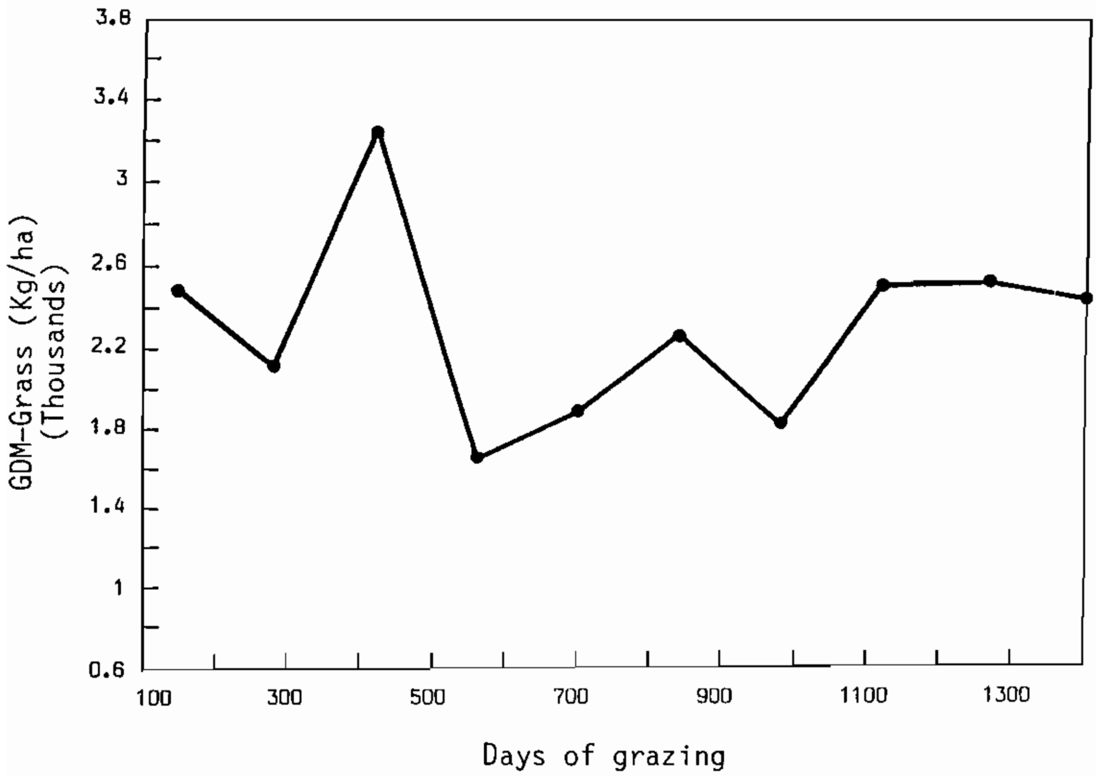


Figure 3. Availability of grass over time in a *B. dictyoneura*/*D. ovalifolium* association managed with rotational grazing (Quilichao).

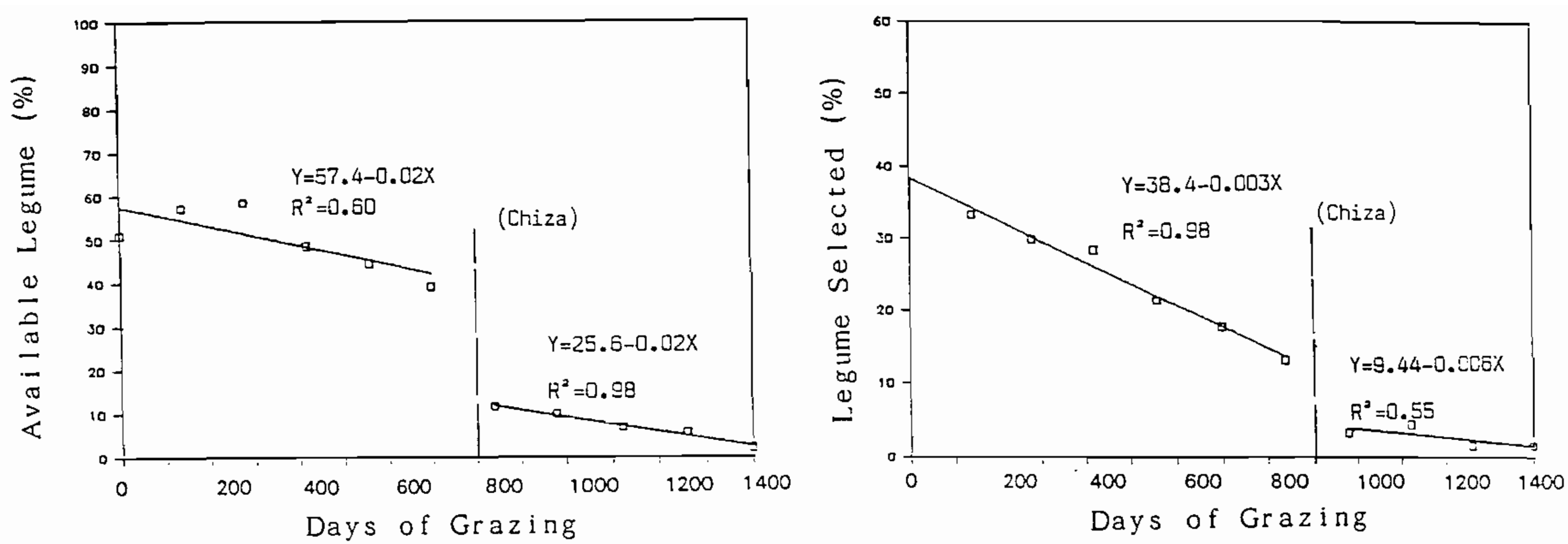


Fig 4. Dynamics of available and selected legume in a pasture of <u>Brachiaria dictyoneura</u>/ <u>Desmodum ovalifolium</u> under rotational grazing (Quilichao).

time (t = days) of protein in the grass ($Y = 8.9-0.003t$ $R^2 = .77$), but not with a reduction in digestibility, which tended to increase over time ($Y = 54.1 + 0.007t$ $R^2 = .50$). Likewise, protein in the diet selected decreased linearly over time ($Y = 12.0 - 0.004t$ $R^2 = .81$).

To summarize, the protein level in the grass diminished 1% per year (9 to 5%), while the protein in the diet disminished 1.5% per year (12 to 6%), to the point where it became limiting during the last year. The protein level in the diet explained almost 70% of the variation observed in daily weight gain (Figure 5).

It is evident that reduction in animal production observed over time in this study was related with the loss of legume and protein in the grass. It is possible that the loss of legume implied a reduction in recycled nitrogen and possibly an increase in the nitrogen immobilized by the grass. It is suggested that in future grazing studies measurements of nitrogen recycled in pastures with and without legumes be included, in order to better understand process of degradation and/or stability of pastures.

Flexible grazing management. This year in the Quilichao Substation an alternate flexible grazing management trial was concluded with associations of *A. gayanus* with *C. macrocarpum* 5713 and *C. acutifolium* 5277 + 5568 under two grazing pressures. Results indicated that the grazing intenstity affected persistence of both *Centrosema* species (Figure 6). The grazing system affected the grass/legume balance only in the case of *C. macrocarpum*, under a moderate grazing pressure. In the case of the less productive legume and/or less adapted to the site (*C. acutifolium*), grazing system did not affect the grass/legume balance in the low or high levels of forage on offer.

Weight gains obtained in this trial during the third year of grazing were associated with the presence or absence of legumes in the pastures as well as with grazing intensity (Table 9).

Table 9. Weight in associations under alternate/flexible grazing management (Quilichao, 1988-3rd. year of grazing).

Associations	Level of forage on offer	
	Low[1/]	High[2/]
	($g\ A^{-1} day^{-1}$)	
A. gayanus/ *C. acutifolium* 5277 + 5568	238[c]	310[b]
A. gayanus/ *C. macrocarpum* 5713	243[c]	443[a]

1/= 4.9 A ha^{-1}
2/= 3.3 A ha^{-1}
a,b,c = Different means (P .05).

At present another grazing trial using alternate flexible grazing management is being carried out in the Quilichao Substation, with the association of *B. dictyoneura* cv. Llanero/ *C. macrocarpum* 5713. After a year of grazing, the management imposed was to favor the grass (Table 10). An alternate grazing 7/7 system was initially used, being gradually changed to 28/28, to avoid legume dominance. Under the management imposed, the pasture has stabilized at 60% grass and 40% legume, with high legume consumption levels (Table 10). Weight gains after 1 year of grazing have averaged 430 g A^{-1} day^{-1}, equivalent to 157 kg A^{-1} $year^{-1}$, using a very high stocking rate (4.5 AU ha^{-1} where AU = 400 kg LW).

A very interesting aspect in this

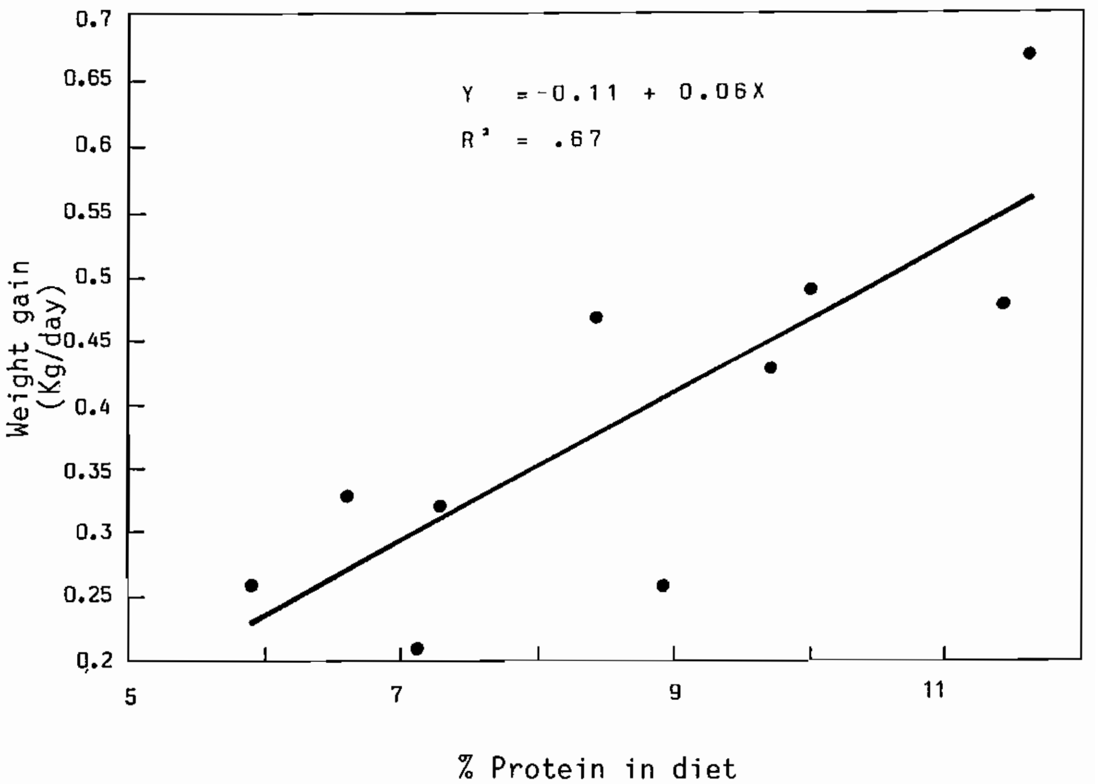


Figure 5. Relation between weight gain and protein in the diet selected in a *B. dictyoneura*/*D. ovalifolium* association under rotational grazing (Quilichao).

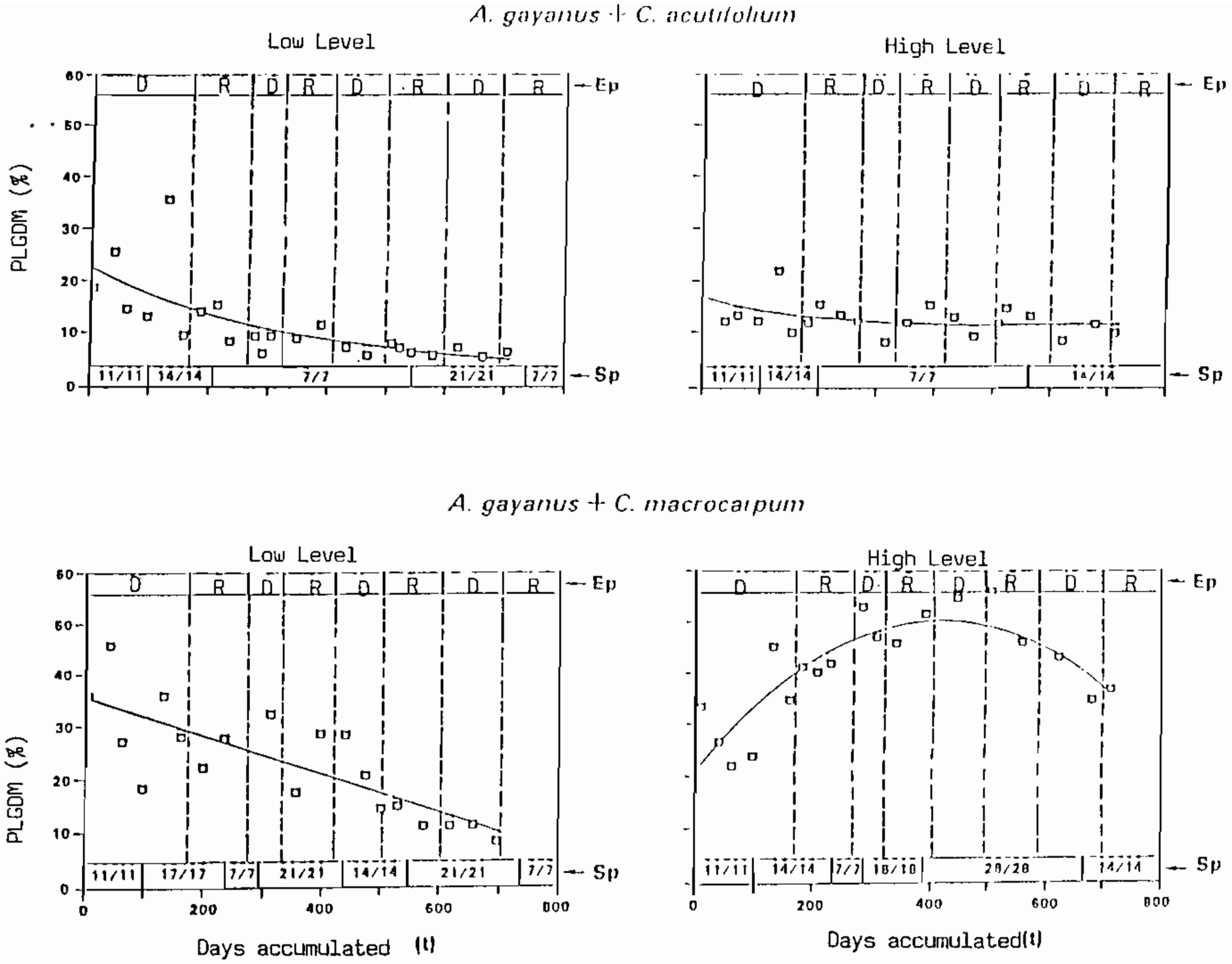


Figure 6. Dynamics of legume proportion on the green dry matter (PLGDM) in two associations under two forage levels with flexible grazing managements (Quilichao).

Table 10. Legume available and selected legume proportion in _B. dictyoneura_/_C. macrocarpum_ association under flexible grazing (Quilichao 1988-1st. year of grazing).

Period (Days of grazing)	Grazing system (O/R)[1/]	Legume (%)	
		Offer	Diet
I (70)	7/7	50.0	25.1
II (84)	14/14	55.6	48.5
III (35)	17.5/17.5	61.0	31.0
IV (42)	21/21	50.0	21.0
V (168)	28/28	41.5	42.2

1/ Occupation/rest days.

trial is that related to quality of grass on offer and diet selected. The level of crude protein in the green grass dry matter has varied between 8 and 10%, with a 9% average throughout the year. Protein in the diet selected by esophageal-fistulated animals was also very high, averaging 12% for the year. It will be interesting to see how this pasture evolves over time in relation to quality of the forage on offer.

The experiments conducted in Quilichao using the flexible grazing have demonstrated that with this strategy it is possible to: 1) reduce the experimental area; 2) select the more productive and persistent association for a given site; 3) define ranges of stocking rate and frequency of grazing for adequate grass-legume balance; and 4) estimate animal production potential of the pastures under evaluation.

PASTURE EVALUATION IN FARMS

As was mentioned at the beginning of this report, the Pasture Quality and Productivity Section initiated this year work on pastures evaluation in farms in the Colombian Llanos. The objectives of this work are:

1) Evaluate germplasm under grazing.
2) Evaluate pure grass and grass-legume associations and grazing management strategies.
3) Evaluate different measurement techniques in the pasture and in the animal.
4) Monitor the grazing management of improved pastures by farmers.

To evaluate the germplasm under grazing, small replicated areas (1 ha) have been planted with Category IV-V-VI legumes (e.g., _C. brasilianum_, _C. acutifolium_) within a pasture established by the farmer with a grass (e.g., _B. dictyoneura_, _B. decumbens_). With this strategy the farmer imposes the grazing management and the legume planted is monitored in terms of productivity and persistence. Results of this type of trial could be that: 1) the legume disappears due to over-grazing or for being very palatable or 2) the legume tends to dominate the grass either because of low palatability and/or high invasion capacity (e.g., seed, stolons). Both in the case that the legume disappears or dominates, the conclusion is that a deferred grazing system or at least a grazing system different from the one used by the farmer in the pasture is required. The information that can be obtained with this type of trial could be useful in the search for combinations of legume-grass germplasm/ farmer management for a given site.

To evaluate grasses alone and in association with legumes and management strategies, relatively large areas (10 ha) have been planted to grasses (*B. dictyoneura* - *B. humidicola*) and mixtures (*B. dictyoneura/C. acutifolium-S. capitata*, *B. humidicola/ A. pintoi*, and *B. dictyoneura/C. brasilianum*). The grazing management for these pastures will be defined between the farmer and the technician. Weight gains and pasture attributes will be measured using different methods.

Monitoring of improved pastures managed by farmers includes pure grasses (e.g., *B. decumbens*, *A. gayanus*, *B. humidicola*) and associations. Different parameters are being recorded, including stocking rates, occupation/rest periods, type and animal category. Moreover, periodic samplings of the pastures will be done to determine availability and botanical composition using different methods; weight gain of some permanent animals will be recorded.

16. Seed Production

INTRODUCTION

The objectives of the Section are:

1. Conduct seed multiplication of promising accessions to provide experimental and basic seed for the Program's activities.

2. Conduct applied research on the most relevant limitations of seed production technology, especially in relation with the key species of the Tropical Pastures Program and the RIEPT and with the new cultivars released by national institutions.

3. Contribute to the progressive development of seed supply (including the experimental, basic, and commercial classes) of various forage species and cultivars in the tropical countries of Latin America.

During 1988, the main activities of the Section were: seed multiplication and distribution, applied research, and training. This report describes progress made in these activities.

SEED MULTIPLICATION AND DISTRIBUTION

A. Multiplication by the Section

As in previous years, field production activities were continued at both Quilichao and Carimagua, while support activities such as greenhouse propagation, seed conditioning, seed testing, and seed storage and distribution were centered at Palmira.

The activities of seed multiplication of legume species are summarized in Table 1. A total of 53 accessions of 18 species with emphasis on accessions Centrosema spp., Desmodium spp., and Pueraria phaseoloides were involved. New areas totalling 8.5 ha were established (mainly Desmodium spp.), to generate a total area 19.3 ha dedicated to multiplication. Composite seed production was 822 kg, including significative amounts of C. acutifolium, C. macrocarpum, and Desmodium spp.

Grass seed multiplication activities are summarized in Table 2. A total of 29 accessions of 10 species, mainly Brachiaria spp. and P. maximum, were involved. Approximately 0.2 ha new areas, were established to provide a total area of 16 ha dedicated to this activity. Composite seed produced was 1,036 kg, primarily of B. dictyoneura cv. Llanero.

B. Multiplication with others

Several opportunities were utilized to make use of alternative mechanisms for obtaining seed, such as production on a contract basis and joint production with other partners (share farming). These activities are summarized in Table 3.

Seed of C. basilianum CIAT 5234 and C. macrocarpum CIAT 5713 were produced on a contract basis with a seed enterprise in Valledupar. The Section also participated in joint production endeavors with cattle growers in the Llanos, especially taking care of the harvesting operation. Production of approximately 1,000 kg of seed of cv. Llanero by this production mechanism is noteworthy.

C. Generalities

A basic strategy this year has been to broaden the mechanisms of obtaining seed. Of the total composite seed production during the year, approximately 50% was derived from self multiplication and 50% by other mechanisms. Global activities are summarized in Table 4. A total of 80 accessions, mainly legumes, are under multiplication and composite production reached 1.300 kg of legumes and 2,000 kg of grasses, primarily of B. dictyoneura cv. Llanero.

During the year, the Section responded to 361 different requests for seed and distributed a total of 2,531 kg of which 588 and 1,943 kg were of various grassses and legumes respectively. Details of this distribution are shown in Table 5.

APPLIED RESEARCH

A. Management and seed yield of C. acutifolium cv. Vichada in the Llanos

Experience over the period 1984-86 indicates serious limitations for seed production of cv. Vichada at the Carimagua experimental station. During 1987 a multilocational trial was established at five sites located between Carimagua and the Andean foothills. In each case the comparisons included were: (a) physical support (with and without) and (b) fertilization levels (50 kg P_2O_5 vs. a composite of 50 kg P_2O_5 + 50 kg K_2O + 20 kg Mg + 12 kg S). Seed harvesting took place from December 1987 to March 1988. Seed yield did not respond to the more complete fertilization, but a significant response was observed for the support treatment (Tables 6 and 7). With support, seed yields ranged from 118 to 523 kg/ha (Table 7). The highest yields were associated with better moisture availability in the soil during February and March. It was concluded that the best option for favorable seed yields are in foothills region compared to the highland plains (Table 8). This implies that seed production of cv. Vichada seems to be more favored outside the region where it is adapted as a forage.

B. Harvesting methods for B. dictyoneura

During the year, several harvests of cv. Llanero were performed in the farm 'La Loma'. Commercial harvesting of a large area was conducted by several machines and methods during a one week-period. A formal comparison of harvest methods was carried out on the day determined as optimum harvest maturity. Some results are summarized in Table 9.

Harvesting of large areas requires starting operations slightly before optimum harvest maturity. On the other hand, trials in small areas permit choosing the optimum date. Optimum harvest maturity of cv. Llanero on this occasion lasted a short period and was restricted to a maximum of 2-3 days. This explains the large difference between maximum yield levels recorded of 70 kg/ha, and the yields obtained from very large areas (26-33 kg/ha). High contents (60-80%) of pure seed in the crude seed were achieved with all methods used. Immediately after harvesting, tetrazolium viability was high (approx. 75%) and differences were not recorded between the methods used. On average, seeds harvested with the beater showed a higher unit weight than those harvested manually (568 and 505 mg/100, respectively).

C. Case studies of seed supply development

1) Humid Tropics, Peru

A collaborative project was initiated in 1986 among INIAA, IVITA, and CIAT to develop a pasture seed project. Initially the main effort was to form a "Seed Project Nucleus", that is, a group of agronomists and technicians with experience, minimum field resources, and initial sources of basic seed, operating within an experimental station. Nuclei were established in two complementary geographic regions, Pucallpa and Tarapoto.

Once these nuclei were operational and with some experience, they began to expand seed multiplication. Due to the total lack of existing seed enterprises in these regions, the nuclei participated in joint production efforts in collaboration with a varying number of "multipliers" who were actually graziers interested in expanding of their areas of improved pastures. Activities were initiated in Tarapoto in 1986 with eight graziers, and in Pucallpa in 1987, with four selected graziers. In each case, an agreement was defined to share or divide seed produced based on the value of contributions made to the production process. The project nuclei were responsible for provision of basic seed, technical assistance, and in some cases for participation in harvesting. Thus, the project nuclei are stimulating an increase in the number of multipliers and in the volume of seed produced at the regional level.

2) Colombia

In the eastern plains region of Colombia, new pasture cultivars have been released and expectations are high for their adoption by graziers. On the other hand, the levels of demand for seed at the commercial level is limited. While several seed enterprises operate in the region they have shown little or no involvement in seed production of the new pasture cultivars up to the present.

In an attempt to change this situation a collaborative project was initiated during 1988 beween CIAT and the existing seed enterprises to promote their participation in seed production of *Stylosanthes capitata* cv. 'Capica', *Centrosema acutifolium* cv. 'Vichada', and *Brachiaria dictyoneura* cv. 'Llanero', among other materials. CIAT's Seed Unit offered contracts to purchase the seed produced, thereby eliminating concern on the part of these enterprises as to marketing their production.

Taking into account the diversity of species and cultivars required, a relative classification was defined of the potential for seed production in various zones of the country (Table 10). In the negotiations with the seed enterprises, the location of the production areas was determined on the basis of this classification. Eight seed enterprises located in five different geographic regions, entered into contracts for producing one or more materials. In addition, one grazier organization and an individual cattleman were also involved as multipliers.

As of August 1988, 20 ha of cv. Vichada, 45 ha of cv. Capica, and 30 ha of cv. Llanero had been established for seed multiplication. The Seed Production Section of the Tropical Pastures Program and the Seed Unit are offering technical assistance to these seed enterprises.

TRAINING

During the year, two professionals conducted their specialization phase of the Tropical Pastures Course in the Section. These professionals came from CEPLAC, Brazil and the Ministry of Agriculture, Honduras. In addition, a professional from CPATU, Brazil, completed three months of in-service training.

In collaboration with INIAA, Peru, the Section organized a Workshop to analyze the current situation of pasture seeds in the humid tropics of Peru. Ten professionals from Peru participated in the six-day Workshop which was held in Tarapoto during June. In addition, two professionals from Ecuador, one from Mexico, and one from Costa Rica were invited to share common experiences. A detailed Workshop proceedings is being developed.

Table 1. Summary of seed multiplication activities of legume species accesions for the period October 1987-1988.

Species	Total accessions (No.)	Areas under multiplication New (ha)	Areas under multiplication Total (ha)	Seed produced[1] (kg)
Arachis pintoi	1	-	2.0	0.140
Centrosema acutifolium	1	-	3.24	371.0
Centrosema brasilianum	4	1.2	1.51	28.2
Centrosema macrocarpum	3	0.68	1.28	170.5
Desmodium heterocarpon	1	-	0.016	0.450
Desmodium ovalifolium	6	3.13	7.11	70.99
Desmodium strigillosum	3	-	0.062	23.89
Desmodium heterophyllum	1	-	0.075	6.78
Desmodium velutinum	1	-	0.04	0.633
Diochlea guianensis	2	-	0.024	12.6
Flemingia macrophylla	2	-	0.128	8.125
Leucaena leucocephala	2	-	0.012	4.47
Pueraria phaseoloides	10	0.022	0.205	42.19
Stylosanthes capitata cv. Capica	1	2	2	55.0
Stylosanthes capitata	5	1.5	1.5	-
Stylosanthes viscosa	6	-	0.05	6.834
Tadehagi sp.	1	-	0.004	0.060
Zornia glabra	2	-	0.125	19.36
Zornia latifolia	1	-	0.003	0.860
TOTAL	53	8.53	19.38	822.08

1/ Classified seed (with a minimum pure seed content of 50%).

Table 2. Summary of seed multiplication activities of grass species and accessions for the period October 1987-1988.

Species	Total accessions (no.)	Areas under multiplication New (ha)	Areas under multiplication Total (ha)	Seed produced[1] (kg)
Brachiaria decumbens	2	-	1.109	15.527
Andropogon gayanus	2	-	0.014	3.18
Panicum maximum	6	-	0.23	0.803
Brachiaria humidicola	5	-	0.4735	0.584
Brachiaria dictyoneura cv. Llanero	1	0.1	11.5	998.0
Brachiaria brizantha	4	0.1	1.89	15.44
Melinis minutiflora	4	-	0.016	2.02
Paspalum spp.	4	-	0.008	0.729
King grass	1	-	0.88	--
TOTAL	29	0.2	16.120	1036.2

[1]= Classified seed (with a minimum pure seed content of 70%).

Table 3. Summary of multiplication activities with other partners, for the period October 1987-1988.

Material	Multiplier	Seed received[1] Proportion (%)	Weight (kg)	
	A. PRODUCTION VIA CONTRACTS			
Centrosema brasilianum CIAT 5234	Distribuidora del Valle Ltda.	100	188	
Centrosema macrocarpum CIAT 5713	Distribuidora del Valle Ltda.	100	10	
Subtotal				198
	B. JOINT PRODUCTION (SHARE FARMING)			
Arachis pintoi CIAT 17434	Hacienda Alta Gracia	50	12	
Stylosanthes capitata cv. Capica	Hacienda Alta Gracia	25	229	
	Hacienda Chenevo	25	63	
	Hacienda Santa Catalina	25	13	
Brachiaria dictyoneura cv. Llanero	Hacienda La Loma	30	1000	
Brachiaria brizantha cv. La Libertad	Fondo Ganadero Meta	10	11	
Subtotal				1328
TOTAL				1526

1 = Legumes : Classified Seed (with a minimum of 90% pure seed).
Grasses : Classified Seed (with a minimum of 70% pure seed).

Table 4. Summary of activities carried out independently and in collaboration with other partners for all the multiplication of grass and egume accessions carried out over the period October 1987-1988.

Seed production mechanisms	LEGUMES			GRASSES			TOTAL		
	Acces. (No.)	Area (ha)	Weight[1] (kg)	Acces. (No.)	Area (ha)	Weight[2] (kg)	Acces. (No.)	Area (ha)	Weight (kg)
Self-multiplication	53	19.38	822	27	16.12	1036	80	35.5	1858
Production via contracts	2	1.0	198	-	-	-	2	1.0	198
Joint production	2	8[3]	317	2	27.6[3]	1011	4	35.6	1328
TOTAL	53	28.38	1337	27	43.7	2047	80	72.1	3384

[1] Legumes: Classified seed (with a minimum of 90% pure seed).
[2] Grasses: Classified seed (with a minimum of 70% pure seed).
[3] Includes only the area committed to CIAT.

Table 5. Seed distribution over the period October 1987-1988

SEED REQUESTS Objective /Source	No.	SEED VOLUME Grasses (kg)	Legumes (kg)	Total (kg)
A) PASTURE GERMPLASM EVALUATION				
1. PPT members	108	94.2	949.6	1043.80
2. Regional Trials	55	42.40	67.90	110.30
3. National Institutions	120	138.55	535.80	674,35
4. Other CIAT Programs	15	15.92	41.90	57.82
5. Private Entities	47	11.36	59.14	70.50
Subtotal	345	302.43	1654.34	1956.77
B) SEED MULTIPLICATION				
1. National Institutions	4	4.0	25.4	29.4
2. CIAT Seed Unit	4	-	17.6	21.6
3. Seed Supply Development Project (Colombia)	8	281.5	246.2	527.7
Subtotal	16	285.5	289.2	574.7
C) TOTAL	361	587.93	1943.54	2531.47

Table 6. Summary of support and fertilization effects on seed yield based on a trial carried out at five localities in the Llanos during the period 1987-1988.

SOURCE OF VARIATION	SIGNIFCANCE[1] LEVEL				
	B. Aires	Paraíso	Bruselas	Quimaira	La Vega
Support sistem	**	NS	**	**	*
Fertilization	NS	NS	NS	NS	NS
System x Fertilization	*	NS	NS	NS	NS

*Significative difference at the level of $P < 0.05$.
**Significatives differences at level of $P < 0.01$.
NS: No significative difference.

Table 7. Seed yield of *C. acutifolium* cv. Vichada with and without support at five locations in the Llanos during 1987-1988.

SUPPORT SYSTEM	SEED YIELD (kg/ha)[1]				
	B. Aires	Paraíso	Bruselas	Quimaira	La Vega
With some type of support	118 a[2]	198 a	282 a	326 a	523 a
Without support	28 b	156 a	10 b	14 b	196 b

[1]= Samples from 0.01 ha, with three replications
[2]= Means followed by the same letter are not statistically different at $P < 0.05$.

Table 8. Summary of seed yield of C. acutifolium cv. Vichada by geographic location in the Llanos

Geographic region	Seed yield[1] kg/ha	%
Andean foothills	377 a	100
Highland plains	158 b	41.9

[1]= Refers to the average of three localities in the Andean foothills and two localities in the highland plains.

Table 9. Summary of yield and quality of seed of Brachiaria dictyoneura cv. Llanero in relation to harvest method.

Harvest Method	Area harvested (ha)		Harvesting period (days)		Purity of Crude seed (%,Weight)		Pure seed yield (kg/ha)		Unit weight of full spikelets (mg/100)		Viability in TZ at 1 month (%, N°)	
	A[1]	B[2]	A	B	A	B	A	B	A	B	A	B
A. DIRECT COMBINE												
1. John Deere	68	--	6	--	60	--	26	--	524	--	79	--
2. Claas	12	0.1x3	2	1	83	86	33	41	578	549	71	79
B. BEATER												
1. One pass	20	--	6	--	74	--	6	--	588		77	--
2. Two passes	--	0.1 x 3	--	1	--	80	--	27	--	549	--	77
C. TECHNIFIED MANUAL		0.1 x 3	--	1	--	71	--	70	--	487	--	71
D. MANUAL, AFTER ONE PASS WITH BEATER	5	--	6	--	65	--	27	--	524	--	78	--

[1]= Refers to a harvesting activities under large-scale commercial conditions.
[2]= Refers to harvesting done in a formal trial with 0.1 ha with three replications.

Table 10. Classification of the relative potential for seed production of different forage species in several geographic regions of Colombia Colombia

Material	CLASSIFICATION OF RELATIVE PRODUCTION POTENTIAL[1]				
	North Coast*	Tolima*	Valle del Cauca*	Andean foothills	Highland plains
A. LEGUMES					
1. Centrosema acutifolium cv. Vichada	A	B	A	A/B	C
2. Stylosanthes capitata cv. Capica	C	C	C	B/C	A
3. Centrosema macrocarpum	A	B	A	B	C
4. Desmodium ovalifolium	C	C	C	A	C
5. Arachis pintoi					
i) Seeds	C	B	C	C	C
ii) Vegetative material	C	C	C	A	A
B. GRASSES					
1. Brachiaria decumbens cv. common	B/C	C	C	A/B	A/B
2. Brachiaria dictyoneura cv. Llanero	B/C	C	C	A/B	A/B
3. Andropogon gayanus cv. Carimagua 1	A	A/B	A/B	C	B

[1] = A: High or acceptable; B: Intermediate or possible; C: Low or not recommended.

* With supplementary irrigation during the second semester of the year, for legumes only.

17. Livestock Production Systems

The objectives of the Section continued unchanged during the past year, although more emphasis was placed on on-farm work than in the recent past. Simultaneously, the on-station experimental work decreased, as a consequence of the termination of the largest, systems experiment carried out by the Section at Carimagua. The latter experiment, that lasted 75 months, was concluded in July 1988 and is currently being analyzed. Results of the latter are not presented, although the previous Annual Reports have presented progress reports.

A major highlight of this year's activities is the initiation of the Dual Purpose Livestock Project, partially financed by the German Agency for Technical Cooperation, GTZ, and carried out jointly by the Department of Animal Production of the Technical University of Berlin and the Economy and Livestock Production Systems Sections of the Program.

A second major highlight was the creation of a joint ICA-CIAT model for technology transference and validation for the well drained savannas of the Meta Department, called CRECED of the Altillanura, which will provide an institutional umbrella for all of the on-farm work carried out in the region. From the Program's point of view, it also represents the possibility of field testing a different approach to on-farm pasture testing and validation, while simultaneously providing ICA the means for a more effective transference of technology. The feedback of the latter is expected to represent an important contribution to on-station screening of pasture species and mixtures.

Lastly, Carimagua's experimental prototype of a small, family-managed ranch, the so called Family Unit, completed four years since its goal was changed in 1983, to become a dual-purpose operation producing both milk and beef. A still not definitive analysis of physical performance is included in the present report.

Reproductive performance on *Brachiaria decumbens*.

This experiment completed 6 years in late 1988, since it was initiated with weaned heifers. The trial, that runs a herd of 30 females on 30 ha of *Brachiaria decumbens* plus 5 ha of *Slylosanthes capitata*, aims to quantify the reproductive performance of females raised on a relatively high plane of nutrition, and as was indicated in previous reports, constitutes a positive control to the System's experiment.

During the course of the experiment, the *Brachiaria decumbens* pasture has been mechanically renovated twice, with a single pass of discs. The latter is a common practice in the region and aims to stimulate new and vigorous regrowth. The *Stylosanthes capitata* pasture, sown initially as a protein bank, has since been invaded by Brachiaria decumbens, and the legume was progressively displaced by the grass to the extent that its current contribution to total dry matter availability is less than 5%; this contrasts markedly with on-farm observations, and is most likely related to the relatively heavy soil at the site of the experiment.

During the current year the cows in this experiment begun their 4th or 5th calving, and are between 8 and 9 years old, a situation that contrasts markedly with the results of the ETES study regarding longevity vis-a-vis reproductive performance in savanna-based animals. Despite the short calving intervals, relative to savanna cows, the animals in the present experiment have retained relatively high liveweights (Figure 1), although there appears to be a slight trend for decreasing weights with time. Whether this trend is significant, and is related to either age of the cows and/or the pasture, has not been determined as yet. As indicated above, the calving intervals are rather short and apparently have become shorter with successive calvings. Given that the results reported for the last two calvings (Table 1) are still preliminary, the significance of these findings has not yet been analyzed.

Given the results obtained so far, it is important to determine the longevity of animals raised under these conditions, in contrast to the well documented poor lifetime performance of cows on unimproved savanna.

Table 1. Calving intervals of cows grazing on Brachiaria decumbens pastures.

Calving interval No.	Length months	s
1	15.3	4.9
2	14.1	3.3
3*	13.1	2.3
4*	13.0	0.9

* Based on incomplete calvings.

Reproductive performance on Brachiaria humidicola

This experiment aims to study the effects of very low levels of nutrition on the reproductive performance of grazing heifers, and on their subsequent long term productivity as adult cows. The experiment comprises two replicates in time. The first of these is now five years old, and had three treatments applied to weaned heifers until they reached 270 kg linliveweight. The treatments consisted of three different stocking rates on a Bachiaria humidicola pasture to attain low rates of growth. Preliminary results of that phase of the experiment were reported in previous Annual Reports. After reaching 270 kg liveweight the three groups of heifers were moved to a common paddock, also of Brachiaria humidicola. The animals are currently reaching their third calvings. Despite their relatively low liveweight (Figure 2), the first calving interval (i.e., interval between the first and second calving) ranged on average, between 18 and 20 months (Table 2), although at fairly advanced ages.

A preliminary analysis of conception rates (first conception) was carried

Table 2. Intervals (definitive) between the first and second calving.

Weight gain	Interval, months	Calving rate %
High	19.4	61.9
Medium	18.8	63.8
Low	19.5	61.6
High No.2*	18.7	64.3

* Second temporal replicate.

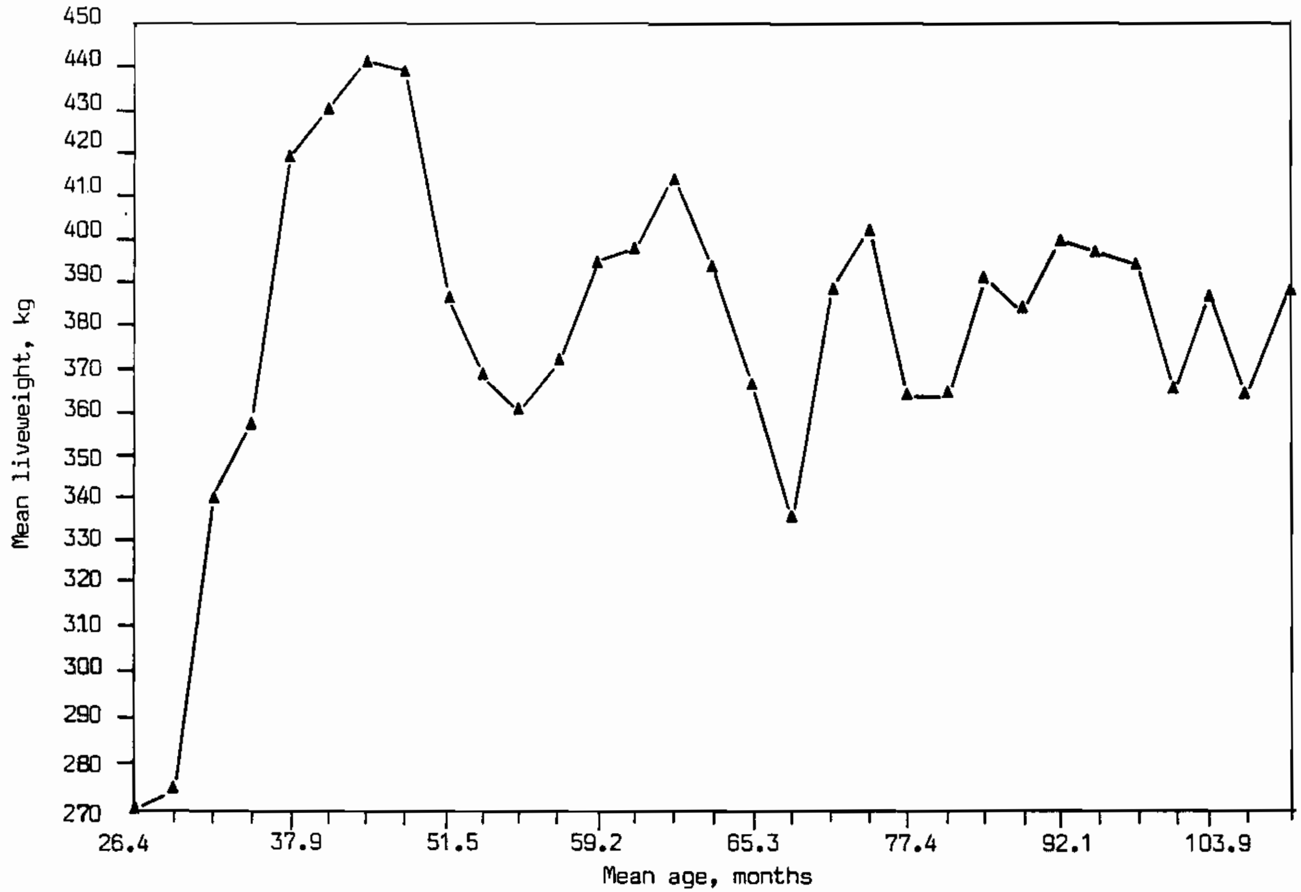


Figure 1. Evolution of liveweight in cows grazing on Brachiaria decumbens

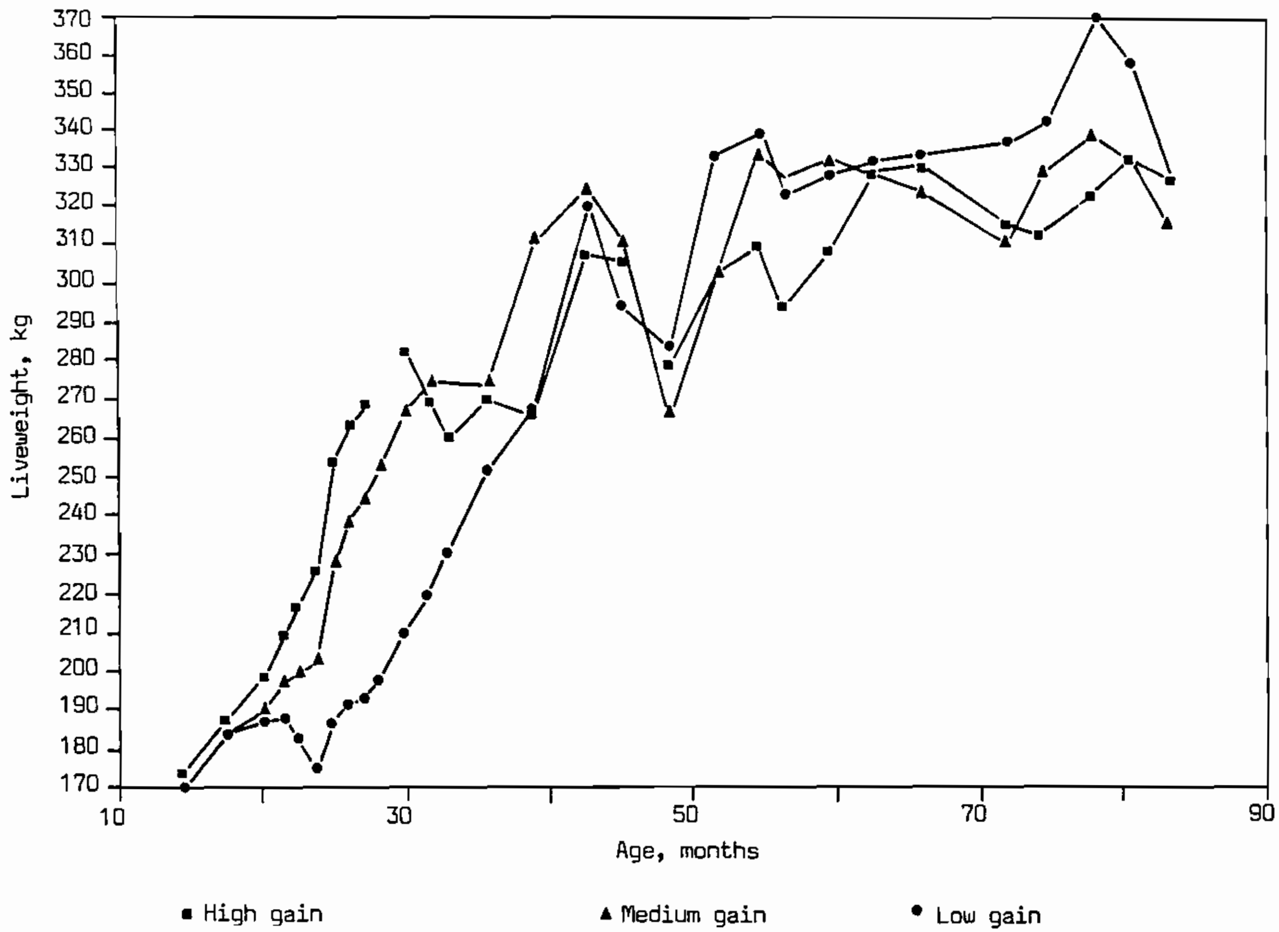


Figure 2. Evolution of liveweights in three groups of heifers

out by regressing the accumulated rates of conception on the respective liveweights. A sigmoidal model was fitted to the data for each of the three treatments. The resulting equations were used to estimate the weights required to achieve 50 and 75% conception rates. The preliminary results (Table 3) thus obtained suggest that the response of reproductive performance to increasing liveweight in the range of 270 to 310 kg is extremely steep. If this hypothesis is correct, it would explain the marked changes in reproductive performance that have been reported in past annual reports when sown pastures are incorporated to the grazing system. It further suggest that rather large improvements in reproductive performance could be achieved through modests changes in liveweight, which would probably not require high quality pastures. These conclusions are still tentative, and require a more sophisticated analysis of the available data.

Table 3. Predicated liveweights required for given rates of conception at first mating.

Weight gain as heifer	50% conception Weight, kg	75% conception Weight, kg
High	280	290
Medium	279	291
Low	272	304
All	271	292

The second temporal replication of the above three treatments is now one and a half year old. Contrary to the first replicate, upon attainment of 270 kg liveweight, the animals in each of the three groups were subdivided in two subgroups; one of these remained on Brachiaria humidicola pastures, whereas the second subgroup was transferred to a Brachiaria decumbens pasture to promote compensatory growth. Thus, six groups of animals were conformed, representing the factorial combination of three rates of growth leading to 270 kg liveweight, and two rates of gain thereafter. A summary of the rates of gain achieved until the first conception is shown in Table 4. These animals are presently in their first calving season.

Technology validation and transference

As reported in previous Annual Reports, ICA and CIAT had jointly undertaken a pilot project of on-farm pasture technology validation that would provide support for technology transference on a more massive scale. To institutionalize this pilot project within the current operational structure of ICA, the latter decided to create a regional Center for technology validation and for training of ranchers, extension agents and others. Several of these regional centers have been created throughout Colombia, under the name of CRECED. The "CRECED de la Altillanura" is headquartered in Puerto Lopez, 200 km West of Carimagua and 90 km East of Villavicencio, the capital city of the Meta Department. It is staffed by 7 professionals and a similar number of technicians; the CRECED has two branches in Puerto Gaitán and Cabuyaro. The on-farm activities of the Tropical Pastures Program in the eastern plains will now be undertaken under the umbrella, and with the technical support of, this CRECED. This center was created in July 1988, but did not become fully operational until later in the year. Nevertheless, it has already offered one short (one week) course for ranchers on pasture and livestock management, has held field days and has undertaken on-farm demonstrations related to pasture establishment and management, as well as on several annual crops.

Table 4. Weight gains of heifers subjected to different plans of nutrition.

Rate of gain		Rate of gain, kg/day	
Period 1	Period 2	Period 1	Period 2
High	High	0.197	0.215
High	Low	0.197	0.246
Medium	High	0.192	0.265
Medium	Low	0.192	0.117
Low	High	0.096	0.347
Low	Low	0.096	0.194

The provision of technical assistance for on-farm pasture establishment and management, initiated in 1985, continued in the present year. Table 5 shows the areas planted under technical supervision of the project over the last three years.

A second type of technical assistance provided by the project refers to on-farm seed multiplication of released cultivars whose demand is not yet covered by established commercial enterprises. This is especially the case of Brachiaria dictyoneura cv. Llanero; several ranchers without previous experience in pasture seed production have undertaken its multiplication. This information is summarized in Table 6, but it should be noted that additional areas have been harvested under different contractual forms, information about which can be found in the Seeds Section of this report.

Family Unit

As indicated above, the Family Unit has now completed four years operating as a family-run dual purpose operation. This was made possible by the duplication of the area sown to grass-legume pastures and the replacement of about one fourth of the cows by crossbred (Zebu x Brown Swiss) heifers, as described in previous Annual Reports.

Milking for cheese-making has been restricted to the wet season, whereas during the dry season a few cows are milked only for self consumption in the unit. On average, 10-13 cows have been milked once a day throughout the wet season, without receiving any type of supplement other than the salt lick. Within these limitations, and considering that the Andropogon gayanus-based pastures are known to be of only medium quality, milk yields have fallen within expectations. Milk yield averages, and other relevant parameters, for both the crossbred and the pure zebu cows are summarized in Table 7, according to the ordinal number of the lactation concerned. What has been most surprising is that throughout the period of time involved, cows liveweights have tended to remain constant or even increased slightly (Figure 3). Furthermore, it has been observed that milked cows, which had absolute priority in access to the improved pastures, were actually increasing their liveweights during lactation (Table 8). One possible explanation of this phenomenon is that their genetic milk potential is limiting the expression of the pasture potential for milk production, thereby redirecting the nutrients ingested towards weight gain.

The introduction of milking has implied very significant changes in the intensity of pasture use in the Family

Table 5. Summary of plantings of improved pastures on farm in the eastern plains of Colombia.

Sown Species	Hectares			
	1986	1987	1988	Total
Andropogon gayanus + Stylosanthes capitata	210	2500	480	3190
Andropogon gayanus + Centrosema brasilianum	30	80	150	260
Andropogon gayanus + Pueraria phaseoloides	-	-	20	20
Andropogon gayanus + Centrosema acutifolium	10	10	-	20
Andropogon gayanus	30	120	-	150
Brachiaria decumbens + Stylosanthes capitata	25	570	380	975
Brachiaria decumbens + Centrosema brasilianum	-	-	100	100
Brachiaria decumbens	-	250	100	350
Brachiaria dictyoneura + Stylosanthes capitata	-	200	-	200
Brachiaria dictyoneura + Centrosema brasilianum	-	-	40	40
Brachiaria dictyoneura + Arachis pintoi	-	30	-	30
Brachiaria dictyoneura	50	450	455	955
Brachiaria humidicola + Arachis pintoi	-	-	20	20
Stylosanthes capitata	30	140	55	225
Arachis pintoi	5	5	-	10
TOTAL	390	4355	1800	6535

Table 6. Harvested seed of *B. dictyoneura* cv. Llanero on farms in the eastern plains of Colombia.

Farm	Area (ha)	Species	Quantity CS*	Quantity kg
La Loma	100	*B. dictyoneura*	4.000	
Pavijay	20	*B. dictyoneura*	800	
Malibú	20	*B. dictyoneura*	100	
Buenos Aires	10	*B. dictyoneura*	180	
El Paraíso	4	*B. dictyoneura*	70	
		T o t a l		5150

* Crude Seed.

Table 7. Milk production in the Family Unit according to location number and breed of the cow.

Lactation No.	Crossbred Length day	Crossbred Total milk kg	Crossbred Milk kg/day	Zebus Length day	Zebus Total milk kg	Zebus Milk kg/day
1	165	497	2.3	213	385	2.3
2	182	545	2.8	299	516	2.9
3	164	378	3.6	130	596	2.9

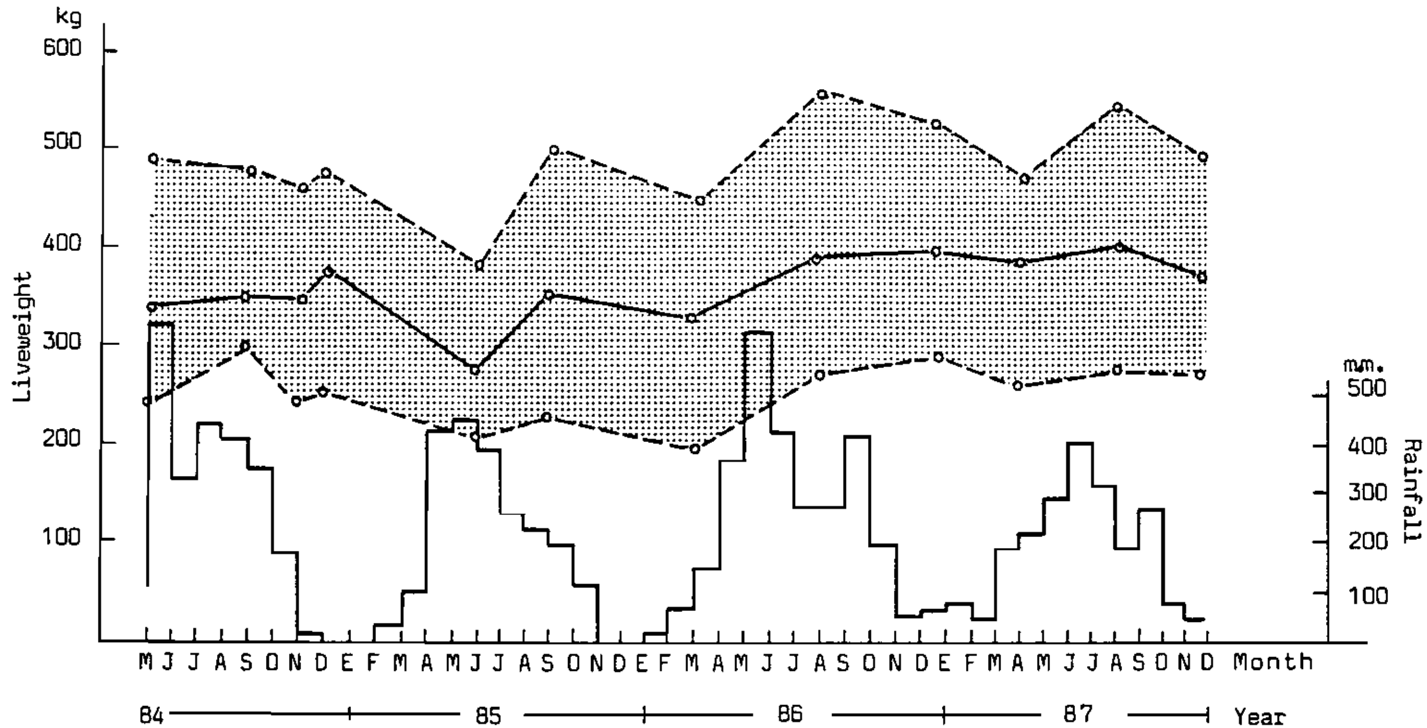


Figure 3. Evolution of mean cow liveweight (and range) in the Family Unit, and monthly rainfall

Unit. Figure 4 shows the contribution of all pastures to grazing animal units (1 AU-day is one animal unit grazing for one day); it is clear that beginning in 1985, when the area of sown pastures was increased to 50 ha (16% of the total area), the contribution of the savanna (84% of the area), decreased to under 50%. It should also be noted that the relatively small area of sown pastures was responsible for all of the milk produced. This means that a relatively small area of intensively utilized sown pastures provided not only all of the milk produced in the Unit, but was also responsible for maintaining high liveweights in the cows (Table 8), and weaning reasonable heavy calves (Table 9).

In turn, this very intensive use of sown pastures had implications on pasture persistence. In effect, the oldest paddock of Andropogon gayanus - Pueraria phaseoloides, which completed 9 years in 1988, degraded; whether this was partially due to the buildup of the population of leaf-cutting ants (described in the Entomology Section) is not known, but the net effect is that the paddock will have to be replanted.

Lastly, it should be noted that milking has not had negative effects on reproductive performance. As shown in Table 10, preliminary information regarding calving intervals, suggests that there are no differences between milked and not milked cows.

On farm research: Cerrados Region

On farm research for the Cerrados is centered at present in Brasilia (Brazil) in a joint collaborative effort with EMBRAPA-CPAC. The main objective of this project is to generate feedback regarding the bioeconomic potential of grass-legume pastures under farmers conditions.

Three improved pasture strategies have been selected for on-farm testing:

Table 8. Mean liveweight of cows at calving and weaning classified by breed and physiological condition

Breed and physiological condition	n	Weight immediately post calving kg	Adjusted (270 d) Weaning weight kg
All cows	84	333	375
All crossbred	30	353	402
All others	54	323	344
Crossbreds. milked	25	341	406
Others, milked	26	339	371
Crossbreds, not milked	5	413	381
Others, not milked	28	306	320

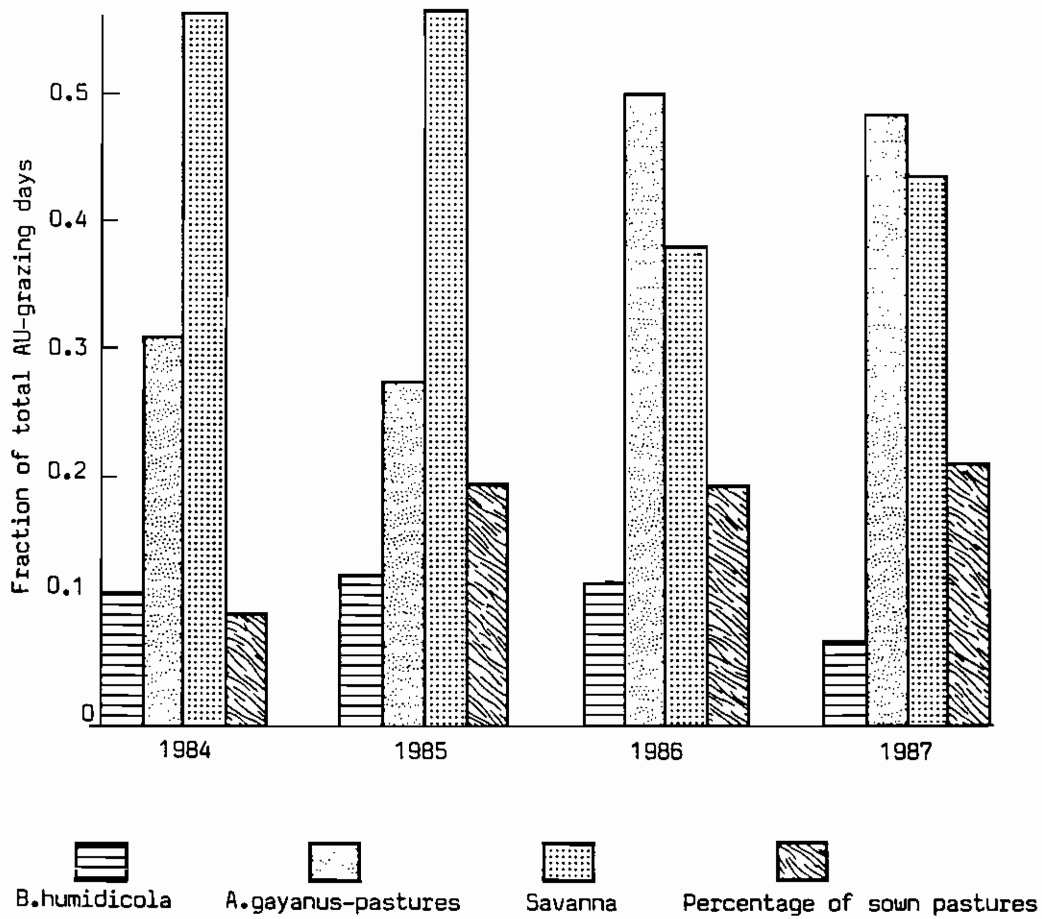


Figure 4. Pasture utilization (as animal unit-grazing days) and percentage of sown pastures in the Family Unit

Table 9. Weaning weight of calves adjusted to 270 days

Breed and physiological condition of dam	n	Liveweight kg
All animals	93	162
All crossbreds	26	166
All others	67	161
Crossbreds, milked	23	165
Others, milked	29	162
Crossbreds, not milked	3	174
Others, not milked	38	160

Table 10. Calving intervals of cows according to breed and physiological condition

Calving Interval No.	Breed	Milked ?	n	Calving interval, months
1	Crossbred	yes	12	21.5
	Other	yes	15	21.5
	Other	no	15	18.7
2	Crossbred	yes	7	18.3
	Other	yes	8	19.1

a) Grass-legume pastures based on Andropogon gayanus in association with S. capitata, S. macrocephala, Centrosema brasilianum, and/or Calopogonium mucunoides.

b) Pasture reclamation techniques to recuperate old degraded stands of Brachiaria decumbens and Brachiaria ruziziensis. This is a widespread situation for pastures in the Cerrados ecosystem, due to poor management practices (i.e. overgrazing) and lack of application of maintenance fertilizer.

c) "Protein banks", combining pure stands of Leucaena leucocephala (Cv. (Cunningham) on 30% of the area to complement either an already established grass pasture (i.e., Brachiaria decumbens), or a new one (i.e., Andropogon gayanus) or, alternatively, the native Cerrado vegetation where the protein bank will represent in this case only 6% of the total area utilized. While the first two options can better fit small to medium farms, the latter is being justified for relatively larger landholders.

The major field efforts have been concentrated in Silvania, State of Goias (approximately, 200 km SW of Brasilia), and more recently in Barreiras, Bahía State (550-600 km NE of Brasilia). The first location is broadly characterized by small to medium-size farms in soils of average fertility for the Cerrado region, and mostly dual-purpose cattle. Larger farms predominate at the second site with lower soil fertility and slightly lower rainfall conditions. Despite the low fertility of soils in the latter region soybeans are increasingly important while cattle raising is a relative minor activity at present.

Based on 1980 Census data Silvania producers had an average farm size of 228 ha, with 77 heads of cattle per farm. Annual crops (mainly, maize and rice) represented 8.7% of the total land available, while 18.7% were introduced grasses (i.e., Brachiaria sp.), and 56.1% naturalized grasses (i.e., Hyparrhenia rufa, Melinis minutiflora, Panicum maximum, Brachiaria mutica). About 47% of the herds were oriented towards beef production, 40% towards dairy, and 12.5% to both. The proportion of cows in the herds was 42% in terms of heads, which implies that the region is not a fattening one but is rather characterized by cow-calf operations. The average stocking rate was only 0.41 head (all ages) per hectare and year. The number of milking cows per farm was 19, producing 700 liters of milk per head and year, with 79% of this output being marketed to processing plants located in the area.

In the Silvania region the pastures established in the cooperating farms had an average size of 5 ha per farm. Establishment costs were shared as follows: CIAT-CPAC provided the inputs (seeds and agrochemicals), and the farmers supplied machinery, labour, fences, water supplies and animals. On the other hand, in the Barreiras region all inputs, except seeds, were provided by the farmers, reflecting their better-off economic conditions.

A total of 12 farmers (covering 14 experiments) were selected to participate in this project in Silvania, and one in Barreiras during the 1987/88 planting season (November through January), and six additional ones are being added in Barreiras for the 1988/89 season, reaching a total of 21 experiments.

On half of the experiments planted last year there was no need for any further reseeding since the stands were reasonable to excellent. On the contrary, in three trials (20% of the total for that year), plant losses were almost complete or very close to that, which will require replanting in the next season. On the remaining 30% of the experiments, the losses were partial and some reseeding will be required.

At this point it is interesting to evaluate the reasons behind these losses as a way to learn from past failures:

a) Two of the three major failures occurred on grass-legume pastures. These were associated with severe weed infestation in relatively high fertility soils with a history of previous annual crops, as well as a very significant presence of leaf-cutting ants. These two factors did not affect all the sown species simultaneously, but rather separately (one in each location). In addition, the lack of use of a roller for compacting the seedbed immediately after planting, was also identified as a factor determining irregular plant distribution and thus, partial failures, in Andropogon and Stylosanthes stands.

b) A large portion of one of the Leucaena leucocephala stands was lost due to a termite attack on the seedlings. In another case, although termites were also active, the farmer responded very rapidly and successfully in controlling the damage.

c) Although no major losses were experienced with the pasture reclamation strategy, the resulting legume stands were poor. Several factors contributed to sub-optimal establishment, including ant predation, low planting density and relatively light seedbed preparation. The latter was effected with a single, light disking, which left behind a rather high population of Brachiaria spp. which was thus able to outcompete the introduced legumes.

Another lesson learned from these trials was the fact that due to machinery (and possible man-power) limitations, farmers normally tend to plant crops early in the rainy season and only later they are ready to do the same for pasture. This has the implication that the duration of the growth period for the grass-legume stands is shortened by two to three months, reducing their chances for a stronger initial establishment, and making them more vulnerable to severe ant attacks. In addition to the other crop/pasture interactions noted (weeds, fertility levels, etc.), these experiences give extra value and justification for early on-farm validation studies of the new germplasm coming out of the selection process, to better understand the biotic and abiotic factors determining the success of grass-legume pasture establishment.

All newly introduced species were allowed to set seed during the establishment year, to insure the existence of a large seed reserve in the soil. Also, the general lack of uniformity in seed distribution at planting time, and the uneven resulting stands, imply that this practice is essential. Following seed setting, little additional rainfall was available; therefore, initiation of grazing was posponed until the following rainy season, when it is anticipated that animal performance will be evaluated.

Parallel to the field work reported above, a thorough and detailed analysis of the livestock industry in the Cerrado region was undertaken, with the aim of better understanding the context in which new pasture technology must fit.

Also as part of the above diagnostic study, an ex-ante simulation analysis was carried out to estimate the incremental physical productivity levels likely to be required by farmers for a successful adoption of new pastures. A 12% internal rate of return (IRR) was assumed to be required over the productive life of the new pastures.

Some of the most important conclusions reached in this study are as follows:

a) To achieve a 12% IRR the average cattle farmer of the Cerrado region using the pasture technologies proposed above, would have to obtain a 35-40% increase in dairy production (i.e., 342 lts of additional milk per cow and per year) or, alternatively, 88 kg more of liveweight gain per head per year, relative to the average weight gains and milk production obtainable with traditional grazing practices.

b) If the above increases are realized, and adoption is widespread, positive implications on domestic beef and milk supplies are anticipated, leading to large increases in domestic consumption of both commodities and/or increases of beef exports and reduction of milk imports.

c) A deliberate shortening of the productive life of the new pastures (i.e., from nine to six years, to allow for a crop-pasture rotation) would demand additional gains in expected physical productivity, to cover for essentially the same initial investments, unless capital outlays during the establishment phase can be significantly reduced by taking advantage of the accumulated (residual) fertility left behind by prior crop cycles.

d) The utilization of an anual crop (i.e., maize or rice) in association with the establishment of a protein bank results in very high marginal returns to the initial investments. If this practice is not applied, the IRR can drop to 25-50% that of the crop/protein bank association. Additionally, crop/pasture associations contribute remarkably well to partially finance the initial outlays in pasture investments.

e) Given that this simulation was based on the analysis of a few cases, it was not possible to draw statistically valid conclusions regarding the different strategies under experimentation. In principle it seems that all of the three approaches are economically and financially sound technologies.

f) Despite the conclusion in (e), it seems clear though that the protein bank strategy will demand from cattle producers more care and management relative to the other two procedures and therefore, its selection will be more justified in small to medium-sized farms.

g) Although neither economical nor technical restrictions appear to be present for the execution of pasture investments in Brazil, at least two potential limitations may slow down the implementation phase:

   i) Lack of liquidity by cattle producers to finance these investments (i.e., at present, rural credit for Brazilian cattlemen is not available), whenever the farmer cannot or is not willing to use crop-pastures associations or rotations.

   ii) The perception by farmers of risks in pasture establishment, that may lead them to demand a rate of return larger than the 12% assumed in the present study, to compensate for partial or total losses in the initial outlay of capital. However, it seems clear that at least part of the risks incurred in the situation described above were associated more with the learning process that with the intrinsic uncertainties of the proposed technologies.

18. Economics

Activities of the Economics Section in 1988 fell into three main areas: policy analysis, microeconomics of improved pasture technology and on farm research.

Policy Analysis

Earlier work of the section documented the shifts in the consumption patterns of meats in tropical Latin America during the last two decades. A significant increase in poultry consumption and an important degree of substitution of beef by poultry were observed. This led some analysts to question the attractiveness of investing in research to develop improved pasture technology.

To address this question a consumer producer surplus model was developed for tropical Latin America's beef market. Impact of pasture research was simulated for a 30 year period assuming a logistic adoption function with a ceiling of 10% of the region's savanna lands improved. Experimental results in terms of production increases per hectare were discounted by a factor of 0.67 to represent commercial production levels. Both closed and open economy scenarios were run. In each case scenarios with and without poultry substituting beef at the same rate observed historically for Brazil (the country with the largest decrease in relative price of poultry to beef) were run.

The results show that the return to improved pasture research in the Latin American tropics in high even if poultry continues to substitute for beef in domestic consumption and no exports are possible. The returns are very high if beef surpluses can be exported at prices close to historical levels or above. Given the growing pressure to reduce support to agriculture in developed countries, it is expected that international beef prices will trend higher. A series of sensitivity analyses for delays in the start of the adoption process, for a lower final ceiling on adoption and for increases in research costs document that given tropical Latin America's agricultural resource endowment, research into increasing the productivity of pastures on acid soils makes good economic sense.

To increase our understanding of the dairy based development process occurring in Caquetá, Colombia, a MS student from Hohenheim University conducted her thesis research on dairy development in the humid tropics, the case of Caquetá, Colombia with the objective of identifying the sectorial and regional factors explaining the observed process. Such an understanding should improve our ability to identify regions with a similar potential in order to target on-farm work and increase our awareness of other factors required besides technology to induce such a process.

The main findings of the study were:

a) The macroeconomic scenario was relatively favorable for dual-purpose tropical dairy production in Colombia during the period 1974/86. Consumption of milk and particularly of dairy products was growing; due to increases in crop production in certain areas close to the markets (such as the Cauca Valley) there were incentives to expand production in more distant areas.

b) The Caquetá region had had an active inflow of migrants during the 1950's and 60's. Crop potential is limited due to low soils fertility, high rainfall and great distance to major markets. The farming system evolved to small to medium sized cattle operations with an ample supply of family labor and few alternative uses for their resources which could enhance the cash flow.

c) Upon installation of a basic infrastructure for collection of fluid milk, its production grew rapidly from 23 million liters in 1974 to 57 million liters in 1986.

d) An econometric analysis showed that growth in production was mainly achieved through horizontal expansion of the system through the incorporation of additional cattle and additional farms. This last factor was very clearly linked to the expansion of the road infrastructure.

e) No significant supply response to changes in the relative price of beef to milk could be determined. This may be due to the limited variability in relative prices observed during the study period and to the small size of most farms thus turning labor into relatively fixed production factor.

f) There is very limited farm level evidence of increases in productivity per cow. Thus expansion, as it occurred in the past, would imply a substantial pressure on natural resources. The low productivity achieved by the existing system, which limits income growth and investment, begs the need for technical change to increase welfare of the settlers and reduce pressure on the ecosystem.

The ongoing strategic planning process has taken up an important share of CIAT economists' time. The major effort has been to draw up future scenarios for agriculture in developing countries and to present an outlook for CIAT's commodities in such scenarios. In the case of the Tropical Pastures Program the emphasis has been on beef and milk in tropical Latin America.

Microeconomic Analyses

During 1988 the seventh survey of prices of inputs and outputs of relevance for pasture technology was undertaken among researchers of the RIEPT. A 55% response to the mail survey was achieved.

Over the years 1983/87, in spite of high variability both across locations and overtime a trend of decreasing cost of the standard basket of inputs for pasture establishment, both in current US dollar terms and in kg of beef, can be observed (Table 1). In US$ the average reduction was of 7% and in terms of kg of beef it was of 17%.

It should be noted that the RIEPT locations reporting have changed overtime thus somewhat limiting the validity of the comparisons.

Among the inputs considered phosphate fertilizer price dropped at an annual rate of -3.1%, labour at a rate of -2.8% and fuels at a rate of -5.5%.

Table 1. Evolution of the cost structure of a basket of inputs for pasture establishment at RIEPT sites, 1983/1987 (US$/ha)

Inputs	1 9 8 3		1 9 8 4		1 9 8 5		1 9 8 6		1 9 8 7	
Fertilizers	38.92	(46.02)	40.70	(45.11)	35.75	(46.68)	38.87	(48.48)	34.16	(43.07)
Labor	17.77	(21.01)	17.53	(19.43)	13.57	(17.72)	14.16	(17.66)	17.15	(21.63)
Fencing wire	12.37	(14.63)	15.59	(17.28)	16.75	(21.87)	13.50	(16.84)	15.08	(19.02)
Fuel	15.51	(18.34)	16.41	(18.18)	10.52	(13.73)	13.65	(17.02)	12.91	(16.28)
Total cost										
. US$/ha	84.57	(100.00)	90.23	(100.00)	76.59	(100.00)	80.18	(100.00)	79.30	(100.00)
. kg beef liveweight	117.4		108.7		116.0		109.8		97.9	
Number of sites included	20		26		32		28		29	
Average beef price (US$/kg liveweight)	0.72		0.83		0.66		0.73		0.81	

Figures in brackets are percentages of the total cost in a given year

Only fencing wire showed an increasing price trend (2.5% p.a.). These trends expressed in current US$ reflect the fact that most Latin American economies have had to devalue their currencies in the context of the structural adjustment as a reflection of net capital outflows. Fencing wire, which has a larger imported cost component therefore shows an increase in price. It can be concluded that the macroeconomic setting has supplied the appropriate price signals for more intensive use of domestic resources, such as land, labour and fertilizers for the establishment of improved pastures.

Seed costs have a high incidence in costs of pasture establishment and thus seed prices and seed production costs are an important factor in determining microeconomic viability of improved pasture technology, itself a critical factor affecting adoption of the technology and consequently impact.

Seed production costs were budgeted for the three forage cultivars recently released by ICA in Colombia *Brachiaria dictyoneura* cv Llanero, *Centrosema acutifolium* cv Vichada and *Stylosanthes capitata* cv Capica under the conditions of the Eastern Plains of Colombia assuming that the average seed yields achieved by the Tropical Pastures Program Seed Section will be obtained and their standard agronomic practices are used. Seed producers were expected to require a 10% annual real return on capital invested in the operation.

Costs were below the commercial price of *Pueraria phaseoloides* (the only comparable seed on the market) for the case of Capica due to its high yield and ease of harvesting. *Brachiaria dictyoneura* costs are about in line with the price of *B. decumbens* (the closest substitute) on the market in spite of the fact that *B. dictyoneura* has a three times higher seed yield. This clearly reflects the fact that on the market *B. decumbens* seed is produced through opportunistic harvesting of already established pastures where the marginal costs are only the foregone grazing and the harvesting costs. Similar arrangements should allow for price reductions of *B. dictyoneura* if it is adopted more widely.

Centrosema acutifolium cv Vichada had by far the highest production costs (about US$20/kg seed). This clearly relates the expected seed yields (100 kg and 80 kg in the first and second year respectively) vis a vis the high costs of establishing and harvesting it. The existing production technique requires wood and wire support structures, very high labor input for growing the crop on the support and harvesting it manually. It additionally requires about twice the expenditure of purchased inputs needed to grow a seed crop of *S. capitata* cv Capica. Production costs of Vichada will have to be reduced in order to enhance the probability of adoption. Strategies to achieve it include the identification of locations with higher yield potential, development of lower cost support mechanisms, and agronomic practices allowing mechanized harvesting. Such research is underway in the Seed Section.

The existence of a 10 year old grazing trial at Carimagua comparing *B. decumbens* versus a *B. decumbens/P. phaseoloides* association made it possible to undertake an ex-post analysis of the comparative economics of these pastures.

The objective was to assess the benefits of including a legume and to obtain some preliminary assessment of the stability of such benefits overtime and the sensitivity of the results to the main sources of risk: decreases in beef prices, variability in yields and establishment failures.

A further question of interest to the program was the sensitivity of the results to fertilizer use given the fact that levels of fertilization used in the experiment were higher than those considered necessary at present in view of more recent research results and the observed performance of B. decumbens on farms with substantially lower levels of fertilization. The simulation model developed used experimental data on weight gains, carrying capacity in AU, establishment and maintenance inputs. Prices were those of the November 1987 and were held constant over the 10 year evaluation period. Stocking rates were adjusted downward to reflect the fact that commercial fattening operations use heavier animals than those used experimentally.

The model computes the marginal internal rate of returns corresponding to the cash flow of the incremental investments needed in an ongoing ranching operation to establish the pastures, stock them with feeder cattle and maintain the investment over the 10 year period.

The yield information (Table 2) shows that the grass-legume association outyielded the straight grass pasture in both the dry and the wet season (by 82% and 27% respectively in terms of weight gains per animal). But additionally the weight gains of grass-legume mixture presented coefficients of variation of only about half the magnitude of these of the straight grass pasture. The rate of return over a 10 year period of the mixture was of 26.8% versus 18.0% for the straight grass pasture. If the same yields could be maintained with the lowered fertilizer recommendations the IRR's would rise to 30% and 22% respectively. With yields at the lower bound of the 95% confidence range of weight gains per animal, the grass-legume association attains an IRR of 20% p.a., still above the 18% return of the B. decumbens pasture (both with fertilization costs as actually occurred in the experiment).

Pasture establishment failures are a larger risk in associated pastures due to the additional expenditure for legume seed. Under minimum input conditions legume and grass seed costs amount to about 40% of total establishment costs. To test the sensitivity of the IRR of grass-legume pastures to this risk, the total failure of establishment involving new seeding of the whole mixture was simulated. The IRR dropped from 30% to 25% under conditions of minimum fertilization. Under the experimental fertilization the IRR decreased from 26.8% to 20.0%.

In a relatively closed economy, as presently is the case of the beef market in Colombia, treadmill effects of technical change are bound to reduce prices. In order to assess the price level at which farmers would achieve the same rate of return they are presently obtaining with B. decumbens pastures, simulation runs with prices decreasing over the 10 year period to levels 10% to 50% below the current price levels were made. It was observed that with the yield levels achieved experimentally and fertilization costs incurred, prices could drop by up to 27% before IRR's leveled off. If minimum input fertilization was assumed prices could drop by up to 40% over the 10 year period.

These results indicate that there may be substantial room for price reductions before decreased profitability puts a break to the adoption process.

The present value of the marginal resources needed to establish a grass-legume mixture instead of a straight grass pasture is relatively modest (about US$55/ha at a 12% discount rate) and it generates a very high marginal IRR (approximately 125% p.a.). Nevertheless the incremental

Table 2. Weight gains achieved in grass-legume association versus a pure grass pasture and their variability by season at Carimagua. 1979/87

	Dry Season		Wet Season		Average	
	Grass[1]	Association[2]	Grass[1]	Association[2]	Grass[1]	Association[2]
Weight gains (g/head/day):						
. Mean	257.89	470.33	381.89	483.11	339.57	478.77
. Standard deviation	174.68	178.43	113.56	67.41	70.67	65.50
. Variability coefficient	67.88	37.87	29.74	13.95	23.65	13.68
. "t" value for difference of means	-2.0 *		-2.66*		-4.13*	
Average stocking rate	1.17	1.17	2.05	1.91		

* Indicates significant differences at $\alpha = 0.05\%$

1/ B. decumbens

2/ B. decumbens/P. phaseoloides

Source: TERGAS (1984), CIAT (several years) benefits are also low in absolute terms (an annuity of about US$40/ha/-annum). This may not be enough incentive for some farmers to shift to grass-legume pastures and to make the required changes in the management of their operations. This question can be tackled more appropriately within the context of on-farm research.

On-farm Research

On-farm research continued to be the major thrust of the Section in 1988. As stated in the 1987 Annual Report a series of initiatives were taken up, which should document the technical and microeconomic viability of using grass-legume pastures under farmer conditions and generate feedback to the program on constraints for their adoption.

An additional expected output is the development of appropriate methodologies for on-farm research, which ought to be made available to NARDs through the RIEPT.

a) Cauca/Valle region

Strategy and objectives of this collaborative effort with regional development institutions were presented in the 1987 report. Major activities in 1988 included:

- Analysis of the first results of the Regional Trial B in Mondomo: this trial indicated that *Centrosemas* might be a valuable germplasm alternative for this ecotype, particularly *Centrosema macrocarpum* CIAT 5740. The initial selection of *Desmodium ovalifolium* CIAT 350 and *Arachis pintoi* CIAT 17434 was disappointing due to the lack of adaptation of *Arachis pintoi* to most soils and the extremely slow establishment of *D. ovalifolium*. This has led to the establishment of Regional Trial Type A including a wider range of legume germplasm, particularly *Centrosemas*.

- Vegetative material of *Brachiaria dictyoneura* CIAT 6133 and *B. humidicola* CIAT 679 were made available to 45 farmers in the first semester of 1988. In the second semester a similar demand is taking place. Demand for legume material has been weak due to lack of credibility and grazing trials to document impact in the region.

- A database was established on users of the vegetative material delivered, which is generating feedback on the range of adaptation of the materials, establishment techniques by farmers and problems encountered. Table 3 presents the major features of *B. dictyoneura* users in Cauca.

- Establishment of mixed pastures on farms to monitor production under grazing with dairy cows. Based on the above reported experiences pastures have been established as cocktails with *B. decumbens* CIAT 606, *B. dictyoneura* CIAT 6133 as grass components and *C. macrocarpum* CIAT 5713 and CIAT 5740, *C. acutifolium* CIAT 5568 and CIAT 5277, and *D. ovalifolium* CIAT 350 and CIAT 3788 as legume components on four farms.

  Grazing has been initiated in two cases and the rest should be ready within the first semester of 1989.

- Agronomic trials on the introduction of legumes into existing native pastures in the Jamundí region have been completed and a grazing trial of legume strips in native pastures is under way. A pasture establishment trial in association with cassava crop has been planted in the Mondomo region. These trials are managed by the Soils and Plant Nutrition Section of the Program.

Table 3. Characteristics of early users of B. dictyoneura cv Llanero in Northern Cauca/Colombia, 1988 (45 farmers)

Average plot size	0.6 ha
Plot history:	
Cassava	48%
Fallow	22%
Native pasture	16%
Vegetables	12%
Plot altitude:	
between 1650 and 1850 m.a.s.l.	23%
Plot purpose:	
Pasture	58%
Multiplication of vegetative material	38%
Expansion plans:	
B. dictyoneura	80%
B. humidicola	7%
B. decumbens	5%
Farm size:	
Under 5 ha	32%
Under 10 ha	64%
Under 20 ha	83%
Cattle ownership:	
Have cows	77%
Milk cows	65%
Milk cows in dry season	60%

Source: Survey

b) Caquetá (Colombia)

In this region collaborative activities between CIAT and the regional institutions ICA, Fondo Ganadero del Valle del Cauca (FGV), NESTLE de Colombia, Universidad de Amazonía, INCORA, SENA have been very active.

- Several BS thesis projects were undertaken in the area of pasture establishment rendering insights into questions of use of fire, herbicides and mechanization to establish grass-legume pastures at reduced costs.

- Adaptation of the germplasm tested (mainly D.ovalifolium CIAT 350, A. pintoi CIAT 17434, B. dictyoneura CIAT 6133, has been very successful. Based on information of the Regional Trial B at ICA-Macagual and other experience in the ecosystem Stylosanthes guianensis CIAT 184, C. acutifolium CIAT 5568 and CIAT 5277, and C. macrocarpum CIAT 5713 were introduced for seed multiplication and on farm trials.

- Several institutions have successfully established vegetative material multiplication lots and these materials are already being made available to farmers.

- Commercial scale pasture establishments were made at Hacienda "La Rueda"-FGV and Hacienda "La Vorágine". They are starting to be grazed and should generate weight gain and milk production information.

- In collaboration with the Technical University of Berlin (TUB) and ICA a project was started to assess the contribution of grass-legume pastures for milk production in dual purpose herds. Research is conducted both on-station and on-farms. Plots of grass-legume pastures involving several legumes (Stylosanthes guianensis CIAT 184, D.ovalifolium CIAT 350, Centrosema macrocarpum CIAT 5713, C. acutifolium CIAT 5277) and the grasses Brachiaria dictyoneura and B.decumbens have been already established on four small farms and on the ICA-Macagual Research Station. Grazing should start in April-May 1989.

c) Napo (Ecuador)

The Tropical Pastures Program was involved in a diagnostic survey of smallfarmer agriculture in the lowland tropics of Northeastern Ecuador in 1986. This was a collaborative activity with USAID, IDRC, ICA and DINAF/MAG. CIAT was then asked to collaborate in a more in depth study of the technical and economic viability of the pastures and agroforestry technologies being developed as well as an ex-ante assessment of the potential impact of the project. Such an activity coincided with the CIAT interest to expand its expertise in humid tropics farming systems and particularly agroforestry systems. The marked differences in rainfall, soil fertility and socioeconomic environment with the Pucallpa region made it particularly attractive to expand the institution's stock of knowledge in this area in general and to generate feedback on the performance of selected forage germplasm under these conditions.

A project proposal by FUNDAGRO/CIAT resulted in the funding of a CIAT Postdoctoral Fellow to work with a sociologist hired by FUNDAGRO for 18 months in a project entitled "socio-economic impact of improved agro-silvopastoral technology for humid tropics smallholders in Napo, Ecuador. The economist was posted in Quito in August, 1988.

The Ecuatorian Amazonia is generally acknowledged to be a very fragile ecosystem. Existing land settlement tends to make a very inefficient use of this resource leading to its degradation. On the other hand, Ecuador is under pressure to use this ecosystem as a second best alternative to politically non-feasible solutions such as agrarian reforms or complete bans on land use.

To cope with this dilemma several institutions (MAG-DINAF, INIAP, AID, IICA, IDRC, CIAT) are working in the development of more productive, and sustainable low external input systems which combined with appropriate land tenure policies will reduce the pressure to clear increasing areas of forest.

Within that context the Agroforestry Project of Napo Province (MAG-DINAF/-AID), has been introducing improved pasture and agroforestry technology in smallholdings of the region since 1983. This project calls for a need to assess, through on-farm research, the extent at which such innovations are fulfilling the objective of developing economically viable and ecologically stable farming systems. To do so a collaborative agreement among CIAT/-FUNDAGRO/MAG/AID is in effect since August 1988.

The main objective of this study is to determine the potential technical and socioeconomic impact of technological innovations promoted by the Agroforestry Project MAG-DINAF/AID in the colonization area of Napo Province where red latosols prevail. To accomplish such a general objective the study aims to:

- Quantify the technical coefficients of the major agroforestry system's components under both the traditional and improved technology.

- Appraise the technical and economic feasibility of the new improved technology at both farm and regional level.

- Appraise the progress made by the project in terms of adoption of improved agroforestry and pasture techniques by producers.

- Document changes in the socioeconomic environment (project output markets, policies influencing regional development) to understand the performance of the project.

- Quantify the performance of the project through an assessment of financial costs and project benefits.

- Document the distribution of project benefits among different farmer groups and consumers and its impact on people's welfare.

The study assumes that a major impact of the ongoing transfer of improved technology by the Agroforestry Project will be an increased farm income (I) over time.

In turn, farm income can be expressed as:

$$I=f(TP,PP,LP,CP,SP,IS,PR,AR/E,RE)$$

Where:

TP = trees productivity
PP = pastures productivity
LP = livestock productivity
CP = coffee productivity
SP = species persistence
IS = input savings (labor and purchased inputs, i.e. herbicides and pesticides)
PR = input-output price relationships
AR = adoption rate of improved technology
E = ecological environment, and
RE = farmer's resource endowment

By estimating the farm income stream coming from both traditional and improved agroforestry techniques an income surplus can be generated which is assumed to represent the net impact of the technology transfer process at the farm level. This surplus can be adjusted by the rate of adoption of new technologies to determine the project's impact at regional level within a farm/region simulation model framework. Using a consumer producer surplus frame the distribution of project impacts between different farmer groups and consumers will be examined. Through surveys of the target farmer population it will be determined how this surplus is allocated by farmers to better housing, nutrition, education, etc.

To derive technical coefficients of the agroforestry system, selected farms (farm case studies) which are adopting project technologies are monitored. This information will be used to analyze the private profitability of the improved technology and its acceptability by producers.

Data is being gathered at plot level including physical measures such as: cattle inventories, stocking rates, liveweight gains, cattle extraction rates, tree growth, coffee yields, use of labor and purchased inputs, costs of pasture as well as coffee and tree establishment and maintenance, evolution of soil conditions (fertility, compaction), botanical composition of pastures overtime, pasture quality and productivity, incidence of pests and diseases, etc. These parameters will allow an assessment of the agroeconomic performance of trees/legume-coffee associations and trees/grass-legume associations to generate feedback for further research and development activities.

Main technological innovations monitored are:

- Introduction and management of timber trees (mainly Cordia alliodora, Jacaranda copaia and Schizolobium spp) associated to Brachiaria humidicola INIAP-NAPO-701 and coffee (Coffea canephora var robusta).

- Utilization of Desmodium ovalifolium CIAT 350 as a cover crop in coffee plantations.

- Establishment and management of Brachiaria humidicola INIAP-701 and Desmodium ovalifolium CIAT 350 associations with trees.

Since the start of this activity (August 1988) 27 farmers have been identified who have accepted to participate in a range of on-farm research activities, mainly involving detailed monitoring of plots with introduced technologies and control treatments. These activities include:

- Measurement of productivity of young coffee plantations (less than 5 years old) with and without timber trees and legume ground cover of Desmodium ovalifolium CIAT 350.

- Assessment of the impact of improved management of older coffee plantations with and without timber trees intercropped and legume ground cover (D. ovalifolium CIAT 350).

- Monitoring of persistence of Brachiaria decumbens CIAT 606 and B. humidicola CIAT 679 under farm conditions.

- On-farm agronomic evaluation of promising new Brachiaria cultivar B. brizantha CIAT 6780 cv Marandu and B. dictyoneura CIAT 6133 cv Llanero.

- Establishment of grass-legume associations and introduction of legumes to existing B. humidicola swards.

All these on-farm case studies involve monitoring of agronomic performance as well as use of labor and purchased inputs in order to generate the coefficients required for the subsequent economic analyses.

In October 1988 the Agroforestry Project Team detected sparsely scattered foci of the insect Stephanoderes hampei attacking coffee plantations in the region. This insect is a major pest in coffee which is expected to severely reduce the productivity of coffee plantations in this area. Given the dominant role of coffee as an income source and the lack of other alternatives, an increased interest in pastures and possibly an expansion of dual-purpose milk production are to be expected. Thus the project may be able to make a very timely contribution to the diversification and sustainability of the farming systems.

d) Pucallpa (Perú)

The initiation of the project "the role of pastures in mixed farming systems in the Western Amazon" by a Rockefeller Foundation Post Doctoral Anthropologist was reported in the 1987 Annual Report. A detailed account of the objectives, methodology and initial activities was then given.

Livestock, and particularly cattle raising, is an integral component of farming systems among settlers who colonize the western Amazon. Cattle are grazed on planted pastures that are sown with or shortly following annual crops (maize, rice or cassava) in systems of shifting cultivation. The planted pastures (Brachiaria decumbens in the area of interest) are initially productive but after three to four years declining fertility, soil compaction and weed invasion lead to a process of pasture degradation resulting in lower productivity. Eventually the land is abandoned and must remain fallow for extended periods of time until the plot recovers, vegetation is cut and burned and the cycle starts again.

This system of "shifting grazing" is inherently unstable due to its negative environmental impacts. The process of grazing and weed control accompanied by periodic burning and bouts of overgrazing leading to soil compaction, increased run-off and erosion, and delays the process of natural vegetation recuperation upon which the small farmer depends in order to resow annual crops and fresh pastures which form the basis of the farming strategy.

The Tropical Pastures Program is developing new technological options for these farmers consisting principally of improved pasture grasses and tropical forage legumes that are able to persist and maintain their productivity over extended periods of time. The inclusion of legumes is critical due to their biological nitrogen fixing capability and their contribution of protein in the animals' diet. This project has involved the introduction of improved pasture species in farmers' fields in order to gauge their adaptability to prevailing agroecological conditions and management strategies and to assess their potential impact on. The goal of the research is to determine whether grass-legume mixtures are compatible with current farming systems and to assess their potential for large-scale adoption. This research attempts to evaluate the technology from the farmer's perspective in order to anticipate barriers to successful use and adoption.

The research has basically focused on three major aspects of pasture adaptation and adoptability: (1) factors affecting pasture establishment, (2) comparative establishment costs of improved vs traditional pastures, and (3) the impact of improved pastures on animal production. In addition the project has also been investigating the feasibility of artisanal forage seed production by small farmers and the effect of Rhizobium inoculation on legume establishment under on-farm conditions.

On-farm trials covering 20 hectares were sown in October-November 1987 on twelve farms in the Pucallpa region. One farm was eliminated from the project due to lack of collaboration of the farmer while three more, located at some distance from Pucallpa were eliminated (after successful pasture establishment) due to problems of political violence in the region. Thus eight farms are currently under study.

Establishment. Pastures were successfully established on all the farms under observation. In all cases pastures were established after cutting and burning bush fallows of 1-5 hectares. The lots were chosen by the farmers and had lain fallow from 4-8 years before sowing. Before burning the plots were studied in order to determine their approximate biomass, botanical composition and soil chemistry. After sowing the plots were carefully monitored in order to document the establishment process and facilitate the identification of key factors in the establishment of grass-legume pasture in this environment. Data was collected on botanical composition of the pastures, rate of soil coverage and the labor input required during the establishment phase. The same data was recorded for control plots of Brachiaria decumbens sown adjacent to the grass-legume mixtures. Key factors affecting pasture establishment are the following:

1) Years of fallow: the fallow period is important for the recovery of soil fertility and the progressive suppression of weedy flora as abandoned fields are colonized by native arboreal vegetation.

2) Land use history: the type of land use preceding abandonment and initiation of the fallow is important in determining the rate of soil/vegetation recovery and subsequent suitability for cultivation. It appears that under current conditions grazing postpones recovery of fertility and domination of aggressive pasture weeds.

3) Management: management, especially labor input for weeding (the primary and most variable input) is important in pasture establishment. The importance of management varies with the difficulty of initial conditions; in shorter or more degraded fallows management is critical for successful establishment while after longer fallows its importance is reduced. To a certain extent management can be substituted for time in shortening the fallow cycle.

4) Appropriate germplasm: Different germplasm is appropriate for specific agroecological zones, microenvironmental conditions and management strategies. Improved pastures are context specific and recommendation guidelines must specify the correct match of germplasm and environmental conditions.

While these conclusions regarding establishment are not entirely surprising the documentation of possible negative impacts of grazing is an insight that deserves increased attention by researchers. To what extent can these negative impacts be avoided by appropriate germplasm? To what extent are improved management skills necessary to avoid degradation -- independent of germplasm? And to what extent are negative impacts an inevitable consequence of grazing on heavy soils in a humid environment?

On the positive side this research illustrated that improved pastures establish readily after relatively short fallow periods without excessive labor investment and with no chemical inputs (Data on labor inputs is still under analysis, but it appears that only marginal increases in labor are necessary to establish grass-legume pastures compared to _Brachiaria decumbens_). Complex management and high labor inputs are not necessary to establish grass-legume pastures and difficulty in establishment does not appear to be a barrier to technology adoption.

Impact on animal production. In October 1988 the project initiated data collection on animal production on four of the eight farms under observation. The other four farmers burned their plots at the end of the dry season to control excessive weed growth and the pastures are in the process of recovery. They will enter in production at the end of 1988/-beginning of 1989. Data on animal production will be assessed through daily measurement of milk production by cows that are grazed in rotation on grass-legume and pure grass pastures. The hypothesis to be tested is that the improved diet of grass-legume pastures will increase milk production when the animals are grazing these paddocks and decline when animals graze pure grass pastures. Farmers have been trained to keep daily records of milk production of individual animals -- the latter allowing us to control for varying genetic potential among animals and differing stages within the lactation period, both of which are important exogenous variables influencing milk production. At the same time we will continue to document the floristic evolution and forage production of these pastures to compare their persistence and productivity over time. These data probably are the first set of on-farm data from the South American humid tropics measuring the impact of grass-legume pastures on animal production. As such they are very valuable in calculating cost-benefit ratios of technology adoption, impacts of improved pastures on farmer incomes and potential effects of mass adoption on regional economies.

Artisanal Seed Production. In November 1987 the project planted two small (0.25 ha and 0.33 ha) seed multiplication plots of _Stylosanthes guianensis_ on farms. The management techniques employed in the two plots were varied. The 0.33 ha plot was sown according to CIAT Tropical Pastures Program Seed Section guidelines: their was no companion planting, the seed crop was planted in rows, fertilized and received two weedings. The smaller plot was intercropped with rice, sown broadcast, received no fertilizer and one light weeding. The plots were harvested in July 1988. Table 4 presents a comparative economic analysis of the costs of production of the two plots. Note that although yield was much lower on the smaller, intercropped plot, so

Table 4. Comparative costs of artisanal seed production of Stylosanthes guianensis in Pucallpa, Peru. 1987/88 (US$)[1]

	Plot 1 (Size 0.33 ha)	Plot 2 (Size 0.25 ha)
Production (kg)	28.0	6.8
Costs:		
Labor[2]	175.0	31.3
Fertilizer	7.4	
Insecticide	0.2	
Machinery	6.3	
Others	3.3	2.2
Total cost	192.1	33.5
Cost per kg	6.9	4.9
Return per man-day[3]	3.4	4.8

1/ Preliminary figures.
Exchange rate:
- Nov/87 = Inti 80/US
- Jun/88 = Inti 165/US

2/ Wage per man-day inputed at US$2.5

3/ At a purchase price of US$9.1 per kg seed

were labor input and other costs, enabling this farmer to produce seed at a lower cost per kilogram and realize a larger return per labor unit. The comparison is not entirely fair as the two plots were quite different from the outset --with the larger plot sown in a 6 year bush fallow and the smaller plot sown in cut primary forest. Also the crop year was atypical with the farmer of the smaller plot loosing most of his rice crop to drought. It should also be noted that now that the plots are established they can continue to be harvested with no additional establishment costs, lowering the costs of production substantially. The relatively high labor input in harvesting is a disadvantage in farming systems like those under study in which labor, not land, is limiting. But fortunately the harvest occurs during a slack period in labor demand, avoiding conflict with other essential farming activities.

Despite the data's limitations, the results are instructive and suggest that in order to justify the costs of additional inputs for forage seed production a companion crop such as maize which would produce a marketable harvest (in most years) would aid in reducing costs. The experience also suggests that artisanal seed production of Stylosanthes guianensis is feasible at early stages in the seed multiplication process before commercial growers become involved provided that the seed purchase is guaranteed.

Legume inoculation on-farm. At the time of sowing grass-legume pastures it was decided to sow one half of the study plot with seed inoculated with the appropriate Rhizobium strain recommended by the program microbiologist. The other half of the plot was sown with no inoculation. The hypothesis tested was that inoculation would increase significantly the quantity of legume in the field. During the establishment phase data on botanical composition were recorded separately for inoculated and non-inoculated treatments. At the end of the establishment period the percentage of legume in the two treatments was analyzed by performing an analysis of variance on the logarithms of the percentages. Significant differences could be detected between farms (p=0.001) and treatments (p=0.02). Significantly more legumes were growing in the inoculated fields. While the data on biological yield are interesting this result does not answer the question of whether legume inoculation has a significant impact on economic yield and is therefore justified at the farm level. This research can not answer that question but suggests lines for future study.

Conclusion. The research reported here presents some interesting preliminary results. The area where the most solid inferences can be made is in the area of pasture establishment. It appears that, given appropriate germplasm and farmer management, that establishment of improved grass-legume pastures is feasible in relatively short bush fallow systems. This research is less clear on issues such as impacts on productivity and pasture persistence, though these issues can be addressed in the present research design given sufficient time.

This research also suggests priority areas for future study. Particularly urgent is more research on the dynamics of pasture degradation in the humid tropics in an attempt to separate out factors associated with soils, germplasm and management. More thought needs to be given to the implications of pasture degradation in mixed farming systems where the integration with food crops is an essential element of farmer survival strategies.

On-farm research in pastures is capable of producing valuable research results, though as with all pasture research the long time frame requires longer term investment in research and considerable patience. The long term nature of the research presents particular obstacles in the on-farm setting where farmer collaboration with researchers may have a limit. For example it is not clear how long farmers will be willing to record data on milk production before "informant exhaustion" sets in. Continued on-farm research is essential in order to generate realistic technical coefficients of existing systems, document the impact of improved pastures on animal production and predict the potential return to research investment in tropical pastures.

Other Activities

The section continued to collaborate with ICA in the field of economic analyses of activities in the Eastern Llanos. In line with the increasing effort by ICA to transfer Carimagua Research Station results to farmers, an ex-ante analysis of the economics of such an extension program was made. It documented that a small scale effort with two professionals, five technicians and funds to operate efficiently could have a substantial impact generating an internal rate of return of between 25% and 60% p.a. in real terms according to the assumptions made about the extent to which more intensive dual-purpose production could be developed in the region.

The section is also collaborating with overseas universities in the supervision of two Ph.D dissertations of economists working with NARS in Colombia and Peru. Dissertation topics in both cases relate closely to areas of common interest to the CIAT Tropical Pastures Program and the respective national institution.

19. Training in Tropical Pastures: Present and Future

Events at CIAT

In collaboration with the different sections of the Tropical Pastures Program (TPP), during 1988 Training and Communications Program (TCP) offered research training to 70 professionals from 15 countries in 11 different disciplines. Training included various categories, as shown in Table 1. The sections that dedicated more time in this task were: Pasture Quality, 67.1 man/months. Soils/Plant Nutrition, 39.7; Agronomy, 20.7; Seed Production, 12.6; and Pasture Development, 10.9. Table 2 presents the number of researchers trained per country of origin during 1988.

Regular training events

The intensive multidisciplinary phase of the XI Scientific Research Training Program for Tropical Pasture Production was carried out between 1 February and April 29, with the participation of 26 professionals from 10 countries in tropical America (Table 3). Of these professionals, 13 stayed for the Specialization Phase in different disciplines, depending on their specific interests and areas of research. Length of these varied from 1 to 4 months. Eleven participated in a special event on "Methodologies for the Evaluation of Pastures under Grazing Trials".

Special training events

Between 9 May and 10 June, 1988, the Course/Workshop on "Methodology for the Evaluation of Pastures under Grazing Trials" was carried out at CIAT. This event was organized by the Pasture Quality and Productivity section of the TPP and the TCP. A total of 27 researchers from eight Latin American countries participated; 16 of these are currently participating in grazing trials in the RIEPT and 11 the XI Scientific Research Program for the Production and Utilization of Tropical Pastures, received this Course-Workshop as their Specialization Phase (Table 4).

The event included four cycles, as follows: A first, one-week cycle of conferences and discussion for which the following lecturers were invited: Dr. Lucia Pearson de Vaccaro, Universidad Central de Venezuela, Dr. Danilo Pezo, CATIE (Costa Rica), Dr. Domicio do Nascimento, Jr. (University of Vicosa, Brazil). Members of CIAT's TPP also participated as lecturers. A second, two-weeks cycle of field practices on sampling methodologies in pastures; third, one-week cycle on data processing and analysis of experiments under grazing in the microcomputer; and fourth, one-week cycle on the elaboration of a special project.

Decentralized Events

At the country level

The experiences acquiered by CIAT's Training and Communications and

Table 1. Professionals trained at CIAT during 1988 by Program or Unit, discipline of specialization and training category.

	TRAINING CATEGORY															
	Visiting Researcher Associate				Visiting Researcher						Special Course		Intensive Multidisciplinary Course			
PROGRAM: PASTURES	Thesis Ph.D.		No. Thesis		Thesis MS		Specialization		Specialización + Intensive Multidisciplin. Course						Sub-totales	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
DISCIPLINE:																
AGRONOMY									4	(20.7)					4	(20.7)
PASTURE DEVELOPMENT					1	(3.6)	2	(7.3)							3	(10.9)
ECONOMICS AND SOCIAL SCIENCES									1	(3.6)					1	(3.6)
ENTOMOLOGY							2	(1.6)							2	(1.6)
FARMS-SYSTEMS									2	(6.7)					2	(6.7)
PHYSIOLOGY									1	(5.5)					1	(5.5)
INTERDISCIPLINE													2	(4.1)	2	(4.1)
PASTURE QUALITY					1	(12.0)	1	(1.0)			27	(29.2)	11	(24.9)	40	(67.1)
PATHOLOGY							1	(2.6)							1	(2.6)
PRODUCTION	1	(2.1)													1	(2.1)
SEEDS							1	(2.8)	2	(9.8)					3	(12.6)
SOILS	1	(0.2)			1	(12.0)	6	(11.5)	3	(16.0)					11	(39.7)
TOTAL PROGRAM	2	(2.3)			3	(27.6)	13	(26.8)	13	(62.3)	27	(29.2)	13	(29.0)	71	(177.2)

Table 2. Number of professional trained in CIAT, DURING 1988 category and country of origin.

PROGRAM: PASTURES	TRAINING CATEGORY															
	Visiting Researcher Associate				Visiting Researcher						Special Course		Intensive Multidisciplinary Course			
	Thesis Ph.D.		No. Thesis		Thesis MS		Specialization		Specialización + Intensive Multidisciplin. Course						Sub-totales	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
LATIN AMERICA AND THE CARIBBEAN																
ARGENTINA							1	(1.0)							1	(1.0)
BOLIVIA											1	(1.2)	1	(2.3)	2	(3.5)
BRAZIL							6	(15.5)	2	(10.4)	7	(8.2)	3	(6.0)	18	(40.1)
COLOMBIA	1	(2.1)			1	(12.0)			1	(5.5)	7	(7.1)	3	(6.6)	13	(33.3)
COSTA RICA									2	(11.8)	1	(1.0)	1	(2.3)	4	(15.1)
CUBA									1	(3.2)					1	(3.2)
ECUADOR							3	(3.0)							3	(3.0)
GUATEMALA									1	(5.4)					1	(5.4)
HONDURAS									3	(11.8)					3	(11.8)
MEXICO							2	(4.7)	1	(3.5)	5	(5.0)	2	(4.5)	10	(17.7)
PANAMA											1	(1.0)			1	(1.0)
PERU					2	(15.6)			2	(10.7)	4	(4.6)	2	(4.9)	10	(35.8)
VENEZUELA							1	(2.6)			1	(1.1)	1	(2.4)	3	(6.1)
DEVELOPED COUNTRIES																
SWITZERLAND	1	(0.2)													1	(0.2)
TOTAL PROGRAM	2	(2.3)			3	(27.6)	13	(26.8)	13	(62.3)	27	(29.2)	13	(29.0)	71	(177.2)

Table 3. Information on the researchers participating in the XI Scientific Research Program in Tropical Pastures, 1988.

Name	Country	Institution	Profession	Work areas[a]	Time % in Trop.Past. activities	Type of Training: Courses + Specialization	Duration (weeds): F.I.	F.E.	C.E.[c]
Ruddy Rodrigo Meneses	Bolivia	CIF-La Violeta	Eng.Agr.	3-4-5-6-7-9-11-16	35	SC[b] + SC[c]	9	-	5
Nilzemary Lima de Silva	Brazil	EMBRAPA	Eng.Agr.	4	100	SC + CE	9	-	5
Sebastino de Oliveira	Brazil	CEPLAC/CEPEC	Eng.Agr.	9-10-13	70	SC + CE	9	-	5
Marcos Almeida Souza	Brazil	CEPLAC/CEPEC	Eng.Agr.		70	SC + Soil Microbiology	9	15	-
Claudia de Paula Rezende	Brazil	CEPLAC	Zoot.	4-12a	70	SC + Seed Production	9	14	-
Beatriz Lampp	Brazil	Univ.Fed.MS	Zoot.	1-9	40	SC	9	-	-
María Cristina Cardona B.	Colombia	CENICAFE	Med.Vet.Zoot.	4-13	80	SC + CE	9	-	5
Guillermo Conrado Delgado	Colombia	Inst.Asun.Nucl.	Eng.Agr.	7-17	30	SC	0	-	-
Jorge Marín Agudelo	Colombia	Sec.Agr.Ant.	Zoot.	3-4-7-9-11	10	SC + CE	9	-	5
Gustavo Maldonado Ferrucho	Colombia	ICA	Eng.Agr.	1-3-4--6-7-9	100	SC + CE + Ecophysiology	9	10	5
José Carlos Vargas Zeledón	Costa Rica	MAG	Lic.in Agron.	1-5-6-7-7-8-9-11	20	SC + Forages Agronomy	9	17	-
Marco Vinicio Lopo DiPalma	Costa Rica	MAG	Eng.Agr.Zoot.	1-4	20	SC + Forages Agronomy	9	17	-
Ricardo Rodriguez Navarro	Costa Rica	MAG	Eng.Agr.Zoot.	4-9	20	SC + CE	9	-	5
Jesús N. Alberto Pérez	Cuba	MINAG	Eng.Zoot.	3-12b-12c	100	SC + Past.in Livestock Prod.	9	4	-
Byron Omar Barrios Chicas	Guatemala	ICTA	Eng.Agr.		80	SC + Forages Agronomy	9	17	-
Jorge Américo Rush Ochoa	Honduras	SAN	Eng.Agr.	12a-12b-12c	30	SC + Seed Production	9	12	-
Tulio Edgardo Chinchilla	Honduras	SAN	Eng.Agr.	13	40	SC + Past.in Livestock Prod.	9	8	-
Elizabeth Santacreo Ponce	Honduras	SAN	Eng.Agr.	17	0	SC + Economics	9	8	-
Edgar Enrique Souza R.	Mexico	INIFAP	Eng.Agr.Zoot.	1-3-4-8-12a	80	SC + CE + Forages Agronomy	9	-	5
Manuel Barrón Arredondo	Mexico	INIFAP	Eng.Agr.Zoot.	4-9	80	SC + CE	9	-	5
Juan Esteban Reyes J.	Mexico	INIFAP	Eng.Agr.	1-3-7-9-13	100	SC + CE	9	-	5
P. Deyay Lara Carretero	Peru	EEY-INIAA	Eng.Zoot.	1-4-7-9-12a-12b	100	SC + CE	9	-	5
Edgardo Leoncio Braul G.	Peru	PEP	Eng.Zoot.	13	40	SC + Soils/Plant Nutrition	9	15	-
Gustavo Horacio Celi A.	Peru	Univ.Nal. U.	Eng.Agr.	1-17	20	SC + Soils/Plant Nutrition	9	15	-
Luis Eduardo Hernández S.	Peru	IVITA/INIAA/CIAT	Eng.Zoot.	4-11-12a-12b-13-14	100	SC + Past.in Livestock Prod.	9	3	-
Adolfo Ramón Torres Q.	Venezuela	FONAIAP	Eng.Agr.	1-2-3-12c	100	SC + CE	9	-	5

a/ Code of working areas: 1 = Germplasm Evaluation; 2 = Plant Breeding; 3 = Agronomy Tropical Pastures; 4 = Regional Trials-RIEPT; 5 = Plant Pathology; 6 = Entomology; 7 = Soils/Plant Nutrition; 8 = Soils Microbiology; 9 = Pasture Quality and Productivity; 10 = Ecophysiology; 11 = Pasture Development; 12a = Seed Production-Research;; 12b = Basic Seed Production; 12c = Commercial Seed Production; 13 = Livestock Production;; 14 = Agricultural Economics; 15 = Biotechnology; 16 = Recuperation of Degraded Pastures; 17 = Others.

b/ Intensive Multidisciplinary Course and Study Trip.-

c/ Special Course "Methodology for the Evaluation of Pastures under Grazing Trials".

Table 4. Information on researchers participating in the Course-Workshop.

Name	Country	Institution	Profession	Activity	Discipline	Dedication (%)
Ruddy Rodrigo Meneses A.	Bolivia	C.I.F. La Violeta	Eng.Agr.	Research	Agr.pastures	100
Saladino Goncalves Nunes	Brazil	EMBRAPA/CNPGC	Eng.Agr.M.S.	Research	Eval.Pasture Manag.	100
Carlos Alberto Goncalves	Brazil	EMBRAPA/UEPAE	Eng.Agr.M.S.	Research	Pastures	100
Nilzemary Lima de Silva	Brazil	EMBRAPA/UEPAE	Eng.Agr.	Research	Forages	100
Jones Bastos de Veiga	Brazil	EMBRAPA/CPATU	Eng.Agr.Ph.D.	Research	Eval.pastures	100
Lourival Vilela	Brazil	EMBRAPA/CPAC	Eng.Agr.M.S.	Research	Pastures	100
Moacir Gbrial Saueressig	Brazil	EMBRAPA/CPAC	Med.Vet.M.S.	Research	Pastures	80
Sebastino de Oliveira	Brazil	EMATER-MG	Eng.Agr.	Extension	Pastures	70
Raul Antonio Pérez B.	Colombia	ICA	Eng.Agr.	Research	Pasture evaluation	100
Jaime E. Velásquez	Colombia	ICA	Zoot.M.S.	Research	Pasture evaluation	100
Gustavo Maldonado	Colombia	ICA	Eng.Agr.	Research	Agron.pasture	100
Arnulfo Gómez C.	Colombia	ICA	Eng.Agr.	Research	Agron.pasture	100
Jorge Marín A.	Colombia	Sec.de Agr.de Antioquia	Zoot.	Extension	Pasture evaluation	100
María Cristina Cardona	Colombia	CENICAFE	Med.Vet.Zoot.	Research	Pastures	80
Carlos Franco	Colombia	CENICAFE	Med.Vet.	Research	Pastures	80
Ricardo Rodriguez	Costa Rica	MINAG	Eng.Agr.	Research	Pasture evaluation	100
Javier F. Enriquez	México	INIFAP	Eng.Agr.	Research	Pasture evaluation	100
Manual Barrón	Mexico	INIFAP	Eng.Agr.	Research	Forages	100
Juan Esteban Reyes	Mexico	INIFAP	Eng.Agr.	Research	Forages	100
Edgar Enrique Sosa R.	Mexico	INIFAP	Eng.Agr.	Research	Agron.pastures	80
Epignardo Castillo G.	Mexico	FMVZ-UNAM	Eng.Agr.	Research.doc.	Pastures	90
David Marcel Urriola	Panama	IDIAP	Eng.Agr.M.S.	Research	Agron.pastures	90
Kenneth Reátegui del A.	Peru	INIAA	Eng.Agr.M.S.	Research	Pastures	80
P. Dayey Lara C.	Peru	INIAA	Eng.Agr.	Research	Pasture evaluation	100
Hernán Maldonado	Peru	INIAA	Eng.Agr.M	Research	Pasture production	100
Jorge W. Vela A.	Peru	INIAA-CIPA XXIII	Zoot.	Research	Pastures	90
Adolfo Ramón Torres Q.	Venezuela	FONAIAP	Eng.Agr.	Research	Pastures	100

Tropical Pastures Programs through their programs for Developing Research Capabilities in the production and utilization of tropical pastures at CIAT-Palmira, together with research, results focusing on the selection of germplasm adapted to the different ecosystems of tropical America have led to the development of improved pasture technologies which permit better use of the available resources in livestock and frontier areas. These activities aim to the strengthening of tropical pastures research in national institutions.

The latter creates a very appropriate frame for the development of research courses at the country level, oriented according to the learning needs and priorities of livestock development in the region. This in-country courses aim to the strengthening of the link between research and extension programs, including the development agencies operating in each country. Therefore the TCP and TPP initiated research activities at the country level on November 1986.

In addition, it is important to highlight the effort of the Seed Production section of the TPP, which has been coordinating, in collaboration with the TCP, specialized and decentralized training activities as part of their project for the seed multiplication, production, and promotion of forage grass and legume seeds at the country level, within the TPP's target area of the TPP.

Two training events at the country level were conducted during 1988. The first one took place in Tarapoto, Department of San Martín, Peru. This course on "Tropical Pastures Seed in the Peruvian Forests: Current Situation, Strategies, and Plans" was offered to 14 professionals from 6 countries (4 foreign students, 8 officers from Peruvian institutions, and 2 from CIAT), for the practical on-farm discussions and planning additional 12 collaborators from 8 national institutions and 4 producers of the Tarapoto and Cuñumbuque regions joined the course (Tables 5 and 6).

The event was organized by the Instituto Nacional de Investigación Agraria y Agroindustrial (INIAA) and CIAT. The workshop was developed as follows: A first, three-days phase analyzed the current national situation, its limitations, and possible strategies and recommendations. The second phase allowed participants to exchange experiences with other collaborators; one day was spent in the field and the other was used to discuss experiences. During the third phase, plans and future activities in forage seed multiplication, production, promotion, and research was defined.

The second event took place at the Experiment Station of the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP) in the State of Monagas (Venezuela). This seminar on "Methodologies for the Agronomic Evaluation of Tropical Pastures" was addressed at researchers of FONAIAP's Pastures Research Program. Twenty-nine professionals participated (Table 7). The event counted was organized by personnel in the Forage Program of the Technonology and Communications Transfer Section of Monagas the Experiment Station. Eng. Adalberto Florez, National Coordinator of FONAIAP's Forage Program; Dr. Pedro J. Argel, adviser of PRODETEC; and personnel from CIAT's Research and Communications Program also collaborated.

<u>Training support events carried out by other institutions</u>

During 1988 the Training and Communication Program, in collaboration with

Table 5. Participants in Phases I, II, and III of the Workshop on: "Seed of Tropical Pastures in the Peruvian Forest--Present situation, strategies, and plans-- Tarapoto, Peru, May 30 - June 4, 1988.

Last name	First Name	Country	Region	Institution
Sihuay Lindo	Jorge Daniel	Peru	Lima	INIAA
Hidalgo Ríos	Leonardo Fulvio	Peru	Pucallpa	Univ. Nac. Ucayali
Reyes Atac	César Augusto	Peru	Pucallpa	IVITA
Schaus Andaluz	Rodolfo	Peru	Pucallpa	INIAA
Castro Gonzáles	Pio Enrique	Peru	Tarapoto	PRODEGAL
Documet Perea	Alfonso Enrique	Peru	Tarapoto	CORDESAM
Pérez Alvarado	Ricardo César	Peru	Tarapoto	IST
Silva del Aguila	Justo Germán	Peru	Tarapoto	INIAA
Diulgheroff	Stefano	Costa Rica	San José	CIAT-IICA
Farfán Domo	Carlos Anicel	Ecuador	Porto Viejo	INIAP
González Morcillo	Raul Lorenzo	Ecuador	Payamino	INIAP
Peralta Martínes	Armando	Mexico	Iguala	INFAR
Cardozo	Carlos Iván	Colombia	Cali	CIAT
Durán Castro[1]	Carlos Vicente	Colombia	Cali	CIAT
Ferguson	John E.	Colombia	Cali	CIAT

1/ Support Coordinator of the Workshop.

Table 6. Participants in Phase II--collaborators-- of the workshop on "Seed of Tropical Pastures in the Peruvian Forest --present situation, strategies, and plans-- Tarapoto, Peru, May 30 - June 4, 1988.

Last name	First name	Country	Region	Institution
Bartolini	Humberto	Peru	Tarapoto	Productor/Univ.Nal. San Martín/Gloria S.A.
Cárdenas	Juvencio	Peru	Tarapoto	Productor
Carraso Pérez	Pedro Aurelio	Peru	Iquitos	INIAA
Hunnisett	Gary	Peru	Tarapoto	Bco. Agrario del Perú
Linares	Jaime	Peru	Tarapoto	IST
López Cárdenas	Washington	Peru	Tarapoto	Consultor particular
Otoya Zapata	Víctor Eduardo.	Peru	Tarapoto	Gloria S.A.
Ramírez	Daniel	Peru	Tarapoto	Selva Industria S.A.
Rosales del Río	Carlos Daniel	Peru	Tarapoto	Ministerio de Agric.
Sánchez	Federico	Peru	Tarapoto	Productor
Villachica León	Jorge Hugo	Peru	Lima	INIAA

Table 7. Information on the participants in the Seminar.

Name	Profession	Institution	Region	Activity	Time Dedicated	
					Pastures	Others
Ramírez R., César Antonio	Eng.Agr.	DIPROAGRO		Researcher - Promotion	50%	50%
Rodriguez S., Tania M.	Eng.Agr.M.Sc.	FONAIAP	Monagas	Researcher	-	100
Rivero M., Abraham M.	Eng.Agr.	FONAIAP	Calabozo	Researcher	100	
González T., Rafael D.	Eng.Agr.	FONAIAP	Araure	Researcher	100	
Navarro D., Luis	Zoot.M.Sc.	FONAIAP	Anzoátegui	Researcher	20	80
Vásquez V., Dionisio R.	Zoot.M.Sc.	Univ.de Oriente	Monagas	Researcher - Teaching	90	10
Urbano de B., Diamelis C.	Eng.Agr.	FONAIAP	Mérida	Researcher	100	
Torres G., Guillermo R.	Zoot.M.Sc.	FONAIAP	Apure	Researcher	100	
Sánchez G., Alexander J.	Eng.Agr.	FONAIAP	Falcon	Researcher	100	
Sanabria V., Damalys M.	Zoot.M.Sc.	FONAIAP	Monagas	Researcher	100	
Rodriguez P., Alfredo	Eng.Agr.M.Sc.	FONAIAP	Zulia	Researcher	100	
Rodriguez de L., Iraide E.	Eng.Agr.	FONAIAP	Anzoátegui	Researcher	100	
Rodriguez M., Martín	Zoot.	FONAIAP	Monagas	Researcher	100	
Romero, Carlos José	Eng.Agr.O.E.A.	FONAIAP	Falcon	Researcher	100	
Querales C., Pablo R.	Eng.R.N.R.	FONAIAP	Apure	Researcher	100	
Pérez S., Gregorio C.	Eng.Agr.	FONAIAP	Lara	Researcher - Promotion	100	
Pérez V., Julio Hernán	Eng.Agr.	MAC-FONAIAP	Caracas	Fomento	50	50
Manrique, Ursulino	Zoot.M.Sc.	FONAIAP	Monagas	Researcher	100	
Lanz R., Marco Antonio	Eng.Agr.M.Sc.	FONAIAP	Portuguesa	Researcher - Promotion	50	50
Gil G., José Luis	Biologist	FONAIAP	Aragua	Researcher - Fomento	100	
González R., Marcial C.	Zoot.M.Sc.	Univ. de Oriente	Monagas	Researcher - Teaching	100	
Fariñas M., José Gregorio	Biologist	FONAIAP	Monagas	Researcher	100	
Espinoza M., Freddy M.	Zoot.	FONAIAP	Aragua	Researcher	100	
Caraballo M., Alfredo E.	Eng.Agr.M.Sc.	FONAIAP	Zulia	Researcher	100	
Barreto M., Luis Alberto	Zoot.	FONAIAP	Guárico	Researcher - Promotion	100	
Alínnen, Nidia	Eng.Agr.	FONAIAP	Apure	Researcher	100	
Aryanli P., Patricia M.	Eng.Agr.	FONAIAP	Aragua	Researcher	100	
Araque H., César A.	Zoot.M.Sc.	FONAIAP	Táchira	Researcher - Promotion	80	20
Acosta G., Rafael A.	M.V.Ph.D.	FONAIAP	Guárico	Researcher - Promotion	50	50

CIAT's Tropical Pastures Program, backstopped the Banco Ganadero de Colombia in the organization of four seminars, which took place in Palmira, Valledupar, Florencia, and Villavicencio. The objective was that of promoting and developing professionals from the national institutions and entities existing in each region. The subjects included updating the participants knowledge of the ecosystem; the availability of grasses and legumes adapted to each ecosystem; pasture development and establishment; management practices for the establishment of forage grass and legume pastures; and, finally, the possibilities for adopting and using these technologies within the current situation. Perspectives for grass and legume pasture development in each region were also discussed. A total of 164 professionals attended the four events. Lecturers from the Instituto Colombiano Agropecuario (ICA) and from CIAT's Tropical Pastures Program were invited to participate. The support provided by CIAT"s TCP in planning, organizing, and carrying out these seminars was very important.

EVOLUTION AND SCOPE OF TRAINING

Comparing the various research categories of professionals trained during 1988 with the average for the period 1980-87 (Table 8) shows an increase in the number of participants in the multidisciplinary course and specialization phases in contrast with the other categories which remain stable. It is important to point out the effort of the TPP and the TCP in the development of special events during the last 4 years. Relevant among these was the Course/Workshop on "Methodologies for the Evaluation of Pastures under Grazing Trials" held at CIAT's headquarters in Palmira, with the participation of 27 professionals from 8 countries in tropical America.

Comparing disciplines (Table 9) interest can be observed during 1988 in areas such as Pasture Quality, Soils, Pasture Development, and Ecophysiology. Worth mentioning is the effort in the Soils/Plant Nutrition section in training 7 professionals during 1988 in directed specializations in soil microbiology.

A total of 420 professionals have received training in research within the Tropical Pastures Program at CIAT-Palmira, with an intensity of 2,001.6 man/months or 4.77 man/months per professional trained in the period 1980-1988.

Table 10 presents data on professionals trained at CIAT by disciplines; the sections of the TPP that trained more professionals during the period 1980-1988 were Pasture Quality, Seed Production, Agronomy, and Soils/Plant Nutrition with 88, 73, 61, and 55 professionals trained, respectively.

Analysis of data on professionals trained at CIAT, by research categories and countries of origin during the period 1980-1988 (Table 11) shows that the countries with the greater numbers of participants were Bolivia, Brazil, Colombia, Cuba, Mexico, Panama, and Peru. These countries are located within the target area where the TPP concentrates its greater efforts in developing improved tropical pastures technologies.

Table 12 shows that the number of professionals trained at CIAT increased to 65 in 1988, 27 of which participated in the special course of the Quality ahd Productivity section of the TPP. Of the total number of professionals trained during 1980-1988, 5.7 and 5.9% were dedicated to research for a postgraduate thesis at

Table 8. Comparison by training categories of professionals trained year 1988 vs. average 1980-1987.

Categories		No.ofde Participants Prom.Years 1980-87	1988	
A	Multidisciplinary Course	4	2	
B	Spec. + Mult. Course	17.4	23	(11[a])
C	Specialization	10.9	9	
D	(B + C)	28.3	32	(11[a])
E	MS Thesis	2.9	2	
D	Ph.D. Thesis	1.4	1	
G	Special Courses	(26[b], 25[b])	27[c]	(11[a])

In parenthesis No. of participants in special events.

a/ Participants in the Multidisciplinary Course and Special Course as Specialization.

b/ Participants in the Special Courses on Seed Production 84 and 86, respectively.

c/ Special Course: Methodologies Grazing Trials.

Table 9. Comparison by disciplines of professionals trained, year 1988 vs. average 1980-87.

Disciplines	Average 1980-98	1988	
Agronomy	7.1	4	
Pasture Development	1.8	3	
Economics + Social Sci.	.9	1	
Entomology	1	2	
Farms-Systems	2.3	2	
Physiology	0.8	2	
Pasture Quality	6	13	(11[a])
Pathology	.9	1	
Production	0.8	1	
Seeds	2.4 (26[b], 25[b])	3	
Soils	5.5	11	(7[c])

In parenthesis number of participants in special events.

a/ Participants in the Multidisciplinary Course and Special Course as Specialization.

b/ Participants in the Special Courses on Seed Production 84 and 86, respectively.

c/ Participants in directed specialization in soil microbiology (Rhizobiology).

Cuadro 10. **Profesionales capacitados en el CIAT por Programa o Unidad, disciplina de especialización y categoría de capacitación desde 1980 hasta 1988.**

PROGRAM: PASTURES	TRAINING CATEGORY															
	Visiting Researcher Associate				Visiting Researcher						Special Course		Intensive Multidisciplinary Course			
	Thesis Ph.D.		No. Thesis		Thesis MS		Special-ization		Specialización + Intensive Multidisciplin. Course						Sub-totales	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
DISCIPLINE:																
ADM.EXPTL.STATION									1	(3.9)					1	(3.9)
AGRONOMY	1	(32.6)			3	(53.6)	14	(41.6)	43	(213.3)					61	(341.1)
BIOTECHNOLOGY									1	(4.9)					1	(4.9)
TRAINING + COMM.									1	(4.4)					1	(4.4)
PASTURE DEVELOPMENT					1	22.6)	6	(26.5)	10	(50.7)					17	(99.8)
ECONOMICS + SOC.SCI.			1	(0.8)	3	(24.5)	9	(20.9)	3	(14.0)					16	(60.2)
ENTOMOLOGY					2	(11.9)	6	(20.2)	2	(16.7)					10	(48.8)
FARMS-SYSTEMS	1	(33.1)					2	(2.9)	17	(78.7)					20	(114.7)
PHYSIOLOGY	1	(18.8)	1	(18.4)	1	(1.4)	1	(2.7)	4	(24.5)					8	(65.8)
INTERDISCIPLINARY			2	(2.3)									34	(71.5)	36	(73.8)
PASTURE QUALITY	3	(104.9)	2	(5.3)	6	(113.1)	14	(26.3)	25	(161.0)	27	(29.2)	11	(24.9)	88	(464.7)
IMPROVEMENT			1	(3.4)											1	(3.4)
PATHOLOGY					1	(16.1)	4	(18.1)	3	(20.6)					8	(54.8)
PRODUCTION	1	(2.1)							6	(27.3)					7	(29.4)
GENETIC RESOURCES	2	(59.1)			2	(23.0)	7	(11.5)	3	(20.6)					14	(105.8)
HEALTH, ANIMAL MGMT.							2	(9.6)	1	(5.4)					3	(15.0)
SEEDS			1	(12.5)	2	(26.2)	7	(19.9)	12	(59.4)	51	(42.1)			73	(160.1)
SOILS	3	(64.9)	4	(66.8)	4	(31.9)	24	(58.9)	20	(128.5)					55	(351.0)
TOTAL PROGRAM	12	(315.5)	12	(109.5)	25	(324.3)	96	(259.1)	152	(825.5)	78	(71.3)	45	(96.4)	420	(2001.6)

Table 11. Number and man/month of professional trained in CIAT from 1980-1988.

PROGRAM: PASTURES	TRAINING CATEGORY															
	Visiting Researcher Associate				Visiting Researcher						Special Course		Intensive Multidisciplinary Course			
	Thesis Ph.D.		No. Thesis		Thesis MS		Special-ization		Specialización + Intensive Multidisciplin. Course						Sub-totales	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
LATIN AMERICA AND THE CARIBBEAN																
ANTIGUA							1	(1.9)							1	(1.9)
ARGENTINA			1	(39.8)			2	(2.3)			2	(1.7)	2	(4.0)	7	(47.8)
BARBADOS							1	(1.0)							1	(1.0)
BELIZE							1	(1.1)	1	(1.9)					2	(3.0)
BOLIVIA					1	(10.7)	3	(6.2)	11	(66.4)	7	(5.3)	2	(4.6)	24	(93.2)
BRAZIL			3	(8.0)	2	(27.0)	20	(64.3)	20	(106.1)	12	(11.6)	6	(12.8)	63	(229.8)
CHILE							2	(1.4)							2	(1.[illegible])
COLOMBIA	3	(59.1)			13	(116.0)	9	(28.2)	15	(82.8)	15	(13.1)	18	(37.7)	73	(336.9)
COSTA RICA			1	(1.3)					4	(20.5)	4	(3.5)	3	(7.1)	12	(32.4)
CUBA			1	(3.4)			23	(84.1)	8	(37.1)	2	(2.3)			34	(126.9)
ECUADOR					1	(8.5)	7	(9.0)	3	(21.2)	1	(1.0)	3	(6.3)	16	(46.0)
GUATEMALA							1	(2.9)	3	(14.1)	2	(2.0)			6	(19.0)
GUYANA					1	(12.0)									1	(12.0)
HAITI			1	(6.9)											1	(6.9)
HONDURAS									9	(40.7)	3	(2.7)			12	(43.6)
MEXICO							7	(15.3)	12	(72.9)	9	(8.8)	6	(12.5)	34	(109.5)
NICARAGUA	1	(36.7)			1	(32.7)			12	(61.5)	1	(0.8)			15	(131.7)
PANAMA							5	(4.0)	14	(78.4)	4	(3.8)			23	(86.2)
PARAGUAY							2	(2.9)	2	(11.9)	1	(1.2)			5	(16.0)
PERU			1	(0.8)	5	(105.9)	5	(10.2)	23	(144.3)	11	(10.2)	4	(9.0)	49	(280.4)
DOMINICAN REP.									9	(44.8)					9	(44.8)
VENEZUELA	1	(18.8)			1	(11.5)	3	(12.9)	5	(20.9)	4	(3.3)	1	(2.4)	15	(69.8)

Table 11. Continued.

PROGRAM: PASTURES	TRAINING CATEGORY: Visiting Researcher Associate — Thesis Ph.D. No.	Months	Visiting Researcher Associate — No. Thesis No.	Months	Visiting Researcher — Thesis MS No.	Months	Visiting Researcher — Special-ization No.	Months	Visiting Researcher — Specialización + Intensive Multidisciplin. Course No.	Months	Special Course No.	Months	Intensive Multidisciplinary Course No.	Months	Sub-totales No.	Months
ASIA:																
REP.OF CHINA			1	(12.5)											1	(12.5)
THAILAND			1	(1.0)	1	(1.0)									2	(2.0)
AFRICA:																
UGANDA					1	(1.7)									1	(1.7)
DEVELOPED COUNTRIES:																
GERMANY	5	(159.9)			1	(6.0)									6	(165.9)
UNITED STATES	1	(8.0)	1	(17.4)	1	(2.7)									3	(28.1)
UNITED KINGDOM			1	(18.4)											1	(18.4)
SWITZERLAND	1	(33.0)													1	(33.0)
TOTAL PROGRAM	12	(315.5)	12	(109.5)	25	(324.3)	96	(259.1)	152	(825.5)	78	(71.3)	45	(96.4)	420	(2001.6)

Table 12. Number and man/months of professionals trained in CIAT per category each year.

PROGRAM: PASTURES	TRAINING CATEGORY																	
	Visiting Researcher Associate				Visiting Researcher						Special Course		Intensive Multidisciplinary Course					
	Thesis Ph.D.		No. Thesis		Thesis MS		Special-ization		Specialización + Intensive Multidisciplin. Course						Sub-totales	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
YEARS OF TRAININT:																
1980	4	(131.9)	4	(61.9)	4	(92.1)	10	(43.6)	21	(104.2)			6	(15.5)	43	(284.7)
1981	3	(62.0)	1	(6.9)	4	(48.8)	8	(23.6)	12	(65.1)			5	(11.4)	33	(217.8)
1982			5	(9.8)	3	(22.6)	13	(19.1)	15	(70.5)			2	(4.4)	38	(126.4)
1983	1	(23.9)			4	(37.7)	4	(12.7)	20	(109.3)			2	(4.1)	31	(187.7)
1984	2	(62.6)	2	(30.9)	1	(6.8)	3	(8.6)	19	(111.2)	26	(16.2)	1	(2.3)	54	(238.6)
1985	1	(33.0)			3	(41.5)	12	(31.3)	13	(78.1)			4	(7.4)	33	(191.3)
1986					3	(59.4)	16	(36.9)	17	(102.6)	25	(25.9)	3	(5.4)	64	(220.2)
1987					1	(1.4)	21	(67.9)	22	(122.2)			9	(16.9)	53	(208.4)
1988	1	(2.1)			2	(24.0)	9	(15.4)	13	(62.3)	27	(29.2)	13	(29.0)	65	(162.0)
TOTAL	12	(315.5)	12	(109.5)	25	(324.3)	96	(259.1)	152	(825.5)	778	(71.3)	45	(96.4)	420	(2001.6)

the Ph.D. and MS level, respectively. During this same period 18.6% received training through ad hoc courses on specific subjects, 22.9% participated in the execution or carried out a research project as specialization within a discipline, 36.2% attended the Intensive Multidisciplinary Course and continued in the specialization phase to learn the specific techniques of the TPP, and only 10.7% attended exclusively the Intensive Multidisciplinary Course. A decrease is observed in the man/month intensity per professional trained during the period. For example, in 1980 the dedication per professional trained was 6.62 man/months while in 1988 it was only 2.49 man/months; this indicates that the basic disciplines initially received greater attention while in 1988 efforts were concentrated in conducting the Course/Workshop on "Methodology for the Evaluation of Pastures under Grazing Trials" addressed at a special audience, among which were professionals who already had experience in this field (59.3%) and others who had participated in the Intensive Multidisciplinary Course.

The chronologic revision by triennium of professionals trained at CIAT by discipline and country of origin shows that more emphasis was placed during the first treiennium to the following disciplines: Agronomy, Pasture Quality, and Soils/Plant Nutrition and during the last period to Pasture Quality, Seed Production, and Soils/Plant Nutrition (Figure 1). Figure 2 shows tendencies in relation to the number of professionals trained by country or origin for the three periods and the total for the period 1980-1988, which is in agreement with priorities established to cover regions where infertile, acid soils prevail.

In special courses at the country level, the Training and Communications Program and the Tropical Pastures Program have trained 118 professionals between 1986 (initiation) and 1988 (Table 13).

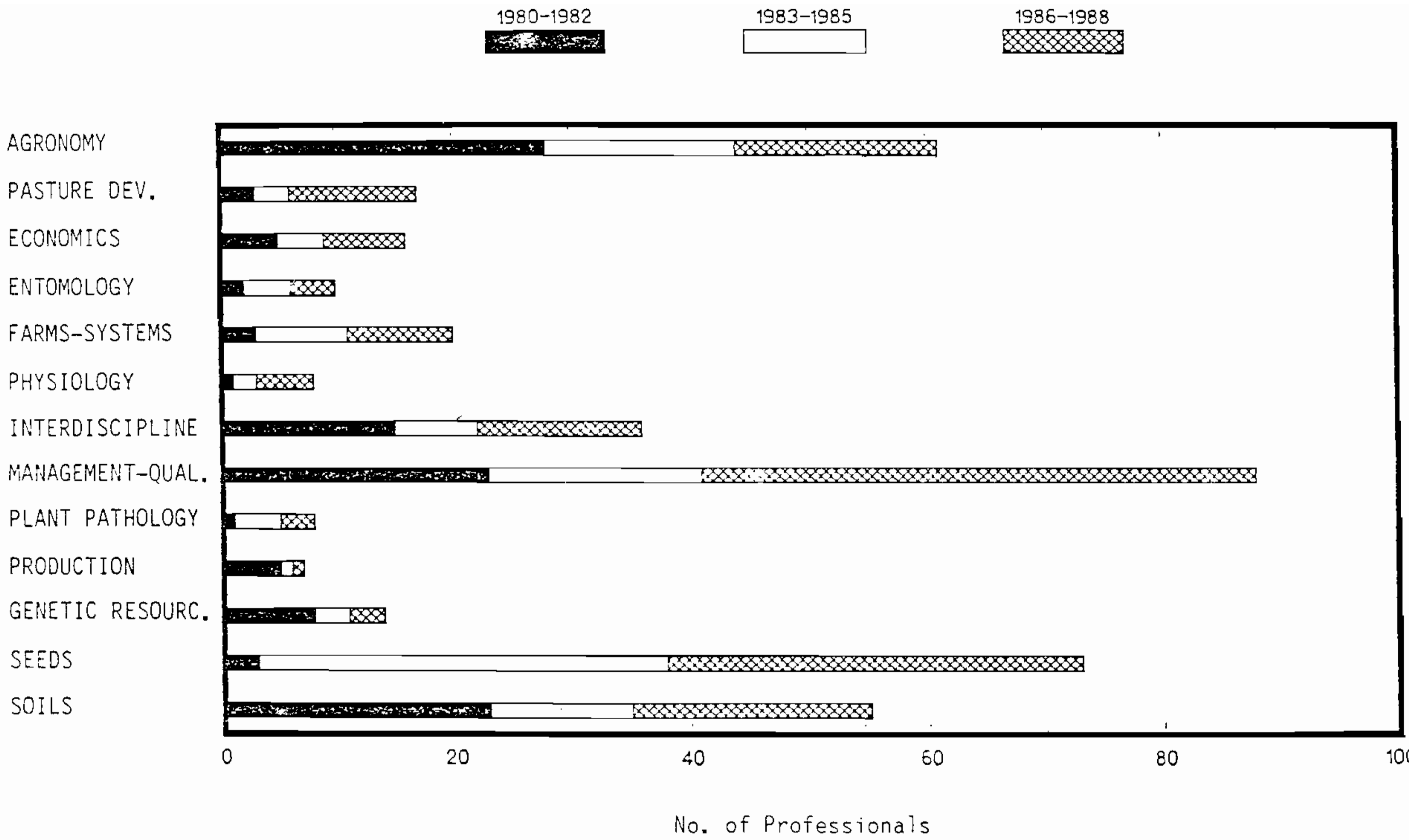


Figure 1. Professionals trained by discipline. Tropical Pastures Program. 1980-1988.

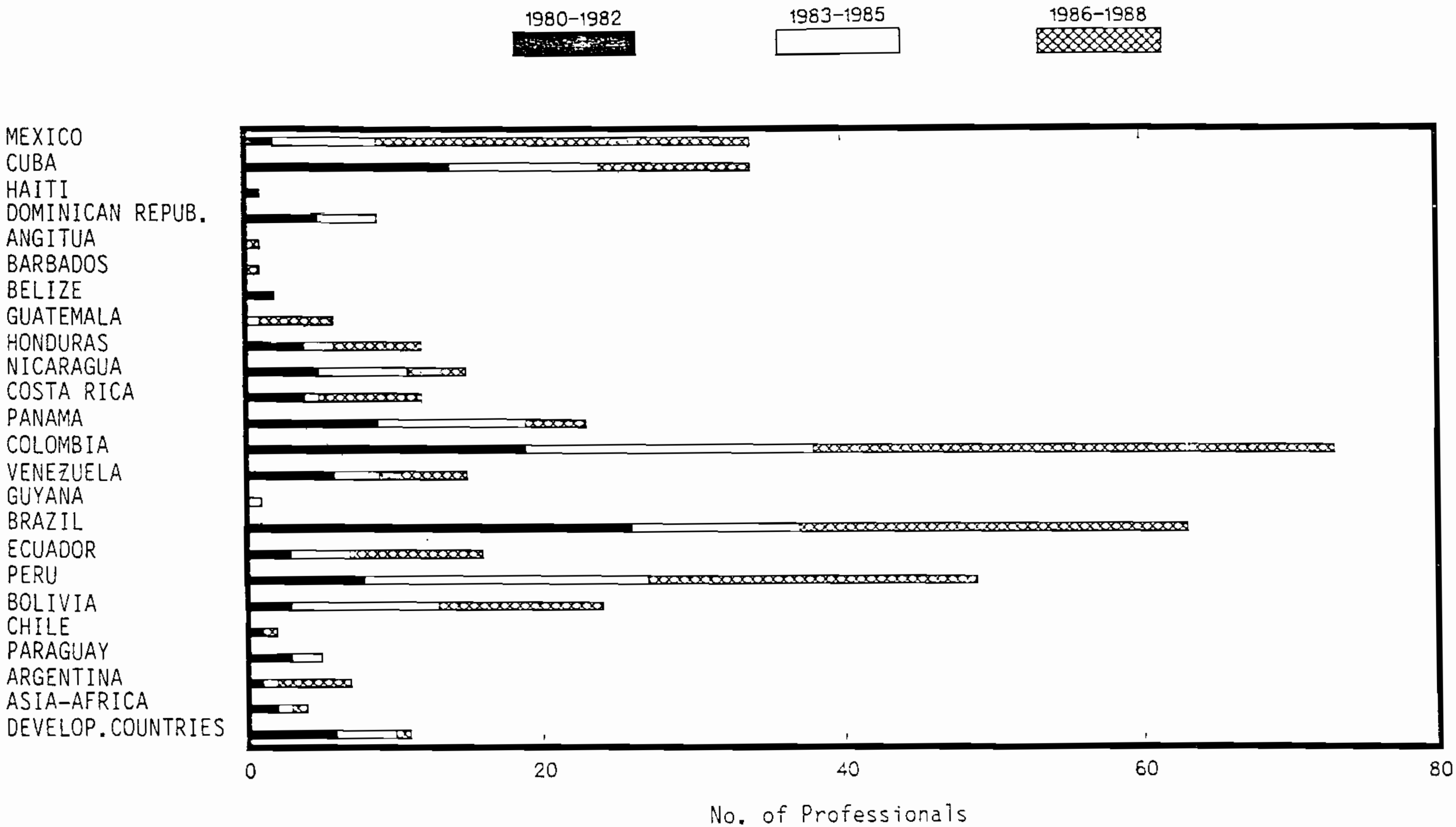


Figure 2. Professionals trained by countries. Tropical Pastures Program. 1980-1988.

Table 13. Professionals trained by year at country level during the period 1986-1987.

Year	Country	Training event	Participating Institutions	Professional trained
1986	Panamá	Seminar-Workshop: Acid soils and pasture establishment	IDIAP/U. Rutgers/CIAT	17
1987	Perú	Course-Workshop: Pasture Establishment, maintenance, and production in the Peruvian tropics	INIAA/IVITA/CORDEU/CIAT	32
1987	Panamá	Workshop meeting: Define present status and outline stragegies to improve the supply of pasture seeds in the Republic of Panama	IDIAP-CIAT	17
1988	Perú	Workshop: Tropical pasture seeds in the Peruvian forest. Present situation, strategies, and plans	INIAA-CIAT	24*
1988	Venezuela	Seminar: Methodologies for the agronomic evaluation of tropical pastures	FONAIAP/PRODETEC/CIAT	28
			TOTAL	118

* Includes 12 participants as responsible collaborators of forage seed activities attending Phase II.

20. Biotechnology

Collaboration of the Biotechnology Research Unit (BRU) with the Tropical Pastures Program (TPP) included:

a) Use in vitro techniques for the exchange of Brachiaria germplasm;
b) Isozyme electrophoresis for the characterization of Brachiaria species, and
c) continue evaluation of Stylosanthes progenies regenerated from callus cultures.

Brachiaria Germplasm Exchange

In 1988, a total of 68 Brachiaria spp. accessions were introduced from ILCA, Ethiopia, to CIAT In the form of sterile shoot tip cultures. This material has been micropropagated in its majority and transplanted to the greenhouse for phytosanitary evaluation.

Our of the collection transferred from African countries to CIAT in 1986-86, 229 accessions have been distributed this year to IVITA, Peru (112 accession), and IICA, Costa Rica (117 accessions).

Electrophoretic Isoenzyme Characterization of Brachiaria species

The genus Brachiaria includes highly apomictic species and some with various levels of sexuality. Once sexual plants have been identified within apomictic populations, crosses between apomictic plants (as pollinator) and sexual plants (as receptors) would allow the release of the genetic variability within these species; early detection of hybrid plants in the F_1 progeny would greatly facilitate the tasks. Isozyme patterns could be used as markers for the selection of hybrid plants.

In collaboration with Tropical Pastures breeders (J. Miles) work was carried out to develop electrophoretic techniques.

a) Out of 4 enzymes tested α, β-Esterase (EST) provided the best discriminatory power among 15 accessions of 3 Brachiaria spp. tested: B. brizantha (apomictic), B. ruziziensis (sexual), and B. decumbens (apomictic).

b) Out of 4 different tissues analyzed (seed, root, stem and leaf), leaf tissue provided the best isozyme α, β-EST patterns.

c) There was not any effect of the age of the plant in the field (1 to 6 months) or in the greenhouse, neither between the part of the leaf (apical, middle or basal) (Figure 1) nor the hour of the day of sampling on the pattern of α, β-EST.

d) The most polymorphic accessions of sexual and apomictic species have been chosen to carry out crosses.

e) Preliminary analysis α, β-EST

Figure 1. Esterase isozyme patterns of Brachiaria species. Enzyme was extracted from apical (A), medium (M) and basal (B) parts of second and third leaves.

electrophoresis of F_1 plantlets show in various individuals allele segregation in some enzyme loci. Further analysis of these materials should allow interpretation of segregation patterns and possible hybridization. The analysis of α, and β-EST separately should facilitate analysis and interpretation.

Somaclonal Variation in Stylosanthes

In previous work we have reported on the development of plant regeneration techniques from leaf derived callus on the one hand and leaf misophyll protoplasts on the other of S. guianensis, S. capitata, and S. macrocephala. We have also shown the occurrence of cytological and morphological variability in cell suspension cultures and in the regenerated (R_1) plants of S. guianensis.

In this opportunity we report the assessment of variability in S. guianensis, CIAT 2243, in first generation selfed lines (R_2 lines) derived from 76 regenerated (R_1) plants, compared with the original check genotype in a replicated field trial at CIAT-Quilichao for 8 agronomic trials. We also report on the evaluation of a few lines (R_3 lines) selected out of the R_2 lines, for a few traits in the same site. Work carried out in collaboration with Tropical Pastures breeder (J. Miles).

Evaluation of first generation selfed lines (R_2 lines)

For five of the eight traits measured, diploid (2X) and tetraploid (4X) (induced by tissue culture) differed. Where comparable traits were measured in the R_1 and R_2 generations, the difference between 2X and 4X were in the same direction (Table 1), i.e. larger leaves, larger internodes, and shorter stems for 4X than for 2X. Seed weight of the 4X R_1 plants was greater than for 2X but did not differ by ploidy in the R_2 lines.

For all traits, except seed weight 2X R_2 progenies different from the check entires were obtained (Table 2). Leaf size tended to be greater for R_2 progenies than for checks, a trend similar to that found in the SC_1 generation. However, the direction of induced differences for internode length and maximum stem length detected in the R_2 lines was reversed relative to that found in the R_1. Differences were detected among the 10 tetraploid R_2 progenies for 4 of 8 traits measured.

The major effect of in vitro callus culture on the S. guianensis line used was relative to the high rate of tetraploidy. The fact that 4X differed phenotypically from 2X suggests that induction of tetraploidy might be exploited in S. guianensis breeding. The phenotypic differences between induced 4X and 2X genotypes appear to be stable over the sexual generation.

Differences observed in the R_1 plants were not consistently expressed in the R_2 progenies, and in fact, no correlation between R_1 parent phenotype and mean R_2 progeny phenotype was detected suggesting that R_1 phenotype is not a reliable expression of the genetic change induced by in vitro culture. Hence, selection among induced genetic variants should be developed at last until the R_2 generation and followed to the R_3 generation.

The number of progenies observed was relatively small (only 760), and larger populations would probably yield geno- types superior to the original. However, a few R_2 lines were selected which showed average values in some characters superior to the check. Selfed seed was collected from these lines for evaluation in the same location.

Evaluation of selected second generation selfed ilnes (R_3)

Selfed seed of R_2 lines was obtained, germinated and transplanted to the field (CIAT-QUILICHAO), with 10 replicates each, and compared with the check CIAT 2243 self progeny.

Lines selected for this evaluation:

Ploidy	R_2 line No.	Main attributes in the the R_2 generation
Diploid	18	Leaf area, vigor
Diploid	26	Reaction to anthracnose, seed production
Diploid	52	Vigor
Diploid	57	Vigor, maximum radius
Tetraploid	5	Vigor, reaction to anthracnose

Table 3 shows that except reaction to anthracnose in CIAT-Quilichao, none of the diploid R_3 lines differed from the check line. Number of stems, maximum radius, vigor and leaf area did not differed from the check. Line 26 was significantly more tolerant to anthracnose than the check. The diploid line 5 had significantly higher tolerance to anthracnose larger leaf area and vigor than the check line, and significantly smaller maximum radius than the check.

These results show that the relative tolerance to anthracnose of line 26 observed in R_2 generation was transmitted to its progeny in the R_3 generation; similarly, the vigor and tolerance to anthracnose of the tetraploid line 5 also was transmitted to its progeny.

The "rare" phenotypes detected in the R_2 generation, i.e. chlorotic, bushy-type architecture and the by-foliated leaves have also been transmitted to its selfed progeny (R_3 lines).

This work has demonstrated the occurrence of heritable genetic variation through in vitro culture of *S. guianensis*. Further evaluation of lines 26 (diploid) and 5 (tetraploid) should be conducted to ascertain their agronomic usefulness.

Table 1. Assessment of self progeny (R_2 lines) of diploid or tetraploid *S. guianensis* plants regenerated from tissue culture.

Trait	Diploids a (70 plants)	Tetraploids[1] (10 plants)	
Leaf area (cm^2)	0.818	1.142	***
Stem number	3.3	3.3	n.s.
Internode length	4.16	4.32	**
Maximum radius	97.4	75.7	***
% dry matter	50.1	54.0	***
Anthracnose reaction	2.7	2.5	***
Seed yield/plant (mg)	0.317	0.093	***
100-seed wt (mg/plant)	219.4	217.8	n.s.

1/ Means of 15 single plant replicates.

n.s. = No significant (0.05).

, * = Different at 0.01 or 0.001, respectively.

Table 2. Comparison of check progeny (CIAT 2243) with first generation selfed progenies (R_2) of tissue culture derived diploid *S. guianensis* plants for 8 traits.

Trait	Check*	Range diploids	Number of diploid lines	
			Less than**	Greater than
Leaf area (cm^2)	0.76	0.64 - 1.1	2	20
Stem number	3.7	2.7 - 3.9	18	0
Internode length (cm)	4.2	3.6 - 4.5	4	0
Maximum radius (cm)	106.0	72.0 -110.0	20	0
% dry matter	50.6	46.1 - 54.3	4	1
Anthracnose reaction	2.2	1.5 - 3.9	0	16
Seed yield (g/plant)	0.5	0.1 - 0.9	24	1
100-seed wt (mg)	222.0	192.0 -289.0	0	0

* Means of 60 single plant-replicates.

** Significantly different from check mean (0.05).

Table 3. Means for five traits in second generation selfed lines (R_3) of tissue culture regenerated plants as compared to the check selfed progeny CIAT 2243, S. guianensis.

R_3 line No. Anthracnose	Ploidy*	No. stems	Maximum	Vigor radius	Leaf	Reaction to area
26	Diploid	4.8 A	1.4 AB	3.8 AB	1.5 B	2.0 BC
18	Diploid	4.6 A	1.4 A	4.2 AB	1.4 B	2.7 AB
57	Diploid	4.2 A	1.3 B	3.8 AB	1.6 B	3.0 A
52	Diploid	4.2 A	1.4 AB	3.6 AB	1.3 B	2.8 AB
5	Tetraploid	3.6 A	0.9 C	4.6 A	2.3 A	1.6 C
Check	--	4.2 A	1.4 AB	3.4 B	1.6 B	3.1 A

* 2X and 4X tissue culture induced lines.

Means with the same letter are not significantly different (0.05).

21. Agroecological Studies

CENTRAL AMERICAN DATABASE

Purpose

In order to assist the Tropical Pastures Program, TPP, in its move to Central America and the Caribbean the Agroecological Studies Unit, AEU, is creating a database of agroecological information. This consists of information on soils, actual land use (pastures) and climate. Although the TPP is mainly interested in the moderately acid and infertile pastures areas, the data collection is sufficiently complete to be of use to other CIAT commodities who have an interest in Central America and the Caribbean.

THE PROCESS

The initial stage of the work consisted of reviewing the information on soils, actual land use (pastures), climate... available in CIAT. This stage was followed by the collection of secondary information from national and international institutions visited throughout the region and other places. The information was then selected, extracted, standardized and mapped for each of the countries involved. The final results are being incorporated into CIAT's database.

The countries visited were Panama, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala, Mexico, Belize, Dominican Republic, Haiti, Cuba and the United States (Land Tenure Center, University of Wisconsin).

Numerous institutions were visited (See Table 1). The first ones to be contacted during the meeting of the Red Internacional de Evaluación de Pastos Tropicales, RIEPT, in David, Panama in 1987 were those related to agriculture, pastures, or animal production. Contacts were then extended to other institutions related to statistics and census, geography natural resources, meteorology, etc. More than 95 institutions were visited during these trips. Many of these were different to those normally visited by CIAT scientists.

SELECTED SOILS INFORMATION

The compiled maps range in numbers from 1 for Nicaragua, Honduras, El Salvador... to more than 130 for Panama at scales between 1:20,000 for Panama and 1:1.000.000 for Honduras and Mexico. All maps are being rescaled at 1:500.000. For Belize, the classification system is a local one and the legend is not self-explanatory. Guatemala has an old local system consisting only of profile descriptions and it was necessary to reclassify these descriptions into FAO/Soil Taxonomy. The Cuban system was difficult to transfer into FAO/Soil taxonomy systems especially for their mountain soils. Panama, Costa Rica, Nicaragua, Honduras, El Salvador and Dominican Republic are all classified with old

TABLE 1. Number and type of Institutions / Sections visited

Country	* 1	2	3	4	5	6	7	8	
PANAMA	1	3	3	2	1	1		1	12
COSTA RICA	1	2	2	1	1		1	1	9
NICARAGUA	1	3	1	1	1				7
HONDURAS	1	2	1	1	1	2	1		9
EL SALVADOR	2	1	4	2	2	1			12
GUATEMALA	1	1	3	2	1				8
BELIZE	1	1	2	1					5
MEXICO	4	1	1	1	1	1		1	10
DOMINICAN REPUBLIC	1	3	1	3	2	1		1	12
HAITI	1	1	1	1	1			1	6
CUBA	1	1	1		1				4
(USA)							1		1
	15	19	20	15	12	6	3	5	95+

* 1: Statistics, Census
2: Geographic
3: Agricultural, Pastures, Animal production
4: Meteorological, Hydrological
5: Natural resources (Soils)
6: Economics, Other technical
7: Universities, Training
8: International

U.S. systems or with different levels and modifications of Soil Taxonomy. Mexico used a modified version of the FAO, 1974 system. Soils information for Haiti has been supplied by the agricultural Development Support Project, ADS-II (USAID) database.

The soil maps with varying scales and classification systems for the different countries follow a series of transformations until a uniform soils map for the whole region is produced. Initially (Figure 1) all the maps are rescaled to 1:500.000. Next the different classification systems are standardized, eg. Figure 2 shows a standardization to FAO system. And finally the soil mapping units are matched across borders (Figure 3) using additional help from geology, vegetation and topography maps as well as landsat imagery...

Selected Actual Land Use (pastures) information

The compiled information for actual land use (pastures) consists mainly of Censos Agropecuarios; actual land use maps varying in numbers between 1 and 12 and in scales between 1:200.000 and 1:1.000.000; and other information such as diagnósticos ganaderos, encuestas ganaderas, anuarios estadísticos, planes operativos, and Landsat imagery. All the data are standardized, mapped and rescaled at 1:500.000.

Figure 4 is an example showing the number of ha of pastures and their distribution in Panama and Costa Rica based on the Mapa División Político Administrativo de Panamá,1970; the Mapa Físico-Político de Costa Rica, 1974; the information on pastures by

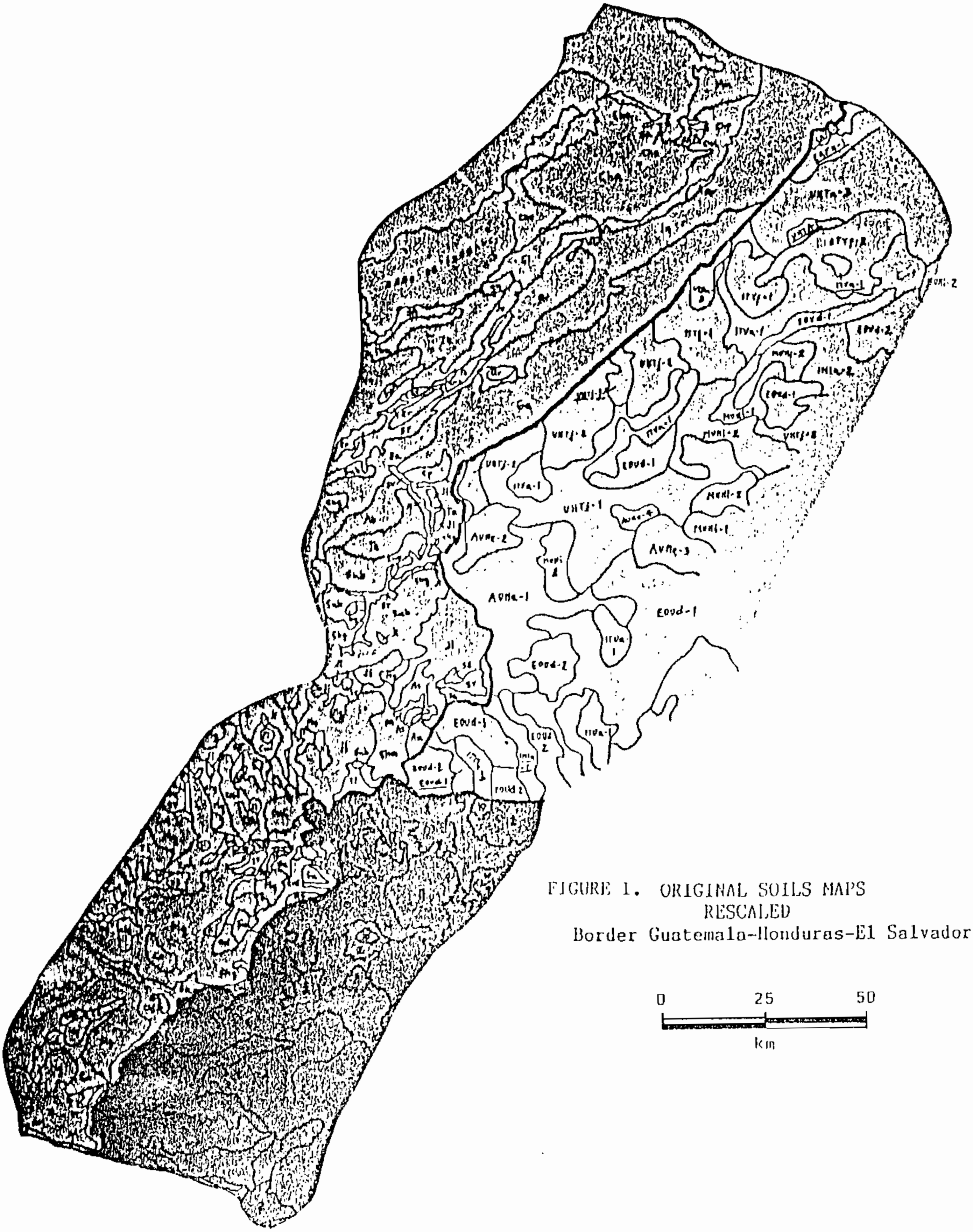


FIGURE 1. ORIGINAL SOILS MAPS RESCALED
Border Guatemala-Honduras-El Salvador

0 25 50
km

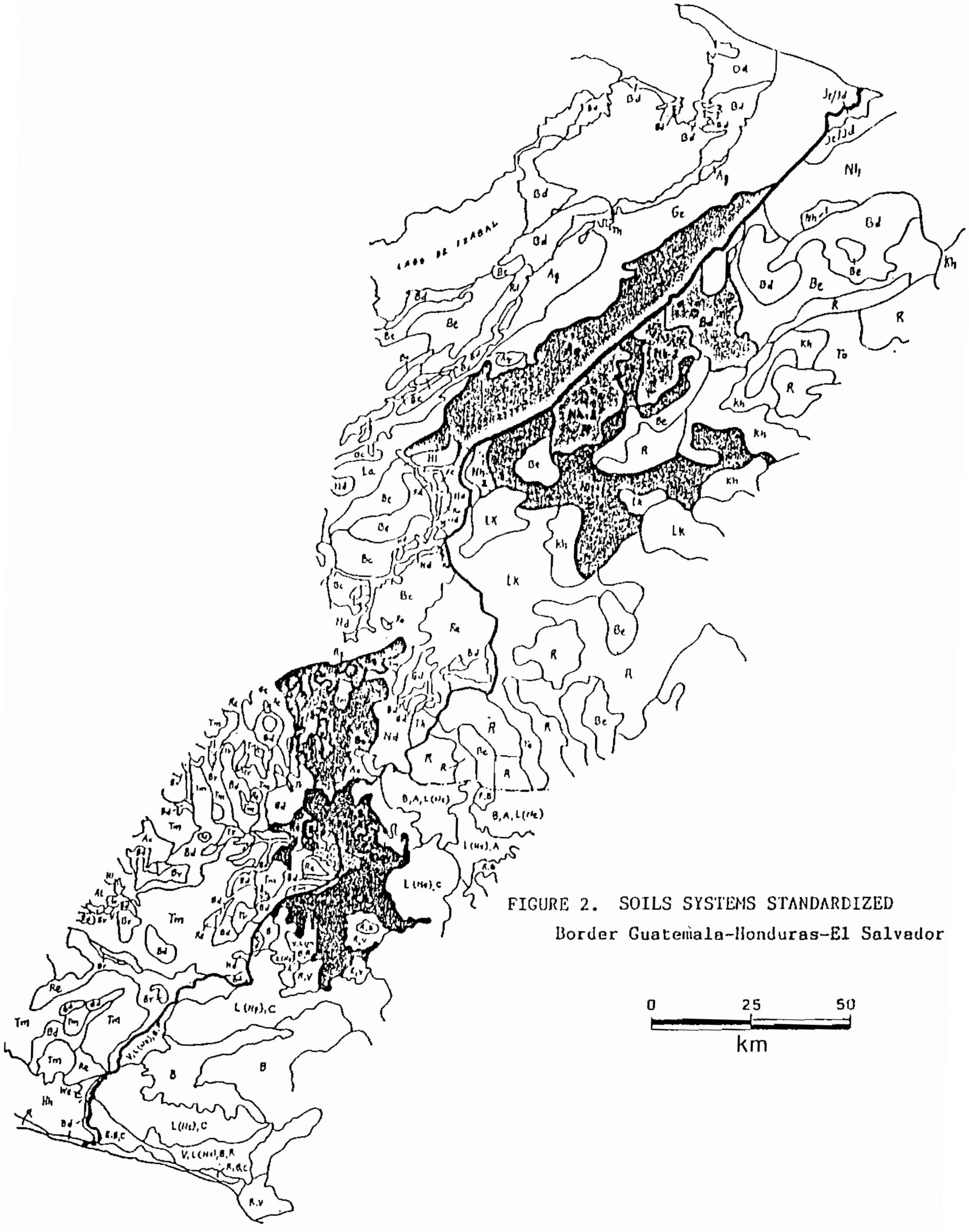


FIGURE 2. SOILS SYSTEMS STANDARDIZED
Border Guatemala-Honduras-El Salvador

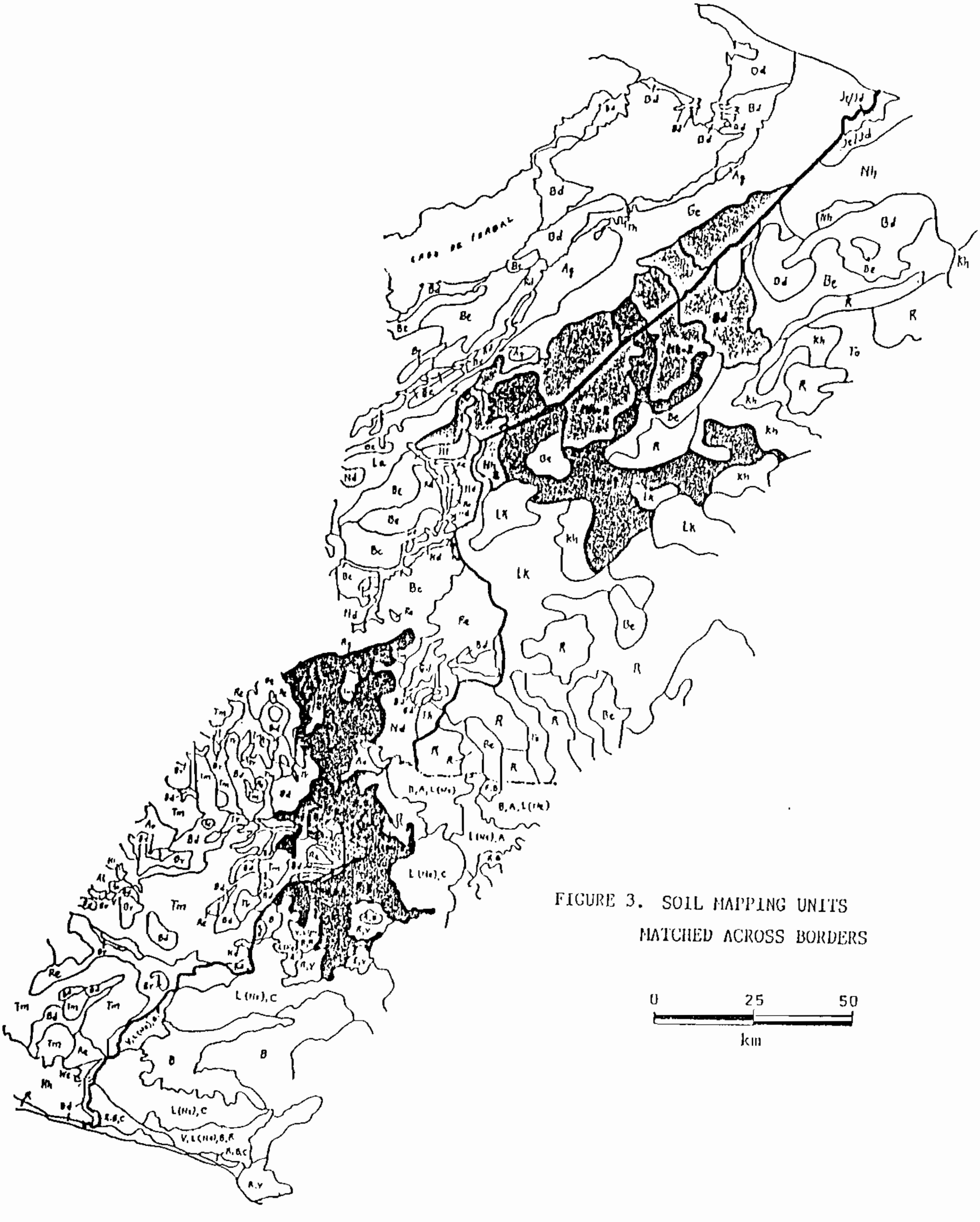


FIGURE 3. SOIL MAPPING UNITS MATCHED ACROSS BORDERS

0 25 50
km

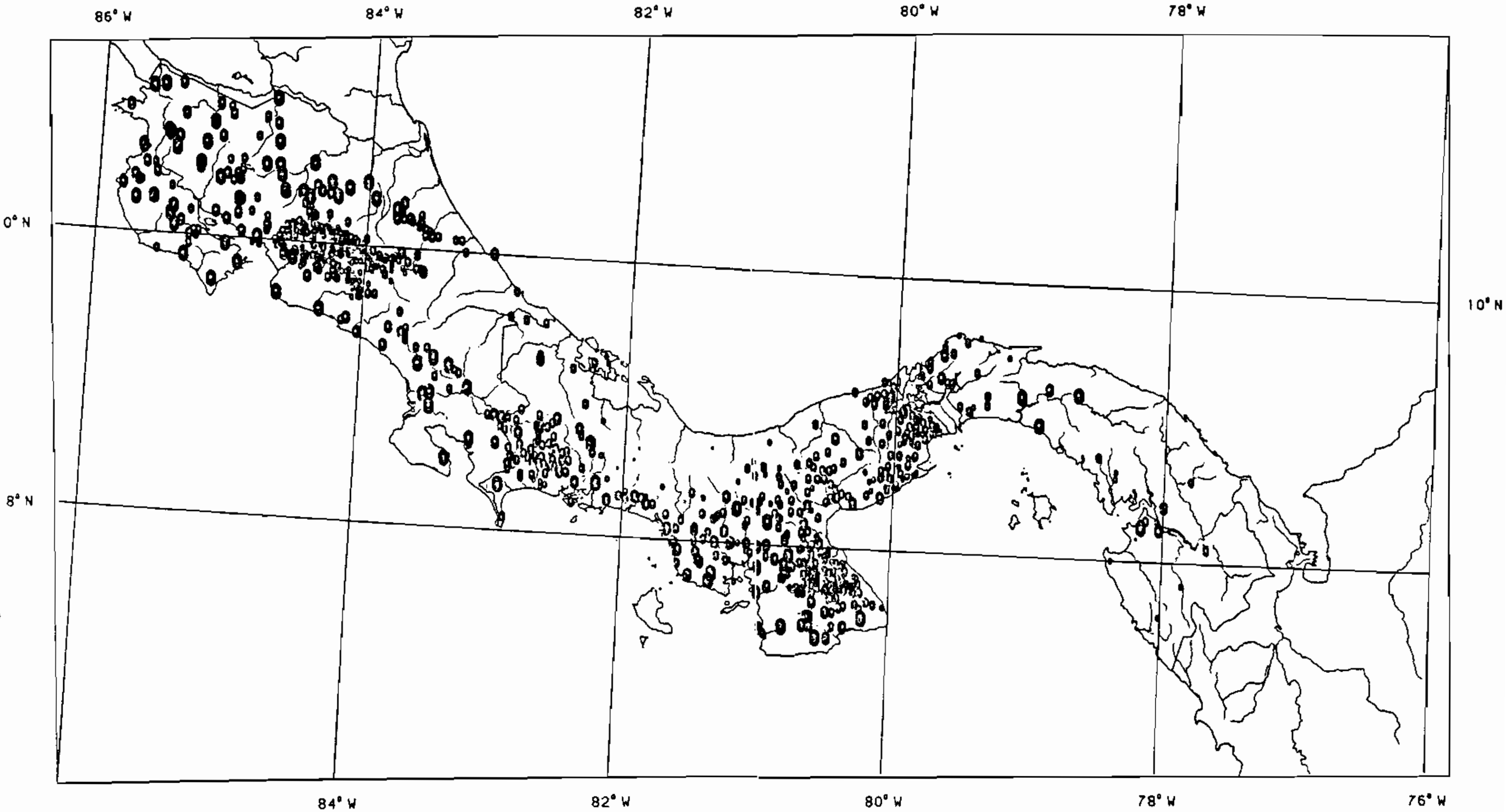


FIGURE 4. PASTURES (ha) IN COSTA RICA AND PANAMA

- 10-100 ha
- 100-1000 ha
- 1000-5000 ha
- 5000-10000 ha
- > 10000 ha

corregimiento or distrito from the Censo Agropecuario de Panamá, 1980; and from the Tabulados Censo Agropecuario de Costa Rica, 1984; the information of geographic coordinates from The Panama and the Canal Zone gazetteer, 1969; and the Costa Rica gazetteer, 1983; and the information of coasts, islands, lakes, rivers and boundaries from the CIAT database (World database II).

Climatic information

Historic daily meteorological data have been collected in variety of forms, either as documents, diskettes or magnetic tapes. This is being catalogued for future detailed studies.

Long term climatic data are being directly incorporated into the existing CIAT climate database South American Mean Meteorological Data, SAMMDATA, which now contains data for more than 6500 stations in Latin America.

Assembling the Database

Digitization of the Soil maps is now on the way. Data on pasture areas and heads of cattle are being transcribed from the census information and converted into geographic data files. Digitization of actual land use (pastures) maps will follow. An overlay of this information with that already contained in the climate database will allow an accurate analysis of the situation of pastures in Central American and the Caribbean.

22. List of Membes of the Tropical Pastures Program

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César Reyes, Ing. Agr. (IVITA)
Rodolfo Schaus, M.Sc. (INIAA)
Jorge Vela, Ing. Agr. (INIAA)

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* Left during 1988.
** On sabbatical leave.
*** Attached to the Program during 1988.

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