Annual Report 1986

Tropical Pastures

Working Document No. 25, 1987

Centro Internacional de Agricultura tropical

Index

Introduction

Latin America's preference for meat and milk can be traced to colonial times. European colonizers introduced cattle and sheep into the New World with the idea of utilizing the native ranges in the highlands, tropical savannas and shrubby semi-arid regions of the continent. As might be expected, settlements first sprung up in accessible lands, where there were better soils and where climatic conditions were more similar to the temperate European environment. Such areas were the coasts, the Andean valleys, and the mountainous regions of Central America. From the 16th century onwards, cattle, sheep, and horses, played a dominant role in the colonization and economic growth of tropical Latin America. This role was enhanced by the introduction of grass species from Africa.

In the late 17th and early 18th centuries, as a consequence of the slave trade, the African grasses Hyparrhenia rufa ("Yaragua", "Faragua", or "Puntero") and Panicum maximum ("Guinea", "Castilla", or "Coloniao") were accidentally introduced into the New World, the former being introduced into the Brazilian coasts, and the latter into both Brazil and Barbados. These grasses, intentionally as well as accidentally, spread into south-central Brazil, Venezuela, Colombia, Peru, Central American, and the Caribbean countries. Similarly, in the 18th century, Melinis minutiflora ("Molasses grass") and Brachiaria mutica ("Para grass") found their way from Angola to Brazil and the Caribbean countries. Throughout the next century, molasses grass rapidly spread into the lower humid areas of the Andes (Parsons, 1972)[1]. Without a doubt, these four grasses are the historical basis of the development of cattle-raising in tropical America.

These traditional grasses successfully colonized the best lands of the region, eventually becoming naturalized; and they sustained, together with several native legumes, the growth of the cattle herds in the rich frontiers of the past, the prime land of today.

Today, the 250 million cattle existing in tropical America outnumber by about 10 times the cattle stock of South East Asia and by a factor of two the herd of tropical Africa. The relative cattle availability per inhabitant is larger by far in tropical America than in other tropical regions of the world (Table 1). This shows the importance of cattle production in our continent.

In recent years the cattle ranching industry has been pushed away from these fertile lands to make way for the expansion of crop production, brought about in response to demographic and economic growth. Beef and milk production are being forced into marginal and frontier lands such as the hilly acid soils of the Cauca

1/ Parson, J.J. Journal of Range Management, 25, 12, 1972.

Table 1. Relative cattle availability in tropical regions.

Tropical Latin America	0.69
Tropical Africa	0.37
South East Asia	0.07
India	0.24

Source: FAO, 1985.

Valley, the Oxisols and Ultisols of the humid tropic and the tropical savannas.

Unfortunately these traditional grasses fail when exposed to grazing and utilization on these poorer soils. After the establishment of grasses such as P. maximum which demand high fertility in these Oxisols or Ultisols, such areas rapidly degrade into low productivity pastures or weedy areas. Due to the low carrying capacity and low quality of native pasture vegetation, cattle production in these lands is of low efficiency, exhibiting low levels of productivity per area and per animal.

On the other hand, rural urban migration has been very intense in Latin America (Table 2). The degree of urbanization is substantially higher in Latin America than in the other developing regions of the world.

Table 2. Degree of urbanization by developing regions.

	%
Latin America	68.4
Africa	35.6
Near East	48.0
Far East	38.2

Source: IBRD, 1985.

This has induced important shifts in the food consumption patterns of the population, such as the rapid increase in rice, beef and dairy products consumption and the decline of other food commodities. Beef and milk are both important in the diet of urban consumers as shown by their high expenditure shares, generally the highest of all food items (Table 3). This has turned them into wage goods, that is to say products whose price directly affects the cost of living and real incomes. Thus pricing of these commodities is a politically sensitive issue and governments are aware of the importance of ample and stable supplies of these commodities to the urban population. The high degree of urbanization and the wage good nature of these commodities have tended to induce Latin American governments to inflict policies in these markets that often benefit consumers and slow down inflation, but only rarely benefit producers.

The high preference for these products is documented by high expenditure elasticities (Table 4). During the periods of rapid economic growth, demand clearly outpaced supply of both beef and milk creating upward pressures on prices due to the high income elasticity of these commodities (Table 5). The recent economic recession reduced this demand pressure but economic recovery will cause similar demand pressures in the future.

Table 3. Expenditure shares of beef and milk of the Latin American urban poor*.

Product	Range
	%
Beef	12 - 26
Milk	7 - 13

* Poorest 25% of population.

In the other hand, this is a continent rich in land resources yet under utilized. This is the case of the predominantly acid poor soils (Oxisols and Ultisols) of the 800 million ha of tropical savannas and humid tropics in Central and South America that occur in marginal and frontier lands.

To facilitate the expansion of crop production on prime land, thus releasing fertile areas presently used for cattle production, and to increase productivity of beef and milk in poor acid marginal and frontier lands, new pasture technology is required. The problems faced are:

Table 4. Expenditure elasticity of beef and milk of the urban poor*.

Product	Expenditure Elasticity
Beef	0.8 - 1.3
Milk	0.9 - 1.2

* Poorest 25% of population.

Table 5. Growth of potential demand and production of beef and milk in Tropical America (1970-1981).

	Growth of	
	Beef	Milk
	%	
Demand	5.3	5.0
Production	2.2	3.7

Source: CIAT, 1982.

1) <u>Lack of adapted commercial cultivars</u>

Unfortunately, several improved tropical grasses and legumes introduced to our continent 15 to 20 years ago from Australia, fail on acid infertile soils and cannot resist the higher disease and pest pressures that occur in our continent, the center of diversity of most pasture legumes. Even within the same continent, it is difficult to widely extrapolate screening results made at one site. What is good for humid environment may not be adapted to or useful in an ecosystem with a long dry season, such as the savannas.

2) <u>The different role played by new forage plants at the farm level</u>

In addition to the environmental constraints the characteristics of the predominant farming system in a specific region will require different solutions to improve its primary production. This implies different cultivars, with specific characteristics such as carrying capacity, palatability, tolerance to weed competition, etc.

3) <u>The economic constraints for adoption</u>

On top of these problems, the new technology must be successfully adopted by farmers whose access to capital for investing in new pasture technology is not dependable. This is a result of typical cattle price cycles and the influence of the country's policies which affect the input/product prices, as mentioned before.

These problems call for a technical solution based on several new adapted germplasm options able to produce and to persist with minimum inputs under specific ecosystem/farming system combinations.

The Tropical Pastures Program is undertaking the challenge of producing such technological options through an active partnership with national research programs, where pasture technology can be finally selected and adjust to increase animal productivity in a reliable and appropriate fashion through the use of better pastures at the regional and farming system level.

Consequently, the specific objective of the program is:

> "To develop sustainable low input, low risk pasture technology options, to increase beef and milk production in the acid infertiles soils of the marginal and frontier lands of the tropical American lowlands".

To accomplish these objectives the general strategies followed by the program are:

1. Development of a wide germplasm base: to explore and screen from the existing natural variability those plants that are better adapted.

2. Low input philosophy implying:

   a) Minimum fertilization at establishment.
   b) Effective N fixation through grass/legume pasture association; and
   c) Appropriate management for effective utilization and nutrient recycling.

3. Farming system perspective, meaning the continuous exposure of the new technologies to producers, and assessment of farmers neeeds in terms of pastures.

4. Networking, essential for pursuing the previous strategies, through which immense economies of scales can be captured and the pasture research effort in the continent can be catalyzed. This implies fully decentralized screening and technology development. Our immediate partners are: ICA in Colombia at Carimagua for the "llanos" ecosystem; EMBRAPA-CPAC at Planaltina, Brazil for the "Cerrados" ecosystem. INIPA and IVITA at Pucallpa, Peru for the Humid Tropics. Since 1987, CATIE and the Ministry of Agriculture in Costa Rica, for the major ecosystems of Central America. At these locations germplasm and technology options are developed, resulting in pre-selection for adjustment in as many sites as possible in cooperation with other NRI in the continent through the RIEPT (Red Internacional de Evaluación de Pastos Tropicales) (Figure 1).

The final aims of the Program in cooperation with National Research Institutions in tropical America are: 1) To increase beef and milk production to positively affect the nutrition of the human population. 2) To improve cattle nutrition in acid-poor fertility soils. 3) To release fertile lands presently utilized with cattle production for the expansion of crop production. 4) To contribute to the conservation and improvement of fragile soils and ecosystems. Thus, providing productive and sustainable pasture technology options for the economically and ecologically sound development of marginal and frontier lands.

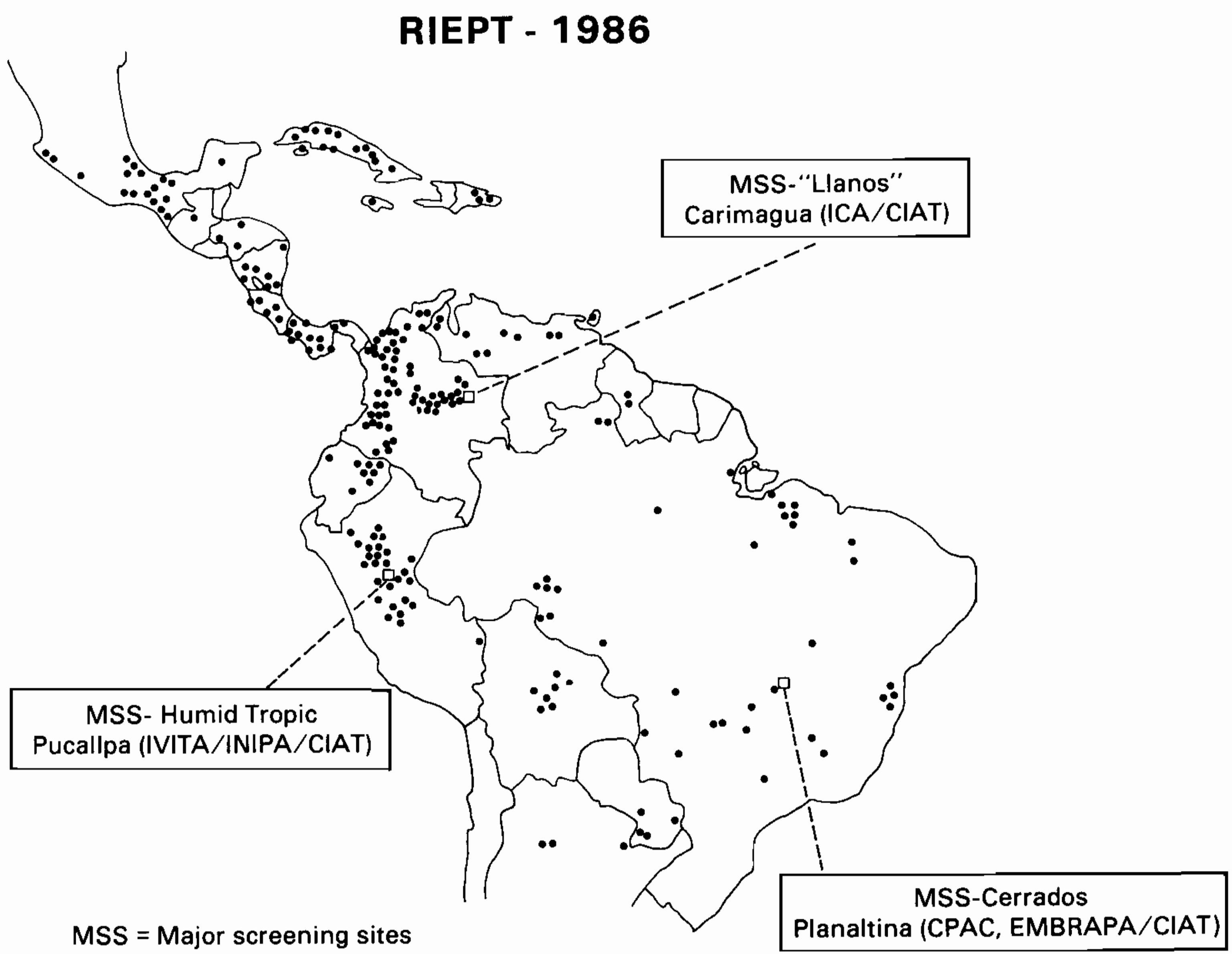


Figura 1. Tropical Pastures Program major screening sites and RIEPT sites.

Germplasm

During 1986 the Germplasm section continued concentrating its efforts on:

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

COLLECTION AND INTRODUCTION OF GERMPLASM

Collection of Germplasm

Germplasm collection activities during 1986 took place in Colombia, Venezuela, Mexico and Indonesia.

a) Colombia: In collaboration with the CIAT Genetic Resources Unit three collection trips were carried out. During the first one (a joint venture with the Australian CSIRO), the North Coast departments Bolívar, Atlántico, Magdalena, Guajira, and Cesar were sampled for native legumes, placing particular emphasis on tetraploid *Stylosanthes hamata* and *Centrosema* spp. The second trip was a joint venture with the Secretaría de Planeación y Desarrollo del Guaviare and consisted of some exploratory sampling of the native legume flora in the San José del Guaviare area. During the third trip, which was carried out in cooperation with the Universidad Nacional de Colombia (Medellín), the Medellín - Turbo transect and the Urabá Antioqueño region (= Northwest Antioquia) were sampled, again with particular emphasis on the genus *Centrosema*. The respective collection routes are presented in Figure 1. Altogether, 336 legume samples were collected, almost one-third of which was *Centrosema* (Table 1).

b) Venezuela: Two collecting missions were carried out in collaboration with the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP), both of them aiming particularly at *Centrosema* germplasm. The first trip covered part of the Northwest region of the state of Bolívar as well as the Territory of Amazonas, between Caicara and south of Pto. Ayacucho, on the Orinoco. During the second trip the eastern and southern portions of the state of Bolívar were sampled, including the Gran Sabana area and extending into the Santa Elena de Uairén - Boa Vista transect in Roraima Territory, Brazil. The respective collection routes are presented in Figure 2. Altogether, 469 legume samples were collected, 25% of them species of *Centrosema* (Table 2).

c) Mexico: In collaboration with the Instituto de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), a major portion of tropical Mexico was covered during a mission which concentrated on collecting *Centrosema* germplasm (Figure 3). Altogether 393 legume samples were collected, of which 20% was *Centrosema* (Table 3).

Figure 1. Routes of systematic collection of tropical forage legume germplasm in Colombia, 1986 (in collaboration with the CIAT Genetic Resources Unit and with CSIRO, Secretaría de Planeación y Desarrollo del Guaviare, and Universidad Nacional de Colombia, Medellín).

Table 1. Summary of tropical forage legume germplasm collected in Colombia, in collaboration with the CIAT Genetic Resources Unit, 1986 (No. of samples).

Genera	North Coast	Guaviare	Northwest Antioquia	Total
Aeschynomene	2	1	1	4
Calopogonium	10	3	6	19
Centrosema	67	3	33	103
acutifolium	-	1	-	1
macrocarpum	10	2	14	26
plumieri	15	-	6	21
pubescens	37	-	13	50
sagittatum	1	-	-	1
schottii	2	-	-	2
virginianum	2	-	-	2
Desmodium	9	5	13	27
Galactia	12	-	2	14
Macroptilium/Vigna	17	-	11	28
Stylosanthes	57	4	2	63
guianensis	5	4	2	11
hamata	48	-	-	48
humilis	4	-	-	4
Zornia	3	1	1	5
Other genera*	42	5	26	73
Total	219	22	95	336

* *Abrus* (2), *Acacia* (1), *Alysicarpus* (6), *Bauhinia* (3), *Canavalia* (14), *Chamaecrista* (2), *Crotalaria* (4), *Desmanthus* (6), *Dioclea* (4), *Gliricidia* (1), *Indigofera* (3), *Leucaena* (4), *Mucuna* (3), *Phaseolus* (2), *Prosopis* (1), *Rhynchosia* (3), *Tephrosia* (3), *Teramnus* (11).

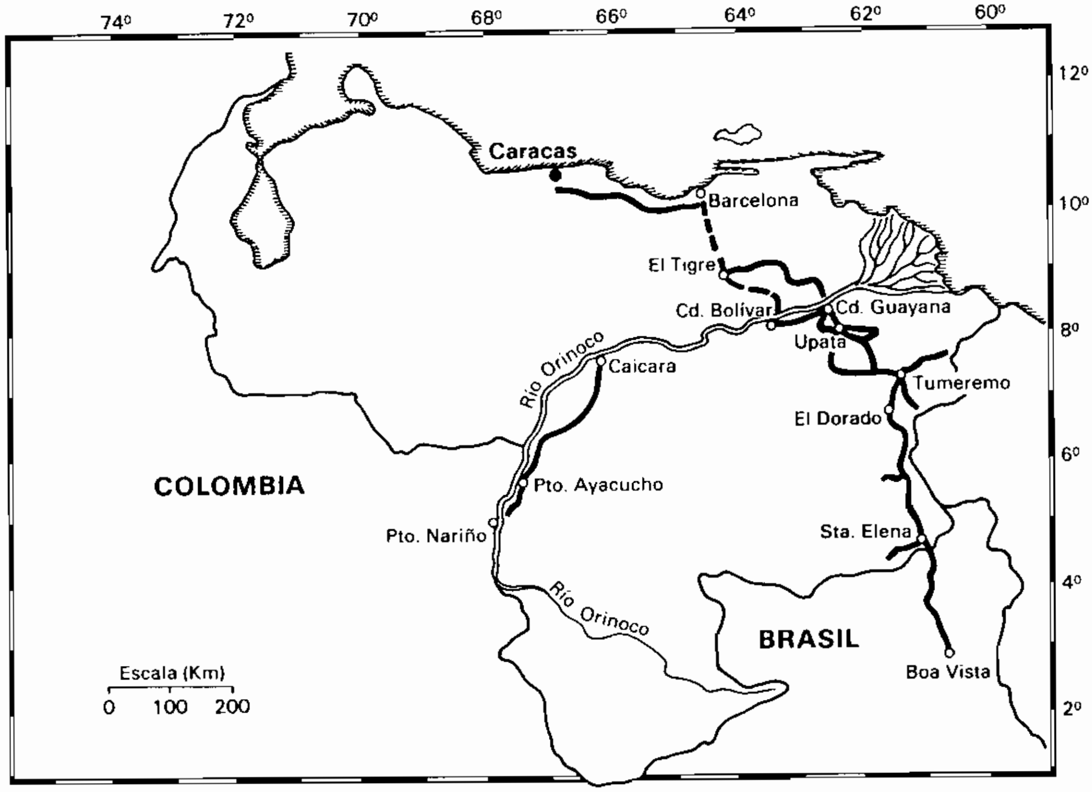


Figure 2. Routes of systematic collection of tropical forage legume germplasm in Venezuela, 1986 (FONAIAP-CIAT).

d) Indonesia: In September 1986, the second part of an IBPGR-cofunded mission to collect native forage legume germplasm in Sumatra was carried out in collaboration with the Research Institute for Animal Production (BPT) and the Sukarami Research Institute for Food Crops (SARIF). During this year's mission the northern part of the island was covered (Figure 4). Emphasis was on collecting germplasm of *Desmodium*, its allied genera (*Codariocalyx*, *Dendrolobium*, *Dicerma*, *Phyllodium*, and *Tadehagi*), and of *Pueraria*. Altogether 243 samples were collected, 60% of which were within the priority species (Table 4).

Introduction of Germplasm

With respect to the introduction of germplasm through exchange with other institutions, an important contribution was received from IBPGR in the form of original seeds collected in Indonesia. The donation consisted of approx. 550 samples, mainly legumes native of/or naturalized in Indonesia, of which 33% were *Desmodium* spp.

With the additions made during the year (approx. 2200 accessions), the collection of the CIAT Tropical Pastures Program has now increased to approximately 18500 accessions, 13% of which is grass germplasm (Table 5). The particular value of this collection lies in the fact that the majority of accessions originate from regions with acid, low-fertility soils. The collection is maintained by the CIAT Genetic Resources Unit. In Table 6 an inventory of germplasm of those species is presented, which the Tropical Pastures Program considers as "key" species on the basis of their performance in experiments in the major ecosystems. The figures indicate that with the exception of *Arachis pintoi*, *Centrosema acutifolium* (in previous annual reports referred to as *Centrosema* sp.n.) and *Zornia glabra*, fairly large numbers of accessions are now available. Considering the diversity that can be observed

Table 2. Summary of tropical forage legume germplasm collected in Venezuela, 1986 (No. of samples).

Genera	T.F. Amazonas/ Orinoco	Bolívar	Total	*Centrosema* species	T.F. Amazonas/ Orinoco	Bolívar	Total
Abrus	1	2	3	*C. acutifolium*	5	-	5
Aeschynomene	5	24	29	*C. brasilianum*	7	22	29
Alysicarpus	-	4	4	*C. grazielae*	1	1	2
Calopogonium	4	4	8	*C. macrocarpum*	15	27	42
Canavalia	3	7	10	*C. pascuorum*	1	2	3
Centrosema	44	78	122	*C. plumieri*	1	2	3
Desmanthus	2	10	12	*C. pubescens*	7	21	28
Desmodium	12	66	78	*C. sagittatum*	1	-	1
Dioclea	7	25	32	*C. schottii*	1	-	1
Galactia	14	17	31	*C. "tetragonolobum"*	5	-	5
Macroptilium/Vigna	9	15	24	*C. triquetrum*	-	2	2
Mucuna	-	5	5	*C. virginianum*	-	1	1
Rhynchosia	1	11	12				
Stylosanthes	7	52	59				
Zornia	5	20	25				
Other genera*	5	10	15				
Total	119	350	469	Total	44	78	122

* *Chaetocalyx*, *Chamaecrista*, *Clitoria*, *Erythrina*, *Indigofera*, *Tephrosia*, *Teramnus*, *Paspalum* (grass)

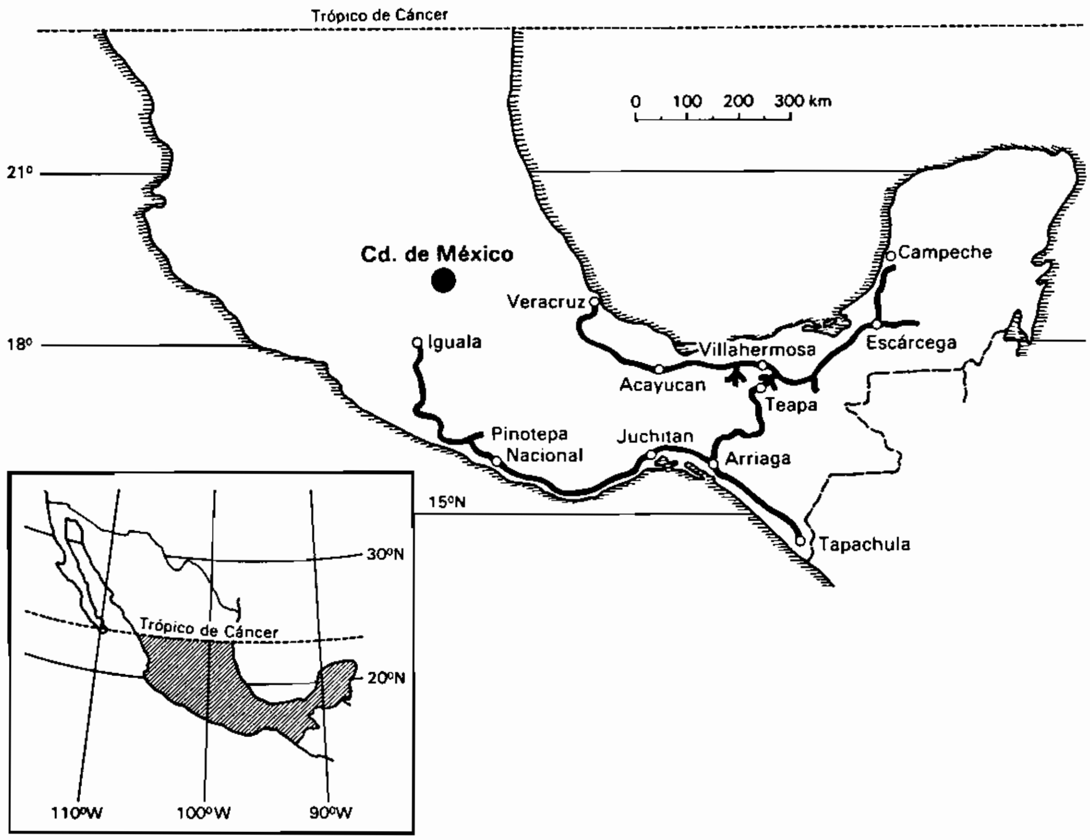


Figure 3. Routes of systematic collection of tropical forage legume germplasm in Mexico, 1986 (INIFAP-CIAT).

Table 3. Summary of tropical forage legume germplasm collected in Mexico, 1986.

Genera	No. of samples	*Centrosema* species	No. of samples
Aeschynomene	27	*C. macrocarpum*	14
Calopogonium	36	*C. plumieri*	14
Canavalia	11	*C. pubescens*	33
Centrosema	77	*C. sagittatum*	6
Chamaecrista	5	*C. schiedeanum*	4
Crotalaria	7	*C. schottii*	5
Desmanthus	15	*C. virginianum*	1
Desmodium	65		
Galactia	18		
Leucaena	12		
Macroptilium	21		
Rhynchosia	26		
Stylosanthes	13		
Teramnus	13		
Vigna/*Phaseolus*	33		
Other genera*	14		
Total	393	Total	77

* *Calliandra* (3), *Clitoria* (1), *Dioclea* (1), *Eriosema* (2), *Erythrina* (1), *Gliricidia* (1) *Mucuna* (3), *Zornia* (2).

Figure 4. Routes of systematic collection of tropical forage legume germplasm in Sumatra/Indonesia, 1986 (BPT-SARIF-CIAT-IBPGR).

among accessions in introduction plots, these collections offer considerable potential for selection and/or breeding work.

MULTIPLICATION AND MAINTENANCE

As in previous years, the multiplication of legume and grass germplasm continued to be one of the important service functions of the Germplasm section. During 1986, the seed multiplication activities consisted essentially of:

- Germplasm multiplied from potted plants in the Palmira greenhouse and/or from single plants or small, space-planted plots in specific germplasm multiplication areas of CIAT-Palmira or at CIAT-Quilichao: approximately 1400 accessions.

- Initial seed increase of all germplasm material under preliminary evaluation at CIAT-Quilichao approximately 2000 accessions.

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

CHARACTERIZATION AND PRELIMINARY EVALUATION

Germplasm of priority or "key" species and of new, agronomically-unknown or only little-known genera and species, is established in CIAT-Quilichao for seed increase and for observations on the most important plant descriptors (plant form, growth habit, flowering time, perenniality, etc.). On the basis of monthly ratings during a total of 12-24 months, germplasm adaptation to the Quilichao environment is

Table 4. Summary of tropical forage legume germplasm collected in Sumatra, Indonesia, 1986.

High priority species	No. of samples	Other genera	No. of samples
Desmodium gangeticum	7	*Abrus*	1
Desmodium heterocarpon	27	*Aeschynomene*	6
Desmodium heterophyllum	23	*Alysicarpus*	14
Desmodium laxiflorum	6	*Cajanus*	6
Desmodium ovalifolium	12	*Christia*	1
Desmodium repandum	5	*Clitoria*	4
Desmodium sequax	3	*Crotalaria*	4
Desmodium strigillosum	2	*Derris*	1
Desmodium styracifolium	1	*Dunbaria*	2
Desmodium triflorum	3	*Flemingia*	16
Desmodium velutinum	5	*Mucuna*	1
Desmodium sp. aff. *D. adscendens*	3	*Pseudarthria*	2
Desmodium sp. aff. *D. styracifolium*	4	*Pycnospora*	5
		Rhynchosia	1
Total *Desmodium* spp.	101	*Smithia*	5
		Tephrosia	1
Codariocalyx gyroides	13	*Teyleria*	5
Dendrolobium spp.	3	*Vigna*	3
Dicerma spp.	3	*Uraria*	20
Phyllodium spp.	8		
Tadehagi spp.	8	Total other genera	98
Pueraria phaseoloides	9		
Total high priority species	145	Grand total	243

Table 5. Introduction of tropical forage germplasm through collection and exchange with other institutions during 1986 (No. of accessions).

Genera	Collections				Introductions through exchange	Total 1986	Total collection Dec. 31, 1986
	Colombia	Venezuela	Mexico and Costa Rica	Indonesia (Sumatra)			
Aeschynomene	4	29	33	6	17	89	866
Calopogonium	20	8	37	-	22	87	492
Centrosema	108	122	88	-	65	383	1930
Desmodium	31	78	75	101	204	489	2548
Galactia	14	31	20	-	-	65	571
Macroptilium/Vigna	31	24	61	3	40	159	1200
Pueraria	-	-	2	9	29	40	185
Stylosanthes	81	59	16	-	-	156	3282
Zornia	6	25	3	-	-	34	955
Other legume genera	86	91	152	124	231	684	4213
Total legumes	381	467	487	243	608	2186	16242
Andropogon	-	-	-	-	-	-	115
Brachiaria	-	-	-	-	31	31	1035
Panicum	-	-	-	-	-	-	536
Other grass genera	-	-	2	-	44	46	719
Total grasses	-	-	2	-	75	77	2405
Grand total	381	467	489	243	683	2263	18647

Table 6. Inventory of germplasm of key species in the CIAT tropical forage collection (December 31, 1986).

Species	No. of accessions originating from: America Tropical	SE Asia	Tropical Africa
Arachis pintoi	10		
Centrosema acutifolium	36		
Centrosema brasilianum	212		
Centrosema macrocarpum	322		
Centrosema pubescens	740		
Stylosanthes capitata	283		
Stylosanthes guianensis var. pauciflora	217		
Stylosanthes macrocephala	115		
Zornia glabra	23		
Desmodium heterophyllum		90	
Desmodium ovalifolium		131	
Pueraria phaseoloides		157	
Andropogon gayanus			104
Brachiaria spp.			1035
Panicum maximum			497

assessed in terms of (a) yield potential on a very acid, infertile Ultisol, including regrowth after cutting and performance during the two rather short but severe dry seasons that prevail in Quilichao, (b) disease and insect resistance and (c) seed production potential. Establishment and evaluation methodology is that of Category I used also at other TPP germplasm evaluation sites.

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

In Table 7 the Category I trials which existed during 1986 in CIAT-Quilichao, are listed. They refer to altogether approximately 1600 legume accessions and almost 850 grass accessions. Some key observations on these trials are:

- Periandra spp.: Within the small collection tested (27 accessions representing 4-5 species) only one as yet unidentified species seems to be well adapted to the Quilichao conditions.

- Centrosema arenarium and C. brachypodum: Both species, which are closely related, are well adapted to the Quilichao conditions. The C. brachypodum lines seem to be somewhat more productive than C. arenarium. Most of them root very well at the nodes of trailing stems, whereas C. arenarium is more an erect bush type. C. arenarium flowers very early and has a high seed production potential; C. brachypodum flowers very late but profusely. However, little seed is formed.

- Centrosema "tetragonolobum": This is a new, undescribed species. It seems to be closely related to C. brasilianum, and may even be a form of C. brasilianum. The 12

Table 7. Multiplication and characterization of germplasm in CIAT-Quilichao at Category I level during 1986.

A. "New", agronomically unknown or only little-known species		No. of acc.	B. Priority or "key" species		No. of acc.
Legumes:	Desmodium velutinum	72	Legumes:	Arachis pintoi	8
	Dioclea guianensis	143		Centrosema acutifolium	35
	Flemingia macrophylla	32		Centrosema brasilianum	103
	Periandra spp.	27		Centrosema macrocarpum	230
				Centrosema pubescens	575
	Centrosema arenarium	2		Desmodium heterophyllum	63
	Centrosema brachypodum	5		Desmodium ovalifolium	124
	Centrosema grazielae	46		Pueraria phaseoloides	97
	Centrosema schiedeanum	26			
	Centrosema sp.n. (type 5117)	6	Grasses:	Brachiaria spp.	400
	Centrosema "tetragonolobum"	12		Panicum maximum	443
Total		371	Total		2077

accessions under evaluation seem to be very Rhizoctonia-tolerant.

- Arachis pintoi exhibits poor growth and CIAT 17434 is more vigorous than the other accessions.

- Centrosema acutifolium: In comparison with the forms from Central Brazil (var."matogrossense") the accessions from the Orinoco region in Colombia and Venezuela (var. "orinocense") are more productive in terms of DM yields, root less at the nodes of trailing stems, and are later flowering with a higher seed production potential.

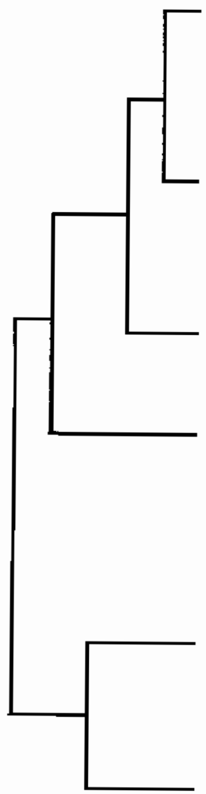
- Centrosema brasilianum: In an ongoing trial with 62 accessions, CIAT 5657, 5671, 15387 and several new accessions from the Island of Marajó (Pará/ Brazil), were outstanding with respect to tolerance to Rhizoctonia foliar blight and, consequently, DM yield.

- Centrosema macrocarpum: The result of a now concluded preliminary evaluation trial with 105 accessions, was the classification of materials by cluster analysis into six distinct groups on the basis of (1) dry matter production potential, (2) capacity to root at the nodes of trailing stems, and (3) seed production potential (Table 8). Accessions in cluster group 4 seem to be particularly interesting because of high DM and seed yields as well as their excellent capacity to root at the nodes of trailing stems. All accessions from Central America are in the non-adapted cluster group 6.

- Desmodium heterophyllum: Not one accession adapted well to the severe drought stress in the second semester of 1986.

- Desmodium ovalifolium: The collection of 84 accessions showed marked variation with respect to a series of plant characters including growth habit, lateral growth, number of days to first flower, content of crude protein and tannins in

Table 8. Classification of a *Centrosema macrocarpum* collection (105 accessions) into six cluster groups, based on DM production, number of rooted stolon nodes and seed production.



Dendrogram	Cluster No.	Accessions No.	Accessions %	DM Yield (kg/plot)[1] Mean	DM Yield (kg/plot)[1] Range	No. rooted nodes/m^2 [2] Mean	No. rooted nodes/m^2 [2] Range	Seed Yield (g/plot)[3] Mean	Seed Yield (g/plot)[3] Range
	1	12	11	9.0	8.3- 9.7	668	255-922	440	104-1028
	2	27	26	7.3	6.5- 8.2	571	26-1353	196	0- 776
	3	3	3	7.5	5.4- 9.6	3681	3336-4189	60	30- 110
	4	10[4]	9	11.3	9.8-13.5	1139	565-1860	430	40-1096
	5	26	25	5.0	3.6-6.1	297	0-1588	369	0-1543
	6	27	26	2.3	0.5-3.5	118	0- 378	53	0- 409

1/ Material accumulated during 13 months growth; 2/ Counts cutting of 13 mo-old plants; 3/ 2 weekly harvests during 9 months; 4/ CIAT Nos. 5744, 15057, 15059, 15073, 15085, 15098, 15103, 15106, 15320, 15362.

leaves, and relative acceptability. This variation suggests that the *D. ovalifolium* collection can provide a sufficiently broad genetic base for future selection and breeding work.

Grasses: The *Panicum maximum* collection in the field is at present being primarily used as a seed source, whilst the collection of *Brachiaria* species is in the establishment phase. Characterization and preliminary evaluation of both collections will start in 1987.

FUTURE PLANS

Missions to collect native legume germplasm in SE Asia (tropical China and Central/North Thailand) and Brazil are projected for 1987. All trips will be planned and eventually executed in collaboration with the respective national institutions. Multiplication and characterization work at CIAT-Palmira and CIAT-Quilichao will continue in a routine way.

Plant Breeding

INTRODUCTION

Ongoing breeding projects in Andropogon gayanus and Stylosanthes guianensis advanced during 1986 towards achieving previously stated breeding objectives (Annual Reports 1981-85). Second cycle, short stature A. gayanus parental clones are being evaluated and recombined. Vegetatively propagated short clones are being compared, under grazing and associated with Stylosanthes capitata, with standard, tall A. gayanus CIAT 621.

Pedigree-selected S. guianensis progenies of the original diallel set of crosses are being multiplied for initial evaluation under grazing in 1987. Almost no new artificial hybridization is being conducted as a recurrent selection scheme, based on natural outcrossing, can now be considered fully implemented and is yielding large numbers of new recombinants for field testing and selection. More than 300 mutant seedlings, potentially useful as marker traits, were selected from a mutation breeding program for progeny testing and studies of inheritance.

Preliminary breeding studies have been initiated in Centrosema. Parental accessions are being field evaluated and diallel crosses are being formed for studies of Rhizoctonia foliar blight resistance in C. brasilianum. A series of interspecific crosses has been initiated in an attempt to establish the limits of available gene pools in Centrosema spp.

BREEDING AND GENETICS

A. gayanus, short stature population

The selection project to develop a short statured A. gayanus population initiated a second cycle in 1986 with the establishment of replicated trials at Quilichao and Carimagua of 200 clones selected from the open-pollinated progeny of first-cycle parents. The trial at Quilichao will serve also as a recombination block with open-pollinated seed harvested from the selected clones in early 1987.

Data on plant height and fresh weight forage yield on four dates at Quilichao and on plant height on one date at Carimagua show substantial genetic variation still remains in the population after one cycle of selection (Table 1).

Genetic correlations between evaluation dates at Quilichao are consistently high, indicating that fewer evaluations will give reliable results within locations (Table 2).

Genetic correlations for plant height between Quilichao and Carimagua differ widely by date (Table 3) suggesting genotype interaction with location may be important for plant height. However, results of selection at the two sites are essentially identical (Table 4). Selection on the basis of both Quilichao and Carimagua performance ought to result in genotypes with more consistent performance over locations.

Table 1. Mean plant height and fresh weight forage yield and broad-sense heritability for 200 A. gayanus clones at Quilichao and at Carimagua.

Trait	Evaluation Site	Evaluation Date	Mean	H^2
Plant height (cm)	Quilichao	30 May 86	132.3	0.83***
	Quilichao	24 Jul. 86	142.6	0.91***
	Quilichao	16 Sep. 86	96.1	0.85***
	Quilichao	10 Nov. 86	140.9	0.93***
	Carimagua	11 Nov. 86	158.7	0.94***
Fresh wt. forage yield (g/plant)	Quilichao	05 Jun. 86	456.5	0.80***
	Quilichao	25 Jul. 86	712.1	0.86***
	Quilichao	17 Sep. 86	387.2	0.84***
	Quilichao	11 Nov. 86	1518.0	0.89***

*** Genetic component of variance differs from zero ($P < 0.001$).

Table 2. Genetic correlations for A. gayanus plant height between evaluation dates at Quilichao.

Date	Date		
	24.07.86	16.09.86	10.11.86
30.05.86	0.86	0.68	0.58
24.07.86		0.77	0.68
16.09.86			0.57

Three first-cycle clones and CIAT 621 were established this year by the Pasture Productivity Section, associated with S. capitata, in a small-plot grazing trial to evaluate several hypotheses regarding short stature A. gayanus performance, particularly with regard to compatibility with legumes.

A. gayanus, late-flowering populations

Twenty-two clones obtained by the Forage Agronomy Section by selection on late flowering habit at Carimagua (4°, 02' N) were established this year at Carimagua in a 10-replicate, single-plant-plot recombination block. Open-pollinated seed will be harvested separately by clone for progeny tests in 1987. Although no formal comparison is possible due the absence of a standard check in this planting, all selected clones appear to be substantially later flowering than CIAT 621. Visual ratings of earliness to flower and leaf:stem ratio made in early November, indicate that the 22 clones differ in both attributes.

Table 3. Genetic correlations between Carimagua and Quilichao for A. gayanus plant height on one evaluation date at Carimagua and four dates at Quilichao.

Carimagua	Quilichao	Coefficient of Genetic Correlation
11 Nov.86	30 May.86	0.71
	24 Jul.86	0.73
	16 Sep.86	0.55
	10 Nov.86	0.34

Table 4. Mean plant height and fresh weight forage yield of selected A. gayanus clones, by selection site.

Trait	Evaluation Site	Evaluation Date	Site of Selection		
			Quilichao	Carimagua	
Plant height (cm)	Quilichao	30 May. 86	132.0	132.6	NS
	Quilichao	24 Jul. 86	141.5	143.7	NS
	Quilichao	16 Sep. 86	100.1	92.3	NS
	Quilichao	10 Nov. 86	137.5	144.2	*
	Carimagua	11 Nov. 86	160.4	156.8	NS
Fresh wt. forage yield (g/plant)	Quilichao	05 Jun. 86	426.3	486.1	NS
	Quilichao	25 Jul. 86	707.5	716.7	NS
	Quilichao	17 Sep. 86	450.9	324.7	NS
	Quilichao	11 Nov. 86	1462.4	1572.3	NS

NS = Means do not differ significantly (P > 0.05)
* = Means differ significantly (P > 0.05).

A. gayanus, seed quality and seedling vigor

Two trials were established this year in collaboration with the Seed Production Section with the aim of investigating the effects of genotype (both within- and between-accession), productin site, and level of nitrogen fertilizer on seed yield and quality, and on the vigor of resulting seedlings.

Plots 10 x 10 m of CIAT 621 and CIAT 6053 were established at Quilichao (3°, 06' N) and near Valledupar, Colombia (approx. 10°N) to investigate the effects of location (principally latitude), on seed yield and quality. These plots will not be harvested until early 1987, when seed quality evaluations will be performed. An attempt will be made to compare these results with quality determinations on samples of standard commercial seed lots (of CIAT 621) from the Villavicencio area and from the north coast of Colombia.

A more detailed trial was established this year at Quilichao with the objective of evaluating genetic variation within and among accessions of A. gayanus (five clones within each of three accessions) and the effect of fertilizer nitrogen (0 vs. 184 kg/ha) on seed yield and quality and, eventually, on the vigor of the resulting seedlings. Single-plant sub-plots (clones) within bordered main-plots (N levels) were established in May. Nitrogen treatments were imposed following a uniform cut in early November. Seed samples will be obtained during December, 1986 and January, 1987, for subsequent determinations of seed quality, caryopsis content, caryopsis size, germination (rate and percent) and dry matter yield of the resulting seedlings.

The results of these two trials ought to clarify the relative importance of genotype and environmental effects on seed quality and seedling vigor in A. gayanus. If genetic variation is found to be a large component of seed quality and seedling vigor then consideration will be given to the initiation of selection on these attributes.

S. guianensis, initial diallel series of crosses

Pedigree advance

Fifty pedigree-selected F_3 and F_4 progenies were selected from a total of 518 progenies included in a small-plot agronomic trial at Carimagua in 1985 on the basis of first season performance (principally survival and seed set). These progenies were established in seed multiplication plots at Quilichao in 1986 with two planting dates and two replications. Twenty-two of the 50 progenies have been eliminated based on second season performance at Carimagua. On the basis of Quilichao seed yields, the selected progenies will be further reduced to approximately 10. These will be advanced to small-plot grazing trials (Category 3) in 1987 in collaboration with the Forage Agronomy Section at Carimagua. The 10 selections will be the product of the first cycle of hybridization and selection in S. guianensis which began in 1981.

Bulk advance

Segregating progenies from the first series of crosses are also being handled by a bulk generation advance scheme. Three cycles (generations) have been completed and fourth cycle bulks were established at Carimagua in 1986. The large increases in bulk seed yield observed from the first to the second cycle did not continue through the third cycle (Table 5). However, several additional cycles will be needed to establish long-term trends.

Natural selection

The effect of natural selection under grazing on the genetically heterogeneous population resulting from blending F_2 seed from the initial diallel series of crosses is being investigated. Natural selection plots were established in 1984 with two associations (A. gayanus vs. native savanna). Three stocking rate grazing treatments were imposed on each association in 1985. By June, 1986, (approx. one year after initiating grazing treatments) S. guianensis had nearly disappeared from the A. gayanus plots at all stocking rates. Surviving plants were sampled and progeny of these will be evaluated as seed supplies permit. Grazing was suspended on the A. gayanus plots in 1986.

An adequate S. guianensis population remains in the native savanna associations. Legume plants were sampled in June, 1986, (as last year) with the objective of documenting the effects of natural selection over time. Unfortunately the method of transplanting surviving plants from the

Table 5. Seed yield, by cycle, of <u>Stylosanthes guianensis</u> bulk advance populations.

Bulk Population	Approximate Harvest Date	Cycle First	Cycle Second	Cycle Third
		kg/ha		
1	01 Oct.	0.43	9.07	2.11
2	15 Oct.	4.38	19.69	6.43
3	29 Oct.	3.48	8.28	9.07
4	12 Nov.	0.08	0.60	
5	26 Nov.	0.13	0.06	
6	10 Dec.	0.12	0.04	1.05
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
11	18 Feb.	0.26	10.11	5.42
12	04 Mar.	1.33	5.38	11.13

grazed pasture to pots has not been successful this year, with only about 15% survival. In future years direct sampling of seed from surviving plants will be attempted, with exclusion of animals from the paddocks, if necessary.

<u>New crosses</u>

Almost no artificial manual hybridization is currently being done in <u>S. guianensis</u>, as the recurrent selection scheme proposed in previous annual reports can now be considered fully implemented.

Last year it was optimistically projected that 400 to 500 S_1, progenies resulting from the first cycle recombination block would be in field evaluation trials this year. In fact seed production on S_0 plants was not as high as expected and sufficient S_1 seed for inclusion in the direct-seeded field trial was obtained for only 284 families.

Last year's crossing block of promising var. <u>pauciflora</u> lines yielded 100 progeny of white-flowered plants for testing at Carimagua and for a plant-out at Quilichao to identify yellow-flowered outcrosses (S_0 individuals). Results of the plant-out appear to indicate a lower rate of outcrossing than had been observed in previous years. Of a total of 8,192 plants, only 252 (2.98%) were yellow-flowered outcrosses. While the total rate of outcrossing is greater, this is the lowest proportion of identifiable outcrosses obtained in three years (Table 6). Although hives of bees (<u>Apis mellifera</u>) were placed in the crossing block during the 1985 season, there appears to be a substantial diminution in the populations of wild bees of the genera <u>Exomalopsis</u>, <u>Augochloropsis</u>, and <u>Melissodes</u> which may explain the decrease in observed outcrossing. It appears that larger open-pollinated populations will have to be planted to obtain sufficient S_0 individuals (and S_1 progenies).

A large, space-planted crossing block (985 individuals) was established this year at Quilichao. This contained predominantly early-flowering var.

Table 6. Observed outcrossing in *Stylosanthes guianensis* over three years at Santander de Quilichao, Colombia.

Year	Experimental population	Proportion yellow-flowered individuals in progeny of white-flowered plants	Proportion dominant gamete in pollen pool	Estimated total outcrossing
1982-83	F_2 populations	0.067 ($\pm$ 0.007)	0.487	0.138 $\pm$ 0.021
1983-84	F_3 nursery	0.096 ($\pm$ 0.007)	unknown	> 0.096
1984-85	F_3 nursery	0.067 ($\pm$ 0.003)	unknown	> 0.067
1985-86	F_3 nursery	0.030 ($\pm$ 0.002)	unknown	> 0.030

vulgaris F_4 progenies selected at Carimagua. Resulting progenies of white flowered individuals will be included in an agronomic test at Carimagua in 1987 and in a plant-out to identify outcrosses.

The recurrent selection program has effectively been divided into a var. *pauciflora* and an early-flowering, var. *vulgaris* populations, to avoid the infertility problems which are encountered repeatedly in crosses between the two types. Whether greater progress towards the goal of anthracnose resistance and high seed yield will be realized in the var. *pauciflora* population (with inherently higher levels of anthracnose resistance but lower seed production) or in the var. *vulgaris* population (with inherently higher seed production but lower anthracnose resistance) remains to be determined.

S. guianensis, other studies

A small mutation breeding project, initiated in 1985 with the objective of identifying a reliable seedling marker, was continued during 1986 with a screening of large M_2 populations.

As non-nodulating mutants would be useful and might be expected to appear in the M_2 populations, the screening was done in sterile sand, fertilized with a 0-nitrogen nutrient solution and inoculated with a *Rhizobium* strain compatible with *S. guianensis*. Non-nodulating mutants should appear as isolated chlorotic seedlings among normal green seedlings. A number of such off-type, chlorotic individuals have been found (255) and transplanted to pots for seed production. These individuals will be progeny-tested to confirm that the M_2 phenotype is, indeed genetically determined, and crosses will be initiated with normal genotypes to establish the inheritance of the mutants. Other off-type individuals have been identified in the M_2 population, but these are so abnormal as probably to be useless as seedling markers in the breeding program.

Centrosema spp.

Inheritance of reaction to Rhizoctonia in C. brasilianum

A set of 14 promising *C. brasilianum* accessions was direct-seeded at Carimagua and at Quilichao in trials artificially inoculated with *Rhizoctonia*. The inoculum (mycelium grown on maize flour, mixed with sand, and applied directly over the seed before burying), however, was not effective at either location. Although ineffective inoculation has precluded identification of differences in *Rhizoctonia* reaction, large differences among accessions in seedling vigor, dry matter production, and *Cercospora* reaction have been detected at Carimagua. We intend to obtain data on earliness to flower, flowering abundance, and seed yield from these trials. Two 7-parent diallels are being made up from the 14 parental accessions and these will be established in 1987 to study the inheritance of several agronomic traits.

The same 14 accessions were established in flats in an attempt to rank them on Rhizoctonia reaction as seedlings. The seedlings were artificially inoculated with a suspension of mycelium in water. Disease score was rated daily for 6 days. This experiment showed no consistent genetic effect, but it did show a very large effect of position of plot in the planting flat.

Evaluating genetic differences in Rhizoctonia reaction among accessions of C. brasilianum may prove difficult. Field screening using established techniques seems not to be effective or reliable, perhaps due to unfavorable environmental conditions this year. Seedling screening gave inconclusive results due to one of two factors: either (1) differences among a diverse set of accessions for Rhizoctonia reaction are very small (or nonexistent); or (2) the expression of disease symptoms is very sensitive to small environmental effects. In any case, until a reliable screening technique exists, no progress can be expected from a breeding program seeking to enhance resistance to Rhizoctonia. A considerable effort is planned for 1987, in collaboration with the Plant Pathology Section, to clarify the conditions necessary for reliable evaluation of genetic differences in Rhizoctonia reaction in C. brasilianum.

Centrosema spp., interspecific hybridization

An interspecific hybridization program in Centrosema has been initiated with the prime objective of determining the limits of natural gene pools. Initial effort is being concentrated on one group of species morphologically close to C. pubescens and a second group of species close to C. brasilianum (Table 7). Preliminary results are encouraging, although interspecific hybridization is so far only about half as successful as intraspecific hybridization.

Table 7. Summary of interspecific Centrosema crosses.

"Pubescens" Group	Total Crosses	Result Confirmed	Positive*
C. pubescens x C. acutifolium	57	41	6
Reciprocal	93	72	30
C. pubescens x C. grazielae	0	0	0
Reciprocal	0	0	0
C. pubescens x C. macrocarpum	12	7	1
Reciprocal	14	3	0
C. pubescens x C. schiedeanum	0	0	0
Reciprocal	0	0	0
"Brasilianum" Group			
C. brasilianum x C. vexillatum	0	0	0
Reciprocal	0	0	0
C. brasilianum x C. bifidum	1	1	0
Reciprocal	0	0	0
C. brasilianum x C. "Tetragonolobum"	29	6	6
Reciprocal	0	0	0
C. brasilianum x C. angustifolium	9	9	3
Reciprocal	0	0	0
Other cross combinations			
D. arenarium x C. schottii	7	5	1
C. brasilianum x C. acutifolium	13	13	4
C. brasilianum x C. pubescens	16	16	1
C. brasilianum x C. virginianum	25	25	2
C. pubescens x C. arenarium	16	16	1
C. pubescens x C. brachypodum	34	34	2
C. pubescens x C. grandiflorum	4	3	1
C. pubescens x C. schottii	36	36	2
C. schottii x C. pubescens	15	15	2
C. pubescens x C. "tetragonolobum"	1	1	1
C. pubescens x C. virginianum	49	49	5
C. virginianum x C. pubescens	6	6	2
C. virginianum x C. brachypodum	5	5	1
Total, Interspecific Crosses	832	735	71 (9.7%)
Total, Intraspecific Crosses	531	269	59 (21.9%)

* "Positive" indicates pod formation, but not necessarily the formation of mature seed.

Biotechnology

In 1986, the Biotechnology Research Unit (BRU) activities in Tropical Pastures comprised:

a) tissue culture of *Stylosanthes* to (1) assess the occurrence of variability in cell cultures and regenerated plants; (2) develop an *in vitro* selection scheme; (3) develop a protoplast fusion technique;

b) tissue culture of *Brachiaria* to facilitate the distribution of germplasm accessions to national programs;

c) development of electrophoretic techniques for genotype identification in *Desmodium*, *Centrosema* and *Stylosanthes*.

Tissue Culture for Stylosanthes spp.

Basic techniques for plant regeneration of various *Stylosanthes* spp. using leaf-derived callus cultures, cell suspension cultures and leaf mesophyll/cell suspension protoplast cultures have already been described (BRU Ann. Report, 1985). This year, work focused on characterization of different *in vitro* cultures, with special attention to variability.

Variability in S. guianensis callus and cell suspension cultures

1. A variant, habituated, non-morphogenic, callus culture of *S. guianensis* CIAT 2243 (2243-H) has been isolated and its growth characteristics (increase of dry weight in time) have been compared with a normal, morphogenic, callus culture (2243-1) (Figure 1). Habituated callus was able to grow in the absence of growth hormones, while normal calli usually had absolute requirement for at least one growth hormone: auxin or cytokinin. Growth of the habituated callus (2243-H) was optimal on hormone-free and BAP-containing media, was suboptimal with only NAA and was lowest on BAP+NAA containing media. Growth of the morphogenic callus was optimal on BAP+NAA or on BAP containing medium. It was suboptimal on only NAA containing medium and no growth was detected on hormone-free medium. This observation showed, that cytokinin is more important than auxin for the continuous growth of the morphogenic callus (2243-1) of *S. guianensis*. According to the dry weight measurements, habituated calli grew faster than morphogenic ones. Habituated cell cultures may have an importance as feeder cells in transformation or fusion experiments.

2. Observations of phenotypic instability of callus-derived plants of *S. guianensis* CIAT 2243 (BRU Ann. Report, 1985) suggested the possibility of chromosomal instability of callus and cell suspension cultures.

Detailed cytological analysis of two *S. guianensis* cell cultures revealed wide variability in chromosome number. Besides diploid (2n = 20) chromosome number, cells with tetraploid, polyploid and aneuploid chromosome number have been found with high frequency. Morphogenic cell cultures of CIAT 136 had chromosome numbers between 20-100, the majority of cells

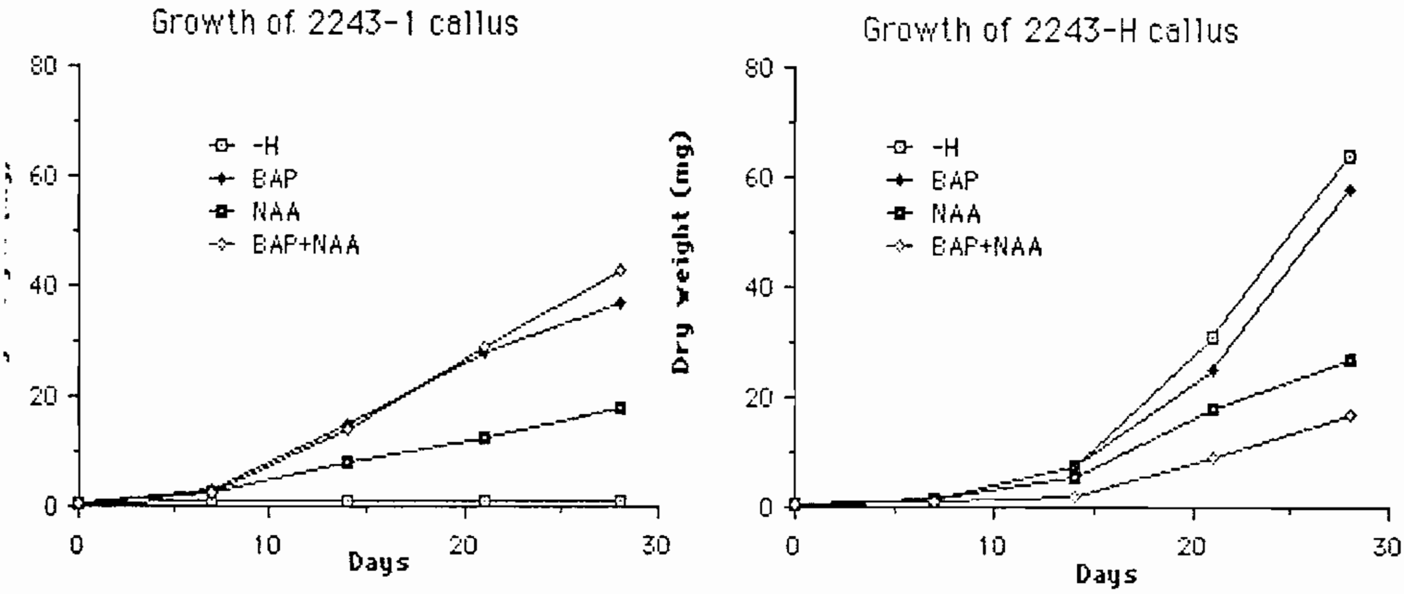


Figure 1. Variation in callus cultures of Stylosanthes guianensis: dry weight increase of normal, morphogenic callus (2243-1) and of a variant, habituated, non-morphogenic callus (2243-H). Note optimal growth of variant callus occurs in hormone free medium, in contrast to normal callus which requires full hormone supplement.

having 26-40 chromosomes (Figure 2). Non-morphogenic, habituated cell cultures of CIAT 2243 (2243H) had chromosome numbers in an even wider range: 18-116 (Figure 2).

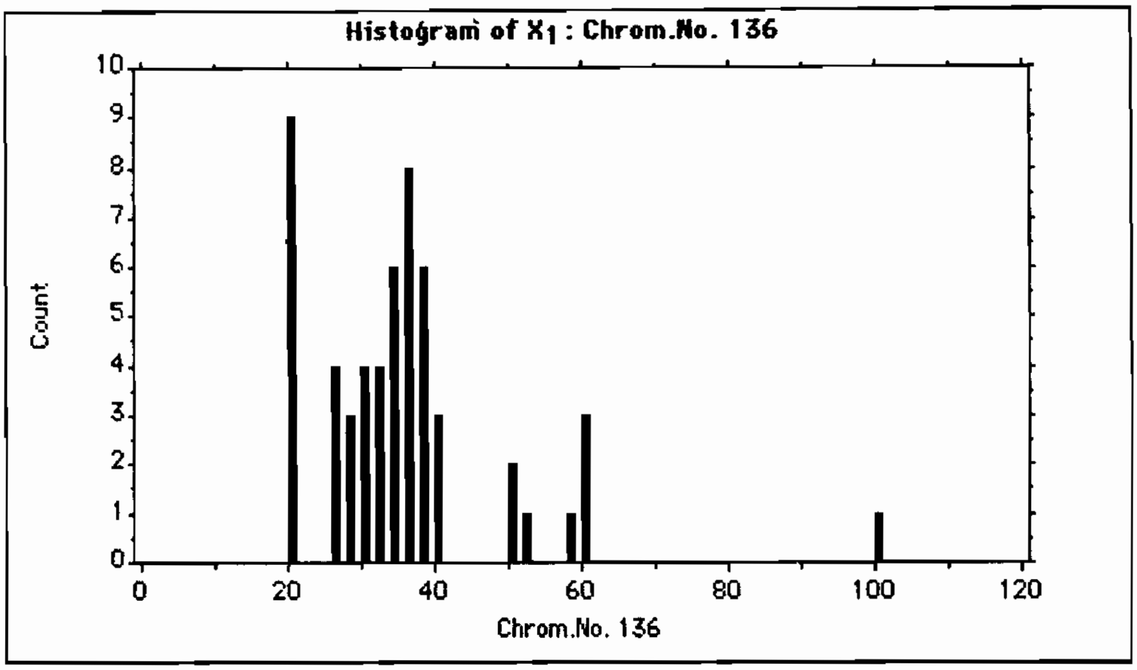
Instability at the chromosome level may be partly responsible for the morphological variability observed. Variability of this type suggests that genetic instability does exist in these cultures, generating a wide range of genetic changes.

No plants with aneuploid chromosome number have been found up to now. That means, that plant regeneration may function as a filter which does not permit plant formation from grossily aberrant cells. Indeed, this is an advantage of somaclonal variation over mutant induction since somaclones can be stabilized immediately in most cases, in contrast to mutants which require several backcross generations.

Variability of S. guianensis plants regenerated from protoplast cultures

Methodologies for Stylosanthes protoplast isolation, culture and regeneration has been described earlier (BRU Ann. Report, 1985). This year, protoplast-derived plants of CIAT 2243 and CIAT 136 have been transferred for greenhouse evaluation. Variation for morphological and cytological characters of protoplast-derived plants was similar to callus-derived SC_1 plants. Tetraploids (2n=4X=40) were found among the regenerated plants of both varieties.

Protoplast-derived cell colonies are considered to have single-cell origin, and plants obtained from them were treated as cloned ones, and labelled individually. Observed variability may have generated from the explant (if leaf mesophyll tissue is not genetically homogeneous) or from the protoplast culture process.



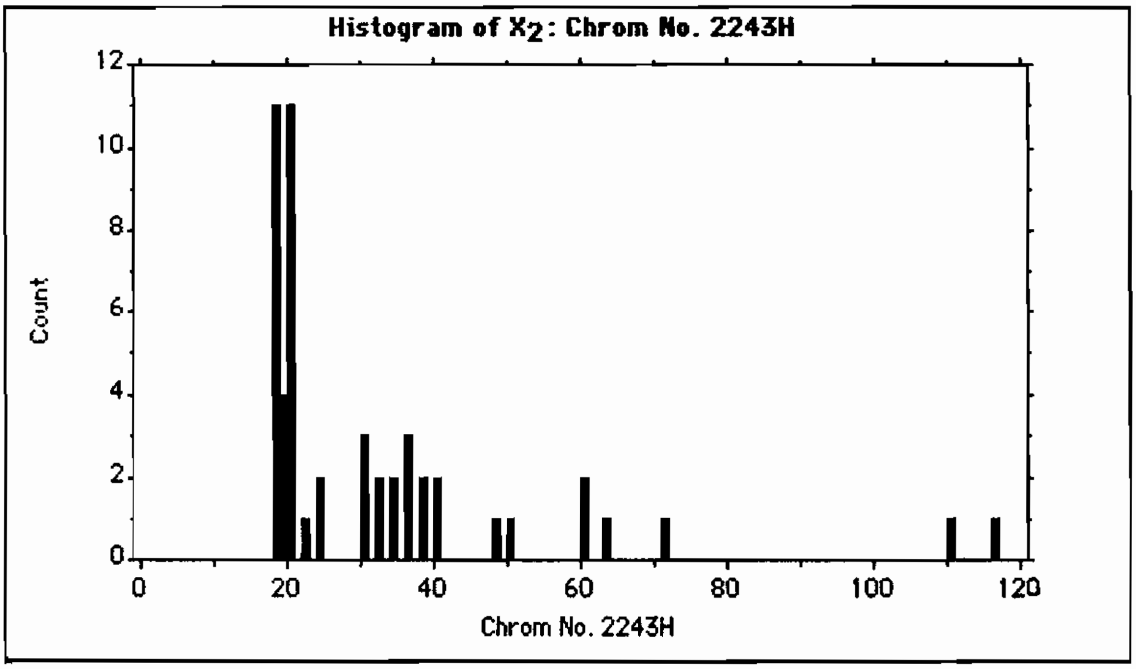


Figure 2. Variability in chromosome number of S.guianensis morphogenic cell suspension cultures of CIAT 136 and non morphogenic habituated, cell suspension cultures of CIAT 2243 (2243 H). Note that even though chromosome number frequencies of 2X=20 prevail, there are cells with 4X, polyploid, and aneuploid numbers.

SC_1 plants of CIAT 2243 were allowed to self in the greenhouse, seed obtained and germinated. Seedlings have been transplanted to the field (Santander de Quilichao) for evaluation of variability in the SC_2 plant population.

<u>Variability of S. guianensis plants regenerated from callus cultures</u>

Callus cultures have been initiated using leaf and hypocotyl explants of *in vitro* germinated *S. guianensis* (CIAT 2243) plantlets. One hundred and forteen plants have been regenerated from 30, 60 and 90 day old callus cultures (0,1, and 2 subcultures, respectively). Regenerated plants have been transferred to greenhouse for evaluation (SC_1 plants). Preliminary data on phenotypic variation of the SC_1 plants was reported earlier (BRU Ann. Report, 1985). Chromosome counts in root tip squashes identified 24 plants out of 114 SC_1 plants (21%) as tetraploids (2n=2X=40). Subculture affected ploidy changes of the regenerated plants: frequency of tetraploids was higher among plants regenerated from 60 and 90 days old callus (Figure 3). Wide variation frequencies were detected in SC_1 plants in vegetative characters such as leaf size, flower size, pubescence and reaction to inoculation with anthracnose cultures (Figure 4). Other characters also varied, e.g. internode distance, seed size and number of seeds per plant. Variant, tetraploid, SC_1 plants had larger and deep green leaves, larger flowers, larger internode distance, bigger seeds, more profuse pubescence and showed relative higher tolerance to anthracnose; plant height and final seed yield were not influenced by ploidy level.

<u>Variability in progenies of regenerated plants</u>

Regenerated (SC_1) plants of *S. guianensis* CIAT 2243 were allowed to self in the greenhouse and seeds of 80 plants were germinated. Fifteen seedlings of each regenerated plant (somaclone) were transplanted to the field (Santander de Quilichao) in randomized plots (SC_2 plants) in collaboration with the Tropical Pastures Program.

In order to assess if the variability observed in SC_1 plants could be transmitted through seeds and to

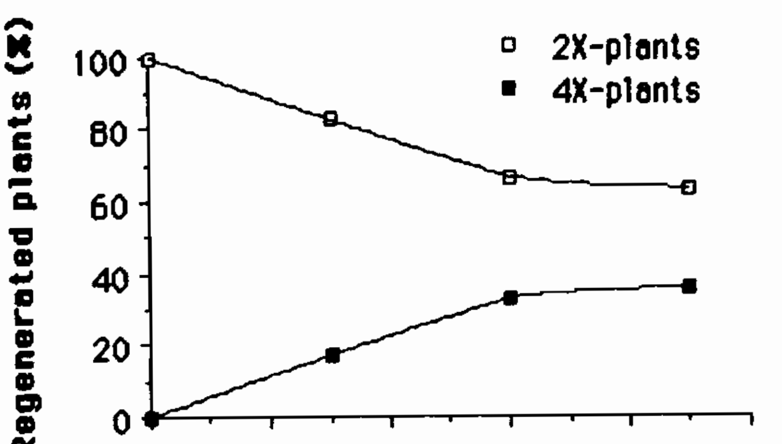


Figure 3. Variation in *Stylosanthes* plants: frequency of diploid and tetraploid plants regenerated from 30, 60 and 90 days old callus cultures (*S. guianensis* CIAT 2243).

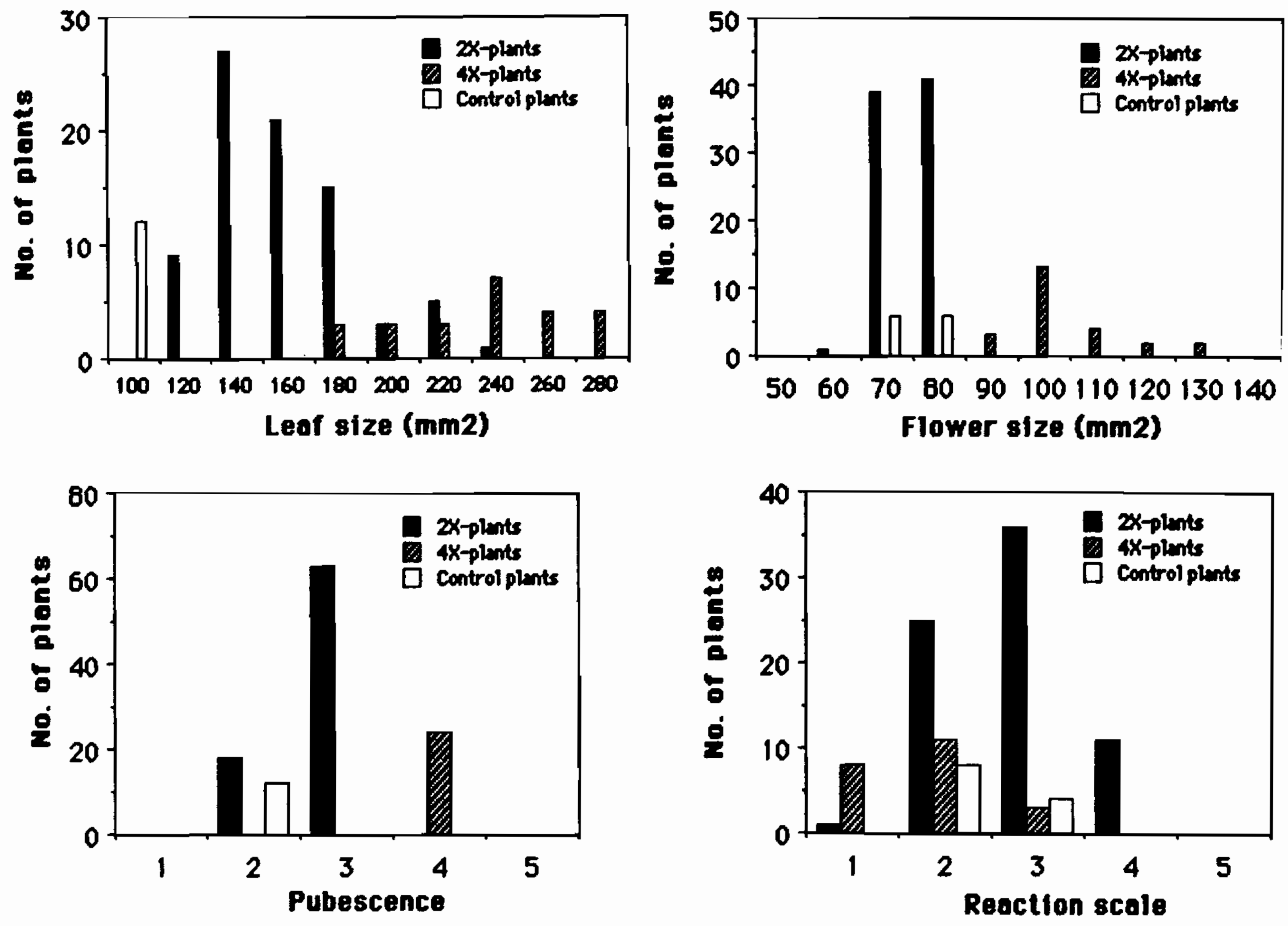


Figure 4. Frequency distribution of leaf size, flower size, pubescence and reaction to anthracnose inoculation of regenerated <u>S.guianensis</u> (CIAT 2243) diploid (2X plants) and tetraploid (4 X plants) variants and parental (control) plants.

determine the extent of such variability, several characters of the SC_2 plants have been evaluated, e.g. plant vigor, lateral expansion, internode distance, leaf size, reaction to anthracnose attack; and others are under evaluation, e.g. flowering, seed production, nitrogen content and digestibility, plant fresh and dry weight, etc. In addition, we assessed if new phenotypes appear within SC_2 families which may result from undetected recessive changes in SC_1 plants.

Figure 5 shows the frequency distributions in the progenies (SC_2 plants) of regenerated plants with regard to number of stems, plant vigor and reaction to anthracnose in the field. SC_2 plants have been grouped into ploidy levels: (67 diploid clones and 10 tetraploid clones) and compared to control plants (3 lines). SC_2 plants displayed wide variability in these characters. Some somaclones had the highest number of stems and vigor as high as the control plants. Similarly, a few somaclones had minimum anthracnose levels (grade 0-1). At this stage of the experiment it is evident that, in spite of having tested only 77 clones, S. guianensis plants regenerated from callus cultures can display variability which has been transmitted through seed. The usefulness of such variability should be evaluated.

Among progenies of regenerated plants (SC_2), new phenotypes have appeared among plants of certain somaclones as a possible result of segregation of recessive mutant alleles: plants with chlorotic, yellowish leaves in two somaclones, with bifoliated leaves in one somaclone and plants with bush-like phenotype in two somaclones (Table 1).

Segregation ratios suggest that chlorotic and bifoliated phenotypes may be determined by single, recessive genes, while more genes may be responsible for the appearance of bush-like phenotypes. Evaluation of these characters through progeny tests will be carried out. Some of these mutants may be useful as markers at the seedling stage of breeding programs.

Protoplast fusion in Stylosanthes spp. Procedures for protoplast isolation and culture of S. guianensis and regeneration of plants from the protoplast- derived colonies have been described earlier (BRU Ann. Report, 1985). It was found that using this procedure plant regeneration is possible from isolated protoplasts of S. capitata and S. macrocephala as well.

Interspecific hybridization of S. guianensis with S. capitata or with S. macrocephala is desirable, but is prevented by incompatibility reactions. Somatic hybridization may overcome these barriers.

To carry out fusion, protoplasts were isolated from mesophyll cells of one parental line and suspension culture cells of the other parental line. Cell suspension cultures have been initiated and maintained as described in earlier (BRU Ann. Report, 1985). Determination of growth characteristics of cell suspensions helped to optimize protoplast isolation. Logarithmic growth of a CIAT 136 cell suspension was detected 2-4 days after subculture (Figure 6). Cells in the log growth phase are considered to be optimal for protoplast isolation and culture. Therefore maintenance of cell suspensions under subculturing every 3-4 days is recommended when

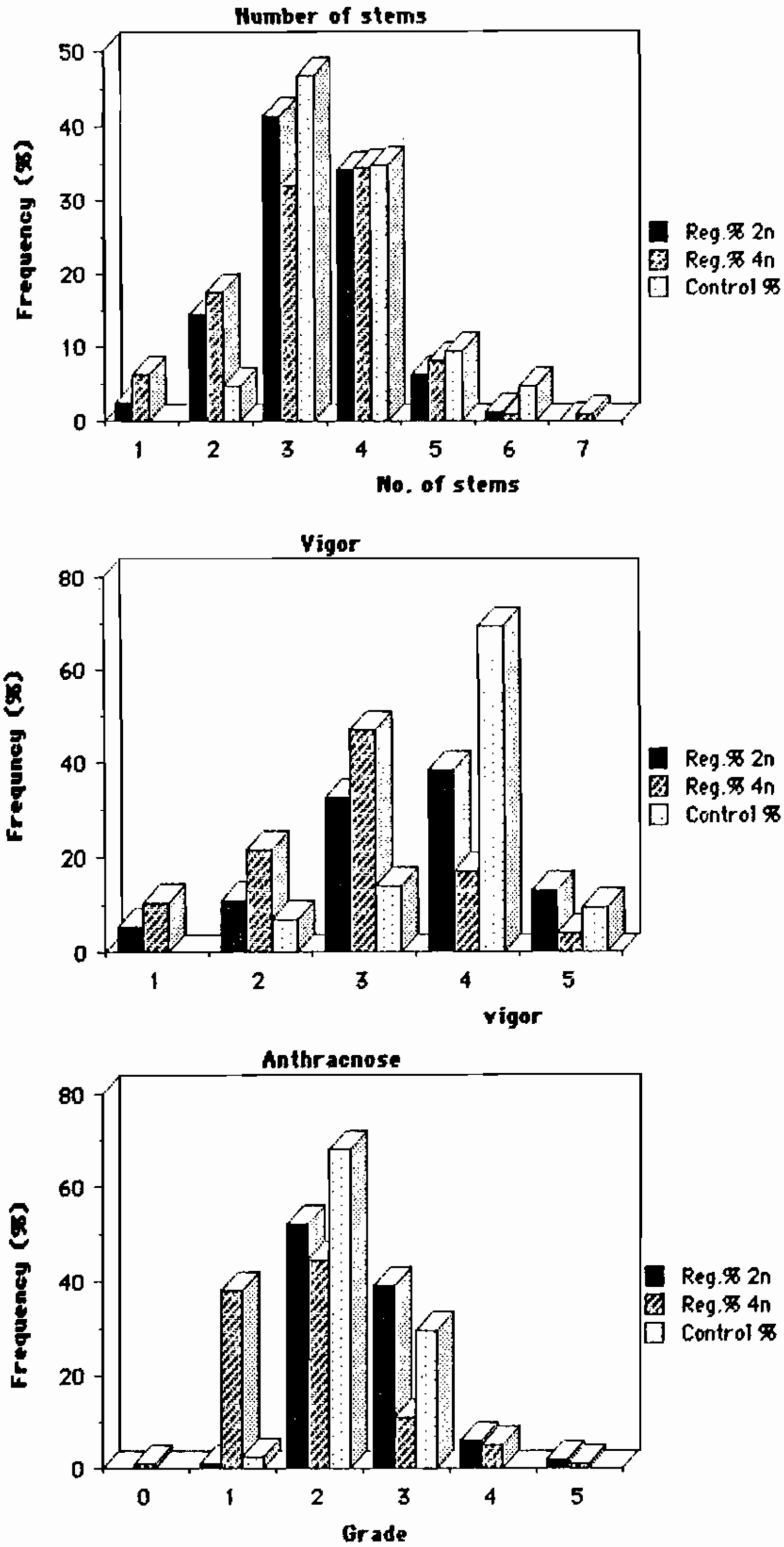


Figure 5. Somaclonal variation in progenies (SC_2) of generated plants of S. guianensis CIAT 2243 grown in Santander de Quilichao. Frequency per cent of plants with variation in number of stems per plant, plant vigor (1 = less vigorous; 5 = very vigorous) and reaction to anthracnose (0 = plants without anthracnose symptoms; 5 = plants dead due to anthracnose).

Table 1. Somaclonal variation in S. guianensis: appearance of unusual phenotypes among SC_2 progenies.

Phenotype	No. of plants Variant	Normal	Approximate ratio
Chlorotic - 1	3	10	1:3
Chlorotic - 2	3	10	1:3
Bifoliated	4	9	1:2
Bush - 1	1	11	1:11
Bush - 2	1	11	1:11

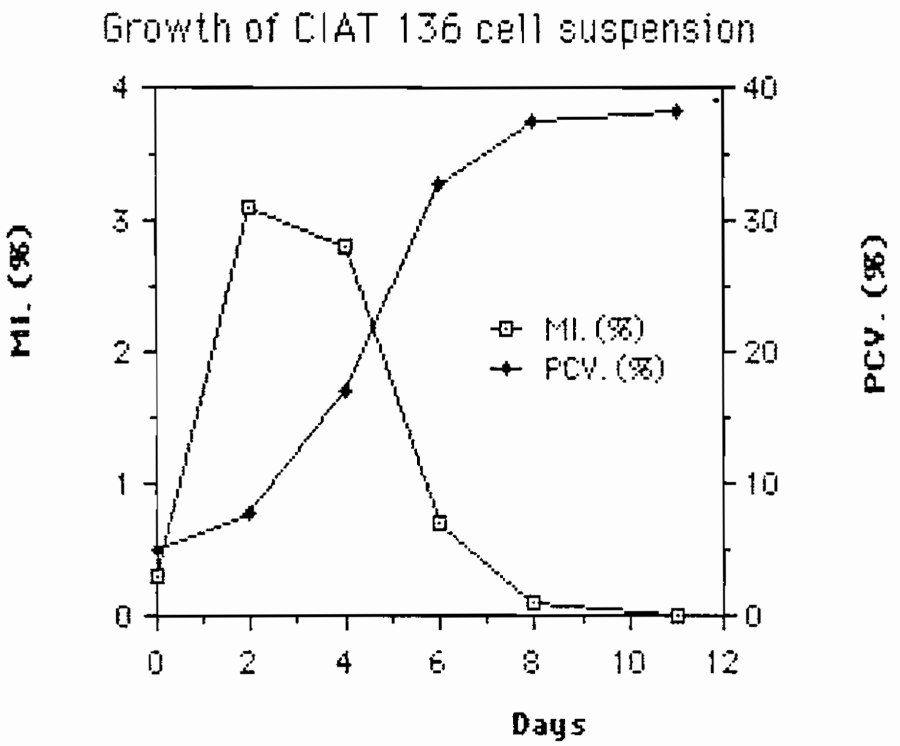


Figure 6. Growth of S. guianensis CIAT 136 cell suspension for protoplast isolation and fusion experiments.
MI : Mitotic Index = (No. mitotic cells/No. total cells) x 100
PCV: Packed Cell Volume = Volume of sedimented cells/total culture volume) x 100
Days: culture period

used for protoplast isolation.

Cell suspension protoplasts of S. guianensis (CIAT 136) were fused with leaf mesophyll protoplasts of S. capitata (CIAT 1019) or with leaf mesophyll protoplasts of S. macrocephala (CIAT 2286). Protoplasts were fused with a standard poly-ethylene-glycol/high Ca + high pH treatment in plastic petri dishes. Fused protoplasts were easy to distinguish due to the presence of visible cytoplasmic markers, characteristic to each of the parental line protoplasts (leaf mesophyll protoplasts have green chloroplasts, while cell suspension protoplasts have more dense cytoplasm and usually starch grains). Usually 1-2% fusion frequency was observed after this treatment (Figure 7).

Fused and unfused protoplasts were cultured in liquid medium, as described before (BRU Ann. Report, 1985). As no selective genetic markers are available at cell level, possible hybrid colonies were selected on the basis of their electrophoretic isoenzyme pattern. Esterase patterns of S. guianensis, S. capitata and S macrocephala differ sharply even at callus level. Through screening of a sufficient number of regenerated colonies, these differences permit selection of putative hybrids.

In a fusion experiment of S. guianensis x S. capitata, 6 possible hybrid colonies were selected from 78 screened electrophoretically. Plant regeneration was induced in these colonies. To date 64 plantlets were obtained.

In a similar fusion experiment 6 possible S. guianensis x S macrocephala hybrid colonies were selected out of 108, with the help of esterase isoenzyme markers. These colonies were recently transferred to plant regeneration medium.

The esterase isoenzyme marker technique used with the S. guianensis + S. capitata fusion products (cell colonies) has been applied to samples obtained from the putative regenerated hybrid plantlets. All samples showed two unique isoenzyme bands, each one of them corresponding to one of the parental lines, which confirms the possibility of somatic hybridization (Figure 8).

This experiments showed:

- It is possible to produce somatic hybrid plants between S. guianensis and S. capitata.
- By biochemical screening it is possible to identify hybrid colonies and regenerate plants in which hybridization can be confirmed later. This is a real advantage in the somatic hybrid production of crop plants where the low protoplast culture efficiency does not permit single cell culture (necessary for mechanical isolation of hybrid cells by micromanipulator), and no selective genetical markers are available at cell level.

Brachiaria Tissue Culture

Collaboration with the TPP continued this year using in vitro techniques for multiplication, maintenance and distribution of Brachiaria germplasm to national programs.

From a total of 431 accessions introduced to CIAT in 1985 as shoot-tip cultures (BRU Ann. Report, 1985), 327 and 332 accessions were micropropagated and shipped in vitro to Brazil and Peru, respectively (Table 2). In Brazil, cultures were shipped to CENARGEN, in route to CPAC, Brasilia. In Peru, cultures were sent to IVITA-Pucallpa where direct potting was carried out.

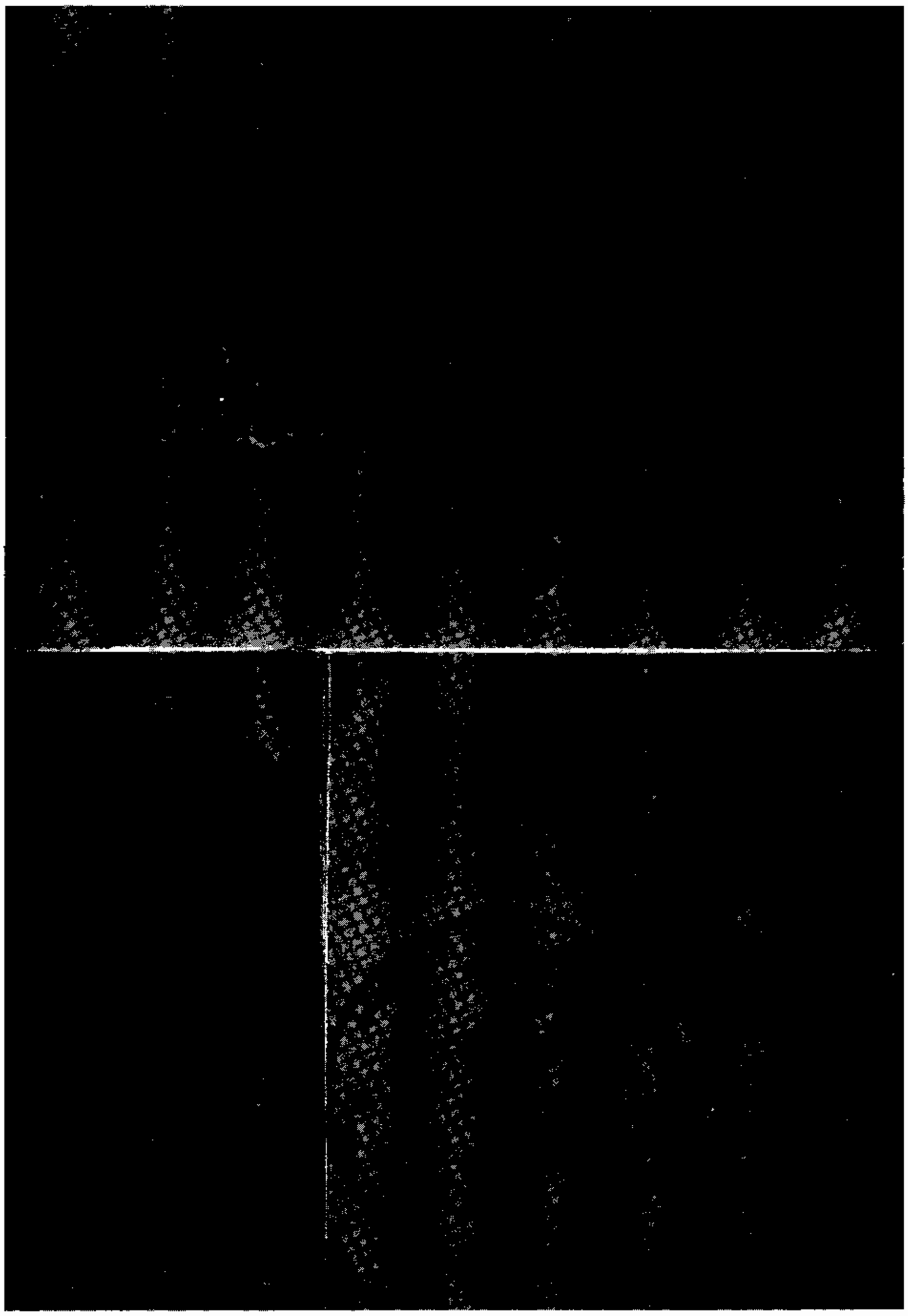


Figure 7. Early events in protoplast fusion between S.guianensis and S.capitata.

A. Heterokaryons of colorless protoplasts from cell suspension cultures of S.guianensis (a) induced to fuse with chlorophyllic chloroplasts of S.capitata (b). Note that both single (above) andmultiple (below) fusions can occur.

B. A hybrid protoplast just after fusion. Note borderline between parental protoplasts still apparent (arrow).

C. Hybrid protoplast one day after fusion. Note unfused protoplast (below).

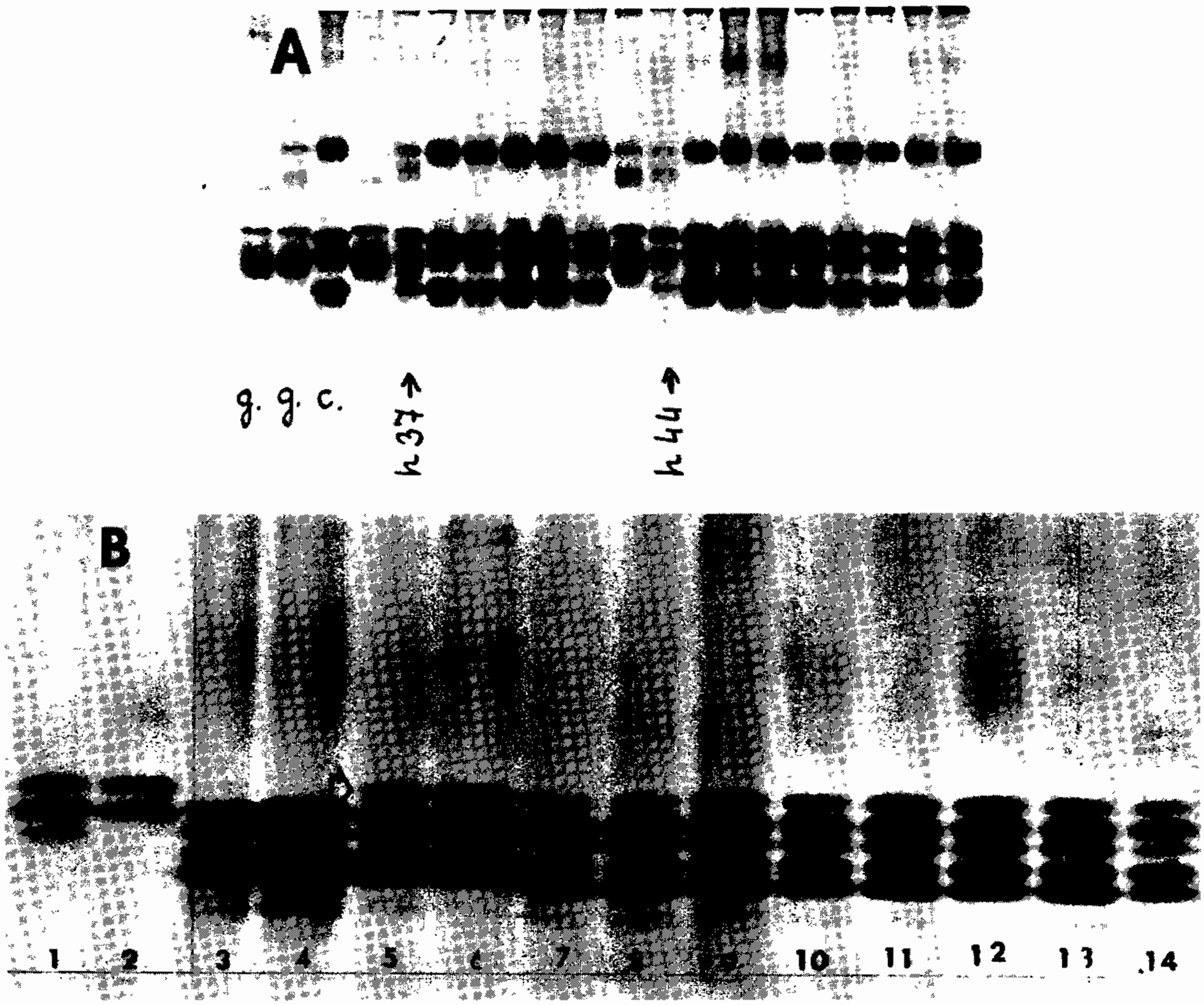


Figure 8. Selection of possible somatic hybrids by electrophoretic isoenzyme analysis of fusion colonies.

Note: Fig. A shows two possible hybrid colonies (h 37 and h 44) out of 16 colonies analyzed. Parental colonies: g (S.guianensis CIAT 136) and c (S. capitata CIAT 1019).

Fig. B shows patterns of parental callus and regenerated plantlet of S. guianensis CIAT 136 (slots 1 and 2), parental callus and regenerated plantlet of S.capitata CIAT 1019 (slots 3 and 4), and the patterns of fusion colonies selected as at Fig. A (slots 5,7,9,11 and 13),and the patterns of plantlets regenerated from these colonies (slots 5-14 show an additional distinct band corresponding to parental line S. guianensis (arrow) and a thick band just below corresponding to S. capitata parental line.

Table 2. Distribution of Brachiaria and other grass germplasm from CIAT to national programs using in vitro techniques.

Grass germplasm species	No. of Accessions	
	CENARGEN/ CPAC (Brazil)	IVITA-Pucallpa (Peru)
Brachiaria brizantha	171	169
humidicola	38	33
dictyoneura	2	3
jubata	37	38
serrata	4	6
decumbens	40	39
leucocrantha	2	1
ruziziensis	14	14
platynota	2	2
arrecta	4	4
bovonei	3	3
nigropedata	1	2
subulifolia	6	5
mutica	1	-
sp.	-	1
Panicum macimum	1	2
Andropogon gayanus	1	7
Eragrostis molliar	-	1
Botriochloa insculputa	-	1
Setaria lindenbergiania	-	1
Total	327	332

Genotype Identification by Electrophoresis

After one and a half years of activity at the University of Manitoba, the IDRC-supported collaborative project was moved to CIAT this year to further develop electrophoretic methodologies and procedures with pastures.

Since the last report (BRU Ann. Report, 1985) work is now underway to develop electrophoretic methodologies for the identification of accessions of Desmodium ovalifolium, Centrosema macrocarpum, Centrosema pubescens and C. acutifolium. Although these pasture legumes belong to one family, procedures which would effectively discriminate accessions are different.

Desmodium ovalifolium was best discriminated when seed meal was extracted in 1% sodium dodecyl sulphate and the extract was partially purified by heat and acid treatments.

Prior to seed protein test, about 7 enzymes were investigated in the seed tissue. Results could not provide adequate discrimination between accessions.

Centrosema macrocarpum, C. pubescens and C. acutifolium were best separated in acid polyacrylamide gel electrophoresis. Storage proteins were extracted in acetate buffer pH 5.8. Electrophoregrams obtained in 10% polyacrylamide gel containing 10% sucrose were found to be genotype specific. Two accessions of

C. acutifolium had different banding patterns to other species (Figure 9).

Work on Stylosanthes is almost complete. A methodology has been developed which has successfully discriminated accessions of S. capitata. Seed proteins were extracted in Tris HCl 0.05M, pH 8.3 and the extract was analyzed using simple PAGE.

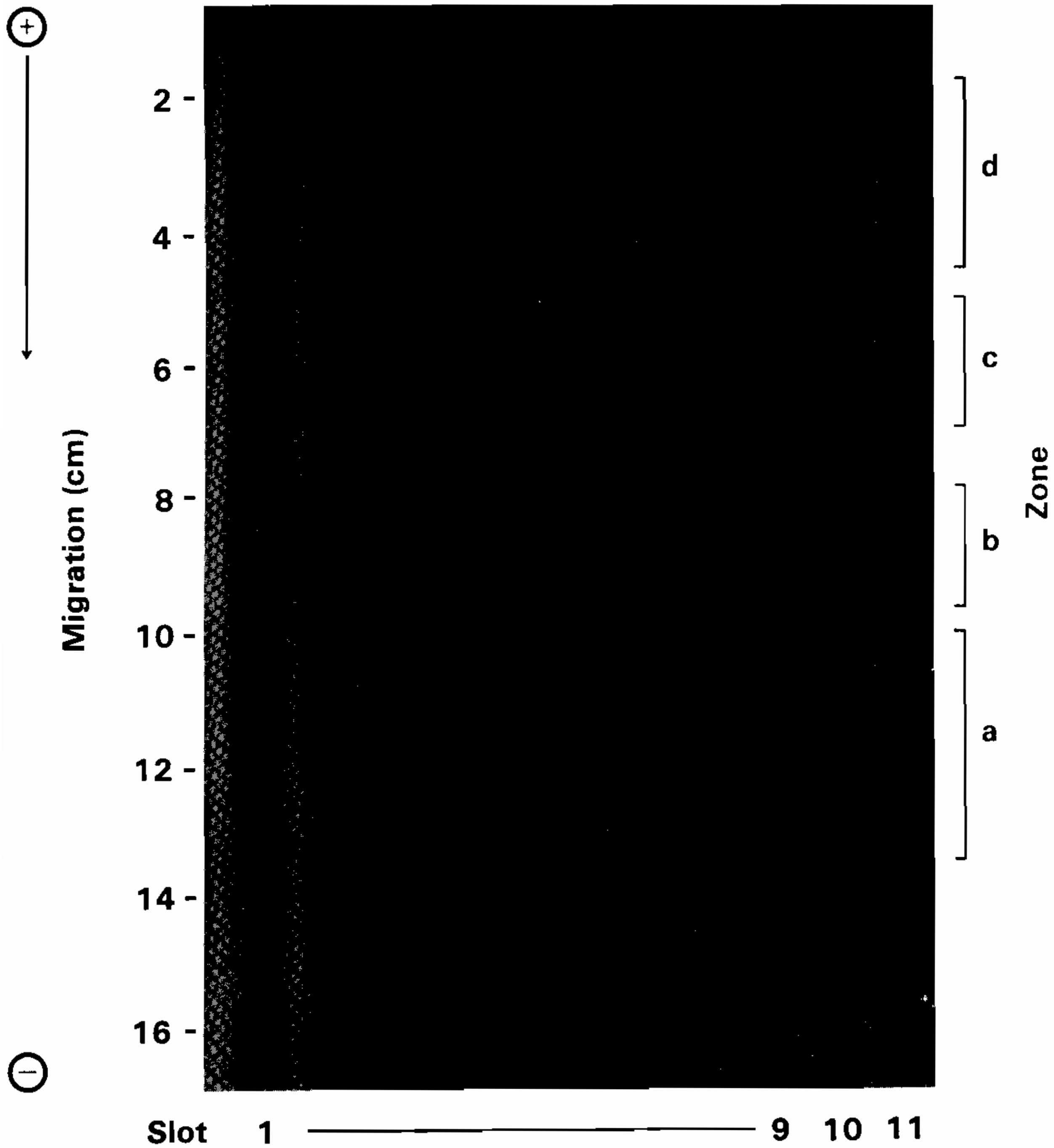


Figure 9.. Acid PAGE electrophoregram of nine accessions of Centrosema pubescens and two accessions of C.sp.n.
Note each slot represents one accession of C.pubescens (1-9) and C. sp.n. (10-11).

Agronomy Carimagua

The agronomy studies conducted at the Carimagua Research Station continued to focus on the selection of legumes and grasses for the "llanos" ecosystem. Due to a change in senior staff, 1986 was a year of transition with a number of older trials terminated and new ones established. Some changes were also made in methodology and experimental sites.

At the Category II level of evaluation, studies were initiated with Stylosanthes scabra, S. macrocephala and Panicum maximum on two new sites at "Yopare" and "La Alcancia". Between sites there is variation in soil texture, aluminium level and organic-matter content (Table 1). "Yopare" and "La Alcancía" reflect the type of variation in soil texture that occurs throughout the "llanos" ecosystem. A change in methodology allowed accessions to be established in native pasture, without removal of vegetation from inter-plot areas. The technique allows for some plant competition and increases potential pest or disease pressure, thereby making Category II evaluation somewhat more realistic. In addition, the soil is protected from erosion and maintenance activities are reduced.

At the Category III level of evaluation there has been a high level of co-operation with the Ecophysiology Section, and certain data from agronomy trials will be found in this part of the report. In addition to selecting promising germplasm under grazing, these integrated studies should give a better understanding of persistence and compatability. The inclusion of different grazing pressures should also allow management options to be predicted.

Table 1. Soil characteristics for the two evaluation sites at Carimagua (Category II).

Parameter		"La Alcancía"	"Yopare"
pH		4.7	4.9
Al	(ME/100 g)	3.2	1.5
Ca	(ME/100 g)	0.12	0.09
Mg	(ME/100 g)	0.08	0.05
P	(PPM)	1.2	1.3
K	(ME/100 g)	0.06	0.04
S	(PPM)	9.6	10.3
Cu	(PPM)	0.78	0.58
Fe	(PPM)	37	42
Mn	(PPM)	2.2	1.8
Zn	(PPM)	0.09	0.06
OM	(%)	3.2	1.7
Clay	(%)	45.95	32.12
Silt	(%)	46.68	35.31
Sand	(%)	7.37	32.57

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.

Dioclea guianensis
18 accessions, mostly from Colombia, have been evaluated and their performance is summarized in Table 2. Seven accessions failed to flower and, with one exception, seed yields were generally poor. There were marked differences in dry-matter yield but the incidence of pests and diseases was low. One accession, CIAT 8806, appeared to combine both a high yield of dry matter with good seed production and a low susceptibility to pests or diseases. However, D. guianensis is known to be of low animal acceptability and, for this reason, may be more suitable as a species for savanna improvement rather than as a component of a cultivated pasture.

Arachis pintoi
A small collection of seven Brazilian accessions were evaluated against the control CIAT 17434. All produced significantly less dry matter than CIAT 17434 (Table 3), which is already in advanced evaluation trials under grazing. The species continues to show good resistance to pests and diseases.

Centrosema macrocarpum
Previous work has demonstrated that accessions with stolons that have a low capacity to root at the nodes and a low seed production potential fail to persist under grazing. Thirty new accessions, mainly from Venezuela and Colombia, were compared with two control accessions. The data for the best of the new accessions are shown in Table 4. These accessions were higher yielding, earlier flowering and produced appreciably greater quantities of seed than the controls. There were also marked differences in the numbers of rooted stolons developed by plants, which were highest in the new accessions. CIAT 15102 from Venezuela appeared to combine good dry matter yield with production of a significant number of rooted stolons and a satisfactory seed yield. The incidence of pests and diseases was low in all accessions.

Pueraria phaseoloides
The main limitations in the commercial cultivar of this species for"llanos" conditions are poor adaptation to low fertility conditions, low drought resistance and variable seed production potential. On the basis of these characteristics six new accessions CIAT 8352, 9279, 17281, 17290, 17325 and 18031 have been selected. The last four accessions were collected in southeast Asia. The species has now been classified into a number of botanical varieties and of special interest is var. subspicata. This type has lobed leaves which are smaller than those of the commercial cultivar. Accessions of this type evaluated at Carimagua retain a very high proportion of green leaves in the dry season. Unfortunately, accessions of var. subspicata in the collection have also shown a generally higher susceptibility to diseases. Consequently, only one of the selected lines (CIAT 17281) is of the botanical variety subspicata. These types occur in northern Thailand where there is a well-defined dry season. Further plant collection in this region would seen desirable and might yield new accessions that were both drought and disease resistant.

Stylosanthes macrocephala
Recently, several accessions of the species have been attacked in a number of locations in the "llanos" by the Rhizoctonia fungus. The symptoms include a severe foliar blight and root rot. In order to screen the collection for resistance to the disease 111 accessions of S. macrocephala were sown in May 1986 at the two new testing sites. Accessions

Table 2. The performance of accessions of *Dioclea guianensis* at Carimagua (Category II).

CIAT No.	Origin	First Flowering	Seed Yield (mg/plant)	Dry Matter Yield[1] (kg/ha)	Plant[2] Diseases	Plant[3] Pests
7800	Colombia	Mid March	370	6498	+	+
7801	Colombia	-	0	4695	+	+
7802	Colombia	-	0	3768	+	+
7803	Colombia	Early April	30	5277	+	+
7804	Colombia	Late March	60	4574	+	+
8160	Colombia	Mid March	270	4814	+	+
8164	Colombia	-	0	3352	++	-
8165	Colombia	-	0	7062	++	+
8193	Colombia	Late March	370	3046	++	+
8194	Colombia	Late March	18	4262	-	+
8195	Colombia	Mid March	18	5242	+	+
8196	Colombia	Early April	60	1971	+	+
8395	Brazil	-	0	4373	+	-
8716	Venezuela	Mid March	170	4768	+	+
8717	Venezuela	-	0	3735	+	+
8718	Venezuela	-	0	4512	-	+
8806	Colombia	Mid March	1580	7156	+	+
9311	Colombia	Late March	40	4735	+++	++
S.E.				1191		

1/ Cut on 22.08.86 2/ *Cercospora* Leaf Spot (July 86) 3/ Leaf-eating insects (July 86).

Table 3. Performance of accessions of *Arachis pintoi* at Carimagua (Category II).

CIAT No.	Sub-Origin	Dry-Matter Yield[1] (kg/ha)	Plant[2] Diseases	Plant LE	Pests[3] LS
17434 (control)	Bahia	1404	+	+	+
18744	Minas Gerais	601	+	+	++
18745	Minas Gerais	1060	+	+	+
18746	Minas Gerais	1004	+	+	+
18747	Bahia	702	+	+	+
18748	Goiás	819	+	+	+
18751	-	812	+	+	++
18752	-	908	+	+	+

1/ Cut on 24.08.86

2/ Anthracnose (July 86)

3/ LE = Leaf-Eating Insects (July 86)

LS = Leaf-Sucking Insects (July 86)

CIAT 1281 (cv. Pioneiro) and 1643 were included as controls. Most of the ac-accessions were collected in the Brazilian states of Bahia and Minas Gerais.

Detailed evaluation of the collection has yet to commence, but some preliminary observations can be made. In general, plants are less vigorous than those of *S. scabra* although there is some intraspecific variation. The best accessions which include CIAT 2056, 10004, 10009 and 10520 are performing similarly at both sites.

Symptoms of *Rhizoctonia* Foliar Blight and Anthracnose have been noted in the same accessions at both sites, and 10 lines have been completely destroyed by disease. Which of the two diseases was responsible for the death of plants is presently under evaluation by the Plant Pathology Section.

Stylosanthes scabra

In past years, accessions of the species have been evaluated at Carimagua, but none was selected because of pest and disease problems. More recently, a large collection of over 500 accessions was assembled at CIAT and 93 of the most promising

Table 4. The performance of elite accessions of Centrosema macrocarpum at Carimagua (Category II).

CIAT No.	Origin	First Flowering	Seed Yield (mg/plant)	Dry-Matter Yield[1] (kg/ha)	Stolons[1] (No./m^2)	Plant[2] Diseases	Plant[3] Pests
5065	Colombia	Early April	140	1905	12	-	+
5452	Colombia	Late March	340	953	45	-	-
(controls)							
5742	Colombia	Early Feb.	2170	4180	60	CLS +	+
15022	Brazil	Mid Feb.	2580	4850	57	CLS +	+
15057	Colombia	Early Feb.	3380	3922	117	CLS + A++	+
15102	Venezuela	Early Feb.	4580	4286	117	CLS +	+
15103	Venezuela	Early Feb.	6820	4800	65	CLS ++	+
15104	Venezuela	Late Feb.	5390	3609	71	-	+
15111	Venezuela	Early Feb.	2680	3393	81	CLS + A+	+
S.E.				694	17		

1/ Cut on 22.08.86
2/ CLS = Cercospora Leaf Spot   A = Anthracnose (July 86)
3/ Leaf-Sucking Insects (July 86)

lines were sown in May 1986 at the "Yopare" and "La Alcancía" sites. 90% of the accessions were collected in Brazil (mainly Bahia) and the remainder in Colombia and Venezuela. The Australian commercial cultivars Seca and Fitzroy were also included as controls.

The collection is well-established and plants are generally much more vigorous than those of S. macrocephala. There is marked variation in morphology but there are no observable differences in performance as yet between sites. Accessions CIAT 1522, 1917, 1926, 2808 and 2818 are particularly promising. Anthracnose symptoms have already appeared and the same three lines (CIAT 2058, 2076, 2084) have been destroyed at both "Yopare" and "La Alcancia". Plants of some accessions e.g. CIAT 2015 have Little Leaf Mycoplasma.

Panicum maximum
The species is one of the best grasses in the tropics and a number of commercial cultivars are available showing considerable morphological variation. These range from the giant robust "cut and carry" types such as cv. Hamil with large leaves and rather thick stems through the medium grazing types of var. trichoglume with fine leaves and stems to the semi-erect types similar to cv. Embu. Unfortunately none is adapted to acid, infertile soils. To identify accessions which grow well under these conditions, a collection of 436 accessions was established at both sites in May 1986. These include as controls the commercial cultivars Petrie Green Panic, Makueni, Common and Hamil.

Preliminary observations have indicated considerable morphological variation, with important differences between accessions in height, leafiness and leaf size. In September, the collection was classified into groups representing the main commercial cultivars. 32.1% was similar to cv. Hamil, 40.6% similar to cv. Common, 27.1% similar to cv. Petrie green panic and 0.2% similar to the cv. Embu. Eighty-six accessions of low to medium height have been chosen for further study.

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.

Species of Centrosema
Ten accessions representing three species of Centrosema are being tested in association with Andropogon gayanus. The legume accessions are C. macrocarpum CIAT 5434, 5629, 5645, 5674, 5740, 5744, 5887; C. acutifolium CIAT 5568, 5277; and C. pubescens "El Porvenir". The trial was established in May 1984 but in January 1986 the management was changed and three grazing pressures (2, 4 or 6 kg green dry matter per 100 kg liveweight) imposed. Each association is grazed for seven days followed by a rest period of 28 days. Samples were taken before and after grazing and in the middle of the rest period to determine regrowth. Sub-samples are partitioned into green leaf and stem and into senescent material. Leaf area is measured. A more detailed discussion of results appears in the Ecophysiology part of this report.

The content of accesions of C. macrocarpum and C. pubescens in the associations was never more than 13%, and this continued to decline to zero at all grazing pressures by the second part of the wet season (September). Data for the two accessions of C. acutifolium are presented in Figure 1.

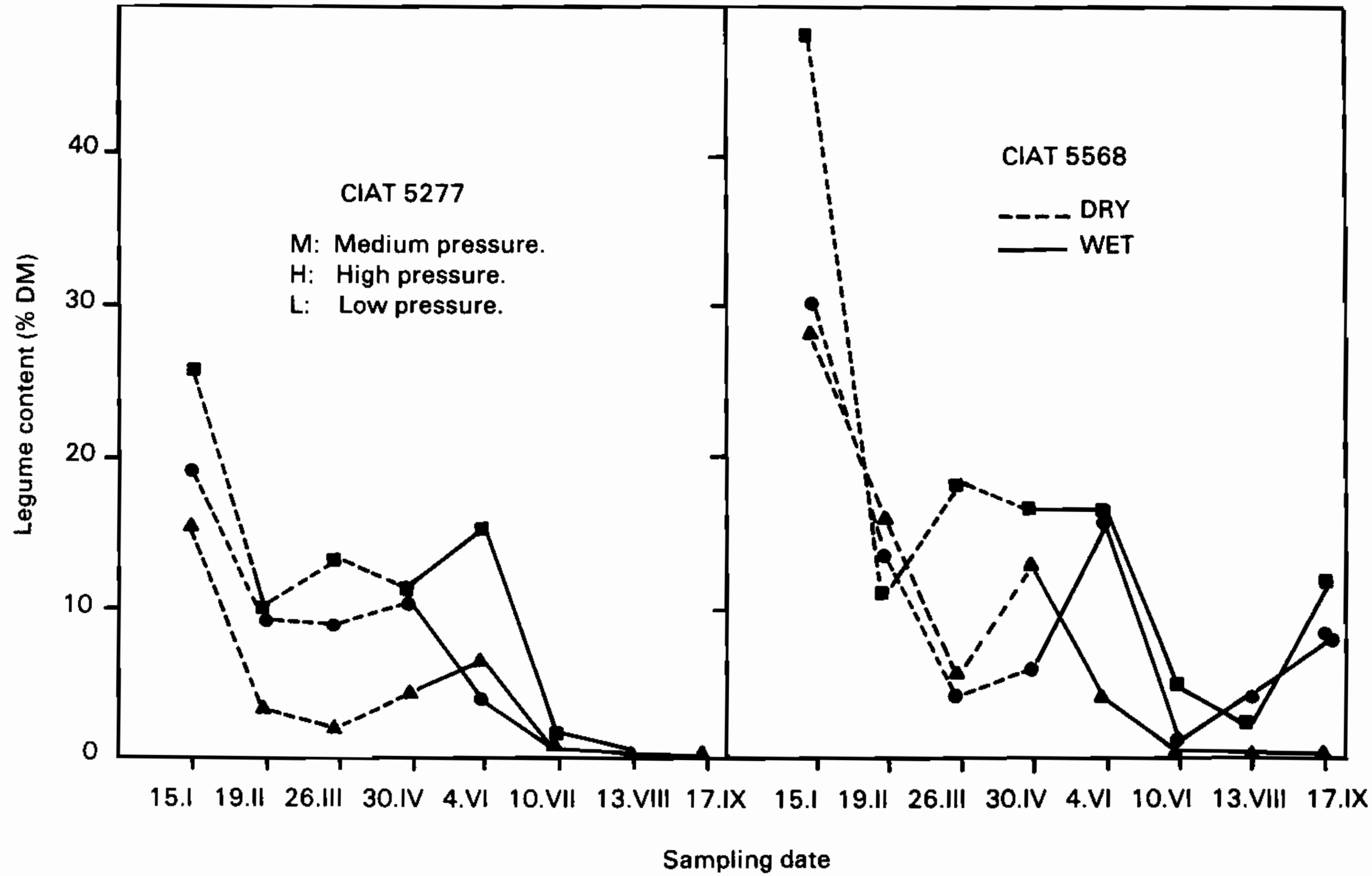


Figure 1. Changes in content of *C. acutifolium* associated with *A. gayanus* at three grazing pressures in Carimagua.

S.E. of a difference in legume yields 4.4

Legume content in these associations also fell over time, and was generally highest at the medium grazing pressure (4 kg/DM/100 kg liveweight). Accession CIAT 5568 persisted better than 5277 although there has now been some recovery in the latter at the medium grazing pressure. Throughout the period, accession CIAT 5568 was more productive than CIAT 5277 (Figure 2).

Symptoms of Rhizoctonia Foliar Blight, Cercospora and Pseudocercospora leaf spot occurred on plants, but the incidence of these diseases was low (Table 5). All accessions were attacked by leaf-eating insects, but relatively little damage was recorded.

Desmodium ovalifolium

Accession CIAT 350 has shown considerable promise for "llanos" conditions as a companion legume for vigorous species of Brachiaria. However, the plant is very susceptible to a stem-nematode (Pterotylenchus cecidogenus) and to False Rust (Synchytrium desmodii). A number of new accessions have been selected that show better tolerance to these pests than CIAT 350. Accordingly, in July 1985 a trial was established to evaluate these accessions under grazing in association with B. dictyoneura CIAT 6133. Two grazing pressures were imposed by variation in the number of days the plots were grazed by animals. At the lowest grazing pressure animals occupied plots for three days followed by a rest period of 32 days. At the highest pressure animals grazed for seven days followed by a rest period of 28 days.

Fistulated steers are being used and the porportion of legume selected is being recorded. The pastures are being sampled as in the Centrosema trial, and grazing commenced on the 31st July, 1986.

Table 6 shows the incidence of both nematode and False Rust at the last sampling at the end of October. Although some galls were noted on plants of CIAT 350 in June, none of the plants has nematode galls at present. The incidence of False Rust is low to moderate, with accession CIAT 13089 having the lowest score.

There has been a marked increase in the legume content in all treatments, regardless of grazing pressure (Table 7). Some problems have been encountered with the fistulated steers, and there is no clear difference in legume selection at the two grazing pressures. However, it appears that in the final sampling in October an appreciable amount of legume was selected which is in accord with visual observations on the sward after grazing. This is an interesting result since the species is known to be of relatively low acceptability. The highest yielding accessions are CIAT 350, 13089, 13092 and 13129, with available dry-matter yields varying from 2500 to 2800 kg/ha in October.

Arachis pintoi

Previous grazing studies have indicated considerable potential for accession CIAT 17434 as a legume for associations containing vigorous species of Brachiaria. Two experiments are currently in progress with this accession of A. pintoi. In the first trial fistulated steers are being used to monitor legume selection throughout the year in associations of B. humidicola CIAT 679, B. dictyoneura CIAT 6133, B. brizantha CIAT 664 and B. ruziziensis CIAT 6291. These results are presented in the Pasture Quality and Production part of this report. In a second trial, associations containing A. pintoi CIAT 17434 with B. humidicola CIAT 679 (control), 6705, 6709, 6369 or B. brizantha CIAT 6294 are being subjected to two grazing pressures. The management of this experiment is the same as for the D. ovalifolium trial, and sampling is being conducted as reported for the evaluation of Centrosema species. The trial was established in October 1984

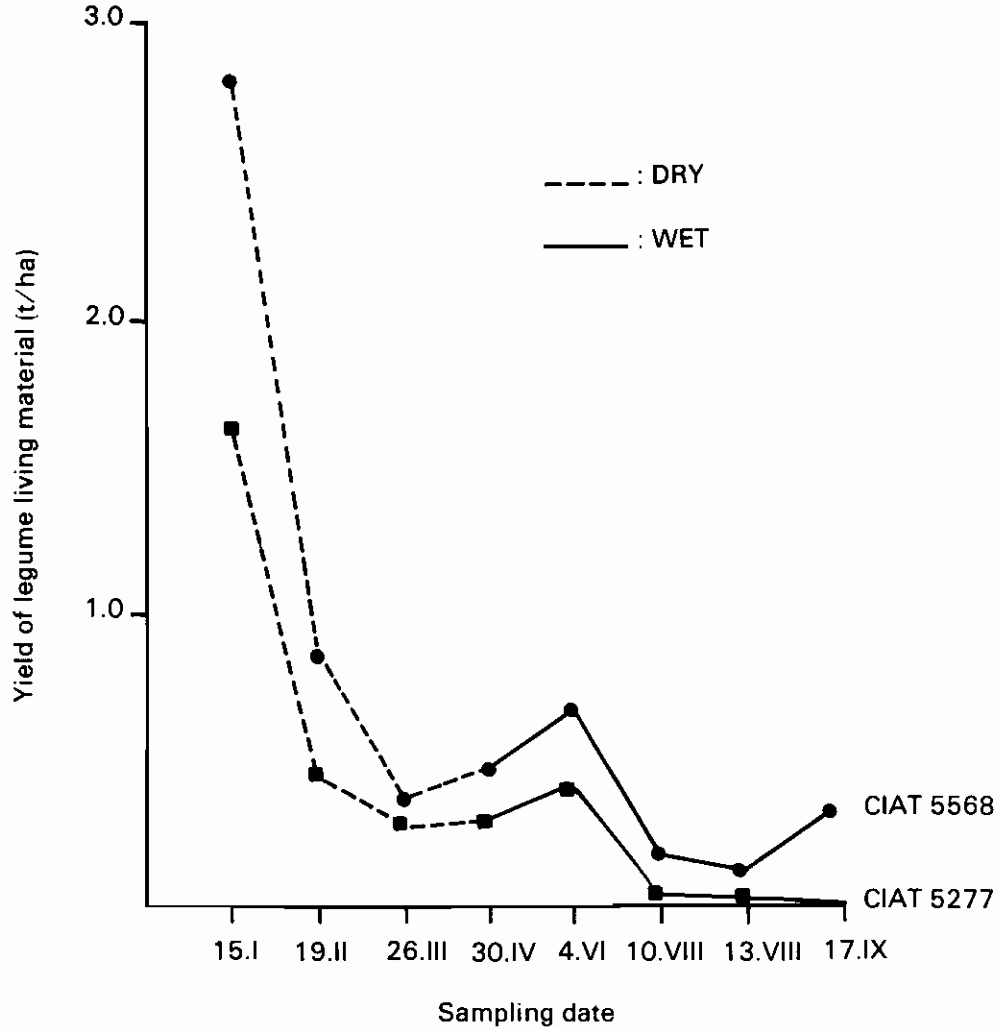


Figure 2. Yield of legume living material (across grazing pressures) in two accessions of *C. acutifolium* under grazing in Carimagua.

S.E. of a difference in legume yields 0.26

Table 5. Disease and pest evaluation in species of *Centrosema* in Carimagua (Category III).

Accession No.	Leaf-Eating Insects	*Pseudocercospora* Leaf Spot	*Cercospora* Leaf Stpo	*Rhizoctonia* Foliar Blight
C. pubescens "El Porvenir"	2.0	-	1.0	1.0
C. acutifolium 5277	1.5	2.5	1.0	-
C. acutifolium 5568	3.0	2.0	-	2.5
C. macrocarpum 5434	2.0	1.0	-	-
C. macrocarpum 5629	2.5	1.0	1.0	-
C. macrocarpum 5645	2.0	1.5	-	1.0
C. macrocarpum 5674	1.0	1.5	-	1.5
C. macrocarpum 5740	2.0	-	-	1.5
C. macrocarpum 5744	3.0	1.5	-	1.5
C. macrocarpum 5887	2.0	1.5	-	2.0

1/ Scores 1.0 - 2.5 Low; 3.0 Moderate; 3.5 - 5.0 High.
2/ Evaluated August 1986.

Table 6. Incidence of stem-nematode and false-rust in accessions of Desmodium ovalifolium under grazing in Carimagua.

CIAT Accessions No.	Stem Nematode Score	% Rows Affected, False Rust Score: 0	1-2	3	4-5*
350	0	15	75	10	-
3776	0	20	70	10	-
3794	0	7	73	20	-
13089	0	32	68	-	-
13092	0	25	68	7	-
13129	0	30	65	5	-

A/* 0 = N symptoms 1-2 = Low incidence.
3 = Moderate incidence 4-5 high incidence.
B/ No differences between grazing pressures.
C/ Recorded 23.10.86.

Table 7. Legume contents and proportion of Desmodium ovalifolium selected in associations with Brachiaria dictyoneura under grazing in Carimagua.

CIAT No.	Early August[1] HGP	LGP	Early September HGP	LGP	Early October HGP	LGP
350	45(-)	53(32)[2]	79(-)	74(66)	95(-)	93(90)
3776	31(24)	24(22)	50(82)	59(53)	70(10)	66(72)
3794	38(38)	34(1)	39(81)	44(-)	70(-)	75(-)
13089	48(46)	42(6)	78(82)	25(1)	86(-)	78(73)
13092	37(25)	41(13)	81(35)	71(-)	88(88)	72(58)
13129	43(43)	41(13)	76(59)	71(87)	87(86)	92(58)

1/ HGP = High Grazing pressure; LGP = Low grazing pressure.
2/ Values in parenthesis = % legume in extrusa.

and grazing commenced on the 17 June 1986.

The effects of grazing pressures on legume content up to the end of September are presented in Table 8. At the initiation of grazing all associations contained a high proportion of legume, and this has increased appreciably over time.

There are no consistent differences between grazing pressures at present. However, across grazing pressures, there is some indication that the new accessions of B. humidicola might be more acceptable than the control CIAT 679. This accession is known to be of relatively low acceptability to the animal. No important pest or disease problems were noted in the trial.

Table 8. Proportion of Arachis pintoi CIAT 17434 in associations of Brachiaria species under grazing in Carimagua.

CIAT Accession No.	High Grazing Pressure				Low Grazing Pressure			
	17.06	22.07	26.08	30.09	17.06	22.07	26.08	30.09
679 (control)	58	70	65	71	45	66	77	83
6294*	63	94	100	93	66	88	94	91
6369	49	78	83	77	42	86	97	89
6705	75	92	90	93	46	67	81	83
6709	68	87	99	98	63	94	100	99

* CIAT 6294 is B. brizantha cv. Marandú. Other accessions are B. humidicola.

Table 9. Legumes established in native pasture at the level of Category III in Carimagua.

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

Legumes in savanna

Some legumes have been identified at CIAT which show good adaptation to the "Llanos" ecosystem, but are poorly consumed by animals particularly when grown with improved grasses of high acceptability. It has been suggested that these plants may be better consumed when associated with native grasses which are acceptable for only a short period in the wet season. To test this hypothesis a trial was sown in June 1986 with eight such species (Table 9). Also included were Centrosema acutifolium CIAT 5277 and C. brasilianum CIAT 5234, which are of high acceptability. Seed of the legumes was sown in rows separated by areas of native pasture, 1.8 m in width. Establishment of the larger-seeded species was excellent, but heavy rains caused wash of small-seeded species. These plots were replanted with seedlings raised in "jiffy-pots". The trial is now well established and should be ready for grazing in the early part of next dry season.

SEED MULTIPLICATION

Seed or vegetative material of a number of promising species is being produced for inclusion in future grazing evaluation trials. The list of species presently under multiplication is given in Table 10. Hopefully, sufficient seed of the accessions of Centrosema brasilianum will soon be available to enable the establishment of a Category III evaluation trial in 1987. Seed of selected lines of Pueraria phaseoloides is being produced at Quilichao where higher yields are attainable.

Table 10. Propagation of seed and vegetative material at Carimagua ("Agronomía" site).

Species	CIAT Accessions
Centrosema brasilianum	5178, 5486, 5657, 5667, 5725, 5810, 5828
Centrosema acutifolium	15086, 15088
Arachis pintoi	17434
Flemingia macrophylla	17403, 17407
Periandra coccinea	5383
Stylosanthes viscosa	1070, 1524, 1538, 1544, 1547, 2341, 2371
Zornia latifolia	728A
Aeschynemene species	7563, 7567
Brachiaria humidicola	6705, 6709, 6369

Agronomy Cerrados

The CIAT-EMBRAPA-IICA collaborative project at CPAC continued during 1985/86 with the primary objective of identifying grasses and legumes adapted to cerrados conditions. The current evaluation program includes 351 legume accessions introduced in 1985/86 and a further 311 legume accessions introduced in the previous season (Table 1). EMBRAPA-CPAC team members directly involved in preliminary germplasm evaluation, selection, seed multiplication and testing of selected forage species under grazing are R.P. de Andrade, F. Beni de Sousa and C.M.C. da Rocha.

PRELIMINARY EVALUATION OF GRASS GERMPLASM (CATEGORY I AND II) ON WELL-DREINED SITES

Some 325 accessions of 14 species of Brachiaria were introduced in meristem culture. This material was successfully established in the quarantine glasshouse at CENARGEN early in September. Fifty-seven accessions, of which less than three cultures were received, have been sub-cultured by CPAC personnel trained in this technique. The collection was released from quarantine on November 4 and vegetative propagation was initiated. In view of the economic potential of new Brachiaria spp. in the cerrados, the evaluation of this collection is of paramount importance and it has a high priority in our program for the coming season (Table 2).

Table 1. Legume germplasm introduced 1985-86.

Species	No. of Accessions
Centrosema arenarium	6
C. brasilianum	41
C. macrocarpum	99
C. acutifolium	15
C. rotundifolium	1
C. vexillatum	1
C. bifidum	1
C. pubescens	5
C. pubescens x C. macrocarpum	5
C. brachypodum	1
Stylosanthes capitata	76
S. guianensis var. pauciflora	64
S. macrocephala	33
Arachis pintoi	1
Periandra coccinea	1
Desmodium canum	1
Total	351

PRELIMINARY EVALUATION OF LEGUME GERMPLASM (CATEGORY I AND II) ON WELL-DRAINED SITES

Centrosema macrocarpum

The majority of the 99 accessions of C. macrocarpum under evaluation in rows are late-flowering ecotypes and did not produce seed in the establishment year. Little leaf mycoplasma

Table 2. Grass germplasm introduced 1985-86.

Species	No. of Accessions
Paspalum sp. aff. plicatulum	16
P. plicatulum	1
P. oteroi	1
P. pumilum	1
P. notatum	2
P. indecorum	2
Paspalum sp.	2
P. urvillei	1
P. pauciciliatum	1
P. lividum	2
P. proliferum	1
P. modestum	2
Axonopus repens	1
A. araujoi	1
A. complanatus	1
Pennisetum sp.	1
Hemarthria altissima	2
Cynodon dactylon	2
Total	40
Brachiaria spp. (meristem cultures)	
B. arrecta	4
B. brizantha	171
B. bovonei	3
B. decumbens	40
B. dictyoneura	2
B. humidicola	38
B. jubata	37
B. leucocrantha	2
B. mutica	1
B. nigropedata	1
B. platynota	2
B. ruziziensis	14
B. serrata	4
B. subulifolia	6
Total	325
Total Grasses	365

affected some accessions and CIAT 5736 (BRA-008397) was lightly infected by Phoma sorphina. Flowering this season commenced in April/May, but most flowers aborted during the dry months and seed yields were very light. The following accessions of C. macrocarpum were selected for further evaluation: CIAT 5593 (BRA-004227), 5901 (BRA-006769), 5913 (BRA-011444), 5989 and 15121 (BRA-011711).

Centrosema brasilianum
All accessions of this promising species were severely affected by little leaf mycoplasma. The disease spread through all stands established on the dark-red latosol (DRL), including the seed multiplication plots planted two years ago and the most recently established introduction plots. Some accessions showed slight recovery during the dry season. The most serious consequence of the disease was that none of the accessions produced seed. The best over-all accessions were CIAT 5178 (BRA-007081), 5234 (BRA-012297) (control) and 5821 (BRA-006190). Rhizoctonia attack was slight to moderate during the wet season.

Centrosema arenarium/C. brachypodum
Several accessions are of considerable intererest. CIAT 15027 (BRA-011461) is an early-flowering ecotype, but is less productive than CIAT 5236 (BRA-002933) or 5850 (BRA-006572). The latter two accessions flowered late and were slightly affected by little leaf mycoplasma. CIAT 5803 (BRA-011452), the leafiest of the six accessions under evaluation, failed to flower and produce seed in the year of establishment.

Desmodium species
D. heterocarpon and D. strigillosum accessions showed good promise on the DRL and at the poorly-drained site ("vãrzea") as well. Seed production of the species was satisfactory at both sites. D. heterocarpon CIAT 13178 (BRA-008478) (purple flowers) was the

leafier type and CIAT 13189 (BRA-008567) (white flowers) was earlier flowering. D. strigillosum CIAT 13159 (BRA-008630) and 13156 (BRA-008613) were the most productive accessions. Both D. heterocarpon and D. strigillosum lost their leaves by the end of June after producing a good seed crop. Some new accessions e.g., D. velutinum and Tadehagi sp. (a genus closely related to Desmodium) exhibited poor performance and drought tolerance in this ecosystem.

Stylosanthes species
Accessions of S. guianensis var. vulgaris, a giant form of the species, are showing good promise. However, seed production is low. The accession selected for grazing evaluation is CIAT 2950 and at CPAC this accession is resistant to anthracnose. Recently an unidentified disease, possibly caused by a soil-borne organism, caused death of plants in the seed multiplication area. An important feature of this species form is rapid establishment attributed to larger seeds. The early seedling vigour of this accession was particularly advantageous when sown simultaneously with upland rice. When the rice crop was harvested, accession CIAT 2950 was fully established and provided high quality grazing during the dry season.

Considerable variation was observed among new introductions of S. capitata. At least two hybrids from the cross CIAT 1097 (BRA-005886) x 1019 (Dr. E. M. Hutton) are outstanding. In hybrid No. 56 seed maturity occurs at the end of May. Another hybrid No. 111 is a month later in flowering and retains green leaf longer into the dry season than cv. Capica or CIAT 1097.

Several accessions of S. capitata were badly affected by anthracnose and some of them died during the wet season. Of the new introductions CIAT 10398 (BRA-029050) and 10414 (BRA-028657) showed excellent early performance and were practically disease-free.

There are distinct growth forms among the new accessions of S. macrocephala. One accession CIAT 10010 (BRA-022985) is very prostrate, another accession CIAT 10019 (BRA-023523) retained its leaves after seed maturity longer than the control cultivar (CIAT 1281 (BRA-003697). However, none were more vigorous than the control.

S. guianensis var. canescens CIAT 10993 (BRA-032826) showed excellent performance. This accession has a low crown position and it is freely branching. Flowering started at the end of February and seed was harvested in mid-May. Anthracnose was restricted to small black lesions (< 1 mm) on the stem of some plants.

Z. glabra
The majority of the 20 accessions under observation was affected by the virus - Meliola complex but CIAT 278 (BRA-010367) and 283 (BRA-010359) were disease-free at the end of the growing season. The latter accession produced a large amount of seed and regenerated from self-sown seed. Most of the adult plants died at the end of the growing season.

SPECIES EVALUATION ON HUMIC GLEY SOILS IN SEASONALLY FLOODED SITES

Seasonally flooded areas ("vārzeas") constitute some 12 million ha or 6% of the "cerrados" of Brazil. These humic gley soils have a low fertility status (Table 3) but due to a high water-table active plant growth is maintained well into the dry season.

Preliminary evaluation of forage species was initiated in the "vārzea" at CPAC in October, 1983. Accessions of Arachis, Canavalia, Centrosema acutifolium, C. macrocarpum and several species of Paspalum were noted as promising by F. Beni de Sousa. In 1985 new accessions of Desmodium ovalifolium, Pueraria phaseoloides and Zornia glabra were introduced. A collection of native grass species,

Table 3. Chemical characteristics of soils of the cerrados in the Federal District, Brazil.

Soil	pH (H_2O)	Org.C (%)	Exchangeable (meq/100) Al	Ca	Mg	K	Al Sat (%)	Extract. P (ppm)	Sorbed P (ppm)
Dark Red Latosol	4.6	1.8	0.74	0.46	0.12	0.05	54	1.0	290
Red Yellow Latosol	4.6	2.2	0.60	0.28	0.08	0.07	58	0.4	405
Humic Gley	4.5	1.1	2.42	0.89	0.12	0.06	69	1.4	110

including *Paspalum*, *Axonopus*, *Hemarthria*, *Cynodon* and *Pennisetum* were also received from CENARGEN in 1986. Most of these species originated from the "Pantanal" and similar seasonally flooded areas. The collection is being propagated by vegetative means in preparation for the establishment of a small plot experiment in the "várzea".

These nursery plots were subjected to common grazing during the dry season and accessions of the following species were selected for further evaluation: *Arachis pintoi*, *Pueraria phaseoloides*, *D. ovalifolium*, *Paspalum plicatulum*, *P. fasciculatum* and *Brachiaria dictyoneura*.

Arachis species

Nine accessions of *A. pintoi* and five *A. repens* are under observation. Accessions of both species remained green during the dry season. The outstanding accession during the dry season was *A. pintoi* CIAT 18750 (BRA-015598) which is very disease-resistant. In general, the *A. pintoi* accessions are more stoloniferous than those of *A. repens*. Good yields during the dry season and a high crude protein content are important features of *A. pintoi*. Diseases recorded on accessions included *Sphaceloma arachidis*, *Cercospora* leafspot, and *Colletrotrichum dematium* which causes black lesions on the runners of plants. *A. repens* BRA 14982 (not yet in CIAT germplasm collection) is also disease-free. The nursery plots were mob-grazed during the dry seasons of 1985 and 1986. Dry matter yields and crude protein percentages are shown in Table 4. All accessions of *A. pintoi* and *A. repens* were preferentially grazed.

Table 4. Presentation yields (DM kg/ha) and CP content of accessions of *Arachis repens* and *A. pintoi* during the dry season in the "vãrzea"

Species	BRA No.	CIAT No.	DM (kg/ha)	CP (%)
A. repens	014770	-[1]	660	10.8
	014788	-	1217	12.4
	014982	-	2117	12.5
	014991	-	2064	12.3
A. pintoi	012122	18744	1295	13.6
	014931	18745	480	12.3
	014940	18746	645	09.8
	015121	18748	1560	14.2
	016883	18752	1625	12.0
	016357	18751	1585	13.4
	015253	18749	600	13.7
	015598	18750	2285	13.4
Means:			1344	12.5
s.e. :			184	0.35

1/ Not yet in CIAT germplasm collection.

A. pintoi is showing good promise for the "vãrzea" and a small-scale grazing experiment is planned to evaluate selected accessions in association with *Brachiaria dictyoneura* CIAT 6133 and *Paspalum* sp. Five accessions of *A. pintoi* including CIAT 17434 (BRA-013251) were multiplied by vegetative means under irrigation on the DRL.

Desmodium ovalifolium

This truly humid tropical species made poor growth on the DRL. In contrast, excellent performance was shown by a number of accessions (Table 5). Eight accessions were flowering at the end of April and most of these produced good seed yields by early July. Noteworthy is CIAT 13110 (BRA-008257) which was flowering profusely by the end of February. Seed was harvested at the end of March. It has since set a second seed crop at the end of May. The control, CIAT 350 did not flower in the first year at this site.

Table 5. Evaluation of Desmodium ovalifolium accessions in the "várzea".

Selected Accessions	Flowering Date*	Observations
CIAT 13110 (BRA-008257), 3666 (BRA-007650)	Early	13110 (BRA-008257)
CIAT 13082 (BRA-008371), 13085 (BRA-008389), 13102 (BRA-007986), 13122 (BRA-008052), 13137 (BRA-008141), 13289 (BRA-008168)	Mid-Season	All accessions set seed by early July
CIAT 13103 (BRA-007994), 13104 (BRA-007001), 13132 (BRA-008109), 13130 (BRA-008095)	Late	13103 (BRA-007994), 13104 (BRA-008001) excellent vigour and stolon growth. 350 (control) no flowering in year of establishment. Only 1 accession affected by little leaf mycoplasma. No nematode damage.

* Early = February
Mid-season = March/April
Late = April onwards.

These was no problem with nematodes. However, during the early part of the wet season iron-toxicity symptoms were observed in all accessions.

Pueraria phaseoloides
Forty-six accessions of P. phaseoloides were evaluated. General performance of these accessions was better in the "várzea" and flowering was a month ahead of the dates of accessions grown on the DRL. First flowering was recorded at the end of April and seed was harvested during the first week of July. At this site all accessions retained green leaves during the dry season. CIAT 17300 (BRA-000761) was selected as the best accession for this site, and was free of the diseases anthracnose and Pseudocercospora leaf spot which affected other lines. It also produced a good seed crop. CIAT 7182 (BRA-0-00582) showed good performance at both sites. Iron-toxicity affected the plants during the early part of the wet season but only in the year of establishment.

Paspalum species
Eight accessions of Paspalum spp. have been established prior to the dry season for evaluation under grazing. Herbage accumulated during the dry season was subjected to common grazing following sample yields taken on August 8. The highest yield was produced by P. fasciculatum (Table 6), although this species showed the poorest leaf to stem ratio. The

Table 6. Presentation dry matter yields of Paspalum spp. in the "várzea".

Paspalum spp.	DM yields accumulated during the dry season (t ha)
P. fasciculatum BRA 002364	11.51
P. plicatulum CPAC 3272	9.84
P. plicatulum CPAC 3227	9.72
P. plicatulum BRA 001490	8.77
P. plicatulum BRA 001449	8.25
P. hydrophyllum BRA 000485	7.48
P. guenoarum BRA 000060	6.80
P. conspersum BRA 000159	5.36
Mean	8.47
s.e.	0.69

performance of P. plicatulum accessions was very good and several accessions showed high leaf yields and excellent palatability. P. plicatulum is a good seed producer and some accessions yielded 600 kg of cleaned seed per hectare.

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

Associations of three grasses with Stylosanthes guianensis var. pauciflora

This continuing experiment was established in December 1983 and comprises three grasses i.e. Andropogon gayanus cv. Planaltina, Panicum maximum CIAT 6116 and Brachiaria brizantha cv. Marandú. Each grass was combined in associations with either S. guianensis var. pauciflora cv. Bandeirante or accession CIAT 2245 (BRA-012378). The grass-legume treatments were evaluated at two stocking rates, 1 an/ha or 2 an/ha with one seasonal change of grazing frequency. The pastures were grazed by one cow per plot, for 2 days every 3 weeks in the wet season and for 4 days every 6 weeks in the dry season.

Legume yields and percentages showed a marked decline during the 18 months under grazing in both high and low SR treatments (Table 7). At the June 1986 sampling there was a higher legume content in the low SR treatments of both stylos. Associations containing CIAT 2245 had the highest legume contents. Weed content of all treatments increased with time although weed invasion was less severe in the low SR treatments. High SR also reduced DM yields of P. maximum and A. gayanus; both grasses appeared to be more palatable than B. brizantha.

Associations of two grasses with species of Centrosema

A small-scale grazing experiment was established in December 1984 with the objective of evaluating three accessions of C. brasilianum (CIAT 5234, (BRA-006025), CIAT 5523 (BRA-003662),

Table 7. Dry matter yield of two *S. guianensis* var. *pauciflora* accessions each grown in association with three grasses.

Legumes	Date of Harvest	*A. gayanus* High	*A. gayanus* Low	*B. brizantha* High	*B. brizantha* Low	*P. maximum* High	*P. maximum* Low
		Stocking rate					
		Dry matter yield (t/ha)					
S. guianensis cv. Bandeirante	1/11	2.95(73)*	3.93(79)	4.22(80)	3.68(84)	2.94(71)	2.64(57)
	16/5	2.31(84)	3.19(69)	3.67(60)	3.69(60)	2.88(62)	3.29(81)
	5/11	0.67(36)	2.20(56)	1.70(46)	1.81(60)	1.11(54)	2.20(80)
	9/6	0.66(10)	2.24(34)	1.81(4)	3.37(20)	1.16(4)	1.60(20)
S. guianensis CIAT 2245							
	1/11	3.22(57)	2.18(65)	2.86(73)	2.88(84)	3.35(78)	2.78(70)
	16/5	3.20(82)	3.16(67)	4.44(26)	4.04(75)	2.53(66)	3.13(78)
	5/11	1.34(50)	2.20(51)	2.14(37)	3.33(64)	1.10(35)	2.10(60)
	9/6	0.95(14)	3.50(33)	2.37(6)	2.34(32)	0.79(15)	1.89(58)

* Values in parentheses are legume contents (0% DM).

CIAT 5924 (BRA-006254), two accessions of C. acutifolium (CIAT 5277 and CIAT 5568 [BRA-004821]) and three C. pubescens x C. macrocarpum lines (CIAT 5062 x 5056, CIAT 5189 x 5062, CIAT 5189 x 5276) each sown with A. gayanus cv. Planaltina or B. brizantha cv. Marandú. The design was a randomized complete block with two replications. Grasses were established in main plots and legumes as sub-plots. Plot size was 250 m^2. Grazing commenced following the first yield cut on 6 November 1985.

The C. brasilianum accessions showed excellent performance and combined very well with A. gayanus. CIAT 5234 was the outstanding accession. In association with A. gayanus legume dominance was recorded at the time of the second harvest in June (Table 8). The legume contents of the B.brizantha plots were approximately 53% of those of the A. gayanus plots. Andropogon was preferentially grazed in association with C. brasilianum which was poorly accepted by the grazing animals.

The legume contents of the two accessions of C. acutifolium and the Centrosema hybrids were much lower at the beginning of grazing, ranging from 3-9% in association with A. gayanus and from nil to 2% in mixtures with B. brizantha. By June 1986 all legumes disappeared from these associations.

An interesting phenomenon was the complete absence of little leaf mycoplasma in the plots of C. brasilianum whilst all accessions of this species were severely affected in the forage nursery on the DRL.

Table 8. Presentation yields (DM kg/ha) of A. gayanus cv. Planaltina and B. brizantha cv. Marandú associated with 8 Centrosema accessions.

	DM (kg/ha)			
	A.gayanus + legumes		B.brizantha + legumes	
	6.11.85	6.06.86	6.11.85	6.06.86
C. brasilianum CIAT 5234	1130(60)*	2267(81)	1350(22)	1840(28)
C. brasilianum CIAT 5523	1217(50)	1520(52)	1822(11)	1659(17)
C. brasilianum CIAT 5824	1540(29)	1297(41)	1577(5)	1722(7)
Centrosema hybrid (CIAT 5062 x 5056)	842 (7)	-	2277(1)	-
Centrosema hybrid (CIAT 5189 x 5062)	1345(6)	-	1535(2)	-
Centrosema hybrid (CIAT 5189 x 5276)	842(7)	-	1475(1)	-
C. acutifolium CIAT 5277	1227(9)	-	2155(0)	-
C. acutifolium CIAT 5568	1384(3)	-	1758(1)	-

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

Evaluation of animal Production from Grass-Legume Pastures (Category IV)

Associations of Andropogon gayanus with species of Stylosanthes
Evaluation of four A. gayanus.- legume associations began in a large-scale grazing trial with stocking rate variables in May, 1983. A. gayanus was associated with S. capitata CIAT 1019, S. capitata 1097, S. guianensis var. pauciflora cv. Bandeirante or S. macrocephala cv. Pioneiro. Each treatment was grazed by four animals; the initial weight of animals was 130 kg. Until the dry season of 1985 animals gained some weight or at least maintained condition during the dry season, but the dry season of 1985 was extremely severe and liveweight losses occurred in all treatments (Table 9). S. capitata persisted well in all stocking rate treatments for the full period under grazing. S. macrocephala was temporarily lost but regenerated during the period when these pastures were rested. S. guianensis has disappeared completely.

REGIONAL EVALUATION OF GGERMPLASM

Evaluation continued of the set of promising accessions established at 12 sites situated between latitudes 3°N and 22°S in the cerrados.

Adapted species have been identified for a range of edaphic and climatic regions in the cerrados. On poor sandy soils in the northern cerrados the best overall performance was shown by Stylosanthes capitata accessions CIAT 1097 and 1019, with CIAT 1097 produced more dry matter. Both accessions exhibited stable resistance to anthracnose. Accession CIAT 2252 (BRA-007522), which is highly susceptible to anthracnose, was included at each site. Noteworthy is the generally good performance of S. capitata 1097 over a wide latitudinal range from Boa Vista (3°N) to Capinópolis and Felixlandia (18°S). It was the most productive and anthracnose resistant of the six accessions included in these trials.

Several accessions of S. guianensis var. pauciflora are well adapted to the soils and climate of the cerrados. However, accessions of this species showed variable performance at different testing sites. Apparently, unstable resistance to pests and diseases is responsible for poor survival and lack of persistence of some of these accessions. In the higher rainfall regions (> 2000 mm) of the northern cerrados accessions CIAT 2245, 2191 and 1095 appear to be better in terms of persistence than the control cv. Bandeirante. At three sites in the south, at Capinópolis (18°S), Felixlândia (18°S) and Sao Carlos (22°S) CIAT 2244 was considered the superior accession. The same accession also performed very well at Amarante, 180 km from Teresina in the State of Piauí. Poor seed production is considered a major problem in all 6 accessions.

Centrosema species showed promise only at two sites; C. macrocarpum (CIAT 5062 and 5065) and Centrosema sp. aff. pubescens (CIAT 438) at Porto Velho (12°S) and Centrosema acutifolium sp. CNPGC 350 at Campo Grande (20°S).

Evaluation of these species will continue for one more year. Advanced testing under grazing of selected germplasm will be initiated during the coming season.

SEED MULTIPLICATION

This season nine accessions of Paspalum spp., four Centrosema hybrids, five accessions of Arachis pintoi and two Stylosanthes capitata hybrids were established for basic seed production. Production of promising accessions of Stylosanthes capitata, S. guianensis var. pauciflora and var. vulgaris continued. For the large scale increase of promising accessions 30 ha

Table 9. Liveweight changes on Andropogon gayanus - legume pastures during the dry season (May to September) and the wet season (October to May) in the third year (1985/86).

Legume in association with Andropogon	Dry season (140 days) SR* 0.6	0.8	1.0	Means	s.e.	Wet season (224 days) 0.9	1.09	1.11	Means	s.e.
	kg gain/animal/day					kg gain/animal/day				
S. capitata CIAT 1019	-0.10	-0.14	-0.14	-0.13		0.71	0.58	0.15	0.48	
S. guianensis cv. Bandeirante	-0.13	-0.14	-0.13	-0.133	0.035	0.72	0.68	0.62	0.67	0.064
S. capitata CIAT 1097	-0.08	-0.10	-0.06	-0.08		0.61	0.66	0.49	0.59	
S. macrocephala cv. Pioneiro	-0.11	-0.10	-0.13	-0.11		0.67	0.64	0.61	0.65	
Means	-0.105	-0.113	-0.115			0.68	0.64	0.47		
s.e.		0.027					0.05			

* SR = Stocking rate (AU ha^{-1})
1 AU = 400 kg liveweight

of land has been set aside. The Paspalum spp. grazing experiment in the "várzea" was harvested for seed prior to grazing and good quantities of basic seed of each accession have been obtained.

Agronomy Humid Tropics

In view of the pasture degradation and increased felling of new areas in humid tropical forests, INIPA, IVITA, and CIAT's Tropical Pastures Program started a collaborative research project for the development of new germplasm options and low input technology to recover degraded areas through establishment of highly productive and stable pastures for the humid tropics. Major germplasm selection activities for the humid tropics have been carried out in the region of Pucallpa, Peru, since November 1985.

Research is conducted at IVITA's Main Station for the Tropics located 59 km from the city of Pucallpa at 8° 22' South latitude and 74° 34' West longitude, and an altitude of 270 masl. Mean average precipitation is 1700 mm/year and mean annual temperature is 25.1°C. The region corresponds to the semievergreen seasonal forest ecosystem. Soils are acid (pH 4) with high Al saturation beginning at a depth of 4 cm. They are classified as Ultisols under two different subgroups: the well-drained ("Typic Paleudult") and the poorly drained ("Aquic Paleudult").

During 1986, 444 legume accessions of the genera Arachis, Centrosema, Desmodium, Pueraria, Stylosanthes, and Zornia plus 8 grass accessions of the genera Andropogon, Brachiaria, and Panicum were established in small plots (Table 1). A total of 385 grass accessions of the genera Andropogon, Brachiaria, and Panicum, and 49 legume accessions of the genera Centrosema, Leucaena, and Erythrina are in the process of establishment (Table 2). The Brachiaria species came primarily from the new collection of materials brought from Africa and transferred from CIAT-Colombia to Peru in the form of shoot-tip cultures in test tubes, in collaboration with CIAT's Biotechnology Unit. Since all this germplasm has been under agronomic evaluation for less than one year, results presented in this report are still preliminary.

AGRONOMIC EVALUATION OF LEGUME GERMPLASM IN SMALL PLOTS (CATEGORY II)

Centrosema macrocarpum

Most of the collection is outstanding for its excellent adaptation to local edaphic and climatic conditions. Considerable variability was found among introductions in terms of morphologic characteristics: leaf shape, size, and pubescence, length of internodes, and length and number of basal horizontal stems. Flowering is seasonal and generally takes place during July and September, i.e., the period of minimum precipitation and short days. Great variability was registered among introductions with respect to initiation of flowering. Flowering and seed production were low overall and 23 accessions did not flower at all. At the beginning of the maximum precipitation period, slight symptoms of Rhizoctonia solani

Table 1. Forage germplasm established in Pucallpa during 1986.

Specie	Number of Accessions
Arachis pintoi	8
Centrosema acutifolium	22
Centrosema brasilianum	8
Centrosema macrocarpum	137
Desmodium heterophyllum	20
Desmodium ovalifolium	82
Pueraria phaseoloides	75
Stylosanthes guianensis	18
Zornia glabra	23
Zornia latifolia	14
Zornia spp.	31
Various legumes	6
Total legumes	444
Andropogon gayanus	1
Brachiaria spp.	5
Panicum maximum	2
Total grasses	8
Total accessions	452

Table 2. Forage germplasm being established in Pucallpa (December 1986).

Specie	Number of Accessions
Andropogon gayanus	3
Brachiaria spp.	358
Panicum maximum	24
Total grasses	385
Centrosema brasilianum	26
Leucaena spp.	20
Erythrina spp.	3
Total legumes	49
Total accessions	434

were detected in most of the collection. However, symptoms have not increased with the advance of the rainy season.

Table 3 presents a classification through cluster analysis of 128 accessions in the collection, based on dry matter yield and rooting of horizontal stem nodes six months after establishment. Accessions pertaining to cluster 2 are outstanding for their high dry matter yields together with their good capacity to form roots in nodes of postrated stems. This latter characteristic is very important for persistence and autopropagation, since propagation through self-sown seed is very limited, especially under grazing. Promising accessions are also found in clusters 1, 6, and 5. Ecotypes CIAT 5065 and 5713 included as controls are in clusters 8 and 3, respectively, with very low to intermediate dry matter yields and good rooting capacity of horizontal stems. Accessions CIAT 5735 and 5674 will be planted in association with Brachiaria dictyoneura in a Category III grazing trial.

Centrosema acutifolium

Overall, this species is characterized by its good adaptation to local and climatic conditions. Ecotypes varied considerably in their time of flowering, mainly during the period of minimum precipitation from June to the beginning of September. Rhizoctonia symptoms have been found in some accessions. Two months after the beginning of the rainy period, the first symptoms of bacteriosis were detected, present mainly in the entries CIAT 15248, 15534, 15353, 15291, 5118, and 5611.

Considerable variability was found among accessions regarding dry matter yield and rooting in the nodes of horizontal stems as evidenced in the first cut performed six months after establishment. Table 4 shows a classification through cluster analysis of 19 accessions based on these two characteristics. The most promising accessions were found in clusters 5 and 6 due to their good dry matter yields and low susceptibility to bacteriosis. However, their stoloniferous capacity varies from low to good, respectively. Cluster 4 accessions have a good rooting capacity of the postrated stems. However, dry matter yields are relatively low and plants are more susceptible to bacteriosis.

Centrosema brasilianum

With respect to morphologic characteristics, CIAT 5487 is outstanding for its round leaves, while the remaining accessions have lanceolated folioles. This species has a more prolonged flowering period than C. acutifolium or C. macrocarpum and is characterized by its high seed-yielding capacity. Rhizoctonia solani was detected in all accessions. CIAT 5487, 5365, and 5178 were most affected.

Dry matter yield in the first cut six months after establishment was not statistically different among the eight accessions (Table 5). Yields varied from 103 to 241 g/m^2 for CIAT 5178 and 5234 (control), respectively.

Desmodium heterophyllum

Two plant types were distinguished among 20 accessions of D. heterophyllum on the basis of morphologic characteristics: (1) plants with small, less abundant, and greyish green colored leaves, and (2) plants with bigger, more abundant, and light green colored leaves.

The collection has a high-flowering capacity and produces seeds abundantly. These drop easily to the soil, giving rise to new plantlets with the first rains. Maximum flowering was observed during July.

Table 3. Classification of 128 Centrosema macrocarpum accessions by cluster analysis based on dry matter yield and rooting of horizontal stem nodes, at first cutting 6 weeks after planting. Pucallpa, October 1986.

Cluster*	CIAT accession No.	Yield ($g DM/m^2$) Mean	Range	No. of sites rooted/m^2 Mean	Range
6	15097-5739-5461 5732-5735	292	(263-351)	6	(2-16)
2	15047-15057-5888 5674-15076-15115	212	(164-251)	24	(18-34)
4	15041-15232-5743 5948-5957-15061 5633-5798-15063 5276-5418-5904 5738-5952-15059 5736-5946-5941 5901-5953-15113 5730	199	(174-238)	4	(0- 6)
5	15048-5744-5395 5421-5478-5613 15056-5616-5447 5629-15050-15103 5392-5673-5951 5391-5460-15098 5404-15111-5427 5959-5947-5620 5737-5731-5940	175	(135-219)	10	(6-16)
3	15038-5416-15102 5741-15094-5950 5954-5062-15093 15119-5733-15078 5713-5942-5742 5479-5943-15095 5274-5864-5887 5639-5563-5593 5635-5740	147	(121-171)	2	(0- 4)
1	15032-5432-15090 15105-5949-15114 5452-15122	127	(92-147)	20	(16-22)

Table 3. (Continued).

Cluster*	CIAT accession No.	Yield (g DM/m^2) Mean	Range	No. of sites rooted/m^2 Mean	Range
7	15040-5064-5960 5449-15117-15120 5394-5956-5734 5911-15091-5434 5961-5393-5955 5645-15101-15104 15109-5411-5450 5275-5861-5396 5944	115	(73-149)	7	(4-12)
8	15073-15083-15077 15118-5412-5065 5945-5592-5573	83	(40-100)	2	(0- 04)

* R^2 - 0.83.

Overall, the collection is characterized by its low dry matter production, especially during the period of minimum precipitation. Accessions pertaining to the first morphologic type compete poorly with weeds. More promising accessions are found, however, among the second morphologic group. CIAT 349 cv. Johnstone (control) was the most productive and vigorous accession, followed by CIAT 13383, 13194, and 13195.

<u>Desmodium ovalifolium</u>

According to their morphologic characteristics, 82 accessions were classified in two groups: (1) postrate plants with less abundant and greyish green to dark leaves (CIAT 13134 is outstanding among this group for its well acuminated leaves); and (2) postrate to semi-erect plants with abundant light green leaves. Through cluster analysis the collection was grouped in 5 clusters according to their speed of establishment expressed by percentage of soil covered by the material at two months of age. This value ranged from 18 to 48% per m^2 (Table 6).

The collection is well adapted to local edaphic and climatic conditions. Major damages caused by pests or diseases have not been observed. However, mild symptoms of <u>Rhizoctonia solani</u> were detected in most introductions after the first rains. Mild mycoplasma was registered in 15 accessions. Considerable variability was found with reference to flowering date and abundance and seed yield. Accessions within the first morphologic group tended to flower more abundantly than others. To date all accessions have flowered, with the exception of CIAT 13134.

Marked differences in estimated dry matter productivity were observed

Table 4. Classification of 19 Centrosema acutifolium accessions based on dry matter yield and rooting of horizontal stem nodes by cluster analysis, at first cutting 6 months after establishment. Pucallpa, October 1986.

Cluster	CIAT accession	Yield ($g DM/m^2$)		No. of sites rooted/m^2	
R^2 = 0.90	No.	Mean	Range	Mean	Range
5	15088-5277-5278-15281	186	165-208	14	10-18
6	15292-5897-5112	178	177-178	41	38-44
1	5610-15084-5568-5611 15086	138	126-145	14	2-24
2	15353-5118-5564	127	115-144	35	28-42
4	15291-5597	125	112-137	71	68-74
3	15248-15534	95	82-107	9	6-12

Table 5. Dry matter yield of 8 Centrosema brasilianum accessions 6 months after establishment. Pucallpa 1986.

CIAT accessions No.	DM yield (g/m^2)
5234	241 a*
5514	157 ab
5657	139 ab
5810	132 ab
5487	118 b
5671	116 b
5365	108 b
5178	103 b

* Means followed by the same letter are not statistically different at α = 0.05 (Duncan's Multiple Range Test).

among accessions. Accessions in the first morphologic group tended to be less productive than the rest. CIAT 350 (control) has good productivity. However, other accessions are also promising for their overall performance (CIAT 3793, CIAT 3788, CIAT 13089, CIAT 13096, CIAT 13094, CIAT 13102, CIAT 13127, CIAT 13127, CIAT 13129, CIAT 13134, and CIAT 13400).

Pueraria phaseoloides

Seventy-four accessions of this species were established to be compared with the commercial cultivar CIAT 9900. Although P. phaseoloides is naturalized in the humid tropics, its utilization as a forage plant is limited due to palatability problems and poor regrowth after defoliation.

The collection includes different

Table 6. Classification of 82 Desmodium ovalifolium accessions based on their establishment speed expressed as percentage soil coverage 2 months after transplanting, by means of cluster analysis (Pucallpa, June 1986).

Cluster (R^2 = 0.95)	CIAT accession No.	Soil coverage $\%/m^2$ Mean	Range
4	13094-13097-13654-13099-13239 13132-13105-13113-13135-13128	45	43-48
3	13088-13134-350-13400-3652 13100-13121-3663-13129-13133 13092-13647-3776-13122-3607 13106-13130-3608-13116-13126 3674-13648-3781	40	37-42
5	13089-13302-3794-13093-13124 3780-13095-13136-13107-13651 13102-13137-3666-13111-13307 13125-13127-13131	35	32-37
1	13030-13083-13096-13289-13098 13085-13103-13117-3784-3668 13108-13118-13120-13109-13081 13082-13101-13115-13090-13104 13110-13305	28	26-31
2	13091-13114-13370-3793-13649 13653-3788-3673-3778	22	18-24

varieties and thus has great variability in morphologic characteristics (i.e., shape, size, and pubescence of leaves). Var. subspicata is outstanding for its lobulated leaves and low dry matter productivity. Var. phaseoloides has big and normally very pubescent romboid-round leaves and is highly productive. Another variety not yet identified has leaves, that are oval, glabrous, and smaller than those of var. phaseoloides. This variety is similar to Centrosema pubescens and is intermediate in productivity. Finally, there is a type with romboid-oval and pubescent folioles and low productivity.

Flowering is seasonal and takes place between June and September. Only one third of the collection flowered this year and flowering was of low intensity.

Mild symptoms of Rhizoctonia were observed in half of the collection one month after the beginning of the maximum precipitation period. Mild symptoms of chewing (mandibulate) and sucking (haustellate) insects were observed in most of the collection, their intensity increasing slightly in the young regrowth after uniform cutting. Most accessions of var. phaseoloides are vigorous and similar to the control CIAT 9900. Accessions 8171, 9188, 17300, 17310, 17314, and 17321, have good regrowth capacity and have greater dry matter productivity. CIAT 17301 and CIAT 17307 are promising among those accessions similar to C. pubescens.

Zornia glabra

Except for CIAT 8858 which has a more postrate growth, the 23 accessions in the collection are very similar in terms of morphologic characteristics and show excellent adaptation to edaphic and climatic conditions. Flowering occurs abundantly and periodically, reaching its minimum during the period of maximum precipitation. Mild symptoms of sucking insects and Rhizoctonia solani were registered in all accessions. Besides the control CIAT 7847, outstanding accessions are: CIAT 286, CIAT 278, CIAT 283, CIAT 8276, and CIAT8288. Utilization as a forage plant in this ecosystem will depend greatly on palatability, which will be studied in the future.

Zornia latifolia

Among the 14 accessions there is considerable variability with respect to growth habit and shape and pubescence of the leaves. Most introductions were attacked by (approximately 20% of plants affected) by chewing and sucking insects. Symptoms of Rhizoctonia were observed in nine accessions and Sphaceloma was detected in CIAT 8425 only. Overall, estimated dry matter productivity was not superior to the control (CIAT 728), and was lower than that of Z. glabra. Besides CIAT 728, promising accessions were found within a morphologic group having postrate growth and high rooting capacity of stem nodes (e.g., CIAT 14053 and CIAT 9199).

Zornia spp.

The 31 accessions show great morphologic variability, within a broad range of species. Most of the material has low estimated dry matter yields and a high percentage of stems in relation to leaves. Overall, the collection has a high autopropagation potential through fallen seed. Mild symptoms of Sphaceloma were detected in 35% of the accessions at the beginning of the period of maximum precipitation and became more pronounced with the onset of the rainy season. Mild symptoms of Rhizoctonia were present in 42% of the collection. Most of the accessions were attacked by chewing and sucking insects, affecting 20% of the plants. Outstanding accessions were CIAT 9896, CIAT 9919, CIAT 14009, CIAT 8648 and CIAT 7506.

Arachis pintoi

The morphologic characteristics of the eight accessions in the collection are very similar. There are certain differences in flower color, being light yellow in CIAT 17434 and more intense yellow in the remaining accessions. Overall, establishment has been poor and plant vigor and productivity low, especially in the period of minimum precipitation during which curling of the leaves is frequently observed. However, the control CIAT 17434 and accession CIAT 18752 are more vigorous and productive than the rest of the introductions. Preliminary observations indicate that plant productivity is greater when grown in association with a grass.

Stylosanthes guianensis

Agronomic evaluations conducted with accessions of this species have resulted in selection and release of CIAT 184 cv. Pucallpa in Peru. In the present experiment, cv. Pucallpa, CIAT 64-A and 136 are being compared with 15 F_4 lines of the Plant Breeding Section of CIAT's Tropical Pastures Program. These lines showed higher dry matter yield and tolerance to anthracnose than CIAT 184 in savanna ecosystems. In this study, however, none of the lines were superior to the control cv. Pucallpa in terms of reaction to anthracnose. Estimated dry matter yield was higher for lines 14-3, 7-7, 6-4, and 16-8 than for cv. Pucallpa.

AGRONOMIC EVALUATION OF FORAGE GERMPLASM IN SMALL PLOTS UNDER SHADE FROM OIL PALM

Forest is the natural vegetation of the humid tropics. Integrated pasture/tree systems are similar to the original vegetation, and should be studied and made available to farmers as an important additional option to productive and persistent pastures for open areas. Both shrubby and tree germplasm has to be evaluated in silvopastoral systems for its adaptability to conditions under the shadow of trees.

In oil palm and India-rubber plantations in the humid tropics, Pueraria phaseoloides is normally used as cover plant. This species is well adapted but has the disadvantage of growing aggressively and climbing on tree limbs, making maintenance of the plantation difficult and affecting tree growth. In an 11-year old oil palm (Elaeis guineensis) plantation 15 km from the IVITA Station via Pucallpa, 24 legume and 8 grass accessions, including P. phaseoloides as control, were established with the object of selecting germplasm to replace Kudzu as cover crop and/or be used in silvopastoral systems. Germplasm included in this trial (Table 7) is mainly material recommended for Regional Trials in the humid tropics.

Performance of the legumes during establishment is shown in Tables 8 and 9. Overall, plants increased their height considerably during the period of minimum precipitation from June to August and, with the exception of D. ovalifolium and F. macrophylla, did not grow higher after the beginning of August. Germplasm increased its soil coverage after August (Table 9). Promising introductions to date are D. ovalifolium 350 and 3788, D. heterophyllum 349, C. macrocarpum 5065, 5713, 5735, and 5452; C. acutifolium 5277 and 5568, and C. brasilianum 5234. The four accessions of C. pubescence are not adapted due to their high susceptibility to Cercospora. In addition, D. heterophyllum 3782, F. macrophylla 17407, Z. glabra 7847, Z. latifolia 728, and A. pintoi 17434 do not seem to have any potential under these conditions.

Performance of grasses with respect to percentage soil covered and height during establishment are shown in

Table 7. Forage germplasm under agronomic evaluation in an *Elaeis guianensis*. plantation. Pucallpa, 1986.

Species	CIAT accession No.
LEGUMES	
Arachis pintoi	17434
Centrosema acutifolium	5112 - 5277 - 5568
Centrosema brasilianum	5671 - 5810 - 5234
Centrosema macrocarpum	5065 - 5452 - 5713 - 5735
Centrosema pubescens	413 - 438 - 5126 - 5189
Desmodium heterophyllum	349 - 3782
Desmodium ovalifolium	350 - 3788
Flemingia macrophylla	17407
Pueraria phaseoloides	9900 - Pn (common)
Zornia latifolia	728
Zornia glabra	7847
GRASSES	
Andropogon gayanus	621
Brachiaria brizantha	6780
Brachiaria decumbens	606
Brachiaria dictyoneura	6133
Brachiaria humidicola	679
Brachiaria subquadripara	16740
Panicum maximum	673 - 6299

Tables 10 and 11. The erect species, *A. gayanus* and *P. maximum*, increased their height considerably during the study period, while soil coverage remained low during the period of minimum precipitation from June to August, achieving the highest percentages with the rains as evidenced by the November evaluation. Among the *Brachiaria* accessions, *B. brizantha* cv. Marandú and *B. decumbens* 606 were outstanding for their high percentage of soil coverage even during the period of minimum precipitation. Severe spittlebug damage was observed in *B. decumbens* and mild damage in *B. humidicola* and *B. subquadripara*, particularly during the wet season. *B. humidicola* and *B. dictyoneura* produce less stolons than in open areas. The most promising accessions are *A. gayanus* 621, *B. brizantha* cv. Marandú and the two accessions of *P. maximum*, 6299 and 673.

In January 1987 the evaluation of dry matter yield under different cutting regimes, at 3, 6, 9, and 12 weeks, will begin in both precipitation periods.

FUTURE PLANS

New material including 385 grass accessions and 49 legume accessions (Table 2) will be evaluated in 1987. Special emphasis will be placed on evaluating the collection of 358 *Brachiaria* accessions for their reaction to spittlebug. In collaboration with the Entomology Section, the collection will be managed to encourage adequate insect

Table 8. Plant height during establishment of 24 legume accessions under shade in an *Elaeis guianensis* plantation. Pucallpa (planting: 21-03-96).

Species	CIAT Accession No.	Plant height (cm) Evaluation date			
		10-06-86	16-07-86	18-08-86	18-11-86
C.m.*	5713	35.7 a**	53.7 a	63.0 b	69.0 a
C.m.	5452	30.7 ab	48.7 a	60.3 b	65.0 a
C.m.	5735	30.3 ab	54.0 a	74.0 a	69.7 a
C.m.	5065	25.7 b	49.7 a	70.0 ab	68.7 a
C.a.	5112	19.0 c	34.0 b	44.3 cd	32.3 bc
C.p.	5126	19.0 c	34.0 b	36.0 defg	27.3 cd
C.a.	5277	17.0 cd	32.7 bc	36.0 defg	27.3 cd
C.b.	5671	16.7 cd	25.7 bcde	32.7 efgh	25.7 cd
C.a.	5568	16.7 cd	32.0 bc	39.7 cdef	35.3 bc
C.p.	438	16.3 cd	28.7 bcd	37.3 def	32.3 bc
C.p.	5189	15.3 cde	27.3 bcd	33.7 efgh	26.3 cd
C.b.	5810	13.7 cdef	26.7 bcd	29.3 fghi	27.3 cd
C.p.	413	13.0 cdef	23.0 cdefg	32.0 efgh	26.0 cd
C.b.	5234	12.7 cdef	23.7 cdef	28.3 fghi	23.3 cd
Z.l.	728	11.3 defg	28.0bcd	42.7 cde	33.7 bc
P.p.	9900	11.0 defgh	17.0 efghi	22.0 hijk	25.0 cd
A.p.	17434	9.0 efgh	12.7 hi	11.0 kl	15.7 de
D.o.	350	8.3 efgh	16.7 efghi	20.3 ijk	44.0 b
P.p.	PN	7.7 fgh	14.3 fghi	20.0 ijk	25.0 cd
F.m.	17407	7.7 fgh	13.7 ghi	15.6 jkl	37.0 bc
D.o.	3788	6.7 fgh	13.0 hi	15.3 jkl	29.3 cd
D.h.	3782	5.0 gh	8.2 hi	8.3 l	10.3 e
Z.g.	77847	4.0 h	13.5 ghi	31.5 efgh	26.3 cd

* See Table 7.

** Means followed by the same letter on each evaluation date are not statistically different at $\alpha = 0.05$ (Duncan's Multiple Range Test).

Table 9. Soil coverage during establishment of 24 legumes accessions under shade in an *Elaeis guinensis* plantation. Pucallpa (planting: 21-03-86).

Species	CIAT Accession No.	Coverage (%/m^2) Evaluation date 10-06-86	16-07-86	18-08-86	18-11-86
C.m.*	5713	25 abc**	21 abcdef	31 abcde	92 ab
C.m.	5452	20 abcd	22 abcde	26 abcde	95 a
C.m.	5735	28 ab	28 abc	33 abcde	97 a
C.m.	5065	20 abcd	21 abcdef	18 cdef	93 ab
C.a.	5112	24 abcd	30 ab	40 a	80 abc
C.p.	5126	22 abcd	23 abcd	29 abcde	66 abcd
C.a.	5277	29 a	28 abc	31 abcde	82 abc
C.b.	5671	18 bcde	26 abcd	30 abcde	73 abc
C.a.	5568	24 abcd	21 abcdef	29 abcde	80 abc
C.p.	438	24 abcd	23 abcd	33 abcde	54 cde
C.p.	5189	18 bcde	22 abcde	34 abcd	69 abcd
C.b.	5810	19 abcde	22 abcde	28 abcde	60 bcd
C.p.	413	27 abc	31 a	28 abcde	39 def
C.b.	5234	18 bcde	29 abc	38 ab	78 abc
Z.l.	728	13 de	15 cdef	20 bcdef	66 abcd
P.p.	9900	21 abcd	23 abcd	24 abcde	67 abcd
D.h.	349	17 cde	24 abcd	37 abc	93 ab
A.p.	17434	25 abc	27 abcd	30 abcde	67 abcd
D.o.	350	17 cde	19 abcdef	30 abcde	97 a
P.p.	PN	19 abcde	20 abcdef	28 abcde	66 abcd
F.m.	17407	9 ef	9 efg	7 ef	28 ef
D.o.	3788	23 abcd	17 bcdef	28 abcde	91 ab
D.h.	3782	14 de	14 defg	15 def	39 def
Z.g.	7847	3 f	2 g	2 f	14 f

* See Table 7.

** Means followed by the same letter on each evaluation date are not statistically different at $\alpha = 0.05$ (Duncan's Multiple Range Test).

Table 10. Plant height during establishment of 8 grass accessions under shade in an <u>Elaeis guinensis</u> plantation. Pucallpa (planting: 21-03-86).

Species	CIAT Accession No.	Plant height (cm) Evaluation date			
		10-06-86	16-07-86	18-08-86	18-11-86
B.b.	6780	61.7 a*	75.7 a	91.0 a	94.7 cd
A.g.	621	54.3 ab	82.0 a	93.0 a	173.3 a
B.d.	6133	48.3 abc	44.7 c	50.3 cd	62.3 de
B.d.	606	39.3 bcd	59.0 abc	77.7 ab	63.0 de
B.s.	16740	34.7 cd	30.1 c	36.7 d	41.3 e
P.m.	673	30.0 d	39.3 c	66.3 bc	113.7 bc
B.h.	679	28.0 d	52.7 bc	55.7 bcd	73.0 de
P.m.	6299	25.7 d	31.0 c	52.3 cd	135.7 b

* See Table 7.

** Means followed by the same letter on each evaluation date are not statistically different at $\alpha = 0.05$ (Duncan's Multiple Range Test).

Table 11. Soil coverage during establishment of 8 grass accessions under shade in an <u>Elaeis guinensis</u> plantation. Pucallpa (planting: 21-03-86).

Species	CIAT Accession No.	Coverage (%/m^2) Evaluation date			
		10-06-86	16-07-86	18-08-86	18-11-86
B.b.	6780	36 a*	31 a	64 a	100 a
A.g.	621	11 b	19 b	26 b	100 a
B.d.	6133	8 b	14 bc	13 b	82 ab
B.d.	606	12 b	17 bc	62 a	86 a
B.s.	16740	7 b	8 bc	14 b	51 b
P.m.	673	11 b	7 bc	18 b	78 ab
B.h.	679	6 b	11 bc	18 b	68 ab
P.m.	6299	9 b	4 c	16 b	78 ab

* See Table 7.

** Means followed by the same letter on each evaluation date are not statistically different at $\alpha = 0.05$ (Duncan's Multiple Range Test).

populations and ensure a reliable screen for host plant resistance to spittlebug.

Two grazing trials in categories III and IV are in the process of establishment in degraded areas of the IVITA Station. The objective of the Category III trial is to evaluate persistence of three associations under different pasture managements: Brachiaria dictyoneura CIAT 6133 associated with Centrosema macrocarpum CIAT 5735/5674, B. dictyoneura CIAT 6133 associated with Desmodium ovalifolium CIAT 350, and B. brizantha cv. Marandu CIAT 678 associated with C. macrocarpum 5735/5674. These associations will be subjected to three stocking rates (2.0, 2.7, and 3.4 AU/ha) in a rotational grazing system with 6 days of occupation and 30 days rest.

The objective of the Category IV experiment is to determine the optimum stocking rate for individual weight gain and weight per area of an association of B. dictyoneura CIAT 6133 and D. ovalifolium CIAT 350. Three stocking rates (2, 3, and 4 yearlings/ha) will be used in a rotational grazing system with 7 days of grazing and 21 days rest, including as control a treatment of B. dictyoneura in pure stand and grazing pressure of 3 yearlings/ha.

Another important activity will be seed production of promising germplasm for future regional trials in the humid tropics.

Within the concept of decentralizing the International Tropical Pastures Evaluation Network into four sub-networks, activities will be established outside Peru in the Brazilian Amazon as well as in Ecuador, Colombia, and Bolivia.

Pasturas Project in Panama (IDIAP/RUTGERS/CIAT)

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

GERMPLASM

Regional Trials Type A (RTA)

Two new RTAs were established during 1986 in contrasting ecosystems in Panama. A trial was established in Torti, located in the eastern part of the country and in El Darien region, and the other in Bijao-Chiriquí, in the extreme west of the country. The sites correspond to a humid or a very humid tropical forest, respectively. Bijao-Chiriqui is located at 1100 meters above sea level (masl) with a mean temperature of 20.7°C and 5920 mm of annual rainfall, while El Darién is a forest zone of active colonization and timber harvest. The Tortisoils have good nutrient content, neutral pH, and only traces of aluminum (Table 1). These soil conditions are common in recently deforested areas, as is the site of the trial.

The species established at Torti include more grass than legume species and among the former, the genus *Brachiaria* predominates (Table 2). Results indicate good coverage and an excellent degree of adaptability of most species two months after the experiment was established, including local materials such as *Hyparrhenia rufa* and *Digitaria swazilandensis*. The most outstanding legumes are *Arachis pintoi* CIAT 17434 and *Pueraria phaseoloides* CIAT 9900 (Kudzu), as well as *Stylosanthes guianensis* CIAT 136 and CIAT 184. *Centrosema brasilianum* CIAT 5234 is the species most attacked by *Rhizoctonia* leaf blight; this disease has been observed to a lower extent in *Centrosema macrocarpum* CIAT 5062 and *C. pubescens* CIAT 5189.

Twenty-seven accessions of grasses and legumes were established in Bijao (Chiriquí) (Table 3) with *Brachiaria*, the predominant grass genus, and *Centrosema* and *Trifolium* the predominant legume genera. Evaluations conducted two months after establishment show differences among the species. The local grasses *Cynodon* sp. (star grass), *Axonopus* sp. (carpet grass), and *Brachiaria decumbens*, known for their high nitrogen requirements and susceptibility to the spittlebug, have shown a better area coverage than the introduced species, with the exception of *Brachiaria humidicola* CIAT 6707.

Table 1. Characteristics of a Torti soil (Panama).

Depth (cm)	Texture	O.M. (%)	pH (H_2O)	P ppm	Exchang.cations. Ca	Mg	K	Sat. Al (%)	Mn	Fe	Zn	Cu
					--- meq/100 g ---							
0-20	Loamy	3.5	6.4	7.8	25.6	7.1	53.2	Tr	64.3	142.5	2.0	4.8

The legumes in this trial have grown slowly, possibly due to the combination of low night temperatures and high rainfall occurring in the area from the beginning of the experiment. However, during the latter months C. macrocarpum accessions have developed vigorously.

Regional Trials B - RTB (Rio Hato

Evaluations during the period of minimum precipitation were completed in the RTBs of Río Hato conducted in collaboration with the Instituto Nacional Agropecuario (INA) and the University of Panama, Faculty of Agronomy (FAUP). Table 4 shows dry matter (DM) yields for the germplasm under evaluation at 3 and 9 weeks of growth; evaluations performed at 6 and 12 weeks showed similar tendencies. A high and sustained DM yield is observed for Andropogon gayanus CIAT 6200 compared with A. gayanus CIAT 621 and Hyparrhenia rufa (jaragua grass), the latter with similar yields. However, the proportion of green leaves was much higher in A. gayanus than in jaragua grass towards the end of the dry period. B. decumbens CIAT 606 and B. humidicola CIAT 679 are the most outstanding in this genus, but B. humidicola CIAT 679 yielded notably less at the 9-week harvest. B. humidicola CIAT 6369 and CIAT 6707 produced the lowest yields among the grasses, but this was explained by the low plant population existing due to the late establishment of the accessions. Digitaria swazilandensis had intermediate yields, very similar for the two harvest periods, indicating little growth capacity of the species under reduced rainfall conditions.

With the exception of Stylosanthes capitata CIAT 10280 and S. macrocephala CIAT 1643 and CIAT 2133, which had poor adaptability in this ecosystem, the Stylosanthes group had the highest DM yields among the legumes. Stylosanthes guianensis CIAT 136 and CIAT 184 and Stylosanthes scabra CIAT 1047 showed higher yields and production increases with age of cutting. Instead Stylosanthes sympodialis CIAT 1044 and Stylosanthes hamata CIAT 147 and CIAT 118 had lower yields at 9 weeks as a consequence of greater defoliation in comparison to the other Stylosanthes species; this was also associated with the fact that S. hamata produced abundant flowers and had high seed formation. Other outstanding legumes for this retention of green forage during the evaluation period, were the accessions of C. macrocarpum whose yields increased for the 9-week period, indicating the plant's capacity to continue growing under conditions of drought stress. However, these yields (close to 3000 kg DM/ha) were inferior to those of the best Stylosanthes accessions. Something similar occurred with the C. pubescens group, Centrosema pubescens CIAT 438 being the outstanding accession for its growth vigor. Neonotonia wightii demonstrated poor performance, as reflected in its yields, while Kudzu suffered severe defoliation and had relatively low yields. Leucaena leucocephala CIAT 17502 evaluated under this regime yielded within the expected ranges,

Table 2. Species established in the RTA in Torti, Panama. (Establishment: August 1986).

Species	CIAT No.	Coverage (%)*	Adaptation**
GRASSES			
Andropogon gayanus	621	96	E
Brachiaria decumbens	606	96	E
B. decumbens	6131	-	-
B. humidicola	639	88	E
B. humidicola	679	88	E
B. humidicola	6707	45	G
B. dictyoneura	6133	96	E
B. ruziziensis	6419	90	E
B. ruziziensis	6291	-	-
B. ruziziensis	654	40	G
B. brizantha	6780	100	E
B. brizantha	6012	50	G
B. brizantha	664	40	G
Panicum maximum	622	100	E
Digitaria swazilandensis	Local	100	E
Dichanthium aristatum	Local	100	G
Hyparrhenia rufa	Local	100	E
LEGUMES			
Arachis pintoi	17434	100	E
Centrosema brasilianum	5234	63	I
C. macrocarpum	5062	63	G
C. pubescens	5189	91	G
Pueraria phaseoloides	9900	100	E
Stylosanthes guianensis	136	93	E
S. guianensis	184	93	E
S. hamata	118	40	G

* 2 months after planting.

** E, excellent; G, good; I, intermediate.

Table 3. Species established in the RTA in Bijao-Volcan-Chiriqui, Panama, 1986.

Species	CIAT No.	Degree of Adaptation *	Coverage (%)
GRASSES			
Brachiaria humidicola	679	I	7
B. humidicola	6369	G	26
B. humidicola	6707	G	30
B. dictyoneura	6133	I	17
B. ruziziensis	655	G	22
B. brizantha	664	G	30
B. brizantha	6780	B	2
B. decumbens	Commercial	G-E	58
B. decumbens	6131	I	21
Cynodon sp. (Star grass)	-	I-G	47
Axonopus sp. (Carpet grass)	-	G-E	45
Setaria anceps	-	G	10
LEGUMES			
Centrosema macrocarpum	5062	B	1
C. macrocarpum	5065	G	4
C. macrocarpum	5478A	I	2
C. macrocarpum	5274	G	3
C. brasilianum	5487	B	1
Desmodium heterophyllum	349	I	3
D. intortum	Native	-	-
Trifolium stenderi	ILCA 6253	I	2
T. tembense	ILCA 5274	I	1
T. quartinianum	ILCA 6301	I	1
T. decorum	ILCA 6303	B	1
T. rueppellianum	ILCA 6260	I	1
Medicago sativa	Florida 77	-	-
Pueraria phaseoloides	Kudzú	I	2
Stylosanthes guianensis	CIAT 184	G	2

Establishment date: August 28, 1986.
Evaluation date: November 13, 1986.
* E, excellent; G, good; I, intermediate; B, bad.

Table 4. Yield (kg DM/ha) during minimum precipitation period of germplasm established in a Regional Trial B in Rio Hato. Panama.

Species	CIAT No.	Yield (kg/DM/ha) 3 weeks	9 weeks
GRASSES			
Hyparrhenia rufa (Jaragua)	Local	5103 cb	6143 cb
Brachiaria decumbens	606	4449 cbd	4627 cbd
B. humidicola	679	7651 b	3784 cbd
B. humidicola	6369	567 d	567 d
B. humidicola	6707	660 d	380 d
Andropogon gayanus	621	5676 cb	6335 b
A. gayanus	6200	11664 a	16958 a
Digitaria swazilandensis	Local	1797 cd	1800 cd
LEGUMES			
Stylosanthes hamata	118	5475 bac	4923 dc
S. hamata	147	8513 a	7178 bc
S. guianensis	136	7661 a	9837 ba
S. guianensis	184	8594 a	8976 ba
S. sympodialis	1044	6522 ba	5027 dc
S. scabra	1047	8142 a	11555 a
S. macrocephala	1643	423 d	850 gf
S. macrocephala	2133	2340 dc	1023 gef
S. capitata	10280 - Capica	1130 d	120 g
Centrosema macrocarpum	5062	2266 dc	3213 def
C. macrocarpum	5065	3030 dc	2813 dgef
C. macrocarpum	5434	2553 dc	2530 dgef
C. macrocarpum	5478	3213 bdc	3970 de
C. pubescens	438	3306 bdc	2247 dgef
C. pubescens	5126	2840 dc	2267 dgef
C. pubescens	5189	2080 dc	1600 gef
Pueraria phaseoloides	9900 - Kudzú	1890 dc	1890 gef
Leucaena leucocephala	17502	2181 dc	2550 dgef
Glycine wightii	216	1323 d	567 gf

a, b, c, d, Different means (P < .05).

increasing its yields slightly for the 9-week period.

As shown in Table 5, seed production and the subsequent generation of Stylosanthes hamata CIAT 118 and Stylosanthes sympodialis CIAT 1044 plantlets were very high. Other species such as Stylosanthes hamata CIAT 416 and Stylosanthes scabra CIAT 1047 were less prolific, but with a sufficient number of plantlets to assure continued persistence of the species. This natural characteristics of surviving via the seed is fundamental in the persistence of species under grazing and must be a factor to be considered in germplasm evaluations.

BRACHIARIA SPECIES

The evaluation of 21 Brachiara spp. ecotypes in Finca Chiriqui (Ultisols) and Gualaca (Inceptisols) was concluded. Table 6 presents final dry matter yield results, leaf proportions, and protein values. The highest yields in both sites were obtained with the B. humidicola ecotypes, particularly in Finca Chiriqui, where the soils are less fertile and spittlebug attach is severe (1985 Annual Report, Tropical Pastures Program, CIAT). However, observations made in Gualaca show that these ecotypes have a smaller leaf proportion than other Brachiaria species, except for B. humidicola CIAT 6369 with a leaf value of 85%, the highest observed. Crude protein contents of the species were very similar, ranging between 8-10% in observations made in Gualaca during the rainy season. The effect of the site on yields was less severe for B. humidicola CIAT 6707, mainly due to its excellent tolerance to spittlebug attack; while the B. decumbens, B. brizantha, B. ruziziensis, and B. eminii ecotypes yielded significantly less in Finca Chiriqui than in Gualaca.

B. humidicola CIAT 6369

Among the Brachiaria group evaluated in Gualaca and Finca Chiriquí, B. humidicola CIAT 6369 is considered as highly promising for its aggressiveness, number of stolons, good soil coverage, high tolerance to drought, moderate susceptibility to spittlebug, and high leaf proportion. A fertilization experiment was established in Gualaca to observe the response of B. humidicola CIAT 6369 already established to low nitrogen (N), phosphorus (P), and sulfur (S) levels. A San Cristobal design was used, plus an additional treatment with high levels of nutrients. Nutrients were applied in the following doses: N: 0, 25, 50, 75, and 150; P: 0, 15, 30, 45, and 90; and S: 0, 10, 20, 30, and 60 kg/ha.

Dry matter yields of the first four harvests are presented in Table 7. A marked effect of nutrients on yields was not observed, at least up to the first 50 kg/ha of applied nitrogen. Without fertilizer application, the species yielded adequately (1701 kg DM/ha) demonstrating its adaptability to the ecosystem and low nutritional requirements. Small yield increases were observed with the application of P and S, and particularly with the application of N. However, S seems to be the key element in the presence of N, since yields obtained with 50 and 20 kg N and S/ha, respectively were very similar to those observed with the highest fertilization dose. Crude protein content was very similar for all treatments--close to 10%--with the exception of a slight increase when high levels of N, P, and S were applied.

SEED MULTIPLICATION

Seed multiplication of promising species has concentrated mainly in Central Province areas of Panama due to their better rainfall distribution, compared to sites such as Gualaca in the extreme west of the country.

Table 5. Number of plantlets/m^2 from *Stylosanthes* spp. seed established in Rio Hato (Panama)*.

Species	Plantlets/m^2
Stylosanthes hamata CIAT 118	6160
Stylosanthes hamata CIAT 147	416
Stylosanthes sympodialis CIAT 1044	2976
Stylosanthes scabra CIAT 1047	176

* Observations made at the beginning of the rainy period.

Table 6. Dry matter yields (t DM/ha), leaf proportion, and crude protein (CP) content of *Brachiaria* spp. established in Finca Chiriqui and Gualaca. Panama, 1986.

Species	CIAT No.	Yields (t DM/ha)*		Leaves	CP**
		Finca Chiriqui	Gualaca	(%)	(%)
B. humidicola	6707	2.03	2.64	38	9.2
B. humidicola	675	1.91	2.78	32	9.2
B. humidicola	682	1.72	2.29	39	9.2
B. humidicola	6705	1.69	2.34	34	9.4
B. humidicola	6709	1.44	2.55	31	9.1
B. humidicola	679	1.42	2.55	34	9.1
B. dictyoneura	6133	1.41	2.19	52	9.2
B. humidicola	6369	0.89	2.36	83	8.5
B. brizantha	6012	0.72	1.75	56	8.8
B. decumbens	Commercial	0.62	2.53	50	10.1
B. decumbens	6131	0.52	1.44	80	9.2
B. ruziziensis	654	0.49	1.58	72	9.9
B. decumbens	6132	0.47	1.68	70	9.4
B. ruziziensis	6130	0.44	1.66	67	9.8
B. ruziziensis	6291	0.41	1.72	74	9.3
B. brizantha	664	0.39	1.74	57	9.9
B. ruziziensis	6419	0.29	1.72	66	9.9
B. brizantha	6298	0.29	1.94	56	9.1
B. ruziziensis	6134	0.25	1.79	68	9.0
B. brizantha	6009	0.25	1.58	64	9.1
B. eminii	6241	0.05	1.84	54	10.0

* Average of 7 and 8 cuts every 5 weeks in Gualaca (Inceptisol) and Finca Chiriqui (Ultisol) during the rainy period.

** Average of 5 cuts in Gualaca; leaf proportion corresponds to an observation done during the rainy period.

Table 7. Yield and quality response of Brachiaria humidicola CIAT 6369 to applied nitrogen (N), phosphorus (P), and sulfur (S) in an Inceptisol in Gualaca. Panama, 1986.

Treatments kg/ha			Yields kg DM/ha*	Crude protein (%)**
N	P	S		
0	0	0	1701	10.3
50	0	0	1621	10.6
0	30	0	1893	10.9
50	30	0	1643	10.4
0	0	20	1854	10.3
50	0	20	2028	10.4
0	30	20	1223	10.4
50	30	20	1785	10.3
25	15	10	1804	10.4
75	15	10	2319	10.6
25	45	10	1719	10.6
25	15	30	1913	10.5
150	90	60	2387	11.1
		LSD 0.05	750	

* Average of 4 cuts every 35 days during the rainy period.
** Average of 2 cuts during the rainy period.

Table 8 shows area planted and seed yields for each species. The greatest seed production efforts have been dedicated to A. gayanus which has become of growing interest since its commercial release in 1983, primarily in the provinces of Los Santos, Herrera, and Veraguas.

Yields of unprocessed seed ranged from 182 to 355 kg/ha. Both site and harvesting practices effected yields. The seed harvested has either been sold to private producers or planted in new seed multiplication plots. At the end of 1986 there were approximately 15.0 ha of seed fields in Soná, Calabacito, Los Santos, Penonomé, Río Hato, and Chepo. This seed multiplication effort conducted by IDIAP in collaboration with private producers, will contribute to reduce the limited commercial availability of A.gayanus seed.

C. macrocarpum CIAT 5065 increased seed yields in relation to the period 1984-1985 (1984 Annual Report, Tropical Pastures Program, CIAT). However, yields could be greater if the species had a better synchronization of flowering under the Gualaca conditions. In this site the dry season begins at different periods and the species flowers and forms seed practically from the end of November until February of the following year. Thus harvest becomes a continuous manual recollection process lasting several months. Given the poor agronomic performance of CIAT 5065 compared to others of the same species, multiplication plots were replaced by Centrosema macrocarpum CIAT 5062 and CIAT 5434 in various localities of Panama.

Table 8. Seed production of forage species during 1985-86 in some sites in Panama.

Species	Site	Area (ha)	Yield (kg/ha)	Total harvested (kg)*
A. gayanus 621	Finca Chiriqui	1.3	190	247
A. gayanus 621	Rio Hato	1.0	250	250
A. gayanus 621	Soná	1.0	355	355
A. gayanus 621	Los Santos	3.0	182	546
C. macrocarpum 5065	Gualaca	0.4	60	24
P. phaseoloides Kudzu	Calabacito	1.0	40	40

* Unprocessed seed.

WEED CONTROL

Weed control activities have aimed at two basic objectives: the control of shrubs and other erect grass weeds such as paspalum (Paspalum virgatum) and bracken (Pteridium aquilinum), and weed control during the establishment of Pueraria phaseoloides - Kudzu (1984-1985 Annual Report, Tropical Pastures Program, CIAT).

a) Control of erect grasses (Paspalum virgatum)

This weed is found throughout Panama in moderate to high fertility soils. It produces abundant viable seed allowing it to invade pastures relatively quickly, especially if they have been overgrazed. The fact that this weed grows vigorously and is scarcely consumed by the animals further enhances its competitiveness with the desired forage species.

During 1986 field experiments were conducted in the localities of Bugaba and Chepo, located in the west and east of Panama, respectively. The foliar herbicides Diuron in concentrations of 1.0, 1.5, and 2.0%; Dalapon--2.0, 3.0, 4.0, and 3.0, + 3.0%--0.75, 1.0, and 1.25% were applied with knapsack sprayer and Glyphosphate--3.0, 5.0, and 7.0% with a wick applicator, in the locality of Bugaba. To increase foliar activity, 0.5% of an agricultural surfactant was added to all herbicides except Glyphosate. Evaluations of degree of control were conducted at 20, 40, and 60 days after application. Results of the first two evaluations are shown in Figure 1. A positive correlation was observed between Diuron dose and the degree of control. The maximum percentage of dead plants was 75% for the 2.0% dose at 60 days, due to regrowth of some plants. On the other hand, there were no marked differences in control among the Dalapon 2.0, 3.0, and 4.0% doses. However, when this herbicide was applied in two doses (3.0 + 3.0%) with an interval of 20 days, plant mortality was 100% at 60 days. The best control was achieved with Glyphosate applied on the leaves, particularly when the application was done with a wick applicator, in which case the 3.0, 5.0, and 7.0% doses were equally effective. Similar control at 60 days was obtained with knapsack sprayer with 1.0 and 1.5% doses. The wick applicator control method provided greater selectivity for the swazi grass (Digitaria swazilandensis) predominating in the site of the trial. The application with knapsack sprayer provided the same control for all the species in the experimental plots.

The same herbicides and application

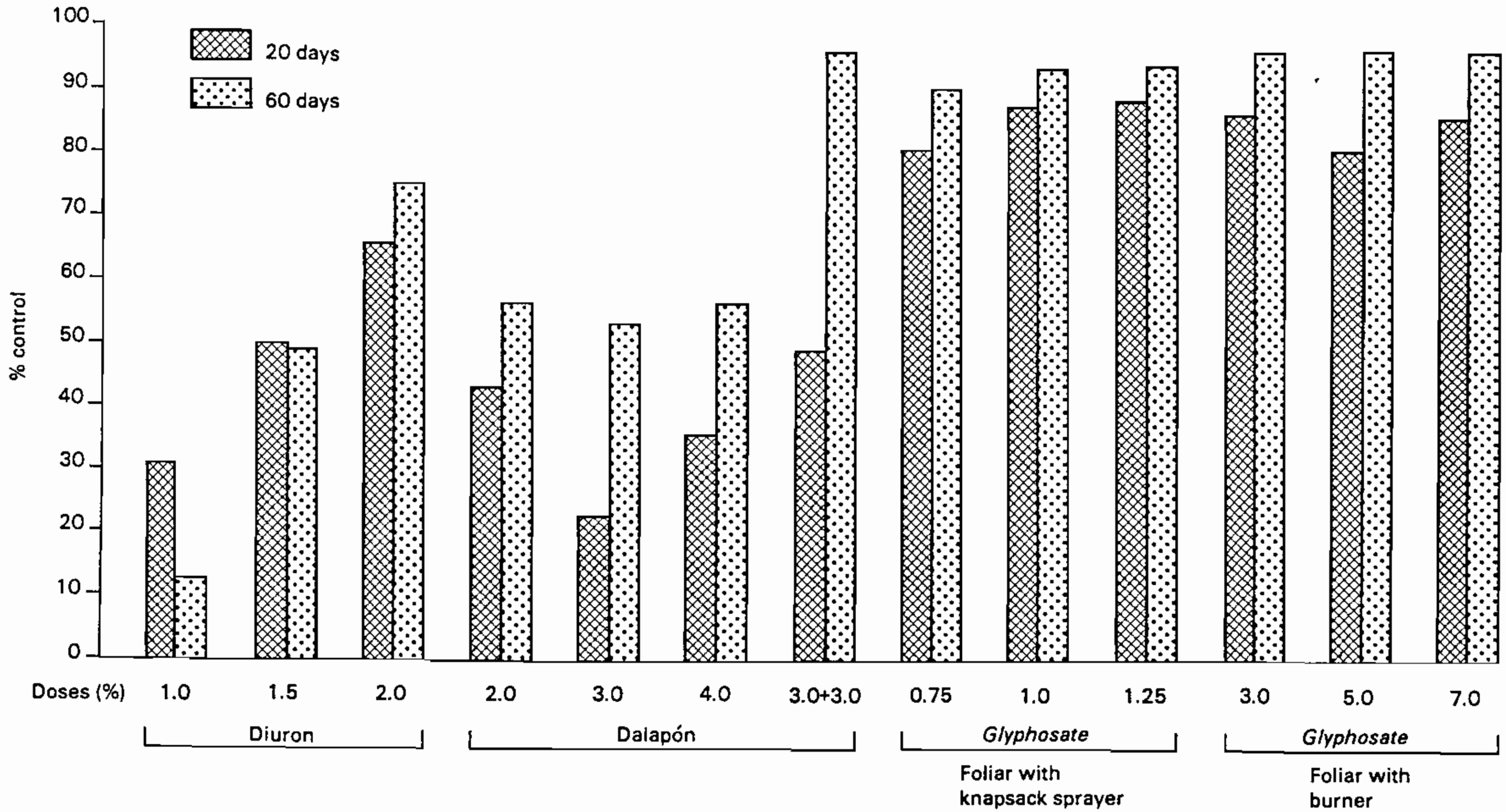


Figure 1. Control of upright paspalum *(Paspalum virgatum)* 20 and 60 days after application of herbicides Diuron, Dalapon, and *Glyphosate* in Bugaba (Panama).

systems were used in Chepo, located in a different ecosystem, but with different doses: Glyphosate 0.5 and 1.0% for foliar application with knapsack sprayer and 3.0, 5.0, and 8.0% for foliar application with wick applicator; Diuron 2.0 + 0.10% surfactant and Dalapon 6.0 + 0.10% surfactant. A swazi pasture invaded with approximately 7500 plants/ha of upright paspalum was chosen for the wick applicator system; while at the site where the herbicide was applied with knapsack sprayer, weed coverage was complete--approximately 15,000 plants/ha, with a height ranging between 0.80 and 1.20 m. Table 9 shows results of control up to 40 days after application of products; foliar application with sprayer of Diuron 2.0% plus surfactant was observed to result in the greatest control and the least regrowth of plants. This result was different from that obtained in Bugaba with similar doses and is due to the fact that a slight rainfall in Chepo, approximately three hours after application of herbicides, stimulated the action of Diuron by washing it towards the zone of the roots where it was more efficiently absorbed. This did not happen with the herbicides Glyphosate and Dalapon.

Glyphosate was applied with a wick applicator to 0.50 to 0.90-m tall upright paspalum plants under favorable environmental conditions. As illustrated in Table 9, the degree of control increased as the herbicide dose increased, reaching complete control at 15 days with the 8.0% dose. In this case the product was highly selective to the swazi grass, which rapidly spread into the area left by dead paspalum plants. There were differences in quantity of herbicide used in the two application systems: while with the wick applicator 711 cc/ha of 8.0% Glyphosate were used, with the foliar application 6500 cc of 1.0% Glyphosate were used. Obviously the plant population in the first case was twice as great and also plants were taller, but still by comparison the wick applicator is the more economic in herbicide use, degree of control, and selectivity to the established grass species. In a population of upright paspalum and in the locality where the application was done with knapsack sprayer, weed control costs with Glyphosate were equivalent to those of land preparation including plowing and raking. On the other hand, all herbicide treatments significatively reduced the populations of upright paspalum regrowing from seed, as shown in Table 10. This weed produces high seed yields and the subsequent plant generations regrow exclusively from this source, thus the importance of considering control methods which reduce the subsequent generation of the species. The herbicides used in this trial have this property, compared with the control.

b) Control of braken (Ptderidium aquilinum)

This weed is widely distributed in Panama, particularly in degraded hill-side pastures and in acid soils with high organic matter. Besides its competitiveness and the invasion of the area destined to the desired species, its consumption is toxic to bovines (hematuria), often causing death.

A weed control trial was established in the locality of Volcán (Chiriquí), situated at 1400 masl and having mean temperatures of 21°C. The herbicide doses were: 2,4-D amine, 3.0, 6.0, and 9.0%; Picloram + 2,4-D amine, 1.5, 3.0, and 4.5%; foliar Glyphosate (applied with knapsack sprayer), 1.0, 2.0, 3.0, and 5.0%, and foliar Glyphosate (applied with wick applicator) 10.0 and 15.0%. Additionally, two manual control treatments were used: (a) cutting with machete and (b) breaking the leaves and superficial rhizomes by hitting them hard with a stick. Table 11

Table 9. Control of upright (*Paspalum virgatum*) with foliar herbicides in Chepo, Panama, 1986.

I. FOLIAR APPLICATION WITH KNAPSACK SPRAYER

Herbicides	Doses (%)	Control (%) 20 days	Control (%) 40 days	Regrosth 60 days
Glyphosate	0.5	30	83	63
Glyphosate	1.0	90	94	44
Diuron	2.0 + 0.10% Surf.	23	93	7
Dalapon	6.0 + 0.10% Surf.	51	95	52

II. FOLIAR APPLICATION WITH WICK APPLICATOR

Herbicide	Doses (%)	Control (%) 15 days	Control (%) 30 days
Glyphosate	3.0	63	80
Glyphosate	5.0	70	90
Glyphosate	8.0	100	100

Glyphosate utilized		(cc)	Plants/ha (No.)
a) Wick applicator: doses (%)	3.0	267	7,500
	5.0	445	
	8.0	711	
b) Sprayer: doses (%)	1.0	6,500	15,000

Table 10. Population of *Paspalum virgatum* plantlets from seed in a weed control trial. Panama, 1986.

Treatment	Doses (%)	Plantlets/m^2
Glyphosate	0.5	11.2
Glyphosate	1.0	13.3
Diuron	2.0 + Surf.	10.8
Dalapon	6.0 + Surf.	10.6
Control	-	79.5

Table 11. Chemical control of bracken (Pteridium aquilinum) in Volcan, Panama, 1986.

Treatments	Doses (%)	Percentage Control 30 days	Percentage Control 90 days	Percentage regrowth at 90 days
2,4-D amine	3.0	50	34	73
2,4-D amine	6.0	85	60	69
2,4-D amine	9.0	90	66	61
Picloran + 2,4-D amine	1.5	37	43	49
Picloran + 2,4-D amine	3.0	69	75	31
Picloran + 2,4-D amine	4.5	86	84	19
Glyphosate	1.0	22	44	10
Glyphosate	2.0	30	54	13
Glyphosate	3.0	60	81	6
Glyphosate	5.0	12	44	10
Glyphosate	10.0 (wick applicator)	20	50	10
Glyphosate	15.0 (wick applicator)	43	78	8
Machete		85	0	100
Hitting with stick		7	0	100
Control		0	0	100

shows results of control evaluation at 30 and 90 days after the application of treatments; none effectively controlled bracken due to its regrowth capacity. However, it is worth noting the high percentage of control with Picloram + 2,4-D amine at 3.0 and 4.5% at 90 days, the highest dose reducing regrowth. The intermediate and high doses of 2,4-D amine resulted in good initial control, but this was subsequently reduced. The contrary was true for Glyphosate which resulted each time in greater control up to the 3.0% dose when applied with knapsack sprayer. With this treatment regrowth levels were reduced to a minimum and the residual effect continued even 90 days after application. Something similar was observed with the wick applicator application, particularly with the 15.0% dose of Glyphosate, which further presented more selectivity grass for established species in these plots. At the end of the experiment it was evident that the plots receiving high doses of 2,4-D amine and Picloram + 2,4-D amine, had a high proportion of grasses; this was not true for the foliar application of Glyphosate with knapsack sprayer. A second application of hormonal herbicides at 90 days was considered necessary and adequate to eliminate weed regrowth.

PASTURE EVALUATION

The first grazing cycle of the animal production trial (RTD) established in Gualaca was completed this year. The grasses B. humidicola, H. rufa, and A. gayanus alone or associated with Kudzu in a rotational system with 14 grazing days and 42 rest, and stocking rates of 2 or 4 AU/ha were evaluated. Table 12 summarizes weight gains per animal in the different treatments during the dry (111 days) and rainy period (224 days). There was a marked effect of stocking rate on weight gains, this being more evident in the case of the

Table 12. Animal liveweight gains in pastures in pure stand and in association with Kudzu established in Gualaca, Panama, 1986.

Pasture	Stocking rate AU/ha	Daily weight gains per period (g/animal/day)		Annual weight gains (kg)	
		Dry[1]	Rainy[2]	Animal	ha
H. rufa	2	177	633	161	322
H. rufa	4	87	528	128	512
A. gayanus	2	359	578	169	338
A. gayanus	4	- 80	593	124	496
B. humidicola	2	199	611	159	318
B. humidicola	4	154	483	125	500
H. rufa + Kudzu	2	145	736	181	362
H. rufa + Kudzu	4	50	536	126	504
A. gayanus + Kudzu	2	502	561	181	362
A. gayanus + Kudzu	4	210	508	137	548
B. humidicola + Kudzu	2	339	517	153	306
B. humidicola + Kudzu	4	212	548	146	584

1/ 111 days.

2/ 224 days.

grass in pure stand during the dry period. The 2 AU/ha stocking rate on A. gayanus resulted in the highest gains during this period, but when the stocking rate was doubled, the animals lost weight. This did not hold true with H. rufa and B. humidicola, the latter showing less variability to the stocking rate effect.

As expected, Kudzu offered the best results in the dry period, with weight gains of up to 502 g per animal per day in the association with A. gayanus and a stocking rate of 2 AU/ha; this gain is very similar to that obtained during the rainy season for the same association. Smaller differences in weight gains were observed during the rainy season as a result of varying pastures and stocking rates. Overall, the contribution of the legume to the total increase in animal weight was approximately 30 kg/ha, taking as a basis total average weight gain per hectare of pastures with and without legumes.

International Tropical Pastures Evaluation Network (RIEPT)

INTRODUCTION

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

ADVANCES OF THE INTERNATIONAL TROPICAL PASTURES EVALUATION NETWORK

General Information

Currently, the RIEPT has 203 regional trials in tropical America. Of these, 140 periodically report information, reflecting an efficiency of 70% information retrieval (Figure 1). Figure 2 presents the geographic distribution of the regional trials established in the period 1978-1986. Regional trials have continuously evolved not only by increasing their numbers but also by diversifying their work: agronomic evaluation (RTA - 27; RTB - 105), evaluation of pastures with animals (RTC - 22; RTD - 18), and research support (Support RT - 31). Tables 1, 2, 3, 4, and 5 show the country, locality, institution, collaborator, and ecosystem of each regional trial reporting information (RTA - RTB - RTC - RTD - RT Support).

RESULTS OF REGIONAL TRIALS BY ECOSYSTEMS

Case study of the forage situation in the coffee-growing area of Colombia

Inspection of the region

Of the 8 million ha making up the coffee-growing area, 1 million are planted to coffee and 4 million to pastures. During recent years, CENICAFE has augmented studies on the diversification of the coffee zone, with special emphasis on the systematic evaluation of pastures in collaboration with the RIEPT.

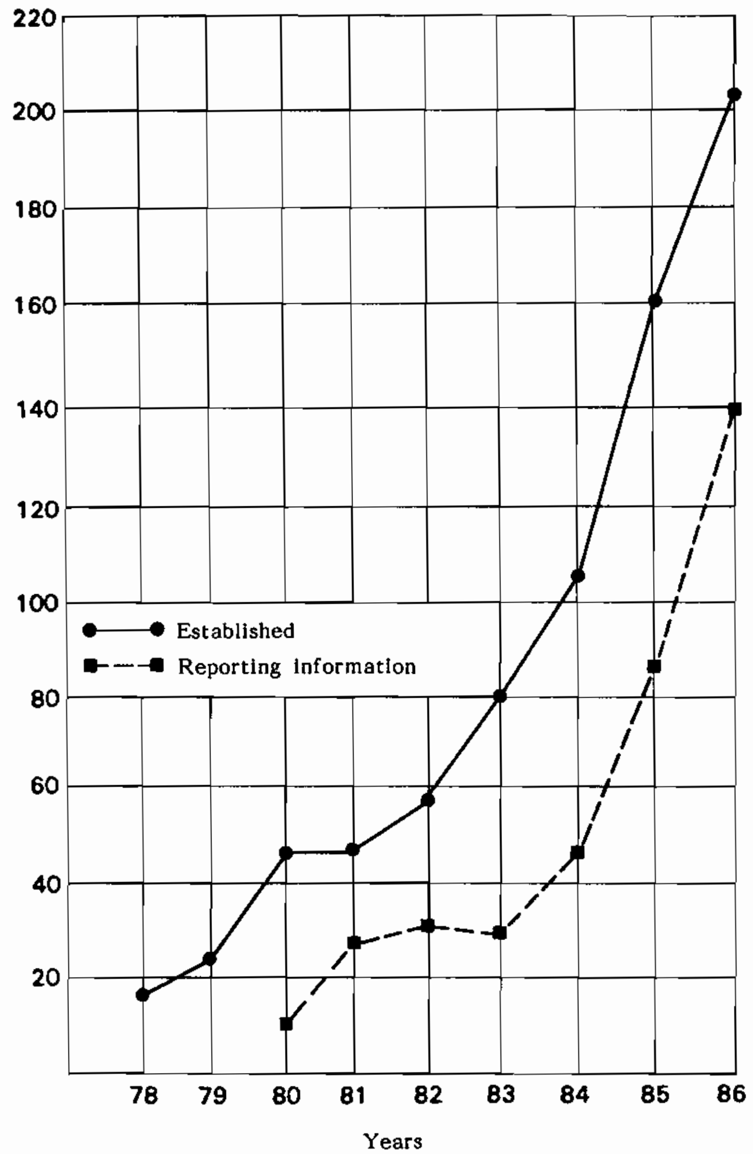


Figure 1. Evolution of the number of regional trials in tropical America, 1978–1986.

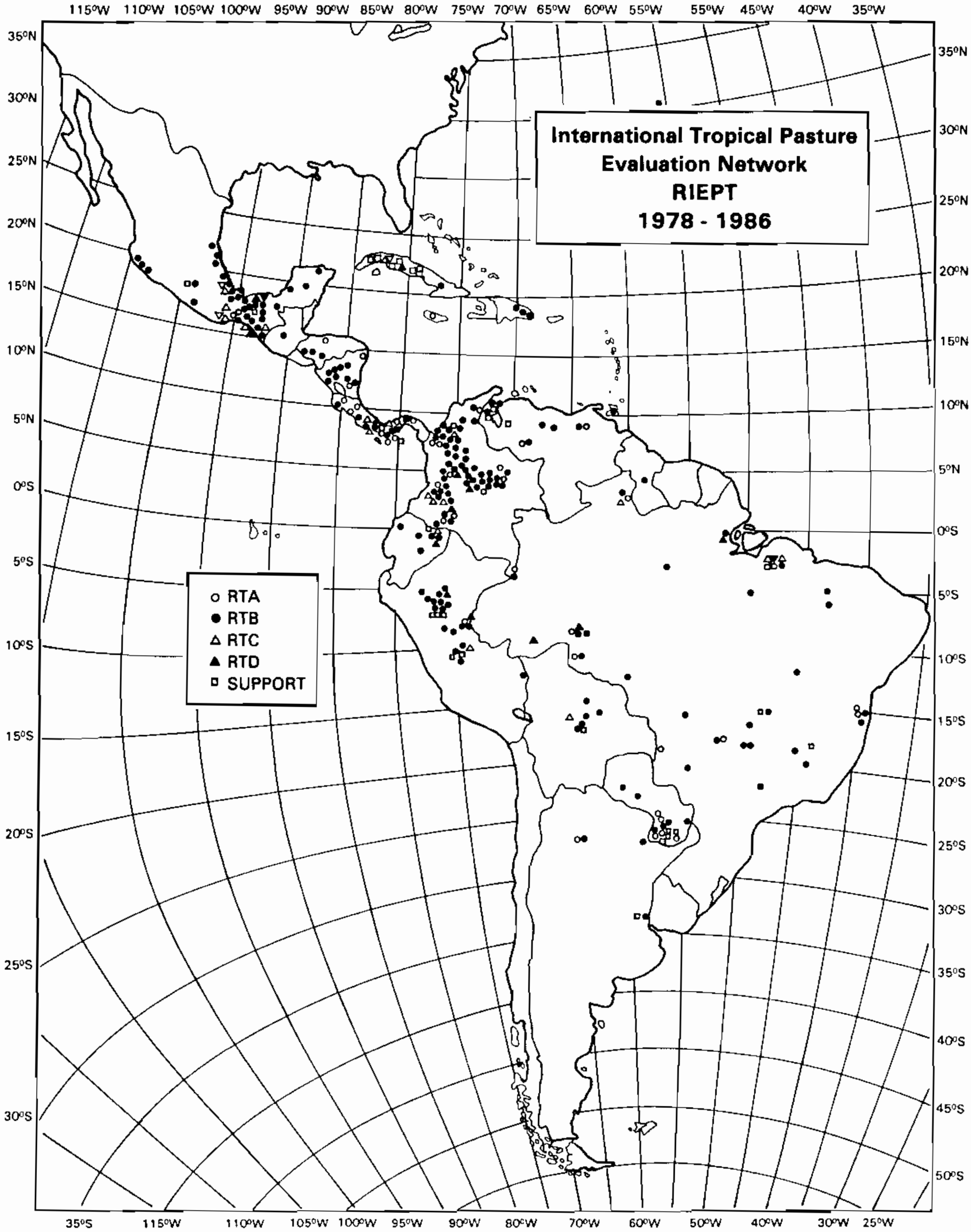


Figure 2. Geographic distribution of the regional trials, 1978–1986.

Table 1. Regional Trials A active during 1986.

Country	Site	Institution/Collaborator	Eco-system*	Planting date
BRAZIL	Boa Vista II	EMBRAPA-UEPAT Boa Vista/ R. Perin, V. Gianluppi	WDIS	V-84
	Itabela II	CEPLAC-CEPEC/M. Moreno, J.M. Pereira, R. Cantarutti	TSSF	III-83
	Porto Velho	EMBRAPA-UEPAE Belém/ C.A. Goncalves	TSSF	X-83
	Itajú	CEPLAC/M. Moreno	TRF	1984
COLOMBIA	La Romelia	CENICAFE/S. Suárez	TSSF	X-84
	Palmira	ICA-CIAT/D. Echeverry, Ensayos Regionales	TSSF	VI-84
	Tulenapa I	ICA/A. Mila	TRF	IV-84
	Tulenapa II	ICA/A. Mila	TRF	IV-84
	Turipaná	ICA	TRF	IV-84
	Motilonia	ICA/J. Barros	TSSF	IV-84
	Las Leonas	CIAT/Ensayos Regionales	WDIS	VI-84
COSTA RICA	Guápiles	MINAG/O.Sánchez, G.Guevara	TRF	1983
	San Carlos	ITCR-MINAG/P. Chaverri. J. López, O. Sánchez	TRF	VI-83
	Piedades Sur	CAR-GRECIA/J.D. Rodriguez	TRF	IX-85
HONDURAS	La Ceiba	CURLA-UNAH/G. Valle	TRF	VIII-83
MEXICO	Juchitán II	INIFAP/A.Córdoba - A.Peralta	WDIS	1984
NICARAGUA	Pto. Cabezas	MIDINRA/O. Miranda	TRF	VI-83
PANAMA	Calabacito	IDIAP/H. Aranda, M. Pinilla	TRF	VII-83
	Divisa	IDIAP/G. González, P. Argel	TRF	VI-84
	El Bongo	IDIAP/O. Duque, E. Vargas	WDIS	IX-83
	Soná	IDIAP/E. Arosemena, L. Tasón, M. Flores	TRF	IX-83
	El Chepo	IDIAP/F. Garibaldo	TRF	IX-83
	Penonome	IDIAP/E. Arosemena	TRF	VII-83
PARAGUAY	Eusebio Ayala	PRONIEGA-MAG/P.Valinotti, O.A. Molas	PDS	XII-83
	Carmen del Paraná	PRONIEGA-MAG/P.Valinotti	WDIS	X-85
	Caapacú II	PRONIEGA-MAG/P.Valinotti	WDIS	I-86
	San Lorenzo	Fac.Veterinaria/A.Rodriguez	WDIS	IV-85

* WDIS = Well-drained, isohyperthermic savanna, "Llanos"; WDTS = Well-drained, isothermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical rain forest; TSSF = Tropical semievergreen seasonal forest.

Table 2. Regional Trials B active during 1986.

Country	Site	Institution/Collaborator	Eco-system*	Planting date
ARGENTINA	Concepción del Uruguay	INTA-SEAG/E. Pitter	WDIS	XI-85
BOLIVIA	Peroto	IBTA/R. Baptista	TSSF	1984
	Yapacaní	CIAT/G. Vega, O. Velasco	TRF	II-85
	San Javier	CIAT/G. Vega	TRF	1985
BRAZIL	Amarante	EMBRAPA-UEPAE Teresina/ G. Moreira	WDTS	I-84
	Barreiras I	EPABA/L.A.B. de Alencar	WDTS	XI-82
	Campo Grande	EMBRAPA-CNPGC/M.I. Penteado	WDTS	XI-83
	Capinópolis	CEPET-UFV/C.P. Zago, M.E. da Cruz, C.M. da Rocha	WDTS	XII-83
	Felixlandia	EPAMIG/N.M. Sousa Costa	WDTS	XI-83
	Amapá	EMBRAPA-UEPAT Macapá/ A.P.Souza,P.R.Meirelles	WDTS	II-84
	Planaltina	EMBRAPA-CPAC/A.O. Barcellos, C.M.da Rocha, D.Thomas	WDTS	I-83
	Sao Carlos	EMBRAPA-UEPAE Sao Carlos/ L.A.Correa, R.Godoy,J.L. da Costa, C.M. da Rocha	WDTS	XII-83
	Vilhena	EMBRAPA-UEPAE Belém/C.A. Goncalves, C.M.da Rocha	WDTS	1984
	Barrolandia II	CEPLAC-CEPEC/J.M. Pereira	TRF	III-83
	Barreiras II	EPABA/L.A.B. de Alencar	WDTS	XII-84
	Jaciara	EMPA/G.S. Lobo	WDTS	XI-83
	Goiania	EMGOPA/J.M. Sobrinho	WDTS	I-84
	Araguaina	EMGOPA/A. Braga	WDIS	XII-84
	Jataí	EMGOPA/E. Barbosa García	WDTS	1985
	Capinópolis II	CEPET-UFV/Zago C.Da Cruz M.	WDTS	III-86
COLOMBIA	Carimagua II	CIAT-La Reserva/P. Avila, R. Gualdrón	WDIS	IX-85
	Carimagua III	CIAT-La Alegría/P. Avila, R. Gualdrón	WDIS	IX-85
	Guadalupe	CIAT/Ensayos Regionales	WDIS	IV-83
	Los Cerezos	ICA/J. Barros	WDIS	IV-84
	Magangué	CIAT/R.Botero, R.Posada	WDIS	V-84
	Amalfi	Sec.Agric.Ant./L.A. Giraldo	TSSF	IV-84
	El Rosario	CENICAFE/S. Suárez, H. Marín	TSSF	1984
	Gigante	CENICAFE/A. Suárez		

* WDIS = Well-drained, isohyperthermic savanna, "Llanos"; WDTS = Well-drained, isothermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical rain forest; TSSF = Tropical semievergreen seasonal forest.

Table 2. (Continued).

Country	Site	Institution/Collaborator	Eco-system*	Planting date
	Paraguaicito	CENICAFE/S. Suárez, L.O. Arias	TSSF	V-83
	Supía	CENICAFE/S. Suárez, L.F. Machado	TSSF	V-83
	Palmira	ICA	TSSF	VI-84
	Quilichao III	CIAT/Ensayos Regionales	TSSF	XI-82
	Quilichao IV	CIAT/Ensayos Regionales	TSSF	IV-85
	El Nus	ICA/F. Báez	TRF	IV-84
	La Libertad	ICA/P. Cuesta	TRF	IV-84
	Mutatá	ICA/H. Restrepo	TRF	IV-84
	Tulenapa	ICA/A. Mila	TRF	IV-84
	Turipaná	ICA	TRF	V-84
	San Marcos	ICA	TSSF	V-84
	Motilonia	ICA/J. Barros	TSSF	V-84
	Caucasia II	Sec.Agric.Ant./J. Marín	TSSF	1985
	Arboletes	Sec.Agric.Ant./E. Osorio	TRF	1985
	Puerto Berrío	Sec.Agr.Ant./O.Velásquez	TRF	1985
	Andes	Sec.Agric.Ant./A.Sánchez	TSSF	1985
	Villavicencio	CIAT-U.TECN.LLANOS/ J.C.Sánchez,G.Gómez	TRF	VI-85
	Las Leonas	CIAT/Ensayos Regionales	WDIS	VI-85
	La Romelia II	CENICAFE/S.Suárez	TSSF	1984
	Necoclí	Sec. Agric./A.Sánchez	TRF	XI-86
	Chigorodó	Sec. Agric./A.Sánchez	TRF	X-86
	Macagual II	ICA/J.Velásquez	TRF	V-86
	Líbano	CENICAFE/S.Suárez, J.J.Hernández	TSSF	X-84
COSTA RICA	Hojancha	MINAG-CORENA/J.J. Gómez, R. de Lucía	TRF	IX-83
ECUADOR	El Napo II	INIAP/J.E.Costales, K.Muñoz	TRF	XI-83
	Coca	INIAP/J.E. Costales	TRF	1983
GUATEMALA	Alto Verapaz	CENTRO UNIV./O. Pineda	TRF	VIII-84
HONDURAS	La Esperanza	SEC.REC.NAT./L. Acosta, H. Cruz	TSSF	VI-83
MEXICO	Cintalapa	INIFAP-SARH/E. Espinoza, A. Peralta	TSSF	VII-84
	Huimanguillo	INIFAP-SARH/J.I. López	TSSF	VI-83
	Isla Veracruz	INIFAP-SARH/J.Enríquez	WDIS	VII-83
	Loma Bonita	INIFAP-SARH/J. Enríquez	WDIS	VIII-83
	Niltepec	INIFAP-SARH/A. Córdova, A. Peralta	WDIS	VII-83
	San Marcos	INIFAP-SARH/A. Peralta	WDIS	VI-84
	Tonalá	INIFAP-SARH/A. Cigarroa, J. Palomo	WDIS	VI-83

Table 2. (Continued).

Country	Site	Institution/Collaborator	Eco-system	Planting date
	Tomatlán	INIFAP-SARH/J.M. Mendoza	WDIS	VII-84
	Jericó	INIFAP-SARH/A. Cigarroa, J. Palomo	TSSF	VI-83
	La Huerta	INIFAP-SARH/H.Regla	TSSF	VII-85
	Villacorzo	INIFAP-SARH/J.G. Moreno, A. Peralta	TSSF	VIII-84
	Jalapa	INIFAP-SARH/S.Amaya	TRF	VII-83
	Acayucán	INIFAP-SARH/J. Enríquez	TSSF	VII-84
	Alvarado	INIFAP-SARH/J. Enríquez	WDIS	VIII-84
	Justicia Social	INIFAP-SARH/M. Sandoval	TSSF	VII-84
	Ebano	INIFAP/C.Maldonado	TSSF	1985
	Altamira	INIFAP/A. Peralta	WDIS	1985
	Aldama	INIFAP/Avila M. González M., Martínez	WDIS	1986
	Paso del Toro	INIFAP/Ortega y López	WDIS	1986
	Playa Vicente	INIFAP/Castellanos O.	TSSF	1986
	Balancán	INIFAP/Espinosa y Ortega	TSSF	1986
	Pichicalco	INIFAP/R.Carmona	TRF	1986
	Tizimín	INIFAP/U.A.Valenzuela, J. Carvajal	TSSF	1986
	Matías Romero	INIFAP/A.Peralta	TSSF	1985
	Juchitán	INIFAP/A. Córdova	WDIS	1985
	Arriaga	INIFAP/Cigarroa A. Palomo J.	WDIS	1985
	Iguala	INIFAP/A. Peralta	WDIS	1985
	Coyal	INIFAP/A. Peralta	TSSF	1985
NICARAGUA	Puerto Cabezas	MIDINRA-DGTA/F. Zelaya, O. Miranda	TRF	1983
	Mina Verde	MIDINRA/L. Castillo	TRF	1986
	Cacao	MIDINRA/L. Castillo	TRF	1986
	Los Zarzales	MIDINRA/L. Castillo	TRF	1986
PANAMA	El Ejido	IDIAP/O. Duque, E. Vargas	TSSF	VII-84
	Río Hato	Fac.Agr./G.González, M.Rodriguez, P.Argel	TSSF	1985
PARAGUAY	Yguazú	AG.COOP.INT.JAPON/K. Yusa	TSSF	XII-84
	Pozo Colorado	PRONIEGA-MAG/P.Valinotti	WDS	1986
	Filadelfia	PRONIEGA-MAG/P.Valinotti	WDS	1986
	Caapucú	PRONIEGA-MAG/P.Valinotti	WDIS	1985
	Caapucú II	PRONIEGA-MAG/P.Valinotti	WDIS	III-86
	Caapucú III	PRONIEGA-MAG/P.Valinotti	WDIS	III-86
PERU	Alto Mayo	INIPA/E.Palacios, E. Calderón	TSSF	1983
	Tingo María	UNAS/E. Cárdenas	TRF	1983

Table 2. (Continued).

Country	Site	Institution/Collaborator	Eco-system	Planting date
	Pto. Bermúdez	INIPA-PEPP-NCSU/K. Reátegui	TRF	V-84
	Pumahuasi	INIPA-CIPA X/H. Ibazeta, K. Reátegui	TRF	1983
	Yurimaguas II	INIPA-NCSU/K. Reátegui	TRF	IX-83
	Iscozacín	PEPP-PP/R. Pérez	TRF	V-84
	Satipo	UNA La Molina/E. Cuadros, M.Rosemberg, F.Passoni	TSSF	X-84
	Pto.Maldonado	CIPA/Chumbimune, E.Cuadros	TRF	X-82
	La Morada	UNAS/E. Cárdenas	TRF	I-83
DOMINICAN REPUBLIC	Haras Nales.	CENIP-SEA/M. Germán	TSSF	XI-83
	Pedro Brand	CENIP-SEA/M. Germán	TSSF	VIII-83
	Valle Seybo	CENIP-SEA/M. Germán	TRF	IX-83
VENEZUELA	Espino	FONAIAP/L.A. Barreto	WDIS	VIII-82
	Maracaibo I	LUZ-CORPOZULIA/I.Urdaneta	TSSF	V-86
	Maracaibo II	LUZ-CORPOZULIA/I.Urdaneta	TSSF	V-86

Results reported correspond to the first survey conducted in 57 municipalities of the coffee-growing region, comprising approximately 500,000 ha in the departments of Antioquia, Caldas, Cauca, Risaralda, and Tolima. The main reason for conducting the survey was to identify and quantify pasture establishment practices, planting systems, use of fertilizers, and prevailing production systems in order to establish regional trials, especially grazing trials, which agreed with the norms used by producers in the area.

Sexual seed and vegetative material (44% and 56% of the cases, respectively,) are used to plant the forage grasses. The predominant planting system is broadcasting (67%), followed by row planting (29%). Table 6 summarizes information on the main grass used and the fertilizer use. Only 6% of grasses for grazing and approximately 20% of grasses for cutting are fertilized. The hybrid Pennisetum was the only grass fertilized in 52% of cases; however, data on doses, period, and type of fertilizer used were not available. The double purpose production system predominates (62%), followed by meat and milk production in 20 and 18% of cases, respectively.

Germplasm evaluation

Since 1982 a series of regional trials (RTA, RTB, RTC, and RTD) have been established in this region where inceptisols (64%) and entisols (30%) predominate. The main climatic and edaphic characteristics of localities where the trials are conducted are described in Tables 7 and 8. Tables 9 and 10 show the grasses and legumes evaluated and Table 11 summarizes the results of grasses and legumes considered promising in the first stage of evaluation in this region. In a parallel way, 33 accessions of L. leucocephala (Table 12) are being evaluated in a RTA in the Experimental

Table 3. Regional Trials C active during 1986.

Country	Site	Institution/Collaborator	Eco-system*	Planting date
BOLIVIA	Chimoré	CIF-UMSS/J. Espinoza, F. Gutiérrez	TRF	IV-82
BRAZIL	Barrolandia	CEPLAC-CEPEC/J. Ribeiro, J.M. Pereira, J.M. Spain, M. Moreno	TRF	XII-83
	Paragominas I	EMBRAPA-CPATU/J.B. da Veiga, E.A. Serrao	TSSF	II-84
	Paragominas II	EMBRAPA-CPATU/E.A.Serrao	TRF	III-86
COLOMBIA	Quilichao I	CIAT-CIID/E.A.Pizarro,C.Lascano	TSSF	XI-83
	Caucasia	UDEA/L.F. Ramírez	TSSF	XI-83
	Quilichao II	CIAT/E.A.Pizarro, C.Lascano	TSSF	V-86
	La Romelia	CENICAFE/S.Suárez, J.Rubio, C. Franco	TSSF	1986
CUBA	San José de Las Lajas	ISCAH-MES/T. Ruiz, M. López, M. Monzote, L. Díaz	WDIS	1983
	San José de Las Lajas	ISCAH-MES/T. Ruiz, M. Monzote, G. Bernal	WDIS	1983
ECUADOR	El Napo	INIAP-CIID/J. Costales	TRF	VIII-83
MEXICO	Juchitán I	INIFAP-SARH/A.Córdova, A.Peralta	WDIS	X-84
	Juchitán II	INIFAP-SARH/A.Córdova, A.Peralta	WDIS	1986
	Arriaga	INIFAP-SARH/A.Cigarroa	WDIS	1985
	Jericó	INIFAP-SARH/A.Cigarroa	TSSF	1985
	I.Veracruz I	INIFAP-SARH/J.Enríquez	WDIS	1986
	I.Veracruz II	INIFAP-SARH/J.Enríquez	WDIS	1986
PANAMA	Chiriquí	FAUP-RUTGERS/N. Pitty, M. Rodríguez, P. Argel	WDIS	VII-84
	Gualaca	IDIAP-CIID/C.Ortega, D.Urriola	WDIS	X-84
PERU	Pulcallpa	IVITA-CIID/H. Huamán	TSSF	X-83
	Pto. Bermúdez	INIPA-PEPP-NCSU/K. Reátegui	TRF	XII-84
DOMINICAN REPULIC	Pedro Brand	CENIP-CIID/Y.Soto	TSSF	1986

* WDIS = well-drained, isohyperthermic savanna, "Llanos"; WDTS = Well-drained, isothermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical rain forest; TSSF = Tropical semievergreen seasonal forest.

Table 4. Regional Trials D active during 1986.

Country	Site	Institution/Collaborator	Eco-system*	Planting date
BRAZIL	Boa Vista	EMBRAPA-UEPAT Boa Vista/ V.Gianluppi, J.D.Santos	WDIS	V-82
	Macapá	EMBRAPA-UEPAT Macapá/ E.A. Serrao, A.P. Souza	WDIS	1982
	Paragominas	EMBRAPA-CPATU/M.B. Días, E.A.Serrao,J.B.da Veiga	TSSF	1982
	Rio Branco	EMBRAPA-UEPAE Rio Branco/ J. Pagani	TSSF	1984
	Porto Velho	EMBRAPA-UEPAE Porto Velho/ C.A. Goncalves	TSSF	IX-84
COLOMBIA	La Libertad	ICA-CIID/R. Pérez	TRF	1984
	La Romelia	CENICAFE/S.Suárez, J.Rubio, C. Franco	TSSF	XII-84
	Quilichao	CIAT-CIID/C. Lascano, E.A. Pizarro	TSSF	V-85
	Macagual	ICA-CIID/J.Velásquez	TRF	1985
CUBA	Indio Hatuey	MES/C.A. Hernández, A.Alfonso, P.Duquesne	WDIS	IX-83
ECUADOR	El Napo	INIAP-CIID/J.Costales	TRF	1983
MEXICO	Huimanguillo I	INIFAP-SARH/J.J.López	TSSF	1986
	Huimanguillo II	INIFAP-SARH/J.J.López	TSSF	1986
	Tonalá	INIFAP-SARH/A.Cigarroa	TSSF	1985
PANAMA	Calabacito	IDIAP-RUTGERS/E. Arosemena, P. Argel	TSSF	1984
	Gualaca	IDIAP-CIID/C. Ortega, D.Urriola	WDIS	X-83
PERU	Pucallpa I	IVITA/A. Riesco, C. Reyes, H. Huamán	TSSF	II-83
	Yurimaguas	INIPA-NCSU/R.Dextre	TRF	1980

* WDIS = Well-drained, isohyperthermic savanna, "Llanos"; WDTS = Well-drained, isothermic savanna, "Cerrados"; PDS = Poorly drained savanna; TRF = Tropical rain forest; TSSF = Tropical semievergreen seasonal forest.

Table 5. Regional Trials for support active during 1986.

Country	Site	Institution/Collaborator	Ecosystem*	Type of Trial
BOLIVIA	Chipiriri	IBTA/A.Ferrufino, F.Saavedra, A. Vallejos	TRF	Establishment and pests
BRAZIL	Paragominas	EMBRAPA-CPATU/J.B.Da Veiga, E.A. Serrao	TSSF	Fertilization
	Cerrados	EMBRAPA-CPAC/G.W. Cosenza	WDTS	Pests and diseases
CUBA	San José de Las Lajas	ISCAH-MES/T.Ruiz, L.E.Díaz	WDIS	Establishment
	San José de Las Lajas	ISCAH-MES/M.Monzote, T.Ruiz, M.López	WDIS	Establishment
	San José de Las Lajas	ISCAH-MES/T.Ruiz, M.Monzote, G. Bernal	WDIS	Evaluation of pastures in association
	San José de Las Lajas	ISCAH-MES/M.López	WDIS	Inoculation
	San José de Las Lajas	ISCAH-MES/A.Barrientos	WDIS	Pests and diseases
	Villa Clara	MES/J.Menéndez, H.Méndez	WDIS	Evaluation of pastures in association
	Indio Hatuey	MES/J.Menéndez, S.Vega	WDIS	Evaluation of pastures in association
	Indio Hatuey	MES/Y.González, C.Matías	WDIS	Seed production
ECUADOR	El Napo	INIAP/K.Muñoz	TRF	Pests and diseases
MEXICO	Huimanguillo	INIFAP-SARH/J.I. López	WDIS	Fertilization (A.g.)
	Huimanguillo	INIFAP-SARH/J.I. López	WDIS	Fertilization (B.d.)
	Tabasco	INIFAP-SARH/S. Amaya	TRF	Fertilization
	Iguala	INIFAP/A. Peralta	WDS	Seed production
PANAMA	Calabacito	IDIAP/H.Aranda, P.Argel	TRF	Establishment
	Chiriquí	IDIAP/D.Urriola, P.Argel,	WDIS	Pests and diseases
PARAGUAY	Carmen de Paraná	PRONIEGA-MAG/P. Valinotti	WDIS	Seed production
	Caapucú	PRONIEGA-MAG/P. Valinotti	WDIS	Pastures in association

Table 5. (Continued).

Country	Site	Institution/Collaborator	Ecosystem	Type of Trial
	Caapucú II	PRONIEGA-MAG/P. Valinotti	WDIS	Seed production
	Caapucú III	PRONIEGA-MAG/P. Valinotti	WDIS	Protein banks
PERU	Puerto Bermúdez	INIPA-PEPP-NCSU/K.Reátegui	TRF	Pests and diseases
	La Esperanza	INIPA-PEPP-NCSU/K.Reátegui	TRF	Pests and diseases
	Tarapoto	INIPA-CIPA X/C.Valles	TSSF	Pests and diseases
	Tarapoto	INIPA-IST/R.Hernández, W.López	TSSF	Pests and diseases
	Tarapoto	INIPA-CIPA X/C.Valles	TSSF	Pests and diseases
VENEZUELA	Guachí	LUZ-CORPOZULIA/I.Urdaneta, R.Paredes	TSSF	Evaluation of pastures in association
	Lago Maracaibo	LUZ-CORPOZULIA/I.Urdaneta	TSSF	Trials in pilot farms
	Maracaibo	LUZ-CORPOZULIA/I.Urdaneta	TSSF	Fertilization in association

Table 6. Area planted to grasses with and without fertilization in the coffee-growing regions of Colombia.

Grasses for grazing	Total area (ha)	Area with fertilization	Area without fertilization
		%	
Paspalum sp.	141.197	0.9	99.1
H. rufa	122.454	7.0	93.0
M. minutiflora	95.223	1.6	98.4
P. clandestinum	33.580	36.8	63.2
P. maximum	20.378	3.0	97.0
A. micay	3.975	0.0	100.0
B. mutica	3.526	0.0	100.0
B. decumbens	2.600	4.0	96.0
C. plectostachyus	1.092	3.8	96.2
MEAN		6.3	93.7
Grasses for cutting			
Pennisetum hybrid	3.364	52.0	48.0
P. purpureum	675	0.0	100.0
A. scoparius	2.190	7.0	93.0
MEAN		19.7	80.3

Source: CENICAFE, 1986.

Table 7. Climatic characteristics and soil chassification in the coffee-growing regions of Colombia.

Site	Altitude (masl)	Precipitation (mm)	Parental material	Taxonomic classification
Chinchiná, Caldas	1370	2563	Volcanic ash	Typic dystrandept isohyperthermic
Buenavista, Quindío	1250	1975	Volcanic ash	Typic dystrandept isohyperthermic
Venecia, Antioquia	1600	2605	Clayolites	Typic dystropept isohyperthermic
Supía, Caldas	1320	1708	Sandy olivinisc	Typic eutropept isohyperthermic
Gigante, Huila	1500	1193	Colluvium	Typic dystrandept isohyperthermic
Líbano, Tolima	1430	2178	Volcanic ash	Typic dystrandept isohyperthermic
Albán, Valle	1400	1416	-	Typic eutropept isohyperthermic

Source: CENICAFE, 1986.

Table 8. Main soil characteristics in the sites of the coffee-growing region of Colombia.

Site	Depth	Clay	Da	pH	Al	Ca	Mg	K	P	Mn
	cm	%	g/cm^3		meq/100 g				ppm	
Chinchiná, Caldas	0 - 20	20	0.7	5.1	0.4	1.2	0.1	0.08	2	8
Buenavista, Quindío	0 - 20	13	0.8	5.8	0.0	7.1	1.2	0.82	45	17
Venecia, Antioquia	0 - 20	49	1.2	4.0	8.2	0.5	0.4	0.22	13	20
Supía, Caldas	0 - 20	35	1.2	5.0	1.7	2.0	1.3	0.23	0	67
Gigante, Huila	0 - 20	23	1.4	5.4	0.2	3.4	1.0	0.32	11	245
Líbano, Tolima	0 - 20	20	0.7	5.2	0.9	3.7	0.8	0.55	2	-
Albán, Valle	0 - 20	30	-	6.0	0.0	9.5	2.0	0.38	3	140

Table 9. Grasses evaluated in the coffee-growing region of Colombia: ERB.

Grasses	CIAT No.
Andropogon gayanus	621, 6054
Axonopus micay	-207*
Brachiaria brizantha	6780
Brachiaria decumbens	606
Brachiaria dictyoneura	6133
Brachiaria humidicola	679
Brachiaria mutica	-194
Brachiaria radicans	-
Brachiaria ruziziensis	6387
Cynodon nlemfuensis	-
Cynodon plectostachyus	-122
Digitaria decumbens	-121
Hemarthria altissima	-
Hyparrhenia rufa	601
Melinis minutiflora	-
Panicum maximum	604,182,622,673
Paspalum sp.	-
Pennisetum clandestinum	-212
Setaria sp.	-183

* Native or naturalized grasses are identified by a negative sign.

Station of Chinchina. Production of the 12 best accessions is shown in Table 13, where it can be observed that accumulated DM yields (leaves + stems < 10 mm in diameter), range between 8.2 and 10.7 t/DM/ha. Simultaneously with the RTA evaluating _L. leucocephala_, a grazing trial (RTD) has been conducted to estimate milk production in _D. decumbens_ alone, _D. decumbens_ + 2 hours daily grazing of 33 accessions of _L. leucocephala_, and _D. decumbens_ + concentrates. In terms of agronomic results CIAT No. 17480, 17481, 17491, and 17492 were outstanding for their resistance to grazing and subsequent recovery.

Well-drained isothermic savannas: Cerrados

Preliminary results of the RTBs established since 1982 in this ecosystem indicate that the most outstanding species are: _S. capitata_, _S. guianensis_, and _S. macrocephala_.

Table 10. Legumes evaluated in the coffee-growing region of Colombia: ERB.

Legume	CIAT No.
A. histrix	9690
A. pintoi	17434
C. mucunoides	-120*
C. acutifolium	5112,5568,5277
C. brasilianum	5234
C. macrocarpum	5065,5713,5744,5062 5568,5577,5730,5616, 5957,5740
C. pubescens	5189,438,442
C. gyroides	3001
D. heterophyllum	349,3782
D. intortum	-185
D. ovalifolium	350,3784
M. atropurpureum	-213
P. phaseoloides	9900
S. capitata	1315,1405,1019, 10280,193
S. guianensis	136,184,196
S. hamata	147
S. humilis	-192
Zornia sp.	7847
Z. latifolia	728,7847

* Native or naturalized grasses are identified by a negative sign.

Table 11. Forage grasses and legumes considered promising in the coffee-growing region of Colombia.

Grasses	CIAT No.
B. decumbens	606
B. dictyoneura	6133
B. humidicola	679
B. ruziziensis	6387
P. maximum	606
Setaria sp.	-183
Legumes	
C. acutifolium	5112-5277-5568
C. macrocarpum	5062-5065-5713-5744
C. pubescens	438
D. ovalifolium	350
P. phaseoloides	9900
S. guianensis	136-184

Table 12. Leucaena leucocephala accessions evaluated in the coffee-growing region of Colombia.

CIAT No.		
-101- 734	/51- 7385	9383- 9411
9415- 9442	9464-17467	17473-17474
17475-17476	17477-17479	17480-17481
17482-17483	17484-17488	17491-17492
17493-17494	17495-17496	17498-17499
17500-17501	17502	

Regional Trial A, La Romelia, and Chinchiná, Colombia.

Regional trials B cover an area of oxisols and ultisols between 3°15'N and 22°01'S, and 15 and 1150 masl; annual precipitation ranges between 900 and 2500 mm.

Mean cover values at 12 weeks after establishment are presented in Table 14. Both the mean and the range are very similar for all legumes evaluated.

Table 15 presents the maximum rate of DM yield per week for the S. capitata accessions. As in previous years and as in the case of the isohyperthermic savannas "Llanos", S. capitata accessions evaluated had similar yields in both evaluation periods. The incidence of anthracnose in one locality (Amarante-Piaui) was severe, probably due to the abundance of native S. capitata plants in the area surrounding the trial.

S. guianensis accessions (Table 16) show a maximum production rate ranging between 191 and 321 kg DM/ha/week and between 31 and 73 kg DM/ha/week for the periods of maximum and minimum precipitation, respectively. The performance of S. guianensis accessions is acceptable throughout the localities in the Cerrados ecosystem.

Table 13. Dry matter production of the best *Leucaena leucocephala* accessions.

Accessions	CIAT No.	DM kg/ha/cutting 1	2	3	4	5	Total accumulated
L. leucocephala	-101	2050	2169	2528	2594	1316	10657
L. leucocephala	7385	1739	1948	2302	1788	1054	8831
L. leucocephala	17467	2479	1626	2369	2207	1096	9777
L. leucocephala	17476	1945	1946	2075	2036	998	9000
L. leucocephala	17481	2452	2078	2197	2222	1079	10028
L. leucocephala	17482	1340	1971	1972	2186	1186	8655
L. leucocephala	17491	2416	2008	2772	1872	1371	10439
L. leucocephala	17492	2032	1808	2381	1794	1343	9358
L. leucocephala	17495	1970	1752	1625	1976	920	8243
L. leucocephala	17498	1891	2213	2243	1909	1017	9273
L. leucocephala	17501	1930	1942	2158	2200	991	9241
L. leucocephala	17502	2153	1700	3127	2558	1121	10659

Source: CENICAFE, La Romelia, Colombia.

Table 14. Coverage of the legume in the Cerrados ecosystem.

Legume	Mean coverate at 12 weeks (%)
C. acutifolium	37 (30 - 44)
S. capitata	33 (22 - 41)
*S. guianensis**	41 (21 - 52)
S. macrocephala	34 (28 - 42)

* Var. *vulgaris* + *pauciflora*.

Table 15. Maximum yield levels in the Cerrados ecosystem: *S. capitata*.

Accessions	Maximum precipit. period	Minimum precipit. period
	--- DM kg/ha/week---	
S. capitata 2252	326	36
S. capitata 1019	310	41
S. capitata 1318	276	29
S. capitata 1097	275	39
	NS	NS
Mean ± SD	297 ± 25	36 ± 5

Table 16. Maximum yield levels in the Cerrados ecosystem: S. guianensis.

Accessions	Maximum precipit. period	Minimum precipit. period
	--- DM kg/ha/week---	
S.guianensis 2244*	321 a***	55 b
S.guianensis 2191*	307 a	63 ab
S.guianensis 2243* "Bandeirante"	292 a	73 a
S.guianensis 1095*	283 a	58 b
S.guienensis 2746**	277 a	52 b
S.guianensis 2245*	276 a	73 a
S.guianensis 2203*	274 a	57 b
S.guianensis 2747**	191 b	31 c
MEAN ± SD	278 ± 39	58 ± 13

* Var. pauciflora; ** var. vulgaris
*** Means followed by different letters are significantly different, P < 0.05.

Table 17. Maximum yield levels in the Cerrados ecosystem: S.macrocephala.

Accessions	Maximum precipit. period	Minimum precipit. period
	---DM kg/ha/week---	
S.macrocephala 10325	423 a*	23 b
S.macrocephala 2053	380 ab	26 b
S.macrocephala 2039	362 ab	35 a
S.macrocephala 2732	337 bc	26 b
S.macrocephala 1281 "Pioneiro"	315 bc	20 bc
S.macrocephala 2271	292 c	13 c
MEAN ± SD	352 ± 47	24 ± 7

* Means followed by different letters are significantly different, P < 0.05.

Mean yields for S. macrocephala (Table 17) are highest during the period of maximum precipitation, but the lowest in the period of minimum precipitation. During the period of maximum precipitation, yields fluctuated between 292 kg DM/ha/week for S. macrocephala CIAT 2271 and 423 kg DM/ha/week for S. macrocephala CIAT 10325; these two accessions and CIAT 2053 are the most outstanding accessions for their productivity and in the case of CIAT 2053 for also having the lowest pest and disease incidence levels throughout localities.

Table 18 shows percentage yields for legumes evaluated during periods of minimum precipitation. C. acutifolium 5112 and S. guianensis vars. vulgaris and pauciflora are the accessions declining more markedly from year to year. On the contrary, S. capitata and S. macrocephala have shown similar yield values during the period of minimum precipitation both in 1983-84 and in 1985-86.

After completing the first evaluation period during 1986, the number of legumes and grasses to be evaluated will be increased; seed of the best accessions evaluated will be multiplied for the establishment of regional trials type C and D (RTC and RTD).

Well-drained isohyperthermic savannas: Llanos

Regional trials type B have been established in various localities of this ecosystem (Table 2) with a new list of germplasm. Having completed two years of evaluation, variance analyses were conducted to assess coverage at 12 weeks after establishment for the maximum rate of production in kg DM/ha/week, for the periods of maximum and minimum precipitation.

Table 19 summarizes the coverage of

Table 18. Percentage dry matter yield during the minimum precipitation period in the Cerrados ecosystem.

Legumes	1983-84	1985-86
C. acutifolium	40	19
S. capitata	14	11
S. guianensis*	27	17
S. macrocephala	9	6

* Var. vulgaris + pauciflora.

Table 19. Coverage of grasses in the savanna ecosystem.

Grasses	Mean coverege (20 ERB, 12 weeks) %
B. humidicola 679	68 a*
B. brizantha 664	66 a
B. decumbens 606	58 b
B. dictyoneura 6133	58 b
A. gayanus 621	54 b
A. gayanus 6200	42 c

* Means followed by different letters are significantly different, P ≤ 0.05.

grasses 12 weeks after establishment. Three well-defined groups can be observed: the first composed by B. humidicola 679 and B. brizantha 664 with mean coverages of 68 and 66%, respectively; the second composed by B. decumbens 606, B. dictyoneura 6133, and A. gayanus 621 with mean coverages between 58 and 54%; and the last A. gayanus 6200 covering 42% of the area.

The grasses B. brizantha 664 and A. gayanus 621 yielded 324 and 732 kg DM/ha/week, respectively, during the period of maximum precipitation, while B. brizantha 664 and B. humidicola 679 yielded 87 and 196 kg DM/ha/week during the period of minimum precipitation (Table 20). The percentage of DM produced during the period of minimum precipitation ranged between 19 and 25%, the mean being 20 $\pm$ 1.5% for A. gayanus and 23 $\pm$ 2% for the Brachiaria species. The only grass that has disappeared from all the localities in the trials is B. ruziziensis CIAT 6419. Coverage of the legumes evaluated ranged from 24 to 69% (Table 21); yields ranged from 101 to 551 kg DM/ha/week for the period of maximum precipitation and from 21 to 128 kg DM/ha/week for the period of maximum precipitation and from 21 to 128 kg DM/ha/week for the period of minimum precipitation (Table 22). It is important to point out that the percentage of DM produced during the period of minimum precipitation was superior to that of accessions of S. macrocephala, C. acutifolium, and S. capitata and inferior to the rest of the legumes evaluated, 31% vs. 18%, respectively (Table 23).

Rate of establishment of A. pintoi CIAT 17434

In a series of regional trials distributed throughout localities situated in the isohyperthermic savanna ecosystem (La Reserva, La Alegría, Las Leonas) to the piedmont (Villavicencio), the legume A. pintoi CIAT 17434 is being evaluated.

Results corresponding to the establishment period (Figure 3) show that A. pintoi increased its coverage up to 40% 12 weeks after establishment as precipitation was more favorable and particularly as the chemical characteristics of the soil improved, especially Ca, Mg, and K contents (Table 24).

Case study of RTBs under commercial exploitation upon completion of the evaluation period

In this same ecosystem, three RTBs, established in 1980, are continuing to be periodically observed. Of the materials planted--2 grasses and 22 legumes (see Annual Reports

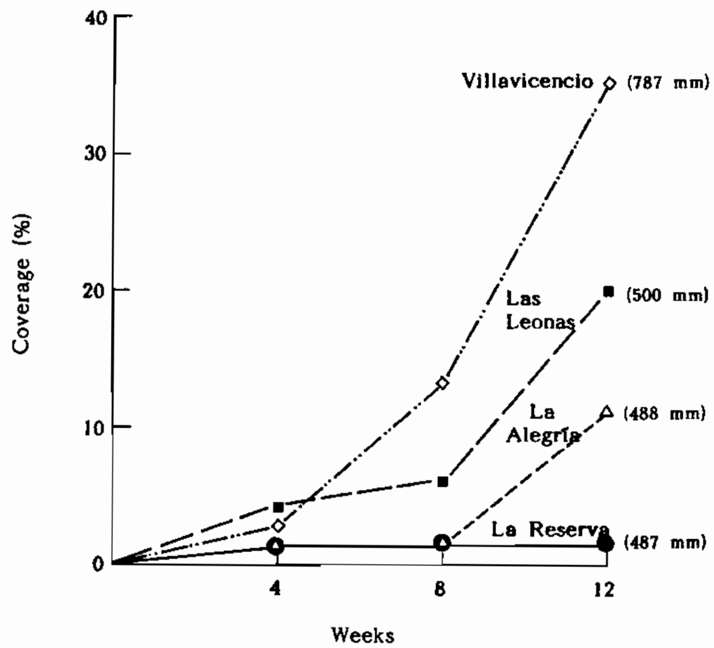


Figure 3. Coverage of <u>Arachis pintoi</u> CIAT 17434 during the establishment period.

Table 20. Maximum yield levels in the savanna ecosystem: grasses.

Grass	CIAT No.	Maximum precipitation period	Minimum precipitation period	DM produced during period of minimum precipitation
		-------- DM kg/ha/week	-------	%
A. gayanus	621	732 a*	173 a	19
B. humidicola	679	703 a	196 a	22
A. gayanus	6200	662 ab	180 a	21
B. dictyoneura	6133	533 b	178 a	25
B. decumbens	606	391 c	130 ab	25
B. brizantha	664	324 c	87 b	21

* Digits followed by a different letter are significantly different, $P < 0.05$.

Table 21. Legume coverage in the savanna ecosystem.

Legumes	Mean coverage* (12 weeks) %
P. phaseoloides 9900	69 a**
D. ovalifolium 3784	65 a
C. brasilianum 5234	62 ab
C. acutifolium 5112	56 bc
S. capitata 10280	56 bc
S. capitata 1441	54 bcd
C. macrocarpum 5065	52 cd
D. ovalifolium 350	51 cd
C. acutifolium 5278	50 cd
Z. glabra 7847	46 d
S. capitata 2044	37 e
Z. latifolia 9199	34 ef
S. macrocephala 1643	27 fg
S. macrocephala 2133	27 fg
S. capitata 1019	24 g

* Mean of 20 Regional Trials B.
** Means followed by different letters are significantly different, $P < 0.05$.

1982-83-84)--only *S. capitata* persists. Table 25 shows that in spite of reduction in the plant numbers, plant density continues to be satisfactory except for the locality of "Paraiso". This value is expected to be maintained since this species of perpetuating is capable itself due to its high rate of seed production. Results obtained in other localities of thes same ecosystem (Table 26) have confirmed this potential with values of 25 to 106 kg seed/ha, concentrated primarily in the first 5 cm of soil.

Adaptability and production of *Leucaena* spp. in the Valle del Cauca, Colombia

In March 1984, 20 accessions of *Leucaena* spp. were established in a collaborative RTS between ICA and CIAT-Palmira in a soil with 51% clay, 7.0 pH, 38 ppm P, and 3.6% OM.

After a period of evaluation between February 1985 and September 1986, the seven best accessions were observed to have high yields both in terms of total dry matter and of edible dry matter. CP contents and IVDMD were high and mimosine content except in

Table 22. Maximum yield levels in the savanna ecosystem: legumes.

Legumes	CIAT No.	Maximum precipitation period	Minimum precipitation period
		DM kg/ha/week	
Z. glabra	7847	551 a*	128 a
Z. latifolia	9199	213 ef	37 gh
C. acutifolium	5278	486 b	92 bc
C. acutifolium	5112	101 h	90 bc
C. brasilianum	5234	288 d	79 bcde
C. macrocarpum	5065	445 bc	86 bcd
D. ovalifolium	350	181 f	55 efg
D. ovalifolium	3784	446 bc	59 defg
S. capitata	10280	269 de	92 bc
S. capitata	1019	176 fg	21 h
S. capitata	2044	149 fgh	70 cdef
S. capitata	1441	109 gh	47 fg
S. macrocephala	2133	165 fgh	106 ab
S. macrocephala	1643	164 fgh	73 cdef
P. phaseoloides	9900	409 c	76 cde

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

Table 23. Percentage dry matter yield during the minimum precipitation period in the savanna ecosystem.

Legumes	%
Zornia sp.	17 ± 3
C. acutifolium	32 ± 22
C. brasilianum	22
C. macrocarpum	16
D. ovalifolium	18 ± 8
S. capitata	25 ± 10
S. macrocephala	35 ± 6
P. phaseoloides	16

two accessions was less than 4% in the fine dry matter fraction (leaves + tender stems < 6 mm in diameter).

PASTURE EVALUATION WITH ANIMALS WITHIN THE RIEPT

The main results of regional trials type C and D (RTC and RTD) with at least two years of consecutive evaluation in Colombia, Ecuador, Panama, and Peru are reported.

A. COLOMBIA

1. La Libertad

In the RTD in La Libertad, associations of *Brachiaria dictyoneura*, *B. brizantha*, *B. humidicola*, and *B. decumbens* with *Pueraria phaseoloides* (Kudzu) were assesed using *B. decumbens* alone as the control for the region. All treatments were grazed alternately with 2, 3, and 4 steers/ha.

Grazing was initiated in December 1984 and completed two years in October 1986. Table 28 shows average daily weight gains per animal during the periods 1984-85 and 1985-86. In all mixtures and more markedly in the pure grass stand, a slight tendency toward reduced weight gains from the first to the second year was observed. A slight

Table 24. Physical and chemical soil characteristics of various sites in the Eastern Plains of Colombia.

Site	Depth (cm)	Sand	Loam	Clay	pH	Exchangeable cations (meq/100g)				P	OM	Al Sat.
		---------	%	-----------		Al	Ca	Mg	K	ppm	%	%
La Reserva	0 - 20	12	53	35	4.5	2.1	0.11	0.05	0.05	1.5	2.5	91
La Alegría	0 - 20	68	23	9	4.8	0.8	0.11	0.06	0.03	2.1	1.1	80
Las Leonas	0 - 20	18	32	50	5.1	1.9	0.37	0.15	0.09	3.2	-	76
Universidad Tecnológica del Llano (Villavicencio)	0 - 20	18	29	53	4.5	4.7	0.28	0.20	0.12	2.9	5.4	89

Table 25. Number of *S. capitata* [1] plants at establishment and in the period following the experiment in the Llanos ecosystem.

Sites	Plants/m²		
	Establishment	Post-experimental period	
	1980	1985	1986
El Viento	65 ± 35	20 ± 10	8 ± 4
Paraíso	86 ± 45	7 ± 12	0**
Guayabal	90 ± 37	7 ± 8	4 ± 3

1/ CIAT No. 1019, 1315*, 1318*, 1342*, 1405, 1693*, 1728*, 1943, 2013.
* Components in cv. Capica CIAT 10280.
** Area invaded by ants.

Table 26. Mean seed yield in the Eastern Plains of Colombia: *S. capitata*.

Legume	Sites	
	Guadalupe*	Alto Menegua*
	kg/ha	
S. capitata 2044	25	65
S. capitata 1441	106	73

* RTB planted in April/83. Evaluation of seed production in May/86, at 0-5 cm depth.

tendency toward lower gains in *B. humidicola* + *P. phaseoloides* (Kudzu) mixture than in the pure stand also was observed. The highest-yielding mixture over the two years was *B. dictyoneura* + Kudzu. The inclusion of Kudzu in *B. decumbens* resulted in an average production increase of 9% over the pure grass. The stocking rate had the expected effect, with total averages of 0.50 kg weight gain per animal/day with 2 animals/ha and a weight loss of 0.36 kg with 4 animals. Lower weight gains with higher stocking rates correspond to a lower availability of GDM/ha (Table 29). This same Table shows that average availability of GDM for *B. decumbens* in pure stand during the last rainy season had decreased to levels below 1 t/ha, thus affecting animal growth. Table 30 shows Kudzu content in mixtures, at the initiation of grazing in the rainy period and at the end of the rainy season. A reduction was observed under the two highest stocking rates, with Kudzu disappearing in all mixtures under the stocking rate of 4 steers/ha. Under the stocking rate of 2 steers/ha, the legume increased from April to October, except for the extreme case of the mixture with *B. humidicola* where Kudzu disappeared under all stocking rates.

Table 27. Production and composition of the best _L. leucocephala_ accessions evaluated in the Cauca Valley, Cauca, Colombia.

CIAT accession No.	DM t/ha*		CP %*		IVDMD %		Mimosine %	
	TDM**	FDM	FDM	CDM	FDM	CDM	FDM	CDM
17467	20.6	15.2	27	10	53	34	3.7	0.6
17475	21.4	15.6	25	9	52	31	3.1	0.5
17488	19.1	13.7	24	9	56	31	4.2	0.7
17491	20.1	14.1	25	8	59	30	3.9	0.6
17495	18.9	13.4	25	8	55	32	4.2	0.7
17498	20.1	14.2	25	8	54	30	3.9	0.6
17502	20.7	14.6	26	10	56	34	3.3	0.6
MEAN ± DE	20 ± 0.9	14 ± 0.8	25 ± 1	9 ± 1	55 ± 2	32 ± 2	3.8 ± 0.4	0.6 ± 0.07
OVERALL MEAN ± SD of 20 accessions	15 ± 4	11 ± 3						

* Accumulation of 10 cuts, at 8-week (7-II-85 10-IX-86).

** Total dry matter (TDM) = fine dry matter (FDM) + coarse dry matter (CDM); FDM = leaves + tender stems (< 6 mm in diameter).

Table 28. Weight gain results in the RTD in "La Libertad", Colombia.

Treatment	Weight gain 1985	1986	$\bar{X}$
	----- kg/AU/day ----		
B. dictyoneura + *P. phaseoloides*	0.50	0.45	0.48
B. brizantha + *P. phaseoloides*	0.49	0.41	0.45
B. humidicola + *P. phaseoloides*	0.43	0.39	0.41
B. decumbens + *P. phaseoloides*	0.45	0.40	0.43
B. decumbens	0.43	0.35	0.39
$\bar{X}$	0.46	0.40	
Stocking rate steers/ha	1985	1986	$\bar{X}$
2	0.49	0.50	0.50
3	0.49	0.42	0.46
4	0.40	0.31	0.36

B. ECUADOR, NAPO - PAYAMINO

The RTD in Payamino was established in 1983, but due to local problems grazing only began in May 1984.

Adjustments during 1986 responded to the dominance of the legumes and reduction of total available biomass. It is expected that with the system of flexible rotational grazing (recommended by CIAT), the balance of the mixture may be improved.

Tables 31 and 32 show that animal production (per animal and per hectare) has decreased over the years (24 and 30% between the 1st and 2nd, and 2nd and 3rd, respectively) with a total reduction in production of 47% between 1984 and 1986. This decrease is in accordance with what could be expected of a high rainfall amazon virgin forest ecosystem. Daily gains per animal during the second year were still adequate for effective animal production, but results for 1986 were below this level. Moreover, it was found that the legume did not increase weight gains per animal or per hectare. Stocking rates of 3 steers/ha seem extreme for these

Table 29. Green dry matter availability in the RTD in "La Libertad", Colombia.

Treatment	Stocking rate/ha 2	3	4	X̄
	------ t/ha ------			
B. dictyoneura + P. phaseoloides	2.1*	1.8	1.3	1.7
B. brizantha + P. phaseoloides	2.0	1.9	1.0	1.6
B. humidicola + P. phaseoloides	2.4	1.9	1.5	1.9
B. decumbens + P. phaseoloides	1.9	1.4	1.0	1.4
B. decumbens	1.2	0.8	0.8	0.9
X̄	1.9	1.5	1.1	

* Mean of 197 days during the maximum precipitation period, 1986.

Table 30. P. phaseoloides content in mixtures in the RTD in "La Libertad", Colombia, 1986.

Treatment	P. phaseoloides content in the association (%)					
	April			October		
	2	3	4	2	3	4
	------ an/ha ------					
B. dictyoneura + P. phaseoloides	15	9	2	24	6	0
B. brizantha + P. phaseoloides	14	7	20	13	2	1
B. humidicola + P. phaseoloides	3	3	0	0	0	0
B. decumbens + P. phaseoloides	11	1	0	44	6	0
X̄	11	5	6	20	4	0

Table 31. Liveweight gain of steers in the RTD in Payamino, Ecuador. 1984-86.

Treatment	kg/animal/day			$\bar{X}$
	1984[1] 123 d	1985[2] 319 d	1986[3] 244 d	
B. humidicola	0.72	0.52	0.33	0.49
B. humidicola + D. ovalifolium	0.72	0.44	0.37	0.46
B. humidicola + D. ovalifolium + F*	0.61	0.49	0.34	0.46
B. humidicola + D. heterophyllum	0.59	0.55	0.37	0.49
$\bar{X}$	0.66	0.50	0.35	

* 20 kg P_2O_5 + 40 K_2O + 10 Mg + 10 S/year

a/ 123 days, continuous grazing; 3 steers/ha.

b/ 319 days, alternating grazing; 3 steers/ha.

c/ 244 days, alternating grazing; January-April, 3 steers/ha.
(attempt to use flexible management) April-July, 2 steers/ha. July-September, 3 steers/ha.

Table 32. Daily beef production in the RTD in Payamino, Ecuador.

Treatment	kg/ha						$\bar{X}$
	1984		1985		1986		
	123 d	kg/ha/day	319 d	kg/ha/day	244 d	kg/ha/day	
B. humidicola	266	2.16	498	1.56	243	1.00	1.47
B. humidicola + D. ovalifolium	266	2.16	421	1.32	222	0.91	1.33
B. humidicola + D. ovalifolium + F	225	1.83	468	1.47	223	0.91	1.33
B. humidicola + D. heterophyllum	218	1.77	526	1.65	243	1.00	1.44
$\bar{X}$		1.98		1.50		0.96	

pastures if judged by the need for a long resting period after each grazing period and by the rapid decrease in available biomass.

C. PANAMA

A RTD was established in Panama during 1984 in the Experimental Station of Gualaca.

The Gualaca trial includes evaluation of three grasses and the inclusion of Kudzu. All pure stand grasses and the associations were grazed under 2 stocking rates in a rotation of 4 plots. Table 33 shows animal gains for the first 252 grazing days and a summary of daily gains per hectare. While the differences were not significant, the performance of A. gayanus 621 seems very promising. There was a marked stocking rate effect on animal gains and per hectare. Daily gains under the stocking rate of 2 steers/ha were adequate for effective animal production; the increase to 4 steers/ha reduced gains per animal to growth levels common in tropical pastures, but resulted in an increase of 60% in production/ha. These changes in animal production were associated with decreases in available green biomass, with the exception of the association B. humidicola + Kudzu, while pasture yields with H. rufa (the traditional grass in Panama and used as control in the trial) decreased to excessively low levels (Table 34). Legume contents in all cases continued to be over 20% of green biomass. Inferior levels were found in the association with B. humidicola (Table 35). The legume population tended to decrease with an increase in the stocking rate, but on average it remained at adequate levels. It must be kept in mind that though this is the first year of grazing, these pastures were established on soils previously used for many years. All pastures received fertilization treatments recommended by CIAT.

D. PERU

In Pucallpa, A. gayanus, B. decumbens, and B. decumbens with a protein bank of Kudzu covering 30% of the area were evaluated. Each pasture was evaluated under continuous grazing with 4 stocking rates 1.8, 2.1, 2.4, and 2.7 steers/ha. The protein bank was permanently available. Results for the first 240 days of experimental grazing are shown in Table 36. Weight gains in all treatments were higher in the wet season than the dry season. The protein bank had a positive effect over the grass without bank, and gains decreased drastically between the rainy and dry seasons with A. gayanus. However, the performance of A. gayanus must be interpreted in the light of the fact that establishment was insufficient from the onset of the trial. In addition, the stocking rate treatment of 2.4 steers/ha was eliminated from the trial due to its poor establishment. Stocking rate effects were as expected. Weight gains, except of A. gayanus in the dry season, were high in all treatments.

FUTURE ACTIVITIES

Strengthening of the RIEPT observed during the past years has consequently brought about more participation and leadership by the Advisory Committee. This was demonstrated by the subjects raised for discussion in the next meeting of the Advisory Committee during 1987 in Panama. A diagnosis will be made on the present situation of pasture evaluation in each of the countries in the RIEPT as well as an analysis of available resources.

Starting in April 1987, and parallel to the four selection centers, four sub-headquarters will operate:

Table 33. Daily liveweight gains of steers in the RTD in Gualaca, Panama. January-September, 1986.

Grass	Pure stand	P. phaseoloides	X̄
	kg/animal		
A. gayanus	0.49	0.52	0.51
B. humidicola	0.41	0.42	0.42
H. rufa	0.44	0.44	0.44
X̄	0.45	0.46	
Stocking rate steers/ha	**Pure stand**	**Grass + Legume**	**Prod./ha kg/ay**
2	0.50	0.51	1.0
4	0.40	0.41	1.6
Difference %	20	20	60

Table 34. Dry matter availability before grazing, in the RTD in Gualaca, Panama, 1986.

Grass	Pure stand		P. phaseoloides		
	January	May	January	May	X
	t/ha				
A. gayanus	4.34	2.05	5.48	5.67	4.39
B. humidicola	7.23	7.27	5.73	7.26	6.87
H. rufa	3.58	0.60	3.70	1.22	2.28
X̄	5.05	3.31	4.97	4.72	
Stocking rate	**Pure stand**		**P. phaseoloides**		
steers/ha	**January**	**May**	**January**	**May**	**X̄**
2	5.34	3.77	5.74	5.41	5.07
4	4.76	2.84	4.19	4.02	3.95
Difference, %	11	25	27	26	22

Table 35. Legume content before grazing in the RTD in Gualaca, Panama, 1986.

Pasture	January	May	$\bar{X}$
	----	%	----
A. gayanus + *P. phaseoloides*	30	40	35
B. humidicola + *P. phaseoloides*	23	24	24
H. rufa + *P. phaseoloides*	38	37	38
$\bar{X}$	30	34	
Stocking rate steers/ha	January	May	$\bar{X}$
2	34	35	35
4	26	32	29
Difference, %	24	9	17

Table 36. Effect of pasture and stocking rate on liveweight gains/animal/day in the RTD in Pucallpa, Peru. 1986.

Pastura	Rainy	Dry	$\bar{X}$
	----- kg/animal/day	----	
B. decumbens	0.53	0.48	0.51
A. gayanus	0.51	0.28	0.40
B. decumbens + *P. phaseoloides* (bank)	0.66	0.51	0.57
$\bar{X}$	0.57	0.42	
Stocking rate steers/ha	Rainy	Dry	
1.8	0.66	0.50	0.58
2.1	0.56	0.43	0.49
2.4	0.63	0.41	0.52
2.7	0.49	0.34	0.40

Llanos (ICA-CIAT, Carimagua, Colombia) for: Colombia, Venezuela, NE Brazil, Guyana, Surinam.

Cerrados (EMBRAPA-CPAC-CIAT, Planaltina, Brazil) for: Brazil, Bolivia, Paraguay, NE Argentina.

Humid Tropics (INIPA-IVITA-CIAT, Pucallpa, Peru) for: Peru, Ecuador, Bolivia, Brazil, Colombia.

Central America and the Caribbean (MAG-IICA-CATIE-ECAG-CIAT-Costa Rica) for: Costa Rica, Mexico, Nicaragua, Panama, Guatemala, Honduras, Cuba, Dominican Republic.

Entomology

Since the arrival in April 1986 of a principal staff entomologist, the Entomology Section has initiated a review of its current activities with the goal of setting research priorities for 1987 and beyond. During this time three main concerns have been examined, namely the problems of spittlebug on Brachiaria, leaf-cutting ant predation of A. gayanus, and the budworm Stegasta bosquella on Stylosanthes capitata. The purpose of this report is to provide the section's evaluation of these problems, summarize research conducted during 1986, and develop a rationale for future investigations.

SPITTLEBUG ON BRACHIARIA

Spittlebug is considered to be the major limiting factor in the utilization of species of Brachiaria as forage grasses in Latin America. Given the genetic variability that is now available for screening, it is possible to select for host plant resistance to spittlebug from CIAT's germplasm bank. Therefore, efforts have been focused on four main areas: a methodology for field screening of Brachiaria collections for host plant resistance, mass rearing of spittlebug species, artificial infestation techniques, and screenhouse and glasshouse studies of host plant resistance mechanisms.

Methodology for host plant resistance screening in field collections

Spittlebug populations have been low at most of the regional trial sites (Tables 1-3). Since at many of the sites, there are significant spittlebug populations causing obvious damage in pastures not far from the trials, it is probable that the collections are maintained under conditions either nonpreferred for oviposition or unsuitable for nymphal development. Specifically, the practice of maintaining alleyways weed-free may result in higher temperatures and lower relative humidities. To encourage the natural spittlebug populations, all future Brachiaria collections should be planted in an area of established B. decumbens or B. humidicola where a significant spittlebug population already exists. Brachiaria should be maintained, or established if necessary, in the alleyways between plots. The width of the alleyways should be left as wide as possible to limit interplot interference. In addition, attempts should be made to establish and augment natural spittlebug populations in the alleyways through artificial infestation and maintenance of favorable environmental conditions. Spittlebug infestation has been

Table 1. Population density of nymphs of *Aeneolamia varia* and *Zulia pubescens* on 36 accessions of *Brachiaria* at La Libertad, Villavicencio.

Species	CIAT Accession No.	Nymphs/m^2*	Species	CIAT Accession No.	Nymphs/m^2*
B. brizantha	667	0.2	*B. ruziziensis*	6130	6.7
B. humidicola	6709	0.5	*B. brizantha*	6009	7.2
B. humidicola	6707	0.5	*B. decumbens*	606	7.2
B. humidicola	679	0.7	*B. brizantha*	6298	7.3
B. decumbens	6131	0.7	*B. brizantha*	6370	7.5
B. brizantha	6294	1.0	*B. humidicola*	6369	7.5
B. brizantha	6297	1.2	*B. ruziziensis*	6134	8.8
B. humidicola	6013	1.5	*B. dictyoneura*	6133	9.3
B. humidicola	6705	1.8	*B. ruziziensis*	6419	9.5
B. decumbens	6058	2.2	*B. brizantha*	6016	10.6
B. eminii	6241	2.5	*B. ruziziensis*	6291	11.7
B. decumbens	6132	2.5	*B. sp.*	6008	12.0
B. humidicola	682	3.2	*B. ruziziensis*	655	12.2
B. ruziziensis	660	3.5	*B. brizantha*	6021	12.5
B. brizantha	665	3.8	*B. brizantha*	664	19.3
B. humidicola	675	4.2	*B. ruziziensis*	654	19.5
B. decumbens	6699	6.5	*B. decumbens*	6700	25.8
B. brizantha	6012	6.5	*B. ruziziensis*	656	26.2

* Mean of two evaluations during the rainy season, three replications per evaluation.

Table 2. Population density of nymphs of *Aeneolamia varia* on 27 accessions of *Brachiaria* at Macagual, Florencia.

Species	CIAT Accession No.	Nymphs/m^2*	Species	CIAT Accession No.	Nymphs/m^2*
B. nigropedata	6386	0.2	*B. decumbens*	6701	2.6
B. decumbens	6698	0.6	*B. decumbens*	6702	3.4
B. humidicola	6705	0.8	*B. brizantha*	6684	3.4
B. humidicola	6738	1.0	*B. ruziziensis*	6678	4.2
B. brizantha	6384	1.0	*B. brizantha*	6675	4.2
B. dictyoneura	6133	1.0	*B. brizantha*	6735	4.4
B. ruziziensis	6711	1.4	*B. brizantha*	6392	4.8
B. brizantha	6421	1.6	*B. brizantha*	6692	6.2
B. decumbens	6693	2.0	*B. brizantha*	6433	6.4
B. decumbens	6699	2.2	*B. brizantha*	6683	7.2
B. ruziziensis	6713	2.4	*B. brizantha*	6387	8.0
B. decumbens	6677	2.4	*B. brizantha*	6385	8.6
B. brizantha	6426	2.6	*B. brizantha*	6674	11.0
B. brizantha	6681	2.6			

* Mean of five evaluations during the rainy season, three replications per evaluation.

Table 3a. Population density of nymphs of *Zulia colombiana* and *Aeneolamia lepidor* on accessions of *Brachiaria* at San José del Nus, Antioquia.

Species	CIAT Accession No.	Nymphs/ m^2*	Species	CIAT Accession No.	Nymphs/ m^2*
B. brizantha	6780	0.0	*B. decumbens*	6131	0.8
B. decumbens	6677	0.0	*B. humidicola*	6738	0.9
B. brizantha	6426	0.0	*B. decumbens*	6702	1.2
B. brizantha	6735	0.2	*B. brizantha*	6421	1.2
B. humidicola	6709	0.2	*B. brizantha*	6016	1.2
B. brizantha	6675	0.2	*B. decumbens*	6698	1.4
B. decumbens	6701	0.4	*B. brizantha*	6682	2.6
B. brizantha	6681	0.4	*B. brizantha*	6433	2.6
B. brizantha	6674	0.4	*B. brizantha*	6687	2.8
B. brizantha	6384	0.4	*B. brizantha*	6683	4.2
B. brizantha	6387	0.6	*B. ruziziensis*	6778	4.6
B. brizantha	6385	0.6	*B. ruziziensis*	6713	6.0

* Mean of three evaluations during the rainy season, three replications per evaluation.
Accessions planted November 21, 1983.

Table 3b. Population density of nymphs of *Zulia colombiana* and *Aeneolamia lepidor* on accessions of *Brachiaria* at San José del Nus, Antioquia.

Species	CIAT Accession No.	Nymphs/ m^2*	Species	CIAT Accession No.	Nymphs/ m^2*
B. decumbens	6693	0.2	*B. brizantha*	6012	2.0
B. brizantha	6690	0.2	*B. brizantha*	6298	2.2
B. brizantha	6688	0.2	*B. dictyoneura*	6133	2.2
B. brizantha	6413	0.2	*B. brizantha*	667	2.2
B. humidicola	6369	0.2	*B. ruziziensis*	6692	2.4
B. humidicola	6705	0.8	*B. brizantha*	665	2.4
B. ruziziensis	6130	0.8	*B. decumbens*	6700	2.6
B. arrecta	6020	0.8	*B. decumbens*	6058	2.6
B. brizantha	6009	0.8	*B. humidicola*	679	2.6
B. humidicola	6707	1.4	*B. humidicola*	675	2.6
B. jobatatha	6409	1.4	*B. ruziziensis*	660	2.6
B. nigropedata	6386	1.4	*B. brizantha*	6686	2.8
B. humidicola	682	1.4	*B. humidicola*	6013	2.8
B. ruziziensis	655	1.4	*B. brizantha*	6424	3.4
B. decumbens	606	1.4	*B. brizantha*	6370	3.4
B. brizantha	6684	1.6	*B. ruziziensis*	6134	3.4
B. decumbens	6699	1.8	*B. ruziziensis*	654	3.4
B. brizantha	6297	1.8	*B. brizantha*	6392	3.6
B. brizantha	6294	1.8	*B. decumbens*	6132	4.0
B. ruziziensis	6291	1.8	*B. ruziziensis*	656	4.8
B. eminii	6241	1.8	*B. ruziziensis*	6711	6.2
B. brizantha	6021	1.8	*B. ruziziensis*	6419	7.8
B. sp	6008	1.8	*B. brizantha*	664	12.0

* Mean of three evaluations during the rainy season, three replications per evaluation.
Accessions planted August 25, 1983.

notably higher at Puerto Bermudez, Perú (Table 4), possibly due to greater precipitation at that site (3300 mm/yr). Puerto Bermudez appears to be an excellent site for screening promising germplasm for the forest ecosystem.

B. decumbens is outstanding for its aggressiveness, rapid recovery from grazing and its resistance to drought. However, the species is highly susceptible to spittlebug feeding damage. B. humidicola and B. dictyoneura, at equivalent spittlebug populations, suffer less feeding damage compared with B. decumbens, i.e., they are relatively tolerant. However, in terms of host plant suitability for insect development and survival, B. humidicola and B. dictyoneura are better hosts than B. decumbens. In Brazil, where B. humidicola has been planted extensively, spittlebug populations have increased to the point where severe damage is being reported in B. decumbens as well. Tolerance is an important component of host plant resistance and a desirable characteristic to select for in promising germplasm. However, its value will be limited unless it is possible to identify and select for some form of antibiosis that will operate to maintain insect populations below economically critical levels. It is not sufficient to simply plant germplasm collections in the field and select those accessions that show the least damage. Under low insect population pressure, those accessions with tolerance will perform well but may fail under conditions of higher insect populations, as in the case of B. humidicola. It is essential in an intensive screening program to insure adequate insect populations and to provide uniform insect infestation of the individual plots. With this in mind, a priority of the Entomology Section has been to develop a mass rearing system for Zulia colombiana and other spittlebug species in order to facilitate life-table studies and artificial infestation of field trials.

Table 4. Population density of spittlebug nymphs on accessions of Brachiaria at Puerto Bermudez, Perú. (1985-86).

Species	CIAT Accession No.	Nymphs/ m^2*	Species	CIAT Accession No.	Nymphs/ m^2*
B. ruziziensis	6713	12.7	B. dictyoneura	6133	80.7
B. ruziziensis	655	28.7	B. brizantha	667	82.3
B. brizantha	6297	29.7	B. decumbens	6132	83.0
			B. ruziziensis	665	84.7
B. humidicola	6738	40.0	B. humidicola	679	84.7
B. brizantha	629	41.3	B. decumbens	6131	89.3
B. arrecta	6020	41.3	B. humidicola	6013	90.7
B. ruziziensis	6134	61.3	B. brizantha	6298	94.7
B. humidicola	6369	62.7	B. ruziziensis	6130	95.0
B. ruziziensis	6291	65.0	B. brizantha	6012	99.0
B. sp.	6008	66.7	B. decumbens	6058	99.7
B. eminii	6241	73.7	B. humidicola	682	112.3
B. decumbens	6009	75.3	B. humidicola	675	118.3

* Mean of five evaluations, three replications per evaluation.

Spittlebug response to Brachiaria collection at Carimagua

B. brizantha CIAT 6294 and 6297 (cv. Marandú) performed well at Carimagua during 1986. Spittlebug infestation of these accessions was low and damage from adult spittlebug feeding was low as well (Table 5). B. brizantha CIAT 6686 also had a very low infestation, but dry matter yield was below average (Table 6 and Figure 1). Rankings of nymphal infestation and damage ratings will be combined with yield and general adaptation data to select Brachiaria accessions for further evaluation in the greenhouse and field trials.

Mass rearing technique for a spittlebug colony

The previous technique for rearing spittlebugs (1985 Annual Report) is unsatisfactory due to contamination with algae and problems associated with the special construction of the rearing chambers. We have found that by simply covering plastic pots with aluminum foil, secondary root development at the soil surface is excellent and provides sufficient feeding sites for spittlebug nymphs. In addition, the foil provides ideal conditions of temperature, relative humidity, and low light intensity for nymph development.

Eggs are collected from a special oviposition chamber. Adults collected from the field or adults emerging from the colony are placed in the chamber and allowed to oviposit in a layer of mud at the bottom of the chamber. The mud substrate is then removed, dissolved in water, sieved, and a flotation technique used to separate out the eggs. These are incubated in the laboratory and are then placed on pieces of moist filter paper at the base of potted grass plants. The pots are covered with aluminum foil and the nymphs left to develop.

With this mass rearing capability it is possible to work year-round, including the dry season when adults are unavailable in the field. Large numbers of eggs and adults of known age are produced, thereby avoiding the variability in laboratory and glass-house experiments. associated with using field collected adults. Using this technique, two spittlebug colonies are being currently maintained: Zulia colombiana at CIAT-Palmira and Aeneolamia reducta at Carimagua.

Artificial infestation

Under ideal conditions, it should be possible to infest Brachiaria in the field with eggs or early instar nymphs from the laboratory colony early in the growing season without having to wait for first generation adults to appear in the field. The goal of artificial infestation is to generate sufficient spittlebug populations to cause severe feeding damage to the most susceptible Brachiaria accessions and thereby provide a rigorous screening for antibiosis and tolerance under field conditions. New methods for preparing and deploying insect eggs in the field are being evaluated. The development of a simple, reliable, consistent technique for infestation that is practical for use at regional trial sites will be one of the main priorities of the section during the coming year.

One aspect of egg biology that is poorly understood is the conditions that induce and maintain egg dormancy. Currently, it is possible to store eggs for no longer than one month (1985 Annual Report). If the conditions that maintain egg dormancy were well understood, it would be possible to accumulate and store large quantities of eggs over a period of time for later use. This is another area that will receive high priority in the coming year. The technique for egg storage to date has been to

Table 5. Population density of nymphs of *Aeneolamia reducta* and rating of adult feeding damage on 65 accessions of *Brachiaria* at Carimagua.

Species	CIAT Accession No.	Nymphs m^2*	Species	CIAT Accession No.	Damage rating**
B. brizantha	6686	0.0	*B. arrecta*	6020	1.4
B. brizantha	6294	0.3	*B. brizantha*	6687	1.5
B. brizantha	6297	0.4	*B. brizantha*	6690	1.5
B. brizantha	6690	0.7	*B. brizantha*	6016	1.6
B. species	6008	1.5	*B. brizantha*	6294	1.6
B. arrecta	6020	1.5	*B. brizantha*	6297	1.6
B. brizantha	6687	1.5	*B. brizantha*	6385	1.6
B. jobata	6409	1.7	*B. brizantha*	6684	1.6
B. decumbens	6698	1.7	*B. brizantha*	6686	1.6
B. brizantha	6674	2.0	*B. brizantha*	6413	1.7
B. brizantha	6681	2.0	*B. brizantha*	6424	1.7
B. brizantha	6016	2.1	*B. brizantha*	6433	1.7
B. brizantha	6421	2.1	*B. brizantha*	6674	1.7
B. decumbens	6131	2.4	*B. dictyoneura*	6133	1.9
B. humidicola	6707	2.6	*B. humidicola*	6369	1.9
B. brizantha	6384	2.7	*B. brizantha*	6387	1.9
B. brizantha	6433	2.8	*B. brizantha*	6399	1.9
B. brizantha	6387	3.0	*B. jobata*	6409	1.9
B. brizantha	6385	3.1	*B. brizantha*	6735	1.9
B. brizantha	6426	3.6	*B. brizantha*	6384	2.0
B. brizantha	6684	3.6	*B. brizantha*	6683	2.0
B. brizantha	6399	3.7	*B. brizantha*	6421	2.1
B. brizantha	6675	4.5	*B. brizantha*	6426	2.1
B. brizantha	6424	4.6	*B. humidicola*	679	2.2
B. brizantha	6735	4.6	*B. humidicola*	682	2.2
B. species	6075	4.7	*B. brizantha*	6675	2.2
B. decumbens	6677	4.7	*B. humidicola*	6707	2.2
B. humidicola	6705	4.8	*B. humidicola*	6709	2.2
B. brizantha	6413	4.9	*B. humidicola*	6013	2.3
B. brizantha	6683	5.2	*B. species*	6075	2.3
B. brizantha	665	5.4	*B. brizantha*	6681	2.4
B. dictyoneura	6133	5.6	*B. humidicola*	6705	2.4
B. humidicola	6738	5.8	*B. species*	6008	2.5
B. humidicola	6709	6.0	*B. brizantha*	6012	2.5
B. humidicola	6013	6.2	*B. decumbens*	6700	2.5
B. humidicola	679	6.8	*B. brizantha*	664	2.6
B. humidicola	682	7.6	*B. brizantha*	665	2.6
B. humidicola	6369	7.7	*B. brizantha*	6009	2.6
B. decumbens	6132	7.9	*B. brizantha*	6021	2.6
B. ruziziensis	6130	8.0	*B. brizantha*	6298	2.6
B. ruziziensis	6713	8.0	*B. decumbens*	6677	2.6
B. eminii	6241	8.5	*B. humidicola*	6738	2.6

Table 5. (Cont'd).

Species	CIAT Accession No.	Nymph m^2*	Species	CIAT Accession No.	Damage rating**
B. brizantha	6298	8.9	B. brizantha	667	2.7
B. ruziziensis	654	9.3	B. decumbens	6058	2.7
B. brizantha	6009	9.6	B. ruziziensis	6130	2.7
B. ruziziensis	6778	9.8	B. ruziziensis	6134	2.7
B. brizantha	667	10.3	B. eminii	6241	2.7
B. decumbens	6701	10.3	B. brizantha	6392	2.7
B. ruziziensis	6711	10.8	B. decumbens	6698	2.7
B. ruziziensis	6692	10.9	B. decumbens	6701	2.7
B. ruziziensis	660	11.2	B. decumbens	6702	2.7
B. brizantha	6370	11.2	B. decumbens	606	2.8
B. ruziziensis	6134	11.3	B. ruziziensis	654	2.8
B. ruziziensis	6419	11.3	B. ruziziensis	655	2.8
B. brizantha	6021	11.5	B. decumbens	6131	2.8
B. decumbens	6702	12.1	B. ruziziensis	6291	2.8
B. ruziziensis	655	12.2	B. brizantha	6370	2.8
B. ruziziensis	6291	12.4	B. ruziziensis	6692	2.8
B. brizantha	6012	13.3	B. ruziziensis	6778	2.8
B. brizantha	6392	14.2	B. ruziziensis	656	2.9
B. decumbens	606	15.7	B. ruziziensis	660	2.9
B. decumbens	6058	15.7	B. decumbens	6132	2.9
B. brizantha	664	17.5	B. ruziziensis	6419	2.9
B. decumbens	6700	18.6	B. ruziziensis	6711	2.9
B. ruziziensis	656	21.0	B. ruziziensis	6713	2.9

* Mean number of nymphs/m^2. Mean of 16 counts from 13 May to 22 December, 1986. Three replications per evaluation date.

** Mean rating of adult feeding damage on a visual scale from 1 (no damage) to 5 (death). Mean of 16 counts from 13 May to 22 December, 1986. Three replications per evaluation date.

Table 6. Dry matter (DM) yield of *Brachiaria* accessions at Carimagua.

Species	CIAT Accession No.	DM Yield* (g/m^2)	Species	CIAT Accession	DM Yield* (g/m^2) No.
B. nigropedata	6386	42.5	*B. brizantha*	6009	204.9
B. arrecta	602	046.2	*B. ruziziensis*	6291	206.8
B. decumbens	6131	96.9	*B. brizantha*	6294	208.7
B. decumbens	6698	100.6	*B. ruziziensis*	6711	208.7
B. jobata	6409	108.1	*B. humidicola*	6013	213.2
B. brizantha	6675	129.8	*B. humidicola*	682	216.2
B. ruziziensis	656	139.2	*B. brizantha*	6384	217.1
B. decumbens	6699	146.1	*B. brizantha*	6012	218.2
B. ruziziensis	6419	146.9	*B. brizantha*	6683	224.7
B. ruziziensis	654	150.6	*B. brizantha*	6433	224.9
B. decumbens	6132	151.7	*B. humidicola*	6369	226.7
B. brizantha	6735	159.1	*B. brizantha*	6297	229.3
B. brizantha	6387	162.4	*B. brizantha*	6690	230.3
B. decumbens	6700	175.0	*B. brizantha*	6674	231.1
B. brizantha	6686	179.3	*B. decumbens*	6702	231.9
B. ruziziensis	655	181.3	*B. ruziziensis*	660	233.4
(?)	6008	181.3	*B. decumbens*	606	234.3
B. brizantha	6016	182.5	*B. brizantha*	6687	234.4
B. brizantha	6681	183.3	*B. brizantha*	6682	238.2
B. ruziziensis	6713	184.5	*B. humidicola*	6707	239.5
B. brizantha	664	191.0	*B. ruziziensis*	6134	240.2
B. brizantha	6399	192.7	*B. decumbens*	6058	246.0
(?)	6075	194.3	*B. humidicola*	6709	246.0
B. brizantha	6385	194.6	*B. brizantha*	667	248.8
B. ruziziensis	6778	195.9	*B. eminii*	6241	254.6
B. ruziziensis	6692	196.2	*B. humidicola*	679	257.1
B. brizantha	6426	196.5	*B. brizantha*	6392	259.6
B. brizantha	6688	197.0	*B. ruziziensis*	6130	261.6
B. humidicola	6705	198.4	*B. brizantha*	6021	264.0
B. brizantha	6298	199.6	*B. humidicola*	6738	269.0
B. brizantha	6421	201.5	*B. dictyoneura*	6133	279.5
B. brizantha	6684	201.7	*B. brizantha*	6370	305.5
B. decumbens	6677	203.2	*B. decumbens*	6701	310.1
B. brizantha	6424	203.3	*B. brizantha*	665	316.2
B. brizantha	6413	204.0	*B. decumbens*	6693	389.7

* Means of three sample dates, three replications per sample.

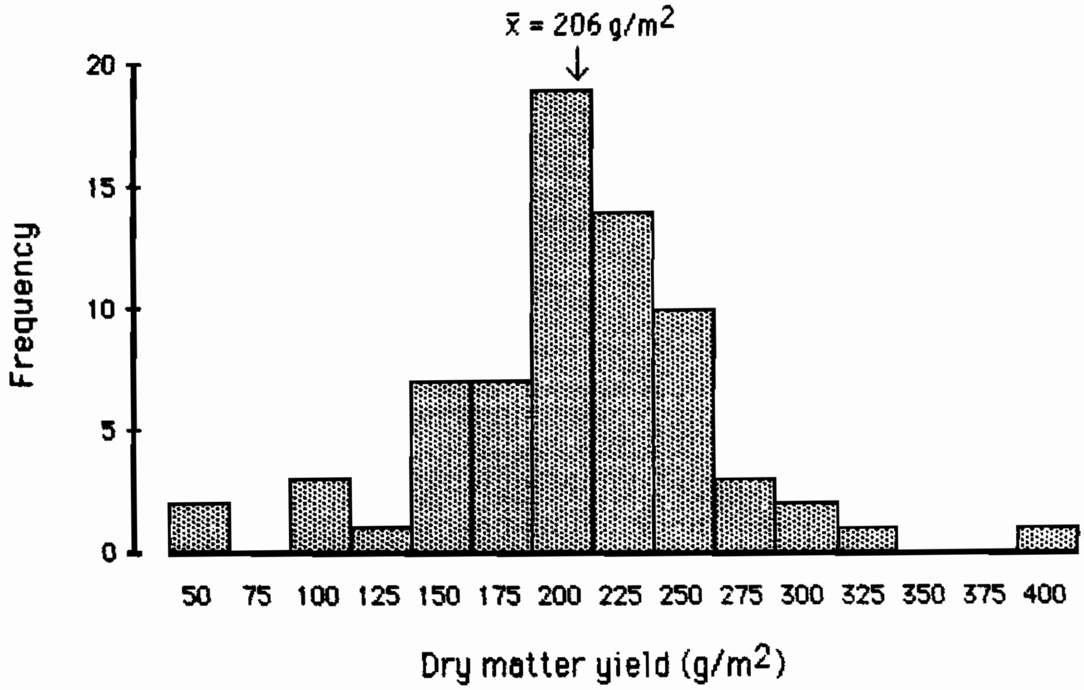


Figure 1. Frequency distribution of dry matter yield for 70 Brachiaria accessions at Carimagua.

separate the eggs from the mud substrate and thereby, in the process, also remove secretions provided by the females' colleterial or accessory glands. It is not known what effect this may have on egg development or dormancy. Experiments are being designed to test various conditions of storage temperature, relative humidity, storage media, and egg preparation on egg dormancy.

Glasshouse antibiosis trials

Although spittlebug populations at several of the evaluation sites have been relatively low, some *Brachiaria* species have been consistently less infested than others. In order to gain some insight on the types of resistance involved (tolerance, nonpreference, antibiosis), life-table studies were initiated using *Zulia colombiana* on selected *Brachiaria* species and accessions. Previous greenhouse trials to evaluate relative host suitability for spittlebug development on accessions of *Brachiaria* are of doubtful value due to inadequate control of environmental conditions (temperature and humidity) for insect survival. Survival from egg to first instar was low and highly variable. Since the reasons for poor performance of spittlebug in the screenhouse on otherwise susceptible germplasm was probably the result of high temperatures and low humidity (i.e., the same problems being observed with the field collections), a new rearing system was developed based on results obtained from experience with the spittlebug colony. By covering plastic pots with aluminum foil, temperature at the soil surface is reduced, relative humidity is increased, and solar radiation is practically eliminated. Under these conditions the rate of survival of nymphs is much greater. By providing a uniform environment for spittlebug development independent of the growth habit of the plant, the differences in spittlebug performance on various accessions can be attributed to direct antibiotic properties in the plant and not to indirect effects on the microhabitat that in turn influence spittlebug survival. Possible resistance mechanisms include physical interference with feeding (e.g. stem hardness, pilosity), host nutrition, and/or secondary plant compounds.

In addition to Brachiaria, other grass species known to be resistant to spittlebug e.g. A. gayanus were included in the antibiosis trials as control. A. gayanus, supports very low spittlebug populations in the field and at least three mechanisms have been proposed to account for this: stem hardness, pilosity, and growth habit. Surprisingly, in our glasshouse studies under optimal conditions of relative humidity and temperature, Zulia colombiana survives well on A. gayanus. Since the rearing method employed provides a uniformly favorable environment, these data suggest that the growth habit of A. gayanus and its effect on the microhabitat experienced by spittlebug nymphs have a large effect on spittlebug survival. Growth habit may be an important character to select for in the Brachiaria collection.

Other characteristics that confer resistance to spittlebug appear to be present in the genus Brachiaria. B. brizantha CIAT 6297 and CIAT 6294 (cv. Marandú) are consistently less infested in field trials compared with B. decumbens and most other Brachiaria species. Cultivar Marandú is a semi-erect accession and this may contribute to lower field infestations under some environmental conditions, as is believed to be the case in A. gayanus. However, in contrast to A. gayanus cv. Marandú retains its resistance to Zulia colombiana in the glasshouse. Under conditions of no-choice and equal initial populations, spittlebugs confined to cv. Marandú perform poorly as reflected in survival to adulthood and development time, compared with B. humidicola and even A. gayanus. This indicates that cv. Marandú is a less suitable host for spittlebug than A. gayanus or B. humidicola under the conditions of temperature and relative humidity prevailing in the trial. Spittlebugs on cv. Marandú seem to move about more frequently in an apparent search for a suitable feeding site. Spittlebug nymphs suffer much higher levels of mortality and develop more slowly on cv. Marandú compared with B. humidicola (Figures 2 and 3).

As a result of these studies, the Brachiaria accession used for the spittlebug colony has been changed from B. decumbens CIAT 606 to B. humidicola CIAT 6707. Accession CIAT6707 is tolerant to spittlebug feeding damage and is a better host for spittlebug nymph development that B. decumbens CIAT 606.

Methodological studies designed to detect useful levels of tolerance to adult feeding damage are currently underway. Combined with the information gained from the antibiosis trials, information from tolerance tests will facilitate the development of techniques to characterize the genetic variability present in the Brachiaria collection in terms of host plant resistance. In addition to allowing for intelligent deployment of germplasm for the various spittlebug population pressures experienced under the diverse environmental conditions of Latin America, such information will be of great value should it become feasible to initiate a Brachiaria breeding program.

Spittlebug adult population at Carimagua during 1986

Beginning on May 29, 1986 weekly counts of adult spittlebug (Aeneolamia reducta) were made in a 160 hectare area (Tomo 5) of B. decumbens established in 1985. These data will serve as a baseline for population studies to be carried out in the future. The curve suggests that there were four generations during the period from May through December

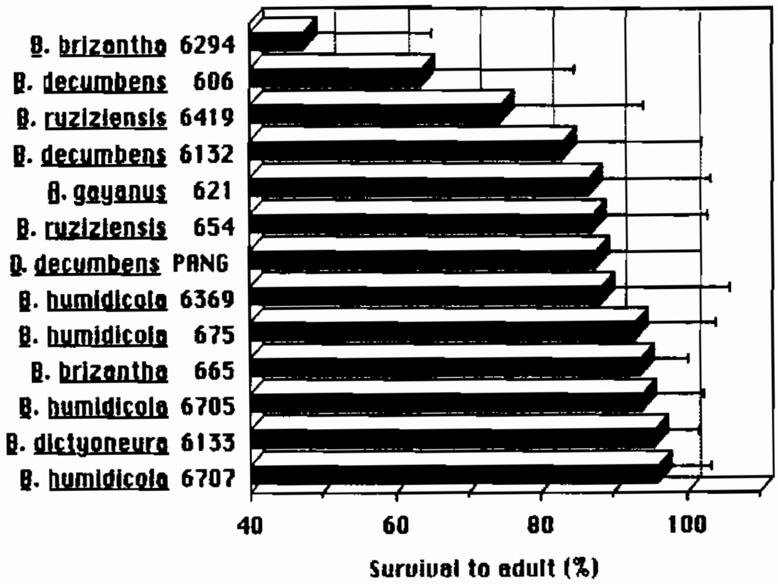


Figure 2. Percent survival of Zulia colombiana nymphs reared on 13 grass accessions in the glasshouse at Palmira. (Bars are 95% confidence intervals.)

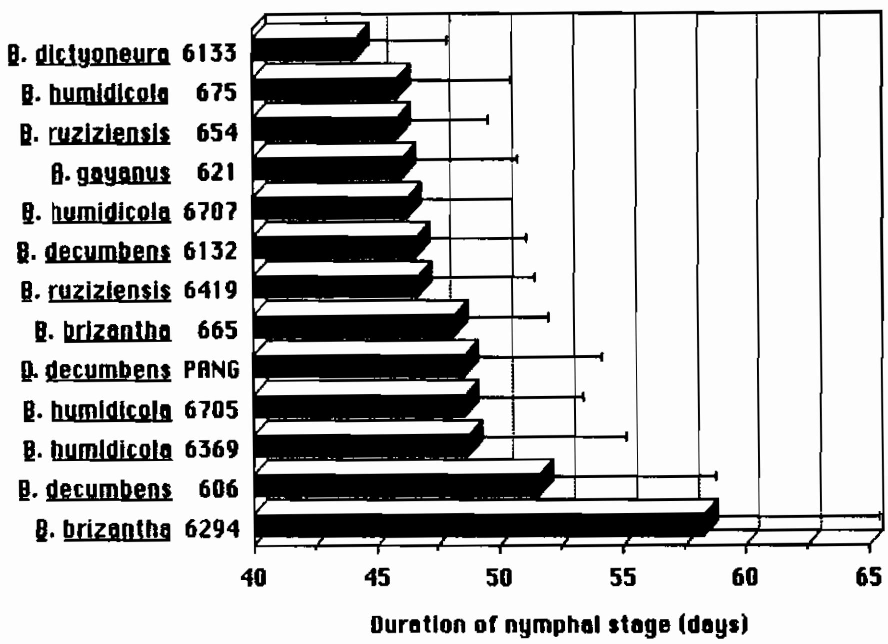


Figure 3. Duration of nymphal stage of Zulia colombiana reared on 13 grass accessions in the glasshouse at Palmira. (Bars are 95% confidence intervals.)

(Figure 4). The first three peaks were separated by a period of approximately 45 days or the time necessary for development from egg to adult. The last peak was delayed somewhat. The time between peaks three and four was approximately 60 days. This may be the result of decreased rainfall that occurred during the latter part of the year (Julian dates 240 through 270) (Figure 5).

GRASS-CUTTING ANTS

Grass-cutting ants show a marked preference for Andropogon gayanus compared with introduced grass species such as Brachiaria humidicola. The advisability of promoting Andropogon will be called into question unless a suitable, low-input technique to control predation by ants can be developed.

Currently, ant control in experimental plots at Carimagua is effected by repeated applications of Aldrin. However, this has become increasingly ineffective and may be a source of the current problem on the experimental station, i.e. pest resurgence due to frequent and heavy application of a nonspecific insecticide. When applied to the soil, Aldrin breaks down relatively quickly through volatilization and epoxidation to Dieldrin. Dieldrin is extremely persistent and residues with insecticidal activity remain for several years. Dieldrin accumulates in animal tissue and is eliminated slowly.

Aldrin pumped into nests has been used successfully to control Atta. However, as this technique is labor intensive and is impractical for control of Acromyrmex whose nests are much smaller, less conspicuous, and

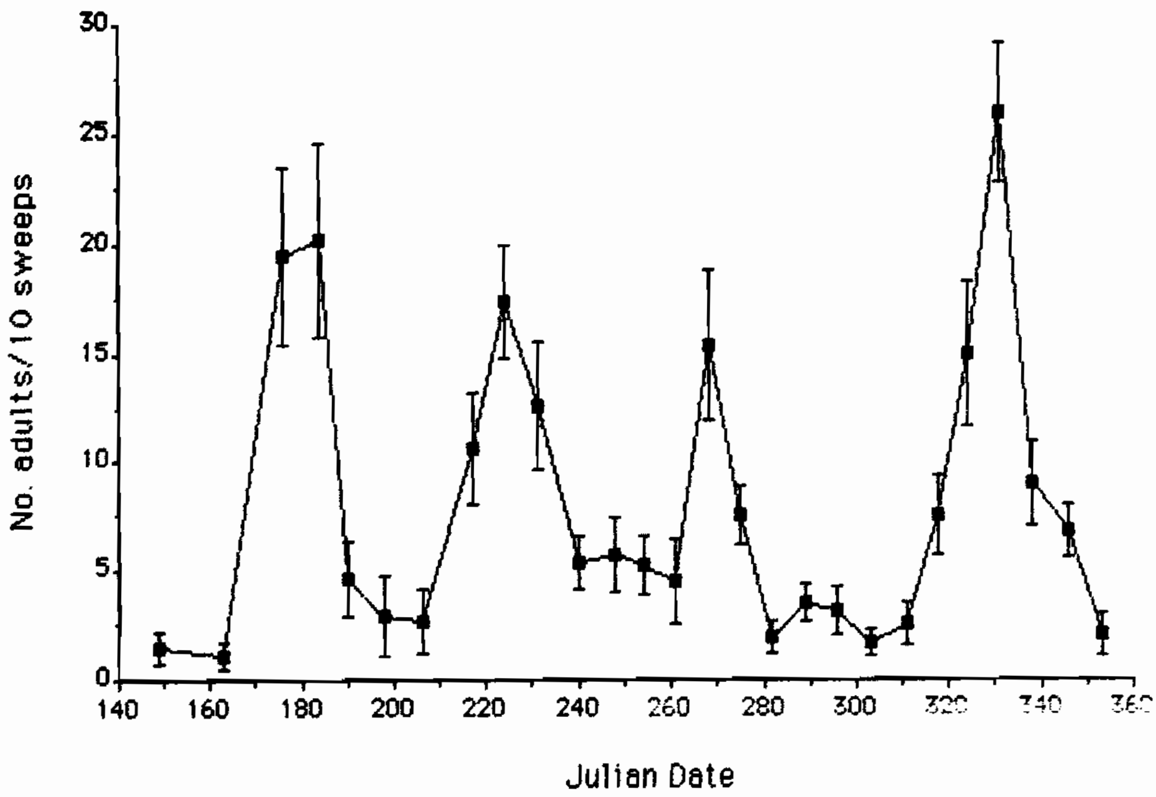


Figure 4. Fluctuation in the adult spittlebug population in a large area of B. decumbens at Carimagua (Bars are 95% confidence intervals, N = 20).

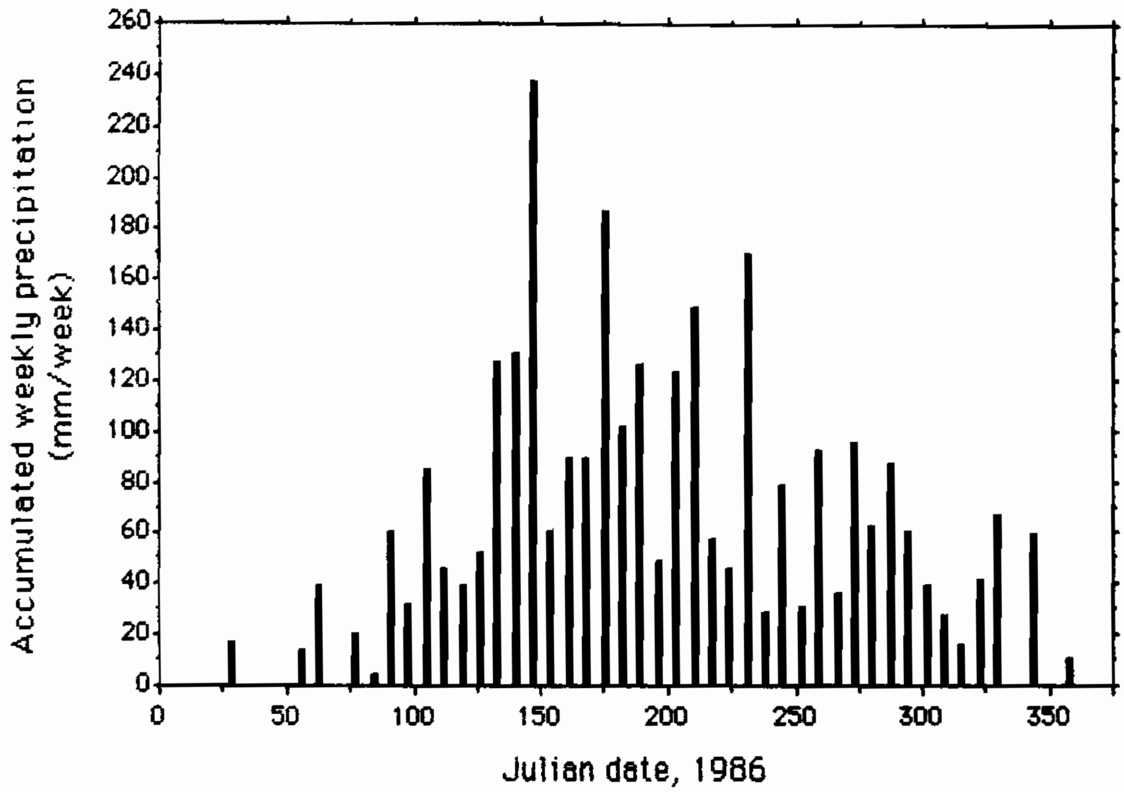


Figure 5. Total weekly precipitation at Carimagua (1986).

occur at very high densities. Nest populations of Acromyrmex in pastures can reach 6000 nests per hectare. As a result, the tendency has been to broadcast Aldrin especially at planting to prevent damage to seedlings, a practice that should be discontinued.

The feasibility of using a toxic bait as a substitute for Aldrin is being explored at Carimagua. Such a bait would consist of a matrix (orange pulp or dried grass and molasses, as an attractant; propionic acid, as a preservative; and the toxicant). One possibility is to use a microencapsulated insecticide such as permethrin, a relatively non-toxic (acute oral LD_{50}:1000 mg/kg) synthetic pyrethroid. Chlorpyrifos (Dursban r) in a microencapsulated formulation (ME) is another possibility being evaluated. Chlorpyrifos is an organophosphorous insecticide, moderately toxic (LD_{50}:135 mg/kg), persistent in soil for weeks, and has low solubility in water. As a dust formulation (Lorsban r), chlorpyrifos is being promoted for ant control in Colombia, probably in part due to the removal of Aldrin from the market. However, as a ME (Dursban r), it is only marketed in the United States.

The use of a bait with a ME insecticide has the following advantages:

1. The bait can be formulated locally, as needed.
2. The microencapsulation greatly reduces the toxicity of the insecticide due to the slow release of the toxin from the capsules. Thus the bait will present a low toxicity to workers.
3. The bait is actively collected by the ants themselves, allowing a much lower rate of application of insecticide per unit area necessary for adequate control.
4. The bait will have fewer non-target effects on other arthropod species.

5. Lower persistence in the soil.

BUDWORM

Since 1984 the Entomology Section has been collecting data on damage caused by the budworm (Stegasta bosquella) in breeding lines of Stylosanthes guianensis in field plots at Quilichao. The evaluations consisted of collecting buds, counting the number of damaged inflorescences (buds with entrance holes), the number of damaged seeds in each damaged inflorescence, and the number of larvae per bud. Correlation studies were undertaken to determine which parameter would be most useful as a screening tool. Since it is excessively time-consuming to tease apart each bud to count larvae and damaged seeds, it would be desirable to develop a nondestructive technique for assessing field damage.

The number of larvae were best correlated with the number of damaged buds (r^2 for linear regression = 0.80). There was also a good and consistent correlation between damaged buds and damaged seed (Figure 6). Future evaluations can now be done in situ much more quickly by simply counting the number of entry holes in a predetermined number of randomly selected buds.

Field infestations did not exceeded 50% infested buds. However, the use of artificial infestation in the glasshouse permitted higher levels of infestation than those encountered in the field. It is clear from Figure 7 that the linear relation between percent damaged buds and percent damaged seed becomes curvilinear when infestation exceeds 50% infested buds. This can be explained as multiple infestation of single buds by more than one larvae as the level of infestation increases. However, with the field population levels that have been observed at Quilichao, the linear relation serves well to estimate seed losses based on the observed number of damaged buds.

Field populations were generally low at Quilichao and the mean yield reduction compared with chemically protected plots has been approximately 15%. In order to promote field populations of budworm at Quilichao, an insect nursery plot has been planted with a mixture of Stylosanthes types. The nursery will be used as a source of adults to be used in glasshouse and field studies.

Field trials and glandular trichomes

Data were collected from the trial at Quilichao of five sampling dates during 1986. Since the accession x sample date interaction was not significant, data were pooled over the sample dates and the results presented in Table 7. Accession CIAT 1949 was consistently more infested. Those accessions with glandular trichomes on the flower bracts were less damaged. However, since the density of glandular trichomes is not highly correlated with damage among accessions possessing glandular trichomes, it is not possible to conclude that they alone are responsible for reduced damage.

Glasshouse trials

Susceptibility of selected Stylosanthes accessions to budworm under glasshouse conditions correlate well with susceptibility in the field (Table 8). Twenty male and 10 female moths were caged on single plants of S. guianensis plants in the glasshouse and evaluated 21 days later for damaged buds. The ranking of susceptibility as determined by percent damaged buds is the same as that observed in the field trials.

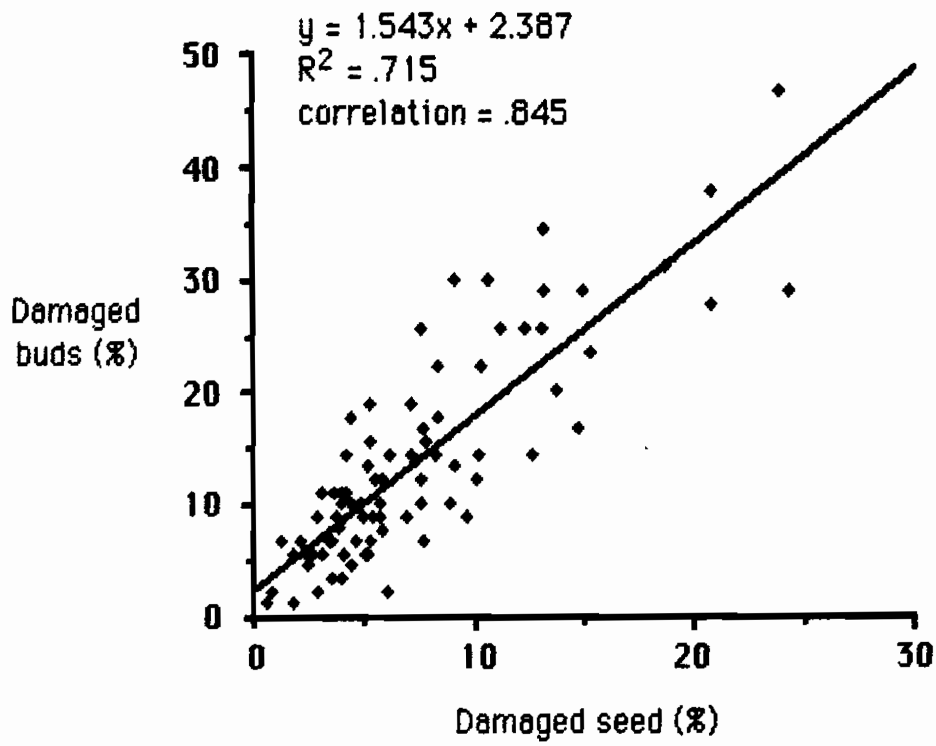


Figure 6. Relation between damaged inflorescences (buds) and damaged seed in accessions of Stylosanthes guianensis caused by the budworm Stegasta bosquella under conditions of natural infestation in the field at Quilichao.

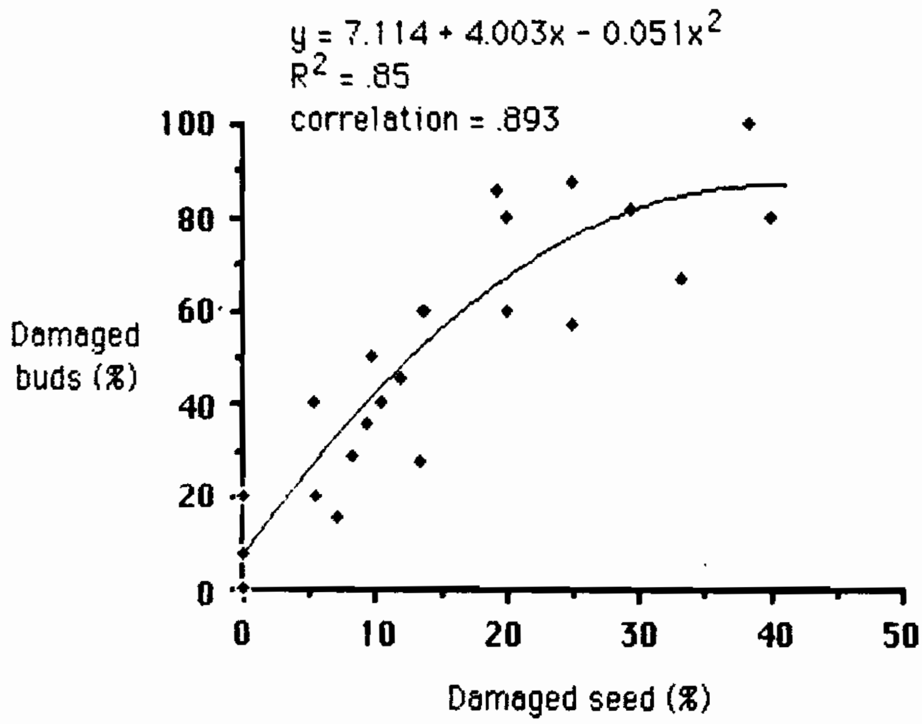


Figure 7. Relation between damaged inflorescences (buds) and damaged seed in accessions of Stylosanthes guianensis caused by the budworm Stegasta bosquella under conditions of artificial infestation in the glasshouse at Palmira.

Table 7. Combined analysis over five evaluation dates of percent damage to inflorescences caused by Stegasta bosquella on 18 accessions of Stylosanthes guianensis var. pauciflora at Quilichao. 1986.

CIAT Accession No.	Presence of glandular tricomes	Damaged buds (%)*	CIAT Accession No.	Presence of glandular tricomes	Damaged buds (%)*
1317	+	6.12a	1062	+	11.80abcd
2639	+	7.27ab	1808	+	13.16abcd
1639	+	7.93ab	2222	+	14.86bcde
2646	+	8.03ab	15	-	17.28cdef
2031	+	9.00abc	1539	+	19.35defg
1633	+	9.32abc	1873	-	24.17efg
2357	+	9.41abc	2312	-	25.87fg
2127	+	9.60abc	1122	-	25.91fg
1275	+	11.22abcd	1949	-	30.30g

* Means followed by the same letter are not significantly different ($\alpha = 0.05$), comparison-wise error date, Duncan's Multiple Range Test.

Table 8. Damage to inflorescences of 8 accessions of S. guianensis var. pauciflora caused by Stegasta bosquella under glasshouse conditions at Palmira.

CIAT Accession No.	Damaged Buds (%)	CIAT Accession No.	Damaged Buds (%)
2639	8.9	15	24.5
1639	15.6	1539	40.0
1275	18.7	1873	60.0
1875	24.4	2312	68.9

STEMBORER

Stemborer (Caloptilia species) damage in 25 accessions of S. capitata (including 15 hybrids) and one accession of S. macrocephala was evaluated in associations with A. gayanus under conditions of natural infestation in the field at Carimagua. In each plot, 13 plants were examined for larval entrance holes. No evidence of stemborer attack was observed on S. macrocephala CIAT 1643 (Table 9). S. capitata CIAT 1318 also showed little damage.

Table 9. Incidence and severity of stemborer attack in July 1985 on 26 accessions of Stylosanthes species grown in association with A. gayanus at Carimagua.

CIAT Accession[1] No.	Incidence[2]	CIAT Accession[1] No.	Severity[3]
*1643	0.0	*1643	0.0
1318	2.3	1318	2.8
1441	3.5	1441	5.0
1019	4.3	2044	5.8
1342	4.8	1019	6.3
2044	5.0	1315	6.3
7	5.3	1728	7.8
1315	5.3	7	8.3
19	5.5	9	8.3
23	6.5	1342	8.3
1728	6.5	1693	11.3
2252	7.3	13	12.3
9	7.5	cv. Capica	12.3
cv. Capica	7.5	23	12.8
13	7.8	2252	12.8
1693	7.8	19	13.5
22	8.3	15	14.3
12	8.5	4	17.0
4	8.8	22	17.0
15	9.0	27	17.8
21	9.3	21	18.8
11	9.8	12	19.0
27	9.8	11	19.8
25	10.0	25	19.8
16	10.3	16	21.3
14	10.8	14	24.3

* S. macrocephala. Other accessions are all S. capitata.
1/ Thirteen plants evaluated in each of 4 replications.
2/ Mean number of plants (out of 13) with larval entrance holes.
3/ Mean number of entrance holes per plant.

Plant Pathology

The responsibilities of the Plant Pathology Section during 1986 included:

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

2. Identification and assessment of diseases of germplasm under pasture evaluation.

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

More emphasis was given to the latter two responsibilities in 1986 than in previous years.

A. STUDIES ON FUNGI AND BACTERIA ASSOCIATED WITH TROPICAL PASTURE PLANTS

Comparative studies of isolates of Colletotrichum gloeosporioides from a range of hosts and environments

A large backlog of more than 1000 isolates was evaluated during the last six months in comparative pathogenicity studies. Hosts included *Pueraria phaseoloides*, *Centrosema* spp., *Stylosanthes* spp. Anthracnose caused by *C. gloeosporioides* was reported as a foliage disease of *P. phaseoloides* accessions in 1985 in the Llanos ecosystem. It was also found in the Cerrados ecosystem on similar accessions in 1986. Comparative studies of isolates obtained from pods and foliage from both sites on six accessions of *P. phaseoloides* clearly showed that isolates are of similar pathogenicities in Brazil and Colombia. *Pueraria phaseoloides* CIAT 17292 and 17293 were least affected by anthracnose.

Colletotrichum gloeosporioides isolates obtained from pod anthracnose of several *Centrosema* species were pathogenic to seedlings of the same species. This has implications for treatment of seed from anthracnosed pods to avoid seedling disease.

Comparison of a group of isolates from cultivated plots and native populations of *Stylosanthes capitata*, *S. pilosa*, *S. scabra* and *S. macrocephala* clearly showed close relationships between the four species with respect to their spectra of pathogenic isolates. As these species commonly occur together in native populations, similarities in race structure was not unexpected.

The finding of major differences in the race structure among populations of *C. gloeosporioides* from *S. guianensis* in the Brazilian Cerrados and elsewhere was confirmed. Among a large collection of *C.gloeosporioides* isolates, the greatest proportion of isolates were virulent only on *S. guianensis* var. *pauciflora*; few isolates being virulent on both var. *vulgaris* and var. *pauciflora* and on var. *vulgaris* alone. In contrast, the race structure of other *C. gloeosporioides* populations from the Llanos and the humid tropics is predominantly the latter two kinds of isolates. It was also interesting to note that only a very small proportion of isolates collected in the Brasilian Cerrados to date are virulent on the "giant" S. guianensis var. vulgaris characterized by CIAT 2950 and 2951. The localized distribution of this morphological type is thought to be responsible.

Reaction of 20 accessions of S. guianensis to anthracnose at nine different sites in Carimagua

Further evaluations were made with respect to the representativeness of the Pista screening site for S. guianensis anthracnose reactions in a collaborative project with the Plant Breeding Section in Carimagua. The original seven sites planted in 1985 were expanded to nine with the inclusion of two further sites in "bajo" areas due to the excellent performance of S. guianensis in the similar Campo de Agronomia site in 1985. Comparison of mean anthracnose reactions clearly shows the high anthracnose stress at the Pista screening site in comparison to significantly lower levels at all other sites (Table 1). To date, the three "bajo" sites "Agronomia", "Puma 1" and "Puma 2" in addition to the distant "Alegria" site have extremely low mean anthracnose levels.

A comparison of the ranking of accessions across all sites planted in 1985 indicated different rankings at each site (Table 2). For example, CIAT 1927 was highly susceptible at Pista 1 ranking 7th but ranked 19th at Pista 2; 14th at Agronomia; 12th at Alegria; 13th at Acuario; and 16th at La Torre and Yopare (Table 2). Similarly, Graham, CIAT 1875, 1275, 1283, among others were most variable in ranking in anthracnose reaction across sites. In general, CIAT 2031, 1808 and 10136 were among the least affected at each site. Ranking differences of the 20 accessions among sites implies that the structure of the C. gloeosporioides population is different at each site. Further evaluation is needed to determine if the ranking is temporary or a stable situation.

Table 1. Comparison of mean reactions of 20 accessions of Stylosanthes guianensis to anthracnose in 9 sites in Carimagua from July, 1985 to October, 1986.

Site	Reaction to anthracnose
Pista 1	3.32 a
Acuario	2.78 b
Pista 2	1.16 c
La Torre	1.15 c
Yopare	1.11 c
Agronomia	0.78 d
Puma 2/86	0.75 d
Alegria	0.53 d
Puma 1/86	0.07 f

Means followed by different letters are significantly different according to Duncan's Multiple Range Test $P < 0.05$.

Evaluation of anthracnose development in a highly variable S. guianensis F2 population in association with A. gayanus and native savanna under grazing.

In collaboration with the Plant Breeding section, anthracnose development and race structure in a highly variable S. guianensis F2 population in association with A. gayanus and native savanna under three stocking rates are being evaluated in Carimagua. After 19 months, survival in the savanna association was considerably better under medium (6.2%) and high (3.6%) stocking rates than under the low (1.0%) stocking rate (Figure 1). Survival in the A. gayanus association was almost zero after 16 months (Figure 2). It is thought that competition with

Table 2. Reaction to anthracnose of 20 accessions of *S. guianensis* in nine sites of Carimagua, from July to August, 1986.

Pista 1 Accession	Pista 1 Ant.[1]	Pista 2 Accession	Pista 2 Ant.	Agronomia Accession	Agronomia Ant.	Alegria Accession	Alegria Ant.	La Torre Accession	La Torre Ant.	Acuario Accession	Acuario Ant.	Yopare Accession	Yopare Ant.	Puma 2[2] Accession	Puma 2[2] Ant.	Puma 1[2] Accession	Puma 1[2] Ant.
2312 a	4.54	Endeavour a	2.71	Graham a	1.71	Cook a	1.35	Cook a	2.17	136 a	4.17	Cook a	2.18	Graham a	2.25	Endeavour a	0.83
1283 a	4.54	Cook a	2.63	136 a	1.70	1539 ab	1.20	2312 ab	2.05	Endeav. ab	3.83	2243 ab	2.00	2812 a	2.17	1283 a	0.67
Cook ab	4.50	Graham ab	2.27	1875 a	1.67	Endeav. ab	1.15	Endeav. abc	1.98	Cook ab	3.77	136 ab	1.98	Endeav. ab	1.67	1280 b	0.00
Endeav. ab	4.44	2312 ab	2.26	Cook ab	1.52	1949 ab	1.13	136 abcd	1.90	184 abc	3.44	1280 ab	1.96	2312 abc	1.50	2031 b	0.00
136 ab	4.40	136 bc	1.78	Endeav. abc	1.28	1875 ab	1.13	1283 abcd	1.78	1875 abc	3.42	Endeav. ab	1.89	1949 abc	1.50	19136 b	0.00
2812 ab	4.39	1875 cd	1.50	2312 abc	1.28	Graham ab	1.05	Graham abcd	1.65	1949 abcd	3.39	2191 abc	1.80	1927 bcd	1.33	2243 b	0.00
1927 abc	4.18	1539 cde	1.41	2191 bcd	0.96	136 bc	0.92	1539 abdce	1.54	2312 abcd	3.29	1949 abcd	1.57	10136 cdef	0.67	2191 b	0.00
1949 abc	4.15	1949 cde	1.37	184 cde	0.85	2312 cd	0.65	2812 bcde	1.38	2243 abcd	3.28	Graham abcd	1.57	1875 cdef	0.67	1808 b	0.00
2191 abc	4.09	184 cde	1.35	1280 def	0.59	184 cd	0.59	1875 cdef	1.33	2812 abcd	3.22	184 abcde	1.26	136 cdef	0.67	1875 b	0.00
2243 abc	4.07	2191 cdef	1.24	1949 def	0.55	1275 de	0.52	184 cdef	1.30	1280 bcd	3.13	1539 bcdef	1.18	2191 def	0.50	2312 b	0.00
1280 abc	3.91	1283 cdef	1.15	2243 def	0.55	2031 ef	0.17	1949 cdef	1.30	Graham bcd	3.09	1875 bcdef	1.17	1275 def	0.50	1539 b	0.00
184 bc	3.78	2812 defg	0.89	1539 def	0.50	1927 ef	0.17	1275 defg	1.18	1539 bcd	3.05	2812 cdefg	0.85	1280 ef	0.33	136 b	0.00
1875 c	3.59	2243 efgh	0.80	1275 def	0.45	1280 ef	0.13	2191 efgh	0.92	1927 bcd	2.96	1283 defg	0.80	184 ef	0.33	184 b	0.00
1539 cd	3.54	1280 fghi	0.63	1927 def	0.44	2812 f	0.09	1280 fghi	0.67	2191 cde	2.72	2312 defg	0.65	2362 ef	0.33	1927 b	0.00
Graham de	2.92	1275 ghi	0.42	1283 def	0.42	2362 f	0.09	2243 ghi	0.59	1283 def	2.36	10136 efg	0.54	1283 f	0.17	1275 b	0.00
1808 e	2.44	2362 hi	0.24	2812 def	0.42	2191 f	0.09	1927ghi	0.52	2031 efg	1.97	1927 fg	0.28	2243 f	0.17	Graham b	0.00
2031 f	1.22	10136 hi	0.23	2031 def	0.37	1283 f	0.07	2031 hi	0.41	2362 fgh	1.48	1808 fg	0.24	1539 f	0.17	Cook b	0.00
2362 fg	0.87	2031 hi	0.18	2362 ef	0.18	2243 f	0.07	2362 i	0.13	1808 ghi	1.28	2362 g	0.15	Cook f	0.17	2362 b	0.00
10136 g	0.44	1927 i	0.13	10136 f	0.11	10136 f	0.04	1808 i	0.09	1275 hi	0.87	1275 g	0.04	2031 f	0.00	2812 b	0.00
1275 g	0.39	1808 i	0.92	1808 f	0.00	1808 f	0.00	10136 i	0.48	2031 g	0.04	1808 f	0.00	1949 b			0.00
X	3.32 a		1.16 c		0.78 d		0.53 d		1.15 c		2.78 b		1.11 c		0.76		0.07

1. Mean of 3 repetitions and 16 evaluations.
2. Planted in May, 1982.

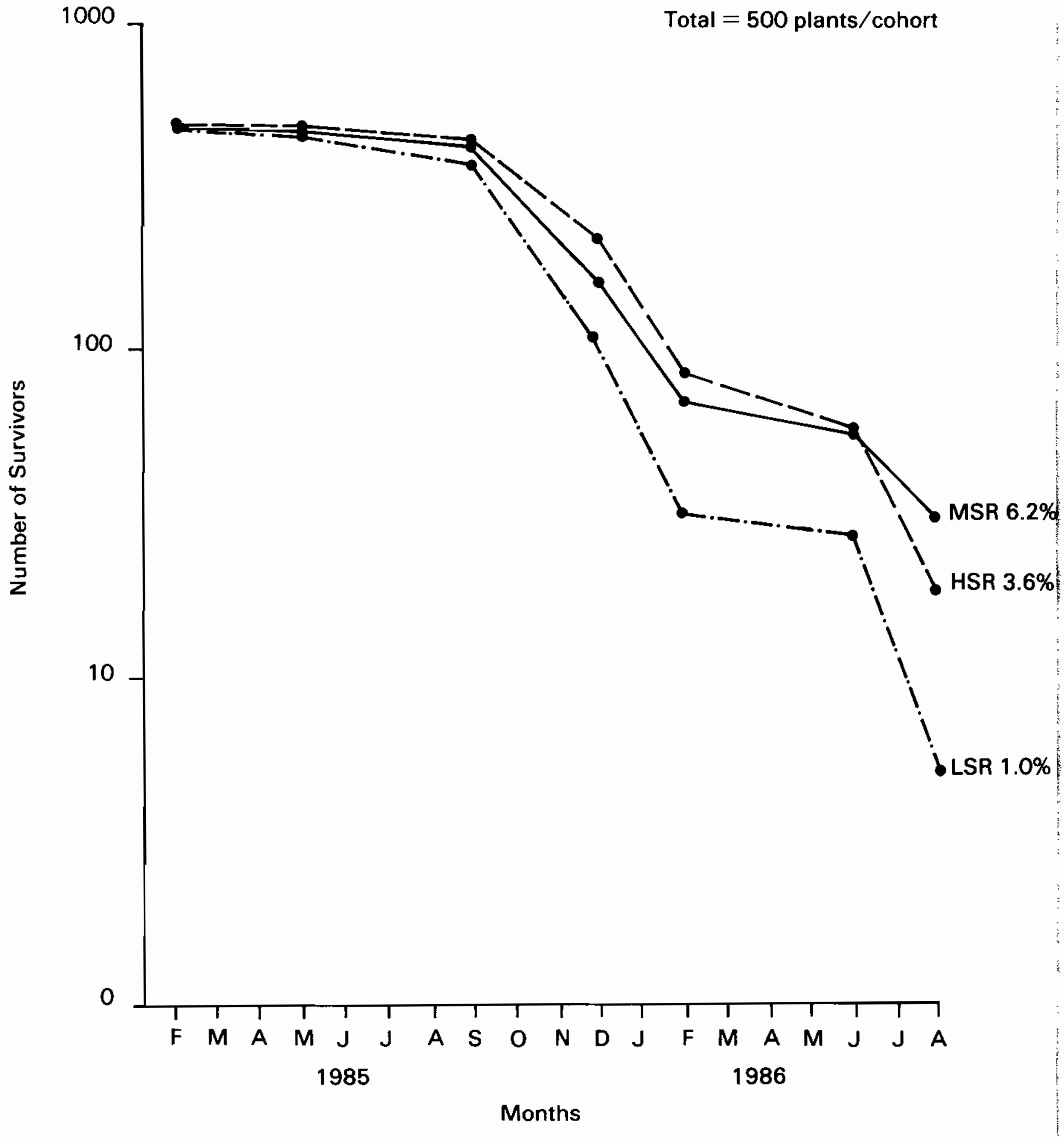


Figure 1. Survival of a heterogeneous populations of *Stylosanthes guianensis* in association with native Carimagua savanna with three different stocking rates from February 1985 to August 1986.

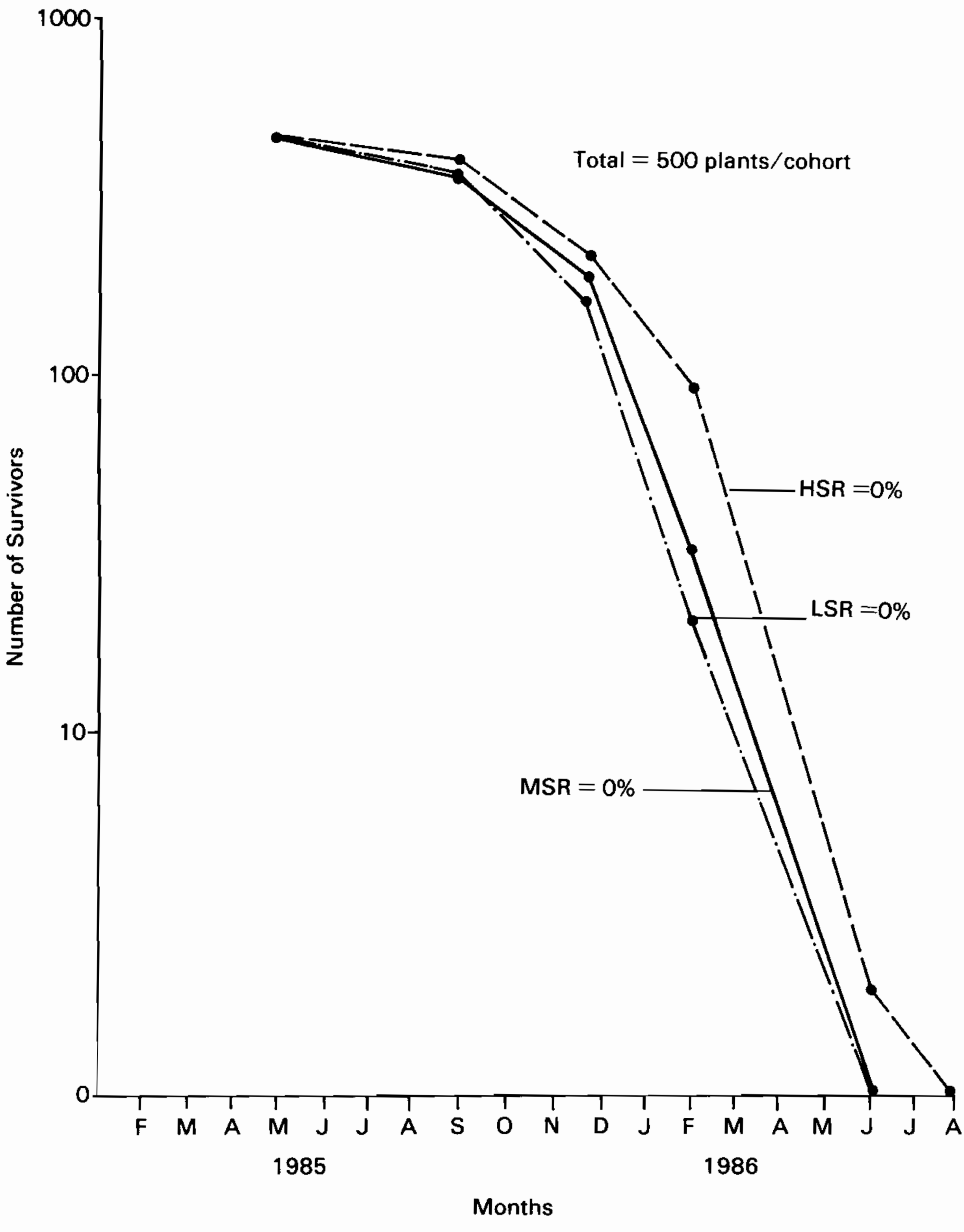


Figure 2. Survival of a heterogeneous populations of *Stylosanthes guianensis* in association with *Andropogon gayanus* with three different stocking rates from February 1985 to August 1986.

extremely vigorous A. gayanus for nutrients, water, light etc. is responsible for the lack of survival of S. guianensis.

Soil seed reserves are relatively low with 0.3 to 1.1 seed per kg dry soil (5 cm depth) in the savanna associations and from 0.2 to 0.7 seed per kg dry soil (5 cm depth) in the A. gayanus associations. Evaluations are continuing four times a year. Collections of anthracnose isolates are also being made for race structure studies. Both in 1985 and 1986, seedlings were sampled from new generations. These will be tested for anthracnose reaction to assess changes in population resistance over time.

Comparative studies of isolates of Rhizoctonia spp.

Comparative studies of approximately 50 isolates of Rhizoctonia spp. from 1984 to 1985 found a complex of three species Rhizoctonia sp. (binucleate), R. zeae and R. solani, including three anastomosis groupings, causing foliar blight of Centrosema spp. and other tropical pasture legumes in major ecosystems of the tropical American lowlands. The collection during 1986 was increased to 220 isolates. Of these, approximately 70% were from different sites in Carimagua, 15% were from the humid tropics (an increasing collection), approximately 10% were tester isolates from other countries while 5% were from other Latin American countries. Approximately 50% were R. solani and 50% R. sp. with very few isolates of R. zeae being found. In Carimagua, across a range of soil types and locations, both R.sp. and R. solani are widely distributed and equally common generally. Rhizoctonia sp. has been shown to dominate at a few sites (eg. Alegria). At the same time, about 80% were obtained from foliar blight of Centrosema spp. (primarily C. brasilianum) while others were obtained from foliar blight of Stylosanthes guianensis and S. macrocephala; Brachiaria spp., Desmodium spp., Pueraria phaseoloides, Cassia spp., Aeschynomene paniculatum, Arachis pintoi, Neonotonia wightii, Phaseolus vulgaris and from soil and mulch.

Pathogenicity tests were made with isolates of R. solani and R. spp. on Centrosema spp. in an attempt to compare inherent susceptibility of accessions. In a comparison of 5 isolates of R. sp.and R. solani on 7 accessions of C. brasilianum, mean virulence across isolates varied from 2.27 to 2.70 for R. sp. and from 2.39 to 2.89 for R. solani (Table 3). It was observed that CIAT 5178 was more susceptible to R. sp. Comparing mean virulence across accessions, isolates

Table 3. Comparison of the reaction of 7 accessions of Centrosema brasilianum to 5 isolates of Rhizoctonia spp. and of R. solani.

Accession of C. brasilianum CIAT No.	Reaction to R. sp.	R. solani
5178	2.66 ab	2.89 a
5365	2.20 c	2.59 b
5810	2.46 b	2.54 bc
5234	2.70 a	2.53 bcd
5671	2.60 ab	2.49 bcd
5657	2.61 ab	2.43 cd
5514	2.27 c	2.39 d

0 = No disease, 5 = plant death.

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

of R. solani from Brachiaria decumbens CIAT 606 and from Phaseolus vulgaris 5564 were more virulent than any isolates from Centrosema spp. (Table 4). With the exception of R. sp. from CIAT 5247 (G), all isolates of R. sp. were of equal virulence. Isolates of R. solani, however, varied greatly in virulence across C. brasilianum accessions (Table 4).

Results clearly show considerable variation among isolates of both R. solani and R. sp. for virulence.

In a comparison of the reaction of 10 accessions of Centrosema spp. to 13 isolates of Rhizoctonia spp., C. macrocarpum CIAT 5065 and 5629, C. pubescens CIAT 438, and C. brasilianum CIAT 5234 were the most susceptible across the 13 isolates. C.macrocarpum CIAT 5452 and 5713 and C. acutifolium CIAT 5568 were the least susceptible (Table 5). C. macrocarpum CIAT 5065 was inherently more susceptible to 13 isolates of Rhizoctonia spp. than any of the three C. brasilianum while C. acutifolium CIAT 5277 was inherently more susceptible than CIAT 5568 (Table 5). As was noted in the previous

Table 5. Comparison of the reaction of 10 accessions of Centrosema spp. to 13 isolates of Rhizoctonia spp.

Species	Accession No.	Reaction*
C. macrocarpum	5065	3.37 a
C. pubescens	438	3.34 a
C. brasilianum	5234	3.31 a
C. macrocarpum	5629	3.28 a
C. brasilianum	5178	3.27 a
C. brasilianum	5514	3.15 ab
C. acutifolium	5277	2.95 bc
C. macrocarpum	5452	2.85 cd
C. macrocarpum	5713	2.82 cd
C. acutifolium	5568	2.62 d

* 0 = no disease, 5 = plant death. Means followed by different letters are significantly different at $P < 0.05$.

study, highest levels of virulence were shown by isolates of R. solani. R. zeae isolated from soil showed significantly lower virulence across 10 accessions of Centrosema spp. than either R. solani or R. sp. (Table 6).

Table 4. Comparison of the virulence of 5 isolates of Rhizoctonia sp. and R. solani on 7 accessions of Centrosema brasilianum.

Isolate No.	Isolate Source	Species of Rhizoctonia	Virulence
011	C.b. 5247 (F)	Rhizoctonia sp.	3.22 a
024	S.m. 10435	Rhizoctonia sp.	3.01 a
022	C.b. 5234	Rhizoctonia sp.	2.84 a
008	C.b. 5247 (C)	Rhizoctonia sp.	2.74 a
012	C.b. 5247 (G)	Rhizoctonia sp.	0.8 b
031	B.d. 606	R. solani	4.48 a
014	P.v. 5564	R. solani	4.18 b
004	C.b. 5369	R. solani	2.88 c
003	C.b. 5178	R. solani	0.83 d
002	C.m. 5372	R. solani	0.40 e

0 = No disease, 5 = plant death.
For each species, means followed by different letters are significantly different at $P < 0.05$.

Table 6. Comparison of the virulence of 13 isolates of Rhizoctonia spp. on 10 accessions of Centrosema spp.

Isolate	Source	Species of Rhizoctonia	Virulence
043	C. b. 5184	R. solani	4.40 a
031	B. d. 606	R. solani	4.38 a
042	C. b. 5178	R. solani	4.18 ab
046	C. a. 5278	R. solani	4.03 bc
047	C. p. 438	R. sp.	3.93 bcd
049	C. b. 5234	R. sp.	3.78 cd
048	C. m. 5062	R. solani	3.65 d
040	C. b. 5178	R. sp.	3.60 d
045	C. a. 5278	R. sp.	3.25 e
050	C. p. 438	R. sp.	2.07 f
041	C. a. 5568	R. sp.	1.35 g
044	C. b. 5178	R. solani	1.23 g
051	Soil	R. zeae	0.40 h

0 = no disease, 5 = plant death.
Means followed by different letters are significantly different at $P < 0.05$.

Reaction of eight accessions of Centrosema spp. to various diseases and pests at seven different sites in Carimagua.

Evaluation of Rhizoctonia foliar blight (RFB) and other diseases and pests of 8 accessions of Centrosema spp. continued at 7 sites widely distributed throughout Carimagua during 1986. With only one exception - the Alegria site - C. acutifolium CIAT 5568 was most affected by RFB (Figures 3-9), while C. macrocarpum CIAT 5062 was least affected by RFB except at the Alegria site (Figure 9) during 1986. RFB has been evaluated in the 7 sites since July 1985. Mean RFB recorded from May to November 1986 was generally greater than levels recorded from July to December 1985 which indicates a build-up of RFB at all sites during the past year. It is interesting to note that the susceptibility of Centrosema spp. to RFB under a wide range of field conditions in Carimagua is different to results from controlled glasshouse evaluations of inherent susceptibility. Particularly, C. macrocarpum CIAT 5062 was the most resistant accession under field conditions but inherently the most susceptible under controlled glasshouse conditions. Similarly, C. acutifolium CIAT 5568 was the most susceptible under field conditions but among the most resistant under controlled glasshouse conditions. It appears that other environmental or morphological factors are important in the development of RFB under field conditions in Centrosema spp. in Carimagua than is inherent susceptible. Various factors will be investigated in detail in Carimagua in 1987.

In addition to RFB, the reaction of 8 accessions of Centrosema spp. to Cercospora leaf spot and various insect pests was evaluated throughout the 7 sites from July 1985 to September 1986 (Tables 7-13). Without exception, greater levels of Cercospora leaf spot were recorded in C. macrocarpum CIAT 5062 than in any other Centrosema spp. Similarly, at almost all sites C. macrocarpum CIAT 5062 was most affected by leaf chewing insects and least affected by leaf sucking insects (Tables 7-13). Accessions of C. brasilianum particularly CIAT 5235 and 5514 were most affected by leaf sucking insects (Tables 7-13).

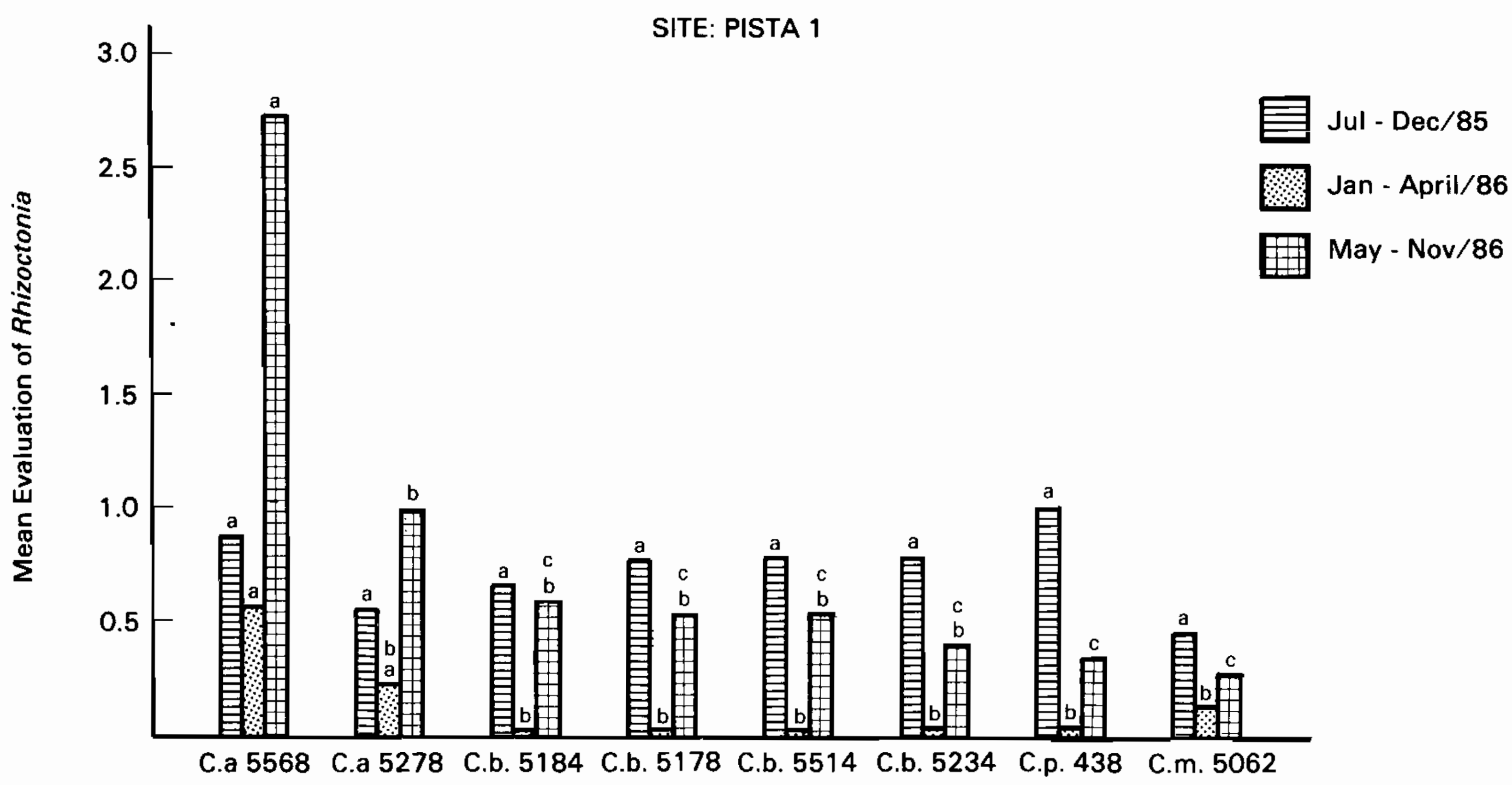


Figure 3. **Reaction to** ***Rhizoctonia*** **foliar blight across periods of eight accessions of** ***Centrosema*** **spp. in seven sites in Carimagua.**

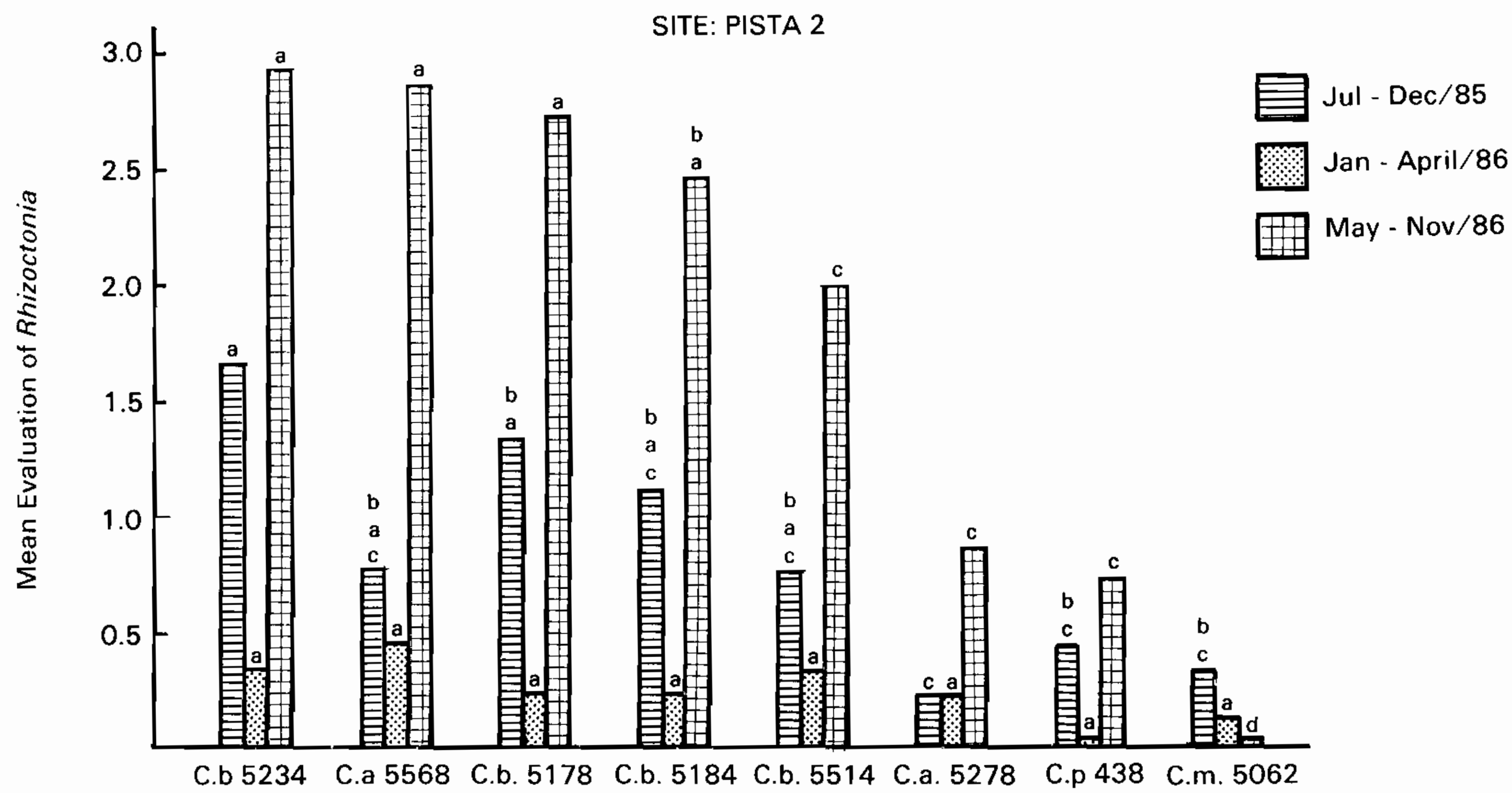


Figure 4. Reaction to *Rhizoctonia* foliar blight across periods of eight accessions of *Centrosema* spp. in seven sites in Carimagua.

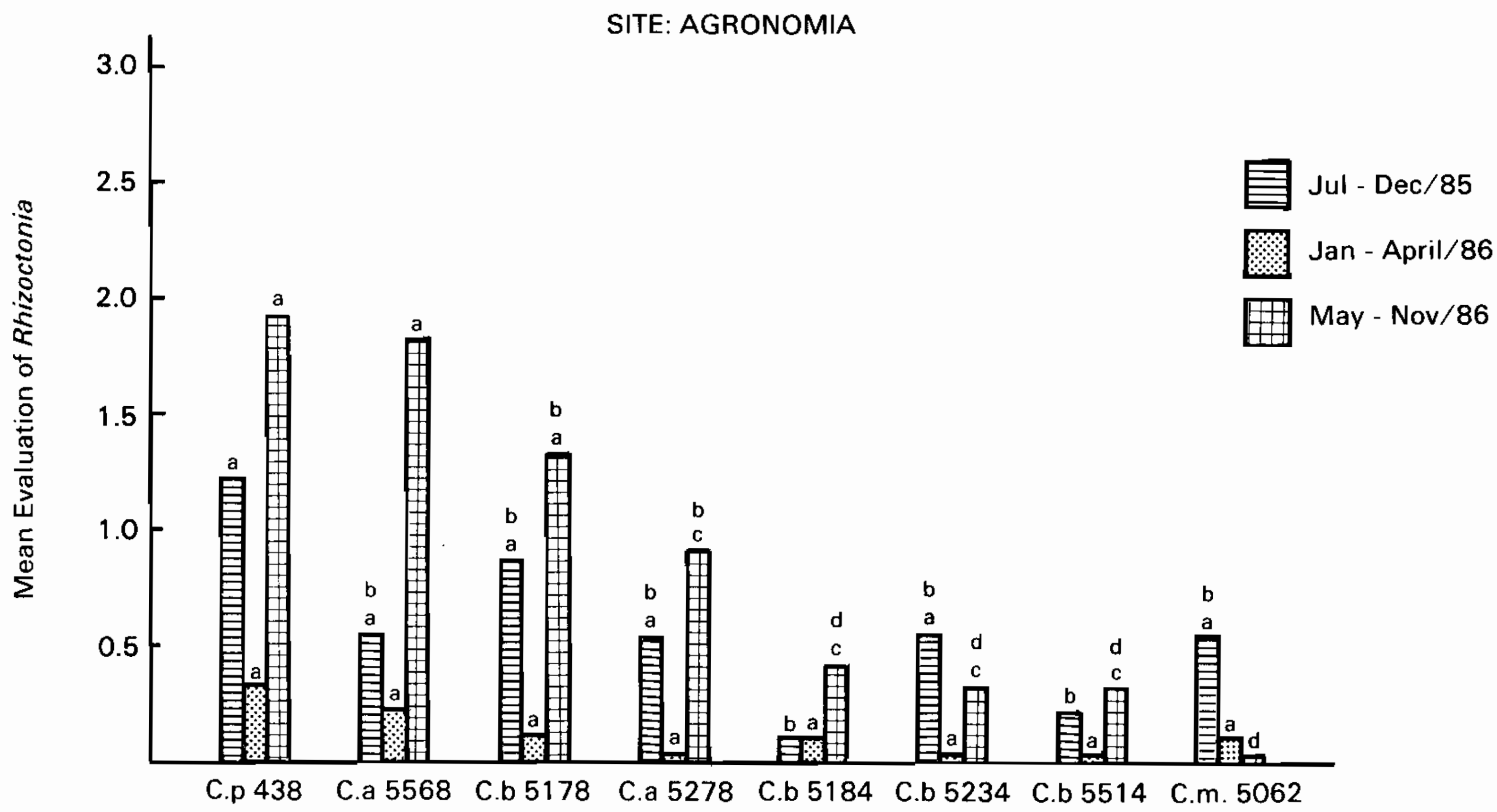


Figure 5. **Reaction to *Rhizoctonia* foliar blight across periods of eight accessions of *Centrosema* spp. in seven sites in Carimagua.**

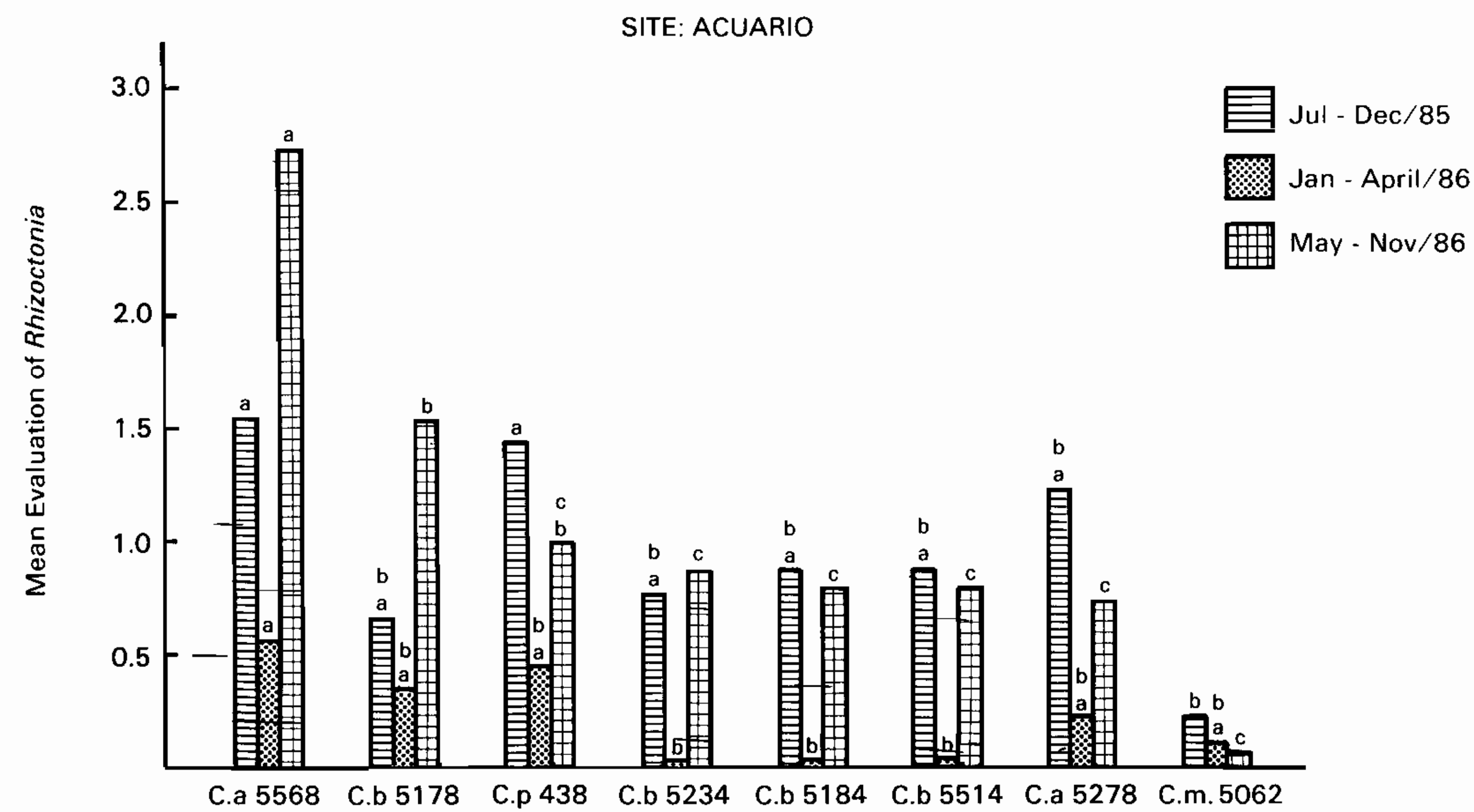


Figure 6. Reaction to *Rhizoctonia* foliar blight across periods of eight accessions of *Centrosema* spp. in seven sites in Carimagua.

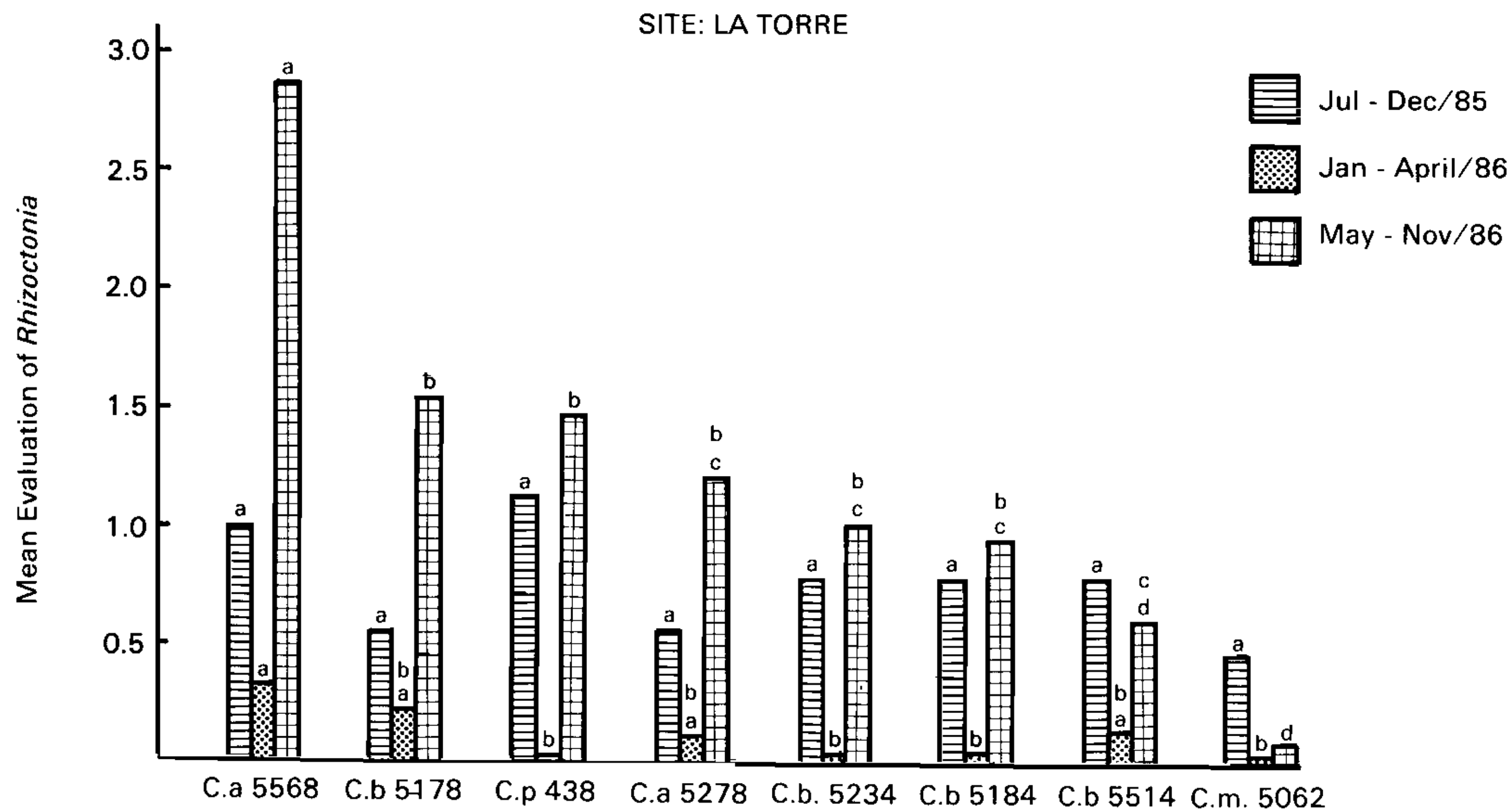


Figure 7. Reaction to *Rhizoctonia* foliar blight across periods of eight accessions of *Centrosema* spp. in seven sites in Carimagua.

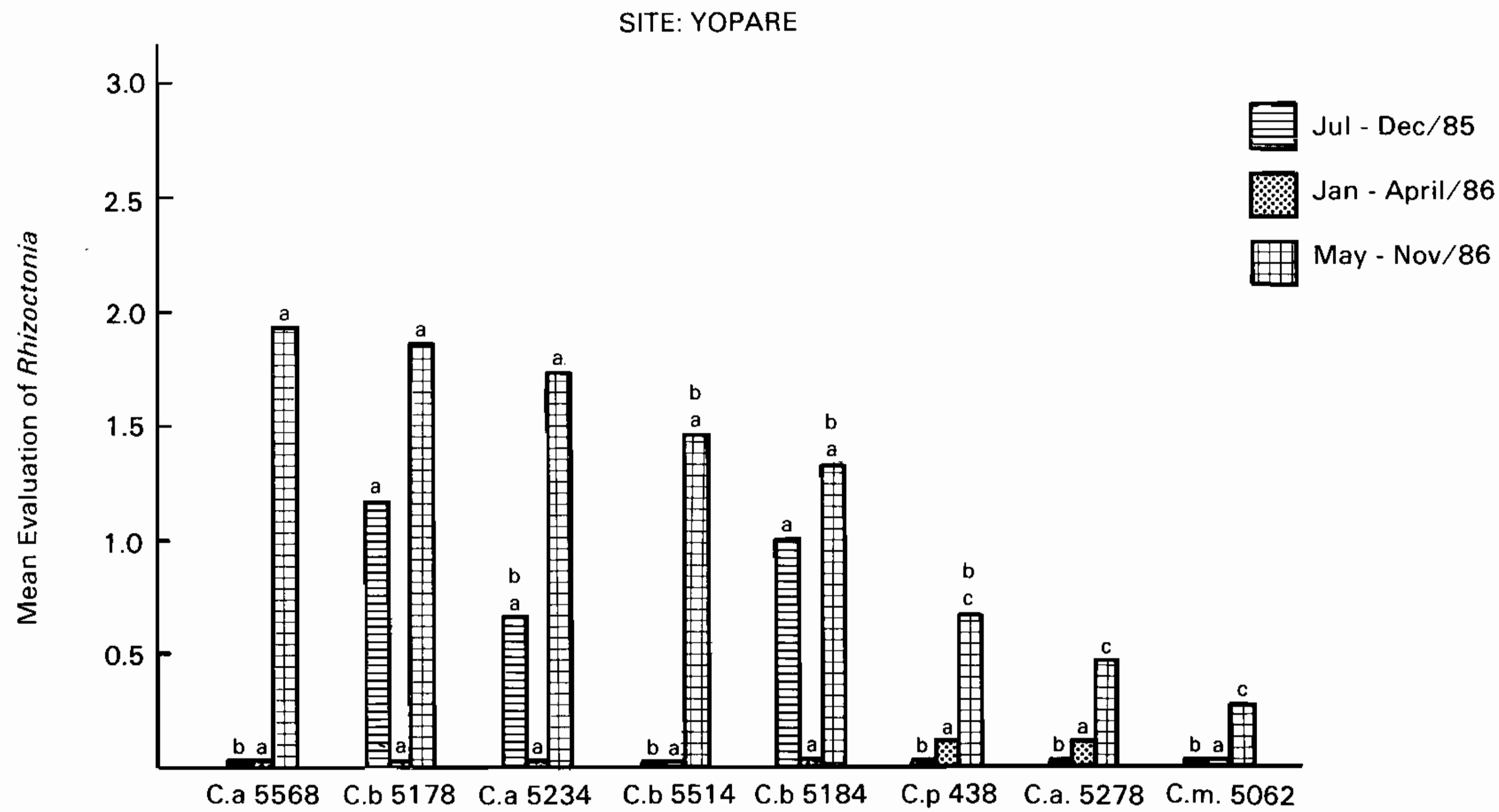


Figure 8. **Reaction to *Rhizoctonia* foliar blight across periods of eight accessions of *Centrosema* spp. in seven sites in Carimagua.**

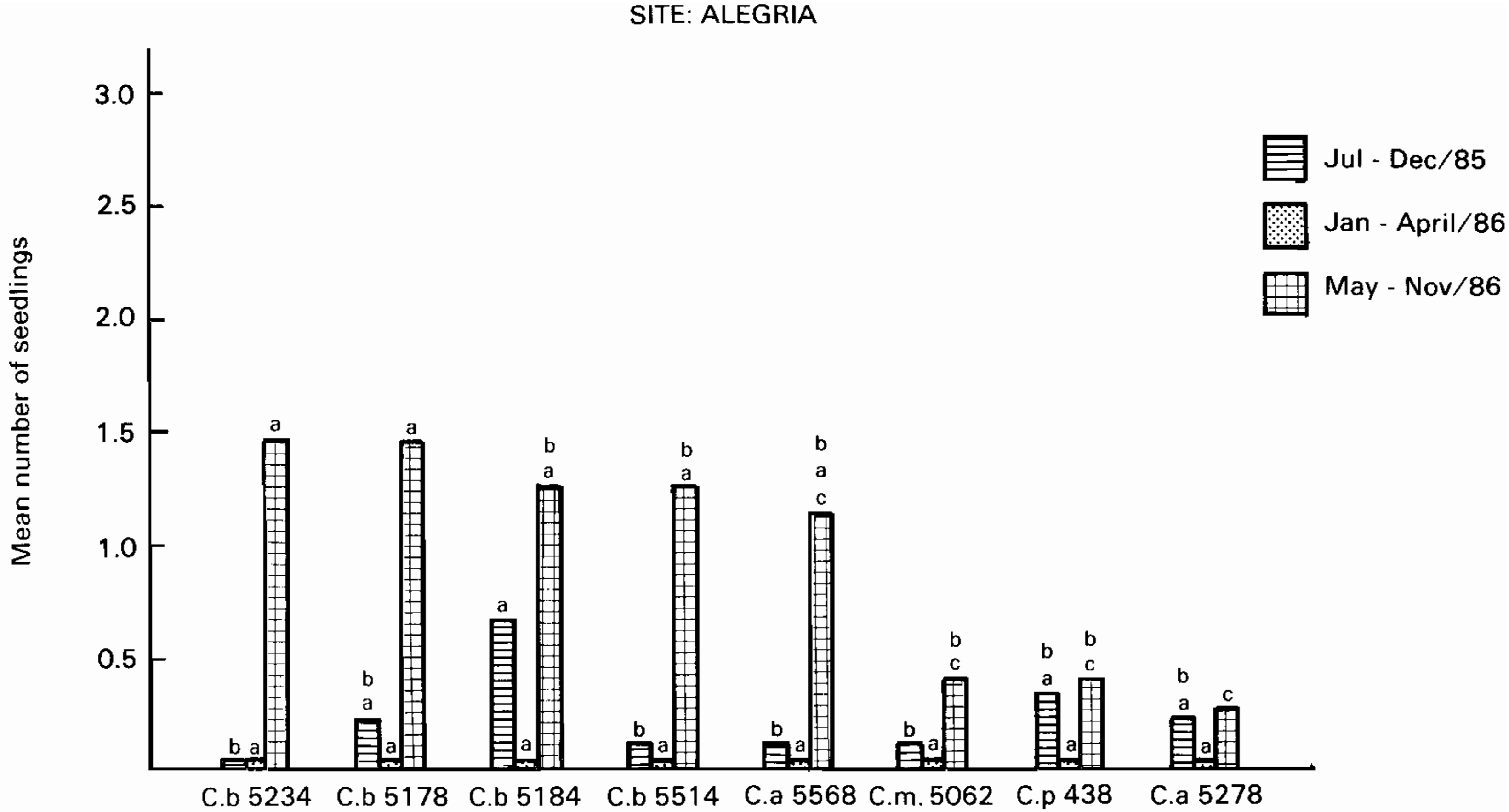


Figure 9. Reaction to *Rhizoctonia* foliar blight across periods of eight accessions of *Centrosema* spp. in seven sites in Carimagua.

Table 7. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: Pista 1.

Especie	Accession	CLS	Reaction to		Vigour
			Leaf eaters	Leaf suckers	
C. macrocarpum	5062	0.81 a	0.83 a	0.00 c	2.00 dc
C. pubescens	438	0.61 ba	0.19 b	0.11 c	2.75 ba
C. brasilianum	5184	0.44 bc	0.00 b	1.22 ba	2.21 c
C. brasilianum	5178	0.22 dc	0.00 b	0.92 b	1.64 d
C. brasilianum	5234	0.22 dc	0.06 b	1.53 a	3.19 a
C. acutifolium	5278	0.11 dc	0.75 a	0.19 c	2.19 c
C. acutifolium	5568	0.11 dc	0.58 a	0.11 c	2.33 bc
C. brasilianum	5514	0.03 d	0.03 b	1.58 a	3.25 a

Means followed by different letters in vertical columns are significantly different at $P < 0.05$.
CLS = Cercospora leaf spot.

Table 8. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: Pista 2.

Especie	Accession	CLS	Reaction to		Vigour
			Leaf eaters	Leaf suckers	
C. macrocarpum	5062	0.83 a	1.31 a	0.03 b	1.92 b
C. pubescens	438	0.50 b	0.36 cb	0.08 b	2.27 b
C. brasilianum	5234	0.08 c	0.03 c	1.08 a	3.54 a
C. brasilianum	5178	0.06 c	0.00c	0.92 a	2.2 b
C. brasilianum	5184	0.06 c	0.00 c	0.89 a	2.20 b
C. acutifolium	5568	0.06 c	0.72 b	0.00 b	2.17 b
C. acutifolium	5278	0.03 c	0.64 b	0.28 b	1.27 b
C. brasilianum	5514	0.00 c	0.00 c	1.31 a	3.17 a

Means followed by different letters in vertical columns are significantly different at $P < 0.05$.
CLS = Cercospora leaf spot.

Of note is the reaction of C. pubescens CIAT 438 and C. acutifolium CIAT 5278 to Cylindrocladium leaf spot across the seven sites. This leaf spot was reported for the first time in 1985. Highest levels were recorded at Pista 1 (Figure 10). It is interesting to note that the variation in reaction to various disease and pest problems across seven sites in Carimagua of 8 accessions of Centrosema spp. is more or less consistent. The vigor and most resistant and susceptible accessions to the various problems are similar across sites. This information is extremely useful to future screening and selection of Centrosema spp. in Carimagua.

Table 9. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: Agronomia

Especie	Accession	CLS	Reaction to Leaf eaters	Reaction to Leaf suckers	Vigour
C. macrocarpum	5062	0.73 a	0.97 a	0.09 c	1.60 cd
C. pubescens	438	0.27 b	0.67 a	0.30 c	2.33 ba
C. brasilianum	5178	0.15 cb	0.06 b	0.94 ba	2.08 bcd
C. brasilianum	5234	0.15 cb	0.12 b	1.33 a	3.00 a
C. brasilianum	5184	0.12 cb	0.12 b	0.82 b	1.46 d
C. acutifolium	5278	0.09 cb	0.76 a	0.09 c	1.62 cd
C. brasilianum	5514	0.03 c	0.00 b	1.12 ba	2.42 ba
C. acutifolium	5568	0.00 c	0.94 a	0.09 c	2.22 bc

Means followed by different letters in vertical columns are significantly different at P < 0.05.
CLS = Cercospora leaf spot.

Table 10. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: Acuario

Especie	Accession	CLS	Reaction to Leaf eaters	Reaction to Leaf suckers	Vigour
C. macrocarpum	5062	1.00 a	1.22 a	0.22 b	2.50 bc
C. brasilianum	5184	0.11 b	0.11 b	1.31 a	2.07 c
C. acutifolium	5278	0.08 b	0.94 a	0.31 b	2.33 bc
C. pubescens	438	0.06 b	1.06 a	0.33 b	3.17 a
C. brasilianum	5234	0.06 b	0.00 b	1.58 a	2.77 ba
C. brasilianum	5514	0.06 b	0.00 b	1.69 a	2.73 ba
C. acutifolium	5568	0.06 b	1.11 a	0.19 b	2.83 ba
C. brasilianum	5178	0.03 b	0.17 b	1.17 a	1.92 c

Means followed by different letters in vertical columns are significantly different at P < 0.05.
CLS = Cercospora leaf spot.

Table 11. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: La Torre

Especie	Accession	CLS	Reaction to		Vigour
			Leaf eaters	Leaf suckers	
C. macrocarpum	5062	0.78 a	1.00 a	0.08 b	1.54 c
C. pubescens	438	0.33 b	1.06 a	0.00 b	2.31 ba
C. brasilianum	5184	0.25 cb	0.00 b	0.75 a	1.44 c
C. brasilianum	5234	0.22 cb	0.00 b	1.03 a	2.67 a
C. brasilianum	5178	0.06 c	0.03 b	0.89 a	2.42 ba
C. acutifolium	5278	0.03 c	0.81 a	0.00 b	1.50 c
C. brasilianum	5514	0.00 c	0.00 b	1.03 a	2.33 ba
C. acutifolium	5568	0.00 c	0.81 a	0.00 b	1.88 bc

Means followed by different letters in vertical columns are significantly different at $P < 0.05$.
CLS = Cercospora leaf spot.

Table 12. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: Yopare.

Especie	Accession	CLS	Reaction to		Vigour
			Leaf eaters	Leaf suckers	
C. macrocarpum	5062	1.11 a	0.81 a	0.08 e	1.79 b
C. acutifolium	5278	0.47 b	0.33 bc	0.19 de	2.13 b
C. pubescens	438	0.42 cb	0.69 ba	0.14 de	1.93 b
C. brasilianum	5184	0.17 cd	0.22 c	0.56 dc	1.83 b
C. acutifolium	5568	0.14 d	0.69 ba	0.19 de	1.73 b
C. brasilianum	5234	0.11 d	0.00 c	1.11 ba	3.10 a
C. brasilianum	5178	0.00 d	0.03 c	0.78 bc	1.85 b
C. brasilianum	5514	0.00 d	0.00 c	1.36 a	2.80 a

Means followed by different letters in vertical columns are significantly different at $P < 0.05$.
CLS = Cercospora leaf spot.

Table 13. Vigour and reaction of eight accessions of Centrosema spp. to different phytosanitary problems in seven sites in Carimagua from July/85 to September/86. Site: Alegria.

Especie	Accession	CLS	Reaction to Leaf eaters	Reaction to Leaf suckers	Vigour
C. macrocarpum	5062	0.78 a	0.14 ba	0.08 b	1.53 b
C. pubescens	438	0.61 ba	0.06 bc	0.03 b	2.27 a
C. acutifolium	5278	0.42 bc	0.22 a	0.03 b	1.20 b
C. acutifolium	5568	0.33 bcd	0.06 bc	0.03 b	1.47 b
C. brasilianum	5514	0.25 ecd	0.00 c	0.75 a	2.43 a
C. brasilianum	5184	0.08 cd	0.00 c	0.25 b	1.20 b
C. brasilianum	5234	0.08 cd	0.00 c	0.48 a	2.06 a
C. brasilianum	5178	0.00 e	0.00 c	0.28 b	1.29 b

Means followed by different letters in vertical columns are significantly different at $P < 0.05$.
CLS = Cercospora leaf spot.

Effect of various soil treatments on development of Rhizoctonia foliar blight in three Centrosema spp.

Although the use of mulch to control RFB of beans has been most successful, use of A. gayanus mulch with various Centrosema spp. stimulated RFB during 1985 and 1986 (Table 14) probably due to fungal colonization of the mulch. In a pasture situation where mulch as litter may accumulate on the soil, more RFB would be expected. No differences were found between the control and the weed treatment while staked plants had significantly less RFB. This is likely to be due to their minimal contact with soil from which initial inoculum initiates.

Reactions of three accessions of three different species of Centrosema to RFB: Cercospora leaf spot (CLS), and eating and sucking insects were compared in the same experiment.

Table 14. Influence of different treatments* on 3 accessions of 3 different species of Centrosema to Rhizoctonia foliar blight.

Treatment	x/85	x/86
Mulch	1.67	1.24 a
Weeds	1.43	0.80 b
Stakes	0.40	0.25 c
Control	1.30	0.71 b

0 = no disease, 5 = dead.
* For rhizoctonia there were no differences among treatments.
Means followed by different letters are significantly different at $P < 0.05$

Although C. macrocarpum CIAT 5065 was the least affected by RFB, it was most affected by CLS and leaf eating insects (Table 15). At the same time, C. brasilianum CIAT 5234 was most

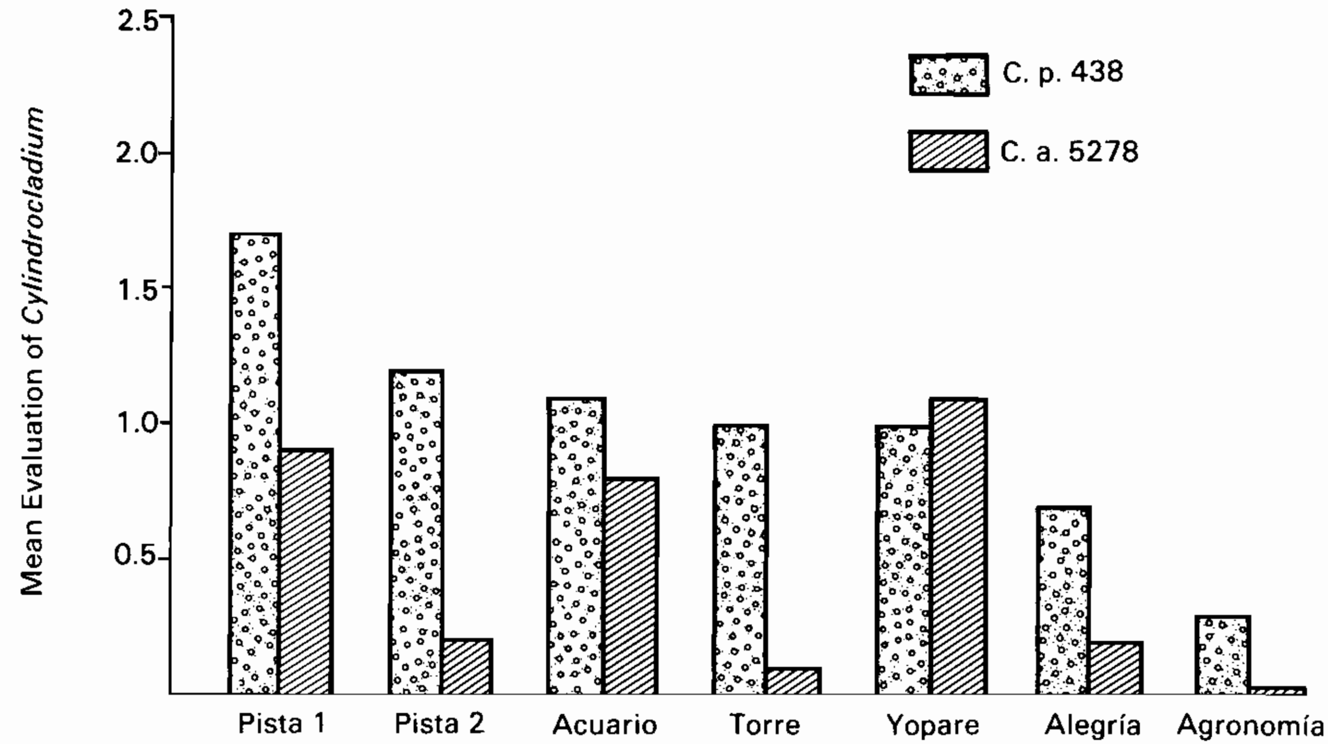


Figure 10. Incidente of *Cylindrocladium* leaf spot in *C. pubescens* CIAT 438 and *C. acutifolium* CIAT 5278 in seven sites in Carimagua from April to September, 1986.

affected by sucking insects and RFB with C. acutifolium CIAT 5568 in the latter case (Table 15).

As C. macrocarpum CIAT 5062/5065 were the most inherently susceptible accessions to RFB under controlled glasshouse conditions, it again appears that other factors are important in the development of RFB under field conditins. Growth habit may be one of those factors. Prostrate C. brasilianum CIAT 5234 was more affected that erect C. macrocarpum CIAT 5062/5065 across many sites in Carimagua during 1985 and 1986. This will be investigated in detail in Carimagua in 1987.

Effect of methods of soil preparation and ammendment on the severity of RFB in C. brasilianum CIAT 5234 in two sites in Carimagua.

A comparison of treatment on the severity of RFB in C. brasilianum CIAT 5234 in Alegria and Pista 2 from June to October, 1986 clearly showed differences at the Alegria site in comparison to the Pista 2 site (Table 16). At Alegria, highest levels of RFB were measured in the Rhizoctonia inoculated treatment. There were no significant differences among different soil preparation methods, however, treatments of fungicide, solarization, lime and burning had significantly lower levels of RFB. Burning is of great interest as it is a common practice in the Colombian llanos ecosystem. This experiment will continue through 1987.

Effect of RFB on C. brasilianum CIAT 5234 in association with A. gayanus and under grazing.

A trial to evaluate the effect of RFB on C. brasilianum CIAT 5234 in association with A. gayanus and under continuous grazing initiated in 1984 was continued during 1986 with additional observations under rotational grazing. Dry matter losses measured during 1986 followed the same trend with greater losses in CIAT 5234 due to RFB being measured under grazing and in association with A. gayanus. Dry matter losses ranged from 0 to 71% under the continuous grazing system

Table 15. Reaction of three accessions of three different species of Centrosema to their principal phytosanitary problems.

Species	Growth habit	Accession	Rhizoctonia	Cercospora	Leaf eaters	Leaf suckers
C. brasilianum	P	5234	0.98 a	0.19 b	0.00 c	2.40 a
C. acutifolium	SE	5568	1.24 a	0.33 b	0.85 b	0.72 b
C. macrocarpum	E	5065	0.02 b	1.67 a	1.26 a	0.38 b

0 = no disease; 5 = dead

P = prostrate; SE = semi-erect; E = erect.

Table 16. Effect of soil preparation methods on the severity of RFB in *C. brasilianum* CIAT 5234 in two sites in Carimagua, June to October, 1986.
Site 1: Alegria

Treatment	Evaluation RFB 0 = no disease; 5 = plant death
Inoculation *Rhizoctonia*	1.50 a
Control*	1.08 ab
Fertilization	1.08 ab
Mulch - *A. gayanus*	0.83 bc
Minimum preparation**	0.75 bcd
Traditional preparation***	0.67 bcde
Inoculation *Trichoderma*	0.58 bcde
Discs (5-10 cm)	0.50 bcde
Fungicide application (Benlate)	0.33 cde
Solarization	0.25 cde
Dolomite (10 t/ha)	0.17 de
Burning	0.08 e

* Native savanna cut + herbicide application.
** Chisel + offset disc.
*** Disc plow + 2 passes offset disc.

Site 2: Pista 2
Until now, there are no differences among treatment. Low levels of RFB = X = 0.08 → 0.42.

and from 0 to 48% under the rotational system. As was observed during 1984 and 1985, highest losses occurred under grazing and in association with *A. gayanus*. Recruitment of seedlings into the adult population under grazing was 2 plants/m^2 under continuous grazing and 0 plants/m^2 under rotational grazing. Soil seed reserves were extremely low being < 1 seed/kg dry soil to 5 cm depth with 7-12% germination over both grazing systems.

The sizable dry matter losses recorded in *C. brasilianum* under both grazing systems and the apparent low level of recruitment of new plants into the pasture cast doubt on the future of *C. brasilianum* CIAT 5234 as an associate of *A. gayanus* in this ecosystem.

Effect of *Synchytrium desmodii* on *Desmodium ovalifolium* CIAT 350 under grazing and in association with *Brachiaria decumbens*.

During 1985-1986, the greatest effect of *S. desmodii* was observed on seedling population. From June, 1985, the seedling population decreased from more than 500 seedlings/m^2 to 0 seedlings/m^2 in October, 1986 (Figure 11). The effect of *S. desmodii* on seedling recruitment is most clear.

Effect of *S. desmodii* on yield of *D. ovalifolium* CIAT 350 with and without flooding in Carimagua.

During evaluations of the incidence and severity of *S. desmodii* false rust disease in pastures of *D. ovalifolium* CIAT 350 in Carimagua, it became obvious that low lying frequently-flooded areas were more severely affected by false rust than rarely-flooded areas. This explained the normally patchy appearance of the disease in pastures.

During 1986, the effect of *S. desmodii* on yield of *D. ovalifolium* CIAT 350 with and without flooding was assessed. After five months of

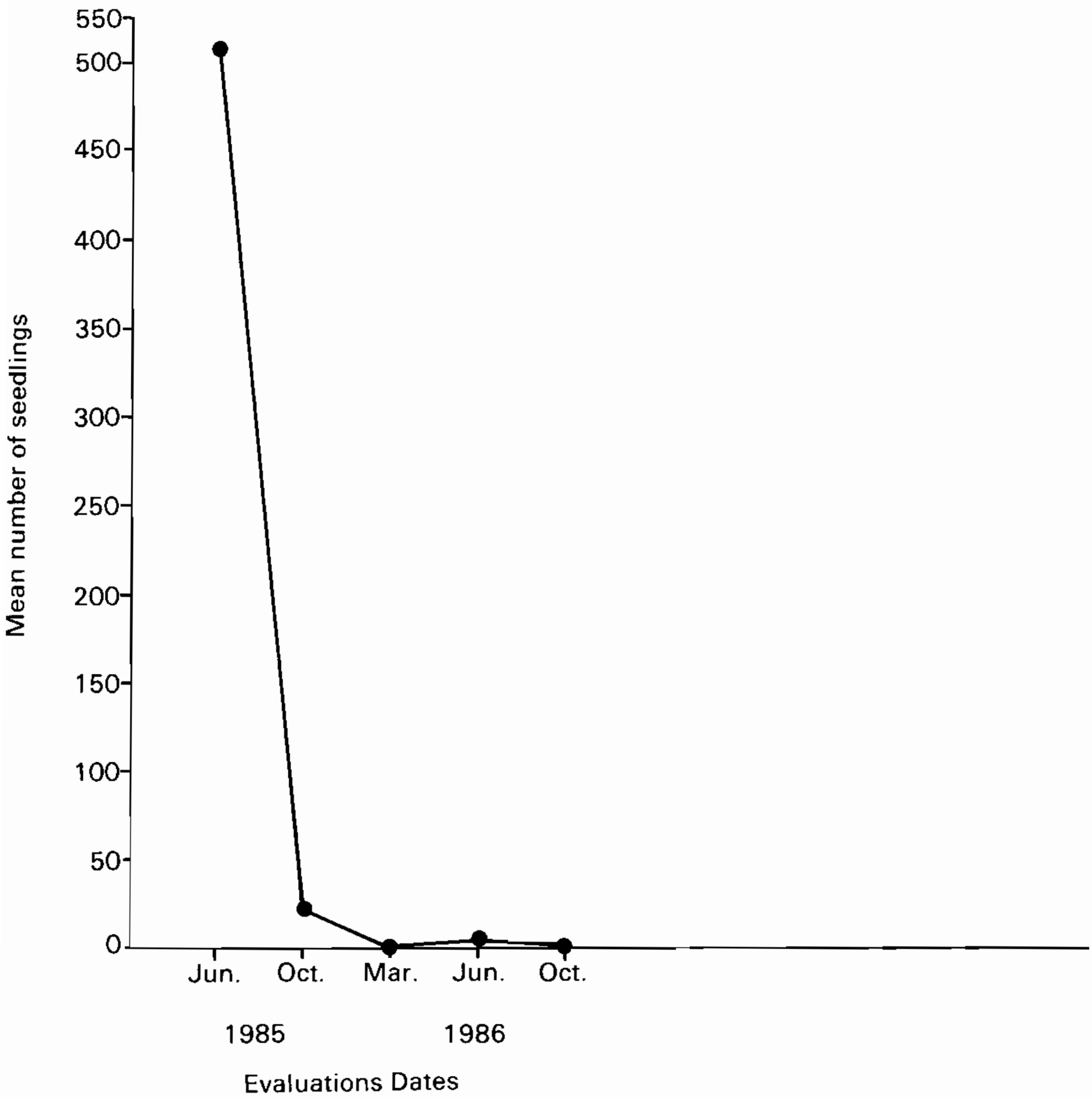


Figure 11. Effect of *Synchytrium desmodii* in populations of seedlings* of *D. ovalifolium* CIAT 350 under grazing in association with *B. decumbens*.

* Each mean is of 32 plots of 1 m^2

evaluation, in the inoculation treatments, levels of false-rust were significantly greater under flooding and dry matter yields were more than three times less under flooding (Table 17). This has precipitated the need to re-evaluate promising accessions of D. ovalifolium using this methodology. Interestingly, periodic flooding appeared to favour production of D. ovalifolium CIAT 350 in the non-inoculated treatment (Table 17).

Diseases of Leucaena spp.

In anticipation of the developing increased interest in Leucaena spp. with movement to the moderately acid soils, 138 accessions of more than 14 species were evaluated for diseases. Among diseases detected were Camptomeris leaf spot, pod rot caused by the bacterium Pseudomonas fluorescens Biotype II and Fusarium sp., powdery mildew and an unidentified micro-organism causing marginal necrosis. Comparing incidence of the three most common diseases: 79.0% of accessions were affected by Camptomeris leaf spot including all accessions of L. leucocephala, 93.5% of accessions were affected by bacterial pod rot and 81.9% by fungal pod rot. Among accessions unaffected by Camptomeris leaf spot were all accessions of L. macrophylla and L. lanceolata which may be of value in future breeding programs while a number of accessions of L. macrophylla, L. leucocephala, L. diversifolia and L. revoluta were unaffected by Fusarium sp. pod rot.

Camptomeris leaf spot was found to lower leaf protein content from 29.8% in healthy leaves to 22.5% in severely affected leaves of the same age. However, levels of Camptomeris leaf spot were less in eight week-old regrowth as compared with mature growth of accessions of L. leucocephala were (Table 18). This implies that a well managed L. leucocephala stand under a rotational grazing and/or cutting system could be maintained relatively free of damage from this disease.

The effect of growth medium and fungicide/bacteriocide treatment on the percentages of P. fluorescens and Fusarium sp. associated with seed from affected pods was determined. On both growth media, over 50% of seed was infected with P. fluorescens (Table 19).

Table 17. Effect of Synchytrium desmodii on yield of Desmodium ovalifolium CIAT 350 in Carimagua.

Treatment	Evaluation of Synchytrium	Dry weight/plot* (gr)
WITH INOCULATION		
With flooding	3.4 a	91.0
Without flooding	2.0 b	301.5
WITHOUT INOCULATION		
With flooding	0.0 c	331.7
Without flooding	0.0 c	289.0

* Mean of two harvests.
0 = no disease; 5 plant death.

Table 18. Reaction of 13 accessions of *L. leucocephala* to Camptomeris leaf spot in mature plants and 8 week-old regrowth.

Accessions	Reaction Mature plant	Regrowth
17222	2.0	0
17221	1.8	0.2
17219	1.6	0
17218	1.6	0
17220	1.6	0
9101	1.6	0.4
9437	1.4	0.3
17480	1.4	0
17482	1.4	0
17484	1.4	0.4
7988	1.1	0.9
766	1.1	1.0

0 = healthy, 2 = moderate level.

In the case of *Fusarium* sp., however, PDA selectively favoured isolation with 30.4% of seed being affected. The control of growth of the bacteria by seed treatment with Kocide resulted in levels of 39% of seed infection by *Fusarium* sp. Although Kocide treatment reduced substantially (to < 1.0%) the percentage infestation of seed with *P. fluorescens*, Difolatan was successful only in reducing percentage infestation of seed with *Fusarium* sp. to 13% (Table 19). The recommendation is that all seed from pods affected by bacterial and/or fungal pod rot should be treated with appropriate bacteriocides and/or fungicides.

Effect of fungi associated with seed of *Andropogon gayanus* CIAT 621 on seed germination and vigour and survival of seedlings.

Recent studies evaluating the problem of lack of vigour and survival in some lots of *A. gayanus* CIAT 621 have ignored the possible effect of seed-borne fungi. A preliminary survey of the fungi most frequently associated with *A. gayanus* CIAT 621 seed found *Rhizopus stolonifer* and *Fusarium* sp. to be most common. In a study of these two fungi alone and in mixture on the germination and vigour and survival of seedlings clearly showed no effect on germination. Levels ranged from 15.3 to 33.3% (Figures 12 and 13). There was however a considerable negative effect of both fungi on seedling vigour and survival. *Rhizopus stolonifer* was the most damaging, mean chlorosis of 5.0 and 93% dead plants being recorded four weeks after seed inoculation in contrast to 3.0 and 60% for *Fusarium* sp. (Figures 12 and 13). The mixture of fungi generally had less effect

Table 19. Effect of growth medium and fungicide/bacteriocide treatment on the percentages of *P. fluorescens* and *Fusarium* spp. associated with seed of 20 accessions of *Leucaena* spp.

Growth medium and treatment	% of seed affected by *P. fluorescens*	*Fusarium* sp.	*P. fluorescens* + *Fusarium* sp.
NA	55.1 a	16.6 bc	26.6 a
P.D.A.	52.5 a	30.4 abc	15.0 b
NA + Kocide	0.2 c	39.2 ab	3.1 c
P.D.A. + Difolatan	20.3 b	13.1 c	0.8 c

NA = Nutrient Agar
P.D.A.= Potato Dextrose Agar
Means in vertical columns followed by different letters are significantly different.

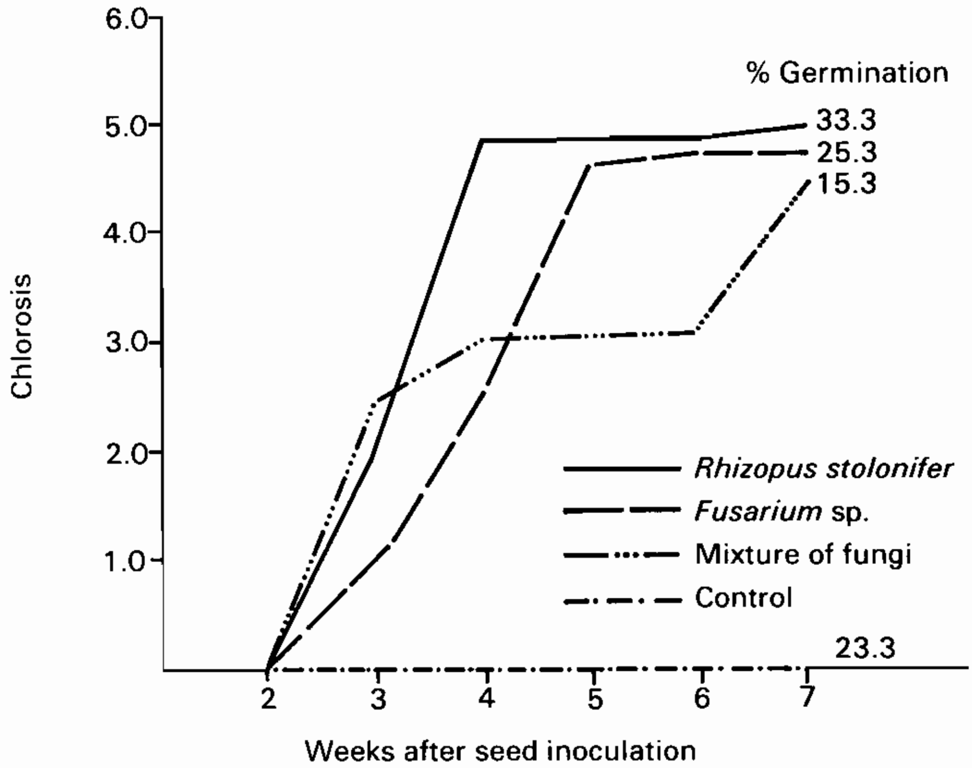


Figure 12. Effect of fungi associated with seed of A. gayanus CIAT 621 on germination and plant vigour.

probably due to dilution of the effect of R. stolonifer. Seven weeks after seed inoculation, 96-97% of seedlings had died in both fungal treatments. Seed-borne fungi may therefore have a considerable effect on the lack of vigour and survival of A. gayanus seedling stands.

Effect of harvesting methods and seed drying of Brachiaria dictyoneura CIAT 6133 harvested in Carimagua on its microflora, viability and germination*.

Twenty three different species of fungi, three species of bacteria and one yeast were detected on PDA. Among them were Curvularia pallescens, C. trifolii, Thielaviopsis sp., Rhizopus stolonifer, Paecilomyces sp., Phoma sorghina, Cladosporium oxysporum, Mucor hiemalis, Nigrospora sacchari, Botyodiplodia theobromae, Penicillium sp. Equally, three bacteria Enterobacter cloacae, Erwinia herbicola and Pseudomonas sp. and the yeast were also common before and after seed drying. The fungi Rhizoctonia sp. and R. zeae were only isolated before seed drying; while Phialophora sp., Trichoderma koningii, T. harzianum; Pestalotiopsis versicolor; Papulaspora sp.,

* Collaborative Ing. Agr. student thesis project between Plant Pathology and Seed Pathology Sections (Student: Rodrigo Torres).

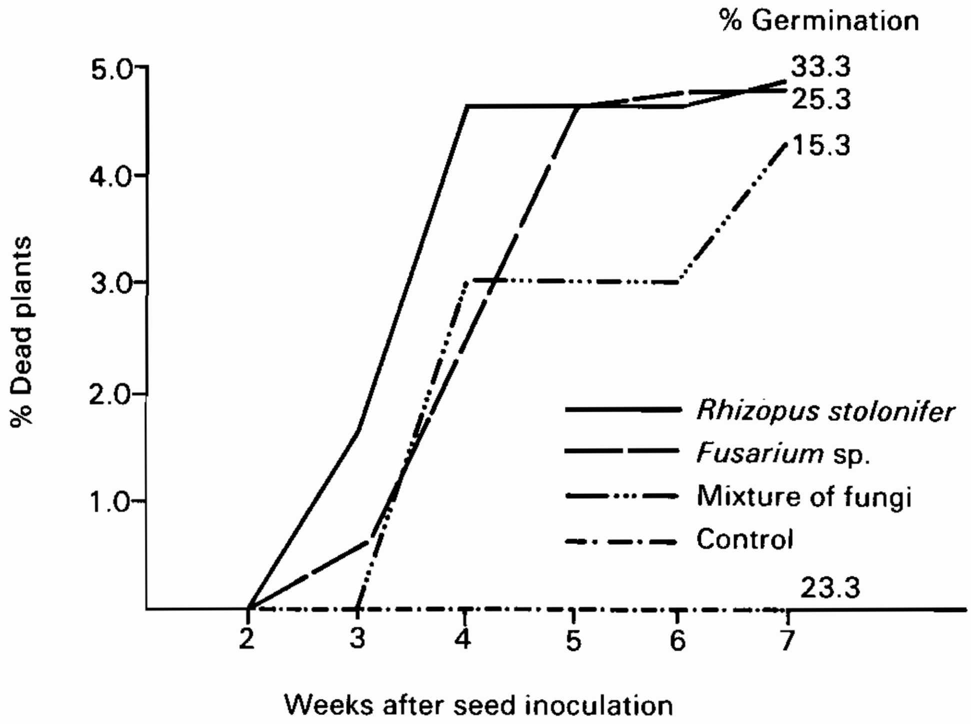


Figure 13. Effect of fungi associated with seed of A. gayanus CIAT 621 in germination and seedling survival.

Curvularia sp. and Penicillium sp. only manifested themselves after seed drying.

Potentially pathogenic fungi isolated included C. pallescens, Thielaviopsis sp., F. acuminatum, C. trifolii, P. sorghina, F. oxysporum, B. theobromae, P. versicolor, Rhizoctonia sp. and R. zeae. Drying did not have a great effect on the frequency of pathogenic fungi associated with seed with the exception of considerably reducing the percentage of F. acuminatum and considerably increasing the percentage of Phoma sorghina (Table 20). Although Rhizoctonia spp. were present before drying, they were not present after drying. At the same time a common antagonist Trichoderma koningii was detected only after drying (Table 20).

Among 12 different treatments, manual harvesting-horizontal pile-sweating 3 days with fungicide was the best treatment for controlling total frequency of micro-organisms. Prior to seed drying, lowest levels of potentially pathogenic fungi were recorded in the treatment manual harvesting + "pila apretada" + fungicide followed by manual harvesting-horizontal pile-sweating 3 days with fungicide. After seed drying, lowest levels of potentially pathogenic fungi were recorded in treatments combined harvesting + fungicide and again manual harvesting horizontal pile-sweating 3 days with fungicide.

Table 20. Mean isolation frequency (%) of potentially pathogenic fungi from seed of *Brachiaria dictyoneura* across harvesting methods before and after seed drying.

Fungus	Frequency %	
	Before drying	After drying
Botrydiplodia theobromae	28.9	26.2
Curvularia pallescens	37.7	33.8
Curvularia trifolii	5.5	4.2
Fusarium acuminatum	29.5	5.2
Fusarium oxysporum	< 1	< 1
Pestalotia sp.	-	< 1
Phoma sorghina	5.3	40.8
Rhizoctonia sp.	< 1	-
Rhizoctonia zeae	< 1	-
Thielaviopsis sp.	< 1	< 1
(*Trichoderma koningii*)	-	< 1

With respect to seed viability, an effect of sweating in the third month after harvesting was observed; the best treatment being combine harvesting with 81.5% viability, followed by manual harvesting without sweating with 72%. An effect of fungicide on seed viability was not observed.

An effect of seed harvesting method on seed germination of *B. dictyoneura*, was not observed but significant differences between techniques used to break seed dormancy were found. The technique Sulphuric Acid + Potassium Nitrate (H_2SO_4 + KNO_3) was the best with 42.9% germination while that with water (H_2O) was 0%. Potassium Nitrate KNO_3 was 1.31% and Sulphuric Acid (H_2SO_4) was 5%.

Pathogenicity of various seed-borne fungi to seedlings of S. capitata and S. macrocephala accessions

Several surveys of potentially pathogenic fungi associated with seed of *S. capitata* and *S. macrocephala* have isolated the following fungi: *Acroconidiella* sp., *Colletotrichum gloeosporioides*, *C. truncatum*, *Cylindrocladium* sp., *Diplodia* sp., *Pestalotia* sp., *Phoma sorghina*, *Phoma* sp., *Phomopsis* sp., *Pyrenochaeta* sp., *Stemphylium* sp. Results of pathogenicity tests carried out with seedlings of *S. capitata*, *S. macrocephala* and *S. guianensis* showed that only the *Colletotrichum* spp. were pathogenic; *C. gloeosporioides* being more virulent on *S. guianensis* accessions and *C. truncatum* being more virulent on *S. macrocephala* CIAT 2133.

Evaluation of the effect of various fungicides on growth of pathogenic isolates of Colletotrichum gloeosporioides and Rhizoctonia spp. in vitro.

The effect of various fungicides on

growth of pathogenic isolates of C. gloeosporioides and Rhizoctonia spp. in vitro was evaluated in an attempt to select the best fungicides for trials where disease control is necessary. With few exceptions, Vitavax (5,6-Dihydro-2-methyl-1,4-oxathiin-3--Carboxanilide) and Benlate (Methyl-(butylcarbomyl)-2-benzimidazo-lecarbamate) were the most effective fungicides over the 15 pathogenic fungi evaluated. Of note, was the inability of Benlate to substantially inhibit growth of C. gloeosporioides isolated from P. phaseoloides CIAT 4600. Of great interest was the inability of Furadan a nematocide, to inhibit growth of any pathogenic isolate (Table 21) and its ability to stimulate sporulation of C. gloeosporioides. Use of Furadan to control nematodes could stimulate fungal diseases. Recommendations can now be made of fungicide treatments to be used in specialized trials.

B. STUDIES ON NEMATODES ASSOCIATED WITH TROPICAL PASTURE PLANTS

Evaluation of resistance of D. ovalifolium to stem gall nematode - Carimagua.

Evaluation of the screening trial established in 1984 in Carimagua continued during 1986. By October 1986, those accessions which had significantly lower gall ratings than CIAT 350 included CIAT 3607, 3776, 3788, 13088, 13089, 13092, 13114, 13119, 13121, 13129, 13131, 13134, 13136 and 13371 (Table 22). Most were among the most promising in 1985.

Evaluation of resistance of D. ovalifolium to stem gall nematode - glasshouse.

Resistance screening continued in the glasshouse with a further 15 accessions evaluated. All accessions produced signficantly fewer nematodes than CIAT 350 and are classed as resistant (Table 23).

Definition of tolerance limits of accessions of Desmodium ovalifolium to Pterotylenchus cecidogenus.

Field and glasshouse trials (Annual Report 1985) have shown that several accessions allowed less reproduction of P. cecidogenus than did CIAT 350 (i.e. they were more resistant). This, however, did not correlate with gall production in the field. To determine whether tolerance (i.e. the ability of the plant to withstand damage caused by the nematode) played a role on gall production, accessions CIAT 350 and 13136 were compared. Both accessions allowed similar nematode reproduction under glasshouse conditions but CIAT 13136 produced significantly less gall tissue in the field than did CIAT 350. Both accessions were inoculated with a range of nematode densities. After 40 days shoot and root weight, shoot and root length and gall weight were measured.

Figures 14-16 show that, for all parameters, the accessions reacted differently. At the same initial nematode density, CIAT 350 was more affected and produced more gall tissue than did CIAT 13136. Tolerance, as well as resistance, is important in determining the success of an accession when infested by stem gall nematode. If it is assumed that tolerance determines the amount of gall tissue produced then CIAT's germplasm collection of D. ovalifolium contains accessions with each combination of resistant/susceptible and tolerant/intolerant. Further work on tolerance of promising accessions to P. cecidogenus is in progress.

Host range of D. ovalifolium

Accessions of several Desmodium species were tested in the glasshouse for host status using the resistance evaluation method. The number of nematodes found in each was expressed as a percentage of that found in CIAT 350 (Table 24). Only D. intortum

Table 21. Effect of various fungicides on control of growth *in vitro* of pathogens of species of *Stylosanthes*, *Centrosema* and *Pueraria*.
Method: Growth medium + fungicide - % of fungal growth.

Isolates	Benlate			Furadan			Kocide			Vitavax			Difolatan			Saprol		
	H	M	L*	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
C. gl. CIAT 1653 Pucallpa, Peru	30	6	11	100	100	100	0	25	30	0	0	0	0	0	0	2	63	83
C. gl. CIAT 1493 Carimagua, Colombia	0	5	8	100	100	100	2	10	12	0	5	5	0	5	7	7	10	12
C. gl. CIAT 2625 Brasil	0	0	0	100	100	100	0	0	25	0	0	0	0	0	0	0	25	75
C. gl. CIAT 126 Quilichao	0	0	0	100	100	100	90	90	95	0	0	0	0	4	5	0	5	80
C. gl. CIAT 2078 Carimagua, Colombia	0	0	0	100	100	100	0	0	20	0	0	0	0	0	0	0	0	7
C. gl. CIAT 1019 Brasil	0	0	0	100	100	100	0	0	12	0	0	0	0	0	0	0	0	17
Rhizoctonia sp. (CIAT 5278)	0	0	0	100	100	100	0	0	15	0	0	0	20	20	25	0	0	0
R. solani (CIAT 5568)	0	0	0	90	90	100	2	30	30	0	0	0	15	15	25	0	0	3
R. solani (CIAT 5369)	0	0	0	90	95	100	5	20	30	0	0	0	10	10	10	0	0	5
R. sp. (CIAT 438)	0	0	0	100	100	100	1	3	10	0	0	0	20	30	30	0	0	17
R. solani (CIAT 5065)	0	0	0	100	100	100	1	2	10	0	0	0	15	15	15	0	0	0
R. sp. (CIAT 5062)	0	0	0	100	100	100	0	0	17	0	3	2	10	30	30	0	10	20
C. gl. 438 Quilichao	0	0	0	100	100	100	0	0	0	0	0	0	0	10	20	0	0	47
C. gl. 469 Quilichao	0	0	0	100	100	100	0	0	0	0	0	0	0	0	0	0	3	30
C. gl. 4600 Carimagua	40	100	100	100	100	100	10	15	20	0	0	0	0	0	0	23	80	80

* Doses: H = High, M = Medium, L = Low
C. gl. = *Colletotrichum gloeosporioides*

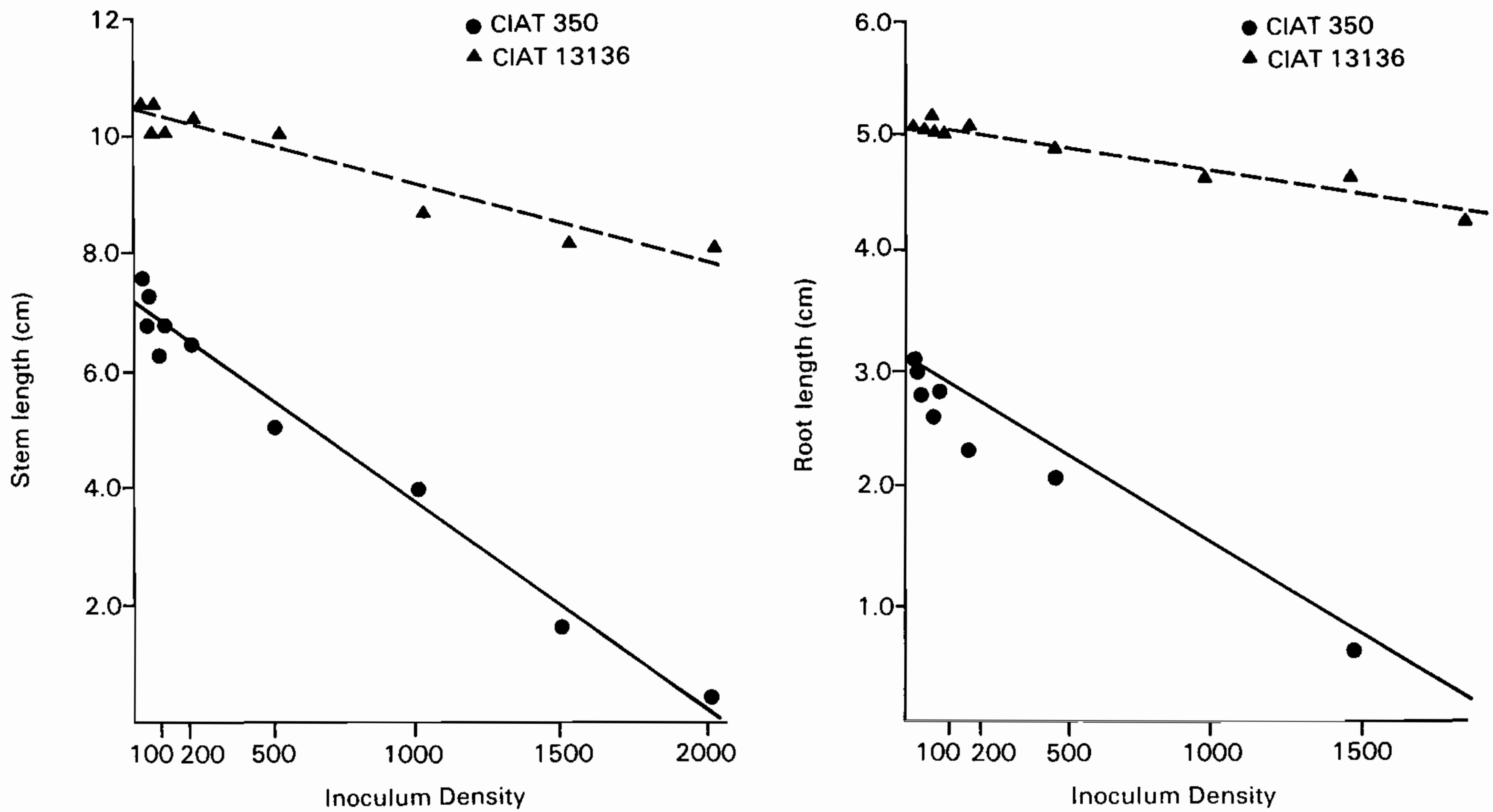


Figure 14. Effect of inoculum density on stem and root length of *D. ovalifolium* CIAT 350 and 13136.

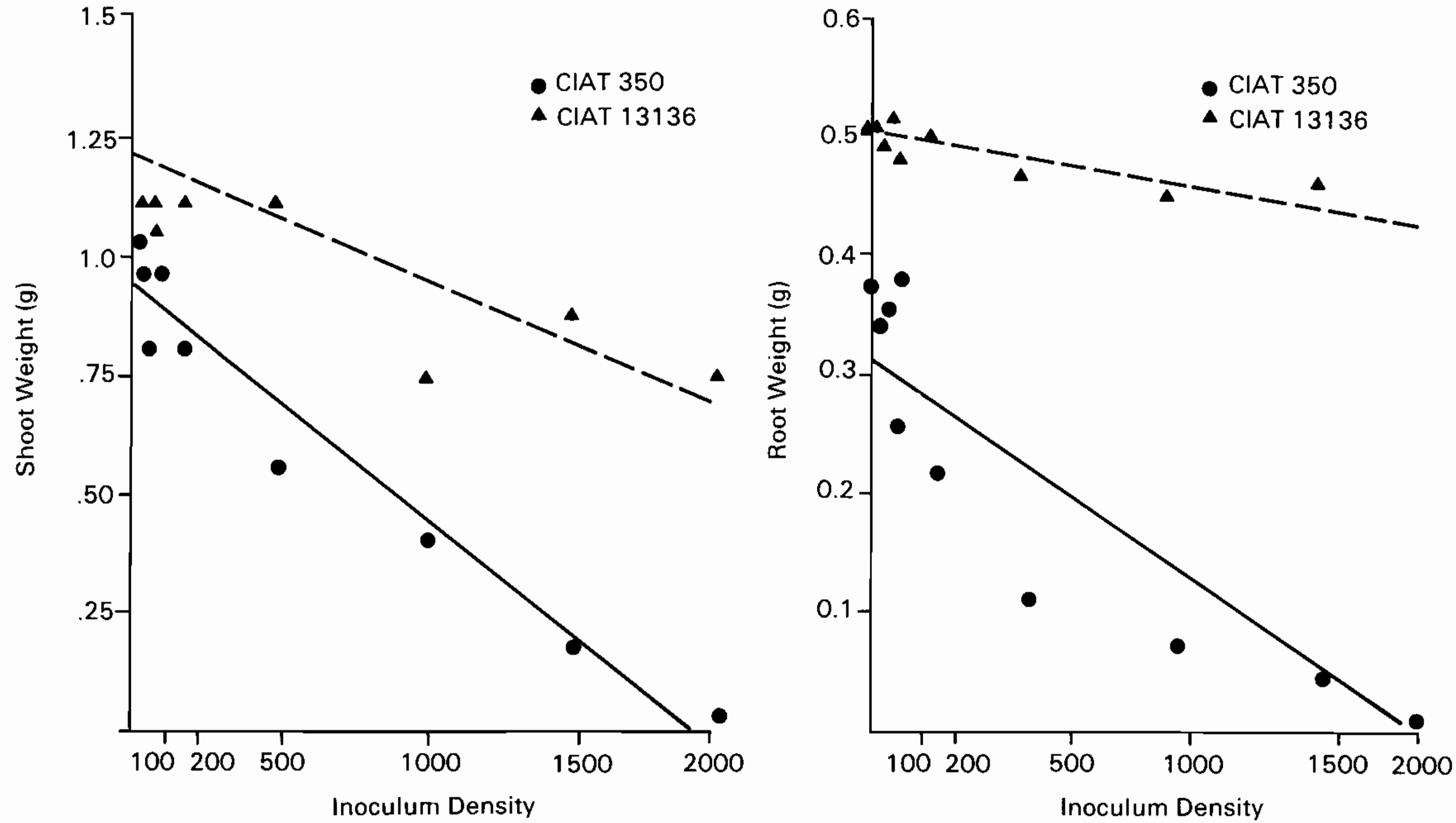


Figure 15. Effect of inoculum density of shoot and root weight of *D. ovalifolium* CIAT 350 and 13136.

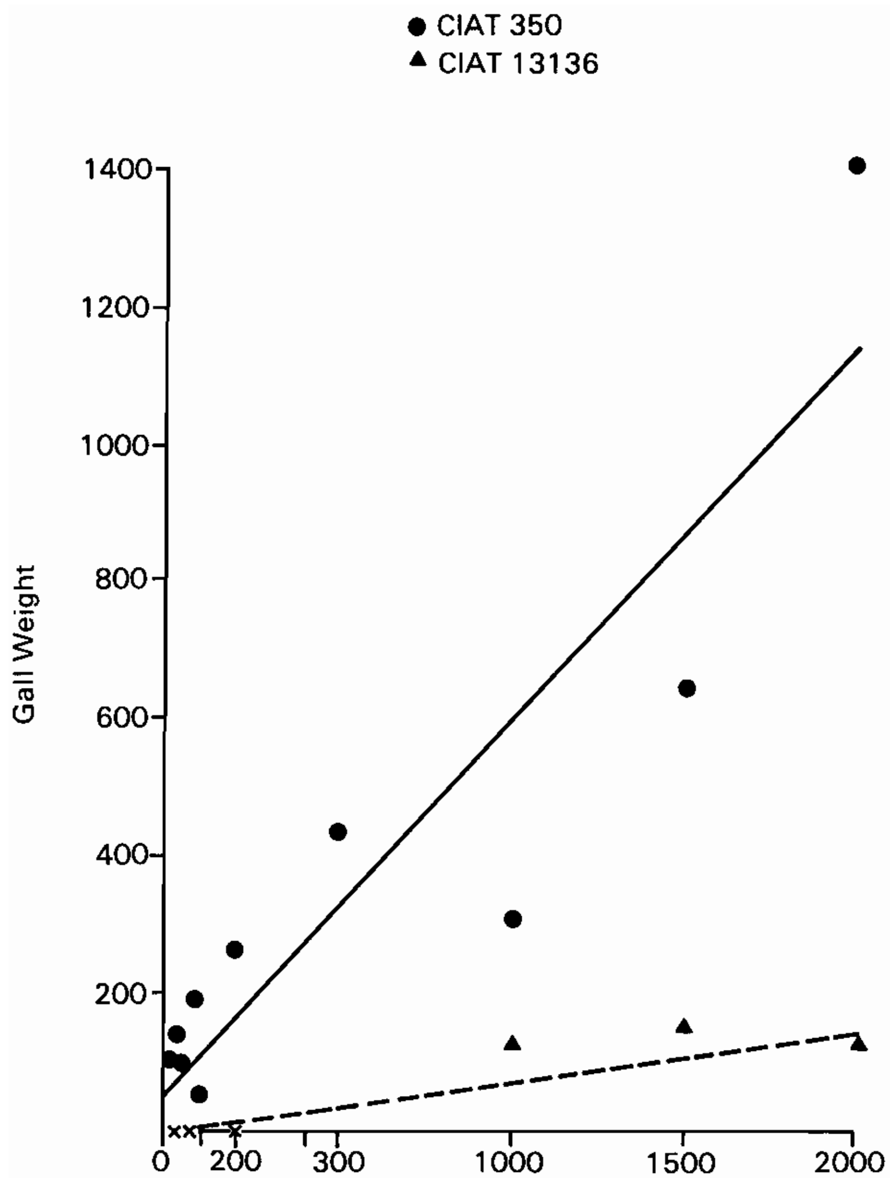


Figure 16. Effect of inoculum density of *Pterotylenchus cecidogenus* on weight of gall produced by *D. ovalifolium* CIAT 350 and 13136.

Table 22. Evaluation of resistance to Pterotylenchus cecidogenus among accessions of D. ovalifolium.

Accession	Vigour	Gall rating
350 E	1.5	1.7
350	2.1	1.5
3607	0.5	0.5
3608	1.9	1.1
3653	1.8	1.9
3666	1.5	1.8
3668	1.7	1.3
3673	1.6	1.5
3674	2.1	1.2
3776	2.3	0.5
3781	1.9	1.3
3784	1.2	1.5
3788	2.3	0.8
3793	1.5	1.0
3794	1.8	1.5
13088	2.6	0.6
13089	2.1	0.6
13092	2.6	0.9
13099	4.8	1.8
13114	2.4	0.7
13115	2.0	1.3
13119	2.3	0.9
13121E	1.9	0.8
13123	1.6	1.1
13128A	2.3	1.3
13129	2.5	0.7
13131	2.6	0.9
13134	0.9	0.9
13136	2.4	0.6
13139	2.0	1.0
13289	2.2	1.3
13305	1.9	2.0
13307	1.4	1.8
13371	2.1	0.9
13400	1.9	1.0

E = planting from vegetative material.

CIAT 3292 was not significantly different from CIAT 350 and, therefore classed as susceptible. D. intortum CIAT 3474 and D. salicifolium CIAT 13304 were significantly more resistant than CIAT 350 but produced 50% of the number found in CIAT 350 so were classed moderately resistant.

Table 23. Evaluation of resistance of Desmodium ovalifolium accessions to Pterotylenchus cecidogenus.

CIAT Accession No.	% Nematodes*
13090	8
13134	9
13370	6
13646	0
13647	5
13648	0
13649	4
13650	5
13651	10
13652	4
13653	2
13654	0
13655	3
13656	8
13657	7

* Number of nematodes as % of those in CIAT 350.

Interaction between wounding of D. ovalifolium and penetration and development by P. cecidogenus

No effect of wounding on penetration by P. cecidogenus of D. ovalifolium CIAT 350 was found in 1985. An experiment set up in 1986, however, clearly showed that wounding increased nematode numbers and gall weight after both 40 and 80 days in D. ovalifolium CIAT 350 (Table 25). At the same time, no effect of wounding was found at 40 days, but there was an obvious effect on decreased root length stem weight, root weight and leaf number at 80 days, when nematodes were inoculated with wounding. It appears that wounding may facilitate the speed of development of damage caused by P. cecidogenus in D. ovalifolium CIAT 350. Further work is required under grazing.

Evaluation of promising accessions of D. ovalifolium under grazing.

A grazing trial (ajedrez-type) was

Table 24. Host status of Desmodium species and number of nematodes produced as percentage of those in CIAT 350.

Species	CIAT Accession No.	% Nematodes
adscendens	3957	0 r
adscendens	3979	7 r
adscendens	13462	0 r
aparine	362	0 r
barbatum	3063	14 r
barbatum	3196	21 r
barbatum	13332	8 r
cajanifolium	3124	27 r
cajanifolium	3204	12 r
cajanifolium	13472	2 r
cinereum	3240	21 r
cuneatum	3698	0 r
discolor	359	3 r
discolor	13422	4 r
discolor	13441	6 r
discolor	3477	4 r
discolor	13605	10 r
gangeticum	3684	46 r
gangeticum	13393	18 r
gangeticum	13677	59 r
hassleri	3686	1 r
heterocarpon	365	3 r
heterocarpon	13026	7 r
heterocarpon	13028	1 r
heterocarpon	13119	12 r
heterophyllum	13196	0 r
heterophyllum	13197	6 r
heterophyllum	13902	2 r
incanum	3184	1 r
incanum	3205	4 r
incanum	13020	1 r
intortum	3291	2 r
intortum	3292	81 s
intortum	3474	55 mr
lanceolatum	3689	19 r
laxiflorum	13299	6 r
laxiflorum	13698	0 r
limense	3699	0 r
microphyllum	13286	3 r
microphyllum	13296	8 r
neomexicanum	3677	35 r
nicaraguense	3070	5 r
nicaraguense	3071	6 r
nicaraguense	3082	5 r
pabulare (?)	3401	0 r
pachyrrhizium	3390	1 r
pachyrrhizium	3398	9 r
procumbens	13300	1 r
purpureum	3691	45 r
renifolium	13234	1 r
renifolium	13235	0 r
salicifolium	13304	60 mr
scorpiurus	300	0 r
scorpiurus	3022	6 r
scorpiurus	3149	11 r
sequax	3813	0 r
sequax	13301	0 r
sequax	13392	2 r
strigillosum	13149	8 r
strigillosum	13153	0 r
strigillosum	13159	13 r
styracifolium	13163	3 r
styracifolium	13166	11 r
styracifolium	13279	0 r
tortuosum	3259	1 r
tortuosum	3265	0 r
tortuosum	3278	1 r
triflorum	3331	1 r
triflorum	13209	2 r
triflorum	13210	0 r
uncinatum	361	0 r

r = resistant, mr = moderately resistant, s = susceptible.

established in collaboration with the Agronomy Section in 1985 in Carimagua to evaluate several promising accessions of D. ovalifolium for reaction to stem gall nematode under grazing. As yet, stem gall nematode build-up has been slow. Promising accessions such as CIAT 13089 are maintaining relatively low gall levels and relatively good vigour (Table 26). Further detailed evaluation is planned for 1987.

Pretreatment of Desmodium ovalifolium seeds for protection against Pterotylenchus cecidogenus

Seed treatment with 500 ppm carbofuran

Table 25. Interaction between wounding and *P. cecidogenus* in *D. ovalifolium* 350.

Wounding	Nematodes	Time of harvest days	No. of nematodes	Stem length cm	Root length cm	Stem weight gr	Root weight gr	Gall weight gr	Leaf No.
+	+	40	72.1	7.4	6.1	.07	.01	.75	10
+	-	40	0	5.4	3.6	.08	.01	0	13
-	+	40	41.2	3.7	1.8	.08	.01	.47	6
-	-	40	0	7.9	8.4	.18	.03	0	12
+	+	80	103.5	7.9	6.3	.17	.04	1.07	10
+	-	80	0	10.8	6.09	.09	.02	0	8
-	+	80	84.4	7.5	4.2	.10	.02	.97	15
-	-	80	0	10.8	8.5	.10	.09	0	18

Table 26. Evaluation under grazing of D. ovalifolium inoculated with P. cecidogenus, stem gall nematode.

Accession		Low grazing pressure	High grazing pressure
13089	Vigour	2.7	2.3
	Nematodes	0.4	0.3
	Synchytrium	0.2	0.2
13092	Vigour	2.8	2.7
	Nematodes	0.3	2.7
	Synchytrium	0.6	0.4
13129	Vigour	2.9	2.6
	Nematodes	0.1	0.2
	Synchytrium	0.3	0.6
350	Vigour	2.7	2.3
	Nematodes	0.4	0.4
	Synchytrium	0.6	0.6
3776	Vigour	2.5	2.4
	Nematodes	0.1	0.1
	Synchytrium	0.3	0.5
3794	Vigour	2.1	2.3
	Nematodes	0.2	0.1
	Synchytrium	0.6	0.6

for 60 minutes has been shown (Annual Report 1985) to protect D. ovalifolium against Pterotylenchus cecidogenus for at least one week. This year the duration of this protection was determined. Benlate was also tested for its capacity to protect.

a) Effect of Benlate as a seed treatment against P. cecidogenus

Seed of D. ovalifolium CIAT 350 were soaked in 100 or 500 ppm benomyl for 1, 5 or 60 minutes, washed with water and pregerminated in petri dishes. Seedlings were sown one per pot and, one week after sowing, were inoculated three times at two day intervals with 70 P. cecidogenus and covered with beakers. Four weeks later the number of nematodes per plant was determined. A treatment with 500 ppm carbofuran for 60 minutes was used as a control.

Treatment with Benlate was equally as effective as carbofuran. Five nematodes were found per control plant. This was not significantly different from the corresponding Carbofuran-treated plants. Other treatments were not as effective as treatment with 500 ppm for 60 minutes. (Table 27).

b) Duration of protection by carbofuran

Seeds of D. ovalifolium CIAT 350 were soaked in 500 ppm carbofuran for 60 minutes, washed well with water and pregerminated in petri dishes. Seedlings were sown one per pot. After 1, 2, 4 or 8 weeks, plants were inoculated three times at two day intervals with 70 P. cecidogenus and covered with beakers. Four weeks after inoculation, the number of

Table 27. Effect of Benlate as a seed treatment of D. ovalifolium CIAT 350 against P. cecidogenus.

Treatment time (min)	Concentration (ppm) 100	500
1	92	22
5	47	17
60	33	6

L.S.D. = 6

Table 28. Number of P. cecidogenus per D. ovalifolium CIAT 350 plant following treatment with 500 ppm carbofuran for 60 minutes and inoculation at various times after sowing.

Weeks after sowing	No. Nematodes
1	8 a
2	12 a
4	35 b
8	35 b

Values followed by the same letter arae not significantly different ($P < 0.05$).

nematodes per plant was determined. Treatment with carbofuran protected seedlings for 2 weeks (Table 28). Inoculation after 4 and 8 weeks may have been less effective than in untreated seeds but this was not tested.

Survey of plant parasitic nematodes associated with tropical pasture plants and native savanna in several sites in Colombia.

A preliminary survey of plant parasitic nematodes associated with tropical pasture plants and native savanna in Carimagua, Villavicencio and Quilichao was conducted by Dr. Siddiqi of the Commonwealth Institute of Parasitology. A wide ranged of promising pasture grasses and legumes were surveyed including healthy vigorous to degraded pastures from 1 to 30 years of age (Table 29). Although the data obtained is still being analyzed, the frequency of occurrence of different genera and species of nematodes is given in Table 30. Several apparently new species have been found including potentially pathogenic Helicotylenchus sp., Monotrichodorus sp., Pratylenchus sp. and Xiphinema sp. The abundance of Pratylenchus zeae and P. brachyurus and their common association with Brachiaria decumbens pastures, often chlorotic, is worthy of note. Endoparasitic Pratylenchus spp., the root lesion nematodes, are perhaps the most important plant nematodes found in the survey and further work on them is necessary.

Research will be undertaken to evaluate host range, extent of damage, and management or control alternatives especially for species of the genera Tylenchulus, Pratylenchus, Monotrichodorus and Xiphinima.

Table 29. Sites, subsites and species surveyed for plant parasitic nematodes during August, 1985.

Sites	Subsites No.	Grass species	Legume species	Pasture age year	Pasture condition
		Introduced:	Introduced:	Sown:	
Carimagua	24	*A. gayanus*	*A. pintoi*	1-30	Healthy
		B. decumbens	*C. brasilianum*	Native:	to
		B. humidicola	*C. macrocarpum*	?	degraded
		H. rufa	*D. ovalifolium*		
		M. minutiflora	*D. heterophyllum*		
			D. heterocarpon		
		Native:			
		A. bicornis	*P. phaseoloides*		
		Paspalum	*S. capitata*		
		Trachypogon sp.	*S. guianensis*		
			S. macrocephala		
			S. viscosa		
			Zornia spp.		
		Introduced:	Introduced:	Sown:	
Villavicencio	7	*B. brizantha*	*D. ovalifolium*	3-16	Healthy
		B. decumbens	*D. heterocarpon*		to
		B. dictyoneura	*P. phaseoloides*	Native:	degraded
		B. humidicola		?	
		H. rufa			
		P. plicatulum			
		Native:			
		A. bicornis			
		Homolepsis sp.			
		Imperata sp.			
		Panicum sp.			
		Paspalum sp.			
		Introduced:	Introduced:	Sown:	
Quilichao	11	*B. brizantha*	*D. ovalifolium*	1-5	Healthy
			D. heterocarpon		to
					degraded

Table 30. Genera, species and frequency of important nematodes found associated with pasture grasses and legumes in Carimagua, Quilichao and Villavicencio, August 1985.

Genus	Species	Frequency %
Helicotylenchus	pseudopaxilli	21.4
	sp. nov.	20.4
	dihystera	9.8
	exallus	4.6
	pseudorobustus	1.7
	stylocerus	1.2
Heterodera	sp.	0.6
Longidorus	laevicapitus	6.4
Meloidogyne	sp.	0.6
Monotrichodorus	sp. nov.	16.2
Pratylenchus	brachyurus	39.9
	zeae	30.0
	sp. nov.	8.7
	coffeae	2.9
	teres	2.3
Pterotylenchus	cecidogenus	0.6
Trophurus	sp.	0.6
Tylenchorhynchus	sp.	8.0
Tylenchulus	sp.	6.4
Xiphinema	brasiliense	8.7
Xiphinema	sp. nov.	2.9

Total number of samples = 173.

Soil Microbiology

In 1986 the major emphasis of the Microbiology Section has been to strengthen links with national program scientists in six countries, who are evaluating rhizobium inoculants on selected legumes in greenhouse and field trials. The objectives of this UNDP-supported practical training program, are summarized in Figure 1. In addition to the initial intensive course run with NifTAL's and MIRCEN's collaboration in Brazil in November 1985, a further practical course was held at CIAT in November 1986, and CIAT collaborated with a course held in Cuba in September 1986. This brings to 14 the number of national program scientists trained on this project to give rhizobiology support to the RIEPT, plus the 15 participants of the course in Cuba, and 10 bean program scientists.

The work is divided into stages (see Figure 1). Experiments in Stages 1_L, 1_R and 2 are being carried out in Peru, Brazil, Mexico, Colombia, Cuba and Panama, in order to determine the need to inoculate selected legumes and evaluate rhizobium strains which have been pre-selected in Carimagua soil. The results will be evaluated in a workshop to be held at CIAT in 1987.

Research at CIAT has been directed towards supporting this network of collaborators, and will be discussed according to the respective stages as shown in Figure 1.

STAGE 1_R

This stage includes all rhizobium strain isolation, characterization, inoculant production for agronomic experiments, improvement of inoculant production methods and inoculation technology, and inoculant quality control.

Strain isolation and inoculant production

A large number (3,283) of rhizobium isolates from 60 genera and 184 species of tropical forage legumes are currently registered in the collection. The 4th edition of the catalogue of evaluated strains was published in early 1986. Table 1 shows the strains which are recommended for inoculation of regional trials B, C, and D in 1987. All trials should be inoculated unless inoculation experiments have shown that there is no response at the site under study (see Annual Report 1985). Inoculants are supplied free of charge by CIAT. In some cases network collaborators have produced inoculants in the countries where they are required, and it is hoped that such collaboration will increase in the future. Table 2 shows that the amount of peat-based inoculant distributed to the Program and network doubled between 1985 and 1986. In addition, 566 vials of freeze-dried inoculant were distributed. A larger freeze-drier funded by the UNDP will be installed in 1987. This will be used to establish a small-scale

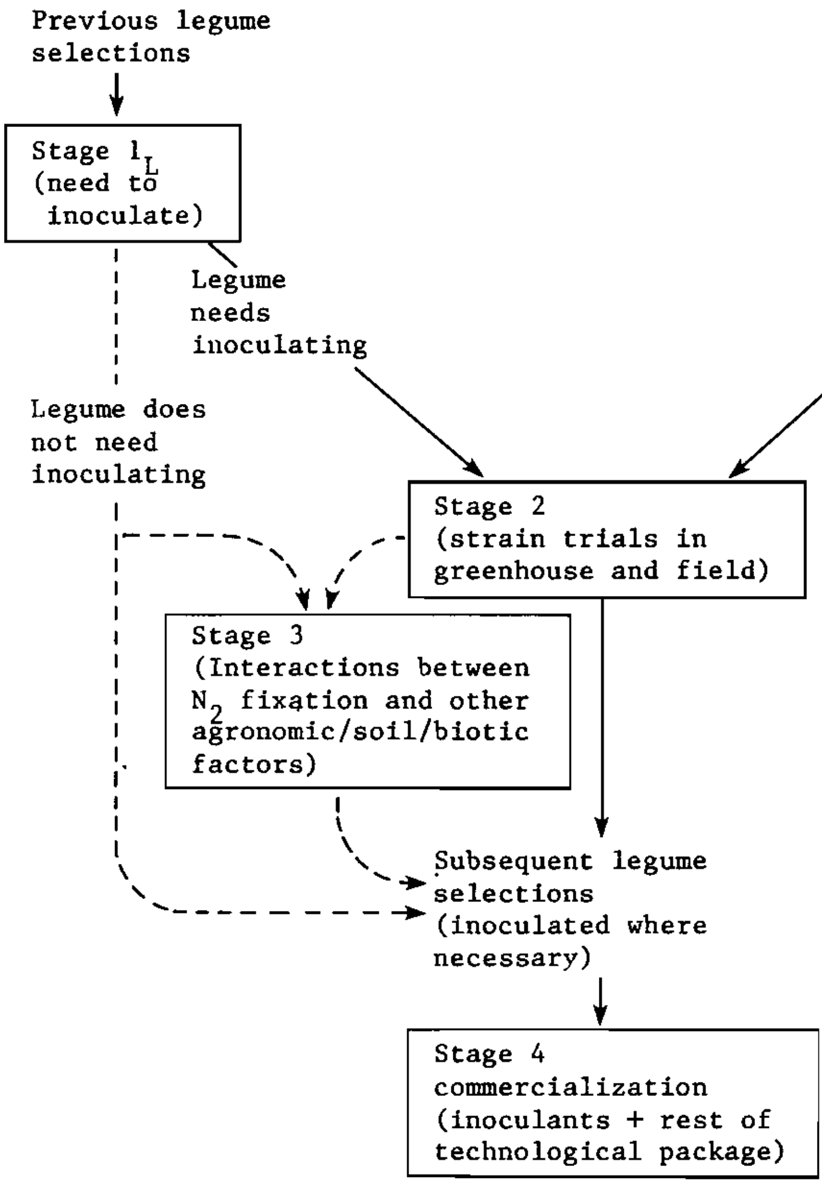


Figure 1. Flow diagram of research objectives in a legume-rhizobium evaluation program, as defined for the collaborative bean-forage legume UNDP-funded project for improving biological nitrogen fixation (Manual for the Evaluation, Selection and Management of the Legume-Rhizobium Symbiosis to Increase Nitrogen Fixation, CIAT, 1987).

Table 1. Currently recommended strains for legumes in Regional Trials B, C and D.

Legume	Strain
Arachis pintoi 17434	3101
Centrosema acutifolium 5112, 5277, 5568	3101
C. brasilianum 5234	3101
C. macrocarpum 5065, 5434, 5452, 5744, 5887, 5713	3101
C. pubescens 438, 442, 5189	1670
Desmodium heterocarpon 3787	3418
D. heterophyllum 349, 3782	2469
D. ovalifolium 350	3418
Leucaena leucocephala	1967
Pueraria phaseoloides 9900	2434
Stylosanthes capitata 10280	870 + 995 + 2138
S. guianensis 64, 136, 184, 1280, 10136	71
Zornia glabra 7847, 8283	71
Z. latifolia 728	71

freeze-dried inoculant production plant at CIAT which will enable us to increase the availability of inoculants in the network, and to solve production problems, thus improving the technology for adoption by commercial vaccine firms.

Strain characterization

Other activities in Stage 1_R include cultural and serological characterization of the most effective strains which have been selected for use in Stage 2 trials by the network collaborators. These strains are listed in Table 3. Cultures and details of strain characteristics are distributed to those interested in testing them, and it is hoped that the network will stimulate interchange of strains and information, so that the most widely adapted strains can be selected, or specific conditions to which they are adapted identified.

The recommendations in Table 1 will be adapted on the basis of this information. It is important to note that Table 3 shows strain-legume combinations which have been effective in a series of different experiments and that not all combinations have been tested. Thus the lack of mention of a given combination does not necessarily mean it is not effective.

Development of improved inoculants

Studies on freeze-dried inoculants have confirmed that suspension in oil does not prevent the freeze-dried rhizobia from dying during storage once they have been applied to seeds, unless the seeds are desiccated, at least when stored under normal (tropical) room conditions. On the other hand, peat-based inoculant using

Table 2. Inoculants distributed in 1986.

Program and network requests (tropical forage legumes)				Farmers requests		
	No.	kg. peat	Freeze-dried vials	Legume	No. requests	g.
Colombia	80	111.27	112	Leucaena	10	133
Other countries	33	0.71	454	Desmodium	1	50
				Soybeans	1	90
				Stylosanthes	3	75
Total 1986	113	111.98	566	Alfalfa	6	645
				Centrosema	3	45
Total 1985	135	59.66	-	Kudzu	5	1135
				Clover	1	15
				Arachis	1	50
				Total 1986	31	2238
				Total 1985	22	4591

Australian peat shows much greater survival on seeds than that reported in the literature. The reasons for this are being investigated.

Evaluations of survival of different freeze-dried rhizobium strains in vacuum-sealed vials at room temperature over four months showed approximately 10^9 cells/vial after this time (Table 4), although numbers of cells of Stylosanthes strains (71, 995, 870, and 2138) were lower, and higher for strains 2335 and 2434 (Desmodium and Kudzu). One vial is recommended for inoculation of one kg of seed. A vial containing 10^9 cells applied to 1 kg of small legume seeds (e.g. Desmodium) would supply 2,000 cells/seed or 30,000 cells/seed of a larger-seeded legume (e.g. Centrosema). Although these numbers are adequate, for smaller-seeded legumes it would be preferable to increase the numbers ten-fold. This can probably be achieved by improving control of conditions during the freeze-drying procedure.

STAGE 1_L

This stage comprises need to inoculate trials, where a wide range of legumes are evaluated for yield and nodulation with two treatments (high and low N availability) in representative soils. No inoculants are used, which permits evaluation of the symbiosis with native strains. A multilocational trial of this type is being set up at six sites in five countries in collaboration with the UNDP trainees, and including Carimagua as one of the sites.

Results from the first cut at Carimagua are shown in Table 5. The primary criteria taken into account in these experiments are the difference in N yield between the plus and minus nitrogen treatments (nitrogen response index: NRI) and N yield in the plus nitrogen treatment. Legumes which yield well in the plus nitrogen treatment and show a large difference in yield between the plus and minus nitrogen treatments (high NRI) are

Table 3. Strains recommended for Stage 2 trials for each legume genus, according to results of all trials carried out to date by CIAT (greenhouse and field).

Legume genus	Strain CIAT No.	Legume ecotype in each genus showing inoculation response	Origin of Strain
Desmodium	46	350	SU 462 (Australia)
	2335	350, 3666, 3784, 3788	D. ovalifolium, Belem, Brazil
	2372	13032	D. incanum, Carimagua, Colombia
	2434	3776, 3788, 3794	M. atropurpureum, Manaus, Brazil
	2469	349, 3666, 3784	D. heterophyllum, Carimagua
	3030	13032	D. incanum, Carimagua
	3101	3776, 3788	C. macrocarpum, S. Marta, Colombia
	3418	350, 365, 3666, 3784, 3776, 3788, 3794, 13089	D. ovalifolium, Thailand
	4099	13089	CB 2085 (Australia)
Centrosema	49	438, 5112, 5277, 5434, 5452, 5568, 5713, 5744, 5887	CB 1923, C101A (Brazil)
	590	5050, 5065, 5744, 5112, 5277, 5568	Centrosema sp., México (= TAL 1146)
	1670	438, 5052, 5065, 5112, 5234, 5434, 5452, 5568, 5713, 5744	C. pubescens, México (RAD 87/03)
	1780	438, 5065, 5112, 5434, 5452, 5568, 5713, 5737, 5744, 5887	C. pubescens, Pucallpa, Perú
	2290	5065, 5112, 5568, 5737, 5744	Centrosema sp., Guamal, Meta, Colombia
	2348	5065, 5744, 5887	C. pubescens, Carimagua
Centrosema (cont'd)	3101	5065, 5062, 5434, 5452, 5568, 5713, 5744, 5887	C. macrocarpum, S. Marta, Colombia
	3111	5062, 5744, 5713, 5452	C. macrocarpum, Brazil
	3196	5065, 5062, 5744, 5887	C. macrocarpum, Paragominas, Brazil
	3334	5065, 5112, 5234, 5744	C. macrocarpum, greenhouse, CIAT
	3694	5112, 5452, 5568, 5713, 5744, 5877	C. bifidum 15087, S. Rita, Vichada, Colombia

Table 3. Cont'd.

Legume genus	Strain CIAT No.	Legume ecotype in each genus showing inoculation response	Origin of Strain
Stylosanthes	71	64, 136, 184, 1280, 10136	Stylosanthes sp., Huila, Colombia
	870	10280	CB 2898 (Australia)
	995	10280	S. capitata, Venezuela
	2138	10280	S. capitata, Nopolis, Goiás, Brazil
Pueraria	643	9900	P. phaseoloides, Chinchiná, Colombia
	2434	9900, 4600	M. atropurpureum, Manaus, Brazil
	3287	9900	P. phaseoloides, Carimagua, Colombia
	3648	9900	P. phaseoloides, Villavicencio, Colombia
	3796	9900	P. phaseoloides, Itabela, Brazil
	3850	9900	P. phaseoloides, Thailand
	3918	9900	TAL 647, UMKL 56, Malaysia
Arachis	2138	17434	S. capitata, Nopolis, Goiás, Brazil
	2335	17434	D. ovalifolium, Belém, Brazil
	3101	17434	C. macrocarpum, S. Marta, Colombia
	3144	17434	A. pintoi, Carimagua
	3806	17434	A. pintoi Meta, Colombia
	3810	17434	A. pintoi, Carimagua
Calopogonium	453	C. mucunoides	C. mucunoides
	454		Meta, Colombia
	3115		C. caeruleum, Quilichao
Flemingia	4203	17403	F. macrophylla, Quilichao
	4215		

Table 4. Numbers of cells per vial after 4 months storage at room temperature of freeze-dried inoculants.

Strain Nos.	Date freeze-dried	Log_{10} No. Cells per vial
3101	17/4/86	9.2 ± 0.53
1670	1/4/86	9.57 ± 0.14
71	2/4/86	7.25 ± 0.25
2335	15/4/86	11.27 ± 0.38
1967	13/5/86	9.12 ± 0.16
2469	15/4/86	9.20 ± 0.27
2434	8/4/86	10.05 ± 0.20
995 + 870 + 2138	29/4/86	8.36 ± 0.32
3418	15/4/86	9.64 ± 0.27
1780	11/4/86	9.20 ± 0.41

adapted to local conditions, and are likely to respond to inoculation with appropriate strains. The data show considerable variation between species and ecotypes. For example *D. heterophyllum* No. 3782 nodulated more effectively with native strains than No. 349. *C. acutifolium* 5277 and 5568 also differed in their ability to nodulate effectively with native strains. There was also a marked difference in nodulation between *Stylosanthes guianensis* CIAT 136 and 184 as compared with *S. guianensis* var. *pauciflora* CIAT 1280, 10136, 2031 and 2362. *Zornia* spp showed surprisingly large NRI's even though the two species were well nodulated, and plants in the low N treatment had high N contents. *Z. glabra* and *Z. latifolia* may be efficient users of soil N. *Arachis pintoi* nodulated abundantly with native strains but the nodules were ineffective, showing a large NRI and plants in the low N treatment with low N contents (1.81%). The comparison of these data from Carimagua with those from the other five sites will provide important information concerning differences in effectiveness of native strains between different sites. It is also important to take into account changes between the first cut (early nodulation) and the later development of the legumes, which may occur in some cases.

STAGE 2

Stage 2 includes all greenhouse experiments where strains are pre-selected in soil cores, and validation in the field of the results of the soil core experiments. The results of this years experiments are included in Table 3. It is interesting to note that strains 2434 and 3101 (Kudzu and *Centrosema* strains, respectively) have shown ability to nodulate effectively on *Desmodium ovalifolium*, and that the Australian strain CB 2085 which had previously been found to be ineffective on *D. ovalifolium* No. 350, was highly effective on *D. ovalifolium* No. 13089. Strain CIAT No. 3418 is

Table 5. Data from first cut (10 weeks) of multilocational need-to-inoculate trial. Carimagua.

Legume	Ecotype No.	NRI[1]	N yield + N	% N - N	Nodules/ plant - N
A. pintoi	17434	54.1	10.06	1.81	28
C. acutifolium	5568	79.2	16.22	1.77	1
C. macrocarpum	5887	79.0	16.87	2.11	3
C. macrocarpum	5065	78.5	13.77	2.03	2
C. pubescens	438	67.3	24.68	2.96	5
C. macrocarpum	5713	60.6	20.04	2.64	4
C. pubescens	442	59.3	12.56	2.82	7
C. pubescens	5189	58.5	21.67	3.11	5
C. acutifolium	5277	55.1	12.30	3.26	4
C. brasilianum	5234	42.3	17.00	3.35	8
D. heterophyllum	349	82.4	6.36	1.52	1
D. heterocarpon	3787	71.9	3.50	1.48	5
D. ovalifolium	350	53.2	3.55	1.85	11
D. heterophyllum	3782	34.9	10.70	2.24	34
L. leucocephala		70.4	3.09	1.94	0
P. phaseoloides	9900	57.1	23.49	2.59	13
S. macrocephala	2286	55.9	7.23	2.38	6.6
S. capitata	1441	54.4	6.76	3.01	5.9
S. capitata	2044	52.9	9.66	2.76	4.2
S. macrocephala	1643	52.2	5.57	2.55	7.9
S. guianensis (p)	1280	51.7	8.09	2.89	7.7
S. macrocephala	2756	51.4	6.55	2.54	8.3
S. guianensis (p)	10136	49.6	5.15	2.57	4.8
S. capitata	1019	45.7	5.26	2.97	6.5
S. guianensis (p)	2031	45.0	9.08	3.08	9.3
S. guianensis	184	44.7	18.50	3.22	31.7
S. macrocephala	2133	43.3	5.24	2.65	6.8
S. capitata	10280	33.5	7.13	2.85	6.3
S. guianensis	136	27.1	13.94	3.13	25.6
S. guianensis (p)	2362	25.1	3.88	2.63	9.9
Z. glabra	7847	73.0	12.83	3.09	18.6
Z. latifolia	728	58.0	13.57	3.55	13.3

1/ $\frac{(\text{N yield} + \text{N}) - (\text{N yield} - \text{N})}{\text{N yield} + \text{N}} \times 100 = \text{NRI}$

(p) var. Pauciflora

still the most widely effective strain on *Desmodium* spp. however, although CB 2085 needs to be tested on more ecotypes to determine whether it also has wide effectivity.

Another strain which stood out as highly effective on Kudzu was CIAT No. 3918, which originated from Malaysia as UMKL 56. This strain (also known as TAL 647) has been reported as effective on Kudzu in Venezuela (Margarita S. de Mallorca, personal communication).

Strains were also selected for *Calopogonium mucunoides* and *Flemingia macrophylla* (Table 3).

STAGE 3

This stage includes studies on interactions of agronomic management factors, soils, other microorganisms, etc., with nitrogen fixation, and inoculation responses. Studies on effects on inoculation responses of soil N mineralization, fertilization, tillage, inoculation methods, mycorrhizas and other soil microorganisms have been carried out. Effects of P and K levels on N_2 fixation, and mineral N dynamics in the soil have also been studied.

Mineral N dynamics

In addition to mineral N release in Carimagua soil in response to land preparation, plant species and N fertilization, mineral N immobilization is now also being studied. Large quantities of added N are immobilized, indicating an important N pool, which is the source of the mineral N released on soil disturbance. The effect of plant species on N immobilization rates is being evaluated.

A study where ^{15}N as NO_3^- or NH_4^+ was added to *B. humidicola* CIAT 679, *B. dictyoneura* CIAT 6133 and *B. decumbens* CIAT 606 plots at Carimagua, showed greater uptake of NO_3^- than NH_4^+ by all three grasses. The difference between NO_3^- and NH_4^+ uptake was greater in *B. humidicola* and *B. decumbens* than in *B. dictyoneura*. These results do not confirm previous observations that *B. humidicola* takes up NH_4^+ more effectively than *B. decumbens* and *B. dictyoneura* in nutrient solution (Annual Report 1983, p. 183). However, greater immobilization of added NH_4^+ in the soil of *B. humidicola* might mask this effect in the field. It appears that the inhibition of nitrification in soil from *B. humidicola* which has been observed frequently in samples from Carimagua (Annual Reports 1983, p. 211; 1985, p. 224) did not affect its ability to take up NO_3^- or NH_4^+ as compared with *B. decumbens* in this experiment, where only low N fertilization levels were used. However, the effect of different grasses on nitrification has been observed only in heavily N-fertilized plots; when the plots are not N-fertilized, no nitrification is observed in soil from any grass. A new experiment has been set up to determine whether NO_3^- is taken up by non-N-fertilized grasses, and to study the effect of pure and associated grasses on the activity and composition of the soil microflora.

Tillage

A field experiment with *C. acutifolium* CIAT 5568 was carried out at Quilichao to evaluate inoculation response using conventional tillage and sowing either in alternate furrows or broadcast with *Andropogon gayanus* CIAT 621, and reduced tillage where the legume was sown in furrows between rows of preestablished *A. gayanus*. Establishment was best with conventional tillage and alternate grass-legume furrows. The most effective inoculant (a mixture of four strains) doubled N yield of the legume. Establishment in furrows gave more than double the legume N yield than with broadcasting, but even with broadcasting, N yield was doubled by inoculation with the strain mixture. The reduced tillage treatment gave much lower legume yields, presumably due to greater competition from the preestablished *A. gayanus*, and the inoculation response was even greater (nine-fold). A strain mixture including strain CIAT No. 49 gave a somewhat inferior performance to the mixture without CIAT 49, confirming results of an experiment reported previously (Informe Anual, 1984, p. 162) which indicated a negative effect of this strain used in mixture on *C. pubescens* CIAT 438 at Quilichao. The results show that even with conventional tillage, where N mineralization is stimulated, inoculation responses are observed.

Inoculation methods

In an experiment at Quilichao, where drought prevented germination of seeds after sowing for 2-3 weeks, peat-based inoculant gave better results than oil-based inoculant, whereas in a collaborative experiment with the Boyce Thompson Institute at Carimagua, where germination occurred immediately after sowing, the two types of inoculant were equally effective. The effect of peat and charcoal on survival of freeze-dried oil-suspended rhizobia on seeds is being evaluated.

Fertilization and measurement of N_2 fixation

In a project funded by the Swiss Development Corporation (Ph.D. thesis, G. Cadisch) the effect of phosphorus and potassium fertilization on nitrogen fixation by different forage legumes is being evaluated by means of the ^{15}N dilution technique. Preestablished legumes with P and K maintenance fertilization showed 70-88% nitrogen derived from fixation (equivalent to 25 - 115 kg N/ha fixed in 17 weeks), whereas without maintenance fertilization the range was much greater (44 - 84% nitrogen derived from fixation). This shows that N yields at high fertilization levels correlate more closely with N_2 fixation rates than at low fertilization rates, where some legumes take up a much larger proportion of soil N than others, so that N yields cannot be relied upon to estimate the N contribution from N_2 fixation. Unfortunately the cost of this method is too great for it to be used routinely. For this reason, the work is orientated towards determining nutrient concentrations in plant tissue below which N_2 fixation is limited.

Mycorrhizae

An EEC-funded project to study vesicular-arbuscular mycorrhizas (VAM) involving collaboration with Rothamsted Experimental Station, U.K. has initiated field trials at Carimagua, reducing the emphasis on direct inoculation of VAM in the field in work reported previously (Annual Reports 1982-1985), to study in more detail the manipulation of the native population.

A two-stage experiment with the first part established in 1986, has been designed to investigate the role of native and inoculated VAM in growth of pasture and crop plants, with and without precropping. The objective is to determine methods for manipulating the mixed native VAM population, which consists of more than 15 different species, to increase total infective propagule numbers or the inoculum potential of individual efficient VAM species within the population.

Preliminary data have shown that numbers of infective propagules are very low in these acid infertile soils and that native VAM infection occurs at a much slower rate than when inoculating with efficient VAM such as the *Glomus manihotis* isolate (CIAT accession No. C-1-1). Similar results were reported by Sieverding (7th NACOM Proc. 1985). Results (Table 6) show the extent of this poor infectivity in cassava which is almost obligately

Table 6. Infection of native and inoculated VA mycorrhizas the root systems of cassava grown at two sites at Carimagua (50 days after planting) using two P sources.

Treatments	% VAM Infection		% of Infection as Vesicles*	
	Yopare	La Pista	Yopare	La Pista
- M/RP	0	1	0	0
+ M/RP	76 ± 6	72 ± 15	97 ± 6	97 ± 8
- M/SP	0	3 ± 11	0	0
+ M/SP	75 ± 13	77 ± 9	80 ± 26	97 ± 6

NB/ Errors are standard deviations of four blocks.
* Indication of presence of inoculated Glomus manihotis isolate within root systems.
-M non-inoculated
+M inoculated
RP Huila Rock Phosphate (50 kg P ha^{-1})
SP Triple Superphosphate (50 kg P ha^{-1})

mycotrophic. Dramatic responses to inoculation of cassava, sorghum, kudzu and Brachiaria dictyoneura were observed. Differences were larger when rock phosphate was used as a P source, where overall growth was less than with superphosphate. For example, in kudzu all inoculated treatments outyielded non-inoculated treatments at both sites, with an average growth increase due to inoculation of 104% for Huila rock phosphate and 27% for triple superphosphate at the recommended rate of 20 kg P ha^{-1}.

With successive harvests it is expected that the yield response of kudzu will decrease due to the build-up of infective propagule numbers of native mycorrhizas. Such improved populations of native mycorrhizas could be used for the benefit of subsequent crops.

Other soil microorganisms

An undergraduate thesis project (Martha Morales) has shown 26 to 40% increases in N yield over the control inoculated with rhizobium only of P. phaseoloides, S. capitata and C. macrocarpum, when grown in soil cores and inoculated with a fluorescent pseudomonad strain Pp 18 or Agrobacterium rhizogenes strain 1000 in combination with rhizobium. This approach shows promise for increasing nitrogen fixation through stimulation of root growth which results from the production of hormones by these bacteria. The strains which have been successful in controlling bacterial blight in cassava (Annual Report 1984, p. 101) were not effective on forage legumes, possibly because they inhibited growth of rhizobium.

STAGE 4

This stage, which involves production of inoculants commercially, and study of their use by farmers, is being initiated in 1987, through the establishment of a pilot inoculant plant at CIAT with UNDP funds, already mentioned under Stage 1_R.

Soil/Plant Nutrition

The overall objective of this Section is to make more efficient the supply of nutrients during pasture establishment and maintenance; to this end research concentrated during 1986 on: (1) identification of key nutrients for germplasm in Category III (Bionutritional studies), (2) fertilization adjustments for the establishment of grass and legume species in Categories IV and V (main germplasm selection sites and support to the RIEPT), and (3) quantification of nutrient application, extraction, and recycling in pastures (evaluation methodology).

1. Bionutritional Studies of Germplasm

From the different techniques used last year (1985 Annual Report), the 2^3 factorial arrangement (K, Mg, and S), with and without N, P, Ca as basic fertilizers was selected for this type of evaluation. This was done bearing in mind that: no accession is able to establish and that there is no response to other nutrients in the absence of P, that Ca is bonded to P in applications of Calfos or phosphoric rock, and that N is supplied by the legume. Furthermore, an absolute control was included without any fertilizer applied. Soil characteristics and fertilization treatments used are described in the 1985 Annual Report. Two *Flemingia macrophylla* accessions (CIAT Nos. 17407 and 17403) were used in one of these trials.

Dry matter production, 90 days after establishment by seeding under the different treatments applied, is shown in Figures 1 and 2. Results show that with basic N, P, Ca fertilization and specifically with P fertilization, the two *F. macrophylla* accessions yielded significantly ($P < 0.05$) without expressing the need for K or Mg for establishment in the Carimagua clayey Oxisol. On the contrary, S applications resulted in a significative yield increase, independent of additional K and Mg applications. These results indicate that, in addition to P and Ca, S is an essential nutrient for this legume.

Centrosema acutifolium (CIAT Nos. 5277 and 5568), *C. macrocarpum* (CIAT Nos. 5452 and 5713), *C. brasilianum* (CIAT Nos. 5810, 5671, and 5234), and *C. pubescens* (CIAT Nos. 438 and 5189) accessions were used in another bionutritional diagnosis trial. Accessions were all planted in a clayey Oxisol (Reserva) from Carimagua under different fertilization treatments using the 2^3 factorial design with K, Mg, and S, plus two additional treatments (a control without fertilizer and two-fold applications of P and Ca). Tables 1, 2, 3, and 4 show dry matter production of these legumes 90 days after planting.

Results obtained with the control were rather low for all accessions; application of only P and Ca resulted in a significative increase in dry matter production, equivalent to a

BASIC FERTILIZATION: N-P-Ca

Figure 1. Nutritional diagnosis of _Flemingia_ _macrophylla_ - 17403

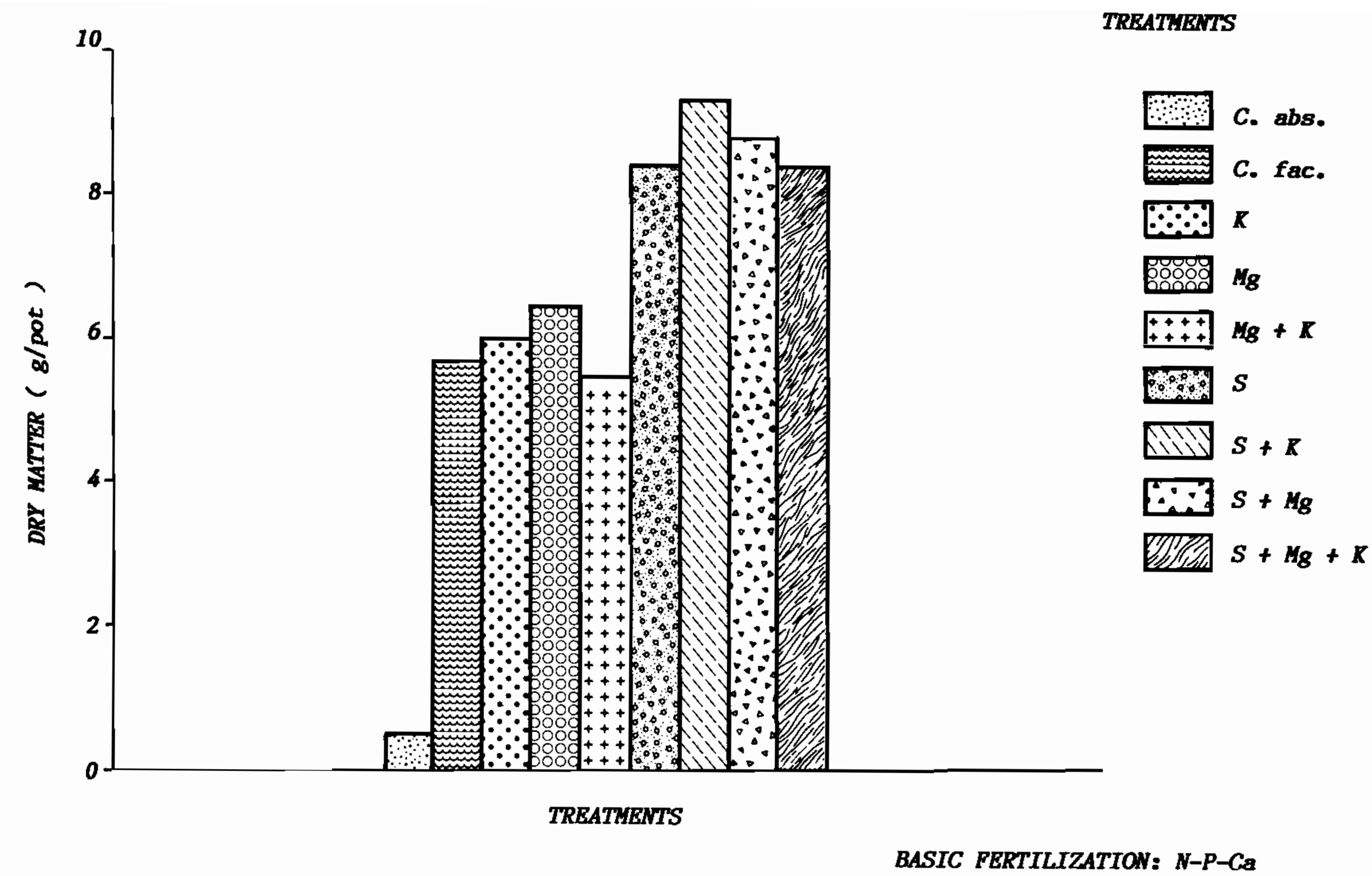


Figure 2. Nutritional diagnosis of <u>Flemingia</u> <u>macrophylla</u> - 17407

Table 1. Dry matter production of two C. acutilifolium accessions in an Oxisol from La Reserva (Carimagua) under two different fertilization treatments, at an age of 90 days in the greenhouse.

Fertilization					CIAT Accession Number	
P	Ca	K	Mg	S	5277	5568
mg/pot					MS g/pot	
0	0	0	0	0	2.20 c	2.36 d
25	125	0	0	0	4.83 b	6.20 bc
25	125	37	0	0	5.40 b	6.63 bc
25	125	0	25	0	4.66 b	5.63 c
25	125	37	25	0	4.70 b	6.50 bc
25	125	0	0	25	5.20 b	7.00 bc
25	125	37	0	25	5.60 b	6.53 bc
25	125	0	25	25	5.10 b	6.60 bc
25*	125*	37*	25*	25*	5.36 b	7.33 ab
50	250	37	25	25	6.66 a	8.26 a

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

* Fertilization dosis equivalent to 20 kg P, 100 kg Ca, 30 kg K, 20 kg Mg, and 20 kg S/ha.

Table 2. Dry matter production of two C. macrocarpum accessions in an Oxisol from La Reserva (Carimagua) under two different fertilization treatments, at an age of 90 days in the greenhouse.

Fertilization					CIAT Accession Number	
P	Ca	K	Mg	S	5452	5713
mg/pot					MS g/pot	
0	0	0	0	0	2.16 c	2.03 d
25	125	0	0	0	5.53 ab	4.93 bc
25	125	37	0	0	5.00 b	5.86 abc
25	125	0	25	0	4.66 b	4.50 c
25	125	37	25	0	5.16 b	4.23 bc
25	125	0	0	25	4.86 b	5.18 bc
25	125	37	0	25	5.93 ab	5.56 abc
25	125	0	25	25	5.16 ab	5.70 abc
25*	125*	37*	25*	25*	5.80 ab	6.53 ab
50	250	37	25	25	6.40 a	7.13 a

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

* Fertilization dosis equivalent to 20 kg P, 100 kg Ca, 30 kg K, 20 kg Mg and 20 kg S/ha.

50-60% increase over the control. Applications of K, Mg, and S in the factorial design described did not show a marked response in the clayey Oxisol, except for Centrosema brasilianum accessions 5671 and 5234 which significantly increased their dry matter production with the application of all K, Mg, and S. Overall, all accessions responded to the two-fold application of P and Ca (50 mg P and 250 mg Ca/pot); this indicates C. brasilianum to be the legume having the greatest response, particularly to increasing P doses.

Another greenhouse trial was conducted to study the behaviour of eight Panicum maximum accessions in a clayey Carimagua Oxisol, fertilized with P and Ca. Eight accessions were used, having a wide range of forage production levels in Carimagua: (from highest to lowest) CIAT Nos. 6299, 6172, 673, 689, 6179, 695, 622, and 604 (1985 Annual Report - Agronomy Section). A factorial design was used with 4 P doses (20, 40, 80, and 160 kg P/eq. ha.) and 3 Ca doses (100, 350, and 700 kg Ca/ha) in a completely randomized block design with 3 replications.

Dry matter production of each accession is shown in Figure 3. Increasing P doses significantly and successively increased dry matter production up to the highest dose, while the Ca doses only increased dry matter yields of accession 689. Differences among accessions were detected in terms of their yield potential, with accessions 6299, 695, and 622 yielding highest and accessions 6179, 673, 689, and 6172 yielding lowest.

In comparing accessions, differences among treatments were always due to differences in the P dose, with the exception of accession 689 which responded to Ca application. Consequently the response of the P. maximum accesions to P application can be classified in two groups: (1) accessions 622, 695, and 6299 with a greater yield potential and varying response to P application, and (2) accessions 673, 689, 6172, and 604 that responded up to the highest P dose, with a low growth rate and therefore a low yield potential.

Critical external P levels were 14 ppm for accession 6299; 16 ppm for 604; 20 ppm for 673, 689, 6172, and 6179; and 25 ppm for 622 and 695. The fact that the great mayority of the accessions studied did not respond to Ca application, suggests that the lowest Ca dose supplied an adequate nutritional level. Therefore, following trials should include doses below 100 kg Ca per hectare in order to determine requirements of this nutrient.

Overall, only the highest P dose increased P tissue content (Table 4). However, accession 6299 increased its P content as the P dose increased from 40 to 160 kg/eq.ha. Accessions 604, 689, 6172, and 6179 only increased their P content at the highest level of applied P.

Ca content was observed to increase as there was an increase in both Ca and P doses (Table 5). Two groups were determined among the accessions: (1) accession 604, with 0.56% Ca concentrations and (2) the rest of the accessions evaluated, with 0.45-0.48% Ca concentrations. These values confirm this species overall capacity to uptake soil Ca.

In general terms, at the low levels of Ca applied no increase in tissue Ca content was observed in a group of accessions, while there was an increase in Ca tissue content in other accessions with the application of Ca and P. This indicates the existence of different Ca contents among accessions. The first group's contents (accessions 622, 6172, 673, 6179, and 695) increase only in the

Table 3. Dry matter production of three C. brasilianum accessions in an Oxisol from La Reserva (Carimagua), under different fertilization treatments, at an age of 90 days in the greenhouse.

Fertilization					CIAT Accession Number		
P	Ca	K	Mg	S	5810	5671	5234
mg/pot					MS g/pot		
0	0	0	0	0	1.73 e	1.53 c	2.26 d
25	125	0	0	0	4.40 bcd	4.40 b	4.23 c
25	125	37	0	0	4.50 bcd	5.40 b	4.73 bc
25	125	0	25	0	3.66 d	4.53 b	5.03 bc
25	125	37	25	0	4.86 bc	4.86 b	5.30 bc
25	125	0	0	25	3.93 cd	5.40 b	5.13 bc
25	125	37	0	25	5.46 ab	4.96 b	5.23 bc
25	125	0	25	25	4.03 cd	4.93 b	4.80 bc
25*	125*	37*	25*	25*	3.73 d	6.93 a	5.86 b
50	250	37	25	25	6.43 a	7.56 a	7.46 a

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

* Fertilization dosis equivalent to 20 kg P, 100 kg Ca, 30 kg K, 20 kg Mg and 20 kg S/ha.

Table 4. Dry matter production of two C. pubescens accessions in an Oxisol from La Reserva (Carimagua) under different fertilization treatments at an age of 90 days in the greenhouse.

Fertilization					CIAT Accession Number	
P	Ca	K	Mg	S	438	5189
mg/pot					MS g/pot	
0	0	0	0	0	1.46 d	1.10 d
25	125	0	0	0	3.90 c	4.83 bc
25	125	37	0	0	4.23 bc	4.10 c
25	125	0	25	0	3.50 c	5.10 bc
25	125	37	25	0	3.46 c	4.36 bc
25	125	0	0	25	4.30 bc	4.70 bc
25	125	37	0	25	4.83 ab	4.66 bc
25	125	0	25	25	3.36 c	4.60 bc
25*	125*	37*	25*	25*	3.66 c	5.36 b
50	250	37	25	25	5.53 a	6.80 a

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

* Fertilization dosis equivalent to 20 kg P, 100 kg Ca, 30 kg K, 20 kg Mg and 20 kg S/ha.

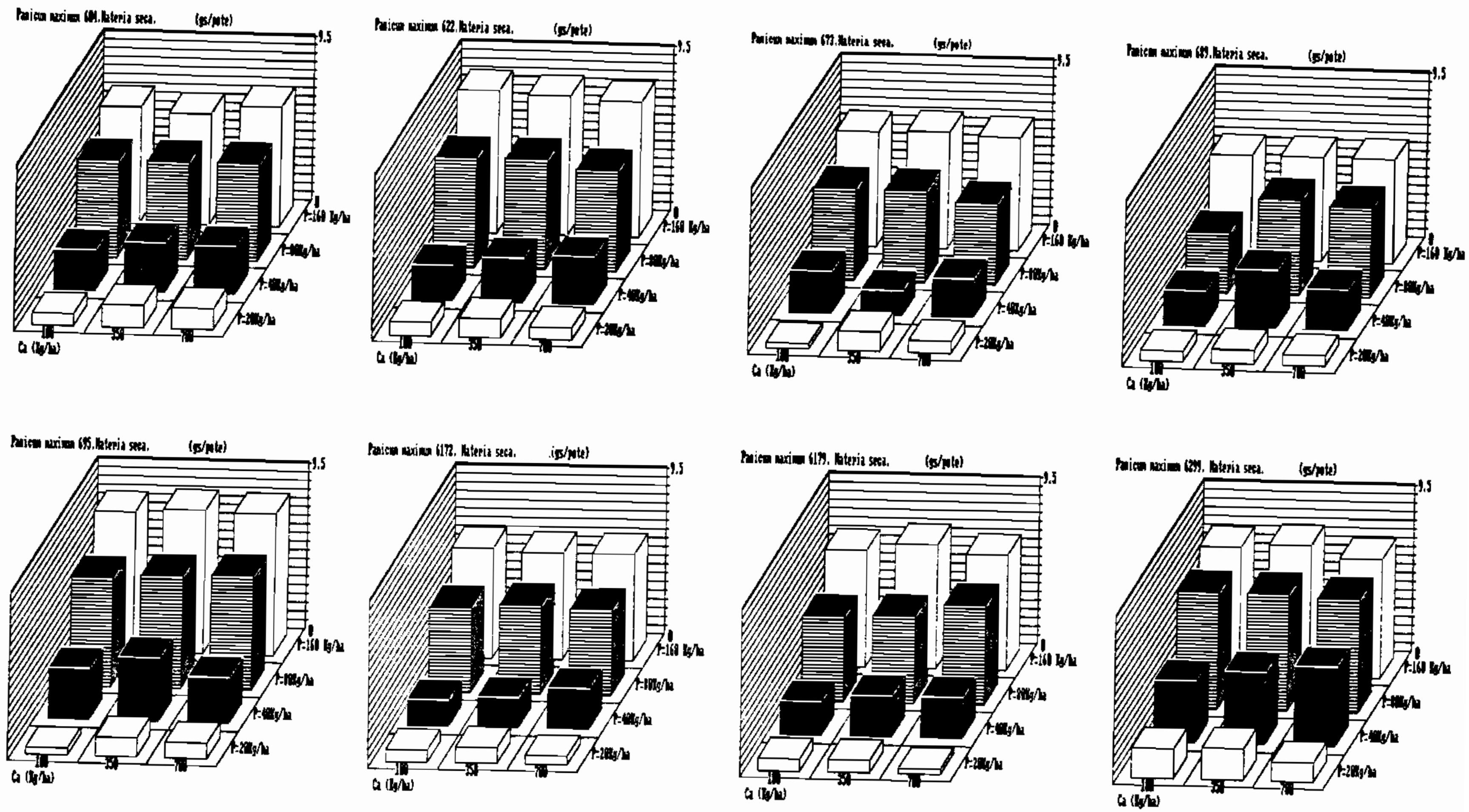


Figure 3. Dry matter production of eight P. maximum accessions fertilized with four doses of P and three doses of Ca in a clayey Carimagua Oxisol.

Table 5. P content (%) in tissues of eight P. maximum accession in relation to P dosis. (Average of nine observations).

P Dosis (kg/ha eq)	P Dosis (mg/pot)	604	622	673	689
20	25	0.12 b	0.10 bc	0.11 b	0.10 b
40	50	0.11 b	0.12 ab	0.10 bc	0.09 b
80	100	0.12 b	0.09 c	0.09 c	0.10 b
160	200	0.15 a	0.14 a	0.15 a	0.15 a

P Dosis (kg/ha eq)	P Dosis (mg/pot)	695	6172	6179	6299
20	25	0.10 b	0.11 b	0.11 b	0.09 bc
40	50	0.09 c	0.11 b	0.10 b	0.08 c
80	100	0.09 c	0.09 b	0.10 b	0.10 b
160	200	0.14 a	0.13 a	0.15 a	0.16 a

Averages followed by the same letter within each accession are not different at 5%.

presence of high levels of available Ca, while the second group (accessions 604, 689, and 6299) are very sensible to changes in the availability of Ca in the soil, that is to say, they are eager for Ca. However, this increase in Ca tissue content was not associated with greater yields, which indicates it was a luxurious consumption.

2. Fertilizer Adjustment for Pasture Establishment

In spite of prevailing, common characteristics--low pH, high Al saturation, low content of P and exchangeable bases (Ca, Mg, K)--the acid, infertile soils have physical and chemical differences which affect production and performance of adapted forage plants. Bearing this in mind, and aware that pasture establishment takes place in a variety of acid soils, fertilization adjustment evaluations were initiated in different soils to identify essential nutritional requirements for successfull establishment. Two associations (A. gayanus cv. Carimagua 1 - S. capitata cv. Capica, and A. gayanus - S. macrocephala 1643) were established in different Carimagua soils, whose characteristics are detailed in Table 7. The experimental design used was the double square modified by Escobar which includes the response to fertilization with 2 nutrients distributed in 12 treatments. Based on previous experience, P and K were

Table 6. Ca content (%) in tissues of eight P. maximum accessions in an Oxisol from Carimagua in relation to treatments applied. (Average of three observations).

Treatm.* Ca	P	Accesa. 604	Treatm. Ca	P	Access. 622	Treatm. Ca	P	Access. 673	Treatm. Ca	P	Access. 689
3	4	0.75	3	4	0.68	3	4	0.70	3	4	0.79
3	3	0.75	3	2	0.64	3	2	0.62	3	3	0.63
3	2	0.75	3	3	0.59	3	3	0.59	2	4	0.57
2	4	0.64	2	4	0.55	2	4	0.52	2	3	0.52
2	3	0.61	2	3	0.45	3	1	0.52	1	4	0.51
2	2	0.59	3	1	0.44	2	3	0.47	3	2	0.48
3	1	0.54	2	2	0.41	2	1	0.46	1	3	0.46
1	3	0.50	1	3	0.39	1	4	0.46	2	2	0.41
2	1	0.50	2	1	0.36	2	2	0.42	3	1	0.35
1	4	0.43	1	2	0.36	1	3	0.39	1	2	0.35
1	2	0.41	1	4	0.35	1	2	0.37	2	1	0.35
1	1	0.26	1	1	0.22	1	1	0.26	1	1	0.18

Treatm.* Ca	P	Access. 695	Treatm. Ca	P	Access. 6172	Treatm. Ca	P	Access. 6179	Treatm. Ca	P	Access. 6299
3	4	0.70	3	4	0.67	3	2	0.63	3	4	0.66
3	2	0.64	3	2	0.61	3	4	0.58	2	4	0.54
3	3	0.58	3	3	0.59	3	3	0.55	3	3	0.54
2	4	0.54	2	4	0.53	3	1	0.50	3	2	0.50
3	1	0.49	3	1	0.48	2	4	0.49	2	3	0.44
2	3	0.46	2	3	0.43	2	2	0.48	1	4	0.42
2	2	0.45	2	2	0.41	2	3	0.47	3	1	0.39
1	2	0.43	1	4	0.38	1	4	0.41	2	2	0.37
1	3	0.40	1	3	0.38	1	3	0.40	1	3	0.35
2	1	0.38	1	2	0.37	1	2	0.37	2	1	0.33
1	4	0.37	2	1	0.35	2	1	0.37	1	2	0.31
1	1	0.20	1	1	0.26	1	1	0.25	1	1	0.25

Averages connected by the same line do not differ at 5%.

* Treatm. Ca: 1 = 100 kg Ca/ha; 2 = 350 kg Ca/ha; 3 = 700 kg Ca/ha.
Treatm. P : 1 = 20 kg P/ha; 2 = 40 kg P/ha; 3 = 80 kg P/ha; 4 = 160 kg P/ha.

Table 7. Texture and chemical characteristics of the soils in five sites in Carimagua.

Site	Soil Particles			Texture	O.M.	pH	Exchangeable Cations				Al.Sat.	P Bray 2	S
	Sand	Lime	Clay				Al	Ca	Mg	K			
	---------- % ---------				%		-------- meq/100 g ------				%	ppm	ppm
Alegría	68	23	9	SL	1.0	4.8	0.8	0.12	0.06	0.04	82	2.1	17
Yopare	32	34	35	SL	2.1	4.9	1.3	0.10	0.05	0.04	90	1.4	15
La "L"	8	51	41	LiC	1.9	4.5	1.8	0.14	0.06	0.04	90	1.6	21
Reserva	12	53	35	LiCL	2.5	4.6	2.1	0.11	0.06	0.05	93	1.6	18
Alcancía	10	48	42	LiC	2.9	4.8	2.7	0.17	0.09	0.06	91	2.0	15

L = Loamy; S - Sandy; C = Clayey; Li = Limy.

considered in this study as essential nutrients in these soils and for these two associations.

One of the factors evaluated in these trials was rainfall distribution at each site, since rainfall distribution can have a greater effect over pasture establishment than the total amount of rainfall in savanna ecosystems. Figure 4 shows weekly rainfall distribution from planting period to the evaluation cutting conducted 20 weeks after the associations had established. Total rainfall (2017 mm) was similar for all sites, but distribution varied; La Reserva and Alcancía had less intensive rainfall but was prolonged over a longer period, in comparison to the other sites. This extreme water saturation in the latter cases, primarily in the Alcancía clayey soil, resulted in slow establishment and therefore lower forage production in relation to the other sites. The sites Alegría and La "L" showed more favorable rainfall distribution cycles.

Based on the surface response regression model, isoquantum lines were observed for dry matter production of the two associations. Figures 5 and 6 show estimated dry matter yields of the two associations as a function of P and K at the 5 sites in the Carimagua area.

The A. gayanus cv. Carimagua 1 - S. capitata cv. Capica association (Figure 5) indicates a general P requirement for its establishment, independent of the texture variation of these soils; this is obviously related to the low availability of P in these soils. Fertilization adjustment was considered for 80% maximum yield obtained at each site; at this yield level, P doses below 20 kg/ha were observed to not be sufficient to reach the level of established dry matter production in any of the sites. Furthermore, P doses greater than 30 kg/ha had a stabilizing effect on legume production but increased A. gayanus production. A reduction in required K was observed as sand content in the soil diminished. In the sandiest (Alegría), 30 kg K/ha seemed to be adequate and compatible with each P level required for a specific level of dry matter production. Doses below and above 30 kg k/ha showed a tendency to increase P requirements at similar production levels. The fertilization level required by this sandy soil to produce 80% of the maximum yield (1600 kg DM/ha) obtained with this association is band application of 20 kg P/ha and 30 kg K/ha. Based on the unit cost of P, which is the most expensive nutrient in Carimagua (phosphoric rock at Col.$210/kg P, triple superphosphate at Col.$286/kg P; Calfós at Col.$323/kg P, and KCl Col$85/kg P--September 1986 prices), recommended fertilization at the other sites is: 25 kg P/ha - 60 kg K/ha in Yopare; 20 kg P/ha - 60 kg K/ha in La "L"; 25 kg P/ha - 10 Kg K/ha in La Reserva; and 20 kg P/ha in Alcancía. Overall, fertilization costs ranged from Col.$6,000 to 12,000 per hectare (US$28-55/ha, at an exchange rate of US$ 1 = Col.$ 217).

P is observed to be the determinant nutrient for the good establishment of the A. gayanus cv. Carimagua 1 - S. macrocephala 1643 association (Figure 6). However, K seems to be necessary not only in sandy soils but also in clayey soils. Fertilization adjustment in economic terms would be: 25 kg P/ha - 20 kg K/ha in Alegría; 20 kg P/ha - 30 kg K/ha in Yopare; 10 kg P/ha - 50 kg K/ha in La "L"; 25 kg P/ha - 50 kg K/ha in Reserva; and 20 kg P/ha in Alcancía. Overall, this fertilization would have a cost of approximately Col.$6,000-8,000 (US$30-40).

The effect of soil texture on establishment was different for grasses and legumes. Thus, A. gayanus established in a similar way in the five sites;

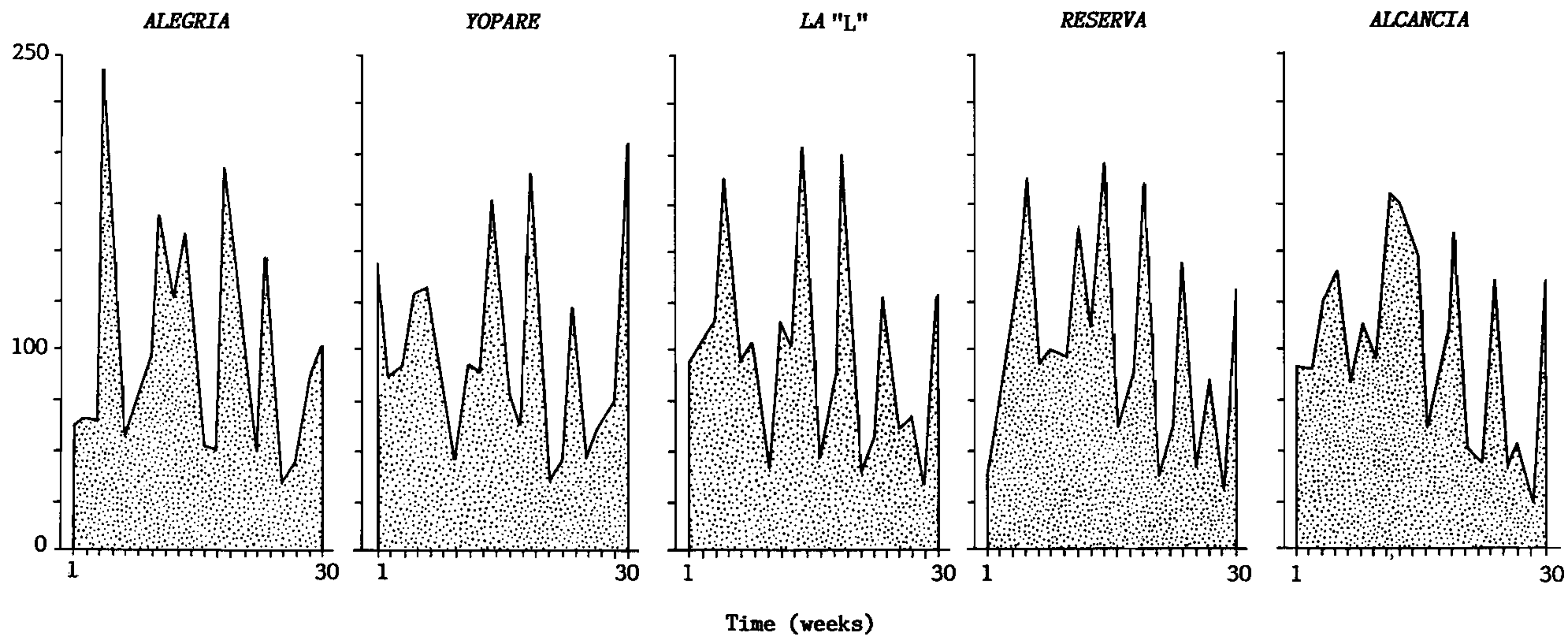


Figure 4. Weekly rainfall distribution at five sites in Carimagua. First week, April 27 - May 3, 1986.

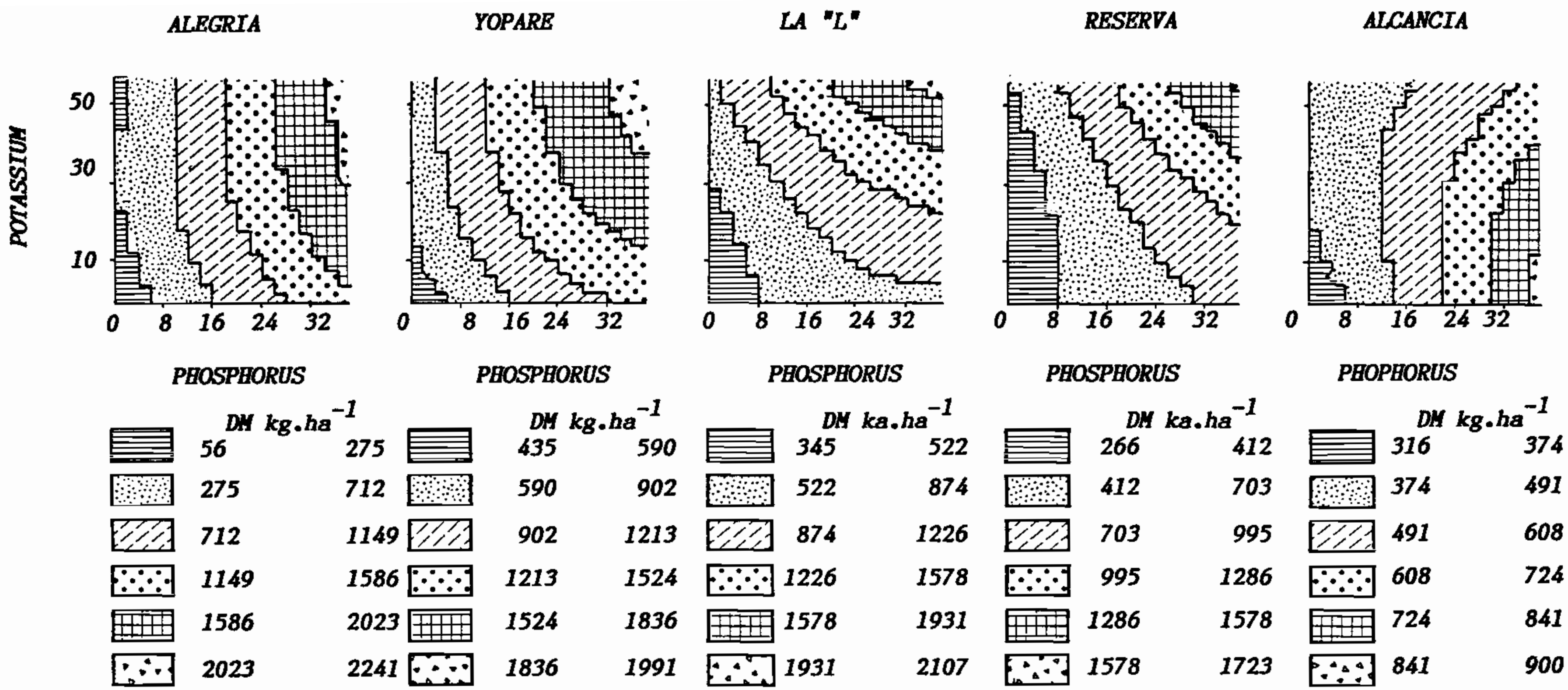


Figure 5. Dry matter production of the A. gayanus - S. capitata association as a function of P and K dosis obtained 20 weeks after establishment in five Oxisols in Carimagua, Colombia.

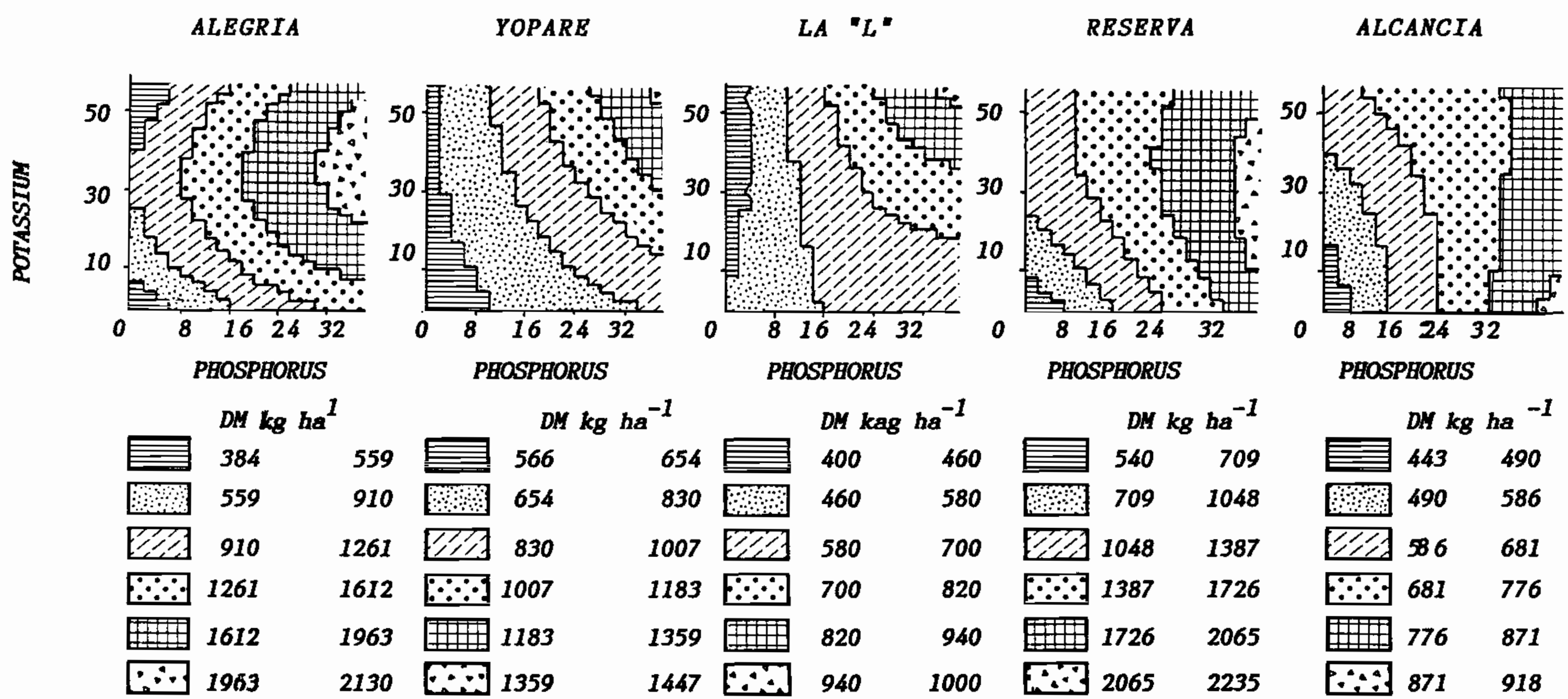


Figure 6. Dry matter production of the A. gayanus - S. macrocephala association as a function of P and K dosis, 20 weeks after establishment in five Oxisols in Carimagua, Caolombia.

however, both legumes did show responses to the site, their establishment being better in sandy soils (Figure 7). With time *A. gayanus* cv. Carimagua 1 would be expected to be less vigorous in sandy soils, which would favor the legume.

3. Quantification of Nutrient Gains and Losses in Pastures (evaluation methodology).

The association *A. gayanus* cv. Carimagua 1 - *S. capitata* continued to be evaluated under three grazing pressures (high, medium, and low) and residual K maintenance fertilization applied two years before. Details on this trial were given in the 1985 Annual Report.

Grazing pressure treatments had marked differences on forage availability but annulled the effect of K fertilization. Therefore, this year's results in terms of forage on offer, plant residues, and changes of certain nutrient in the soil-plant-animal system are presented as a function of grazing pressure throughout the grazing cycles of the year.

Figure 8 shows forage on offer and residual forage during each grazing cycle (7 occupation days and 35 rest days) for each grazing pressure. Changes in forage availability are primarily due to management and not to K maintenance fertilization. It is evident that a low grazing pressure leads to the subutilization of the pasture and results over time in the instability of the legume (*S. capitata*) due to the agressiveness and competition of the grass species (*A. gayanus*). On the other hand, a high stocking rates are associated with the excessive utilization of the pasture, which favors the recovery of the legume during the first cycle; but, the legume also tends to disappear afterwards in the grazing cycles corresponding to the beginning of the dry period (Figure 9).

The effect of grazing pressure was also evaluated in terms of the dynamic of certain nutrients on forage on offer and on residual forage, with the object of measuring nutrient accumulation, stability, or loss in the system. Figure 10 shows changes in N, P and S observed under the three grazing pressures and Figure 11 shows the same data for K, Ca, and Mg. As the grazing pressure increased, a significative reduction in nutrients was observed after each grazing cycle, primarily associated with the lack of available forage. A tendency was observed under medium pressure in which available nutrient in forage on offer and in residual forage were kept constant after each grazing cycle, while during low pressure the tendency was to acccumulate this nutrient. This suggests that the medium pressure would be the most adequate to maintain the pasture stable over time.

The contribution of plant residues was also influenced by pasture management. Figure 12 shows changes occurred in the loss and accummulation of various nutrients. Overall, low stocking rates resulted in the accummulation of plant residues and therefore in an increase in the contribution of nutrients to the system toward the end of the year. In a similar way but to a lower extent, the medium intensity treatment showed the contribution of nutrient in the residue. On the other hand, the high stocking rate resulted in loss of nutrients in the system, associated to the lack of plant residues which in turn determined the poor regrowth. These results clearly indicate that pasture management is one of the most important factors to guarantee the cyclic return of nutrients to the system and thus the ability to establish a pasture over time with the minimum requirements of maintenance fertilization.

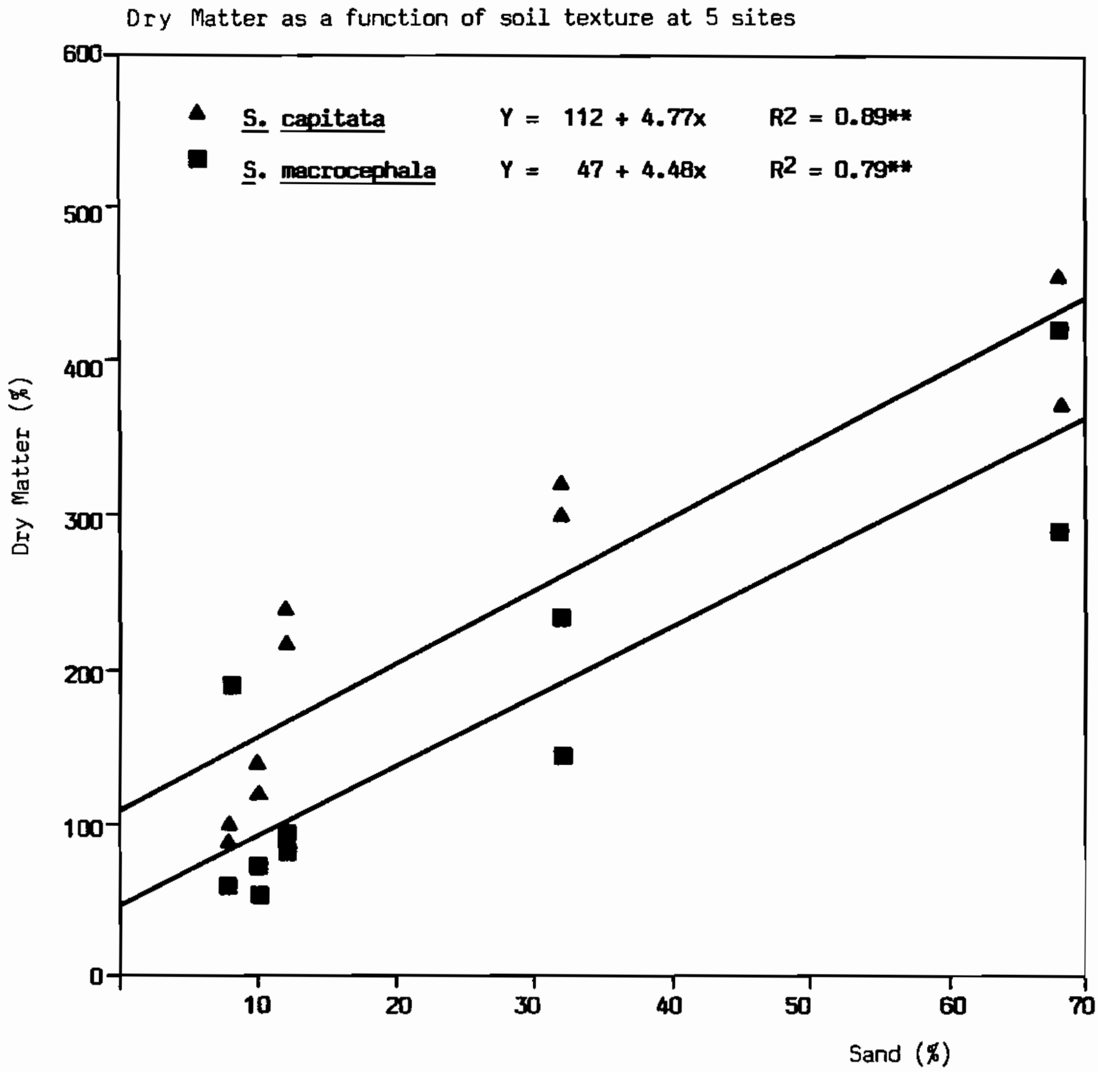


Figure 7. The effect of the soil texture (% sand) on the dry matter production of *S. capitata* cv. Capica and *S. macrocephala* 1643 associated to *A. gayanus* cv. Carimagua 1

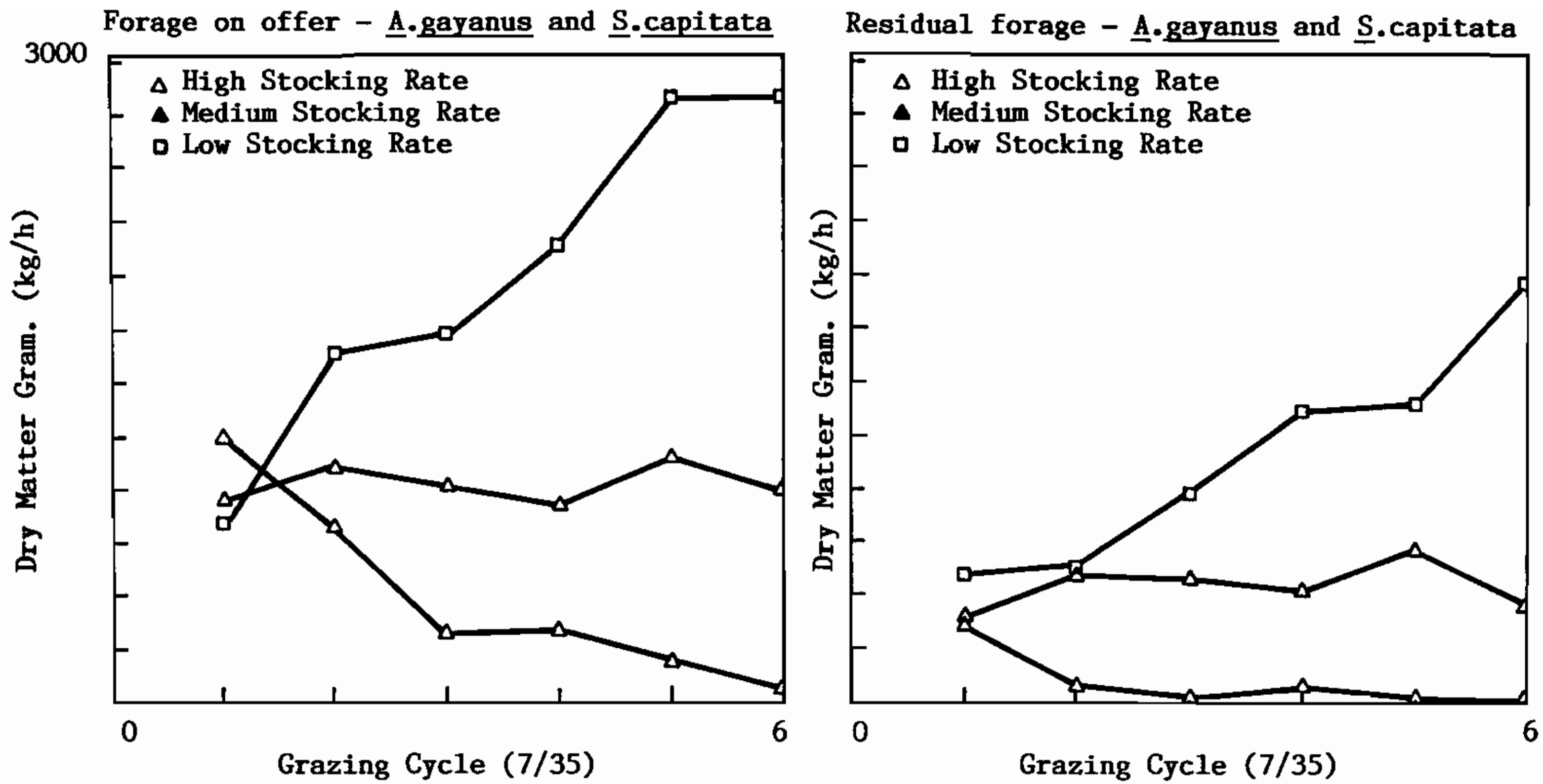


Figure 8. Forage on offer and residual forage in an association of A. gayanus and S. capitata under grazing with three stocking rates.

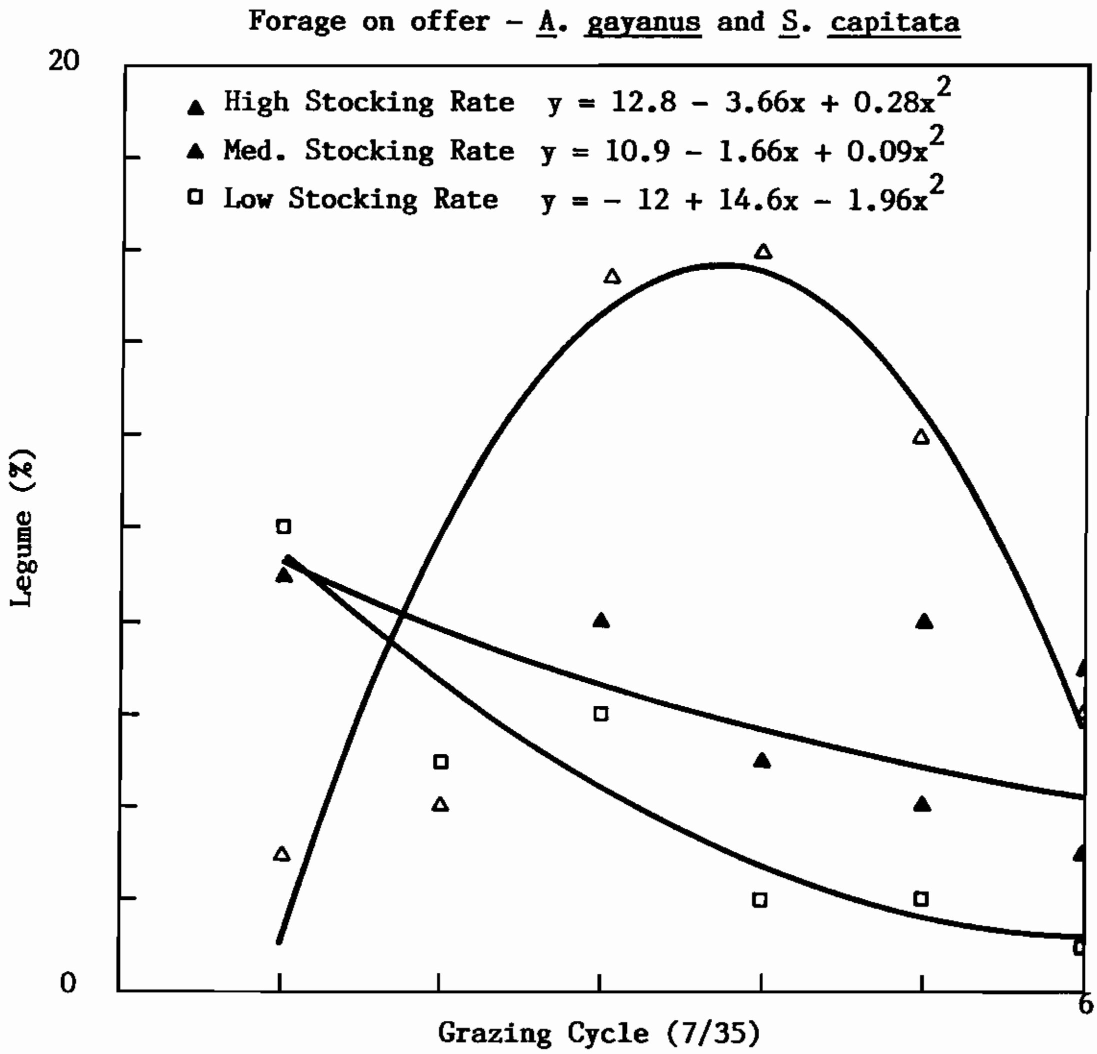


Figure 9. The effect of the stocking rate on the legume availability in an A. gayanus and S. capitata association (Carimagua).

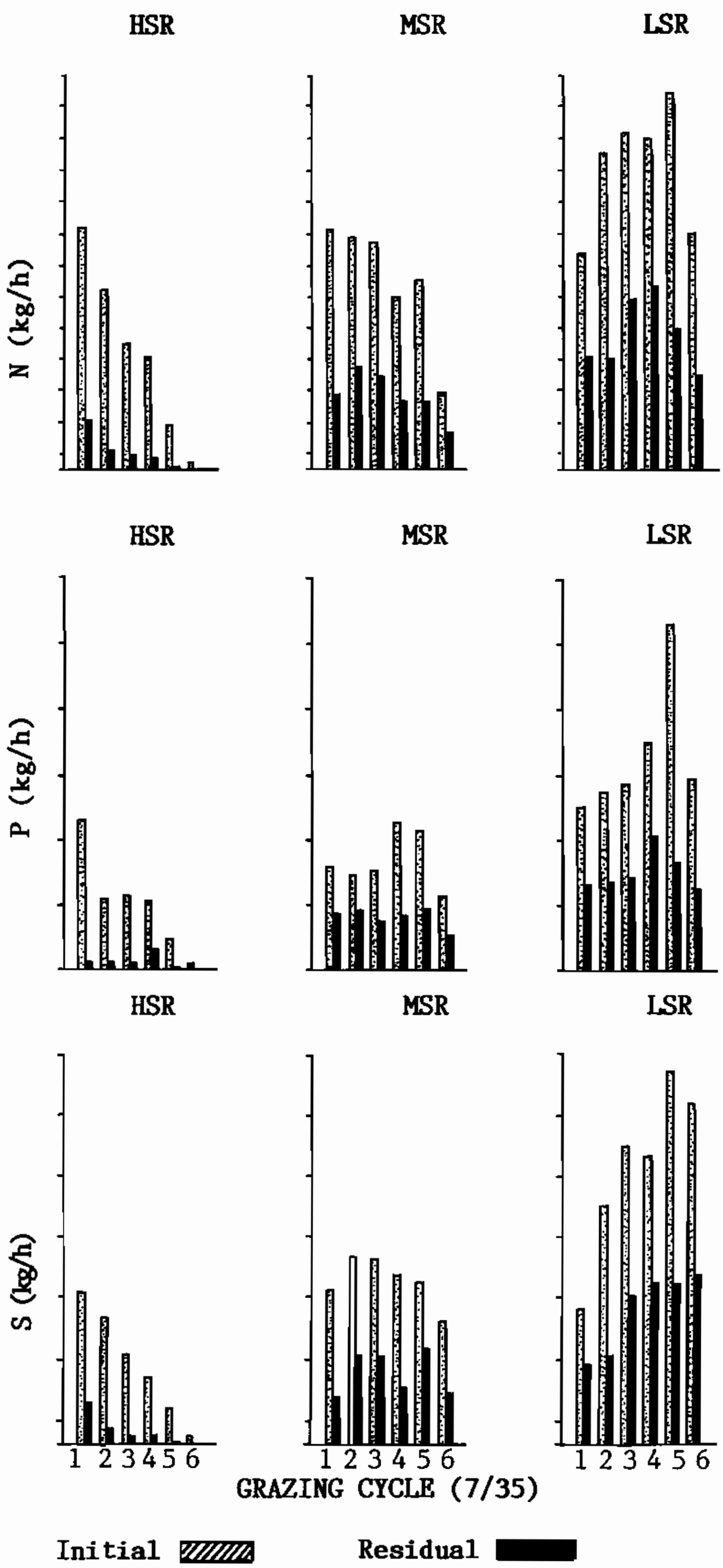


Figure 10. Changes over time of N, P and S availability in initial and residual forage under three stocking rates (Carimagua)

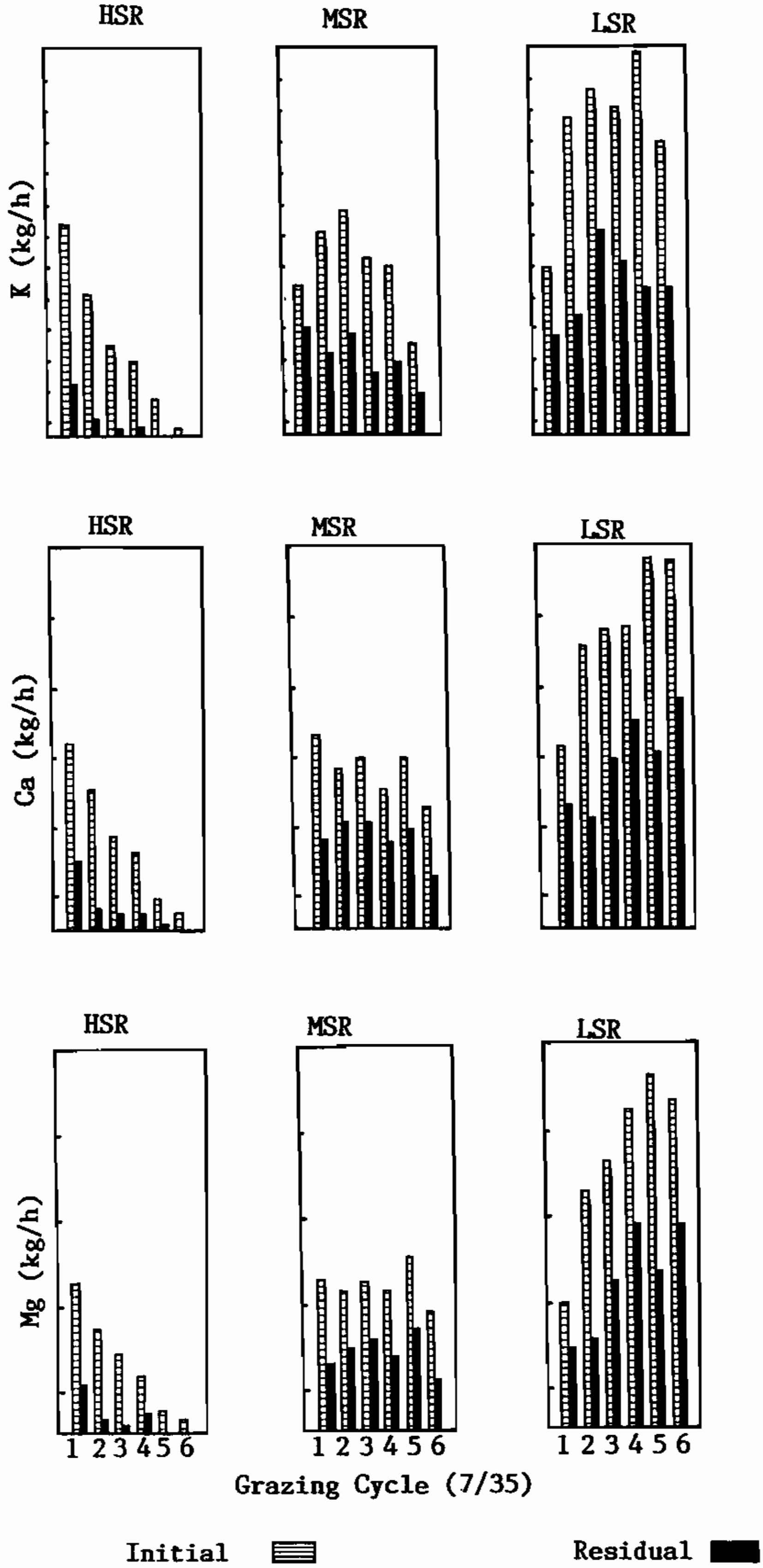


Figure 11. Changes over time of K, Ca and Mg availability in initial and residual forage under 3 stocking rates (Carimagua).

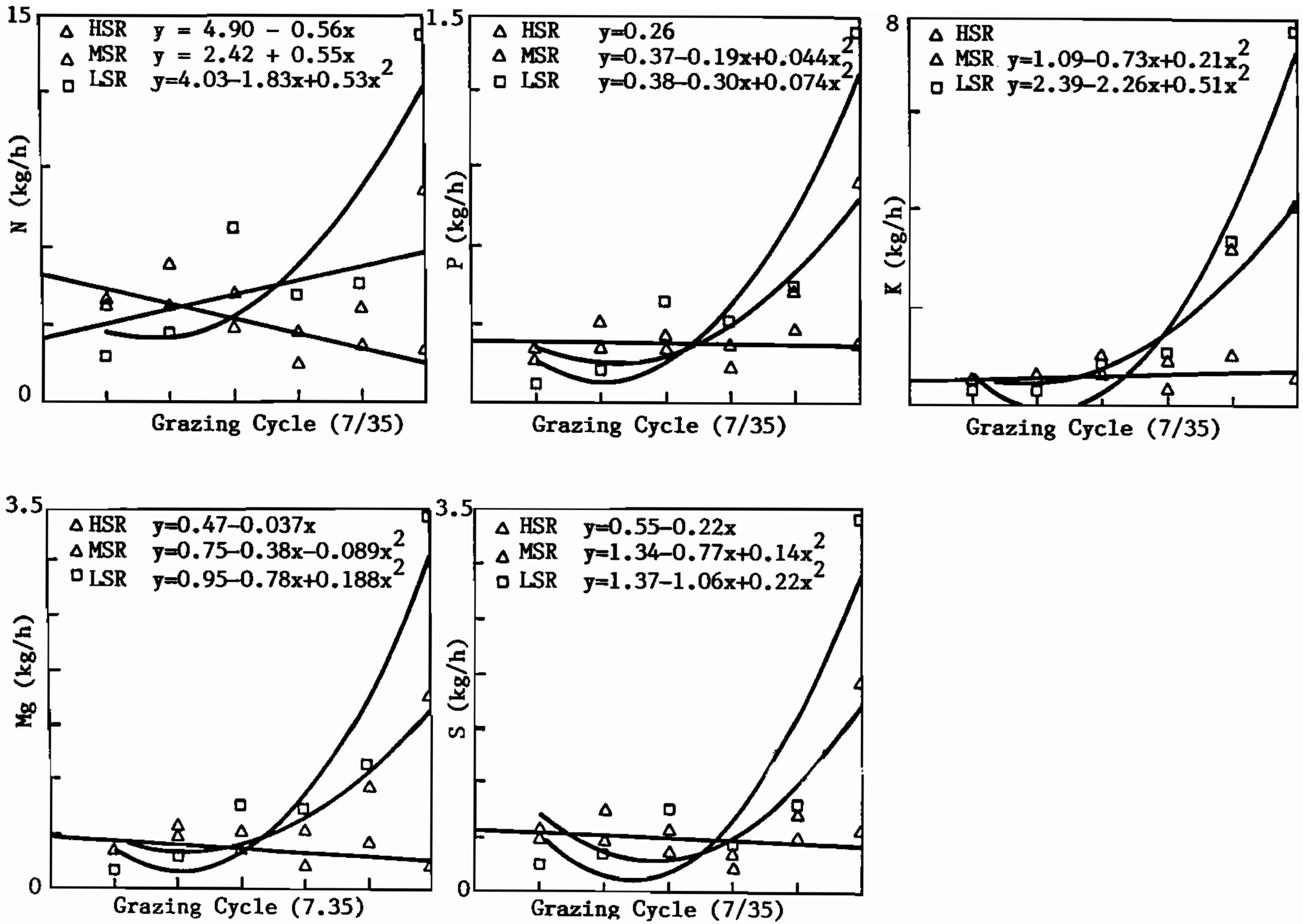


Figure 12. Nutrients profits and losses in plant residues in an A. gayanus and S. capitata association under three stocking rates (Carimagua)

Pasture Development (Carimagua)

INTRODUCTION

The year 1986 has been the wettest recorded since the Carimagua Center was founded in 1970 with a total of over 3000 mm of rainfall compared to an average for the 12 years (1973-1974) of 2180 mm. Some plantings were affected by the intense rains during establishment which resulted in washing and/or burying of seed. The initial development of seedlings was also affected by excessive cloud cover from May to September. The factor which most affected pasture research this year in new plantings as well as in established pastures was the very high water table which led to almost continuous saturation of the soil from June to October. Some species were much more affected than others. The most serious damage occurred in pastures under grazing on nearly level sites where the water table reached the surface of the soil and remained there during more than two months.

Under these very difficult conditions, some species showed remarkable tolerance to excess water. Among the legumes: Desmodium ovalifolium 13089 (and others) and Arachis pintoi 17434; among the grasses: Brachiaria humidicola 679 and B. dictyoneura 6133 were the outstanding accessions.

Species most adversely affected on level sites were the grasses B. decumbens 606 and Andropogon cv. Carimagua 1; the legumes Stylosanthes capitata cv. Capica, Centrosema acutifolium 5277 and Pueraria phaseoloides (Kudzu) were also affected by trampling of animals in saturated pastures.

The effect of excess water in the soil was clearly visible in the contrast between the plots of the Forage Agronomy, Soils and Plant Nutrition and Pasture Development sections in Alcancía where the land is very flat and soils are fine textured (10% sand), and in Yopare where there is sufficient slope for good surface drainage and the soils are sandy loams (approximately 30% sand). Almost without exception the germplasm performed better in Yopare.

The importance of such a wet year in the selection of germplasm is not easily quantified. Meteorological records are available only from 1970 and some are incomplete. For that reason, there is no basis for estimating the probability of occurrence of such a year in the future.

ESTABLISHMENT

Tillage

The reduced tillage system described in previous reports (1984, 1985) has consistently given excellent results on Oxisols under the climatic conditions that prevail in Carimagua. As a consequence, the system has been adopted for nearly all plantings at the Center, including both experimental and commercial fields. Photos 1 and 2 show the chisel plow equipment that is used for the first

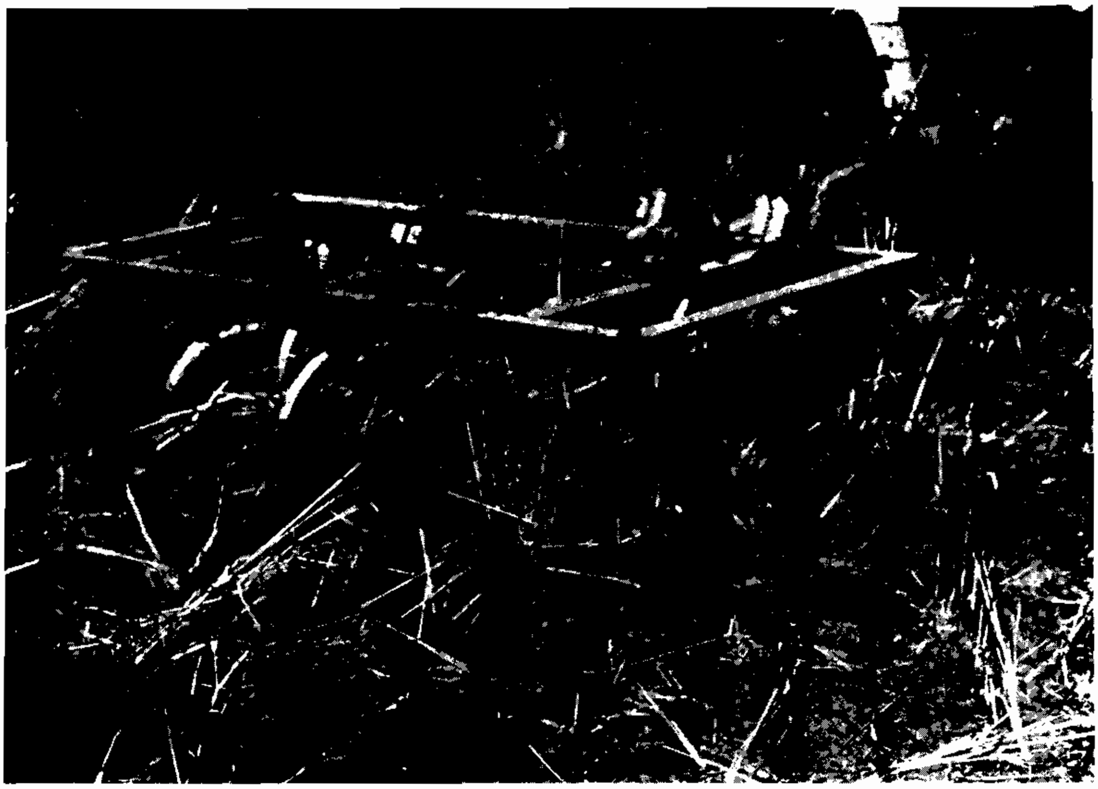


Photo 1. The of the chisel plow has given excellent results in seedbed preparation for planting pastures in Carimagua Oxisols. The second pass is made with an off-set disk.

Photo 2. Chisels are used to break the sod of native savanna and in old pastures, achieving depths of 12 to 15 cm.

pass in reduced tillage. An off-set disk is used for the second pass. Photo 3 shows the condition of the soil after preparation for planting. The resulting seedbed is stable, permeable and resistant to sealing (crusting) and erosion.

Planting

The direct seeding system has also been adapted and has been widely used successfully with several plantings during the year. Examples:

- The introduction of S. capitata cv. Capica in old pastures of B. decumbens in a sandy soil of Alegría (40 ha).
- The introduction of P. phaseoloides (Kudzu) in established pastures of B. decumbens in El Tomo (40 ha) and in pastures of A. gayanus at the Family Farm (12 ha).
- The introduction of B. humidicola in native savanna in El Tomo (190 ha).

The implement used for direct seeding has proven to be especially useful since the individual components continue to fulfill their original functions. The fertilizer spreader and its small seed planting attachment can be secured directly to the three point hitch of the tractor or to a similar hitch which is mounted on the rear frame of the chisel plow. In addition, the chisel plow has been adapted for direct planting using vegetative material and/or seeds. The chisel plow can be used separately for tillage and the fertilizer spreader can be hitched directly to the tractor for maintenance application of fertilizer and for fertilizing and planting simultaneously in fields previously prepared.

The Introduction of Legumes in Pure Grass Pastures

An experiment was carried out to study the feasibility of introducing legumes into an old pasture of B. humidicola. Variables include different fertilizers, tillage and chemical control of the existing grass and different legume species planted at two different densities. Excellent plant populations were obtained where chisel tillage was utilized, with and without herbicide, for all species, planting densities and fertilizers. On the other hand, stands were deficient in treatments without tillage, with or without chemical control. In Figures 1 and 2, the effects of tillage and herbicide are shown for two species and two planting densities during the initial development of the planted legumes. C. brasilianum 5234 was exceptionally vigorous in this stage. The experiment has been managed under periodic grazing in order to control the grass and avoid excessive competition with the introduced legumes. When planted in a 2 x 2 pattern, C. brasilianum covered over 20% of the area in 3 months; 35% coverage was achieved with the 2 x 0.5 m pattern. These results are especially important in view of the large expanses of B. humidicola found in the humid tropics of South America, with important areas already degraded due largely to the lack of nitrogen.

Low Density Seeding of B. dictyoneura 6133 and Arachis pintoi 17434

In view of the potential importance of these two species, an experiment was established to study the feasibility of planting with vegetative material using a system of low density planting (2x2 m) with different levels of tillage. The effect of tillage on the number and length of stolons is shown in Table 1 for both species, along with coverage and weeds observed at 6, 10 and 17 weeks after planting. The very rapid increase of weeds over time, especially in the 0, minimum and reduced tillage treatments clearly demonstrates the importance of early, vigorous development of planted species.

Photo 3. The soil is rough and cloddy, with large quantities of residue and roots still in the surface after reduced tillage is carried out with a chisel plow followed by an off-set disk.

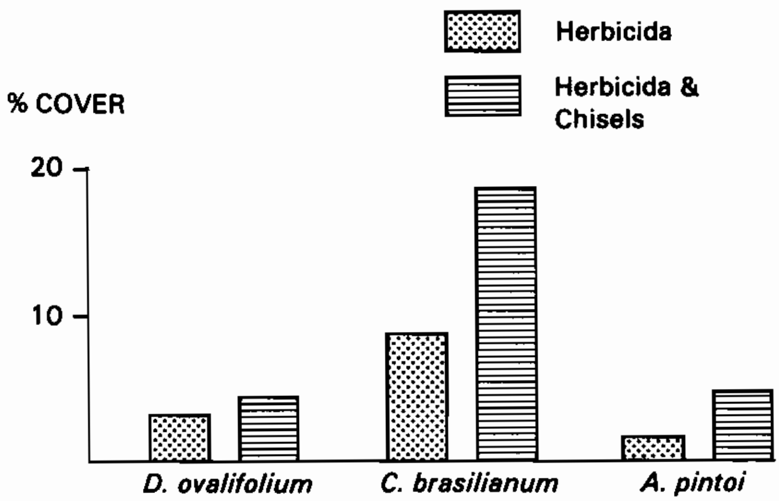


Figure 1. The effect of tillage and herbicide in the development of legumes planted into B. humidicola, three months after planting, Alegría, 1986.

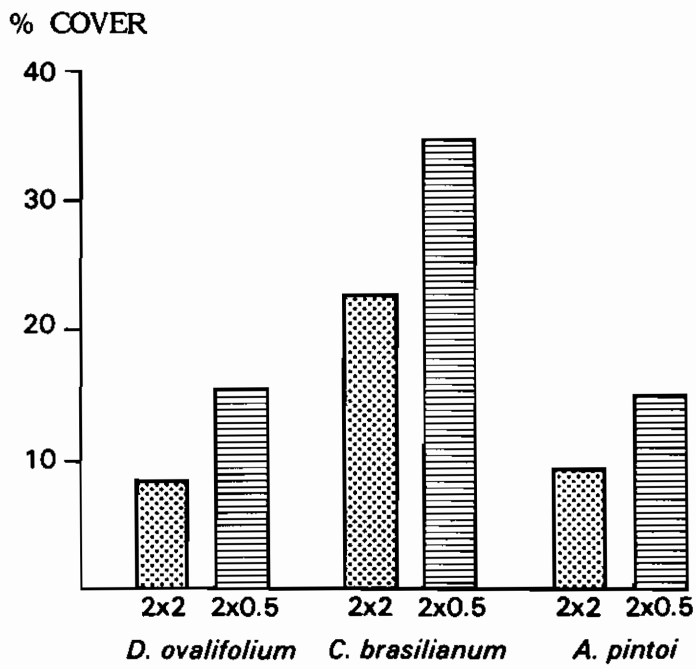


Figure 2. The effect of species and planting densities on the development of legumes planted into B. humidicola pasture, three months after planting, Alegría, 1986.

Table 1. The effect of tillage on the number and lenght of stolons of *A. pintoi* and *B. dictyoneura* and percent weed cover after 6, 10 and 17 weeks from planting in a planting pattern of 2x2 m.

Tillage	Length of stolons (cm)			Weed cover (%)		
	Weeks			Weeks		
	6	10	17	6	10	17
	Arachis pintoi 17434					
Zero	6(2)*	14(4)	48(5)	12	14	75
Minimum	5(2)	14(4)	49(6)	12	11	57
Reduced	5(2)	13(5)	43(7)	3	3	26
Conventional	5(2)	14(5)	43(7)	0	1	11
	Brachiaria dictyoneura 6133					
Zero	6(3)	11(7)	20(13)	12	14	79
Minimum	6(2)	11(5)	20(8)	11	9	58
Reduced	5(2)	11(5)	26(18)	4	3	26
Conventional	6(3)	15(9)	47(30)	0	1	10

* Number of stolons, average/plant.

The effect of competition on the development of planted species can also be seen. A. pintoi 17434 appears to be relatively unaffected by competition in terms of length of stolons, but with the tendency for a greater number of stolons in the treatments which resulted in the least competition. On the other hand, the grass is seen to be very much affected by competition, both in terms of length and number of stolons. There was no effect of phosphorus level beyond 0.4 g of P/planting site (equivalent to 1 kg of P/ha).

Date of Seedbed Preparation and Planting and the Control of Ants

The principal objective of this experiment is to determine the effect of early seedbed preparation (before the beginning of the dry season) vs seedbed preparation after the beginning of the rainy season in the year of planting, and different dates of planting. The experiment suffered from a number of problems, the first being a large lot of seed which had supposedly been tested and found to be of good quality, but had almost no viable seed. Thus it was necessary to repeat the early planting, losing much of the potential advantage of the treatment. In addition, the excessively wet year resulted in a very high water table which directly affected the plantings and also the ant population in the area under study. Some aspects of the study will be repeated.

The Use of Seed-coated Pellets

The work with seed-coated pellets was continued and expanded to include soils of contrasting texture and rates of fertilizer applied at each hill. Figure 3 shows the effect of both factors on D. ovalifolim 13089 and S. capitata cv. Capica. In general, D. ovalifolim achieved greater coverage than S. capitata on both soils, especially when there was appreciable control of native vegetation (30 and 100% of the total area). The optimum fertilizer levels for each planting site range from 2.4 to 6.8 g of complete fertilizer, depending on species and soil.

Experience to date with pellets have led to the following conclusions:

- The solubility of the pellet is a key factor. The first pellets used (1984-85) were satisfactory. The second generation of pellets (1985-86), however, are too insoluble. For that reason, laboratory and greenhouse work is underway both in Japan and CIAT-Palmira in an attempt to define optimum ranges of solubility.
- Tillage as well as chemical control of vegetation at planting strongly favor seedling vigor and initial development and rate of spread.
- It has not been possible to incorporate an herbicide in the pellet to assure control of competing vegetation at the planting site.
- Alternatives for controlling vegetation include row tillage, where this is feasible, using chisels. This practice has been very effective, resulting in excellent development of planted species. It has also been possible to control competing vegetation with a manual application of herbicide at each planting site.

The potential advantages of planting with seed-coated pellets include the following:

- With a complete package of seed, Rhizobium ,fertilizer and herbicide it would be possible to broadcast the pellets in planted grass pastures or native savanna.

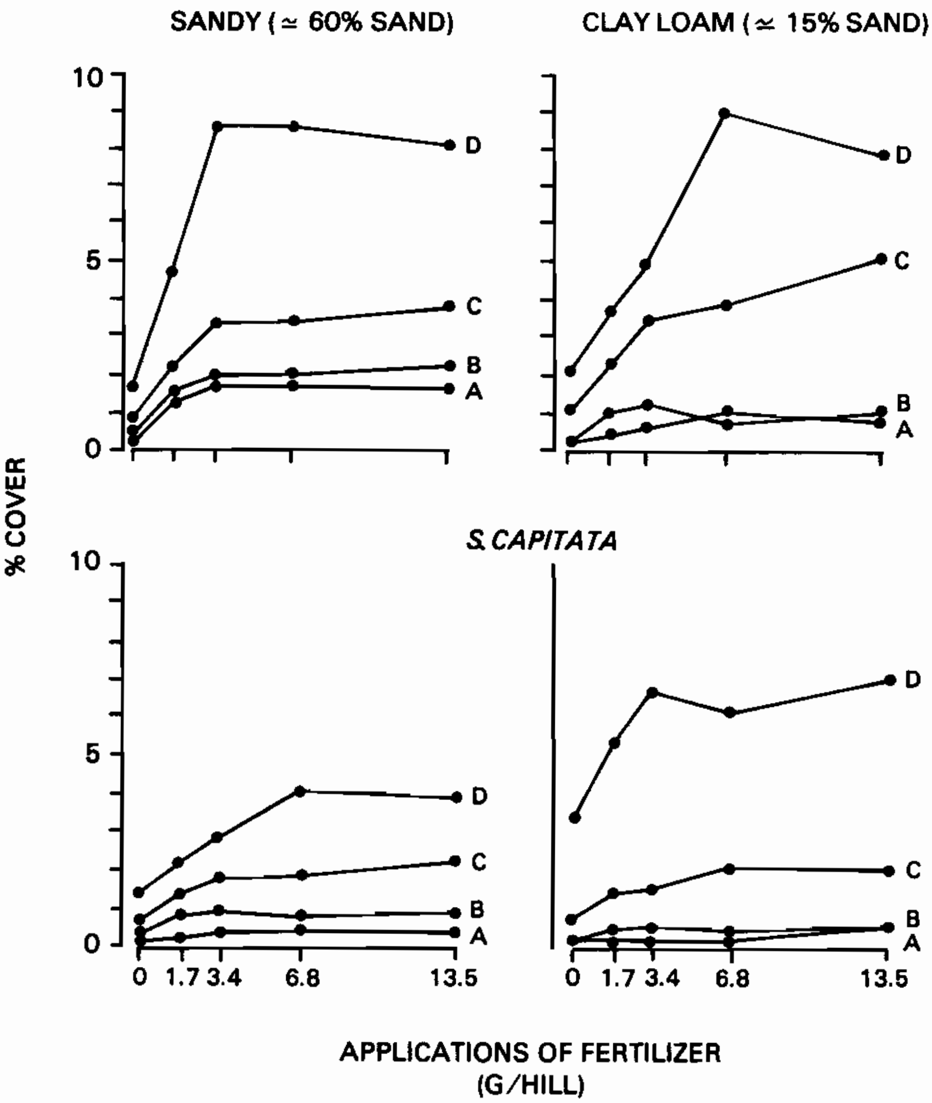


Figure 3. The effect of fertilizer and herbicide in the development of legumes planted into savanna, three months after planting in a low density pattern. Alegria and Alcancia, Carimagua. 1986. Applications of herbicide: A, nil; B, 3%; C, 30%; D, 100% of the area.

- The introduction of improved forage species in native savannas or naturalized savannas located in broken terrain or in regions of cerrado would be feasible even though the use of machinery were not possible.

Limitations for the system include:

- It is viable only for very aggressive forage germplasm.
- The initial development of the introduced species is relatively slow in the absence of some kind of vegetation control due to competition and to predation by insects and other fauna of the planted species.
- The fertilizer in pellet form and

the sticking of seed to the pellet result in a higher cost per unit fertilizer applied. Thus, the system is likely to be econimically attractive primarily for low density planting.

Strategies for the Efficient Use of Phosphorus during establishment

For the second year, an attempt was made to study the effect of planting patterns, levels of phosphorus applied and species on the efficiency of phosphorus during the establishment phase. Again, there were problems of excess water leading to run-off which caused washing of seed and excessive covering of some species, especially in sandy soils. In spite of these problems, the results are quite promising. In Tables 2 and 3, the effects of phosphorus levels and methods of planting and application of fertilizer in the development of two associations are shown in terms of plant height for the A. gayanus cv. Carimagua 1 + S. capitata cv. Capica and in terms of stolon length in the association B. dictyoneura 6133 + A. pintoi 17434. Table 2 clearly shows the effect of planting system. Planting in rows and application of fertilizer in bands was very advantageous. The effect of system is much greater in the case of the heavy textured soil than for the sandy soil, especially for the grass, which suffered much more from competition than the legume. Data in Table 3 show that the grass achieved very limited development in the heavy soil compared to the sandy soil. The legume was able to develop in both sites and showed a clear advantage for row planting. The objective of the study is to define a combination of planting and tillage systems, species and fertilizer levels which would result in lower establishment costs for pastures. The results suggest that the application of fertilizer in bands, especially when planting at a distance of 1 m, results in vigorous plants with rates of only 5 kg P/ha, indicating the possibility of greater efficiency in the use of phosphorus.

MAINTENANCE AND MANAGEMENT

Planting Patterns

The patterns experiment was terminated at the end of 1985. The area was rested from February to May of 1986 at which time a new stand count was made for S. capitata. As had been predicted, a good population of the legume was found as shown in Table 4. The result confirms once again the exceptional persistence of S. capitata cv. Capica. Its recovery during the rest period also demonstrates the potential of using different management strategies to maintain an adequate population, assure seed production and maintain adequate seed reserves in the soil.

Flexible Management

Of the five associations that were planted in 1984 in the first flexible management experiment in Carimagua, only two are presently under grazing: A. gayanus cv. Carimagua 1 + C. acutifolim 5277 and B. dictyoneura 6133 + A. pintoi 17434. The other three associations have failed to persist.

The A. gayanus + C. acutifolium association has proven to be stable and vigorous in spite of large differences between the two replications from the out-set, due to old roads and weed (largely Axonopus purpureii) competition. The heavy predation of ants in the summer of 1985-86 required a reorientation of the dividing fence in Rep. II in order to equitably distribute the affected areas between the two divisions. Persistence and production have been excellent as shown in Figures 4a and 4b.

The association B. dictyoneura 6133 + A. pintoi 17434 was quite vigorous in the year of establishment, however the

Table 2. The effect of methods of planting and fertilizer application and levels of P in the development of A. gayanus cv. Carimagua 1 and S. capitata cv. Capica in two soils. Carimagua, 1986.

Method of Planting and Application	P applied kg ha^{-1}	Plant height (cm)							
		Grass				Legume			
		Alcancía		Alegría		Alcancía		Alegría	
		12*	20*	12	20	12	20	12	20
Broadcast	5	17	55	16	88	12	35	8	27
	10	18	48	27	114	13	29	10	23
	20	20	72	28	147	9	31	7	28
	40	20	85	39	163	14	32	11	21
Bands each 50 cm	5	22	112	29	129	10	33	10	22
	10	19	131	30	159	10	38	16	27
	20	30	140	36	193	15	38	9	27
	40	24	147	40	181	12	37	10	21
Bands each 100 cm	5	29	136	24	170	14	44	10	27
	10	33	132	33	169	11	38	8	31
	20	31	176	38	179	15	43	8	20
	40	38	154	36	191	15	33	10	26

* Age in weeks.

Table 3. The effect of methods of planting and fertilizer application and rates of phosphorus in the development of B. dictyoneura 6133 and A. pintoi 17434 in two soils. Carimagua, 1986.

Method of planting and fertilizer application	P application kg ha^{-1}	Length of stolons (cm)							
		Alcancía-clay loam				Alegría-sandy loam			
		Grass		Legume		Grass		Legume	
		12*	20*	12	20	12	20	12	20
Broadcast	5	11	-	16	11	-	47	-	-
	10	-	-	-	10	10	49	4	-
	20	-	-	13	23	-	46	1	-
	40	-	-	6	-	9	85	4	-
Bands each 50 cm	5	-	-	23	28	-	43	24	42
	10	11	-	23	38	5	76	35	49
	20	-	-	16	39	17	73	26	50
	40	-	-	36	40	-	116	24	50
Bands each 100 cm	5	-	-	21	39	10	84	30	50
	10	-	-	24	39	18	75	7	44
	20	-	-	28	39	34	81	15	56
	40	-	-	21	30	19	113	4	37

* Age in weeks.

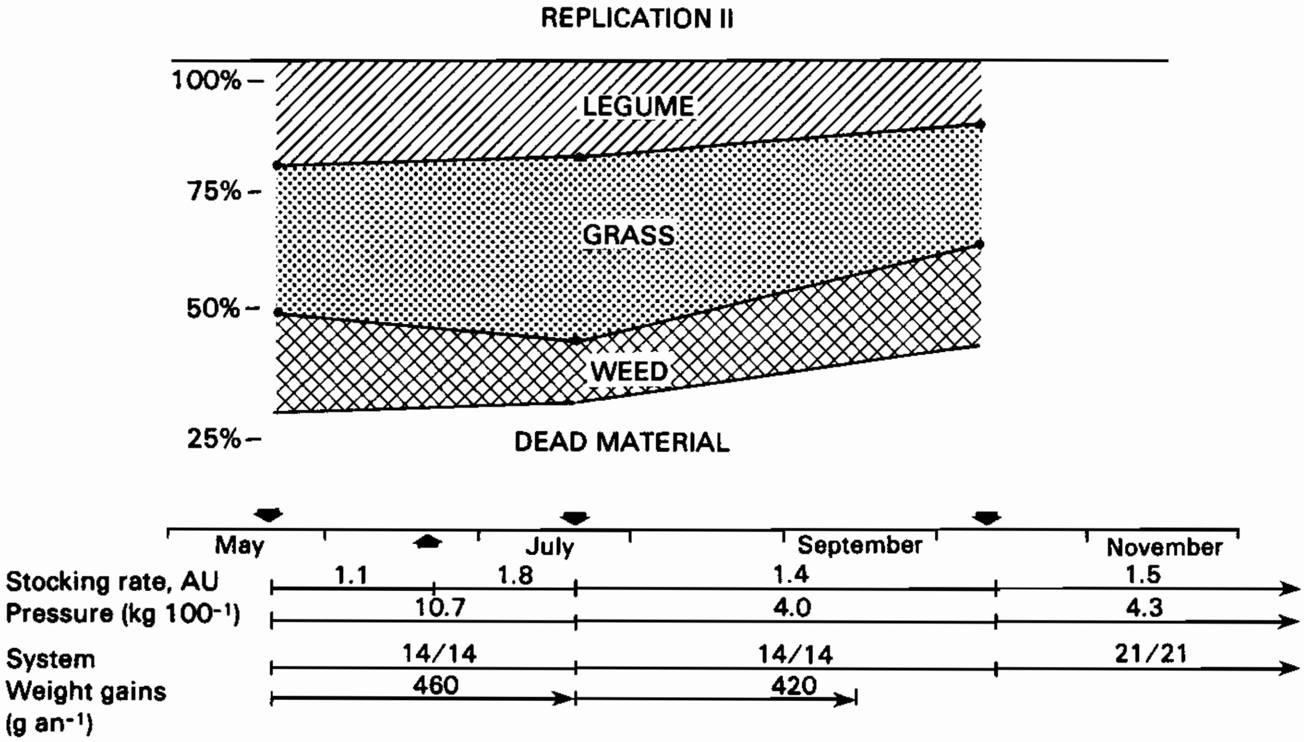


Figure 4a. **The evolution of an association of A. gayanus and C. acutifolium during the rainy season. 1986. Flexible management, Yopare, Carimagua.**

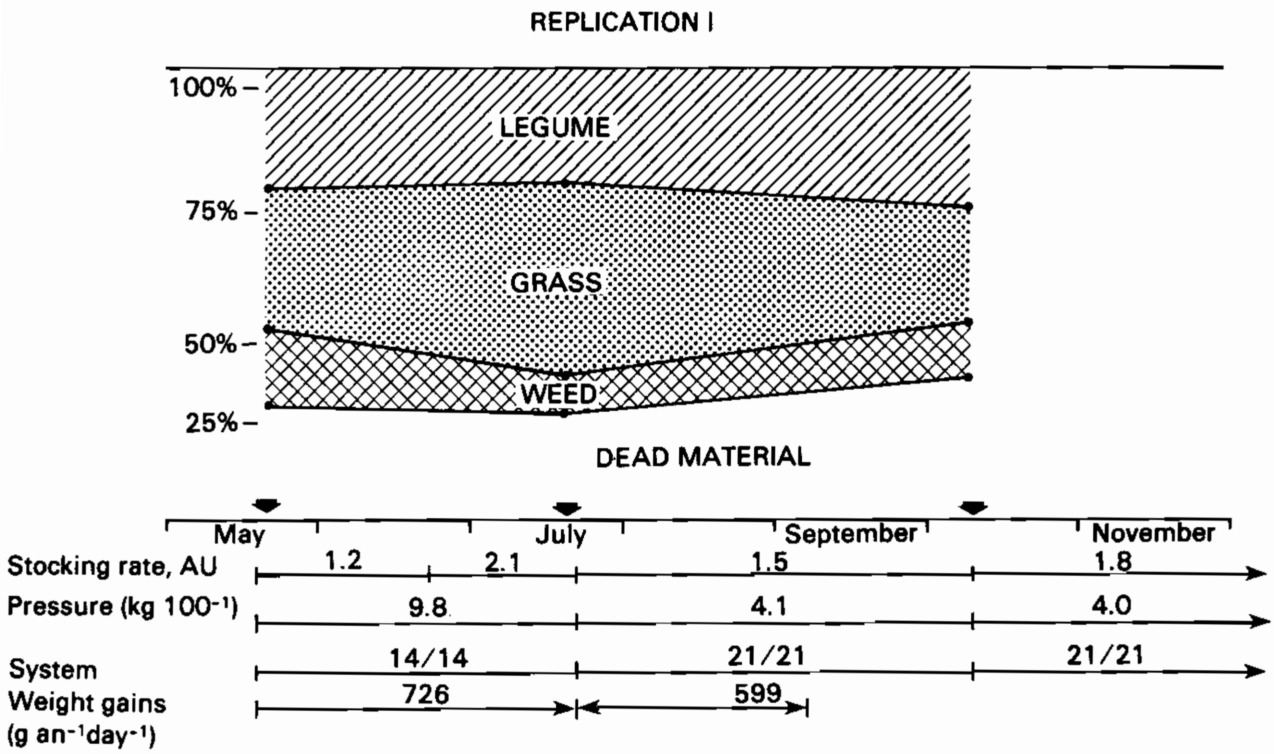


Figure 4b. The evolution of an association of A. gayanus and C. acutifolium during the rainy season, 1986. Flexible management, Yopare, Carimagua.

Table 4. Number of plants (>25 cm height) and seedlings of S. capitata after 4 months rest. Beginning of the rainy season, 4 years after planting.

Accessions	Patrones			
	1:1	2:2	3:3	$\bar{X}$
	No. of plants/m^2			
1315	4.4	4.1	3.9	4.1 c
1318	5.3	4.7	6.1	5.4 abc
1342	4.3	4.6	6.3	5.0 bc
1693	5.6	6.4	6.3	6.1 ab
1728	6.1	6.9	7.3	6.8 a
10280 (Capica)	4.4	5.4	6.8	5.5 abc
$\bar{X}$	5.4	5.8	5.2	NS
	No. of seedlings/m^2			
1315	1.1	1.2	1.4	1.2 c
1318	2.1	2.1	1.8	2.0 ab
1342	1.9	1.3	1.2	1.5 abc
1693	2.2	2.8	2.0	2.0 ab
10280 (Capica)	2.4	1.8	1.6	1.9 abc
$\bar{X}$	1.9	1.7	1.9	NS

legume lost much of its vigor during the first dry season and into the rainy season of 1986. In addition, B. dictyoneura has been slow to form a sod, in spite of its initial vigor. The stand of new plants after the first grazing was very sparce due to the removal of stolons associated with very weak nodal rooting of this species in Carimagua. It was necessary to renovate the pasture in 1986 via tillage with the chisel plow before reseeding the legume. After 2 1/2 years there is a good sod of the grass and the legume is moderately vigorous, with some spread into the grass under grazing. The association A. gayanus + S. macrocephala 1281 had an excellent establishment with good stands of both legume and grass and profuse flowering of the legume toward the end of the first year. However, in 1985 the legume was severely affected by Rhizoctonia and there was almost no legume left at the end of the first year of grazing. There were no new seedlings and almost no mother plants surviving into 1986.

There was also excellent establishment of A. gayanus in the association with C. macrocarpum 5065, but a very deficient stand of the legume due in part to the limited availability of seed for this planting and also to heavy ant predation from neighboring savanna areas during the establishment phase. The initial development of the legume was slow and plants were yellow and generally of low vigor. In 1985, the legume was replanted, but failed, probably because of the strong competition from the grass, and further predation by ants.

The association B. brizantha cv. Marandú + A. pintoi 17434 had excellent initial stands of both components. *A. pintoi* was planted by stolons and not inoculated but grew well during the first year. The grass was planted with seed and developed an excellent stand with good vigor from the out-set. During the dry season of 1984-85, the legume was severely affected by drought. The majority of initial plants survived but recovery during the following rainy season was almost nil. *B. brizantha* cv. Marandú dried up very rapidly during the dry season and developed slowly at the beginning of the following rainy season. Recovery after grazing was also slow and, therefore, its carrying capacity was very low. In 1986 the Marandú pasture was burned early in the rainy season and subsequently tilled with the chisel plow in order to replant *A. pintoi* 17434, as in the association of *B.* dictyoneura 6133. A good initial stand of the legume was obtained, but neither the legume nor the grass show adequate vigor and continue with a very low carrying capacity. It is thought that the lack of vigor after the first year may be due to an acute deficiency of nitrogen due to failure of the legume-rhizobia symbiosis for reasons as yet not clear. Marandú flowered profusely in the first year after planting but produced almost no viable seed. Since it does not spread by stolons, it has not found a dense sward.

In summary, the experience with the five associations under grazing coincides with that of the Pasture Quality and Productivity Section. On the other hand, there is little correlation between these results and the evaluations that have been carried out at the Category III level. It would appear that priority should be given to the testing of methodologies which are more efficient and correlate better with evaluations realized at later stages of germplasm evaluation.

Ecophysiology

During 1986, the direction of the new ecophysiology programme was further defined when a major modelling exercise was undertaken to determine the feasibility of using a mechanistic approach to the plant-animal interface, as briefly discussed in the 1985 Annual Report. The modelling was concluded successfully, with some modification of the original functions, and the model behaved rationally. As a consequence, a major field experiment, which was established during the year, is being undertaken in order to validate the conceptual model.

Although the modelling and the establishment of the field experiment have been the major tasks during 1986, concurrently experiments were conducted to examine some aspects of the water climate of some savanna communities, and of Andropogon gayanus. In addition, the performance of A. gayanus was studied under different frequencies and heights of defoliation and some preliminary studies were carried out on the edaphic adaptation of some Stylosanthes species. Finally, in collaboration with the Agronomy section the growth of the components of grass-legume associations in category 3, was evaluated. Each of these items is discussed more fully below.

MODELLING

It was postulated that the behaviour of a bi-specific mixture in a pasture could be described by seven response functions, as follows:

i) leaf area index as a function of biomass;
ii) growth rate as a function of leaf area index;
iii) senescence rate as a function of biomass;
iv) competition as function of composition;
v) consumption as a function of biomass on offer;
vi) diet selection as a function of composition of the feed on offer; and
vii) the proportion of new recruits of one component in the association as a function of the proportion of adults in the existing population.

Functions (i)-(iv) between them describe the relations between the components during vegetative growth, functions (v) and (vi) describe the effects of the animals by grazing, while (vii) describes the population dynamics.

It is obvious that this series of functions does not offer a complete description of the behaviour of two components of a pasture under all circumstances, but they appear to offer a reasonable starting point, and account for most of the important factors that govern the dynamics of two species growing in association.

The first three functions consider the growth of each species alone, that is without taking account of the effects of cohabitation with its associated species. In this regard, it is necessary to make the distinction between cohabitation (the consequences of occupying the same space, that is the effects of density) and competition (the enhancement or suppression of a species as a consequence of cohabitting with another, rather than with its own kind, at equivalent density). In order to allow for the effects of cohabitation, in each of the response functions (i), (ii) and (iii), the value of the independent variable was taken as its value for the sum of both components, and the response of the dependent variable was scaled by the ratio of the component in the association, or more succinctly:

$$Y_n = f(x_{a+b})*n/(a+b)$$

where:

Y is one of the dependent variables leaf area, growth rate or senescence rate;

x is the corresponding independent variable, a and b refer to the two components of the association, n is either a or b and n/(a+b) is the proportion of component n in the mixture.

In this manner, in each of the response functions under consideration, the cohabiting species affect each other in the same manner as if they were the same species. All other effects are then described by the competition function.

The LAI, growth and senescence functions (Figure 1) were synthesized, and the growth was simulated of pastures of different composition. When the composition of the mixture after a fixed period of growth was plotted against its composition at the start of the growth period, relationships of the classical form described by the Wit (1960) were obtained (Figure 2). Moreover, the form of the curves shows that the species with the higher growth rate will suppress the species with the lower growth rate, and thus dominate the mixture in due course, unless some other factor operates to redress the effect.

Most tropical grasses have the C_4 pathway of photosynthesis and associated anatomical characteristics, which confers on them the potential for higher intrinsic rates of growth compared withplants that have the C_3 pathway of photosynthesis, which includes all the tropical legumes. Therefore, it is to be expected that a bispecific mixture of a tropical (C_4) grass and a tropical legume will move inexorably to grass dominance unless,

1. The grass has an atypically low growth rate such that it matches that of the legume. This may be because the grass has an intrinsically lower growth rate (for whatever reason), or because its growth rate is limited by some other factor, for example, by a low level of soil nitrogen. In this latter case, the grass depends upon the associated legume to supply its nitrogen, and its growth rate will be constrained accordingly.

2. The legume offers the grass competition for factors other than space. It is noteworthy, however, that S. capitata suffers competition from A. gayanus for potassium on the Oxisol soil, of the Colombian llanos and this may occur with other grass/legume associations. There may not, therefore, be much prospect of exploiting competition for nutrients to redress the balance. Nevertheless there is obviously scope for selecting aggressive legumes, especially exploiting those with twining growth habits, which are able to overtop, and hence to shade, the grasses.

3. The disadvantage suffered by the legume during vegetative growth is offset by an advantage

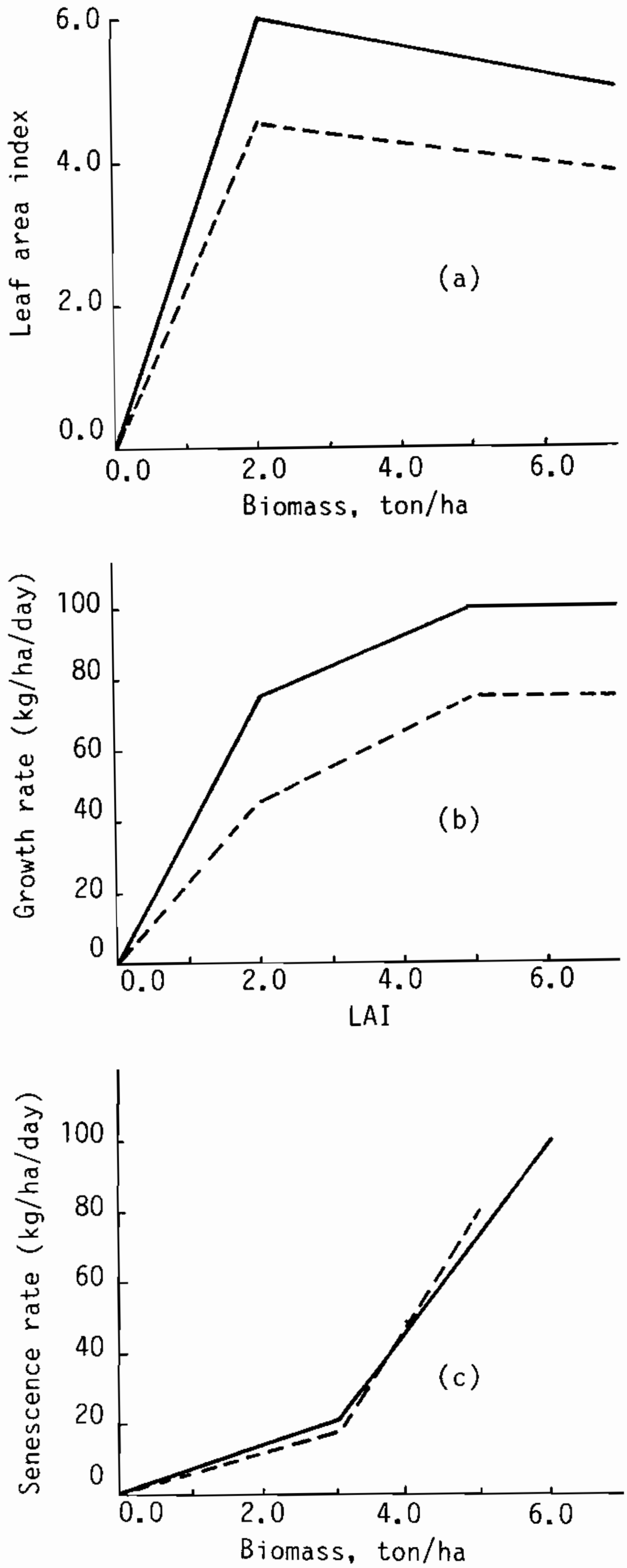


Figure 1. Response functions used in a model of the growth of a bi-specific pasture. (a) Leaf area index as a function of biomass [function (i)]; (b) growth rate as a function of leaf area index [function (ii)]; and (c) senescence rate as a function of biomass [function (iii)].

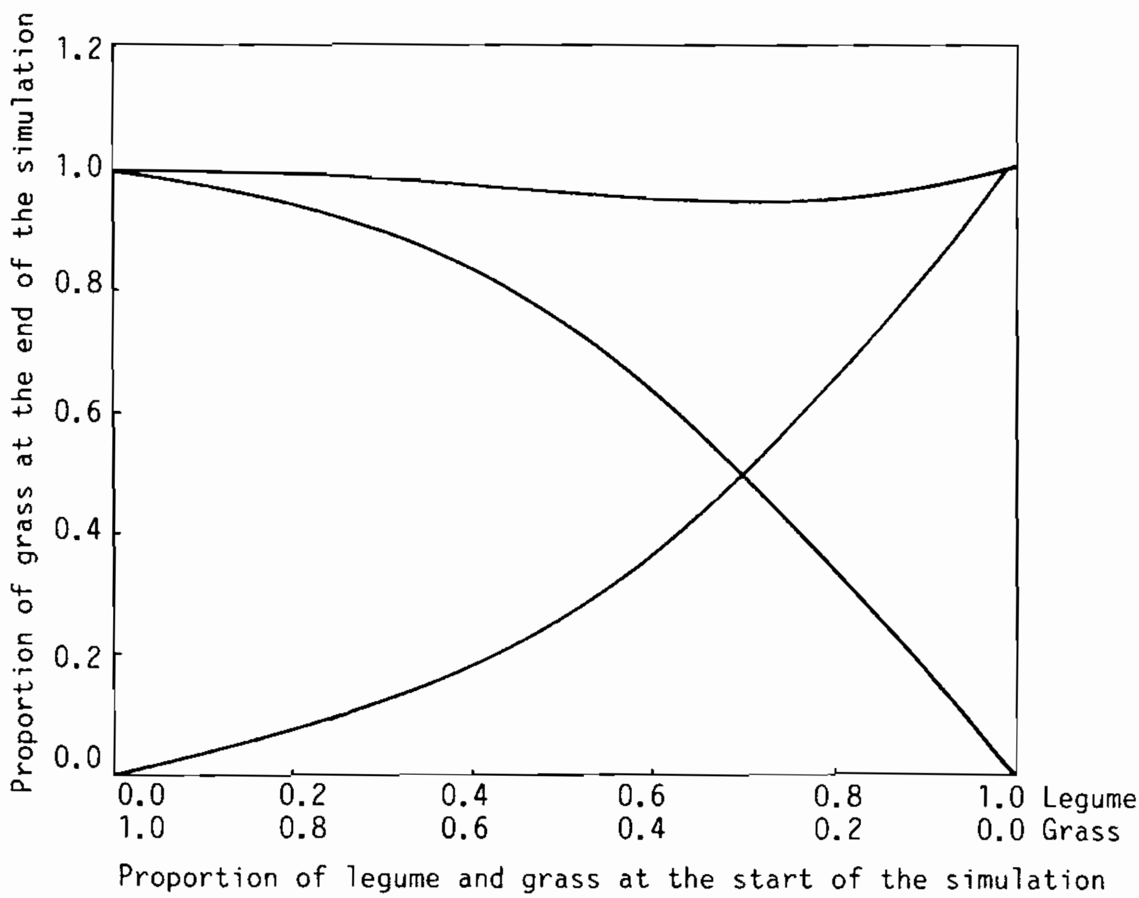


Figure 2. Simulated relative yields of grass and legume components after 56 days of growth. Yield on day 0 was 800 kg/ha, and on day 56 was 3440 and 4550 kg/ha for pure legume and grass swards, respectively. The upper line is the sum of the two proportions.

during some other stage of its life cycle, for example, by differential survival rates' and/or recruitment into the population favouring the legume in order to counteract its inferiority during vegetative growth. The lower recruitment, of course, may be the result of any combination of the many factors involved in population dynamics, and are accounted in the recruitment function (vii) above. However, if the system depends on factors that are displaced in time, it is more likely to be inherently unstable. It is also possible that the pasture management tools such as burning, cultivation, and levels of fertilizer can be exploited at specific times to change pasture composition in a desired direction. Unfortunately there are few data on the effects of these practices, either on survival or on recruitment, so that in grazing systems they must be applied empirically.

4. The grass is preferentially selected by the grazing animals. There is evidence that animals do prefer one component or the other of a mixture, and often select the grass and in doing so favour the legume, but the preference seems to vary during the year. The use of grazing animals to "manage" pastures implies manipulation of differential selection by the animals in such a way as to meet a goal of a predetermined composition deemed to be desirable.

It is worth re-emphasizing that the tendency of the grasses to go to dominance can be lessened if the grass species chosen during the selection process have lower growth rates. It seems that hitherto one of the major criteria upon which selection is based, at least in the early stages of the evaluation process, is high yield of dry matter, which almost universally means that accessions with high growth rates are selected. The summary above suggests that other growth criteria may be more appropriate. For example, a grass species with a rather lower dry matter yield (implying a lower growth rate) may be much more desirable in terms of legume compatibility. The further possibility exists that lower yields may also be associated with a higher digestibility, so that there may not be any penalty in terms of animal performance in selecting lower yielding grasses.

STUDIES OF THE PLANT/ANIMAL INTERFACE

Following the modelling exercise reported above, an experiment has been established in the field at Carimagua, consisting of four associations:

Andropogon gayanus cv. Carimagua 1 - *Stylosanthes capitata* cv. Capica
Andropogon gayanus cv. Carimagua 1 - *Centrosema acutifolium* CIAT 5277
Brachiaria dictyoneura CIAT 6133 - *Arachis pintoi* CIAT 17434
Brachiaria dictyoneura CIAT 6133 - *Desmodium ovalifolium* CIAT 3788

These four associations have been established in three ratios of grass/legume (high, medium and low), and each of these association/proportion combinations will be grazed at each of three grazing pressures (high, medium and low), with oesophageal-fistulated cattle, commencing at the start of the wet season in April 1987.

Despite the capacity of the plants to compensate for different densities, thus far it has been possible to maintain the proportions of legume and grass relatively easily by differential defoliation within the rows of grass and legume. This approach will be continued for as long as possible in order to derive the response functions related to composition.

The only problem that has been encountered is some yellowing in *Arachis pintoi*, concentrated in the older leaves. Plant analysis showed that the only mineral element in atypical concentrations was iron at 1500 ppm, about 3 times that expected. It is hypothesized that during the very wet conditions that prevailed at Carimagua during 1986, coupled with the flat site chosen for the experiment, and particularly with low plant cover during establishment, the soil remained waterlogged for much of the period after planting. This in turn lead to high redox potentials and to greater solubility of ferric iron and toxic levels in the plants. It is noteworthy that as the weather became somewhat drier during November, the younger leaves were less affected, though there was no recovery of colour in the older leaves, which is consistent with a toxicity problem.

WATER CLIMATE OF ANDROPOGON GAYANUS AND SOME SAVANNA COMMUNITIES

The savanna communities remain the major productive resource of the llanos, but they have been little studied. Moreover, development of sown pastures will mean replacement of the savanna communities with exotic swards. It is likely that some of the savanna communities (perhaps as indicators of the soils on which they grow) are better suited to some grass/legume associations than are others. If so, a knowledge of the interrelationships between the floristics of the savanna communities and some of the edaphic characters will undoubtedly prove useful in site selection in the future. It is therefore desirable to increase our understanding of the savanna communities in terms of their soils and their floristics.

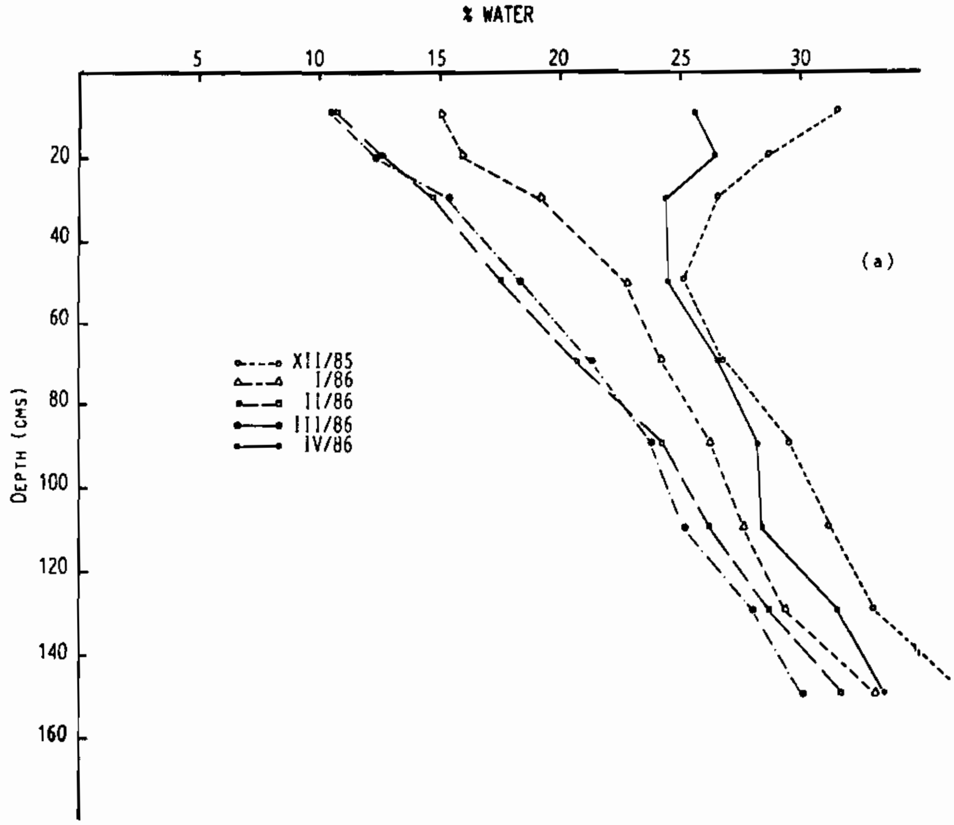
As part of a program to address this objective, a number of transects were selected at Carimagua, which traversed the interfluves between Caño Carimagua and Rio Muco, supplemented with transects in the Alegria and Tomo areas. Within these transects, and largely on the basis of the published soils descriptions of Carimagua, 32 sites were chosen subjectively to sample the soils and floristic variation of the major land classes. At each site the floristic frequency was determined using up to 100 quadrats at each site, variable depending on the size, and hence the importance, of the land unit and the variability of the community.

Detailed analysis of the data will be undertaken during next year. However, it is noteworthy that there exist large variations in water availability between sites, and apparently in the ability of the savanna species to utilize it during the dry season. In Figure 3 data for two contrasting sites are presented showing patterns of water extraction between December and April. Initially the savanna plants use the water in the upper part of the profile, but as the dry season progresses, the water at depth is slowly withdrawn, presumably as a survival mechanisms rather than for production of much dry matter.

A comparison with A.gayanus (Figure 4) shows rather similar patterns to those above, although here a formal comparison was made between a savanna community, with both pastures either defoliated or not. Not unexpectedly, defoliation reduced the rate of water extraction in both the savanna and in A. gayanus, especially at depth. Moreover, the savanna community extracted more water from the shallower layers of the soil than did A.gayanus, suggesting different patterns of water use.

DEFOLIATION OF ANDROPOGON GAYANUS

A. gayanus is commonly believed to recover very slowly, or to have a very long lag phase following heavy grazing, with the implication that the plant has an inherently atypical slow rate of growth following removal of its leaf material. In general,



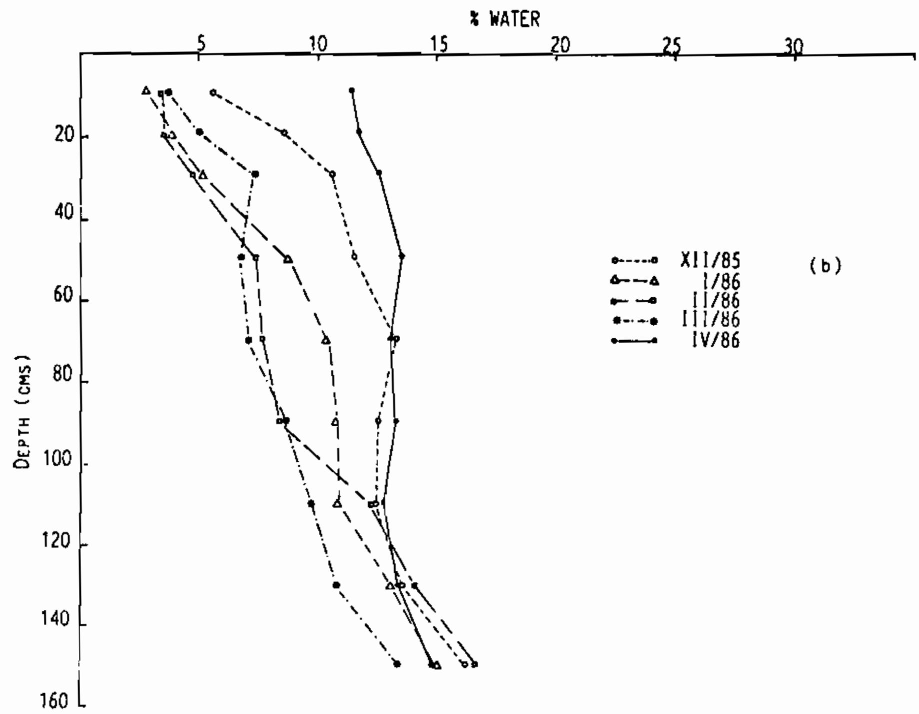


Figure 3. Gravimetric water content during the dry season of two contrasting soils at Carimagua carrying savanna communities (a) site D on transect 1, a clay soil; (b) site D on transect 5, a sandy soil.

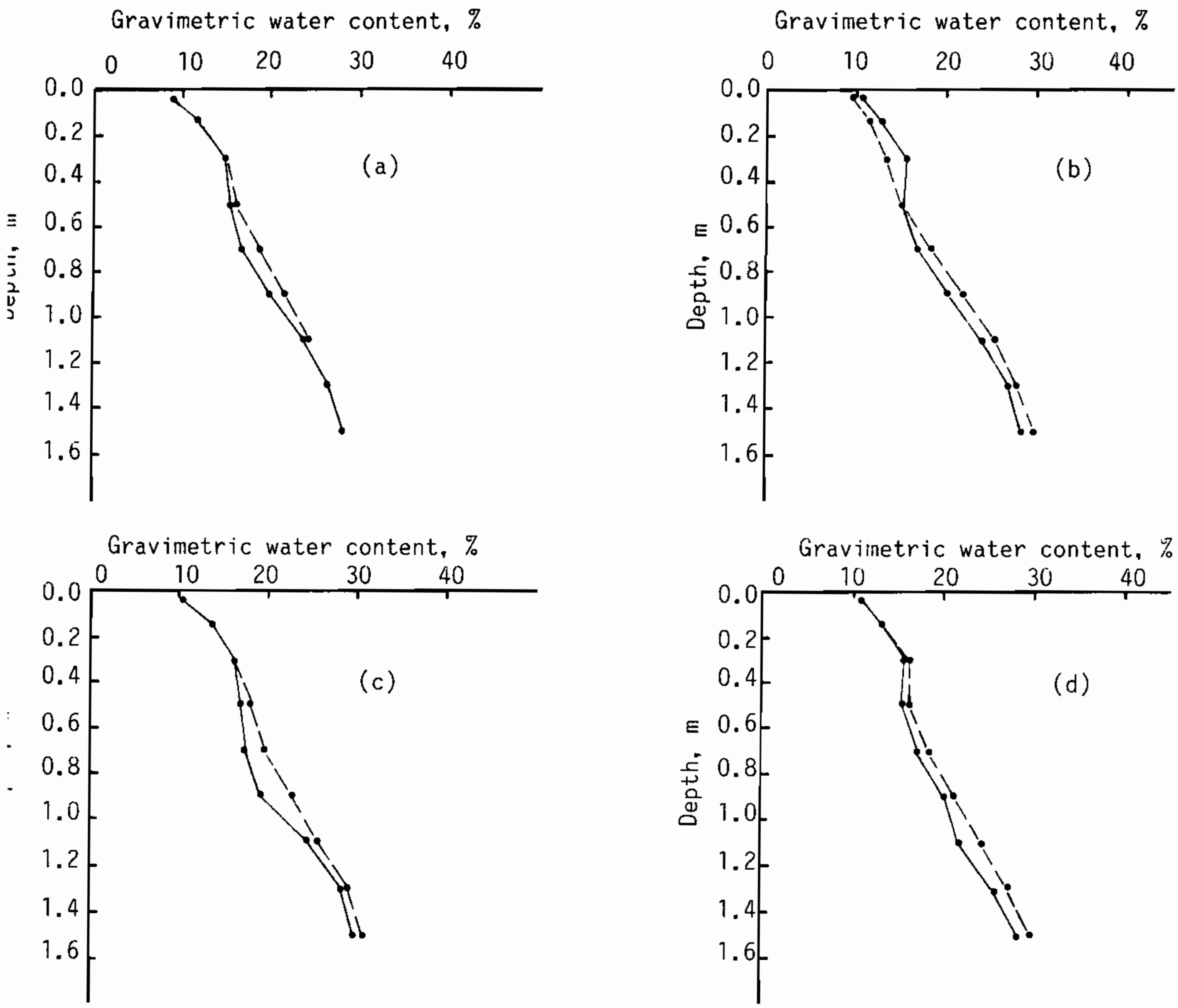


Figure 4. Change in gravimetric water content between mid-January (•– –•) and mid-March (•——•) of a clay soil growing a savanna community (a) defoliated at 10 cm in late December, and (b) without defoliation and Andropogon gayanus; (c) defoliated as above; and (d) without defoliation.

however, the growth rate of grasses following defoliation is a function of the residual leaf area. Moreover, the ability of a forage species to be able to withstand both light and severe defoliation is fundamental to its success as a forage plant. Therefore, if there is some unusual problem with the ability of A. gayanus to regrow following defoliation, it is important to understand the reasons for the limitation, with the objective of seeking ways to avoid or to overcome it through selection or breeding.

During 1986, an experiment was carried out at Carimagua on an old stand of A. gayanus, defoliating it to 10, 20, and 40 cm each 4, 6, or 8 weeks in a factorial design. The usual problems of heterogeneity of A. gayanus cv. Carimagua 1 were encountered, which was reduced by weighting the statistical analysis for tussock ground area. Each week, samples were cut at the defoliation height in order to measure regrowth, and each two weeks the yield below the height of defoliation was also determined. For each sample, the yield of dry matter was determined, subsamples were separated by hand into dead and living material, and the latter was separated into stem and leaf, and the specific leaf area measured. Rate of leaf extension were also measured. In this way a description of the behavior of A. gayanus under light, intermediate and severe defoliation was obtained.

Certainly, the absolute rates of growth following defoliation were low (Figure 5), justifying the belief that recovery is slow. However the reason appears to lie in the canopy architecture of a stand of A. gayanus. In the stand on which this experiment was conducted, the tussocks of the plants covered an average of only 22 percent of the total ground area, and observation suggests that this is normal for established stands. Therefore when such a stand is heavily defoliated, the leaf area indices are inevitably low (immediately after the 10-cm defoliations reported here the LAI was less than 0.1), so that it is inevitable that absolute growth rates are low following defoliation.

PRELIMINARY STUDIES ON EDAPHIC ADAPTATION

It is commonly observed that Stylosanthes capitata grows better on sandier soils compared with heavier soils, and moreover, that it persists better in associations with A.gayanus on lighter soils. The reasons for this difference are unclear, but it raises the question of the nature of edaphic adaptation and its cause. There do not appear to be large differences in nutrient content between the sandy and heavier soils at Carimagua, but there are substantial differences in their water characteristics. Pot culture studies were therefore conducted at Palmira with the objective of determining the interaction between growth of S. capitata and of S. guianensis on soils of contrasting texture from Carimagua. Superimposed on the different soils were levels and frequencies of watering in a factorial design:

Levels of watering		Soils		Species
100		sand		
80		(Alegría)		S.capitata CIAT 1315
70	x		x	
60		clayey		S.guianensis
50		(La Reserva)		CIAT 184

The experiment was grown with nitrogen (although a small set of treatments were included to evaluate the effect of inoculation).

The main features of the data are summarized in Figures 6 and 7. There was a significant interaction between species, soils, and watering level in

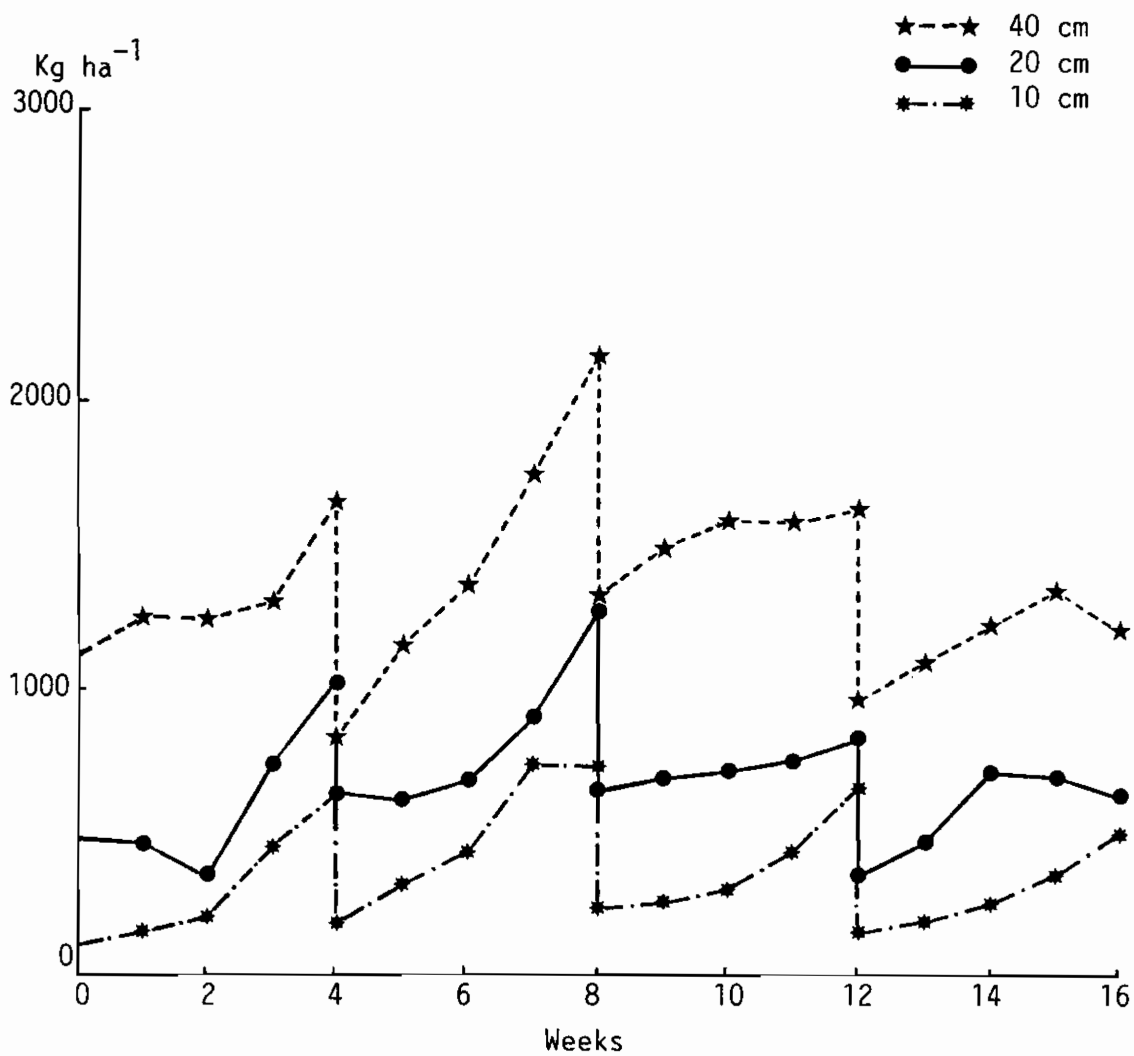


Figure 5. Dry matter yields of live stem and leaf <u>Andropogon gayanus</u> defoliated each four weeks at 10, 20 and 40 cm.

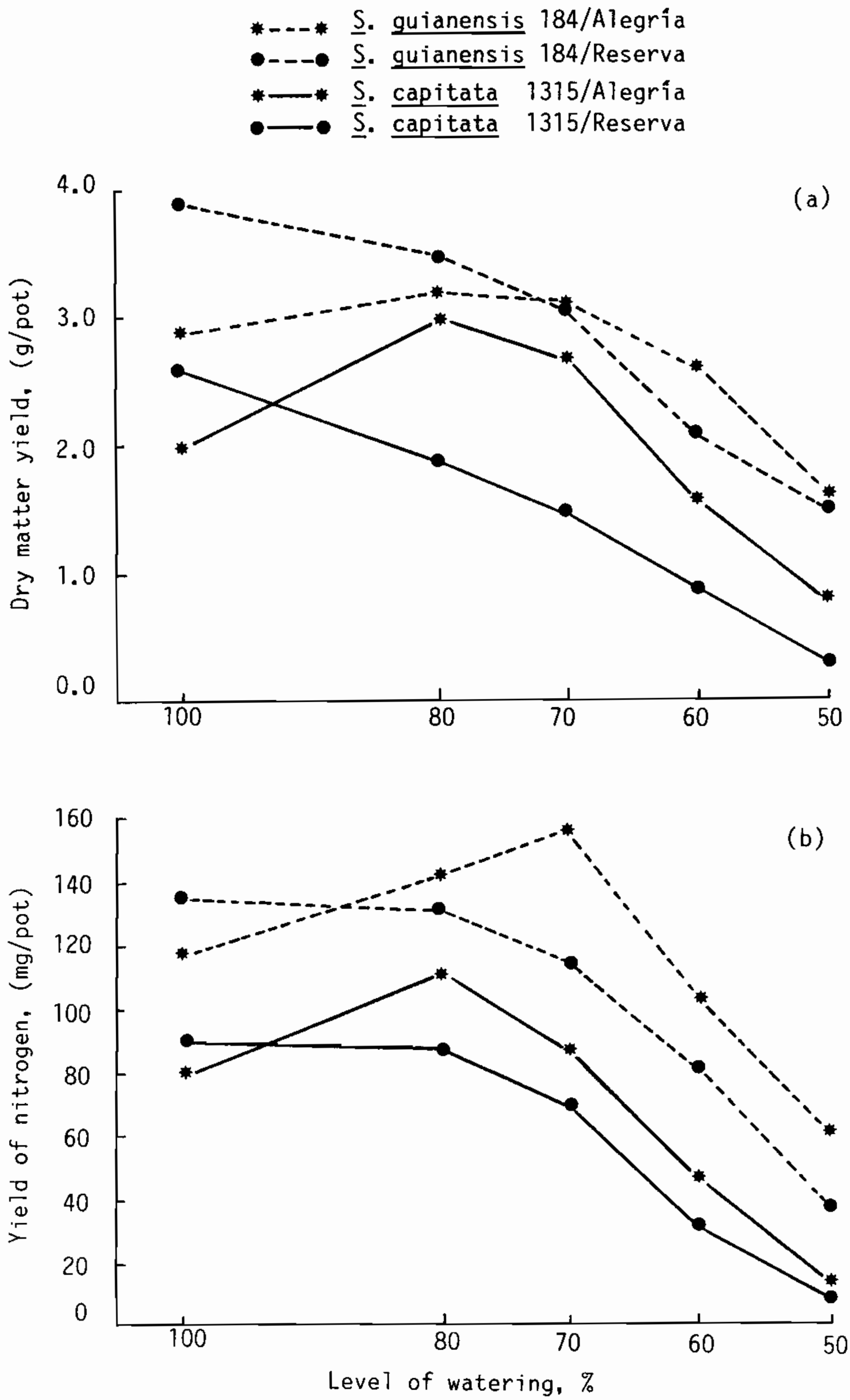


Figure 6. The effect of level of watering on S. capitata and S. guianensis grown on live soils of contrasting texture on (a) dry matter yield, and (b) nitrogen yield (date are means of watering frequencies).

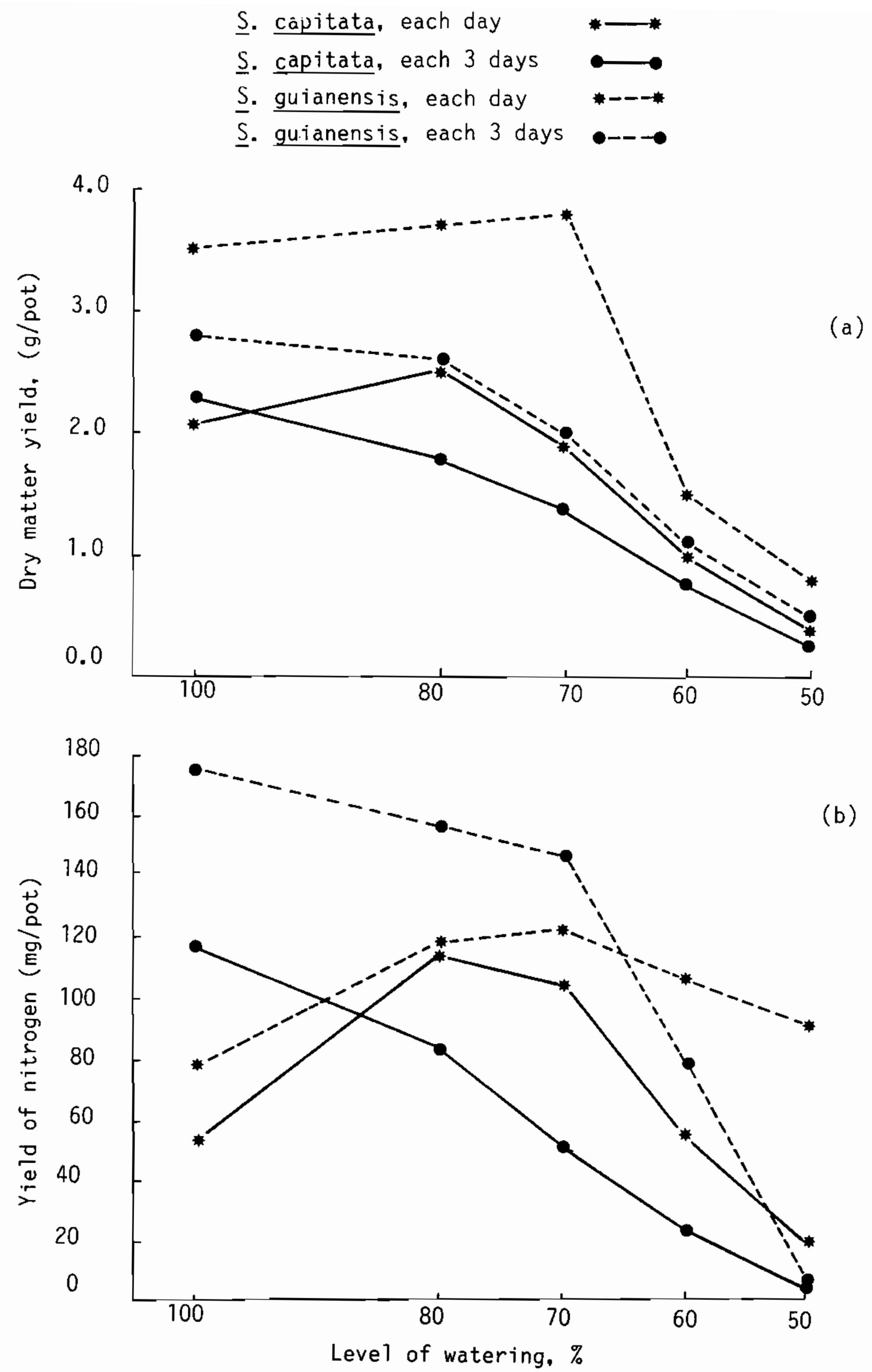


Figure 7. The effect of frequency and level of watering on S. capitata and S. guianensis on (a) dry matter yield, and (b) nitrogen yield (data are means of soils).

both yield of dry matter and yield of nitrogen. With both species, dry matter yields fell more or less uniformly on the lighter (Alegria) soil, but on the heavier (Reserva) soil, yields increased significantly as watering level decreased to 80 percent. In both cases, the proportional changes were much higher in S. capitata than in S. guianensis, which with the different forms of the relation gave the signficant interaction. Although it is not possible to attribute causal relationship, because the concentrations of nitrogen in the tops are lower when dry matter yields are reduced (in S. capitata at 100, 60 and 50 percent on Reserva soil, and at 60 and 50 percent on Alegria soil), it is reasonable to hypothesize that nitrogen was responsible for the effects observed, although the reasons are unclear.

GROWTH OF GRASS/LEGUME ASSOCIATIONS IN CATEGORY 3

This is a collaborative program with Agronomy (Carimagua) in order to understand in more detail the behavior the associations under evaluation in Category 3. Measurements are made of the regrowth phase of experiments grazed rotationally. The associations being studied are:

A. gayanus/ecotypes of Centrosema species,
ecotypes of Brachiaria species/Arachis pintoi, and
Brachiaria dictyoneura/selections of Desmodium ovalifolium

Of these, the latter two experiments have only been under evaluation for a two or three cycles of grazing and it is too early to present results of them. However, for the Centrosema/Andropogon experiment, data have been collected since mid-January. This was the third year of operation of this experiment, and by now only two ecotypes of Centrosema produced any substantial amount of dry matter during 1986, and even the best of those gave less than 20 percent for much of the year. The experiment therefore gave a unique opportunity to examine the growth of A. gayanus cv. Carimagua 1 with all its variability, because within each main plot (grazing pressures), 30 one meter squared quadrats were harvested, giving substantially increased precision of the estimates. As above, the amount of live leaf and stem, the leaf area and the amount of dead material was measured, at two-weekly intervals.

The outstanding feature ot the data is the large amount of dead material in an A. gayanus pasture, the relatively low yields of living material, especially of leaf, and hence the low leaf area indices, which confirm the data of the defoliation study. The low amounts of leaf and live stem are especially noteworthy, although the latter does not seem to be much eaten by the cattle if there is much leaf present. (Examination of the curves for leaf, stem and total material in Figure 8 show that the main changes during each grazing period is in the leaf fraction). The dynamics of dead material are obviously very important in this species, and emphasize the need to measure rates of tissue turnover in order to determine the senescence function, mentioned in the modelling section.

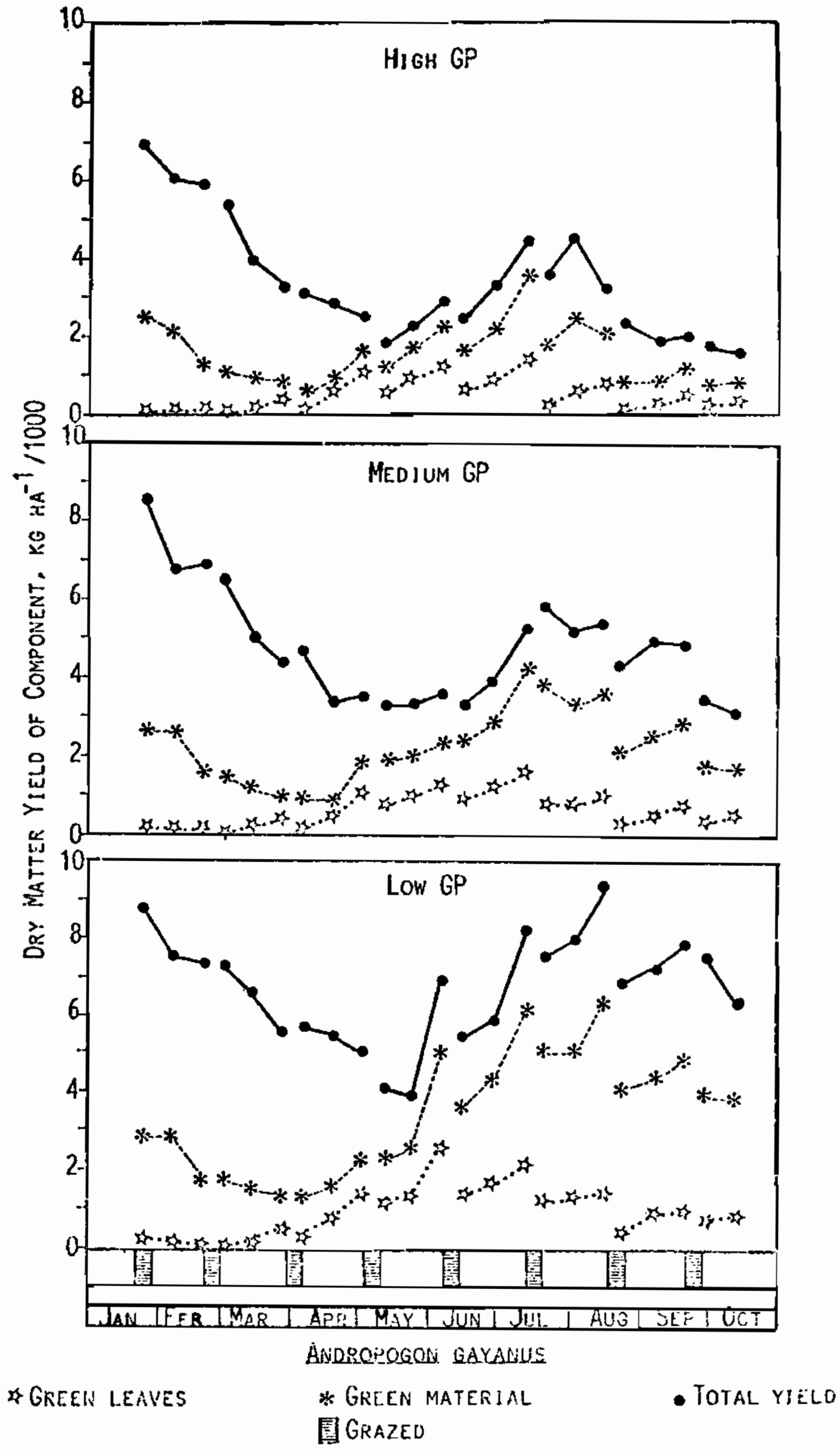


Figure 8. Yields between January and October, 1986 of various components of <u>Andropogon</u> <u>gayanus</u> grazed in a rotational system (7 days grazing, 28 rest) at three grazing pressures.

Pasture Quality and Productivity

The Pasture Quality and Productivity Section concentrates research on (1) quality factors of promising germplasm, (2) pasture productivity and management with germplasm in Category IV, and (3) nutritional factors limiting animal production in improved pastures and native savanna. A complementary activity of the Section is to develop methodologies for germplasm evaluation under grazing, which are relevant for the activities of the RIEPT.

Following is a summary of results of research projects completed during 1986 and a progress report of on-going projects.

QUALITY FACTORS IN GERMPLASM

The evaluation of quality factors in promising germplasm of the Pastures Program continues to be carried out mainly at the CIAT-Quilichao Sub-station. During 1986 the quality of contrasting *Brachiaria brizantha* ecotypes was evaluated and a study to evaluate the potential animal productivity of clones of *Andropogon gayanus* under grazing was completed. In Carimagua, the quality of *Arachis pintoi* CIAT 17434 in association with *Brachiaria* spp. was evaluated under grazing conditions.

Quality of Brachiaria brizantha

The species *B. brizantha* has been gaining interest as a grass with potential for acid soils with low fertility, particularly with respect to tolerance and/or resistance to spittlebug. To determine the potential quality of *B. brizantha*, two morphologically contrasting ecotypes were selected. The materials were fertilized with 50 kg nitrogen and an 8-week regrowth was offered to wethers housed in metabolism crates. Results (Table 1) indicated a greater

Table 1. Quality attributes of *Brachiaria brizantha*[1] ecotypes evaluated with crated sheep (Quilichao).

Parameter	(CIAT 6424)[2]	(CIAT 6294 + 6297)[2]
Forage offered		
Leaf proportion (%)	47.5	66.5
Crude protein (%)		
Leaves	10.1	9.4
Stems	5.8	5.4
Intake ($gm/kg^{.75}$/day)		
Dry matter	52.7[a]	61.2[b]
Leaves	40.0[a]	53.8[b]
Digestibility (%)		
Dry matter	55.0	52.4
Neutral detergent fiber	57.8	55.7

1/ Data are averages of two evaluations with sheep in metabolic crates.
2/ 8 week regrowth.
a, b different means (P >.05).

proportion of leaves in accessions 6294 + 6297 compared to accession 6424. This difference was related to a higher intake of the more leafy ecotypes, but not with greater dry matter or fiber digestibility. Based on these results, it is suggested that the leaf:stem ratio should be measured as criterion of selection in accessions of Brachiaria spp. showing tolerance and/or resistance to spittlebug.

Animal productivity in clones of A. gayanus

As reported in 1985, no differences were found after 420 days of grazing in liveweight gains between clones of A. gayanus selected for leafiness in comparison to the commercial cultivar Carimagua 1 (CIAT 621). The experiment continued during 120 days more, for a total of 560 grazing days. The analysis of results (Table 2) indicated that there were no differences among clones in terms of attributes of the available forage. However, there was a tendency ($P < .10$) for greater weight gains with the control (CIAT 621). A more detailed analysis of results showed that eventhough the proportion of leaves in the green dry matter was similar among clones, the leafy clone had a greater proportion of leaves in the dead matter, before and after grazing (Table 3). On the other hand, it was also interesting to observe that during the dry period the leafy clone yielded less green dry matter than the commercial cultivar (Table 4), resulting in lower weight gains during this period of the year. Finally, in terms of the plant architecture, measured before and after grazing, a lower utilization of leaves was evident in the lower strata (10-30 cm) of the leafy clone (11%) as compared with the commercial A. gayanus (25%).

Table 2. Summary of results obtained with clones of A. gayanus under grazing[1] (Quilichao).

MEDICIONES	Clones of A. gayanus: Leafy	Stemmy	621 (control)
Forage on offer			
Availability (GDM ha^{-1})	3489	3315	3507
Leaf proportion (%)	47	42	42
IVDMD of leaves (%)	49.5	49.5	50.0
Leaf crude protein (%)	9.1	8.9	9.3
Forage selected			
Leaf proportion (%)	93^a	86^b	88^b
IVDMD (%)	50.5	49.9	50.5
Protein (%)	11.2	11.3	11.1
Grazing Pressure (kg GDM/100 kg LW/day)	11.3	11.6	10.7
Weight gain (g $A^{-1}day^{-1}$)	428^c	425^c	515^d

1/ Values reported are averages for 560 grazing days.
a, b Different means ($P < .05$).
c, d Different means ($P < .10$).

Table 3. Leaf and stem proportion in the dead matter of clones of *A. gayanus* under grazing (Quilichao).

Clones	Initiation of grazing 1st day)		End of grazing (8th day)	
	Dead leaves	Dead stems	Dead leaaves	Dead stems
	------------ % ------------		------------ % ------------	
Leafy[1]	87	13	77	23
Stemmy[2]	61	39	58	42
CIAT 621[3]	67	33	61	39

1/ 40% dead dry matter in total forage at the beginning of grazing.
2/ 43% dead dry matter in total forage at the beginning of grazing.
3/ 47% dead dry matter in total forage at the beginning of grazing.

Table 4. Effect of season of the year on availability of green dry matter (GDM) in clones of *A. gayanus* under grazing.

Season	Clones of A. gayanus		
	Leafy	Stemmy	CIAT-621 (control)
	(kg GDM ha^{-1})		
Dry[1]	2932 (42)*	2845 (41)	3796 (51)
Rainy[2]	4852 (56)	4584 (55)	4530 (46)

1/ WB = -52   2/ WB = +558
* Leaf % in green dry matter.

At least within the range of leafiness evaluated, the results of this study suggest that there would be no advantage in terms of animal productivity in selecting *A. gayanus* genotypes with greater proportion of leaves because of: (a) high proportion of the leaves are in the dead matter, not consumed by the grazing animals, (2) productivity of the leafy genotypes would be lower during the dry period, and (3) apparent difficulty of grazing animals to harvest leaves in the lower strata of the plant.

Future research activities with *A. gayanus* include a small plot grazing trial at Carimagua in collaboration with the Plant Breeding Section. The study includes three clones of *A. gauanus* of low stature and CIAT 621 (as a control) in association with *S. capitata* cv. Capica, to assess the effect of grass competition on development and vigor of 2nd generation *S. capitata* seedlings.

Quality of associations with Arachis pintoi

One of the most promising legumes being evaluated in Carimagua is *A. pintoi* (17434), particularly for the high degree of compatibility with aggressive grasses of the genus *Brachiaria*. During 1986 the quality and acceptability of *A. pintoi* (17434) in association with *B. humidicola* (679), *B. dictyoneura* (6133), *B. ruziziensis* (6291), and *B. brizantha* (664) were studied in collaboration with the Agronomy Section. Each association in two replications was grazed by esophageal-fistulated animals in a rotational grazing system of 7 days of occupation and 21 days of rest. Starting in January (dry period) monthly samplings were done to determine botanical composition of the forage on offer and forage selected by the fistulated animals. Samples of available and selected forage were analyzed to determine their nutritional quality (Table 5). It was interesting to observe the high protein level in the leaves and stems of the legume even during the dry period. However, even more interesting was the high protein levels in the associated grasses. Noteworthy is the very high protein level in B. humidicola during the wet period, contrasting with the very low levels found in this grass in monoculture.

The proportion of A. pintoi in the forage on offer and forage selected by the fistulated animals are presented in Table 6. Both in the dry and wet seasons the proportion of legume in the available forage was greater in the associations with B. ruziziensis (4291) and B. brizantha (664) due to the spittlebug damage to these grasses. The legume percentage in the forage selected was high in all associations and no differences ($P < .05$) were observed between seasons of the year. The high quality of A. pintoi is reflected in the high protein levels and in vitro dry matter digestibility values measured in the selected diet in the dry and wet seasons.

Results of this study indicate that associations of A. pintoi with B. humidicola and B. dictyoneura offer high quality forage throughout the year and this should translate in high liveweight gains. During 1987 category IV grazing trials will be established at Carimagua with A. pintoi in mixture with B. humidicola and B. dictyoneura to assess animal productivity and grazing management requirements.

PASTURE MANAGEMENT AND PRODUCTIVITY

Studies on pasture management and productivity continue to be the main research activity of the Section. During 1986, the evaluation of an experiment under grazing with B. dictyoneura (6133) and D. ovalifolium (350) continued in Quilichao. In addition a grazing trial (RTD) was initiated at Quilichao, using the flexible management approach proposed as alternative methodology for the RIEPT. Evaluation of associations of A. gayanus cv. Carimagua 1 with C. brasilianum (5234), C. acutifolium (5277 + 5568), and S. macrocephala (1643) continued in Carimagua under different pasture management systems and a trial with Centrosema species was initiated in Category IV using flexible management.

Grazing Trials - Quilichao

Grazing of Brachiaria dictyoneura + Desmodium ovalifolium

This report summarizes the results of 2.5 years of grazing of an association of B. dictyoneura (6133) and D. ovalifolium (350) using a rotational system of 7 days of occupation and 21 days of rest. In Table 7 a summary of liveweight gains obtained during six grazing periods is presented. During periods I through IV (560 days) weight gains ranged between 400 and 490 g A^{-1} day^{-1}, with no differences among stocking rates. This led to the decision of increasing stocking rates during the following two periods, which did result in weight gain differences (168 to 394 g A^{-1} day^{-1}). Although individual weight gains in this association have not been very high (400 g A^{-1} day^{-1}), production per hectare has reached 700-800 kg/year, due to the association's high carrying capacity.

Results of measurements of pasture attributes are presented in Figures 1 and 2. Availability of the grass and legume (Figure 1) has fluctuated over time, as a result of stocking rate increases, dry period stress, and earthworm attack on the legume. D. ovalifolium (350) suffered heavy defoliation during the dry period corresponding to the 4th evaluation,

Table 5. Crude protein in leaves and stems on offer of Brachiaria spp. and A. pintoi (17434) in association under grazing (Carimagua).

A. pintoi pasture		Season	Crude protein (%)			
			Grass		Legume	
			Leaves	Stems	Leaves	Stems
B. humidicola	(679)	Dry[1]	5.6	3.6	14.6	11.3
B. dictyoneura	(6133)		5.3	3.0	15.0	13.0
B. ruziziensis	(6291)		9.2	7.3	14.0	11.8
B. brizantha	(664)		10.3	3.5	13.0	13.2
		$\bar{X}$	7.5	4.4	14.2	12.3
B. humidicola	(679)	Rainy[2]	10.1	7.1	20.7	11.8
B. dictyoneura	(6133)		7.5	5.4	21.7	11.0
B. ruziziensis	(6291)		11.2	8.1	19.8	12.1
B. brizantha	(664)		9.9	5.1	19.5	11.9
		$\bar{X}$	9.7	6.4	20.4	11.7

1/ Sampling in January and March, 1986.
2/ Sampling in May and June, 1986.

Table 6. Botanical composition and quality attributes of Brachiaria spp. + A. pintoi (17434) pastures under grazing during two seasons of the year (Carimagua).

A. pintoi pasture		Season	Leguminosa		Forage Selected	
			On offer (%)	Selected (%)	IVDMD (%)	CP (%)
B. humidicola	(679)	Dry[1]	18.8	36.8	60.5	8.7
B. dictyoneura	(6133)		26.4	22.7	63.7	8.2
B. ruziziensis	(6291)		34.2	48.9	60.4	11.4
B. brizantha	(664)		35.2	40.5	59.5	10.5
		$\bar{X}$	28.7[a]	37.2[a]	61.0[a]	9.7[a]
B. humidicola	(679)	Rainy[2]	28.4	25.8	71.1	13.3
B. dictyoneura	(6133)		38.0	43.8	67.4	13.5
B. ruziziensis	(6291)		65.3	49.2	68.5	15.7
B. brizantha	(664)		69.0	79.1	64.9	18.7
		$\bar{X}$	50.2[b]	49.5[a]	68.0[b]	15.3[b]

1/ Sampling in January and March, 1986.
2/ Sampling in May and July, 1986.
a, b different means ($P < .05$).

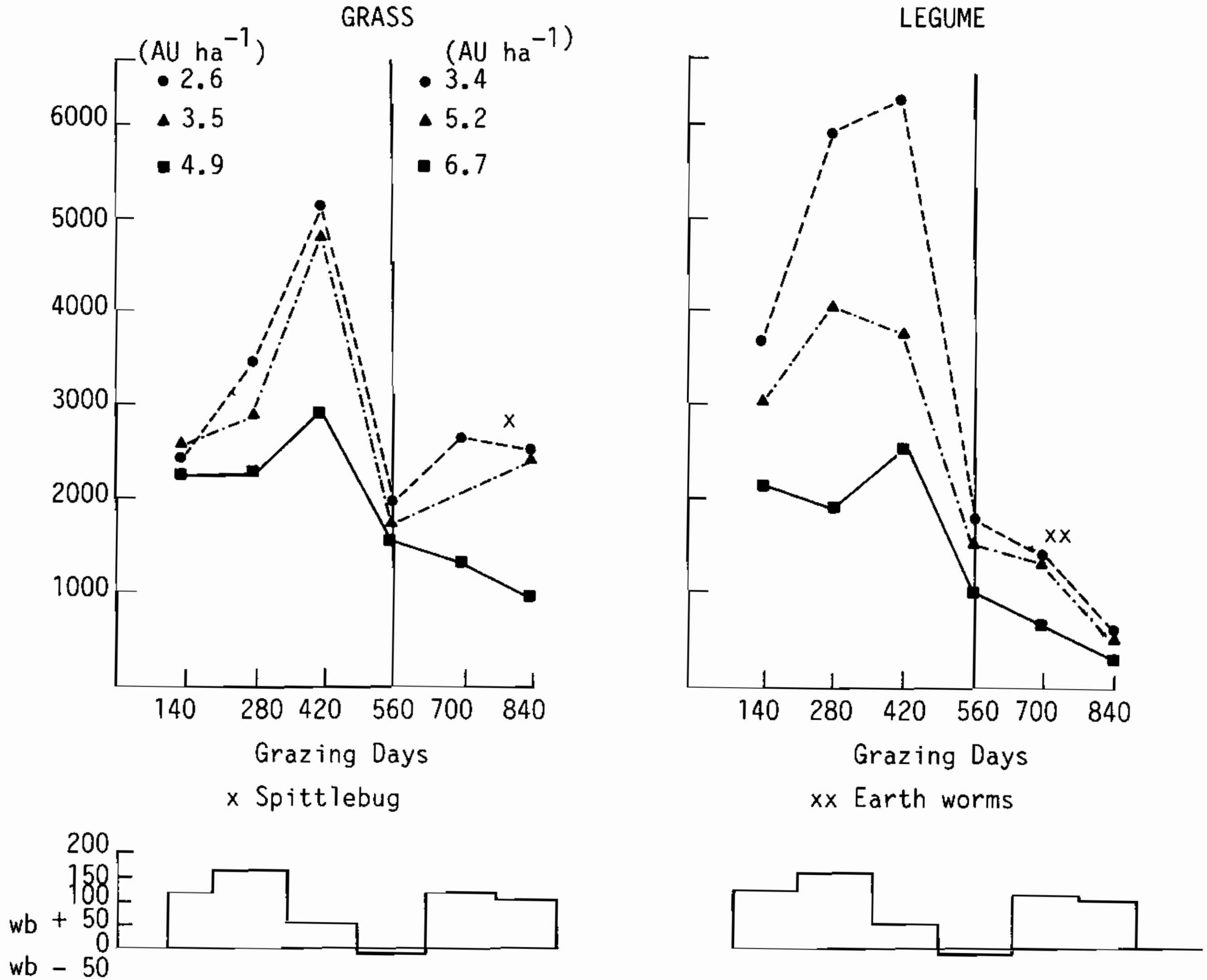


Figure 1. Avilability of green dry matter (GDM) and legume in B. dictyoneura + D. ovalifolium (350) pastures under three stocking rates and rotational grazing (Quilichao).

Table 7. Animal liveweight gains (LWG) in a *B. dictyoneura* + *D. ovalifolium* (350) pasture under three stocking rates and rotational grazing (Quilichao).

Stocking rate ($AU\ ha^{-1}$)[1]		Evaluation	Liveweight gain	
			$g\ A^{-1} day^{-1}$	$kg\ ha^{-1} year^{-1}$
High	(5.9)	I - IV (560 days)	400	861
Medium	(3.5)		480	613
Low	(2.6)		489	464
High	(6.7)	V - VI (280 days)	168	411
Medium	(5.2)		365	693
Low	(3.9)		394	561

1/ AU = 400 kg LW.

which also coincided with the increase in stocking rates. In the case of the grass, a localized spittlebug attack was detected during the 6th evaluation period, in the low and intermediate stocking rates, but recovery was excellent. The quality of forage on offer (Figure 2) has also varied over time. Crude protein in the grass has decreased particularly under the intermediate and low stocking rates, which is associated with lower legume availability. In contrast, the *in vitro* digestibility has increased as a consequence of a higher proportion of green regrowth under the higher stocking rates used in the two last evaluation periods. Legume quality has not varied greatly over time, having in general low *in vitro* digestibility and intermediate protein levels.

One of the recognized limiting factors of *D. ovalifolium* (350) is its low acceptability by the grazing animals. However, legume selectivity in this trial has been relatively high under all stocking rates and closely related with legume availability in the pasture (Table 8).

This study will continue for at least two more years, making stocking rate adjustments depending on forage availability and/or weight gains. Final analysis of results will seek to establish relationships between pasture attributes and weight gains.

Grazing of *Andropogon gayanus* + *Centrosema* spp.

As part of the research activities of support to the RIEPT, a grazing trial type D (RTD) with flexible management was initiated at Quilichao. During 1985 associations of *A. gayanus* cv. Carimagua 1 with *C. acutifolium* (5277 + 5568) and *C. macrocarpum* (5713) were established. Grazing began in January 1986 including two ranges of grazing pressure (3-5 and 6-8 kg GDM . 100 kg LW^{-1} day^{-1}) in both associations. The initial grazing was an alternate system of 7/7 days which has been adjusted over time as changes in grass legume portion have been observed. Initial results of this trial are presented in Table 9 for a period of maximum and minimum rainfall. Large differences between legumes have developed in terms of contribution to the pasture as well as in selectivity and liveweight gain. The proportion of *C. macrocarpum* 5713 has been high in the pasture and in the selected

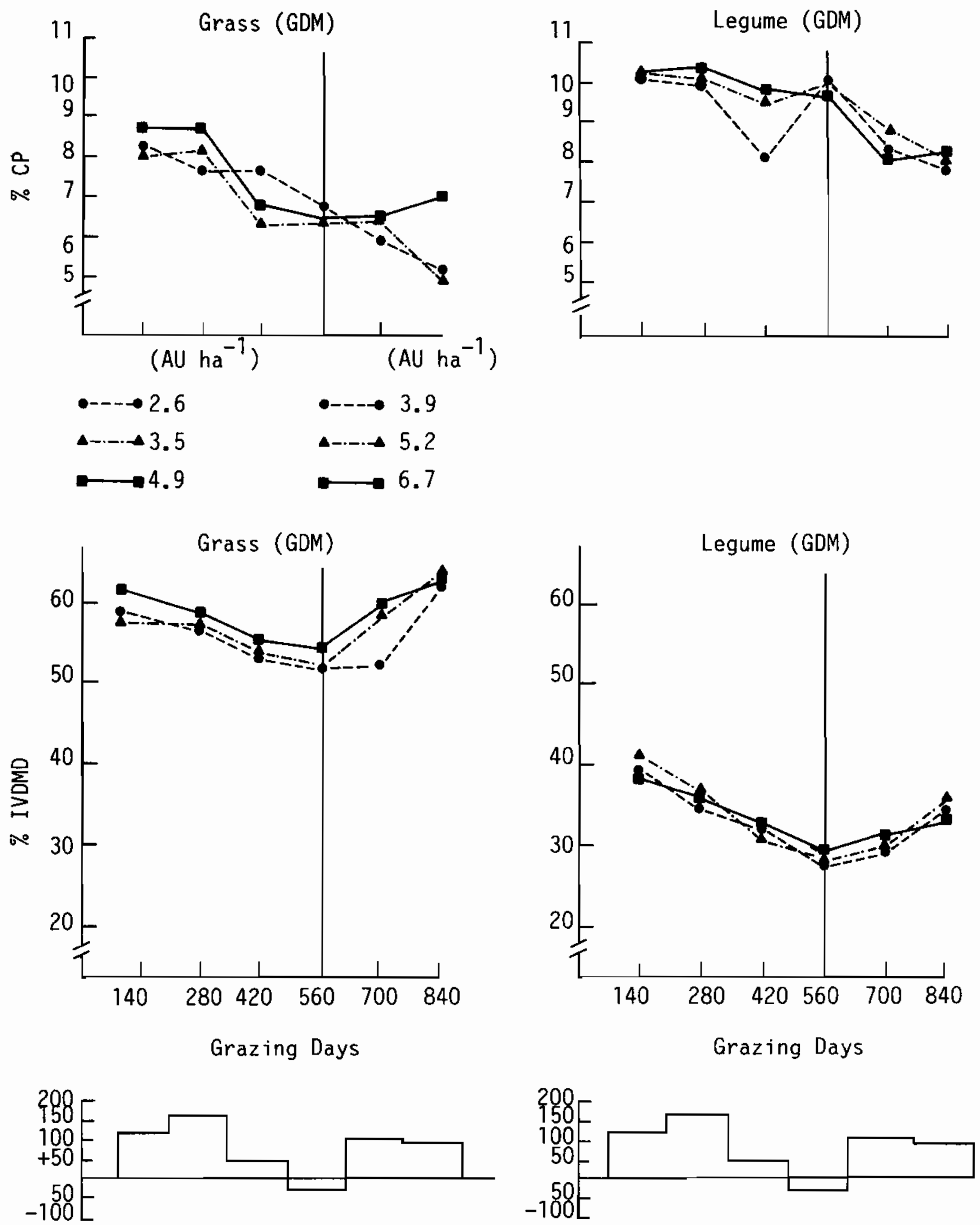


Figure 2. Crude protein (CP) content and *in vitro* dry matter digestibility (IVDMD) of grass and legume green dry matter (GDM) on offer in a *B. dictyoneura* + *D. ovalifolium* 350 pasture under three stocking rates and rotational grazing (Quilichao).

Table 8. Botanical composition of the forage on offer and selected by fistulated steers on a B. dictyoneura + D. ovalifolium (350) pasture under three stocking rates and rotational grazing (Quilichao).

Stocking rate ($AU\ ha^{-1}$)[1]		Evaluation	Legume (%)	
			Available	Selected
High	(4.9)	I - IV (560 days)	45.3	26.5
Medium	(3.5)		50.8	28.1
Low	(2.6)		55.8	29.2
High	(6.7)	V - VI (280 days)	27.6	11.8
Medium	(5.2)		26.3	15.2
Low	(3.9)		22.8	11.3

diet both during the wet and dry periods. Consequently, weight gains in this association, regardless of grazing pressure, have been greater than in the association with C. acutifolium (5277 + 5568), particularly in the dry period.

Differences in the performance of the two legume species included in the trial have determined different management strategies. In associations with C. macrocarpum 5713, the grazing system has been directed to favor the grass through an alternate system of 21/21 days. In the associations with C. acutifolium 5277 + 5568, a 7/7 grazing system has been imposed to favor the legume. Stocking rates have been adjusted periodically to maintain grazing pressure within the defined ranges.

Grazing Trials - Carimagua

Grazing of Brachiaria decumbens with and without legume

The grazing trial with B. decumbens alone and in association with Kudzu entered its 8th year of evaluation. Towards the end of 1985 the decision was taken to increase the stocking rates in this trial, given the great amount of available forage in the associated pastures. Stocking rates were increased during the dry period from 1.0 to 1.5 A ha^{-1}, both in the monoculture and in the association. However, because of spittlebug attack in the association it was not possible to increase the stocking rates (2.5 A ha^{-1}) in these pastures during the wet season. Stocking rates were increased in monoculture. Grass and legume availability in each pasture and replication are presented in Figure 3. At the beginning of the rains the amount of green dry matter of grass was greater in the association than in the pure grass stands. However, due to spittlebug attack in 100% of replication 1 and in 50% of replication 2, green dry matter availability in the association was considerably reduced. This reduction in the grass proportion has favored Kudzu in the two replications of the trial.

Spittlebug attack in the B. decumbens + Kudzu pastures also affected weight gains (Table 10). During the dry period, animals in the associated grass had excellent weight gains (282 g A^{-1} day^{-1}), but lost weight (-15 g A^{-1} day^{-1}) in the pure grass, under the same stocking rates (1.5 A ha^{-1}). During the transition period, from February to March, animals practically

Table 9. Initial pasture responses and liveweight gains (LWG) results in *A. gayanus* pastures in association with legumes under flexible grazing management (Quilichao).

Association	Maximum rainfall[1]				Minimum rainfall[2]			
		Leguminosa				Leguminosa		
	AU ha^{-1}	Avail. (%)	Selec. (%)	g $A^{-1}day^{-1}$	AU ha^{-1}	Avail. (%)	Selec. (%)	g $A^{-1}day^{-1}$
A. gayanus 621 + *C. macrocarpum* 5713								
High pressure (3-5)[3]	3.7	32.3	15.8	579	2.3	28.5	33.1	445
Low pressure (6-8)[3]	3.2	30.7	41.0	711	1.5	42.6	69.8	471
A. gayanus 621 + *C. acutifolium* 5568 - 5277								
High pressure (3-5)	3.7	19.4	2.7	532	2.6	11.3	21.3	304
Low pressure (6-8)	2.3	14.5	1.1	603	2.1	13.3	30.7	263

1/ 172 days (water balance: biweekly average = 68.1 ± 39.7).

2/ 94 days (water balance: biweekly average = 42.2 ± 18.3).

3/ kg green dry matter 100. kg $LW^{-1}day^{-1}$.

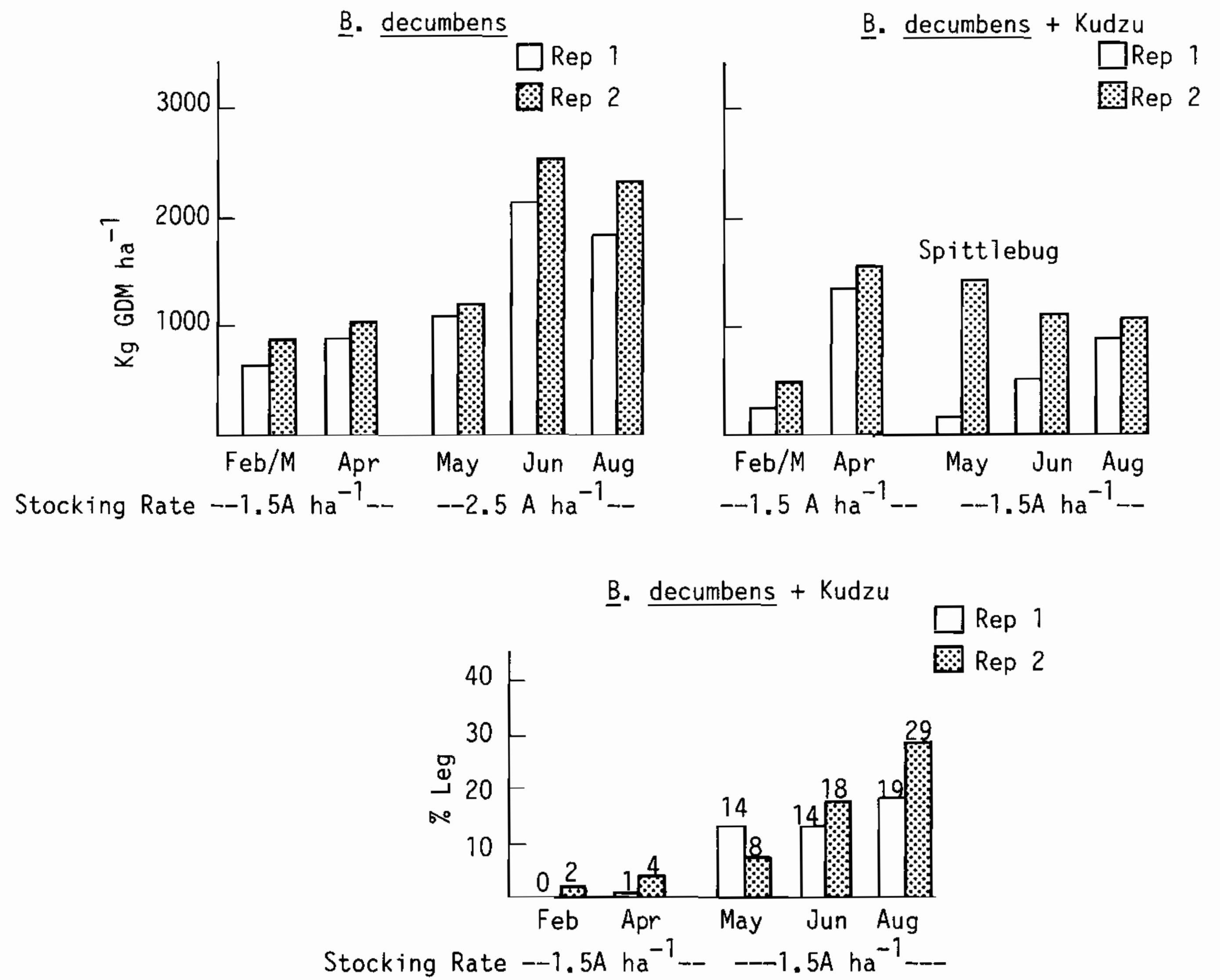


Figure 3. Grass availability (green dry matter) in *B. decumbens* pastures in pure stand and in association with Kudzu (Carimagua, 8 years of grazing).

Table 10. Liveweight changes in B. decumbens pastures in pure stand and associated with Kudzu (Carimagua - 8th year under grazing).

Pasture	Period of the year	Carga rate (A ha^{-1})	Weight changes R$_1$	R$_2$	$\bar{X}$
			---------- g A^{-1} day^{-1}		---------
B. decumbens	Dry[1]	1.5	30	-59	-15
	Transition:[2]	1.5			
	P$_1$[3]		45	27	36
	P$_2$		839	732	786
	Rainy	2.5	266**	101**	184
B. decumbens + Kudzu	Dry	1.5	232	332	282
	Transition:	1.5			
	P$_1$		-268	161	-54
	P$_2$		475*	755*	615
	Rainy	1.5	455	393	424

1/ December to January (12 mm rainfall).
2/ February to March (150 mm rainfall).
3/ April to May (802 mm rainfall).
4/ June to October (1835 mm rainfall).
* Spittlebug (100% attack to replication 1; 50% to replication 2).
** Puddling.

maintained their weight in both treatments. However, during the period between April and May, coinciding with the spittlebug attack, weight gains, to a great extent compensatory, were lower in the association (475 g A^{-1} day^{-1}) than in monoculture (786 g A^{-1} day^{-1}). The negative effect of the spittlebug attack on animal productivity was also reflected in greater weight gains in replication 2 (attack of 50%) compared to replication 1 (attack of 100%). During the wet period, excessive in 1986, B. decumbens pastures in monoculture were waterlogged, which undoubtedly contributed to low weight gains (184 g A^{-1} day^{-1}), in comparison with the association (424 g A^{-1} day^{-1}).

Results obtained this year are interesting, since they clearly show the susceptibility of B. decumbens to spittlebug, especially if there is forage accumulation as occurred in the association. As a result of the spittlebug attack, the carrying capacity of the pasture and individual animal weight gains were reduced. The trial will continue, with adjustment of stocking rates depending on forage availability and monitoring the botanical composition of the pasture (i.e., legumes, weeds) and the quality of forage on offer and selected by grazing animals.

Grazing of Andropogon gayanus with and without legumes

The grazing trial with A. gayanus with and without legumes and under continuous and rotational grazing systems, ended this year. Weight gains obtained during the dry and wet seasons are presented in Table 11. During 1985 weight gains were greater in the associations than in monoculture, with no differences between grazing systems. Similar results were

Table 11. Liveweight gains in A. gayanus in pure stand and in association with legumes under continuous (CG) and rotational grazing (RG) (Carimagua).

A. gayanus pasture	Stocking rate ($A\ ha^{-1}$)	Season	1985[1] CG	1985[1] RG	1986[2] CG	1986[2] RG
			($g\ A^{-1}day^{-1}$)		($g\ A^{-1}day^{-1}$)	
Pure stand	2.0	Dry	-[3]	-165	25	-91
		Rainy	412[a]	417[a]	333[a]	300[a]
+ C. macrocarpum (5065)	2.0	Dry	39	- 40	-72	18
+ S. capitata		Rainy	696[b]	491[a]	262[a]	374[ab]
+ C. brasilianum (5234)	2.0	Dry	34	45	36	54
+ S. capitata		Rainy	644[b]	653[b]	329[a]	390[b]

1/ 141 days dry season, 222 days rainy season.
2/ 138 days dry season, 210 days rainy season.
3/ Without grazing.
a, b, different means ($P < .05$).

obtained in 1984, during the wet period (Annual Report, 1984). This year's weight gains were low in all pastures regardless of grazing systems, mainly due to low availability of the grass resulting from ant (Acromyrmex sp.) attack. As indicated in Table 12, the availability of green dry matter of the grass was reduced considerably over time, both in the dry and wet periods; this is in contrast with the high proportions of the legumes S. capitata and C. brasilianum (5234) (Figure 4).

From the results of this grazing trial several conclusions can be made:

1. The inclusion of legumes (i.e., S. capitata, C. brasilianum 5234) contributed significatively to increase liveweight gains in A. gayanus during the dry and wet seasons.

2. The rotational grazing system imposed (7/21) favored A. gayanus, while continuous grazing favored the legumes, particularly C. brasilianum (5234).

3. The productivity of A. gayanus was significantly affected by continuous grazing at a set stocking rate of 2 A ha^{-1} and by ant attack.

Grazing of Andropogon gayanus with legumes in Category IV

Evaluation of associations of A. gayanus with C. acutifolium (5277 + 5568) and S. macrocephala (1643) continued during 1986 under different management treatments at two sites in Carimagua with different soil textures. Results of liveweight gains during 1986 are presented in Table 13 for Yopare (29% sand) and Table 14 for La "L" (4% sand). In Yopare the animals suffered severe weight losses during the dry period in A. gayanus + S. macrocephala (1643), contrasting with weight gains in mixtures with C. acutifolium (5277 + 5568). During the wet season weight gains on A. gayanus + C. acutifolium were affected by

Table 12. Availability of grass green dry matter (GGDM) in A. gayanus in pure stand and in association with legumes under continuous grazing (CG) and rotational grazing (RG) (Carimagua).

A. gayanus pasture	Stocking rate ($A\ ha^{-1}$)	Season	1985[1] CG	1985[1] RG	1986[2] CG	1986[2] RG
			GGDM ($kg\ ha^{-1}$)		GGDM ($kg\ ha^{-1}$)	
Pure stand	2.0	Dry	407	828	119	337
		Rainy	381	1650	194*	199**
C. macrocarpum 5065 + S. capitata	2.0	Dry	877	1563	172	518
		Rainy	1293	2502	1287	605**
C. brasilianum 5234 + S. capitata	2.0	Dry	1034	1393	170	349
		Rainy	1362	3289	91	468**

* Ants (Atta).
** Ants (Acromyrmex).
1/ Dry (Jaunary-March); Rainy (May-November).
2/ Dry (December-March); Rainy (January-September).

Table 13. Liveweight gains in A. gayanus associated with legumes under different grazing management systems (Yopare-Carimagua, 1986).

A. gayanus pasture	Season (days)	Stocking rate ($A\ ha^{-1}$)[1]	Continuous 0.75	Continuous 1.0	Continuous 1.5	Rotational 1.5
			($g\ A^{-1}día^{-1}$)			($g\ A^{-1}día^{-1}$)
+ C acutifolium (5277 + 5568)	Dry (117)		- 9	+ 85	*	+115
+ S. macrocephala (1643)			-152	-103	*	-278
+ C. acutifolium (5277 + 5568)	Rainy (246)		671	530	532	591
+ S. macrocephala (1643)			709	607	420**	327**

1/ Dry stocking rate/Rainy stocking rate.
* Descanso.
** Ants (Acromyrmex) (225 grazing days).

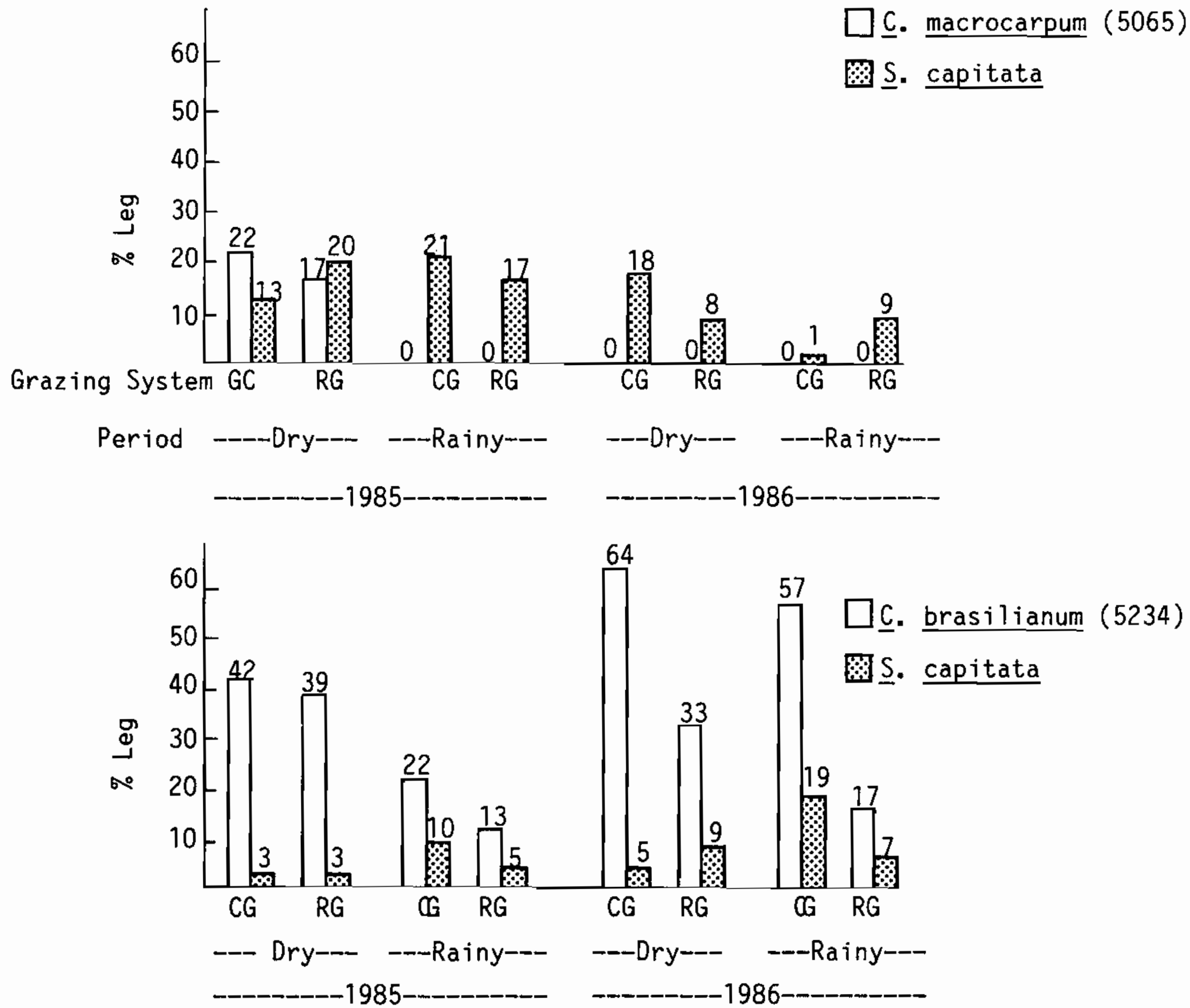


Figure 4. Legume proportion in *A. gayanus* pastures under continuous grazing (CG) and rotational grazing (RG) (Carimagua).

Table 14. Liveweight gains in A. gayanus associated with legumes under different grazing management systems (La "L" - Carimagua, 1986).

A. gayanus pasture	Season (Days)	Stocking rate ($A\ ha^{-1}$)	Continuous grazing 0.85[1] / 1.5 ($g\ A^{-1} day^{-1}$)	1.2[1] / 2.0	1.7	Rotational graz. 1.7[1] / 3.0 ($g\ A^{-1} day^{-1}$)
+ C. acutifolium (5277 + 5568)	Dry (117)		- 32	- 15	- 67	-145
+ S. macrocephala (1643)			- 34	- 89	-133	-195
+ C. acutifolium (5277 + 5568)	Rainy (246)		668	554	*	372
+ S. macrocephala (1643)			208	237**	*	211**

1/ Dry stocking rate/Rainy stocking rate.
* Rest period.
** Ants (Acromyrmex).

stocking rate, being higher under the low stocking rate and continuous grazing treatment. An ant (Acromyrmex sp.) attack affected the A. gayanus associated with S. macrocephala (1643) during the wet period, particularly in the high stocking rates under continuous and rotational grazing, which resulted in low animal weight gains in these treatments. At the la "L" site, animals lost weight during the dry period in both C. acutifolium (5277 + 5568) and S. macrocephala (1643) associations due to low legume availability. During the wet period a severe ant attack also occurred in La "L" in the A. gayanus associated with S. macrocephala (1643), thus resulting in low weight gains for the intermediate (continuous grazing) and high (rotational grazing) stocking rate treatments.

A large difference between sites has been observed in terms of the productivity of A. gayanus. The grass has been more productive and vigorous in La "L" than in Yopare and this has determined different carrying capacities. On the other hand, the low productivity of A. gayanus in both sites when managed with 1.7-2.0 A ha^{-1} under continuous grazing, confirms other experimental results.

In this trial C. acutifolium (5277 + 5568) has performed differently in each site (Figure 5). While the legume percentage in Yopare has remained high over time, in La "L" it practically disappeared during the first months of the 1986 dry season. Various factors may have contributed to this: (1) lower population of legume at the beginning of grazing in La "L" due to establishment problems (i.e., invasion of Panicum rudgi), (2) greater vigor and development of A. gayanus at La "L" site and as a consequence, greater competition with the legume, (3) greater legume consumption by the grazing animals

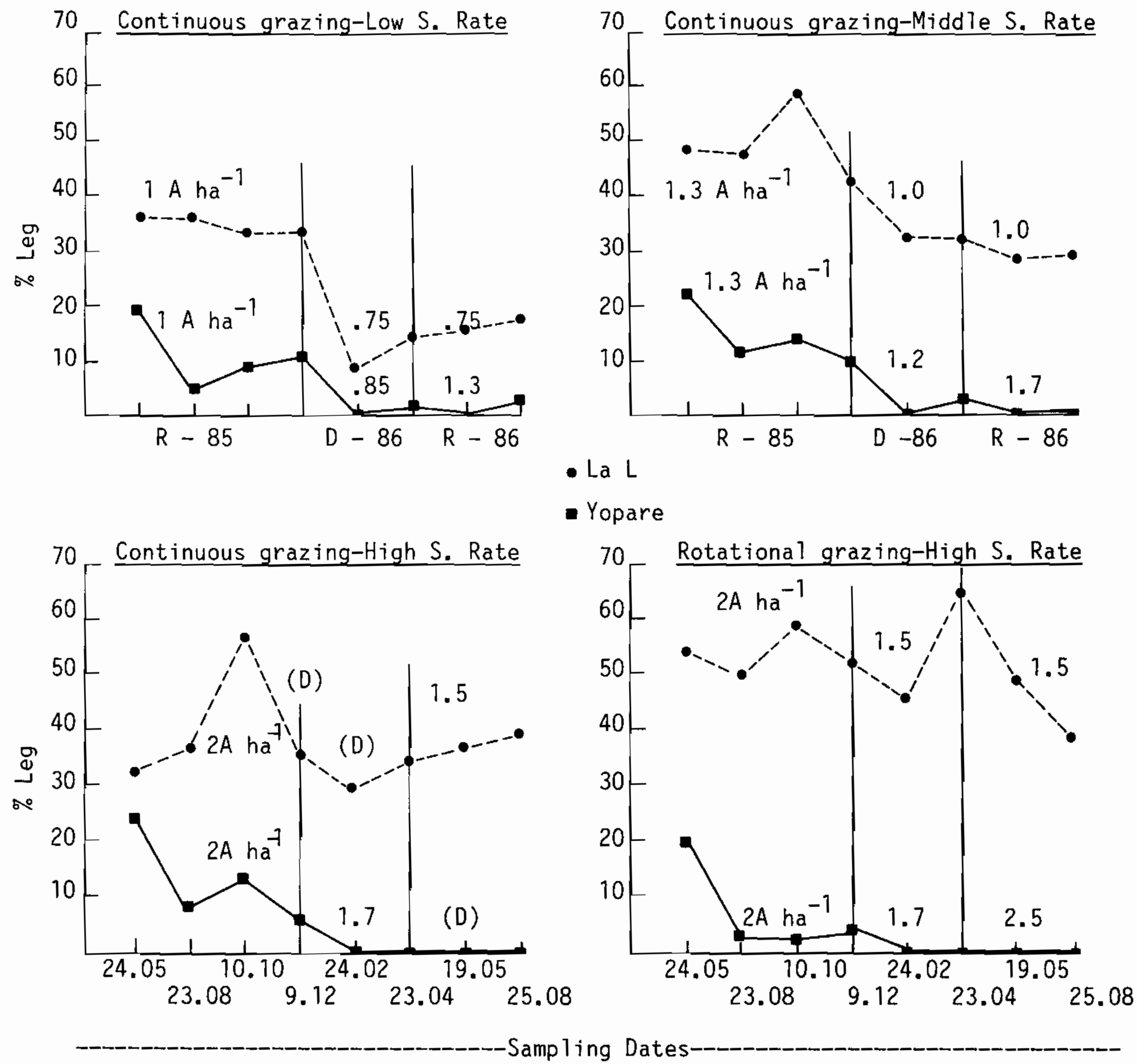


Figure 5. Botanical composition of an *A. gayanus* + *Centrosema acutifolium* (5277 + 5568) association, in two sites under different management systems (Carimagua).

because of overmaturity of A. gayanus at la "L" due to initial undergrazing.

Measurements on animal selectivity have shown a marked effect of the season of the year on the preference of grazing animals for C. acutifolium (5277 + 5568) (Table 15). The legume proportion in the diet selected was very high towards the end of the wet season and during the dry period. On the other hand, a marked preference for C. acutifolium was observed towards the end of the rains under the low stocking rate; this explains the lower legume content in the available forage and diet selected during the dry period in this treatment (Figure 5).

Results obtained up to now clearly indicate that C. acutifolium is a legume that contributes significantly to animal gains in association with A. gayanus both in the dry and wet periods, under a rather broad range of pasture management systems. These results contrast with the low persistence of S. macrocephala (1643), independently of the pasture management system used.

Table 15. Legume proportion in the forage selected by fistulated animals in A. gayanus + C. acutifolium (5277-5568) pastures under different grazing management systems (Yopare-Carimagua).

Period	Grazing system			
	Continuous			Rotational
(year)	HSR[1]	MSR[2]	LSR[3]	HSR[1]
	-- (% legume in diet) --			
Rainy (85)	17	0	0	0
End rainy (85)	28	38	63	17
Dry (86)	20	32	3	76
Rainy (86)	5	4	9	2

1/ 2A ha^{-1} (1985); 1.5A ha^{-1} (1986).

2/ 1.3A ha^{-1} (1985); 1.0A ha^{-1} (1986).

3/ 1.0A ha^{-1} (1985); 0.75A ha^{-1} (1986).

Grazing of associations with Centrosemana spp.

This year grazing was initiated in associations of A. gayanus and B. brizantha cv. Marandu + B. dictyoneura (6133) with C. brasilianum (5234), C. acutifolium (5277), and C. macrocarpum (5452), using two ranges of grazing pressure and a flexible management strategy. Weight gains during the wet season (Table 16) have been greater in the associations with A. gayanus than with B. brizantha cv. Marandu + B. dictyoneura because of the poor performance of Marandu, possibly due to poor adaptation to low soil fertility. No major differences have been observed up to now in animal performance between species of Centrosema. Overall, animal weight gains in this trial have been lower than expected, which could be attributed to excessive management of animals and sampling of the pastures.

The legumes included in this trial have performed differently, regardless of grazing pressure. In Table 17 it can be observed that both with A. gayanus and B. brizantha cv. Marandu + B. dictyoneura (6133), the legume in highest proportion is C. acutifolium 5277. Consequently, the management system imposed has been different for the associations under evaluation. Grazing management of Brachiaria spp mixture has been directed to favor the grass, particularly in associations with C. acutifolium (5277). In the pastures with A. gayanus an alternate grazing system of 14/14 days has been imposed but gradually tending to a 7/7 system in mixtures with C. brasilianum 5234 and C. macrocarpum 5455, to favor the legume.

Table 16. Liveweight gains in grass + legume associations under two grazing pressures and a flexible management system (216 days wet season, days, Carimagua, 1986).

Asociation	High stocking rate (3 - 5)[1]	Low stocking rate (6 - 8)[1]	Average
	g $A^{-1}day^{-1}$		
A. gayanus			
+ *C. brasilianum* (5234)	463	437	450
+ *C. acutifolium* (5277)	410	528	469
+ *C. macrocarpum* (5452)	366	597	482
$\bar{X}$	413	521	
B. brizantha + *B. dictyoneura* (Savanna)			
+ *C. brasilianum* (5234)	447	361	404
+ *C. acutifolium* (5277)	352	338	345
+ *C. macrocarpum* (5452)	314	539	427
$\bar{X}$	371	413	

1/ kg grass green dry matter. 100 kg $LW^{-1}day^{-1}$.

Table 17. Botanical composition of associations under two grazing pressures and a flexible management system (161 days, Carimagua, 1986).

Association	Grazing management (O/D)[1]	High grazing pressure (3-5)[2]	Grazing management (O/R)[1]	Low grazing pressure (6-8)[2]
		Leg. %		Leg. %
A. gayanus				
+ *C. brasilianum* (5234)	14/14	15	14/14	21
+ *C. acutifolium* (5277)	14/14	41	14/14	36
+ *C. macrocarpum* (5452)	9/9	18	14/14	11
B. brizantha + *B. dictyoneura* (Savanna)				
+ *C. brasilianum* (5234)	18/18	19	14/14	25
+ *C. acutifolium* (5277)	21/21	36	18/18	34
+ *C. macrocarpum* (5452)	14/14	20	14/14	19

1/ Días ocupación/días descanso.
2/ kg MSVG/100 kg PV/día.

New plantings

During 1986 a new grazing trial was established in Carimagua with *B. decumbens* alone and in association with a mixture of *S. capitata* cv. Capica, *C. brasilianum* (5234), and *C. acutifolium* (5277). The experiment includes two stocking rates in an alternate grazing system with two replications. With the exception of *C. brasilianum*, the establishment of sown species has been excellent and grazing will begin this year towards the end of the wet season.

NUTRITIONAL STUDIES IN NATIVE SAVANNA

For several years the Section has been conducting research on native savanna in the Colombian llanos, with the objective of defining its nutritional limitations. These studies have been performed by postgraduate thesis students; this report includes results of two studies already completed.

Nutritional limitations in savanna managed with fire

The analysis of results obtained in a study conducted in Carimagua in well-drained savanna managed with traditional burning and two stocking rates (0.37 and 0.75 A ha^{-1}) was completed. This study was designed to establish relationships between quality factors of native grasses and weight gains recorded in grazing animals. In Figure 6 it can be observed that animal gains were not related to protein level in the diet selected, but were positively related to digestibility, with these two variables not being correlated (r = .38 NS). On the other hand, a high correlation was found between availability of digestible green matter (corrected by grazing frequency in areas burnt in different periods) and voluntary intake of organic matter (Figure 7).

From this study it can be concluded that the low liveweight gains observed in animals grazing native pastures managed with fire in well-drained savannas, is mainly due to low intake of digestible nutrients (i.e., energy and protein), associated with low digestibility of the forage on offer and low availability of green dry matter in the burnt areas where animals concentrate their grazing activity.

Productivity of savanna + legumes

It has been suggested that an alternative to legume banks or protein banks to supplement native savanna, is the introduction of legumes into the savanna with the elimination of burning. With this strategy the legumes would correct protein deficiencies of the unburnt native grasses and stimulate greater intake of dry matter, resulting in a more efficient utilization of energy accumulated in the biomass. To prove this hypothesis the Pasture Development Section established in Carimagua a trial which included different levels of legume per animal (750, 1500, and 2250 m^2), combined with stocking rates (0.33, 0.66, 1.0, and 1.33 A ha^{-1}). Grazing was initiated in May 1984, but detailed measurements were only carried out starting in June 1985 in the 1500 m^2 and 2250 m^2/animal levels. Liveweight gains (Table 18) were higher for the control (burning) than in treatments including legumes. In the legume treatments the highest animal gains were recorded in the 1500 m^2/animal level with low stocking rate (0.33 A ha^{-1}) and at the 2250 m^2/animal level with a high stocking rate (1.0 A ha^{-1}), yet weight gains were very low. Undoubtedly a very low level of legume availability contributed to these results, as shown in Table 19. During the first year, when the proportion of *S. capitata* was adequate, weight gains reached levels of 400 g A^{-1} day^{-1} in some savanna treatments without burning under high stocking rates (See Annual Report, 1984).

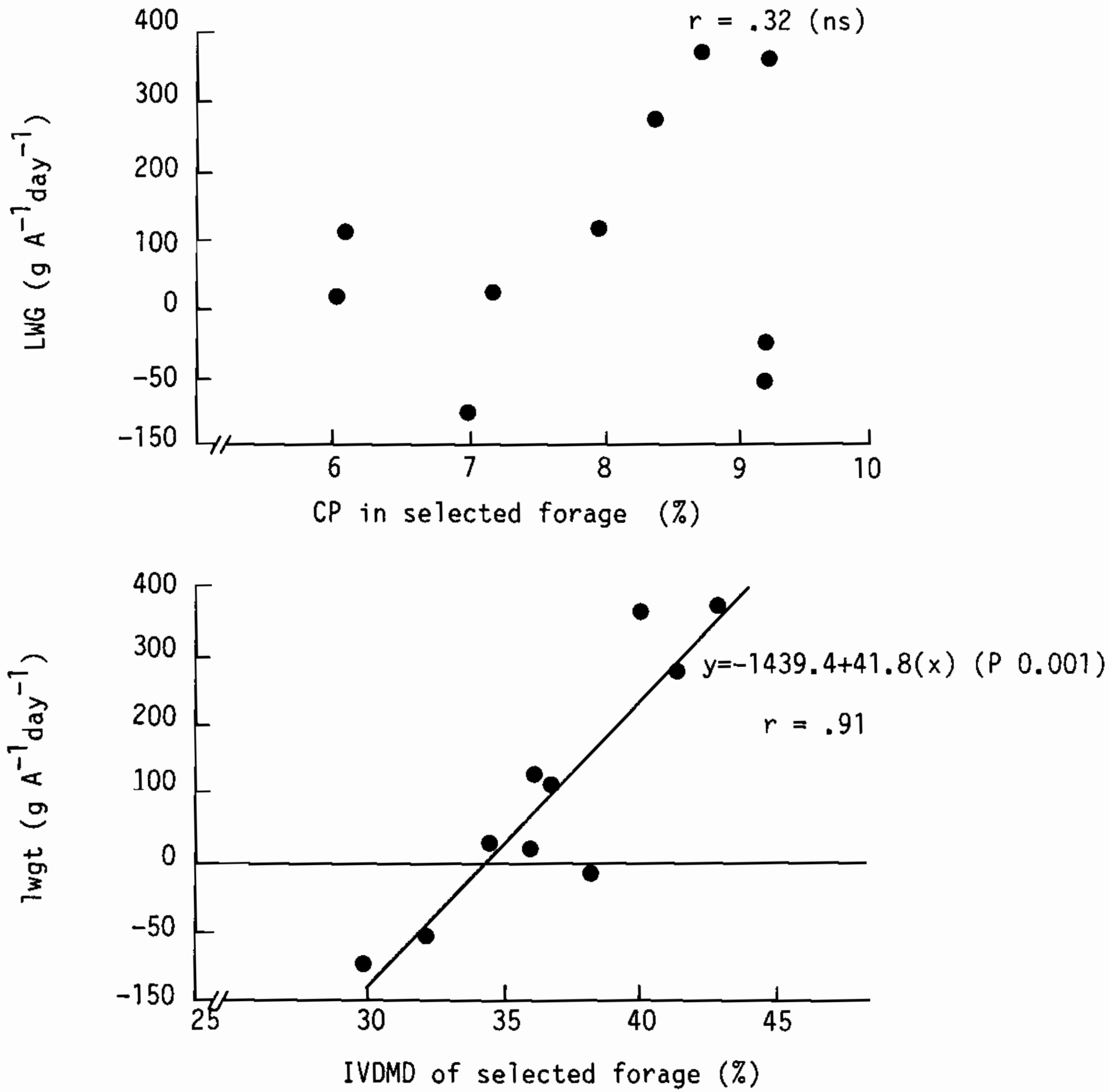


Figure 6. Relationship between liveweight gains (LWG) with crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) of forage selected and daily in native savanna managed with fire.

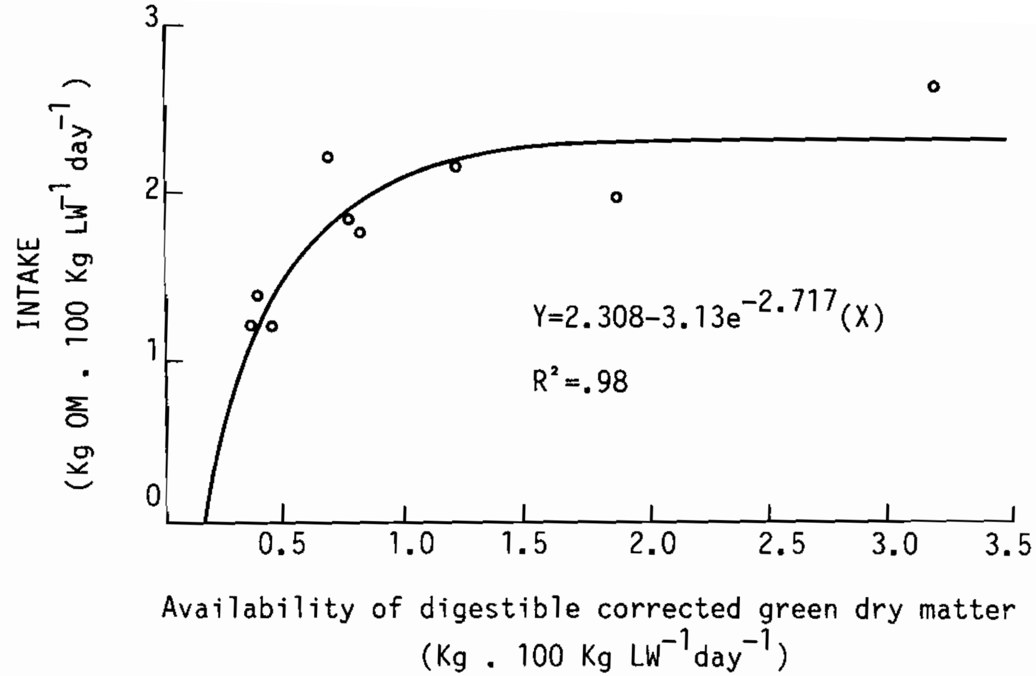


Figure 7. Relationship between voluntary intake of organic matter and availability of digestible green dry matter corrected for frequency of grazing in native savanna managed with fire.

Table 18. Effect of stocking rate on liveweight gains in native savanna without burning + legume (S. capitata) under continuous grazing (Carimagua).

Legume level m^2/animal	Stocking rate A ha^{-1}	Liveweight gains (g $A^{-1}day^{-1}$)		
		R_1	R_2	X
		g $A^{-1}day^{-1}$		
1500	0.33	75	246	160[d]
1500	0.66	-35	147	56[e]
1500	1.00	63	66	64[e]
1500	1.33	-19	125	53[e]
2250	0.66	-10	140	65[e]
2250	1.00	140	104	122[f]
0 (burning)	0.33	220	405	312[c]
	MEAN	62[a]	176[b]	105

a, b) Different means (P < 0.01).
c,d,e,f) Means are different (P < 0.05).

Table 19. Grass and legume availability in native savanna managed without burning and under continuous grazing (Carimagua).

Legume level m^2/animal	Stocking rate A ha^{-1}	Available forage (kg A^{-1}))			
		Grass[1]		Legume[2]	
		R_1	R_2	R_1	R_2
1500	0.33	7922	9266	15	58
1500	0.66	3149	4161	2	59
1500	1.00	2047	2408	69	69
1500	1.33	1205	1477	38	95
2250	0.66	3904	4286	56	80
2250	1.00	1981	2062	162	182
0 (burning)	0.33	5069	6952	0	0
	MEAN	3611[a]	4373[b]	57[c]	91[a]

1/ G = Green dry matter, native grasses. L = Total legume (S. capitata) dry matter.
a,b = Different means (P < .05). c,d = Different means (P < .05).

Both in terms of forage availability and weight gains a strong replication effect was observed; this effect was related to % sand in the soil (replication 1, 45% sand; replication 2, 31% sand). Likewise, crude protein content in the diet selected by grazing was higher in replication 2 (8.1%) as comapred with replication 1 (6.9%), possibly due to a greater selection possibility and differences in floristic composition.

From this study it is evident that the contribution of S. capitata cv. Capica to weight gains was minimum, because of its low availability in the pasture as a result of high palatability and thus intake by the grazing animals. On the other hand, the most limiting nutritional factor in savanna without burning was the low digestibility of the native grasses, due to a very high proportion of indigestible fiber. It is suggested that the ideal legume to complement unburnt savanna should have the following attributes:

1. Rapid establishment.

2. Highly aggressive and with high potential to invade.

3. Medium relative palatability, but with a high concentration of available nutrients (i.e., crude proteins and energy).

4. Tolerance to accidental fires.

Currently the Agronomy Section in Carimagua is evaluating various legumes in small plots in association with savanna in order to identify potential species to introduce into native savanna pastures.

Seed Production

INTRODUCTION

The objectives of the Section are

a) to conduct seed multiplication of promising germplasm accessions so as to provide both seed for experimental purposes and basic seed.

b) to conduct applied research on relevant limitations to seed production technology, especially as regards the key species to the Tropical Pastures Program and the RIEPT and new cultivars released by national programs.

c) to contribute towards the progressive development of a seed supply (including experimental, basic and commercial classes) of various pasture species, within the countries of Tropical Latin America.

During 1986, the major activities of the Section were seed multiplication, applied research, technical collaboration and training. These activities are described in the following progress report.

SEED MULTIPLICATION AND DISTRIBUTION

As in previous years, field production activities were continued at both Quilichao and Carimagua, while support facilities for greenhouse propagation, seed conditioning, seed testing, seed storage and distribution were centred at Palmira.

Seed multiplication activities of legumes species are summarized in Table 1. A total of 107 accessions of 24 species of legumes were under multiplication, with an emphasis upon *Centrosema* spp., *Desmodium* spp. and *Pueraria phaseoloides*. New seed multiplication areas of 11 ha (principally *Centrosema* spp.) were established to provide a total area under multiplication of 24 ha. Seed produced totalled 1.767 kg and included significant volumes of *Stylosanthes capitata*, *C. brasilianum*, *C. acutifolium*, *C. macrocarpum* and *Desmodium* spp.

Seed multiplication activities of grass species are summarized in Table 2. A total of 35 accessions of 11 species were under multiplication, predominantly *Brachiaria* spp. and *P. maximum*. Approximately 3 ha of new multiplication areas were established (mainly *B. dictyoneura*) to provide a total of 13 ha under multiplication. A total of 380 kg of seed was produced, principally of *B. dictyoneura*.

Composite seed multiplication activities are summarized in Table 3, which also provides an overview of the relative contributions of Quilichao and Carimagua. At Quilichao, a large number of materials are placed under initial seed multiplication, involving intensive efforts at plant propagation, crop management and hand harvesting, on relatively small individual production areas and last year, 532 kg of seed were produced

Table 1. Summary of seed multiplication activities of legume species and accessions between October 1985-1986.

Species	Total accessions (No.)	Multiplication areas New (ha)	Multiplication areas Total (ha)	Seed produced[1] (kg)
A. pintoi	1	0.8	2.03	16.624
C. brasilianum	11	1.74	3.955	376.05
C. macrocarpum	13	1.27	2.45	162.197
C. rotundifolium	1	-	0.005	1.468
C. acutifolium	2	3.65	5.04	171.63
C. schiedeanum	2	-	0.01	2.235
Canavalia brasiliensis	1	-	0.002	2.880
Cratylia floribunda	1	-	0.002	1.007
Chamaecrista rotundifolia	2	-	0.01	1.203
D. heterocarpon	4	-	0.101	19.120
D. heterophyllum	3	0.07	0.175	0.510
D. ovalifolium	15	1.175	2.51	23.076
D. strigillosum	4	-	0.087	102.484
D. velotinum	1	-	0.04	0.528
Dioclea guianensis	2	-	0.024	18.764
Flemingia macrophyla	2	0.05	0.15	5.600
Leucaena spp.	3	-	0.003	27.892
P. phaseoloides	14	0.189	0.341	3.536
S. capitata	3	1.0	3.422	771.469
S. guianensis	8	-	1.407	37.373
S. macrocephala	3	1.0	2.10	14.716
S. viscosa	7	0.066	0.066	-
Tadehagi sp.	2	-	0.008	0.670
Zornia spp.	2	0.125	0.508	6.413
Total	107	11.135	24.446	1767.445

1 = Classified seed with > 90% pure seed content.

Table 2. Summary of seed multiplication activities of grass species and accessions between Octobre 1985-1986.

Species	Total accessions (No.)	Multiplication areas New (ha)	Multiplication areas Total (ha)	Seed produced[1] (kg)
A. gayanus	3	-	0.21	10.650
B. brizantha	4	0.2	1.563	15.731
B. decumbens	3	-	1.01	64.990
B. dictyoneura	1	2.0	9.00	281.207
B. humidicola	5	0.1	0.474	3.215
M. minutiflora	4	-	0.016	0.004
P. maximum	9	0.1	0.249	4.587
Paspalum spp.	3	-	0.012	0.458
P. purpureum	1	-	0.004	-
King grass	1	0.5	0.880	-
Caña forrajera	1	-	0.01	-
Total	35	2.9	13.428	380.842

1/ Classified seed with > 40% pure seed content.

Table 3. Summary of seed multiplication activities at different locations for all grass and legume accessions.

Location	Total Accessions (No.)	Multiplication Areas New (ha)	Multiplication Areas Total (ha)	Seed produced Grasses (kg)	Seed produced Legumes (kg)	Seed produced Total (kg)
Quilichao	134	2.7	7.0	32	500	532
Carimagua	26	8.1	27.9	329	1.267	1.616
Total	142	10.8	34.9	361	1.767	2.148

therein. At Carimagua, fewer materials are multiplied, production areas are larger, seed harvesting is conducted both manually and mechanically and last year a total of 1,616 kg were produced therein. The total composite volume of seed produced in 1985-1986 (i.e. all grasses and legumes at both locations) was 2,148 kg.

Seed distribution was conducted jointly with the Regional Trials Section which responds to requests from the RIETP Network collaborators. In responding to a total of 416 requests, a total of 1.558 kg of seed was distributed, predominantly of legume accessions. Members of the Program were the major recipients of seed for experimental purposes utilized in the conduct of germplasm and pasture evaluation activities. Requests for basic seed for seed multiplication activities were willingly met, but were not substantial. Table 4 presents a summary of this activity.

APPLIED RESEARCH

a) Fertilization and seed yield in Brachiaria decumbens

Various fertilizer treatments were superimposed upon an established area of B. decumbens at the onset of the growing season in Carimagua. The fertilizer treatments consisted of a factorial arrangement of two levels of composite fertilizer (with and without 100 kg/ha of TSP + 60 kg/ha KCl), and four levels of nitrogen (0,50, 50 + 50, 100, kg N/ha). Seed was harvested manually and results are summarized in Table 5. A significant response in pure seed yield was recorded from the combined effects of the composite plus nitrogenous fertilizers. The effect of nitrogen was only significant in association with the composite fertilizer and there was no effect above 50 kg/ha nor to split applications. The seed yield response was due to increased inflorescence density. Neither nitrogen or composite fertilizer had any systematic effect on seed viability (at 1 mo. post harvest) or caryopsis size.

b) Comparison of harvest methods in B. decumbens

An extensive area of established B. decumbens was scheduled to be harvested using a tractor mounted reel-beater harvestor. An experiment was designed to compare the relative efficiency of this harvestor to both manual and combine harvesting. Unfortunately, exceptionally high rainfall prevented the arrival of this harvestor. The experiment, however, was conducted finally with the methods shown in Table 6, where the results are also summarized.

The manual harvesting methods resulted in higher yields of pure seed but of lower viability (at 1 mo post-harvest) when. compared to direct combining. The higher quality of seed from the combine apparently results from (a) a higher proportion, both by number and by weight, of spikelets containing a caryopsis within the population of harvested spikelets and (b) a larger sized caryopsis (unit weight) in the pure seed fraction. Overall, under the conditions of this experiment, the manual method resulted in higher yields of pure-viable-seed at the time of harvest.

c) Phenology and seed yield of B. dictyoneura

B. dictyoneura has been under seed multiplication at Carimagua for several years. Summaries of observations of phenology and recorded seed yields, in comparison with B. decumbens, are presented in Tables 7 and 8.

In general, both species commence flowering in approximately early to mid June, reach peak flowering about two weeks later and arrive at harvest

Table 4. Seed distribution between October 1985 - October 1986.

Objective/Source	Seed Request (No.)	Seed Volume: Grasses (kg)	Seed Volume: Legumes (kg)	Seed Volume: Total (kg)
A. Germplasm and Pastures Evaluation				
I) TPP Members	185	96	1.080	1.176
II) Regional Trials (RIEPT)	61	24	60	84
III) National Institutions	93	56	120	176
IV) Other CIAT Programs	25	13	33	46
V) Individuals	37	4	25	29
Subtotal	401	193	1.318	1.511
B. Seed Multiplication				
I) CIAT Seed Unit	4	8	2	10
II) National Institutions	11	22	15	37
Subtotal	15	30	17	47
C. Total	416	223	1.335	1.558

Table 5. Effect of composite and nitrogen fertilizer on inflorescende density and pure seed yield and quality in *Brachiaria decumbens*, Carimagua, July 1986.

Fertilizer Application: Composite[1]	Fertilizer Application: Nitrogen (kg/ha	Inflorescence Density (No./m^2)	Pure Seed: Yield (kg/ha)	Pure Seed: TZ Viability[2] (% No.)	Pure Seed: Caryopsis Weight (mg/100)
-	0	13 B	10 B	89 A	218 AB
-	50	16 B	12 B	85 AB	219 AB
-	50 + 50	18 B	11 B	73 C	202 B
-	100	10 B	10 B	76 BC	229 A
+	-	25 B	17 B	80 ABC	181 C
+	50	84 A	45 A	83 ABC	205 B
+	50 + 50	92 A	37 A	88 A	209 AB
+	100	108 A	44 A	87 A	206 B

1/ TSP 100 kg/ha + 60 kg/ha KCl (≡ 45 P_2O_5 + 14 CaO + 36 K_2O), where + = with, and - = without.

2/ 1 month post harvest.

Table 6. Comparison of harvest methods in *Brachiaria decumbens* in Carimagua, July 1986.

Harvest Method	Harvested spikelets with caryopsis*		Pure Seed		Caryopsis Unit Weight	Yield of Pure-viable-seed
	% No.	% Weight	Yield (kg/ha)	TZ Viability (% No.)	(mg/100)	(kg/ha)
1. Manual, horizontal heaps	16 b	36.5 b	43 a	77 b	206	33
2. Manual, vertical heaps	16 b	33.5 b	34 a	76 b	204	26
3. Direct combining	27 a	57.4 a	21 b	87 a	243	17

* Refers to harvested spikelet population before any seed conditioning.

Table 7. Summary of phenology of established stands of Brachiaria decumbens and B. dictyoneura in Carimagua, 1984-1986.

Species	Year	Flowering		Harvest Maturity
		Commencement	Peak	
B. decumbens	1985	10 June	25 June	11 July
	1986	7 June	20 June	3 July
B. dictyoneura	1984	18 June	4 July	16 July
	1985	5 June	20 June	4 July
	1986	19 May	6 June	20 June

Table 8. Summary of seed yield data of Brachiaria decumbens and B. dictyoneura in Carimagua, 1981-1986.

Species	Marvest Method	Pure Seed Yield (kg/ha)		
		Mean	Range	n*
B. decumbens	Manual	26	6-67	7
	Combine	13	1-40	5
B. dictyoneura	Manual	60	34-86	3
	Combine	40	12-80	7

* Number of independent observations within the mean.

maturity in early to mid July. In 1986, B. dictyoneura tended to flower and mature two weeks earlier than B. decumbens.

Pure seed yield data is limited to a few independent observations from various seed multiplication areas under similar management. Both species appear to react similarly to harvest method, with manual harvesting recovering more seed than the combine. In the case of both means and ranges, B. dictyoneura has shown higher pure seed yield than B. decumbens.

d) Phenology and seed yields of Centrosema spp.

Large seed multiplication areas of both C. acutifolium and C. brasilianum were established in Carimagua in May 1985. The dry season was exerting its full effects by early December.

C. brasilianum CIAT 5234 reached peak flowering before the on-set of dry and windy conditions and high seed yields were obtained from sequencial manual recolection of pods, Table 9.

Table 9. Flowering, harvest maturity and seed yield of two Centrosema spp. in Carimagua, 1985-1986.

Centrosema species	Phenology		Harvest maturity period	Seed Yield	
	Initiation flowering	Maximum flowering		Conventional support (kg/ha)	Stake support (kg/ha)
C. brasilianum	22 October	1 December	10 December-20 February	313	123
C. acutifolium	6 November	1 January	M January-F February	74	39

C. acutifolium CIAT 5277, however, is later flowering and peak flowering was not recorded until early January when very dry and windy conditions prevailed. Seed set and seed yields were reduced as a consequence.

Seed multiplication areas were managed using both conventional post/wire trellis and vertical stakes (of king grass, sugar cane and tree branches). The stake support system yielded an average of approximately 50% of the seed yields from conventional trellis, (Table 9). Important aspects influencing the performance of stakes were (i) degree of regrowth and competition with Centrosema spp. (high in the case of young king grass); time of introduction of stakes and upward entwineing of Centrosema spp.); lodging (tree branches less than the mature grass stakes).

In the case of C. acutifolium a formal experiment was conducted comparing the role of alternative systems of physical support and planting system upon seed yield (Table 10). The conventional post/wire trellis and stakes of king grass introduced in August, gave a positive yield response to support. The fact that grass stakes can provided similar yields to the conventional trellis system is highly encouraging as a cost reduction strategy. Row plantings of support system was generally advantageous tc broadcast planting.

TECHNICAL COLLABORATION

a) CIAT Seed Unit

Close collaboration was conductec during the year. The two major joint activities were,
(i) the II Intensive Course oı Tropical Pastures Seed Production (se‹ Training), and

(ii) basic seed multiplication, o: Centrosema acutifolium CIAT 5277 C. brasilianum CIAT 5234 and C macrocarpum CIAT 5713, by a productio and purchase contract agreement with . seed grower. The Valledupar region o the north coast of Colombia was chose as the production region because o favorable latitude (10°N), rainfal distribution and general soil charac teristics.

Table 10. The effect of types of physical support and planting management upon seed yield of Centrosema acutifolium CIAT 5277. Carimagua, 1985-1986.

Type of support	Seed Yield (g/36 m^2)		
	Rows	Broadcast	Average
1. Conventional trellis	462	243	353 A
2. King grass stakes (June)	213	134	173 B
3. King grass stakes (August)	506	191	349 A
4. Sorghum	93	86	79 B
5. Cassava	220	97	139 B
6. A. gayanus	136	63	99 B
7. Without (ground sward)	59	38	48 B
Average	241 A	119 B	

The contract grower was experienced with grass seed production but not with Centrosema, a new crop to the region. His contributions are to provide land and labour, to conduct establishment, management, manual harvesting, drying and packaging, according to written contract specifications for each of the three Centrosema spp. The Seed Unit is providing, 50% of finance, seed conditioning, seed analysis and make payment to the grower. The Seed Production Section of the Tropical Pastures Program is providing, 50% of finance, the contract specifications, basic seed for planting, and technical assistance to the grower. Crop establishment and vegetative development have proceeded well to date. Approximately half of each crop area was provided with conventional trellis support while the other half was supported by stakes of king grass or tree branches.

The utilization of this seed production mechanism is important not only for increasing basic seed of Centrosema spp. but to demonstrate its utility for more general application by national seed programs.

b) Visits to National Programs

As part of a general strategy to promote expanded seed multiplication activities within national programs, visits were made to,

i) Peru. In February one week was spent as part of a three man team of consultants reviewing the future activites of INIPA as regards pasture seed activities. In the area of tropical pastures, the team visited both Tarapoto and Pucallpa. Recommendations were made for an expansion of both seed multiplication and applied seed production research, with these to be conducted jointly, in support of and as part, of on-farm pasture evaluation activities. In addition, it was recommended that financial support be sought from state development corporations. Later in the year, both CORDESAM and CORDEU corporations approved funding for INIPA- Tarapoto and IVITA-Pucallpa, respectively, and this has allowed pasture seed program expansion for the 1986-87 growing season.

ii) Costa Rica. A short visit was made in April, along with other Program members, to participate in a review of pasture and seed activities and to select candidates for the 1986 pastures Seed Course at CIAT.

iii) Mexico. During May, a tour was made of the Regional Trial locations, to provide background for expanded seed multiplication activities. In addition, discussions were held on candidates for the 1986 pastures Seed Course at CIAT.

iv) Cuba. During September a visit allowed a brief review of the pasture seed program, participation in a three day pasture seed short course, and candidate selection for the 1986 pasture Seed Course at CIAT.

TRAINING

a) During a visit to Cuba in September, a three day short course on seed production was conducted involving 18 participants from the Ministry of Agriculture and State dairy farms. The short-course was conducted at 'Nina Bonita' Experimental Station near Habana.

b) The second Intensive Course on Tropical Pastures Seed Production, was conducted at CIAT, Palmira, from October 6th - November 7th, 1986. The course was organized as a joint activity between the Tropical Pastures Program and the Seed Unit and was conducted in Spanish. A significant effort was made prior to the course to communicate with relevant national institutions and to seek out the most relevant candidates. Priority was given to those institutions and candidates who have responsibilities for seed activities in relation to the pasture evaluation activities of the RIEPT. The course had 28 participants from 16 countries in Central and South America.

The objectives of the course were: (i) improve the understanding of and priorities towards pasture seed activities within national research institutions; (ii) improve the knowledge and skills of the selected participants and (iii) contribute towards progressive expansion of seed supply of the important species and cultivars within each country.

The subject material of the course emphasized the following areas:

- pasture research, pasture development, animal production, demand for seeds;

- seed crop establishment and management, seed harvesting, seed conditioning, seed testing and quality assurance;

- the process of release of new cultivars;

- seed multiplication, seed classes, the role of basic seed;

- commercial seed production;

- seed industry structure and interrelations, the role of seed research.

The subject materials were presented by means of lectures; laboratory, plant and field practicals; discussion groups; written revision exercises; a field tour and a special project. Four external lecturers joined the course during the third week and participated fully in the field tour conducted during the fourth week when the participants visited pasture and seed activities on the north coast of Colombia around Valledupar and in the eastern plains of Colombia around Puerto López and Villavicencio. The field tour was highly benefical in all aspects and was a productive mechanism to best integrate and utilize the external lecturers. Each participant also developed a special project on a selected topic relevant to his future plans. This excercise challenged the participants to look ahead and to focus upon and integrate the most relevant parts of the course to their particular interests and situation.

As the majority of participants presently have only part time assignments to seed activities, much of the benefit of the course will depend upon future decisions by program leaders within national programs to expand pasture seed programs consistent with advances in pasture evaluation and development.

Cattle Production Systems

REPRODUCTIVE PERFORMANCE OF HEIFERS

An on going experiment is studying the effect of growth rate between weaning and 280 kg liveweight on the subsequent reproductive performance of heifers. The parameters studied include the number and frequency of the first heats identified through the use of a marker bull and also through rectal palpations, age at calving and calf performance. The experiment is being repeated.

To obtain growth rates resembling those observed under savanna conditions, weaned heifers have been subjected to three stocking rates on B. humidicola pastures, with ad libitum mineral suplementation. The results of the first replicate have been partially reported in the 1983 Annual Report. The second replicate begun in 1984, and some results are shown in Table 1.

Seasonal variations in liveweight gains (Figure 1) have been marked, especially during the two dry seasons experienced during the trial. In effect, between the months of January and April, and independently of the stocking rate considered, liveweight losses ranged between 300 and 600 g per head per day, depending upon the year. It is possible to infer the nature of the nutritional deficiencies from the results of regular serum analyses performed during the experiment. One of the most sensible parameters was the concentration of blood urea nitrogen (BUN), shown in Figure 2. Although under non limiting conditions BUN tends to rise with increases in protein intake, the limitatations imposed by the low forage availability in all three stocking rates suggest that the high levels of BUN observed during the dry season reflect energy deficiencies that induced tissue mobilization. The latter view is supported by the concentration of nitrogen in the fecal organic matter (NMO) observed during the last year of the experiment (Figure 3). It is generally considered that a concentration of around 1.4% NMO is indicative of adequate levels of dietary protein (7%). This concentration was not attained during the period December-March, but it was well above that threshold during the rainy season.

On the other hand, all the parameters of mineral nutrition suggest that there were no marked mineral deficiencies. The concentration of serum inorganic phosphorus (Pi) was always above 6 mg%, independently of season and stocking rate. There were marked oscillations in the consumption of the mineral lick, that affected the fecal concentration of minerals. As an example, Figure 4 shows the concentration of P in fecal organic matter, which was always above the levels generally considered indicative of deficiencies (0.3 to 0.4%). Of course, the fecal mineral concentration reflects not only the consumption of the mineral supplement but also the ingestion of minerals in the forage and soil, especially in the highest

Table 1. Age and weight at first heat in Brahman heifers subject to three regimes of liveweight gain.

Stocking rate UA/ha	Weight gain g/d	Age at heat days*	Weight at heat kg
1.28	197	886	251
1.71	192	991	263
2.24	96	905	217

* Identified by marker bull.

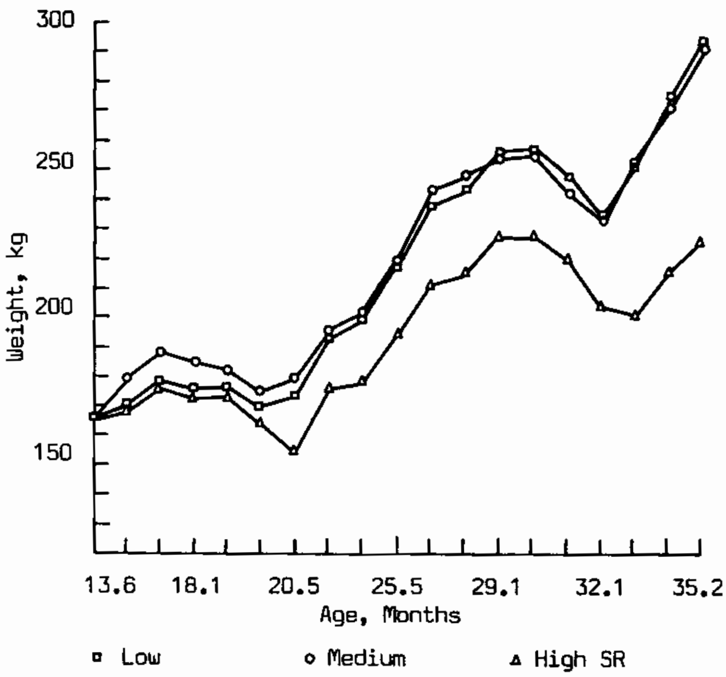


Figure 1. Evolution of liveweight in relation to age, in heifers subject to three stocking rates (SR).
(September 1984 - June 1986).

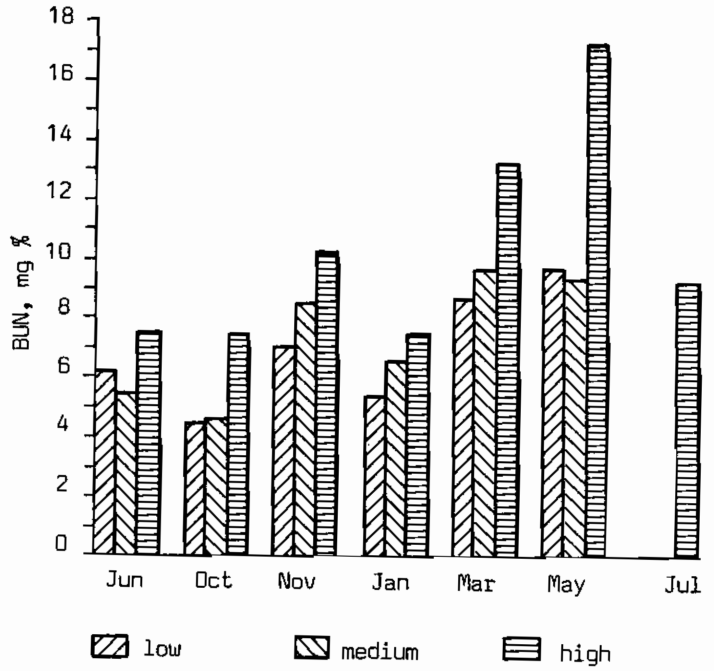


Figure 2. Concentration of blood urea nitrogen (BUN) in heifers subject to three stocking rates (June 1985-July 1986).

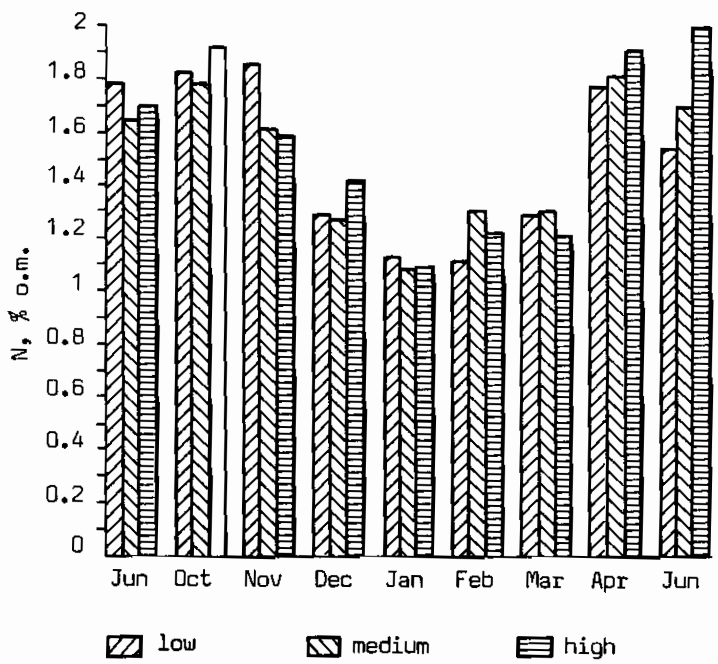


Figure 3. Nitrogen concnetration in fecal organic matter of heifers subject to three stocking rates (June 1985-July 1986).

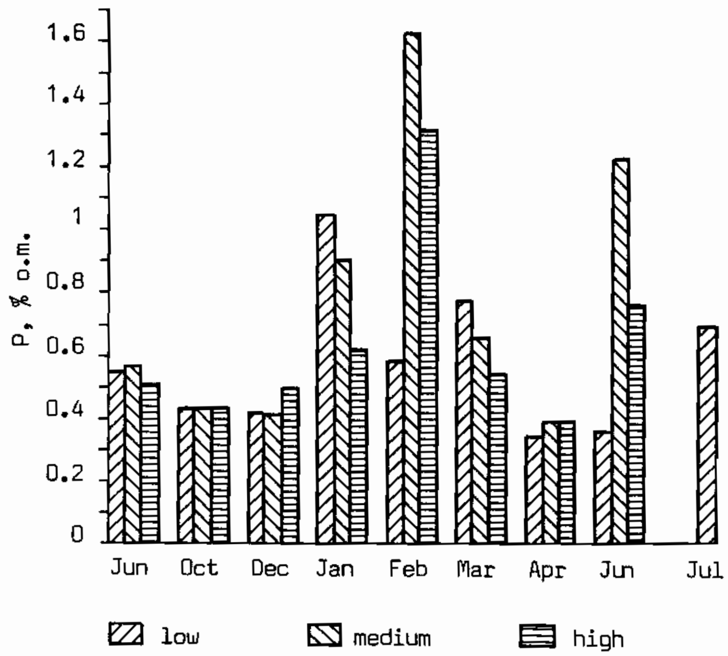


Figure 4. Phosphorus concentration in fecal organic matter of heifers subject to three stocking rates (June 1985-July 1986)

stocking rate where forage availability was always very low.

The animals of the first replicate are now reaching their third conception. Since leaving their respective stocking rates, they have remained on B. humidicola pastures under common grazing, alternating with savanna during the dry season. Thus, it has been possible to reproduce under fairly controlled conditions, the nutritional limitations experienced under more extensive conditions. As a consequence, it has been possible to maintain liveweights identical to those reported for ranches of the region, normally associated with poor reproductive performance. Table 2 shows the ages upon reaching a mean liveweight of 270 kg, and age at first calving.

The data available so far suggest that despite the existing nutritional limitations, the heifers that had been subjected to the high stocking rate until reaching 270 kg liveweight, have partially compensated that situation in terms of reproductive performance. Thus, the regression coefficient of age at first calving on age at 270 kg was only 0.4 (Figure 5), clearly indicating a marked, although partial, compensatory effect.

The results obtained so far suggest that heifers raised under conditions of marginal nutrition as experienced in the present trial possess a marked capacity to respond to modest improvements in nutrition, which then supports the strategic use of small areas of sown pastures to improve reproductive performance. Similarly, these results show that even in the presence of a complete mineral supplement, animal performance is a function of forage availability and quality which influence energy consumption.

Table 2 Mean age at 270 kg liveweight and at the first calving in heifers subject to three stocking rates.

Stocking rate an/ha	Liveweight g/d	Age at 270 kg months	Age at 1st. calving months
1.72	311	26.8[a]	43.3[a]
2.35	220	29.2[b]	44.7[a]
3.23	17*	38.4[c]	48.6[b]
Se	-	2.32	4.99

* The animals left the treatment upon reaching 225 kg.
Means followed by different letters, diffre significantly ($P < 0.05$)

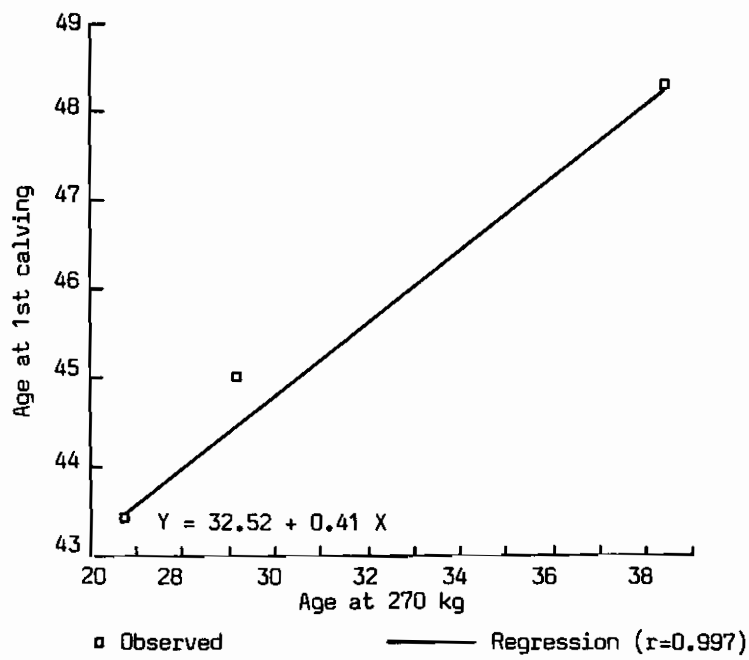


Figure 5. Regression of age at fist calving on age at 270 kg.

Reproductive performance on Brachiaria decumbens

This experiment, at present into its fourth year, studies the reproductive performance of cows stocked at 1.2 AU/ha on Brachiaria decumbens. The animals, that begun the experiment as heifers, were initially mated at 350 kg weight. The latter liveweight is above that required for conception, but it had been hoped that by so doing, there would be no detrimental residual effects of an early calving. Nevertheless, the pasture has been unable to prevent large weight losses during the first lactation, as shown in Figure 6, although there appears to be reduced fluctuations with increasing age of the cows.

Despite the marked oscillations in weight, it is clear that reproductive performance has not been compromised (Table 3), which once again suggests that it is possible to obtain high calving and weaning rates under extensive grazing conditions in the Eastern Plains of Colombia, provided animals have access to improved pastures.

Table 3. Age al calving and calving intervals in Brahman cows grazing B. decumbens.

Calving No.	Age at calving months	Calving interval months
1	47.8 ± 4.6	-
2	63.3 ± 5.5	13.5 ± 2.7
3	76.4 ± 5.8	13.5 ± 2.7
4*	85.1 ± 4.3	11.7 ± 0.6

* Data to September 1986.

Early weaning on improved pastures

The Section has continued working on early weaning, together with the Pasture Quality and Productivity section. During the 1986 rainy season,

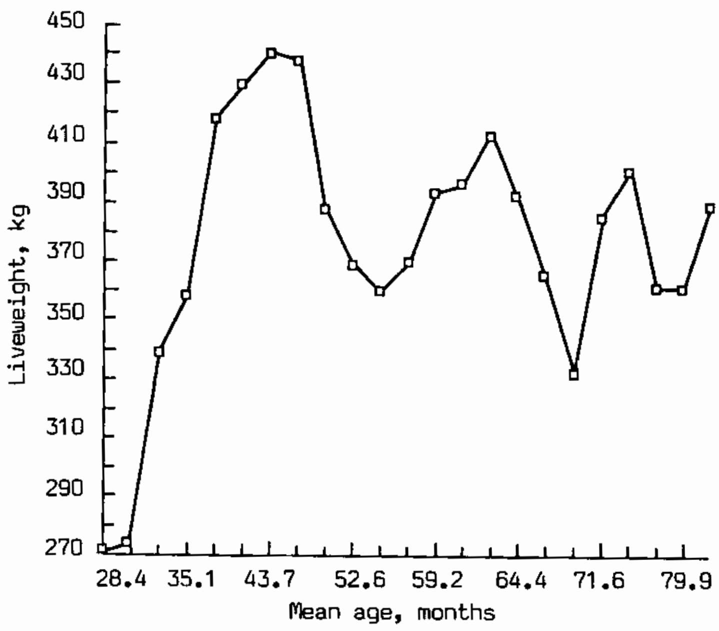


Figure 6 Liveweight of Brahman cows under continuous grazing on Brachiaria decumbens.

an experiment begun with the aim of comparing the liveweight gains of calves weaned at 3 months of age on pastures of *A. gayanus-Centrosema acutifolium* 5277, *A. gayanus-Pueraria phaseoloides* and *A. gayanus* respectively. All the pastures were stocked at a low stocking rate of 5 calves/ha, and subjected to rotational grazing with 7 days of occupation and 21 d of rest. Unfortunately, due to the exceptionally heavy rains that occurred in that year, the pastures were partially flooded and pasture regrowth was severely reduced, resulting in poor animal performance (Figure 7). Initially, while forage availability was ample, acceptable liveweight gains were recorded. The effect of green forage availability on weight gains is shown in Figure 8.

Despite these results, and based on the observations of the two previous years, early weaning on grass-legume pastures seems feasible provided green forage availability is non limiting. Nevertheless, the experiment will be repeated.

In the meantime, the reproductive performance of the dams of early vs normally weaned calves in 1984 and 1985 continuous to be monitored. The data available so far (Table 4) confirms the well known effect of early weaning on reproductive performance.

FAMILY FARM

During the last 3 years a number of modifications have been implemented (Table 5) in the Family Unit with the objective of evolving towards a dual-purpose system destined to produce beef and milk processed as cheese.

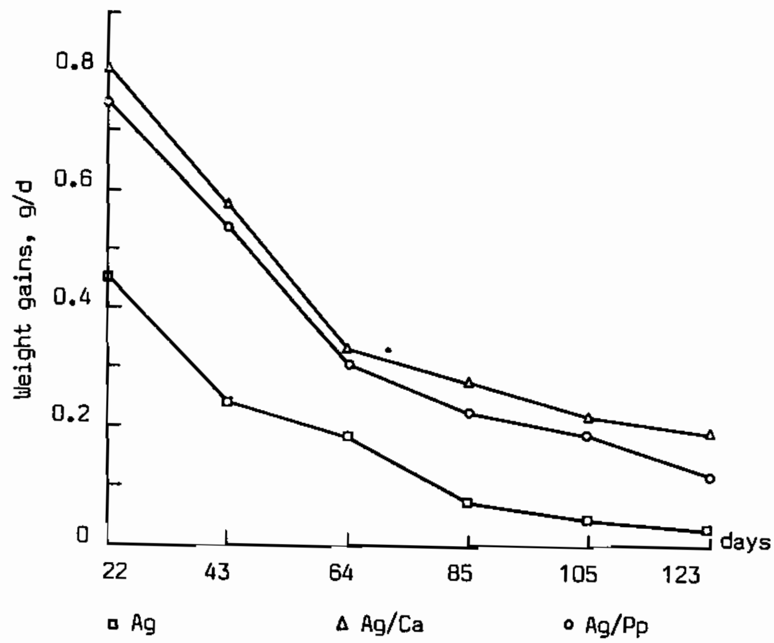


Figure 7. Accumulated daily liveweight gain in calves weaned at 3 months of age and on three different pastures.

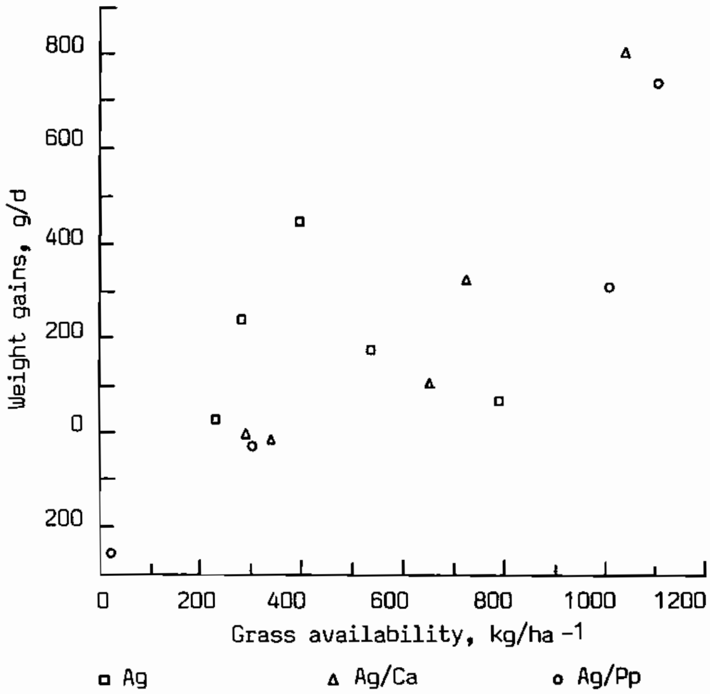


Figure 8. Liveweight gains of early weaned calves in relation to grass green leaf availability in three pastures

Table 4 Effect of weaning age on cow's reproductive performance.

Weaning age days	Calving interval months	Calving %
110	15.5 ± 4.1	77
166	17.7 ± 3.3	68
319	23.2 ± 1.7	52

Due to new plantings made in 1984 and 1985, the area actually available for grazing temporarily decreased; thus, changes in animal performance were only realized in 1985 and 1986. Preliminary data, not yet fully analyzed, are shown in Table 6. The levels of milk production are modest in absolute terms, but are much higher than those generally reported for the very limited number of ranches that milk cows in the eastern plains of Colombia, and in 1986 the yields per cow attained levels comparable to those of the piedmont region, a region much better endowed. So far, there is no evidence that milk production has had a detrimental effect on beef production.

The Family Unit has now over 10 years of existence; having documented its bioeconomic performance, obviously influenced by access to the markets, the newly created program of Technology Transfer of ICA begun in 1986 to use it for demonstration purposes, with the main aim of showing the use of simple techniques based on the planned and strategic use of grass-legume associations.

Table 5. Changes in the available resources in the Family Unit, during 1984-1986.

1984	.	New planting of *A. gayanus*/*Pueraria phaseoloides* to complete 48 ha.
	.	Introduction of 17 heifers and 1 bull Cebu x Brown Swiss.
	.	Beginning of once-a-day milking, during the rainy season.
1986	.	Planting of 5 ha of *A. gayanus*-*S. capitata* for calves.

Table 6. Milk and cheese production in the Family Unit.

	1984	1985	1986*
Period of milking	May 1 - Nov. 30	Aug.1 - Jan.26	Apr.14 - Nov.30
Days	212	179	231
Cheese, kg	688	443	598
Cows milked	9-14	9-14	8-12
Milk, kg/d.cow	1.97 ± 0.5	2.6 ± 0.7	2.82 ± 0.10

* data to November 30, 1986.

ON-FARM PERFORMANCE OF IMPROVED PASTURES

The oldest on-farm monitored grass-legume pastures are now 7 years old. The large majority of the 450 ha of Andropogon gayanus-Stylosanthes capitata sown in cooperating ranches located in the Eastern Plains of Colombia in the period 1979-1981 still persist. The only exception is the loss of approximately one-third of a 80 ha planting in one of the ranches, due to severe overgrazing during the 85/86 dry season, combined with an exceptionally severe ant attack. These two factors led to loss of part of the A. gayanus population, whereas S. capitata was unaffected. Similar situations have been observed in Carimagua in experimental plots subject to continuous grazing with high stocking rates.

The generally good persistence of the majority of the pastures in several ranches with changing soils conditions and very variable management is highly encouraging, specially in view that with only one exception, none of the padocks have ever been refertilized.

In view of the consistency of the animal performance data collected during this long observation period, and considering the need to evaluate newer associations, it was decided to discontinue monitoring animal performance in two of the ranches: ranch 04, monitored since 1979 and where the effect of improved pastures on whole herd reproductive efficiency has been documented, and ranch 17 where a long term study of fattening was conducted. Nevertheless, the botanical composition of the respective pastures will continue to be monitored.

New species and associations have been planted in the years 1985 and 1986 in a number of cooperating ranches. Subject to seed availability, Category IV and V accessions such as Centrosema acutifolium 5277, C. brasilianum 5234, Arachis pintoi 17434 and Brachiaria dictyoneura 6133 have been planted in several different associations, some with the inclusion of A. gayanus. The areas planted are shown in Table 7.

As was done in the past, it is intended to document the levels of animal production obtained in these pastures and their persistence under farmer's management.

PILOT PROGRAM OF PASTURE VALIDATION AND TECHNOLOGY TRANSFERENCE

In 1985, ICA (Instituto Colombiano Agropecuario) created a technology transference program in Carimagua with the aim of providing technical advise to ranchers in the region of well drained savannas. During 1986, the Livestock Systems section actively cooperated in this pilot activity since it is considered an original attempt in livestock extension, with very few precedents in tropical America. As such, the program has to be considered a pilot activity that merits to be carefully documented.

During 1985, this program concentrated on multiplying the seed suply of cultivars, such as Stylosanthes capitata cv. Capica, which were scarce or non-existent in the market. Following contacts with ranchers associations, and other public and private institutions, interested farmers were identified in 1986. At that stage, the demand significantly exceeded the operative capacity of the small group in charge of the program, which was compounded by the very harsh climatic conditions prevalent in that year. In general, the program provided free technical assistance for the establishment of pastures and seed multiplication lots, and also supplied seed not available in the market at cost; in some cases, depending upon the distance involved, machinery was also rented.

Table 7. On-farm pastures sown with accessions in Categories IV and V.

Pastures	Año	
	1985	1986
A. gayanus + *S. capitata*, ha	67	223
farms	2	13
A. gayanus + *C. brasilianum* 5234, ha	6	41
farms	2	3
A. gayanus + *C. acutifolium* 5277, ha	11	27
farms	2	4
A. gayanus + *C. brasilianum* 5234 + *S. capitata*, Capica, ha	-	18
farms	-	1
B. decumbens + *S. capitata*, ha	-	29
farms	-	3
B. dictyoneura 6133 + *A. pintoi* 17434, ha	5	-
farms	3	-
B. humidicola 679 + *A. pintoi* 17434, ha	-	1
farms	-	1

An important area of seed lots and pure plantings was established (Table 8). These areas can eventually be used for seed (sexual or vegetative) multiplication. It was interesting to observe that there was also demand for pure plantings of *A. gayanus*, although seed of the latter is abundant in the market. The issue of on farm sexual seed multiplication, where machinery is generally limiting, is an as yet unresolved problem. In this sense, the technology transference program also contacted a number of seed enterprises, in an attempt to involve them in the multiplication of pasture seed, espcially that of legumes. With this purpose, a number of meetings and visits to ranches was made during 1986. Other, related, activities are discussed in the report of the Seed section and also that of the Seed Unit.

As indicated above, the program was also involved in the planting of grass-legume associations. The number of ranches involved, and the area planted are shown in Table 9.

Table 8. On farm plantings with pure species

	Pure species and seedlings 1984	1985	1986
C. acutifolium 5277, ha	-	0.25	1.25
farms	-	1	2
A. pintoi 17434, ha	-	1.8	4
farms	-	3	2
S. capitata, Capica, ha	5	16	41
farms	1	3	1
B. dictyoneura 6133, ha	-	20	62.5
farms	-	5	11
A. gayanus, Carimagua, ha	-	-	66
farms	-	-	2

Table 9. Associated pastures planted by the Technology Transference program of Carimagua in 1986.

	No. Ranches	No. paddocks	Total area ha
A. gayanus - S. capitata	13	17	223
B. decumbens - S. capitata	3	3	29
B. humidicola - A. pintoi	1	1	1
A. gayanus - C. acutifolium 5277	4	4	27
A. gayanus - C. brasilianum 5234	3	3	41

SIMULATION PROJECT

Work this year has involved the building of an interactive computer system to allow operation of the beef model in as flexible a manner as possible, the building and incorporation of forage growth routines in association with the Ecophysiology section, and preliminary experimentation with these, especially sensitivity analysis. Some documentation has also been undertaken.

The structure of this review falls into three parts: a brief description of the complete system, a look at some of the results from the experimentation carried out to date with the beef and pasture models, and an outline of future work and intended documentation.

SYSTEM STRUCTURE

Beef Model

The relationships operating within the beef component have been documented elsewhere; it allows the development of a beef herd to be simulated for up to 20 years. Major characteristics were described in last year's report, along with the results of the validation runs. Herd dynamics have changed slightly (Figure 9), in that provision now exists for the buying of followers or breeders.

Forage Routines

Two distinct methods are used to simulate forage quality and quantity. Investigation here is seriously constrained by lack of data with which to build empirical models. At this stage savanna growth and quality are still modelled using tables of typical values over time; interpolation is performed to derive relevant values for any particular day. The approach taken is really to suggest that availability of savanna *per se* is less likely to be limiting to animal production than the quality of such forage.

The same cannot be said for any improved pasture there may be. The structure of the improved pasture model is described in the Ecophysiology report for this year. Two problems in particular can be identified: how to handle the dry season to allow year-to-year simulation of growth, and how to model digestibility. For the first of these, work is in progress to incorporate a relationship which modifies growth rates and senescence rates for the dry season, which can be linked to water stress.

For the problem of digestibility, a number of methods were tried to relate this parameter to model output (for example, the proportion of new herbage in the pasture, defined in some way). No wholly satisfactory method has been found to date, so interpolation tables are used, although it is acknowledged that this fails to take account of animal interactions on pasture quality.

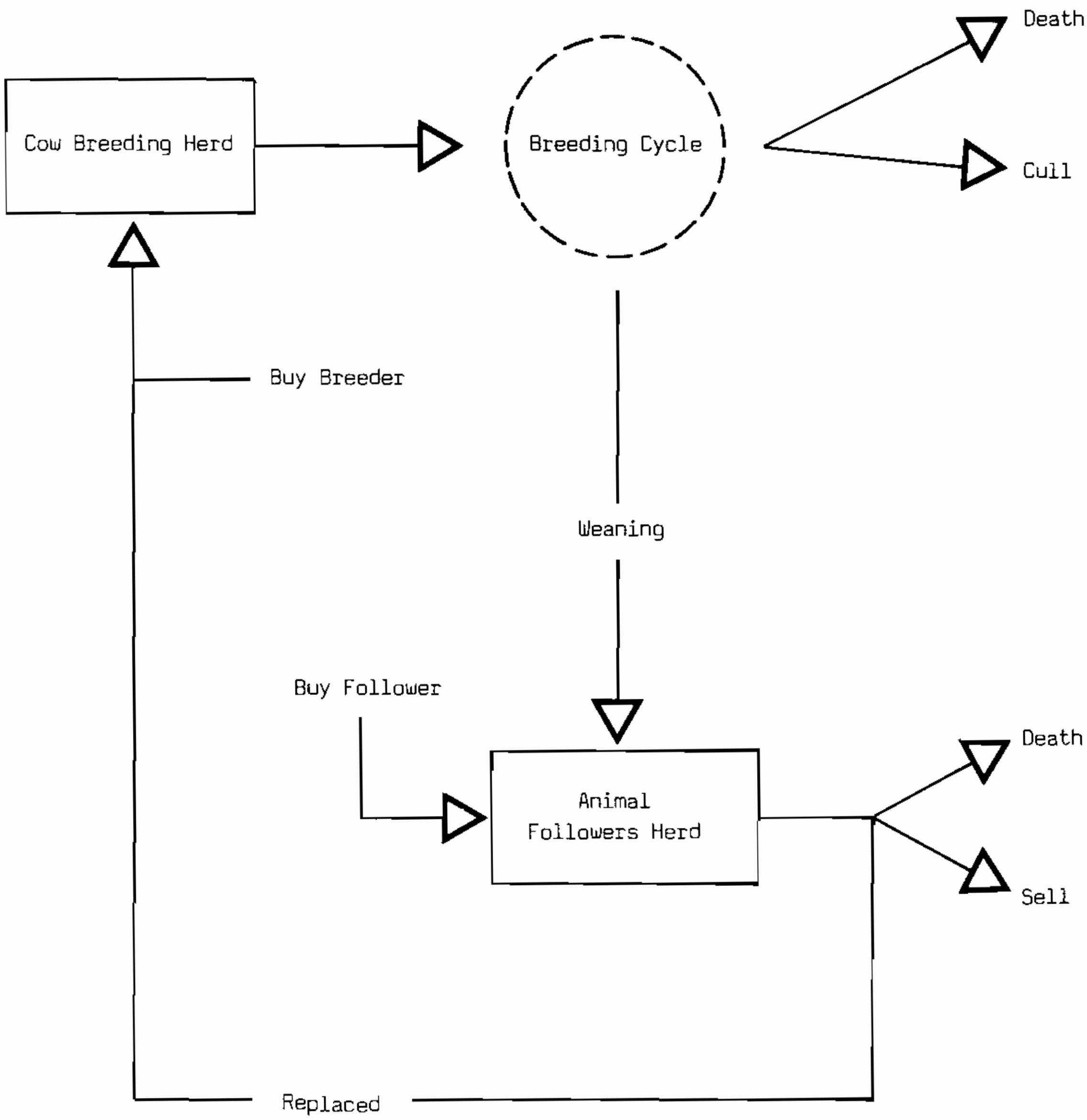


Figure 9. Rusmob V4.1 Herd dynamics.

Many of the forage functional relationships can be seen as experimental variables, in effect - a ramification of using conceptual models in situations where hard data do not yet exist. It is not necessarily disadvantageous per se, but it does necessitate experimentation to find out which of the conceptual relationships are robust and insensitive to change, and which are not.

General System Structure

Some of the general features of the system can be enumerated:

- Simulation runs of up to 20 years can be carried out, with breeding herds of up to 30-40 animals.

- A run can be carried out entirely in a batch mode, whereby decisions are made using fixed decision rules built into the model.

Table 10. Animal physiological status groups.

Group	Status	Group	Status
1	Dry empty	14	Female age < 1 yr
2	Pregnant 1-3 mos	15	1-2 yr
3	4-6 mos	16	2-3 yr
4	7-9 mos	17	3-4 yr
5	Lactating 1-3 mos	18	> 4 yr
6	4-6 mos	19	Male age < 1 yr
7	7-9 mos	20	1-2 yr
8	Pregnant 1-3, lactating 3-6 mos	21	2-3 yr
9	7-9 mos	22	3-4 yr
10	Pregnant 4-6, lactating 7-9 mos	23	> 4 yr
11	- null -		
12	Calf male < 12 mos		
13	Calf female < 12 mos		
	Breeding Herd		Followers herd

- A run can be carried out in an interactive mode; the simulation can be halted at any time, the animals, forage or cash flows inspected, and almost any management may be imposed for as long or as short a time as required.

- At the end of the run, net present values and internal rates of return are calculated, if possible; these may be incremental, compared with a base-line cash flow. Economic re-analysis is then possible, by the re-reading of the entire event file for the run. This file keeps a record of every significant event (conception, death, sale, for instance) that happens to each animal. Thus, the influence of a drop in price can be examined on the same biological sequence of events without having to re-run the entire simulation.

- Animals may be divided into mobs on the basis of age, sex, or physiological status (Table 10), and then fed a variety of forage within mobs. Provision also exists for rotational grazing of improved pasture.

- Available forage resources number four; three different types of savanna are allowed, as is one paddock (or multiple paddocks for rotational grazing) of improved grass-legume pasture. How this is fed is entirely up to the user, within the limits of an extensive set of alloable combinations. New resources can be brought into the run at any stage of the simulation.

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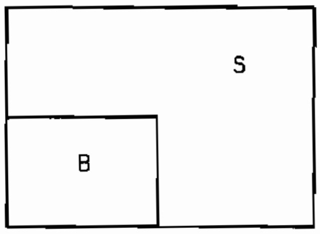
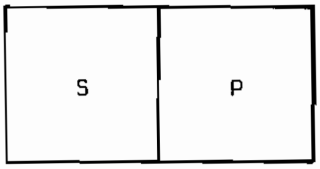


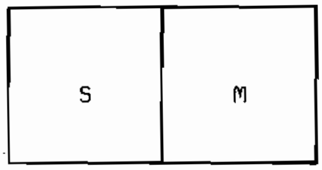
Free access or strategic
Diet = S (+B)
Preference functions needed

TYPE II



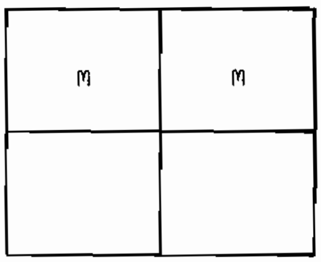
Rotational or stretegic
Diet = S or P
No preference functions

TYPE III



Rotational or stretegic
Diet = S or M
No preference functions

TYPE IV



Rotational
Diet = M
No preference functions

NOTE - Assumed that animal has access to one type of savanna only.
- Assumed that legume/grass preference functions are extant.
- Basically any system can be imposed within the structure of rusmob.
- S = Savanna
  M = Mixture of legume and grass
  B = Bank of improved pasture
  P = Pure sward, legume or grass

Figure 10. Rusmob W4.1 Sample grazing system.

Animals may be sold, bought, culled or weaned as appropriate using the interactive system, or these activities can take place according to decision rules embedded within the model.

The types of grazing system that can be handled are illustrated in Figure 10. Note that only one system requires explicit preference functions other than those embedded in the pasture model (type I).

Price generation

Annual data from 20 years at the Feria in Medellin were analyzed to identify cycles and trends. Monthly data from 1975 were analyzed to investigate seasonal variation. The yearly data were deflated and de-trended to produce the time series shown in Figure 11. It is assumed that a cosine wave of a certain period and amplitude is sufficient to fit the data. Annual prices are calculated using a cycle of 6 years with no trend imposed. This average value is then multiplied by a monthly factor to account for seasonal variation, the monthly factors being the average of 11 years' oscillations about recorded means. An input required of the user, in addition to cycle lengths and amplitudes, is the point in the cycle where the user wants to begin, since this parameter can have enormous influence on herd capitalization. Cycle parameters were calculated for both male and female animals.

Figure 12 shows simulated prices for 24 years (four complete cycles); the buying price for animals is assumed to be correlated (r = 0.7) with the female sale price. Its actual value is determined randomly, using a relation which takes account of the theoretical degree of correlation, so that at some times, the sale price is greater than the buying price, and at other times it is less. This was deemed necessary to preclude the possibility of the user (or the model itself, in an unconstrained optimization situation) becoming a stock dealer rather than a rancher.

EXPERIMENTATION

The results from four series of sensitivity analyses are summarized; the first two series deal with the sensitivity of the beef model, the third with the effects of different

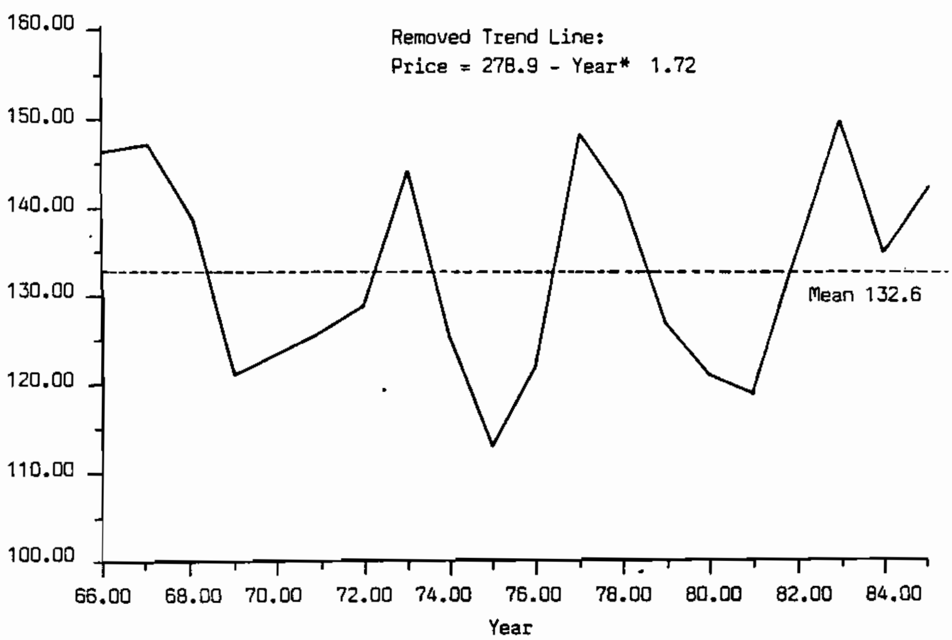


Figure 11. Detrended and deflated steer prices. Medellín 1966-1985.

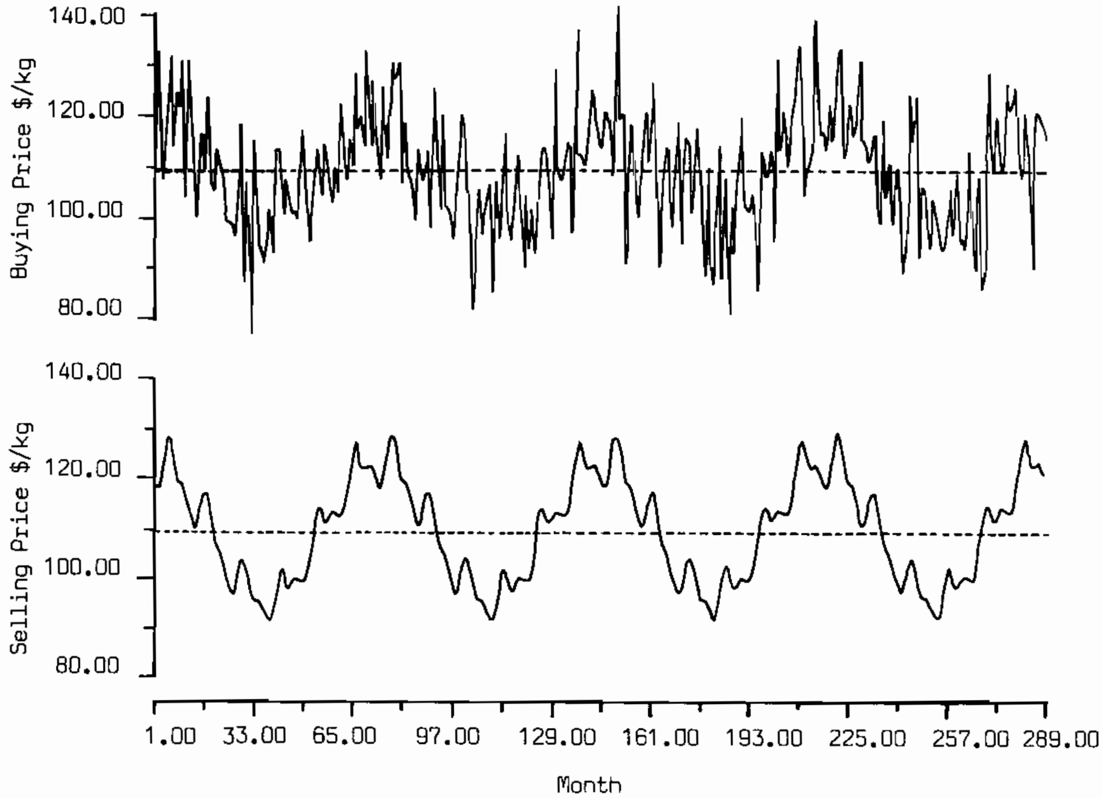


Figure 12. Correlated female bying and selling prices: Four complete cycles. Correlation coefficients: Calculated = 0.67, Theoretical = 0.70.

preference functions on beef production, and the fourth series investigates the sensitivity of the improved pasture model.

Series 1

The effects of changes to a number of the parameters of the beef model, for example the time step and herd size, have been well-documented in previous work. The object here was to look at a variety of other parameters, perturb them by 10%, and look at the effects of such perturbations on model output, in an attempt to identify highly sensitive parameters. Five replicates of each treatment (Table 11 a) were carried out. Results are shown in Table 11b, in terms of the mean and average coefficient of variations for the five replicates. Variances are low, with the exception of mortality (part of which is directly stochastic), since not all of the variability inherent in the system is being taken into account. In addition, no statistics are quoted; due to the absence of experimental error, significant differences become a function of replication, and may have more to do with the model than with real life.

The importance of faecal dry matter output (VIP) is underlined; a 10% increase in this parameter leads to an increase in production of some 37%. It is also clear that an increase in system quality will lead to increases in conception and weaning percentages, in weaning weight and production, but to reductions in age at first calving, in conception interval and in mortality.

Average diet digestibility (DIG) has a huge effect - a 10% increase leads to a 90% increase in production. Being an energy-based model, such an effect

Table 11a. Sensitivity analysis - Series 1 treatments.

No.	Parameter		Standard	Perturbed
1	baseline			
2	VIP	faecal dry matter output, DM/kgLW/day	0.0094	0.0103
3	WMAX	mobilizable tissue for lactation, kg/day	1.40	1.54
4	PP	relative birth weight	15.0	13.6
5	PMA	potential milk yield, kg/day	5.0	5.5
6	NWEAN	weaning age, days	270	245
7	DIG	mean diet digestibility, %	44.6	49.1
8	DIGGEN	energy content of feed, MJ/kg	15.185	16.704
9	RATE	normative weight curve parameter	0.054	0.059
10	MANDAT (1)	first yearly management date	210	0
11	MANDAT (2)	second yearly management date	330	0

Table 11b. Sensitivity analysis - Series 1 - Results summary.

Treatment		Output Parameter						
		Conception %	Weaning %	Age 1st partum years	Weaning weight kg	Conception interval days	Production kg/AU/yr	Mortality %
baseline		48	30	4.0	130	598	38	19
VIP	+	60	42	3.4	145	505	52	13
WMAX	+	45	31	4.1	132	632	39	20
PP	-	48	30	4.0	132	601	38	20
PMA	+	46	29	4.0	135	621	37	19
NWEAN	-	47	30	4.0	124	605	38	25
DIG	+	83	57	3.1	157	381	72	12
DIGGEN	+	64	44	3.3	146	490	54	13
RATE	+	46	30	3.9	133	612	39	20
MANDAT 1	-	47	31	4.0	132	601	38	25
MANDAT 2	-	49	31	4.0	132	598	37	25
Average CV%		3	6	3	2	3	5	13

is not surprising, especially when it is remembered that the pure savanna base-line system is close to being the worst biologically feasible system there is. The shape of the monthly digestibility distribution remained unchanged; the effects of changes in the shape rather than in the location of this distribution are looked at in a subsequent analysis.

In summary, faecal dry matter output (VIP), average diet digestibility (DIG) and the energy content of feed (DIGGEN) have very important effects, and there may be some potential for lowering the age at weaning, though this may be offset to a degree by increased follower death. The effects of changes in PMA and WMAX are of interest, in that their effects are not unequivocal, but can be explained by reference to the functions operating in the model.

A supplemental series of runs was carried out to look at the response curve of production to diet digestibility and to changes in the variance of the monthly digestibility values. Figure 13 shows the graph of monthly transformed digestibilities, with low, medium and high variances. The response curves of changes in mean digestibility on production and weaning percentage are shown in Figure 14. Both curves are steep and slightly convex (denoting diminishing marginal returns to increases in average digestibility). From the table of results (Table 12), the effects of changing the variance are not immediately obvious, although the dry-season high-variance digestibility distribution is having profound effects on calf mortality through starvation. The reaction of the model to the low-variance diet is interesting, and would appear to suggest that production is increasingly adversely affected by increasing variability in the diet.

Series 2

To gain a deeper insight into the action of the model, a four-factor full factorial experiment was set up, with the main aim of identifying important interactions. The factors chosen were faecal dry matter output (VIP), average diet digestibility (DIG), maximum amount of mobilizable tissue to support lactation (WMAX), and potential milk yield (PMA) - the first two because of their highly sensitive nature, and the last two because of their opposing tendencies both to raise and lower different output parameters. Three replicates of each were carried out. Five percent perturbations were used.

ANOVA on the sixteen treatments was carried out in GENSTAT for all interactions up to and including those of the second order. Table 13 lists the only significant interactions

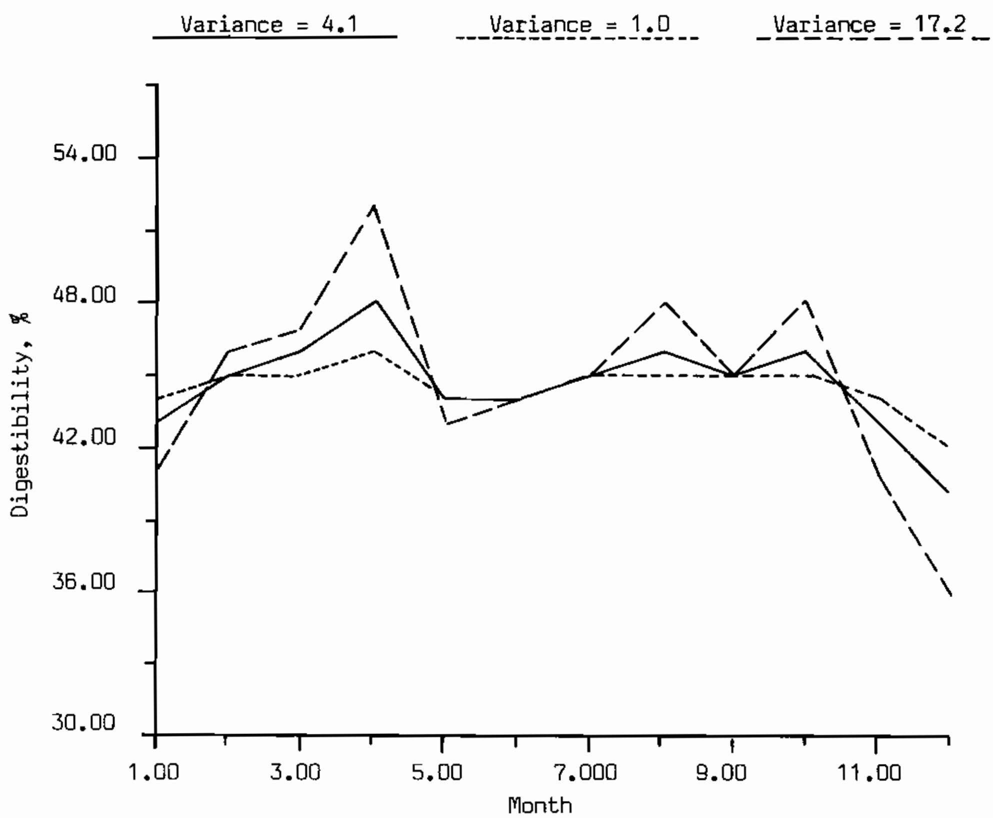


Figure 13. Sensitivity analysis - series 1 - mean monthly. Digestibility time series: Low, standard and high variance treatments.

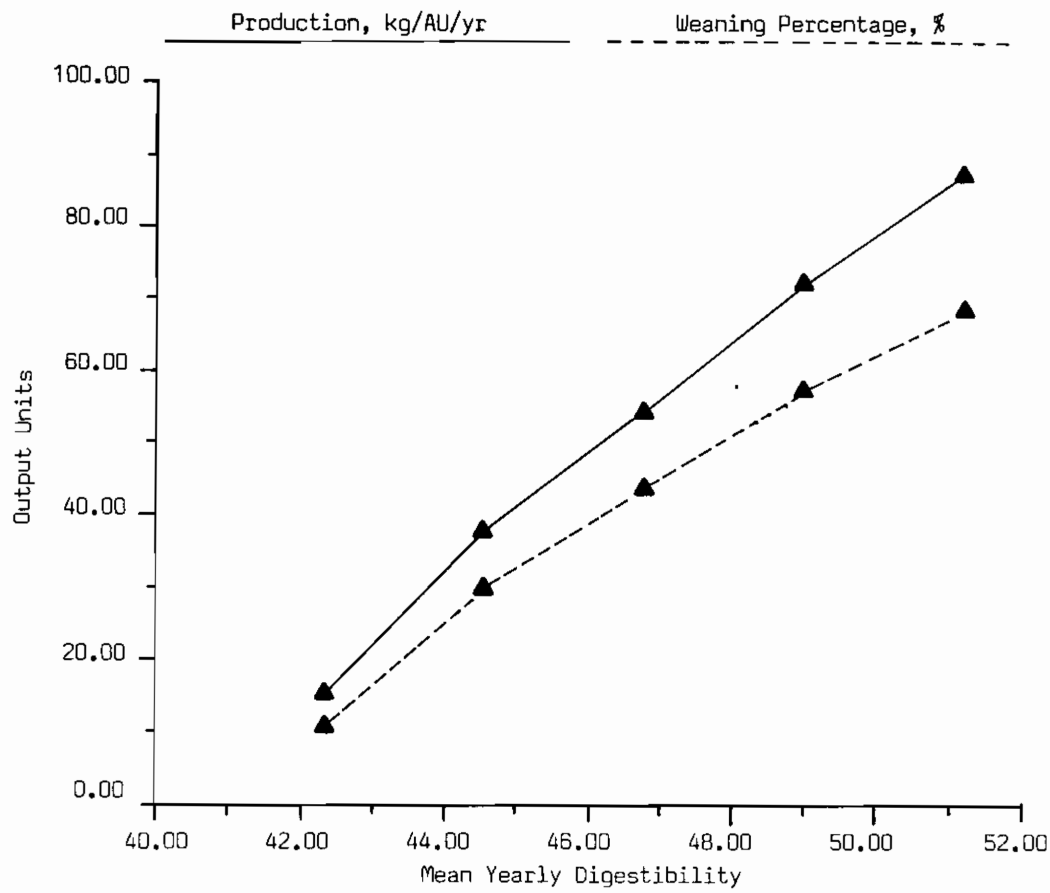


Figure 14. Sensitivity analysis - series 1 - response of rusmob to an increase in mean yearly diet digestibility.

Table 12. Sensitivity analysis - Series 1 - Changes in the mean and in the variance of the monthly digestibility distribution.

Treatment	Output Parameter						
	Conception %	Weaning %	Age 1st partum years	Weaning weight kg	Conception interval days	Production kg/AU/yr	Mortality %
mean - 5%	50	11	4.4	113	644	15	27
baseline	48	30	4.0	130	598	38	19
mean + 5%	62	44	3.3	146	493	54	12
mean + 10%	83	57	3.1	157	381	72	12
mean + 15%	97	68	2.8	166	338	87	13
variance -	44	32	4.1	135	630	39	9*
baseline	48	30	4.0	130	596	38	16*
variance +	54	25	3.9	122	553	34	37*
Average CV%	3	6	3	2	3	5	13

* Calf mortality.

Table 13. Sensitivity analysis - Series 2 - Four factor full factorial ANOVA results - Faecal dry matter output (VIP), mean diet digestibility (DIG), potential milk yield per cow (PMA), and amount of tissue mobilizable per day to meet lactation needs (WMAX).

Output Parameter	Significance Table		
Conception %	VIP**	DIG**	
Weaning %	VIP**	DIG**	
Mortality %	VIP*	DIG*	VIP.DIG*
Age 1st. partum	VIP**	DIG**	
Weaning weight kg	VIP**	DIG**	PMA*
Conception interval	VIP**	DIG**	
Production kg/AU/yr	VIP**	DIG**	

* $P < 0.05$ ** $P < 0.01$

found for the seven output parameters. Principal components analysis was then performed, in an attempt to relate model output to parameter changes in as simple a way as possible. The first two principal components explain some 97% of the variance (Table 14). In essence, the first component is dominated by highly significant digestibility and faecal dry matter output variance ratios, the former accounting for nearly 80% of the sum-of-squares for this component's ANOVA. The second component is dominated by the interaction between these two parameters. Detailed results of this analysis can be found in a separate document. The most important findings are summarized below:

1. Diet digestibility is of crucial importance to the operation of the model, and the model is highly sensitive to this factor. Faecal dry matter output operates in a similar way, but is of less importance.

2. The model is clearly energy-sensitive, since the only real way in which to affect significantly the output variables is to change those inputs which deal more or less directly with it. Conversely, a variable such as potential milk yield has no clear effect on system quality taken as a whole at such low digestibilities, since the output parameters move in ways which tend to be self-balancing.

3. There is a threshold level in terms of the energy status of the herd above which starvation ceases to be important. Once this threshold level is reached, further increases in energy status have essentially no effect on mortality.

4. It is likely that if starvation mortality can be reduced, then standard probabilistic mortality

Table 14. Sensitivity analysis - Series 2 - Principal components analysis of the correlation matrix.

Output Parameter	Component				
	1	2	3	4	...
Conception %	0.386*	0.282*			
Weaning %	0.391*	0.155			
Mortality %	-0.300*	0.912*			
Age 1st. partum	-0.390*	0.039	...	...	...
Weaning weight kg	0.388*	-0.045			
Conception interval	-0.388*	-0.185			
Production kg/AU/yr	0.393*	0.166			
Variance accounted for %	90.0	7.3	1.0	0.9	...
Cumulated % Variance	90.0	97.3	98.3	99.2	...

(some 12% per year, which cannot be affected by nutritional means) tends to favour younger, more fertile animals at the expense of older, less fertile animals. This is an effect over and above the obvious one whereby energy increases lead to better system quality.

Series 3

The third series of sensitivity analysis runs was aimed at investigating the effects on beef production of changes in improved forage preference functions. There is little data on which to base their construction, so the resultant sensitivity of secondary production is of much interest. In effect, one year runs were used, as at the end of each year respective grass and legume biomasses were set to their original values as at the start of the run. There were five treatments with three replicates of ten-year runs. The selection functions used are shown in Figure 15. The extent of preference is expressed in terms of the ratio of the area of the shape above or below the straight diagonal (preference function type V) formed by the function used to the total area above or below the line, called the Preference Function Area Index (PFAI).

An idea of the different effects of each treatment is obtained if the biomass plots for treatments 1 and 4 are examined (Figure 16). It can be seen from Table 15 that average ingested digestibility rank-correlates perfectly with production per animal unit per year. In other words, selection is acting by changing the effective digestibility of the diet. For treatment 2 (legume actively selected for), the animals select a diet of higher digestibility than the one on offer, whereas for treatments 3, 4 and 5, the animals are penalizing themselves. (This has interesting ramifications for the concept of the maximization of net energy intake.) What is of more importance is the size

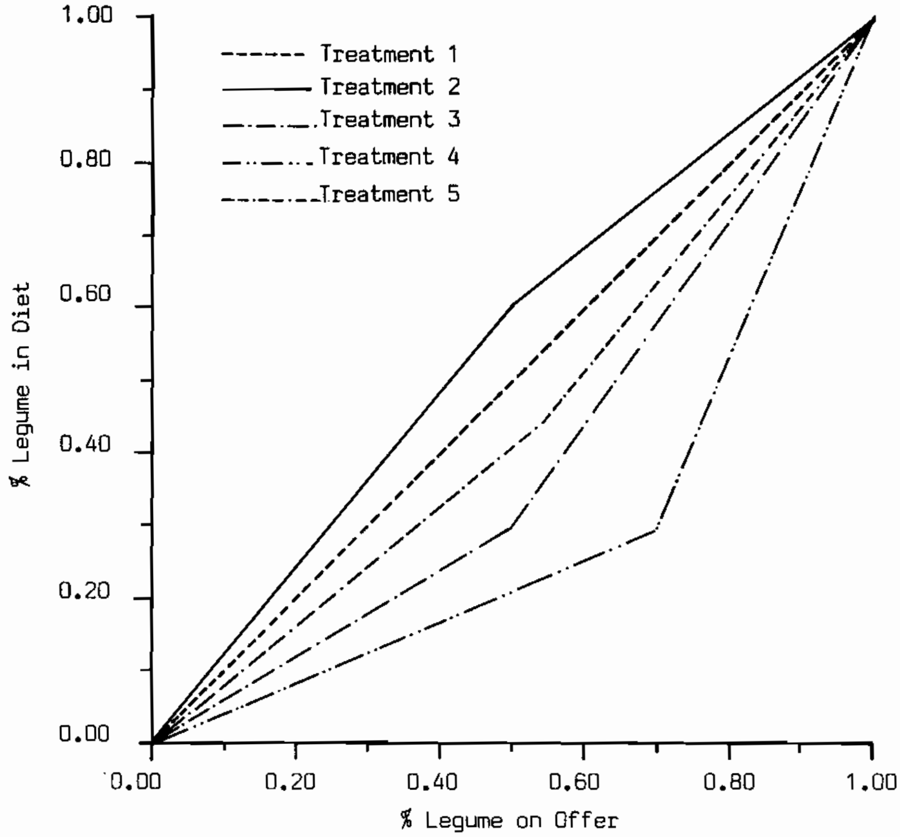


Figure 15. Sensitivity analysis - series 3 - preference functions, treatments 1-5.

of the changes; if treatments 1 and 4 are compared, it can be seen that an increase in ingested digestibility of 5.3% increases production by 18%. The production levels for treatment 2 are within the bounds set by treatments 1 and 4.

Despite the limitations of the experiment (digestibility time series of the same shape, separated by the same relative factor; constant preference functions over time, etc.), it is clear that information is needed to define preference functions, since their effect may clearly be very large. Experiments are underway in the Ecophysiology and Pasture Quality and Nutrition sections which should provide useful data for this purpose.

Series 4

The final series of sensitivity analysis experiments investigated the robustness of primary production per se to changes in the growth functions in the pasture model. A number of one replicate (no variability) treatments were set up, without animals; one set was concerned with pure pasture, and the second, with mixtures and hence competition. Parameters were perturbed in three ways: an increase in 10% in the y direction, 10% in the x direction, and 10% in the x and y direction. The resultant areas under the functions are thus increased by factors of 1.10, 1.10, and 1.21 respectively.

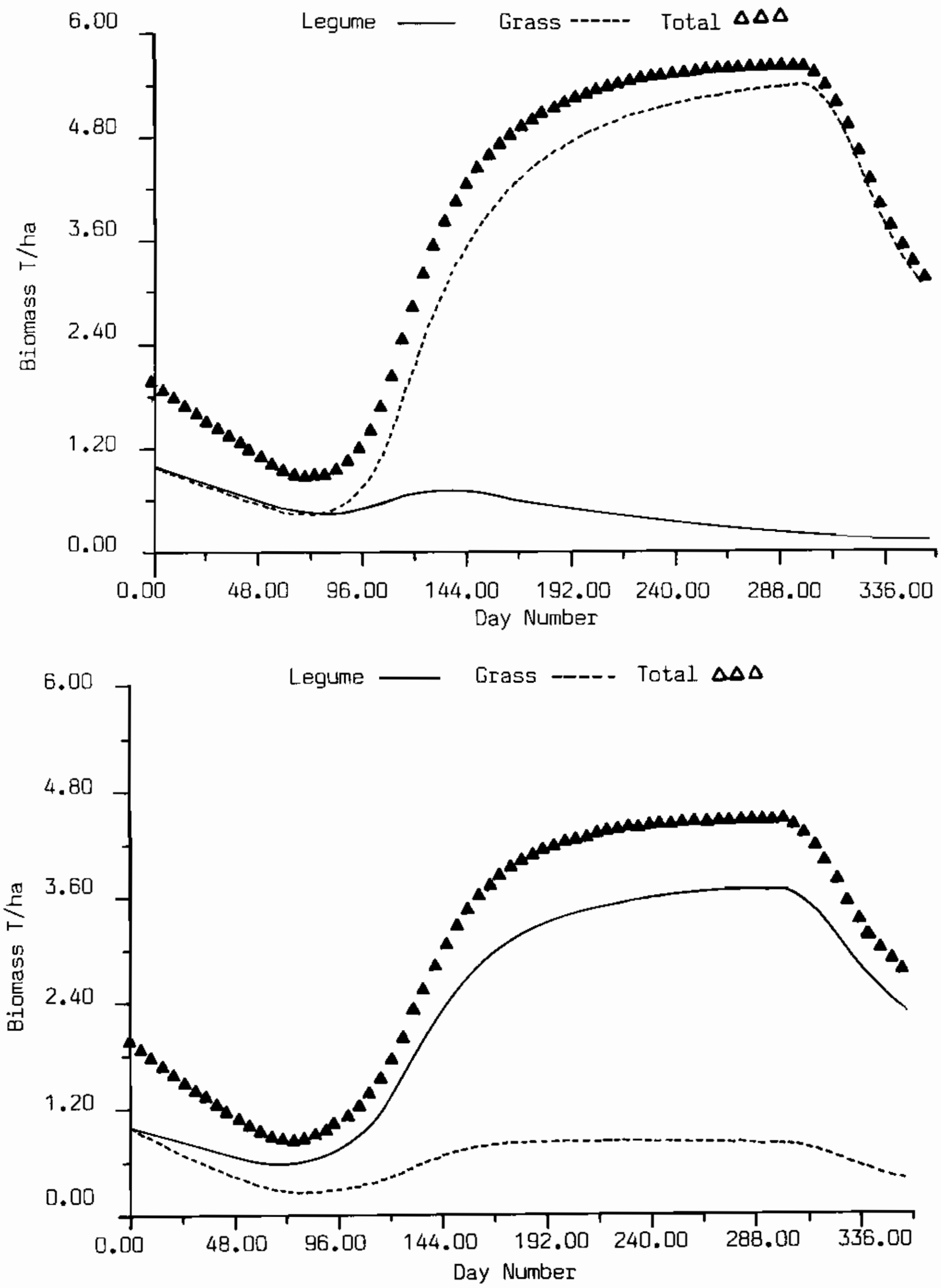


Figure 16. Sensitivity analysis - series 3 - ten year average biomass curves against time: Treatment 1 (no preference) and Treatment 4 (heavy negative legume preference).

Table 15. Sensitivity analysis - Series 3 - The effect of preference functions on beef production.

Treatment			Digestibility					Production kg/AU/yr		
			Forage on Offer		Ingested					
No.	PFAI	Legume Selection	X	s	X	s	rank	X	s	rank
1	0.0	none	47.1	3.8	47.1	3.8	3	61.1	2.9	3
2	+0.1	slightly positive	46.9	3.6	47.2	3.8	2	62.4	1.2	2
3	-0.2	moderately negative	47.8	4.2	46.8	3.8	5	58.0	1.2	5
4	-0.4	heavily negative	52.5	3.7	49.6	3.6	1	72.0	3.1	1
5	-0.1	slightly negative	47.5	4.1	47.0	3.9	4	60.8	2.6	4

- Values of digestibility given were assembled into ten-year monthly averages, which were themselves averaged.

- PFAI = preference function area index, defined as (y-x), where the elbow of the function has coordinates (x, y).

The ten treatments for the legume pasture are shown in Table 16, with results in terms of the ceiling yield, days to ceiling yield, and cumulative production (area under the curve) to that time. Ceiling yield was defined to have been attained if the biomass on day t differed from that of day t-1 by less than 1.0 kg. A gauge of the sensitivity of each function can be obtained from summing and averaging the absolute values of the percentage changes observed; these are 1.5%, 7.8% and 3.6%, respectively. Senescence is of greatest sensitivity; this is not surprising, since this is a one-stage process related directly to biomass, whereas growth is a two-stage process (as a function of leaf area index which is itself a function of biomass). In view of this, some more treatments were set up to examine changes over a wider range for the senescence function. Results are shown in Figure 17, where it can be seen that changes in the x-y direction tend to damp down, to some extent, the large but opposing tendencies which exist if changes are made to the parameters in the x and y directions separately. The response is approximately linear, a 10% change in parameters leading to a 6% change in cumulative production.

Similar results were obtained for the pure grass pasture, although owing to the nature of the functions, ceiling yields were higher and growth rates were faster than those of the pure legume pasture.

Another set of treatments looked at the effects of 10% perturbations in the y-direction only to the growth function for a grass legume mixture. No non-spatial competition was introduced at this stage. The effects on persistence of the legume, measured as the legume content ratio over time, were not marked; neither were those on yield or cumulative production to day 210. Apparently changes in the growth functions for mixtures are considerably damped in comparison with the same changes made to mono-component pastures.

Table 16. Sensitivity analysis - Series 4 - Results, treatments 1-10:Legume pasture, sensitivity to 10% perturbations in pasture model functions.

Treatment			Ceiling Yield t/ha		Days to Ceiling Yield		Cumulative Production m/ha	
1	-	-	4.76		208		0.653	
2	I	y	4.79	(+1)	200	(-4)	0.652	(0)
3	I	x	4.76	(0)	219	(+5)	0.665	(+2)
4	I	xy	4.80	(+1)	208	(0)	0.657	(+1)
5	II	y	4.55	(-4)	198	(-5)	0.584	(-10)
6	II	x	5.23	(+10)	224	(+8)	0.781	(+20)
7	II	xy	5.00	(+5)	212	(+2)	0.695	(+7)
8	III	y	4.99	(+5)	203	(-2)	0.683	(+5)
9	III	x	4.58	(-4)	209	(-0)	0.604	(-7)
10	III	xy	4.77	(0)	201	(-3)	0.621	(-5)

(-) Percentage change from value in Treatment 1; I, II and III are the pasture model leaf area index, senescence and growth rate function, respectively; x, y, or xy indicates direction of perturbation.

The last subset of treatments looked at the response to changes in the competition function (see Figure 18), which relates potential growth rate to actual growth rate. A useful way of looking at competition effects is to construct de Wit replacement diagrams, where relative yields after a certain length of time are plotted against a range of plant densities at time zero, in effect. Seven "replicates" of each of these treatments were carried out, but with the initial ratio of legume-to-total-biomass set at 0.0, 0.1, 0.3, 0.5, 0.7, 0.9 and 1.0, with total initial biomass being kept constant at 800 kg/ha. Figure 19 contains de Wit diagrams, which show what happens by day 84 for the three levels of competition; these constitute classic expression of such effects, where relative yields are decreasing for increasingly severe competition. The effects of the last two treatments are also shown, where mutually beneficial and detrimental competition are imposed, respectively. These illustrate the ability of the competition function alone to produce very different types of response.

To summarize series 4:

- in pure swards, senescence is particularly sensitive;
- for mixed swards, functions I, II and II tend to act on yield and persistence to a limited degree only, while function IV (the competition function) tends to act on legume persistence to the exclusion of yield;
- for mixed swards, making the

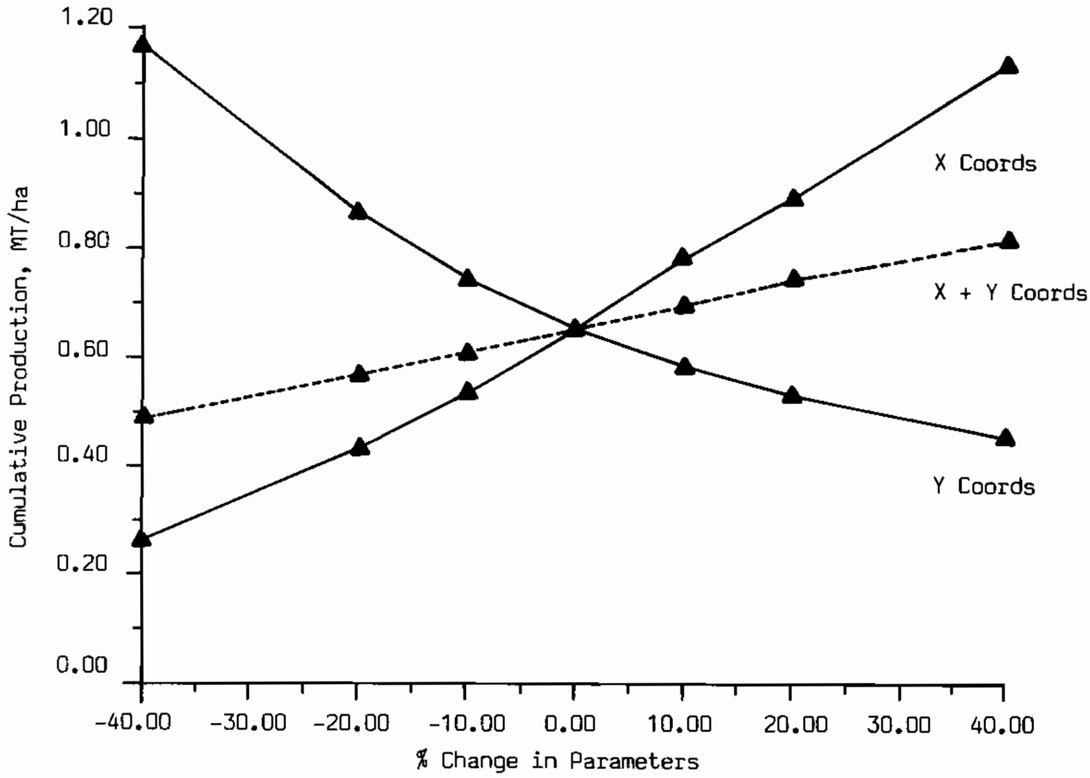


Figure 17. Sensitivity analysis - series 4 - the effect of perturbations on the parameters of the legume senescence function in various directions on the cumulative production to day 210 of a pure legume pasture.

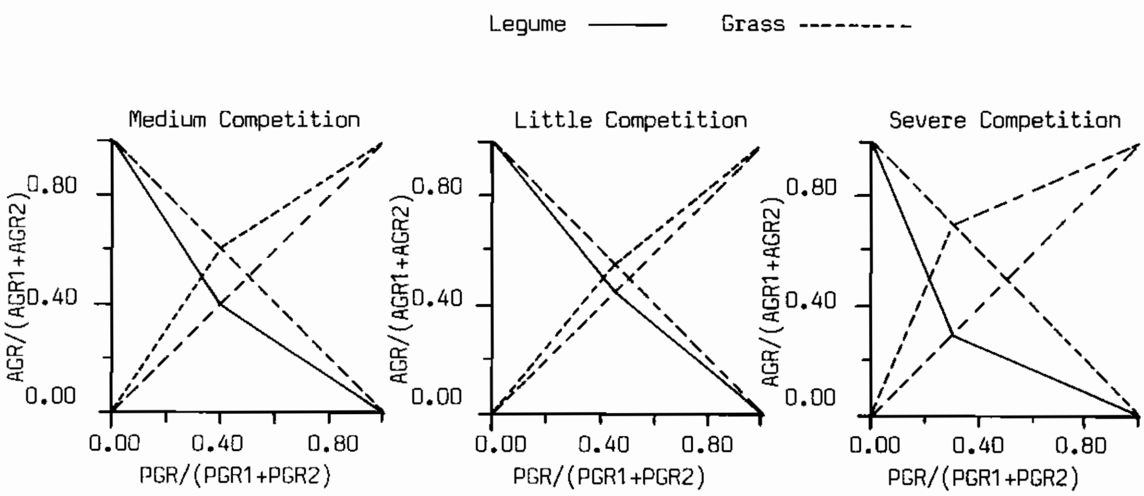


Figure 18. Sensitivity analysis - series 4 - three competition functions of varying severity relating actual growth rate of legume or grass (AGR1 and AGR2) to potential growth rate (PGR1 and PGR2).

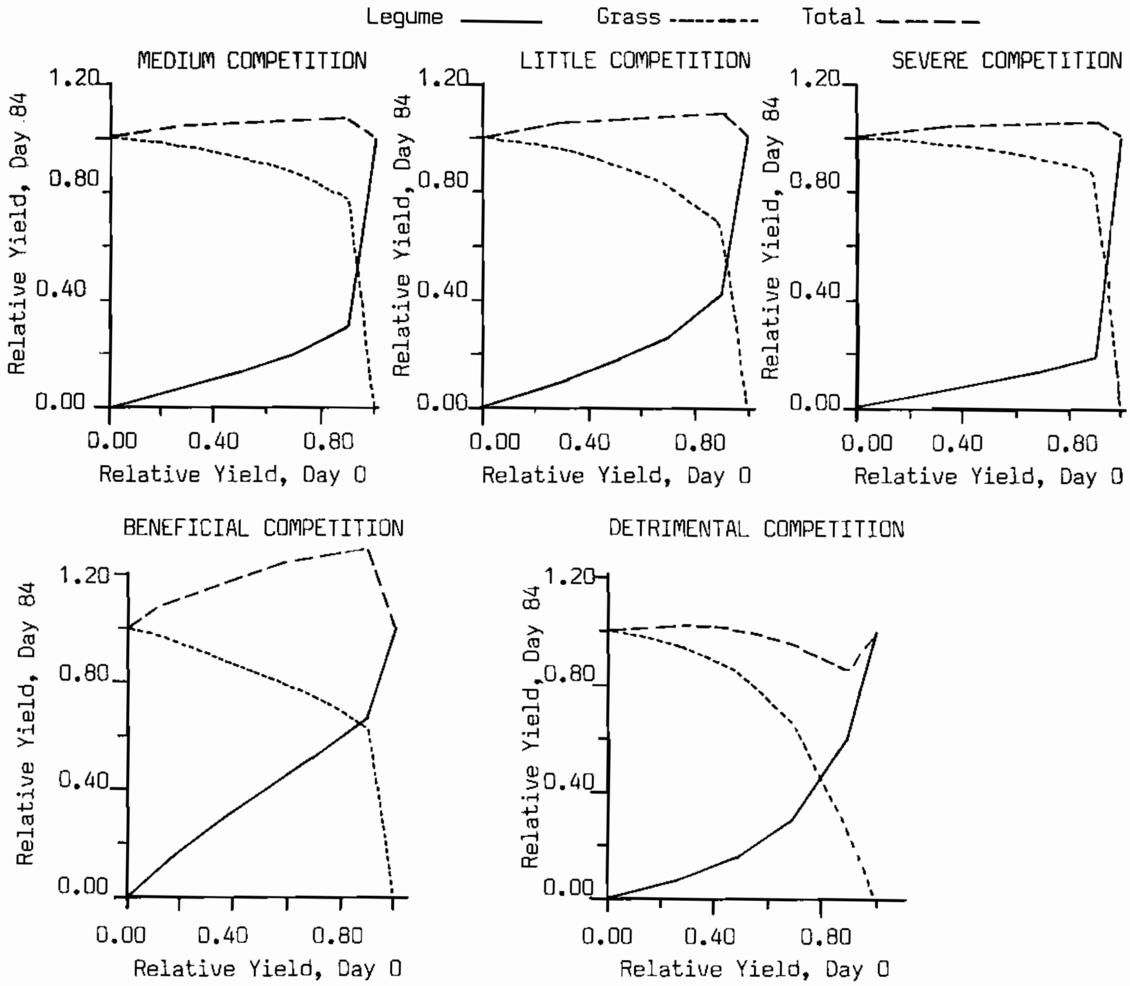


Figure 19. Sensitivity analysis - series 4 - De Wit replacement diagrams for five types of competition function: (l) Medium severe, (ii) Slight, (iii) Severe, (IV) Mutually beneficial, (V) Mutually detrimental.

legume act more like the grass tends to stabilize the system, in terms of the speed of decline of legume persistence, while increasing the discrepancy works in the opposite direction;

- where one species both competes successfully and has higher growth rates, the actual form of the competition function has little effect on yield. By making the successfully competing component the competed-against, the effect of higher growth rates can easily be offset by a sufficiently severe competition function;

- the form of competition function used has results which are reflected in a sensible way in replacement diagrams, i.e., most of the classic responses can be obtained by changing this function alone.

FUTURE WORK

Experimental Program Stages I and II

Experimentation with the model is a two-part process. The first is concerned with initial runs of a large set of management strategies with the aim of identifying a much smaller subset of feasible possibilities. These management strategies include such things as early weaning, different grazing systems, concentrating the breeding season, using different proportions of improved pasture, assigning the improved pasture in different ways, and the selling of animals at different ages or weights or at a different time of the year. For any which look promising, cashflow analysis will be carried out to compare the new production possibility with a base-line all-savanna system. It may also be worthwhile to optimize certain continuous variables; a hill-climbing technique could be used to identify the (model) optimum of weaning age, for instance.

For stage II, the most promising subset of feasible alternatives will be taken and output parameter probability distribution functions (P^{dfs}) will be generated, to allow some sort of risk analysis, such as Mean-Variance or Stochastic Dominance analysis. Ultimately, it would be desirable for the pasture models to be driven by a weather parameter simulation model; such a model could be constructed easily - the hard part is relating weather parameters to the growth functions. A quicker way of deriving output pdfs might be to define year types (such as good, medium, and bad), and impute forage quantity and quality values corresponding to each year type. Then, by imputing probabilities as to the likelihood of the occurrence of each year type on the basis of weather records, pdfs could be derived. This would allow the stability of new production systems to be examined, even if only in a fairly subjective way. As the results from some of the Ecophysiology section's experiments are collected, there is obvious scope for incorporating these directly into the model and thus rendering some of the previously conceptual relationships empirical. At a later date, a weather simulator should be built to drive the modules concerned with primary production, in a effort to derive more objective output pdfs.

Documentation

Version 1 of a document detailing the workings of the model and containing user notes has been written. Another document, dealing with a description and the results of all experimentation, is in the process of being compiled.

Economics

Consistent with the recommendations of the January 1986 in-depth review of the Tropical Pastures Program activities, and the degree of advancement of several legume materials in the program's germplasm selection strategy, the Economics Section as well as the whole Pastures-in-farming-systems unit directed their attention to increased on-farm testing and seed multiplication in order to accelerate the final stages of technology development and exposure of technology to farmers, seed industry and the rural sector in general.

This was undertaken from the perspective of CIAT being a development-oriented research organisation, thus requiring effective interaction with other partners involved in the continuum from basic research to development activities.

This sharpened focus on interacting with national research programs and other development agencies implied that substantial effort was to be made in scouting for opportunities for collaborative work, involving travel to countries of the region, participation at several conferences and meetings, preparation of project proposals, definition of priorities, training of counterparts, and in a few cases initiation of activities. These activities, where CIAT's role is understood as a catalytic one, contributing methodologies, training and germplasm, were undertaken in addition to the research interests of the program.

Adoption and Impact of Andropogon gayanus in the Geoeconomic Region of Brasilia

This collaborative project with EMBRAPA-CPAC[1] was initiated in late 1985 and is now in its final stage. This report includes only some of the highlights. The survey methodology and sampling frame were presented in the 1985 report. Data are preliminary and thus subject to revision.

Adopters and non-adopters of *A. gayanus* in the Geoeconomic Region of Brasilia differed in terms of land resource endowment (Table 1). Adopters owned larger farms with soils of lower fertility. Cerrados farmers clasify land in to three categories:

- "Cerrados": acid infertile savannas with sparse tree vegetation.
- "Cultura": more fertile areas with heavier tree vegetation requiring clearing for agricultural utilization.
- "Varzeas": lowlands with seasonal drainage problems.

1/ EMBRAPA-CPAC-CIAT: Avaliacao do proceso de difusao e do impacto do capim Andropogon (*Andropogon gayanus* var. *bisquamulatus*) cv. Planaltina nos Cerrados do Brasil.

Table 1. Land resources and land use of adopters and non-adopters of *A. gayanus*, Geoeconomic Region of Brasilia, 1985.

		Adopters (ha)	Non-adopters (ha)
A.	Land resources		
	Farm size	690	407
	Area in:		
	. "Cerrados" soils	498	171
	. "Cultura" soils	164	225
	. "Varzea" soils	28	11
B.	Land use		
	Area in:		
	. Sown pasture	263	204
	. *A. gayanus*	31	0
	. *B. decumbens*	67	50
	. *B. ruziziensis*	38	8
	. *B. brizantha*	4	3
	. *P. maximum*	16	20
	. *H. rufa*	90	113
	. *M. minutiflora*	3	6
	. Other pastures[1]	14	4
	Native pastures	308	143
	Crops	106	49
	. Rice	36	9
	. Beans	5	4
	. Corn	25	30
	. Soybeans	38	0
	. Perennial crops[2]	6	2
	Other areas	9	11

1/ Mainly *B. humidicola*
2/ Mainly coffee

Source: Survey, preliminary.

Adopter farms have 72% of their land in "Cerrados" type soils while non-adopters have only 42% of their land in this type of soil.

Average area of *A. gayanus* is 31 ha per farm, which correspond to 12% of the area of sown pastures. Naturalized *Hyparrhenia rufa*, *Brachiaria decumbens* and *Panicum maximum* are the most important introduced pastures on non-adopting farms while the Brachiarias (*decumbens*, *ruziziensis*, *brizantha*, *humidicola*) are the predominant materials on adopter farms. This pinpoints the fact that Andropogon is preferentially being used by farms with less fertile soils.

This point is further supported by the different cropping patterns of both types of farms. While adopters grow approximately similar areas of rice, soybeans and corn, non-adopters concentrate on corn, a crop which can only be grown on the more fertile "cultura" soils.

Andropogon adopters tended to be more inclined to milk cows with varying degrees of intensity than non-adopters (80% of adopters versus 60% of non-adopters). Adopters milked twice as many cows both in the dry and in the wet season than non-adopters. A higher proportion of adopters tended to milk twice daily.

In spite of the fact that cow-calf production was the predominant livestock enterprise on both types of farms, a clear tendency could be observed for non-adopters to be more involved in steer fattening. These farms had more fattening steers, both in absolute numbers (53 v. 39) and particularly as a percentage of cattle inventory (23% v. 11%), a fact consistent with the more fertile soils on these farms and the corresponding higher quality pastures, particularly P. maximum.

Soil samples were taken from the A. gayanus plots on adopter farms and from the less fertile plots of non-adopters, assuming that these would be theoretical candidates for establishing A. gayanus. No differences in soil texture were encountered and only very minor differences in soil chemistry were fund. pH was slightly lower on adopter farms (5.46 v. 5.73), Al saturation higher (29.7% v 18.2%), and phosphorus levels of 2.42 ppm against 4.85 ppm. Larger differences were to be expected in line with variations in land use patterns. This may have been caused by the soil sampling technique, particularly for non-adopting farms, where plots sampled do not necessarily represent the areas the farmers plan to put to pastures in the short term. The other possible explanation is that the interaction with crops and the more common use made of fertilizers turn soil chemical characteristics into a less important criterion for adopting A. gayanus than has been observed for the case of Colombia.

Knowledge about A. gayanus was spread mainly through informal contacts with neighbors, who also were the most important source of the initial seed obtained. Later plantings were to a large extent established with A. gayanus seed harvested on-farm. Andropogon was usually established after one or more years of crops (69% of cases); one third of all farms established it directly after land clearing and only 8% planted it to replace another pasture. This clearly supports the need for more in-depth studies of the interactions of pastures and crops under Cerrados conditions, and particularly, of the strategies needed to reduce establishment costs by linking pasture plantings to crop production.

Most pastures were sown broadcast by hand, immediately after land preparation without covering the seed. Eighty percent of all A. gayanus pastures were sown on soils defined by farmers as "Cerrado".

No significant differences were observed in terms of establishment and maintenance practices between A. gayanus and the other pastures, mainly B. decumbens. Problems at establishment were slightly more frequent in A. gayanus than in other grasses. Once Andropogon was established, very few problems were reported; they were mainly due to ant attack while other grasses presented more problems, particularly spittlebug. A. gayanus was generally grazed by the whole herd; the individual group of animals most frequently grazing it was milking cows. This pattern was similar to that of the other grasses.

In terms of impact on production, increases in carrying capacity, particularly during the rainy season, were most frequently reported. The major positive attribute of the material is seen to be its high wet season production; the major disadvantage is its bunchy architecture. This contrasts somewhat with the views of researchers emphasizing its dry season performance and its compatibility with legumes, an attribute of limited value to farmers due to the lack of adapted and productive forage legumes on the market.

CPAC and CIAT plan to initiate on-farm testing of promising grass and legume materials in the Cerrados in 1987. It is expected that this activity will substantially improve our understanding of existing farming systems and thus improve our efficiency in designing appropriate forage alternatives for this ecosystem.

Characterization of smallholder farming systems in the humid tropics: The case of Napo, Ecuador

This year the program initiated major germplasm screening activities for the humid tropics in cooperation with IVITA and INIPA at Pucallpa, Peru. The pastures network, RIEPT, has already been working in the field of forage germplasm evaluation at several locations in the humid tropics for several years. Among these locations, one of the sites with the most advanced germplasm evaluation program (grazing trials) is the INIAP Experimental Station of Payamino at Napo, Ecuador.

At the request of the staff in charge of the forage evaluation program and IDRC, who is funding part of this research program, staff ot the Systems and Economics Section undertook a brief reconnaissance trip, to identify steps to be taken to move existing technology to farmers and to define research priorities for the forage evaluation team. This activity led to the identification of a need for a diagnostic survey to characterize existing farming systems and their bottlenecks as a prerequisite for the design of further research activities both on-farm and on station.

Given the existence of an AID funded agroforestry project working on transfer of technology, for whom a diagnostic study of existing production systems would be of value, all institutions pooled resources in an informal cooperation agreement. This resulted in an activity involving MAG, INIAP, AID, IDRC, IICA and CIAT. Beyond the specific interest of the program in contributing to the definition of research priorities for INIAP's pasture research at the Payamino Station, the program is interested in acquiring expertise in the diagnosis of constraints of humid tropics farming systems. These systems differ substantially from savanna systems in terms of their complexity by involving pastures, annual and perennial crops as well as trees, their dynamics due to the rapid changes in soil fertility status over time, and their social aspects (migrant settlers of different origin, existence of off-farm employment in some cases, etc.). Given the activities started in Peru in a humid tropics ecosystem with a marked dry season, involvement in Napo (without a dry season, better soils, less regional population) will enrich the humid tropics stock of knowledge of the program and allow more precise generalizations.

The fieldwork of the survey was undertaken in March 1986. The survey is presently in the final stages of analysis and should be published in early 1987. The survey region comprises areas of less than 450 m above sea level with approximately 3000 mm of annual rainfall without a marked dry season. Lowest monthly rainfall is 180 mm. Geographically the region comprises the Cantõn

Francisco de Orellana, which is part of the Napo Province. Of the total area of 845,000 ha, 145,500 have been allocated to settlers (approximately 3300 families). The study area comprises an effectively occupied area of 57,800 ha with 1.100 farms located on three different types of soils: alluvial, volcanic and red hill soils (mainly Ultisols). A 10% sample of the farms was drawn at random, thus maintaining the same relative frequency by soil type in the sample as in the region under study.

Of a total of 107 farmers surveyed, 47 were operating on red soils, 33 on volcanic soils and 27 on alluvial soils. There was a slight tendency of red soils settlers to have arrived later and to have come with less resources (cash and cattle). Properties were very similar in total size (mean 46 ha) but land use did present important differences by soil type (Table 2). Red hill farms present the smallest area cleared and the highest proportion of it in crops, namely coffee, a crop particularly adapted to acid soils and hilly topography. Due to their limited capital or cattle these farmers have established very few pastures.

Mean land use of the area under crops (6.5 ha) is a follows: coffee 5.2 ha, corn 0.5 ha, cocoa 0.2 ha, the rest being in subsistence crops (0.6 ha, mainly bananas, plantains, cassava, and rice). Compared with older surveys, the region has clearly shifted in its farming system away from subsistence crops to market-oriented commodities, particularly coffee, cocoa, some corn and cattle. This is consistent with the limited potential for traditional food crops due to the low population in the region and the high transport costs to larger markets, e.g. Quito.

Among the pastures, elephant grass predominates on alluvial and red soils. On volcanic soils Brachiaria decumbens is the leading grass. It is in second place on the two other soil types. B. humidicola was recently introduced by INIAP. It is present on 17% of the red hill farms; for the whole region its coverage amounts to 13% of the farms. All farms had trees of commercial value, the main tree being "Laurel" (Cordia alliodora) followed by "Jacaranda" (Jacaranda copaea) and "Cedro" (Cedrela fiseles). Existing tree densities are below those considered optimal for

Table 2. Mean land use by predominant soil type. Napo, Ecuador, 1986.

	Soil type			
	Alluvial	Volcanic	Red Hills	Weighted mean
Number of farms	27	33	47	107
Area (ha):				
.Farm	45.6	48.1	44.7	46.0
.Cleared	17.4	23.3	9.6	15.8
.Crop	6.0	8.5	5.1	6.5
.Pastures	7.0	10.0	4.1	6.6
.Fallow	4.0	4.0	0.9	2.6

Source: Survey (preliminary).

agroforestry systems.

Only 9 of the 107 settlers came with cattle to the region. Presently 63 of them own cattle (7.25 head each on average). Chicken are widespread and an important source of cash to provide for short term needs (on 83% of farms, with mean of 23.7 chicks per farm).

Labour availability seems to play a critical role in shaping the production system. This is due to the labour intensive nature of coffee production which is the major crop. Coffee accounts for 56% of all man-days employed on alluvial soil farms, 64% on volcanic soil farms and 68% on red hill farms. This explains the facts that 45% of all labour employed is hired labour, that farmers are interested in expanding pastures and less labour-intensive livestock production systems, that 41% of the farms use herbicides, and that farmers are attracted by Brachiaria pastures which require less labour for maintainance than elephant grass.

Regional average stocking rate of 0.93 animals per hectare of pastures is well below experimental results. Whether this is due to lack of access to capital or cattle or to other agronomic restrictions on pasture productivity (e.g. soil compaction) is an on-going research issue.

The survey does not supply conclusive evidence of pasture degradation in the Napo region. Elephant grass plots of up to 14 years of age were found and only seven cases of planting pastures after pastures were reported. This may be due to the fact that most settlement occurred only a few years ago, that many pastures were established on fertile soils, or it may be due to the limited use made of the pastures owing to lack of cattle. All pastures exhibit spittlebug problems; highest attack frequencies were reported for P. purpureum, P. fasciculatum and Echinochloa polystachya.

Budgeting analyses based on survey coefficients indicate that at present prices farms generate an average gross revenue of US$2.500 per annum, 84% of it due to coffee sales and 11% due to cattle. This pinpoints the dependency of the farming system on coffee prices, which were relatively high during the survey period.

Given the volatility of international coffee prices, there is a clear rationale for diversifying the production system. Cattle and trees can both be efficient enterprises in which to invest incomes of good coffee years, while requiring limited labour, but capable of generating cash flow in years of low coffee prices.

Cash costs are extremely low in these production systems, reaching levels of about 6% of gross revenue. Of these, transportation amounts to 38% of the total. The system generates cash returns of US$4 per man-day employed, a value similar to the official rural minimum wage (US$4.75). The cash returns achieved somewhat underestimate total productivity because some labour is used to expand coffee plantations and pastures, thus generating on-farm capital.

Of a total of 107 farmers surveyed, 23 declared their highest priority for expansion to be coffee while 49 stated interest in expanding pastures. The highest frequency among farmers interested in expanding pastures was recorded for B. humidicola (19 cases) followed by B. decumbens (16 cases).

Due to transportation costs, limited local food demand, and soils and labour opportunity cost, settlers have limited alternatives for diversification, a major objective given the high dependency on coffee. Coffee will continue to be the main source of income in the short and medium term. Research to improve productivity would therefore have a potential to increase incomes. Harvest and weed control are the most time-consuming operations. Improved tree management might reduce harvesting labour. Leguminous cover crops are a promising avenue to reduce weed control costs and increase production due to the nitrogen input into the system.

Inclusion of marketable trees in coffee plots and pastures seems to be an attractive proposition due to the low labour input and their potential value, assuming the same prices of today will prevail at harvest. Expansion of cattle production is attractive to settlers due to its labour productivity and its role as a cash flow buffer owing to its easy sale at any time. It is a high value product, making its sale outside the region feasible. Major concerns relate to the limited number of cattle available, the low savings capacity of settlers to invest in cattle, and the low stocking rates of pastures observed. It is proposed that research be undertaken to analyze the productivity of existing pastures on different types of soils, to test the sustainability of forage production and the economic feasibility of cattle production in agroforestry systems, particularly on the more fragile red hilly soils, and to then feed these results back to researchers and policy makers.

A joint project with local institutions is being submitted for funding by USAID to monitor the performance of existing production systems and to test improved pastures, cover crops and trees in agroforestry systems on-farm.

Pilot study of dairy product consumption, Palmira, Colombia

Milk production is very attractive in development terms due to its potential to generate rural income for small-to medium-sized producers in areas with limited crop potential. Given the elastic demand of milk and dairy products in contrast with the generally inelastic demand of most staple foods, expansion of dairy production will not reduce prices, and thus incomes of farmers, very rapidly.

This process has been observed in many areas throughout the Latin American tropics but it has generally been associated with fertile soils producing forage of a quality high enough to produce milk yields that make milking economically attractive. The improved pasture technology for acid soils being developed by the program could make dual purpose milk production a viable option for the acid soils regions, consequently increasing substantially the potential national milk output.

In order to assess the potential impact of such development, and thus to contribute to the decision making process of program research priorities, it is necessary to understand the consumption patterns of milk and dairy products. Previous studies had dealt with milk and dairy products as one aggregate commodity. This perspective nevertheless masks important differences in demand parameters for individual products and therefore does not allow more precise assessment of potential benefits of increased milk supply and their distribution among families of different income strata and among members of the family. This is related to the issue of appropriate levels of high-quality protein intake by children being clearly associated with child development as well as the income effect of a reduction in the price of milk or dairy products for different types of households.

In order to develop methodologies for this type of study a small survey was undertaken in Palmira, a medium sized city with strong linkages to the rural sector, very close to CIAT headquarters. The survey comprised a two stage random sample of 180 households stratified by socioeconomic status according to the classification of the city administration.

The general objective of the survey was to characterize consumption patterns of individual dairy products by income level and to attempt to measure intrahousehold allocation, the specific hypothesis being that low income families allocate a larger proportion of milk consumed to children considered sensitive to protein deficiencies.

Table 3 presents selected indicators of Palmira households. Incomes of the households surveyed in Palmira are above the national average. Additionally, the survey is only representative of the areas included in Palmira city maps. These do not include squatter settlements outside the official boundaries of the city. This is reflected in expenditure shares for milk and dairy products being above those reported both for Cali in 1980 (RUBINSTEIN and NORES) and the national figures (SANINT et al., 1985). The magnitude of the expenditure share even in the lowest stratum (the poorest 26% of the population) clearly makes these products candidates for increasing consumer incomes via reduced prices.

The overriding importance of fluid milk particularly in low income households (Table 4), indicates that a reduction in its price would be a good mechanism to achieve this. A surprising result of the survey was the importance of raw milk supplying 59% of all fluid milk consumed in Palmira and particularly the fact that its consumption increased with rising incomes. This is explained by the rural urban links of landowning families, the quality of milk being associated with knowing the producer, and the size of the city in relation to the surrounding supply area making direct marketing of raw milk very competive, etc. Another interesting fact is the very low consumption of dairy products in terms of equivalent fluid milk, particularly in the lower income strata.

Relative frequencies of consumption (Table 5) confirm the increasing level of raw milk consumption with income level, while pasteurized milk frequencies remain approximately constant. The use of infant formula milk presents unexpectedly high frequencies. This explains the high level of powdered milk consumption reported in Table 4 which includes infant formulas under this category. Nevertheless the relatively low number of cases implies that these results have to be interpreted with caution.

At all income levels milk consumption (milk plus dairy products) is markedly higher for children than for adults. Among low income families preferential allocation of milk to children is more clear-cut than at high levels (Table 6). Children receive more than three times the amount of milk (total including dairy products, in terms of fluid milk equivalent) consumed by adults in all but the highest income families.

These results support the hypothesis of preferential allocation of milk to children for the case of Palmira. The pattern is not very specific for low income population groups; more targeted interventions than general price reductions are thus needed if the welfare of the urban poor is to be improved efficiently via milk-related policies and programs.

<u>Evolution of N:P fertilizer price ratios</u>

The relative price of nitrogen to phosphorus is considered a key variable in explaining the attractiveness of legume-grass associations over nitrogen-fertilized grass pastures.

A recent study (HARRISON, 1986)

Table 3. Demand parameters of Palmira households by income level, 1986

	Income Level				
	1 (lowest)	2	3	4 (highest)	Average[1]
Number of households sampled	39	66	40	35	180
Expansion factor	0.263	0.662	0.069	0.006	1.00
Household income index[2]	100.0	226.5	391.8	556.5	206.6
Expenditure share for milk and dairy products of total food expenditure	9.1	12.9	15.7	16.9	12.5
Fluid milk[3] expenditure as percentage of total dairy expenditure	81.4	66.1	69.2	57.2	68.3

1/ Average weighted by expansion factors for total population.
2/ Income of level 1 equals 100.
3/ Includes raw and pasteurized milk.

Source: Survey

Table 4. Structure of milk and dairy products[1] consumption by income level. Palmira, Colombia, 1986 (kg/person/year).

	Income Strata[2]				
Product	1 (lowest)	2	3 (highest)	4	Average[3]
Raw milk	25.7	52.9	128.2	102.1	51.3
Pasteurized milk	34.4	35.3	43.1	65.3	35.8
Dry milk	28.9	23.9	7.3	3.7	23.9
Subtotal	89.0	112.1	178.6	171.1	111.0
Cheese	6.0	20.6	30.0	49.0	17.0
Total	95.0	132.7	208.6	220.1	128.0

1/ In terms of fluid milk equivalent
2/ Income level of household block as defined by city administration
3/ Average weighted by expansion factor
Source: Survey

Table 5. Relative frequency[1] of consumption of individual dairy products by age group and income stratum. Palmira, 1986.

Product	Adults >18				Children =<3			
	1	2	3	4	1	2	3	4
Number of households with persons of the age category j	39	66	40	35	16	14	4	2
Percentage of:								
. Raw milk	17.9	42.4	62.5	62.9	12.5	21.4	75.0	100.0
. Pasteurized milk	43.6	46.9	30.0	42.9	6.2	7.1	25.0	50.0
. Powdered milk	5.1	9.1	7.5	2.9	18.8	50.0	25.0	0
. Infant formula milk	-	-	-	-	62.5	78.5	50.0	50.0
. Cottage cheese	5.1	31.8	40.0	57.1	0	7.1	50.0	100.0
. Fresh cheese	12.8	33.3	25.0	31.4	6.2	7.1	25.0	0
. Yogurt	0	4.5	10.0	14.2	0	0	0	0

1/ Frequency = n_{ij}/N_j
where:
n = number of households with persons of the age category j which consume the product i
N = number of households with persons of the age category j.

Source: Survey.

Table 6. Per capita consumption of milk[1] by age group and income level. Palmira, Colombia, 1986 (kg/year)

Income level	Age group (years) >18	>7 and =<18	>3 and =<7	<=3	Index (5)/(2)
(1)	(2)	(3)	(4)	(5)	(6)
1 (low)	55.64	54.60	132.60	182.00	3.27[2]
2	94.12	77.48	146.64	301.60	3.20[2]
3	169.00	141.96	238.68	312.00	1.85[2]
4 (high)	175.76	164.84	185.64	306.80	1.75

1/ Includes raw, pasteurized, dry and baby formula milk in terms of equivalent fluid milk.
2/ Means of consumption of adults and children =<3 differ significantly at $\alpha = 0.01$

Source: Survey

Table 7. Evolution of real nitrogen and phosphorus prices and N:P price ratio on international markets.

	Growth rate[1] (%)		Coefficient of variation (%)	Range
Urea (1963/1986)	-2.1	(-2.4)	43.3	101 - 564[2]
Triple superphosphate (1967/1986)	-0.35	(-2.8)	61.8	98 - 542[2]
Rock phosphate (1969/1986)	0.49	(-1.0)	46.7	30 - 107[2]
N:P price ratio (urea/TSP) (1967/1986)	-1.2	(0.4)	19.2	0.35 - 0.75
N:P ratio (urea/rock phosphate) (1963/1986)	-2.6	(-1.4)	25.2	0.51 - 1.26

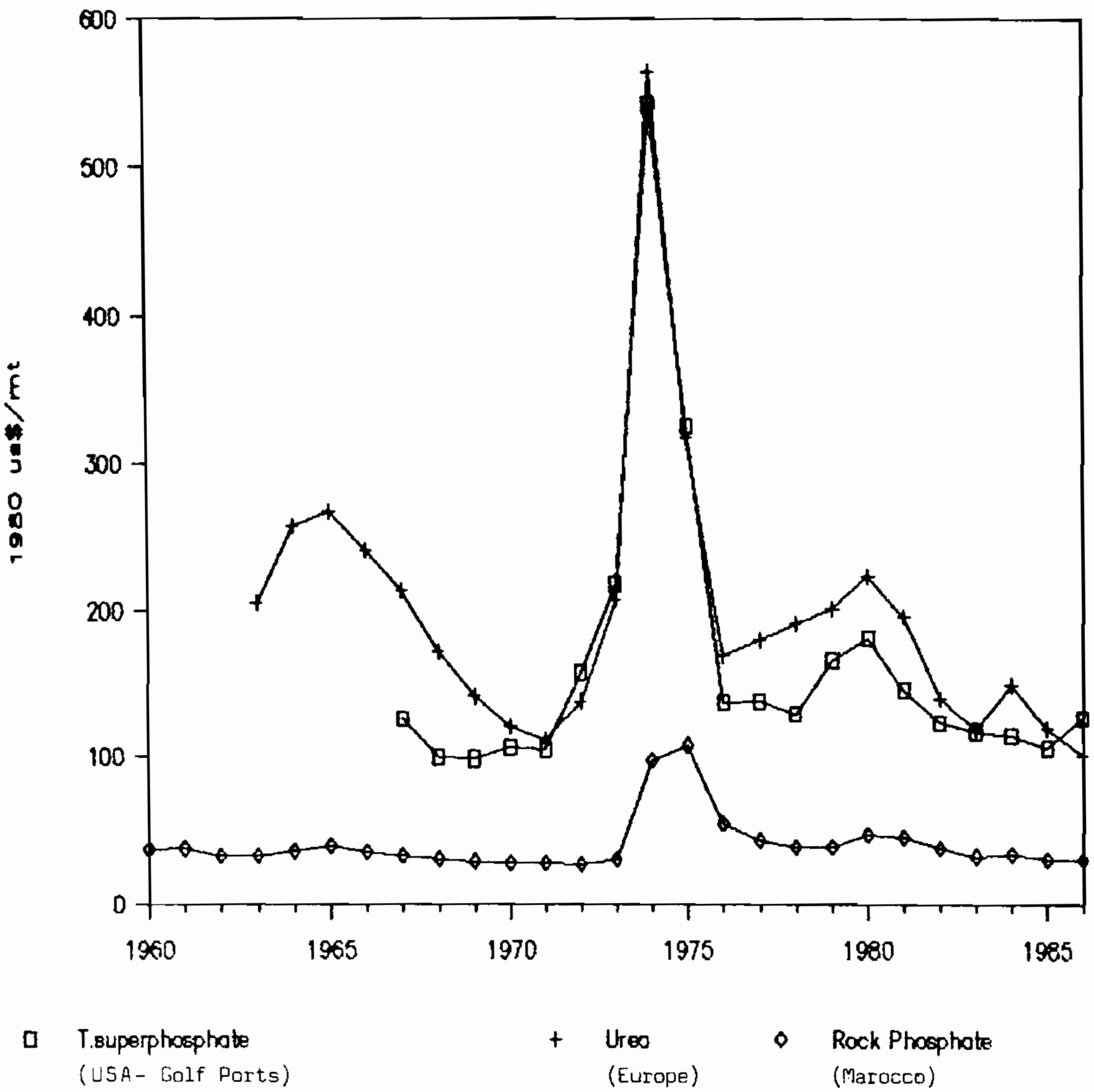
1/ Figures in brackets refer to the period 1970/1986
2/ In 1980 US$/MT

Source: Own calculations based on IMF data

suggests that in Australia the N:P price ratio dropped from 1.5 in 1957 to 0.5 in 1985. This drastic change in relative price is hypothesized to have influenced the reduction of research resources allocated to legume grass associations. In order to test whether this pattern of changing N:P price ratios is a specifically Australian phenomenon or is of a more general nature, the evolution of N:P price ratios was studied at world market prices and at domestic prices of selected Latin American countries.

Real US$ prices of urea, the most important nitrogen source, and triple superphosphate (TSP) have declined since the sixties. This decline has been more marked for urea (Table 7). The large coefficients of variation and ample ranges are mainly due to the price peak of the early seventies associated with the oil crisis (Figure 1), clearly indicating the importance of energy in the production costs of urea and triple superphosphate.

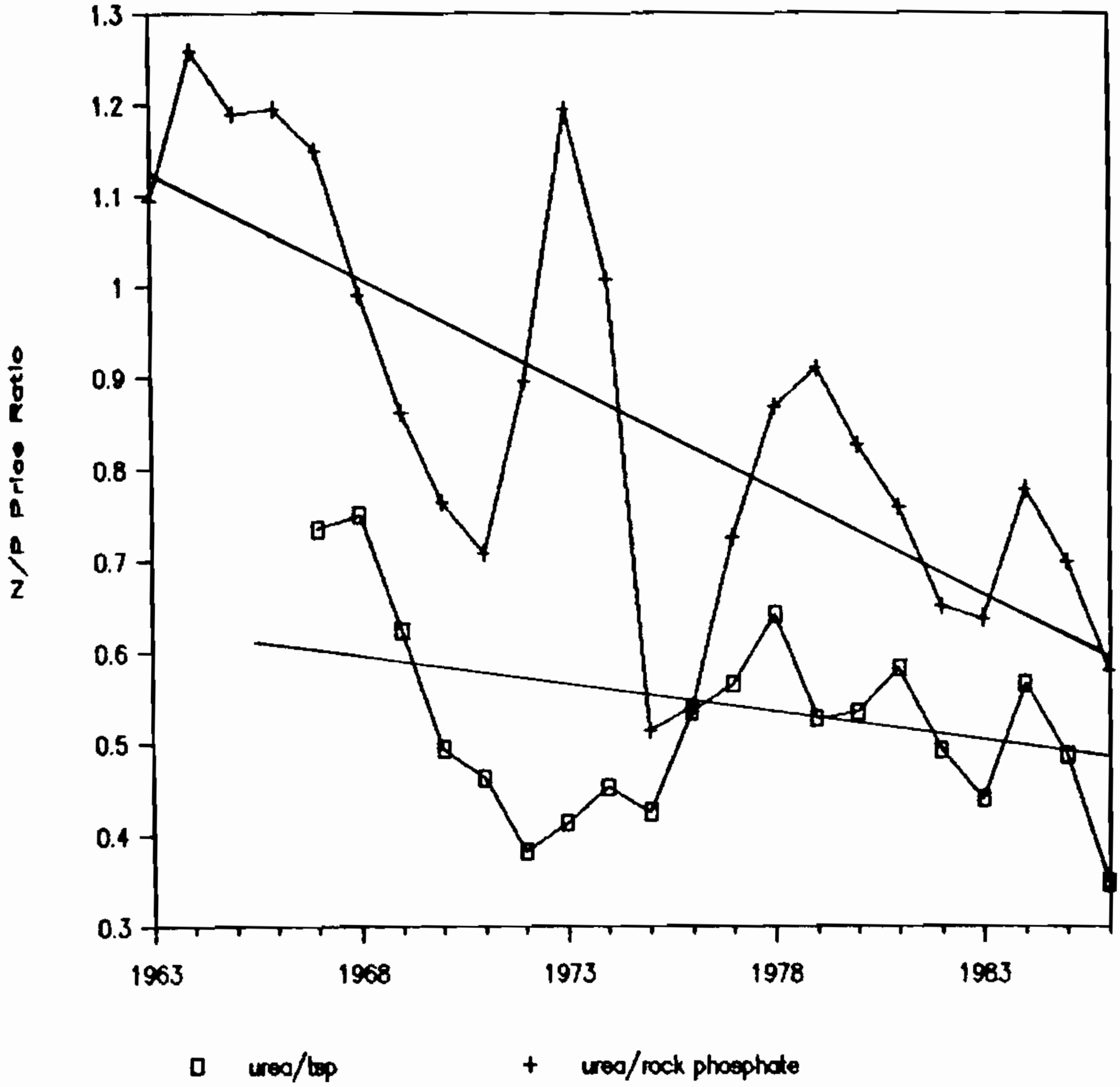
Rock phosphates follow essentially the same trend but the impact of the oil crisis in the early seventies is of less importance, consistent with the fact that less energy is required in their processing. Nevertheless rock phosphates are to some extent a substitute for TSP and are an input to TSP production, so the same pattern of price movements is observed. The net effect of these tendencies in terms of price ratios is shown in Figure 2 and Table 7. On the international market nitrogen has become cheaper in relation to phosphorus, particularly from rock phosphate. This is of particular relevance to the pasture technology being developed for acid soils, because rock phosphates are particularly suited as a phosphorus source under such conditions. But these price ratios have fluctuated widely. In 1964 the price of 1 kg of N was 1.26 times the price of one kg of P_2O_5 from rock phosphate. In 1975 the same kg of N costed only 0.51 times the cost of 1 kg of P_2O_5. This



* Deflacted by wholesale price index of the USA, 1980=100.

Source: IMF (1986)

Figure 1. Real fertilizers prices (FOB)*. International market: 1960/86.



$Y_1 = 45.948 - 0.02283^{**}\ T, \quad R^2 = 0.52$

$Y_2 = 14.297 - 0.0069^{***}\ T, \quad R^2 = 0.15$

* Price ratio expressed in terms of prices of one unit of N_2 or P_2O_5 from different sources (urea, triple superphosphate and rock phosphate)

** $\alpha = 0.01$

*** $\alpha = 0.05$

Figure 2. Nitrogen - Phosphorus price ratio.* International market: 1963/86.

variability makes it difficult for research organisations to use these movements in defining long term research priorities.

At the individual country level an even more heterogeneous situation is encountered in domestic price terms (Table 8). The relative cost of nitrogen has dropped in Brazil and Uruguay, while it has increased moderately in Colombia, Chile, Peru and Venezuela. This is related to notable differences in fertilizer supply situation and fertilizer policies as well as to general macroeconomic policies. This is documented by the level and variability of the ratio of farm-gate to international price of nitrogen and phosphorus fertilizers at market exchange rates (Table 9). Extreme cases are Venezuela, with price ratios below parity and the lowest correlation coefficients, and Brazil with correlation coefficients above 0.90, indicating that price movements on the international market are readily transmitted to Brazilian farmers. Correlation coefficients tend to be lower for phosphorus than for nitrogen, due probably to more domestic production of the former, making it easier for governments to pursue policies independent of world market trends.

It can be concluded that the trend of declining N:P price ratios is not as strong on international markets as it is in Australia, and is by no means a strong, general trend in Latin American countries.

Table 8. Annual growth rate of relative price of nitrogen-phosphorus in selected Latin American countries and Australia.

Country	Period	Annual growth rate of N:P price ratio (%)
Colombia	1970/85	0.29[a]
Chile	1974/85	1.2 [b]
Brazil	1970/85	
Sao Paulo		-2.1 [b]
Minas Gerais		-1.5 [b]
Goias		-4.8 [b]
Peru	1970/82	1.4 [b]
		-2.1 [c]
Uruguay	1974/86	-3.0 [d]
Venezuela	1970/86	0.24[a]
Australia	1957/85	-4.3 [d]

a/ Unspecified nutrient source
b/ Urea/triple superphosphate
c/ Ammonium sulphate/triple superphosphate
d/ Urea/single superphosphate
e/ Urea/rock phosphate

Sources: Own calculations

Table 9. Ratio of domestic to international price of nitrogen and phosphorus fertilizers at market exchange rates in selected countries of Latin America, 1970/1985.

Year	Colombia		Venezuela		Brazil		Perú		Chile	
	N	P	N	P	N	P	N	P	N	P
1970	1.92	1.80	0.96	0.97	nd	nd	1.28	1.72	nd	nd
1974	0.62	0.70	0.18	0.19	1.28	1.22	0.65	0.38	0.66	0.60
1980	1.47	1.79	0.46	0.46	1.57	2.05	1.03	1.28	1.05	1.28
1985	2.32	2.77	0.41	0.39	2.02	2.95	nd	nd	2.77	2.46
(R)[1]	0.54	0.47	0.24	0.16	0.96	0.95	0.89	0.36	0.60	0.59

1/ Correlation coefficient between international and domestic price in US$ at market exchange rate.

Source: Own calculations.

Training

During 1986 the Tropical Pastures Program (TPP) in collaboration with the Training and Conferences Program, offered training in research to 73 professionals in 15 different disciplines thus, fullfilling one of its principle objectives. As shown in Table 1, this was carried out in various categories or training modalities. The sections which contributed the greatest time to training this year were: Seed Production with 50.8 man-months, Pasture Quality and Productivity with 36.9 man-months, and Agronomy (Carimagua) with 33.0 man-months

The Intensive Multidisciplinary Phase of the IX Program on Scientific Training in Research for the Production of Tropical Pastures was carried out between February 3 and March 26, with the participation of 20 professionals from eight countries of Tropical America (Table 2). Eighteen of these professionals remained at CIAT to continue with the Specialization Phase in different disciplines depending on the participant's interest and the speciality requested. Each course lasted 2 to 8 months, depending on the section of the TPP where it was conducted.

Between October 6 and November 7 the II Intensive Course on Pasture Seed Production was carried out with the participation of 28 researchers from 11 Latin American countries. The Scientific Training Program, the Tropical Pastures Program, and the Seed Unit participated in the organization of this course.

Initiating another training modality within the TPP, the first in-country course was conducted this year in Gualaca (Panama) under the name of Workshop-Seminar on Acid Soils and Pasture Establishment. The course was attended by 17 professionals from different official organizations in Panama. The IDIAP, the University of Rutgers, and CIAT participated in the organization of this event.

EXTENT OF TRAINING IN TROPICAL PASTURES

A total of 381 professionals have received training in research with the Tropical Pastures Program in the period 1978-1986 (Table 3).

Training offered included different categories or training modalities: M.S. or Ph.D. thesis, Specialization in Research, Specialization plus an Intensive Multidisciplinary Course, Fellowship, Intensive Multidisciplinary Course, or Short Course and an Intensive Course on Pasture Seed Production.

Table 4 shows the information on the number of professionals trained by country in the IX Training Programs in Tropical Pastures. The majority of participants came from Brazil, Colombia, Peru, Panama, and Bolivia. This proportion meets established priorities in relation to the areas with low-fertility acid soils in these countries, as illustrated in Figure 1.

Table 1. Researchers trained in the Tropical Pastures Program during 1986 by categories and man/months in each section.

Section	Training Categories													
	Visiting Research Associates													
	Ph.D Tesis		No.Thesis		MS Thesis		Specia-lization		Specializ. plus Intensive Multidisc. Course		Trainee		Intensive Multidis. Course		Subtotals	
	No.	M/M[1]	No.	M/M	No.	M/M	No.	M/M	No.	M/M	No.	M/M	No.	M/M	No.	M/M
Germplasm	1	6.9							2	8.1					3	15.0
Agronomy (Carimagua)							1	5.4	2	15.6	1	12.0			4	33.0
Regional Trials							1	2.1	3	12.6					4	15.5
Entomology					1	4.9									1	4.9
Plant Pathology	1	5.1					1	5.1								
Soil/Plant Nutrition									3	19.5					3	19.5
Soil Microbiology	1	3.3					5	2.7							6	6.0
Pasture Quality and Productivity					1	4.0	3	10.2	3	22.7					7	36.9
Ecophysiology			1	2.4			1	0.6	1	8.0					3	11.0
Pasture Development					1	2.0	1	2.9	1	3.5					3	8.4
Seed Production					1	9.8	1	5.1	1	6.9					3	21.8
Livestock Systems	1	12.0							1	4.8					2	16.8
Economics							3	7.2							3	7.2
Intensive Phase (Short Course)													2	3.6	2	3.6
Course on Seed Production													28	29.0	28	29.0
Total	3	22.2	1	2.4	4	20.7	16	37.0	18	106.8	1	12.0	30	32.6	73	233.7

1/ Equivalent to man/months of training.

Table 2. Information on researchers participating in the IX Scientific Training Program in Tropical Pastures, 1986.

Country and Name	Institution	Training	Duration (weeks) I.P.*	S.P.
Bolivia				
Daniel Claure	Univ.Técnica del Beni	ST+Soil/Plant Nutrition	8	10
Francisco Gareca	Univ.Mayor de San Simón	ST+Pastures in Livestock Systems	8	13
Brazil				
Luiz A. Borges de Alencar	EPABA	ST+Pasture Quality and Productivity	8	10
Colombia				
Lázaro Hugo Lemus	Univ.Técnica de Los Llanos	ST+Ecophysiology	8	26
Carlos Franco	CENICAFE	ST	8	
Euler F. Chuquimarca	Univ. de Nariño	ST+Soil/Plant Nutrition	8	26
Luis Eduardo Hoyos	Univ. de Córdoba	ST+Forage Agronomy	8	26
Fernando Monsalve	Univ. Nacional de Colombia	ST+Seed Production	8	10
Cuba				
Héctor Martínez	Ministerio de la Agricultura	ST+Pasture Establishment and Development	8	10
México				
Uriel Valenzuela	INIP-SARH	ST+Pasture Quality and Productivity	8	26
José Avila	INIP-SARH	ST+Pasture Quality and Productivity	8	26
Jorge A. Basulto	INIFAP	ST+Forage Agronomy	8	35
Jorge G. Moreno	INIFAP	ST+Plant Protection	8	10
José C. Maldonado	INIFAP	ST+Regional Trials	8	10
Nicaragua				
José A. Oporta	MIDINRA	ST+Pasture Establishment and Development	8	8
Perú				
Rosa D. Díaz	INIPA-CIPA XVIII	ST+Soil/Plant Nutrition	8	26
Ricardo C. Pérez	Instituto Tecnológico Nor-Oriental	ST+Pasture Quality and Productivity	8	26
Ronal Pérez	Proyecto Especial Pichis-Palcazu	ST	8	
Venezuela				
Patricia Argenti	FONAIAP	ST+Regional Trials	8	10
Aracelis Carmona	FONAIAP	ST+Forage Plants Germplasm	8	10

* IP = Intensive phase, SP = Specialization phase.

Table 3. Visiting researchers trained per year and type of research within the TPP during the period 1978-1986.

Year	Training Categories							Total/Year
	Research Associates	Visiting Researchers						
	Ph.D. Thesis	MS Thesis	Specialization in Research	SC+Specializ.	Short Course (SC)	Seed Production Course	Thesis Trainee	
1978	1	2	9	20				32
1979	3	6	12	24				45
1980	2	2	13	17	8			42
1981	3		12	12	5			32
1982		3	18	15	2			38
1983	1	4	4	19	3			31
1984	2	1	6	19	2	25		55
1985	1	2	13	13	4			33
1986	3	4	17	18	2	28	1	73
Subtotal	16	24	104	157	26	53	1	381
Total	40 (10.4%)		261 (68.5%)		26 (6.8%)	53 (13.9%)	1 (0.26%)	

Table 4. Number of participants* by country in the nine training programs on tropical pastures conducted at CIAT, 1978-86.

Country	Training Program									Total	%
	I	II	III	IV	V	VI	VII	VIII	IX		
Argentina	1									1	0.5
Bolivia	1	2	2	1		1	3	1	2	13	7.0
Brazil	7	3	5	4	5		3	1	1	29	15.7
Belize		2								2	1.1
Colombia	4	4	5	3	3	2		3	5	29	15.7
Costa Rica			1	1	1					3	1.6
Cuba	1		2				1		1	5	2.7
Ecuador		2	1			1		1		5	2.7
Guatemala								1		1	0.5
Holanda						1				1	0.5
Honduras			2	1	1	1				5	2.7
Haití				1						1	0.5
México				1			2	3	5	11	5.9
Nicaragua	2	1	2		1	3	2	1	1	13	7.0
Panamá	1		2	3		6	2	1		15	8.1
Paraguay							1	1		2	1.1
Perú	3	4	3	2	1	3	4	4	3	27	14.6
Dom.Republic	1	1		4	2	1	1		10	5.4	
Venezuela	1	5	2	1			1		2	12	6.5
										185	100.0

* Does not include professionals conducting MS or Ph.D. postgraduate training, or Special Researchers.

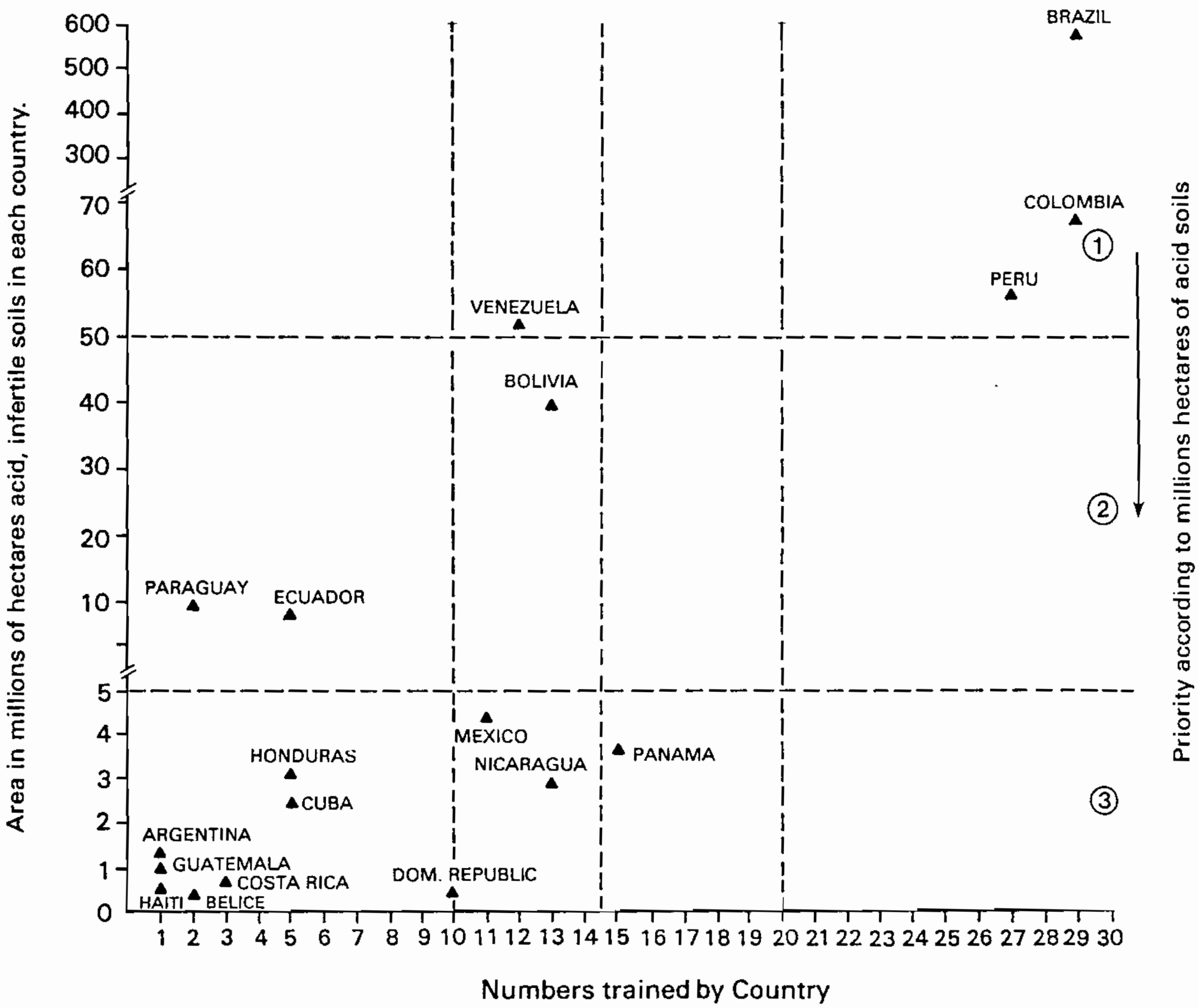


Figure 1. **Relation between number of researchers trained and area in millions of hectares of acid soils by country, in the nine programs of training in tropical pastures, 1978-1986.**

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