Annual Report 1989

Tropical Pastures

Working Document No. 70, 1990

CIAT Centro Internacional de Agricultura tropical

Index

1. Introduction

Nineteen eighty-nine was an unusual year for the Program, in some ways a turning point. After several years of virtually no staff changes, this year several members left and were replaced. Dr. Jill Lenné, the Pathologist of the program since 1978 and Dr. Rosemary Bradley, soil microbiologist for seven years, both resigned. Dr. Bert Grof retired after almost twenty years in CIAT as a forage agronomist in Palmira, the Colombian Llanos and the Cerrados of Brazil; Dr. José Salinas left the program after eight years as soil plant nutritionist at headquarters and later for two years as specialist in pastures reclamation in the humid tropics; and Dr. Derrick Thomas left to join ILCA after twelve years in the program. The valuable contribution of these scientists is well recognized in the program and by scientists in our target area (RIEPT). We might ask why they all left in the same year. I believe that it is chance; after several years in one job, they were seeking a change, and obtained suitable opportunities at the same time.

There are new faces in the program replacing those who left. Dr. Brigitte Maass is the Program's new germplasm specialist in the GRU; Dr. Peter Trutmann (ex Bean Program member) is the new pathologist in the program; Dr. Richard Thomas is the nitrogen fixation and recycling specialist; Dr. Idupulapati Rao is the soil/plant relations and nutrient cycling specialist; and Dr. Miguel Ara, has replaced Dr. Salinas at Pucallpa. In addition, we now have Dr. George Rippstein seconded to the Program from the French IEMVT/CIRAD. His role is to study changes and stability of the savannas as the pressure on these lands intensifies with the introduction of improved pasture technology.

Coming back to the idea of 1989 being a turning point in the Program, during the year a number of activities were already in process, directed towards the Program's strategies to meet the challenges of the 90's.

For this presentation, then, I will emphasize highlights of research achievements and relate them to the Program's strategies for the 90's.

Lets first review the goals of the Program.

The goal is:
"To contribute to the overall economic growth and social welfare of both rural and urban ppopulations in the tropics by increasing their access to beef and milk products through increases in the productivity of sustainable pasture-based production systems in acid soils".

The four main strategies of the program for the 90's are:

1. Document the soundness and commercial feasibility of using legume-grass pastures.

2. Develop sustainable pasture-based production systems on marginal lands.

3. Enhance the capacity of improved pastures to maintain or recover soil quality in poor acid soils.

4. Strengthen national capabilities for the development of legume based pastures based on new germplasm.

Let me talk about the first strategy-"documenting the soundness and commercial feasibility of using legume-grass pastures". The soundness of grass-legume pastures as compared both with native grasslands and grass alone pastures has been well documented experimentally in terms of live weight gains and reproductive performance. In Carimagua legume-grass pastures have more than doubled live-weight gains per animal and have increased the productivity of the land ten fold (Figure 1). Similarly, the age of cows at first calving and the calving interval are reduced when they graze on improved pastures as compared with savanna (Figure 2).

The Program is now active in the humid tropics and Central America, where small farmers predominate using farming systems that include dual-purpose cattle (beef and milk). The Program has therefore included the evaluation of improved pastures in terms of milk production. On-farm evaluation of grass alone and legume-grass pastures in terms of milk production is being carried out at Pucallpa, in Perú; in the piedmont of the Llanos; and in the Caqueta area in Colombia in cooperation with NARD's. In addition, on-station grazing experiments to measure milk production in grass and legume-grass pastures are either being established or are presently being conducted in the IVITA station at Pucallpa, in La Libertad (ICA), Villavicencio and at Quilichao.

The experiment in Quilichao involves three grasses grown either alone or in association with two Centrosema species. The first year's results for a dry and a wet season periods showed

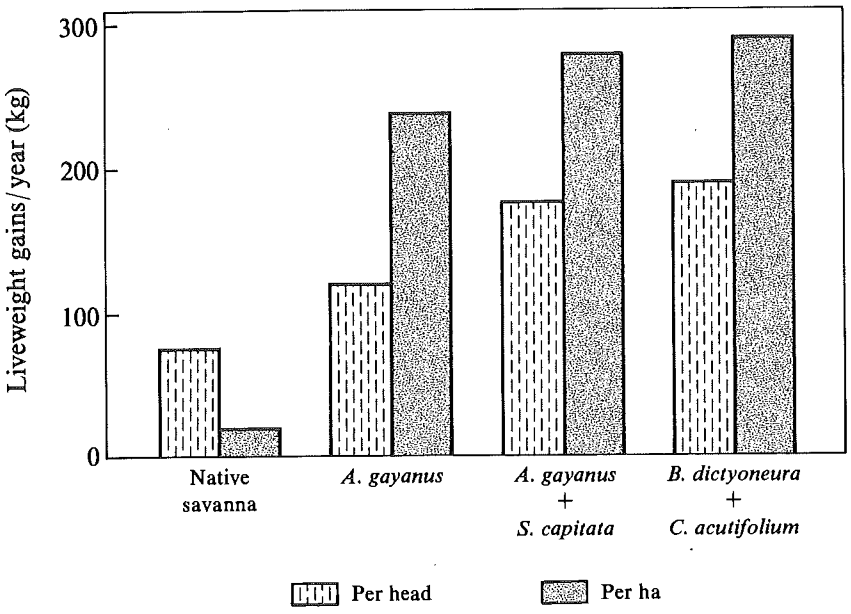


Figure 1. Potential productivity of native savanna and improved pastures in Carimagua, Colombian Llanos.

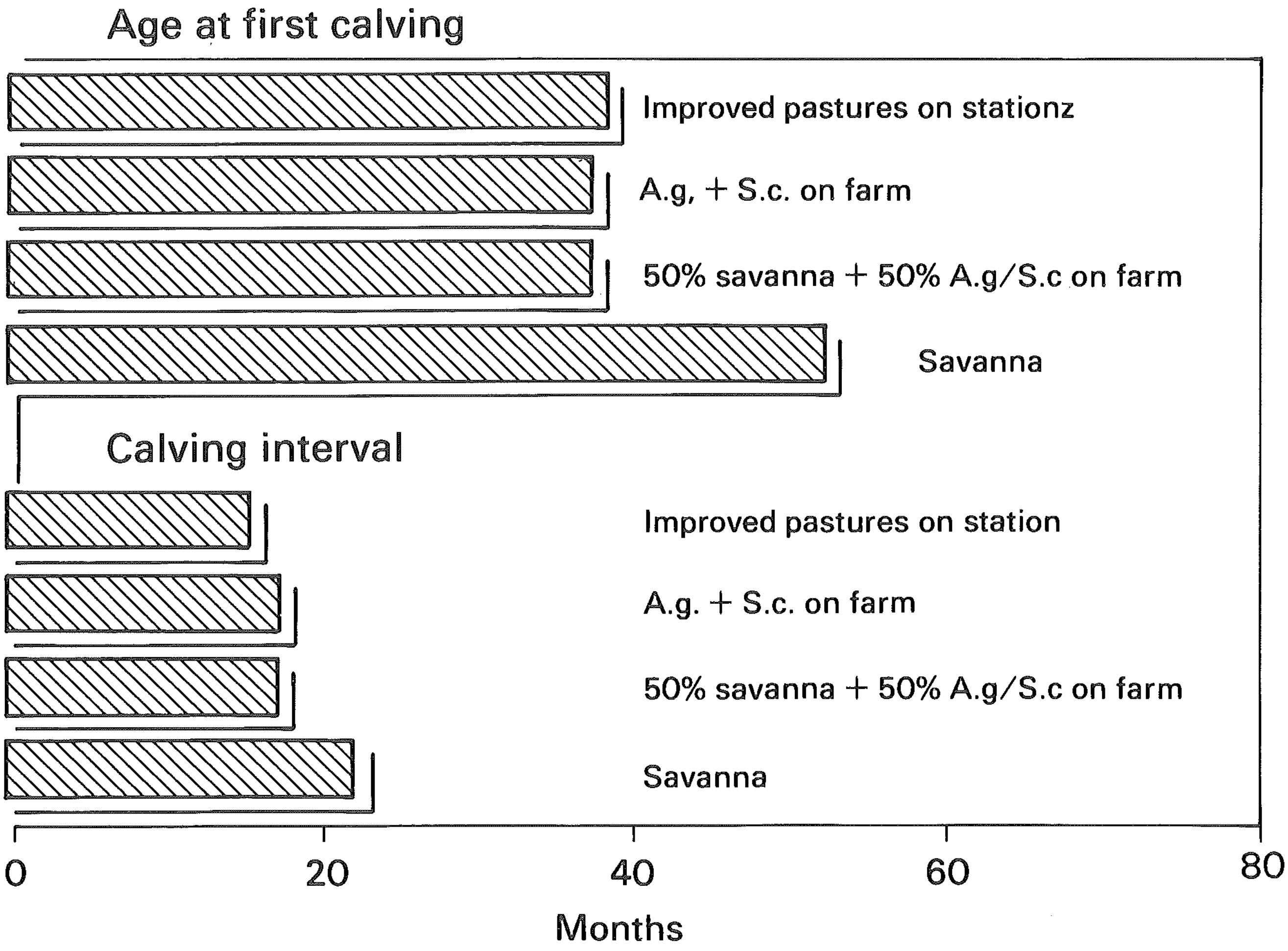


Figure 2. **Reproductive performance of cows in different pastures systems.**

an increase of about 20% in milk production per cow due to the legumes, in pastures with Brachiaria dictyoneura (Figure 3). This increment in absolute terms, represents about two liters of milk per cow per day, and has obvious implications in terms of both of total income and in improving the cash-flow of the farmer.

There is no doubt that the new pasture technology, based on adapted germplasm, has a high potential for increasing beef and milk production on marginal lands with infertile acid soils, as demonstrated by results of these experiments, mostly on-station. However, this is not enough to achieve credibility which is needed before massive adoption of legume-grass pastures, by farmers will take place.

As indicated before, the strategy proposed for the 90's is the direct involvement of the Tropical Pastures Program in linking research and development in two or three regions of our target area. With the availability of reliable technologies of legume-grass pastures, and through an increasing presence of ICA in intensifying the links between research and development through the CRECED, there are clear indications that the Llanos of Colombia should be one of the areas selected. Early in the next decade the Program will select two other regions, representative of contrasting environments and farming systems, in which to develop the same collaboration with national programs in evaluating approaches to link between research and development.

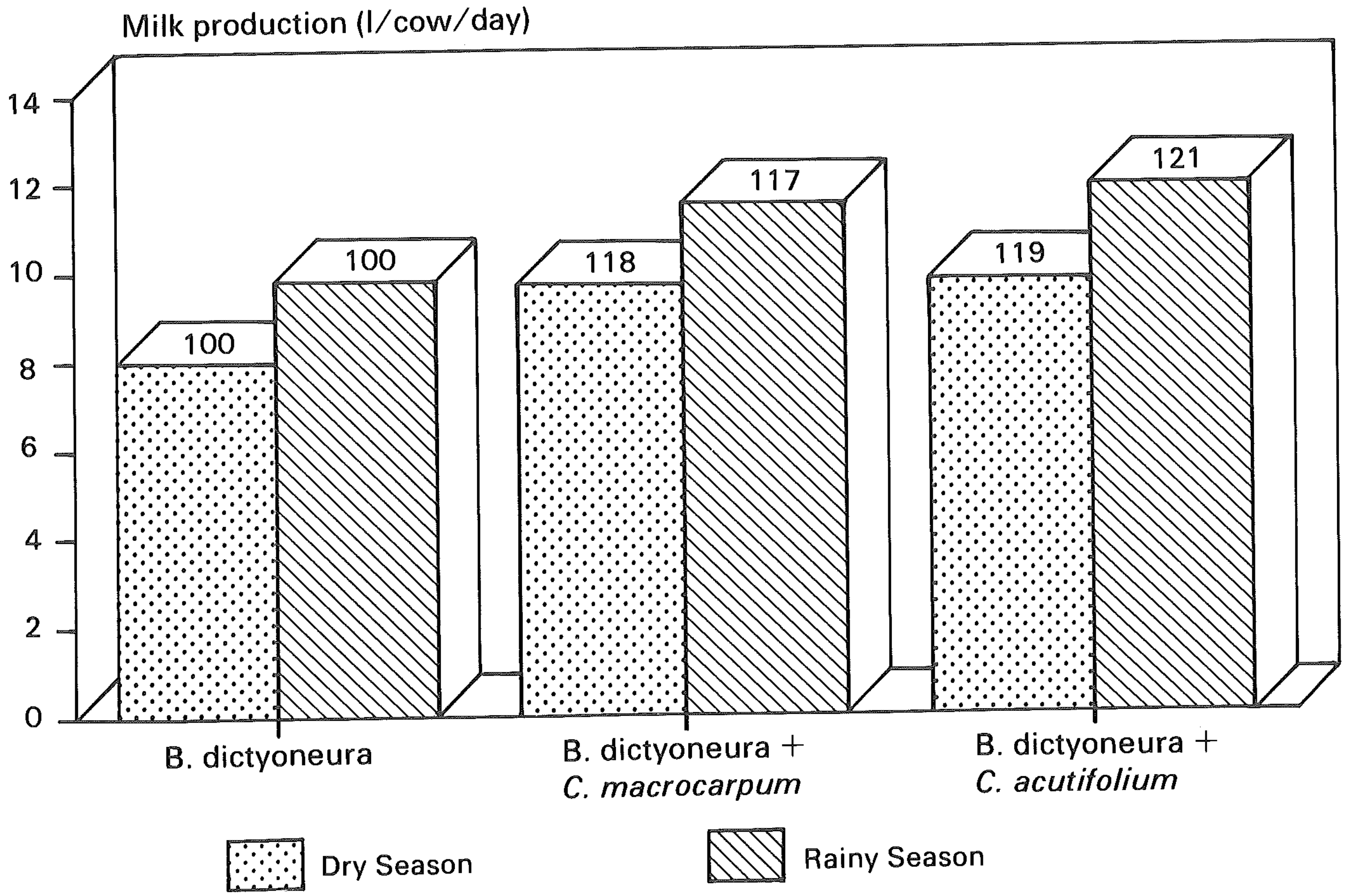


Figure 3. Milk production from different pastures at CIAT - Quilichao.

It is now very clear to the Program that despite the availability of sound pasture technologies, broad-scale adoption by farmers is limited by the availability of seed of the new cultivars. One of the critical factors of linking research to development is to break this "bottle neck" through the promotion of commercial seed production by private enterprises, farmer associations, and national programs.

Historically the Tropical Pasture Program has provided seed for agronomic evaluation, for grazing trials, and for on-farm research. During the last five years this role has been complemented by the Seed Unit, which has been instrumental in providing basic seed of released materials for supply to commercial seed-growers. Obviously the Program and CIAT cannot continue to cope with the demand created by the massive continental research effort of the RIEPT, far less provide basic seed of any cultivars that achieve successful adoption by farmers. Therefore, other sources of basic and commercial seed must be developed.

Figure 4 documents the large initial involvement of the Tropical Pastures Program in seed production in support of the research and release process of the first two cultivars released, Andropogon gayanus cv. Carimagua 1, and Stylosanthes capitata cv. Capica. Until 1980, the program supplied a

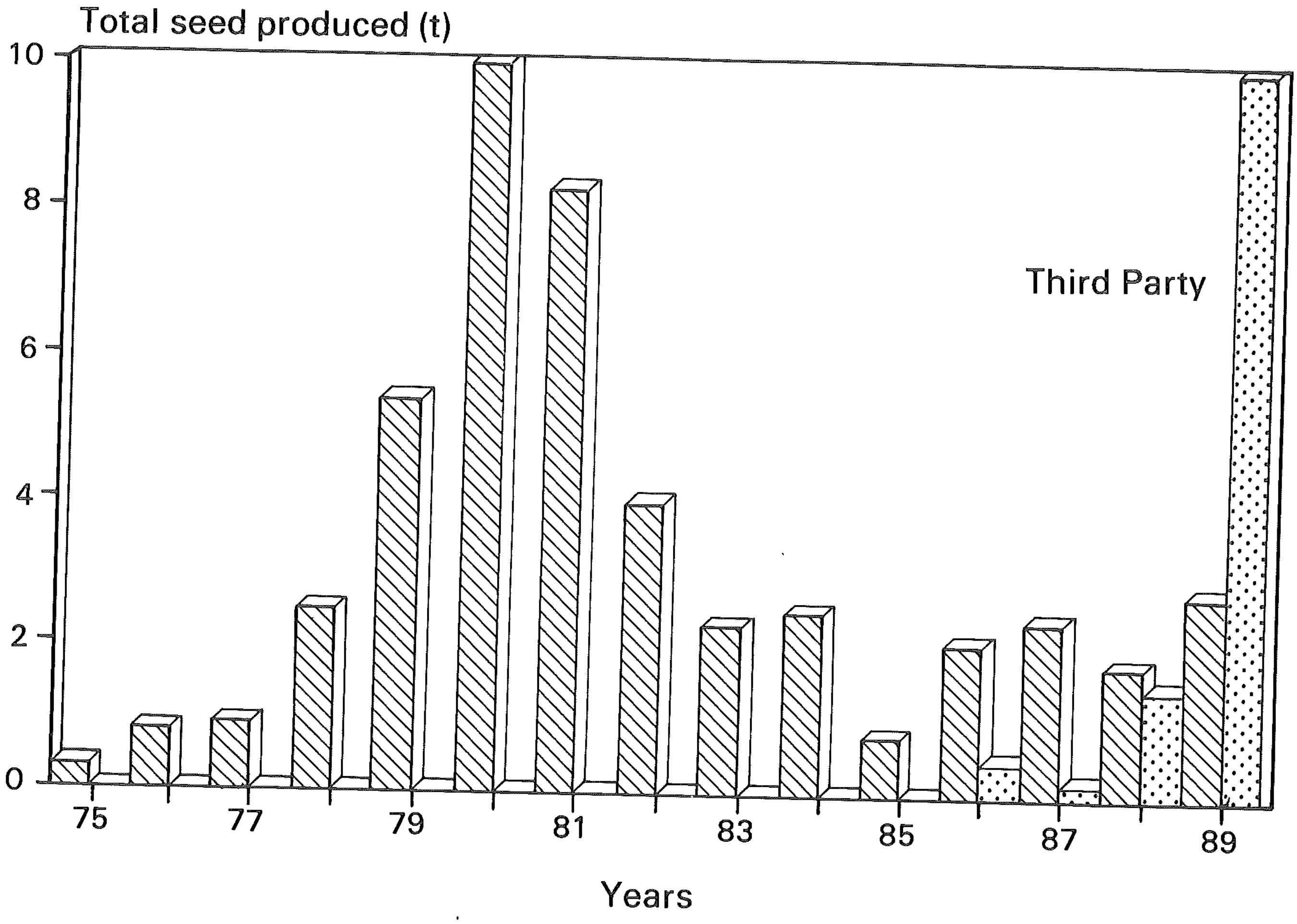


Figure 4. Evolution of internal (CIAT) and third-party seed multiplication.

large proportion of the seed required for germplasm evaluation in agronomic and grazing trials in major research sites and in the RIEPT. From 1980 onward the amount of seed supplied by the Program declined to a stable figure of about 2 tons per year. This occurred while an important effort was mounted to train national programs in seed production and to convince leaders of the NARDs to develop their own seed production projects. As a result of a growing involvement of NARDs, seed companies, and farmers' associations in these activities, there has been a rapid increase in the amount of seed multiplied by third parties during the last two years. The Program will continue to promote this effort, and confidently expects that the process will continue to expand.

The activities of Carimagua and the CRECED on the Colombian Llanos provides a good example of linking research and development. In 1985, a committee was created by the ICA/CIAT Council of Carimagua to provide guidelines for the transfer of the best available technology from Carimagua to the farmers of the Llanos. Among the activities undertaken by the committee were seed production, on-farm research, and commercial plantings, which were carried out by an ICA extension worker and a CIAT associate. During the first three years of this program 5.000 hectares of pastures were planted, mostly to grass-legume mixtures, in about 100 farms, as shown in Figure 5.

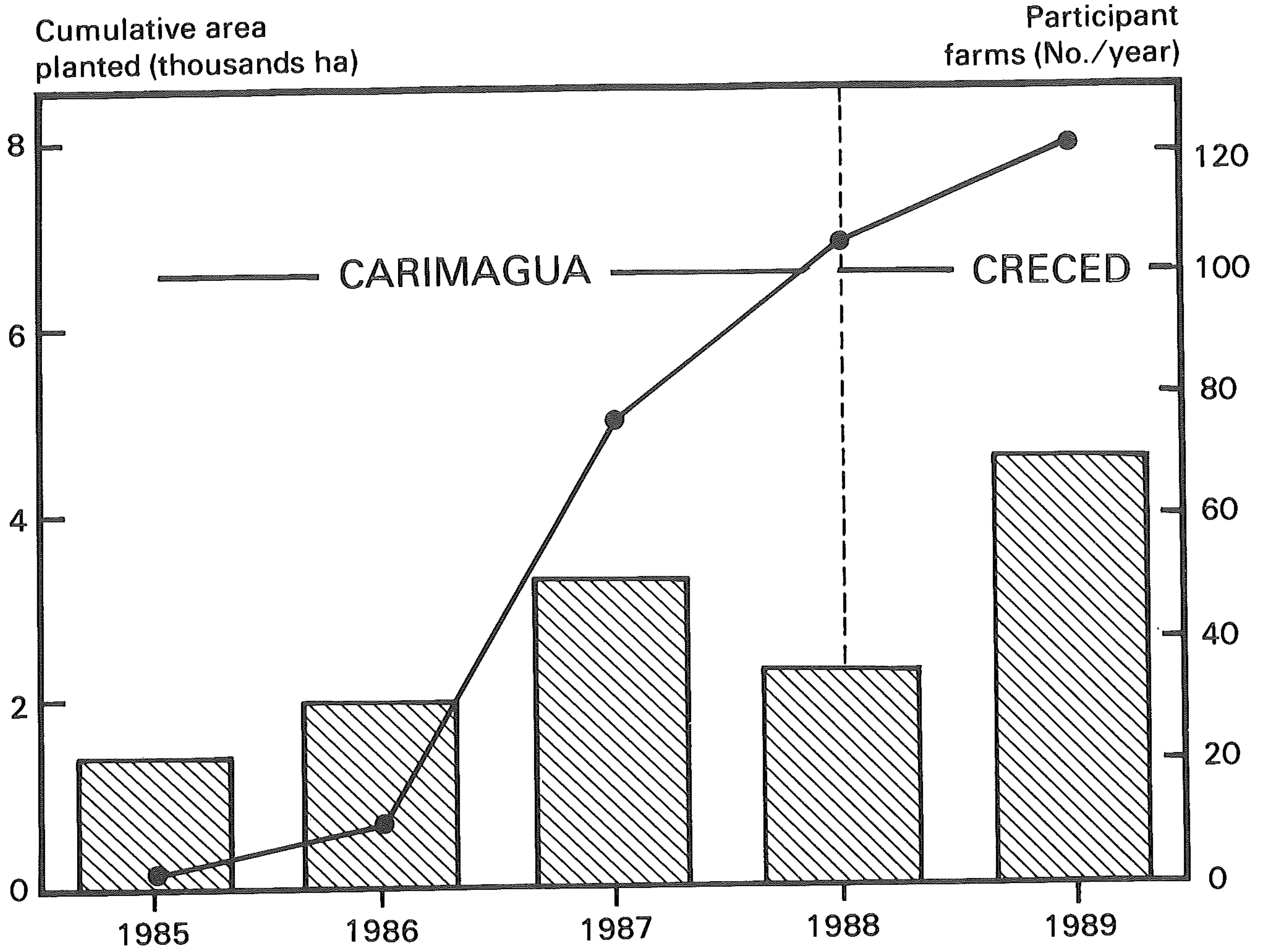


Figure 5. Number of participant farms and cumulative area planted to improved pastures by Carimagua and CRECED in the Colombian "Llanos".

From this start, ICA formalized its on-farm and technology transfer activities with the creation of the CRECED-Puerto Lopez in 1988, to which the Program passed the leadership role for the activities of technology transfer in this region. To face this challenge, ICA appointed two new professionals who attended the Program's intensive course in tropical pastures early in 1989. The logistics and execution of the 1989 plantings on farms of the Llanos were jointly planned by ICA regional members and the program members involved in on-farm activities.

In spite of the lack of experience of these two new ICA pasture specialist, the achievements of the CRECED are striking. In 1989 they planted more than 1.000 hectares of grass-legume pasture on 70 farms (Figure 5). In addition, they planted several seed production plots and, with the assistance of CIAT's Training and Pastures Programs, they trained a number of private regional extension workers in the technology of pasture establishment. This initiative was under the joint sponsorship of ICA and the Banco Ganadero, and was in the form of a course that took place in Carimagua and in farms of the Llanos. In order to document the pasture adoption process, and to contribute to the design of strategies for the establishment of legume credibility in the Llanos, a CEGA-CIAT survey was undertaken covering 86 randomly selected farms in Puerto López and Puerto Gaitán, comprising a substantial part of the well drained plains of the Llanos.

In 1979 the ETES Project estimated that 3% of the area was planted to introduced pastures. This new study documents that today 13% of the area has been improved with pastures (90,000 ha).

Figure 6 shows that in 1979 about 25% of the farms had some sown pastures, and these were exclusively grasses (*H. rufa*, *Melinis minutiflora* and *B. decumbens*). Presently 90% of the farms have established some improved pastures. They are still mainly planting grasses, though of the new generation: *B. decumbens*, *B. humidicola*, *A. gayanus*, and *B. dictyoneura*. However 8% of the area planted is of legume-grass pastures, mainly *A. gayanus* or *B. decumbens* with *S. capitata*.

In the past, the Llanos of Colombia was considered a frontier with limited potential for development because of

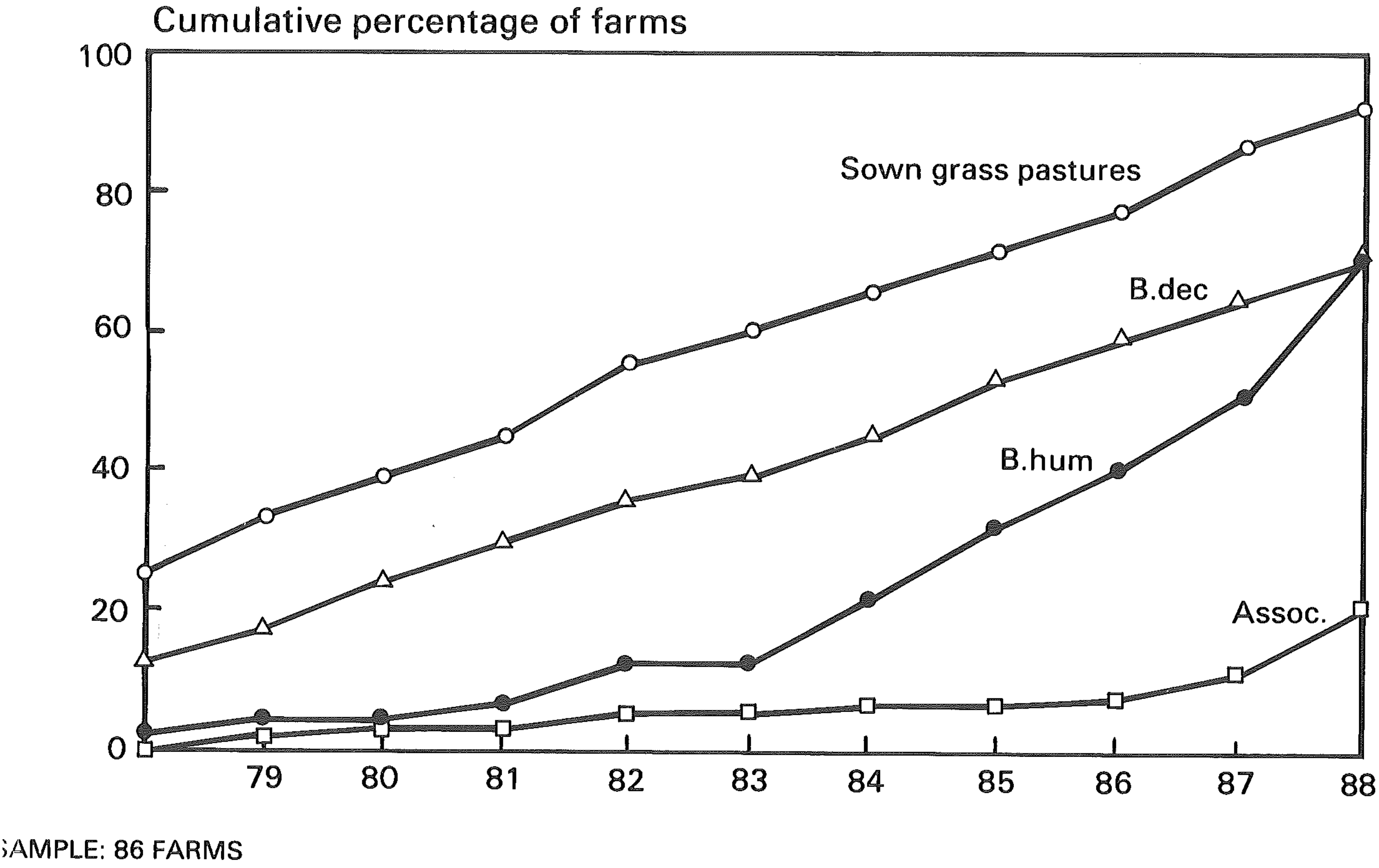


Figure 6. Evolution of the number of adopters by pasture species in the Eastern Plains of Colombia. 1979-88.

the lack of infrastructure and poverty of soils. However, during the past decade important changes have occurred:

1. The road infrastructure is improving.
2. Oil has been discovered and is under exploitation bringing resources for development.
3. The social unrest in other traditional farming regions of Colombia has shifted investment towards the Llanos, where security is greater.
4. This has triggered land subdivision and higher land prices, developments that favor intensification of land use.
5. Simultaneously, the availability of pasture technologies adapted to the low fertility soils is allowing farmers to efficiently intensify the land use.

Since legume adoption is our major challenge, emphasis was given in this survey to the understanding of the decision process of Capica adoption. It was clear that the legume was well accepted by those who tried it; however, the two major bottle necks were INFORMATION AND SEED AVAILABILITY.

We are left in no doubt that the Llanos is an appropriate target for our direct involvement in the linking of research to development. The Program should continue to back up this CRECED effort in order to ensure that the grass-legume pasture technology is sufficiently exposed to farmers in the region so as to establish the required credibility.

Let us now consider our second strategy for the 90's: "Develop sustainable pasture-based production systems on marginal lands".

Earlier this week during the rice program presentations, you were informed by Dr. Sanz, of the potential benefits of associating rice cropping and pasture technology in the savanna ecosystem (Llanos). At this point, I would like to stress the fact that this first CIAT's interprogram project has demonstrated that cooperation and joint work between Programs in CIAT is possible and can function productively.

Let us first visualize rice as a pioneer crop for pasture establishment. It was clearly documented that establishing grass-legume pastures simultaneously or within a 30 day period after rice had no detrimental effects on rice yield. This is an indication of minimal competition between the pasture plants and rice. Both the legume and grass components of the pastures were initially suppressed by the shading of the rice plants, more so the B. dictyoneura pasture at the rice harvesting time. However, 60 days after the harvesting of rice, about five months after planting, excellent legume-grass stands were obtained in response to the high levels of fertility remaining in the soil after the rice crop (Figure 7). Commercial pastures are commonly established in virgin savanna in the Llanos with only 20 kilograms of P, 20 kg K, 100 kg of Ca, 20 kg of Mg and 10 kg of S/ha, and up to one year may elapse before the pasture is ready for grazing. In contrast, under the fertilizer applied to upland rice including 80 kg of N and 150% more P, 400% more K, 50% more Ca, and 20% more Mg, the resulting pastures have developed sufficiently so as to be ready for initial grazing by the end of the rains, only 6-7 months after establishment.

This is, moreover, an excellent demonstration of the value of the Program's philosophy of screening germplasm under low fertilizer inputs, which has allowed us to obtain grass and legume plants to develop a pasture technology that performs well under a wide range of soil fertility conditions. Not only can the new grasses and legumes be established and be productive with minimal inputs.

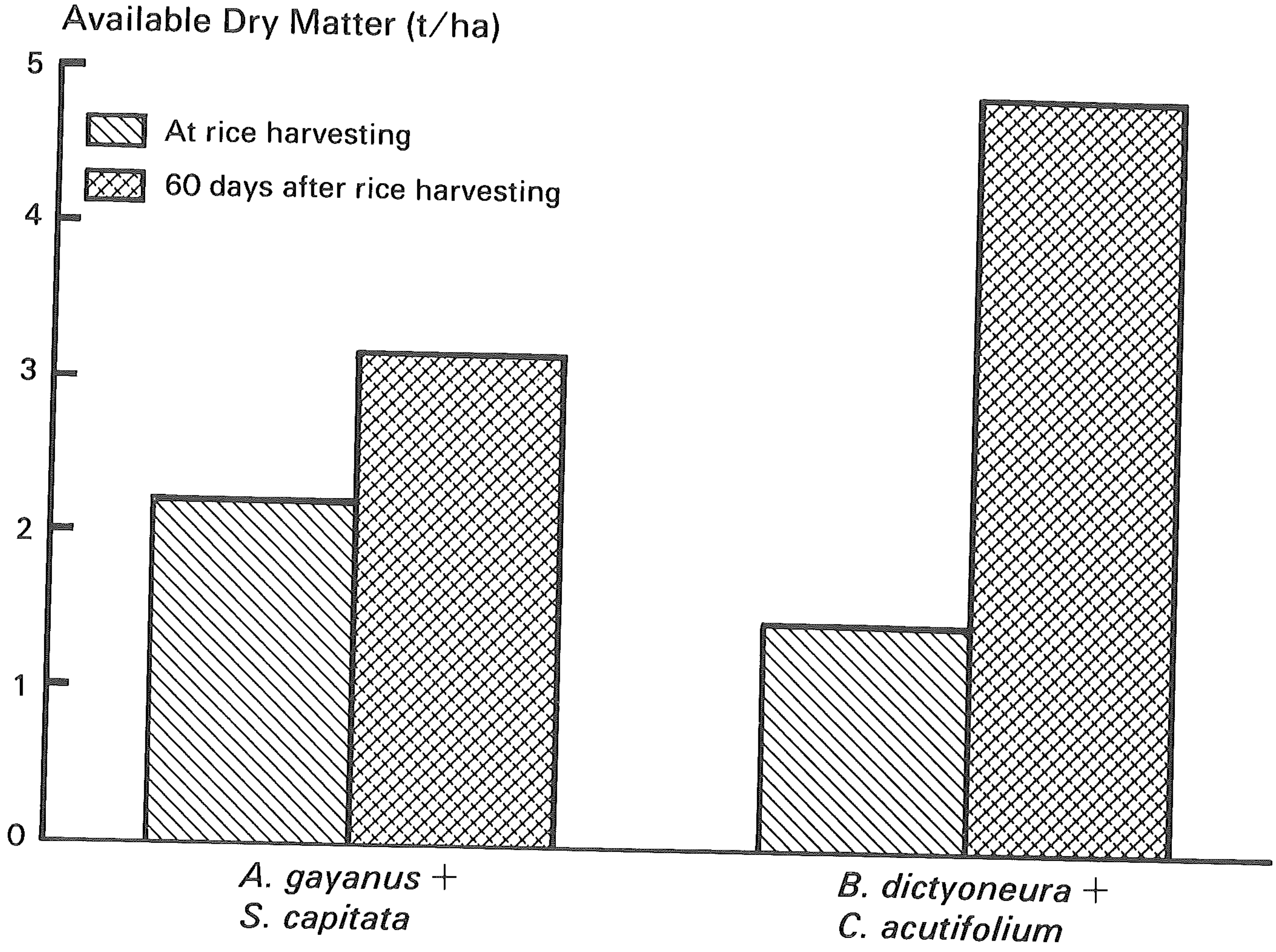


Figure 7. Response of two pastures to the residual effect of rice fertilization.

They also respond to higher levels of fertilizer inputs. The immediate plan is to establish a grazing trial to evaluate through time the performance of these one hectare pastures as part of the ICA-CIAT research activities of CRECED.

Without doubt, the new upland rice lines for the Llanos will contribute greatly to rice production in the region and also provide a tremendous impetus to the rapid adoption of the new grass-legume pasture technology being developed by the TPP.

Let me now talk about the alternative system--that is pastures followed by rice. Figure 8 shows the results of the experiments conducted in Carimagua where more than 3 tons/ha of rice were produced after a 10 year-old legume-grass pasture. Moreover, there was no response to either nitrogen or phosphorus fertilizer. After grass alone, more than 3 tons/ha of rice were obtained and here with a clear response to N fertilization. The maximum rice yield after virgin savanna was only about 2 tons and this was obtained only with the highest levels of N and P fertilization. These are striking results that convincingly demonstrate the soil improvement capacity of pastures in general, and particularly of grass-legume pastures.

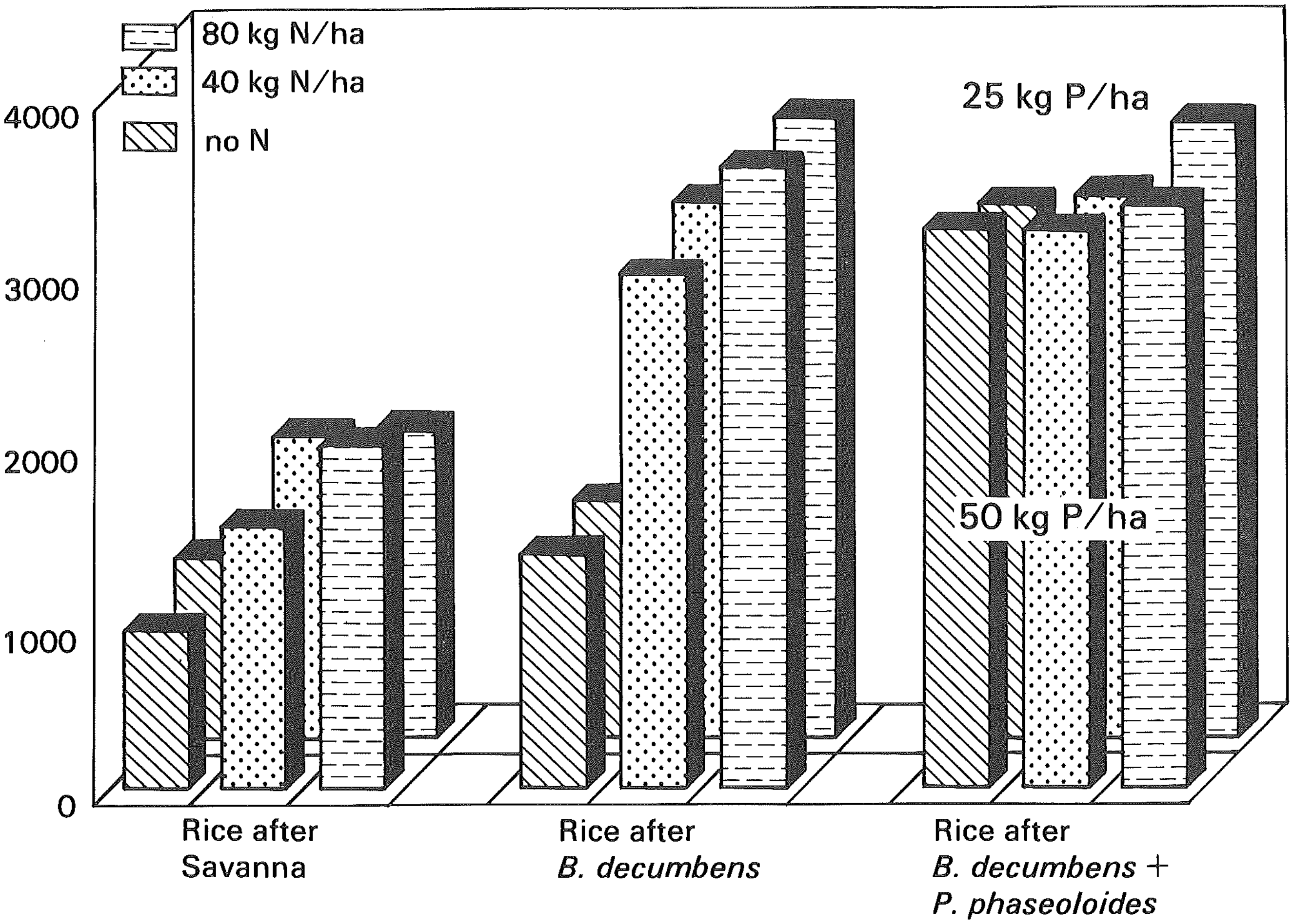


Figure 8. Rice yields after 10 years of improved pastures and savanna in response to different levels of N & P fertilization.

The effect of pasture to improve the nitrogen status of the soil is not new. In 1980, John Russell of CSIRO reviewed data from the Waite Institute in South Australia for different cropping systems including permanent pastures and wheat-pasture rotations. He presented a simulation model of soil nitrogen percent vs. time under the different land-use systems. A clear reduction in the nitrogen content of the soil occurred under continuous wheat cropping. Further, there was no increase in soil nitrogen when fallow was included after wheat (bottom curve). In contrast nitrogen levels in the soil increased under permanent pasture, while a wheat-pasture rotation gave stable levels of soil nitrogen (Figure 9).

Dr Albert Fischer of the Rice Program found that the total biomass yield of upland-rice responded almost linearly to increasing levels of nitrogen fertilizer; but in terms of grain yield, the response was limited by increase intra species competition and higher disease and pest problems. As shown in Figure 8, the maximum yields of rice in both Mata Azul (on-farm) and in Carimagua after savanna were only about 2 tons/ha with 80 kg/ha of N fertilizer, in contrast to the maximum yields of rice after a grass-legume pasture of 3 tons/ha. This

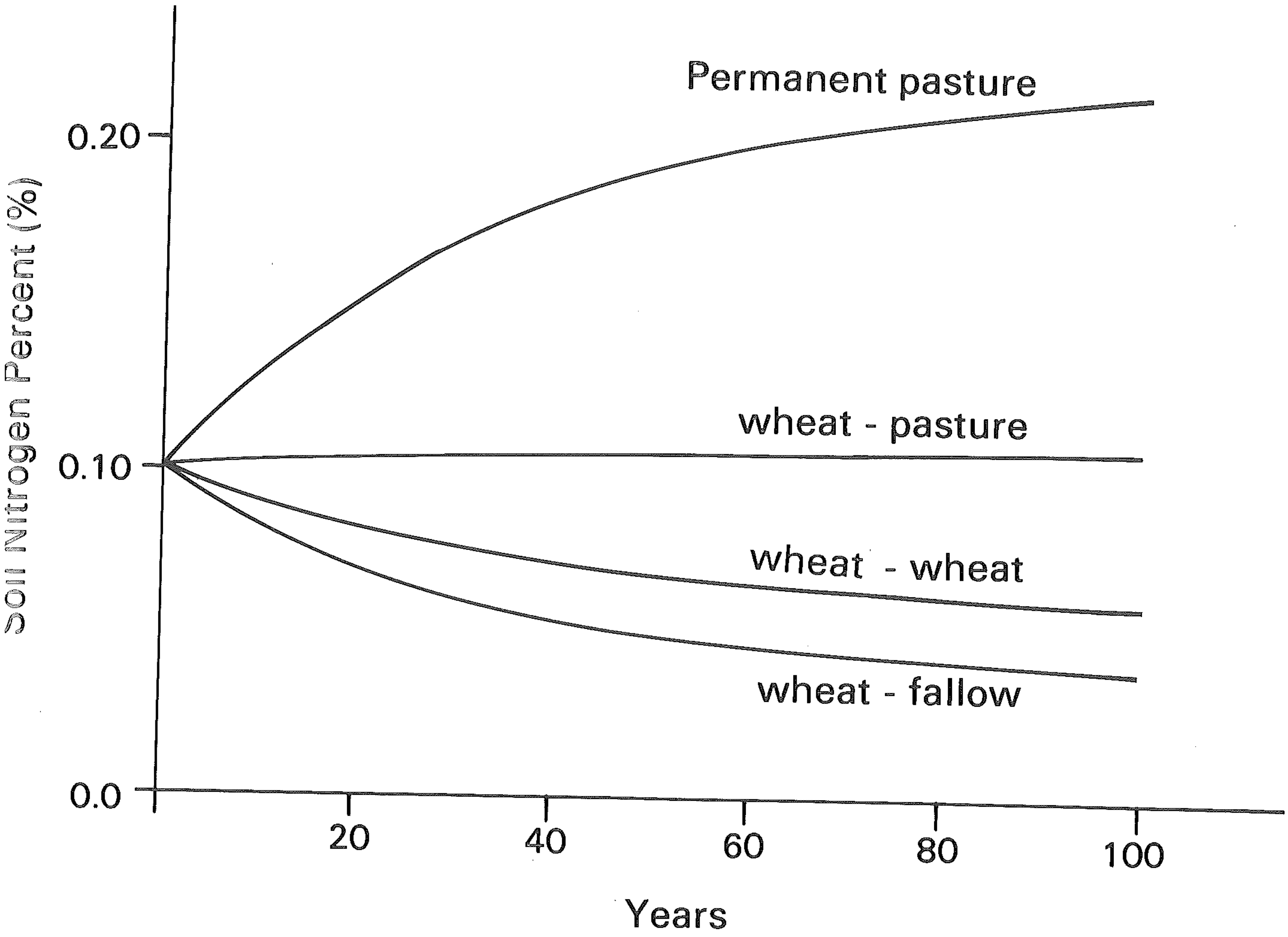


Figure 9. Soil N changes under different land use systems at Waite Agricultural Research Institute (From Russell, 1980).

raises the question, what causes this difference in productivity? The improvement after pasture must be due to some factor other than nitrogen, such as:

1) an improvement in soil structure, which is also highly related to soil/water/plant relations;

2) a higher level of organic matter and nutrient concentration in the top soil, implying a pumping-up of nutrients by the pasture from the lower soil profile;

3) changes in the top soil microbial and macro-fauna.

Deep and profuse root systems of adapted pastures improve soil structure and is the key for nutrient turnover.

Figure 10 illustrates what Dr. Spain has called the pumping effect. After four years of pasture at Carimagua, there were increments in both calcium and magnesium levels in the upper soil profile, with no changes in the K level.

Under irrigated rice micorrhyza do not contribute to the efficiency of P uptake; however under upland rice

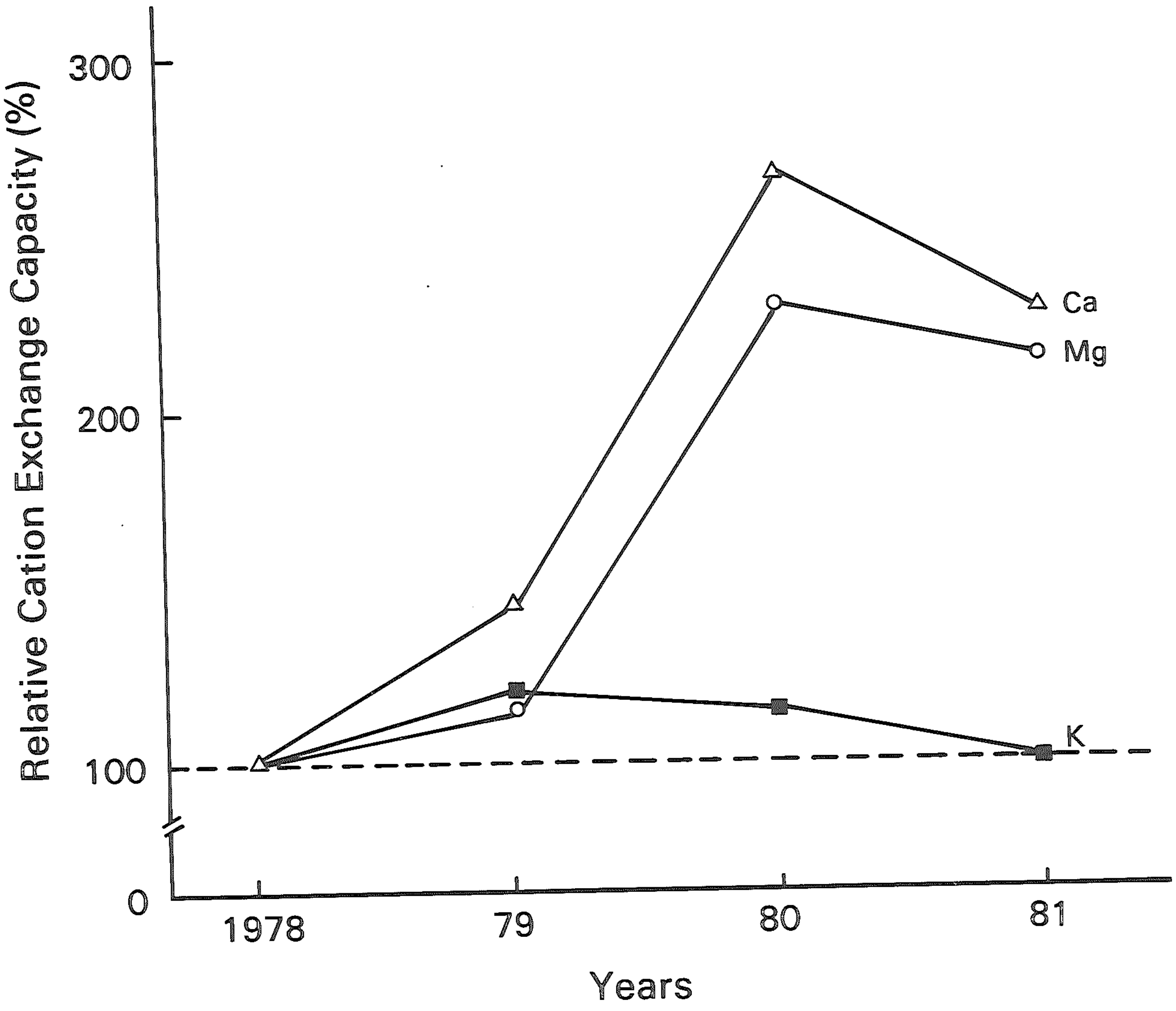


Figure 10. Relative increases of Ca, Mg and K under an A. gayanus + P. phaseoloides

conditions these microorganisms do play a role.

Dr. Saif's early work at Carimagua demonstrated that the inoculation potential of VA Micorrhyza increases at the onset of the rains. However, the number of spores in the soil increases much faster under improved pastures than under the native vegetation of the savanna (Figure 11).

Recent data from Yurimaguas, obtained by the Trop Soil Project, has documented the beneficial effects of legume-grass pastures in increasing the biomass of macrofauna (mostly earth worms and insects) in the top soil compared with primary and secondary forest. In contrast, both low and high input cropping and shifting cultivation drastically reduced the biomass of macrofauna in the topsoil (Figure 12).

It seems clear that efficient nutrient turnover, improvement of soil structure, and higher microbial and macrofauna activity of the soils under pastures can explain the additional yield of rice beyond what can be obtained with fertilizers.

The work done so far in the rice-pastures-rice sequence is very exciting, but we must recognize that we are just scratching the surface in terms of the knowledge required to develop appropriate technologies for the sustained integration of crops and pastures in marginal savanna areas. There are other important new crops options that have been developed for acid oxisol and ultisol soils, for example, the work of the Cassava Program to develop varieties for the Llanos, the INTSORMIL program to develop sorghum for acid soils, the CIMMYT work at CIAT to select corn plants tolerant of acid soils and the new cultivars of soybean developed by EMBRAPA and ICA. On the other hand, a major effort is required to develop tolerance to acid soils in N_2 fixing multipurpose trees that are suitable for integration into silvopastoral systems. Improved pastures can also be integrated with timber plantations or tree crops such as mangoes, cashew nut, oil palm, peach palm, and so on. For this purpose shade tolerant grasses and legumes will be required.

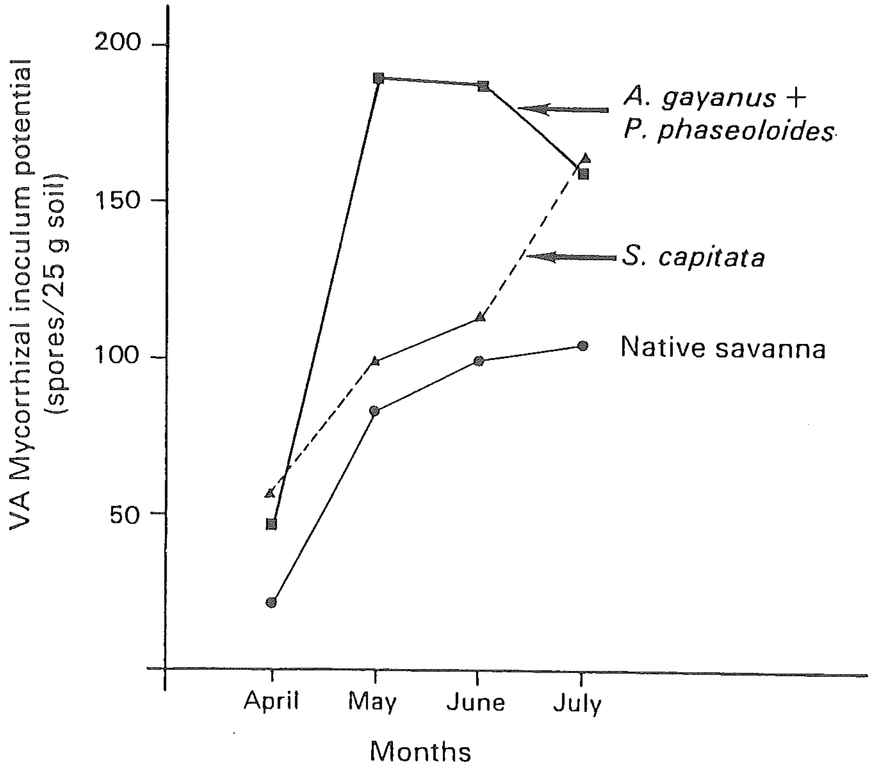


Figure 11. VA Mycorrhizal inoculum potential at the onset of the rainy season in a Carimagua Oxisol (from: TPP Annual Report 1982).

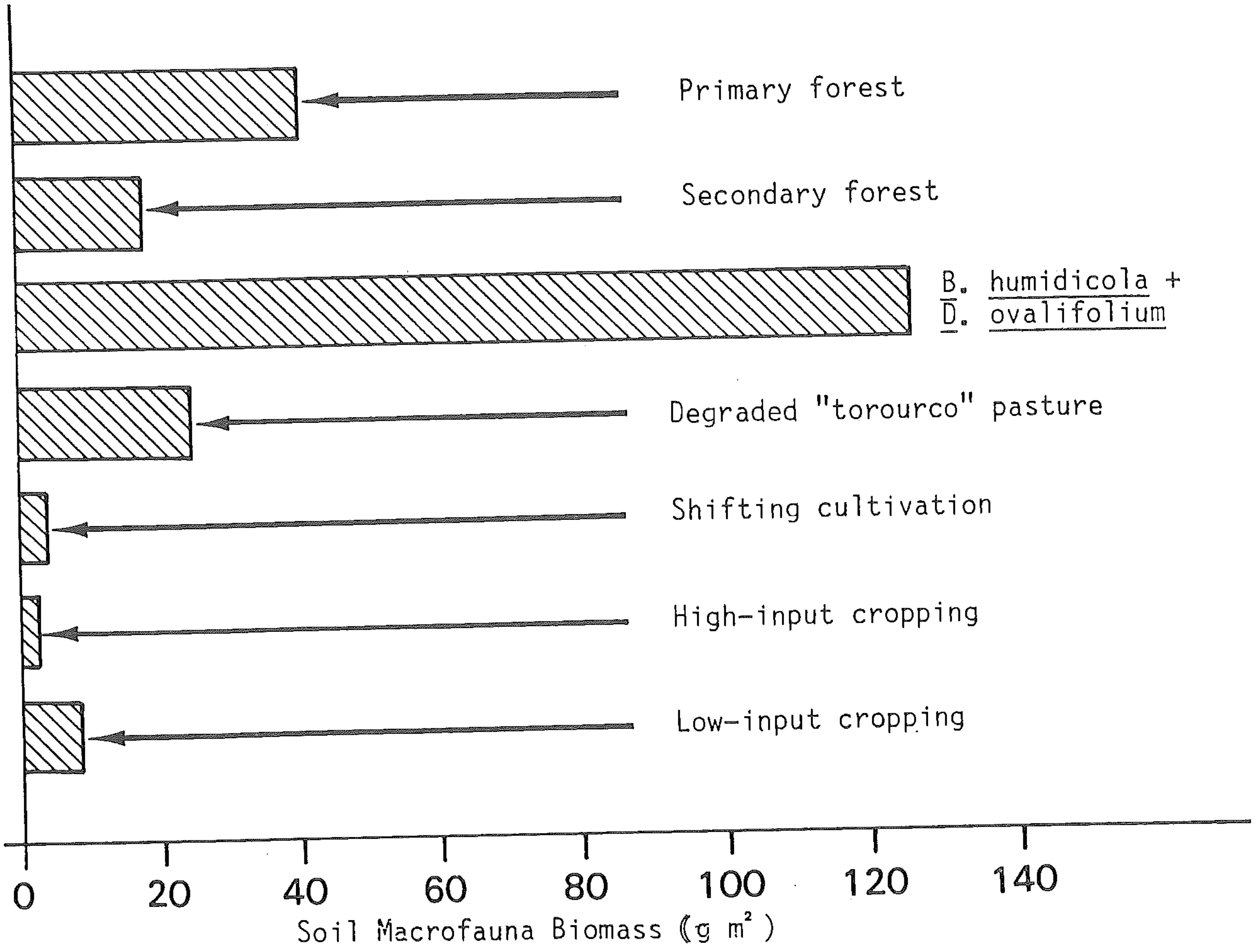


Figure 12. Macrofauna biomass present in the soil under different land use systems at Yurimaguas (from: TropSoils, 1987).

Looking for grasses tolerant to shade conditions, 37 accessions of Axonopus spp., Paspalum spp. and Stenotaphorum secundatum were collected from shaded environments in tropical America, and Southeast Asia.

They were evaluated in Quilichao under open and shaded conditions. Variability was found among accessions of the same species and among species (Photo 1).

Axonopus compressus, Paspalum conjugatum and Stenotaphrum secundatum are species with potential to find grasses that perform well under shaded conditions; and, given their shallow root systems, with minimal competition to the plantation trees.

As a highlight of the work at Pucallpa I would like to report the potential of S. guianensis cv Pucallpa to improve soil conditions under degraded native grassland (called "Torourco") with no soil preparation and the simultaneous broadcasting of seeds and 100 kg of rock phosphate. This was done in February this year; after 9 months a high biomass level has been achieved (Photo 2). This opens the possibility of recovering degraded "Torourco" pastures reducing from 10 year the fallow time required to have sufficient biomass of purma or secondary forest to

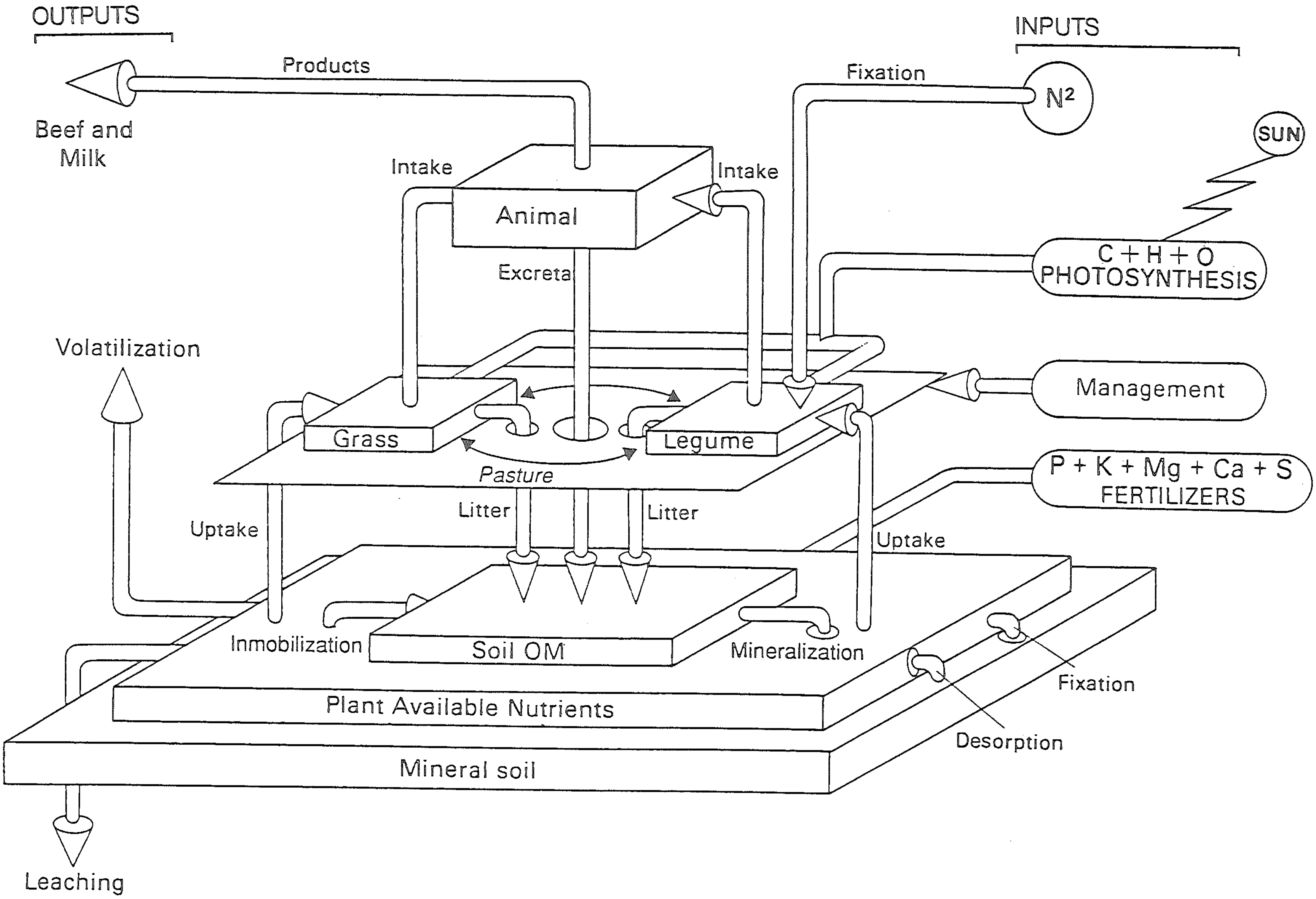


Figure 13. Model of nutrient relationship in grazed pastures.

Photo 1. Shade preferring grass: Axonopus compressus

Photo 2. Non-mechainzed establishment of Stylosanthes guianensis cv. Pucallpa (CIAT 184). Biomass accumulation 9 months after oversowing a degraded "Torourco" area at Pucallpa, Peru.

burn, to only two to three years. This is particularly important since small dual purpose farmers of the humid tropics often have no access to mechanization and their "Purmas" are generally far from their dwelling and management infrastructure.

Recovering this humid tropics degraded land with grass-legume pastures will require an association with crops in order to pay for the inputs and/or time invested; and this provides an open opportunity for the development of sustainable agro-silvopastoral systems.

All this calls for a strong involvement in the 90's of the Tropical Pastures Program in research leading to the integration of crops and trees within pasture-based production systems in the savannas and rainforest areas of the continent.

In order to achieve maximum contribution of grass-legume pastures to sustainability in marginal acid soil areas, these pastures should be stable in a grass-legume balance and effective in nitrogen fixation and soil nutrient recycling.

Although improved germplasm is an important component of pasture stability, the Program recognizes that germplasm alone can not resolve all issues. The effects of different management practices such systems of grazing management, the strategic application of external inputs, will define the degree of stability and productivity of pasture systems on different soils.

The foregoing leads us to the next of the Program's strategies, that is to enhance the role of improved pastures to maintain or recover soil fertility; in other words "understanding the pastures complex", which include the following two main trusts:

1) Understanding the environmental and management factors affecting persistence and competition of pasture plants under grazing.

2) Understanding the effective utilization of native and applied nutrients and their recycling.

To study the pasture complex (Figure 13), a multidisciplinary team has been assembled in the program including: a soil scientist, a plant nutrition physiologist, N_2-fixation and turoover specialist, a pasture ecophysiologist, a grassland ecologist and an animal nutritionist/grazing management specialist.

This team will develop the appropriate techniques and methodologies for the assessment of the different compartments and fluxes in the model and to study their dynamics and relative importance as determinants of pasture productivity and stability.

The main outcome of this major effort of the Program will be the development of a greater understanding of the principles of management of grazed tropical pastures. This will provide the basis for scientists, developers, and farmers to arrive at sound recommendations for the better utilization and maintenance of new pasture technology on infertile acid soils. It is obvious that these recommendations will be different in contrasting environments, including ecosystems and farming systems, but having the basic knowledge and understanding the principles will allow these differences to be taken into account. For this reason the other important outcome of this research effort will be to develop simple and reliable methodologies that can be applied by researchers in national programs (RIEPT) specific to the monitoring of the pastures in order to make the required local adjustments.

The next important strategy proposed for the 90's is "to strengthen national capabilities in the context of supply and demands for germplasm for the development of legume-based pasture technologies". This is a two-pronged strategy: the first branch includes the continuation of the development of technology and back-stopping of the NARDs within the RIEPT in Tropical America; and the second branch is related to the globalization of our germplasm work.

The first part of this strategy is related to the RIEPT, and includes selective or strategic expansion of the germplasm collection to facilitate response to the specific needs of the regions. An example of this activity includes the collection of key materials such as Hyparrhemia rufa after a clear and strong request of RIEPT for the dryer savanna areas of Central and South America (Photo 3). These collections were initiated during 1989 in cooperation with NARDs in Cameroun and Togo.

A continued emphasis of the Program should be the collections to expand the variability of leguminous trees and shrubs for infertile acid soils. Some species such us Cratilia floribumda and Flemingia macrophylla are showing high levels of adaptation to the oxisols and ultisols and could be used to provide forage during the end of the dry season and also have the potential to be used in alley cropping systems in the acid soil areas.

During the 80's the expansion of the variability of germplasm had come mostly from collections and introductions. Today the Program and RIEPT have identified key species and explored sufficient natural variability within them, so as clearly to define major constraints that can only

Photo 3. Dr. R. Schultze-Kraft (CIAT) and Dr. B. Peyre de Fabregues (IEMVT) collecting grasses in West African savannas.

be overcome by plant breeding (intraspecific and interspecific crossing). Consequently during the 90's the plant improvement work of the Program is expected to grow.

Today three main new projects are visualized:

1) to incorporate resistance to spittle bug in *Brachiaria* spp.;

2) interspecific breeding within *Centrosema* spp. to solve the problems of seed production and disease threats, and

3) improvement of the nutritional quality of grasses (i.e. *A. gayanus*, *B. dictyoneuria* spp.).

This work is already under way and important results are being obtained. For example, in the case of *Brachiaria* spp., as reported last year, the apomictic habit of reproduction has been broken. This year, interspecific crosses between *Brachiaria brizantha* and *Brachiaria ruziziensis* have been confirmed. There are more than 600 new interspecific crosses with the highly spittlebug resistant *Brachiaria brizantha* cv. Marandú, which at this stage is limited by its requirements for high levels of soil nutrients (Photo 4).

As you may recall from the last years presentation *B. jubata* was identified as a plant that negatively affect the survival of spittlebug nymphs by preventing normal molting.

In order to have a sufficiently rapid and reliable technique to evaluate large numbers of progeny generated by sexual crosses, work has been underway to identify the chemical basis of resistance to spittlebug. It has been demonstrated that spittlebug nymphs feed on xylem vessels. We believe that the factors responsible for the high level of resistance in species such as *B. jubata* and *B. brizantha* are present in the xylem. Therefore, a bioassay technique was developed using corn plants grown in a nutrient solution to test for the presence of active compounds in plant chemical extracts. Because we suspect that the basis of resistance in *B. jubata* is hormonal in nature, we are also testing the effect of known insect hormones on spittlebug physiology. Ecdysone is one of the insect hormones that control the molting process. Table 1 simply demonstrates that nymphs fed on corn roots grown in a solution containing ecdysone experience greater mortality associated with molting, similar to the mortality observed among nymphs fed on certain accessions of *B. jubata*. This system lets us study spittlebug response to individual plant components. We are using this system to identify the mechanism of resistance to spittlebug in order to develop a rapid screening technique based on a chemical marker. This will, in large part, eliminate the need for expensive and time-consuming bioassays.

Table 1. Response of spittlebug nymphs (*A. reducta*) reared on roots of maize plants grown in test solutions.

Treatment	Total No. moults	Mortality
Water only	9	1
Nutrient solution only	10	1
Water + ecdysone	0	5
Nutrient solution + ecdysone	7	7

Centrosema acutifolium cv Vichada, the accession CIAT 5277, is affected by "Factor X"a syndrome of unclear nature that destroys plants; while the CIAT 5568 is not affected. F1 crosses (Photo 5) between these two accessions

Photo 4. *Brachiaria brizantha* x *B. ruziziensis* F_1 crosses in the field at Carimagua.

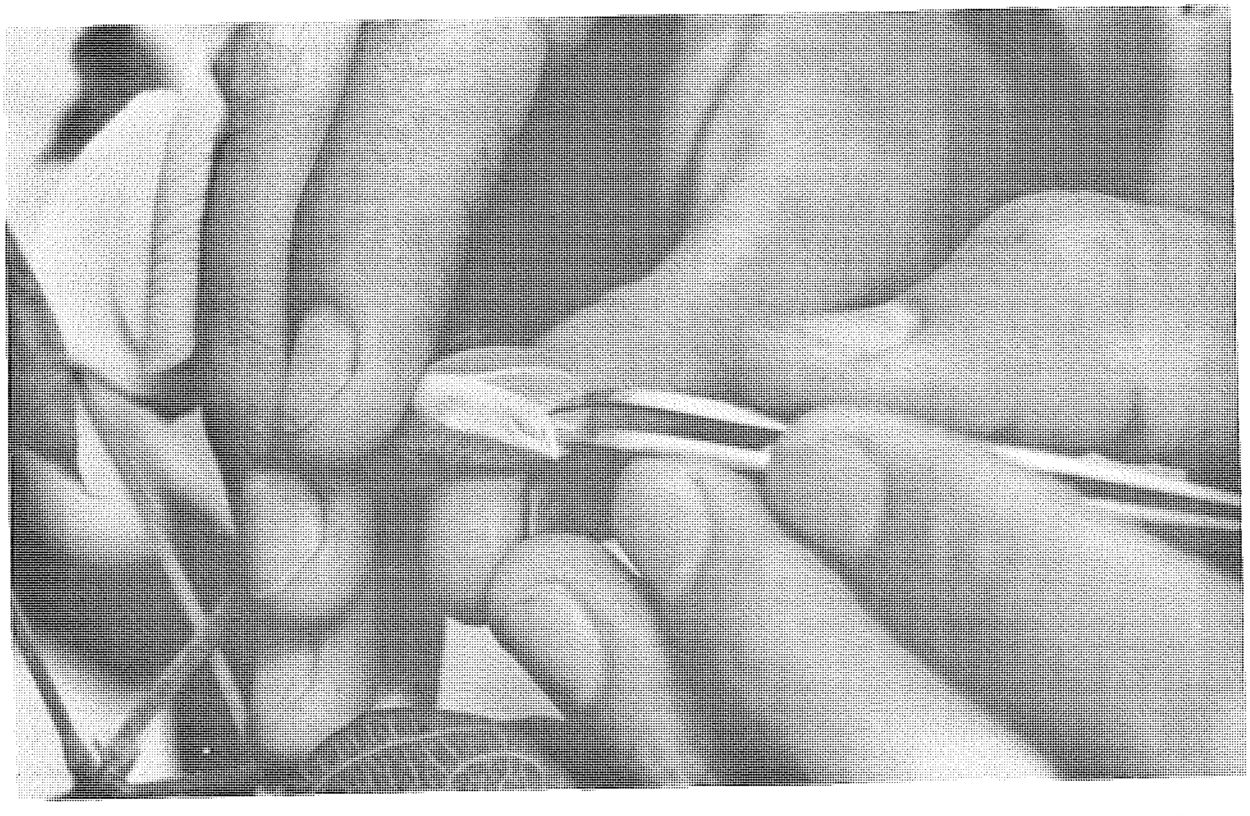


Photo 5. Hibridization of *Centrosema* spp.: promising project to solve disease constraint in the genus.

are now under evaluation to combine resistance to Factor X with the high adaptation and performance under grazing of Vichada. Similarly F2 crosses of C. brasilianum x C. tetragonolodum are now under field evaluation in Carimagua and Quilichao to select Rhyzoctonia resistant lines.

During the next decade the Program also hopes to explore other ways to expand selectively the variability of the germplasm base through the use of biotechnology. Based on the experience of the BRU with protoplast-fusion between Stylosanthes guianensis and Stylosanthes capitata, and on the availability of a gene for resistance to a non specific systemic herbicide (Basta), a biotechnology project has been initiated to incorporate resistance to this herbicide into Stylosanthes guianensis and Arachis pintoi. With the cooperation of the TPP, and with the help of a Senior Visiting Scientist from Louisiana State University (Dr. A. M. Thro), the GRU will attempt to incorporate this herbicide resistance factor into these legumes. If successful, this will have important implications in the establishment and maintenance of legume-grass pastures in areas where weed invasion is high, such as in the humid tropics or after cropping.

During the 90's the role of the Program in supporting the NARDs with new germplasm will be an important part of its work within the RIEPT. However, it is visualized that RIEPT researchers and the NARDs will increase their pasture development and on-farm activities to link research with development. As a consequence, the Program visualizes that its four agronomists, who presently coordinate the sub-networks of the RIEPT will partially shift their emphasis away from germplasm screening to aspects of pasture development. One good example of this is the work in Costa Rica where Dr. Argel has advanced four new grass (A. gayanus; B. brizantha 6780; B. dictyoneura 6133 and B. humidicola 6369) and four new legume selections (A. pintoi 17434; C. macrocarpum 5713 and 5442; S. guianensis 184) to the stage of grazing trials, and he is already establishing farmers plots for seed production in order to conduct on-farm research in the near future. During 1989 more than 6 tons of planting materials have been delivered to farmers through MAG.

In Costa Rica as well as in Pucallpa, Perú, A, pintoi CIAT 17434 selected in Carimagua, is outyielded by other more productive and better N2-fixing accessions. The seed production potential of these accessions has been evaluated on a heavy textured Ultisol at Pucallpa. While the Carimagua selection CIAT 17434 did not set seed, other accessions have high seed yield potential (Table 2).

Table 2. Seed production potential of Arachis pintoi in an Ultisol at Pucallpa.

Accession	No.seeds/m^2	kg/ha
17434	0	0
18745	1352	1552
18746	1213	1532
18752	300	500

Similarly, different accessions of C. macrocarpum are being selected for the high weed potential conditions of the Humid Tropics at Pucallpa and Costa Rica. The C. macrocarpum CIAT 5432; 5447; 5452; 15047 and 15115 (the stars on top of the curve in Figure 14) have more than 15 rooted nodes 3 months after sowing and acceptable seed yields; while the Carimagua selections only have 2 to 4 rooted points 3 months after establishment. Seed production of these new selections is already underway.

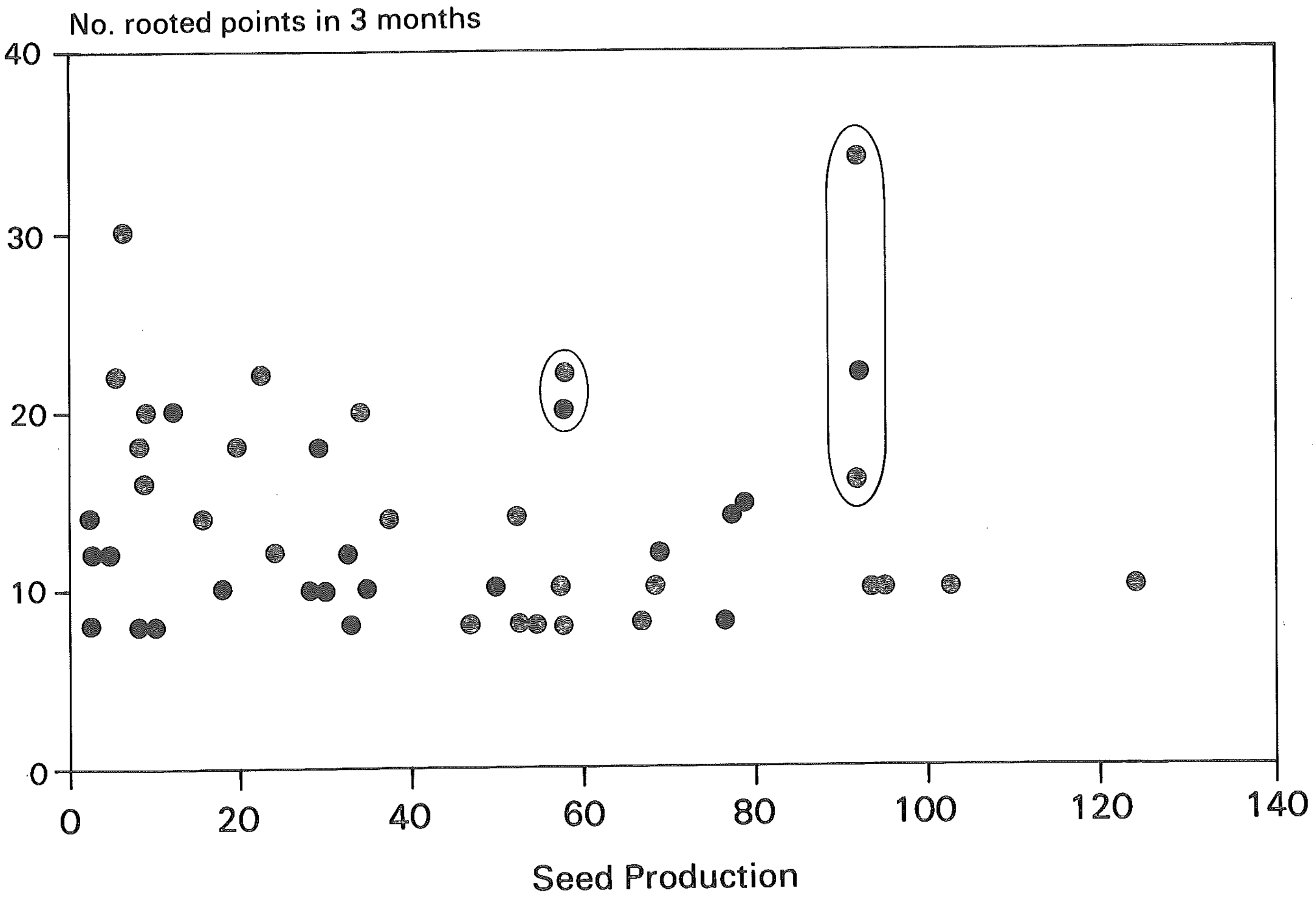


Figure 14. C. macrocarpum accessions selected for high weed potential conditions of the Humid Tropics at Pucallpa and Costa Rica.

These differences in the selections at different major screening sites once more justify and confirms the validity of a decentralized germplasm screening approach of the Program and the RIEPT.

In the Brazilian Cerrados it is estimated that 640,000 ha are planted to A. gayanus cv. Planaltina pastures, which are yielding 25,000 tons of beef/year. However, the Program recognizes that it does not yet have enough legumes sufficiently reliable to be adopted by farmers in this ecosystem. Therefore, a major effort is now being made in the Cerrados of Brazil, and 600 new legume entries are being introduced this year for screening at CPAC.

The RIEPT has been so far very successfully screened forage germplasm and identified final selections for further work under grazing, both on-station and on-farm. The cooperative work of the RIEPT has allowed important economies of scale, particularly in effective extrapolation of the results and in the opportunistic advancement of germplasm and in the rapid movement from agronomic trials to grazing trials and some times even straigth to on-farm testing. It has been particularly important in this cooperative research process that the RIEPT Advisory Committee has made adequate definition of methodologies and techniques for the guidance of the different stages of pasture research and development work. During the coming year the advisory committee of RIEPT will meet in Peru to discuss methodologies, approaches and techniques for on-farm research.

The other direction in the strategy of strengthening the NARDs is the extension of the Program's work in germplasm to a global basis. Quarantine is a major concern regarding the globalization effort of the Program to provide germplasm, especially legumes for the poor acid soils of Africa and Southeast Asia.

After the identification of virus in Centrosema spp., Arachis pintoi and Stylosanthes spp. (Photo 6), the Virology Research Unit (VRU), in cooperation with our Plant Pathology Section, conducted important work to identify and then characterize them. The results show that the virus of A. pintoi is the same as a virus of Stylosanthes spp. and Arachis hypogaea (common peanut). Similarly, the virus of Centrosema spp. is the same as one occurring in soybeans. Both viruses are already widely distributed in Africa, Southeast Asia and Latin America.

Despite of the minimal quarantine importance of these viruses, the VRU has developed various methods for the detection of viruses in vegetative and sexual planting materials. These are being used to produce clean seeds of germplasm at risk of carrying viruses.

During 1989 two new networks were launched. In May, as part of the consultation exercise of the Program's strategic plan, national research

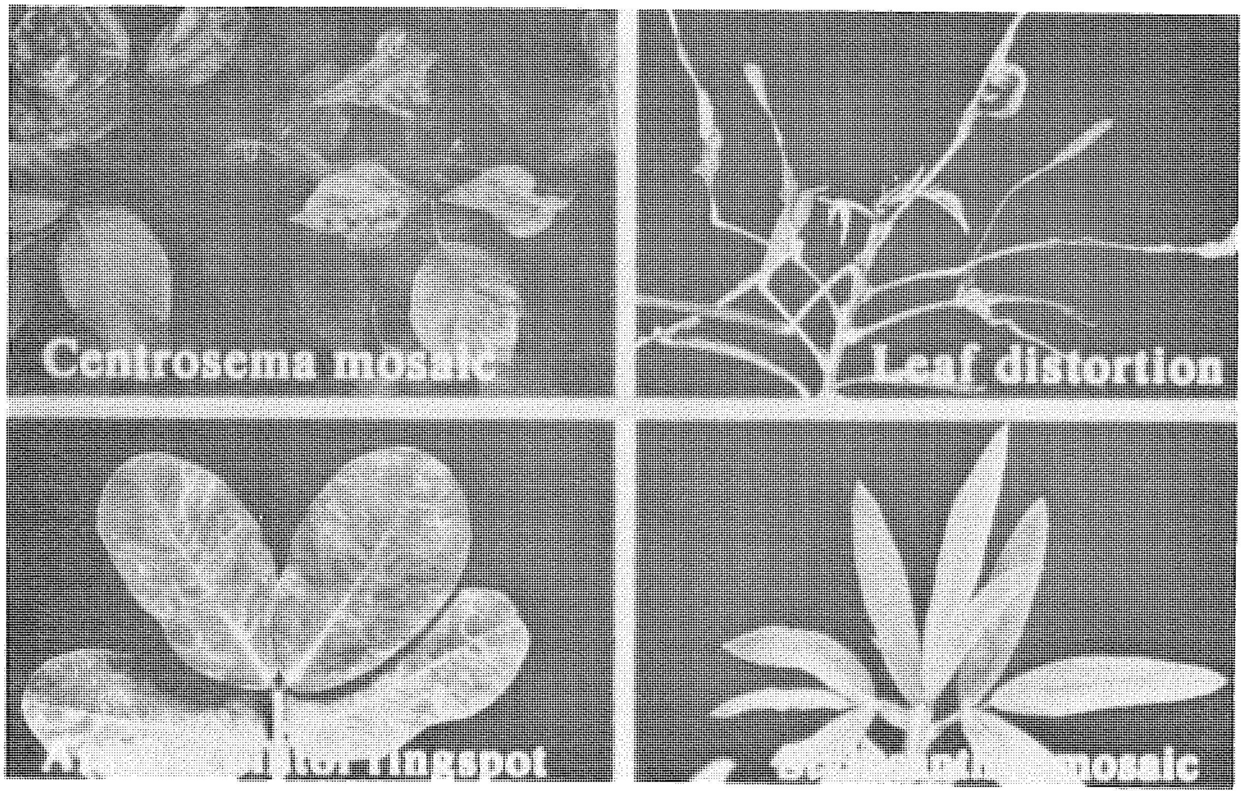


Photo 6. Virus symptoms in Arachis pintoi, Centrosema spp. and Stylosanthes spp.

institution of South East Asia, in association with CIAT and CSIRO, created the South East Asian Forage Research and Development network (SEAFRAD) to undertake a major cooperative forage research work in the region (Photo 7).

The Southeast Asian regional economy is growing rapidly. Per capita incomes are increasing at 1.5 to 2.5% yearly. This, together with the high income elasticity of beef and dairy products, are triggering growth in demand for these products. However, the ruminant animal/human population ratio is only 1/5 that of Tropical America.

On the other hand large areas of predominantly rainforest with acid poor soils in the Philippines, Thailand, South China, Sri Lanka, Malaysia, and Indonesia have been disturbed by shifting cultivation leaving behind large areas of derived *Imperata cylindrica* grasslands and plantation agriculture. The grasses and legumes selected for adaptation to acid poor soils of the subhumid and humid ecosystems of Tropical America have tremendous potential to contribute to SE Asian livestock production through the improvement of the *Imperata* grasslands. We can also develop shade-tolerant grasses and legumes, as well as specific management strategies for integrating pastures with tree plantations.

Early during the 90's the Program plans to outpost one agronomist in SE Asia to screen germplasm and coordinate the Network activities.

Shifting our attention to Africa, desertification of the Sahel is causing an increasing displacement of cattle herds into the subhumid savanna

Photo 7. West and Central African pasture scientists during Togo meeting to organize the West and Central African Feed Resources Network (WCAFRN).

zone. Simultaneously, agriculturist from the more humid zones are also settling in this savanna area. Therefore, this region is under imminent threat of degradation. In November 1989, the West and Central African Feed Resources network, which is a joint project between ILCA, the French IEMVT (CIRAD) and CIAT, was launched for the development of new legume options for the subhumid savannas of the region. The network's steering committee has been selected among national programs, and Dr. Peyre de Fabregue (IEMVT) has been appointed to coordinate the network for the first two years. Dr Fabregue will also be appointed as an associate scientist of both ILCA and CIAT (Photo 8).

Within this strategy of the globalization of CIAT's Pasture Program, the TPP will assume only the role of germplasm development and networking. The associated international institutions such as CSIRO for the Southeast Asian network, and ILCA and IEMVT for the West and Central African network, will fulfill the roles of developing pastures and their utilization for their respective regions.

Final Remarks

Based on the achievements of the 80's in terms of:

- the development of new pasture technology using grasses and legumes adapted to the acid soils regions of Tropical America,

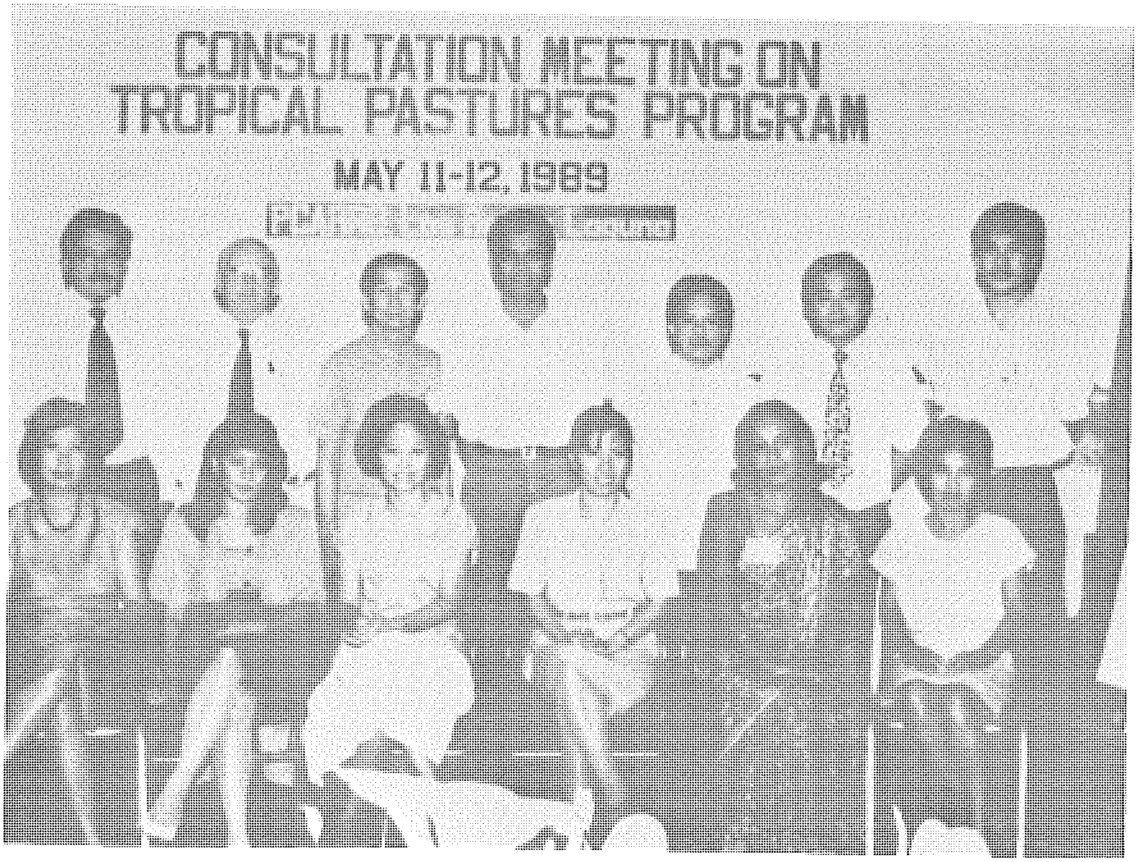


Photo 8. Southeast Asian pasture scientists members of SEAFRAD Network during consultation meeting on the TPP Strategic Plan.

the documentation of the potential contribution of this new pasture technology to animal productivity and soil improvement; as well as

- the initial adoption of these pastures by farmers.

The Program visualizes that the most important challenge of the coming decade is to assure impact!

2. Germplasm

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

COLLECTION OF GERMPLASM

During 1989, collection activities were principally in response to international requests in the form of: (1) a particular search for Centrosema germplasm in Honduras--as a result of one of the recommendations of the International Workshop on Centrosema held in February 1987--, and (2) search for African grass germplasm in Cameroun, particularly Hyparrhenia spp.--as a result of one of the recommendations of the RIEPT Advisory Committee.

Honduras

The collection was done in collaboration with the Secretaría de Recursos Naturales of Honduras and, in the Zamorano area, with the Escuela Agrícola Panamericana. It covered a major portion of the central, northern, western and southern provinces (Figure 1). A total of 417 legume samples was collected, in addition to one grass, Tripsacum andersonii (Table 1). Twenty percent of the legumes correspond to 8 different species of the high-priority genus Centrosema. Other frequently collected genera with a recognized forage potential are Desmodium, Aeschynomene, Stylosanthes, Vigna, Macroptilium, Teramnus, Calopogonium and Galactia, with 17, 8, 8, 7, 6, 5, 5, and 5% of the collected legumes, respectively.

Cameroun

The collection trip was a joint venture with the Institut de Recherches Zootechniques (IRZ) and concentrated on the northern half of the country beyond 4^{o} N (Figure 2). Unfortunately, the second half of September proved to be too early to find ripe seed on most of the species of interest, particularly in the high-priority genus Hyparrhenia. Therefore, more than 2/3 of all collected grasses were collected in the form of vegetative material, i.e. rooted, basal stem segments. That material was then sent to the International Livestock Centre for Africa (ILCA) in Addis Ababa, Ethiopia who had kindly offered to handle the eventual seed multiplication. Altogether 134 samples were collected (Table 2), 84% of which are grasses. Of these, Hyparrhenia (36 samples, = 32% of all grasses), Andropogon (31 samples, = 28%), Brachiaria (15 samples, = 13%), and Panicum (11 samples, = 10%) were the most frequently found genera. Regarding legumes, the most frequently collected genus was Desmodium.

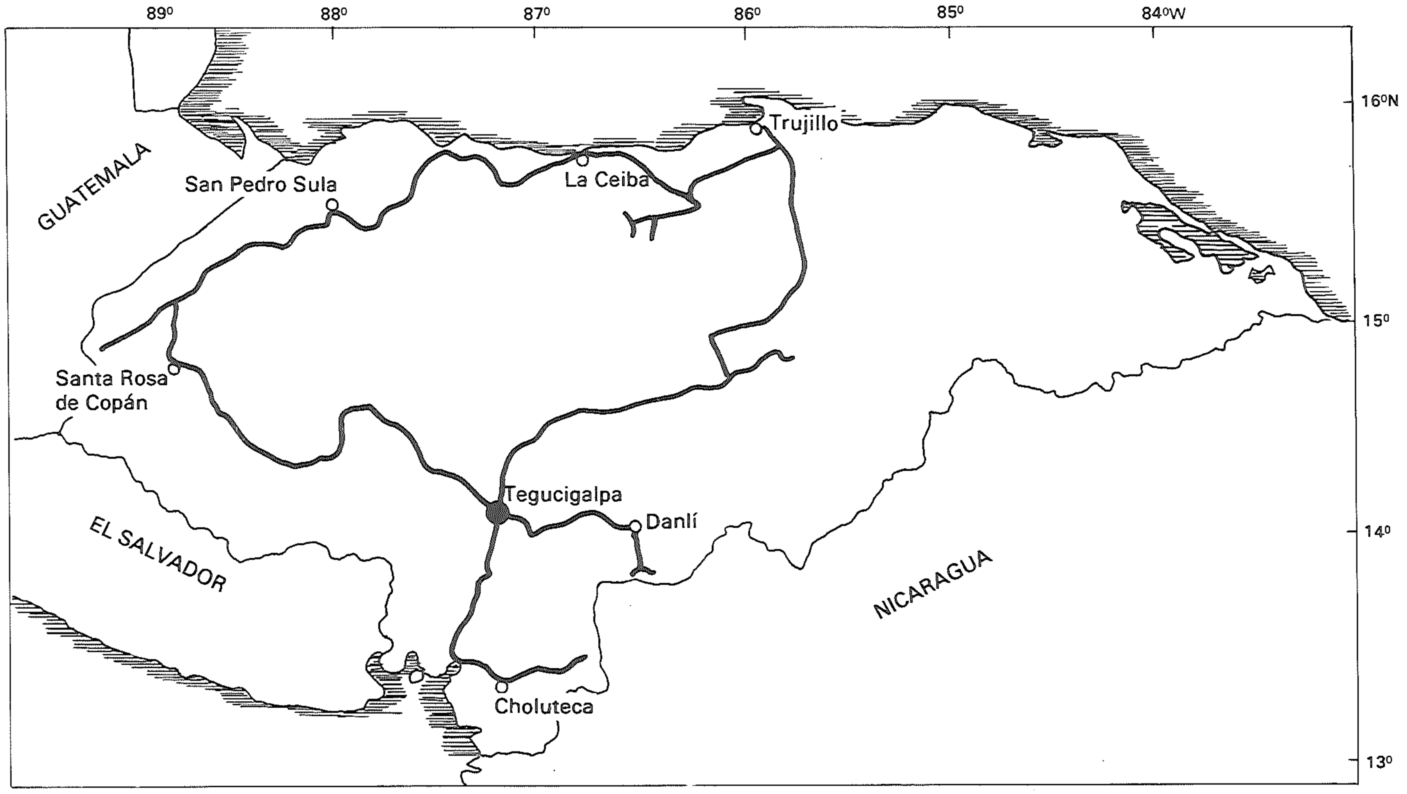


Figure 1. Routes of systematic collection of tropical forage legume germplasm in Honduras, February 1989 (Secretaría RR.NN. - CIAT - EAP).

Table 1. Summary of tropical forage legume germplasm collected in Honduras; February 1989 (Secretaría RR.NN. - CIAT - EAP).

Species of particular interest	No. of Samples	Other species	No. of Samples
Centrosema angustifolium	2	*Aeschynomene* spp.	39
Centrosema macrocarpum	10	*Calopogonium* spp.	21
Centrosema plumieri	12	*Canavalia* spp.	8
Centrosema pubescens	32	*Desmanthus* spp.	7
Centrosema sagittatum	10	*Desmodium* spp.	69
Centrosema schiedeanum	12	*Galactia* spp.	20
Centrosema schottii	1	*Macroptilium* spp.	24
Centrosema virginianum	3	*Phaseolus* spp.	11
		Rhynchosia spp.	16
Total *Centrosema*	82	*Stylosanthes* spp.	35
		Teramnus spp.	22
Shrubs:		*Vigna* spp.	28
Calliandra spp.	10	*Zornia* spp.	9
Erythrina spp.	1	Other genera*	14
Leucaena spp.	2		
Total shrubs	13	Total	323

* *Pachyrhizus* (3), *Alysicarpus* (2), *Chamaecrista* (2), *Pueraria* (natural.) (2), *Dioclea* (1), *Crotalaria* (1), *Flemingia* (natural.) (1), *Indigofera* (1), grass *Tripsacum* (1).

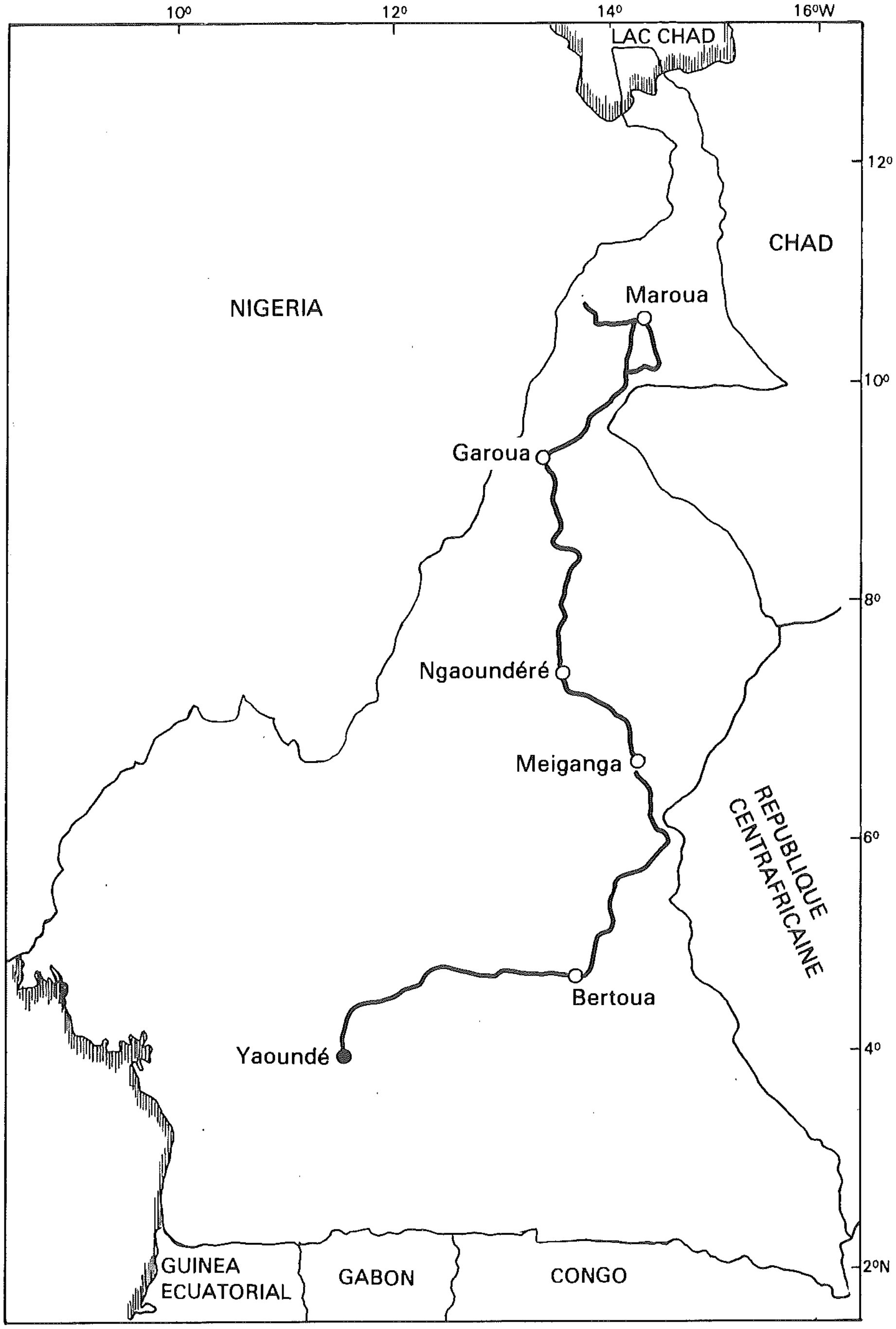


Figure 2. Routes of systematic collection of tropical forage germplasm in Cameroun, September 1989 (IRZ-CIAT).

Table 2. Summary of tropical forage germplasm collected in Cameroun; September 1989 (IRZ - CIAT).

Grasses	No. of Samples	Legumes	No. of Samples
Andropogon gayanus	22	*Aeschynomene indica*	1
Andropogon spp.	9	*Alysicarpus* sp.	1
Axonopus compressus	1	*Desmodium ramosissimum*	4
Brachiaria brizantha	13	*Desmodium setigerum*	1
Brachiaria jubata	2	*Desmodium velutinum*	3
Chloris spp.	4	*Eriosema* sp.	1
Digitaria diagonalis	1	*Flemingia macrophylla*	1
Echinochloa spp.	4	*Pseudarthria hookeri*	1
Hyparrhenia bracteata	2	*Rhynchosia minima*	1
Hyparrhenia diplandra	7	*Sesbania sesban*	1
Hyparrhenia dissoluta	1	*Stylosanthes fruticosa*	2
Hyparrhenia filipendula	6	*Teramnus* sp.	1
Hyparrhenia rufa	5	*Vigna* sp.	1
Hyparrhenia weltwitschii	3	*Zornia glochidiata*	3
Hyparrhenia sp.	12		
Loudetia spp.	2		
Panicum spp.	11		
Paspalum scrobiculatum	2		
Pennisetum spp.	2		
Setaria spp.	3		
Total samples	112	Total samples	22

Other collections

Another important, though minor, collection was done on 4 November 1989 in Togo, on the occasion of the initiation workshop of the West and Central African Animal Feed Resources Network held at Avetonou. During an improvised excursion with the participation of scientists from the Ecole Supérieure d'Agronomie/Université du Bénin (Togo), IEMVT and CIAT, a total of 31 germplasm samples were collected along the Kpalime - Atakpame transect (Table 3). Also here it was still too early to find ripe seeds for many grasses and legumes. The high proportion of legumes in the native vegetation -- which is also reflected in Table 3 -- is particularly noteworthy.

MULTIPLICATION AND MAINTENANCE

As in previous years, the multiplication of legume and grass germplasm of particular interest to the Tropical Pastures Program was also in 1989 an important service function of the Germplasm section. The seed multiplication activities consisted essentially of:

- Germplasm multiplication from potted plants in the Palmira greenhouse and/or from single plants of small, space-planted plots in specific germplasm multiplication areas at CIAT-Palmira and CIAT-Quilichao, including the grass collections of Brachiaria spp. (500 accessions), Panicum maximum (440 accessions) and Hyparrhenia spp. (30 accessions): approximately 1620 accessions.

- Initial seed increase of all germplasm under preliminary evaluation at CIAT-Quilichao: approximately 700 accessions.

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

CHARACTERIZATION AND PRELIMINARY EVALUATION

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

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

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

Dioclea guianensis

A collection of Dioclea guianensis was exposed to common grazing by young

Table 3. Summary of tropical forage germplasm collected in Togo on 4 November 1989 (ESA - IEMVT - CIAT).

Grasses	No. of Samples	Legumes	No. of Samples
Andropogon gayanus	2	Alysicarpus ovalifolius	1
Brachiaria jubata	1	Alysicarpus sp.	1
Chloris gayana	1	Caesalpinia (?) sp.	1
Digitaria polybothra	1	Chamaecrista rotundifolia	2
Hyparrhenia diplandra	1	Desmodium gangeticum	1
Hyparrhenia rufa	1	Desmodium ramosissimum	1
Hyparrhenia sp.	2	Desmodium velutinum	3
Paspalum scrobiculatum	1	Desmodium sp.	1
		Indigofera hirsuta	1
		Sesbania sesban	1
		Stylosanthes fruticosa	3
		Vigna sp.	2
		Zornia glochidiata	2
		Zornia sp.	1
Total samples	10	Total samples	21

Zebu steers in order to assess during a 1-week observation period the relative palatability of the 101 accessions that had survived after 2 years of preliminary agronomic evaluation under cutting. According to the results (Figure 3), there is some interesting variation in this species which is known to be of low palatability. Particularly the accessions in the 3 groups with a palatability index higher than 3.0, merit attention for further studies. They are accessions CIAT 18122 and 19051; CIAT 19053, 19060, 19061, 19063 and 19069; and CIAT 19062, respectively.

Centrosema brasilianum

In 1989, the preliminary evaluation of a 112-accession collection of new Centrosema brasilianum germplasm concluded and data are, at present, being analyzed. In Figure 4, the frequency distribution for seed production, a particularly important plant character, is presented. Four groups, comprising a total of 10% of the collection, stand out with seed yields higher than 250 g/8 plants. The respective accessions, whose high seed production potential under Quilichao conditions coincides with tolerance to Rhizoctonia Foliar Blight, merit attention for further evaluations; they are: CIAT 15286, 15890 and 25040; CIAT 15273, 15398, 15405 and 15819; CIAT 15387 and 15824; and CIAT 15385.

Desmodium strigillosum

This Southeast Asian species has, together with D. velutinum and Flemingia macrophylla, attracted attention in Carimagua experiments because of its potential to improve the native-savanna diet of grazing animals (see Agronomy Llanos report, this volume). In order to assess the variation in CIAT's small D. strigillosum germplasm collection, a

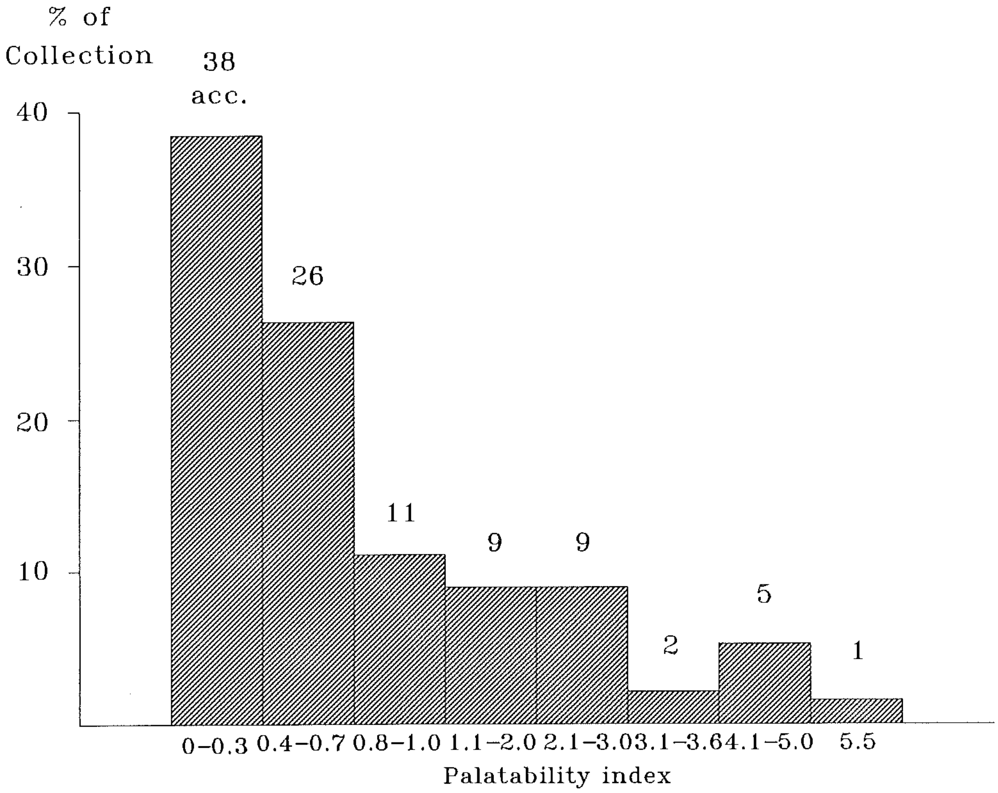
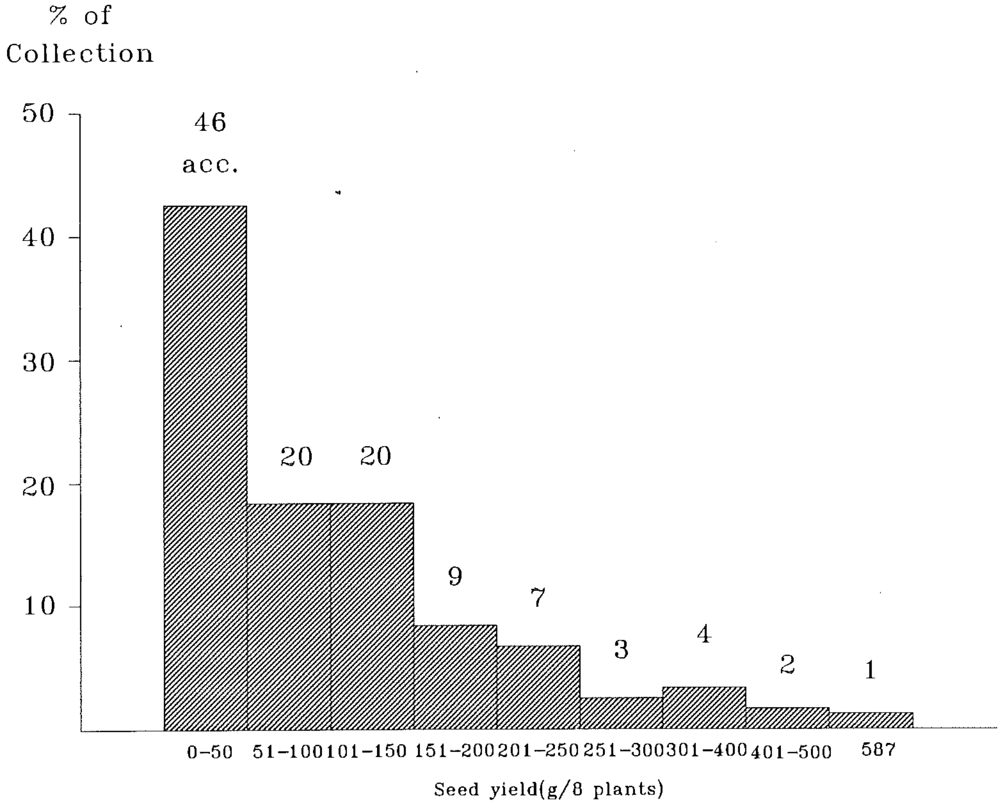


Figure 3. Classification of a *Dioclea guianensis* collection (101 accessions) into 8 palatability groups (Quilichao 1989).



igure 4. Classification of a *Centrosema brasilianum* collection (112 accessions) into 9 seed-yield groups (cumulative yields of 8 plants during a 9-month harvesting-period with 2 passes/week; Quilichao 1988/89).

preliminary agronomic evaluation of the available 10 accessions, together with D. heterocarpon CIAT 13189 as control accession, is being conducted at Quilichao. Results produced to date indicate a moderate degree of variability (Table 4).

Flemingia macrophylla

Preliminary results from an evaluation trial with 28 accessions representing new germplasm of this Southeast Asian leguminous shrub show that also this species is well adapted to the Quilichao environment and that the collection contains useful variation (Table 5). It is interesting to note that the highest yielding accessions also have the highest number of basal branches.

Desmodium velutinum

This species is less adapted to the Quilichao soil conditions and yields of the 44 accessions comprised in a new collection that is presently being studied, are low (Figure 5). Nevertheless, the collection appears to contain useful variation. The accessions in the four highest-yielding groups merit further attention; they are CIAT 23920, 23980 and 23981; CIAT 23966; CIAT 23982; and CIAT 23990, respectively.

Codariocalyx gyroides

Codariocalyx gyroides is a Southeast Asian fodder shrub of which CIAT has built up a significant collection of germplasm originating from tropical China, Thailand, Papua New Guinea and Indonesia (Sumatra). This collection, with CIAT 3001 as control accession, is presently being evaluated. Preliminary results indicate useful variation also in this species (Table 6).

Cratylia argentea (syn. C. floribunda)

This is a twining shrub from Central Brazil which has proved to be well adapted to the Quilichao soil. So far only 11 germplasm accessions are available. According to preliminary results (Table 7), this small collection is quite variable, CIAT 18668 being a particularly outstanding accession. The high protein content in all accessions is noteworthy.

Calopogonium mucunoides

In response to the particular interest of EMBRAPA-CPAC colleages in this species -- because of its proven potential for "Cerrados" conditions with somewhat higher soil fertility --, a collection of 223 Calopogonium mucunoides accessions has recently been established. Among the first data available is the percentage of soil cover three months after transplanting the collection into the field (Figure 6). As can be expected with a collection of this size, there is considerable variation among accessions.

Leguminous shrubs and trees

In order to compare the potential of a series of partly well-known and partly unknown, forage shrubs and trees on two contrasting soils, a preliminary-evaluation experiment was established in CIAT-Quilichao (Ultisol; pH 4.0, P 5.3 ppm; Al 5.5 me) and in CIAT-Palmira (Vertisol; pH 7.7, P 84.6 ppm, no Al). The following germplasm was used: Acacia angustissima and A. tortuosa, Albizia lebbeck, Cajanus cajan, Calliandra calothyrsus and C. grandiflora, Clitoria fairchildiana, Codariocalyx gyroides, Cratylia argentea, Dendrolobium sp. and D. umbellatum, Desmodium velutinum (2 accessions), Erythrina fusca and E. poeppigiana, Flemingia macrophylla, Gliricidia sepium, Leucaena diversifolia and L. leucocephala,

Table 4. Preliminary agronomic evaluation of a collection of *Desmodium strigillosum* (Quilichao 1988/89).

CIAT No.	Total DM production in 5 cuts (g/plant)	Total seed production in 9 mo (g/8 plants)	CP content in leaves[1] (%)	P content in leaves[1] (%)	Ca content in leaves[1] (%)
23724	352.3 a	249.5	20.5	0.20	0.36
13661	324.1 ab	278.8	19.4	0.17	0.32
13149	313.2 ab	229.8	20.3	0.18	0.29
13156	302.8 ab	310.6	19.1	0.15	0.33
13155	249.9 ab	313.2	18.7	0.14	0.26
13158	239.2 ab	175.8	21.7	0.19	0.35
13153	224.3 b	265.5	19.4	0.18	0.36
23723	207.8 bc	112.4	19.2	0.16	0.27
13159	206.2 bc	279.9	20.3	0.18	0.27
13386	85.5 cd	16.4	21.5	0.17	0.54
13189	26.5 d	17.4	22.2	0.19	0.52

a, b, c, d = significant differences at P = 0.05.
1/ 3-month old regrowth.

Table 5. Preliminary agronomic evaluation of a collection of _Flemingia macrophylla_ (Quilichao 1988/89).

CIAT No.	Total DM production in 4 cuts (g/plant)	Total seed production in 10 mo (g/8 plants)	No. of basal branches/plant[1]	CP content in leaves[2] (%)
17405	263	107	22.1	20.5
17412	257	132	20.0	21.0
17400	229	107	20.5	22.3
17411	226	85	19.6	22.1
17404	214	167	15.4	21.2
19798	213	17	13.2	22.1
17403	204	72	15.9	20.1
17407	201	120	19.8	20.5
20631	191	294	15.5	21.0
20625	186	118	15.5	21.2
21241	177	429	15.4	21.5
19454	165	383	13.1	20.6
801	162	173	16.2	20.3
7184	151	225	13.1	22.6
17413	145	182	15.0	17.9
19457	145	262	13.2	21.5
20744	142	77	16.5	21.5
21249	140	153	19.4	20.8
20626	135	294	15.6	21.2
19799	130	39	13.1	19.3
20624	119	29	12.6	18.2
19824	118	67	15.0	19.1
19453	114	95	16.7	21.9
20623	105	40	12.3	19.6
20618	94	129	14.8	19.4
18438	83	1	15.6	22.8
21248	68	29	13.2	20.7
20617	41	90	10.7	18.0

1/ Between soil surface and 10 cm cutting height.
2/ 3-month old regrowth.

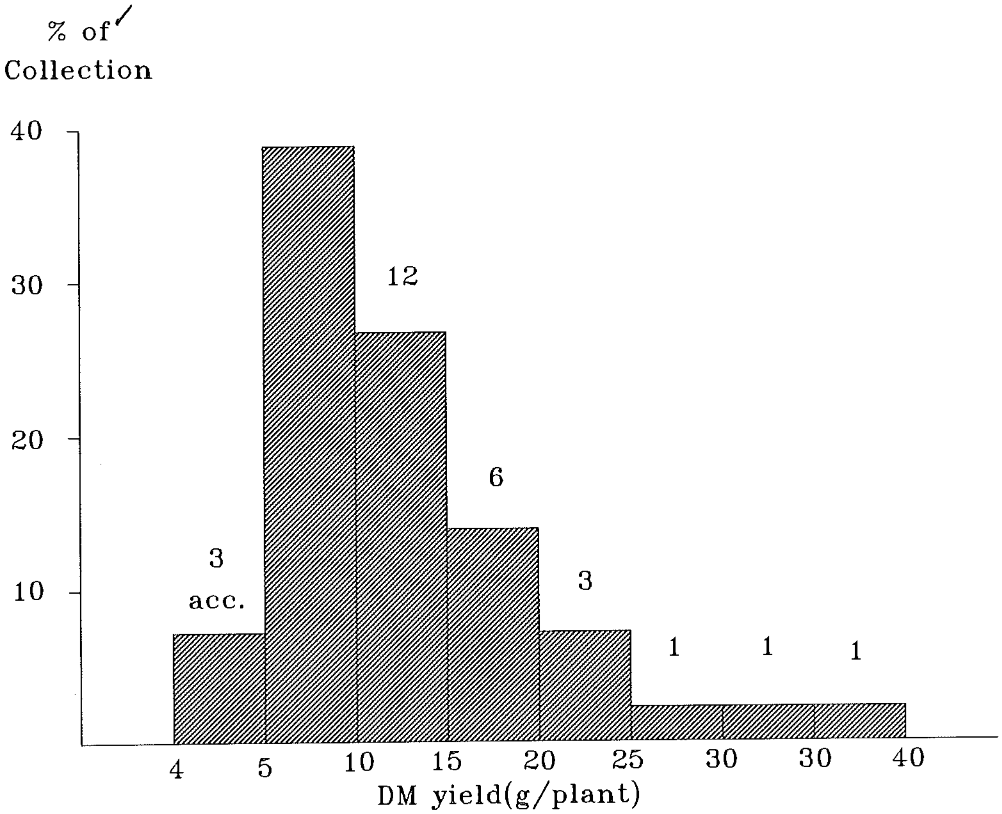


Figure 5. Classification of a Desmodium velutinum collection (44 accessions into 8 DM-yield groups (cumulative yields of 2 cuts of 3-month regrowth; Quilichao 1988/89).

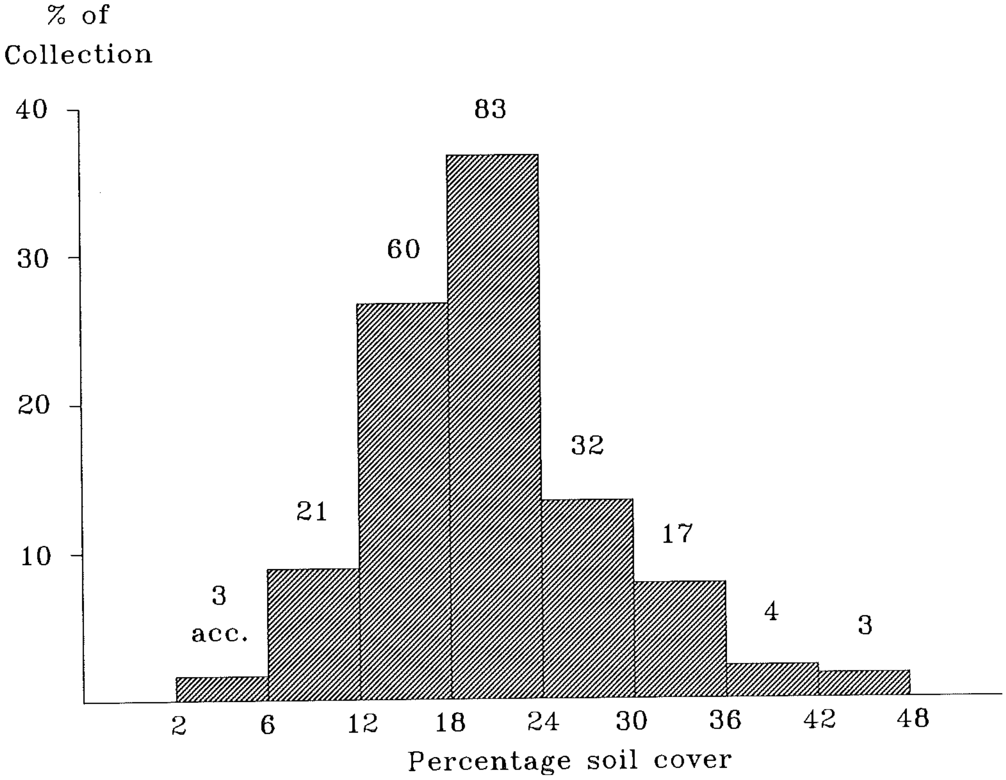


Figure 6. Classification of a Calopogonium mucunoides collection (223 accessions) into 8 groups of soil-cover percentage (measured 3 months after transplanting to the field; Quilichao 1989).

Table 6. Preliminary agronomic evaluation of a collection of Codariocalyx gyroides (Quilichao 1988/89).

CIAT No.	Total DM production in 3 cuts (g/plant)	Total seed production in 11 mo (g/8 plants)	No. of basal branches/plant[1]	CP content in leaves[2] (%)
33134	336.2	471.1	61.3	21.9
13980	323.2	242.2	82.2	19.3
33131	247.8	331.4	51.5	20.3
13547	209.5	295.2	57.9	19.3
23748	199.0	173.0	38.9	21.4
13979	192.5	152.4	65.9	19.4
13984	186.6	141.7	77.2	18.8
3001	184.0	707.0	44.5	20.8
13548	177.4	19.5	66.2	20.3
23747	162.4	498.9	54.7	19.8
23742	161.1	517.2	38.9	20.6
23745	157.5	255.0	41.3	22.3
23746	143.2	328.5	56.7	23.8
23740	142.4	469.0	40.5	21.4
23744	141.9	432.7	45.4	21.0
13985	141.0	19.0	35.3	20.1
23741	126.8	616.0	46.8	19.8
23736	124.0	272.0	30.6	20.3
33133	102.7	971.6	44.7	22.1
13986	100.5	432.6	43.4	19.6
23743	95.6	236.2	32.8	20.3
13982	59.8	173.9	40.6	19.4
13983	56.2	133.3	39.6	17.7
13395	2.4	29.3	23.5	20.1

1/ Between soil surface and 10 cm cutting height.
2/ 3-month old regrowth.

Table 7. Preliminary agronomic evaluation of a collection of *Cratylia argentea* (syn. *C. floribunda*) (Quilichao 1988/89).

CIAT No.	Total DM production in 2 cuts (g/plant)	Total seed production in 7 mo (g/8 plants)	No. of basal branches/plant^1	CP content in leaves^2 (%)
18668	543.9 a	1161	17.8 a	32.8
18675	386.0 ab	0	11.1 b	25.9
18676	366.4 ab	477	10.8 b	29.8
18957	320.5 ab	67	10.8 b	29.4
18671	298.7 ab	1129	11.3 b	32.8
18674	275.3 ab	688	12.4 b	27.1
18672	272.7 ab	764	10.8 b	30.1
18673	217.3 b	360	9.8 b	23.6
18666	207.7 b	422	8.1 b	32.8
18516	195.8 b	61	8.8 b	29.4
18667	170.0 b	14	9.5 b	31.7

a, b = significant differences at $P = 0.05$.

1/ Between soil surface and 30 cm cutting height.

2/ 3-month old regrowth.

Phyllodium longipes and P. pulchellum, and Sesbania sesban (2 accessions). According to preliminary results obtained at the end of the second 1989 dry season, Cratylia floribunda, Flemingia macrophylla, and Calliandra grandiflora are best-adapted to the Quilichao soil.

At CIAT-Palmira, Clitoria fairchildiana Codariocalyx gyroides, Phyllodium pulchellum and Erythrina fusca have serious adaptation problems, presumably because of soil-salinity intolerance.

DOCUMENTATION

An important achievement during 1989 was the conclusion and production of a 322-page world catalog of Centrosema germplasm. This catalog is based on the collections held at CIAT, CSIRO, EMBRAPA-CENARGEN, ILCA and University of Florida-AREC Fort Pierce, and its publication is co-sponsored by IBPGR.

3. Plant Breeding

INTRODUCTION AND HIGHLIGHTS

The objectives of the Plant Breeding Section continue to be to create, through directed genetic modification, improved genotypes of a limited number of key pasture plant species.

A considerable shift in the Section's activities came this year with a closing out of activities at the CIAT-Quilichao station and a corresponding expansion and consolidation of field research activities at Carimagua.

A major breeding project in *Stylosanthes guianensis* has yielded materials which are now being compared with a standard check accession in a large grazing trial at Carimagua. It is anticipated that continued cycles of recurrent selection will further improve disease and insect resistance and seed yield, though the proportion of the Section's resources devoted to this species is declining.

A more modest selection project has reduced plant height in *Andropogon gayanus*. In spite of difficulties in the establishment of half-sib progenies this year at Carimagua, we hope to identify progenies sufficiently uniform for incorporation into a synthetic variety for testing under grazing.

Fifty progenies from an interspecific *Centrosema* cross are under testing this year in collaboration with the Plant Pathology Section to assess the potential of developing Rhizoctonia resistance in *C. brasilianum*. F1 hybrids between *C. acutifolium* cv. 'Vichada' and a Brazilian accession have been obtained with the aim of solving several deficiencies in the commercial cultivar, including disease susceptibility and unreliable seed production.

The inheritance of an artificially induced, non-nitrogen-fixing seedling marker in *S. guianensis* is being studied in a range of genetic backgrounds and the marker is being incorporated into breeding populations.

A growing breeding initiative is developing in the important grass genus *Brachiaria*. Experimental interspecific hybrids have been confirmed by analysis of isozyme banding patterns. The first of these experimental hybrids have been established in the field at Carimagua. These, along with newer hybrids, will provide the opportunity for detailed studies of the inheritance of mode of reproduction in *Brachiaria*.

BREEDING PROJECTS

Stylosanthes guianensis

Diallel crosses

An original diallel series of crosses, which was initiated in 1981, was advanced by pedigree, by bulk advance, and by natural selection under grazing. Two lines resulting from pedigree selection and a bulk of progenies from plants surviving four years' natural selection under grazing have been included in a large grazing trial established this year at Carimagua in collaboration with the Agronomy Section. This trial is designed to assess several factors simultaneously: 1. The persistence and productivity of the three experimental S. guianensis genotypes resulting from the hybridization program will be compared with that of a standard, anthracnose- and stem-borer-resistant germplasm accession of S. guianensis var. pauciflora, CIAT 10136, with two different companion grasses, B. dictyoneura and B. decumbens. 2. The effect of S. guianensis on animal live weight gain will be assessed, separately for each of the two Brachiarias. 3. The persistence and productivity under grazing and animal performance of S. guianensis var. pauciflora will be compared with that of S. capitata cv. 'capica'. Establishment of this 10-ha trial was excellent for the legumes and satisfactory for the two grasses. We anticipate the initiation of grazing treatments by the onset of the 1990 rainy season.

The establishment of this grazing trial is something of a milestone for the Section as it marks the end of the first cycle of pedigree selection on the first set of S. guianensis hybrids.

Natural selection. S. guianensis still persists in the natural selection paddocks and grazing, which was initiated in 1985, continues. However, it seems likely that it will be more productive to initiate a second cycle of natural selection than to continue the first cycle indefinitely.

Bulk advance. One additional cycle of bulk advance was conducted during 1988-89. During 1990 we intend to develop a series of selfed lines from these bulk populations so as to assess the effects of this line of breeding.

Recurrent selection
We anticipate that additional cycles of selection and recombination will improve the survival of S. guianensis var. vulgaris by enhancing disease and pest resistance and will increase seed yield potential in S. guianensis var. pauciflora. However, given that the selection cycle requires three to four years, rapid gains cannot be expected. Since recurrent selection is becoming a routine procedure, future progress will require a smaller proportion of the Section's resources than the S. guianensis breeding work has over the past eight years, permitting increasing attention being devoted to the improvement of other species.

A large S. guianensis var. pauciflora crossing block was established at Carimagua this year and a set of 256 S1 progenies planted for field evaluation at Carimagua.

Andropogon gayanus

Short stature population
We experienced considerable difficulty this year in getting half-sib progenies from the short stature A. gayanus population established at Carimagua due to poor germination and seedling growth. The problem appears to be related to some factor in the Carimagua glasshouse environment as the same seed germinates well at CIAT-Palmira. We were able to obtain approx. 2,000 seedlings for transplant to a field trial, but these are a very unbalanced set of the 100 families from selected parental clones. We ought, nevertheless, on the basis of the attributes of these plants, to be able to identify uniform progenies with the desirable characteristics of short stature, high yield, and high leaf:stem ratio for inclusion in a short-stature synthetic variety for larger scale testing under grazing.

Late flowering population

The first data on yield, earliness to flower, and leaf:stem ratio have been obtained from half-sib progenies produced from late-flowering clones selected by Dr. B. Grof. The late-flowering progenies are, indeed, demonstrably later than the standard check CIAT 621, and yield more (Table 1). However, on the particular harvest date no difference in leaf:stem ratio was detected (Table 1).

Further data on these progenies, both from Carimagua and Quilichao, ought to clarify the characteristics of these selected materials and permit the selection of a small number of materials for the formation of a late-flowering synthetic variety for large scale testing under grazing.

OTHER STUDIES

S. guianensis

Crosses between two F2-derived, non-nitrogen-fixing mutant lines have been made to determine whether one or two independent mutants have been obtained.

We are also studying the inheritance of the non-nitrogen-fixing mutant in a diversity of genetic backgrounds. Fourteen F1 hybrids have been obtained, involving both F2-derived mutants and five germplasm accessions, (Table 2) and small quantities of F2 seed have already been harvested from several of these hybrids. Screening of F2 populations will commence in 1990.

Anticipating that the marker will segregate qualitatively independently of the background genotype, we have commenced incorporation of the marker into S. guianensis breeding populations which are undergoing recurrent selection. A reliable seedling marker in these populations will significantly improve the efficiency of the recurrent selection scheme relying on low level natural outcrossing to achieve genetic recombination as has been outlined in previous annual reports.

Table 1. Yield, earliness, and leafiness of 23 late-flowering Andropogon gayanus half-sib families or CIAT 621[A].

	D.M. Yield	Days to flower[A]	Proportion leaf
	- g -		
Late flowering selections	7010.4***	47.3***	0.647
CIAT 621	4006.7	11.8	0.634

[A] Data from a single harvest period at one location.

[B] Days from 01 April 1989.

*** Selections differ from CIAT 621 ($P < 0.001$).

Centrosema

Centrosema brasilianum

A sample of 50 F3 progenies from interspecific crosses between C. brasilianum and C. tetragonolobum are being evaluated in a field trial at Carimagua under the direct supervision of the Plant Pathology Section. We will be particularly interested in assessing the potential of this cross to incorporate field resistance to Rhizoctonia foliar blight in C. brasilianum.

C. acutifolium

Six F1 plants have been obtained from a cross between a Brazilian accession (CIAT 5568) and C. acutifolium cv. 'Vichada'. This cross holds tremendous promise in solving a series of disease problems in C. acutifolium, particularly susceptibility of cv. Vichada to "Factor X", to Cylindrocladium leaf spot, and to bacteriosis, as CIAT 5568 is resistant to all three diseases. It is anticipated that early generation, disease resistant selections will be crossed to early and high seed producing genotypes of C. pubescens to develop superior Centrosema cultivars.

Brachiaria spp.

More than 800 putative hybrid plants have been produced. We have electrophoretic confirmation of the hybrid nature of many of these (Fig. 1).

We hope, during the coming year to obtain data on the inheritance of mode of reproduction in the B. decumbens/B. brizantha/B. ruziziensis species complex.

Table 2. Fl hybrids obtained with Stylosanthes guianensis non-nitrogen-fixing mutant lines.

Female	x Male	Botanical var. of normal parent
CIAT 10136	x 172-8	var. pauciflora
CIAT 02031	x 172-8	var. pauciflora
172-8	x CIAT 10136	var. pauciflora
172-2	x CIAT 01639	var. vulgaris
173-8	x CIAT 01539	var. vulgaris
172-3	x CIAT 01539	var. vulgaris
CIAT 10136	x 172-3	var. pauciflora
172-8	x CIAT 01539	var. vulgaris
CIAT 10136	x 173-8	var. pauciflora
CIAT 02031	x 172-14	var. pauciflora
172-2	x CIAT 01539	var. vulgaris
172-3	x CIAT 00184	var. vulgaris

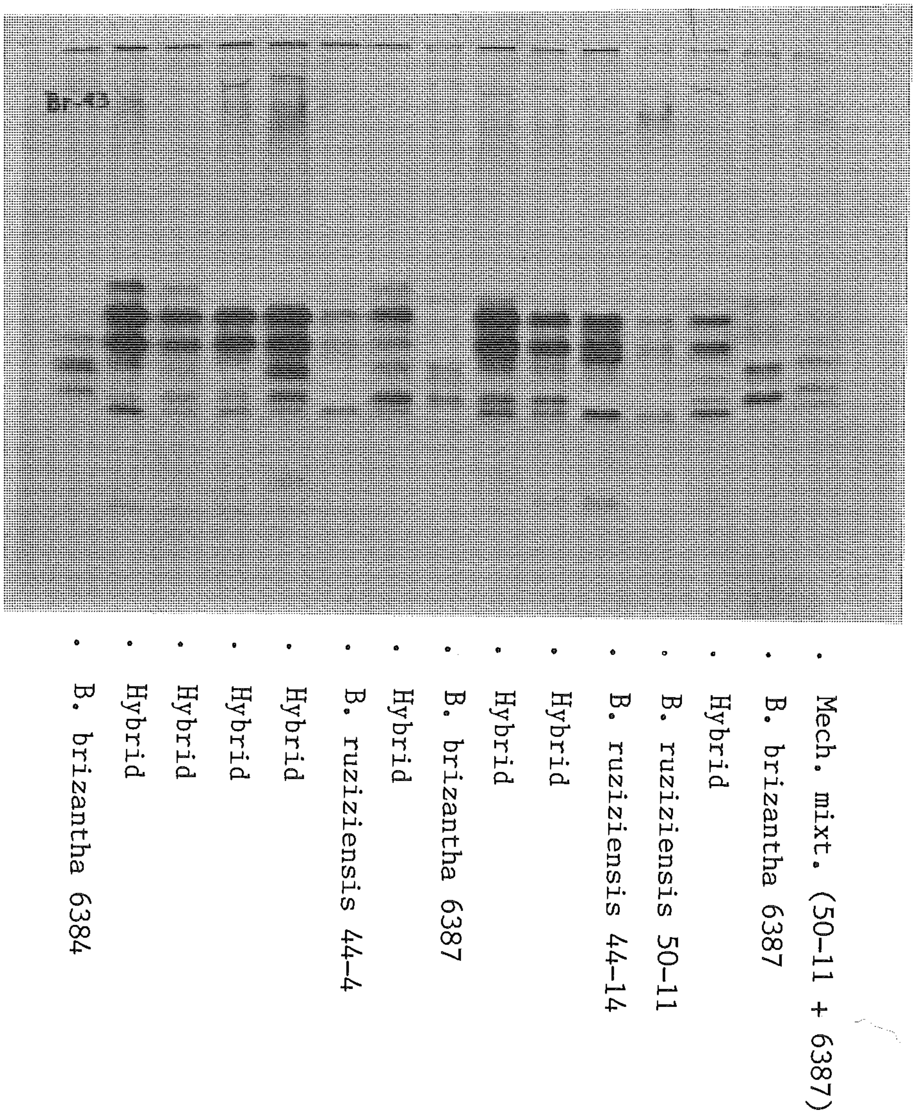


Figure 1. Alpha-beta esterase banding pattern of 15 Brachiaria genotypes, including parentals and interspecific hybrids.

4. Plant Pathology

INTRODUCTION

The objectives of the section in 1989 continued to be:

1) Diagnosis of diseases of tropical pasture germplasm.

2) Assessment of the importance and potential importance of detected diseases.

3) Development of control strategies for diseases.

With the help of ICA efforts continued and were reinforced to prescreen new germplasm to avoid introduction of diseases, and to minimize chances of shipping diseases internationally. In addition, due to current program emphasis, priority research time was allocated to diseases of Centrosema. Work also continued on diseases of the genera Stylosanthes, Desmodium, Arachis and Brachiaria.

Centrosema

Investigation continued on Rhizoctonia Foliar Blight (RFB) of C. brasilianum, Wilt syndrome (factor x) and bacterial blight of C. acutifolium, Die-back of C. macrocarpum, and through the VRU on the characterization of the Centrosema viruses.

a) Rhizoctonia Foliar Blight of C. brasilianum

Glasshouse studies:
Inoculations of 192 ecotypes of C. brasilianum individually with isolates of R. solani AG1 and AG4 as well as a binucleate Rhizoctonia sp. resulted in large variation of the reaction of controls CIAT 5234. Thus comparisons between ecotypes could not be made with confidence. Research is continuing to achieve consistancy in reaction of inoculations in known materials before evaluating more materials.

Field Studies:
Low RFB pressure due to lack of rain prevented adequate comparison between glasshouse evaluation methodology and the field. Trials have now been sown in two locations, Quilichao and Carimagua, to compare not only host reactions between glasshouse and the field, but also between locations.

b) Wilt Syndrome of C. acutifolium

Wilt of C. acutifolium cv vichada (5277), previously described as die-back syndrome or factor x continued to be a serious problem in seed production plots in the Llanos and Valle of Colombia and was found also for the first time in Bahia, Brazil.

Last year, isolations from infected plants yielded various potential pathogens, including Fusarium, Curvularia, Phoma and Meloidogyne arenaria. Fusarium was able to cause a wilt only after wounding. The other fungi proved non pathogenic. In addition, the problem was found predominantly in staked plants, rather than unstaked ones. Similarly, wilt syndrome has not been observed in pasture. Hence, physiological or physical stress associated with staking plants was suggested as a possible cause.

Research to determine if the cause is microbiological continued this year. A trial, installed by the germplasm section, to evaluate *C. acutifolium* Orinoco type for resistance is being monitored for wilt syndrome. After six months wilt syndrome has now been observed on all *C. acutifolium* Orinoco type germplasm tested except 15812 (Table 1). The Brazilian type *C. acutifolium* has so far been totally resistant.

The results of the in depth evaluation per plant in the germplasm plot are shown in Table 2. No single parameter evaluated correlated well to the development of wilt, with the possible exception of stem lesions. Weekly applications of the fungicide did not reduce wilting at the time this report was written. Various fungi were isolated from stem lesions, including *C.gloeosporioides*, *Phoma* sp., *Phomopsis* sp., *Dreschlera* sp., *Curvularia* sp., and *Fusarium* spp. Pathogenicity test of these fungi have not been completed. However, it is interesting that similar organisms were isolated from wilt affected plant at other sites in previous years. In previous tests these fungi were not pathogenic, with the exception of *Fusarium*, which infected through wounded tissue (CIAT Ann Rep 1988). Roots of plants with varying degrees of wilt syndrome in Villarica have sofar all yielded *Meloidogyne* sp., *Fusarium* spp., and *Rhizoctonia solani*. Evaluation of seed used in lots affected by Wilt syndrome yielded mainly bacteria, few of these fluorescent Pseudomonas, and fewer fungi, including *Fusarium* and *C. gloeosporioides*. If the problem is indeed caused by microorganisms then it is probably caused by root pathogens. In this case, the widespread nature of the problem in areas never cultivated with *Centrosema* spp. is unusual.

At this stage it is important that other possible causes such as soil type, physiological stress from staking, and soil moisture conditions also be investigated.

c) Wilt of *C.macrocarpum*

Pathogenicity tests with *C. gloeosporioides* from *C. macrocarpum* affected with a wilt, possibly related to the Wilt syndrome of *C. acutifolium* cv vichada, were inoculated on *C. macrocarpum*, *C. acutifolium* cv vichada (5277) and *C. acutifolium* (5568). The latter is known not to suffer from Wilt syndrome. Three out of six *C. acutifolium* 5277 plants wilted. No other plants of *C. acutifolium* 5568, *C. macrocarpum* 152246 or the controls wilted. Stem lesions were observed at an early stage on *C. acutifolium* 5277, and *C. macrocarpum*. At flowering stem lesions were observed on some plants of all accessions. However, wilt symptoms observed from *C. gloeosporioides* infections caused a yellowing then a turgor loss in leaves and death. This differs from Wilt syndrome affected *C. acutifolium* where wilt occurs rapidly, the plant collapses without a previous yellowing of leaves.

d) Bacterial Blight

Bacterial blight, caused by *Pseudomonas fluorescens* Biotype II, is a serious problem in seed multiplications of especially *C. acutifolium* cv vichada, and in plots sown with infected seed. As a control measure the use of strategic foliar applications of chemicals was reported in 1988. Bravo 500 + Kocide 101 was the best overall treatment in Quilichao where it significantly ($P = 0.05$) reduced both foliar bacterial blight,and seed borne fluorescent Pseudomonas, and significantly ($P = 0.05$) increased yield.

Table 1. Wilt syndrome severity of accessions of *C. acutifolium* Orinoco type after 6 months in Villarica (Cauca), Colombia.

Accession	% Wilting or wilted after 6 months	Accession	% Wilted after 6 months
5277	25	15814	7
5278	4	15815	7
5568*	0	15816	1
15084	15	15445	7
15086	1	15446	16
15088	6	15447	5
15812	0	15448	2
15813	11		

* Resistant control (Brazilian type *C. acutifolium*).

This year studies continued on the use of seed treatments to eliminate *P. flourescens* from contaminated seed. The first group of experiments tested the use of microwave and conventional oven heat, cold temperatures, the use of the chemicals copper oxide and carboxin, and the use of the antibiotic rifampicine. Microwave treatment of 1 minute at power levels of 30/48°C and above eliminated bacteria from seed, but higher temperatures significantly (P = 0.05) reduced germination (Table 3). Conventional oven heat significantly (P = 0.05) reduced and almost eliminated bacteria at temperatures of 50°C and above after 7 days, but significantly (P = 0.05) reduced germination from 95 to 45%. (Table 4). Temperatures of 4°C and significantly (0.05) reduced infection after 24 days in both *C. acutifolium* and *C. pubescens* (Table 5). Rifampicine was the only chemical treatment that significantly (P = 0.05) reduced Pseudomonas infection and did not reduce germination (Table 6). However, over the time span used infection in *C. acutifolium* seed was not totally eliminated. From these studies we conclude the most efficient treatment for elimination of *P. fluorescens* and maintenance of germination is the microwave treatment.

In the second group of experiments agricultural Streptomycin was evaluated due to its easy availability in comparison to Rifampicine and microwave ovens. Streptomycin significantly (P = 0.05) reduced infection only after 1 hour soaking time without severely affecting germination (Table 7). However, the level of *P. fluorescens* still viable in seed was still unacceptably high.

Table 2. Mean values over 5 evaluation periods of various factors possibly associated with Centrosema wilt in Villa Rica (Cauca), Colombia.

Accession	Benomyl	Leaves* turgor loss or death	Stem lesions*		Petiole* lesions	Leaf lesions*				Die-back	Plant death	Vigor
			Pathogen	Physical		Anthr	Bact	Herbic	Other			
5277	No	0.7	3.8	0.9	0.4	0.2	0.9		0.3	0.8	1	2.6
	Yes	1.0	2.6	0.7	1.5	0.1	2.0		0.4	2.2	2	2.2
5568	No	0.1	0.4	0.2	0.1	0.1	0.2		0.2	0.5	0	1.2
	Yes	0.2	0.5	0.2	0.1	0.2	0.1		0.2	0.4	0	1.6
15448	No	1.4	0.6	0.4	0.3	0.1	0.9		0.3	2.1	0	2.1
	Yes	0.4	0.5	0.4	0.3	0.2	1.2		0.4	1.3	0	1.8

* % surface are affected.

Table 3. Effect of 1 minute microwave treatment, on the infection levels of *Pseudomonas fluorescens* Biotype 2 and germination of *Centrosema* seed.

Accession	Heating power/Temp. (°C)	Germination[2] (%)	Infection[3] (%)
C. pubescens	Control[1]	40.0 a	58.4 a
	10/39	59.0 a	25.0 b
	30/48	88.0 b	0.0 c
	50/54	59.0 ac	0.0 c
	70/61	42.0 ac	0.0 c
	90/72	29.0 d	0.0 c
C. acutifolium 5277	Control	95.0 a	57.1 a
	10/39	86.0 a	25.0 b
	30/48	81.0 a	0.0 c
	50/54	68.0 a	0.0 c
	70/71	31.0 b	0.0 c
	90/72	18.0 c	0.0 c

Means followed by different letters are significantly (P = 0.05) (DMRT)

1. Seeds harvested in Santander de Quilichao from plots with high bacteriosis incidence.
2. Mean of 4 rep. with 100 sed/rep., ISTA rules (International Seed Testing Association), germinated in petri dishes with humid filter paper with 20 seeds/dish.
3. Mean of 4 rep. of 100 seeds/rep. in petri dishes with King B medium with 10 seeds/dish.

Table 4. Effect of conventional oven treatment on the infection level of *Pseudomona fluorescens* Biotype 2 and germination of *Centrosema* seed.

Accession	Temp. (°C)	Time (days)	Germination (%)	Infection (%)
C. pubescens 438	Control		40.0 a	58.4 a
	40	7	60.0 a	33.0 a
		14	70.0 a	13.0 b
		21	78.0 a	6.6 b
	50	7	58.0 a	1.2 b
		14	73.0 a	0.0 c
		21	63.0 a	0.0 c
	60	7	57.0 a	5.0 bd
		14	59.0 a	0.0 ce
		21	74.0 a	0.0 ce
	70	7	52.0 a	0.0 ce
		14	43.0 a	0.0 ce
		21	22.0 b	0.0 ce
C. acutifolium	Control		95.0 a	57.1 a
	40	7	54.0 b	53.3 a
		14	59.0 b	59.9 a
		21	55.0 b	16.1 b
	50	7	45.0 b	0.0 c
		14	48.3 b	2.0 c
		21	45.0 b	0.0 c
	60	7	49.3 b	4.0 c
		14	41.6 b	0.0 c
		21	45.3 b	0.0 c
	70	7	45.3 b	0.0 c
		14	42.0 b	0.0 c
	2	21	22.0 b	0.0 c

Means followed by different letters are significantly (P = 0.05) (DMRT)

Table 5. Effect of cold (4°C) on the infection level of *Pseudomonas fluorescens* Biotype 2 and germination of *Centrosema* seed.

Accession	Time (days)	Germination (%)	Infection (%)
C. pubescens 438	Control	40.0 a	58.4 a
	12	74.0 a	51.3 a
	16	83.0 a	10.8 b
	24	66.0 a	16.6 b
C. acutifolium 5277	Control	95.0 a	57.1 a
	12	84.0 a	66.5 a
	16	79.0 a	64.1 a
	24	98.0 a	9.1 b

Means followed by different letters are significantly (P = 0.05) (DMRT).

Table 6. Effect of chemical treatments on the infection level of *Pseudomonas fluorescens* Biotype 2 and germination of *Centrosema* seed.

Accession	Treatment	Germination (%)	Infection (%)
C. pubescens 438	Control	40.0 b	54.8 a
	Copper Oxide	46.0 b	47.6 a
	Carboxin	96.0 a	8.0 b
	Rifampicine*	94.2 a	0.0 b
C. acutifolium 5277	Control	95.0 a	57.1 a
	Copper Oxide	97.0 a	56.2 a
	Carboxin	100.0 a	35.7 a
	Rifampicine*	93.7 a	2.2 b

Means followed by different letters are significantly (P = 0.05) (DMRT).
* Rifampicine = Antibiotic.

Table 7. Effectiveness of commercial streptomycin in eliminating *P. fluorescens* from *C. acutifolium* seed.

Streptomycin application (g/Kg seed)	Soaking time (min)	% seed with *P.fluorescens*	% seed germinating
0.0	30	43.6	85.0
	60	46.0	79.0
	90	43.3	76.0
	120	45.3	76.0
2.5	30	20.0	73.0
	60	16.3	73.0
	90	20.3	70.0
5.0	30	12.0	69.0
	60	4.0	68.0
	90	2.0	66.0
	120	0.0	62.0

Research will continue on the use of microwave and antibiotics to eliminate *P. fluorescens* from seed. In particular the potential of microwave technology will be verified and the effect of soaking seed longer with streptomycin will be studied.

STYLOSANTHES DISEASES

Anthracnose, caused by *Colletotrichum gloeosporioides*, is an important constraint to *Stylosanthes* in the Cerrados, Brazil and in Costa Rica, Central America. Research is being continued in the form of a Collaborative AIDAB funded project with CSIRO, Australia, through increased participation in pathology by EMBRAPA in Brazil, and through work at CIAT.

The objective of the collaborative project is to characterize and to compare isolates of *C. gloeosporioides* from tropical America, Australia, Africa and the south east Asia/Pacific region in order to better understand the pathogenic variability. The objectives are divided into:

a) Development of standardized International inoculation and evaluation methodology.

b) Development of an international differential set to enable interregional comparison.

c) Characterization and comparison of isolates from the various regions using deferential sets, as well as starch-gel electrophresis and reduced fragment length polymorphisms. The first phase of this project has now been completed.

a) Development of standardized inoculation techniques being conducted by CSIRO included leaf dipping, spraying seedlings, drop inoculation. Of these, leaf dipping and spraying to incipient run-off could be used ,but did not result in even spore distribution. Diseases severity was favoured by leaf wetness period of 12 hours, and maximum infection at 36 hours. Severity was relatively unaffected when the wet-period was interrupted briefly in the initial 12 hours, provided a continuous wet-period or relative humidity above 85% was maintained for the next 24 hours.

In order to reduce variability between plants detached leaves are being evaluated. If these prove successful this method could be used to compare isolates. One problem has been genetic variability of Stylosanthes accessions.

b) An international differential set is being developed by CIAT, in collaboration with Queen's University of Belfast, and the Queensland Department of Primary Industries.

c) Comparison of isolates at CSIRO has been most effective using RFLPs rather than starch gel electrophoresis. A DNA probe, pkB2, has been produced, highly diagnostic for type A and B C. gloeosporioides. It produces a complex banding pattern for type B isolates and a simple pattern for type A isolates . Using this probe, a preliminary comparison was made with isolates from the Americas, Africa and Asia (Table 8). Close similarity was observed between S. guianensis anthracnose isolate 21808 type B, and two isolates each from Peru and Colombia, 1 isolate from Nigeria, and a S. hamata isolate from Nigeria. No isolates reacted similarly to SR4 type A anthracnose from S. scabra. A more general survey will be made in phase 2 of the project.

Biology of the infection process*

In order to manipulate C. gloeosporioides better a more thorough understanding is required of the biology of the pathogen. This year the infection process was studied more thoroughly. In particular, the variation of isolates was studied in cultural characteristics, germination, appressoria formation, and infection of leaves of various ages of different S. guianensis accessions. Short, white , cottony mycelium was produced on oat meal agar by 70% of isolates and 100% produced orange spore masses. At 24°C, after 48 hours mean growth and pathogenicity were 12.3 mm and 0.33 respectively. However, significant ($P = 0.05$) differences were observed between isolate groups (Tables 9 and 10). Differences were observed in germination and appressoria production between isolates (Figure 1). These trends were highly correlated over time (R sq=0.98 and 0.96 respectively). Germination was highest and infection lowest on mature leaves (Figure 2).

BRACHIARIA DISEASES

Rust

Uromyces setariae-italicae Yosh was reported last year as the first potentially important disease of widespread tropical pasture grasses, particularly of the genus Brachiaria, of which around 20-25 million hectares have so far been planted in Latin America. The rust has now been observed on Brachiaria spp. in Bahia and the Cerrados of Brazil, in the Llanos and Valle in Colombia, in Napo and Puyo, Ecuador, and in three locations in Costa Rica. A survey is being conducted to determine the extent and severity of the disease on farm.

Concurrently, the Brachiaria collection is being screened for resistance to rust in the Llanos, with the idea of screening most promising accessions over wider locations. Isolates are being collected and multiplied on B. humidicola in the glasshouse for use in preliminary screening and pathogenic variation studies. The population dynamics of U. setariae-italicae is being monitored in the Llanos and a trial on cultural control methods has been established and is being evaluated.

In addition, a series of trials are

---

* Undergraduate student thesis of Belisario Volverás Mambuscay

Table 8. Similarity between C. *gloeosporioides* isolates using the DNA probe pKB2.

ENZ	S. scabra	S. guianensis											
	Aust. A	Aust B	Peru	Peru	Peru	Peru	Colombia	Colombia	Colombia	Brazil	Africa	Ethiopia	Nigeria
	SR4	21808	12785	12794	12797	12796	13954	13916	13925	13777	226 A	13758	332 A
Bamgl	A	B	-	B	B	-	B	B	B	b	b	-	b
Hind 111	A	B	-	B	B	-	B	b	B	B	b	-	B
EcoR 1	A	B	-	B	B	-	B	b	B	b	-	-	B
pST 1	A	B	-	B	B	-	B	B	B	B	b	b	B

	Stylosanthes													
	scabra	guianensis	capitata			hamata			macrocephala		scabra	frutic.	pilosa	bifl.
	Aust	Aust	Brazil	Africa	Nigeria	Nigeria	Nigeria	Thail	Brazil	Nigeria	Colombia	Colombia	Brazil	USA
Bamhl	A	B	b	b	b	B	b	b	-	-	-	b	b	B
Hind 111	A	B	b	b	b	B	b	b	-	-	-	b	b	b
EccRl	A	B	a	b	b	B	b	b	-	-	-	b	b	b
Pstl	A	B	a	b	b	B	b	b	-	-	-	b	b	B

A = Type A B = Type B a, b = Faint bands visible, not obviously in the pattern of a Type A or B

- = No bands at all.

Isolates that appear similar to Type B: B, C, E, G, K, from S. guianensis and O from S. hamata; and a bit like Type B: F, H from S. *guianensis* and W from S. *biflora*.

Table 9. Mean growth (mm) after 48 hours of incubation of 54 C. gloeosporioides isolations grouped per plant (sub-origin).

Plant	Growth[a]
A4	16.27 a[b]
A3	14.8 ab
B1	13.25 bc
B5	12.95 bcd
C1	12.35 cd
B7	10.78 de
C2	10.63 de
C3	10.6 de
A5	9.14 e
I 136 Q (Control)	9.0 e
DMS ($P < 0.05$)	2.26

---

a/ Mean of 30 observations (6 isolations/rep.)

b/ Means followed by the same letter are not different (P = 0.05) (DMRT).

Table 10. Pathogenicity of 54 isolations of C. gloeosporioides grouped per plant (sub-origin).

Complete plant	Pathogencity[a]
I136 Q	1.52[c] a[b]
B7	0.64 b
C2	0.38 c
B1	0.30 cd
B5	0.23 de
C1	0.14 ef
C3	0.13 ef
A4	0.08 ef
A3	0.06 f
A5	0.04 f
DMS ($P < 0.05$)	0.14

---

a/ Mean of 162 observations (6 isolates x 9 accessions x 3 reps).

b/ Means followed by the same letter are not different at P = 0.05. (DMRT).

c/ 0 = non pathogenic isolates
5 = highly pathogenic isolates

planned for the following season to assess production losses due to rust.

Only one evaluation has been completed of the Brachiaria collection, and as expected at this early stage of establishment variation is large. However, infection of spreaders is high and even. Symptomless accessions in the preliminary evaluation are presented in Table 11. So far pustules have not been found on 42% of accessions, including representatives of each of the major species.

Population Dynamics

The population dynamics of U.setariae-italicae is being monitored in the Llanos, Colombia. There was a rapid rise in pustule number in the first eight weeks and there after a sharp drop, which coincided with a heavy attack of U. setariae-italicae by an Endoluca sp. (Figure 3). Pustule number per area of green, mature leaves, also decreased after 8 weeks (Figure 4). It suggests plants either became more resistant to infection, or inadequate amounts of inoculum was produced to infect newly available host tissue. Observations from greenhouse infections, however, suggest that the latter hypothesis is more correct. It is likely that biological control of rust by Endoluca sp. is an important factor in limiting the severity of rust in the Llanos ecosystem, as the mycoparasite has been found in most locations where rust has been found. The mycoparasitism of the rust pathogen will be investigated more fully.

The effect of preseason burning, and cuttings at 2, 4 and 8 weeks on the

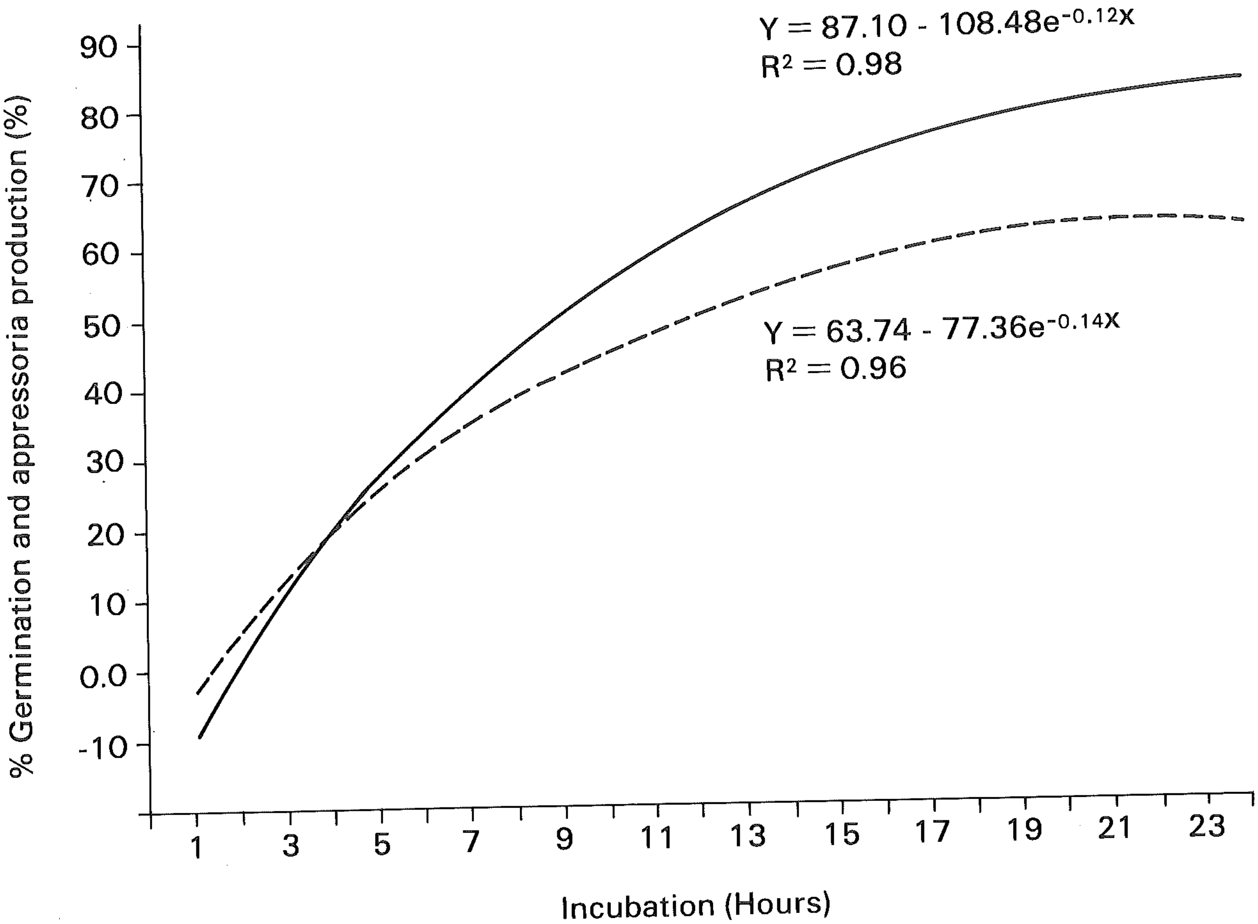


Figure 1. **Development over time of the germination process (– – –) and appressoria production (——) of the 54 isolate population of *C. gloeosporioides*.**

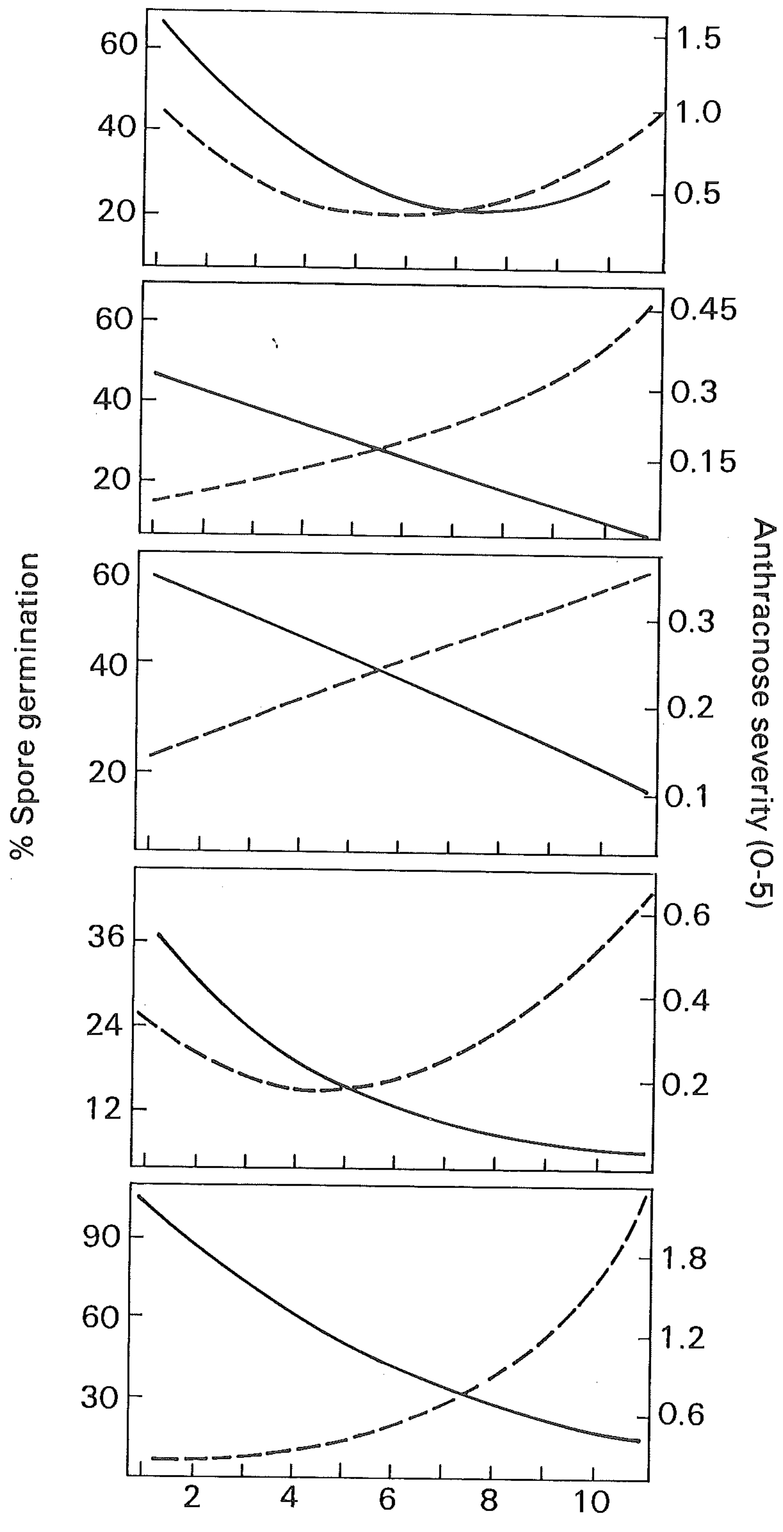


Figure 2. **Effect of leaf age of five *S. guianensis* accessions on spore germination (-----) of *C. gloeosporioides* (I136Q) and on anthracnose severity (——).**

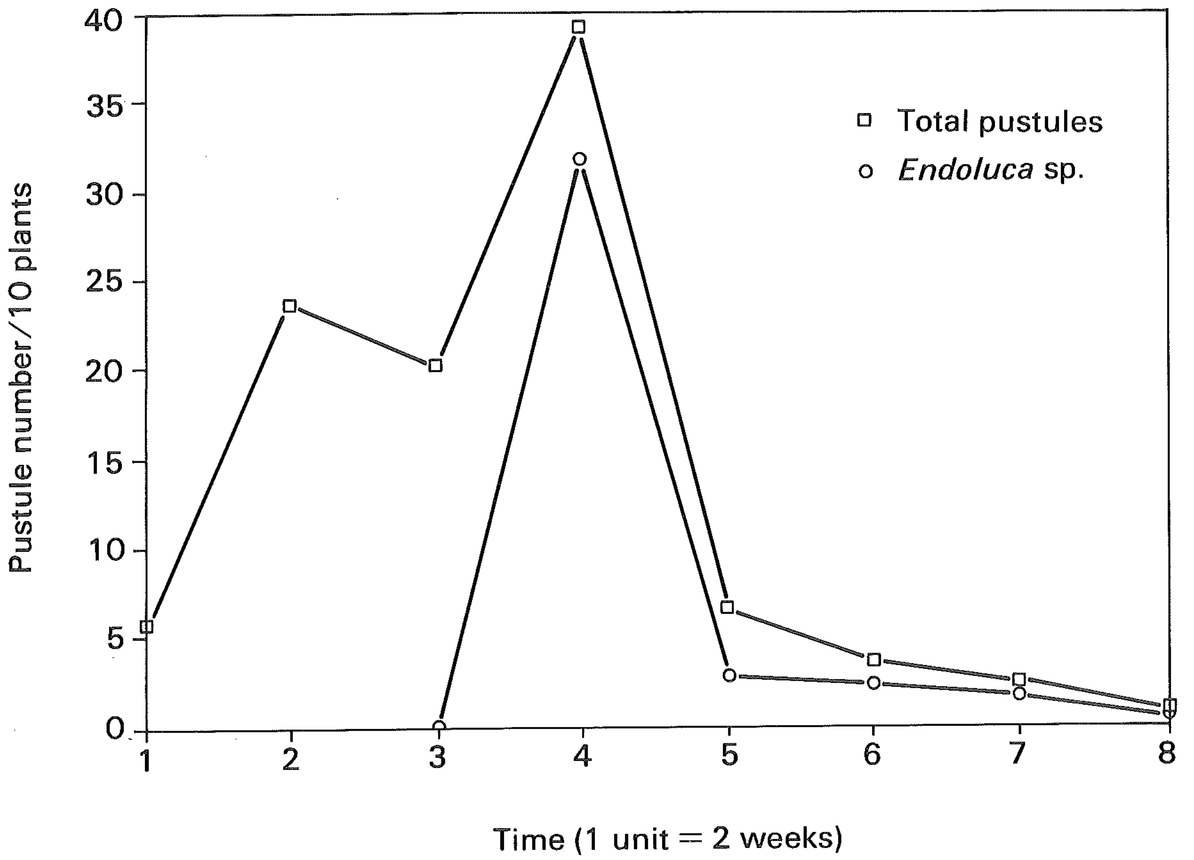


Figure 3. **Dynamics of** *U. setariae-italicae* **and** *Endoluca* **sp. on** *B. humidicola*.

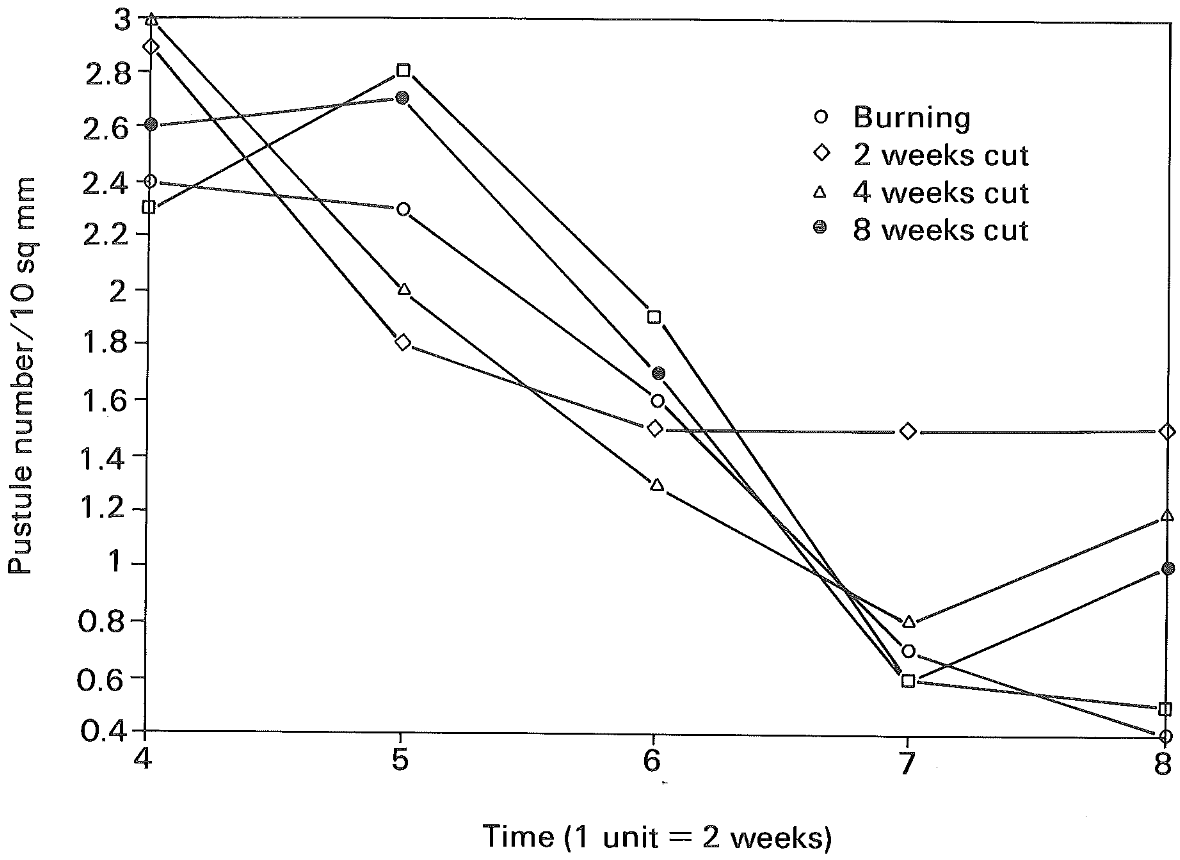


Figure 4. **Effect of cultural practices on rust development *B. humidicola*.**

Table 11. Brachiaria accessions without rust pustules after preliminary evaluation at Carimagua, Colombia.

Species	Accession CIAT No.	Species	Accession CIAT No.
B. bovonei	26353	*B. brizantha*	16827
B. decumbens	26294	*B. brizantha*	16485
B. decumbens	26292	*B. brizantha*	16460
B. decumbens	26186	*B. brizantha*	16126
B. decumbens	16503	*B. brizantha*	6780
B. decumbens	6693	*B. brizantha*	6012
B. decumbens	6687	*B. brizantha*	665
B. decumbens	6701	*B. dictyoneura*	16187
B. decumbens	6131	*B. brizantha*	6690
B. humidicola	16879	*B. ruziziensis*	655
B. humidicola	16882	*B. arrecta*	16884
B. jubata	16896		

development of rust on *B. humidicola* is also being monitored at Carimagua. Results to date show the incidence on rust on plant leaves was highest when *Brachiaria* was not cut and lowest when cut every 2 and 4 weeks (Figure 5). In each case, the rust incidence increased in the first 6 weeks in all treatments and then dropped to lower levels depending on the treatment. The effect of burning plots before the start of the season, as is commonly practiced was unclear in the early stages of the season, but after 6 weeks followed the trends of the control (Figure 6). No differences were observed in total pustule numbers to observations after 4 weeks, but after eight weeks cut treatments ant 2, 4 and 8 weeks as well as the burning treatment had fewer pustules than the control (Figure 7).

DESMODIUM DISEASES

Stem Gall Nematode

An evaluation of resistance to *Pterotylenchus cecidogenus* continued under controlled conditions of all remaining accessions of *Desmodium*. The results show high levels of resistance to the nematode are available in *D. ovalifolium*, *D. strigulosum*, and *D. velutinum* (Table 12). Apart from evaluating for possible race structures in *P. cecidogenus* work will be discontinued on this pathogen.

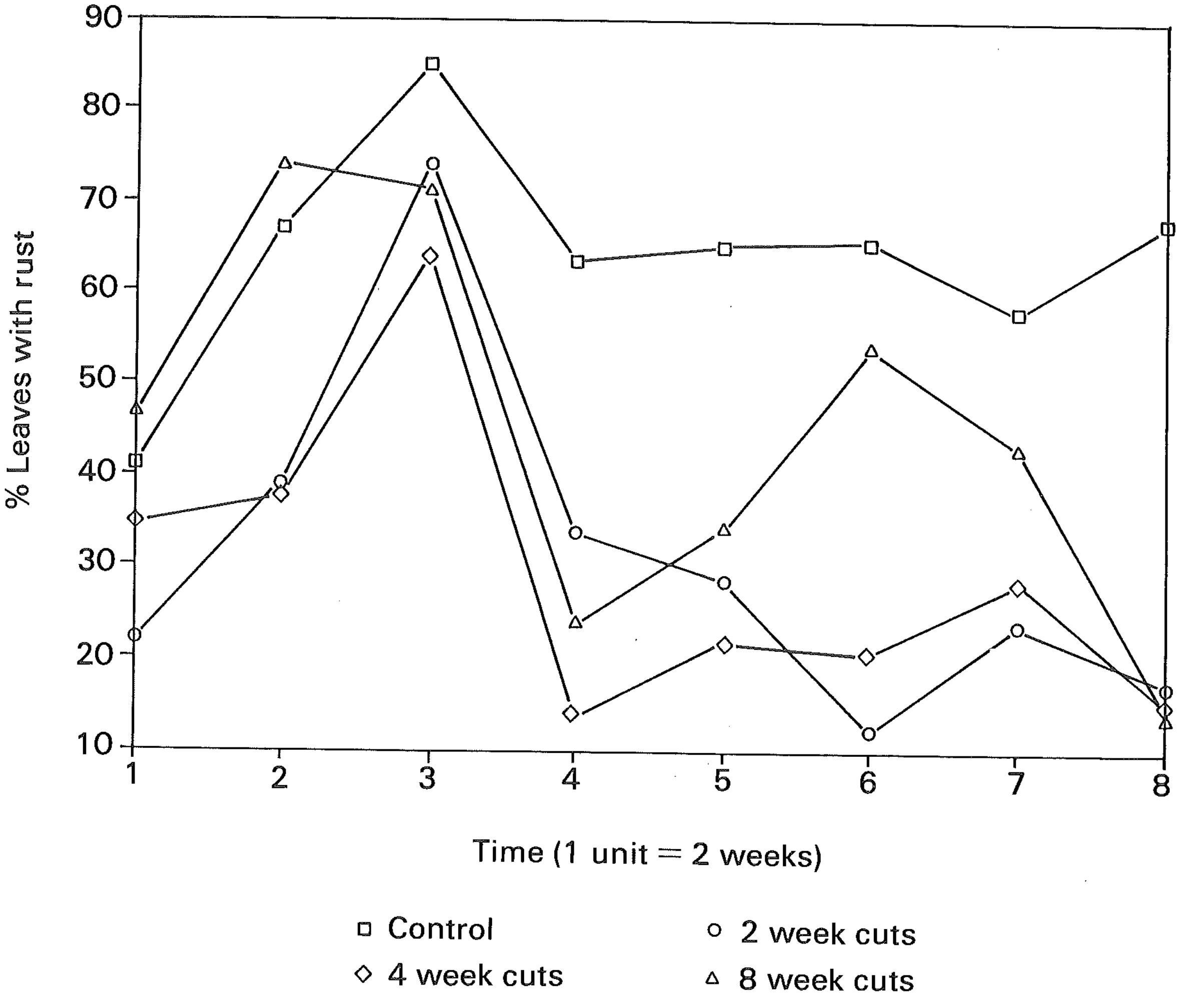


Figure 5. Rust development under different cutting programs.

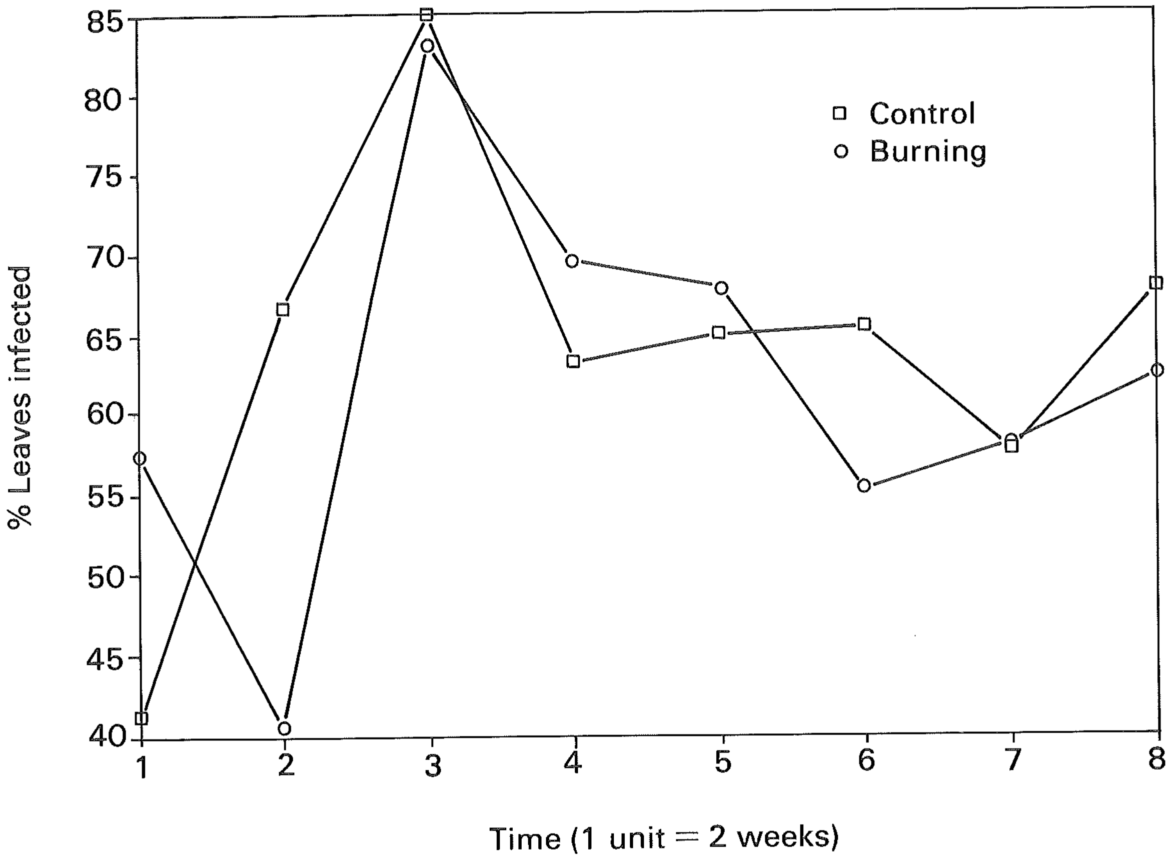


Figure 6. **Rust incidence with and without burning on** *Brachiaria humidicola*.

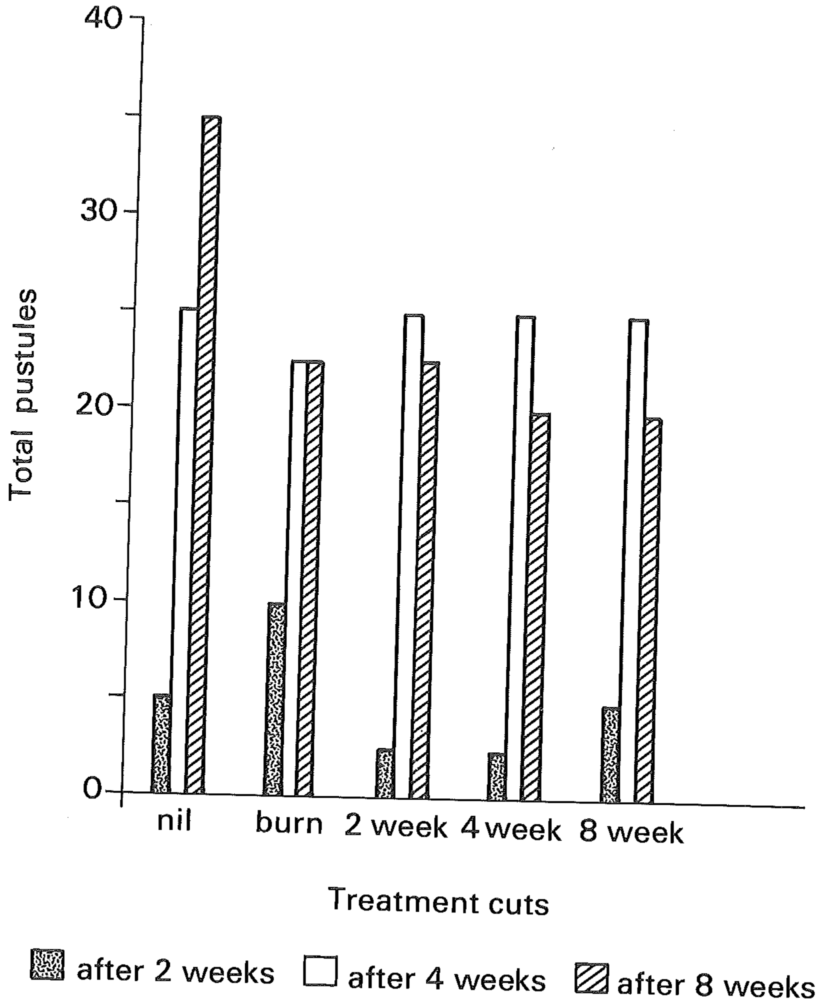


Figure 7. Total pustule development *B. humidicola* subjected to various cultural control treatments.

Table 12. Reaction of *Desmodium* spp. to *Pterotylenchus cecidogenus* under controlled conditions.

Species	Accession CIAT No.	Stem galls	x number nematodes	Species	Accession CIAT No.	Stem galls	x number nematodes	Species	Accession CIAT No.	Stem galls	x number nematodes
D.ovalifolium	23612	4	75.1	D.ovalifolium	13650	+	51.6	D.velutinum	13676	-	0.0
D.ovalifolium	23615	-	7.3	D.ovalifolium	13134	+	139.5	D.velutinum	13526	-	9.0
D.ovalifolium	23618	-	7.4	D.ovalifolium	3674	+	121.9	D.velutinum	13218	-	0.0
D.ovalifolium	23621	-	5.6	D.ovalifolium	350*	+	109.6	D.velutinum	13215	+	38.6
D.ovalifolium	23622	-	5.7	D.ovalifolium	13089**	-	0.0	D.velutinum	13227	+	16.0
D.ovalifolium	23624	-	0.3	D.strigillosum	13149	+	6.0	D.velutinum	13695	-	0.0
D.ovalifolium	23625	-	0.0	D.strigillosum	13153	+	19.0	D.velutinum	13219	-	0.0
D.ovalifolium	23627	-	0.0	D.strigillosum	13155	+	33.0	D.velutinum	13697	+	26.3
D.ovalifolium	23628	+	33.1	D.strigillosum	13156	+	64.0	D.velutinum	13391	-	0.0
D.ovalifolium	23629	-	0.8	D.strigillosum	13158	+	98.0	D.velutinum	13945	-	10.3
D.ovalifolium	13119	-	2.3	D.strigillosum	13159	+	26.0	D.velutinum	13948	-	0.0
D.ovalifolium	13733	+	41.8	D.strigillosum	13368	+	124.0	D.velutinum	13147	-	0.0
D.ovalifolium	23664	+	29.0	D.strigillosum	13661	-	0.0	D.velutinum	13689	-	0.0
D.ovalifolium	13138	+	36.0	D.strigillosum	23723	+	24.0	D.velutinum	13323	-	0.0
D.ovalifolium	13112	-	2.0	D.ovalifolium	350*	+	146.0	D.velutinum	13953	-	0.0
D.ovalifolium	3780	-	2.0	D.ovalifolium	13089**	-	0.0	D.velutinum	13688	-	0.0
D.ovalifolium	23762	-	6.0	D.velutinum	23280	-	0.0	D.velutinum	13212	-	0.0
D.ovalifolium	13305	+	14.0	D.velutinum	23079	-	13.0	D.velutinum	13211	-	0.0
D.ovalifolium	13140	-	2.0	D.velutinum	23322	+	7.3	D.velutinum	13952	-	0.0
D.ovalifolium	13121	+	14.0	D.velutinum	23325	-	8.0	D.velutinum	13954	-	0.0
D.ovalifolium	13030	+	52.0	D.velutinum	23320	+	16.3	D.velutinum	13207	-	0.0
D.ovalifolium	3781	+	12.0	D.velutinum	23324	-	1.0	D.velutinum	13687	-	0.0
D.ovalifolium	23630	+	29.0	D.velutinum	13222	+	16.0	D.velutinum	13204	+	35.6
D.ovalifolium	13646	+	104.6	D.velutinum	13220	+	29.3	D.velutinum	23160	+	20.3
D.ovalifolium	13090	+	180.8	D.velutinum	13221	+	16.0	D.velutinum	23277	+	25.3
D.ovalifolium	13370	-	0.0	D.velutinum	23278	-	11.0	D.velutinum	23158	+	17.0
D.ovalifolium	13098	+	83.4	D.velutinum	23081	-	0.0	D.velutinum	23157	-	0.0
D.ovalifolium	13648	+	99.9	D.velutinum	23083	+	13.0	D.velutinum	23136	-	0.0
D.ovalifolium	13131	-	0.0	D.velutinum	23085	+	14.3	D.velutinum	13693	-	0.0
D.ovalifolium	13096	+	88.6	D.velutinum	23135	+	20.0	D.velutinum	23271	-	0.0
D.ovalifolium	13099	+	97.6	D.velutinum	23134	-	1.0	D.velutinum	23273	+	40.6
D.ovalifolium	13647	+	119.1	D.velutinum	23080	-	0.0	D.velutinum	23274	-	0.0
D.ovalifolium	13649	-	0.0	D.velutinum	23132	+	15.3	D.velutinum	23691	-	0.0
D.ovalifolium	13657	+	172.5	D.velutinum	23086	+	31.0	D.velutinum	23276	-	0.0
D.ovalifolium	13656	+	125.4	D.velutinum	23133	+	12.0	D.velutinum	23275	-	0.0
D.ovalifolium	13655	-	0.0	D.velutinum	23082	+	2.0	D.velutinum	13692	-	0.0
D.ovalifolium	13654	+	110.9	D.velutinum	13217	+	20.6	D.velutinum	13217	+	20.6
D.ovalifolium	13653	+	27.6	D.velutinum	13694	+	27.6	D.velutinum	13526	-	9.0
D.ovalifolium	13652	-	0.0	D.velutinum	13216	-	0.0	D.velutinum	13227	+	16.0
D.ovalifolium	13651	-	0.0	D.velutinum	13214	+	17.3	D.velutinum	23227	+	16.0
D.velutinum	13213	+	30.6	D.ovalifolium	350*	+	14.0	D.ovalifolium	13089**	-	0.0

5. Entomology

INTRODUCTION

The effort of the entomology section has been concentrated on two major pests of forages: spittlebugs and leaf-cutter ants. The major objective of the section remains that of selecting adapted accessions of *Brachiaria* resistant to spittlebugs in the field and of identifying resistant accessions by means of bioassay as candidates for inclusion in a breeding program. In addition to the ongoing evaluation of the germplasm collection, for the first time sexual tetraploid *B. ruziziensis* clones were evaluated for spittlebug resistance.

A new methodology has been developed to enable testing of plant fractions for activity against spittlebug nymphs. This technique should facilitate identification of chemical mechanisms of resistance to spittlebugs in *Brachiaria* spp.

An effort was initiated this year to determine a threshold population density of colonies of the leaf-cutter *Acromyrmex landolti* in areas of native savanna sown with the highly susceptible *Andropogon gayanus*.

The bioassay methodology for evaluation of host plant resistance was adapted for use on rice lines and routine evaluation by the Entomology Section of the Rice Program has begun for spittlebug resistance (see Rice Program annual report).

I. HOST PLANT RESISTANCE TO SPITTLEBUGS

1989 spittlebug population at Carimagua

Significant spittlebug damage was not observed this year at Carimagua compared with the severe damage that occurred during 1988. By plotting population and precipitation data for 1986 through 1989, several observations can be made (Fig. 1A). The high damage observed during 1988 was due to a heavy infestation of nymphs that followed a large generation of adults that occurred around 1 July, 1988. The peak adult population was approximately 2.5 times greater that any other peak that has occurred in the other three years for which data are available. Second, by comparing the area under the population curve (Fig. 1B) it appears that the total spittlebug population for 1988 was not significantly greater than for the other three years. Rather, what was outstanding in 1988 was the synchronization of the spittlebug generations resulting in a very high population pressure during a relatively short period of time. Finally, precipitation during the dry season 1987-1988 was atypical in that rainfall was totally absent for a period of three months (Fig. 1A). This suggests that the unusually dry winter of 1987-1988 may have synchronized development in aestivating eggs resulting in simultaneous eclosion when the rains began in April-May, 1988. Laboratory tests are underway to test the effect

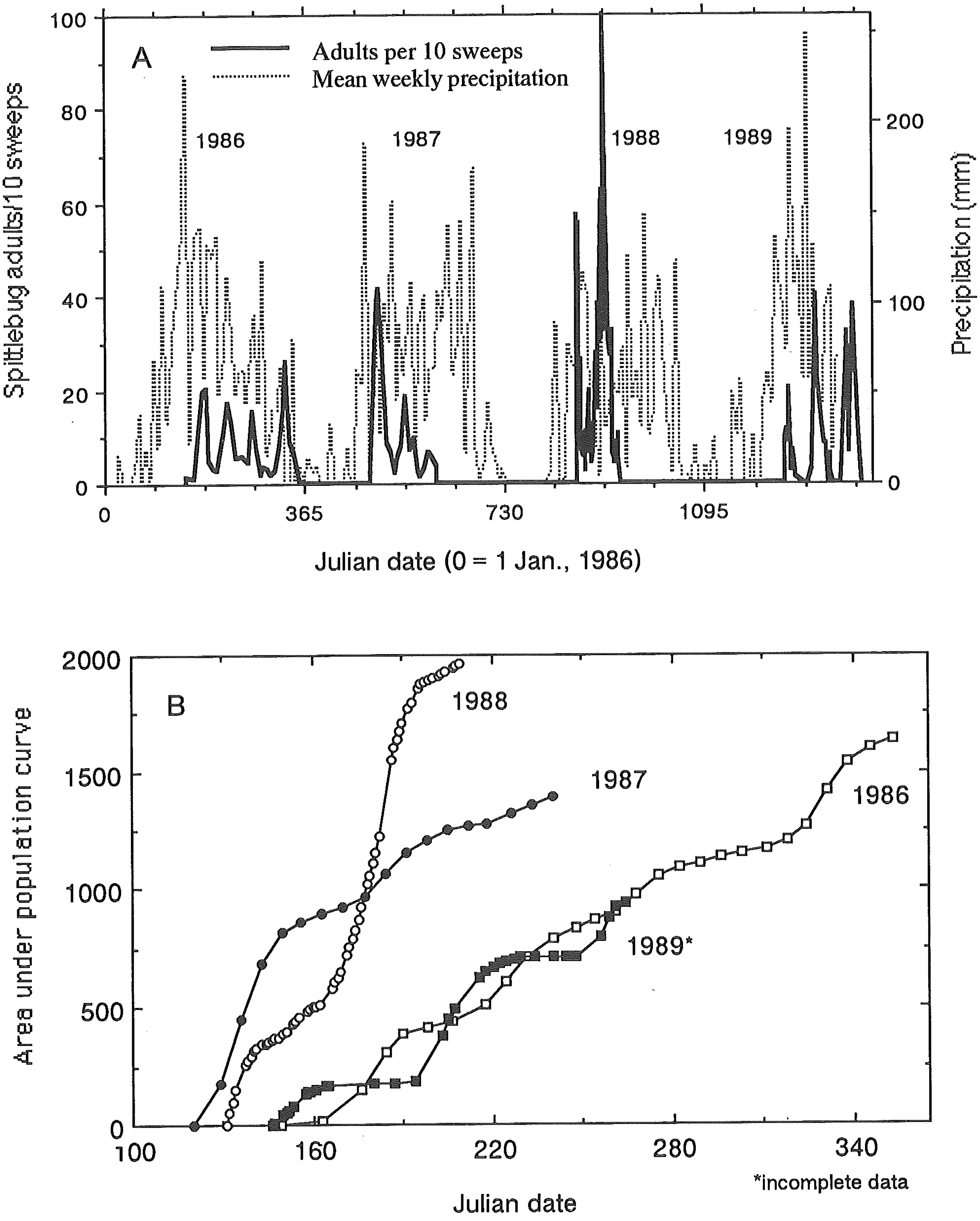


Figure 1. A: Adult spittlebug populations and rainfall over four years at Carimagua. B: Area accumulated under the population curve for spittlebug at Carimagua. Data for 1989 are incomplete.

of dry conditions on eggs of varying developmental stages.

Although spittlebug populations were not abnormally low during 1989, the population was not high enough at any given time to cause severe damage to the susceptible controls and therefore it was not possible to make a reliable assessment of resistance in the field collection of *Brachiaria*.

Field evaluation of *Brachiaria* collection

In collaboration with the Agronomy section, 15 additional *Brachiaria* accessions (plus controls) were planted at Carimagua in 1988. These accessions were evaluated during 1989 for edaphic adaptation (Table 1). Using an arbitrary, subjective rating scale and percent coverage of the 2x3 m plots, four accessions were selected (*B. brizantha* CIAT 16170, 16146-1, 26556-P, and 26564-G). Due to insufficient spittlebug pressure, no data was collected regarding susceptibility to spittlebug. However, these accessions were rated as susceptible in the glasshouse trial (see below).

Table 1. Ratings of 21 *Brachiaria* accessions planted at Carimagua during 1988.

15 June, 1989					September, 1989				
Accession	Mean* cover (%)	S.D. Cover	Vigor**	S.D. Vigor	Accession	Mean cover (%)	S.D. Cover	Vigor**	S.D. Vigor
26646	100.0	0.0	4.0	0.0	26646	100.0	0.0	4.0	0.0
606	100.0	0.0	3.5	0.0	606	100.0	0.0	4.0	0.0
6297	90.0	0.0	3.5	0.0	679	100.0	0.0	3.5	0.0
16146-1	75.0	15.0	3.5	0.0	6133	100.0	0.0	3.5	0.0
26564-G	82.5	7.5	3.3	0.3	6297	100.0	0.0	3.5	0.0
6133	95.0	5.0	3.0	0.5	16170	87.5	12.5	3.5	0.5
16170	80.0	0.0	3.0	0.0	16146-1	75.0	25.0	3.5	0.5
16296	60.0	20.0	3.0	0.0	26556-P	100.0	0.0	3.3	0.3
16331	50.0	0.0	3.0	0.0	16350	95.0	5.0	2.8	0.3
26556-P	42.5	32.5	2.8	0.3	16296	62.5	37.5	2.5	0.5
26564-P	40.0	10.0	2.5	0.5	16331	50.0	0.0	2.5	0.0
679	85.0	5.0	2.3	0.3	16166	52.5	27.5	1.8	0.8
16350	82.5	7.5	2.3	0.3	16166	52.5	27.5	1.8	0.8
16166	40.0	20.0	2.0	0.5	26564-P	17.5	7.5	1.3	0.3
16832	50.0	25.0	2.0	0.5	16127	17.5	7.5	1.5	0.5
16146-A	35.0	25.0	1.8	0.3	655	25.0	25.0	1.0	1.0
16176	12.5	2.5	1.8	0.3	16832	25.0	25.0	1.0	1.0
16445	15.0	5.0	1.5	0.0	16445	25.0	25.0	0.8	0.8
655	10.0	0.0	1.0	0.0	16176	5.0	5.0	0.5	0.5
16134¿	5.0	5.0	1.0	1.0	16134	0.0	0.0	0.0	0.0

* Visual rating scale of 0 (failure to establish) to 4 (excellent establishment).
** Percent coverage of 2x3 m plot. 2 replications.

Glasshouse bioassay for host plant resistance to spittlebug

One hundred and nine previously untested Brachiaria accessions were evaluated in the glasshouse for antibiotic resistance to spittlebug using the technique previously described (CIAT Annual Report 1987, 1988). Of these, three were identified as highly resistant (B. jubata CIAT 16203, B. ruziziensis CIAT 26163, and B. decumbens 26185) and two as moderately resistant (B. jubata CIAT 16896 and B. brizantha CIAT 16313) (Fig. 2). This is the first report of a resistant accession of B. ruziziensis or B. decumbens and further testing is underway.

In order to confirm the resistance of accessions selected by the glasshouse mass screening technique, eight accessions identified as resistant in previous screens were compared again with the resistant control B. brizantha cv. Marandú (CIAT 6294) and the susceptible controls B. decumbens cv. Basilisk (CIAT 606) and B. dictyoneura cv. Llanero (CIAT 6133). In all cases, resistance was confirmed (Fig. 3).

Tetraploid B. ruziziensis

In collaboration with the Plant Breeding Section, 88 induced tetraploid sexual B. ruziziensis clones were evaluated for antibiotic resistance to Aeneolamia reducta in a screenhouse. B. decumbens cv. Basilisk and B. brizantha cv. Marandú were used as susceptible and resistant controls, respectively. B. jubata CIAT 16531 was included as an additional resistant control (for results see Plant Breeding Section).

Mechanisms of resistance in B. jubata and B. brizantha cv. Marandú

To date, we have accumulated strong circumstantial evidence that there is a phytochemical basis to the high level of antibiotic resistance observed in B. jubata CIAT 16531 (CIAT Annual Report 1988). In order to test for activity in extracts of resistant plants, a bioassay technique using intact maize roots was developed (Fig. 4). Nymphs are easily reared on maize and xylem feeding by nymphs on corn roots has been demonstrated by staining with methylene blue. The maize root bioassay will be used to demonstrate activity in root extracts of B. jubata CIAT 16531 and other highly resistant accessions. Fractions of extracts from freeze-dried roots of some Brachiaria species have been obtained through cooperation with Cornell University.

Feeding rate and assimilation efficiency of adult spittlebugs

The liquid excreta of adult spittlebugs can be collected in a Parafilm sachet and measured as an estimate of feeding rate. Adults produce less excreta and presumably feed less on the antibiotic accessions B. jubata CIAT 16531 and B. brizantha cv. Marandú compared with the susceptible B. decumbens cv. Basilisk and the tolerant B. dictyoneura cv. Llanero (Table 2). Assimilation (conversion of food into insect weight) is correspondingly lower in cv. Marandú compared with cvs. Basilisk and Llanero. However, assimilation by spittlebug on B. jubata CIAT 16531 did not differ from the susceptible controls. A relatively high concentration of sugar was found in excreta of insects fed on that species wich indicates either a) a difference in xylem sap content, or b) adults on B. jubata CIAT 16531 do not feed exclusively from the xylem. The contract between cv. Marandú and B. jubata 16531 is further evidence that the resistance mechanism in B. jubata CIAT 16531 is distinct from that in cv. Marandú and that B. jubata CIAT 16531 is a potentially valuable source of additional genetic variability for Brachiaria breeding.

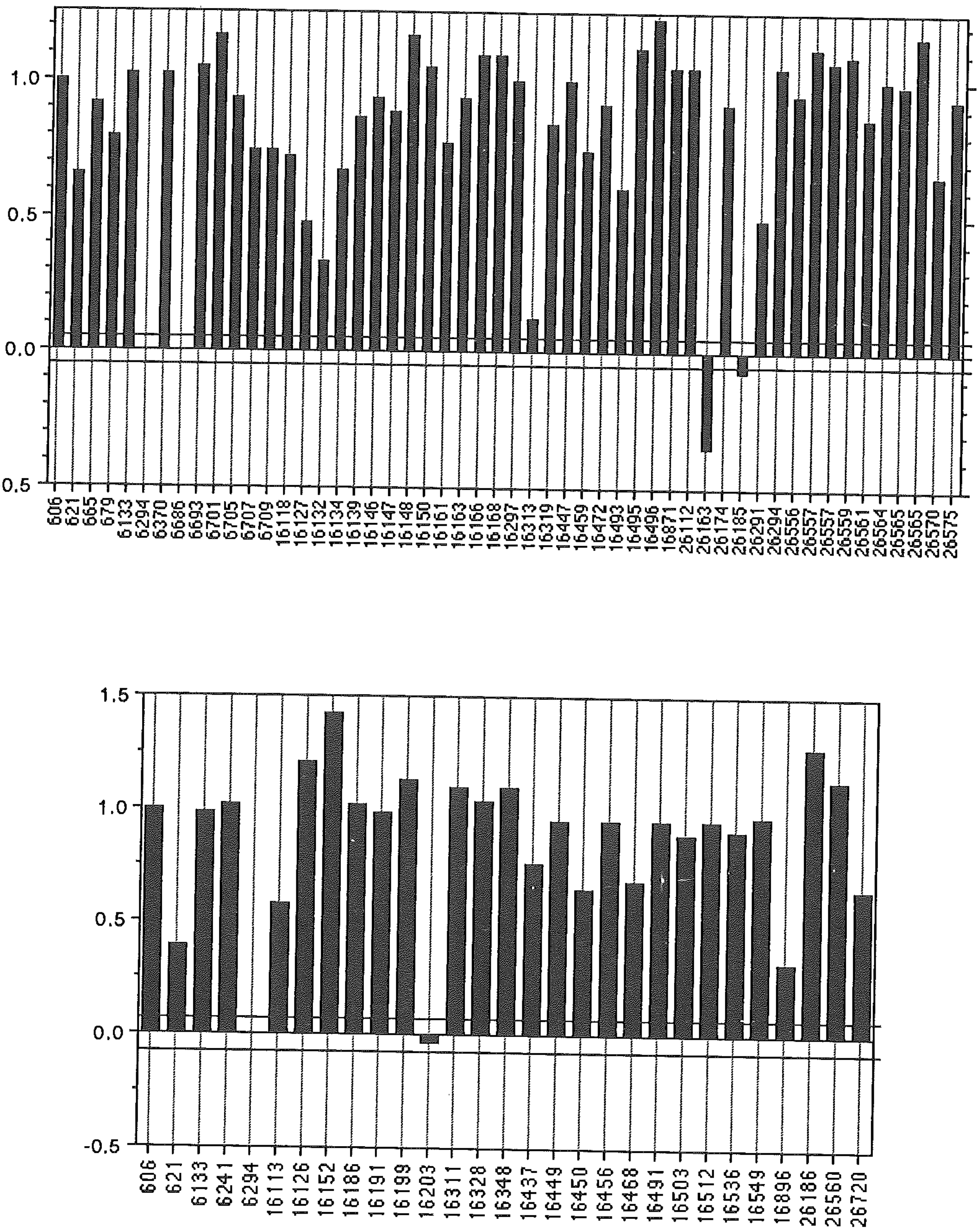


Figure 2. Index of adult emergence of spittlebugs on two cohorts of Brachiaria accessions in the glasshouse (0 = emergence on resistant control, B. brizantha CIAT 6294; 1 = emergence on susceptible control, B. decumbens CIAT 606). The solid line above and below the origin represent the standard deviation of the resistant control. Ten replications, 10 nymphs per rep.

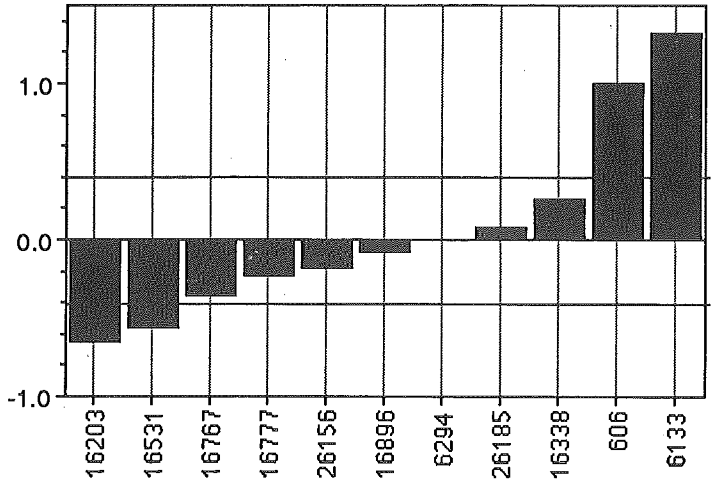


Figure 3. Index od adult emergence on eight resistant Brachiaria accessions (0 = emergence on resistant control, B. brizantha CIAT 6294; 1 = emercence on susceptible control, B. decumbens CIAT 606). The solid line above and below the origin represent the standard deviation of the resistant control. Ten replications, 10 nymphs per rep.

Table 2. Rate of excretion, sugar content of excreta, rate of assimilation, and assimilation efficiency of adult female spittlebugs on species of Brachiaria.

Species	Excretion (mg/day)*	Sugar excreta (%)	% Sugar content (wt/wt DM)	Sugar conc. in excreta (%)	Assimil. (mg/day)*
B. decumbens cv. Basilisk	878.7 a	0.74	0.5	0.00369	4.6 ab
B. dictyoneura cv. Llanero	893.1 a	1.74	0.9	0.01583	5.2 a
B. brizantha cv. Marandú	389.8 b	0.70	1.1	0.00794	3.5 b
B. jubata CIAT 16531	219.1 b	1.92	11.0	0.21168	5.2 a

* DMRT

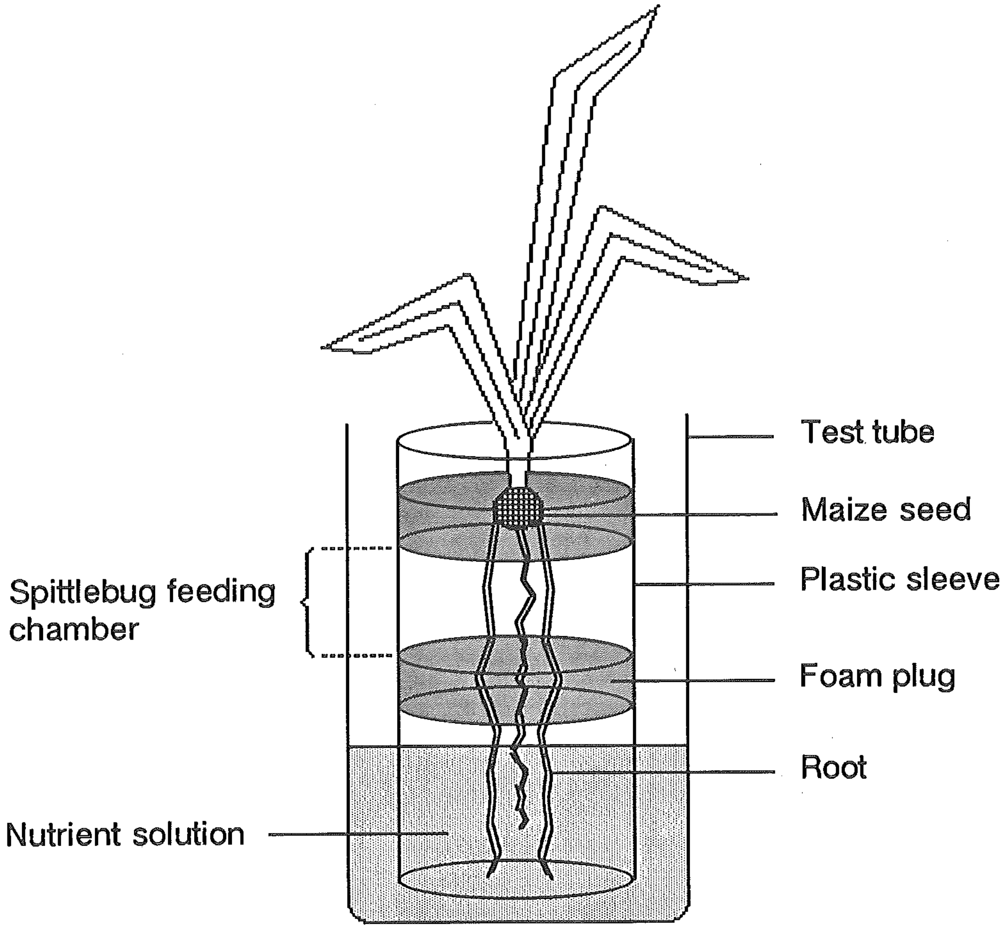


Figure 4. Schematic drawing of apparatus designed to allow spittlebug nymphs to feed for extended periods in an observation chamber on maize roots growing in a nutrient medium.

Oviposition on *B. jubata*

Adult spittlebugs reared as nymphs under identical conditions in the colony were placed on either *B. jubata* CIAT 16531 or *B. dictyoneura* cv. Llanero as they emerged from the last moult. Sixty adults (1:1 male:female) were placed in oviposition cages provisioned with one or the other grass species. Total oviposition and the number of viable eggs were calculated to compare the effect of grass species on fertility. Adults females in cages with *B. jubata* CIAT 16531 oviposited on the average more than twice as many eggs as females in cages with cv. Llanero (Table 3).

II. LEAF-CUTTER ANTS

Leaf-cutter ants (*Atta* and *Acromyrmex* spp.) will become more important with expansion of agricultural activity into the savanna where leaf-cutters are abundant. Intensification of pasture systems through planting of improved forages is the primary factor contributing to increased economic participation of the eastern plains of Colombia in the national economy.

Extension of roads and services is expected to encourage expansion of crops and mixed crop and pasture systems into the savanna ecosystem. Thus, pest control in pastures, particularly of leaf-cutters, will become more important as more intensive systems of land use and integrated cropping systems are adopted.

Effect of soil preparation and grass species on *Acromyrmex landolti*

To study the effect of timing of soil preparation on ant colony density, six plots (60 x 60m) of native savanna known to have high populations of *Ac. landolti* and no *Atta* colonies, were seeded with *Andropogon gayanus* in May, 1988. Three of the plots were prepared in December, 1987 at the beginning of the dry season (early preparation). The remaining three plots were prepared at planting with the beginning of rains in May, 1988 (late preparation). Preparation consisted of a single pass with chisels spaced 25 cm apart at a depth of 15 cm. At sowing, a single pass was made with an off-set disc simultaneously with fertilizer and seed

Tabla 3. Oviposition of *A. reducta* caged on 2 species of *Brachiaria* grass. 60 individuals (1:1 male:female) per cage, 5 replicates.

Species	Total oviposition*	Viable eggs*	% viable eggs*
B. jubata CIAT 16531	1470 (0.015)	907 (0.064)	60.0 (0.538)
B. dictyoneura cv. Llanero	643	377	53.8

* Numbers in parenthesis are probability of a greater t, Student's t test (N = 5).

application. Fertilization at planting consisted of 50, 20, 12, and 12 kg/ha of P, K, Mg, and S, respectively.

Counts of Ac. landolti colonies were made of the entire area in December, 1987, before the savanna was disturbed and at planting with the onset of the rains in May, 1988. Success of establishment was determined in July, 1989 as the percent of total row length with established seedlings. Percent establishment of A. gayanus seedlings did not differ between plots prepared in December at the beginning of the dry season (14.6 ± 17.0%) and those prepared in May at the end of the dry season (2.0 ± 0.7%). Damage by Ac. landolti was high in all plots and establishment of seedlings was poor. However, we observed a decline in colony density during the dry season in plots prepared in December compared with those prepared in May (Fig. 5). With the beginning of the rains and further preparation at planting in May, colony density decreased in both treatments compared with undisturbed savanna to about 15% of the initial number of colonies observed in December. Thus, soil preparation is a major source of colony mortality whenever it is done

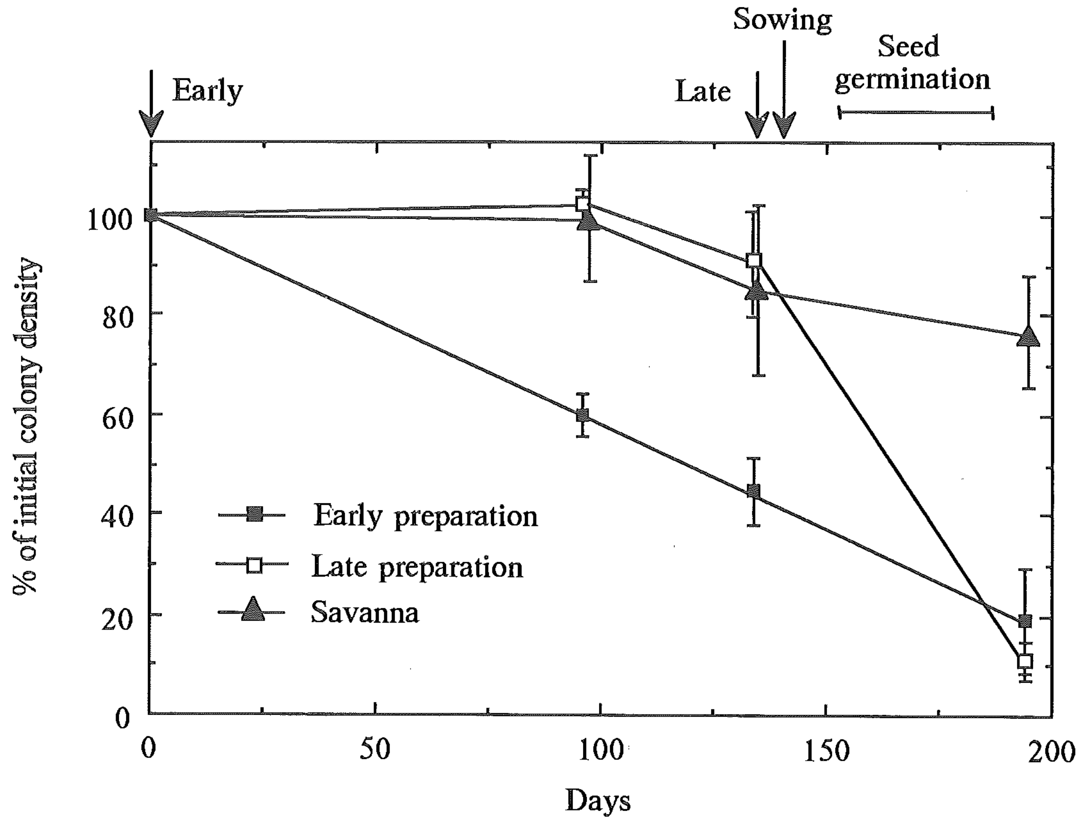


Figure 5. Effect of timing of land preparation on colony density of Acromyrmex landolti during the dry season with an adjacent area of undisturbed savanna as control. Arrows indicate timing of early and late preparation and sowing date. Day 0 = December 22, 1987. Bars are standard deviation.

but in heavily infested areas, the recommended minimal soil tillage for pasture establishment is not sufficient to avoid significant damage from ant predation.

Since it was impossible to establish *A. gayanus* by seed due to ant predation of seedlings, the same area was used in a split plot design to test the hypothesis generated from the surveys, namely that *B. humidicola* has a suppressive effect on *Ac. landolti* populations. Main plots (60 x 60m) consisted of early and late soil preparation, as above. Subplots (30 x 60m) were planted with either *A. gayanus* or *B. humidicola* in July, 1988. Vegetative material of both cultivars was used to insure successful establishment.

Colony density one year after establishment in the plots with early preparation was equivalent to that in the plots with late preparation (Fig. 6A). There was a small but significant effect of grass species on colony density (P=0.03) with fewer active colonies in plots of *B. humidicola* compared with plots of *A. gayanus*. More striking, however, was the obviously greater activity of colonies in the plots of *A. gayanus* compared with those in plots of *B. humidicola* as indicated by the amount of soil excavated and deposited at the nest entrances. In February 1989, soil excavated by all colonies was collected and measured volumetrically with a graduated cylinder. Colonies in plots of *B. humidicola* were much less active compared with those in native savanna or in *A. gayanus*. The volume of soil excavated by *Ac. landolti* was not affected by timing of soil preparation while a large difference was observed in the amount of soil excavated between colonies located in plots of the two grass species (Figure 6B). Mean volume of soil excavated by colonies in *B. humidicola* and *A. gayanus* was 223 and 1473 cc/colony, respectively. If it is assumed that the soil excavated had accumulated only since the last rains in December, then the amount of soil brought to the surface during a two month period by a density of 1,000 colonies/ha in a pasture of *A. gayanus* would be equal to 1.5 m^3/ha. The excellent physical properties and drainage of these savanna soils may be attributable in part to the considerable movement of subsoil by leaf-cutters.

The tendency of *Ac. landolti* to increase in *A. gayanus* will limit the utility of this grass in association with gramineous crops such as rice. *B. humidicola*, however, has a remarkably high level of resistance to leaf-cutters and may even be used to reduce or eliminate leaf-cutter colonies in infested areas. From the study of adjacent pastures of savanna, *B. humidicola*, and *A. gayanus* (CIAT Annual Report 1988), it is evident that colonies of *Ac. landolti* die out over time or migrate from swards of *B. humidicola*. The greatly reduced volume of soil excavated by colonies during the dry season in *B. humidicola* may be an indication of reduced foraging activity related to colony decline and incipient death.

Although land preparation appeared to be a major source of mortality of *Ac. landolti* colonies, timing of preparation had no effect on number of active colonies present during the critical period of seed germination (Fig. 5). Strategies for control of *Ac. landolti* should include strategic use of grass germplasm options based on an assessment of the area to be planted in terms of actual ant population and conditions known to influence ants (drainage), and knowledge of the susceptibility to ant predation of available forage grass varieties. Thus there is a need for economic thresholds based on colony density as a decision-making aid.

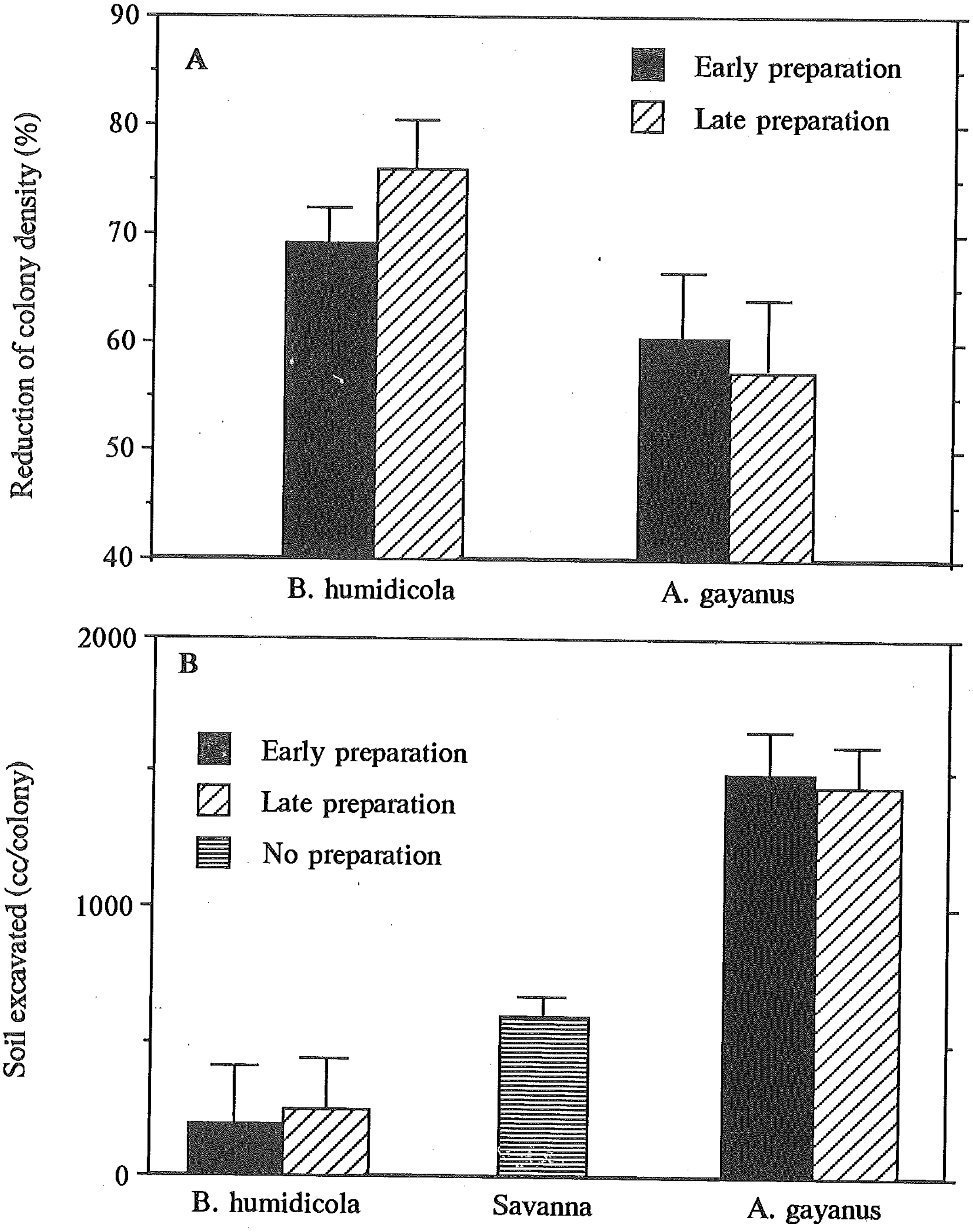


Figure 6 Effect of timing of soil preparation and grass species on density (A) and activity (B) of colonies of Acromyrmex landolti one year after preparation. Bars are standard deviation.

III. CENTRAL INSECT COLLECTION

The insect collections of the four commodity programs (Beans, Rice, Cassava, and Tropical Pastures) have been consolidated into a single collection curated by a research assistant. A large quantity of material was discarded due to improper preparation, lack of collection data, contamination, or poor condition of the specimens. The remaining material has been combined into a single taxonomic collection while separate crop-specific collections of principal species of economic importance are being prepared as material becomes available. A data base has been created that will eventually include information for all specimens on locality, host plant, taxonomic identification, habit, physical location in the collection, etc. This data base will be made available to national programs and other collaborators.

IV. COLLABORATIVE TRIALS WITH RICE PROGRAM

It is anticipated that the movement of rice into the eastern savanna of Colombia and the adoption of rice and pasture systems in these areas will create new pest problems on rice. In particular, spittlebugs may cause damage to rice when associated with a spittlebug-susceptible grass such as *B. decumbens* cv. Basilisk. The bioassay methodology developed for evaluation of host plant resistance to spittlebugs in *Brachiaria* germplasm has been adapted for use on rice lines and evaluation by the Entomology section of the Rice Program for spittlebug resistance is being carried out (see Rice Program annual report). In addition, collaborative field trials are planned at Carimagua.

Damage threshold for *Acromyrmex landolti* in *Andropogon gayanus*

During 1989, six sites were chosen with a range of densities of *A. landolti* colonies and planted with seed of *A. gayanus*. Due to poor seed germination, data from all plots are not yet available. Figure 7 presents data from three sites showing the relation between colony density and the number of seedlings harvested by leaf-cutters. When data on establishment success are available, a threshold value will be calculated.

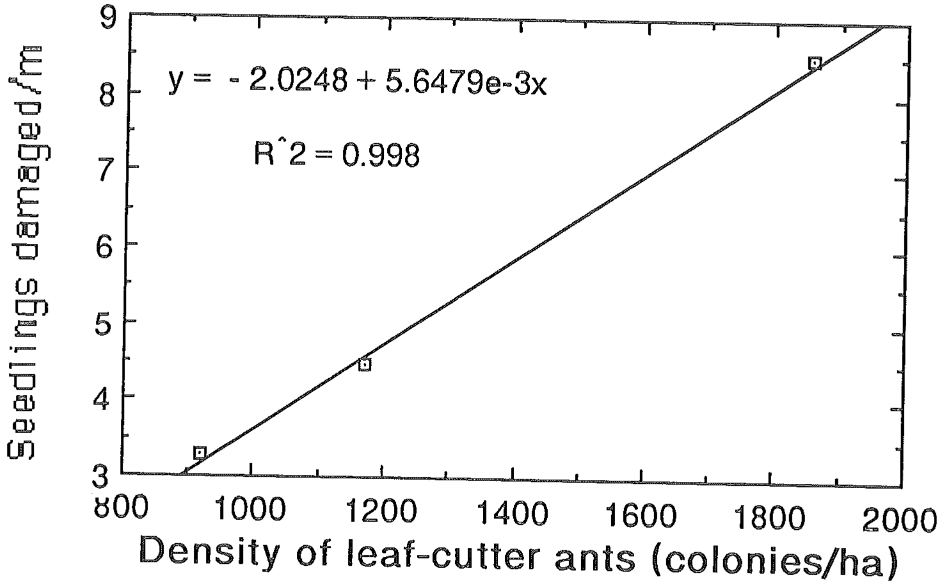


Figure 7. Relationship between the density of colonies of the leaf-cutter *Acromyrmex landolti* and the number of seedlings of *Andropogon gayanus* harvested by ants per meter of row sown. Data incomplete.

6. Agronomy Llanos

During 1989, the Agronomy Llanos section continued with its research emphasis on the identification of pasture species adapted to the biotic and edaphic stresses of the Llanos ecosystem. Whereas most work was carried out at the ICA Carimagua Research Center, new research activities were initiated in the piedemonte region at the ICA Experiment Station La Libertad, near Villavicencio.

PRELIMINARY EVALUATION (CATEGORY II) - CARIMAGUA

A wide range of species is presently being tested on two different soils in Carimagua (Table 1).

As far as trials established prior to 1989 are concerned, the following summarizing comments can be made:

Pueraria phaseoloides

The collection exhibits at both sites considerable variation in soil adaptation and plant vigor. After two years of evaluation, the most productive accessions are as follows:

- On the light-textured soil at Yopare: CIAT 18382, 17278, 18381, 17313, 17291, 18384, 17307, 17298, 19815 and 17308.
- On the heavier-textured soil at Alcancía: CIAT 18381, 17313, 17298, 17279, 17295, 18031, 18384, 18382, 18377 and 17316.

It is noteworthy that among the ten most productive lines at each site, there are five accessions common to both sites (CIAT 17298, 17313, 18381, 18382 and 18384).

Desmodium ovalifolium

Synchytrium false-rust continues to be the major constraint in this species. At both sites, accessions CIAT 13089, 13657, 13648, 23626 and 23656 show good performance.

Centrosema acutifolium

The germplasm under evaluation consists of the whole collection of this species (26 available accessions). The most productive accessions represent at both sites the var. *orinocense*, that is, the cv. Vichada type of *C. acutifolium*. Accessions CIAT 15088, 15086, 15447, 15448 and 15084 show superior vigor at both sites.

Centrosema tetragonolobum

None of the accessions can be considered as adapted to the Carimagua environment.

New germplasm (material established in 1989)

Germplasm established in 1989 includes:

- New *Brachiaria* accessions (45), within the continuing search for spittle-bug resistant material (collaborative trial with TPP Entomology);

Table 1. Germplasm under Category II evaluation at two sites in Carimagua (Alcancía and Yopare), 1989.

Germplasm established pre-1989		Germplasm established in 1989	
Species	No. of accessions	Species	No. of accessions
Pueraria phaseoloides	99	*Brachiaria* spp.	45[1]
Desmodium ovalifolium	52	*Cratylia argentea*	10
Centrosema acutifolium	26	*Desmodium velutinum*	59
Centrosema tetragonolobum	10	*Desmodium strigillosum*	10
		Flemingia macrophylla	42
		Dioclea guianensis	19
		Centrosema arenarium	5
		Centrosema brachypodum	6
		Centrosema capitatum	8

1/ Also established at ICA-La Libertad (Villavicencio).

- The whole collections of *Cratylia argentea* (syn. *C. floribunda*), *Desmodium strigillosum*, *D. velutinum*, and *Flemingia macrophylla* with 10, 10, 59 and 42 available accessions, respectively. These collections are evaluated because of the promise shown in Quilichao (*C. argentea*) and in the Category III - savanna trial (the other species), respectively;

- 18 *Dioclea guianensis* accessions that had been selected because of their good performance in Quilichao (including palatability); they are being compared with an earlier Carimagua selection;

- The small collections of three little-known *Centrosema* species, i.e., *C. arenarium*, *C. brachypodum*, and *C. capitatum* which, based on their origins, might have a potential for savanna conditions.

PRELIMINARY EVALUATION (CATEGORY II) - VILLAVICENCIO

Since January 1989, regional trials in the western part of the Llanos Orientales and germplasm evaluation for the piedemonte region are handled from the ICA Experiment Station La Libertad, near Villavicencio. Table 2 informs about the trials and germplasm material presently under evaluation.

The regional trials established pre-1989 have not concluded yet. According to preliminary analyses, *Stylosanthes guianensis* var. *pauciflora* hybrids, *S. capitata*, and *Desmodium ovalifolium* are the most productive and soil-covering species during the wet season. During the dry, *S. guianensis* var. *pauciflora* stands out.

New trials established during 1989 include 3 Regional Trials B each with 35 legume accessions. Furthermore, at La Libertad the whole collection of *Pueraria phaseoloides* (163 available

Table 2. Agronomic evaluation of germplasm in the western part of the Llanos Orientales (Villavicencio - Puerto López - Puerto Gaitán).

Trials established in 1989		Trials established pre-1989	
Species/Trials	No. of accessions	Species/Trials	No. of accessions
Brachiaria spp.	45[1]	RT-B Maracay	30
Panicum maximum	30	RT-B Malibú	28
Pueraria phaseoloides	163	RT-B Pizano	21
Centrosema pubescens	27		
RT[2]-B Mata Azul	35		
RT-B Maracaibo	35		
RT-B El Capricho	35		

1/ Also established in Carimagua. 2/ RT = Regional Trial.

accessions) and 45 new Brachiaria accessions were established. In addition, 30 Panicum maximum accessions, selected from several years' evaluation in Carimagua, and 27 Centrosema pubescens accessions are evaluated. The C. pubescens evaluation forms part of a multilocational trial series of this species.

This newly established material is expected to have a higher potential for the more humid and, edaphically, somewhat less stressful conditions of the piedemonte region than to the altillanura environment such as in Carimagua.

OTHER EVALUATIONS UNDER CUTTING

At both the Carimagua and La Libertad stations, 34 Brachiaria accessions selected from the previous evaluation work with 265 accessions at Carimagua during the past years, were established in 1989 as a collaborative project with the TPP Entomology section. The objective is to assess in more detail (1) the adaptation of these selected accessions to acid, low-fertility soils and, (2) their resistance to spittlebugs. The evaluation methodology includes two insecticide treatments (with and without insecticide).

EVALUATION UNDER GRAZING (CATEGORY III) - CARIMAGUA

Low-palatability legumes in native savanna

In this experiment, several legumes -- which cafeteria grazing trials in Quilichao had shown to be of low palatability to cattle -- were tested in association with native savanna.

The experiment was recently concluded, and in Table 3 the legume percentages in (a) the forage on offer and (b) the forage consumed, are presented for the 5 most vigorous of the tested species and for the control Centrosema acutifolium cv. Vichada. The data suggest a strong seasonal palatability effect: Except for the control, legumes were very little consumed during the wet season, while consumption was high during the first dry season and, for Centrosema arenarium and Desmodium velutinum, also during the second dry season (which received some out-of-season rainfall).

Table 3. Proportion of legume leaf in the forage on offer and selected by oesophageal-fistulated steers in associations of legume and native pasture in the dry and wet seasons.

Native pasture/legume association	Legume on offer (%)			Legume in extrusa (%)		
	Dry^1 (1987-88)	Wet^2 (1988)	Dry (1988-89)	Dry (1987-88)	Wet (1988)	Dry (1988-89)
Centrosema arenarium	13	12	22	14	2	49
Desmodium strigillosum	20	42	47	38	8	7
Desmodium velutinum	18	40	19	49	7	18
Flemingia macrophylla	25	39	49	55	6	28
Tadehagi triquetrum	14	15	27	22	4	11
Centrosema acutifolium cv. Vichada (control)	55	42	67	54	22	45
LSD^3	14	24	17	40	18	12

1/ Dry season values are means of three samplings at beginning of each grazing cycle in early (December), mid (February) and late (April) dry season.

2/ Sampled in mid-wet season (August).

3/ Least significant difference ($P \leq 0.05$).

It is concluded that the best adapted of the species tested, such as Flemingia macrophylla, merit animal-production evaluation in native savanna, and further agronomic and animal-consumption evaluation in association with improved grasses.

Centrosema brasilianum in association with two grasses

In this experiment, the performance of 9 Centrosema brasilianum accessions, each associated with Andropogon gayanus and with Brachiaria dictyoneura, is studied under an intermittent-grazing regime. In 1989, that is, in the second year under grazing, legume percentages have stabilized at a somewhat low level (Table 4), with the notable exception of C. brasilianum accessions CIAT 5486 and 5828. The data suggest that, under the experimental conditions, Brachiaria dictyoneura is a more suitable grass for associations with C. brasilianum than Andropogon gayanus.

Flemingia macrophylla in association with Brachiaria spp.

Grazing of this experiment with oesophageal-fistulated steers will start in December 1989. The principal objective is to determine whether the high consumption of F. macrophylla during the dry season also holds for associations with improved grasses. Grasses in this experiment are the two most common Brachiaria species in the Colombian Llanos, i.e., B. decumbens and B. humidicola.

Table 4. Legume percentage in Centrosema brasilianum - grass pastures (Category III evaluation; Carimagua - Alcancía 1989).

Centrosema brasilianum CIAT No.	Andropogon gayanus		Brachiaria dictyoneura	
	May 89	Sept 89	May 89	Sept 89
5178	1.1	1.7	4.7	4.6
5234	1.5	1.3	3.2	2.3
5486	4.0	6.1	16.7	20.1
5657	1.3	1.1	3.5	6.3
5667	1.5	1.3	1.6	1.5
5671	1.9	1.9	3.3	2.5
5725	3.3	4.2	5.7	4.0
5810	1.4	1.4	5.2	4.0
5828	4.5	6.9	10.3	8.8

7. Agronomy Cerrados

The EMBRAPA/CPAC/CIAT collaborative project at the Centro de Pesquisa Agropecuaria dos Cerrados (CPAC) continues to pursue the main objective of identifying forage grasses and legumes adapted to the "Cerrados" conditions.

Members of the EMBRAPA/CPAC team directly involved in germplasm evaluation and selection, and initial seed multiplication, are Mário Soter Franca-Dantas, Marco Antonio de Souza, Ronaldo P. de Andrade, María Alice S. Oliveira, and Luiz Carlos B. Nasser.

PROGRAM OF ACTIVITIES

Introduction and evaluation activities, as well as selection, have been currently modified in order to accelerate the process and, at the same time, exert more pressure on the germplasm evaluated. The main criteria are: disease and pest incidence (especially spittlebug in the case of grasses), agronomic performance during the dry period, and recovery from the effects of factors such as rainfall, cuttings, fire, etc. Reduced emphasis is placed on estimating total dry matter production and practicing routine bromatological analyses. At the same time, the number of regional trials is expected to grow, given the great magnitude of the ecosystem and its large variability in soils, texture, and organic matter, as well as its varying characteristics in terms of altitude and rainfall distribution. Table 1 and 2 present the grass and legume germplasm to be introduced for evaluation during the current agricultural year. Table 1 shows that among grasses, emphasis is being given to _B. brizantha_ and _Paspalum_ spp. aff. _P. plicatulum_ on the basis of previous experience when the mentioned genera and species were found to have outstanding agronomic characteristics.

In turn, to increase the pressure potential of pests and/or diseases, _B. ruziziensis_ will be planted between plots in order to increase the degree of competition and reduce erosion risks, as well as maintenance costs.

Table 2 shows both forage and shruby legume germplasm, in view of the fact that these can play an important role in this ecosystems.

Preliminary evaluation of forage grasses and legumes during the dry period

Grasses

Panicum maximum

Hybrids from Dr. E. M. Hutton's selection work were evaluated during the dry period. Evaluations included production, vigor, and retention of green color in the foliar lamina.

Table 3 summarizes results achieved. Cv. Makueni and CPAC 3148 were the only materials having moderate yields, ranging from 10 to 6% of the total produced during the period of minimum precipitation.

Table 1. Grass germplasm.

Grasses	No. of Grasses	Priority*
Axonopus spp.	3	1
Brachiaria bovonei	2	1
B. brizantha	100*	1
B. decumbens	16*	1
B. dictyoneura	8*	1
B. humidicola	19**	1
Panicum maximum	25	2
Paspalum spp. aff. *P. plicatulum*	30	1

* Meristem culture.

** 1 = 1989; 2 = 1990.

Table 2. Legume germplasm.

Legumes	No. of accessions	Priority*
Aeschynomene spp.	14	2
Arachis glabrata	12	1
A. pintoi	10	1
Arachis spp.	3-4	1
Cajanus scarabaeoides	20	3
Calopogonium mucunoides	50	1
Cassia rotundifolia	15	1
Cratylia floribunda	12	2
Centrosema acutifolium	40	1
C. brasilianum	12	1
C. tetragonolobum	12	1
Codariocalix gyroides	25	2
Desmodium barbatum	12	2
D. heterocarpon	50	2
D. velutium	100	2
Flemingia macrophilia	15	1
Sesbania spp.	15	1
Stylosanthes scabra	20	1
Zornia latifolia	20	3
Z. glabra	25	3

* 1 and 2 = Introduced in 1989.
3 = To be introduced in 1990.

** 1 = 1989; 2 = 1990.

Table 3. Average yield of *Panicum maximum* accessions during the dry period.

CPAC No.	Yield during rainy period (kg DM/ha) (October-May)	Yield during dry period (kg DM/ha) First half (4-V/ 14-VII)	Second half (14-VII/ 14-IX)	Accumulated (4-V/ 14-IX)
3144	2630 ± 1061	-	-	-
3142	2521 ± 976	-	-	-
3146	2165 ± 528	-	-	-
3148	1850 ± 1581*	-	75	41
3141	1831 ± 2044	-	-	-
cv. Coloniao	4744 ± 2466	-	-	-
cv. Makueni	2516 ± 757	100	110	73

P. maximum accessions retained their green color from the onset (5-V-89) up to the first eight weeks of the dry period. Two weeks later (13-VII-89) only cv. Makueni continued green. During the rainy period, cv. Makueni was also outstanding among the hybrids (Table 4).

Table 4. Regrowth capacity of *Panicum maximum* accessions at the onset of the rainy period.

CPAC No.	kg DM/ha*
3141	110 ± 35
3142	113 ± 40
3144	118 ± 19
3145	91
3146	103 ± 32
3148	107 ± 21
$\bar{X}$ ± DE	107 ± 9
cv. Makueni	424 + 60

* 14-IX-89 - 23-X-89 = 38 growth days.

Paspalum spp.

Table 5 shows accumulated dry matter production during 175 growth days in the rainy period. Yields range from 3 to 7 t DM/ha, contrasting with values reported in previous documents (see 1987 and 1988 Annual Reports where yields ranged from 16 to 29 t DM/ha).

These low values can be partially explained by the fact that the experiment area was not fertilized, cuttings had been previously done, and low temperatures were recorded during the past dry period (July, 8.45 ± 2.65° C minimum temperature, with values as low as 2.8° C).

In spite of the experiment area being located in a partially-flooded low with a relatively superficial ground water level (0.81 - 1.22 m), yields achieved (Table 6) are relatively low (429 ± 116 kg DM/ha) during a period accumulated over 130 growth days, which corresponds to 10% total annual production. Accessions BRA 3913, 9610, and 9661, in addition to their

Table 5. Dry matter yield of Paspalum spp accessions during the rainy period in seasonal flooded land: EMBRAPA-CPAC-Brazil.

Species	BRA* No.	Yield** (t/ha)
Paspalum sp. aff. P. plicatulum	9407	6.7
P. sp. aff. P. plicatulum	9661***	5.7
P. sp. aff. P. plicatulum	3913	5.2
P. sp. aff. P. plicatulum	9431	5.1
P. sp. aff. P. plicatulum	8486	4.4
P. sp. aff. P. plicatulum	9628	3.5
P. sp. aff. P. plicatulum	3638	3.4
P. sp. aff. P. plicatulum	9610***	3.0
P. urvillei	10685***	3.6
P. urvillei	7323	2.9

* BRA Nos. 3891, 3905, and 6203 very poor growth.
** Accumulated dry matter yield from 10-XI-88 to 5-V-89, 175 days.
*** Several attacked by ants.

good agronomic performance and good health conditions, also have average IVDMD values of 54, 53, and 50%, respectively.

Brachiaria spp.

Of the 343 Brachiaria accessions introduced in 1987, 24 were selected. Partial evaluation results had been presented in previous reports (1987 and 1988). This report includes data on yield and quality for the last period of maximum precipitation and for evaluations conducted during the dry period.

Table 7 summarizes average yields at 3, 6, 9, and 12 months regrowth during the period of maximum precipitation. With the exception of B. humidicola CIAT 26154, the average of the other groups is similar to that of cv. Marandú, with B. decumbens CIAT 16488 outyielding the control by 50%.

Nutritive value of the selected accessions is shown in Table 8. Average values of crude protein content and IVDMD are similar to those published for tropical forage species. The main factor currently limiting selection under these conditions is the low incidence in the field of the spittlebug (Deois flavopicta); this lack of pressure hinders the selection process since it constitutes the important limiting factor for evaluation, and not production and/or forage quality. Average values of nymphs/m^2 (Table 9) are not sufficiently high to cause symptoms and/or damage to the accessions evaluated.

During the 1989 dry period, yield and number of live and dry (dead) tillers were estimated.

Table 10 shows variation among live and dry tillers during the period of minimum precipitation. Preliminary results show that reduction in live tillers was 50% for the average of the accessions evaluated and 47% for the local control, while the increase in dead tillers was 20 and 88%, respectively.

Dry matter yields (Table 11) are low for most accessions evaluated during the dry period and similar to those of cv. Marandú. Average dry matter production was 1 ± 0.478 kg/day; yet, once the rainy season had started (Table 12), production increased to 15 ± 3 kg DM/day. Accessions CIAT 16121, 16319, 16467, 16549, 16488, and 16500 were outstanding among the group.

Table 6. Dry matter yield of Paspalum spp. accessions during the dry period in a seasonal flooded land: EMBRAPA-CPAC, Brazil.

BRA No.	Yield (kg DM)					
	First half (5-V to 18-VII)		Second half (18-VII to 12-IX)		Whole period (5-V to 12-IX)	
	per ha	per day	per ha	per day	per ha	per day
P. plicatulum						
3638	442	6	343	4	544	4
3913	533	7	161	3	306	2
8486	342	5	251	7	388	3
9407	442	6	264	5	281	2
9431	169	2	242	4	383	3
9610	394	5	243	4	544	4
9661	611	8	304	5	527	4
9628	469	6	251	5	370	3
P. urvillei						
7223	255	3	160	3	624	5
10685	223	3	275	5	345	3
	388±141	5±2	249±56	5±1	429±116	3±1

Table 7. Average yields (g DM/m^2) of Brachiaria spp. accessions during the maximum precipitation period.

Ecotype CIAT No.	Weeks 3	6	9	12
B. brizantha				
16107	23	139	371	266
16121	40	167	565	539
16135	21	102	276	312
16168	24	146	471	504
16294	32	156	345	367
16301	28	140	274	436
16306	33	156	228	321
16307	26	118	342	413
16311	25	95	223	363
16315	40	124	238	319
16318	21	144	320	391
16319	40	183	570	463
16339	31	134	285	330
16467	53	168	392	452
16473	37	176	384	413
16549	47	221	348	550
16827	28	127	242	285
16829	42	219	323	453
26110	41	134	370	248
$\bar{X}$ ± SD	33 ± 9	150 ± 34	346 ± 101	391 ± 90
B. decumbens				
16488	38	241	612	813
16500	29	243	340	428
26181	32	154	258	432
26185	25	68	85	106
$\bar{X}$ ± SD	31 ± 5	177 ± 83	324 ± 220	445 ± 289
B. humidicola				
26154	44	62	98	196
cv. Marandu	31	154	288	416

Table 8. Nutritive value of *Brachiaria* spp. accessions during the maximum precipitation period.

	Weeks							
Ecotype CIAT No.	CP (%)	IVDMD (%)	CP (%)	IVDMD (%)	CP (%)	IVDMD (%)	CP (%)	IVDMD (%)
B. brizantha								
16107	23	67	16	58	11	65	10	66
16121	24	69	16	68	11	65	9	62
16135	24	70	17	69	9	62	8	64
16168	24	69	16	69	10	62	9	65
16294	23	66	16	63	10	63	10	56
16301	23	68	14	59	11	64	8	63
16306	22	68	16	56	11	63	9	63
16307	24	68	15	65	9	60	9	59
16311	14	72	17	67	11	58	10	58
16315	19	62	14	55	10	59	7	56
16318	25	69	15	62	13	62	9	62
16319	22	68	13	66	7	54	7	58
16339	20	65	14	62	12	61	9	61
16467	22	65	13	58	9	59	8	57
16473	21	68	14	67	9	64	9	61
16549	24	68	15	63	9	60	7	58
16827	23	68	15	65	12	63	10	63
16829	21	68	15	67	10	60	7	52
26110	22	67	14	61	9	61	8	59
$\bar{X}$ ± SD	22±2	68± 2	15±1	64±4	10±2	63±5	8±2	60±4
B. decumbens								
16488	20	70	14	69	11	60	9	62
16500	26	66	16	67	11	58	9	59
26181	25	68	17	66	11	65	9	64
26185	22	69	6	55	8	68	6	55
$\bar{X}$ ± SD	23+3	68±2	13±5	64±6	10±2	63±5	8±2	60±4
B. humidicola								
26154	25	58	7	53	7	53	5	46
cv. Marandu *B. brizantha*	--	67	17	66	12	65	10	60

Table 9. Number of Deois flavopicta nymphs in accessions of Brachiaria spp.

CIAT No.	No. of nymphs/m^2
B. brizantha	
6780*	0
16107	2
16121	4
16135	1
16168	1
16294	0
16301	1
16306	0
16307	0
16311	0
16315	0
16318	2
16319	1
16339	0
16467	2
16473	2
16549	2
16827	1
16829	1
26110	1
$\bar{X}$ + SD	1 _ 1
B. decumbens	
16488	7
16500	2
16181	2
26185	13
$\bar{X}$ + SD	6 _ 2
B. humidicola	
26154	15

* Local control, cv. Marandu.

LEGUMES

Desmodium ovalifolium

Seventy accessions of D. ovalifolium were planted in March 1985 in a partially-flooded low. The materials were evaluated over a two-year period under periodical cuttings. Practically no cuttings were practiced in this trial during 1987 and 1988; this enables evaluation of the degree of adaptation and aggressiveness of these materials.

Table 13 summarizes results of evaluations conducted during the 1989 dry period. Twenty percent of the material planted is promising, being CIAT 13136 outstanding for its excellent performance. Performance of 63% of the group ranged from intermediate to poor, and the remaining 17% of the accessions planted disappeared from the plot and the area is now invaded by local grasses and weeds.

Centrosema spp.

Forty three Centrosema accessions were established in December 1987 in a dark-red latosol (Table 14). During the 1989 dry period various parameters were evaluated: vigor, % weed invasion, flowering, color and retention of leaflets, and pest and disease incidence.

C. brasilianum 5234 and C. brachypodum 5859 are outstanding among the group. Percentage invasion in plots of the germplasm evaluated varied from 5 to 50%. Weed invasion in C. brasilianum 5234 and C. brachypodum 5850 was 9 and 5%, respectively.

Green leaflets of C. brachypodum 5850 were observed throughout the dry period, while those of C. brasilianum 5233 remained green only half of the period (May - July).

Most accessions evaluated were affected by mycoplasma and rhizoctonia; incidence was moderate during the dry period.

Seed production was acceptable in the case of C. brasilianum 5234 and null in C. brachypodum 5850.

Table 10. Evaluation of number of live and dead tillers in *Brachiaria* spp. accessions during the dry period.

CIAT No.	3 weeks (12-V)		12 weeks (13-VII)		21 weeks (15-IX)	
	Live	Dead	Live	Dead	Live	Dead
B. brizantha						
16107	97	79	59	77	45	148
16121*	128	68	83	97	53	72
16135	60	118	61	138	27	119
16168	67	87	42	102	41	85
16294	86	77	67	113	54	109
16301	103	106	62	108	37	150
16306	61	77	31	90	30	77
16307	41	53	33	53	18	58
16311	43	51	27	62	19	57
16315	91	87	61	71	53	70
16318	125	83	88	151	68	82
16319*	78	105	39	118	30	102
16339	102	126	59	98	50	111
16467*	111	109	67	92	57	151
16473	101	119	65	128	51	160
16548*	121	90	72	93	59	106
16827	138	47	91	79	72	76
16829	132	18	84	44	57	55
26110	58	82	35	87	26	84
B. decumbens						
16488*	130	102	91	109	63	131
16500*	151	75	117	95	102	101
26181	103	41	85	51	41	47
$\bar{X} \pm$ SD	97 ± 32	82 ± 28	65 ± 23	93 ± 28	48 ± 20	98 ± 34
cv. Marandú	103	25	74	36	55	47

* Selected.

Table 11. Dry matter yield (kg/ha) of Brachiaria accessions during the dry period.

CPAC No.	First cycle (20-IV/17-VII)	Second cycle (17-VII/15-IX)	Accumulated production (20-IV/15-IX)
B. brizantha			
16107	176	76	69
16121*	130	71	282
16135	106	83	161
16168	117	91	176
16294	142	80	171
16301	125	88	114
16306	183	113	263
16307	84	125	200
16311	110	110	137
16315	159	51	115
16318	92	89	149
16319*	84	105	94
16339	93	50	113
16467*	170	141	350
16473	233	114	215
16549*	74	32	90
16827	218	76	113
16829	363	69	115
26110	330	89	156
$\bar{X} \pm$ SD	157 ± 81	87 ± 27	162 ± 73
B. decumbens			
16488*	263	193	255
16500*	170	99	167
26181	290	82	162
$\bar{X} \pm$ SD	241 ± 63	125 ± 60	195 ± 52
cv. Marandú	537	109	175

Table 12. Average dry matter production production of *Brachiaria* spp. accessions after the rainy period had started.*

CIAT No.	Kg DM	
	ha	day
B. brizantha		
16107	470	12
16121	472	13
16135	431	11
16168	587	15
16294	757	20
16301	480	13
16306	740	20
16307	570	15
16311	485	13
16315	652	17
16318	462	12
16319	490	13
16339	500	13
16467	625	17
16473	716	19
16549	318	9
16827	539	4
16829	758	20
26110	620	16
$\bar{X} \pm$ SD	562 ± 123	15 ± 3
B. decumbens		
16488	714	19
16500	635	17
26181	362	10
$\bar{X} \pm$ SD	570 ± 185	15 ± 5
cv. Marandú	658	17

* 38 growth days.

Table 13. Evaluation of degree of adaptation and leaf retention of *Desmodium ovalifolium* at the end of the dry period.

Degree of adaptation	CIAT No.	Percentage of material planted
Excellent	13136	1
Good	350-3607-3673-3778-3781-3788 13085-13092-13109-13122-13125 13126-13289	19
Intermediate	3652-3663-3666-3776-3780-3784 13081-13082-13083-13088-13089 13091-13095-13098-13099-13101 13103-13104-13105-13110-13111 13113-13115-13117-13120-13124 131128A-13129-13130-13131-13133 13137-13138-13302	48
Poor	3668-3674-3794-13086-13087-13097 13100-13114-13132-13135	14
Disappeared	3608-3793-13096-13102-13107 13108-13116-13127-13128-13305 13307-13400	17

Planting date = 14-III-85; evaluation = 8-VIII-89; Local = EMBRAPA-CPAC.

Table 14. *Centrosema* spp. germplasm under evaluation.

Species	No. of accessions	CIAT No.
C. brasilianum	30	15528-15818-15819-15820-15821-15822-15823 15824-15889-15890-15891-15894-15895-15899 15908-15909-15387-15398-15525- 5324 (5224 x 5234)
C. tetragonolobum	6	15087-15089-15836-15838-15839-15840
C. acutifolium	5	15249-15530-15531-15533-5112
C. brachypodum	1	5850
C. capitatum	1	15680
TOTAL	43	

8. Agronomy Humid Tropics

During 1989 the INIAA-IVITA-CIAT collaborative project has continued evaluating forage germplasm under humid tropical conditions at the IVITA Experimental Station, Pucallpa, Peru. The principal objective of the Agronomy Section is to select legumes and grasses adapted to the abiotic and biotic conditions of the humid tropics, for the successful establishment of highly productive and stable pastures, as well as for the reclamation of degraded areas.

Within the International Tropical Pastures Evaluation Network (RIEPT), the materials identified as promising are distributed. Later, national institutions select germplasm adapted to the diverse environmental conditions of the humid tropical ecosistem.

The Pucallpa region corresponds to the tropical semi-evergreen seasonal forest ecosystem, with the following climatic and edaphic characteristics: medium annual temperature of 25.1°C, annual precipitation of 2049 mm (Fig. 1), and predominantly acid and low fertility Ultisol soils. The year 1989 was relatively humid, consequently, the experiments could still be established until April without major problems. However, these recent data obtained refer exclusively to the dry season, and do not reflect the species' entire potential of adaptation to environmental conditions.

AGRONOMIC EVALUATION OF LEGUME AND GRASS GERMPLASM (CATEGORY II)

In the category-II evaluation, screening is performed in small plots. Generally, records are taken on adaptation to prevalent environmental conditions, which include plant vigor and competitiveness (ground cover) in the establishment phase, resistance to pests and diseases, dry matter yield, flowering time and seed production. The evaluations are mainly realized in sites of degraded pastures with Ultisols which differ mainly in their draining quality.

During 1989, a total of 196 legume accessions were evaluated, 113 herbaceous and 83 shrubs. In addition, 238 grass accessions were evaluated (Table 1). All the experiments with legumes were recently established, so here only some preliminary results will be reported.

Aeschynomene americana

Due to its relatively late sowing in the season, the collection of 41 accessions of Aeschynomene americana accelerated their generative cycle, while biomass production of green leaves was not very high. All accessions lignified rapidly and flowering and seed set started early.

Nevertheless, great variability was detected between accessions. CIAT 18966 from Venezuela showed the best vigor from the very beginning. Others with good vigor were CIAT 9256, 9876,

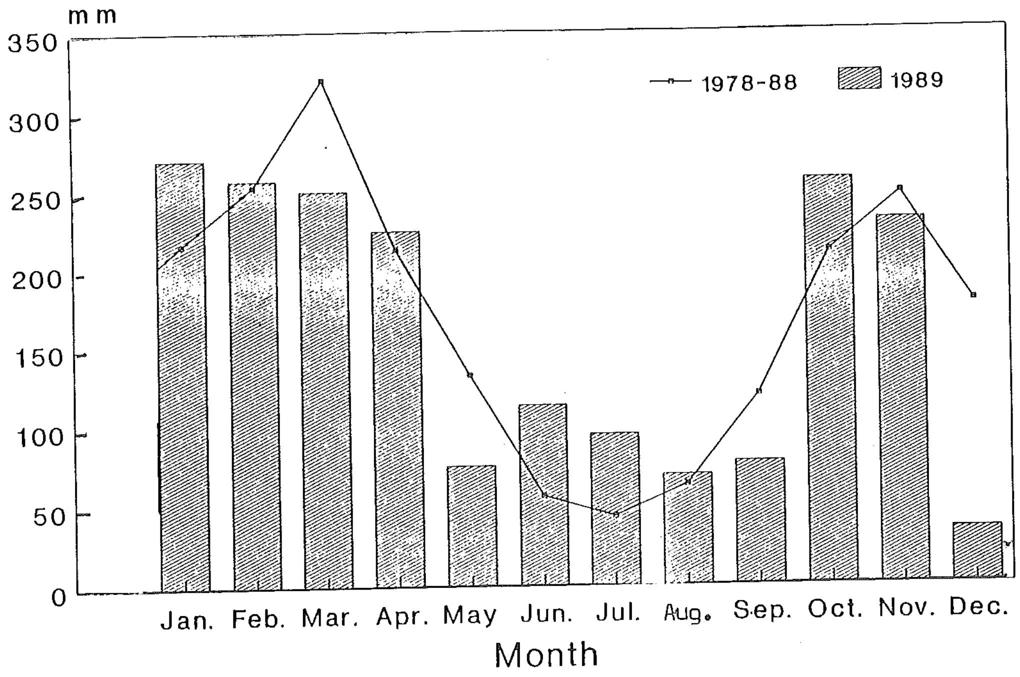


Figure 1. Precipitation at the IVITA Station, 1989 and 1978-88.

Table 1. Agronomic evaluation of legume and grass germplasm at CIAT-Pucallpa during 1989 (Category-II).

Species	No. of accessions	Establishment year
Herbaceous Legumes		
Aeschynomene americana	41	1989
Arachis pintoi	8	1986/89
Cajanus (Atylosia) scarabaeoides	18	1989
Centrosema brachypodum	2	1989
Centrosema capitatum	4	1989
Centrosema fasciculatum	2	1989
Centrosema pubescens	25	1988/89
Centrosema tetragonolobum	12	1989
Centrosema sagittatum	1	1989
Shrubby Legumes		
Cajanus cajan	14	1989
Codariocalyx gyroides	8	1989
Cratylia floribunda	2	
Desmodium velutinum	7	1989
Flemingia macrophylla	10	1989
Sesbania spp.	32	1989
Tadehagi triquetrum	7	1989
Tadehagi sp.	3	1989
Grasses		
Brachiaria spp.	213	1988
Panicum maximum	25	1987

17586, 18310 from Colombia, 18225 from Venezuela, and 20182 from Mexico. The accessions differed mainly in their growth habit, and there was considerable variation in flower onset.

Although this species is supposed to be annual, considerable variation was observed regarding survival after a cut and in dry season conditions (Table 2); 67% of the surviving material was of Colombian and 33% of Venezuelan origin, which represent much higher percentages than in the collection tested (C. America 27%, Colombia 39%, Venezuela 20%, Peru 2%, Brazil 5%, S.E. Asia 7%).

The performance of the local control (Ucayali, Peru) was generally poor.

Arachis pintoi

The agronomic evaluation of 8 accessions was completed with an analysis of seed production. Apparently, the flower abundance formerly observed does not coincide with seed production. The absence of seeds for the accession CIAT 17434 in a soil depth up to 15 cm after three experimental years was mostly unexpected (Table 3).

In a new experiment, using the same 8 accessions of A. pintoi, the competitiveness in the association with Brachiaria dictyoneura is evaluated. In the establishment phase, the following phenomena were observed:

Table 3. Seed production of 8 Arachis pintoi accessions up to 15 cm soil depth at Pucallpa during 1989.

CIAT No.	No. Pods/m^2	Seed yield (g/m^2) (with pods)
17434	0 a*	0 a
18747	137.3 b	18.27 b
18748	246.7 b	40.27 bc
18752	298.7 bc	49.87 bc
18751	678.7 bcd	84.53 c
18744	901.3 cd	156.00 c
18746	1213.3 cd	153.20 c
18745	1353.3 d	155.30 c

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

Table 2. Agronomic evaluation of Aeschynomene americana at Pucallpa during 1989.

% of Survival 2 months after cut	Accession, CIAT No.
0-1	Local Control. 315, 356, 3087, 3153, 3229, 7000, 7009, 7012, 7446, 7701, 7834, 8096, 8269, 8625, 8779, 8838, 9056, 9065, 9256, 9876, 9881, 9997, 17586, 18241, 18963, 19408, 19496, 19900, 20179, 20182
3-5	9149, 18310, 18966
13-38	7257, 8774, 8778, 9557, 18225
46	17864

a. CIAT 17434, 18744, 18745, 18746, and 18751 reached an acceptable ground cover (> 10% with and > 30% without B. dictyoneura) relatively soon.

b. In the first total DM yield (including weeds), no significant differences among accessions could be detected. The average legume percentage of DM in the association was 6.1% and that of B. dictyoneura 85.7%. In the treatment without the grass, the legume content was 8.4%, the rest being weeds.

c. CIAT 18745 and 18752 in the grass association, and CIAT 18744, 18746, 18747, and 18751 without the grass, obtained >10% of the DM yield.

d. Although showing a low ground cover, CIAT 18752 contributed a relatively high percentage to the DM yield.

Cajanus (Atylosia) scarabaeoides

Cajanus scarabaeoides is considered to be one of the most drought resistant species; however, it is not known how its adaptation to infertile and acid soils would be. There was considerable difference among the 18 accessions sown, referring to their establishment phase (Table 4). CIAT 17396 from Thailand performed significantly different in terms of higher soil cover, vigor and less susceptibility to Rhizoctonia. The accession was among the three latest in the beginning of flowering; nevertheless, seed production started relatively early. Most of the accessions maintained a high percentage of green leaves during the dry season.

Centrosema pubescens

The multilocational trial with 25 accessions of C. pubescens was sown at two sites with different drainage at Pucallpa. After nearly one year at a badly drained site and half a year at a better drained site, some preliminary conclusions can be drawn (Table 5).

In the establishment phase, on both soil types, CIAT 15160 was outstanding, and both CIAT 15150 and 15470 yielded much higher than the general average.

Nevertheless, there was some interaction between sites and accessions: on the better drained site, CIAT 15154 and 15474 showed high initial yields, while on the badly drained site, CIAT 5627 and the control CIAT 438 had higher initial yields than the average.

As far as other characters such as rooting at nodes of trailing stems and ground cover are concerned, CIAT 15880 and 5631 and CIAT 15160 and 15474, respectively, showed the most rapid establishment.

Summarizing the results of three dry matter harvests on the badly drained soil, CIAT 15160 and 5627 were outstanding and yielded nearly double the control CIAT 438. CIAT 5634 and 15150 had relatively high yields as well. However, none of these accessions reached the yield levels of the control accessions of C. acutifolium, CIAT 5277, 5568, and 15086.

Leaf-eating and rasping insects, as well as disease incidence of Cercospora and/or Rhizoctonia, did not cause major damage, although some differences of susceptibility among accessions could be observed.

Centrosema spp.

Although established relatively late in the season, the various species of Centrosema showed reasonable vigor. In the first evaluation of ground cover, no difference could be detected among species and/or accessions. In

Table 4. Preliminary agronomic evaluation of _Cajanus scarabaeoides_ (5 months after transplanting) at Pucallpa during 1989.

Variable	Average	Range	Superior CIAT No.
Ground cover (%)	24.1	11.2 - 50.8	17396
Vigor (1-5)	2.8	2.0 - 4.0	17396
Eating insects (0-5)	1.4	0.7 - 2.0	20615
Rasping insects (0-5)	1.7	0 - 3.3	17396, 18415
50% flowering (days)*	64.8	56.0 - 83.5	
Beginning of seed set (days)*	104.5	86.0 - 115.0	

* After transplanting.

Table 5. Agronomic traits in the establishment phase of promising material of _C. pubescens_ at Pucallpa during 1989.

CIAT No.	Initial DM yield (g/m^2)		Ground cover (%)	
	Badly drained	Well drained	Badly drained	Well drained
438	88.0	78.3	70.5	29.2
5277*	123.2	84.7	90.3	41.8
5568*	153.4	152.5	95.8	33.7
15086*	91.9	99.9	91.5	39.5
5627	89.0	-	87.8	-
5631	65.1	49.4	80.5	36.7
5634	76.8	57.3	86.5	35.4
15150	87.4	105.1	81.5	37.5
15154	66.6	106.3	75.5	30.6
15160	109.9	115.3	95.3	38.5
15470	85.5	92.8	87.8	28.9
15474	65.4	102.0	86.3	41.2
15880	51.1	37.1	90.8	30.1

* _C. acutifolium_ (control)

the second evaluation, considerable difference existed; C. acutifolium and C. tetragonolobum especially, showed high percentages, while establishment of C. brachypodum and C. capitatum was still poor (Table 6). The best accessions in terms of rapid ground cover besides C. acutifolium CIAT 5278 were C. tetragonolobum CIAT 15089 and 15839. The incidence of leaf-destroying insects and fungus diseases was not yet very high.

Desmodium ovalifolium

At the end of the wet season, the evaluation of 82 D. ovalifolium accessions was concluded with a second test for relative acceptability for cattle. Again, highest preference was shown for CIAT 350, followed by CIAT 13030 and 13095. However, in an analysis of variance for both preference indices CIAT 350, 13653, and 13030 were the best of the accessions evaluated. Other accessions were not very consistent over both field replications. The correlation between both preference indices was low (r = 0.29).

Pueraria phaseoloides

The agronomic results of the experiment have been reported in the previous TPP annual report. However, the trial was finished with a second evaluation of the relative acceptability by cattle, in the dry season. The new evaluation for acceptability strikingly showed that mainly the same accessions already reported had the highest preference indices, namely CIAT 17307, 17286, and the local check.

Shrubby legumes

The evaluation of shrubby legumes for the humid tropics focuses on two main objectives: the supply of forage and the managed fallow ("enpurme") after a period of grazing and soil degradation. Hence, not only are the forage value and acceptability for grazing animals of interest but also rapid establishment and biomass production of a species and/or accession. Legumes are of special interest because of their ability to enrich the soil in terms of nitrogen, and to take advantage of mycorrhiza.

Table 6. Preliminary agronomic evaluation of several species of Centrosema at Pucallpa during 1989.

Species	No. of accessions	% Ground cover (2 months)*	% Ground cover (3 months)*	Rhizoctonia (5 months)*
C. acutifolium	3	13.2	39.3	1.7
C. brachypodum	1	8.3	15.1	1.5
C. brasilianum	2	8.2	30.5	1.3
C. capitatum	2	4.8	15.8	1.7
C. macrocarpum	3	7.8	25.6	1.0
C. tetragonolobum	11	13.0	35.7	1.5

* After transplanting.

In a split experiment (Table 7), a total of 51 accessions of 7 shrubby species were evaluated. Establishment was relatively slow because of the dry season effect. Accessions of Codariocalyx gyroides, Tadehagi triquetrum, and Cajanus cajan obviously showed the best vigor. Several accessions of Flemingia macrophylla suffered from heavy attack of leaf-cutting ants.

This experiment is going to last for two more years. Two field replications are submitted to a cutting regime and two replications will grow without any limitation in order to evaluate flowering time and seed production.

Brachiaria spp.

The evaluation of 213 accessions of 10 Brachiaria species was continued during 1989. After the initial establishment phase, a cutting regime with 9-week intervals was applied. Dry matter yields were recorded in the dry and rainy season, vigor and incidence of pests and diseases were evaluated monthly.

Although established in surroundings of highly susceptible B. decumbens, the presence of spittle bug was unfortunately negligible. Because spittle bug is the main limitation of several Brachiaria species in the American tropics, an additional evaluation should be conducted at a highly infested site, at least for the most promising accessions.

Accessions of B. ruziziensis, B. humidicola, and B. decumbens showed the quickest establishment in terms of ground cover and competition with weeds due to their stoloniferous growth habit. Nevertheless, most B. brizantha and B. jubata accessions suffered little weed competition in spite of their growth habit, because of plant height (Table 8). Obviously, the higher growing species B. brizantha, B. jubata, and B. ruziziensis produced their biomass through higher proportions of stems.

Considerable variability also existed within each species as is shown for B. brizantha (Table 9), where accessions covered several classes for the agronomic traits listed.

Dry matter yields during the dry and rainy season are shown in Table 10. In the wet season, 12 accessions of B. brizantha yielded over 1000 g DM/m^2 (CIAT 6385, 16098, 16124, 16130, 16145, 16158, 16160, 16197, 16302, 16306, 16312, and 16320), while none of the other species reached a similar level. The best accessions in DM production (over 500 g DM/m^2) were CIAT 606, 6702, 26297 for B. decumbens; CIAT 26154 for B. humidicola, CIAT 16195, 16468, 16514, 16532, 16536, 16538, 16542, and 26327 for B. jubata, and CIAT 6101, and 26170 for B. ruziziensis.

The behavior of accessions during the dry season is of key interest. So, the good adaptation of B. jubata under the conditions at Pucallpa during the dry season was unexpected. Some B. jubata are known to not allow spittle bug nymphs to completely develop. The mean DM yield of 24 accessions tested was close to that of B.brizantha, although maximum accession DM yields were quite different. Regarding the other species evaluated, only a few accessions of B. decumbens reached the maximum yield of B. jubata. The best accessions were CIAT 16525, 26122, and 26327.

Outstanding accessions of B. brizantha in terms of DM yield in the dry season were CIAT 16318, 16310, and 16305 for grazing purposes, while CIAT 16130, an erect plant type, seems to be more promising for cut-and-carry purposes. The best accessions of B. decumbens were CIAT 6058, 16500, and 6702.

B. humidicola accessions looked poor during the dry season, and there was obviously some phosphorus deficiency. None of the other species of Brachiaria tested looked promising.

Table 7. Preliminary agronomic evaluation (4 months after transplanting) of several species of shrubby legumes at Pucallpa during 1989.

Trial	Species	No. of accessions	Plant height	Plant diameter	Stem thickness	Height of branching	Flowering (50%)**
			----------	------ cm	------------	----------	-- days --
A	*Cratylia floribunda*	2	39.6 c*	26.5 b	5.1 c	42.7 a	-
	Codariocalyx gyroides	8	67.2 a	55.2 a	9.6 a	1.8 c	135.0 a
	Flemingia macrophylla	10	54.0 b	50.9 a	8.0 b	6.5 b	131.9 a
	Tadehagi triquetrum	3	53.5 b	61.5 a	5.8 c	0 c	113.8 b
	Tadehagi sp.	7	55.8 b	57.0 a	5.5 c	0.9 c	115.6 b
B	*Cajanus cajan*	7	81.1 a	39.7 a	7.5 a	16.2 a	113.5 a
	Desmodium velutinum	14	27.5 b	25.4 b	3.3 b	0.8 b	112.5 a

* Means followed by the same letter for each trial are not significantly different ($P < 0.05$).

** After transplanting.

Table 8. Agronomic traits in the establishment phase of *Brachiaria* spp. at Pucallpa during 1988.

Species	No. of accessions	Ground cover[1] (%)	Weeds[1] (g/m^2)	Plant Height[1] (cm)	Leafiness[2] (% DM)
B. ruziziensis	17	97.4 a[3]	16.5 b	33.6 b	43.3 c
B. humidicola	26	95.8 a	20.4 b	14.9 d	67.9 b
B. decumbens	41	92.8 a	13.8 b	27.9 bc	57.5 c
B. arrecta	4	82.2 ab	18.5 b	31.1 b	33.4 c
B. platynota	1	80.5 ab	55.5 a	12.0 d	83.0 a
B. brizantha	94	69.8 b	13.1 b	51.2 a	39.6 c
B. dictyoneura	2	58.5 bc	13.8 b	24.5 bc	48.5 c
B. jubata	24	53.9 c	20.9 b	35.9 b	33.9 c
B. bovonei	2	35.3 d	72.5 a	25.3 bc	64.5 b
B. subulifolia	2	25.5 d	28.0 b	18.3 cd	65.5 b

1/ 4 months after transplanting.

2/ 9 weeks old regrowth.

3/ Means followed by the same letter are not significantly different ($P < 0.05$).

Table 9. Classification of 94 accessions of _B_. _brizantha_ for agronomic traits in the establishment phase at Pucallpa during 1988.

Ground cover[1] (%)	No. of accessions	Weeds[1] (g/m^2)	No. of accessions	Plant height[1] (cm)	No. of accessions	Leafiness[2] (% DM)	No. of accessions
		> 100	0	> 100	2		
81 - 100	30	81 - 100	1	81 - 100	2	81 - 100	0
61 - 80	36	61 - 80	1	61 - 80	16	61 - 80	6
41 - 60	21	41 - 60	4	41 - 60	48	41 - 60	29
21 - 40	6	21 - 40	11	21 - 40	24	21 - 40	59
1 - 20	1	1 - 20	77	1 - 20	2	1 - 20	0

1/ 4 months after transplanting.
2/ 9 weeks old regrowth.

Table 10. Dry matter yields of *Brachiaria* spp. at Pucallpa, during 1988 and 1989 (9 weeks old regrowth).

Species	No. of accessions	Wet season		Dry season	
		Mean (g/m^2)	Range (g/m^2)	Mean (g/m^2)	Range (g/m^2)
B. brizantha	94	665 a*	151-1516	171 a	48-415
B. jubata	24	441 abc	146-653	164 ab	103-263
B. bovonei	2	503 ab	390-616	147 ab	101-192
B. dictyoneura	2	200 c	124-275	144 ab	116-172
B. subulifolia	3	114 bc	26-202	130 ab	149-190
B. ruziziensis	17	386 bc	213-540	123 ab	82-210
B. decumbens	41	251 bc	59-781	118 ab	35-286
B. platynota	1	213 c	-	114 ab	-
B. humidicola	26	254 bc	64-508	80 b	19-157
B. arrecta	4	187 c	172-200	80 b	66-100

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

Generally, the incidence of pests and diseases was not severe. Only *B. arrecta* accessions suffered to a certain extent from sucking insects.

This experiment will continue for nearly another year. In addition, about 200 new accessions of several species of *Brachiaria* are being planted for initial evaluation in the 1989/90 season.

Panicum maximum

Although having few problems during the establishment phase, all 24 accessions evaluated did not seem to be adapted to the humid tropics of Pucallpa. They suffered extraordinarily from different fungus diseases (*Phoma*, *Helminthosporium*, drying of leaf tips, etc.), so that the foliar tissue was reduced, and they never showed high dry-matter yields. In addition, the incidence of rasping insects was very high. The dry-matter yields decreased in the course of 1986 to 1989. The panicles suffered from high rust presence, so practically no seed at all was produced. In conclusion, none of the accessions of *P. maximum* tested could be recommended for environments similar to Pucallpa.

EVALUATION OF GRASS AND LEGUME ASSOCIATIONS UNDER GRAZING
(CATEGORY III)

In the category-III evaluation, associations of promising legumes and grasses are screened for their compatibility as well as for their persistence under grazing.

The design of the grazing experiment established in March 1987 was described in detail in the TPP Annual Report 1988. After more than one year of grazing, the first results lead to some preliminary conclusions. For thirteen grazing cycles, each with 6 days grazing and 30 days rest, from 23 Feb. 1988 to 29 May 1989, some results are shown in Figures 2-4. The forage analyses for *in vitro* dry-matter digestibility and nitrogen are still under way.

Referring to the persistence of associations, the mixture of

Brachiaria dictyoneura cv. Llanero + Centrosema macrocarpum CIAT 5674/5735 (Bd + Cm) was more stable than that of B. dictyoneura cv. Llanero + Desmodium ovalifolium CIAT 350 (Bd + Do), where the legume tended to dominate the pasture (Fig. 2). Nevertheless, the association of B. brizantha cv. Marandu + C. macrocarpum CIAT 5674/5735 (Bb + Cm) showed the highest percentage of uncovered soil and weeds, and had the lowest legume percentage.

Within the different stocking rates (2.0, 2.7 and 3.4 AU/ha), the medium stocking rate maintained the best balance of components for the associations Bb + Cm and Bd + Cm. The lower and/or higher stocking rates tended to increase the percentage of uncovered soil and/or weeds, while the sown grass and legume components were decreasing. In the association Bd + Do, especially in the middle and high stocking rates, the legume tended to dominate.

Referring to the relation between legume intake and legume on offer in the association Bd + Do, there was a relatively low legume selection by oesophageal-fistulated steers (14.74% over stocking rates) compared to the proportion of legume in the forage on offer (33.13%) (Fig. 3). In the association Bb + Cm, the legume percentage in the forage on offer (15.58%) as well as in the forage selected by the animals (7.95%) was very low. The best legume selection (24.22%) in relation to its availability in the sward (35.85%) was observed in the association Bd + Cm.

Forage availability depended on season (Fig. 4) Nevertheless, there was a certain relationship between ground cover and forage on offer. In all three associations, the low stocking rate showed, on average, the highest forage availability, while the high stocking rate tended to have the lowest forage availability, and the medium stocking rate was in between. The lowest dry-matter yield (over stocking rates) has been recorded for the association Bd + Cm (1811 kg/ha) and the highest for Bd + Do (2665 kg/ha), while in the association Bd + Cm the dry-matter yield was in between (2334 kg/ha).

This experiment will be evaluated for another year, although the association Bb + Cm will be excluded because of its low forage availability and obviously failed establishment. In future experiments, B. brizantha should not be planted in rows but insted broadcasted to avoid the animals trampling between the rows, and thereby damaging the legume component.

SEED MULTIPLICATION

The activity of multiplying seed is considered vitally important for meeting future demand for possible promising accessions. During 1989, category II experiments of Centrosema acutifolium, C. brasilianum, C. macrocarpum and Desmodium ovalifolium (all sown in 1986) were maintained for seed multiplication of the most promising accessions. The agronomic field evaluations were already finished before, and their respective results were reported in former Annual Reports.

It is worthwhile to comment that the great majority of the C. macrocarpum accessions showed an extraordinary vigor during this fourth year of evaluation, and the damage caused by leaf-eating insects and/or diseases such as Rhizoctonia, was without major importance. Basing on the results of this experiment, the accession CIAT 15047 unites most of the desirable factors in it but, there are others which also merit attention, such as CIAT 5735, 15014, 15097, and 15115

Contrarily, the vigor of C.acutifolium was somewhat less, caused by a certain incidence of Rhizoctonia, especially

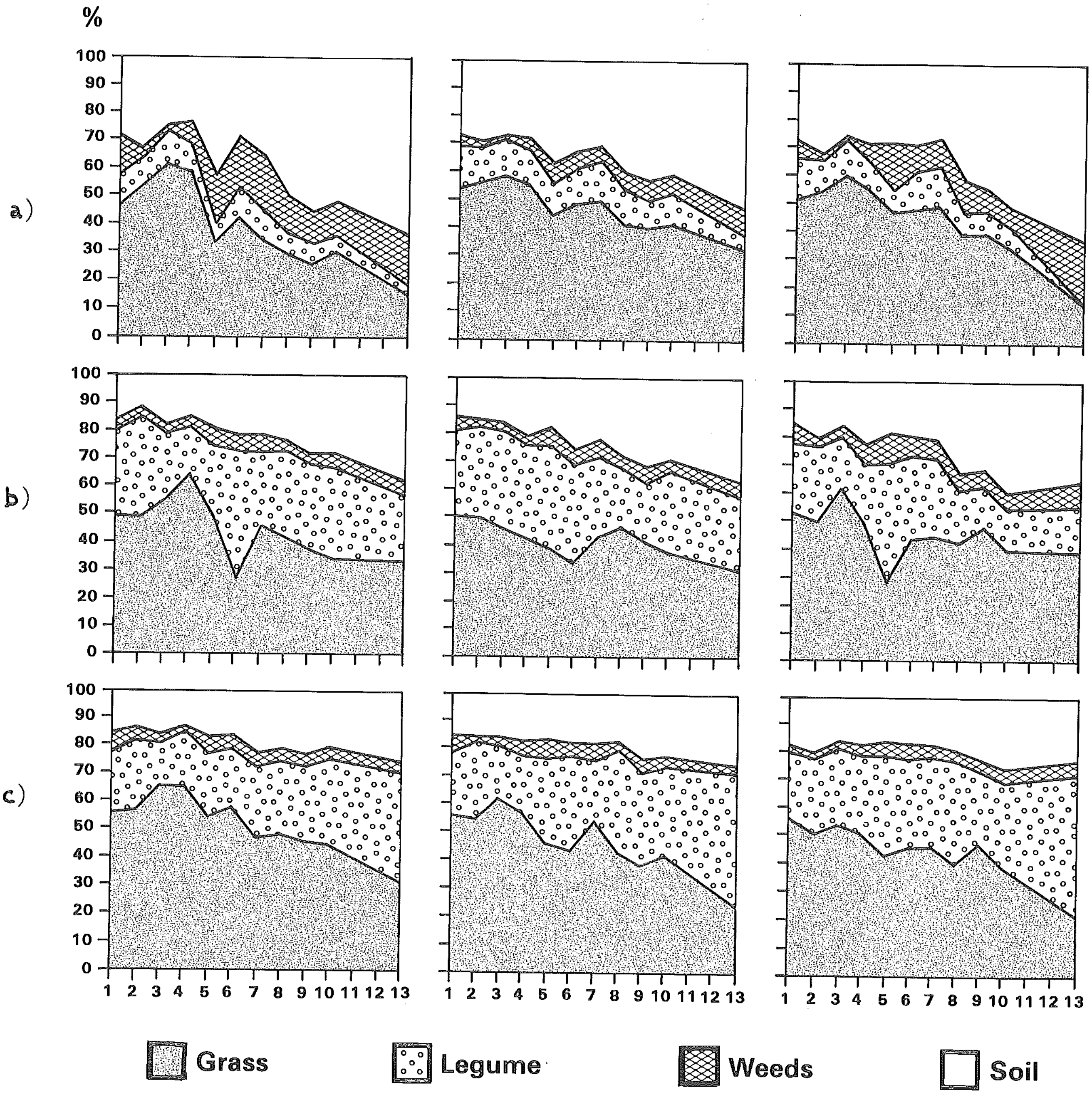


Figure 2. Botanical composition of three grass-legume pastures during 13 grazing cycles (Feb. 88 - May 89) at Pucallpa (Category III evaluation).
a) B. brizantha + C. macrocarpum; b) B. dictyoneura + C. macrocarpum; c) B. dictyoneura + D. ovalifolium; each pasture with three stocking rates (2.0, 2.7, and 3.4 AU/ha from the left, respectively).

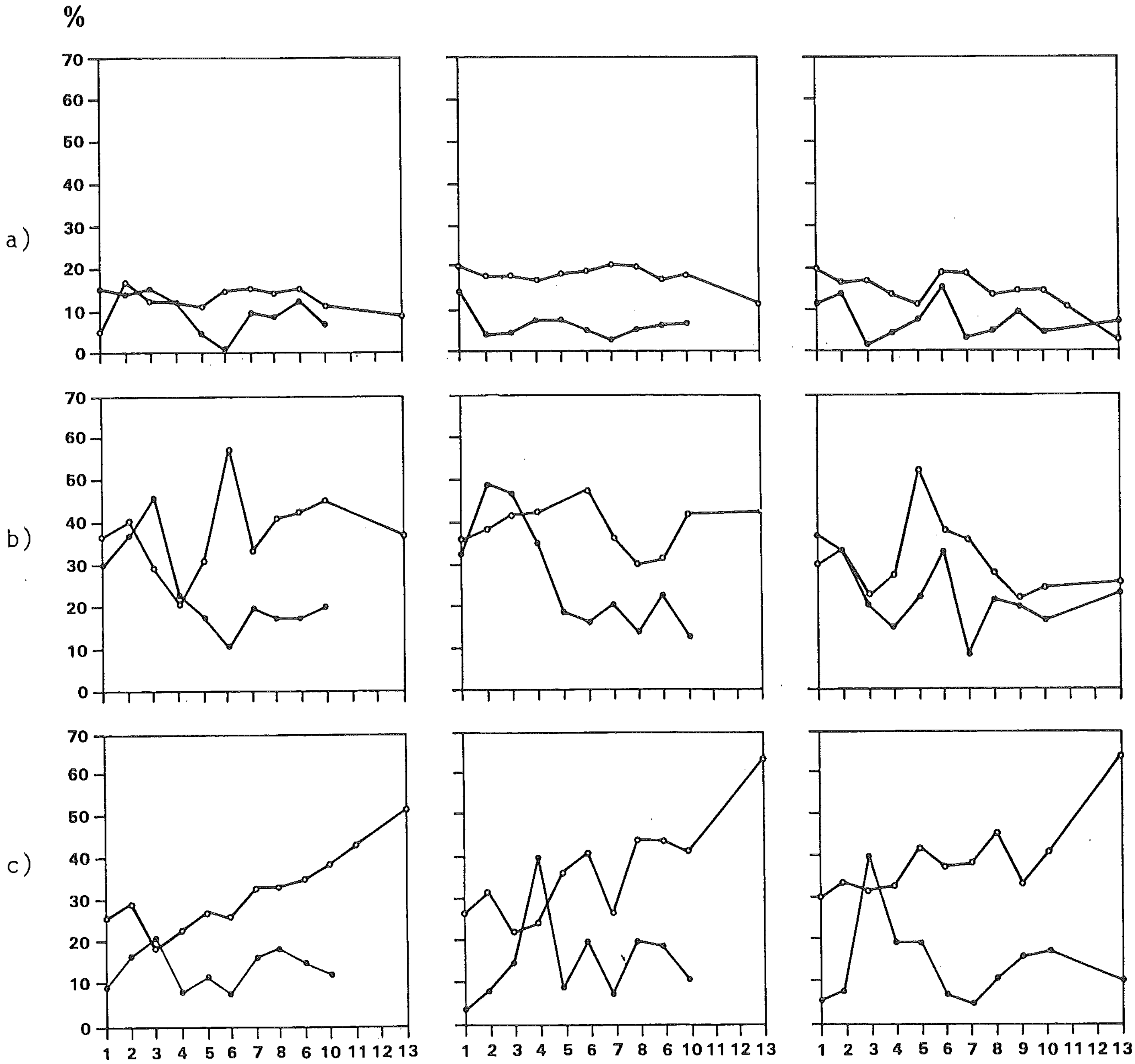


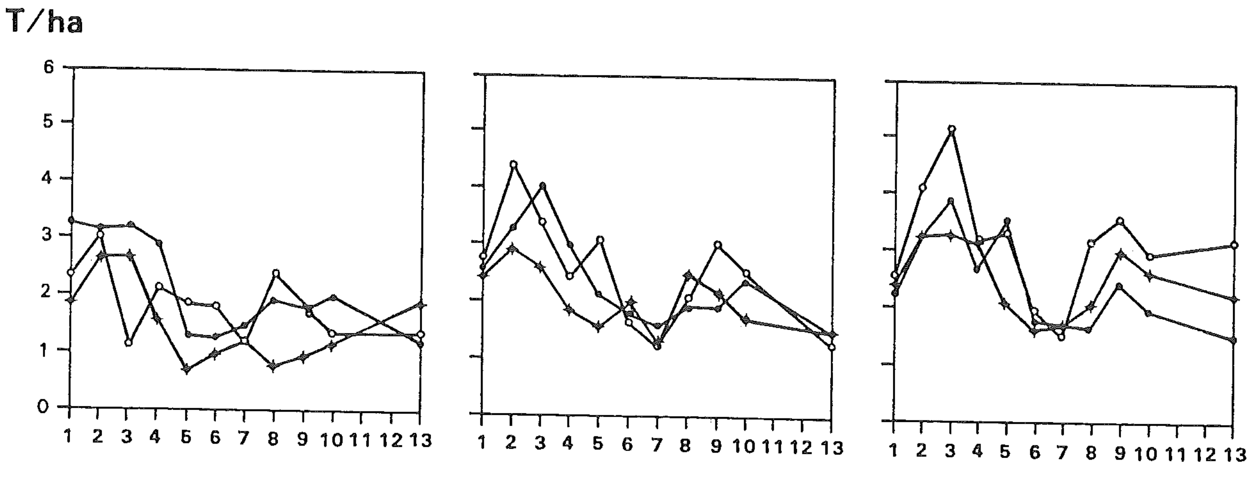
Figure 3. Proportion of legume in the forage on offer (o) and selected (●) by oesophageal-fistulated steers in three grass-legume associations during 13 grazing cycles (Feb.88 - May 89) at Pucallpa (Category III evaluation).
a) *B. brizantha* + *C. macrocarpum*; b) *B. dictyoneura* + *C. macrocarpum*; c) *B. dictyoneura* + *D. ovalifolium*; each association with three stocking rates (2.0, 2.7, and 3.4 AU/ha from the left, respectively).

in the dry season. The most promising accessions from earlier results were CIAT 5112, 5278, 15086, and 15088.

Generally, C. brasilianum does not seem to be adapted to the conditions of Pucallpa, because of its great susceptibility to Rhizoctonia. The great majority of the accessions did not maintain a high proportion of green leaves during the dry season, although their seed production was relatively high. The most promising accessions were CIAT 5657 and 15387.

RIEPT HUMID TROPICS

The first general meeting for the humid tropics is being prepared for Lima in August 1990. Up to now 27 presentations have been received from collaborators in Bolivia (7), Brazil (15), and Ecuador (5). Further presentations are expected, both from collaborators in the mentioned countries and in Colombia and Peru.



a) b) c)

Figure 4. Total dry-matter yield of three grass-legume pastures: a) B. brizantha + C. macrocarpum; b) B. dictyoneura + C. macrocarpum; c) B. dictyoneura + D. ovalifolium), each with three stocking rates (2.0 (o), 2.7 (●), and 3.4 (✦) AU/ha) during 13 grazing cycles (Feb.88 - May 89) at Pucallpa (Category III evaluation).

9. Agronomy Central America and the Caribbean

The primary objectives of the CIAT/MAG/CATIE/IICA collaborative project in tropical pastures are to identify and select forage grasses and legumes adapted to the low- and moderate-fertility soils in México, Central America, and the Caribbean. Activities include preliminary selection of germplasm, seed multiplication, and trials under grazing of selected species.

Germplasm adaptation evaluations were initiated in 1987 at three contrasting sites in the country. These sites are: a) Guápiles (Los Diamantes Experiment Station, Ministry of Agriculture), humid tropic (4260 mm of precipitation), Inceptisols, without a marked dry period; b) Atenas (Escuela Centroamericana de Ganadería - ECAG), subhumid tropic (1600 mm of precipitation), Inceptisols, 5-6 months dry period; and c) San Isidro (El Porvenir Farm belonging to the Cooperative of Farmers and Cattle Growers - COOPEAGRI), seasonal semievergreen forest (2950 mm of precipitation), Ultisols, 3-4 months dry period. Average temperature variations during the year are similar for the three sites and range from 22.8 to 24.0°C. Acidity in the upper layer is moderate in Atenas (pH 5.9) and Guápiles (pH 5.5), while San Isidro is the site with the highest rate of exchangeable Al (3.3 meq/100 g of soil) and the greatest acidity (pH 4.6). More complete soil and climate details for these sites can be found in the 1987 and 1988 Annual Reports.

GERMPLASM EVALUATION (CATEGORY II)

GRASSES

Panicum spp.

The two-year evaluation of 50 *P. maximum* accessions (including a local control and 2 *P. coloratum* accessions) was completed this year. High variability was found among species and accessions, particularly in terms of yield, leaf-stem ratio, crude protein content, and IVDMD (1988 Annual Report).

Table 1 presents the 16 *P. maximum* accessions that yielded 2.5 or more tons of dry matter per hectare in cuttings carried out every 4 weeks. Among these, the following accessions were outstanding for their leaf-stem ratio: CIAT 16051, 16028, 16061, and 6868; CIAT 6299 (cv. Tobiatá) is also among the high-yielding group. The three first accessions and Tobiatá are similar to cv. Hamil, while CIAT 6868 is closer to cv. Común. A total of 63% of the most outstanding 16 accessions belong to the latter variety.

Accessions *P. maximum* CIAT 6969 and 16020 which showed a high leaf-stem ratio (5.5 and 4.2, respectively), had intermediate yields, as well as the accession *P. coloratum* CIAT 6461; another accession of this species (CIAT 6063) had the lowest yield and practically disappeared from the plots. Accessions of the Embu type (CIAT 6181, 6115, 6180, 6875, and 6114) showed the least adaptation to

Table 1. Average dry matter yield (t ha^{-1}) of 52 Panicum accessions established in Guápiles, Costa Rica 1989.

Species	CIAT No.	DM yield (t ha^{-1})*
Pm	16051	3.3 a**
Pm	16017	3.3 ab
Pm	16028	3.3 ab
Pm	6215	3.0 abc
Pm	622	2.9 abcd
Pm	16061	3.0 abcd
Pm	6299	2.8 abcde
Pm	6177	2.8 abcde
Pm	6983	2.8 abcde
Pm	6095	2.8 abcde
Pm	16011	2.7 abcdef
Pm	6172	2.7 bcdefg
Pm	6536	2.6 cdefgh
Pm	6868	2.5 cdefghi
Pm	6871	2.5 cdefghi
Pm	16039	2.4 cdefghij
Pm	6945	2.4 cdefghijk
Pm	6798	2.4 cdefghijkl
Pm	673	2.4 cdefghikjl
Pm	6923	2.4 cdefghijkl
Pc	6461	2.3 cdefghijkl
Pm	16062	2.3 cdefghijkl
Pm	6898	2.3 cdefghijklm
Pm	6872	2.3 defghijklm
Pm	6094	2.2 efghijklm
Pm	6969	2.1 fghikjlmn
Pm	6974	2.1 ghijklmno
Pm	6907	2.1 ghijklmno
Pm	6949	2.0 ghijklmno
Pm	6942	2.0 hijklmno
Pm	6828	2.0 hijklmno
Pm	16020	2.0 hijklmno
Pm	6971	2.0 hijklmno
Pm	604	1.9 hijklmno
Pm	6164	1.9 hijklmno
Pm	6890	1.9 ijklmno
Pm	6109	1.8 jklmnop
Pm	6601	1.7 lmnopq
Pm	Local	1.7 mnopr
Pm	6000	1.6 nopqr
Pm	6554	1.6 nopqr
Pm	6179	1.6 nopqr
Pm	6600	1.5 nopqrs
Pm	16067	1.4 opqrs
Pm	6114	1.2 pqrs
Pm	6181	1.2 pqrs
Pm	6115	1.2 qrs
Pm	6180	1.1 rs
Pm	6875	0.9 st
Pc	6063	0.4 t

* Average of 18 cuttings every 4 weeks.
** $P < 0.05$, Duncan multiple range test.

the conditions prevalent in Guápiles and therefore forage yields were significatively lower ($P < 0.05$).

The disease with the highest incidence was foliar blight, caused by the fungus Cercospora sp., primarily affecting the local accession and CIAT 604. The Hamil-type accessions showed the lowest damage by pests and diseases, while the Embu-type were the most attacked by leaf suckers, yet the incidence ranged from low to very moderate.

Overall, a considerable number of P. maximum accessions, similar to cultivars Hamil, Común, and Green Panic have shown good adaptation to the edaphic and climatic conditions in Guápiles. This is partially explained by the fact that this site does not have severe environmental humidity stress since precipitation is never below 100 mm; furthermore, the upper soil layer has a high content (10.8%) of organic matter and acceptable Ca (5.44 meq/100g), Mg (2.30 meq/100 g), K (1.27 meq/100 g), and P (8.3 ppm) levels. This Panicum collection will be subjected to intermittent mob grazing as another selection factor in order to measure regrowth and tolerance to trampling. Thus, the most outstanding species can be selected for future evaluations.

Brachiaria spp.

Establishment of 290 different Brachiaria species in Guápiles was initiated in October 1987, for agronomic and adaptation evaluation. Of these, 57 accessions completed their 2-year evaluation period, with a total of 15 cuttings practiced every 6 weeks. Table 2 shows average dry matter yields for this group; a high variability among species and accessions can be observed.

Accessions of species jubata (3), humidicola (8), decumbens (8), brizantha (7), ruziziensis (4), and dictyoneura (1) yielded an average of 2.5 or more tons dry matter per hectare in cuttings practiced every 6 weeks; the highest yielding was B. decumbens CIAT 16497, an accession showing semierect growth, a low leaf-stem ratio, abundant flowering, acceptable crude protein content (11.8%), and intermediate IVDMD (1988 Annual Report). On the other hand, accessions CIAT 667, 606, 26175, 26170, and 664 have better quality indices, higher number of rooted nodes, and low susceptibility to pests and diseases under the conditions in Guápiles. However, it is important to highlight that pressure by pests (for example spittlebug) is very moderate at this site.

B. jubata CIAT 16157 and 16530 are outstanding among the high-yielding accessions. Accession CIAT 16531 has been observed to interfere with the hormone control of molting in spittlebug nymphs (Annual Report 1988). All B. jubata accessions have a semierect growth habit, poor production of stolons, and a low leaf-stem ratio; yet, their crude protein contents and IVDMD are acceptable. Overall, however, their value as a forage grass is considered to be low.

To date, some commercial and well-known accessions or varieties (B. decumbens CIAT 606, B. brizantha CIAT 6780, B. humidicola CIAT 679, and B. dictyoneura CIAT 6133) have shown good adaptation and are among the most outstanding in terms of yield; nonetheless, final selection of materials can only be done when evaluation of all accessions has been completed in the next year.

Grasses in Atenas and San Isidro

Agronomic and adaptation evaluations were completed for a group of grasses of the genera Andropogon, Brachiaria, and Panicum in San Isidro. These varieties were compared against a local control (M. minutiflora) and another control (H. rufa). Table 3 shows accumulated yields over 11 cuttings after 2 years of evaluation. A. gayanus accessions are outstanding for their high yields, followed by Brachiaria spp. and Panicum spp. Local accessions were less productive and persistent, reflecting the poor adaptation of these species to Ultisol conditions with high aluminum saturation levels. Under these conditions, it is interesting to observe that yields of Panicum accessions, though not outstanding, were comparable ($P < 0.05$) to those of Brachiaria, except for accession CIAT 6179.

Performance of these grasses in San Isidro (Table 4) shows high variability in terms of degree of adaptation and incidence of the beetle-Homoptera complex, leaf chewers, and spittlebug. The predominant spittlebug species was Prosapia simulans which severely affected B. decumbens CIAT 606, but without completely destroying the plant. Large populations of the

Table 2. Average dry matter yield (t ha^{-1}) of 57 Brachiaria accessions established in Guápiles, Costa Rica 1989.

Species	CIAT No.	DM yield (t ha^{-1})*	Species	CIAT No.	DM yield (t ha^{-1})*
B. dec	16497	5.1 a**	B. dec	16502	2.7 hijklmnop
B. bri	667	5.0 a	B. hum	16874	2.6 hijklmnopq
B. dec	606	4.7 ab	B. jub	16532	2.5 hijklmnopq
B. ruz	26175	4.6 ab	B. are	16844	2.5 ijklmnopqr
B. bri	16305	4.6 ab	B. jub	16538	2.3 jklmnopqrs
B. ruz	26170	4.6 ab	B. hum	26141	2.3 jklmnopqrs
B. bri	664	4.2 abc	B. dec	26298	2.3 jklmnopqrst
B. bri	6387	3.9 bcd	B. bri	16476	2.1 klmnopqrstu
B. bri	6780	3.8 bcde	B. jub	16710	2.1 klmnopqrstu
B. dic	6133	3.8 bcdef	B. jub	16514	2.1 lmnopqrstu
B. bri	6294	3.8 bcdef	b. dec	26300	2.0 mnopqrstu
B. ruz	26347	3.7 bcdefg	B. dec	16493	1.9 nopqrstu
B. hum	16178	3.5 cdefgh	B. are	16846	1.9 nopqrstu
B. hum	679	3.5 cdefghi	B. jub	16534	1.9 nopqrstu
B. ruz	26174	3.5 cdefghi	B. ruz	26163	1.9 nopqrstu
B. hum	6369	3.4 cdefghi	B. bri	16445	1.8 opqrstu
B. dec	26186	3.2 cdefghij	B. jub	16524	1.7 pqrstu
B. hum	6705	3.1 defghij	B. are	16845	1.7 pqrstu
B. hum	16182	3.1 defghijk	B. jub	16518	1.7 pqrstu
B. hum	16866	3.1 defghijk	B. jub	16523	1.6 qrstu
B. dec	26308	3.1 defghijkl	B. dec	26305	1.6 qrstu
B. dec	16494	3.0 defghijklm	B. jub	16203	1.5 rstu
B. jub	16517	2.9 defghjiklmn	B. jub	16541	1.5 rstu
B. dec	26185	2.8 efghijklmno	B. dec	26294	1.4 stu
B. hum	16891	2.8 efghijklmno	B. jub	16358	1.4 stu
B. jub	16530	2.7 fghikjlmnop	B. jub	16359	1.3 stu
B. bri	26127	2.7 ghijklmnop	B. jub	16529	1.2 tu
B. dec	26296	2.7 ghijklmnop	B. jub	16522	1.0 u
			B. dem	16175	0.1 v

* Average of 15 cuttings every 6 weeks.

** $P < 0.05$, Duncan multiple range test.

Table 3. Accumulated dry matter yield (t ha^{-1}) of grasses established in San Isidro. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t ha^{-1})*	% of the accumulated yield during dry period (+)
Andropogon gayanus	6053	20.8 a**	22
Andropogon gayanus	621	20.3 a	16
Andropogon gayanus	6766	18.3 ab	25
Brachiaria humidicola	679	15.3 bc	21
Brachiaria dictyoneura	6133	14.7 c	16
Brachiaria brizantha	6387	14.4 c	19
Brachiaria brizantha	6780	14.2 c	19
Brachiaria decumbens	606	13.1 c	18
Panicum maximum	622	12.0 cd	15
Brachiaria humidicola	6369	12.0 cd	28
Panicum maximum	6000	11.7 cd	12
Panicum maximum	673	11.6 cd	23
Panicum maximum	695	11.5 cd	17
Panicum maximum	6179	8.6 de	17
Melinis minutiflora	Local	7.4 e	22
Hyparrhenia rufa	Local	5.8 e	12

* Accumulation of 11 cuttings every 6-7 weeks.
** $P < 0.05$, Duncan multiple range test.
(+) 3-4 months, length of dry season.

Table 4. Response to adaptation, coverage, and pest variables of grasses established in San Isidro. Costa Rica 1989.

Variable	F value	R^2	cv (%)
Adaptation	14.48 **	0.88	17.25
Coverage	2.26 ns	0.53	12.00
Flea beetle - Homoptera	39.27 **	0.95	9.18
Chewers	8.87 **	0.81	9.31
Spittlebug	5.64 *	0.74	48.40

** $P < 0.01$; * $P < 0.05$.

insect were also observed in *B. dictyoneura* CIAT 6133 and accessions of *B. humidicola*, but without apparent damage to them. Insect populations were cyclic at the beginning of the rainy period and high mortality indices of the adult were observed due to the attack of the fungus *Mucor* sp. This pathogen seems to exert its effect after oviposition of the insect, as indicated by the recurrent attack of nymphs observed, followed by death of the adults.

A large number of *Andropogon* and *Brachiaria* accessions have been evaluated simultaneously in Atenas. In general terms, yields of these grasses have been greater at this site than at San Isidro (Table 5). Outstanding for their yield are various *A. gayanus* accessions, particularly CIAT 621. In spite of the fact that Atenas has better soils (Inceptisols), it has a more prolonged and severe dry period than San Isidro; for this reason, regrowth of species is much lower in this locality. CIAT 6369 was the least productive among the *B. humidicola* accessions at both sites, with the difference that both yield and summer regrowth were greater in San Isidro than in Atenas. This is more a climatic than edaphic effect on this accession which prefers high rainfall conditions, well-distributed throughout the year. In the same way, in Atenas, *B. decumbens* CIAT 606 was the highest-yielding (28.0 t/ha) of this genera; this value is more than two-fold the yield for San Isidro; yet, summer regrowth was much greater here, in spite of the fact that spittlebug attack was more severe. *B. dictyoneura* CIAT 6133 has also shown outstanding performance in Atenas (27.2 t/ha), comparable with the best *A. gayanus* accessions.

LEGUMES

A large number of forage legumes were established for adaptation evaluation in Atenas, San Isidro, and Guápiles in 1987. Final cuttings for evaluation were performed at the two first sites and are still underway in Guápiles. In addition to the species and accessions described in Table 6, the following forage species were also established: *Flemingia macrophylla*, *Cratylia floribunda*, *Codaryocalyx gyroides*, *Arachis pintoi*, *Zornia latifolia*, *Z. glabra*, *Pueraria phaseoloides*, *P. montana* var. *chinensis*, *Stylosanthes macrocephala*, *Calopogonium muconoides*, *Canavalia brasiliensis*, *Chamaecrista rotundifolia*, *Aeschynomene americana*, *A. villosa*, *Alysicarpus vaginalis*, *Desmanthus virgatus*, *Macroptilium atropurpureum*, *Vigna adenantha*, *Centrosema capitatum*, *C. grandiflorum*, *C. plumieri*, *C. schottii*, *C.arenarium*, *C. virginiarum*, *C. brachypodum*, *C. rotundifolium*, *C. vexillatum*, *Desmodium heterocarpum*, and *D. strigillosum* (see 1987 Tropical Pastures Program Annual Report for more information).

Effect of site on yields

In addition to recording incidence of pests and diseases, and other phenologic characteristics, legume evaluation has been carried out practicing periodical cuttings, which add up to 11 in San Isidro, 9 in Guápiles, and 12 in Atenas as of October 1989. In spite of the disparity in the number of cuttings, it is possible to make yield comparisons among species and accessions common to the three localities, using as a reference the weighted average dry matter yield per month (Table 7) and applying the Scheffe test for comparison among groups with a different number of observations.

Stylosanthes spp.

Among this genera, *S. guianensis* accessions represent the largest number of legumes evaluated; thus for example, 6 accessions were shared by Guápiles, Atenas, and San Isidro, and

Table 5. Accumulated dry matter yield (t ha^{-1}) of grasses established in Atenas. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t ha^{-1})*	% of the accumulated yield during dry period (+)
A. gayanus	6207	48.7 a**	5
A. gayanus	6697	39.4 ab	10
A. gayanus	6368	38.9 abc	11
A. gayanus	6694	35.4 abcd	11
A. gayanus	6220	35.0 abcd	12
A. gayanus	6757	34.9 abcde	11
A. gayanus	16974	34.9 abcde	10
A. gayanus	16984	34.9 abcde	13
A. gayanus	621	33.4 abcdef	10
A. gayanus	6216	32.4 bcdef	10
A. gayanus	6214	32.3 bcdef	9
A. gayanus	16978	32.2 bcdef	14
A. gayanus	6265	32.1 bcdef	11
A. gayanus	16979	32.0 bcdef	11
A. gayanus	6219	30.8 bcdefg	10
A. gayanus	16983	30.1 bcdefg	14
A. gayanus	16991	30.1 bcdefg	14
A. gayanus	6218	30.0 bcdefg	7
A. gayanus	16975	29.3 bcdefgh	11
A. gayanus	6233	29.1 bcdefgh	11
A. gayanus	6224	28.9 bcdefghi	10
A. gayanus	6377	28.4 bcdefghi	9
B. decumbens	606	28.0 bcdefghi	9
A. gayanus	6054	27.6 bcdefghi	10
A. gayanus	6201	27.4 bcdefghi	12
B. dictyoneura	6133	27.2 bcdefghi	9
A. gayanus	6759	26.7 bcdefghi	8
A. gayanus	16985	26.0 bcdefghi	13
A. gayanus	6234	25.7 bcdefghi	10
A. gayanus	6202	24.2 bcdefghij	8
A. gayanus	6200	24.1 bcdefghij	16
A. gayanus	6695	22.5 cdefghij	12
A. gayanus	6221	22.4 defghij	9
B. brizantha	667	22.3 defghij	15
B. brizantha	6387	18.5 efghij	12
B. brizantha	6780	18.1 fghij	13
B. brizantha	664	14.6 ghij	20
B. humidicola	679	13.5 hij	14
B. brizantha	6294	13.3 hij	13
B. humidicola	6705	12.8 ij	20
B. humidicola	6369	9.2 j	7

* Accumulation of 11 cuttings every 6-8 weeks.

** $P < 0.05$, Duncan multiple range test.

(+) 5-6 months, length of dry season.

Table 6. Partial list of forage legume species and accessions for evaluation in the Atenas, Guápiles, and San Isidro sites. Costa Rica 1989.

Species	CIAT No.	Site		
		Atenas	Guápiles	San Isidro
C. acutifolium	5277	*	*	*
	5278	*	*	
	5564	*	*	
	5568	*	*	*
	5609	*	*	
	5610	*	*	
	15084	*	*	
	15353	*	*	
	15446	*	*	
C. brasilianum	5178	*		*
	5234	*		*
	5365	*		*
	5657	*		*
	5671	*		*
	5810	*		*
C. macrocarpum	5065	*	*	*
	5434	*	*	
	5452	*	*	*
	5620	*	*	*
	5629	*	*	
	5674	*	*	*
	5713	*	*	*
	5733	*	*	*
	5744	*	*	*
	5887	*	*	*
	5911	*	*	
	5857	*	*	*
	5990	*	*	
	15014	*	*	*
	15108	*	*	
	15121	*	*	
	15232	*	*	
	15238	*	*	
	15362	*	*	
	15451	*	*	
	15806	*	*	
C. pubescens	438	*	*	*
	442	*	*	*

* Indicates establishment at that site

(continues)

Table 6. (Continued).

Species	CIAT No.	Site		
		Atenas	Guápiles	San Isidro
	5050	*	*	
	5053	*	*	
	5126	*	*	*
	5172	*	*	*
	5189	*	*	*
	5720	*	*	
	5878	*	*	
	5914	*	*	
S. capitata	1019	*		*
	1078	*		*
	1097	*		*
	1441	*		*
	2044	*		*
	2252	*		*
	10280	*		*
S. guianensis	15	*		
	21	*	*	*
	64	*	*	
	136	*	*	*
	184	*	*	*
	191	*	*	
	1175	*	*	*
	1280	*	*	*
	1283	*	*	
	2031	*	*	*
	10136	*	*	*
	11362	*	*	
	11363	*	*	
	11364	*	*	
	11365	*	*	
	11366	*	*	
	11367	*	*	
	11368	*	*	
	11369	*	*	
	11370	*	*	
	11371	*	*	

* Indicates establishment at that site.

(continues)

Table 6. (Continued).

Species	CIAT No.	Site Atenas	 Guápiles	 San Isidro
	11372	*	*	
	11373	*	*	
	11374	*	*	
	11375	*	*	
	11376	*	*	
	64A	*	*	
D. ovalifolium	350		*	*
	3673		*	*
	3776		*	*
	3781		*	*
	3784		*	*
	3788		*	*

* Indicates establishment at that site.

26 accessions by Guápiles and Atenas, as shown in Table 7.

High variability in adaptation has been observed among species and accessions; however, as a group, S. guianensis accessions have been the most productive in the locality of Guápiles, in comparison with Atenas and San Isidro. The latter site's soils are poorer, as mentioned before, in addition to having a more marked dry period each year, from December to April. However, Atenas, with a more prolonged dry period but with better soils, showed intermediate yields, though significatively inferior ($P < 0.05$) to those observed in Guápiles. Another favorable factor in the latter site has been the lower incidence of foliar diseases, which will be further discussed later on.

The highest-yielding accessions of S. guianensis belong to the morphological groups of the var. guianensis (Common type), including cv. Pucallpa (CIAT 184), as illustrated in Table 8, 9, and 10. This cultivar was outyielded only in Guápiles by CIAT 136 (Table 9). The contrary was true in Atenas, at the same time that performance of the two accessions was similar ($P < 0.05$) in San Isidro (Table 10), but with better summer regrowth for CIAT 136. This is indicative of the broad range of adaptation of these accessions. Also outstanding were CIAT 21, CIAT 1175, CIAT 11362, CIAT 191, and CIAT 11375, among others. Cv. Graham (CIAT 15) produced intermediate yields in Atenas.

Seven accessions of S. capitata confirm their superior adaptation to acid soils with high aluminum content, as are the soils of San Isidro in comparison with those of Atenas (Table 7). Thus for example, CIAT 10280 (cv. Capica) yielded 9.3 and 5.3 t DM/ha, respectively, in these localities (Table 10 and 11); something similar happened with the other accessions conforming this cultivar (CIAT 1097, CIAT 1078, and CIAT 1019).

Table 7. Comparisons based on weighted average of monthly dry matter yield (kg ha^{-1}) of forage legumes established in the Atenas, Guápiles, and San Isidro sites. Costa Rica 1989.

	Species site	Yield (kg ha^{-1})		Species site	Yield (kg ha^{-1})
A.	*S. guianensis*		E.	*C. acutifolium*	
	(6 accessions)			(2 accessions)	
	Guápiles	1036 a*		Guápiles	543 a
	Atenas	734 b		San Isidro	314 b
	San Isidro	497 c		Atenas	152 c
	(26 accessions)			(9 accessions)	
	Guápiles	1081 a		Guápiles	601 a
	Atenas	648 b		Atenas	194 b
B.	*S. capitata*		F.	*C. brasilianum*	
	(7 accessions)			(6 accessions)	
	San Isidro	375 a		Atenas	271 a
	Atenas	166 b		San Isidro	260 a
C.	*D. ovalifolium*		G.	*C. pubescens*	
	(6 accessions)			(5 accessions)	
	Guápiles	694 a		Guápiles	462 a
	San Isidro	576 a		Atenas	167 b
				San Isidro	134 c
D.	*C. macrocarpum*			(10 accessions)	
	(11 accessions)			Guápiles	419 a
	Guápiles	839 a		Atenas	152 b
	Atenas	444 b			
	San Isidro	327 c			

* $P < 0.05$, Scheffe's test.

Table 8. Accumulated dry matter yield (t ha^{-1}) of 27 Stylosanthes guianensis accessions established in Atenas. Costa Rica 1989.

Species	Accumulated yield (t ha^{-1})*	% of theaccumulated yield during dry period (+)
184 cv. Pucallpa	25.8 a**	16
1175	24.2 ab	16
11362	21.9 abc	17
21	20.8 abcd	17
191	19.7 abcde	14
11374	19.1 abcde	15
11375	18.1 abcdef	12
136	17.4 bcdefg	16
11372	17.2 bcdefg	14
11366	15.1 cdefgh	11
2031 var. pauciflora	14.1 cdefgh	22
15 cv. Graham	13.2 defgh	14
11367	13.0 defgh	12
1283 var. pauciflora	12.7 defgh	23
11364	12.6 defgh	8
64A	12.2 efgh	19
11376	12.0 efgh	7
11371	11.8 efgh	11
11369	11.5 efgh	11
1280 var. pauciflora	11.4 efgh	20
64	10.4 fgh	10
11363	10.1 fgh	15
11368	10.1 fgh	12
11370	9.7 fgh	13
11373	9.5 fgh	18
11365	8.8 gh	18
10136 var. pauciflora	8.4 h	32

* Accumulation of 11 evaluation cuts every 7-8 weeks.

** $P < 0.05$, Duncan multiple range test.

(+) 5-6 months, length of dry season.

Table 9. Accumulated dry matter yield (t ha^{-1}) of 31 Stylosanthes accessions established in Guápiles. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})
S. guianensis	136	35.8 a**
S. guianensis	64A	34.2 ab
S. guianensis	11375	31.0 abc
S. guianensis	11362	31.0 abc
S. guianensis	21	28.0 abc
S. guianensis	191	28.0 abc
S. guianensis	11373	27.8 abcd
S. guianensis	1175	27.0 bcd
S. guianensis	11372	26.9 bcde
S. guianensis	11371	26.6 bcde
S. guianensis	11376	26.3 bcde
S. guianensis cv. Pucallpa	184	25.7 bcde
S. guianensis	11365	25.6 bcdf
S. guianensis	64	24.3 bcdef
S. guianensis	11363	23.9 cdefg
S. guianensis	11367	22.4 defgh
S. guianensis	11374	22.4 defgh
S. guianensis	11366	22.4 defgh
S. guianensis	11369	20.9 defghi
S. guianensis	11370	20.9 defghi
S. guianensis var. pauciflora	1280	18.6 efghi
S. guianensis	11364	17.6 fghi
S. guianensis var. pauciflora	1283	17.2 ghij
S. guianensis	11368	15.8 hij
S. guianensis var. pauciflora	2031	13.9 ijk
S. guianensis var. pauciflora	10136	9.6 jkl
S. macrocephala	1281	8.0 kl
S. macrocephala	2133	5.1 l
S. guianensis	2243	2.5 l
S. guianensis	2244	2.4 l
S. guianensis	2191	1.9 l

* Accumulation of 9 evaluation cuts every 8 weeks.
** $P < 0.05$, Duncan multiple range test.

Table 10. Accumulated dry matter yield (t ha^{-1}) of *Stylosanthes* accessions established in San Isidro. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*	% of the accumulated yield during dry period (+)
S. macrocephala	2133	14.5 a**	20
S. guianensis	184 cv. Pucallpa	14.1 a	21
S. macrocephala	2756	13.3 ab	12
S. macrocephala	1643	12.5 abc	7
S. guianensis	2362 var. pauciflora	12.5 abc	18
S. guianensis	136	12.4 abcd	26
S. capitata	1097	11.7 abcde	15
S. guianensis	2031 var. pauciflora	11.7 abcde	13
S. guianensis	1280 var. pauciflora	11.5 abcde	18
S. capitata	1078	10.9 bcdef	24
S. guianensis	21	10.8 bcdef	18
S. guianensis	10136 var. pauciflora	10.5 bcdef	19
S. capitata	10137	10.1 cdef	12
S. guianensis	1639	10.0 cdef	18
S. guianensis	1873	9.9 cdef	14
S. macrocephala	2286	9.7 cdef	10
S. capitata	2044	9.7 cdef	9
S. capitata	10280	9.3 defg	15
S. guianensis	1275	9.0 efgh	16
S. guianensis	1539	8.8 efgh	14
S. capitata	2252	8.1 fgh	8
S. capitata	1019	6.5 gh	14
S. capitata	1441	6.1 h	6

* Accumulation of 11 evaluation cuttings every 6-7 weeks.

** $P < 0.05$, Duncan multiple range test.

(+) 3-4 months, length of dry season.

Table 11. Accumulated dry matter yield (t ha^{-1}) of Stylosanthes accessions established in Atenas. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*	% of the accumulated yield during dry period (+)
Stylosanthes capitata	1342	7.1 a**	13
Stylosanthes hamata	2770	6.5 ab	21
Stylosanthes capitata	1318	5.4 ab	22
Stylosanthes capitata	10280	5.3 ab	16
Stylosanthes capitata	1078	5.3 ab	12
Stylosanthes hamata	147	5.1 abc	23
Stylosanthes capitata	2252	5.0 abc	11
Stylosanthes capitata	1728	4.8 bcd	16
Stylosanthes capitata	1315	4.6 bcd	10
Stylosanthes capitata	2044	4.6 bcd	13
Stylosanthes capitata	1693	4.3 bcde	9
Stylosanthes humilis	1304	2.9 cdef	0
Stylosanthes capitata	1097	2.6 defg	24
Stylosanthes capitata	1943	2.3 efgh	7
Stylosanthes humilis	2420	2.0 fgh	0
Stylosanthes capitata	1441	1.8 fgh	14
Stylosanthes capitata	1019	0.8 fgh	9
Stylosanthes capitata	124	0.5 gh	19

* Accumulation of 10 cuttings every 7-8 weeks.
** $P < 0.05$, Duncan multiple range test.
(+) 5-6 months, length of dry season.

Much less affected by the site's conditions were CIAT 1280 and CIAT 2031, accessions of *S. guianensis* var. *pauciflora*, which had similar yields in Atenas, San Isidro, and even Guápiles for the latter of the two (Tables 8, 9, and 10); however, relative yields of the *pauciflora* accessions were not among the best in Guápiles for the genera *Stylosanthes*, but were the highest in San Isidro where, as in Atenas, they were also outstanding for their greater percentage of regrowth during the dry period.

S. macrocephala CIAT 2133 showed the highest yields in San Isidro (Table 10), but poor performance in Guápiles (Table 9), showing poor adaptation of the species to rainy tropical conditions. All accessions of this species suffer severe defoliation toward the end of the dry period when maturity is taking place and floral buds are falling off. These plants regenerate very well from seed during the following rainy cycle.

S. humilis accessions CIAT 1304 and CIAT 2420 produced scarce forage in Atenas, in addition to being markedly annual (Table 11). Furthermore, and with the exception of *S. hamata* accessions CIAT 2770 and CIAT 147, this species had a poor performance in this ecosystem; accessions CIAT 118 and CIAT 1040 disappeared during the first evaluation year, while CIAT 124 had the lowest yield (0.5 t DM/ha in 10 cuttings) among the *Stylosanthes* species.

Desmodium spp.

The largest number of accessions of this genera were established in Guápiles (53) in comparison to those in San Isidro (12). Table 7 indicates that yield differences ($P < 0.05$) were not observed for the six *D. ovalifolium* accessions shared by the two sites (CIAT 350, CIAT 3784, CIAT 3788, CIAT 3776, CIAT 3673, and CIAT 3781). This demonstrates the species' good adaptation both under humid tropic conditions as in seasonal forest with acid soils having a high aluminum content.

Tables 12 and 13 show comparative yields of all these accessions. In Guápiles, *D. ovalifolium* accessions, as well as *D. velutinum* CIAT 13218, produced the highest yields; in the case of San Isidro, *D. heterocarpum* CIAT 3787 has to be included also among the outstanding accessions.

D. strigillosum accessions showed intermediate yields, very similar in both sites, while *D. heterophyllum* was the least productive species, including CIAT 349 in Guápiles (humid tropic). The main reason for this species' low performance was its poor regrowth after cuttings and the effect of weed invasion.

Centrosema spp.

Of this genera, 61 accessions were established in 1987 in Atenas, 56 in Guápiles, and 37 in San Isidro, for adaptation evaluation. *C. macrocarpum* was the species with the greatest number of entries; however, only 11 accessions were shared simultaneously by the three sites: CIAT 5065, CIAT 5452, CIAT 5620, CIAT 5674, CIAT 5713, CIAT 5733, CIAT 5735, CIAT 5744, CIAT 5887, CIAT 5957, and CIAT 15014 (Table 6).

Overall, conditions in Guápiles have been the most favorable for growth and dry matter yield of all *Centrosema* species (Table 7), with the exception of *C. brasilianum* which was not planted at this site due to the species' known susceptibility to foliar blight by *Rhizoctonia*. However, the high productivity of the *Centrosema* accessions in Guápiles is due in part to the low incidence to date of diseases and to a sustained growth practically during the whole year thanks to favorable moisture conditions. On the other hand, San

Table 12. Accumulated dry matter yield (t ha^{-1}) of 53 Desmodium accessions established in Guápiles. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*
D. ovalifolium	13129	26.8 a**
D. velutinum	13218	26.4 ab
D. ovalifolium	13400	25.1 abc
D. ovalifolium	13127	22.9 abcd
D. ovalifolium	13113	22.4 abcde
D. ovalifolium	3607	22.0 abcdef
D. ovalifolium	13092	21.7 abcdefg
D. ovalifolium	13096	21.5 abcdefgh
D. ovalifolium	350	21.1 abcedfgh
D. ovalifolium	3778	20.3 abcedefhi
D. ovalifolium	13305	20.2 abcdefghi
D. ovalifolium	3668	19.1 bcdefghij
D. ovalifolium	13099	19.9 cdefghij
D. ovalifolium	13097	18.5 cdefghijk
D. ovalifolium	13089	18.3 cdefghijk
D. ovalifolium	13102	18.0 cdefghijk
D. ovalifolium	13105	17.3 defghijk
D. ovalifolium	13086	17.0 defghijk
D. ovalifolium	3673	17.0 defghijk
D. ovalifolium	3781	16.5 defghijkl
D. ovalifolium	13091	16.1 defghijkl
D. ovalifolium	13289	16.0 defghijkl
D. ovalifolium	3608	15.5 defghijklm
D. ovalifolium	3784	15.1 efghijklmn
D. ovalifolium	3788	14.8 efghijklmn
D. ovalifolium	13030	14.6 fghijklmn
D. ovalifolium	3780	14.6 fghijklmn
D. ovalifolium	3776	14.4 fghijklmn
D. heterocarpum	13178	14.2 ghijklmn
D. ovalifolium	13123	13.9 hijklmn
D. ovalifolium	3793	13.2 ijklmn
D. ovalifolium	13370	11.9 jklmno
D. ovalifolium	13085	11.8 jklmno
D. ovalifolium	13082	11.7 jklmno
D. ovalifolium	13371	11.2 klmno
D. ovalifolium	13083	11.0 klmno
D. strigillosum	13155	9.3 lmnop
D. strigillosum	13153	9.3 lmnop

* Accumulation of 9 evaluation cuttings every 8 weeks.
** $P < 0.05$, Duncan multiple range test.

(continues)

Table 12. (Continued).

Species	CIAT No.	Accumulated yield ($t DM ha^{-1}$)*
D. heterocarpum	13189	9.0 lmnop
D. ovalifolium	13115	8.2 mnopq
D. strigillosum	13158	7.8 nopqr
D. heterophyllum	349	5.1 opqrs
D. heterophyllum	13195	2.5 pqrs
D. heterophyllum	13202	2.3 pqrs
D. heterophyllum	13198	1.5 qrs
D. heterophyllum	3774	1.0 rs
D. heterophyllum	13666	1.0 rs
D. heterophyllum	13197	0.7 rs
D. heterophyllum	13191	0.2 s
D. heterophyllum	13200	0.2 s
D. heterophyllum	13669	0.2 s
D. heterophyllum	13203	0.1 s

* Accumulation of 9 evaluation cuttings every 8 weeks.
** $P < 0.05$, Duncan multiple range test.

Isidro was the site where C. macrocarpum and C. pubescens showed the lowest yields, while yields in Atenas have been intermediate for these species. The latter site has been the least favorable for C. acutifolium accessions (Table 7), particularly due to bacteriosis and foliar damage by Cylindrocladium.

Tables 14 and 15 show comparative yields for all Centrosema accessions under evaluation in Guápiles and San Isidro; yields in Atenas were intermediate and are not shown. In Guápiles, C. acutifolium CIAT 5277 (cv. Vichada) was less productive than this species, being outyielded by eight other accessions in the species, including CIAT 5568 (Table 14). CIAT 5610 and CIAT 5564 presented accumulative yields of 19.8 and 20.2 t DM/ha, respectively, which were comparable to the most productive C. macrocarpum accessions ($P < 0.05$).

In San Isidro, C. macrocarpum has also been the most outstanding species, even though average yields have been half of those registered in Guápiles; thus, for example, CIAT 5065, CIAT 5735, CIAT 5452, and CIAT 5957 had cumulative yields of 19.8 and 10.2, 22.0 and 9.8, 20.0 and 9.7, and 16.1 and 9.2 t DM/ha in San Isidro and Guápiles, respectively. In addition to less favorable climatic and edaphic conditions in the first site, the higher incidence of diseases has contributed to the lower yields. It is important to highlight C. macrocarpum's considerable growth during the dry period in San Isidro (Table 15), where it contributed as much as 41% to accumulated yield (CIAT 5887), with the whole group contributing on average around 30%. CIAT 5674 was the most productive in

Table 13. Accumulated dry matter yield (t ha^{-1}) of Desmodium accessions established in San Isidro. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*	% of the accumulated yield during dry season (+)
D. ovalifolium	3784	24.5 a**	13
D. ovalifolium	3781	20.5 ab	14
D. heterocarpum	3787	11.2 abc	14
D. ovalifolium	350	10.8 abc	17
D. strigillosum	13155	10.0 abc	13
D. strigillosum	13158	9.4 abc	12
D. ovalifolium	3776	9.4 abc	10
D. ovalifolium	3673	9.1 abc	7
D. strigillosum	13153	8.7 bc	16
D. ovalifolium	3788	8.1 bc	13
D. heterophyllum	349	3.2 c	10
D. heterophyllum	3782	0.4 c	0

* Accumulation of 11 cuttings every 6-7 weeks.
** $P < 0.05$, Duncan multiple range test.
(+) 3-4 months, length of dry season.

Atenas (14.7 t DM/ha); its relative yield during the dry period represented 33% of the cumulative total. Following at this site were CIAT 15108, CIAT 5629, CIAT 5735, CIAT 15806, CIAT 5620, CIAT 5065, CIAT 5452, and CIAT 5713, among others.

None of the C. pubescens accessions were outstanding yielders in San Isidro, but rather are grouped in the lower part of the scale, as is the case with CIAT 5126 which was the lowest-yielding at this site (Table 15). However, in Guápiles, accessions CIAT 5172, CIAT 5189, CIAT 5878, and CIAT 442 have had yields comparable ($P < 0.05$) to those of the best C. macrocarpum accessions, with the exception of CIAT 5733 (Table 14).

Accessions of the species C. plumieri, C.capitatum, C.schotti, C. virginianum, C. brachypodum, C. vexillatum, C. grazielae, and C. schiedeanum have been less outstanding both in Atenas and in San Isidro and Guápiles. Accession CIAT 5066 of the latter species occupied the last place in terms of yield in Atenas (294 t DM/ha accumulated over 12 cuttings); on the other hand, C. arenarium CIAT 5236 and C. tetragonolobum CIAT 15087 had intermediate yields in Guápiles (Table 14).

Other legumes

In comparison to Atenas, Guápiles has also proved to be a more favorable site for growth of Cratylia floribunda CIAT 18516 (8.6 and 24.7 t DM/ha of yield accumulated over 12 and 9 cuttings, respectively, at each site); something similar has happened with Flemingia macrophylla accessions CIAT

Table 14. Accumulated dry matter yield (t ha^{-1}) of *Centrosema* accessions established in Guápiles. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*
C. macrocarpum	5733	26.3 a**
C. macrocarpum	5911	22.4 ab
C. macrocarpum	15121	22.4 abc
C. macrocarpum	5735	22.0 abc
C. macrocarpum	5744	21.9 abc
C. macrocarpum	5674	20.3 abcd
C. acutifolium	5564	20.2 abcd
C. macrocarpum	5452	20.0 abcd
C. macrocarpum	15232	19.9 abcd
C. acutifolium	5610	19.8 abcd
C. macrocarpum	5065	19.8 abcd
C. macrocarpum	5629	19.8 abcd
C. macrocarpum	15014	19.8 abcd
C. macrocarpum	5434	18.6 bcde
C. macrocarpum	5713	18.4 bcdef
C. macrocarpum	15652	18.1 bcdefg
C. macrocarpum	15451	17.9 bcdefg
C. acutifolium	5609	17.6 bcdefg
C. macrocarpum	5620	17.3 bcdefgh
C. acutifolium	5568	17.0 bcdefgh
C. pubescens	5172	16.6 bcdefghi
C. tetragonolobum	15087	16.2 bcdefghij
C. macrocarpum	5957	16.1 bcdefghij
C. macrocarpum	15238	15.9 bcdefghij
C. macrocarpum	5887	15.7 bcdefghij
C. macrocarpum	15108	15.4 cdefghij
C. pubescens	5189	14.7 defghijk
C. macrocarpum	15362	14.2 defghijkl
C. pubescens	5878	14.2 defghijkl
C. macrocarpum	5990	13.9 defghijkl
C. macrocarpum	15806	12.8 efghijklm
C. pubescens	442	12.4 efghijklm
C. acutifolium	15353	12.3 efghijklm
C. acutifolium	15084	11.6 fghijklmn
C. pubescens	5914	11.2 ghijklmn
C. arenarium	5236	10.6 hijklmno
C. pubescens	5720	10.5 hijklmno
C. pubescens	438	10.5 hijklmno

* Accumulation of 9 evaluation cuttings every 8 weeks.

** $P < 0.05$, Duncan multiple range test.

(continues)

Table 14. (Continued).

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*
C. acutifolium	5278	9.8 ijklmnop
C. acutifolium	15446	9.3 jklmnopq
C. acutifolium	5277	8.3 klmnopqr
C. pubescens	5050	8.2 klmnopqr
C. capitatum	15680	8.2 klmnopqr
C. grandiflorum	5989	7.5 lmnopqr
C. plumieri	5099	7.0 mnopqr
C. pubescens	5126	4.9 nopqr
C. plumieri	5229	4.3 opqr
C. schottii	5079	4.0 opqr
C. arenarium	5599	3.5 pqr
C. plumieri	5194	3.0 pqr
C. schottii	5077	3.0 pqr
C. pubescens	5053	3.0 pqr
C. virginianum	474	2.8 qr
C. brachypodum	5803	2.1 r
C. rotundifolium	5283	1.8 r
C. vexillatum	15079	1.8 r

* Accumulation of 9 evaluation cuttings every 8 weeks.
** $P < 0.05$, Duncan multiple range test.

17403, CIAT 17407, CIAT 17400, CIAT 7184, and CIAT 801 which have accumulated yields from 42.9 to 51.7 t DM/ha in Guápiles, in comparison to a range going from 1.8 to 5.1 t DM/ha in Atenas. Crude protein content of Flemingia accessions has been around 20%, but IVDMD is considerably low (28% for CIAT 17400 and CIAT 7184, 26% for CIAT 17407, and 33% for CIAT 17403); therefore this genera's value as a forage legume is not considered to be high.

Codariocalyx gyroides CIAT 3001 had a poor performance in Atenas, San Isidro, and Guápiles; accumulated yields in almost 2 years of evaluation have been 2.6, 8.8, and 5.4 t DM/ha, respectively for the three sites. High plant mortality due to the root rot nematode was observed in San Isidro; the plant also seems to be very susceptible to defoliations during the dry period, as happens in Atenas.

Both Zornia latifolia CIAT 728 and CIAT 9199 have performed better in Guápiles than in San Isidro (accumulated yields of 7.6 and 14.1, 4.4 and 8.2 t DM/ha, respectively, in both sites), while yields of Z. glabra accessions CIAT 8283, CIAT 8279, and CIAT 7847 have been lower than the previously mentioned, but also more productive in Guápiles. These species have shown poor competitive ability with weeds and high defoliation levels during the dry period in San Isidro.

Arachis pintoi CIAT 17434 had an accumulated yield of 10.9 t DM/ha over

Table 15. Accumulated dry matter yield (t ha^{-1}) of Centrosema accessions established in San Isidro. Costa Rica 1989.

Species	CIAT No.	Accumulated yield (t DM ha^{-1})*	% of the accumulated yield during dry season
C. macrocarpum	5065	10.2 a**	27
C. macrocarpum	5735	9.8 ab	39
C. macrocarpum	5452	9.8 ab	22
C. macrocarpum	5957	9.2 abc	38
C. macrocarpum	5737	8.4 abcd	34
C. macrocarpum	5674	8.3 abcde	28
C. acutifolium	5568	8.1 abcdef	33
C. macrocarpum	5740	8.0 abcdefg	35
C. macrocarpum	5733	7.7 abcdefgh	30
C. brasilianum	5657	7.6 abcdefgh	21
C. macrocarpum	5713	7.2 bcdefgh	27
C. brasilianum	5178	7.1 bcdefgh	33
C. macrocarpum	5620	6.9 cdefgh	24
C. acutifolium	5277	6.8 cdefgh	22
C. brasilianum	5671	6.6 cdefghi	26
C. brasilianum	5487	6.5 cdefghi	33
C. arenarium	5236	6.5 cdefghi	26
C. schiedeanum	5161	6.4 cdefghi	17
C. brasilianum	5514	6.2 cdefghi	28
C. macrocarpum	5744	5.8 defghij	23
C. macrocarpum	5887	5.6 defghijk	41
C. brasilianum	5810	5.5 efghijk	30
C. hibrido	5935	5.3 fghijkl	27
C. brasilianum	5365	5.2 ghijkl	27
C. schiedeanum	5201	5.2 ghijkl	23
C. pubescens	5189	5.0 hijkl	26
C. brasilianum	5234	5.0 hijkl	29
C. macrocarpum	15014	5.0 hijkl	34
C. hibrido	5933	3.8 ijklm	18
C. hibrido	5931	3.1 jklm	15
C. pubescens	438	3.1 jklm	13
C. hibrido	5932	3.0 klm	17
C. pubescens	5172	3.0 klm	11
C. pubescens	442	2.9 klm	17
C. hibrido	5934	2.9 klm	7
C. hibrido	5930	2.6 lm	4
C. pubescens	5126	1.8 m	10

* Accumulation of 11 cuttings every 6-7 weeks.

** $P < 0.05$, Duncan multiple range test.

9 cuttings in Guápiles, and 2.6 in San Isidro over 11 cuttings. Other accessions evaluated in Guápiles were CIAT 18744, CIAT 18747, CIAT 18748, CIAT 18751, IRFL 2273 (CIAT 20693 *Arachis* sp.), CIAT 18746, and CIAT 18745, with yields of 10.5, 10.5, 8.5, 6.4, 3.8, and 3.7 t DM/ha, respectively, over 9 cuttings. CIAT 17434 has shown overall chlorosis in evaluation plots in both localities, which seems to be associated with a loss in effectiveness of rhizobium or with other nutritional problems not yet identified. It has been interesting to observe that this chlorotic condition is slight or nonexistent when the mentioned accession is associated with a grass; thus the accession continues to be considered as a promising forage species, particularly for its high competitive ability--derived from its stoloniferous growth habit--and for its favorable quality factors--25% crude protein and 58% IVDMD. Accessions CIAT 18744 and CIAT 18748 have been free of chlorosis to date.

Aeschynomene americana and *A. villosa* accessions have been poor yielders and shown low persistence in Guápiles (cuttings every 8 weeks). The greatest yield observed has been that of IRFL 1725 with 9.3 t DM/ha (accumulated over 11 cuttings), while *A. villosa* accessions (IRFL 2927 and IRFL 2331) have practically disappeared due to their poor recovery after cuttings and low competitive ability with invading weeds. Something similar has happened to *Alysicarpus vaginalis* IRFL 3240.

Desmanthus virgatus IRFL 99474 and IRFL 1857 have been more persistent and productive in Guápiles. Accumulated yields over 9 cuttings have been 35.4 and 24.4 t DM/ha, respectively, which are comparable with outstanding accessions of *C. macrocarpum* and *D. ovalifolium* at the same site. Performance of *Pueraria montana* CIAT 17277 has been similar (28.4 t DM/ha for the same evaluation period). This has been *Pueraria*'s most productive and persistent species in Guápiles.

Another 21 accessions, including *P. phaseoloides* CIAT 9900 (Kudzú) have had persistence problems, probably due to very low cuttings (less than 10-cm height), in addition to being the legume species with the greatest indices of foliar diseases--chlorosis and defoliation--probably caused by *Rhizoctonia*.

In San Isidro, production of *Calopogonium muconoides* CIAT 8118 and *Canavalia brasiliensis* CIAT 18515 has been very low (1.9 and 4.8 t DM/ha, respectively, accumulated over 11 cuttings). The most outstanding have been *Chamaecrista rotundifolia* CIAT 8202 and CIAT 8201 and *Dioclea guianensis* CIAT 7801 and CIAT 7351 with accumulated yields of 9 t DM/ha on average; yet, other quality factors reduce this species' value as a promising forage.

New Legume Germplasm

a) *Centrosema pubescens*

On 1 June 1989 a multilocational trial of *C. pubescens* selections was established in San Isidro. The objective of this trial is to evaluate adaptation, and dry matter and seed productivity of the 23 accessions of this species, in comparison with four controls (*C. acutifolium* CIAT 5277 and CIAT 5568, and *C. pubescens* CIAT 413 and CIAT 438).

The 23 *C. pubescens* accessions selected are: CIAT 5006 from the Dominican Republic; CIAT 5133 and 15043 from Colombia; CIAT 5167, 5169, 5172, 5189, 5627, 5631, 5634, 15132, 15133, 15144, 15149, 15150, 15154, 15160, 15872, 15875, and 15880 from Venezuela; CIAT 5596 (BRA- 004537) from Brazil; CIAT 15470 and 15474 from Panama. All these accessions were normally established; the first evaluation cutting will be performed on the third week of December.

c) Stylosanthes scabra

During July a new trial was established in Atenas to evaluate the adaptation and seasonal dry matter productivity of 20 S. scabra accessions. These were selected from a group of this species which was initially evaluated in Carimagua (Colombia) and demonstrated tolerance to anthracnose and to the stem borer. These are: CIAT 4 (cv. Seca), 1009 (cv. Fitzroy), 1060, 1082, 1708, 1991, 2015, 2492, 10077, 10525, and 10732 from Brazil; CIAT 1036, 1129, and 1380 from Colombia; CIAT 1522, 1526, 1917, 1926, 2808, and 2818 from Venezuela. The trial is already completely established. A uniform cutting was performed and the first evaluation will be done during the last week of November.

Leaf Diseases

The first grass legume germplasm to be established in Atenas, San Isidro, and Guápiles was planted two years ago. Leaf diseases in legumes caused by Cercospora, Rhizoctonia, Cylindrocladium, and bacteriosis, were reported to have greater incidence in San Isidro (Annual Report 1988), but the degree of severity in the most susceptible legumes was not superior to 20% of damage (for example, C. acutifolium CIAT 5657; Chamaecrista rotundifolia CIAT 8201 and CIAT 8202, P. phaseoloides CIAT 9900; S. guianensis CIAT 1280; and C. macrocarpum CIAT 5065, CIAT 5452, CIAT 5713, CIAT 5733, CIAT 5735, and CIAT 5740). Besides severe bacteriosis in C. acutifolium CIAT 5277 in Atenas, other diseases with high incidence were not reported at this site nor in Guápiles.

Except for the last site, the incidence of leaf diseases has increased during 1989, affecting both grasses and legumes in San Isidro and Atenas. Foliar blight caused by Rhizoctonia is the most severe disease in San Isidro. Damages are estimated between 25 and 50% of foliar death in several accessions of Centrosema (C. macrocarpum CIAT 5735, CIAT 5674, CIAT 5065, CIAT 5744, CIAT 5737, CIAT 5713, CIAT 5365, CIAT 5733, CIAT 5740, CIAT 5957, CIAT 5887, CIAT 15014, and CIAT 5452; C. brasilianum CIAT 5234, CIAT 5487, CIAT 5671, CIAT 5657, CIAT 5810, and CIAT 5514; C. acutifolium CIAT 5256 and CIAT 5277). Incidence has been lower in accessions of C. pubescens (CIAT 438, CIAT 5189) and in C. acutifolium CIAT 5568. Rhizoctonia has also affected (25-50% damage) various grass accessions (P. maximum CIAT 6000, CIAT 622 and CIAT 673; B. decumbens CIAT 606 and B. brizantha CIAT 6780). Other grass accessions such as those of A. gayanus, B. dictyoneura CIAT 6133, and B. humidicola CIAT 679 and CIAT 6369 have shown lower incidence of this disease. Of this last species, accession CIAT 6705 has shown moderate to high incidence of rust caused by Uromyces setaria-italicae; for this reason it is not considered to be promising at the moment.

A simultaneous complex of diseases, as has been observed during the last year in Atenas, is common under field conditions. Practically all herbaceous legumes (Stylosanthes, Centrosema) have had high incidence of Mycoplasma (little leaf), bacteriosis, anthracnose, Cylindrocladium, and Rhizoctonia. The little leaf disease is more severe C. macrocarpum CIAT 5713 and C. pubescens CIAT 438 seed multiplication plots, while anthracnose damage has increased in S. guianensis CIAT 184. It is obvious that the reaction of these legume species differs among pathogens, but this needs to be studied in more detail.

SEED PRODUCTION

Multiplication plots of promising germplasm seed were established since 1987 in the localities of Atenas, San Isidro, and Guápiles. Besides the physical production of seed, the latter has served to characterize the species phenologically in relation to flowering (initiation and maximum), maturation period, and potential seed yield.

Table 16 shows seed production and yields (kg/ha) of species of Centrosema, Desmodium, P. phaseoloides CIAT 9900, and S guianensis CIAT 184. In Atenas--with a well-defined dry period starting in November--greater seed yields of C. brasilianum CIAT 5234 and C. macrocarpum CIAT 5713 (641 and 189 kg/ha, respectively) have been obtained; San Isidro is less favorable for the reproduction of Centrosema. On the other hand, D. ovalifolium flowers and forms seed abundantly under Guápiles conditions, where high environmental humidity predominates practically all year round. CIAT accession 350 has the highest yield (232 kg/ha), which is significatively superior to that harvested in San Isidro (69 kg/ha). S. guianensis CIAT 184 suffered severe attacks by the budworm (Stegasta sp.) in Atenas, thus explaining the low seed yield observed.

Species of Brachiaria and A. gayanus CIAT 621 represent the grass germplasm established for seed multiplication. Table 17 presents seed yields and total seed harvested; overall, San Isidro has proven to be more favorable than Atenas and Guápiles for flowering and seed setting among these grasses, with the exception of B. decumbens CIAT 606, which has suffered recurrent spittlebug attacks in San Isidro and has seen its reproductive capacity affected. Noteworthy is the high seed yield of B. dictyoneura CIAT 6133 in San Isidro (247 kg/ha), in comparison with Guápiles where spikelets were severely attacked by birds, or Atenas where the uniform cutting was performed too late (June 8) in terms of the onset of flowering (June 23 of the same year).

Seed Distribution

Table 18 shows the amount (kg) and number of requests for experimental and basic seed of forage grasses and legumes during the period January-October 1989. In total there were 67 requests; Costa Rica was the main client as here are the headquarters of the CIAT-CAC regional pastures project. A large volume (6301 kg) of basic seed of both grasses and legumes was distributed in vegetative form in the Atlantic zone (humid tropic of this country; of this volume, most were seed A. pintoi CIAT 17434 and B. dictyoneura CIAT 6133. The greatest percentage of the seed was used for seedbeds in cattle farms and for the establishment of two grazing trials (one RTC and one RTD) at the Experiment Station Los Diamantes (MAG) and in the Farm La Rambla (Rio Frio) of the University of Costa Rica (UCR).

New Areas

During the period April-October, 1989, new seed multiplication areas were established jointly with several collaborators, as illustrated in Table 19. B. dictyoneura CIAT 6133 and A. pintoi CIAT 17434, are the forage species with more area planted, particularly because of the potential demonstrated by the legume for the humid tropics, and of the grass for subhumid conditions and poorer soils. With these plantings, sufficient basic seed is expected to be available for the establishment of new seedbeds in 1990 and the establishment of validation paddocks in farms of producers in collaboration with MAG and CATIE.

GRAZING TRIALS (CATEGORIES III AND IV)

Pasture evaluations with animals began in 1989 with the establishment of two type-D trials (RTD--animal productivity) and two type-C trials (RTC--compatibility and persistence). Table 20 shows the different classes of pastures proposed, current stage of establishment, and main entities responsible for these trials.

Table 16. Total harvested and seed yields of forage legumes established in different sites in Costa Rica. November 1988 to October 1989 harvest.

Species		Site	Pure seed yield (kg/ha)	Total harvested (kg)
C. brasilianum	CIAT 5234	Atenas	641	178
C. macrocarpum	CIAT 5713	Atenas San Isidro	189 51	75
C. macrocarpum	CIAT 5452	San Isidro	14	9
C. macrocarpum	CIAT 5620	San Isidro	17	2
C. macrocarpum	CIAT 5957	San Isidro	8	1
C. pubescens	CIAT 438	Atenas	75	21
D. ovalifolium	CIAT 350	San Isidro Guápiles	69 232	59
D. ovalifolium	CIAT 3788	Guápiles	143	10
D. ovalifolium	CIAT 13089	Guápiles	118	7
P. phaseoloides	CIAT 9900	San Isidro	67	22
S. guianensis	CIAT 184	Atenas San Isidro	6 51	9.5
TOTAL				393.5

Table 17 Total harvested and seed yields of forage grasses established in different sites in Costa Rica. November 1988 to October 1988 harvest.

Species		Site	Pure yield (kg/ha)	Total harvested (kg)
A. gayanus	CIAT 621	Atenas	111	
		San Isidro	148	158*
B. brizantha	CIAT 6780	Atenas	83**	
		San Isidro	81	83.3
B. decumbens	CIAT 606	Atenas	70	
		San Isidro	14	24
B. dictyoneura	CIAT 6133	Atenas	7	
		San Isidro	247	
		Guápiles	40	61
B. humidicola	CIAT 679	San Isidro	160	1.8
B. humidicola	CIAT 6369	San Isidro	14	0.5
B. humidicola	CIAT 6705	San Isidro	55	21

* 30% purity for *A. gayanus* and 80-90% for *Brachiaria*.
** Two harvests in Atenas and one in San Isidro.

Table 18. Amounts (kg) and number of experimental and basic tropical forage seed requested, received during the period January-October, 1989 in Costa Rica.

Country	Region	No. of requests	Legumes (kg)	Grasses (kg)	Vegetative material (kg)*	Purpose
Costa Rica	South Pacific	18	13.6	82.1	5.0	RTB, seedbeds, protein banks.
	Dry Pacific	13	30.3	126.0	--	RTB, RTC, seedbeds.
	Central Pacific	6	6.7	5.0	22.0	Seedbeds, RTB
	Atlantic Zone	19	11.5	--	6301.0	RTD, RTC, seedbeds in farms.
	CATIE/Turrialba	3	0.8	--	--	RTB, coverage.
El Salvador	---	1	0.8	--	--	RTB.
Panama	David	2	15.0	2.2	--	Seedbeds.
Honduras	Comayagua Ceiba Otoro	2	0.2	--	7.0	Seedbeds, RTB.
Guatemala	---	1	0.13	0.13	--	RTB.
Belize	Central Farm	1	0.2	0.18	--	RTB.
Mexico	Campeche	1	2.8	1.7	--	Seedbeds.
TOTAL		67	82.03	217.31	6683.0	

* _A_. _pintoi_ CIAT 17434, _B_. _dictyoneura_ CIAT 6133, and _B_. _brizantha_ CIAT 6780.

Table 19. List of collaborators, area planted, and forage species established for basic multiplication during 1989 in Costa Rica.

Species	CIAT No.	Area (ha) Old	Area (ha) New	Entity in charge of multiplication	Site
B. dictyoneura	6133	0.66	1.2	Sta. Clara Farm-MAG*	Guápiles
			0.3	Agrícola La Colonial-MAG	Guápiles
			0.3	Ganadera Farm-MAG	Guápiles
			1.5	COOPEAGRI (El Porvenir)	San Isidro
			0.2	La Pacífica	Guanacaste
			1.0	MAG-E. Jiménez Núñez	Guanacaste
			4.5		
B. brizantha	6780	1.50	0.3	Sta. Clara Farm-MAG	Guápiles
B. humidicola	6369	0.09	0.1	Los Diamantes-MAG	Guápiles
			0.1	COOPEAGRI	San Isidro
			0.2		
A. pintoi	17434	0.84	0.1	Sta. Clara Farm-MAG	Guápiles
			0.1	La Chaqueta Farm-MAG	Guápiles
			0.3	Ganadera Farm-MAG	Guápiles
			0.2	CATIE	Turrialba
			0.1	COOPEAGRI	San Isidro
			1.1		
S. guianensis	184	0.8	0.15	COOPEAGRI	San Isidro
			0.38	La Pacífica	Guanacaste
			0.25	El Tempisque Farm-MAG	Guanacaste
			0.78		
C. brasilianum	5234	0.25	0.25	El Tempisque Farm-MAG	Guanacaste
C. macrocarpum	5713	0.65	0.38	La Pacífica	Guanacaste

* Ministry of Agriculture.

Table 20. Type of trial and pastures being established for evaluation under grazing in collaboration with various institutions in Costa Rica (1989).

Type of trial	Site	Pasture	Current status	Principal entity in charge
RTC	Guápiles	1. B. brizantha 6780 + A. pintoi 17434	Under establishment (replantings)	CATIE/MAG/ U. of Wageningen
		2. B. brizantha 6780 + C. macrocarpum 5713		
		3. B. brizantha 6780 + S. guianensis 184		
		4. B. humidicola 6369 + A. pintoi 17434		
		5. B. humidicola 6369 + S. guianensis 184		
RTC	Cañas (Guanacaste)	1. H. rufa + C. macrocarpum 5713 and 5674 + C. brasilianum 5234	Under establishment (replantings)	Ecological center La Pacífica - MAG
		2. H. rufa + S. guianensis 184		
		3. B. brizantha 6780 + C. macrocarpum 5713 and 5674 + S. guianensis 184 + C. brasilianum 5234		
		4. B. dictyoneura 6133 + C. macrocarpum 5713 and 5674 + C. brasilianum 5234		
		5. A. gayanus 621 + C. macrocarpum 5713 and 5674 + C. brasilianum 5234		
RTD	Guápiles	1. B. brizantha 6780		
		2. B. brizantha 6780 + A. pintoi 17434 + C. macrocarpum 5713	Already established	MAG
RTD	Río Frío	1. B. dictyoneura 6133 + S. guianensis 184 + A. pintoi 17434	Under establishment	U. of Costa Rica

The Guápiles RTC has been designed to generate information that will facilitate understanding of the mechanisms by which legumes survive under grazing in association with grasses.

The experiments consist of a complete factorial design of two grasses (*B. brizantha* CIAT 6780 and *B. humidicola* CIAT 6369), three legumes (*A. pintoi* CIAT 17434, *C. macrocarpum* CIAT 5713, and *S. guianensis* CIAT 184) and two stocking rates (2 and 3 AU/ha). The management regime includes plots under rotational grazing which will be occupied by two animals during 4 days, followed by 24 days of rest. Each treatment is replicated twice.

In the RTC of the Centro Ecológico "La Pacífica", the components of each association were planted in separate lines in order to monitor their persistence. The design consists of plots divided in space and time, as follows: main plot, stocking rates (1.5/0.75 and 3.0/1.5 AU/ha, rainy/dry, resp.); subplot, pastures; subsubplot, grazing cycle. The grazing system is rotational, with 7 days occupation and 28 days rest, and each treatment is replicated twice.

The more advanced RTD being established is that in Guápiles, in collaboration with MAG. *B. brizantha* CIAT 6780 and *A. pintoi* 17434 were planted simultaneously in vegetative form, while *C. macrocarpum* CIAT 5713 was planted using gamic seed. Except for the latter accession, which has suffered severe attacks by leaf chewers, the other components are well established; to date, the grass presents greater vigor and dominance. A rotational grazing system (7/21 days); with two stocking rates (1.5 and 3.0 AU/ha) and two replications is used in this trial. The *B. dictyoneura* CIAT 6133 + *A. pintoi* CIAT 17434 and *S. guianensis* CIAT 184 pasture in Río Frío and the University of Costa Rica, will be subjected to a rotational grazing system with 7/28 days and stocking rates of 1.5 and 2.5 AU/ha. This trial is now underway.

10. N Cycling and Fixation

INTRODUCTION

This report covers the work done and completed in 1989 by the soil microbiology section and outlines the background and rationale of the change in direction to be taken by the section during 1990.

The sections activities will be discussed under the following headings:

- Rhizobium collection
  - organization
  - survival studies
  - production of inoculants
  - rhizobium ecology
- Legume-rhizobium evaluation interactions.
  - glasshouse studies
  - rhizobium + phosphorus
  - field studies
- N cycling in grazed pastures
  - theoretical studies

RHIZOBIUM COLLECTION

a) Organization

The Pasture Programme currently holds over 4,000 rhizobium strains for tropical forage legumes. In 1989 70% of the collection was lyophilized and stored. The remainder will be stored during 1990.

Previously the collection was managed in subgroups (Ann. Report 1987). This year the collection of active strains has been reduced to those of interest to the Pasture Programme; to facilitate this the strains have been placed in three groups.

The first group is made up of the four most requested strains which are used for the production of large quantities of inoculants for the following legumes: *Stylosanthes capitata*, *Centrosema* spp., *Arachis pintoi*, *Pueraria phaseoloides* and *Desmodium* species.

The second group consists of seven strains which are used to prepare smaller quantities of inoculants than those in group 1 and which are used in agronomic experiments by other units of CIAT.

The third group consists of an additional fourteen strains previously on the recommended list. This collection of 25 strains from groups 1-3 is maintained either lyophilized or in the refrigerator. These have been purified and characterized, and are regularly sub-cultured to supply the stocks for the production of inoculants.

This collection needs to be checked every 6 months for mutations.

b) Survival studies

The great demand for inoculants from group 1 requires high numbers of bacteria at reduced costs. In this study two types of media were used, Balatti and Levadura-Mannitol, which were diluted with water and preinoculated with 10% of the expected numbers in log phase growth. This work was done because i) there are reports that use of Balatti medium results in greater bacterial growth and less gum production, ii) Levadura-Mannitol medium is rich in nutrients and increases gum production and contains costly mannitol.

The treatments for survival were:

i) culture in Balatti medium
ii) " " Levadura-Mannitol
iii) " " Water + 1% Levadura-Mannitol
iv) " " Water + 1% Balatti
all at an initial pH of 5.5

The initial populations were:

CIAT Strain No.	No. of cells
3101	3.5 x 10^8
4099	2.9 x 10^8
3918	2.3 x 10^8
995	0.72 x 10^8

Results

Growth of strains 3101 and 4099 was increased in Balatti medium compared with Levadura-Mannitol with generation times of 7.24 hours versus 8.1 h for 3101 and 7.1 h versus 7.4 h for strain 4099 in Balatti, and Levadura-Mannitol, respectively. CIAT strain 3918 which is recommended for kudzu, did not survive in Balatti medium as a 67% mortality was observed which may have been the result of mutation.

Similarly strain 995, which is recommended for Stylosanthes capitata, did not survive in Balatti medium (Figures 1 and 2). The pH changes in the media are shown in Figure 3. The results indicate that Balatti medium can increase the growth for some strains, for example those in category X (Ann. Rept. 1984) but it is toxic to slow growing strains with generation times greater than 10 h or to those which produce acid (e.g. strain 3918).

Inoculant production

There was a small increase in inoculant production this year due to the request from ICA for CIAT to supply inoculants for the Llanos Orientales. All these inoculants were made in ICA peat. It should be mentioned that inoculant production for Centrosema sp, CIAT 3101 in ICA peat uses the strain diluted 10 times with sterile water to obtain a greater yield. This differs from the production of strain 995 (recommended for Stylosanthes capitata) as the latter dies in water and shows inferior growth in Levadura-Mannitol media. The use of dilution is an alternative method for large scale production at low cost but is specific for certain strains (e.g. Category X, growth in Levadura-Mannitol ≦ 3 x 10^9 cms) which "survive" well in peat. Production of strain 3101 resulted in a marked increase in the effort required by the group to satisfy demand.

The quantities of inoculants requested in 1989 is presented in Table 1. The section can no longer support requests from commercial sources.

Rhizobial ecology

The selection of Bradyrhizobium germplasm for high fixation potential, survival and competitiveness in the soil is an important aspect of the pasture programmes efforts to introduce productive and sustainable grass/legume mixtures into pastures. Of particular importance is the ability of the introduced strain to persist in an environment which may or may not contain populations of native rhizobia. We have observed that the good responses to inoculation during legume establishment sometimes do not persist into the following year. This could be due to a number of factors including an increased effectiveness of native strains, the accumulation of

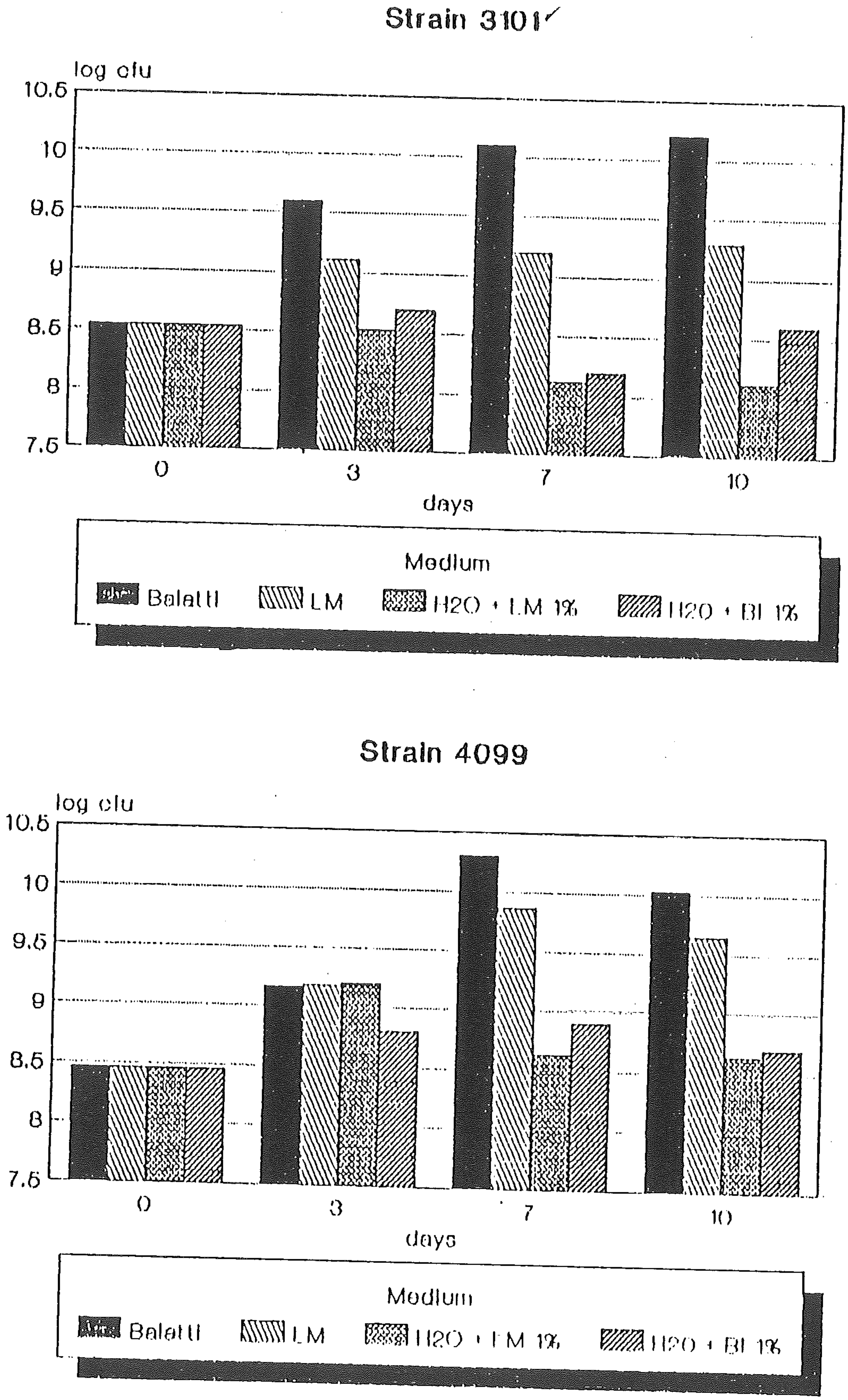


Fig. 1 Survival of Group 1 in different media

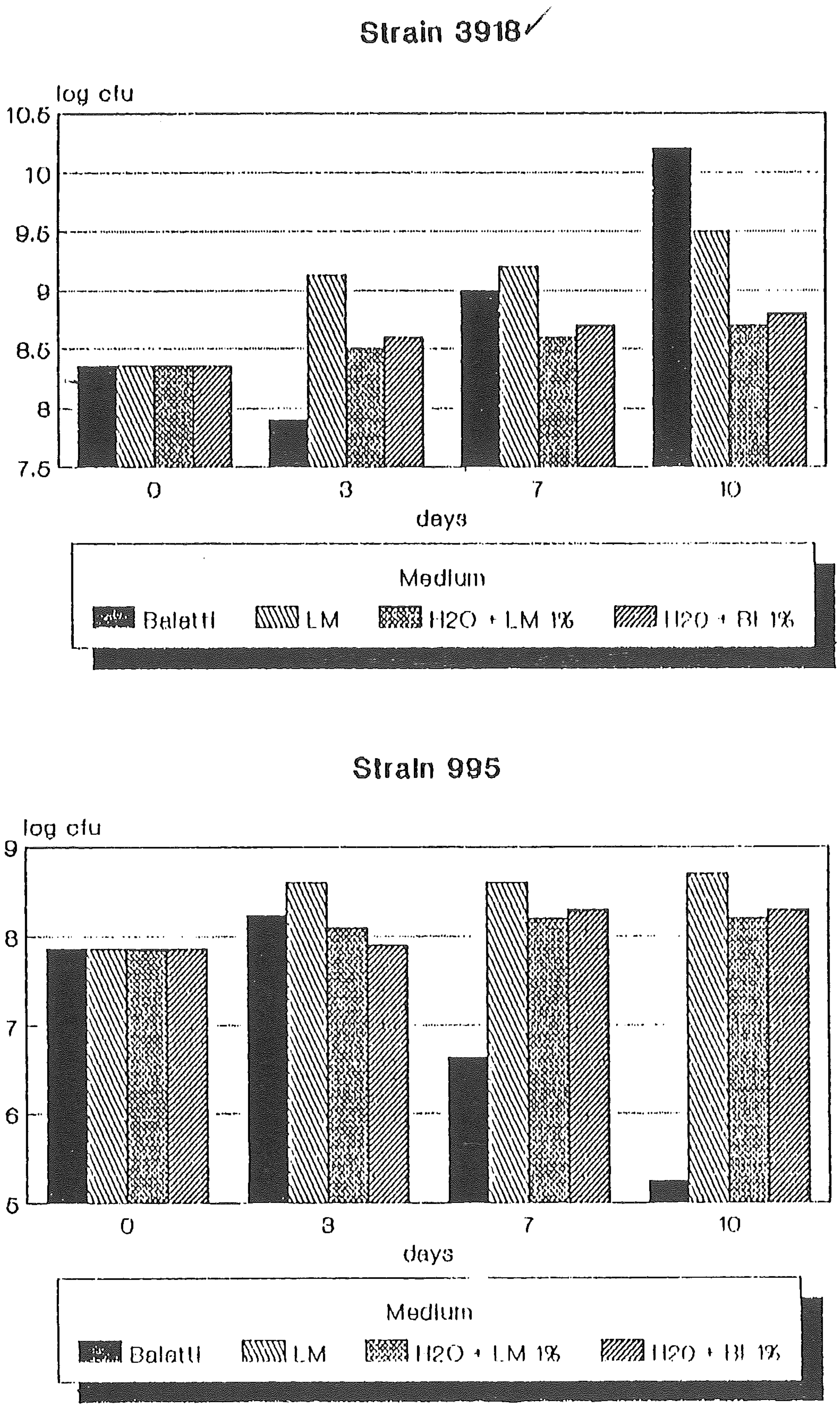
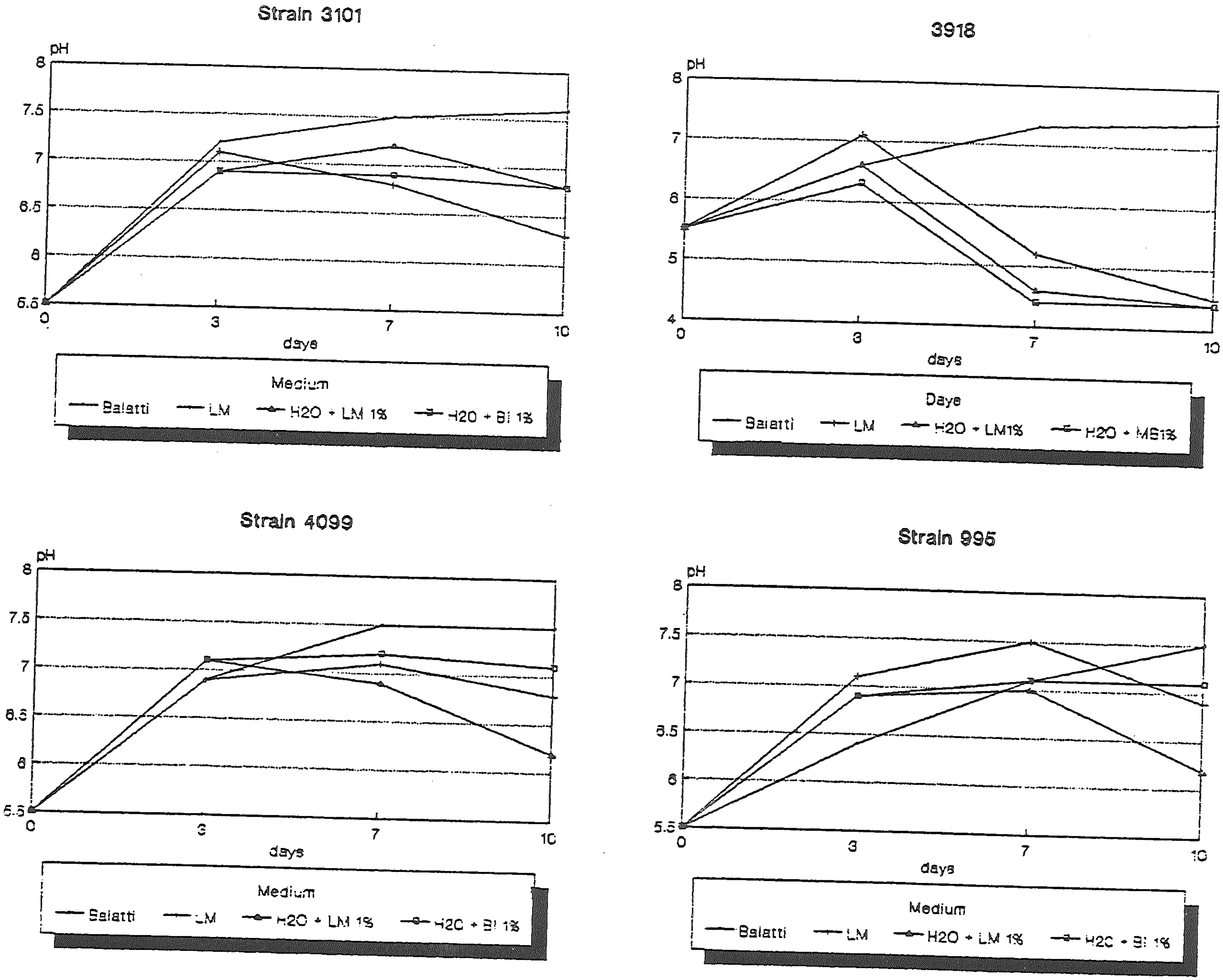


Fig. 2 Survival of Group 1 strain in different media


Strain 3101

3918

Strain 4099

Strain 995

Fig. 3 pH changes in different media with Group 1 strains

Table 1. Quantities of inoculants produced in 1989 and origin of request

			1 9 8 9						
			Non-commercial requests (grs)						Commercials
Legume	Strain CIAT	Type of request	E-F	N-A	N-J	J-A	S-O	Total grs	Total grs.
Centrosema spp		INT	2640	8490	4425	14612	3950	34117	
y Arachis	3101	EXT	530	2320	65020	300	305	68475	6150
S. capitata	995	INT	35	2280	4725	26250	10	33300	
		EXT	30	240	13000	0	0	130270	5100
S. guianensis	4969	INT	0	1080	0	0	225	1305	
		EXT	65	510	0	0	30	605	0
S. hamata	861	INT	0	0	15	0	0	15	
		EXT	0	0	0	0	0	0	0
S. Bcabra	4103	INT	0	150	0	0	0	150	
		EXT	0	0	0	0	0	0	450
D. ovalifolium	4099	INT	300	450	0	600	645	1995	
		EXT	0	0	0	0	219	219	0
P. phaseoloides	3918	INT	180	105	10	0	15	310	
		EXT	0	0	0	0	30	30	20035
E. glauca	35	INT	0	220	0	0	0	255	
		EXT	0	0	0	0	0	0	0
G. sepium	3920	INT	0	150	9	0	0	159	
		EXT	0	0	0	0	0	0	450
L. leucocephala	1967	INT	105	75	0	0	0	330	
		EXT	150	0	0	0	0	150	150
Zornia glabra	4100	INT	190	30	0	0	0	220	
		EXT	50	195	0	0	45	290	0
M. sativa*	44	INT	75	0	0	0	0	75	
		EXT	0	0	0	0	0	0	10050
T. repens*	61	INT	0	0	15	0	0	15	
		EXT	0	0	0	0	0	0	0

Total requests received: 106

* At present inoculant is not prepared for these legumes.

N in the soil or a lack of persistence of the inoculated strain. The application of strain-typing techniques is required in order to determine which strain(s) are in the soil and which are occuping the nodules. Part of the sections efforts have therefore been devoted to developing an appropriate technique. An outline of the methods used is given in Figure 4. These are briefly described:

1. Direct - Elisa (enzyme-linked immunosorbent assay). Rabbit antibody (Ab) for different rhizobium strains, is labelled with peroxidase. The enzyme reaction is measured colorimetically.
2. Indirect - Elisa. This technique includes the binding of two different kinds of antibody. The first stage is the detection of the antigen (Ag) with the unlabelled antibody. Then the Ab-Ag complex is detected by another specific antibody or Protein A. The specific Ab or Protein A is labelled with alkaline phosphatase and the reaction is measured colorimetically.
3. DOT - Elisa. For this technique direct or indirect Elisa can be used but nitrocellulose membranes are used instead of polystyrene microtiler plates (immunlon) normally used in Elisa techniques.

For these studies antibodies were derived from two Bradyrhizobium strains; CIAT 3101 (effective on *Centrosema* spp.) and 4099 (effective on *Desmodium ovalifolium*).

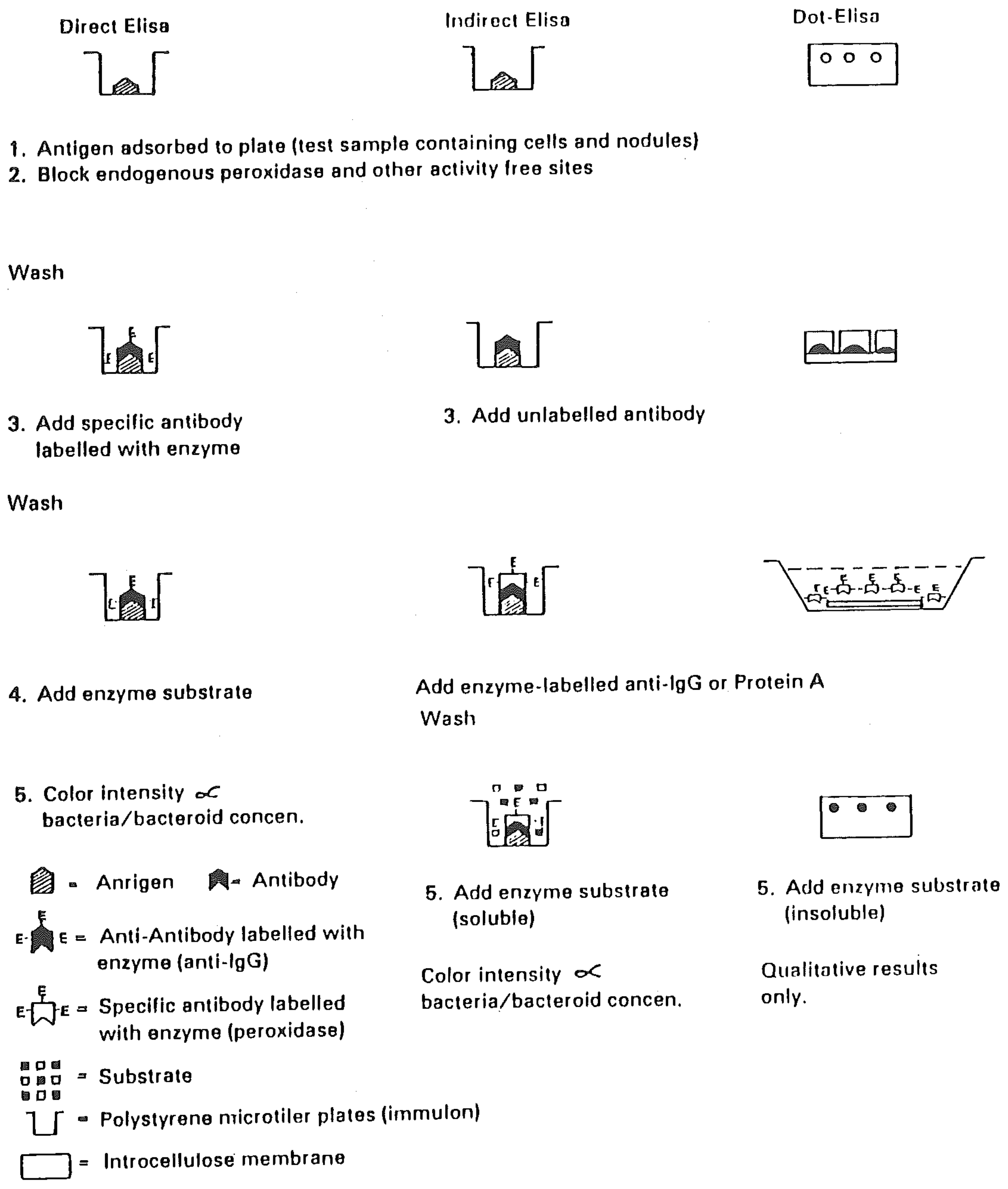
Results

Direct Elisa - There was a highly specific reaction for strain 3101 but not for 4099.

Indirect Elisa -
- a) with Protein A high background reactions were observed in both strains tested giving a high % of false positives.
- b) Immunoglobulin (Ig6) - Both strains gave highly specific positive results.

DOT - Elisa -
- a) direct + peroxidase - Specific results for both strains but results were qualitative, no qualification is possible.
- b) indirect + Protein A - Specific for cells and bacteroid forms of 3101 but only for cells of 4099.
- c) indirect + Ig6 - Similar results obtained to the indirect + Protein A above.

The direct - Elisa appears to be an appropriate technique for 3101 but not 4099. However this technique has the disadvantages of 1) requiring large amounts of Ab for conjugation with peroxidase and 2) requiring a separate antibody from each strain. In contrast the indirect Elisa method uses pure unlabelled Ab in small amounts. In addition the indirect Elisa is more sensitive than the direct Elisa. The DOT-Elisa gave the same result as the Elisa method but quantification was not possible. Overall the best technique for identification of bacteria cells and bacteroid forms was the indirect Elisa used with Ig6.



Direct Elisa

Indirect Elisa

Dot-Elisa

1. Antigen adsorbed to plate (test sample containing cells and nodules)
2. Block endogenous peroxidase and other activity free sites

Wash

3. Add specific antibody labelled with enzyme

3. Add unlabelled antibody

Wash

4. Add enzyme substrate

Add enzyme-labelled anti-IgG or Protein A

Wash

5. Color intensity ∝ bacteria/bacteroid concen.

5. Add enzyme substrate (soluble)

Color intensity ∝ bacteria/bacteroid concen.

5. Add enzyme substrate (insoluble)

Qualitative results only.

▨ = Anrigen

Antibody

E = Anti-Antibody labelled with enzyme (anti-IgG)

E = Specific antibody labelled with enzyme (peroxidase)

= Substrate

= Polystyrene microtiler plates (immulon)

= Introcellulose membrane

Fig. 4 Principles of the Elisa and immunodott technique for typing <u>Bradyrhizobium</u> strains.

LEGUME-RHIZOBIUM EVALUATION

1. Glasshouse studies

During 1989 the following legumes were evaluated: Pueraria phaseoloides accession numbers 9900, 8352, 17325, 9279, 18031, 17281, 17290; Flemingia macrophylla 17403, 17407; two ecotypes of Stylosanthes guianensis, 184 and 10136 and, Codariocalyx gyroides 3001.

Pueraria phaseoloides

All four Rhizobium strains (2434-3918-3850-4396) increased total N in above-ground parts of the seven accessions (Figure 5). Strains 2434 and 3918 were the most effective. Strain 4396, which is recommended by Nitragin, increased the total N in the seven accessions but these increases were only significant with accession 17325.

All rhizobium strains increased nodulation of the different accessions. However the results with accession 17281 were not significant with respect to total N and this accession also had the least number of nodules.

Flemingia macrophylla

The results of two ecotypes of Flemingia macrophylla inoculated with twelve strains of Rhizobium are shown in Fig. 6. Greatest total N and number of nodules were observed with accession 17407. Accession 17403 also responded significantly to inoculation. Greatest total N in above-ground parts of either accession was obtained with strain 4099 which is the recommended strain for Desmodium ovalifolium. Strain 5009 also produced significant increases in both accessions. Of the two accessions 17407 produced the greatest number of nodules and dry weight.

Codariocalyx gyroides

Eighteen rhizobium strains were tested with Codariocalyx gyroides in Carimagua soil. Twelve strains were isolated from different sites (Colombia-México-Hawaii) and the other six were strains from the forage legume programme. Only six strains increased total N in the above-ground parts compared with the uninoculated control (Table 2). Strains 4099 and 3418 which are effective with Desmodium were not effective with Codariocalyx. There was no relationship between nodule number and N in foliage. The increases obtained with the test strains were not significant and further selection of effective strains are required as there was a response to N fertilization.

Stylosanthes guianensis

Of the 27 rhizobium strain tested with two accessions of Stylosanthes guianensis, ten increased dry matter production in S. guianensis 184, but only two strains were better than the control with S. guianensis 10136 (Table 3). Results for N are not yet available.

Effect of rhizobium inoculation on the absorption of phosphorus by Stylosanthes capitata 10280.

This work is a continuation of the interaction between S. capitata and P level (Ann. Rept. 1988). S. capitata 10280 (Capica) was grown in soil cores in the glasshouse with three levels of phosphorus 15, 50 and 100 kg P/ha in two soils of different textures, one was a heavier soil with only 12% sand (La Reserva) the other was lighter with 48% sand (Yopare).

With the highest level of P, inoculation with rhizobium strains increased the uptake of P compared with an uninoculated control in la Reserva soil. However, only strain 870 gave a statistically significant increase (Table 4A).

On the other hand in Yopare soil inoculation with rhizobia resulted in less P uptake compared with the control with the exception of strain 2138 (Table 4B).

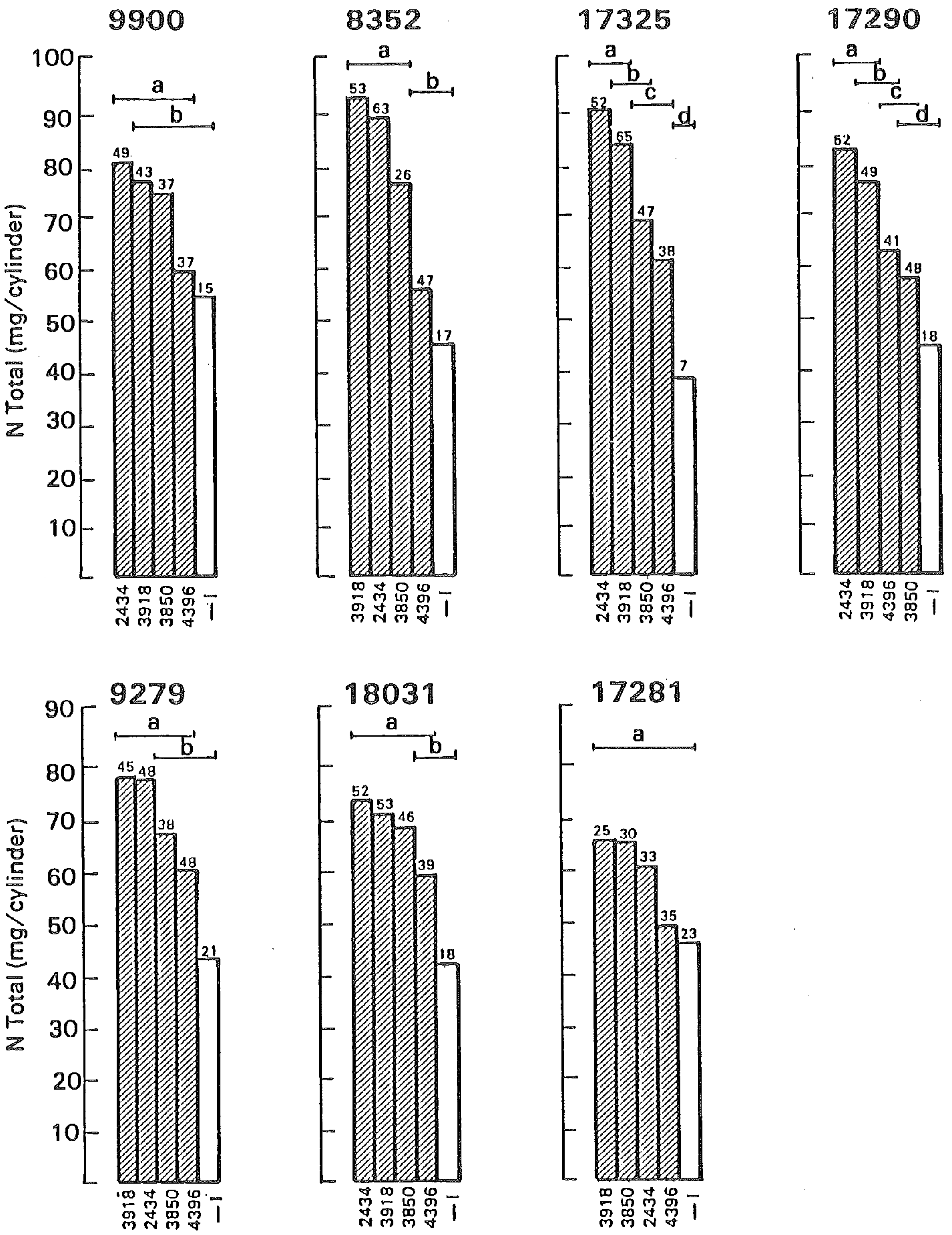


Fig. 5 Total N in foliage of 7 accessions of <u>Pueraria phaseoloides</u> (kudzu) inoculated with rhizobium strains and grown in undisturbed soil cores from Carimagua.

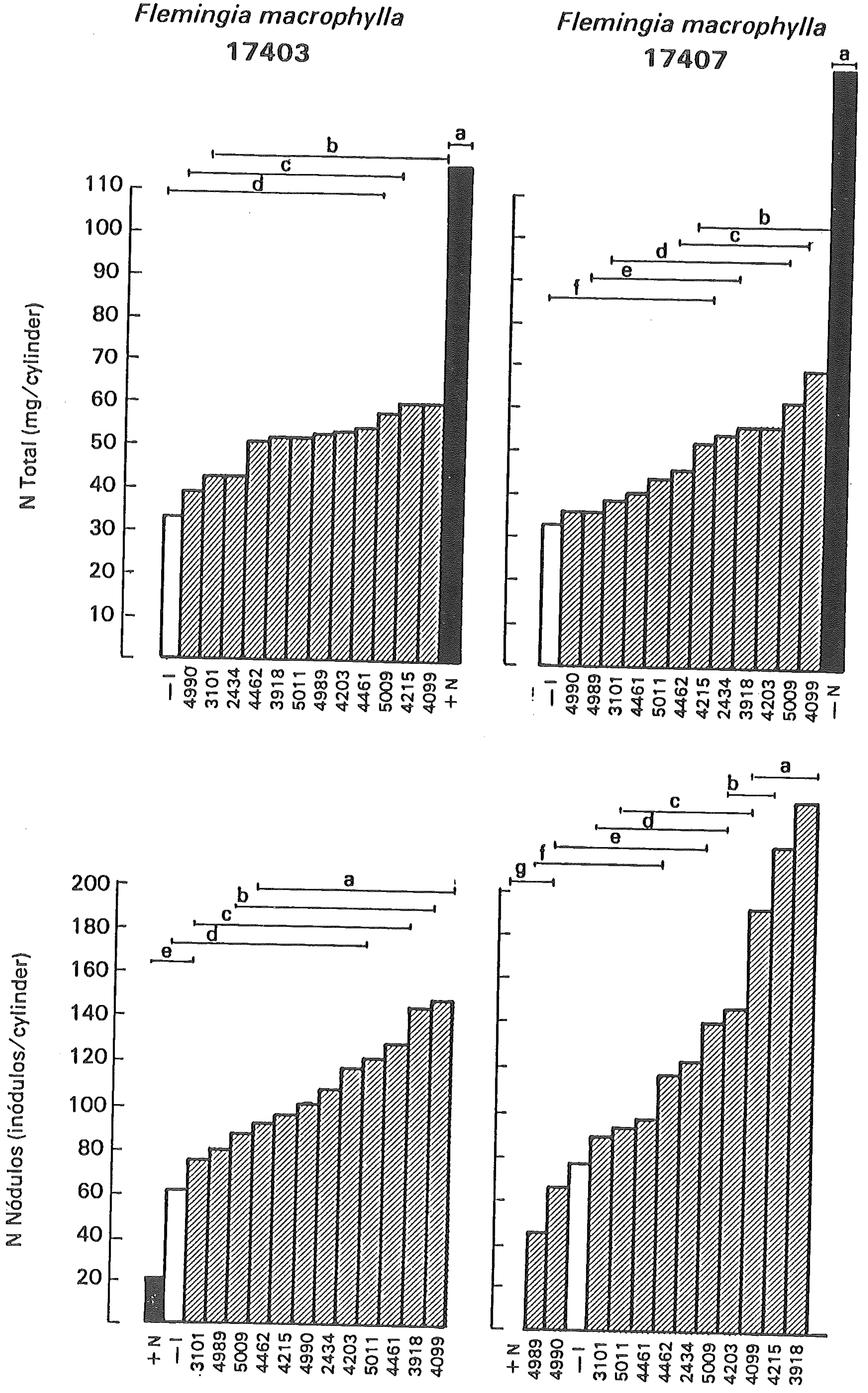


Fig. 6 Total N foliage and nodulation of 2 accessions of *Flemingia marophylla* inoculated with different rhizobium strains and grown in undisturbed soil cores from Carimagua.

Table 2. Production of foliage total N and nodulation with 18 rhizobium strains and two controls -I and +N in *Codariocalyx gyroides* CIAT 3001.

Treatment	N in foliage mg N/cylinder	No. of nodules
+N	98.81	19
4880	64.90	48
2335	63.55	73
1506	61.07	53
4880 B	60.78	46
3258	59.66	40
3264	57.23	58
-I	54.83	49
3155	54.15	56
3336	53.99	64
3176	53.95	65
3164	53.62	49
3629	53.10	62
2469	53.08	61
4099	52.40	41
3188	49.22	56
3148	46.41	55
3418	44.31	68
3150	41.85	60
805	33.01	119

Table 3. Dry matter production of two accessions of Stylosanthes guianensis 184 and 10136, in undisturbed soil cores from Carimagua and inoculated with rhizobium strains.

S. guianensis 184		*S. guianensis* 10136	
Treatment	Dry matter mg/core	Treatment	Dry matter mg/core
+ Nitrógeno	4.02	+ Nitrógeno	4.04
4995	3.54	4887	3.29
4888	3.44	5012	3.16
4887	3.44	-Inoc	3.07
5013	3.44	4995	3.03
5012	3.38	4103	3.13
4881	3.26	3041	3.01
97	3.26	4875	2.96
4103	3.23	2434	2.93
4101	3.17	4100	2.90
861	3.14	1315	2.88
-Inoc	3.11	4994	2.86
4875	3.07	97	2.85
1238	3.02	4881	2.84
2434	3.01	2016	2.83
271	3.01	4964	2.80
4994	3.01	1312	2.80
4969	2.97	271	2.78
1463	2.97	4969	2.76
4965	2.95	861	2.74
2016	2.90	5013	2.74
4100	2.89	1463	2.73
1018	2.86	1238	2.72
2131	2.74	4888	2.69
1312	2.70	4965	2.62
1315	2.69	162	2.59
3041	2.68	4101	2.50
162	2.33	2131	2.44
4969	2.22	1018	2.34

Table 4A. Effect of rhizobium strain on the uptake of P by *S. capitata* 10280 grown with three levels of P (25/50/100 kg P/ha).

A. RESERVA SOIL

Treatment	High P	Medium P mg P/cylinder	Low P
870	9.27 a	4.28 fgh	3.07 ghi
2138	6.64 bcde	3.90 ghi	2.16 i
3541	8.00 abc	3.92 ghi	2.75 hi
+N	8.23 ab	5.99 def	2.75 hi
995	7.56 abcd	4.88 efg	3.62 ghi
-I	6.31 cde	4.34 fgh	2.99 ghi

Table 4B

B. YOPARE SOIL

Treatment	High P	Medium P mg P/cylinder	Low P
870	9.24 ab	4.49 cde	2.60 ef
2138	10.40 a	3.91 cdef	2.37 f
3541	8.50 b	4.70 cd	2.96 def
+N	8.11 b	5.28 c	3.96 cdef
995	8.76 ab	3.68 cdef	2.29 f
-I	9.58 ab	4.12 cdef	2.70 ef

In la Reserva soil there was a significant positive response to N at the highest P level but a slight decrease in Yopare soil which was not significant.

In the other P treatments there were no significant treatment differences. In the absence of information about the status of these plants with respect to mycorrhizae further interpretation of these results is not possible.

Evaluation of legume-rhizobium interaction in *Stylosanthes capitata* 10280 (cv Capica).

S. capitata has been observed to behave differently from other forage legumes with respect to its interaction with P. *viz.* - at high rates of applied P the effect of inoculation has been negative unlike the positive responses observed for *Centrosema acutifolium* 5277 (Vichada) and *Pueraria phaseoloides* 9900 (Ann. Rept. 1988). This negative effect has been decreased when plants were also inoculated with the bacterium Pseudomonas Pp 18 and at low levels of P the presence of *Pseudomonas* increased the response of Capica to inoculation (Ann. Rept. 1988). These responses were observed in the glasshouse and this year a trial was conducted in the field at Carimagua. Results to date confirm the special case of Capica. DM production increased with inoculation at 20 kg P/ha. The presence of *Pseudomonas* appeared to increase this resposne with strain CIAT 955 but not CIAT 1460 (Table 5). At 40 kg P the presence of *Pseudomonas* appeared to alleviate the negative response to inoculation at high P. There was little effect of *Pseudomonas* inoculation alone on DM production but there was evidence that legume growth was enhanced by the presence of *Pseudomonas* and rhizobium strain 995 at all levels of P, but not with strain 1460. This may be due to a stimulation of root growth.

This interaction was also studied with *Centrosema acutifolium* (Vichada) and two rhizobium strains (CIAT 3101, 3694). Different interactions between rhizobium + Pseudomonas were observed depending on the level of P and rhizobium strain. With low and medium levels of P there was an increase in DM production with Pseudomonas + 3101 compared with inoculation with 3101 only, but at the high P level the effect was negative (Table 6).

The results with Pseudomonas + 3694 differed with an incresed DM production compared with the uninoculated control but no effect of pseudomonas with 3694 at the low and medium P level (Table 6). However at the high level the presence of pseudomonas appeared to increase the stimulating effect of strain 3694.

Inoculation with only pseudomonas appeared to increase DM production at lower levels of P but not at the highest level of P.

While this effect of Pseudomonas is of anecdotal interest, the complicated legume x strain x bacteria effects and the unlikelihood of there being any potential for the management of these effects in a practical way, suggests that this area of research should be terminated.

NITROGEN CYCLING IN GRAZED PASTURES

The efficient cycling of nutrients in pastures which traditionally receive zero or low inputs of fertilizers and lime, is a prerequisite for long term sustainability. Even with more highly productive improved pastures there is a need to retain and cycle nutrients within the soil-plant-animal system in order to minimize maintenance fertilizer requirements. Previous work has indicated that the introduction of a N_2-fixing legume into pasture can markedly increase animal productivity and can at the same time produce stable pastures.

Table 5. Effect of level and inoculation with rhizobium and Pseudomonas on DM production of <u>Stylosanthes capitata</u> after 16 weeks growth.

(mg DM/cylinder)

Inoculants	P level 10	 20	 40
	....	kg/ha	....
- Inoculant	356.73 ± 7.74	329.17 ± 6.69	619.00 ± 30.57
+ 995	348.67 ± 20.82	530.67 ± 25.20	473.13 ± 11.42
+ 1460	291.43 ± 8.74	547.10 ± 18.49	499.23 ± 21.14
+ Pp18*	321.20 ± 5.93	467.37 ± 12.93	482.57 ± 16.05
+ 995 + Pp18	377.90 ± 18.84	614.66 ± 8.52	629.87 ± 14.53
+ 1460 + Pp18	328.43 ± 10.46	491.53 ± 21.55	557.30 ± 25.86

± SE

* Pseudomonas

Table 6. Effect of level and inoculation with rhizobium and Pseudomonas on DM production of <u>Centrosema acutifolium</u> after 16 weeks growth.

(mg DM/cylinder)

Incoulants	P level 10	 20	 40
	....	kg/ha	....
-Inoculant	242.57 ± 4.69	228.83 ± 6.66	440.20 ± 9.34
+ 3101	405.90 ± 12.88	514.10 ± 48.60	563.87 ± 13.49
+ 3694	351.57 ± 20.41	442.30 ± 3.61	486.63 ± 3.69
+ Pp18	395.90 ± 3.36	348.67 ± 26.00	328.83 ± 14.43
+ 3101 + Pp18	533.40 ± 22.61	569.83 ± 16.46	375.30 ± 16.82
+ 3694 + Pp18	334.57 ± 23.05	428.50 ± 16.74	674.30 ± 23.62

For tropical grasslands the role of N cycling in pasture production is poorly understood and yet the benefits of a legume as a source of N and high quality herbage are frequently expounded. A new programme on N cycling aims to document the soundness of using grass/legume pastures and to develop technologies which will result in sustainable pasture systems.

Using the sparse amount of information available from the literature and by judicious extrapolation of findings from temperate and sub-tropical pastures, the N cycle has been simulated for a number of grass and grass/legume crops with different levels of pasture utilization. The basic N cycle used for this exercise is shown in Figure 7. Fluxes were estimated using as a starting point, the annual herbage DM and N production levels reported in the literature and the following assumptions:

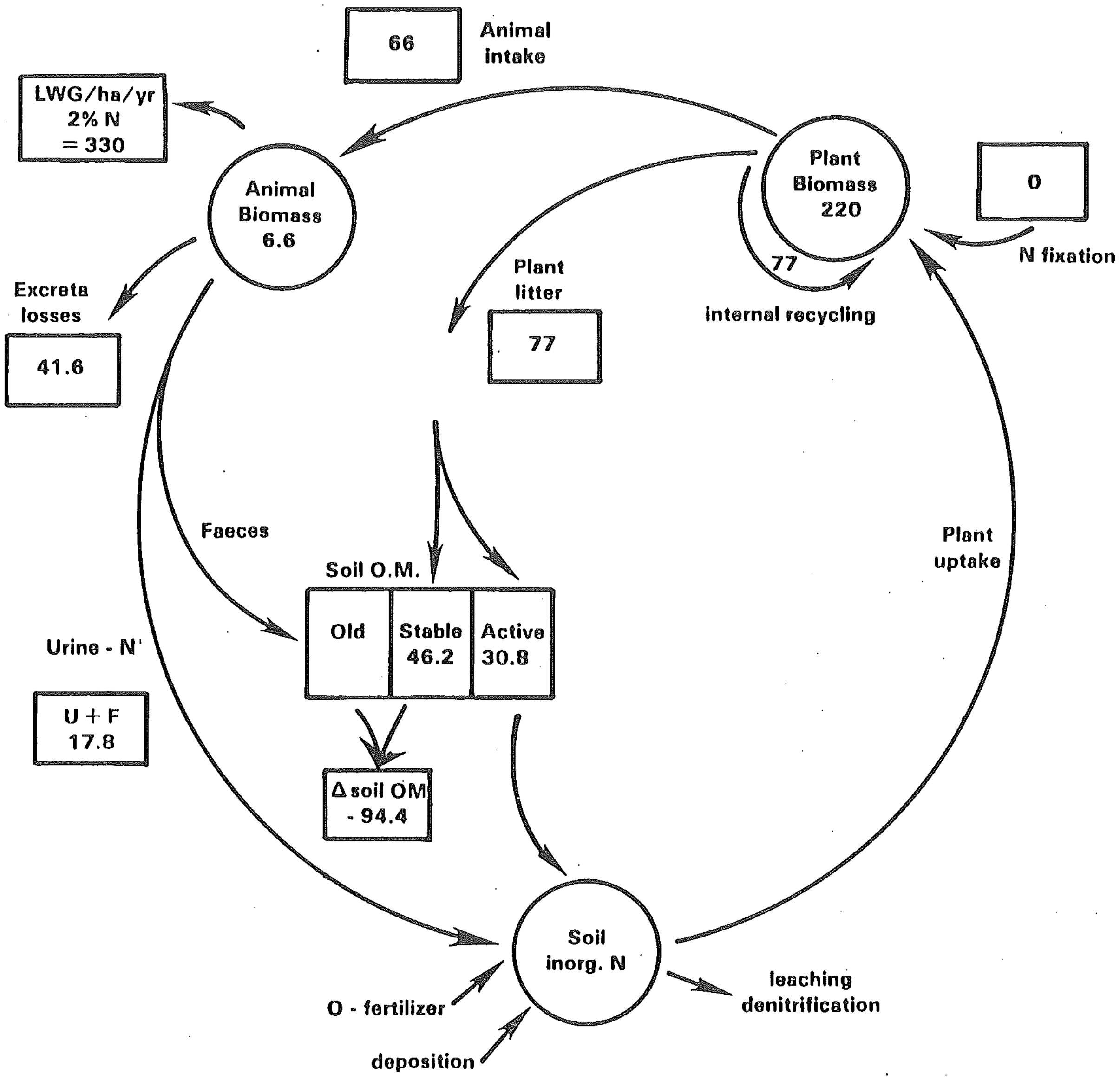
- The pasture is at steady state on an annual basis.
- Between 50-60% of herbage N is internally recycled (remobilised) from senescing leaves to growing tissues.
- Animals retain only 10% of ingested N, the remainder is excreted and animal LWG contains 2 or 2.5% N.
- 70% of N in excreta is lost from the available soil N pool via volatilization, leaching and denitrification.
- 40% of the plant litter enters the available soil N pool over a period of 1-5 years, the remainder enters stable or recalcitrant pools which only become available for uptake by plants over long time periods.
- With the exception of excreta, losses of N via volatilization, leaching and denitrification are small and are balanced by an input of N from atmospheric deposition when no fertilizer N is added.

Using these assumptions it is possible to simulate the flux of N from the plant biomass to the soil inorganic-N pool via the animal. The cycle is then balanced by invoking a supply of N from the soil organic matter pool to the plant biomass, excluding recently added litter. The example in Figure 7 is a grass-only pasture receiving no N fertilizer or input from N_2 fixation. When animals ingest 30% of the available herbage (220 kg N/ha) the cycle requires an input from soil OM of 94.4 kg N to obtain a balance. This system is unlikely to be sustainable with low soil OM levels.

The effect of the introduction of a legume into a similar yielding pasture is illustrated in Figure 8. Here it is assumed that the N content of grass is 1% (w/w) and that of the legume 2.5% (w/w). In this example the pasture is more palatable and utilization is 40%. The input from biological N_2-fixation is assumed to be 90% of the total above-ground legume biomass N. The herbage yield data was obtained from published values for a Brachiaria/Arachis pintoi association. In this cycle because of the N input from fixation, there is a negligible drain on the soil OM pool even with a 33% increase in pasture utilization and a 53% increase in animal LWG compared with the N cycle in Figure 7. This simulation clearly demonstrates the benefits of the introduction of a legume into pastures.

Data from temperate pastures suggest that the main factor determining long term pasture sustainability is the relative balance between herbage consumed by the animal (% utilization) and that returned to the soil via plant litter. High rates of pasture utilization result in greater fluxes of nutrients through the animal with greater associated losses via excretion. There is less translocation of N from senescing tissue to new growth and less return of litter to

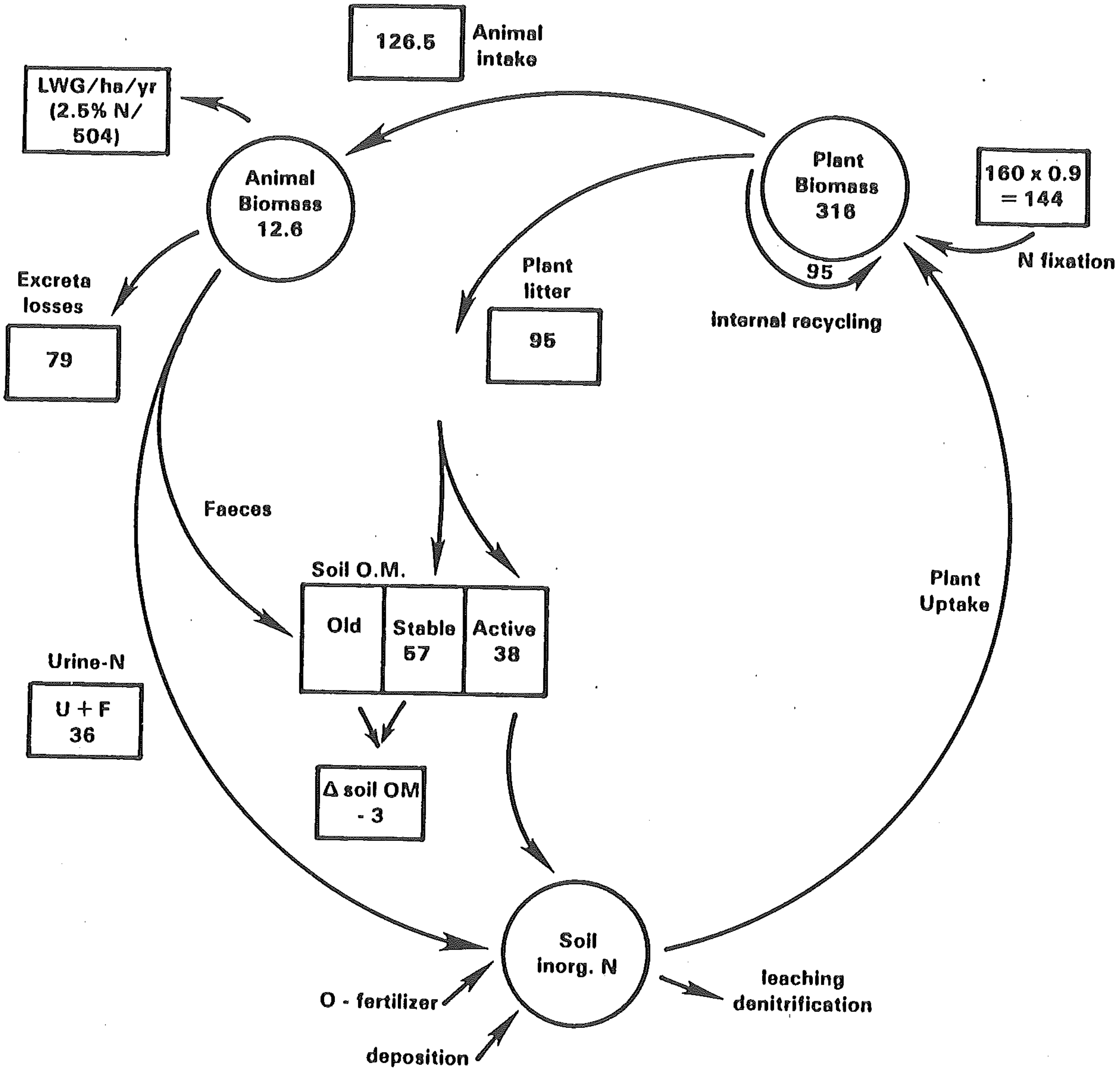
t DM/ha/yr = 22
kg N/ha/yr = 220
Utilization = 30%



U + F = 17.8
Litter = 30.8
Remob = 77
Sum = 125.6
Δ soil = 220 - 125.6

Fig. 7 The N cycle of a grass only pasture producing 22 t DM/ha/yr

t DM/ha/yr 15.6 + 6.4 = 22
kg N/ha/yr 156 + 160 = 316
Utilization = 40%



U + F = 36
Litter = 38
Remob = 95
N_2 fixed = 144
Sum = 313
Δ soil = 316 - 313

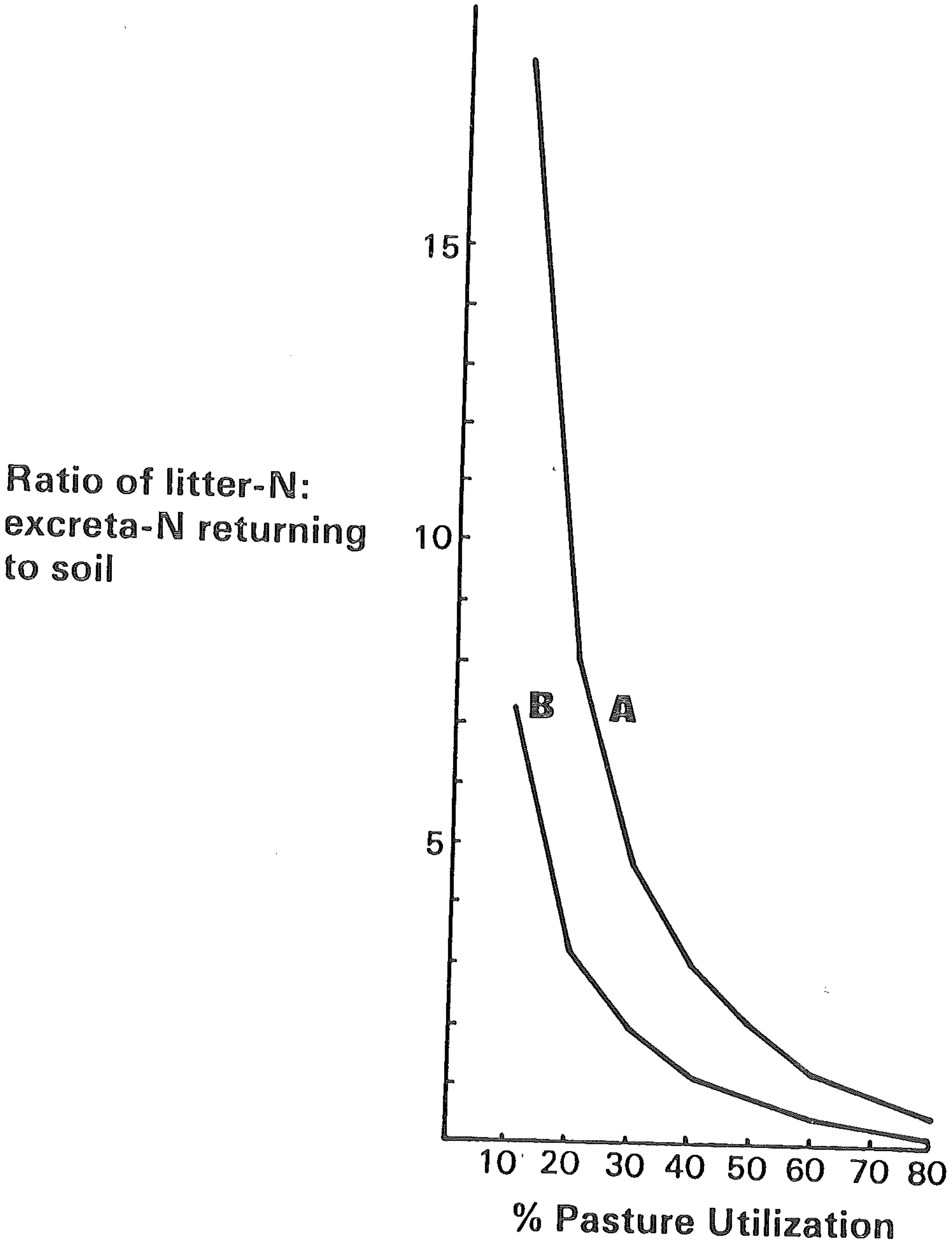
Fig. 8 The N cycle of a grass-legume pasture producing 22 t DM/ha/yr.

the soil. Consequently soil organic N reserves are depleted or there is a greater requirement for N_2-fixation to maintain a balance. At the other extreme however, with low rates of utilization, the large amounts of plant litter returned to the soil can result in immobilization of N due to the high C:N ratio of the litter and consequently, lower levels of subsequent production.

The relationship between herbage utilization and the ratio of litter return: excreta return is shown in Figure 9. This simulation is based on a 70% loss of excreta-N and a 50% remobilization or internal cycling of N from leaves and stems (Curve A). If a value of 40% recovery of litter N by new herbage over a short period of 1-5 years is applied, a relationship shown in Curve B is obtained. In both examples the relationship is exponential rather than linear and is independent of the annual herbage production level. In order to develop rules for sustainable pasture management an indication of the range of litter : excreta ratios that result in only small negative or positive changes in soil OM would be required.

The simulation of the N cycle was taken further by use of different levels of N input via legume N_2-fixation. Figure 8 is an example. The estimated amounts of biologically fixed N_2 needed to balance the cycle without requiring any depletion of soil organic N varies with pasture utilization as illustrated in Figure 10. A linear relationship was obtained with the intercept on the y axis indicating a minimum legume input of about 30% of the total plant biomass N. If the N content of legumes is 2.5% (w/w) compared with 1% for the grass then this value would represent about 15% of the total herbage DM. For tropical pastures with a utilization range of 10-40% the required input of fixed N would range from 34-48% of the total herbage N or if the legume fixes 90% of its N this range increases to 38-53% of the above ground herbage. This range converts to 20-35% on a DM basis using the %N contents quoted above. It should be noted however that these estimations do not include below-ground production and turnover or any allowance for selective grazing of the legume.

To determine the relevance of these stimulations it will be necessary to collect a sufficient data base and to verify some of the assumptions stated earlier. These will include: a) quantification of N_2 fixation and transfer of N to companion grasses, b) rates of decomposition of plant litter under different environmental conditions, c) fate of excretal-N and partitioning of nutrients between the animal and plant, d) quantification of plant internal nutrient cycling. This will be done initially with grass and grass/legume associations known to be relatively productive and stable. This will aid the development of models which can be used predictively for successful pasture establishment, production and maintenance.



Curve A - assumes 50% of leaf + stem N is remobilised before senescence and 30% recovery of excreta-N by herbage.

Curve B - as for A plus a 40% recovery of litter N by herbage over 1-5 years.

Fig. 9 The relationship between % utilization of pasture and the ratio of litter N: excreta-N returns.

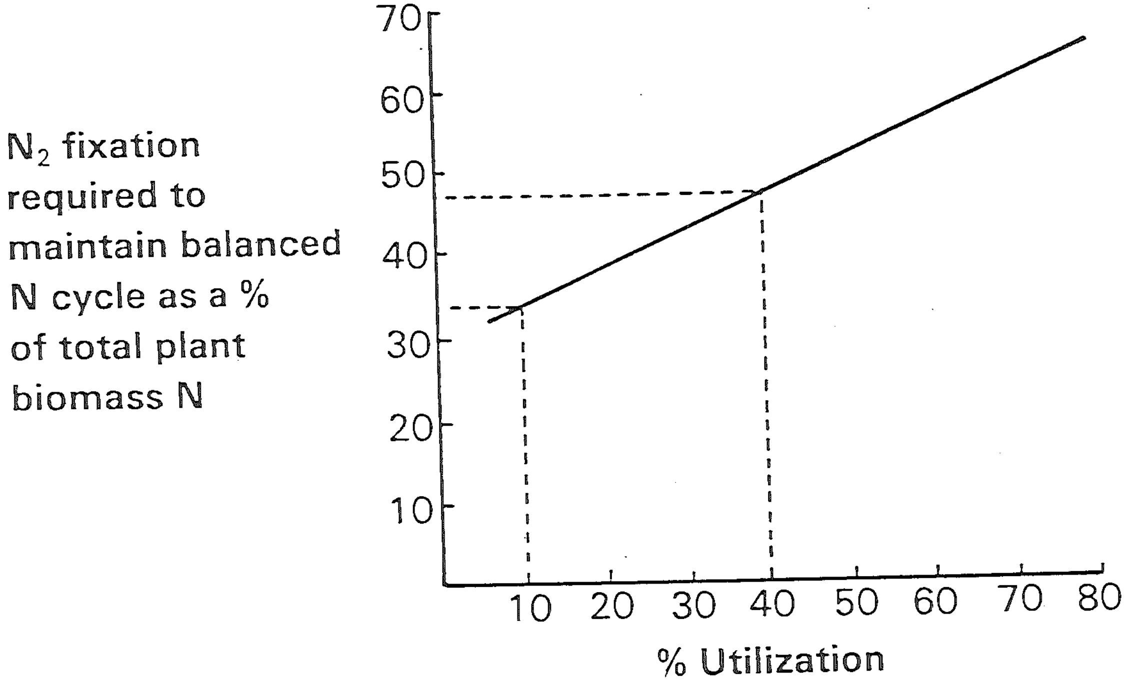


Fig. 10 Amounts of N_2 fixation required to balance the N cycle, without invoking a drain on soil organic N, as a function of pasture utilization.

11. Soil/Plant Relationship and Nutrient Cycling

During last year efforts were concentrated on the assessment of the soil, plant and management factors influencing P dynamics in acid tolerant pasture species. The especific objectives of the work were:

1. To determine the influence of soil properties, specially texture on soil P status and availability of fertilizer phosphorus for plant growth.

2. To estimate the residual effect of low phosphorus rates on the establisment of new pasture populations and on the maintenance of the productivity of planted pastures.

3. To determine phosphorus fertilization needs for grass-legume pastures under grazing.

4. To quantify the components of the phosphorus cycle in legume based pastures under grazing.

Most of the work is being conducted in an Oxisol of Carimagua, which is caracterized by low pH, low nutrient availability and high aluminium saturation. Clay content is dominated by kaolinite and Fe and Al oxides. Phosphorus fixation capacity of these soils is lower than other Oxisols of the Cerrados of Brazil.

EFFECT OF SOIL TEXTURE ON P AVAILABILITY

Experiments were conducted in the greenhouse in order to study the relationship between clay content and soil P test levels. Samples from several soils of Carimagua with increasing clay content received P rates ranging from 0 to 20 kg P/ha. The results of a sequential extraction using several extractants showed that available P decreased exponentially with time in all soils. However available P was consistently higher in the light soils (CIAT, 1988). After six months of incubation soil test P levels were still higher in the light soil than in the heavy soil (Table 1). In order to relate P availability with plant growth _A. gayanus_ and _C. acutifolium_ were planted in the incubated pots. Results showed a better response to added P in the species in the light soil, as a result of the higher P availability (Figures 1 and 2). _A. gayanus_ grew poorly in the clay soil, probably as a result of the low mycorrhizal infection found in the roots (3%). Infection levels were higher in the sandy soils (16%). _Centrosema_ species appeared to be less affected due to differences in mycorrhizal populations in the two soils.

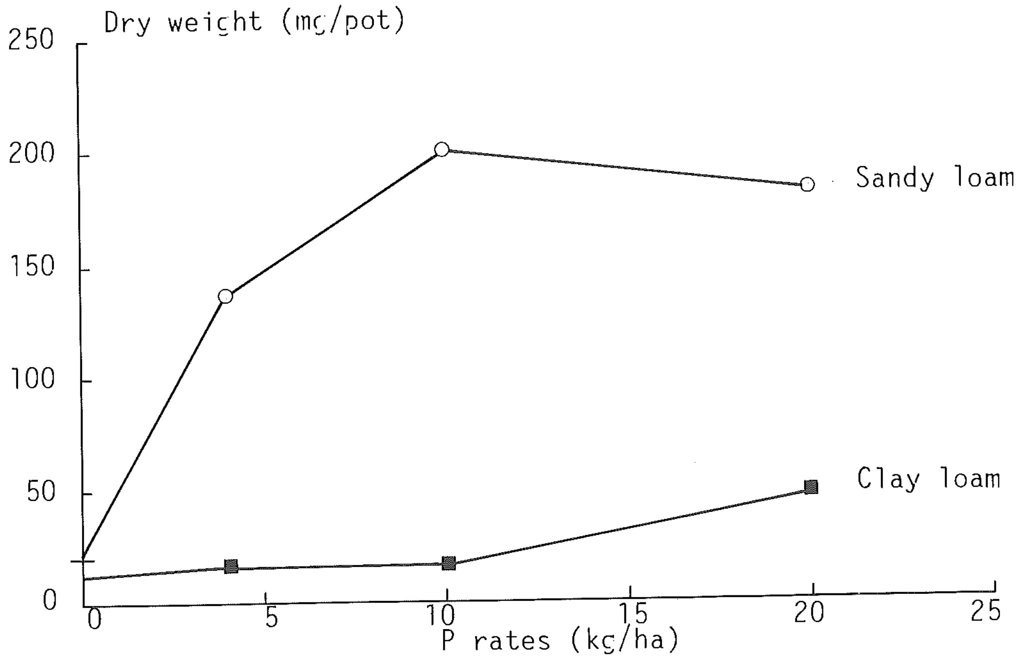


Figure 1. Effect of residual P on growth of *A. gayanus*.

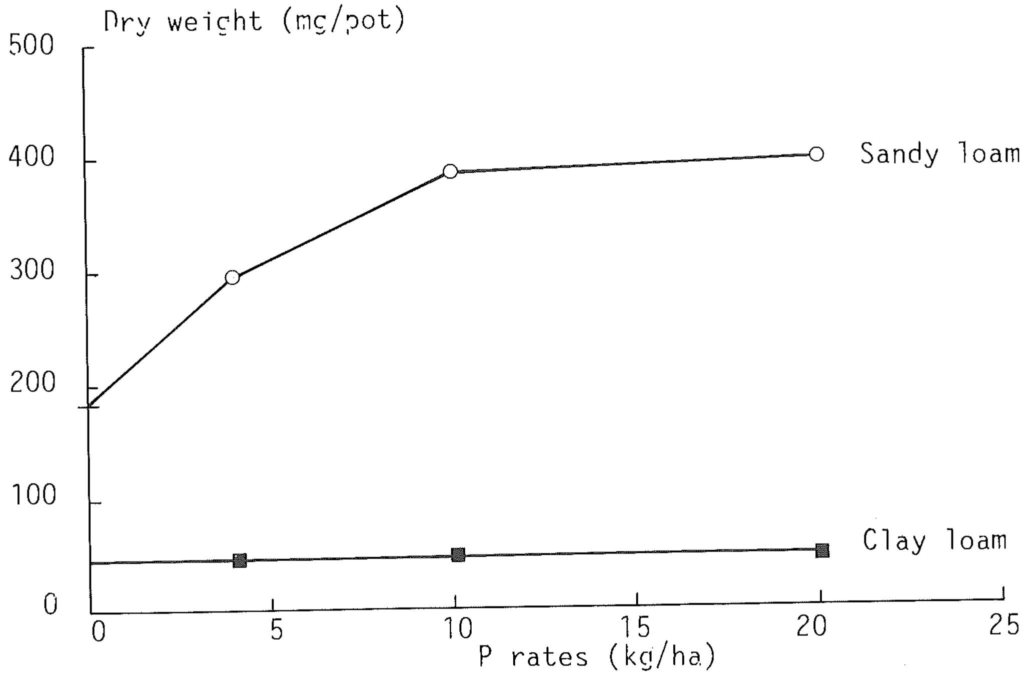


Figure 2. Residual effect of P on growth of *C. acutifolium*.

Table 1. Available phosphorus (Bray II) in two Oxisols of Carimagua of different texture after six months of incubation in the Greenhouse.

P rates (kg/ha)	Reserva Clay loam (34% clay)	Alegría Sandy loam (28clay)
	----- (Bray II ppm)	-----
0	1.9	2.1
4	2.3	3.9
10	2.7	3.9
20	3.5	4.3
MEAN		2.8 3.5

In order to check the effectiveness of the mycorrhiza, half of the incubated pots were inoculated with species of Glomus maniotis. There was a positive effect on the growth of A. gayanus in the heavy soil. However, differences between soils remained unchanged.

These results suggest that clay content influences P availability for the establishment of acid tolerant pastures in soils of the Llanos. This parameter could be used to adjust P fertilization for the establishment of acid tolerant species in soil of the Llanos with similar soil mineralogy.

RESIDUAL EFFECTS OF PHOSPHORUS FERTILIZATION ON PASTURE ESTABLISHMENT AND PRODUCTIVITY

In the process of pasture establishment and renovation after crops or pastures, it is important to consider the residual effect of P fertilization. A field experiment was carried out using two soils of Carimagua that received 5, 10, 20 and 40 kg P-ha in 1985. Standing vegetation was removed fron the area and plots were split to study the residual effect of added P as compared to fresh additions (20 kg P/ha broadcasted or 5 kg P/ha in bands) on the establishment of two grasses (A. gayanus and B. dictyoneura), and two legumes (S. capitata and C. acutifolium) planted in monocultures. Results of the first cutting indicated that the residual effect of added P increased with the P levels applied and that the relative yields of A. gayanus and S. capitata in the residual plots were between 50 to 70% the yields obtained with fresh applications (Table 2). This evidence suggests that it is still possible to have a beneficial effect of low P residual levels for the establishment of improved pasture. Field observations have shown that weed populations increased markedly in the plots receiving fresh P additions.

The residual effect of phosphorus fertilization on the productivity of two pastures under clipping was evaluated for its third year. The experiment considered four P rates and three planting methods. (see Annual Report, 1988).

Dry matter yields after six weeks of regrowth showed that there was response to P addition in A. gayanus in the clay soil and in D. ovalifolium in the sandy soil (Figures 3 and 4). The lack of response of A. gayanus to P treatments in the sandy soil has been accompanied by a decreasing vigor of the plants and a marked increase in weed population. Work is in progress to determine the effect of N application on phosphorus responses and plant growth. Responses of D. ovalifolium to P application in the sandy soil could be related to the capacity of the legume to meet its own N requirements via N-fixation.

PHOSPHORUS FERTILIZATION NEEDS FOR ACID TOLERANT PASTURES UNDER GRAZING

Small plot experiments conducted in Carimagua in 1988 showed that there was not any significant effect of 10 and 20 kg P in yields of A. gayanus and B. dictyoneura pastures, alone and

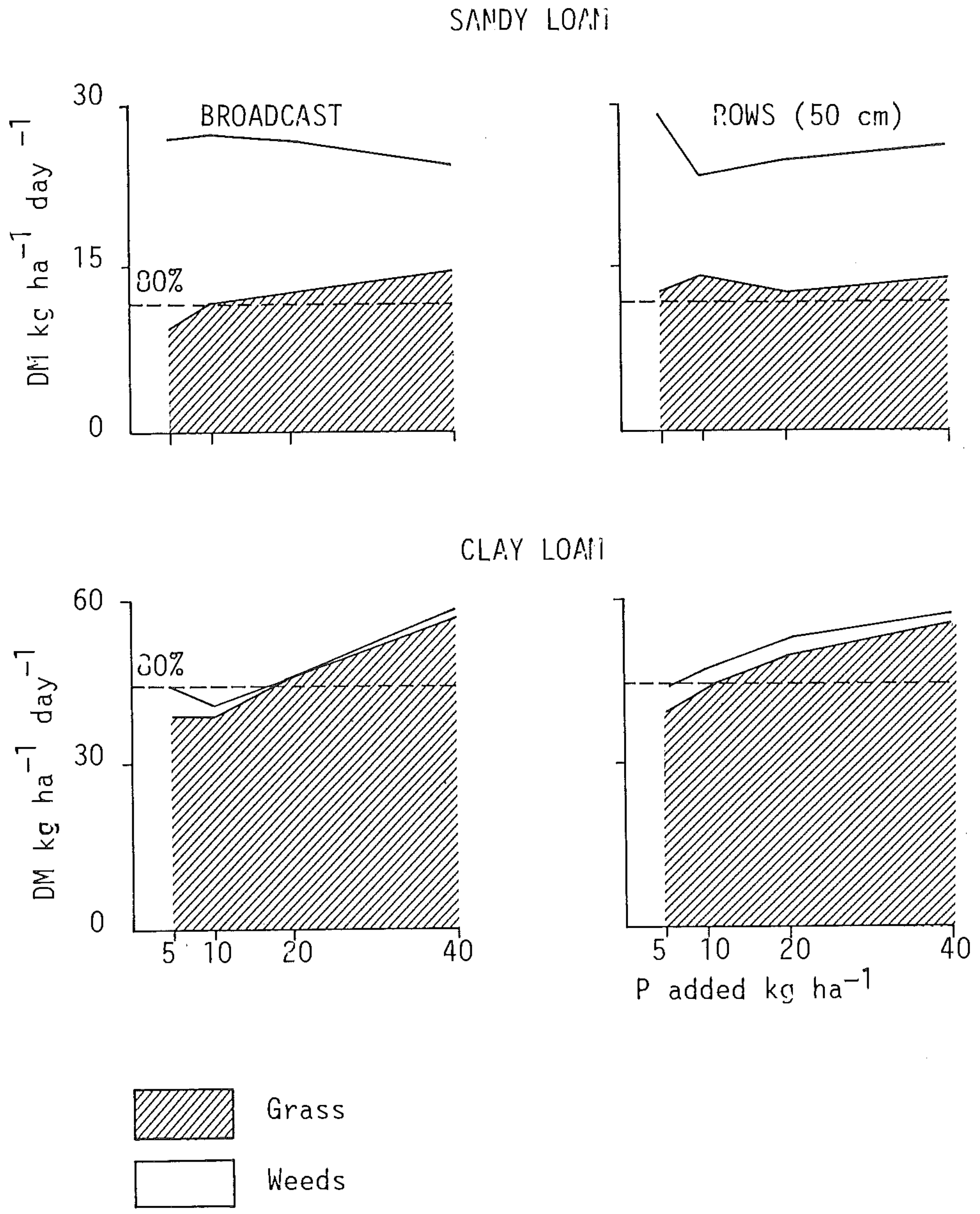


Figure 3. Residual effect of several P rates on the productivity of *A. gayanus* planted with several methods.

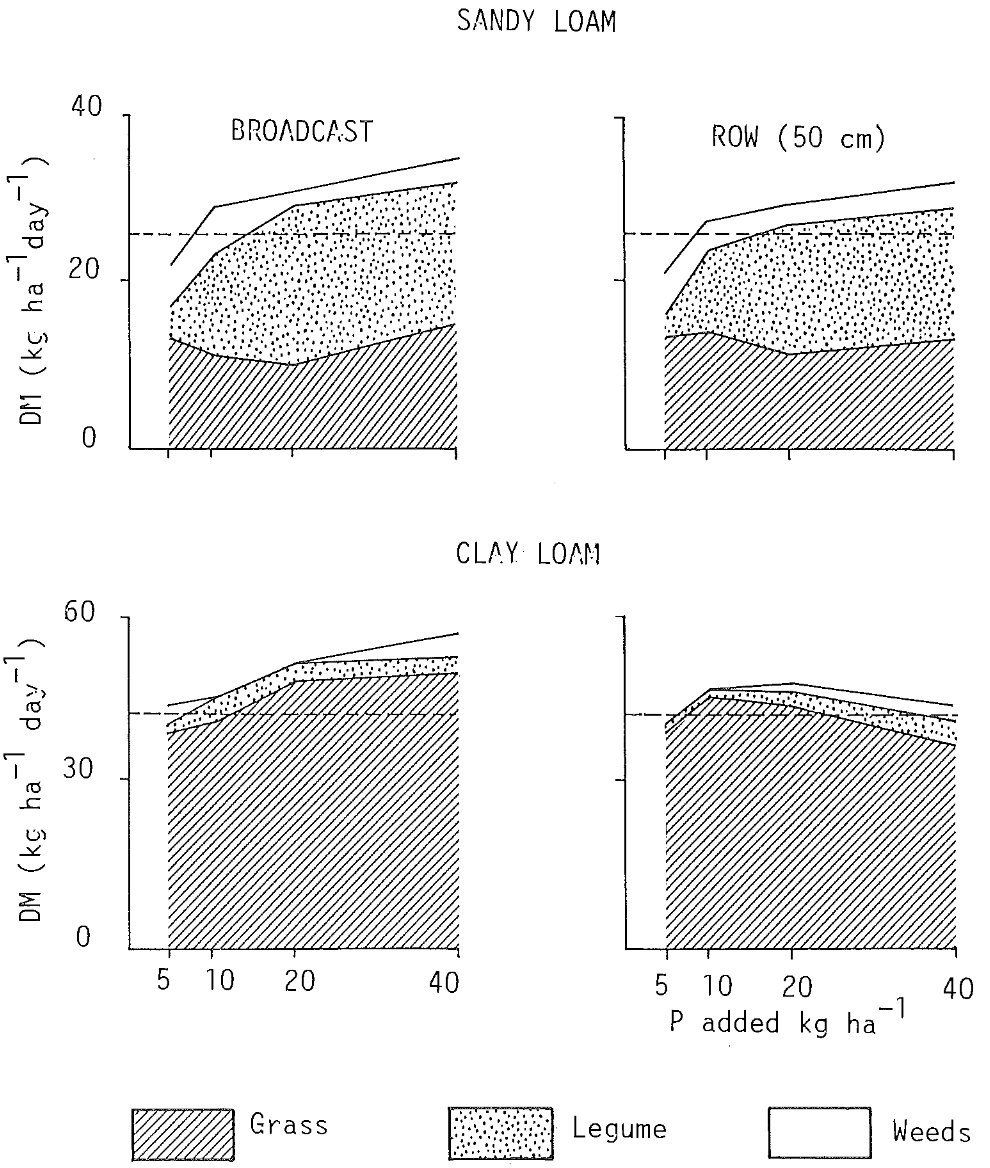


Figure 4. Residual effect of several P rates on the productivity of *B. dictyoneura* + *D. ovalifolium* planted with several methods.

Table 2. Effect of residual and fresh phosphorus fertilization on the establishment of new pasture populations in two soils of Carimagua.

P rates (kg/ha)	*A. gayanus*		*S. capitata*	
	Sandy loam	Clay loam	Sandy loam	Clay loam
	DM (kg/ha)			
Residual	865	2098	1469	1057
20	1230	3633	2406	1728
Effect of Residual P (%)	70	57	61	63

in association with *C. acutifolium* c.v Vichada under grazing. These pastures were established in 1985 using 20 kg P/ha and have not received maintenance fertilization since then. However, there was a consistent increase in the P level in the tissue of the grasses suggesting that some other nutritional factor was limiting pasture productivity (see An. Rep. 1988). During the present year, field work was conducted to identify those nutrient limitations using a diagnostic experiment. The experiment was established in small plots on a wider range soils and grazed pastures (Table 3) to test the effect of N, P, S and basic fertilization on dry matter production (Table 4)). Dry matter yields of the species after six weeks of growth showed that grass responses to P fertilization were very small in the absence of Nitrogen (Figure 5). On the contrary, nitrogen responses particulary in the *B. decumbens* pastures were consistent across soil type, management and presence of legumes (Table 5). In turn, the legumes *Stylosanthes capitata* and *P. phaseoloides* grown in association with *B. decumbens* responded markedly to 10 kg P additions. Phosphorus fertilization, as it is suggested by the results is an important management tool to maintain the legume component in the pasture and nitrogen is more limiting than phosphorus for the grasses. Lack of response to P in grasses could be attributed to the residual effect of added P in the previous years.

COMPONENTS OF PHOSPHORUS CYCLING IN GRAZED PASTURES

Preliminar work has been done in order to quantify some of the biotic and non biotic components of P cycling in a grazed pasture. Soil and plant date from a *B. humidicola* + *D. ovalifolium* grown in two soils were used for this purpose. The results have shown that the magnitude of the different P pools are influenced by the soil texture (Figure 6). Soil P reserves (Organic + Fe-P) are higher in the heavy soil (Reserva) while the short-term available P fraction (exchangeable, Ca-P and Al-P) tend to be higher in the light soil (Alegría). Interestingly enough is that the P pool size in the phytomass and residues is higher than the pool size in the available fraction. This shows the ability of acid tolerant pastures species to accumulate P in these components of the recycling process. However, the magnitude of these components is largely affected by grazing. It is expected that under adequate grazing management P recycling can be efficiently maintained diminishing external requirements for maintenance.

Table 3. General characteristics of the pastures used in the diagnostic experiment.

Pasture		Age (years)	Site	Fertilization kg/ha	Management
1.	*B. decumbens*	10	Alegría	20 (E), 20(M)	C.G
2.	*B. decumbens* + *S. capita*	10 3	Alegría	20 (E), 20(M)	A.G.
3.	*B. decumbens*	10	Alegría	20 (E), 20(M)	A.G.
4.	Native savanna		Yopare	Non,	C.G.
5.	*B. dictyoneura*	5	Yopare	20 (E), 10(M)	F.G.
6.	*B. brizantha*	5	Yopare	20 (E), 10(M)	F.G.
7.	*B. decumbens*	11	Int II	20 (E), 50(M)	A.G.
8.	*B. decumbens* + *P. phaseoloides*	11	Int II	20 (E), 50(M)	A.G.
9.	Native savanna	-	Int II	Non	C.G.

E = Establishment fertilization.
M = Maintenance fertilization.
C.G. = Continuous grazing.
A.G. = Alternate grazing.
F.G. = Flexible grazing.

Table 4. Arrangement of the treatments used in the diagnostic experiment.

	Elements applied (kg/ha)				Treatment designation
	N	S	P	(Ca+Mg+K+Micro)	
1.	0	0	0	-	Absolute check
2.	0	0	0	+	- (N, P, S)
3.	0	0	10	+	+ P
4.	25	0	0	+	+ N
5.	25	20	0	+	- P
6.	0	20	10	+	- N
7.	25	0	10	+	- S
8.	25	20	10	+	+ P + N + S
9.	50	20	10	+	+ P + 2N + S
10.	25	20	20	+	+ 2P + N + S

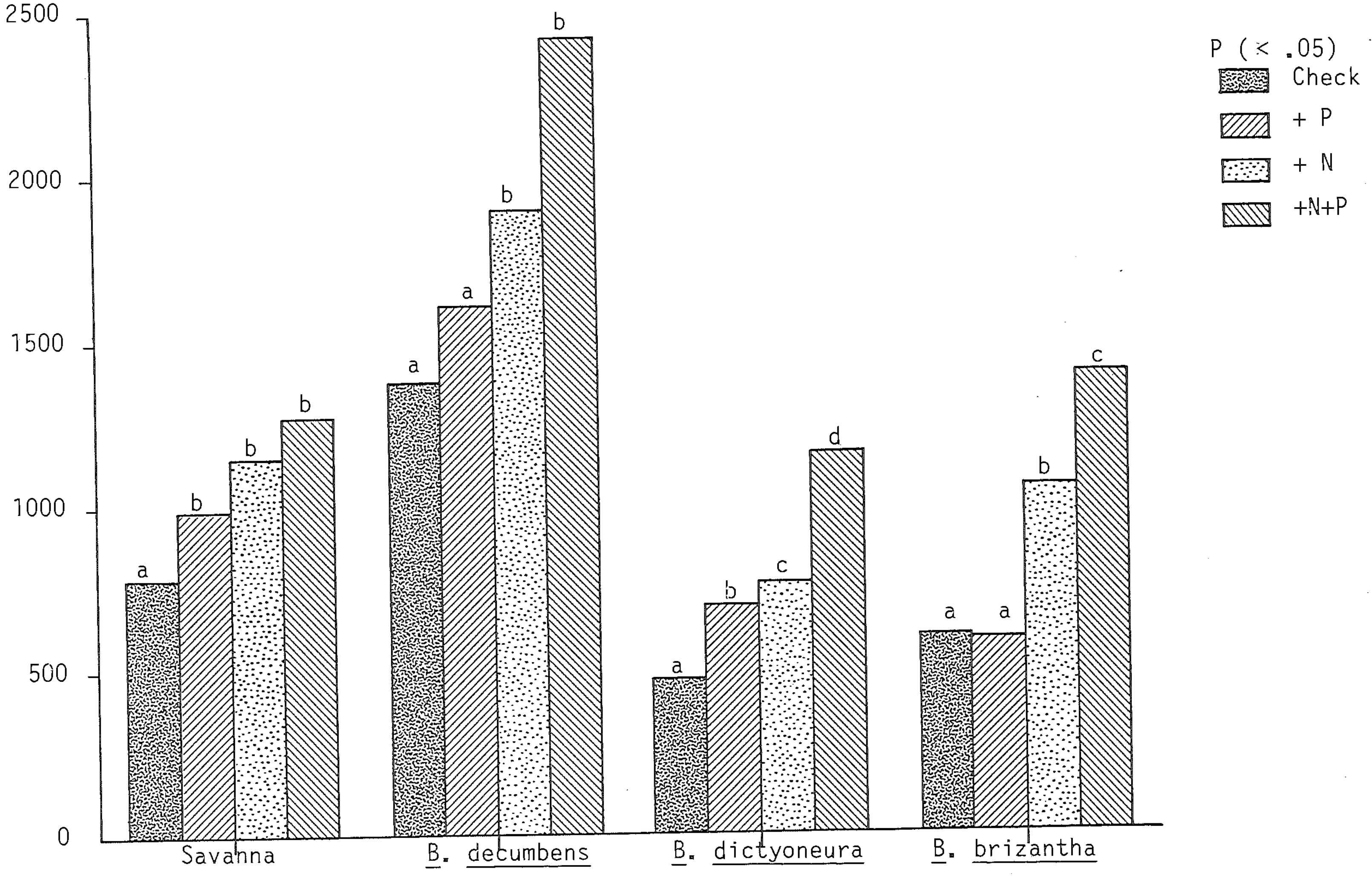


Figure 5. Response to N and P in several grasses under grazing.

Table 5. Response to N and P fertilization in a *B. decumbens* pasture alone and in association with two legumes under grazing.

Species	Site	Check		+P		+N	
		D.M.	% N	D.M.	% P	D.M.	% N
1. *B. decumbens*	Alegría	983	1.18	1083	0.13	2200	1.23
2. *B. decumbens*+		1913	1.18	2069	0.13	3397	1.12
S. capitata	Alegría	225	2.49	513	0.15	251	2.77
3. *B. decumbens*	Int. II	960	1.26	704	0.12	1384	1.15
4. *B. decumbens*+		1000	1.54	1181	0.15	1733	1.65
P. phaseoloides	"	332	3.22	825	0.20	601	3.61

Organic phosphorus

Soil sampling with depth carried out in several native and improved pastures in Carimagua has shown that both total and Organic P tended to be higher in the 0-5 cm topsoil of improved pastures than in the native savanna due not only to P fertilization that received improved pastures but also to a higher biomass turnover (Table 6). The proportion of P in the organic frantion was higher in the light soil than in the heavy soil.

Mycorrhizal population

Mycorrhiza population were also measured in the same pastures. Number of spores were higher in the grass-legume mixtures than in the pure grass pasture and savanna (Table 7). This effect was particulary significant in the *B. decumbens* + *P. phaseoloides* pasture. The higher amount of spores under this pasture, could be due to the reported beneficial effect of the legume on mycorrhizal populations (CIAT, 1987). Characterization of population by depth showed that the number of spores was significantly higher in the 0-5 cm topsoil than in the 5-20 cm depth (149 and 67 spores per 100 gm soil respectively).
Future work will attempt to estimate seasonal changes in the organic-P status and relate such changes to plant growth. Lack of response to P fertilization observed in some of the grasses could be related to an efficient utilization of organic P sources.

Phosphorus release from litter is in progress. It is hypothesized that the amounts of P going back to the soil are influenced by decomposition rate of the litter and grazing management. Pool sizes and transfers will be assembled in a simple model to determine P recycling efficiency in legume based pastures and P needs for legume based pastures.

ZINC FERTILIZATION FOR THE ESTABLISHMENT OF TWO FORAGE LEGUMES

Centrosema acutifolium 5277 cv Vichada has shown to be well adapted to acid soils with high aluminium saturation and low nutrient availability. However, some of these soils have low zinc levels that could become limiting for plant growth. A field experiment was conducted in a sandy soil (54% sand) in order to evaluate potential

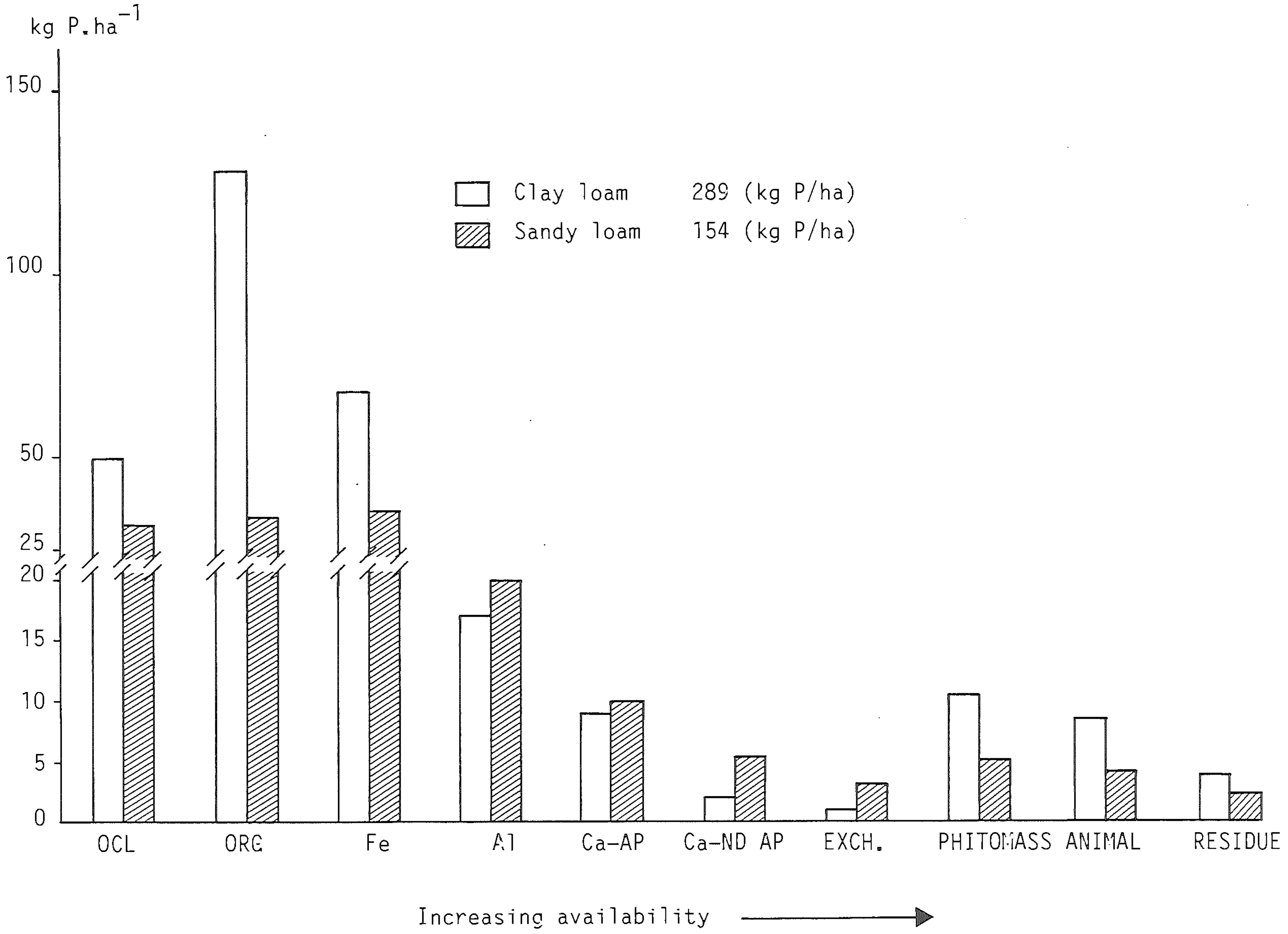


Figure 6. P status of two Haplustox in Carimagua.

Table 6. Soil Phosphorus fractions in the 0-5 cm topsoil of several pastures under grazing in Carimagua.

Pasture	Soil texture	Total-P	Organic-P	% Org P
		---------------- kg P/ha	-------------	
Savanna	Sandy loam	44.8	6.5	14.5
A. gayanus	' ' '	61.6	14.9	24.1
A. gayanus/ *C. acutifolium*	, , ,	69.0	23.3	33.7
Savanna	Clay loam	99.4	36.3	36.5
B. decumbens	, , ,	124.7	41.9	33.6
B. decumbens/ *P. phaseoloides*	, , ,	114.5	37.4	32.6

Table 7. Number of mycorrhizal spores found in the 0-20 cm topsoil of several pastures under grazing in Carimagua.

Pasture	Number of spores (100 gm soil)	
	Pure grass	Associated
B. dictyoneura + *C. acutifolium*	84 (a)	106 (a)
A. gayanus + *C. acutifolium*	91 (a)	116 (a)
B. decumbens + Kudzu	108 (a)	173 (b)

Zinc deficiencies in the presence of increasing P levels and two methods of application.

The results at 8 weeks of planting showed a strong reduction in plant yields of *C. acutifolium* in the absence of Zinc application regardless of the phosphorus rate and method of aplication (Table 8). Plants showed retarded growth on a chlorosis typical of the Zinc deficiencies. *S. capitata* was less sensitive to low Zn levels than *C. acutifolium* in the light soil. Available Zn levels in the soil were 0.3 ppm which is below the critical level of 0.5 ppm (CIAT, 1981).

Soil data from several locations in the Colombian Llanos, have shown that zinc status are close to the critical level (Table 9). These results indicate that attention should be given to zinc fertilization, especially in light soils.

Table 8. Effect of phosphorus fertilization rates, methods and sources on the yields of *C. acutifolium* CIAT 5277 grown in a sandy Oxisol in presence or absence of zinc fertilization.

Fertilization rate (kg/ha)	Method	Zinc added (2 kg/ha)	Fresh weight (g/m^2)
500 c[1] 22	Rows	- Zinc	36 d
500 c 22	Rows	+ Zinc	138 a
500 c 22	Broadcast	- Zinc	24 d
500 c 22	Broadcast	+ Zinc	124 a
100 s 22	Rows	- Zinc	75 c
100 s 22	Rows	+ Zinc	101 b
100 c 5	Rows	+ Zinc	40 d
100 c 5	Rows	+ Zinc	84 c

Columns followed by the same letter are not statistically different (LSD 0.05%).

Source of P Calfos (10% P205).

1/ Phosphorus source: c = Calfos (10% P_2O_5)
s = Triple Superphosphate

Table 9. Zinc availability in several locations of the Colombian llanos.

Location	Description	Texture	Available Zn
Carimagua	Reserva	Clay loam	0.4
	Alegría (SL)	Sandy loam	0.6
	Hato cuatro	Clay loam	1.0
Puerto Gaitán	Savanna	Sandy	0.4
El Guayabal	A.g. + S.c.	Sandy	0.4
	Bajo	Clay	2.3
El Paraíso	Sabana	Clay	0.8
El Viento	*A. gayanus*	-	0.5
Las Leonas	*A. gayanus*	-	0.6

Source: Salinas, Castilla and Gualdrón. (Unpublished).

12. Pasture Reclamation Humid Tropic

Research activities in Pasture Reclamation in the Humid Tropics are primarily focused on increasing the productivity of pastures invaded by weeds and dominated by native pastures of low productivity and low nutritive value. With this objective, both on-station and on-farm research were conducted. All research activities were carried out jointly with the national institutions of IVITA and INIAA.

1. Pasture reclamation at the experiment station

Agronomists working for national institutions have been considered to have an overall knowledge of producers' conditions in the region for which they are responsible. However, the need to generate acceptable technologies in scientific and practical terms has been identified in order that adoption by the farmer does not turn into myth and that results obtained at the experimental level be pertinent to the problems faced by producers. Therefore, on-farm research becomes a key component in technology adoption as it considers those factors that inhibit or enhance adoption of new technologies.

Trials in the experiment station are conducted at IVITA's headquarters, located 59 km from the city of Pucallpa, Perú. Geographical location is 8°22' latitude south and 74°34' longitude west, at an altitude of 270 masl. Average annual precipitation is 1770 mm, showing considerable variation in its weekly distribution (Figure 1), with June, July, and August being the dryest months. Soils in the region are acid (pH less than 5), with high Al saturation levels found at depths of 40 cm; these have been classified as Ultisols with two distinct subgroups: the well-drained "Typic paleudult" and the poorly-drained "Aquic paleudult". The region falls within the tropical semi-evergreen seasonal forest ecosystem. Overall, the region has a rolling contour, with slopes ranging from 5 to 60%; flat plains are located primarily along the rivers' banks. These plains have been under alluvial influence and show light textures of the clayey-loamy type, contrasting with the rolling topography which is primarily of the clayey type.

1.1 Use of pioneer crops in pasture reclamation

An option for recovering native pastures--called "torourco" in this region--includes growing annual crops such as rice, maize, and cowpea. The crop is planted first, and the forage grass/legume mixture is established afterwards. These pastures are adapted to the bio-edapho-climatic conditions and are more productive and have a higher nutritive value than the native pastures. This option also includes the use of fertilizers and tillage to improve soil fertility and reduce soil compaction, a typical characteristic of torourco soils.

Figure 2 shows the effect of fertilization and tillage intensity (number of off-set diskings) on maize

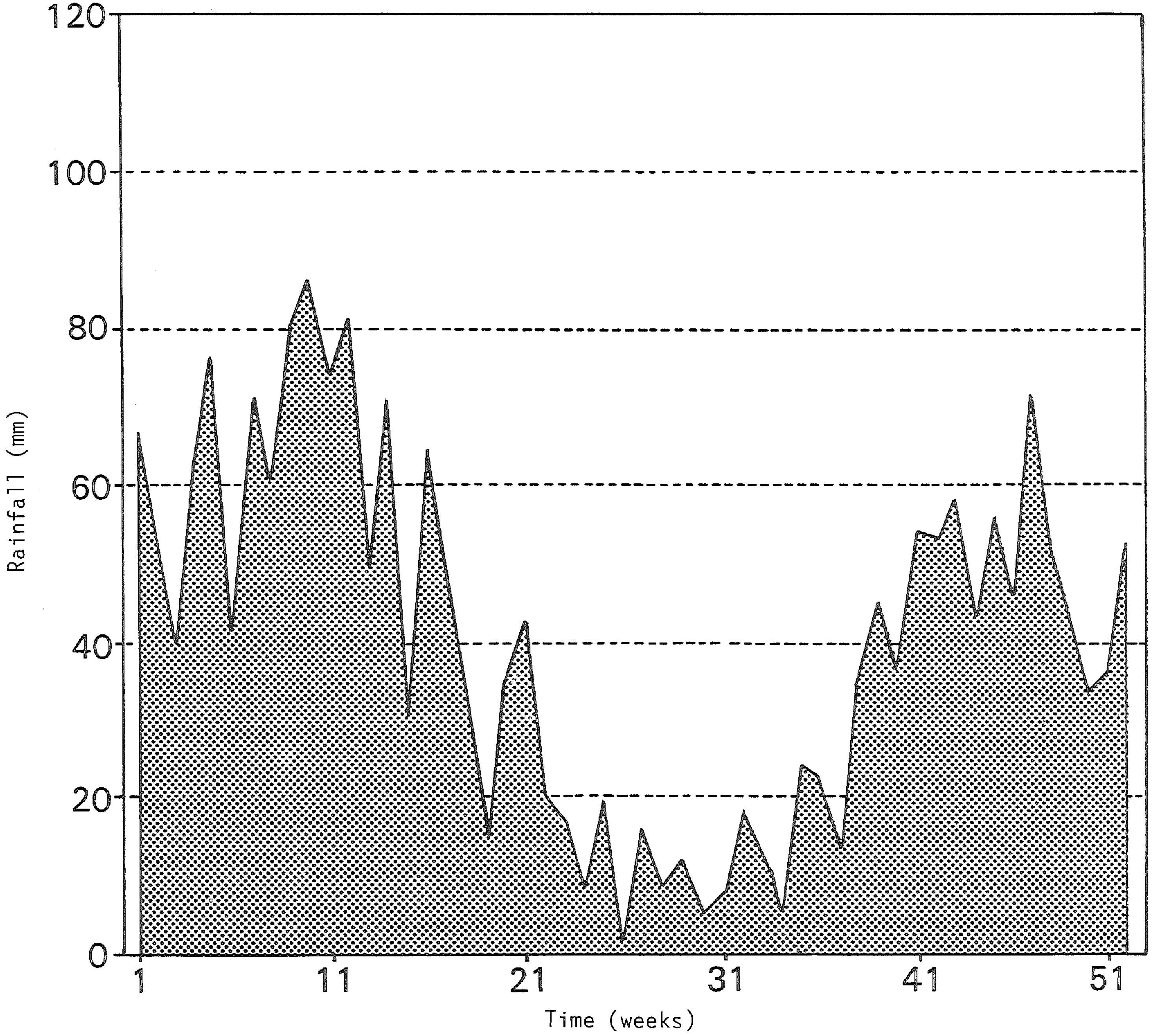


Figure 1. Average rainfall during 10 years (1978–1989) in the IVITA Experiment Station, Pucallpa, Peru.

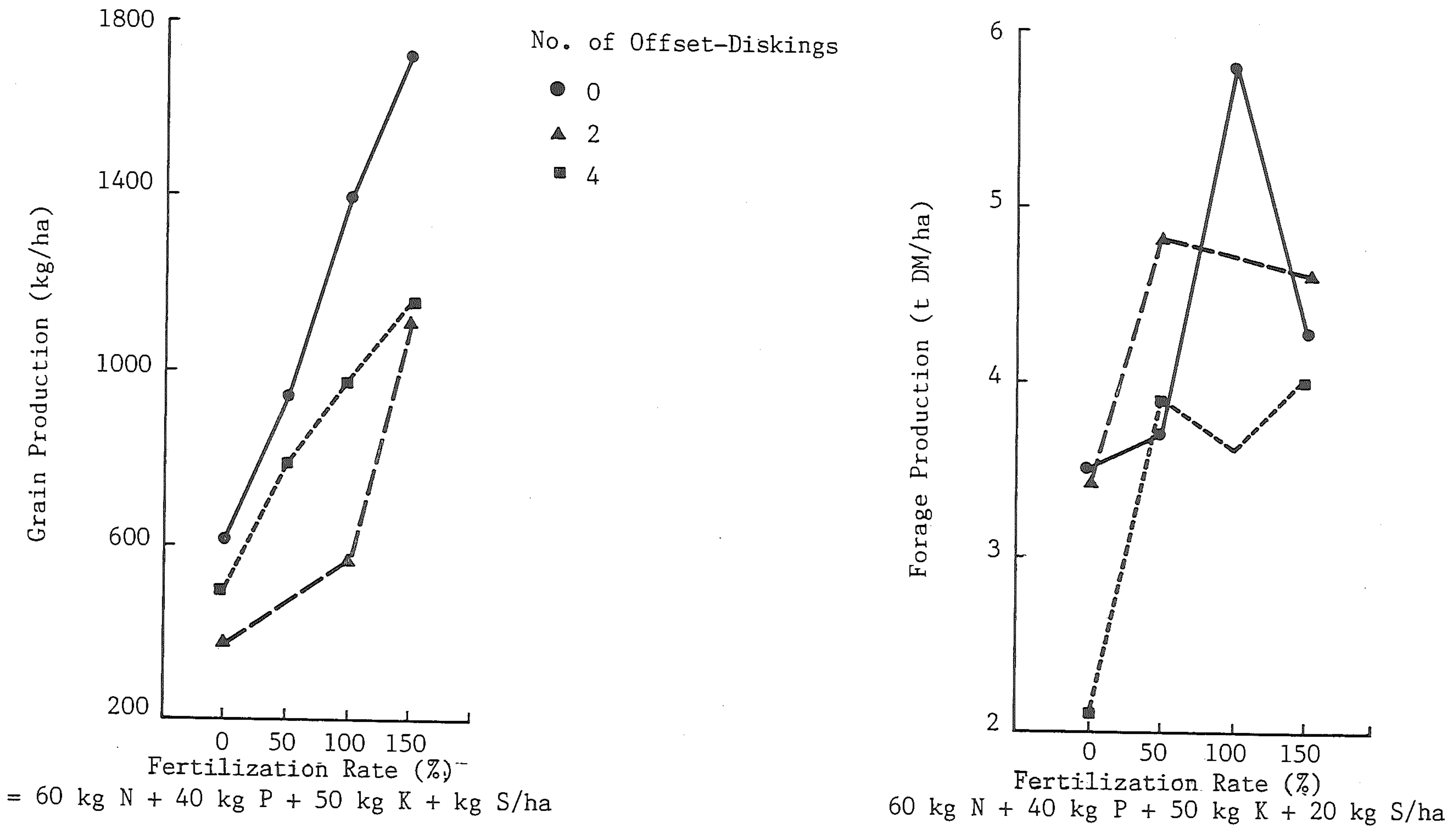


Figure 2. Production of maize (var. Cubano Amarillo) and of Stylosanthes guianensis (cv. Pucallpa) under different fertilization doses and tillage intensities (number of off-set diskings) in a torourco (native grasses) pasture in Pucallpa, Peru.

yields (var. Cubano Amarillo) and forage production of Stylosanthes guianensis (cv. Pucallpa), which was the legume planted in association with maize. The response of maize to fertilization was reduced by tillage intensity and response to fertilization was optimum without tillage. This indicates that the degree of soil compaction does not seem to limit maize root development and that the response to the lowest level of fertilization with tillage implied the invasion of weeds (primarily broad-leaf weeds) as a result of upsetting the soil and destroying the native torourco grass. Performance of the forage legume also shows a similar response pattern to that of maize. In both cases, intensification in soil preparation resulted in greater weed invasion and competition, and became the factor limiting productivity of both maize and S. guianensis cv. Pucallpa.

The use of mixed systems (crops and pastures) requires knowledge of interactive patterns such as planting pattern, density, and period; type of crop and association; compatibility of the crop with the pasture association, etc. Figure 3 shows an example of the effect of planting period on yields of cowpea and of the association S. guianensis cv. Pucallpa + Brachiaria dictyoneura 6133. Months included in this trial cover the beginning of the rainy season (September) and the rainy season (October, November, December, and January).

Partial results indicate that October and November are the most appropriate for planting cowpea. The dry periods (called "veranillos" in the region) occur at the end of December and during January and cause yield reductions both in the crop and in the association. Decreased precipitation during October, in comparison with November 1988, favored S. guianensis and B. dictyoneura establishment during the first and second month, respectively. Overall forage production was high, yet production of S. guianensis cv. Pucallpa and B. dictyoneura 6133 was highest during October and November, respectively. This indicates the advantage of planting the forage legume first, and then planting both the cowpea and the grass 30 days afterwards.

1.2 Rice varieties tolerant to acid soils as a pioneer crop in pastures

The presence of large areas with low-productivity and low-quality native pastures in the Latin American tropics highlight the need for production alternatives including weed-controlling crops, such as rice, and emphasizing adequate management techniques to guarantee promising yields by decreasing weed competition and establishing improved pastures at the livestock producer level.

Rice growing in the low areas of the jungle is practiced under favorable climatic conditions, allowing seeding throughout the year during the rainy period or with irrigation. Large volumes of rice are produced and varieties are adapted to the acid soils (pH around 4.5) predominating in the region.

Reclamation of extense, degraded natural pasture areas implies the need for solutions resulting in short-term profitability, including a pool of rice varieties tolerant to acid soils, a minimum use of inputs, and the association of improved pastures based on grasses and legumes adapted to the natural ecosystem.

The trial was conducted in a degraded, torourco pasture (Paspalum spp. + Mimosa pudica) at IVITA's Experiment Station in Pucallpa. Land preparation involved two off-set diskings; soil samples were taken for each treatment. The dose of dolomitic lime was broadcasted over each plot, then

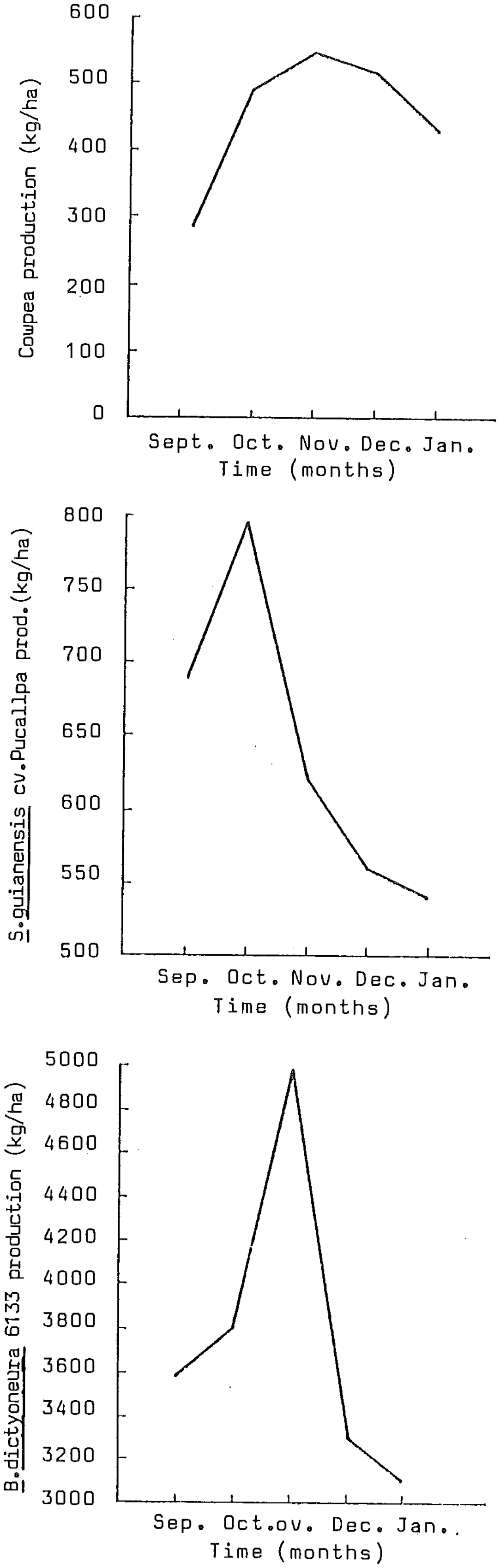


Figure 3. Effect of planting period on the production of cowpea and of an association of Stylosanthes guianensis cv. Pucallpa + Brachiaria dictyoneura 6133, established after a torourco pasture in Pucallpa, Peru.

incorporated manually, and the soil was slightly levelled afterwards. A complete randomized block design was used with three replications for each rice variety.

Technical aspects involved in establishing the trial and fertilizer amounts and periods of application are shown in Table 1.

A total of 12 rows, 25 cm apart, were manually opened length-wise in each experimental unit (3 x $8m^2$). Planting was done on 3, November, 1988, after application of a continuous flow of the phosphorus source, which was later incorporated manually.

Before application of the first N and K dose, manual weeding was performed with a hoe in all treatments. Once fertilized, small rows were opened among rice rows for planting _B. dictyoneura_ + _A. pintoi_ in association.

During the latter stages of the maturation phase, fungus attacks of the false smut (_Ustilago virens_) were observed in varieties CT 6194 -16 - 1 - 2 - 3 and CICA 8; the first variety was also attacked by kernel smut (_Tilletia barcloyana_). No severe pest attacks were observed.

Evaluations included the following parameters: initiation of flowering, plant height at harvest, vegetative cycle, grain yield, weight of 100 grains, and reaction to leaf scalding.

Results obtained are shown in Figure 4 and Table 2; response of rice varieties ranged from 321 to 2398 kg grain/ha. Varieties IAC-165 and Col.1/M 312 A were outstanding, with yields over 2000 kg/ha under upland conditions. The main factor reducing yields was disease incidence, primarily leaf scald. Other characteristics to be considered for

Table 1. Most important cultural practices used for planting, including different periods of fertilizer application.

Parameter	Amount	Application
Planting density	1 g/lineal m	At planting (3 Nov./88)
Distance between rows	25 cm	At planting
Fertilization:		
- Dolomitic lime	250 kg/ha	Broadcasted before planting
- Urea	50 kg N/ha	Band application, 30 and 60 days after planting
- Triple superphosphate	25 kg P/ha	Band application at planting
- Potassium chloride	50 kg K/ha	Pand application, 30 and 60 days after planting

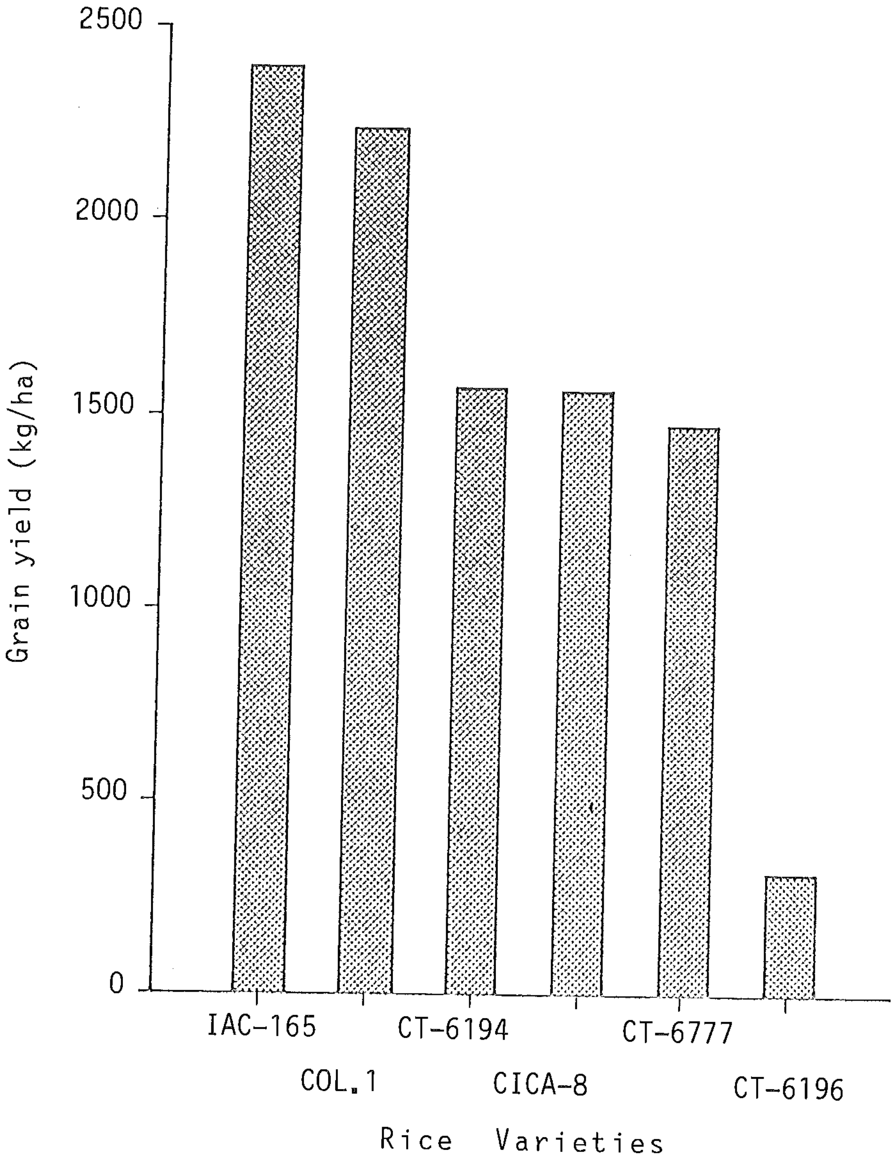


Figure 4. Grain yield of 6 rice varieties selected as tolerant to acid soils in an Ultisol in Pucallpa, Peru.

selecting varieties for this region are: early flowering, intermediate height, and a short vegetative cycle (120 days). Planting of IAC-165 and Col.1/M 312 A plus a forage grass/legume association has been scheduled for 1989/90, to be carried out jointly with producers in the region. The objective is validating the technology and studying the degree of adoption of this technology under torourco conditions. It is important to highlight that rice is planted in this region both in varzeas (fertile alluvial soils) and in old "purmas" (secondary forest regrowth of over 10 years) which have been previously burnt, using rice varieties that are not adapted to acid soils.

1.3 Incorporation of cowpea residues to establish pastures in torourco areas

Cowpea (var. Chiclayo marrón) was planted in May, 1988, in an area of degraded torourco. This legume is early-maturing and was observed to form grains 70 days after planting, when harvesting was initiated. After harvesting, soil samples were taken at 0-5, 5-10, and 10-20 cm depths; cowpea residues were then incorporated into the soil. In order to compare the effect and contribution of N from the residues on the establishment of _B. dictyoneura_ 6133, four N fertilization treatments (0, 50, 100, and 150 kg N/ha in the form of urea) were applied.

On 30 September, 1988, the improved pasture was planted. Coverage was evaluated at 4 and 8 weeks post-emergence, and available forage and dry matter were evaluated at 10 weeks postemergence. Basic fertilization consisted in band application of 20 kg P/ha, 40 kg K/ha, and 20 kg S/ha.

Cowpea yield (260 kg/ha) was relatively low, partially due to grasshopper attack. Partial control was done with powdered Aldrin (3 kg/ha).

Table 3 shows grass coverage 4 and 8 weeks after planting. The treatment involving incorporation of cowpea

Table 2. Evaluation of rice varieties tolerant to acid soils. Pucallpa, Peru, 1989'

Rice variety	Grain yield (kg/ha)	Initiation of flowering (days)	Plant height (cm)	Vegetative period (days)	Degree of leaf scald* (%)
IAC-165	2398 a	67	150	120	1 (3)
Col.1/M312A	2240 a	70	108	130	1 (7)
CT 6194-16-1-2-3	1519 b	83	106	125	2 (14)
CICA 8	15696 b	81	100	139	2 (22)
CT 6777-8-14-2-1E	1480 b	83	112	145	3 (35)
CT 6196-33-10-3-2	321 c	81	1230	134	5 (90)

* 0 = No disease (0%)
1 = 1-10% disease attack
2 = 10-30% disease attack
3 = 30-50% disease attack
4 = 50-80% disease attack
5 = 80-100% disease attack

Table 3. Coverage of Brachiaria dictyoneura 6133 at 4 and 8 weeks after planting.

Treataments (kg N/ha)	Age in weeks	
	4	8
0	16.65	82.50
50	17.58	89.58
100	17.65	93.55
150	20.56	90.63
Mixture (B. dictyoneura + S. guianensis)	22.09	98.30
Cowpea residues	30.31	97.66

residues shows greater coverage, followed by the treatment of incorporation of cowpea residues planting a pasture association (B. dictyoneura + S. guianensis). These results evidence the beneficial effect of incorporating organic matter (2.93 MT/ha of 100%-dry cowpea residue). It has been estimated that this amount of organic matter incorporated supplied the soil with approximately 100 kg N/ha.

Figure 5 shows dry matter forage production in terms of the different N treatments applied, comparing the treatment using cowpea residues (CR) with the treatment including the grass/legume association (GL).

As observed in Figure 5, response of the grass to N is lineal, forage production with the incorporation of cowpea residues being equivalent to that with the 125 kg N/ha treatment. This is a promising result, indicating that with a pioneer cowpea crop and incorporation of residues after grain harvesting, B. dictyoneura can be established, with good forage availability only 2½ months later. Superiority of the CR treatment over the GL treatment was primarily due to greater grass plant density, and also, to the fact that the legume did not offer competition to the grass due to its aggressiveness, as shown in terms of coverage. N contribution from the cowpea residues seems to be very high (125 kg/ha), and allows the grass to grow aggressively, overwhelming both legumes and weeds. This trial will continue under evaluation in order to observe residual effects of the different treatments.

1.4 Use of ash from sawmills

The area of Pucallpa is characterized for its timber industry, supplying national and international markets. Sawmills are common along 35-km of the Federico Basadre highway on the outskirts of Pucallpa. These sawmills daily accumulate several tons of saw dust and lumber residues which are burnt and piled up. The intention is to recycle this ash as a source of nutrients in pasture reclamation, using it as a local source of fertilizer in pioneer crops, tree plantings, and pasture establishment in the torourco areas.

Ash samples from various sawmills were collected to study their mineral composition and determine their potential as fertilizer. Table 4 shows the mineral composition of samples collected from five sawmills in the region. According to this characterization, outstanding minerals are silica, calcium, iron, manganese, zinc, and copper; contents of P, K, and Mg were low. Consequently, this sawdust ash can be used to improve the chemical conditions of cation exchange since Pucallpa acid soils have very low contents of silica, and Al and Fe sesquioxides are predominant. Furthermore, they would increase P availability if mixed with phosphoric rock by reducing its P-fixing capacity. This subject requires more research on soil factors and on plant reaction to the application of the sawdust ash.

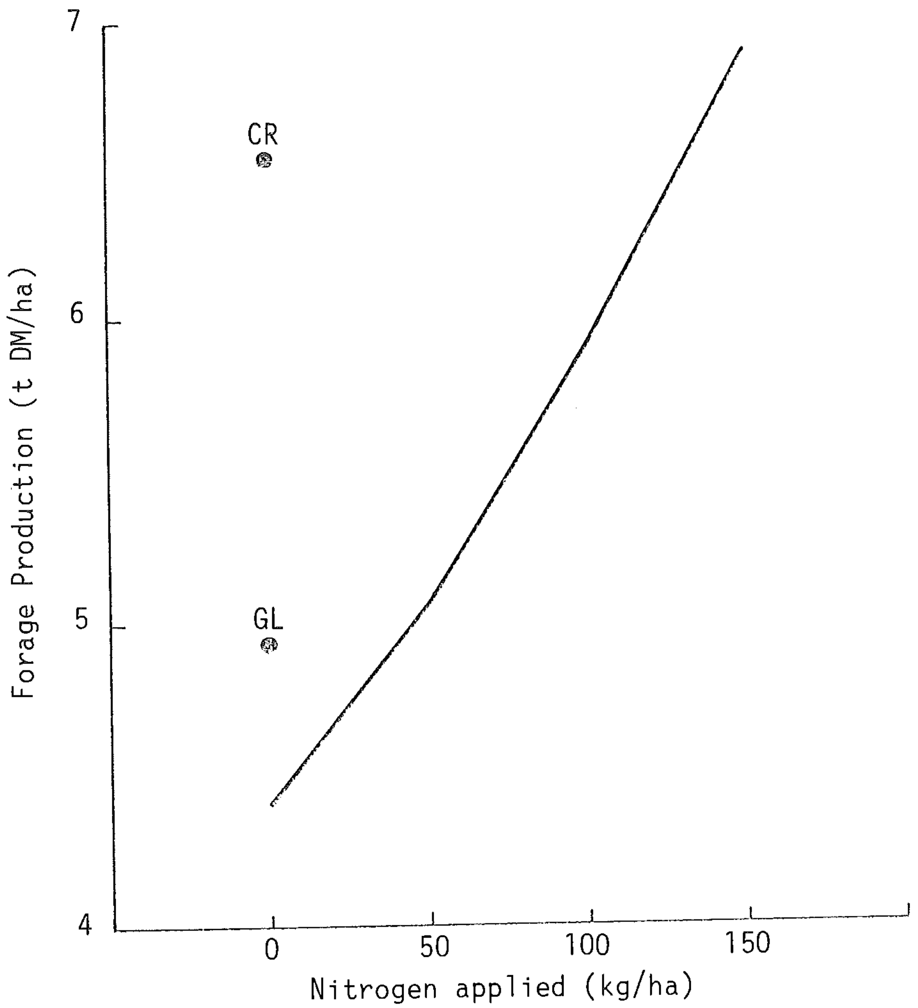


Figure 5. Forage production of *Brachiaria dictyoneura* 6133 10 weeks after planting in relation to N doses applied, and production achieved with the incorporation of cowpea residues (CR) to a grass in pure stand and in association with *Stylosanthes guianensis* cv. Pucallpa (GL).

Table 4. Mineral composition of five ash samples taken from the sawmills in Pucallpa, Peru.

Sample No.	Minerals								
	P	K	Ca	Mg	Si	Zn	Cu	Mn	Fe
	%					ppm			
1	0.09	0.69	2.90	0.26	59.73	38.9	10.7	135	5400
2	0.09	0.70	2.92	0.31	57.60	39.9	10.3	188	6770
3	0.10	0.52	3.49	0.31	55.16	43.9	22.4	275	7640
4	0.08	0.40	2.48	0.17	60.56	36.9	16.4	224	7620
5	1.01	4.00	19.30	6.36	21.54	126.4	317.0	735	6060

2. Trials under evaluation

2.1 Experiment Station

RP-07-89 Effect of fertilization on the establishment and seed production of 3 *Centrosema* species (*C. macrocarpum*, *C. acutifolium*, and *C. brasilianum*) in torourco areas.

RP-10-88 Nutritional diagnosis with P-S-K of *Arachis pintoi* and *B. dictyoneura* in three soils in the Pucallpa region.

RP-11-88 Effect of incorporating cowpea residues and applying N fertilizers on the establishment of *B. dictyoneura* in torourco-type degraded pastures.

RP-12-88 Planting dates for associating cowpea and *B. dictyoneura* + *S. guianensis* mixtures in torourco areas.

RP-14-89 Rice varietal trials for tolerance to acid soil conditions, in association with mixtures of *B. dictyoneura* + *A. pintoi*.

RP-15-89 Cowpea varietal trials for tolerance to acid soil conditions and to pests and diseases.

2.2 Farms of producers (reclamation trials under grazing)

RP-06-88 Reclamation of a degraded *B. decumbens* pasture with the introduction of *Centrosema macrocarpum* (IVITA, km 59).

RP-08-88 Establishment of improved pastures in association with cowpea planted in strips in a degraded, torourco-type pasture (San Jorge Farm, km 59).

RP-16-88 Establishment of *B. dictyoneura* in pure stand and in association with *C. pubescens* and *S. guianensis* in strips in a degraded, torourco-type pasture (Rizopatron Farm, km 39).

RP-1788 Reclamation of a degraded *B. decumbens* pasture with the incorporation of legumes (*D. ovalifolium* and *S. guianensis*) (Uamoca Farm, km 45).

RP-18-89 Reclamation of a degraded, torourco-type pasture with the introduction of *B. dictyoneura* seedbeds (J.M. Toledo Farm).

3. Identification and description of research problems and alternatives

Two situations were identified in pasture reclamation, related to the ecosystem's physiography, emphasizing areas where acid, infertile soils are predominant. These two situations refer to areas which can be managed through mechanization and those that cannot be mechanized, independently of their agronomic characteristics, but rather because of socioeconomic factor involving the degree of development of the infrastructure and the availability of agricultural equipment and inputs. Following is the list of problems identified, by order of importance, in the process of reclaiming either purma or tororurco degraded areas:

Problem identified	Degree of Importance	
	Mechanizable areas	Non-mechan. areas
1. Germplasm	++++	++++
2. Weed control	++++	++++
3. Seed availability	++++	++++
4. Grass/legume mixtures	++++	++++
5. Physical conditions of the soil	+++	++++
6. Annual crops	+++	++
7. Use of fertilizers	+++	++
8. Use of herbicides	+++	+
9. Agricultural equipment	++++	+
10. Grazing management	+++	+++

+ = slight importance; ++= intermediate importance; +++ = important; ++++ = very important.

Research alternatives suggested have been grouped into: basic research, experiment-station research, and on-farm research.

3.1 Basic research

a) Studies on grass-legume compatibility with crops and tree species (physiological and morphological aspects).

b) Selection of herbicides depending on promising germplasm and type of weeds.

c) Basic studies on erosion, run-off, and soil compaction.

d) Development of agricultural implements for animal traction in slopy areas.

e) Development of quick and simple methods for diagnosing soil fertility.

3.2 On-station research

a) Weeds: Diagnosis of predominant species, herbicide application periods, weed ecoloy and phenology during pasture establishment, biological control of weeds, aggressiveness of germplasm in the dynamics of weed control.
Evaluation of the use of different animals during pasture establishment to control weed competition.

b) Crops: Selection of crops (varieties).
Fertilization adjustments.
Studies on effect of burning and coverage on the physical and chemical properties of the soil, as well as effect of germplasm and weeds.
Methods for crop and pasture establishment.

c) Mixtures: Compatibility among grasses and legumes.
Planting methods, patterns, and periods.

d) Tillage: Soil compaction.
In mechanizable areas: efficient use of machinery and evaluation of tillage methods.
In non-mechanizable areas: use of fallow, evaluation of legumes in terms of their ability to loosen the soil.

e) Compaction: Characterization of the degree of soil compaction under different saturations, and its importance as a factor limiting crop and/or pasture establishment.

f) Recycling: Recycling studies in contrasting situations, ranging from the virgin forest to the torourco areas.

3.3 Producers (on-farm research)

a) Characterization of traditional crop and pasture establishment methods.
b) Introduction of selected grasses and legumes following both the traditional producer's system and improved systems.
c) Validation of best pasture reclamation options, i.e. introduction of legumes in native or improved grasses which are already established.
d) Evaluation of seed production costs before grazing.
e) Introduction of silvipastoral systems based on industrial or fruit tree species.

The process of confronting our technology under real producer conditions should start as soon as possible in order to learn quickly and modify the strategies. In many cases the factors limiting technology adoption are more socioeconomic than strictly agronomic. The starting point in reclamation of degraded areas should be the producer and the problems he encounters in his farm. Thus can the problems to be solved in the reclamation of degraded pastures be determined. The contrary, to develop a basic technology at the experiment station and then "impose" it on the farmer is the wrong approach.

13. Pasture Development Cerrados

The Cerrados Pasture Development Section, based at the Cerrado Research Center of EMBRAPA (CPAC), works primarily on pasture establishment, renovation and management. Research activities are defined by five ongoing projects from 1987 and 1988 and two new projects initiated in 1989, all jointly staffed and funded by EMBRAPA and CIAT. The CIAT senior staff member also maintains contact and collaborates with other pasture research groups in Brazil.

Field research is always affected by weather conditions, especially rainfall. The 1988-89 rainy season contrasted sharply with the previous year at CPAC. Total precipitation (June 1988 through May 1989) was somewhat lower (1310 mm vs 1617 mm for 1987-88), however, distribution is often more important than total precipitation. The first three months were wetter than usual with monthly totals of approximately 250 mm for October, November and December. The late rainy season was unusually dry with infrequent showers from mid-March onward (Figure 1). The weekly distribution of rainfall highlights the importance of frequent short drouth periods, "veranicos", during the growing season. The "veranicos" were particularly pronounced in mid-November, late January and after mid-March. Following an unusually early start, the dry season (May through September) proved to be rather benign with significant precipitation occurring almost every month.

ESTABLISHMENT

Time of seedbed preparation and planting

The details of this experiment are given in the 1988 annual report. The effects of date of planting on the survival of three grasses are shown in Figure 2. Late dry season and early wet season plantings are only possible after early dry season (May) seedbed preparation. Survival data shown for November and January plantings are averages for May and October (traditional) seedbed preparation dates since there was no measurable effect of that variable. *Andropogon gayanus* was almost totally eliminated in the October (after 100 mm of rain) and November plantings. Early season losses were largely caused by the stemborer *Elasmopalpus lignosellus* and by a number of other insects including grasshoppers, crickets, and a small *Coleoptera* beetle. It is difficult to know the extent of damage caused by specific insects in field trials but it appeared that the two early plantings greatly reduced damage caused by leaf cutting ants, probably due to the considerable lag, estimated to be 30 to 45 days, in initiation of harvest by ants after the beginning of the rains. Surprisingly, the late season planting resulted in the best survival of *A. gayanus*, as shown in Figure 2d. The planting done during a dry period in late January was followed by unusually favorable rainfall distribution in February, in contrast to the frequent occurrence of "veranicos" in that month. *Panicum*

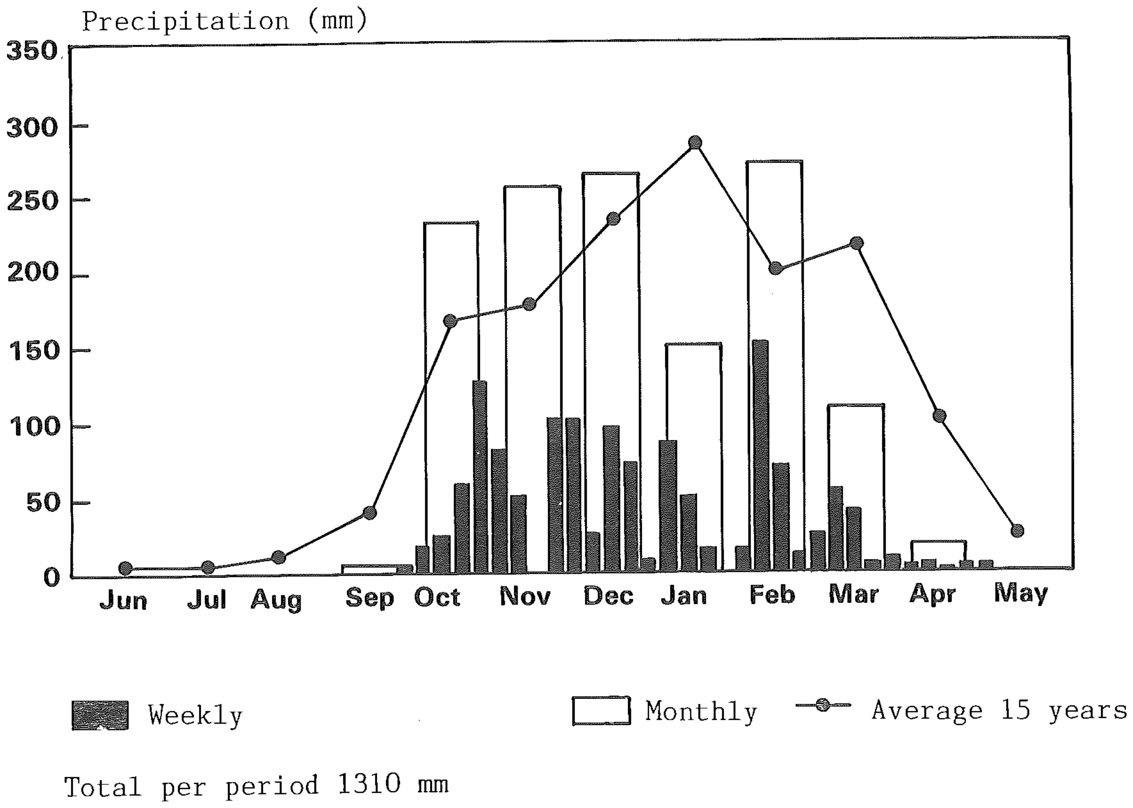


Figure 1. Monthly and weekly rainfall distribution at CPAC, Planaltina, during the 1988-89 agricultural year and 15 year monthly averages. CPAC. 1989.

maximum stands were most affected in the earliest planting as seen in Figure 2a. Brachiaria brizantha cv. Marandu was not seriously affected at any planting date. This has been attributed to its outstanding seedling vigor, however, the fact that it shows so little insect damage alongside totally decimated plots of A. gayanus and sometimes severely damaged P. maximum might indicate some type of natural protection such as antibiosis.

One of the advantages of early planting is the potential for rapid establishment of the pasture thus providing forage toward the end of the rainy season and during the dry season in the year of establishment.

Table 1 shows the accumulated forage for the different treatments 14 weeks after emergence. Early plantings of Marandu and P. maximum had accumulated over a ton of green dry matter when they were cut in January. November plantings of these two grasses had accumulated nearly 1.5 tons of forage by March. Andropogon gayanus was so severely affected by insects that very little forage was produced and weed competition was more severe than with the other grasses.

This trial, initiated in 1988, will be repeated for at least two more years in an attempt to measure the effect of year. In addition it has been replicated this year on a clay loam soil which contrasts with the sandy soil site. Preliminary observations indicate a major role of some as yet undetermined factor related to prior preparation of the area occupied by

Table 1. The effect of date of seedbed preparation and planting date on the forage production of three grasses and associated legumes 14 weeks after emergence. CPAC. 1989.

Association	Planting Date			
	September (Dry Soil)	October (100 mm rain)	November (450 mm rain)	$\overline{X}$
	D.M. kg/ha			
A. gayanus				
Grass	19	5	7	10
Legumes	361	493	310	388
Weeds	126	216	677	340
B. brizantha				
Grass	1078	1161	1408	1216
Legumes	118	212	131	154
Weeds	19	67	95	60
P. maximum				
Grass	775	1174	1482	1144
Legumes	285	421	108	271
Weeds	80	81	122	94

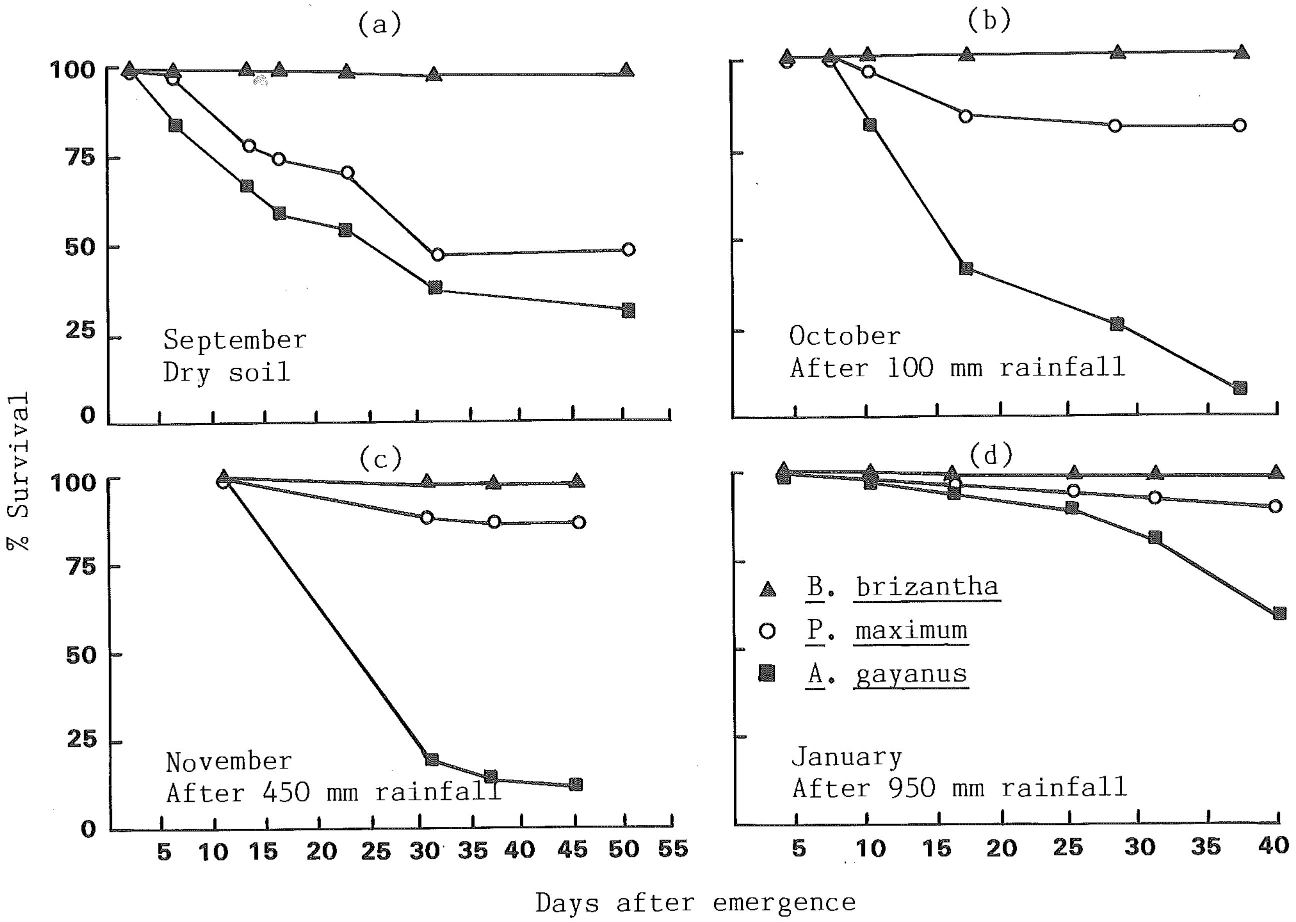


Figure 2. The effect of four planting dates on the survival of three grasses during the establishment phase. CPAC. 1989.

one of the two reps on the clay loam soil. The small area in question, prepared and limed in 1987 but not required for the management strategies experiment, was left untended to be taken over by native species. The other rep was located on an adjacent undisturbed plot and both reps were prepared in May for the initiation of planting in September. All species came to excellent stands in both reps from the plantings in the late dry season and after 100 mm rainfall. The rep on the soil which was prepared in 1987 has suffered very little insect damage while the rep planted on the virgin plot has been almost totally destroyed by grasshoppers, crickets and other insects. The most obvious difference in the two areas is the large amount of plant residue present in the surface layer of the virgin soil contrasting with the very small amount of fresh residue in the previously disturbed area. The sandy site, also characterized by an abundance of fresh plant residue in the surface, has suffered similar early season damage this year, much more severe than in 1988. We are presently sampling the two areas to do insect counts in collaboration with the project entomologist.

In summary, it would appear that even though early plantings escape severe predation by leaf cutter ants, a host of other insects are present in virgin savanna areas that can cause heavy if not total loss of unprotected early season plantings. Precautionary measures are being taken to protect new experimental plantings, especially those after native savanna or on old pasture sites where a large amount of plant residue is present in the surface soil. Systemic insecticides are being used to treat seed and for in-row application as a possible economic and ecologically acceptable means of protecting seedlings.

The Ca x P x grass species experiment was continued this year. *Panicum maximum* CPAC 3148 finally achieved adequate stands to be included in the comparison with *B. decumbens* cv. Marandu, however, stands of *A. gayanus* are still deficient. The response of *P. maximum* to lime and P was similar to that reported for Marandu last year. There was a strong response to P and no measurable response to lime. The yields of Marandu were much lower than in the first year. A common criticism of the grass is that excellent first year performance is followed by a sharp decline in productivity. Nitrogen deficiency is probably the factor primarily responsible for this decline. Applications of N are now routinely made after each cut of all pure grass plots.

The Ca x P x legume species alone and associated with *A. gayanus* experiment continues to have serious problems of stands of the grass and lack of vigor of *S. capitata*.

RENOVATION

A cycle of annual crops was used as a strategy for renovating a degraded *B. decumbens* pasture in an experiment briefly described in the 1988 annual report. Corn, sorghum and rice were planted along with a mixture of forage legumes after thorough seedbed preparation, liming and fertilization. The legumes were also planted directly without crops. The existing stand of *Brachiaria* was successfully destroyed by disking late in the dry season but seed reserves in the soil resulted in a dense and vigorous stand of grass which had to be controlled manually between crop rows to avoid excessive competition. Legumes came to a good stand in all of the crop treatments. Corn and sorghum did not appear to be adversely affected by competition from the residual grass and planted legumes but by harvest, rice was overtopped by the *Brachiaria* and legumes and yield was undoubtedly suppressed. Crop and forage yields are presented in Table 2. Corn yields were far superior to both sorghum and rice, probably due primarily to bird damage sustained by the latter two crops. Corn also benefitted from better stands, sustained less insect damage to seedlings and suffered less competition from the forage species especially compared with rice. Sorghum developed well and where stands were adequate and the heads were bagged to protect them from bird damage yields were calculated at over 3 tons of grain/ha. All crop treatments resulted in better and more vigorous stands of legumes than those obtained when the legumes were planted directly after controlling the old stand of *Brachiaria*. The first year's results have provided an excellent base for future investigation in the area of pasture renovation. It is obvious from this trial and other experience that even old, degraded *B. decumbens* pastures often have large reserves of viable seed in the soil resulting in dense, highly competitive stands when the old sod is destroyed by tilling. Work done by scientists at the EMBRAPA National Rice and Bean Center (CNPAF), indicates that deep tillage with a moldboard plow is sufficient to bury *Brachiaria* seeds and thus reduce competition with a subsequent rice crop without need for additional control of the grass during the crop cycle. An alternative for row crops would be to space rows wide enough apart to allow for mechanical

Table 2. The effect of tillage, fertilizer and associated crops on the renovation of a degraded B. decumbens pasture as measured by grass and legume forage yields and grain production from the companion crops. CPAC. 1989.

Treatments	Grass		Legumes		Grain
	Weeks after planting				
	10	17	10	17	
	kg/ha				
1. Check	2461 bc[1]	2690 c			
2. Offset disk	1329 def	2299 bc			
3. T2 + basic fertilizer + lime (20%)[2]	3460 a	3977 ab			
4. T3 + disk plow	1650 cde	2942 abc			
5. T4 + legumes	1092 ef	3650 abc	50 b	445 b	
6. T5 + 69 - 84-48 NPK[3] for corn + lime (35%)	438 f	1850 c	83 b	403 b	3664
7. T6 for sorghum	2301 bcd	4980 a	489 a	1316 a	961
8. T5 + 41 - 63-36 NPK[4] for rice + lime (20%)	3158 ab	3633 abc	481 a	1666 a	322

1/ Duncan test - 5% level.

2/ Basic fertilizer = 6 - 90 - 45 NPK + 30 kg/ha fritted trace elements + lime to 20% base saturation; applied to treatments 3-8.

3/ In-row fertilizer + N top dressing for corn and sorghum + lime to 35% base saturation.

4/ In-row fertilizer + N top dressing for rice, no additional lime.

inter-row weed control with standard cultivators. Chemical control of the grass with a pre-emerge herbicide may be a viable option for crops like rice, depending on weed species present and the cost of the herbicide.

Attempts to renovate A. gayanus pastures by introducing legumes were again frustrated in 1988. Excellent stands of grass were obtained from seed reserves in the soil after dry season tillage destroyed the original stand. A sparse stand of legumes from seed reserves was reinforced by additional seed. Within a period of 15 days, heavy insect predation almost totally destroyed the new seedlings of both grass and legumes and the land remained essentially bare for several months. This experience and others reported in earlier annual reports lead us to believe that the insect potential in old Andropogon pastures is exceptionally high. Renovation may require the use of insecticides to protect new seedlings. A cycle of chemically protected crops also appears to reduce insect potential. Another alternative might be to till the land and leave it fallow until fresh residues decompose, thus reducing the insect population. The opportunity cost of a long fallow might be prohibitive in more intensive systems.

GRAZING MANAGEMENT

The grazing management trial established in 1987 and described in the '88 report is completing the first year of experimental grazing of the first rep. The second rep, replanted last year, is well established and has been grazed in preparation for initiation of experimental grazing. In an attempt to reduce start-up problems in an experiment that includes a number of grazing systems, a cutting regime has been developed which consists of a uniform cut of the entire area after heavy pre-experimental grazing has removed most of the accumulated forage. This is followed by a series of cuts timed so that all pastures and divisions within rotationally grazed pastures have 21 days of regrowth when the animals first enter the paddock. The cutting calendar is rather complex but has eliminated the problem of unequal forage availability within and among treatments as animals enter the different paddocks. The cutting sequence is carried out only once at the beginning of the experiment.

Animal performance was excellent during the first nine months of experimental grazing as shown in Figures 3 and 4. Little difference was observed among treatments until the beginning of the rather mild dry season. Animals essentially maintained weight for the duration of the dry on all A. gayanus x Stylosanthes spp. pastures while those on an A. gayanus x C. brasilianum association in a parallel trial sustained appreciable weight loss. This difference was probably due primarily to the large differences in botanical composition in the different pastures as shown in Table 3. The data shown are from a mid-June sampling, well into the dry season. The A. gayanus x Stylosanthes spp. pastures had a uniformly high legume content, > 50%, while the Centrosema brasilianum CIAT 5234 pastures had < 15% legume. Most of the legume component in the Stylosanthes pastures was from S.guianensis cv. Bandeirante, the only legume that retained significant green leaf during the dry. Stylosanthes macrocephala and S. capitata lost most of their leaves following flowering in March and May, respectively. Centrosema defoliated shortly after the onset of the dry with the exception of plants growing in Andropogon tussocks. This sudden defoliation does not appear to be the result of water stress. It may be due to rather low night temperatures during June and July at an altitude of 1200 m, latitude 15° South.

As part of our management strategy for

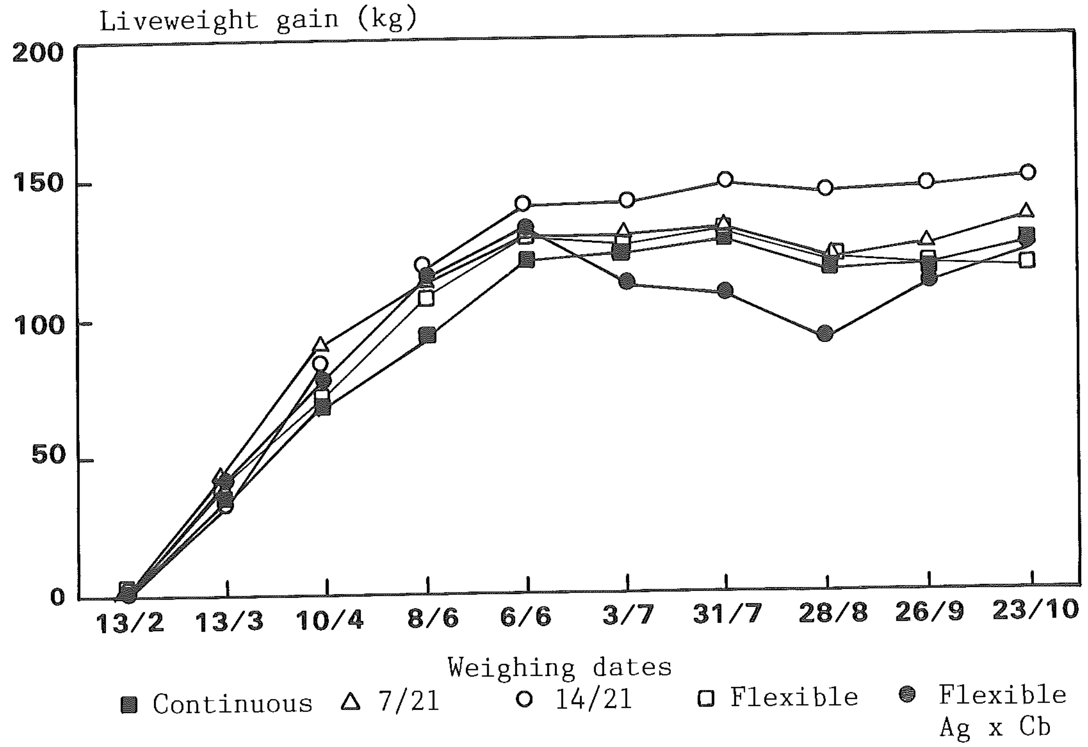


Figure 3. Cumulative liveweight gain per hectare in the management strategies trial. CPAC. 1989.

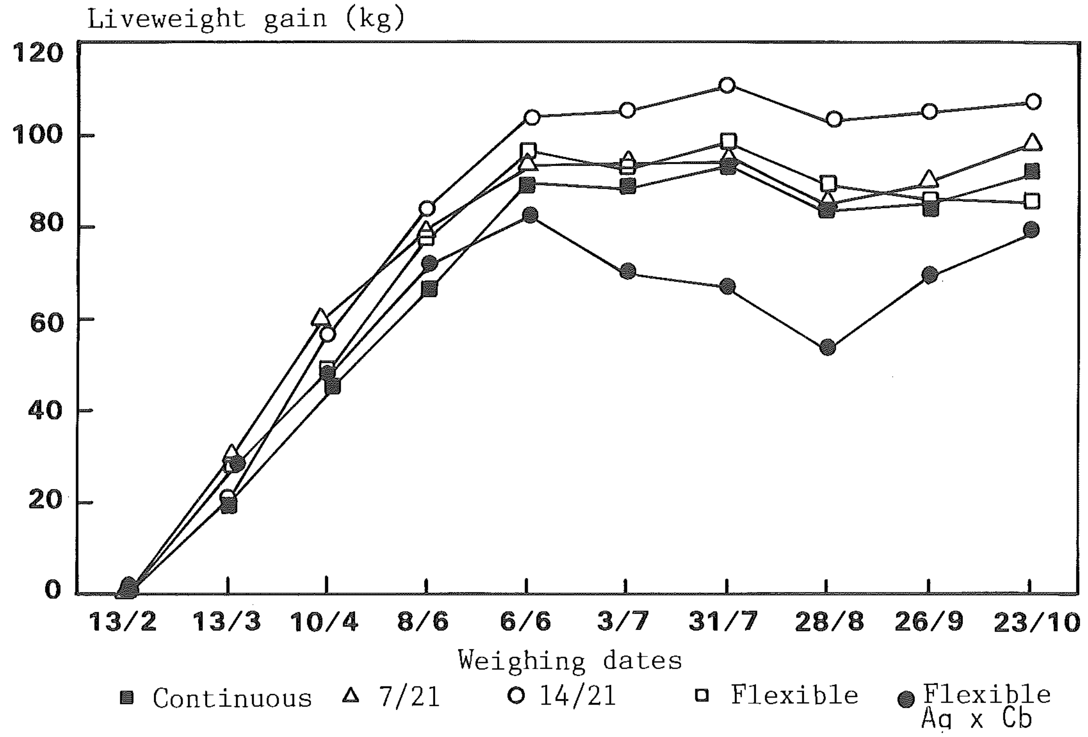


Figure 4. Cumulative animal liveweight gain per animal in the management strategies trial. CPAC. 1989.

Table 3. The effect of grazing management and associated legumes on total forage availability and botanical composition of pastures in management strategies trial. June, 1989, CPAC.

Treatments	D.M. kg/ha	Botanical Composition					
		A.g.	S.g.	S.m.	S.c.	C.b.	Weed
		%					
Continuous	4964	28	62	4	2	--	5
7/21	6609	36	57	4	2	--	3
14/21	4981	35	52	6	4	--	5
Flexible	4653	27	55	2	2	--	5
Flexible (Ag x Cb)	3996	77	--	--	--	14	10

this experiment, all pastures are rested for 28 days (one weighing period) after the beginning of the rainy season to permit recovery of reserves, forage volume and leaf area. It is anticipated that this spelling will result in greater total forage and animal production and improved stability and persistence of pasture components. It does not differ greatly from a strategy commonly pursued by producers in the region and corresponds to a season when availability and quality of native range is relatively good following late dry season burning and vigorous regrowth with the onset of the rains. One of the problems anticipated in the coming year is the loss of original stands of legumes due to the biannual nature of the *Stylosanthes* components. The original plants in the rep under grazing during the last year are already beginning to die. It remains to be seen if some combination of management will allow the successful development of legume seedlings to replace the waning population of original plants. There are large numbers of *S. capitata* and *S. macrocephala* seedlings but very few new *S. guianensis* plants. Marked plants are being monitored to follow population dynamics. Seed reserves are also monitored at the beginning of each rainy season.

NEW EXPERIMENTS

Two new trials are being initiated in 1989. One trial comprises a factorial combination of lime and P levels in rather large screening blocks designed specifically to complement the selection process as it has been traditionally conducted. It has been designated "Stage 1.5" since the materials being tested have passed through the early stages of screening, and are in line for Stage 2 or more advanced trials. This is the first step in the development of supporting research with the aim of speeding the flow of germplasm through to the release stage. Ten legumes and ten grasses are being screened during 1989-90.

Another trial is designed to aid in

the search for compatible legume-grass pastures under different fertility conditions. The variables under study are: associated grass and fertility level. The trial will be managed under grazing and will allow the measurement of grass species effect in terms of animal performance. Almost all of the grazing trials at CPAC have been conducted with *Stylosanthes* species and *A. gayanus* cv. Planaltina as the associated grass. Given the biannual nature of most *Stylosanthes* species, seedling recruitment is their only way of maintaining stands; a strategy severely hampered, if not completely blocked, by the use of a rustic, competitive, strongly perennial grass such as *A. gayanus*. Both *S. capitata* and *S. macrocephala* are prolific seeders often resulting in dense stands of seedlings which have thus far failed to develop in the competitive environment of a mature stand of *A. gayanus*. Five grasses (*Panicum maximum* CPAC 3148, *P. maximum* cv. Centenario, *B. brizantha* cv. Marandu, *B. decumbens* cv. Basilisk, and *A. gayanus*, the latter used as a control) are associated with a mixture of legumes (*Centrosema* spp. hybrid CPAC 2510, *Neonotonia wightii* commercial cv., *Calopogonium mucunoides* commercial cv., and *Stylosanthes capitata* CPAC 56) grown under two fertility regimes. The lower level is the current recommendation for the establishment of pastures directly following the clearing of native campo cerrado. The other fertility treatment is based on recommended levels for correction of fertility and acidity of recently cleared cerrado soils to be used for soybean production. It is anticipated that compatibility and productivity will be strongly affected by associated grass and fertility level and interactions between the two. The competitive abilities of the different components of the legume mixture are also expected to be strongly affected by both variables.

It has long been observed that compaction after planting of forage species often greatly improves stands and seedling vigor. Equipment appropriate for cerrado conditions has not been found in the local market. The agricultural engineering staff has assisted in the design and fabrication of compaction wheels for the cereal planter used for row planting of pastures. The compaction wheels are being tested for the first time in the current planting season. A roller-compactor based on an Australian design, making use of old tires, is being constructed for use in compacting the entire area after broadcast seeding. This implement will be used primarily for the establishment of *Andropogon* pastures. A satisfactory method for row seeding this species has not yet been found for cerrado conditions.

FUTURE PLANS

An exploratory project was approved this year to develop a knowledge base for research initiatives in the area of integration of crop and livestock farming in the cerrado region. It has been proposed that field trials should be preceded, or at least accompanied, by the development of theoretical models of integrated production systems to help in planning research and interpretation of results. Sources of information include published literature and unpublished results from relevant research, especially that conducted under cerrado or similar environments, and visits to selected farms presently employing some degree of integration. This preliminary phase will be followed by the establishment of field trials, some of which will probably make use of existing pasture or crop areas, with the aim of measuring the effects of a cycle of pastures on crops and the effects of residual fertility and reduced biotic pressures from the crop cycle on pastures.

14. Pasture Establishment in the Llanos

THE USE OF MACRO-PELLETS FOR OVERSEEDING LEGUMES

The main purpose of using macro-pellets is to place the fertilizer and the seeds in the same place using smaller amounts of fertilizer and seeds in an area than with conventional establishment methods.

Until now, adequate concentrations of fertilizer in the pellet and the size of pellet have been identified.

Concerning to establishment method, minimum tillage or band spray of herbicide to savanna before seeding legumes has proved to be successful.

DIRECT OVERSEEDING OF MACRO-PELLETED LEGUME INTO BURNT SAVANNA

The ideal method of establishment would be oversowing macro-pelleted seed into savanna without tillage and without using herbicide.

In this case, the factor limiting legume establishment will be the suppression of growth of newly elongating legume roots by the roots of savanna grass. Burning and grazing of savanna grass might prevent the elongation of savanna grass root.

In this year, macro-pelleted legume seeds were directly sown after burning savanna. And cattles were grazed as soon as possible. So far, seedling of legumes are growing well showing possible usefulness of this method.

Preparation of pellets and overseeding

Size and fertilizer composition of macro-pellet are as shown in Table 1.

About 30 seeds of *Desmodium ovalifolium* (CIAT 13089) were put in a small paper bag of 10 x 5 cm after inoculation. And each one pellet were put in each paper bags.

Pellets were sown in 2 x 2 m just after burning savanna.

Results of experiment

Four experiments were done in two locations of sandy-soil (Alegria, Carimagua) and of sandy-loam-soil (Yopare, Carimagua) in two sowing times of late May and late August.

Result of experiment in sandy-soil sown in late May are shown in Table 2. In this experiment, treatment of sowing one month after burning, sowing after cutting and sowing after minimum tillage were also done for comparison. For each treatment, 12.5 a of savanna was used and cattles are free to access to experimental site from surrounding native savanna.

Percentage of growing seedlings in both burning treatment are higher than in other treatment. Seedlings are growing well showing no difference of size among treatments.

In the experiment in sandy-loam-soil sown in late May, seedlings were severely damaged by grass-hopper.

Table 1. Size and fertilizer composition of macro-pellet.

Diameter (cm)	DM weight (g)	g/pellet P	K	Mg	Ca	S
3 x 1.5	8.8	0.31	0.33	0.19	1.18	0.40

Table 2. Percentage of growing seedlings and size of seedlings in experiment in sandy-soil sown in late May 1989.

Methods of sowing	Growing seedlings (% of the total number of sowing spots)	Size of seedlings (Coverage diameter) (cm)
Sowing immediately after burning	83	11
Sowing one month after burning	82	10
Sowing after cutting	63	8
Sowing after minimum tillage	63	9

Investigated in 15 September 1989.

In this experiment, three treatments of sowing of immediately after burning, one month after burning and minimum tillage were included.

Reseeding was done after 2.5 months (middle of August) from first seeding. As a result, times of sowing were 2.5 months after burning and 3.5 months after inimum tillage. Three hectares of burning treatment and 1 ha of minimum tillage treatment were used with stocking rate of 1 animal/ha.

As shown in Table 3, there are no difference of % of growing seedling and size of seedling between burning and minimum tillage treatment. And in all treatment, seedlings are growing well.

In late August, each 1 ha of savannas were burnt in both sandy-soil and sandy-loam-soil and pelleted seeds were sown immediately after burning where cattles are free to access from surrounding savanna.

In the experiment in sandy-soil, 50% of seedling disappeared because of dry

Table 3. Percentage of growing seedlings and size of seedlings in experiment in sandy-loam-soil sown in middle of August 1989.

Methods of sowing	Growing seedlings (% of the total number of sowing spots)	Size of seedlings (Coverage diameter) (cm)
Sowing 2.5 months after burning	77	5.2
Sowing 3.5 months after minimum tillage	76	4.9

Investigated in 13 October 1989.

climate while in sandy-loam-soil, % of growing seedlings and size of seedlings are satisfactory (Table 4).

Possibility of direct sowing of pellets

Among four experiment of direct sowing into burnt savanna, two are going quite well which are in sandy-soil sown in late May and sandy-loam-soil sown in late August.

In experiment in sandy-soil sown in late August, half of seedlings disappeared because of drought. In this soil with low water holding capacity, danger of drought seems frequent. But we cannot find special damage of drought on direct sowing after burning. Damage of drought can be considered on every methods of establishment.

In experiment in sandy-loam-soil sown in late May, almost all seedling disappeared by the damage of grass hopper. In this case, damage of insect were also equal on every methods of establishment. In this experiment, pellets were sown again resulting seeding time 2.5 months after burning. Seedlings are growing well showing that if grazing are continued after burning, oversowing

Table 4. Percentage of growing seedlings and size of seedlings in sandy-soil and in sandy-loam-soil sown immediately after burning in late August 1989.

Type of soil	Growing seedlings (% of the total number of sowing spots)	Size of seedlings (Coverage diameter) (cm)
Sandy-soil	55	2.5
Sandy-loam-soil	89	6

Investigated in 12 October 1989.

can be done in several months after burning.

Difference could not be found among treatment of burning, cutting and minimum tillage.

From these results, direct overseeding of macro-pelleted legume into burnt savanna can be recommended.

Plan of future and problems to be solved

Direct sowing of pellet will be accepted by the small farmers who have not machines for cultivation or cutting. With pelletizer which will arrive in CIAT on December 1989 from TARC, production of pellets will start using domestic material.

In the future, aerial sowing to wider area will be possible.

In the experiment in this year, *Desmodium ovalifolium* was used for direct sowing. Selection of suitable species of legume for oversowing including tree legumes will be necessary.

Further study for adequate time of seeding is needed including less dangerous time of insect and drought. Also limiting date for sowing before dry season should be decided.

In the experiment in this year, days of sowing after burning varied from one day to 2.5 months, resulting no clear difference. But considering of root competition, sowing just after burning should be recommended.

15. Ecophysiology

This year marked a change of emphasis away from the main core experiment that has occupied the major part of the section's work for the last three years towards some studies that supplement and complement this effort. These studies have focussed on the flowering responses of Centrosema species, the rates of leaf emergence and senescence of Digitaria decumbens pastures under grazing, the establishment of a large experiment to study the competitive relations between the components of contrasting associations when grown on soils of different textures, and some studies on the establishment of Arachis pintoi. Observations were continued on the residual effects of fire on Stylosanthes capitata sown into a savanna, and plots of some advanced materials were established for tests of the effects of fire in the future.

CARIMAGUA

The reaction of four associations to different forage allowance.

Four associations were established at different establishment ratios to give legume dominant, grass dominant swards, and an intermediate composition. The associations were

- Andropogon gayanus cv Carimagua 1 - Stylosanthes capitata cv Capica
- Andropogon gayanus cv Carimagua 1 - Centrosema acutifolium cv Vichada
- Brachiaria dictyoneura CIAT 6133 - Desmodium ovalifolium CIAT 3788
- Brachiaria dictyoneura CIAT 6133 - Arachis pintoi CIAT 17434

The grasses and legumes were sown in alternate rows on 50 cm centers with the recommended rates of fertilizer (20 kg P, 10 kg K, 8 kg S), and were topdressed each year with half this rate. Within each of the associations, each of the three compositions treatments were grazed at three levels of forage allowance, heavy light and an intermediate rate, the actual levels of which varied throughout the experiment as required to maintain satisfactory amounts of residual forage in the lowest forage allowance. Grazing was carried out in a rotational system with a cycle of 35 days, within which occupation was varied to obtain the required grazing pressure, but with a maximum occupation of 3-1/2 days in each cycle. Each association was grazed by the same group of fistulated cattle in order to avoid changes of preference, and when these cattle were not grazing the experimental plots, they were rested in a pasture of the same association adjacent to the plots.

Samples were clipped at ground level from four quadrats allocated by ranked sets, immediately before the animals entered the plots and immediately after they left. Each sample was clipped into 20 cm strata (A. gayanus) or 10-cm strata (B. dictyoneura), and further separated into leaf, stem, and dead material of each component. Samples were collected from the fistulated steers with which the plots were grazed at the start of each grazing period in each plot.

The populations of Stylosanthes declined rapidly during the second year, and by the start of 1989 the legume was making little contribution to the biomass of the pasture. It was obvious, that despite germination of seeds from the seedbank that accumulated in the first and second years, these seedlings were unable to grow successfully to adult plants. This is common experience with this association growing on heavy soils, and especially under more or less short cycles of grazing. There were no substantial differences between the forage allowance treatments, nor between the different establishment ratios.

Desmodium ovalifolium was attacked by Cynchitrium, starting in plots that were being grazed during very wet weather. Because the legume performed in a patchy and thus unreliable manner, it was difficult to make comparisons between treatments. Gradually the legume populations were declining, and it was decided to replace the accession of D. ovalifolium sown in this experiment with another resistant to Cynchitrium and to nematodes.

Centrosema acutifolium has also not persisted in this experiment, and its proportion of the biomass has declined to low levels over the three years of the experiment, and during 1989 its contribution has been very low, and little affected by initial starting population or by the grazing treatments.

Arachis pintoi alone of the legumes sown in this experiment has been outstanding. In the year of establishment from vegetative cuttings, it established and grew well. However, the establishment year was unusually wet, and the plants exhibited a severe chlorosis towards the end of the growing season. Analyses suggested that the plants were affected by toxic levels of iron in the tissues, possibly brought about by the waterlogged conditions. Subsequently during the dry season, the stolons of these plants were severely affected by Rhizoctonia, and many if them died or became depauperate. Recovery during the second year was very slow, but there was a spectacular improvement during 1988, and in 1989, the association has been outstanding. The cattle have gained in excess of 630g/day liveweight during the six months to 31 October, and the proportion of the legume has increased to about 35 percent of the biomass, irrespective of the starting proportion.

The stolons of A. pintoi are able to establish independent plants, which survive the dry season. Moreover, it has been observed that A. pintoi grows larger leaves of a much darker green colour when a stolon crosses through a tussock of the associated grass. The reasons for this behaviour are unclear, but the implications as an adaptive mechanism to competitive growth with associated species are clear.

It is clear that under the management cycle imposed in this experiment, only A. pintoi/B. dictyoneura has maintained a reasonable balance of grass and legume. The factors that appear to be responsible are the characteristics of A. pintoi which fit it to tolerate both grazing and competition from the companion grass. These include prostrate and stoloniferous habit in which the stolons establish aggressively in any bare ground, elevated leaves which offer competition for light to the companion grass, a large volume of seed which is buried, and vigorous seedlings by virtue of the large seeds. The growth characteristics of the plant protect the growing points from consumption by the grazing animal. In many of its characteristics A. pintoi is remarkably similar to white clover.

FUTURE PLANS

The two failed associations have been re-established, in the case of D. ovalifolium with an accession resistant to stem-gall nematodes, and in the case of S. capitata, cv. Capica was re-established, broadcast between the rows of grass, which were heavily defoliated. The rest areas of both these associations, to which the grazing animals were withdrawn as necessary, and which were the same size as the as the plot areas were also resown, and together comprise 1 hectare of each association of the two re-established associations and of A. pintoi/B. dictyoneura. It is planned to use these areas to test the effect of grazing system, initially to contrast a 7/7 with a 28/28 day rotation, and to seek to measure the population dynamics and growth rates and senescence in attempt to understand how grazing system affects stability of the association.

Multisite experiment.

It is commonly observed that any one association may react differently under the same management on sites with contrasting soil textures. An understanding of the factors responsible for the different reactions is essential if recommendations for pasture management are to be soundly based. It is difficult to see how soil texture itself could affect plant growth, except in unusual circumstances, and of the possible factors, it seems that the soil nutrient status, and competition for nutrients are the most likely to be responsible.

In order to understand more about the factors controlling the relations between the components of grass-legume associations on soils of contrasting textures, identical experiments were established on four sites at Carimagua with sand contents covering the range from 11 to 50 percent.

The treatments consisted of five associations, in general repeating those sown in the main experiment described above, which represent the materials in advanced categories of evaluation. The associations were

Andropogon gayanus cv Carimagua 1 -
  Stylosanthes capitata cv Capica
Andropogon gayanas cv Carimagua 1 -
  Centrosema acutifolium cv Vichada
Brachiaria dictyoneura CIAT6133 -
  Desmodium ovalifolium CIAT13089
Brachiaria dictyoneura CIAT6133 -
  Arachis pintoi CIAT17434
Brachiaria dictyoneura CIAT6133 -
  Centrosema acutifolium cv Vichada

The plants were all individually established on 50 cm centers, in a spatial arrangement to give the appropriate proportions. Within each association the components were established in a replacement series of five proportions, 0.00, 0.25, 0.50, 0.75, and 1.00, as split plots, which were further split to the nutrient treatments below.

Replicates I and II

A factorial arrangement of phosphorus (nil and 20 kg/ha) and potassium (also nil and 10 kg/ha), with a basal dressing of sulphur (8 kg/ha) and magnesium (8 kg/ha).

Replicates III and IV.

A factorial arrangement of sulphur (nil and 8 kg/ha) and magnesium (also nil and 8 kg/ha), with a basal dressing of phosphorus (20 kg/ha) and potassium (10 kg/ha).

Following a uniformization cut at 10 cm in August, 1989, the experiments have been harvested at six-week intervals, and the harvested material separated into the components. Detailed analysis of the data will depend not only on the yields of dry matter between the components, but the yield of nutrients supplied, which must await chemical analysis of the samples. Preliminary examination of the data suggest that the *A. gayanus* compete with *S. capitata* for phosphorus, and that the application of P fertilizer tends to improve the competitive advantage of the grass. In contrast, *A. pintoi*, which although is apparently rather less efficient in its utilization of applied phosphorus, is also more responsive to it, and competes more vigorously for it, so that its competitive position is improved as phosphorus is applied.

The establishment of Arachis pintoi

Arachis pintoi is commonly found to be difficult to establish. The evidence supporting this assertion is largely anecdotal, but there were clear problems associated with its establishment in the core experiment above. In general, its growth during the second and third years following seeding are reported to be slow, with yellow unthrifty plants.

In an experiment in large (50 kg soil) boxes at Palmira, typical slow growth of *A. pintoi* was observed, which did not appear to be associated with nutrient deficiencies, because fertilizers were applied at the recommended rates. Several kilograms of soil were collected from a healthy, vigorous stand of *A. pintoi* at Carimagua, and placed in about 10 litres of water. The supernatant was watered on the boxes, and was followed immediately by a dramatic improvement in growth of the *A. pintoi* plants. It was hypothesized that the effect was due to inoculation of the plants with a biological factor, possibly miccorrhyzae, rather than an effect of nutrients.

In order to test this hypothesis in the field, an factorial experiment was established in the field at Carimagua on a soil with 12 percent of sand, and using stolons of *A. pintoi* as planting material. The treatments were:

Macronutrients (P 20 kg/ha, K 10 kg/ha S 8 kg/ha, Mg 12 kg/ha)
Micronutrients (Mo,B,Cu,Zn)
Inoculated with *Bradyrhizobium*
Inoculated with the supernatant of a suspension of soil taken from a healthy, vigorous stand of *A. pintoi*.
Calcium carbonate (1 t/ha)

There were large responses to additional macronutrients, and interactions between macronutrients and inoculation with Bradyrhizobium (Table 1).

Table 1. The effects of calcium and a mixture of P, K, S, and Mg on the early growth of *A. pintoi* at Carimagua (2 November, 1989).

	Basal macronutrients	Additional micronutrients
Lime, nil	24	81
Lime, 1 ton/ha	47	75

A second series of small experiments were established to contrast the establishment of *A. pintoi* on different land facets on the transect of the Yopare landsystem at Carimagua. The major representative sites chosen initially were an upland well drained site (facet wdu), an upland poorly drained site, and an upland sandy site. At each site the following treatments were applied in a complete factorial with two replicates:

a). *A. pintoi* sown as seed or vegetative material (stolons).
b). Macronutrients (P 20 kg/ha, K 10 kg/ha, S 8 kg/ha, Mg 12 kg/ha)
c). Inoculated with *Bradyrhizobium*.

Preliminary results show large differences between the seed and stolons treatments. On the poorly drained upland site, establishment from seed has been very poor, presumably because the wet conditions were ,unsuitable for the germination of seed, but favoured the satisfactory establishment of stolons. In contrast, seeds established much better on the sandy site, presumably the less favourable water relations of the sandy soil on this site do not favour the ready establishment of stolons, which take time to develop functional roots, whilst seedlings more rapidly develop a functional root system. In the preliminary evaluations, there were no clear responses (six weeks) to the other treatments.

PALMIRA

Photoperiod responses of Centrosema species.

It is of concern that Centrosema acutifolium cv Vichada does not produce very much seed in the field at Carimagua. For this reason the seed is costly, and it also has important implications in the survival of swards of cv Vichada under grazing. However, there are reports of good seed yields in Mexico, which suggests that the cultivar has a short-day flowering response, which is not met in equatorial latitudes.

At 3 degrees (Carimagua and Palmira) the daylength varies only by approximately 35 minutes so that plants with a short day requirement less than 11h 45m will not flower at this latitude if their requirement is quantitative, or will flower slowly with reduced seed production if their requirement is qualitative. In a preliminary experiment of sequential sowings of a range of Centrosema accessions in the greenhouse at Palmira over a two year period, it was inferred that C. macrocarpum CIAT 5452 and 5713 and C. acutifolium CIAT 5568 and 5277 were short day plants, while C. arenarium CIAT 5236, C. brasilianum CIAT 5234, and C. pubescens CIAT 438 were day-neutral.

Further experiments are being carried out to determine the daylength responses of this material using fixed solar exposure of 8h, and varying the photoperiod between 9h and 15h, using lightproof enclosures and supplemental artificial light. These data will be reported next year.

It is commonly found that flowering in tropical legumes can be stimulated by a short period of drought, so that seed production can be enhanced by strategic use of irrigation during the dry season. In order to investigate whether this technique could be used with Centrosema species, C.macrocarpum CIAT 5713, C. acutifolium var matograsense CIAT 5568 and C. acutifolium var orinosense CIAT 5277 were exposed to simulated drought in large cylinders of soil in the greenhouse in Palmira under natural photoperiod, compared with well-watered controls. Although the plant growth was severely affected by the levels of drought imposed, there was no evidence of stimulation of flowering in these accessions.

16. Pasture Quality and Productivity

During 1989 the Pasture Quality and Productivity Section continued to evaluate pasture persistence and productivity in grazing experiments conducted at the Quilichao sub-station and at Carimagua. In addition, new plantings of grass and grass-legume associations were done in farms, and grazing records taken in commercial pastures in the Llanos of Colombia.

One new development during 1989, was the initiation of a grazing trial in Quilichao to measure the effect of legumes in terms of milk production.

GRAZING EXPERIMENTS IN QUILICHAO

For several years grazing experiments have been conducted at Quilichao using methodologies or developing methodologies which could be relevant to the RIEPT. What follows is a report on the effect of grazing on legume persistence and on the effect of legumes on milk production.

Legume persistence in small plots. A prototype Regional Trial C (ERC) was established in 1984 and results obtained with the first group of associations were reported in 1987. New associations of B. brizantha cv. Marandú + C. acutifolium (CIAT 5277 and 5568) and of B. dictyoneura cv. Llanero + Arachis pintoi (CIAT 17434) were subject to three grazing frequencies (2, 4, 6 weeks rest) and two grazing intensities (2.4 and 3.6 UA ha^{-1}).

In the associations with B. brizantha cv. Marandú, the two C. acutifolium ecotypes did not persist, regardless of grazing frequency or intensity (Figure 1). After one year of grazing the legume disappeared from the plots and no seedling were observed coming from soil-seed reserves. It was interesting to note that the availability of green dry matter of Marandú declined with time (Figure 2), related to low growth rate and high accumulation of dead material (60% of the total dry matter) in the grass in all treatments.

The results of this experiment indicate that B. brizantha cv. Marandú is not compatible with some Centrosema species and has poor adaptation to the soils (low pH, high Al and OM) and/or rainfall pattern (1.800 mm with bi-modal distribution) of Quilichao.

The legume A. pintoi is very promising for acid soils in humid areas of the tropics, due to its high quality and compatibility with agressive stoloniferous grasses (i.e. Brachiaria spp.).

In a small-plot grazing experiment at Quilichao which included A. pintoi in association with B. dictyoneura, the legume content in the pastures has not increased after two years of grazing (Figure 3). This has been associated with a significant decline in legume during the dry periods of the year. However, it should be pointed that the amount of A. pintoi in the pastures has been affected by grazing management (Figure 4). The more

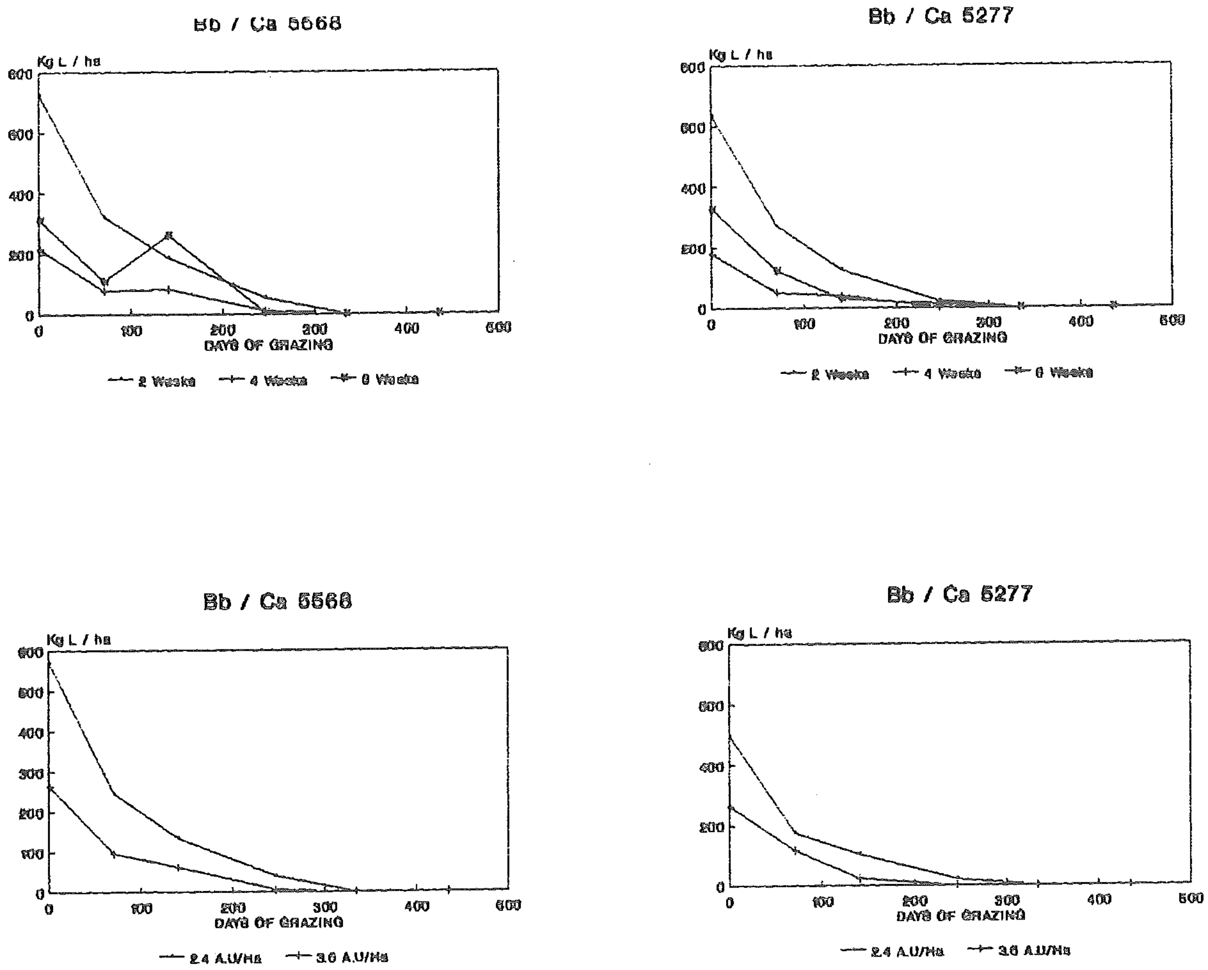


Figure 1. Legume content in pastures of B. brizantha cv. Marandu + C. acutifolium under different frequencies of grazing and stocking rates (Quilichao).

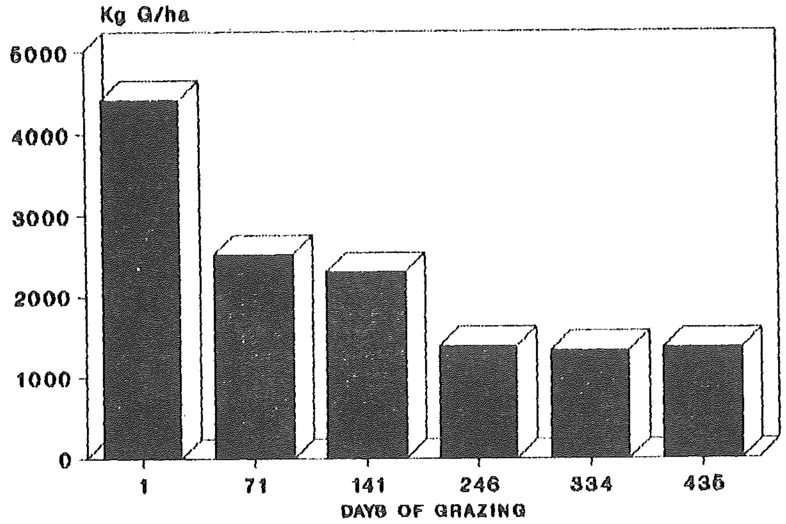


Figure 2. Grass availability (green dry matter) in a pasture of B. brizantha cv. Marandu + C. acutifolium over time (Quilichao).

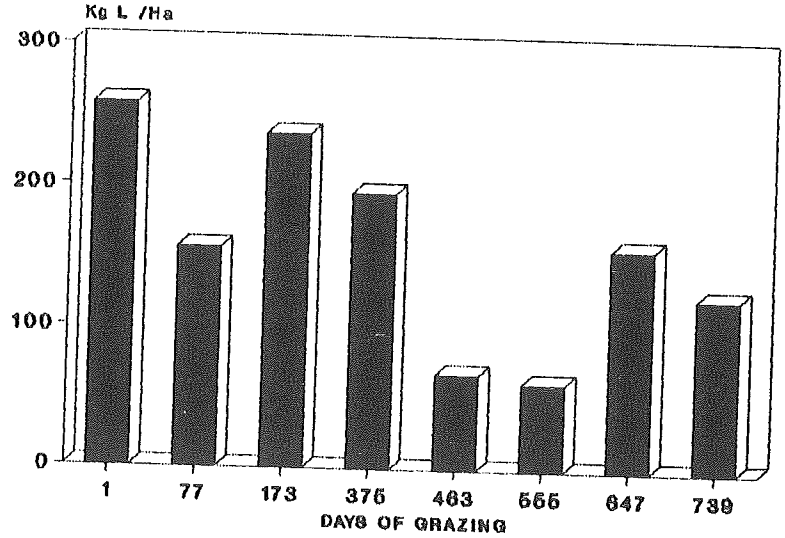


Figure 3. Legume content in pastures of B. dictyoneura + A. pintoi over time (Quilichao).

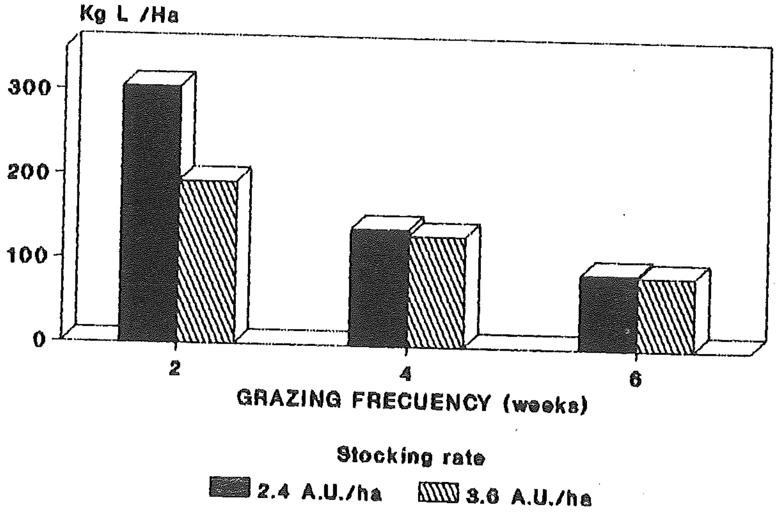


Figure 4. Legume content in pastures of B. dictyoneura + A. pintoi under different grazing management treatments (Quilichao).

frequent grazing (2 weeks) has favored the legume in both low and high grazing intensities.

It is suggested, that the bi-modal distribution of rainfall in Quilichao does not favor the growth of A. pintoi. At Carimagua, with an uni-modal distribution of rains, the proportion of A. pintoi has increased overtime in several associations with Brachiaria spp. under grazing.

Persistence and productivity of a B. dictyoneura + C. macrocarpum pasture. A grazing trial with B. dictyoneura in association with C. macrocarpum (CIAT 5273) managed with an alternate/ flexible system continued for another year. The legume proportion in the forage on offer is presented in Figure 5. Regardles of grazing system, the legume content in the pasture dropped to less than 20% by the end of the second year. During the first year, the grazing strategy applied was to favor the grass (i.e. less frequent grazing). In contrast, during the second year, grazing has been more frequent to favor the legume, but with no sucess.

In spite of the decline in legume content in the pasture, liveweight gains during the second year were as high as in the first year (1st year 438 g A^{-1} day^{-1} and 2nd year 472 g A^{-1} day^{-1}). Annual liveweight gains in this pasture has averaged 166 kg/A and 714 kg/ha.

There is no question, that this association has been very productive but unstable and that very little has been accomplished by modifying the grazing frequency. It is possible, that the legume has not persisted either because the grazing intensity being used is to high or because there has been death of initial plants, with little plant recruitment from soil-seed reserves. In order to determine the causes of legume decline in the pasture, it is obviously necessary to have more than one grazing intensity, followed by detailed measurements on individual marked plants.

Legume contribution to milk production. Through the years, the Tropical Pastures Program has demonstrated the benefits of grass-legume pastures in terms of liveweight gains. With the

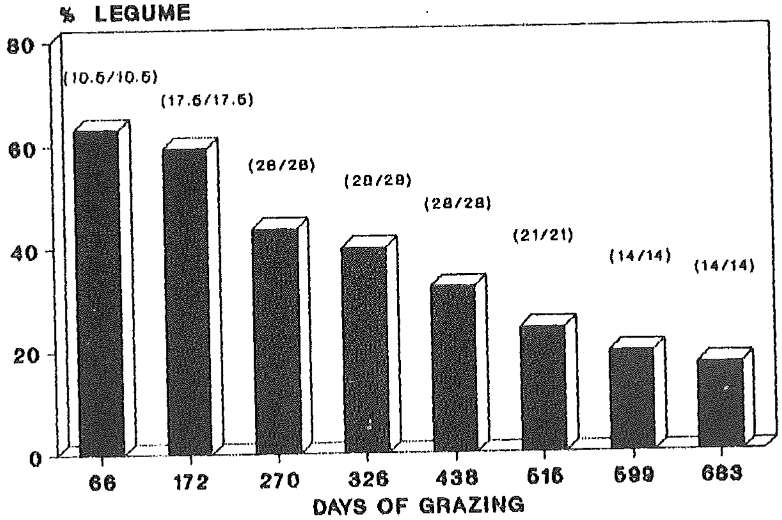


Figure 5. Legume proportion in a pasture or B. dictyoneura + C. macrocarpum 5713 under flexible alternate grazing system (Quilichao).

* Grazing system (days on/days of rest)

increasing involvement of the program in areas where dual-cattle production systems predominate (i.e. Central America) it was considered important to determine the contribution to milk production of legumes that have been selected for acid-low fertility soils.

A grazing experiment comprising nine pastures of 1 ha each was established last year in Quilichao. The nine pastures resulted from the combination of three grasses (A. gayanus cv. Carimagua 1, B. decumbens cv. Basilisk and B. dictyoneura cv. Llanero) with two legumes (C. acutifolium CIAT 5568 and C. macrocarpum CIAT 5273).

The grass alone and grass-legume pastures were grazed by upgraded Holstein cows (1 cow ha^{-1}) using a change-over design which included 3 pastures and 3 periods of 14 days each (7 days adjustment and 7 days measurement). Results on milk production from a dry season period are presented in Figure 6. A significant effect of the legume in milk production was observed with B. dictyoneura (19% increment) and B. decumbens (17% increment). The smaller increment (7%) in milk production due to legumes observed in A. gayanus was not significant. During the wet season a large increment (21%) in milk production due to legumes was recorded in B. dictyoneura associated with the two Centrosema species (Figure 7). In contrast, during this same period, milk production was similar in B. decumbens and A. gayanus alone and in association with legumes.

The relatively high increments in milk production observed in B. dictyoneura + legumes in the dry and wet seasons were associated with a high legume proportion in the forage on offer (Table 1). On the other hand, the greater increment in milk production due to legumes in B. decumbens as compared with A. gayanus during the dry season, could be related with legume selectivity. Estimates on legume in the diet through analysis of forage prehended by grazing cows, indicated that animals selected a diet with 30% legume in B. decumbens and a diet with 20% legume in A. gayanus.

These initial results show the potential beneficial role of legumes for milk production in tropical areas with acid soils of low-natural fertility. Productive and high quality legumes in association with grasses could result in milk increases in the order of 20% or even higher if the grass is N defficient, provided they comprise a relatively high proportion (20-30%) of the forage on offer.

GRAZING EXPERIMENTS IN CARIMAGUA

During 1989 several grazing trials continued to be evaluated in Carimagua and new grazing experiments with Category IV and V grasses and legumes were initiated (C. acutifolium + savanna under different stocking rates and B. dictyoneura alone and with A. pintoi under different managements). In addition, a new grazing experiment was established with Flemingia macrophylla in association with savanna and B. humidicola.

Native grasses in association with C. acutifolium. This experiment completed its third and last year of evaluation. Liveweight gains recorded during 1989 are summarized in Table 2. During the dry season animals gained weight in all pastures, with the exception of the high stocking rate (1.5 A ha^{-1}) continuous grazing treatment. During the rainy season the highest gains were recorded in the continuous grazing-low stocking rate treatment (0.75 A ha^{-1}).

The legume selection index in the dry and wet seasons was greater than 1 indicating that animals selected a higher proportion of legume than what was available. However, the selection index during 1989 (avg. LSI=1.3)

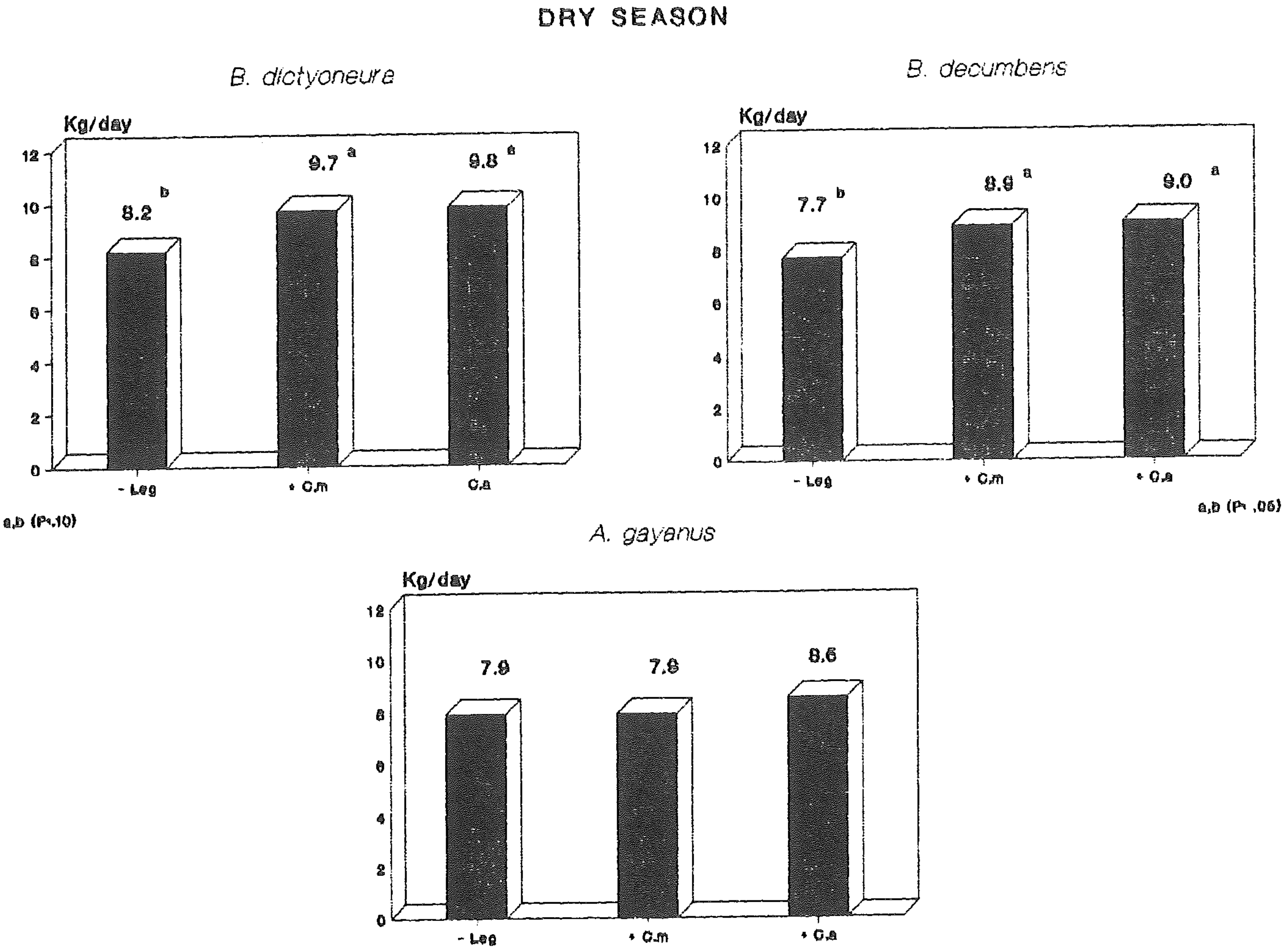


Figure 6. Milk production in a pasture with grass alone and in association with two legumes during a dry period (Quilichao).

was lower than in 1988 (avg. LSI = 3.0). This difference in legume selection Index between years, is associated with a decline in the proportion of native grasses and a corresponding increase in legume proportion (32% in 1988 to 56% in 1989) in the forage on offer. Liveweight gains during the rainy season were lower in 1989 (avg. 211 g A^{-1} day^{-1}) as compared with 1988 (avg. 354 g A^{-1} day^{-1}), associated with lower total dry matter availability in the pastures.

In summary, the results of this experiment indicate that in pasture systems with native grasses of low quality associated with a legume, animals exhibit a high degree of substitution of low quality forage by legumes. In addition, some native grasses of erect growth habit (i.e. Andropogon bicornis) appear to have low persistence when subject to relatively high grazing intensity. It is hoped, that a more clear definition of the effect of high grazing pressure on the persistence of native grasses will come from an experiment in

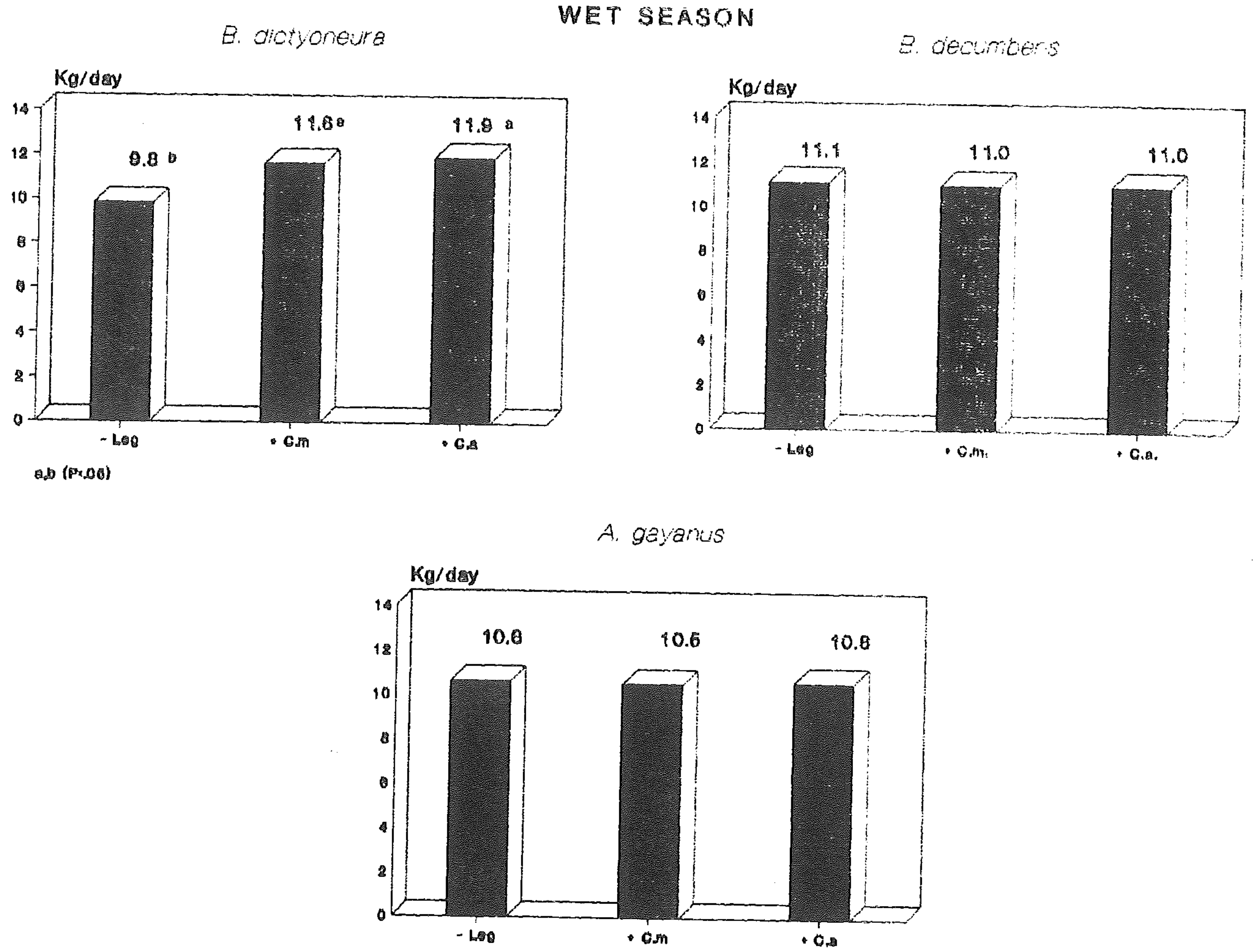


Figure 7. Milk production in a pasture of grass alone and in associations with two legumes during a wet period (Quilichao).

progress in Carimagua. This experiment includes C. acutifolium cv. Vichada in association with a more representative savanna managed without burning and with different stocking rates.

B. dictyoneura in association with C. acutifolium. Pastures of B. dictyoneura cv. Llanero which had legume initially (i.e. C. macrocarpum or C. brasilianum), but that later disappeared (see 1988 Annual Report) were continued to be used as controls, to compare animal production with B. dictyoneura + C. acutifolium cv. Vichada. In the fourth year of grazing, liveweight gains were only slightly higher in the association (316 g A^{-1} day^{-1}) as compared with the grass alone pastures (239 g A^{-1} day^{-1}) (Table 3). This was associated with a large drop in legume content in the pastures, in both low and high stocking rates.

During the four years of grazing, animal production in B. dictyoneura + C. acutifolium cv. Vichada, has ranged from 130 to 150 kg A^{-1} year^{-1}, in the absence of maintenance

Table 1. Legume content in pastures grazed by milking cows (Quilichao).

PASTURES	DRY SEASON		WET SEASON	
	Leg_1*	Leg_2** (%)	Leg_1	Leg_2 (%)
A. gayanus				
+ *C. macrocarpum*	4.9	2.8	8.8	1.4
+ *C. acutifolium*	5.2	1.7	6.9	1.6
B. decumbens				
+ *C. macrocarpum*	3.1	0.7	5.0	1.0
+ *C. acutifolium*	1.8	0.8	2.3	1.0
B. dictyoneura				
+ *C. macrocarpum*	30.8	9.3	37.7	6.9
+ *C. acutifolium*	29.4	5.8	25.2	1.0

* Leg_1 = Planted legume
**Leg_2 = *Desmodium barbatum* (spontaneous)

Table 2. Liveweight gain of steers grazing *C. acutifolium* associated with low quality native grasses under different management systems (Carimagua 1989 - 3rd year of grazing).

GRAZING SYSTEM	STOCKING RATE ($A\ ha^{-1}$)	SEASON	
		Dry^1 ($g\ A^{-1}\ day^{-1}$)	Wet^1
Continuous	0.75	293 a	365 a
Continuous	1.0	43 c	156 b
Continuous	1.5	-13 c	114 b
Rotational	1.5	162 b	209 b

1 = 152 and 211 days of dry and wet season, respectively.
a,b,c means within season are different (P _ .05)

Table 3. Liveweight gain of steers grazing *B. dictyoneura* alone and in association with *C. acutifolium* cv. Vichada (Carimagua 1989 - 4th year of grazing).

GRAZING SYSTEM	A ha^{-1} (dry/wet)	SEASON	
		Dry^1	Wet^1
		(g A^{-1} day^{-1})	
B. dictyoneura	2/2	177	313
	2/3	147	261
B. dictyoneura/ *C. acutifolium*	2/2	162	469
	2/3	181	346

1 = 133 and 211 days, dry and wet seasons, respectively.

fertilization. It is possible that with fertilization the legume could have persisted longer, particularly in the lower stocking rate treatments (2 A ha^{-1} year-round). Work should be done to determine the need of maintenance fertilization for the persistence of *C. acutifolium* cv. Vichada grown in association with contrasting grasses at sites with different soil textures.

B. humidicola in association with D. ovalifolium. A grazing experiment including *B. humidicola* (CIAT 679) alone and in association with *D. ovalifolium* (CIAT 13089) replicated at two sites in Carimagua, completed the second year of evaluation. In the site with more sandy soils (site 2 30% sand) the stocking rates imposed have been 2 and 3 ha^{-1} during the whole year. However, because of more grass availability in the heavy soil (site 1-3% sand), the stocking rates in the rainy season were increased from 2 to 3 A ha^{-1} and from 3 to 4 A ha^{-1}.

The legume content in the low and high stocking rate treatments increased with time in the two sites (Figures 8 and 9), as a result of low palatability. However, the increase in legume was more pronounced in the more sandy soil (site 2) in both stocking rates, to the point that pastures have become legume dominant. The strategy of increasing the rest period during the rainy season in order to favor the grass, has not helped to improve the grass-legume balance (see Figures 8 and 9).

Liveweight gains in these pastures have been a reflection of grass-legume balance (Table 4). Both in the dry and wet season, gains have been greater in site 1, where pastures have not become legume dominant. In addition, the legume has only contributed to animal gains in the dry season in the site with better grass-legume balance. During the rainy season liveweight gains have not been significantly increased due to legume at either site (see Table 4).

The quality of the forage selected by esophageal fistulated steers in both sites in summarized in Figure 10. The IVDMD of the diet has been higher in the pure grass pastures than in the grass-legume associations. In addition, the IVDMD of the forage selected in grass-legume pastures has been consistently higher in the site where pastures are not legume dominant, obviously due to less legume consumption. It is well documented that *D. ovalifolium* has low digestibility, associated to high tannin content. As expected, in both sites the protein level of the forage selected has been higher in the grass-legume pastures than in the pure-grass pastures, particularly in the site where the pastures are legume dominant. It is interesting to note that after two years of grazing, the forage selected in the pure grass pastures was marginal in protein (6%), which agrees with other results from Carimagua.

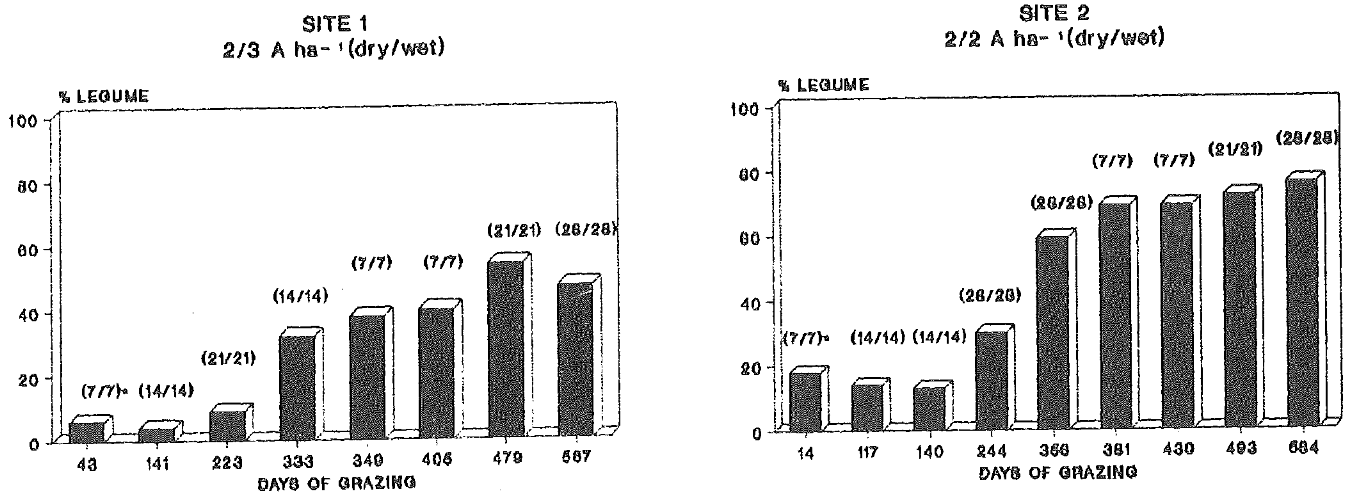


Figure 8. Legume content in pasture of B. humidicola/D. ovalifolium 13089 under flexible alternate grazing (Site 1 = La L, heavy soil; Site 2 = Yopare, light soil)(Carimagua)
* Grazing system (days on/days rest).

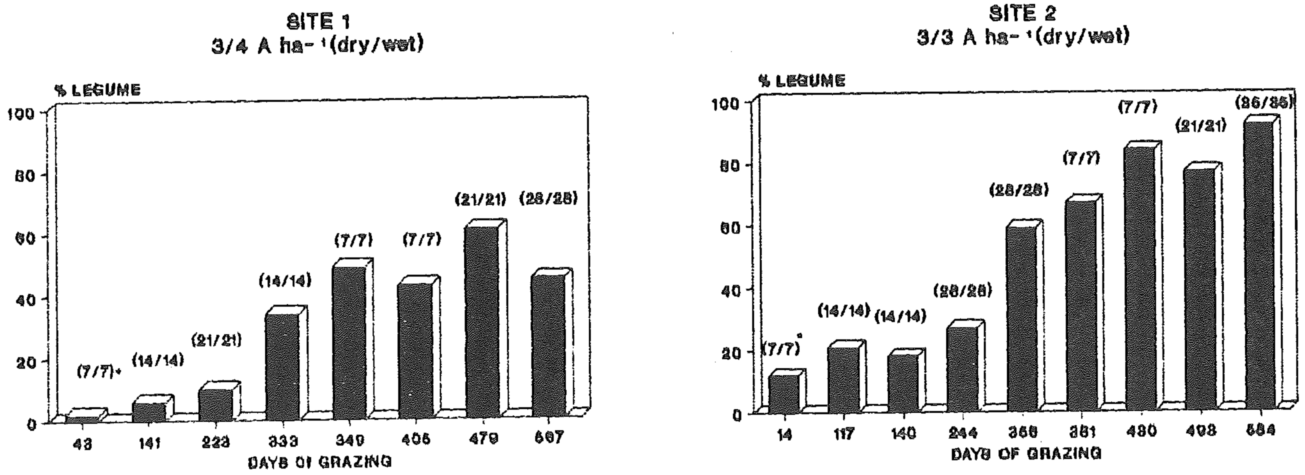


Figure 9. Legume content in pastures of B. humidicola/D. ovalifolium 13089 under flexible alternate grazing (Site 1 = La L, heavy soil; Site 2 = Yopare, light soil)(Carimagua).
* Grazing system (days on/days rest).

Table 4. Liveweight gains of steers grazing *B. humidicola* alone or in association with *D. ovalifolium* 13089 (Carimagua 1989 - 2nd year of grazing).

PASTURES	A ha^{-1} (Dry/Wet)	Site 1[1]		A ha^{-1} (Dry/Wet)	Site 2[1]	
		Dry[2] (g A^{-1}	Wet[2] day^{-1})		Dry[3] (gA^{-1}	Wet[3] day^{-1})
B. humidicola	3/4	61	273	3/3	2	227
B. humidicola/D.o.	2/3	163	313	2/2	-75	156
B. humidicola/D.o.	3/4	-40	236	3/3	-17	133

1 = Site 1 = La L (heavy textured soil)
Site 2 = Yopare (Light textured soil)
2 = 138 days dry and 216 days wet
3 = 137 days dry and 218 days wet

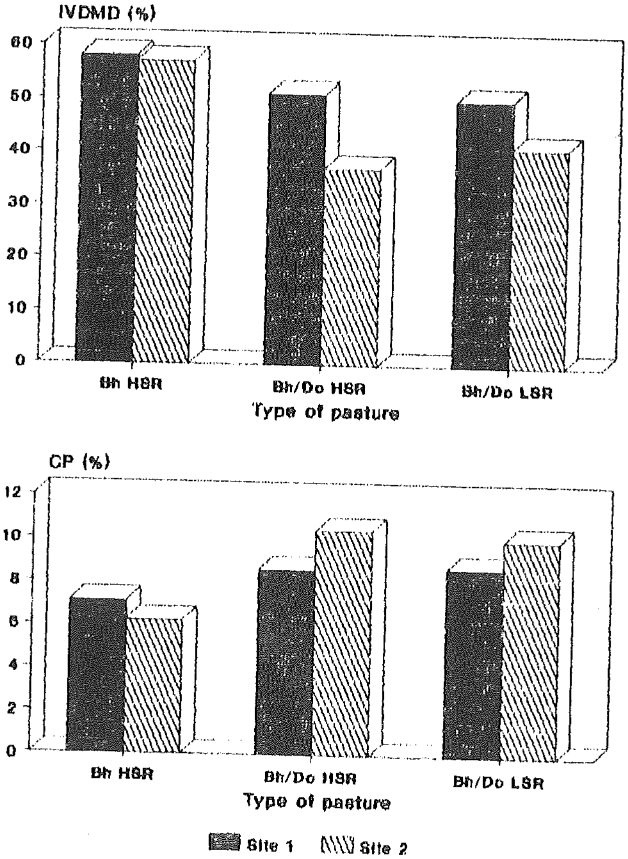


Figure 10. Quality of the diet selected by esophageal fistulated steers grazing *B. humidicola* alone and in association with *D. ovalifolium* 13089 (Site 1 = La L, heavy soil; Site 2 = Yopare, light soil) (Carimagua).

The results obtained so far in this grazing experiment indicate that the association of B. humidicola + D ovalifolium (CIAT 13089) has not been very productive in terms of individual animal performance. In addition, this association can easily become legume dominant, particularly in sites with soils of sandy texture which appear to limit the growth rate of the grass. Under these conditions, increasing rest periods has not helped to maintain a good grass-legume balance in the pasture. In heavy soils the legume content in the pastures has also increased with time, regardless of stocking rate. However, it would seem that in this soil-texture growth rate of the grass is not greatly limited and thus increasing rest period could help to keep a good grass-legume balance in the pasture.

PROTEIN AND ENERGY BANKS IN SAVANNA

Nutritional studies conducted in well drained savanna managed with fire in the Llanos of Colombia, have indicated that low intake of digestible energy limits animal gains. The low intake of energy in savanna is the result of limited availability of forage in burnt areas where cattle spend most of their time grazing. In addition, the forage selected in burnt and unburnt areas is of very low digestibility.

To further test the concept that energy limits the performance of animals grazing savanna managed with fire, two grazing experiments were conducted in Carimagua during 1988 and 1989. In the first experiment, liveweight gains were recorded in steers grazing savanna and savanna complemented with an energy bank (2000 m^2 A^{-1}) comprised of A. gayanus with a small component of S. capitata. The second experiment conducted this year included a comparison of a protein bank (Kudzu - 2.000 m^2 A^{-1}) and an energy bank (A. gayanus + S. capitata - 2.000 m^2 A^{-1}). In both years, two stocking rates were imposed and animals had free access all year-round to either the energy or protein bank. A salt-mineral mix with 8% P was supplemented ad.lib. all year-round. In both experiments, the savanna was rotationally-burnt three times a year (December, April and August).

Liveweight gains of animals grazing savanna and savanna + energy bank at two stocking rate levels (0.25 and 0.50 A ha^{-1}) are presented in Figure 11. In both stocking rates, annual gains were higher (P _ .05) in animals with free access to the energy bank. The increment in liveweight gain due to the energy bank was greater at the low stocking rate (52%) as compared with the high stocking rate (29%). A close analysis of seasonal liveweight gains (see Figure 11) indicates that during the dry season animals only maintained their weight in all treatments. In contrast, during the rainy season there was a clear advantage of the energy bank.

Liveweight gains of steers grazing savanna complemented with a protein or energy bank are summarized in Figure 12. During 362 days, which include 119 days of dry season, gains were not affected by stocking rate, but were 39% higher in animals with access to the energy bank (157 kg/A) as compared with the protein bank (113 kg/A). Contrary to what was expected, the advantage of the energy bank in terms of liveweight gain was observed in both seasons of the year. The dry season of 1989 was very mild and could possibly explain these results.

During the dry and wet seasons of the year, animals have spent a greater proportion of time grazing the energy bank than the protein bank (Table 5). More than 50% of the effective day-light grazing time was spent in the energy bank. In spite of this, animals have not overgrazed the grass at either stocking rate, as shown in Figure 13. It is possible that the relatively good quality of the savanna

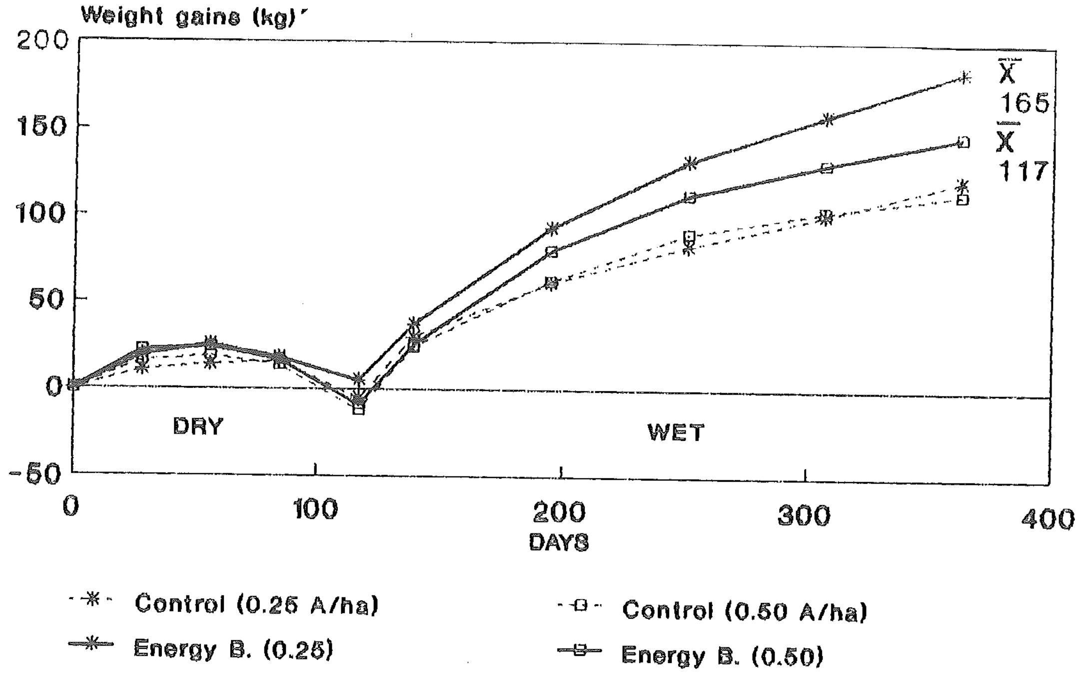


Figure 11. Liveweight gains of steers grazing savanna with and without free access to an energy bank (Carimagua).

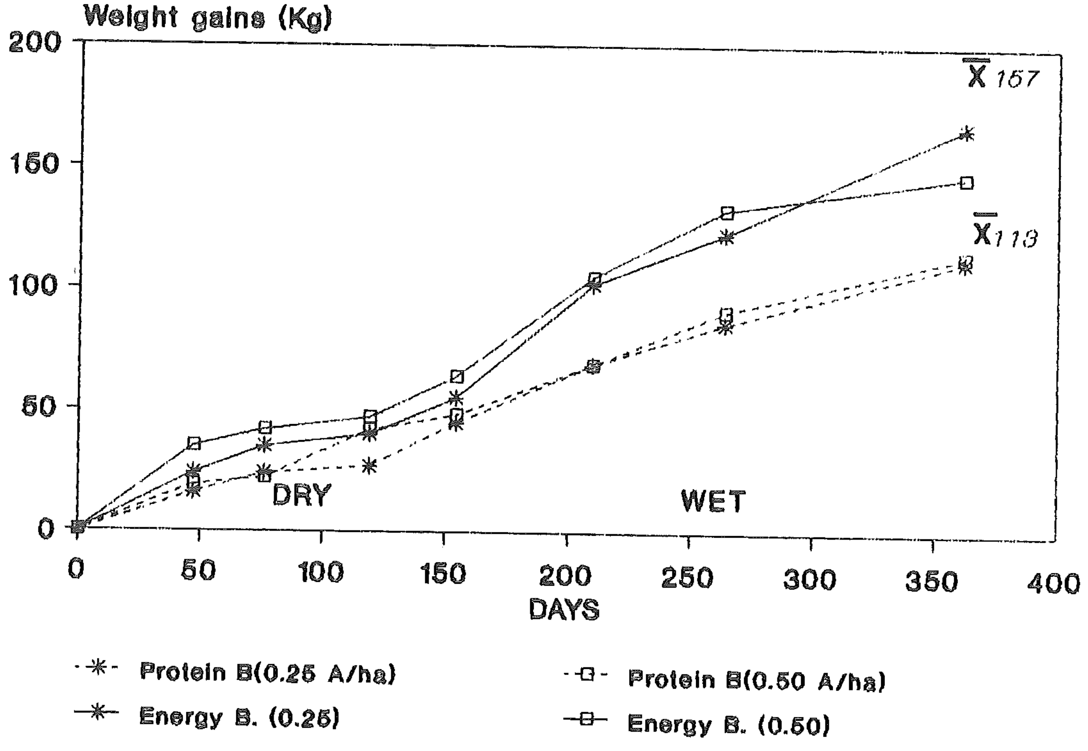


Figure 12. Liveweight gains of steers grazing savanna with free access to a protein (PB) and energy bank (EB) (Carimagua).

Table 5. Grazing behaviour of animals in savanna complemented with a protein bank (PB) or an energy bank (EB) (Carimagua, 1989).

STOCKING RATE	DRY SEASON (%)[1]		WET SEASON(%)	
(A ha^1)	PB[2]	EB[3]	PB	EB
0.25	14	42	12	57
0.50	16	63	18	59
MEAN	15	52	15	58

1 = Proportion of time grazing (6.00-17.00 h)
2 = 2.000 m^2 of <u>Pueraria phaseoloides</u> (Kudzú)/animal
3 = 2.000 m^2 of <u>A</u>. <u>gayanus</u> + <u>S</u>. <u>capitata</u>/animal

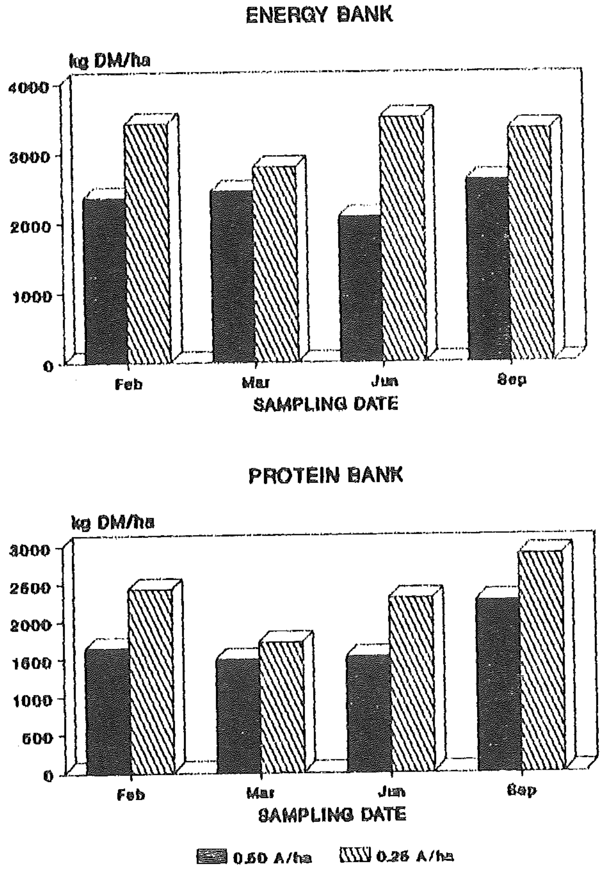


Figure 13. Forage availability in a protein bank (Kudzu) and an energy bank (<u>A</u>. <u>gayanus</u>/<u>S</u>. <u>capitata</u>) managed with free access and used to complement savanna (Carimagua).

used in these grazing studies and the rotational burning system implemented, have resulted in a good utilization by grazing animals of the grass in the bank.

From the data presented, it is clear that large increases in individual animal gains can be obtained in savanna when complemented with small areas of a medium quality grass, such as A. gayanus. One explanation for this response, is the higher digestibility of the improved grass. In the studies reported, the forage selected by esophageal fistulated steers in savanna has averaged 10% CP and 40% IVDMD, whereas in the energy bank the CP and IVDMD of the diet averaged 9.7 and 50%, respectively. The higher digestibility together with more forage availability in the energy bank relative to the burnt savanna should have resulted in an overall increase of dry matter intake. In the case of the protein bank, the diet selected has been high in protein (15%), but low in IVDMD (41%), possibly resulting in low intake.

In summary, it would seem that the best complement for animals grazing savanna in the Llanos of Colombia is a bank comprised of a grass-legume mixture. The grass should provide energy for the animal, particularly during the rainy season, and the legume should provide nitrogen for the grass and protein for the animals during the dry season. Alternatively, one could consider supplementing savanna with a pure legume pasture during the dry season and with a grass-legume pasture during the wet season.

STUDIES ON SELECTIVITY OF Arachis pintoi

Previously it had been reported that legume selectivity by esophageal fistulated animals in associations of A. pintoi (CIAT 17434) with Brachiaria spp. was high all year-round. As a consequence, protein and in vitro digestibility of the diet selected in these pastures was more than adequate to meet requirements of high producing animals (see 1987 Annual Report). To further study selectivity of A. pintoi in association with a grass, an experiment was set up to compare legume selection by resident-intact and none-resident-esophageal fistulated animals. With both types of animals, the proportion of legume in the diet was estimated by analyzing the ratio of $13_C/12_C$ in the feces.

The percentage of legume selected by none-resident and resident animals is presented in Figure 14. On the average, the legume proportion in the diet was less ($P < .05$) for resident animals (29%) than for none-resident esophageal fistulated steers (41%). It is interesting to note that differences between groups of animals were small in the November and December sampling periods. However, when the permanent animals were replaced by new ones in late December, the differences in legume selectivity between groups became very large in subsequent sampling periods. These results suggest that consumption of A. pintoi under grazing is dependent on previous adjustment of the animals to the legume, of at least 6 months. The animals sampled in November and December of 1988 had been in the B. dictyoneura/A. pintoi pasture since May of the same year. The higher selection of A. pintoi by none-resident esophageal fistulated steers can only be explained by the fact that these animals are continously being used to sample grass-legume pastures, including mixtures with A. pintoi.

In this study it was interesting to determine if legume percentage in the diet estimated through analysis of extrusa samples by stereoscope readings and $13_C/12_C$ ratio were similar. Results presented in Figure 15 show a high correlation ($r=.97$ $P < .001$)

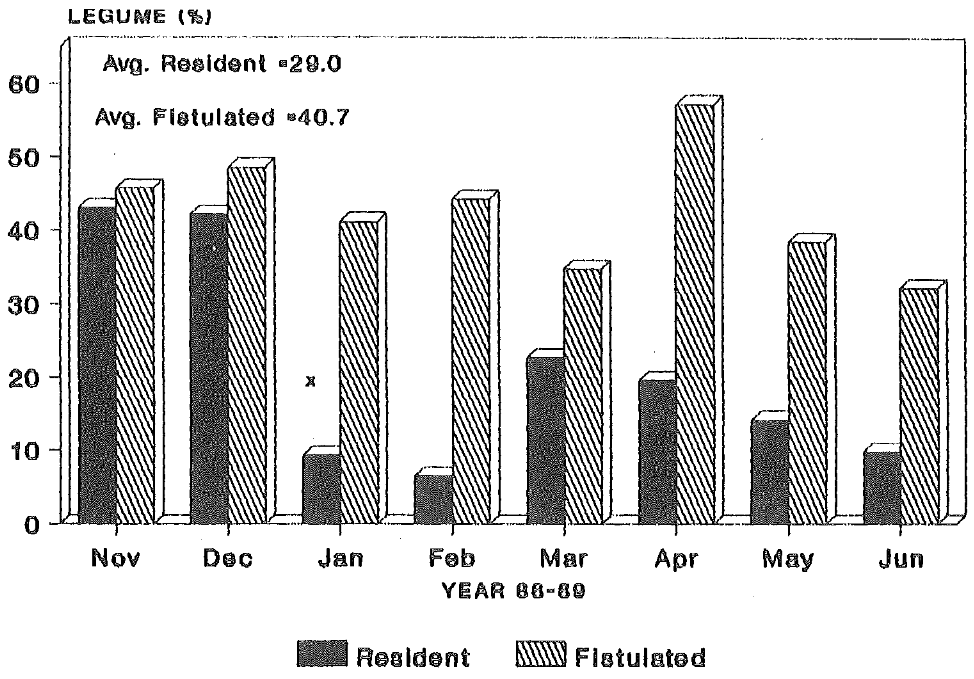


Figure 14. Legume selectivity by resident-intact animals and by fistulated - none-resident animals grazing a *B. dictyoneura*/*A. pintoi* pasture (selectivity estimated by $13_C/12_C$ in feces) (Carimagua).

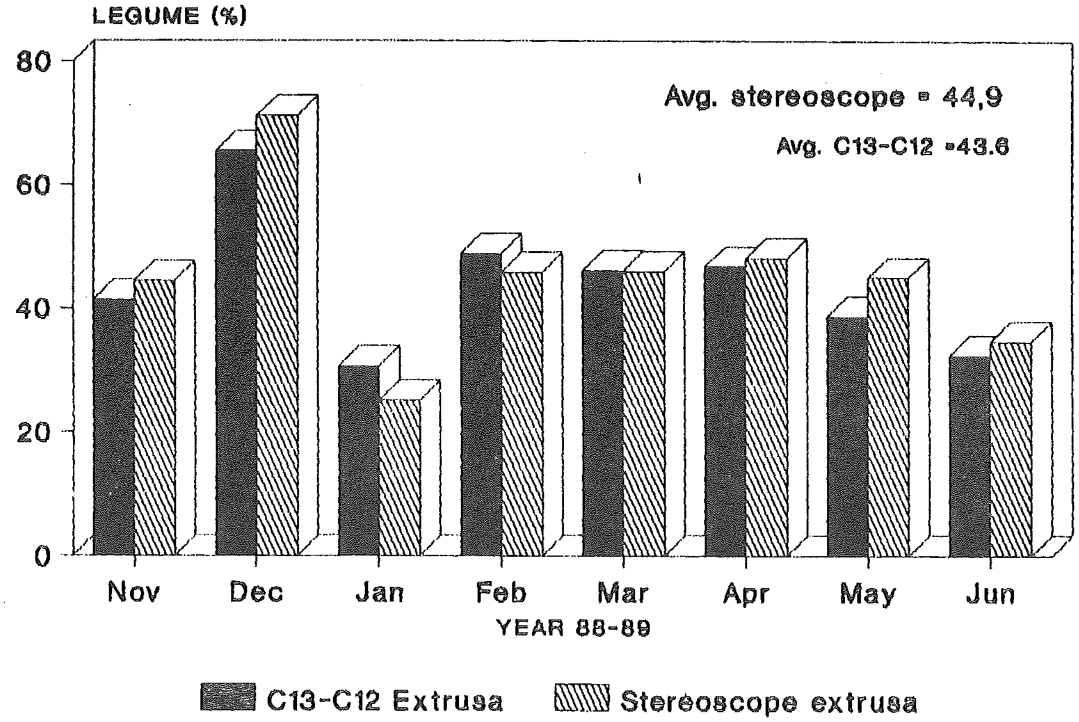


Figure 15. Legume selectivity by fistulated none-resident animals grazing a *B. dictyoneura*/*A. pintoi* pasture (selectivity estimated by reading extrusa with a stereoscope and by $13_C/12_C$ in extrusa) (Carimagua).

between methods. On the other hand, estimates of legume proportion in the diet of fistulated animals obtained by reading extrusa samples in a stereoscope and by $13_C/12_C$ ratio in feces, were similar in absolute terms (Figure 16) but were poorly correlated (r=+.44 NS). However, the correlation between methods (r=+.71 P < .05) was higher when the data was expressed as legume selection Index (% legume diet/% legume pasture). These results indicate that estimates of percentage of A. pintoi in the diet obtained by readings of extrusa samples in a stereoscope using the hit-point method are accurate, but do not represent the diet selected by the permanent animals used to monitor liveweight gains.

As expected, the high selectivity of A. pintoi by esophageal fistulated animals resulted in a diet with high levels of protein and IVDMD in the dry and wet season (Figure 17). Voluntary dry matter intake was also very high (2.6% of body weight) and varied very little between seasons of the year (Figure 17).

The results presented in this section, confirm the high quality of A. pintoi in terms of nutrient concentration and potential intake. However, to achieve this high intake potential it appears that the animals should be previously adapted to the legume. This would not be a problem in commercial pastures, but it does have research implications. The adaptation period by the animals of at least 6 months suggested by this study could result in an underestimation of the potential productivity (i.e. animal gains) of A. pintoi based pastures if animals are changed every year, as is the case in our research at Carimagua.

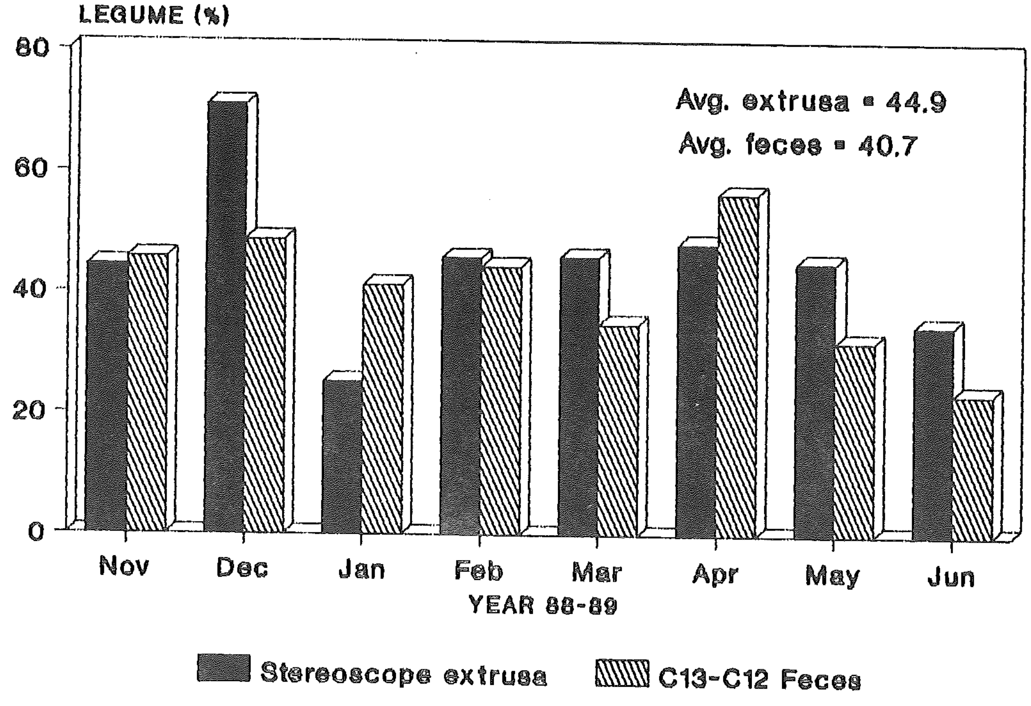


Figure 16. Legume selectivity by fistulated none-resident animals grazing a B. dictyoneura/A. pintoi pasture (selectivity estimated by reading extrusa with a stereoscope and by $13_C/12_C$ in feces (Carimagua).

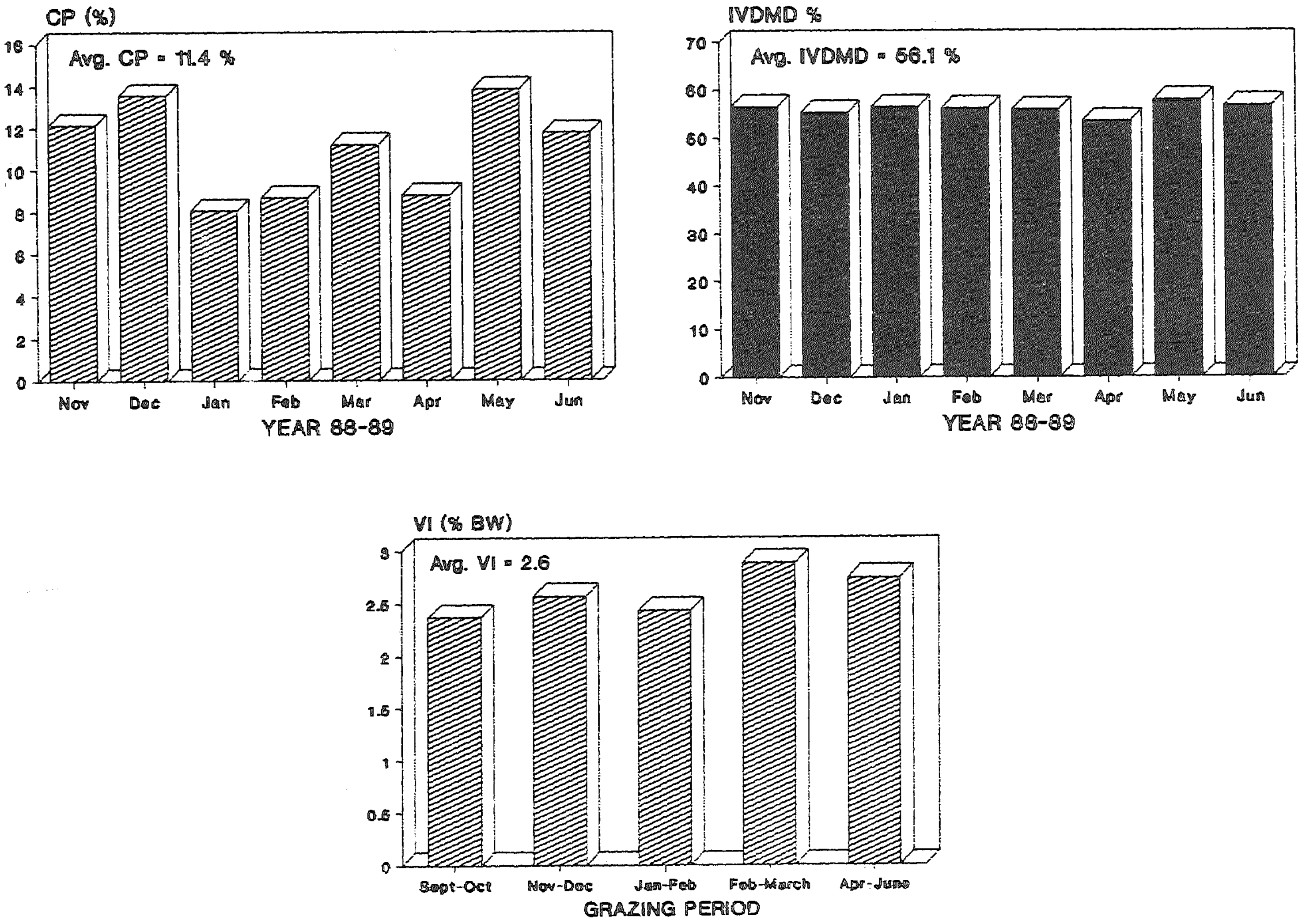


Figure 17. Quality of the diet and voluntary intake of fistulated none-resident steers grazing a B. dictyoneura/A. pintoi pasture (Carimagua).

HEIGHT OF A. gayanus AND PERSISTENCE OF S. capitata

One limitation of S. capitata cv. Capica when in association with grasses such as A. gayanus, is that seedling have low vigour (i.e. dwarf). This lack of vigour of seedlings of Capica has been associated with competition by the grass for soil nutrients (i.e. potassium). A working hypothesis put forward by the program was that the vigour of seedlings of S. capitata could be increased if the legume was associated with a less competitive genotype of A. gayanus.

The Plant Breeding Section of the Program selected three clones of A. gayanus of lower stature than the commercial cv. Carimagua 1 (CIAT 621). These three clones together with the commercial cultivar were established in small plots in Carimagua in association with Capica. One year after establishment, the pastures were rotationally grazed (3.5 days on and 24.5 day rest) at two intensity levels (avg. 2.7 and 3.2 UA ha^{-1}). Two of the clones of A. gayanus (no. 06 and 12) were shorter (P_.05) (Figure 18) and 33% less productive in terms of leaf than the commecial cultivar. As expected, the height of all entries of A. gayanus was significantly affected by stocking rate.

The dynamics of mother plants of S. capitata was not affected by stocking rate or clone of A. gayanus (Figure 19). The mother plants of Capica disappeared exponentially by the end of the second year after establishment, confirming the bi-annual nature of this legume and its dependence for persistence on seedling regeneration from soil-seed reserves.

The dynamics of seedlings of Capica in permanent transects was determined in the rows were the legume and the grass were planted. The number of seedlings per m^2 in the legume row was adjusted with a cuadratic model (Figure 20), whereas in the grass the best fit was with a cubic model (Figure 20). In both the legume and grass rows, the number of seedlings (avg. $24/m^2$) was greater even before grazing began, in the association of A. gayanus No. 12 with high stocking as compared with the other treatments (avg. $16/m^2$), which was possibly related to establishment.

An important criteria to define seedling vigour of S. capitata is height, which was measured in permanent transects in the legume and grass rows (Figure 21). The height (cm) of seedling vs. days under grazing, adjusted with a cubic model, was not affected by treatments. The maximum height of seedlings (14 cm) was observed at the begining of the rainy season in the third year. This average height of seedling of S. capitata is considerably greater than that found in the same period in other studies (4 cm) in Carimagua.

The average height of seedlings of S. capitata observed by the end of the grazing study, does not reflect lack of vigour. It is possible that a reduction in stocking rate imposed at the begining of they rainy season in all pastures under rotation favored the growth of seedlings of Capica. One can speculate that the low vigour of Capica seedlings usually observed in grazed pastures (i.e. A. ganaus, B. decumbens, savanna) is more a reflection of high intake and mechanical damage due to trampling by the animal than to competition per se with the grass for soil nutrients.

In summary, the results of this study suggest that there would be little advantage in selecting a low stature genotype of A. gayanus in terms of seedling vigour of S. capitata. On the other hand, the dynamics of the seedling population (number and height) described in this study provide some clues on possible establishment and grazing management strategies which

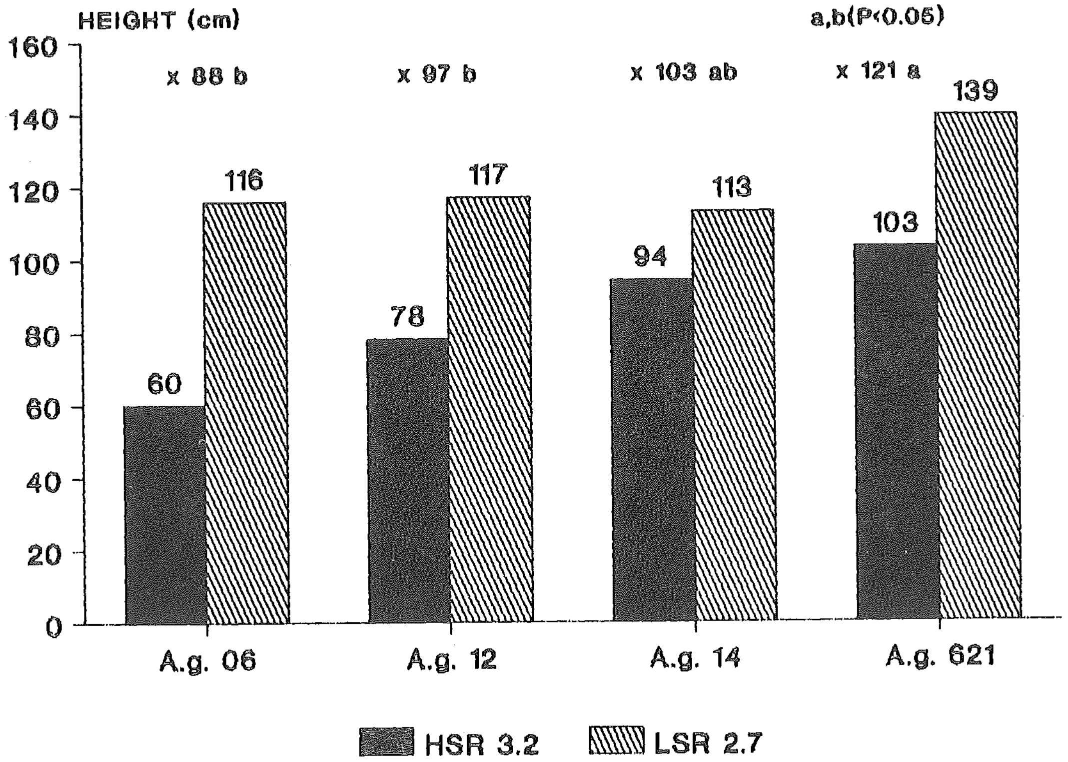


Figure 18. Height of different clones of Andropogon gayanus managed with low (LSR) and high stocking rate (HSR) (Carimagua).

could be implemented to enhace the productivity and persistence of Capica. One possibility is to plant the grass and legume in the same row to prevent overgrazing and mechanical damage of the seedlings. Grazing management of association with Capica should probably include strategic spelling of the pastures at the begining of the rainy season to favor seedling development and thus legume persistence.

ON-FARM PASTURE EVALUATION

As indicated last year, the Pasture Quality and Productivity Section got involved in on-farm pasture evaluation research in the Llanos of Colombia. What follows is a progress report on activities in the farms during 1988-89.

Planting of experimental pastures. One objective of the work in farms is to evaluate the productivity and persistence of pastures with grasses and with grass-legumes mixtures. During 1988 and 1989, a total of 15 ha of pure grass (B. dictyoneura), and 37 ha of grass-legume associations (B. dictyoneura with C. acutifolium, S. capitata, D. ovalifolium) were planted in 4 farms of the Llanos. Plantings done in 1988 are currently under grazing and liveweight gains and botanical composition of the pastures are being recorded.

In general, the establishment of grass and legumes have been sucessfull in most farms. In some cases the

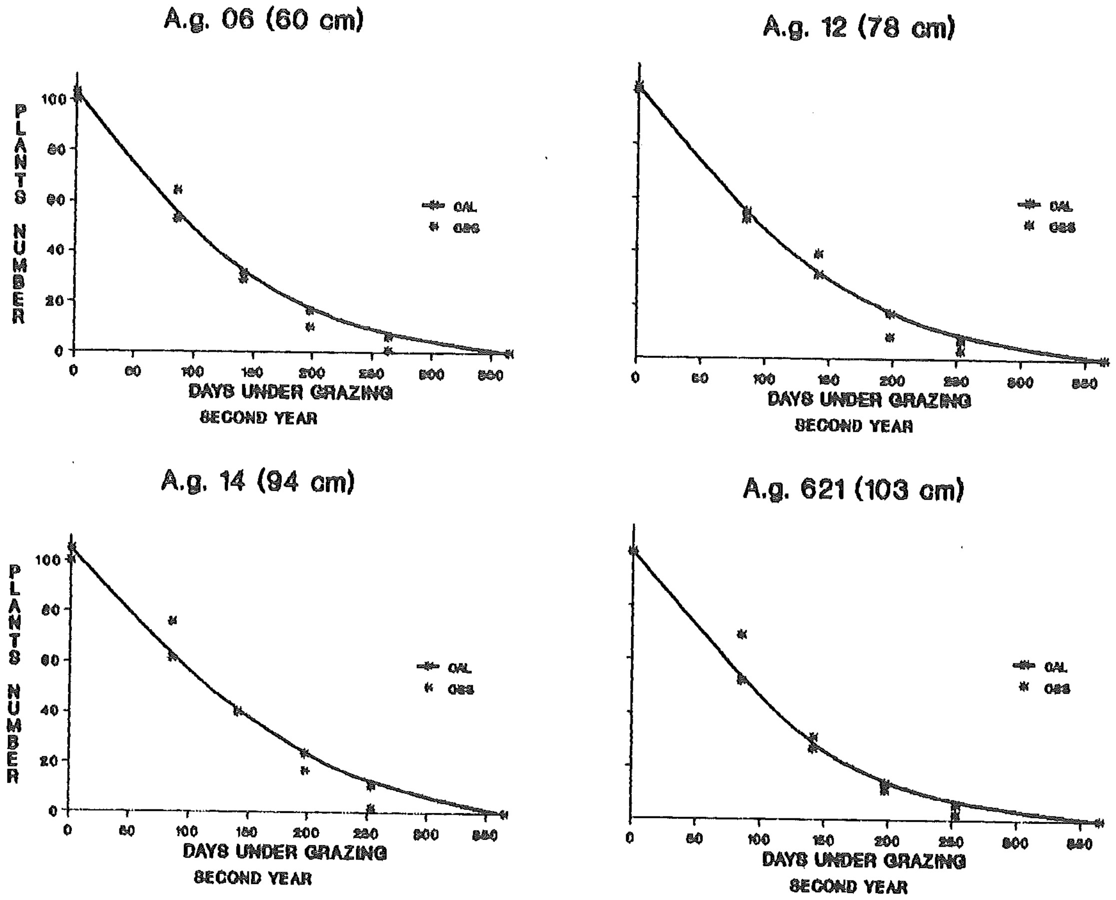


Figure 19. Dynamics under grazing of mother plants of *S. capitata* cv. Capica in association with *A. gayanus* of different stature (high stocking rate treatment) (Carimagua).

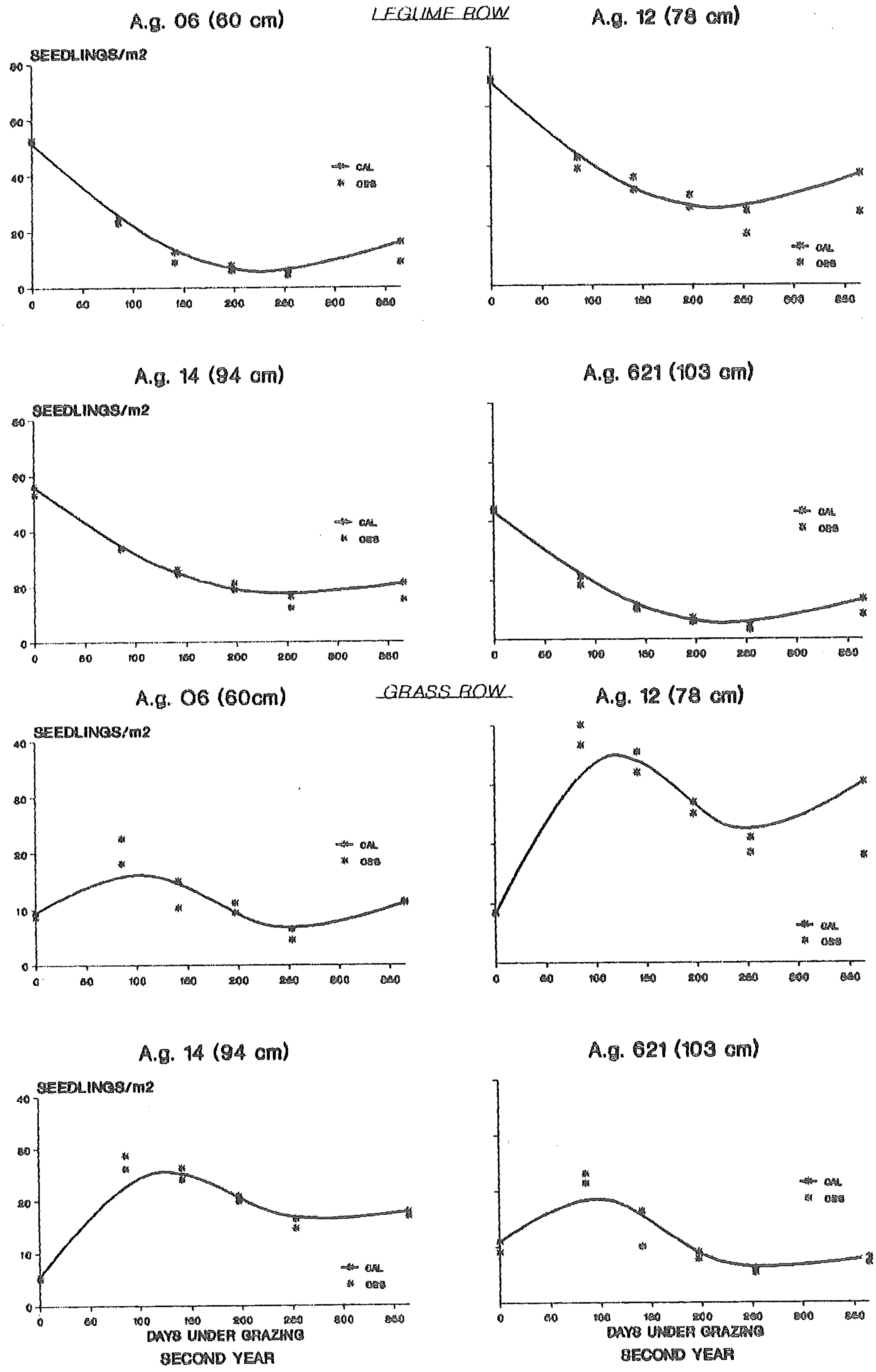


Figure 20. Dynamics under grazing of seedlings of *S. capitata* cv. Capica (seedlings/m^2) in association with *A. gayanus* of different stature (high stocking rate treatment) (Carimagua).

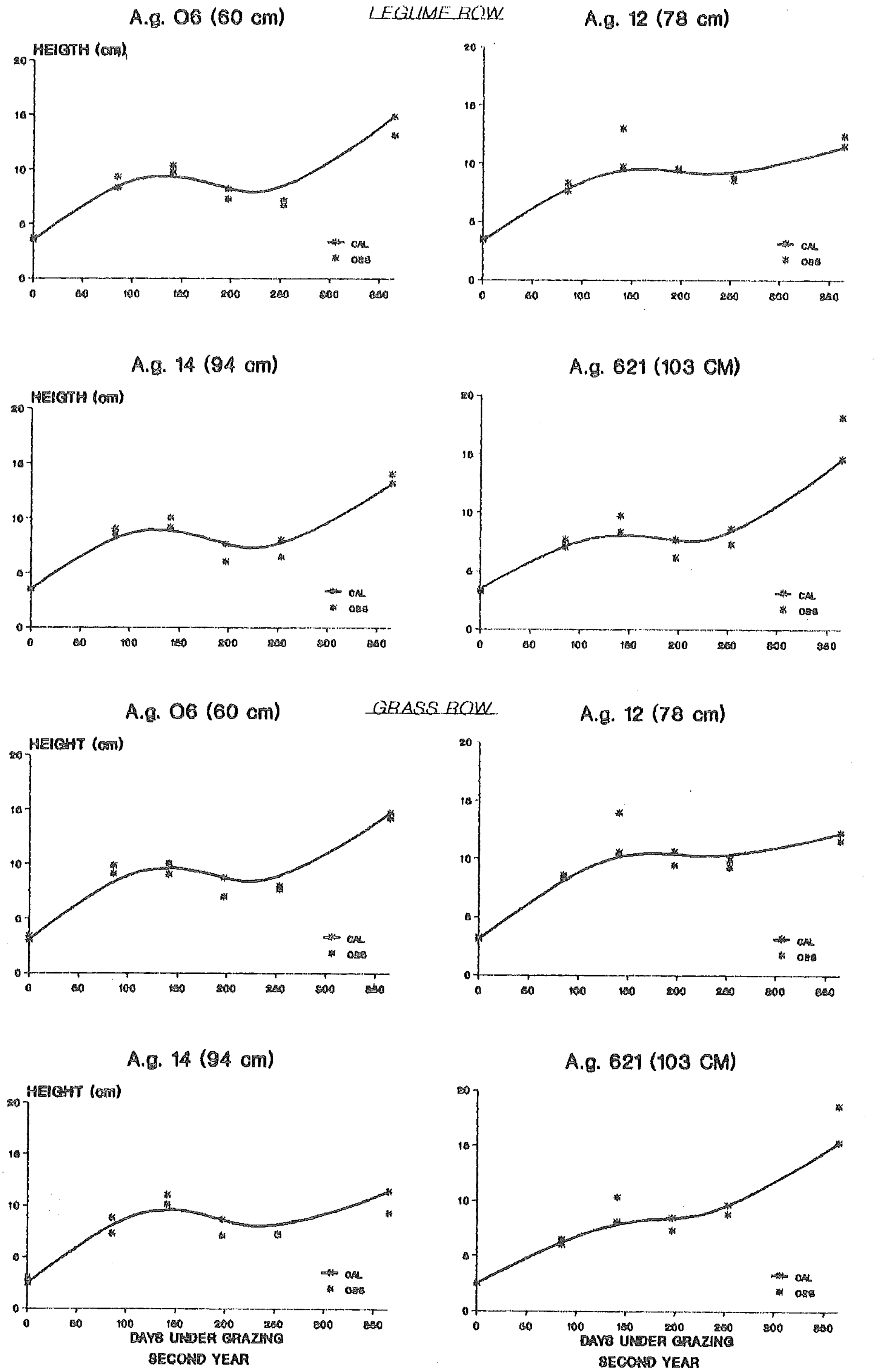


Figure 21. Height under grazing of seedlings of S. capitata cv. Capica in association with A. gayanus of different stature (high stocking rate treatment) (Carimagua).

germination of B. dictyoneura cv. Llanero has been very slow and in the more sandy sites there have been clear defficiencies of Mg and K in C. acutifolium cv. Vichada, since farmers fertilize only with P sources. Ants have also been a problem, particularly in pastures established near gallery forest.

Monitoring of commercial pastures. In order to get some idea of how farmers manage their improve pastures, a total of 101 pastures (44% grass alone and 56% grass-legume) are being monitored in 14 farms in the Llanos. These farms are distributed in a gradient of soil texture and fertility (Table 6). The greatest proportion of the pasture being monitored are in light-textured soils (56%), which have less organic matter, Mg and K and Al saturation as compared with the more heavy soils. In contrast, the P content of the sandy soils is higher than in the clay and clay-loams soils.

On each pasture being monitored a record is kept on the type of animals grazing, days of ocupation and rest and equivalent stocking rates used during the occupation period. In addition, measurements on forage availability and botanical composition are done 4 times a year and where possible a record is kept on liveweight gains.

The grazing management of the improved pastures being monitored is quite variable. An example of the type of grazing and stocking rates being used in some pastures is presented in Table 7. The grazing system varies from continuous to rotational, with deffered grazing, a form of rotational grazing, being a common system. The equivalent stocking rates used are variable, but in general they would seem lower than those used in grazing experiments at Carimagua. Finally, it has been interesting to observe that most grass and grass-legume pastures being monitored are grazed for short periods during the dry season (Table 8), with exception of new pastures of B. dictyoneura cv. Llanero. In our experiments at Carimagua grazing is done all year-round with seasonal adjustments of stocking rate.

Table 6. Soil analysis in pastures being monitored in the Llanos of Colombia.

SOIL TEXTURE	OM (%)	pH	P (PPM)[1]	Ca	Mg	K	Al saturation
				(Meq/100 g)			(%)
Clay (14%)[2]	3.4	4.0	1.8	.19	.073	.064	92.6
Clay-loam (30%)	2.3	4.1	2.3	.27	.066	.062	86.2
Sandy clay loam (16%)	1.8	4.1	2.8	.17	.034	.040	85.5
Sandy loam (40%)	1.2	4.2	3.4	.17	.035	.040	82.4

1 = Bray II.
2 = Number in parenthesis refers to percentage of farms within each soil texture.

Table 7. Grazing management of some pastures in farms of the Llanos of Colombia.

PASTURE	TYPE OF GRAZING	STOCKING RATE/ GRAZING PERIOD (UA/ha)	OCCUPATION[2] (%)
A. gayanus			
+ C. brasilianum	Deffered[3]	4.2	23
+ Capica	Alternate	1.7	100
+ Capica	Continuous	0.4	100
B. decumbens			
+ Capica	Continuous	1.4	100
+ Capica	Deffered	0.8	70
Pure	Continuous	0.6	100
B. humidicola			
Pure	Rotational (4P)	1.8	87
Pure	Deffered	0.7	73

1 = IUA = Lactacting cow + calf (350 kg LW)

2 = % occupation = $\frac{\text{Days of grazing}}{\text{Days of evaluation}} \times 100$

3 = Pastures are rested for variably periods of time

Table 8. Utilization during the dry season of pastures being monitored in farms of the Llanos of Colombia

PASTURES	No. OF PASTURES	DAYS OF OCCUPATION (dry season)
A. gayanus	3	16 (13%)[1]
A. gayanus/ Capica	9	34 (28%)
B. humidicola	3	19 (16%)
B. decumbens	4	67 (56%)
B. dictyoneura	3	120 (100%)

1 = (% occupation)

17. Seed Production

INTRODUCTION

The objectives of the Seed Production Section are:

1. To conduct seed multiplication of promising accessions to provide experimental and basic seed for the Program's activities.

2. To conduct applied research upon the most relevant limitations to seed production technology of the key species (to the Tropical Pastures Program and the RIEPT) and of new cultivars released by national institutions.

3. To contribute to seed supply development (including experimental, basic and commercial seeds) of various forage species and cultivars, within the tropical countries of Latin America.

During 1989 the major activities of the Section included: seed multiplication by both internal and third party mechanisms; seed distribution; applied research; documentation; technical collaboration and training.

This report describes progress made in this diverse and dynamic range of activities.

SEED MULTIPLICATION

Traditionally the principal mechanism for generating seeds for the Program has been for the Section to conduct internal (or self) multiplication. In the last three years, however, a strong emphasis has been given to broadening procurement mechanisms, especially by third party multiplication via share farming agreements and production contracts. The effects of this strategy can be seen in this years results. Total aggregate seed received by the Program increased significantly to approximately 12.8 tons, of which approximately 80% was produced by third parties (or collaborating multipliers).

A) Internal (or self) Multiplication

As in previous years, field production activities were conducted at Quilichao with only a very minor presence at Carimagua. Support activities such as, greenhouse propagation, seed conditioning, seed analysis and seed storage were centered at Palmira.

The multiplication of legume species and accessions is summarized in Table 1. A total of 56 accessions of 18 species were under some level of multiplication, principally *Centrosema* spp., *Desmodium*, *Pueraria* and *Stylosanthes* spp. New multiplication areas of totally 1.2 ha were established to provide a total of 17 ha under seed crop management. Composite seed produced amounted to 1.890 kg, including significant amounts of *C. brasilianum*, *C. macrocarpum*, *D. ovalifolium* and *S. capitata*.

The multiplication of grass species and accessions is summarized in

Table 1. Summary of internal multiplication activities of legume species and accessions between October 1988-89.

Species	Accessions	Multiplication Areas			Seed produced[1]
		New	Established	Total	
	(no.)	(ha)	(ha)	(ha)	(kg)
Centrosema acutifolium	2	-	0.206	0.206	27.6
Centrosema arenarium	1	0.100	-	0.100	0.1
Centrosema brasilianum	7	0.258	1.046	1.304	499.0
Centrosema macrocarpum	3	0	1.27	1.27	420.0
Centrosema pubescens	1	-	0.106	0.106	64.9
Crotylia floribunda	1	-	0.002	0.002	6.4
Desmodium heterophyllum	1	-	0.075	0.075	0
Desmodium ovalifolium	14	0.84	7.606	8.44	171.6
Desmodium strigillosum	1	-	0.020	0.020	-
Diochlea guianensis	3	0.010	0.024	0.034	8.0
Flemingia macrophylla	2	-	0.128	0.128	2.2
Leucaena leucocephala	3	-	0.018	0.018	9.0
Pueraria phaseoloides	7	-	0.173	0.183	18.5
Stylosanthes capitata	6	-	3.5	3.5	632.9
Stylosanthes scabra	1	0.010	-	0.010	-
Tadahagui triquetium	1	-	0.004	0.004	-
Zornia latifolia	1	-	0.003	0.003	-
Arachis pintoi	1	-	1.51	1.61	30.1
Total 18	56	1.218	15,79	17.00	1,890.3

1/ Clean seed, with a pure seed content of 90% min.

Table 2. A total of 27 accessions of 12 species were under some level of multiplication involving 15 ha under seed crop management. Composite seed produced amounted to 834 kg, almost all of which was *B. dictyoneura*.

The total amount of composite seed produced by internal multiplication activities was 2.724 kg, of which approximately 70% was of legumes and approximately 30% was of grasses, (Table 3).

B) Third Party Multiplication

Production contracts were entered into eight seed enterprises and share-farming arrangements were conducted with five graziers or grazier organization. As a result of these activities, an aggregate total of 21 tons of seed was produced. Of this, approximately 10 tons was received by CIAT, including 7.7 tons of legumes and 2.3 tons of grasses. These complex activities are summarized in Table 4, and dealt with in greater detail under another heading (see, Seed Supply Development, Eastern Plains of Colombia).

C) Summary

The nett composite volume of seed generated for the Program use totalled

Table 2. Summary of internal multiplication activities of grass species and accessions between October 1988-89.

Species	Accessions	Multiplication Areas New	Multiplication Areas Established	Multiplication Areas Total	Seed produced[1]
	(no.)	(ha)	(ha)	(ha)	(kg)
<u>Brachiaria</u> <u>dictyoneura</u>	1	-	11.7	11.7	828.6
<u>Brachiaria</u> <u>decumbens</u>	2	-	1.11	1.11	
<u>Brachiaria</u> <u>humidicola</u>	3	-	0.31	0.31	
<u>Brachiaria</u> <u>brizantha</u>	4	-	1.71	1.71	
<u>Andropogon</u> <u>gayanus</u>	2	-	0.015	0.015	1.0
<u>Melinis</u> <u>minutiflora</u>	4	-	0.016	0.016	1.2
<u>Panicum</u> <u>maximum</u>	6	-	0.230	0.230	3.0
<u>Paspalum</u> <u>coryphaeum</u>	1	-	0.004	0.004	0.3
<u>Paspalum</u> <u>secans</u>	1	-	0.004	0.004	0.1
<u>Paspalum</u> <u>guenoarum</u>	1	-	0.004	0.004	-
<u>Pennisetum</u> <u>purpureum</u>	1	-	0.004	0.004	-
King grass	1	-	0.030	0.030	-
Total 12	27	-	15.137	15.137	834.2

1/ Clean seed with a pure seed content of 70% min.

Table 3. Summary of internal multiplication activities of legume and grass species and accessions, between October 1988-89.

Family	Species	Multiplication Areas Accessions	Multiplication Areas New	Multiplication Areas Established	Total	Seed produced[1]
	(no.)	(no.)	(ha)	(ha)	(ha)	(kg)
Legumes	18	56	1.218	15.79	17.00	1890.3
Grasses	12	27	-	15.13	15.13	834.2
Total	30	83	1.218	30.92	32.13	2724.5

1/ Clean seed with a pure seed content of 90% min. for legumes, and 70% min. for grasses.

Table 4. Summary of seed produced by third party multiplication (contracts or share farming agreements), between October 1988-89.

Species/Accession or Cultivar	Total Seed Produced (kg)	Seed Distribution[1] To CIAT (kg)	To Grower (kg)
a) Legumes			
S. capitata cv. Capica	12,872	5,062	7,810
C. acutifolium cv. Vichada	1,790	1,616	174
C. macrocarpum CIAT 5713	998	978	20
Desmodium ovalifolium CIAT 13089	109	109	-
Subtotal:	15,769	7,765	8,004
b) Grasses			
B. dictyoneura cv. Llanero	5,439	2,292	3,147
B. brizantha cv. La Libertad	228	8	220
Subtotal:	5,667	2,300	3,367
c) Composite Total	21,436	10,065	11,371

1/ Clean seed with a pure seed content of 90% min. for legumes and 70% min. for grasses.

approximately 12.8 tons. Of this approximately 75% was legumes and approximately 25% was grasses. The relative contribution to the aggregate volumes by internal and third party multiplication was 21% and 79%, respectively, (Table 5).

D) Revision of activities for the period 1974-89

The Seed Production Section was formed in 1974. Seed multiplication has always been the priority activity of the Section because of the ever increasing demands for seeds (both for experimental purposes and basic seed) of a ever changing and increasing array of species, accessions and cultivars, by the Program and the RIEPT.

Traditionally, the principal mechanism for generating seeds for the Program was for the Section to conduct internal (or self) multiplication with resources of the Section and those of CIAT in general. During a ten year period, 1974-1984 this was how the Section operated. The composite totals of seeds produced ranged between 300 and 9.954 kg/yr with an average of approx. 3.4 tons/yr. In the same period, the average volume of

Table 5. Summary of seed generated for the Tropical Pastures Program according to production mechanism, between Octubre 1988-89.

Production Mechanism	Seed received by Program[1]			
	Legumes (kg)	Grasses (kg)	Total (kg)	(%)
1. Internal multiplication	1,890	834	2,724	21
2. Third party multiplication	7,765	2,300	10,065	79
3. Aggregate Total	9,665	3,134	12,789	100

1/ Clean seed with pure seed content of 90% min. for legumes and 70% for grasses.

seeds produced per accession under multiplication was approx. 60 kg/yr.

From 1985, the Section began to involve itself in alternative production mechanisms. Firstly, starting in 1965, it participated in a few share-farming arrangements with early adopting graziers of S. capitata near to Carimagua via the provision of a combine for harvesting. Secondly, in collaboration with the Seed Unit, it began entering into production and purchase contracts with a few selected seed enterprises for the production of S. capitata and Centrosema spp. This production mechanism has been progressively expanded, involving the Section in the provision of extensive technical assistance to multipliers and in the establishment and operation of a Rotating Fund for Seed Production and Promotion. By 1989, the proportion of seeds received by the Program generated by third parties (collaborating multipliers) had increased to 80%, while the volume of composite seeds received by the Program reached a record 10 tons. In addition, a significant number of novice multipliers have been introduced to the nature of commercial seed production of the new cultivars by their involvement in these production contracts.

Seed multiplication activities during the period 1974-89 are summarized in Tables 6 and 7 and presented graphically in Figures 1 and 2.

SEED DISTRIBUTION

During the year the Section responded to 292 requests for seeds. The vast majority of requests were related to germplasm and pasture evaluation research projects of the Program.

A composite total of approximately 5.6 tons of seeds were distributed, including 1.400 kg of grasses and 4.197 kg of legumes, (Table 8).

Seeds distributed from the new Rotating Fund for seed production and promotion totalled 3,814 kg with a value of US$43,934 (Table 9). This operative procedure is new, and is still being refined. Despite initial resistance from researchers accustomed to receiving seed as a fully subsidized (free) input, this enlightened policy is not only promoting more seed availability for research, but is

Table 6. Summary of the evolution of seed multiplication activities (accessions, areas and multipliers) between 1974 and 1989.

Year	Accessions			Seed Multiplication Areas			Collaborating Multipliers
	Grasses (No.)	Legumes (No.)	Total (No.)	Grasses (ha)	Legumes (ha)	Total (ha)	
1973-74				2.8	6.7	9.5	0
1974-75						26.4	0
1975-76						25.3	0
1976-77	5	65	70			8.5	0
1977-78	2	33	35			15.0	0
1978-79	2	37	39			51.0	0
1979-80	2	31	33				0
1980-81	9	64	73				0
1981-82	8	61	69				0
1982-83	22	108	130	10.2	17.8	28.0	0
1983-84	20	94	114	12.7	17.3	30.0	0
1984-85	34	115	149	11.2	20.6	31.8	0
1985-86	35	107	142	13.4	24.4	37.8	3
1986-87	32	74	106	15.9	19.6	35.5	2
1987-88	27	53	80	16.1	19.3	35.4[1]	
	2	2	4	27.6	9.0	36.6[2]	6
1988-89	27	56	83	15.0	17.0	32.0[1]	
	2	4	6	86.6	71.2	157.0[2]	10

1/ Internal multiplication.
2/ Via production contracts or share farming with third parties.

contributing to establishing a market for pasture seeds of new cultivars.

Aggregate seed stocks on hand total 4.200 kg. This includes 750 kg of 59 accessions of grasses and 3.450 kg of 350 accessions of legumes, (Table 10). The majority of this seed is of accessions discarded during the continuing process of germplasm evaluation, i.e. they do not appear on the current lists of promising germplasm.

SEED PRODUCTION RESEARCH

A) Dynamics of Flowering and Seed Maturation in B. dictyoneura

Two seed crops at different locations were subjected to different management regimes, and sampled sequentially from commencement of flowering to record inflorescence density, pure seed yield and unit weight, and percent full (pure seed) spikelets. Results are summarized in Figures 3 and 4.

Crop One was submitted to "intensive" management involving a precut by slasher in early May followed by a complete fertilizer dressing (50 N + 20 S, kg/ha) immediately thereafter. Crop Two was "without" management, i.e. did not receive either a precut or fertilizer dressing.

Crop Two commenced flowering on 10 June 1989 and by 10 days post commencement of flowering (DPCF) reached a maximum inflorescence density of approximately 20/m^2. This peak density was then maintained

Table 7. Summary of the aggregate total seed produced for the Program between 1974 and 1989, and the relative contributions from internal and third party multiplication.

Year	Internal Multiplication			Third Party Multiplication[1]			Aggregate Totals[2]		
	Grasses (kg)	Legumes (kg)	Total (kg)	Grasses (kg)	Legumes (kg)	Total (kg)	Grasses (kg)	Legumes (kg)	Total (kg)
1973-74									
1974-75			300						300
1975-76		700	700					700	700
1976-77	401	356	757				401	356	757
1977-78	1,456	1,012	2,468				1,456	1,012	2,468
1978-79	3,385	1,974	5,359				3,385	1,974	5,359
1979-80	5,570	4,384	9,954				5,570	4,384	9,954
1980-81	5,000	3,314	8,314				5,000	3,314	8,314
1981-82	743	3308	4051				743	3,308	4,051
1982-83	1,081	1,146	2,227				1,081	1,146	2,227
1983-84	1,064	1,486	2,550				1,064	1,486	2,550
1984-85	158	671	770				158	671	770
1985-86	380	1,767	2,147	-	410	410	380	2,177	2,557
1986-87	1,662	779	2,442	-	209	209	1,662	988	2,651
1987-88	1,036	822	1,858	1,011	515	1,526	2,047	1,337	3,384
1988-89	834	1,890	2,724	2,300	7,765	10,065	3,134	9,655	12,789

1/ Refers only to fraction of total production received by TPP-CIAT.

2/ Clean seed with a pure seed content of 90% min. for legumes and 70% min. for grasses.

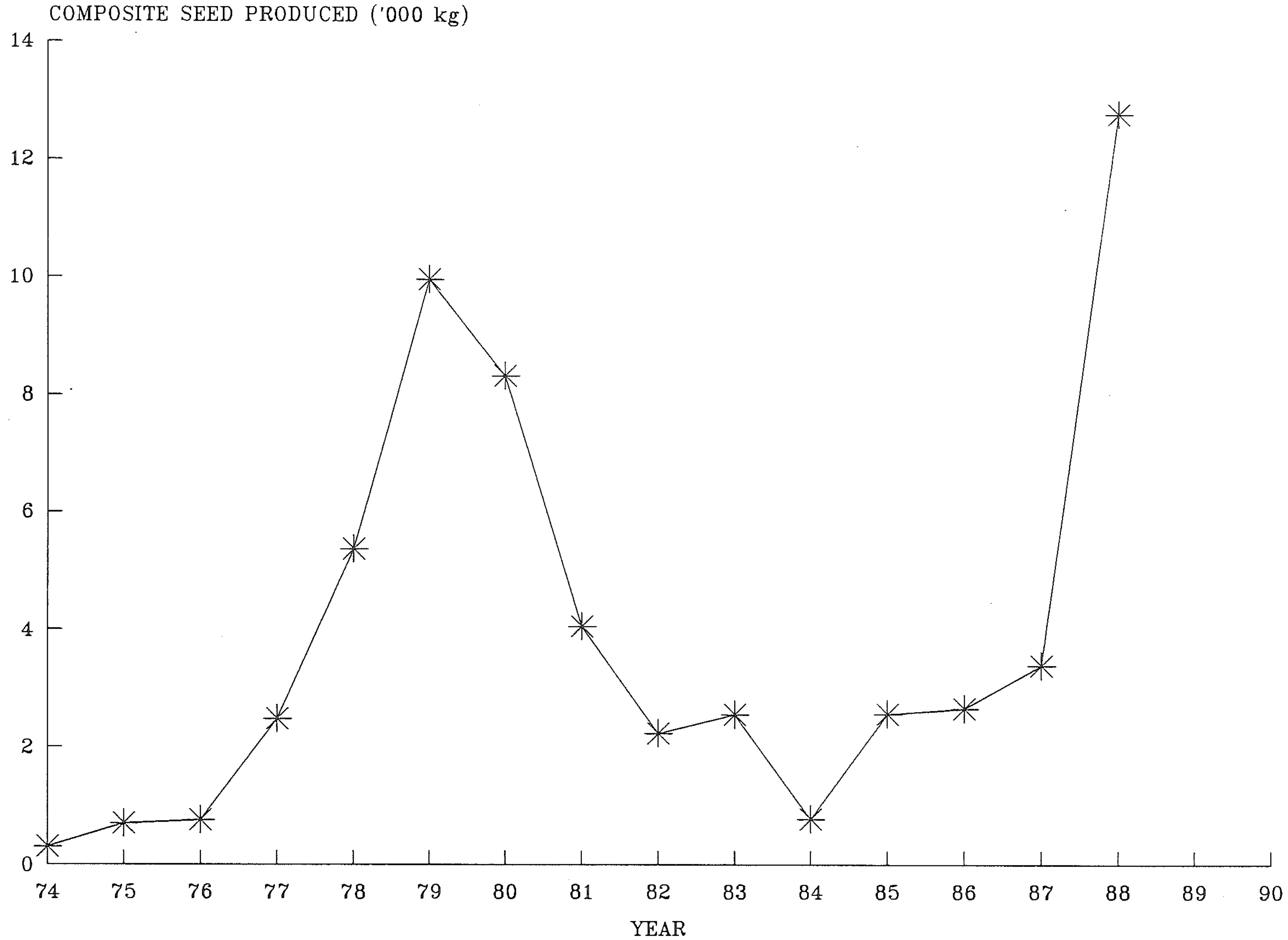


Figure 1. Summary of the evolution of seed multiplication activities. Total composite seed produced by both self and third party seed multiplication mechanisms, between 1974–1989.

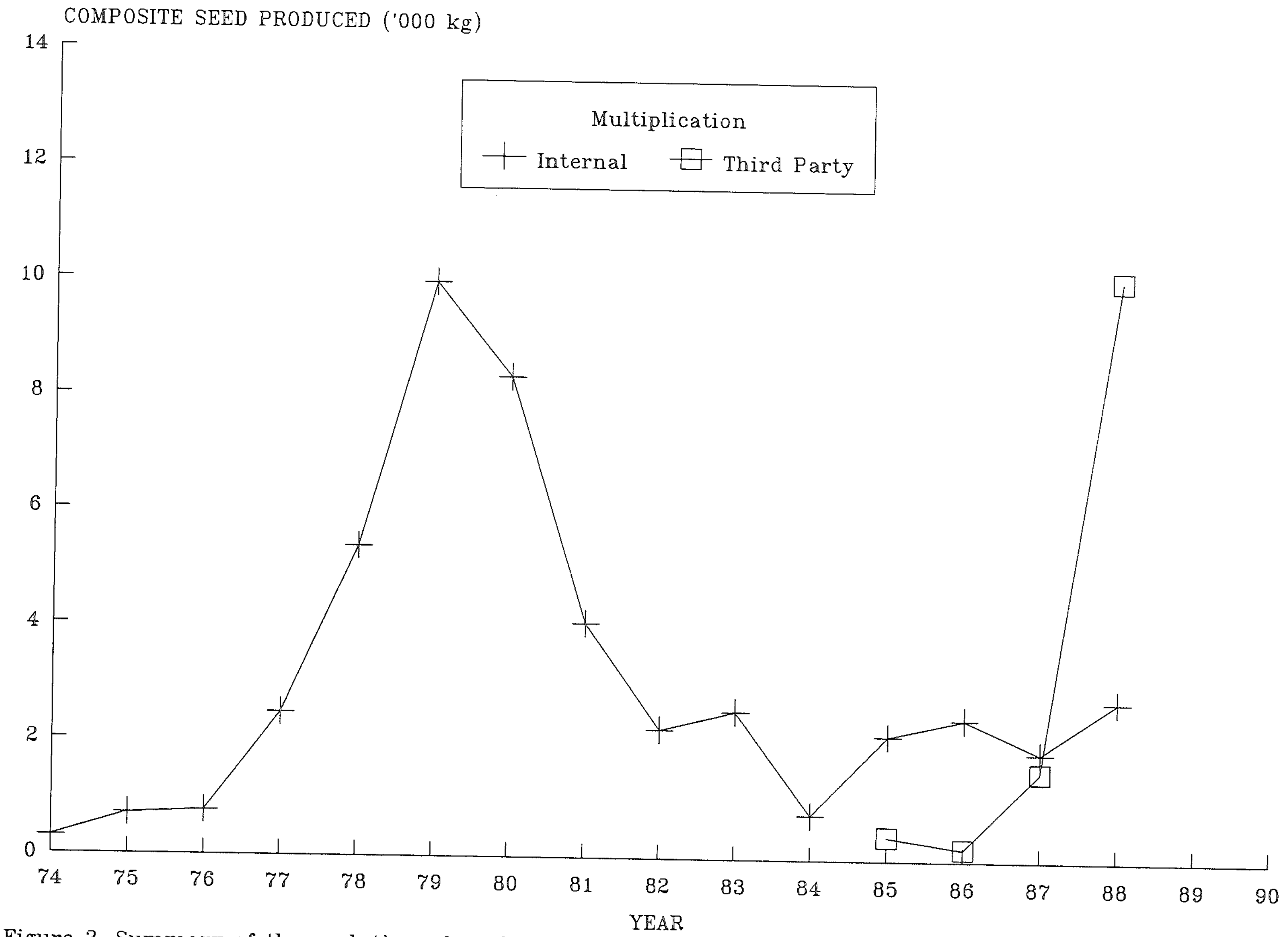


Figure 2. Summary of the evolution of seed multiplication activities showing relative contribution of internal (or self) multiplication and third party multiplication mechanisms, between 1974–1989.

Table 8. Distribution of seeds of grasses and legumes between October 1988-1989.

Seeds Requests Objective/Source		Seed Volume		
	(no.)	Grasses (kg)	Legumes (kg)	Total (kg)
A) Germplasm Pasture Evaluation				
1. TPP Members	84	444	492	936
2. Regional Trials	38	85	83	168
3. National Institutions	65	71	135	206
4. Other CIAT Programs	26	1	108	109
5. Private entities	41	10	125	135
Subtotal:	254	611	943	1,554
B) Pasture Development Projects, Colombia and Venezuela.	30	591	3,223	3,814
C) Seed Multiplication				
1. National Institutions	6	0.5	31	231.5
2. CIAT Seed Unit	2	200	0	200
Subtotal:	8	200.5	31	231.5
D) Total	292	1,402.5	4,197	5,599.5

Table 9. Summary of seed distribution from Rotating Fund for Seed Production and Promotion during 1989.

Client or Stock		Seed Volume			Value
		Grasses (kg)	Legumes (kg)	Total (kg)	(US$)
No.	Description				
1.	TPP - CIAT				
	a) On-farm trials, Caquetá, Col.	50	125	175	2343
	b) On-farm trials, Piedemonte,Col		50	50	767
	c) Cattle Fund, Carimagua, Col.		86	86	1092
	d) Rice/Pastures Project, Col.		44	44	550
	e) On-farm trials, Venezuela	67	1.100	1.167	14271
2.	CRECED, Puerto López, Colombia	300	1,634	1,934	20,013
3.	Seed Enterprises, Colombia				
	a) Seed Production Contracts	68	39	107	1737
	b) Demonstrations of improved pastures	106	133	239	2975
4.	Misecellaneous		12	12	186
5.	Total Sales	591	3,223	3,814	43,934
6.	Seed Stocks on-hand	900	2450	3,350	30,000

Table 10. Summary of existing composite seed stocks, at October 1989.

Family	Species (no.)	Accessions (no.	Composite Seed Stocks (kg)
Grass	8	59	750
Legume	42	350	3,450
Total	50	409	4,200

for a prolonged period. Maximum pure seed yield of approx. 20 kg/ha, occurred at 17 DPCF and was maintained for approx. 8 days before delining markedly as mature spikelets were shed.

Crop One commenced flowering on 25th June 1989. Inflorescence density continued to rise for a prolonged period but reached a high range of 60-80/m^2 at approximately 22-24 DPCF. Maximum pure seed yield in the range of 40-50 kg/ha were recorded at approximately 27 DPCF and was maintained for approximately 3-4 days before declining very markedly as mature spikelets were shed.

In both crops, percent full spikelets increased progressively to reach a peak range, with values of 62-72 by weight and 40-50 by number. These values were reached just prior to the attainment of maximum seed yield. Pure seed unit weight showed a maximum range of 480-550 mg/100 being reached by the time of the maximum inflorescence density. In both crops, the time period between the attainment of peak flowering and the time of maximum seed yield was approximately 7 days.

In summary, the combination of precutting and complete fertilizer dressing favours the attainment of higher inflorescence density, higher maximum seed yields but a shorter period of harvest maturity (only 2-4 days) because of rapid shedding of mature spikelets. Maximum seed yields tended to be recorded approximately 7 days after the attainment of the maximum range of inflorescence density. By harvest maturity, percent full spikelets are 62-72 by weight and 40-50 by number, while pure seed unit weight is in the range of 480-550 mg/100.

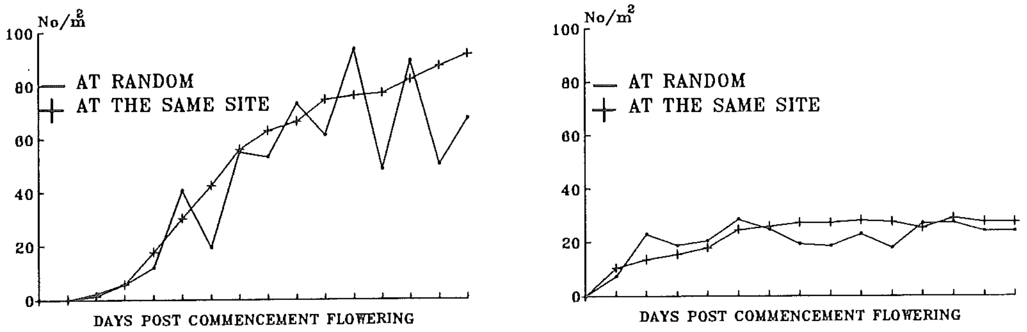
B) Grass Seed Beater Harvestor

Significant expansion of grass seed production, especially of *Brachiaria* spp., is occurring in many countries. The alternatives for harvesting are basically either by hand or combine. As such, these methods are very contrasting in management implications, capital requirements and harvest capacity. A great need exists for intermediate harvesting alternatives.

In the eastern plains of Colombia, *B. decumbens* is harvested commercially by a beater harvestor developed initially by ICA and Semillano Ltda. At CIAT, a joint effort between the Seed Production Section and the Seed Unit has begun to develop general beater harvestor for *Brachiaria* spp., using the Semillano machine as a prototype.

An experimental Model 1, was built in 1987-88. In Model 1 the beater was propelled by a direct drive from supporting wheels, which proved impractical. Model 2 was built in 1988-89 with the beater powered by an

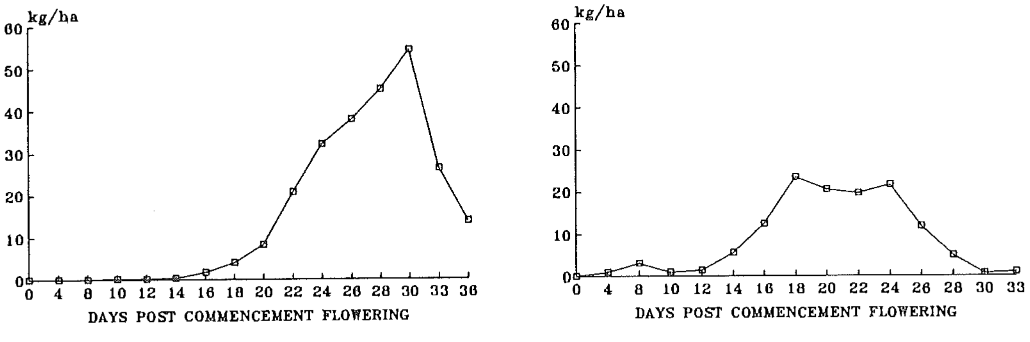
INFLORESCENCE DENSITY



Crop one ("Iraca")

Crop two ("Ocamtal")

PURE SEED YIELD

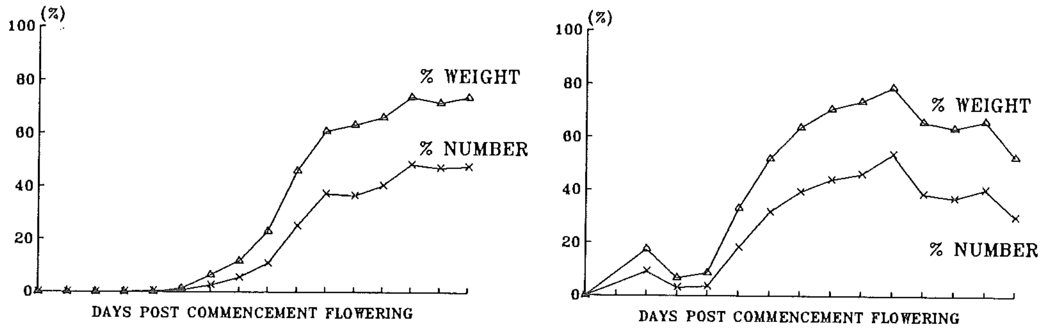


Crop one ("Iraca")

Crop two ("Ocamtal")

Figure 3. Inflorescence density and pure seed yield during flowering and seed maturation of *Brachiaria dictyoneura* in two seed crops.

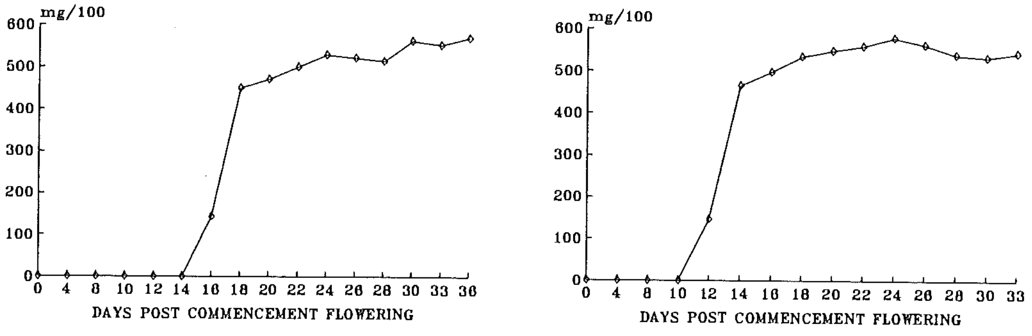
FULL SPIKELETS



Crop one ("Iraca")

Crop two ("Ocamtal")

PURE SEED UNIT WEIGHT



Crop one ("Iraca")

Crop two ("Ocamtal")

Figure 4. Percent full spikelets and pure unit weight during flowering and seed maturation of *Brachiaria dictyoneura* in two seed crops.

electric motor linked to a tractor which also provides support for the beater plus mobility. The machine (Figure 5) was field tested for the first time in July 1989, and operated satisfactorily (see IV-C, Model B).

Plans are now being developed for a Model 3. When finalized, it is planned to construct this model in a commercial workshop in a field situation, most probably Pucallpa, Peru. When that task is achieved, the final plans with a range of options will be made available to seed enterprises and national institutions.

C) Harvesting Methods of Brachiaria spp.

Over the last four years the Section has been committed to harvesting significant areas of seed crops of B. dictyoneura. The Section has taken advantage of these opportunities to make comparisons of alternative harvesting methods and their effects on seed yield and quality.

In the immediate post harvest period, in both 1987 and 1988, physiological seed quality as determined by the tetrazolium test, was not influenced by harvest method, even though manual harvesting was shown to provide lower seed unit weight. At 12 months post harvest, however, germination of manually harvested seed was significantly lower than both combine or beater harvestors (Table 11). This effect, if a general one, would indicate that the combine and beater are more selective for larger and mature cariopses which have greater longevity (i.e. maintain physiological seed quality for a longer period). On the other hand, the manual method may have been conducted with excessive force at time of threshing causing the shedding of many immature spikelets with limited longevity. In addition, it would appear that interpretations of harvest methods on the basis of pure seed yield alone is very questionable.

In July 1989, a further field experiment was conducted comparing alternative harvesting methods, but with the participation of two beater harvestors. These are referred to as Model A, a commercial machine on loan from Semillano Ltda. and Model B, a experimental model from CIAT.

The beaters, in general, harvested crude seed with a higher purity and full (pure seed) spikelets of larger size than manual harvesting. The beaters delivered only half the pure seed yield of the manual methods, Table 12. The range of unit weights of full spikelets over harvest methods was considerable, appproximately 300-600 mg/100, indicating ample scope for selection. In this regard, it is interesting to note that Model B achieved a higher unit seed weight than Model A. Appraisal of physiological seed quality and final conclusions of this experiment will be continued.

The effect of sequencial harvest pass number on pure seed size and yield, as an average of the performance of the two beater harvestors, is presented in Table 13. The first pass delivers the highest seed size and yield, while passes Nos. 2, 3 and 4 do not differ in seed size or yield. Of note however, is that over a seven days period, the beater was consistently delivering high seed size and yield, indicating the potential to capture relatively high cumulative yields of high quality seed from relatively large areas.

CASE STUDIES OF SEED SUPPLY DEVELOPMENT

A) Eastern Plains of Colombia

An improved pastures development project is being organized by ICA-CRECED and CIAT with graziers in the well drained savannas of eastern Colombia. The improved pastures are based principally upon recently

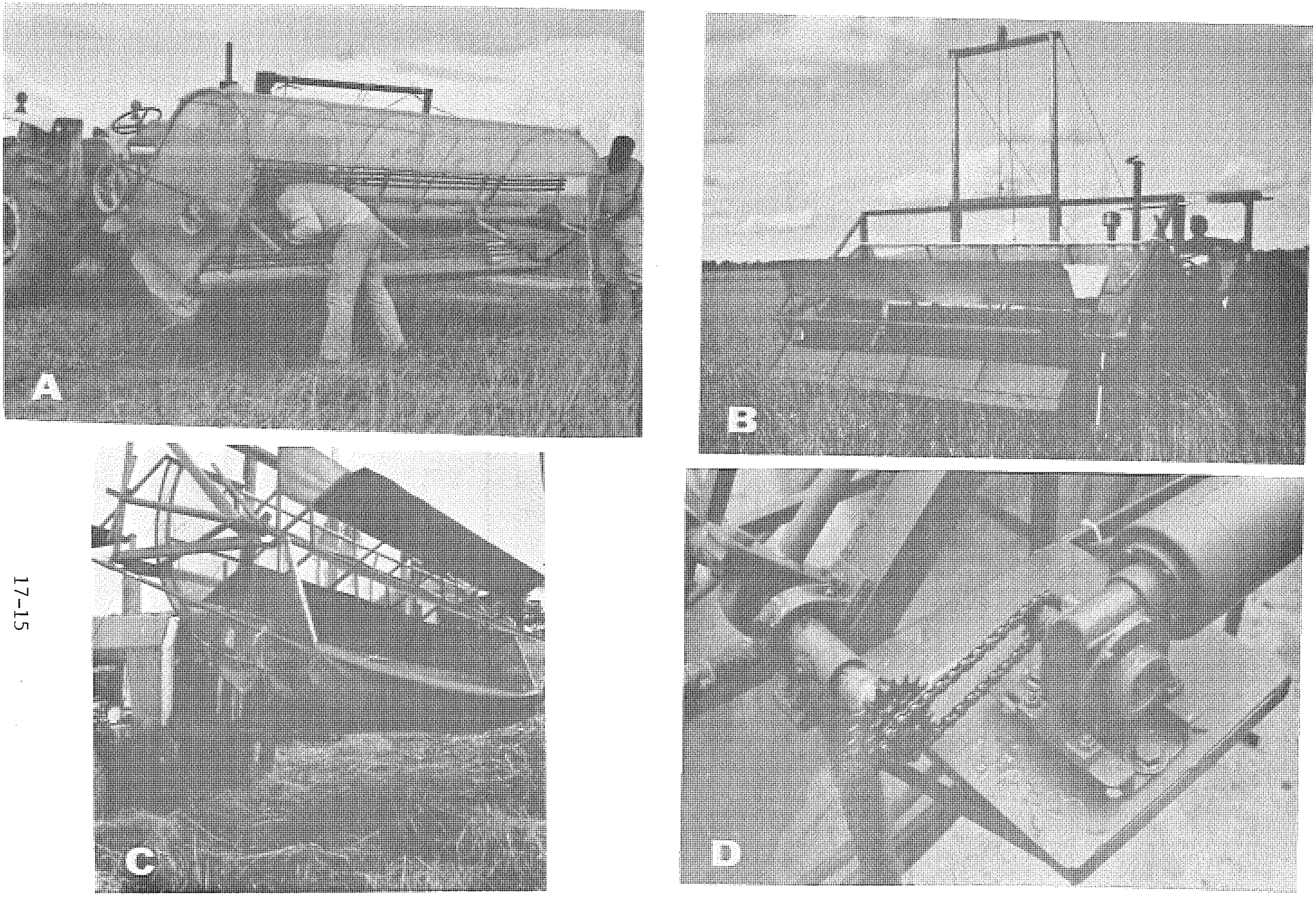


Figure 5. A Commercial beater harvestor of Semillano Ltda. B, C Experimental beater harvestor of CIAT, Model B. D Close up showing electric motor and drive mechanism of Model B.

Table 11. Seed size and quality in Brachiaria dictyoneura, in relation to harvest method.[1]

Harvest Method No.	 Description	Unit Weight Full Spikelets (mg/100)	 Cariopsis (mg/100)	Germination[2] at 12 mo % no.
1	Manual	487 b[3]	244 b	11 b
2	Combine	547 a	297 a	41 a
3	Beater (Model A)	549 a	298 a	46 a

[1]/ Experiment conducted at Hda. La Loma, in July 1988.

[2]/ Plus H_2SO_4 for 30 mins and KNO_3.

[3]/ Means followed by same letter are not statistically different.

Table 12. Purity of crude seed, unit weight and yield of pure seed of Brachiaria dictyoneura, according to harvest method.

No.	Harvest Method[1]	Crude Seed Purity (% wt.)	Pure Seed Unit Weight (mg/100)	 Yield (kg/ha)
1.	Manual, traditional	59.5 cd[2]	495 d	52 abc
2.	Manual, technical	55.5 d	493 d	54 ab
3.	Manual, technical[3]	64.5 c	513 c	60 a
4.	Beater Model A[4]	79.5 b	587 b	33 bc
5.	Beater Model B[4]	85.6 a	608 a	31 c

[1]/ Experiment conducted at Hda. Iraca, via Villavicencio, 18 July 1989.

[2]/ Means followed by same letter are not statistically different at $P < 0.05$ level.

[3]/ At 3 days after No.2.

[4]/ A = Semillano: B = CIAT, each with 4 passes.

Table 13. Size and yield of pure seed of Brachiaria dictyoneura in relation to sequential pass number by beater harvestor.[1]

Sequential Harvest Pass	Pure Seed Unit weight (mg/100)	Pure Seed Yield (kg/ha)
First (18 July 1989)	622 a[2]	10 a
Second (20 July, 1989)	595 b	7 b
Third (23 July 1989)	582 b	8 b
Fourth (26 July 1989)	591 b	7 b

1/ Values presented are means of two models.

2/ Means followed by same letter are not statistically different at $P < 0.05$ level.

released cultivars of Stylosanthes capitata cv. Capica, C. acutifolium cv. Vichada, B. dictyoneura cv. Llanero. At the time of planning this project, the supply of commercial seed of these materials was very limited or zero. Therefore, a seed production project was initiated to generate and deliver seed to the pasture development project and also to promote the expansion of commercial seed production.

This seed project was begun in 1988. The major strategy of the project was to promote the participation of existing or new pasture seed enterprises by means of production and purchase contracts with CIAT. This in turn required the establishment of the operational mechanism of a rotating fund for seed purchases and sales plus the acceptance by researchers and graziers of a monetary value for seed. These are challenging innovations in the institutional and regional environments.

During 1988-89 a total of 14 multipliers located in four different geographic regions of Colombia partici- pated in the seed project (Table 14). Four categories of multipliers are included, these being:

A) Seed enterprises, (eight). The majority of these are in fact agro-livestock supply merchants with little or no expertise in seed production. This has limited their operational capacity and necessitated a heavy input of technical assistance in site selection and seed crop management from the Seed Section and Seed Unit of CIAT.

The modus operandi with the seed enterprises is by means of production and purchase contracts with CIAT. The contract specifies that CIAT will purchase the total production from a specified area of named materials at a fixed price at defined level of quality standards. The contract defines responsibilities for both the multiplier and CIAT and also provides a summary of agronomic practices for seed crop management.

Table 14. Identity and location by geographic region of seed multipliers in Seed Production and Promotion Project, Colombia, 1988-89.

Multiplier		Geographic Region of Colombia			
Group	Name	Cauca Valley	North Coast	Andean Foothills	Eastern Plains
A	Seed Enterprises				
	1 Distribuidora del Valle		+		
	2 Gramicol			+	
	3 Hoechst	+	+	+	+
	4 Pastos y Leguminosas			+	
	5 Semillano			+	
	6 Semilla Pance	+			
	7 Servicampo			+	
	8 Commersia			+	
B	Development or Producer Organizations				
	1 Fondo Ganadero Meta			+	
	2 CRECED, Pto. López			+	+
C	Graziers				
	1 Hda. La Loma			+	
	2 Hda. Paviyay				+
	3 Hda. Paraíso				+
D	Research Institutions				
	1 CIAT - Seed Unit	+			
	- TPP		+		

Basic seed was delivered for planting with costs to be discounted from the value of the first harvest.

When negotiating contacts, all seed enterprises were encouraged to also establish additional seed crops not under contract. In general, of the total area of seed crop established, 50- 75% was under contract.

B) Development or producer organizations, (two). Of these, one is a grazier association and the other is the operational arm of the pasture project (CRECED-Puerto López). Again, both are novice multipliers requiring technical assistance in seed activities sharefarming agreements with the Section. CIAT's main contribution was technical assistance, some inputs, and parcial financing of harvesting.

C) Graziers (three), actually pioneer adopters of improved pastures, interested in expanding their areas of improved pastures. By means of a sharefarming agreement with the Section, they managed their pastures as temporal opportunistic seed crops. CIAT's main contribution was the provision of a combine for harvesting.

As one would expect, not all planted as seed crops resulted in economically viable harvests. Reasons for these included:

a) Lack of appropriate agronomic management (poor site selection, lack weed control, late planting, inadequate fertilization, etc.).

b) Disease stress in the case of C. acutifolium cv. Vichada. Two seed crops were totally lost to a combination of bacteriosis (Pseudomonas fluorescens biotype II), plus a dieback syndrome (unidentified). In addition, bacteriosis reduced seed yields at several other crops.

c) Poor communication, or change of relationship, between contracting seed enterprise and collaborating grazier. Most seed enterprises who contracted with CIAT had to establish additional independent agreements with the collaborating grazier of their choice who provided land or other inputs. Some of these agreements failed, thereby rendering the contract inoperative.

In the first contract year, an aggregate total of approximately 21 tons of composite seeds were produced. Of these, approx. 10 tons were contracted and delivered to CIAT. This included approximately 5 tons of Capica, 1.6 ton of Vichada, 0.9 ton of C. macrocarpum and 2.2 tons of Llanero (Table 15). The project therefore, was outstandingly successful in achieving its production targets while also stimulating the production and availability of seed stocks in commercial channels.

Purchase prices of seed (to multipliers) were aimed at covering estimated costs of production plus a return on capital. Selling prices (to clients) were defined according to market conditions and, if possible, were equal to costs of purchase. In some cases, selling prices were subsidized because of the promotional nature of the pasture development project. In future years, however, any subsidy must be borne by the client pasture development project(s) and not the rotating fund for seeds.

Approximately 2 tons of composite seeds were delivered to CRECED, who assumed responsibility to recover the value from participating graziers. Present indications are that 90% of funds were recovered. In addition, approx. 209 kg of composite seeds were sold to two seed enterprises and a graziers association to allow their establishment of demonstration areas of improved pastures with graziers of their choice.

In the second contract year (1989), eight seed enterprises accepted new production contracts for production targets similar to year one. These seed enterprises all showed a strong interest in expanding production of B. dictyoneura without contracts, clearly indicating their confidence in market demand for this cultivar.

CASE STUDIES OF SEED SUPPLY DEVELOPMENT

B) Humid Tropics, Peru

A collaborative pasture seed project of INIAA, IVITA and CIAT was commenced in 1986. The Section contributes technical collaboration and some finance. A project nucleus was developed at both Tarapoto and Pucallpa.

Seed multiplication was initiated on-station. Due to a total lack of any existing seed enterprises in these regions, seed production was expanded by the project nuclei entering into joint seed production efforts with local small farmer/graziers. In each

Table 15. Summary of seed multiplication areas by geographic region and aggregate seed production by genetic material, during 1988-89.[1]

Genetic Material		Seed Multiplication Areas[2]					Seed Produced	
Group	Name	Cauca Valley (ha)	North Coast (ha)	Andean Foothills (ha)	Eastern Plains (ha)	Total (ha)	Aggregate Total (kg)	Proportion to CIAT (kg)
A	Grasses							
	B. dictyoneura cv. Llanero	-	15	107	57	179	5,439	2,292
	B. brizantha cv. La Libertad	-	-	26	-	26	228	8
B	Legumes							
	C. acutifolium cv. Vichada	6	2	4	-	12	1,790	1,616
	S. capitata cv. Capica			74	153	227	12,872	5,062
	C. macrocarpum CIAT 5713	2	0.6	1.5		4.1	998	978
	D. ovalifolium CIAT 13089			9		9	109	109
	A. pintoi			0.6	0.3	0.9	-	-
	S. guianensis CIAT 184	1	-	-	-	1	-	-
C	Total	9	17.6	222.6	210.3	459.5	21,436	10,065

1/ Participation and activities in Seed Production Promotion Project, Colombia.
2/ Established and under seed crop management as at September 30, 1989.

case an agreement was defined to divide the seed produced in proportion to the value of contribution to the production effort. The project nuclei contributed basic seed, technical assistance, and in some cases, part or fertilizer inputs and participation in harvesting.

The number of such multipliers collaborating with each nucleus is shown in Table 16. The Tarapoto nucleus expanded aggressively in 1986-87 but since then has suffered from a serious erosion of resources (personnel and transport) combined with a lack of participation by the majority of multipliers. The Pucallpa nucleus was able to benefit from this experience and despite also suffering from similar erosion of resources, has achieved more participation from multipliers. Both nuclei now apply more stringent entry requirements to new multipliers, plus a strategy to concentrate expansion with the most successful multipliers.

Total composite seed produced has range between 1-2 tons/gr during the three years of the project, Table 17. This may give the impression that the project is static but this is far from the case. First year figures were boosted by a large harvest and proportion of seed of <u>Andropogon gayanus</u>. Since then, the project has concentrated on other materials, such as <u>S</u>. <u>guianensis</u> and <u>B</u>. <u>dictyoneura</u>. The years 1987-88 and 1988-89 were extremely stressful for the project with a severe deline in the resource base plus a profoundly difficult institutional, economic and social environment. It is to the credit of both nuclei that they have remained active in such adverse circumstances. No expansion of the project can be contemplated until the resource base is significantly improved.

A considerable amount of time was spent this year editing the Proceedings of the Workshop on Tropical Forage Seeds held in Tarapoto in June 1987. For the majority of participants, this was their first experience in the dynamic nature of a genuine Workshop and also their first challenge in writing and documentation. The Proceedings are now published and circulated to the participants and will serve as a point of reference for the seed project but also a milestone in establishing written precedents.

C) <u>National Institutions in Costa Rica, Mexico and Ecuador</u>

In Costa Rica, MAG and CIAT initiated a collaborative pasture seed project in 1987. Multiplication was initiated on the experiment station ("EJN") at Cañas. In 1989, the participants in the project were changed. In addition, the operative strategy was directed towards multiplication with selected graziers. It is planned to conduct a Workshop in early 1990 (similar to the event so productive in Peru), as a means to consolidate this project.

In Ecuador, INIAP and CIAT initiated a collaborative seed project in 1988 with the project nucleus centered at Portoviejo. In 1988, the project was very sucessful in production of approx. 1 ton of <u>Centrosema</u> spp. including 867 kg of <u>C</u>. <u>macrocarpum</u> CIAT 5452. In 1989 production was continued but at a lower level because of a reduction in resources, (Table 18). An attempt to move off-station and initiate multiplication with a few selected graziers was unsucessful, principally for lack of transport.

In Mexico, INIFAP and CIAT initiated a collaborative project in 1987 with the project nuclei centered Iguala and Isla. In addition to seed multiplication, the Iguala nucleus has been active in applied research directed towards alternative support systems and harvesting methods of <u>C</u>. <u>brasilianum</u>. In August 1989, the project coordinator (from Iguala)

Table 16. Number of collaborating multipliers with the two seed project nuclei in humid tropics of Peru between 1986-1989.

Seed Project Nucleus	Multipliers (no.)		
	1986-87	1987-88	1988-89
Tarapoto	8	9	4
Pucallpa	0	7	10
Total	8	16	14

Table 17. Summary of composite seed produced of legumes and grasses in the two seed project nuclei in humid tropics of Peru between 1986-89.

Seed Project Nucleus	Material	Seed Produced (kg)					
		1986-87		1987-88		1988-89	
		A[1]	B[2]	A	B	A	B
Tarapoto	Grasses	1,982	1,500	636	400	377	364
Pucallpa		77	77	194	120	408	285
Tarapoto	Legumes	119	119	16	16	136	136
Pucallpa		108	108	506	450	429	429
	Total	2,286	1,804	1,352	986	1,350	1,194

1/ A = Total composite seed produced by activities of the seed project.

2/ B = Net seed received by seed project.

Table 18. Summary of seed activities by collaborative seed project with INIFAP, Puerto Viejo, Ecuador, in 1988-89.

Material Accession	1988		1989
	Production (kg)	Yield (kg/ha)	Production (kg)
C. pubescens common	209	690	15
C. macrocarpum 5452	867	198	50
C. acutifolium 5277	17	29	8
S. guianensis 184	2	-	
Subtotal	(1095)		
B. brizantha 6780	3	6	4
B. dictyoneura 6133	36	120	
Subtotal	(39)		
Total	1,134		79

travelled to Brazil and participated in a study tour of commercial pasture seed enterprises.

TRAINING

During the year, three professionals participating in the Tropical Pastures Course, conducted their specialization phase in the Section. These professionals came from ICA, Colombia; University of San Simón, Bolivia; and Ministry of Agriculture, Honduras.

18. Livestock Production Systems

During 1989, the activities of the Section involved the continued analysis of pasture components for cattle production in long term experiments set up in Carimagua, and the on farm evaluation of grasses and grass-legume associations. The latter activity has evolved over the years, and during 1989 two major highlights were the increased activity of the CRECED in the Eastern Plains of Colombia and a new set of pastures established in ranches of the Venezuelan savannas in cooperation with FONAIAP.

Reproductive Performance on Brachiaria decumbens

This experiment, now in the seventh year, continues to be monitored. The trial is now reaching a critical stage since the original cows have now attained 10 years of age, a period in which they would begin to be culled in commercial practice. Documentation of their reproductive performance at this and later ages will contribute to clarify the potential role of improved pastures towards lifetime productivity and mortality, which may have economic implications.

In the 1988 report, it was indicated that there was a slight trend for decreasing cow weights with time. An analysis of weights was carried out by fitting a Brody-type growth equation to the liveweights recorded since the beginning of the experiment, as follows:

(Model 1)

$$\text{WEIGHT}_i = A_i\ [1-\exp\ (-K_i * \text{AGE}_i)]$$

for the ith animal, such that i=1,2,...24.

The A_i parameter represents the asymptotic mean liveweight around which mature body size oscillates due to changes in physiological status of the cows, and K_i represents the rate of maturity. Means and standard deviations for both are presented in Table 1.

To test the hypothesis that body weights were decreasing with time, A_i in Model 1 was made a linear function of age, as follows:

$$A_i = B_i - C_i * \text{AGE}$$

and the complete model (Model 2) was refitted to the data.

(Model 2)

$$\text{WEIGHT}_i = (B_i - C_i * \text{AGE}_i)\ [1-\exp\ (-K_i * \text{AGE}_i)]$$

Model 2 fitted the data significantly ($P<0.05$) better than Model 1, thus supporting the initial hypothesis. Descriptive statistics for the respective parameters are shown in Table 2.

The two previous analyses were carried out when cows had had an average of four calvings and had completed three lactations (Table 3).

Table 1. Descriptive statistics for the parameters of the growth equations, Model 1.

	A	K
Mean	388	0.006504
S	56	0.0191737

Table 2. Descriptive statistics for the parameters of Model 2.

	B	C	K
Mean	510	0.04340	0.001697
S	133	0.03682	0.000725

Table 3. Number of calvings and weanings when growth models were fitted to the data.

	No. of calvings	No. of weanings
Mean	4.25	3.67
S	0.85	0.81
Mode	4	3

It is interesting to note that the previously cited decrease of asymptotic weight took place despite having allowed the animals, as maiden heifers, to reach heavy liveweights before joining. As a consequence of the delayed initial mating, the mean conception weight of the heifers was 422±45 kg. Conception eights were closely and positively correlated with mature size (Table 4).

The implications of these correlations is that heifers that conceive at heavier weights tend to reach larger mature sizes. This may certainly reflect inherent differences in size but it may as well suggest that *B. decumbens* by itself is unable to sustain large mature sizes. There is circumstantial evidence that the latter is partly the case.

Table 4. Correlation between heifer conception weight and parameters of the growth equation related to mature size.

Parameter	Model No.	Correlation (r)	P<
A	1	0.84	0.001
B	2	0.44	0.03
C	2	0.12	0.57

Following the above set of analyses, the herd was moved to a recently renovated *B. decumbens* pasture, resulting in rapid increase of liveweights (10-15%), followed again by a new and slow but sustained decline, which suggests that at least under the conditions of the present experiment, the pasture was unable to maintain large cow weights unaltered. Nevertheless, it should be mentioned that a relatively high stocking rate has been used throughout the experiment (mean of 1.6 AU ha^{-1}) and that no adverse effects have been detected in terms of reproductive performance (see 1988 Report). Additional weights in different physiological conditions are shown in Table 5.

Table 5. Weigths of cows grazing B. decumbens in different physiological stages.

Gestation No.	Weight of cow at:		
	Conception[1]	Calving[2]	Weaning
1	421	452	354
2	415	411	341
3	378	388	369
4	369	418	356

1/ 7 days postconception on average
2/ 60-75 days precalving on average

Reproductive Performance on Brachiaria humidicola

As indicated in previous annual reports one of the economically less attractive uses of sown pastures in extensive ranching systems, is the use of costly forages for improving beef heifer nutrition and growth.

Thus, the aim of the current experiment, already described in previous reports, was to determine the long term effects of sustained low growth rates on reproductive performance. New statistical analyses carried out in the past year have clarified trends observed in previous analyses. Regardless of growth rate, all heifers tended to conceive for the first time at similar weights and, consequently, at ages inversely proportional to growth rate (Table 6). Despite the lack of differences in mean weight at conception between treatments, the cumulative proportion of heifers conceiving as a function of liveweight differed significantly between treatments. This trend was detected following the analysis of the so-called survival function ("survival" is here defined as the fraction of animals not yet pregnant). Plots of the survival function against conception age suggested that the Cox's proportional hazard model was appropriate. When the latter was fitted to the data using a lognormal distribution, the effect of treatment (= growth rate) was significant; this effect was due almost exclusively to the lowest growth rate, clearly indicating that the relationship between age at conception and weight in that treatment differed from the rest. In conclusion then, it was found that a single logistic regression of cumulative conceptions on weight was insufficient to account for the effects of previous treatment.

Table 6. Mean weight (CONWGT) and age (CONAGE) at first conception.

Rate of growth	CONWGT (kg)	CONAGE (months)
Low	288a	40.8a
Medium	282a	35.5b
High	282a	34.5b
High 2	300a	36.7b
Se	33	4.7

Vertical means followed by different superscripts are significantly different ($P < 0.05$).

The latter not only affected initial conceptions but also influenced the shape of the subsequent growth curve of the animals. To study the growth curves, a Gompertz equation was fitted to the data of each animal, as follows:

(Model 1)

$$WEIGHT = 31 * \exp [D * (1-\exp (-C*AGE))]$$

where 31 is the assumed birthweight and AGE is expressed in days. Upon analysis of the parameters of Model 1 it was found that most of the between-animal, within-treatment, variation was associated with differences in asymptotic weight (in turn due to the D parameters).

Thus, a more compact model (Model 2, not shown) incorporating a single C per treatment and maintaining individual D's per animal was fitted to the data, without significantly worsening the fit (P>0.10). The most important and unexpected implication of this analysis was the significant (P>0.05) increase in asymptotic weights with decreasing initial growth rates (Table 7). Thus, heifers that grew at very low rates (<100 g.day^{-1}) until reaching 250 kg LW, and subsequently kept in low quality pastures, were able to attain significantly higher mature sizes (although still low in absolute terms) than heifers that grew at more acceptable rates (250-300 g.day^{-1}). The explanation of this unexpected finding resides in the delayed conception of the former, that led to a positive within-treatment correlation between age and conception (Table 8), whereas in the remaining treatments such correlation was inexistent. Thus, delayed growth led to a disproportionate delay in first conception which in turn allowed the animals to reach higher liveweights than otherwise.

Table 7. Mean asymptotic weights estimated upon fitting Gompertz growth equations (Model 2).

Rate of growth	Asymptotic weight (kg)
Low	350 a
Medium	332 ab
High	325 b
High 2	320 b
Se	30

Means with different letters differ significantly (P< 0.05)

Table 8. Within-treatment correlation between weight and age at conception.

Rate of growth	r	P <
Low	0.80	0.001
Medium	-0.06	0.84
High	0.01	0.96
High 2	0.08	0.76

As described in the 1988 Report, a second temporal replication of the experiment is available. Upon reaching a target weight of 270 kg each of the three herds was subdivided. One half of the animals was transferred to *B. decumbens* pastures to allow improved gains, whereas the rest remained in *B. humidicola* pastures. This design allows testing the hypothesis that compensatory growth in the better pastures will be followed by improved reproduction also, thus furnishing an alternative role for pastures differing in quality. The aim of having animals with widely divergent liveweights, as consequence of manipulating their nutrition under realistic grazing conditions, has been attained, judging from the data presented in Table 9.

Reproductive performance of these animals is being monitored.

Table 9. Mean liveweights at the end of two periods (kilograms).

Rate of growth in:		Liveweight at end of	
1st period	2nd period	1st period	2nd period*
High	High	295	408
High	Low	295	373
Medium	High	292	398
Medium	Low	292	320
Low	High	228	364
Low	Low	228	310

* July 1989, 2 years after the end of 1st period.

Early Weaning

Rearing of weaned, 3-month old, cebu calves on sown grass-legume pastures has been under investigation for several years, with very modest results in terms of growth rate and the expected positive results in terms of reproductive performance. Given that the experimental pastures were located in a poorly drained area, it was hypothesized that the observed poor weight gains were partly due to water logging during the rainy season.

In mid-1988 a new experiment was setup in collaboration with the Pasture Quality and Production Section, which includes three pastures located in two replications. The treatments (pasture association) are as follows:

1. A. gayanus - C. acutifolium - C. brasilianum - S. capitata
2. B. dictyoneura - A. pintoi
3. B. dictyoneura - C. acutifolium - C. brasilianum - S. capitata

Each experimental unit has 2 ha, subdivided into four paddocks to allow rotational grazing (7/21 days) with a stocking rate of 5 calves.ha^{-1}.

Grazing begun in August 1989 with 95 days-old calves, with an initial liveweight of 93 kg. A contemporary (control), group of calves remained suckling their dams, grazing native savanna.

Although the pastures established very successfully and forage availability was ample, calf mortality on the two B. dictyoneura-based pastures was very high (12 out of 40 calves died) in the first three months and grazing was discontinued. There is preliminary evidence that voluntary forage intake in these pastures was extremely low, and calf deaths were attributed to starvation.

It is therefore thought that young, weaned, calves as used in this experiment, will require pastures of higher quality and acceptability than those presently available to achieve satisfactory performance. On the other hand, there is already limited evidence that somewhat older and heavier (five month old) calves have acceptable weight gains in A. gayanus-based pastures; this alternative has to be further explored.

The Family Unit

As indicated in previous reports, the main pasture of the Family Unit based on A. gayanus - P. phaseoloides established in 1979 began to degrade in the period 1987-1988 as consequence of very severe grazing pressure by dual purpose cows. Also, in 1988 the Family Unit completed a cycle of four years operating as a dual purpose (milk and beef) production system.

In mid-1989, the old A. gayanus-based pasture was substituted with a new association. Half of the area (11.5 ha) was subjected to minimum tillage and a Brachiaria dictyoneura cv Llanero - Centrosema acutifolium cv Vichada - C. brasilianum CIAT 5234 - Stylosanthes capitata cv Capica was established in rows. The grass was established vegetatively and the legumes from sexual seed. The remaining half of the paddock was tilled by conventional means and the same mixture was planted, with the addition of Arachis pintoi which was also established vegetatively.

In the meantime, new plans are being discussed for the Family Unit, to be implemented in 1990.

Technology Validation and Transference

As reported in 1988, ICA created and implemented a regional extension and training center for the well-drained savannas of Colombia under the name of "CRECED de la Altillanura". The Livestock Production Systems Section contributes to the activities of the CRECED in order to document the methodologies being used for pasture technology transference in the region. Furthermore, the on-farm pasture research activities of the section are also covered under the umbrella of the CRECED, with an increasing involvement of ICA's professional staff.

Numerous activities were carried out in 1989 by the CRECED. Field days, visits and short courses involved over 500 participants, including graziers, students and technical assistants. A special effort was made to reach technical assistants associated with credit agencies and banks with the aim of linking the newly available pasture species and management, to the development agents.

Simultaneously, technical assistance has continued to be made available to individual ranchers. This strategy was slightly modified in 1989 to reach a larger number of graziers than in the past, but with somewhat smaller areas of sown pastures per ranch. Given the continued low supply of legume seed by the established commercial sector, a large volume of seed was made available to a local graziers association at commercially competitive prices. The species involved were B. dictyoneura cv Llanero, S. capitata cv Capica and C. acutifolium cv Vichada. These species, together with B. decumbens and A. gayanus available in local markets, were established with the technical assistance of the CRECED in 70 ranches, for a total of 1100 hectares (range 1-200 ha per ranch). Roughly 75% of this area was sown with grass-legume associations, and the rest with pure stands intended for on-ranch seed multiplication. In decreasing order of importance, the main associations established were:

- B. decumbens - S. capitata
- A. gayanus - S. capitata
- B. dictyoneura - S. capitata
- B. dictyoneura - C. acutifolium

With most of the efforts in 1988-89 dedicated to strengthening the CRECED, on-farm pasture monitoring during those two years decreased to a minimum. Nevertheless, the original A. gayanus-S. capitata associations established in 1979-81 in 7 ranches have been continuously monitored for botanical composition, with the main objective of documenting legume persistence. The data are presently being analyzed. Monitoring pasture utilization and animal performance decreased even further over the period examined, and was restricted to some of the newer associations with C. acutifolium as the legume component, and to A. gayanus-S. capitata in very sandy soils. These data are also being analyzed.

On-Farm Pasture Evaluation in Dual Purpose Systems

This is a new project jointly implemented by the Livestock Production Systems and Economy Sections, in cooperation with ICA and the Technical University of Berlin (TUB), and partly financed by GTZ. The objective of the project is to test grass-alone versus grass-legume associations in small farms with dual purpose cattle, in order to determine the potential contribution of associations to milk production. Other expected benefits are a more thorough understanding of milk production systems in tropical lowlands and the generation of feedback regarding the role of, and problems associated with, grass-legume mixtures in small farms.

The project begun in mid-1988 with the selection of five farms in each of two regions: the area near Villavicencio, Meta and that close to Florencia, Caquetá. The former region is located in the Andean Piedmont, and is typically a savanna area with a mix of crops, fattening and dual purpose enterprises. The latter seldom incorporate other activities. The Caquetá region is also part of the Andean Piedmont but the ecosystem is that of the humid tropics; the area where the cooperating farms were located was colonized several decades ago and under the impulse of private industries has become an important milk supplier. For both regions there was abundant secondary and other information, including own surveys, and there was a significant number of regional trials carried out by ICA that had identified highly promising pasture species.

The strategy for both areas is similar in that it incorporates on-farm comparisons of grass-pastures with grass-legume associations. To minimize risks, a mixture of several legumes was used in all cases (Table 10). The comparison between both types of pasture is being repeated in the respective ICA experimental stations. Other aspects of the strategy differ and are discussed separately.

Table 10. Legume mixture used in Meta and Caquetá.

Legumes	Meta	Caquetá
C. acutifolium (Vichada)	+	
C. brasilianum 5234	+	
C. macrocarpum 5713	+	+
D. ovalifolium 13089	+	+
A. pintoi 17434	+	
S. guianensis (Pucallpa)		+

a) Meta

Given that most of the area of the farms is already planted to sown pastures, very little native savanna remains. Therefore, cooperating farmers were chosen among those that intended to mechanically renovate existing stands of B. decumbens, the predominant species. The legume mixture was originally introduced in strips but later, replantings were made over the whole paddock. A complete fertilizer mixture of 16 kg P, 27 kg K, 16 kg Mg and 33 kg S per hectare was applied to both pastures. Although it is not common practice to apply elements other than P to the grass alone, the decision was taken to apply equal amounts of the mixture to avoid confounding the species sown with the fertilization regime.

b) Caquetá

The main criteria used in selecting farmers in this region was to identify those that intended to establish new pastures in degraded paddocks, generally covered with volunteer grasses. In this case, pasture establishment involved seeding both the legume mixture and the accompanying grass. The control grass was *B. decumbens*, whereas in the association, *B. dictyoneura* was added as well.

Given the virtual absence of machinery in the region and the risks of erosion due to the combination of intense rainfall and steep topography, a zero-tillage technique of pasture establishment was followed, which involved treating the whole paddock with a contact herbicide (paraquat) followed by vegetative planting of *B. decumbens* and sexual seed of the remaining species. Following common practice in the region, supported by other preliminary evidence, no fertilizers were used.

Some selected characteristics of the farms in both regions are shown in Table 11.

Table 11. Salient characteristics of the dual purpose farms in Meta, and Caquetá, in August 1988.

	Meta	Caquetá
	--- Ranges	----
Area of (ha):		
- farm	23-120	86-250
- sown pastures	9-60	76-231
Total cattle (number)	29-120	-
Milking cows (number)	12-25	37-94

Pasture establishment in both regions was initially severely hampered by weed infestation, associated with the relatively low initial growth rate of the perennial species. Methods employed to control weeds were ad hoc, depending on the available resources and nature and severity of the problem, but in general in Caquetá it involved the use of fire and/or herbicides and manual control, whereas in Meta mechanical control and to a lesser extent, herbicides were the preferred tools. This process has already yielded important feedback regarding the problems of on-farm pasture establishment in these two contrasting regions, and the response of the sown species to weed control measures.

It is clear that delays in pasture establishment, and the costs involved in planting the new species, can have important economic implications. Therefore, detailed records of input use and pasture utilization are being kept.

The botanical composition of the pastures in September-October 1989 is shown in Tables 12 and 13. Some of the pastures in Meta are already under grazing, while those of Caquetá are expected to enter the grazing cycle later in the year.

Table 12. Summary of botanical composition in Meta, 1989.

	Range (%)	
Species	Control	Association
B. decumbens	38-81	53-72
Sown legumes	-	8-16
Spontaneous:		
- legumes	0-9	1-16
- grasses	4-48	2-24

Table 13. Summary of botanical composition in Caquetá, 1989.

Species	Range (%)	
	Control	Association
B. decumbens	34-73	23-50
Sown legumes	-	7-64
Spontaneous:		
- legumes	1-9	1-2
- grasses	10-60	10-50

<u>On-farm Pasture Evaluation in the Savannas of Venezuela</u>

In 1989 the Government of Venezuela introduced major changes to its economic policies. As a result of these changes, subsidies to agricultural inputs were eliminated and therefore the prices of fertilizers increased markedly. Until then, farmers in the Venezuelan plains had relied on cheap fertilizers to maintain highly demanding pasture species such as pangola grass and stargrass, and there was little incentive for the use of low input grasses and legumes.

As a result of the above changes, the Venezuelan national research institute, FONAIAP, requested CIAT's help in establishing grass-legume pastures in selected farms, for on-farm testing and monitoring in four states. The species choosen were <u>A. gayanus</u> already released as cv Sabanero, <u>B. decumbens</u> also available in local markets, and <u>B. dictyoneura</u>, <u>S. capitata</u>, <u>C. acutifolium</u>, <u>C. macrocarpum</u> and <u>C. brasilianum</u>. The last five had been tested in several regional trials and based on them plus information from the Colombian savannas, were considered highly promising. With that objective, the program made available seed at cost to FONAIAP (Table 14), which in turn sold it to selected, interested farmers in several states (Figure 1). Furthermore, an associate with ample experience in pasture establishment under similar conditions spent four months in the region helping to set up the new pastures.

Table 14. Species and volume of seed made available to farmers through FONAIAP in 1989.

Species	kg
B. dictyoneura cv Llanero[1]	200
C. macrocarpum 5713	400
C. brasilianum 5234	200
C. acutifolium cv Vichada[1]	200
S. capitata cv Capica[1]	300

[1] Name of the cultivars in Colombia. None of these species has been released in Venezuela as yet.

The four states (Anzoátegui, Bolívar, Guarico and Monagas) represent 37.5 million ha, most of them originally under savanna vegetation. During the last two decades significant areas within these states have been subjected to intensive cropping.

Because of this, the range of conditions encountered in the region is more variable than in comparable savannas of Colombia. In practice, pastures were established in three contrasting conditions: (1) following native savanna, (2) after highly degraded high-input grass pastures (mostly <u>Digitaria decumbens</u>) and (3) following annual crops, such as sorghum and peanuts. Fertilization at planting time was adjusted to the three previous conditions, but was constrained by the absence in the market of phosphoric fertilizers. The most common fertilizer in the region was 12-24-12, which was used to apply the equivalent of 24 kg P_2O_5 in conditions (1) and (2) above, and 12 kg P_2O_5 when pastures followed annual crops. Legume inoculant was available for only two of the 24 paddocks of grass-legume associations established. A summary of the pastures planted is shown in Table 15. A total of 543 ha were established, 329 of which were grass-legume associations. With very few exceptions, associations were paired to the corresponding grass-only pasture within farms, so that it should be possible to compare both types of pastures.

With only exception, seed was broadcasted mixed with the fertilizer.

The planting season was fairly late, August-mid October, and was interrupted by an unexpected and long dry spell.

Although the quality of the seed employed, as checked by both laboratory analysis and in situ field tests, was high, initial germination in some of the earlier plantings was hampered by the dry period. Other problems encountered were the abundance of leaf-cutting ants, weeds (in previously cropped fields) and excessive preparation of the seed bed.

The activities described above were very useful for training purposes as well. Ten local agronomists and four technicians actively participated in the selection of the farms and in establishing the pastures, and it is expected that they will also be responsible for the subsequent monitoring.

Table 15. Species and size of paddocks established in the Venezuelan plains.

Pasture	(1)	(2)	(3)
A. gayanus (Ag)	4	4	2-20
B. decumbens (Bd)	4	4	20-25
B. dictyoneura (Bt)	4	4	1-25
S. capitata	1	1	10
Ag + S. capitata	3	3	20-25
Ag + C. macrocarpum	4	4	10-30
Ag + C. acutifolium	1	1	2
Bd + S. capitata	2	2	15-25
Bd + C. macrocarpum	3	3	20-25
Bt + C. acutifolium	8	8	1-25
Ag + C. macrocarpum + C. acutifolium + C. brasilianum	1	1	20

(1) Number of farms
(2) Number of paddocks
(3) Area per paddock, hectares (ranges)

Figure 1. Approximate location of collaborating farms where experimental pastures where established in 1989.

19. Impact Study and on-Farm Research: Cerrados Region

Average farm size for the Cerrados region is larger than national figures (i.e., 187.3 ha vs. 64.5 ha per farm in 1985, respectively), since representing less than 15 percent of the total number of agricultural units for Brazil, they occupied more than 43 percent of the total land under cultivation. In particular, land devoted to both annual and perennial crops in the Cerrados is proportionately lower than corresponding national figures (i.e., 7.1 percent vs. 11.3 percent for area under annual crops, and 0.9 percent vs. 2.6 percent for perennial crops, in Cerrados and Brazil as a whole, respectively, in 1985).

Thus considering the above concept alone, it can be stated that the Cerrados region has a potential for a more intense land utilization strategy. More important though, the higher the land intensity and agricultural productivity per unit of land that both the brazilian and the international community can reach in this vast tropical savanna region, less pressure will be applied to more fragile ecosystems, like the humid tropics of Amazonia, an area of a world-wide concerns these days on its ability to sustain major land use changes, and for its implications in potentially dramatic negative ecological effects.

On the other hand, for the last two decades Cerrados region has been contributing significantly in the expansion of both area and total production of soybeans, maize, rice, and beans, incorporating 5 million additional hectares under cultivation in these four grains alone since 1970. Even more remarkable, in 1987 average yields for maize, soybeans, and beans in the Cerrados were above corresponding national figures (17.6 percent, 9.7 percent, and 24.5 percent respectively), while for rice was 22.3 percent less productive due to the fact of being cultivated mostly without the benefit of irrigation.

Furthermore, livestock population in the Cerrados comprises a significant and increasing proportion of the total Brazilian cattle industry (approximately 46 percent of the national aggregate), with stocking rates and animal performance levels similar to national averages, and inventory growth rates clearly above the aggregate figures (2.6 percent vs. 1.9 percent per year during the last two decades). The states of Mato Grosso (MT), Mato Grosso do Sul (MS), and Goiás (GO) account for the largest gains in this respect. Dairy production, in particular, has also increased proportionately faster in MS, MT and GO relative to the more traditional Minas Gerais (MG), showing that the intensity of the cattle business is moving to the west in Brazil, parallel to the changing Cerrado's frontier and progress made in infrastructure developments.

<u>Andropogon gayanus</u> and <u>Brachiaria brizantha</u> are the two major improved grasses released during the 1980's that has already reached a positive,

continuous, and autonomous growth in the Cerrados region despite the general lack of government assistance on specific promotion campaigns for its adoption, and/or subsidized credit or agricultural output (input) favorable price policies for the benefit of farmers and ranchers. In this respect CIAT's Tropical Pastures Program had a direct involvement since the early development of Andropogon gayanus, providing for instance intense collaborative efforts to EMBRAPA, aiming to achieve the above goals, a process started more than a decade ago.

Given this general background, one of the most important activities within this section carried on during 1989 was to assess the impact of Andropogon in the Cerrados, both from a technical and economic point of view. Additionally, more economic analysis was approaches to improved pasture technologies, like the ones being conducted at the farm level, as well as some preliminar animal performance results on these same on-farm trials will also be reported.

1. Andropogon gayanus Impact Study for the Cerrados Region

The documentation of this research is presented in a paper called "IMpactos Técnico-Económicos de Andropogon gayanus en los Cerrados de Brasil", which was carried out in a joing effort with an EMBRAPA-CPAC researcher (Ronaldo P. de Andrade). The goal was to get the information needed by personal interviewing a limited number of commercial seed companies (12 in total, located in five different states), which were known by our brazilian counterpart as important in size, showing a reputable name within the industry, and in some cases, he also had professional relationships with their respective owners and/or general managers. Adding to this source of data, a statistically sample was drawn from the large universe of extension offices (EMATER's) spread throughout the most important Cerrados' states from the cattle industry viewpoint. The aim here was letting the professional(s) in charge of these offices to fill out a questionaire raising important issues in relation with Andropogon gayanus. Also, for the purpose of getting a closer idea of farmers' reactions towards Andropogon, a telephone survey applied to cattle farmers and producers was conducted among the counties closer to Brasilia, D.F., an area known as the "geo-economical region of Brasilia" (GEB). Finally, a forth strategy to study the Andropogon issues was its evaluation by means of satelites pictures of representative and contrasting Cerrados areas (five in total, one for each state), both for 1986 and 1988. Since this approach is still underway, it will not be possible to report its results at this point in time. However, it is important to advance that this approach appears to be promising in identifying A. gayanus areas relative to other grasses, like Brachiaria spp., Panicum spp., etc., as well as annual crops, native Cerrados, etc. with a good degree of precision (80 percent approximately).

Among the main conclusions drawn from the above study, the following appear to be the most important:

a) An internal rate of return (IRR) of 55 percent per year was derived when computed the difference between Andropogon's gross additional benefits against all its investments applied for research and development, extension, and establishment costs (it was assumed here that no maintenance costs were needed during its eight-year long productive period). Thus it becomes apparent of the wise decision taken by the international and national community to invest human and monetary resources in this direction. The conclusion proved to be stable although key parameters of the simulation model, such as total establishment costs per unit of Andropogon planted, and its animal productivity were raised and lowered, respectively, in relation to the average expected parameters. Even in the worst possible scenario simulated, a 15% real IRR was still obtained for a 20-year long simulation period.

b) Significant growth rates in the amount of Andropogon seed marketed and planted were confirmed, although the 80's were not in general terms a very favorable period for cattle producers in Brazil (particularly if compared against the 70s). The total accumulated area under Andropogon already established has been estimated in 640,000 ha by 1988/89, with a strong possibility that this area could be doubled during the next four to five years. Using average productivity gains due to Andropogon availability in the Cerrados, it can be argued that 25,500 tons of beef (carcass weight) has been expanded to domestic supply during the last year, if all Andropogon were used exclusively by beef cattle (alternatively, 243 million lt gain of fresh milk could have been added for domestic consumption in 1988/89, if all Andropogon would have been used with dairy cattle). Most likely, however, a combination of net gains in both beef and milk has been achieved in practices, with probably a higher weight for beef and less for milk.

c) When compared the above animal product gains due to Andropogon against corresponding national figures for Brazil, it becomes evident that no major changes can be reported thus far in terms of (i) increase beef export volumes, (ii) reduce dairy product imports, (iii) increase domestic supplies of both products, and/or (iv) reduction in their real price paid by consumers. Still, looking from a different angle, the above productivity gains could have been sufficed to meet the annual requirements of 1:700,000 brazilians showing average beef consumption levels (or alternatively, 3:467,000 people consuming average dairy products).

d) Rates of adoption and areas established under Andropogon in Cerrados were more intense in counties and states closer to Brasilia, D.F. (i.e., the quickest adoption rate was found within the GEB, followed closely by GO and MG as a whole; the slowest was MS). Another important figures found was that 50 percent of the Andropogon adopters were classified as exhibiting medium farm size, 31 percent as large ranchers, while only 15 percent were considered in the small and small to medium size range.

e) Almost every EMATER officer, seed company representative, and farmers consulted, they all ratified a long list of positive characteristics that Andropogon shows, factors well-known by researchers working with improved tropical grasses. At the same time they also emphasized a few negatives or limiting features which suggest that it can be wise to continue investing in research on this grass as a way to overcome those difficulties observed at the farm level; they are: (1) harder to get a well managed and effective animal utilization of Andropogon relative to Brachiaria stands (i.e., many times farmers reach one of the two extremes: undergrazing, or overgrazing), (ii) sometimes it is not easy to get a good start with Andropogon just planted due to various kind of insects that produce significant devastation of the initial plant population, (iii) there is a natural tendency in Andropogon to generate "toseras" which reduces the effective quantity and quality of energy and protein available to animals.

f) Around 90 percent of seed companies surveyed showed there expectation for moderate to high growth rates in Andropogon seed quantities demanded by farmers and ranchers during the next few years, a situation being ratified by the EMATER personnel in GO and farmers within the GEB. In contrast, in MT the intention to establish Andropogon are seen more modestly by EMATER officers.

g) In recent years Andropogon gayanus appears to be the second grass cultivar best sold by seed companies, loosing only to Brachiaria brizantha cv. Marandu. Consequently, present interest for Andropogon is superior to more traditional improved grasses planted in Cerrados, such as B. decumbens, B. humidicola, B. ruziziensis, etc., and also relative to other new cultivars released during this decade, as the case of Panicum maximum cv. Tobiata.

2. Economic profitability of several improved pasture technologies

On the last year annual report some economic results were presented for pasture technologies such a protein banks, pasture reclamation of degraded Brachiaria spp. stands, and grass/legume associations. The study was based on mid-year 1988 input/output price relationships aiming to find the conditions whether it was feasible for farmers and ranchers to reach an average 12 percent annual real interest on pasture investment outlays (plus their corresponding maintenance costs), all along their total productive life (let say, 8 to 9 year long). Meanwhile, the brazilian economy was suffering from a severe price inflation (i.e., consumer price index rose an average of 18.5 percent monthly for the past two years, despite government implementation of two different price/salary freeze schemes during this same period). With such a high inflation rates it is not easy to find that each price in the economy rises at the same speed, giving grounds for significant gains and losses for any enterprise conducting business within that economic environment. All along 1989 it was clear that this process affected the absolute and relative profitability of the cattle industry, especially in relation to the two animal products of our major concern: beef and milk.

Specifically, what happened was that the net milk price received by farmers (already deducted for taxes and freight expenses) which was US$0.107 per liter in February 1989, dropped to US$0.077 per liter by July'89. On the other hand, the net beef price received by farmers which was situated at US$755.6 per metric ton (carcass weight) in February rose to US$1,111 per ton by July of this year. Looking from a different angle, while the relative farm-gate price relationship for carcass-beef/milk was 5.67 in February, it jumped to 11.5 by July, when the general average for the period 1970-88 was 6.81. Consequently, the implication of this disequilibrium is that while it was easier to derive good profitability using improved pasture for dairy production at the beginning of the year, by mid-year the situation changed dramatically in favor of beef.

In absolute terms it was also found a general increases in the investment outlays per hectare for the different forage strategies when comparing input prices (in dollar terms, in the parallel market), for February relative to mid-year ones. Those increases were somehow smaller for pasture renovation procedures applied to degraded Brachiaria spp. (+ 3.1 percent), and for protein banks in association with a Brachiaria already established (+ 2.3 percent). However, for grass/legume association and protein bank + A. gayanus both established simultaneously, the increases were more significant (11.7 and 13.0 percent, respectively). The reasons behind these insonsistences are based on the various input compositions required for developing these pasture strategies, so that if one type of pasture investment demands more of an input whose price rises above the general price level, such a procedure would become clearly more costly.

Consequently, given all these relative and absolute changes in input/output price relationships taken place during such a short period of time, it is useful to recompute the minimum physical productivity required for each of the pasture strategies in order to reach an average annual IRR of 15 percent during all their productive life. The raise from 12 to 15 percent in the IRR measurement of profitability was due as a way to be more confident that cattlemen will be willing to invest in improved pasture despite this general uncertainty on the overall economic environment. Table 1 reports on this simulation showing ex-ante profitability results by animal products and forage strategies, for February and mid-year price levels during 1989.

The above figures represent gains per day and per animal head necessary to reach those high profitability rates above and beyond (that is, additional) those already obtained using average management and forage resource practices most typically of Cerrados conditions. The figures corresponding to the grass/legume associations are not reported here since they are very similar to the "pasture renovation" strategy. In the next section will be comparing these ex-ante productivity gains against actual data coming out from on-farm experiments in the Silvania project.

3. Preliminary animal performance results derived from on-farm trials

A first limitation in using on-farm animal performance data obtained from the Silvania project is that they do not cover a complete 12-month period yet, thus disturbing our comparisons with the above ex-ante annual results. A second drawback is that by aiming to reduce investment that should have been financed either by our project's funds,

Table 1. Additional average productivity gains per head and day.

	Milk		Beef	
	2/89	7/89	2/89	7/89
	lts.		kg.	
Protein Bank + *Brachiaria* already established	0.79	1.19	0.220	0.164
Protein Bank + *A. gayanus* both established simultaneously	1.25	1.94	0.350	0.268
Pasture renovation of a degraded *Brachiaria* spp.	0.90	1.19	0.251	0.164

Source: Saez, R.R. and J.L. Zoby. Beneficios Técnico-Económicos do Emprego de Forrageiras melhoradas, estabelecidas em fazendas, nos Cerrados do Brasil. Selected paper presented at the XXVI Reuniao Anual da Sociedade Brasileira de Zootecnia, Porto Alegre, Brazil, July 1989.

or alternatively with farmers' own resources, there were not specific control paddocks where we could apply the same stocking rates as the ones selected for our treatment paddocks. Thus, in all cases, the stocking rates for the control animals were lower than for the ones using the pasture strategy selected, reducing the expected differences in animal productivity per head (and day) between the two groups. A third difficulty encountered (this one completely unexpected to us) was our failure to get a hold of a portable animal scale which was ordered with enough advance time during 1988. Given the lack of this equipment, the number of on-farm animal observations were reduced sustancially during this year, to farmers using either dairy cattle, and two additional ranchers having their own fixed-scales.

One interest case is the one using dairy cattle grazing a protein bank (composed by 50 percent of <u>Leucaena leucocephala</u> cv. Cunningham, and 50 percent <u>Stylosanthes guianensis</u> cv. Bandeirante) in association with a <u>Brachiaria decumbens</u> established long-time ago. Here during the first 100 days in the 1989 rainy season (January through April) the difference between dairy cows (which were twice milked a day) in and off the experiment was +1.41 lt per animal/day, dropping to +1.0 lt per animal/day during the next five dry season months, giving us a general average gain of 1.17 lt per head/day in favor of the animal using the protein bank. If we compare this latter overall average, relative to the mean for milk production in the above table for this type of forage strategy, it confirms the adequate profitability that this farmer is reaching with this type of investment. Even under the more unfavorable price relationship, the marginal productivity obtained is still very close to the upper level required to reach a 15 percent in IRR on the total capital applied (mid-year 1989 prices).

In two other experiments using introduced legumes for pasture renovation of old <u>Brachiaria</u> spp. stands, we got in one case gains of 500 g per head/day during the first 110 days of rainy season, against 445 g per head/day for animal off the experiment, which were enjoying an extremely low stocking rate due to the fact that our collaborative rancher all of a sudden decided to sell a substantial proportion of his animal inventory. During the dry season, even under this circumstances, while the animals in the experiment were gaining 105 g per head/day, the animal off the trial lost weight at a rate of 94 g per head/day. Overall the experiment during its first eight months period gave us a gain of 134 g per head/day above the "control" animals. This advantage is below the required productivity reported in the above table, but undoubtedly the fact of not being able to equate the same stocking rate between the two groups is distorting the results.

In the other experiment we could begin measuring animal performance starting only in this last dry season due to a change in land ownership of this ranch, which cause a relative long transition period. What is interesting here is that even with a stocking rate of 1.0 UA/ha the renovated <u>Brachiaria</u> showed an increase of 333 g per head/day during a two dry-month period (i.e., August-September), relative to a 267 g per animal/day off the experiment.

Finally, by 1989 mid-dry season it was possible to weigh all remaining animals of the other experiments so that we will be starting to get additional animal product results during the next coming months.

20. Economics

Activities of the Economics Section in 1989 fell into two broad areas: strategic planning of future pasture research and on-farm research.

1. Strategic Planning

As part of CIAT's overall effort to develop a strategic plan for the nineties three specific projects were undertaken: (a) survey of national pasture research institutions, (b) continuation of modelling efforts to analyze ex-ante benefits of pasture research as a tool for resource allocation within the Tropical Pastures Program, and (c) study of the adoption of improved pastures in the Eastern Plains of Colombia.

a) Survey of RIEPT and National Pasture Research Systems

During 1989 a survey was conducted to assess the present status of pasture research in tropical Latin America with emphasis on acid soils areas. Issues of particular interest included stock of human and physical resources in individual countries and regions, evaluation by users of the different services offered by CIAT through RIEPT, research priorities as seen by NARS researchers, training needs, major constraints limiting research and impact achievement and specific recommendations for improvement of research collaboration.

The survey has involved two levels of data collection: a complete census of opinions of all national coordinators of the respective chapters of RIEPT and a brief questionnaire sent to all active researchers involved in the network. The results of these surveys were presented at the Consultation Meeting with National Program Representatives held at CIAT in April 1989.

b) Modexc: Spreadsheet simulation model for ex-ante assessment of research benefits.

Initial work on modelling pasture research benefits for Latin America was reported in 1988. In 1989 this work was continued with the LOTUS programming support of the Biometrics Unit of CIAT, thus turning the model more user-friendly and versatile. The present version computes the economic surplus due to technical change, its distribution among producers and consumers and the rate of return to research and development investments.

The model follows the approach presented by Pachico, Lynam and Jones (1988) which incorporates the concept of a minimum price below which no production will occur and allows the analysts to simulate different types of functional shifts (parallel, divergent, convergent). Surpluses are computed in a conventional consumer/ producer surplus model. The model simulates changes in supply and demand over n periods during which adoption occurs. The diffusion is simulated with user-defined logistic functions which in turn are the driving force of supply shifts. The model explicitly incorporates external shifters of both supply and demand, such as population and income growth, changes in relative prices and exogenous supply shifts.

Once the annual market equilibria are computed for the whole simulation period, the model computes total annual surplus, its distribution among consumers and producers and the partitioning between the surplus due to the technical change under analysis and other sources.

To measure the economic return to funds allocated to the research and development effort, the model can consider investments done up to 10 years before initial adoption takes place and up to 30 years thereafter. Return is expressed as net present value, internal rate of return and benefit cost ratio.

As a preliminary example a run for Brazil is presented in Table 1 using the assumptions listed. Results show the high social return of this investment with a net present value between US$1.04 and 1.06 billion depending on whether the economy is assumed to be closed or open to international markets. Corresponding benefit-cost ratios are of 10.3:1 and 10.5:1 while both runs yield IRRs of 22% p.a.

After an adoption process lasting 30 years 4 million additional hectares of improved pastures would be established. Figure 1 shows the model results for a closed economy run. Figure 1.1 depicts the evolution of market prices over time, Figure 1.2 the gradual increase of the supply function shift as driving force of the model, Figure 1.3 the evolution of the surpluses over time and Figure 1.4 the evolution of the surpluses which can be attributed to the technical change being simulated. This model will be used to develop estimates of potential research benefits for individual countries, as one tool for priority stting in the program.

c) <u>Pasture Adoption Survey of the Eastern Plains of Colombia</u>

In order to estimate the degree of adoption of improved pastures and to identify factors influencing adoption, a sample survey of producers of the two main counties (Puerto Gaitán and Puerto López) of the well-drained savannas of the Eastern Plains of Colombia was undertaken jointly by CEGA (Corporación de Estudios Ganaderos y Agrícolas) and the Tropical Pastures Program.

A sample of 86 farms out of 728 farms listed as producing cattle according to ICA records and of more than 40 hectares were randomly chosen and interviews conducted.

The information requested covered the topics of resource endowment of the farms, land use, evolution of areas of pastures, management practices related to these pastures and planting intentions. An additional set of questions specifically addressed the issue of the adoption of <u>Stylosanthes capitata</u> cv Capica, the first legume released by ICA for that region in 1983.

Table 2 presents the land use in the Puerto López and Puerto Gaitán counties. Approximately 10% of the area is in sown pastures and almost 1% is in legume-grass associations.

The distribution of sown pastures (Table 3) documents the overriding importance of <u>B. decumbens</u> with more than 50% of the area of sown pastures. This is followed by <u>B. humidicola</u>, a material which has not yet been officially released, does not produce sexual seed in Colombia and is acknowledged as of low forage quality but seems to be very attractive to farmers (see also 1985 Annual Report). It is furthermore interesting to note that the traditional sown pastures <u>H. rufa</u>, <u>M. minutiflora</u>, have dropped to

Table 1. Ex-ante simulation of acid soil pasture research benefits, Brazil

Assumptions					Results		
Market		Technology		Financial		Closed economy	Open economy
Price elasticity of: -supply -demand	 0.50 -0.23	Length of diffusion period years.	30	Research investment: US$ 5 millions p.a. for 10 years prior to initial adoption.	Net present value of economic surplus (US$ billions): - Total - Consumer - Producer	 2.94 3.02 -0.08	 2.96 2.70 0.26
Minimum price (US$/MT)	500	Maximum area with adoption potential at initial market prices: - savannas........ - forests.........	 5% of total ≈ 9 million ha 1% of total ≈ 4.5 million ha	Development investment: US$ 3 millions p.a. for 10 years after initial adoption.	Net present value of economic surplus attributable to technical change (US$ billions): - Total - Consumer - Producer	 1.04 3.02 -1.98	 1.06 2.70 -1.64
Initial market equilibrium: -quantity ('000 MT) -price (US$/MT)	 2,150 1,390	Adoption level in: - first year............. - last year...............	 0.3% 99.0%	Discounting rate.. 10%	IRR of research and development investment	22.0	22.1
Export parity price (US$/MT)	1,000	Maximum value of the supply shift at initial prices (K)...............................	1.61		Benefit:cost ratio	10.3:1	10.5:1
Annual growth rates (%): -demand -supply (due to sources other than technological change being analyzed)	 1.5 1.5	Incremental per hectare production due to technology: 0.0968 MT beef carcass weight			Incremental area in improved pastures, last year (million hectares)	3.9	
					Annual growth rate of total production (%)	1.96	

20-3

Figure 1.1 Evolution of the supply function shift over time

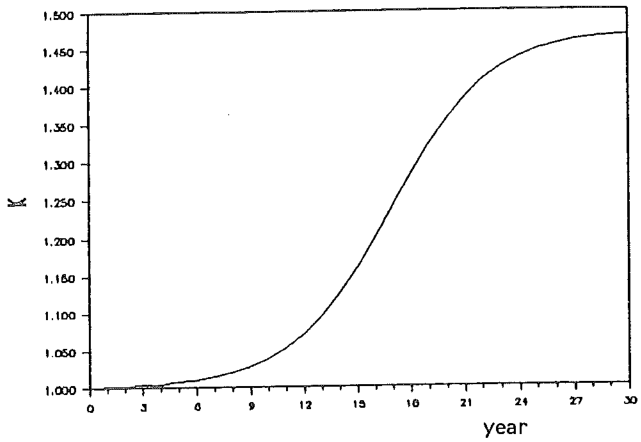


Figure 1.2 Evolution of equilibrium market prices over time

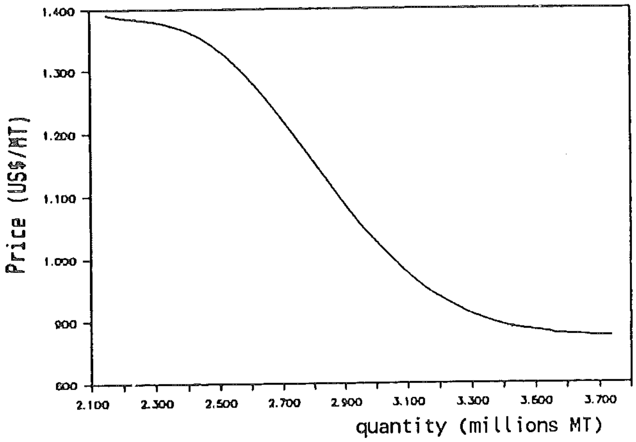


Figure 1.3 Economic surplus due to technical change

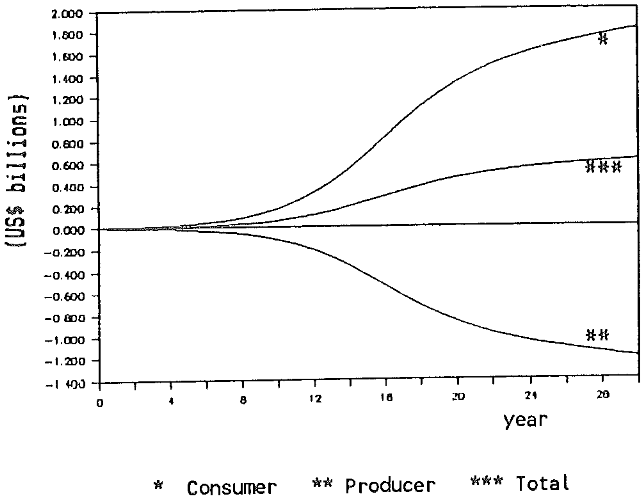


Figure 1.4 Economic surplus due to technical change and other shifts

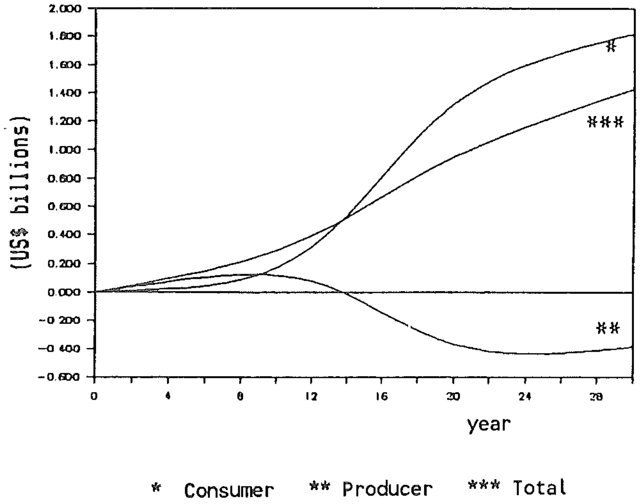


FIGURE 1. IMPACT OF IMPROVED PASTURE TECHNOLOGY FOR ACID SOILS, BRAZIL, CLOSED ECONOMY

Table 2. Land in pastures, Eastern Plains of Colombia, 1989*

Pasture	Estimated area (hectares)	Percentage of error**
Total area	990,029	19.2
Native pastures	871,664	21.7
Improved pastures	90,755	20.4
Legume grass associations	7,009	40.0

* Extrapolated from survey of 86 farms in the Municipios of Puerto López and Puerto Gaitán

** Error probability = 20%

Table 3. Pasture improvements by species. Eastern Plains of Colombia, 1989*

Species	Estimated area (hectares)	Percentage of error**
A. gayanus	3014	44.1
B. decumbens	47853	28.1
B. humidicola	27232	23.8
B. dictyoneura	1731	66.0
B. brizantha	135	83.8
M. minutiflora	635	120.2
H. rufa	1574.5	64.5
Other grasses	1980.8	89.5
Total sown grasses	82399.4	21.3
A.gayanus + S.capitata	2480.0	79.1
A.gayanus + C.acutifolium	338.6	117.2
B.decumbens + S.capitata	1490.0	66.1
B.decumbens + P.phaseoloides	592.6	70.0
B.dictyoneura + S.capitata	846.5	120.2
B.brizantha + P.phaseoloides	677.2	120.2
Total associations	6595.7	39.1
S.capitata (pure)	288.0	113.3

* Extrapolated from survey of 86 farms in the Municipios of Puerto López and Puerto Gaitán

** Error probability = 20%

a very low percentage, documenting the dynamics of the process of pasture establishment.

Among the associations A. gayanus + S. capitata stands out, followed by an important area of B. decumbens + S. capitata. It is impressive to realize that over 800 ha of the association B. dictyoneura + S. capitata exist only one year after the release of the grass.

Adoption rates by species (Table 4) again document the impressive diffusion of B. humidicola, which is present on more farms than B. decumbens. Nevertheless areas of B. humidicola are significantly smaller than those of B. decumbens. It is also worth noting that B. dictyoneura is already present on 9% of the farms.

Table 4. Adoption rates by species. Eastern Plains of Colombia, 1989*

Species of associations	Adoption rate (%)	Percentage of error**
A. gayanus	14	28.7
B. decumbens	65	8.4
B. humidicola	70	7.6
B. dictyoneura	9	36.0
B. brizantha	3	60.7
A. gayanus + S. capitata	7	42.1
A. gayanus + C. acutifolium	1	106.9
B. decumbens + S. capitata	6	46.5

* Extrapolated from survey of 86 farms in the Municipios of Puerto López and Puerto Gaitán

** Error probability = 20%

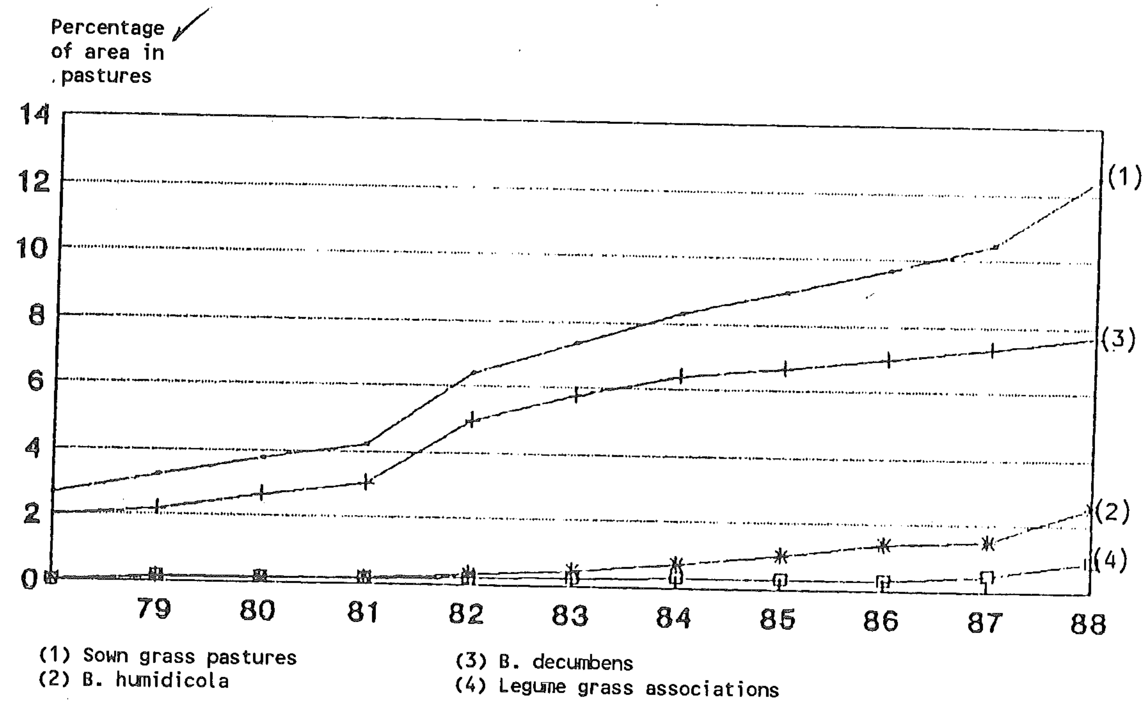
The very dynamic evolution of pasture establishment over the past decade is shown in Figure 2 in terms of percentages of the total area of pastures and in terms of percentages of farmers adopting (Figure 3). Over this period the mean growth rate of the total area of sown pastures has been 15.5%, while the one for B. humidicola was of 44.7% p.a. and the one of legume grass associations was of 16.5% p.a.

At present almost all farms have some sown pastures and every fifth farm has some area with forage legumes (mainly S. capitata).

The very dynamic situation of the Eastern Plains is further documented by the improvements in road infrastructure and the subdivision of farms. This is supported by the fact that 42% of the farm owners surveyed had bought their property in the last 10 years.

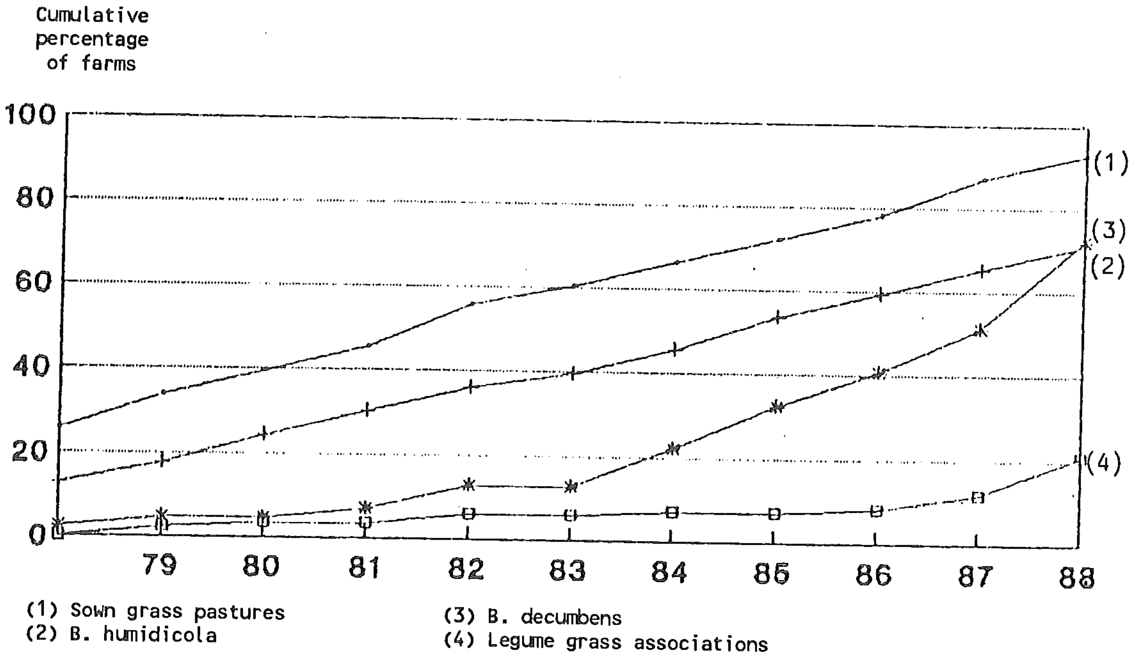
The hypothesis that these new land-owners are the ones mainly responsible for the rapid process of "modernization" is supported by the survey evidence showing that "new-owners" have sown more pastures both in absolute terms (has per farm) and as a percentage of the farm area than "older" ones (Table 5). These farms tend to be managed more intensively as depicted by the fact that significantly more of the recent owners fatten either cull cows or steers on their farms.

In order to contribute to the design of appropriate "downstream" strategies for the diffusion of tropical legume-grass pastures, several questions were included in the survey to better understand decisions taken by farmers in the process of hearing about forage legumes and deciding about testing them on their farms. "Capica" being the first tropical legume formally released in Colombia, was a particularly interesting case study of potential value for decisions related



Sample: 86 farms

FIGURE 2. ADOPTION OF SOWN PASTURES IN THE EASTERN PLAINS OF COLOMBIA, 1979/88



Sample: 86 farms

FIGURE 3. EVOLUTION OF THE NUMBER OF ADOPTERS BY PASTURE SPECIES IN THE EASTERN PLAINS OF COLOMBIA, 1979/88

to other legumes being developed as well.

Table 5. Pasture establishment in the period 1979-88 by date of farm purchase

	Date of farm purchase (1)	Date of farm purchase (2)	All farms
Number of farms	50	36	86
Mean area of pastures established 1979-88:			
-as percentage of total area of pastures (%)	5.19*	8.88*	6.85
-hectares/farm	64.66	125.11	90.40
Percentage of farms fattening cattle (%)	38*	56*	45

(1) Before 1979
(2) Between 1979 and 1988

* Significantly different at 5% error probability

Survey: 86 farms

Information was gathered which allowed the construction of a decision tree. Further questions explained some of the reasons for choosing specific branches of the tree. Figure 4 presents a simplified version of the tree.

The novelty of the innovation is clearly depicted by the fact that 42% of the sampled farm owners had not heard about the cultivar. This clearly indicates that further communication efforts need to be undertaken possibly incorporating additional approaches beyond the publications in farm journals and field days presently used. Difficulties are compounded by the heterogeneous nature of farm owners of the survey region, including barely literate traditional land owners and very sophisticated entrepreneurs, frequently absentee owners living in the major cities.

Eleven (11) of 50 farmers considered Capica not useful for their farms. This may to some extent reflect the site-specific nature of forage legume innovations but may also reflect problems in the accuracy of the message received.

Of 39 farmers considering Capica useful for their farm only 18 actually tested it. This clearly points to an area where improvements could have a substantial impact on adoption. Questions related to this issue suggest that access to Capica seed has been the main limiting factor. This is clearly related to the initial difficulties in involving the formal pasture seed industry in producing and distributing forage legume seed.

This suggests several approaches: producing more on-farm evidence of the merit of the new cultivars to create the demand, cooperate more closely with the seed industry to reduce the costs and risks of developing new materials and finally the need for more direct involvement in seed multiplication by the institution developing the cultivars, if effective initial adoption is to be achieved within a reasonable time frame.

The value of the new material, in our case Capica is supported by the fact that 15 out of 18 farmers who tried it, considered that they achieved "good" results. Six of those 15 even had planted Capica for a second time and four of those six had intentions

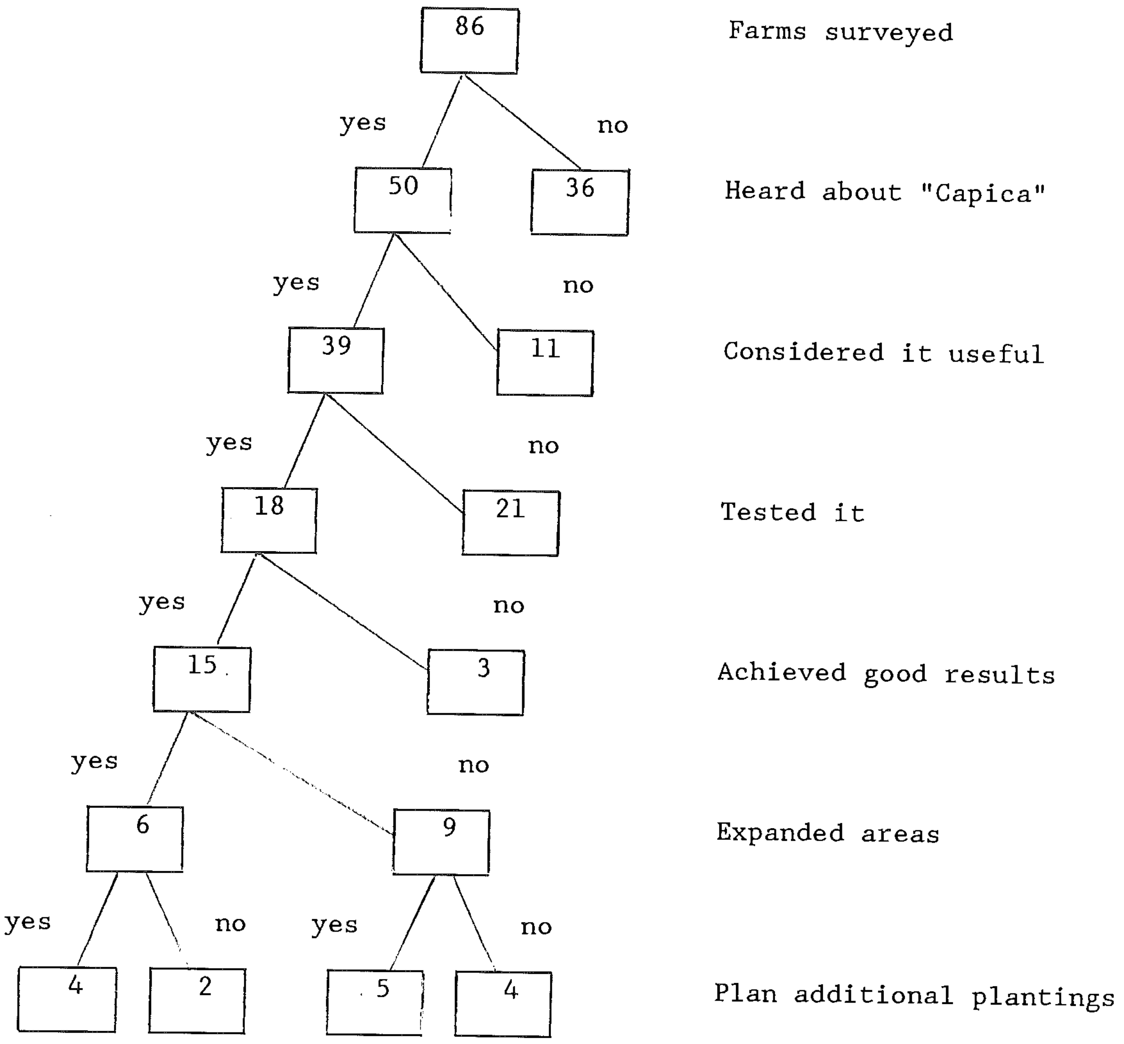


FIGURE 4. DECISION TREE ON "CAPICA" ADOPTION

of further plantings. If we include a further five farmers, who had not yet expanded areas, but were planing to do so, a total of nine out of 18, who actually tested it on their farms, were planing to expand areas of Capica.

The above analysis confirms experimental work showing the merit of Capica and pinpoints two critical areas for adoption and impact: information and early availability of seed for testing by potential adopters.

2. On-farm Research

The section's thrust is to develop appropriate methodologies to generate feedback for pasture researchers from existing farming systems to contribute to a more efficient research investment in tropical pastures. At the same time the section is specifically involved with the testing of technologies being developed by the program and its counterparts from national research programs.

Given the program's focus on incorporating tropical forage legumes into farming systems to enhance efficiency and sustainability of pasture based farming systems and the "novelty" character of this "technology-push" innovation, on farm work is centered around the use of legumes in diverse farming systems. The distribution of responsibilities for OFR within the Tropical Pastures Program, implies that the Economics Section concentrates in the Andean Piedmont regions while the Systems Section does so in savanna ecosystems. Farming systems in the Andean Piedmont tend to be smaller than in the savannas, have less of a drought stress, tend to be diversified family operations frequently with a dairy or dual purpose livestock component and important crop livestock interactions.

For both methodological reasons (ease of measurement, and time horizon to obtain responses) as well as relevance for the region, much of this OFR focuses on documenting the contribution of legumes to milk production in these farming systems and identifying second generation problems of these technologies as a feedback to both CIAT and NARS researchers.

a) Cauca/Valle Region/Colombia

Activities in this region continued along the lines presented in the 1987 and 1988 reports. Given the interest of small farmers in vegetative material of pastures as documented by previous work of the section in Cauca itself as well as in Caquetá, Napo and Pucallpa, the section continued to be involved in the vegetative material distribution scheme operated collaboratively by CVC, FGV and ICA/CIAT.

- During 1988 and the first semester of 1989 a total of 133 farmers bought 1986 bags (20 kg each) of vegetative material of the grasses *B. dictyoneura* (72% of total), *B. humidicola* (25%) and *B. decumbens* (3%) (Table 6). Given the fact that farmers had equal access to both *B. dictyoneura* and *B. humidicola* this result seems to confirm that the former material has superior attributes in the judgement of farmers.

- Difficulties continued with the limited acceptability of the two legumes made available *D. ovalifolium* and *A. pintoi*. Few farmers invested the time to harvest these materials given free. In their judgement the contribution of the legumes is not worth the incremental effort required to establish the mixture. Given these difficulties two approaches were taken: efforts were increased to expand the number of on-farm grazing trials and vegetative material plots were established as mixtures.

Table 6. Purchase of vegetative material of new cultivars by smallholders in Cauca, Colombia, 1988-1989

Period Site	Grass species	Number of bags[1]	Number of clients	Bags/ client (average)
April-May 88:				
Mondomo	B.dictyoneura	260	15	17
Mondomo	B.humidicola	122	9	14
Mondomo	B.humidicola[2]	100	—	—
SALES TOTAL APRIL-MAY 1988................		482	24	20
October-December 88:				
Mondomo	B.dictyoneura	177	18	10
Mondomo	B.humidicola	73	8	9
Pescador	B.dictyoneura	392	33	12
Pescador	B.humidicola	130	12	11
Pescador	B.decumbens	18	2	9
SALES TOTAL OCTOBER-DECEMBER 1988.........		790	73	11
March-July 89:				
Mondomo	B.dictyoneura	263	15	18
Mondomo	B.humidicola	40	1	40
Pescador	B.dictyoneura	346	17	20
Pescador	B.humidicola	25	1	25
Pescador	B.decumbens	40	2	20
SALES TOTAL MARCH-JULY 1989...............		714	36	20
SALES TOTAL 1988-1989.........		1986	133	15

Species	Bags	%	Clients	Bags/ client (average)
B.dictyoneura	1438	72	98	15
B.humidicola	490	25	31	16
B.decumbens	58	3	4	15
TOTAL	1986	100		

[1] 20 kg each

[2] Erosion control

- Pastures for milk production have been established on five farms. Three have both pure grass pastures (B. decumbens plus B. dictyoneura) as well as legume-grass associations including the above grasses plus a cocktail of legumes including D. ovalifolium CIAT 350, Styloshantes guianensis CIAT 184 and C. macrocarpum 5713. The latter two legumes show promise based on the performance in agronomic trials undertaken in the region.

  Due to late planting these legumes had presented poor establishment in 1988 on two additional farms. 1989 establishment was more successful and grazing should start soon. Table 7 shows the pastures being monitored.

Table 7. On-farm grazing trials in Cauca, 1989 (hectares)

Farm	Association	Pure grass	Total
1	1.0	1.5	2.5
2	1.5	2.5	4.0
3	1.0	1.0	2.0
4		1.5	1.5
5		2.0	2.0
Total	3.5	8.5	12.0

- As an additional strategy plots for the production of vegetative material are being established as mixtures from the on-set. Given the rooting ability of all materials involved, the hypothesis to be tested is that farmers will simultaneously introduce the legume with grass to their farms at virtually zero marginal cost.

The database on users of vegetative material was continued. Trends reported last year were confirmed in terms of the small areas of pastures users tend to have (mean of 74 users surveyed = 1.3 ha of pastures, mainly H. rufa, M. minutiflora, B. decumbens). Compared to this area, establishments are relatively important with a mean area per farm of 0.32 ha. Clearly animal production is presently mainly subsistence and savings oriented and for the feeding of draft animals.

It is hypothesized that more adapted pastures as well with improved management will lead to the evolution of the farming systems towards a more sustainable land use including legume-grass pastures, possibly in rotation with crops such as cassava.

Analysis of the database documented a high frequency of repeat sales (18%). It was detected that farmers considered it more attractive to buy vegetative material from the scheme than to use their own given the slowness of pasture establishment and the limited amount of pastures available on each farm. In order to promote on-farm use of established areas as multiplication plots and to enhance the viability of commercial production and trade of vegetative material, the price was increased from US$0.12 to US$0.50 per 20 kg bag. Initial evidence suggests that demand its still beyond the scheme's production capacity at the new price.

Several similar schemes of distribution of vegetative material of new forage cultivars have been set up by national R and D institutions or are in the process thereof. The section will try to monitor these activities to enrich the feedback about the potential and limitations of this approach.

Two further potential roles of legumes have been identified in the context of this OFR activity. *A. pintoi* and *D. ovalifolium* are being used as cover crop under coffee at a limited scale by two farmers. Previous research by the coffee grower federation has documented that coffee yields were not reduced by competition with the legume *D. ovalifolium*. It is hypothesized that the less vigorously growing *A. pintoi* will cause even less competition and better coverage due to its growth habit. Thus labor reductions for weeding could be achieved, some nitrogen introduced to the system and at the same time areas for vegetative multiplication of the material could be developed.

The legume *Centrosema macrocarpum* shows considerable promise for the region based on small plot agronomic trials. It is also being included in legume "cocktails" presently sown in several grazing trials. The fact that this material cannot be multiplied vegetatively on-farm, has drawn attention to the need to develop seed supplies. Major costs involved are labor and staking material for trellises. Given its apparent adaptation to the region, the existence of ample labor with limited alternative income sources and of large areas of fallow land frequently with light tree and schrub vegetation, it is hypothetized that seed production of Centrosemas (for local use or trade) might be an attractive activity.

Thus two exploratory trials have been set up with farmers, in one case using adapted sugar cane as trellises and in another case using an existing native stand of "caña brava" (*Gynerium sagittatum*) to plant Centrosema with a minimum clearing and herbicide use to reduce competition. Farmers will harvest the seed, which will be bought by the collaborative project (CVC-FGV-ICA-CIAT).

In order to test the potential of legume-grass associations in the region surrounding the Santander de Quilichao region, commercial scale plots of associations were established on three farms with dual purpose cattle (Table 8). Beyond the specific testing of the legume hypothesis, these case studies which can be easily monitored from headquarters, give the team an opportunity to test methodologies and approaches hands-on.

Table 8. Pastures monitored on commercial dual purpose farms, acid soils region, Northern Cauca (hectares).

Farm	Association	Pure Grass[1]	Total
6	20[2]	10	30
7	3[2]		3
8	8[3]	8	16
Total	31	18	49

1/ *B. decumbens*
2/ *B. dictyoneura* + *D. ovalifolium*
3/ *B. decumbens* + *C. acutifolium*

b) *Caquetá/Colombia*

The collaborative project to adapt legume grass pasture technology to this region continued very actively in 1989 with the participation of the following institutions; NESTLE, FGV, SENA, INCORA, UNIAMAZONIA, ICA and CIAT.

Materials selected for on-farm work continued to perform well both in agronomic plots and in some cases under grazing. *B. dictyoneura*, *D. ovalifolium* and particularly *A. pintoi* have been under grazing for two years and have persisted and competed well with native vegetation. *S. guyanensis* and C. macrocarpum have established well on farms and are now being grazed for the first time.

The contribution of legumes to milk production is being tested on five commercial farms and at the ICA Research Station-Macagual. This is part of a joint project between TUB (Technical University of Berlin), ICA and CIAT. Details are reported in the chapter on the Systems Section of the Program.

A large scale on-farm grazing trial to measure the weight gain contribution of legumes (a blend of S. macrocarpum, A. pintoi, D. ovalifolium) in a B. humidicola + B. dictyoneura pasture is underway at Hacienda La Rueda. Ex-ante economic analyses showed that incremental weight gains of 35 gr/day/head over the yield of the pure grass treatment (400 gr/head/day) were needed to break even (8.7% increment).

Four BS thesis projects were completed which contribute to the design of an appropriate pasture establishment technology:

- Nitrogen was shown to be the most critical element determining productivity of B. decumbens pastures thus supporting the strategy of including nitrogen fixing legumes to enhance persistence and sustainability of pastures.
- Use of contact herbicides (Paraquat) at a rate of 1 lt/ha of the commercial product (Gramoxone) proved effective in controlling the major weed of sown pastures, the grass Homolepis aturensis, without causing major damage to the sown Brachiaria species as well on the introduced legumes (C. macrocarpum, C. acutifolium, C. pubescens, S. guianensis, D. ovalifolium, A. pintoi).
- The feasibility of establishing legume grass associations in degraded areas of pastures was shown to be feasible with zero-tillage using the herbicide glifosate at a rate of two liters of commercial product (Roundup) per hectare.

Even though conclusive evidence on incremental production due to legume introduction is still lacking several local institutions (FGV, NESTLE, ICA-CRECED) and individual farmers are showing interest in expanding work in this area by themselves. This supports the hypothesis that work is being conducted on issues of relevance to the local farming systems.

c) Napo/Ecuador

CIAT and FUNDAGRO are conducting a study on the socioeconomic impact of improved agrosilvopastoral technology for humid tropics smallholders in Napo, Ecuador. Objectives and methodology were presented in the 1988 report. During 1989 detailed monitoring of farmers' plots with and without innovations were conducted in pastures, trees and coffee to obtain the technical coefficients for economic analyses.

A large sample survey of farmers of the region was undertaken to estimate present rates of adoption of individual agrosilvopastoral innovations. In spite of serious operational difficulties of the counterpart institutions due to problems in the flow of funds, field work is presently being completed and data analysis is under way.

d) Pucallpa/Perú

A detailed report of the establishment phase of this project was presented in last year's annual report. Despite of the departure of the postdoctoral fellow in charge of this project and the political insecurity of the region, monitoring activities continued on eight farms, due to the strong engagement of the Peruvian team.

Monitoring during this phase of the project includes monthly analyses of botanical composition of the pastures, continuous milk recording and recording of use of purchased inputs and labor on the control and treatment pastures.

Monitoring of botanical composition of the pastures is documenting very dynamic changes in the relative importance of individual species in response to various regimes of burning, weeding, grazing regime and initial conditions of the fallow. This fact pinpoints to the importance of pasture management in the humid tropics and the need to understand the determinants of management decisions within the farm system.

An in depth analysis of the database generated by the project, particularly the milk yield data is planed for early 1990, when the first year of recordings is completed on all farms.

Preliminary computations of unweighted averages over cows and seasons indicate that in all cases legume-grass pastures outyielded pure grass pastures. On average the yield increment was of 0.26 kg/cow/day or 10% above the yield of the control treatment (2.61 kg/cow/day). Though not impressive, these results tentatively support the hypothesis of the contribution of the legume, particularly if it is acknowledged that these are first year data, when differences are expected to be masked by the short term mineralization effect of the recent burning. The present status of the project clearly shows the convenience of continuing this monitoring effort for several additional years.

e) Concluding Remarks

On-farm work in the Andean Piedmont over the past two years has highlighted the establishment problems encountered in this region, due to high weed pressure, high rainfall, slopy topography and limited availability and opportunity for the use of soil tillage machinery. This has led to an increasing emphasis on low or zero tillage methods, involving management of plant populations by grazing, burning, and particularly use of herbicides and manual weeding.

This has been achieved through close collaboration across Tropical Pastures Program sections and with the participation BS students doing thesis research.

Difficulties encountered in the establishment phase have delayed the grazing of legume-grass associations. Reasonably well established pastures are now available at all sites and production monitoring has been started. Initial evidence points towards an important element of management involved in maintaining the productivity of these pastures, more related to grazing regime, burning, weeding than to the use of fertilizers. Given the reduced stock of knowledge on the management of these pastures, applied and basic research thereon should have a high pay-off.

21. Scientific Training

EVENTS AT CIAT

In order to comply with its objectives, the Training and Communications Program (TCP), in collaboration with the Tropical Pastures Program (TPP), offered training in research in nine different areas to 32 professionals from 10 countries during 1989. This training was carried out in different categories (Table 1). The sections that dedicated the most time to this task were: Agronomy, with 43.7 man-months; Pasture Quality and Productivity, with 32.6 man/months; Soil-Plant-Animal Relationship and Nutrients Recycling, with 23.4 man-months; Pasture Development, with 16.1 man-months; and Seed Production, with 13.2 man-months. The number of researchers trained by countries during 1989 is presented in Table 2.

Between February 27 and April 28, the Multidisciplinary Intensive Phase of the XII Program of Scientific Training in Research for the Production of Tropical Pastures was held, in which 23 professionals from eight countries of tropical America participated, with 18 professionals staying for the specialization phase (Table 3) in different areas in accordance with the interest and specialty requested by each participant. The duration of this training varied between one and five months.

DECENTRALIZED EVENTS

At the country level

For the purpose of collaborating with institutions in the training of their personnel, CIAT's Training and Communications Program, in collaboration with the TPP, supported decentralized training technology transfer, promotion and development events in collaboration of these institutions. Some events were directed toward professionals who work in transfer and extension to strengthen the linkage between research and extension, also involving development agencies existing in each country. In other events, the need to continue with more specific training activities was detected, within the project of promoting the multiplication and production of forage grass and legume seed for the regions and countries of the area of interest of the Seed Production Section of CIAT's TPP.

For these previous reasons, plus the interest of the national institutions, four decentralized training events were carried out in 1989 (Table 4).

Study tours on pasture seed production in Colombia

Two tours were organized as an integral part of the Project for the Promotion of Pastures Seed Multiplication in Colombia. Each one had two components: one, which included visits to multiplication fields, where participants had a chance to inspect seed cultivar and promising grasses and legumes seed multiplication fields, and the other one was a meeting day which included conferences and discussions aimed at achieving a better focus and coordinatation in

Table 1. Professionals trained in the Tropical Pastures Program, by discipline of specialization and training category during 1989.

	TRAINING CATEGORY															
	Visiting Research Associate				Visiting Researcher						Special Course		Intensive multi-disciplinary course			
PROGRAM: PASTURES	Ph.D Thesis		No Thesis		MS Thesis		Special-ization		Special-ization plus special multi-disciplinary course						Sub-totals	
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
DISCIPLINE:																
Agronomy					1	(9.0)	1	(0.0)	6	(34.7)					8	(43.7)
Pasture Development	1	(7.1)					1	(1.9)	1	(7.1)					3	(16.1)
Entomology									1	(3.2)					1	(3.2)
Farm Systems									2	(10.0)					2	(10.0)
Pasture Quality and Productivity					2	(15.3)			3	(17.3)					5	(32.6)
Interdisciplinary													5	(10.4)	5	(10.4)
Seed Production									3	(13.2)					3	(13.2)
Genetic Resources							1	(1.6)							1	(1.6)
Soils					1	(7.5)	1	(5.5)	2	(10.4)					4	(23.4)
Total Program	1	(7.1)			4	(31.8)	4	(9.0)	18	(95.9)			5	(10.4)	32	(154.2)

Table 2. Number and man-months of professionals trained at the Tropical Pastures Program by category and country of origin, during 1989.

PROGRAM: PASTURES	TRAINING CATEGORY Visiting Research Associate				Visiting Researcher						Special Course		Intensive multi-disciplinary course		Sub-totals	
	Ph.D Thesis		No Thesis		MS Thesis		Special-ization		Special-ization plus special multi-disciplinary course							
	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months	No.	Months
LATIN AMERICA AND THE CARIBBEAN																
Argentine					1	(9.0)									1	(9.0)
Bolivia									2	(11.2)					2	(11.2)
Brazil							4	(9.0)							4	(9.0)
Colombia					2	(15.3)			4	(17.4)			3	(6.2)	9	(38.9)
Ecuador									1	(6.4)			1	(2.1)	2	(8.5)
Guatemala													1	(2.1)	1	(2.1)
Honduras									3	(16.3)					3	(16.3)
Mexico									4	(24.8)					4	(24.8)
Peru	1	(7.1)			1	(7.5)			3	(13.6)					5	(28.2)
Venezuela									1	(6.2)					1	(6.2)
Total Program	1	(7.1)			4	(31.8)	4	(9.0)	18	(95.9)			5	(10.4)	32	(154.2)

Table 3. Information about researchers participating in the XII Tropical Pastures Scientific Training Program, 1989.

Name	Country	Institution	Profession	Occupation			% of time devoted to Trop.Past.	Type of training S.C. + Special.	Duration weeks	
				Research	Ext.	Promotion			S.C.	S.P.
Alfonso Escobar	Bolivia	SEFO/UMSS/COTESU	Agr.Eng.	x			50	S.C.+ Seed Prod.	9	9
José Blanco	Bolivia	IBTA	Agr.Eng.	x			70	S.C.+ Agronomy	9	20
Henry Mateus	Colombia	ICA	Agrostologist	x			100	S.C.+ Livest.Syst.	9	13
Alvaro Rincón	Colombia	ICA	Agr.Eng.	x		x	100	S.C.+ Seed Prod.	9	9
Benjamín Vásquez	Colombia	ICA	Agr.Eng.			x	10	S.C.+ Entomology	9	5
Oscar Pardo	Colombia	ICA	Zootechnist			x	75	S.C.	9	
Blanca Estupiñán	Colombia	ICA	Agr.Eng.			x	80	S.C.	9	
Hernando Castro	Colombia	ICA	DVMZ		x		20	S.C.	9	
Jesús Parada	Colombia	Secret.Desarrollo Agrop.	Zootechnist			x	20	S.C.+ Livest.Syst.	9	13
Angel Motoche	Ecuador	MAG-PROFOGAN	Agr.Eng.	x			80	S.C.	9	
Angel Anzules	Ecuador	INIAP	Agr.Eng.		x		100	S.C.+ Agronomy	9	20
Carlos Corado	Guatemala	DIGESEPE	Zoot.Lic.	x			60	S.C.	9	
Francisco Salatiel	Honduras	Secret.Rec.Nat.	Agr.Eng.	x		x	70	S.C.+ Seed Prod.	9	13
José Florez	Honduras	Secret.Rec.Nat.	Agr.Eng.Zoot.	x			100	S.C.+ Qualty.Prod.	9	13
Bertha Gómez	Honduras	Secret.Rec.Nat.	Agr.Eng.	x	x		100	S.C.+ Agronomy	9	20
Oscar Castellanos	Mexico	INIFAP	Agr.Eng.Zoot.	x		x	80	S.C.+ Agronomy	9	21
Régulo Jiménez	Mexico	INIFAP	Agr.Eng.Zoot.	x			80	S.C.+ Past.Establ.	9	22
Manuel Lara	Mexico	INIFAP	Agr.Eng.	x			100	S.C.+ Reg.Trials	9	13
Alejandro Bustamante	Mexico	INIFAP	Agr.Eng.Zoot.	x			100	S.C.+ Qual.Prod.	9	21
Federico Ramírez	Peru	Univ.Nal.Agr.La Molina	Agr.Eng.	x			10	S.C.+ Soil/Pl.Rel.	9	9
Florencio Dávila	Peru	INIAA	Agr.Eng.	x			100	S.C.+ Soil/Pl.Rel.	9	18
Fernando Passoni	Peru	Conv.INIAA/IVITA/CIAT	Agr.Eng.	x			100	S.C.+ Agronomy	9	5
Marciano Rivero	Venezuela	FONAIAP	Agr.Eng.	x			55	S.C.+ Qual.Prod.	9	19

Table 4. Events carried out by national institutions, with support of CIAT's Tropical Pastures and the Training and Communication Programs in 1989.

Country	Event	Participating Institutions	Professionals trained
Colombia	Study tour of the Llanos in the Pasture Seed Multiplication Project for Colombia.	SEMILLANO Ltda., Servicampo Colombia Ltda., Pastos y Leguminosas Ltda., Hoechst Colombiana S.A., ICA-CRECED, ICA-Certificación de Semillas, ICA-CRI La Libertad, Caja Agraria, Banco Ganadero and CIAT.	33
Colombia	Seminar on tropical pastures for acid soils in the Department of Antioquia.	Secretaría de Agricultura de Antioquia, Universidad Nacional de Medellín, SENA, CORNARE, CIAT.	32
Colombia	Study tour of Valledupar in the Pasture Seed Multiplication Project for Colombia.	Distribuidora del Valle Ltda., Hoechst Colombiana S.A., ICA, CRESEMILLAS-Caja Agraria, Banco Ganadero, CIAT.	15
Colombia	Workshop on the Establishment and Development of Improved Pastures for the Colombian Well-drained Savannas.	ICA-CRECED, Banco Ganadero, INCORA, SENA, Secretaría de Agricultura del Meta, CIAT.	29

future forage seed production and multiplication activities among seed-producing companies and support institutions. Besides, the participants' interest was identified as well as that from institutions, for future seed-multiplication actions. These two events were carried out as follows: the first one took place in the Villavicencio-Puerto López area, in Meta, Colombia, and it was called "Study tour in the Llanos, pastures seed project in Colombia". Attendance were 33 participants. Ten of these were from seed companies, 13 from support institutions and ten from CIAT.

The second one took place in the Valledupar-Codazzi area, Cesar, Colombia, and it was called "Study tour in Valledupar, pastures seed project in Colombia". Fifteen participants attended. Four of them were from seed companies, seven from support institutions, and four from CIAT.

Seminar on Tropical Pastures for Acid Soils in the Department of Antioquia

It took place in Medellin, Colombia, and was lead by technicians from the Secretaria de Agricultura de Antioquia who work in the pastures area in the Beef Cattle Program and Technicians from other institutions on this area.

The objective was to inform the participants about the results of the evaluation of new forage germplasm made by the Secretaría de Agricultura de Antioquia, with collaboration from CIAT's TPP. Twenty-nine participants attended this event.

Workshop on Pasture Establishment and Development for the Well-drained Colombian Savannas

This event took place at the Centro Nacional de Investigaciones (CNI) ICA-CIAT Carimagua, Meta, Colombia, and in cattle farms of the well-drained savanna. ICA's Regional Technology Training, Extension, and Diffusion Center (CRECED) in Puerto López, Meta, Colombia, participated in its organization, as well as Banco Ganadero and CIAT. The event was oriented towards professionals working on technical assistance in national and private institutions at the Colombian well-drained savanna.

The workshop was developed in three phases: a theory-practical one with a five-day duration, which had as an objective to improve upon the knowledge and abilities of participants in general principles for the establishment and development of improved pastures at the Colombian well-drained savanna. It included conferences, discussion tables, and field demonstrations.

The second phase dealt with practices for the establishment of grass and legume associations in producers' farms, with a five-day duration. Participants were divided in five groups and performed practices that included: soil preparation, equipment setting, seed inoculation, fertilizer application, and planting, as a complement to the first phase.

Finally, on a third phase 90 days after the plantings, participants evaluated the results from the second phase through field observations and a discussion table. This event was attended by 29 technical assistants.

22. Biotechnology

In 1989, the Biotechnology Research Unit (BRU) continued to provide support to the Tropical Pastures Program (TPP) in the use of in vitro culture techniques for the micropropagation and international exchange of Brachiaria germplasm.

The amount of material distributed in the form of tissue cultures from CIAT to the National Programs of Brazil and Peru, are:

	Institution	No. accessions
Brazil	EMBRAPA	150
Peru	Pucallpa/CIAT	26
Peru	IVITA/INIAA	23
	Total	199

In previous research done by the BRU, the techniques for plant regeneration of Stylosanthes spp. protoplast and callus cultures was developed and well established. Three Stylosanthes species were used successfully for that work and the field performance of the regenerated plants were also evaluated.

On the other hand, the BRU has developed capabilities for genetic transformation by means of Agrobacterium vectors. A range of vectors and plasmids containing marker genes, both screenable and reporter, are available in the BRU. Southern, Northern, Western techniques for assessing gene incorporation and expression in the plant tissues have also been developed in the BRU.

This year, with the collaboration of the TPP, a project was initiated in the BRU, by means of a sabbatical from Louisiana State University, to take advantage of the availability of those tools for the genetic transformation of Stylosanthes using agronomically important genes.

Other pasture species with relevance for transformation are those from the genus Arachis.

23. Virology

The Virology Research Unit (VRU) officially initiated research this year on the detection and characterization of viruses of economic or quarantine importance to the Tropical Pastures Program (TPP). Particular emphasis was given to tropical forage legumes, considering the well documented susceptibility of most legume species to plant viruses, and the absence of noticeable virus problems in grasses.

Research Priorities and Strategy

The VRU held various meetings with the Leader, agronomists, and past and present pathologists of the TPP to define research priorities for 1989. The consensus was that three of the most promising forage legume genera, namely, *Centrosema* spp., *Stylosanthes* spp., and *Arachis* sp. should be the initial research priorities of the VRU during 1989.

The main strategy followed was the examination of symptomatic and symptomless plant samples of some of the main species of the three genera selected by the TPP. Samples were taken from the three main CIAT experiment stations, Palmira, Santander de Quilichao, and Carimagua, utilized by the TPP. In the case of *A. pintoi*, plant samples were also obtained from farmers' fields.

All plant samples were initially processed for electron microscopy, and the viruses detected maintained in suitable host plants for characterization. The main objective of this characterization work, however, was to develop reliable virus detection tests for diagnostic and quarantine purposes. The following is a progress report of the research conducted by the VRU with plant viruses detected up to November 1989, in selected species of *Centrosema*, *Arachis*, and *Stylosanthes*.

VIRAL DISEASES OF CENTROSEMA SPP.

As reported last year (VRU Ann. Rept. 1988), several accessions of *Centrosema* spp. surveyed at three CIAT experiment stations, Palmira, Santander de Quilichao, and Carimagua, were noticeably affected by severe mosaic and foliar distortion symptoms of probable viral etiology. The virus isolated was characterized this year as described in the following extract of a scientific report on the causal agent.

Results

Filamentous, flexuous particles ca. 715 nm long and 12 nm wide were observed in negatively stained leaf extracts of a mosaic-affected *C. macrocarpum* plant selected as the source of inoculum for this study. The virus was mechanically transmitted from *C. macrocarpum* to five *Centrosema* species, and to susceptible *G. max*, *P. vulgaris* and *V. unguiculata* cultivars (Table 1). None of the other manually inoculated legume species tested showed symptoms or was observed to harbor CeV by electron microscopy or serology.

Table 1. Reaction of selected bean, cowpea, and soybean cultivars to a filamentous virus isolated from mosaic-affected <u>Centrosema macrocarpum</u>

Bean		Cowpea		Soybean	
Cultivar	Reaction	Cultivar	Reaction	Cultivar	Reaction
Dubbele Witte	S	293-476	-	Clark	S
Stringless Green Refugee	L,S	2143 Peru 7	-	Rampage	S
Redlands Greenleaf C	L	5006 ICA	-	Davis	-
Puregold Wax	L	Blackeye	S	York	-
Imuna	-	Bush sitao	-	Marshall	-
Redlands Greenleaf B	L	Monteria	-	Ogden	-
Great Northern 123	-	Red Ripper	-	Kwanggyo	-
Sanilac	-			Buffalo	-
Michelite 61	L			ICA Lili	S
Red Mexican 34	L,S			ICA line 109	S
Pinto 114	-			ICA line 1211	S
Monroe	L,S			ICA Mandarin	S
Great Northern 31	-			ICA Taroa	S
Red Mexican 35	-			ICA Tunia	-
Widusa	L,N,S			Improved Pelican	S
Black Turtle Soup	L,N			Williams	S
Jubila	L,N				
Topcrop	-				
Improved Tendergreen	L,N				
Amanda	-				
Bountiful	S				

Reaction = L = local lesions in inoculated leaves; N = vein necrosis in inoculated leaves; S = systemic infection; - = no infection as determined by absence of symptoms, electron microscopy, and serology.

Symptom expression in Centrosema spp. varied according to the species inoculated. Characteristic leaf distortion and mosaic symptoms (Figure 1) were only observed in C.macrocarpum, approximately 45 days after inoculation. Less conspicuous mosaic and chlorosis symptoms were observed in C. brasilianum, C. pubescens and C. pascuorum plants. Local chlorotic lesions were found on the inoculated primary leaves of C. pascuorum.

The virus systemically infected nine of the 16 soybean cultivars tested (Table 1) inducing a yellow leaf vein clearing. Local and/or systemic symptoms were observed in 13 of the 21 bean cultivars inoculated (Table 1).

Bean cultivars Bountiful and Dubbele Witte were the most susceptible, showing severe mosaic and leaf malformation symptoms. All inoculated bean Dubbele Witte plants eventually died. Cultivars Stringless Green Refugee, Michelite, Red Mexican 34, and Monroe, reacted with ring-shaped local lesions on the manually inoculated primary leaves. Improved Tendergreen, Black Turtle Soup, Jubila, and Widusa, reacted with vein necrosis on the inoculated primary leaves. One Widusa test plant died from systemic necrosis. Cultivars Puregold Wax and Redlands Greenleaf B and C, developed chlorotic local lesions on the inoculated primary leaves. Only one of the seven inoculated cowpea cultivars (Blackeye), became systemically infected and developed mosaic symptoms (Table 1).

The virus was transmitted by the aphid Myzus persicae from Centrosema macrocarpum and bean Dubbele Witte to all test Dubbele Witte and Bountiful bean plants.

The virus was transmitted via the seed of the four C. pubescens accessions (Nos. 438, 5144, 5634, and 15149) and bean cultivar (Dubbele Witte) tested, in percentages of 1.5 (6/400 seeds), 1.4 (11/770 seeds), 2.5 (10/400 seeds), 1.6 (6/380 seeds),and 6% (3/50), respectively.

This virus was isolated with a high degree of purity (Figure 1) following the purification procedure outlined above. Virus yields were 0.5 mg/100 g of bean tissue despite the noticeable virus aggregation problems observed throughout the purification procedure. Purified virus preparations exhibited an A 260/280 ratio of 1.13 and the SDS-PAGE analysis of its coat protein revealed the presence of a single subunit of M_r 32,500. A single nucleic acid molecule of approximately 9 kb was detected in agarose gels.

The examination of ultrathin sections of mosaic-affected C. macrocarpum leaf tissue, revealed the presence of cylindrical inclusions, consisting of pinwheels and scrolls (Figure 2), in the cytoplasm of infected cells.

The virus was serologically indistinguishable from soybean mosaic virus in reciprocal Ouchterlony, ELISA, and SSEM (1,000 to 1,100 particles/1,000 μm^2) tests, and was related to bean common mosaic and watermelon mosaic-2 viruses (weak serological reactions in Ouchterlony tests). The virus did not react with antiserum to blackeye cowpea mosaic virus or passionfruit woodiness virus in SSEM tests.

Discussion

The virus isolated in this study from C. macrocarpum was determined to be a member of the potyvirus group based on its morphology, particle length, aphid transmissibility in a non-persistent manner, presence of 'pinwheel' inclusions in infected plants cells, molecular weight of its capsid protein subunit and nucleic acid genome, ultraviolet spectrum of the viral nucleoprotein, and serological relationship with known members of the potyvirus group.

The close serological relationship of

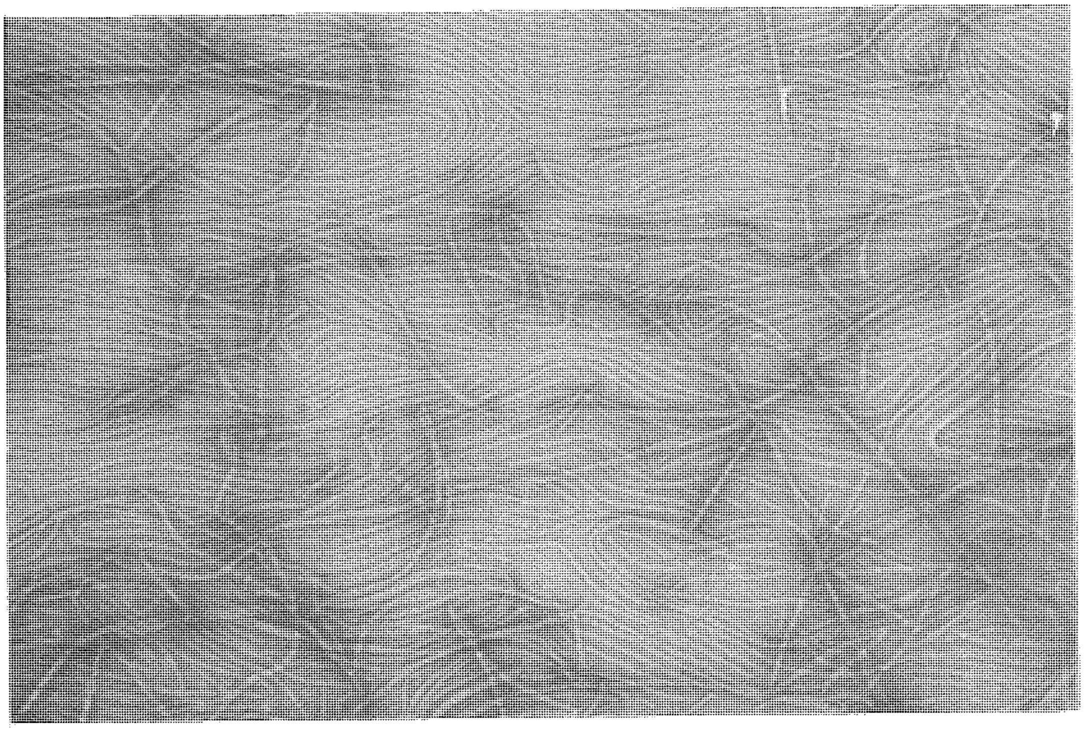


Figure 1. Purified particles of a filamentous virus (SMV-CE) isolated from *Centrosema macrocarpum*.

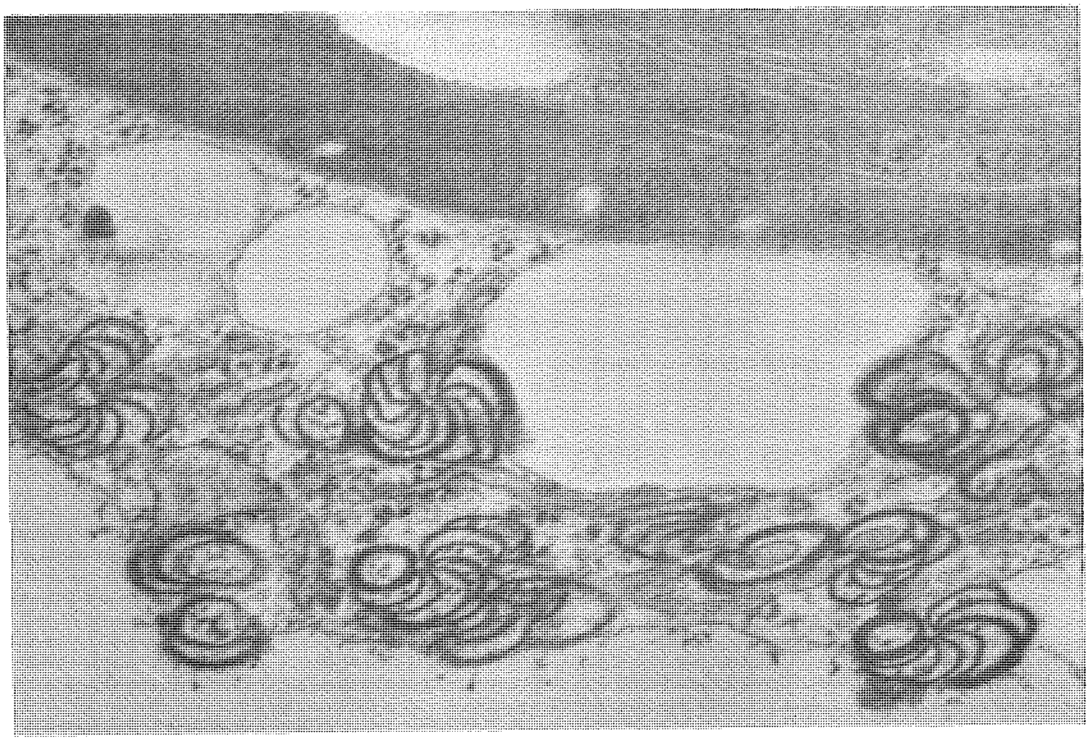


Figure 2. Characteristic cytoplasmic inclusions induced by a potyvirus in infected *Centrosema macrocarpum*.

this virus to soybean mosaic virus (SMV), and its pathogenic behavior in soybean and bean cultivars previously used to differentiate SMV strains, indicate that it belongs to the G_1 group of soybean mosaic virus strains.[1]

Although SMV is known to infect some 16 different species in the Leguminosae, the high incidence of this virus in most *Centrosema* spp. evaluation nurseries established in various geographically-isolated regions of Colombia, and the detection of the virus in the Caribbean area, suggest that SMV is a major viral pathogen of this important tropical forage legume. Also, SMV must be considered a potential constraint to the establishment of mixed grass-legume pastures in the Tropics, particularly in Latin America and Africa, where several forage legume species are being collected and utilized for this purpose. Among the tropical forage legumes currently maintained by the Genetic Resources Unit of CIAT, the plant genera *Astragalus*, *Canavalia*, *Cassia*, *Crotalaria*, *Galactia*, *Lablab*, *Lespedeza*, and *Sesbania* are reported hosts of SMV.

Finally, the demonstration of the seed transmissibility of SMV in *Centrosema* spp. further supports the consideration of this virus as a pathogen of considerable economic importance. We propose the designation SMV-CE for this strain.

As can be concluded from this investigation, the mosaic and leaf distortion of *Centrosema* spp. are caused by a previously known and ubiquitous legume pathogen, soybean mosaic virus. This finding has significant implications for the future of *Centrosema* spp. as a tropical forage legume considering the rapid expansion of soybean plantings in Latin America. In South America alone, the area planted to soybean increased from 1,433,000 has in 1970, to 13,985,000 has in 1987 (FAO data), in response to an increasing demand for soybean products in the international market.

Detection of other Viruses in *Centrosema* spp.

Several *Centrosema* spp. plants affected by virus-like symptoms similar to those described above for the Centrosema strain of soybean mosaic virus (SMV-CE), were serologically tested with the antiserum to SMV-CE. Unexpectedly, some samples did not react with this antiserum, which suggests the presence of other viruses. An electron microscopy examination of these samples, demonstrated the presence of filamentous particles similar to those of SMV-CE (Figure 3). This finding indicates that there are either different centrosema (SMV) virus strains or different potyviruses infecting *Centrosema* spp.

While the new centrosema viruses detected are characterized, the VRU attempted to implement a detection method for *Centrosema* spp. viruses, using a commercial (Agdia) monoclonal antibody produced to detect all members and strains of the potyvirus group. Table 2 shows the results of the test performed with the anti-potyvirus monoclonal antibody using an immuno-enzymatic test (ELISA). As shown, four of the six centrosema potyvirus isolates tested were detected by the anti-poty monoclonal antibody. The SQ-25 and CP-1 isolates, however, were not detected in this test.

Consequently, the CP-1 isolate was increased in *Phaseolus vulgaris* and purified to obtain enough antigen for production of an antiserum. The SQ-25 isolate was serologically related to other potyviruses described later on in this report and, therefore, there was no need to produce another antiserum. The CP-1 isolate was successfully purified and a specific antiserum produced this year.

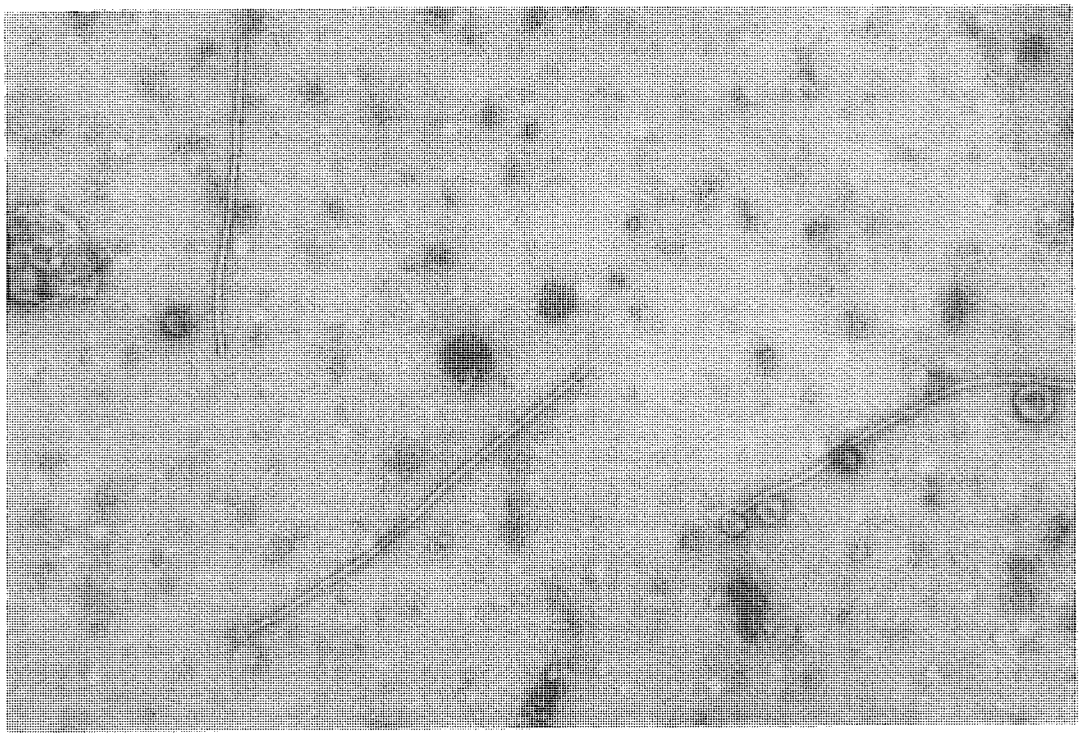


Figure 3. Filamentous virus particles detected in Centrosema spp. plants found free of the SMV-CE potyvirus by serological assays.

Table 2. ELISA (OD_{405}) reaction of different potyviruses isolated from Centrosema spp. to a monoclonal antibody specific for the potyvirus group.

Centrosema isolate[a]	30 min	60 min
SMV-CE	2.9	2.9
CP-1	0.0	0.0
CP-2	2.8	2.8
CP-3	2.8	2.8
SQ-15	1.5	2.8
SQ.25	0.0	0.0
SMV	2.8	2.8

a SMV-CE = centrosema strain of soybean mosaic virus;
CP = CIAT-Palmira isolate No.;
SQ = Santander de Quilichao isolate No.;
SMV = soybean mosaic virus.

In conclusion, it is evident that at least three different potyviruses can infect Centrosema spp. in Colombia. However, the TPP is now in capacity to detect these potyviruses in infected plants and sexual seed.

VIRAL DISEASE(S) OF ARACHIS PINTOI

As reported last year, Arachis pintoi plants with ringspot and yellow mottling were collected in the locality of Ginebra, Valle. These plants were brought to the VRU and shown by electron microscopy to contain a filamentous virus. These plants were used as virus sources for all subsequent characterization work.

The virus was mechanically transmissible to bean (Phaseolus vulgaris), cowpea (Vigna unguiculata), pea (Pisum sativum), soybean (Glycine max), and peanut (Arachis hypogaea), inducing systemic infection in all of these legumes. An electron microscopy study of Arachis pintoi plants affected by the ringspot/mottling disease revealed the presence of 'pinwheel' inclusions (Figure 4) characteristic of the potyvirus group.

The virus was subjected to a purification procedure suitable for plant viruses of the potyvirus group, to obtain a purified preparation (Figure 5). The purified virus was injected in a New Zealand white rabbit to produce an antiserum for diagnostic purposes. After a series of four injections at weekly intervals, the rabbit was bled to obtain the antiserum. The antiserum was successfully used in double immunodiffusion tests to specifically detect the virus in A. pintoi and in a susceptible pea cultivar.

The antiserum was also further purified to obtain the globulin fraction to implement an ELISA test suitable to detect the virus in sexual seed of A. pintoi. For this test, 540 A. pintoi seeds were assayed in groups of 2 and 10 seeds per sample, with negative results, indicating that the seed provided by the TPP was free of this potyvirus. We will be testing seed from virus-infected A. pintoi plants to investigate the possibility of seed transmission of this virus.

Characterization of the A. pintoi potyvirus.

Given the considerable expertise of the Plant Pathology Department of the University of Florida with potyviruses and forage legumes in general, the VRU contacted Dr. F.W. Zetter, a virologist in that Deparment, to request antisera to some of the potyviruses known to infect Arachis spp. This informal cooperation quickly led to the demonstration that the potyvirus isolated from A. pintoi was serologically identical to peanut mottle virus, an ubiquitous potyvirus of world-wide distribution. Work is now in progress to fully characterize the A. pintoi potyvirus as a possible peanut mottle virus strain.

VIRAL DISEASE(S) OF STYLOSANTHES SPP.

A virus survey conducted this year to detect the presence of viruses in Stylosanthes capitata, S. guianensis, and S. macrocephala in two locations, CIAT-Palmira and CIAT-Santander de Quilichao, did not reveal any apparent virus-like diseases. Nevertheless, leaf samples were taken to the VRU for electron microscopy to examine the plants for latent virus infections.

The observation of these samples with the electron microscope revealed the presence of a filamentous virus (Figure 6) in S. macrocephala but not in S. capitata or S. guianensis. The filamentous virus isolated had a mean particle length and morphology similar to those of potyviruses. The virus was mechanically transmitted to beans, causing both mosaic and necrosis, and to Nicotina benthamiana.

In order to establish the possible

Figure 4. Cytoplasmic inclusions induced by a potyvirus in infected cells of Arachis pintoi.

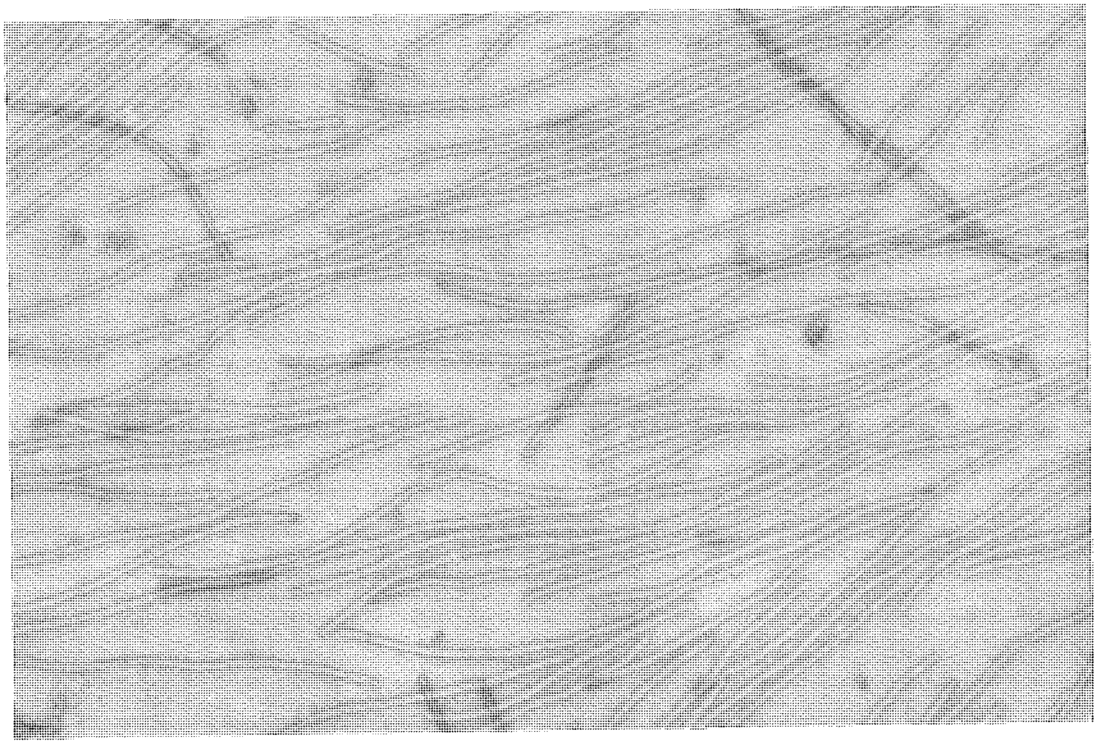


Figure 5. Purified particles of a potyvirus isolated from Arachis pintoi.

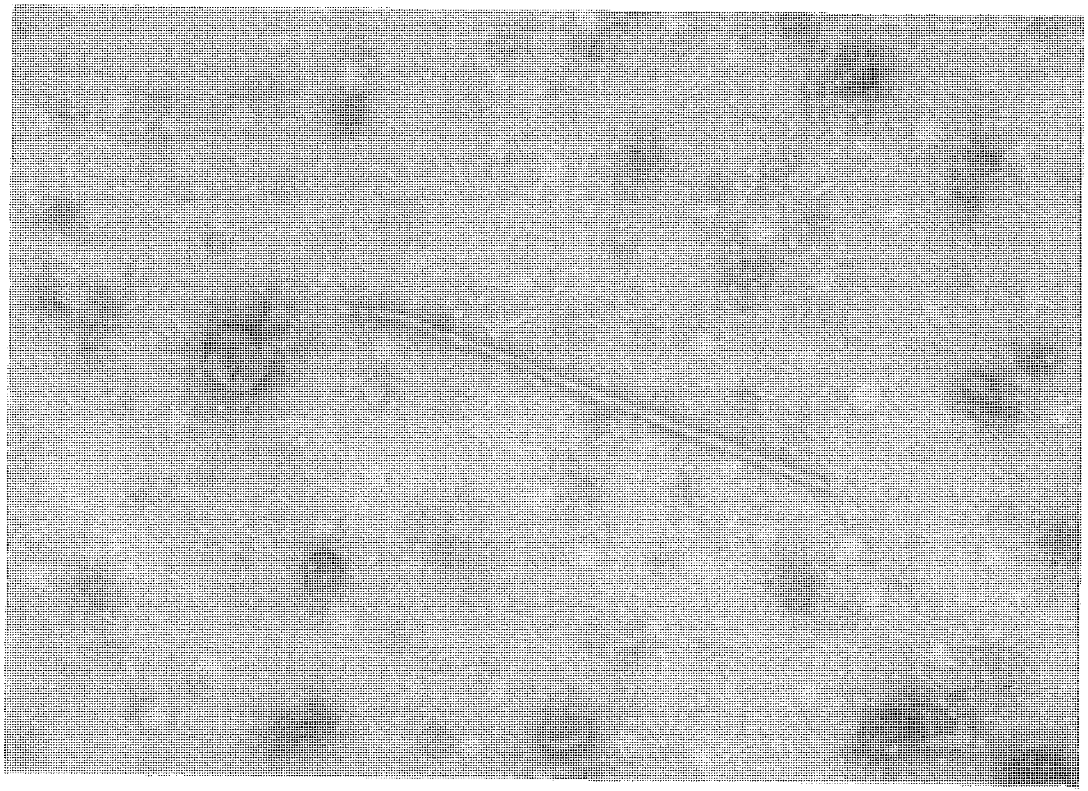


Figure 6. Filamentous virus detected by electron microscopy in leaf extracts of symptomless Stylosanthes macrocephala plants.

relationship between this potyvirus and those isolated from Centrosema spp. and Arachis pintoi, various serological tests were performed. The results of these tests clearly showed serological relationships between the Stylosanthes macrocephala, Arachis pintoi, and Centrosema SQ-25 potyviruses. These findings suggest that we are in the presence of a peanut mottle virus strain(s) capable of attacking Arachis, Centrosema, and Stylosanthes species.

Conclusions and future research strategy

The relatively high incidence of potyviruses in species of Arachis, Centrosema and Stylosanthes, is not surprising considering the broad pathogenicity range of potyviruses in the Leguminosae, and the fact that potyviruses are the largest group of plant viruses known. Also, potyviruses are ubiquitous in legumes due to their transmission by several aphid species and, more important, in the seed of many susceptible legume species.

In the case of Arachis, Centrosema, and Stylosanthes, at least three distinct potyviruses have been already detected. All of these viruses can now be detected and identified by serological means at CIAT, both in infected plants and seed. The quarantine significance of these potyviruses, however, is relatively low, considering that soybean mosaic and peanut mottle viruses are widely distributed in the world. Nevertheless, the VRU is already producing virus-free seed of these forage legumes to meet international standards for the exchange of plant germplasm.

It is evident that the virus characterization work must be continued to determine the extent of pathogenic variability and pathogenicity of these potyviruses in the Centrosema and Stylosanthes species currently evaluated by the Tropical Pastures Program. Also, a more thorough indexing of these species must be conducted to exclude the possible existence of viruses not readily detected by conventional electron microscopy techniques.

24. Rice-Pastures Association

INTRODUCTION

CIAT's activities on sustainability issues had their beginning in the development of production systems for a single commodity. Integrated production policies have recently, however, received increased attention. Integrated production in the forms of multi-and mixed cropping; rotation and relay cropping; and complimentary production systems between plants and animals are an essential part of sustainable tropical agriculture.

A combined project between the Rice and the Tropical Pastures Programs has been implemented to investigate rice-pastures associations and/or rotations in Carimagua and on farmers' fields in the Llanos Orientales. The objective is to find a cropping system that is more productive and more sustainable than the traditional monocropping of rice or pastures in this area of Colombia.

The Llanos Orientales was selected for two reasons: first, extensive cattle production and suitable pastures were already present; and second, rice lines adapted to upland acid soils such as those found in these areas, had just been developed by CIAT's rice breeders. It seemed reasonable to try and team up these two technologies and apply them to the vast eastern plains of Colombia.

Results from experiments conducted to date, reveal that this kind of agricultural system is far more productive and sustainable than pastures and/or rice systems alone,in terms of actual tonnage (from two crops), input costs (costs of planting rice with pastures involves added expense of pastures seed) and the cost to the ecosystem (the fragile chemical and physical properties of oxisols are better protected with rice-pastures cropping than with any monocrop).

RICE-PASTURES PROJECT EXPERIMENTS

Sites

In 1989, a series of agronomy experiments were established in the following three locations in the Colombian savanna, each of which has typical acid soils with low exchangeable cation content and high Al saturation (Table 1).

1) La Balsa, 70 km east of Villavicencio
2) Matazul, 55 km further east
3) Carimagua, 250 km further east

Species planted and fertilization

Experiments were designed using the following adapted pastures species to be sown alone and in mixtures:

Table 1. Soil analyses for the locations of the Rice-Pastures Project during 1989.

LOCATION	M.O.	P (Bray II)	P	Sat Al	Al	Ca	Mg	K
	%		ppm	%	--------- meq 100 g			----------
La Balsa	2.0	2.8	4.6	95	2.7	0.08	0.05	0.08
Matazul	3.8	1.8	4.4	94	3.5	0.18	0.06	0.07
Carimagua								
Previous Bd+Pp (1)	3.3	1.3	4.9	86	3.0	0.39	0.09	0.09
Previous Bd (2)	3.2	1.1	5.1	88	2.9	0.31	0.08	0.07
Previous ns (3)	3.0	2.1	5.0	94	2.9	0.16	0.02	0.06
Previous ns (3)	2.0	2.4	5.2	92	1.5	0.13	-0.01	0.05

(1) Brachiaria decumbens + Pueraria phaseoloides.

(2) Brachiaria decumbens.

(3) Native savannah.

B.decumbens, *P.phaseoloides*, *A.gayanus*, *S. capitata*, *B. dictyoneura*, and *C. acutifolium*. The rice line used was CT6196-33-11-1-3. Fertilization used was 80 kg/ha urea-N (30 kg at 25 days, 20 kg at 40 days and 30 at 60 days after planting), 50 kg/ha P (25 kg as Rock Phosphate and 25 kg as Triple Super Phosphate, applied at sowing time), 100 kg/ha KCl-K (in three applications of 30,50 and 20 kg/ha, together with the urea), and 300 kg Dolomitic lime before planting.

Seeding rates at planting:

Rice = 60 kg/ha
A.gayanus = 10 kg/ha
B.dictyoneura = 3 kg/ha
S.capitata = 3 kg/ha
C.acutifolium = 4 kg/ha

Trials

1. Matazul, replicated in La Balsa:

1.1 *The comparison of rice vs rice-pastures systems:* Randomized block design with 3 treatments (rice monoculture and rice pastures associations), and 3 replications, for a total of 9 plots of 100 m x 100 m = 10.000 m^2 each.

Treatments :
a. Rice monoculture (60 kg/ha, 17 cm between rows),
b. Rice + *B.dictyoneura* + *C.acutifolium* (60 kg/ha, 34 cm between rows),
c. Rice + *A.gayanus* + *S.capitata* (60 kg/ha, 34 cm between rows)

The pastures were planted simultaneously with rice.

1.2 *The effect of row spacing and rice seed rate on the establishment of rice-pasture systems*: Split plot design with cultures (monoculture and associations) as main plots, row spacings x seed rate of rice as subplots, and 3 replications, giving a total of 36 subplots of 40 m x 10 m = 400 m2 each.

Cultures (main plots) :

a. Rice monoculture,
b. Rice + *A.gayanus* + *S.capitata* (pastures planted 30 days after rice),
c. Pastures alone

Row spacings x seed rates for rice (subplots):

a. 34 cm x 60 kg/ha
b. 34 cm x 90 kg/ha
c. 51 cm x 60 kg/ha
d. 51 cm x 90 kg/ha

Within the main plot c. (pastures alone), as there were no rice subplots, a randomized block design with 4 treatments and 3 replications was carried out. The treatments were:

a. Pastures alone with fertilization for rice (control for the main experiment),
b. Pastures alone as above in a. but without N,
c. Pastures alone with fertilization for pastures i.e. 20 kg/ha Rock Phosphate-P, 20 kg/ha KCl-K, 200 kg/ha Dolomitic lime,
d. Pastures alone without fertilization.

1.3 *The establishment of Rice-Pastures systems considering different sowing dates for pastures*: split plot design with sowing dates for pastures as the main plot, associations as the subplot, 3 replications, for a total of 30 subplots of 20 m x 10 m = 200 m2 each.

Sowing dates for pastures (main plots):

a. Simultaneously with rice,
b. 30 days after rice,

c. 60 days after rice,
d. After rice harvest, with light disk,
e. Pastures alone, simultaneous with pastures in d.above, light disk, and fertilizer for pastures.

Asociations (subplots) :

a. Rice + B.dictyoneura + C. acutifolium,
b. Rice + A.gayanus + S.capitata.

2. Experiments in Carimagua :

2.1 Types of land preparation and rice planting systems in different rice-pastures associations : split plot design with a factorial arrangement, where the main plot is at time of ploughing (early and late) and the subplots are cultures x rice planting systems, in three replications. This gives a total of 48 subplots of 50 m x 7.5 m = 375 m2 each.

Ploughing (main plots) :

a. Early - shallow disk (December 1988),
b. Late - Plough for rice (April 1989).

Cultures x rice planting systems (subplots) :

Cultures
a. Rice monoculture,
b. Rice + B.dictyoneura + C. acutifolium,
c. Rice + A.gayanus + S.capitata,
d. B.dictyoneura + C.acutifolium alone, A.gayanus + S.capitata alone.

Rice planting systems :
a. Broadcast (80 kg/ha),
b. Drill (60 kg/ha and 30 cms between rows).

2.2 The effect of ten years of previous pastures growth on rice establishment and production : randomized block design for each of the 3 sites chosen with 3 different previous pastures systems (B.decumbens + P.phaseoloides, B.decumbens, and native savanna). The treatments for each site were P-levels x N-levels, with 3 replications. Total number of plots are 18 of 40 m x 10 m = 400 m2 each per site.

P-levels (50% Triple Super Phosphate + 50% Rock Phosphate):

a. 25 kg/ha,
b. 50 kg/ha.

Urea-N levels :

a. 0 kg/ha N,
b. 40 kg/ha N (15 kg at 25 days, 10 kg at 40 days, and 15 kg at 60 days after planting),
c. 80 kg/ha N (30 kg, 20 kg and 30 kg at the same times as in b. above).

RESULTS AND DISCUSSION

The results shown below, are only those of Matazul AND Carimagua. At the time of writing this report, harvests from these trials all planted in 1989 had been completed in Matazul, and Carimagua, and not yet begun at La Balsa (this will take place in late November 1989).

Results-Matazul

The comparison of rice vs rice-pastures systems

To break even in rice monoculture with the utilized inputs at current prices, it is necessary to produce 1.6 ton/ha. Associations of rice-pastures, however, cost exactly the same as rice monocropping practices, except for the addition of the pastures seed cost as all other costs will be accrued in monocropping anyway (land preparation, fertilizer); or, pastures agronomic needs can be dealt with at the same time as are those for rice (pastures planting being simultaneous with fertilizer applications). The following results come from one hectare plots which makes clear the possibilities for commercial production.

Averaging rice yields for the 3 replications in Table 2, gave 2228 kg/ha for rice monoculture, 2089 kg/ha for the association with B.dictyoneura and C.acutifolium, and 1960 kg/ha for the association with A.gayanus and S.capitata.

It is clear that the new upland rice lines for acid soils gave desirable yields even when grown with little fertilizer, and did not show yield reduction when associated with improved pastures.

The rice was harvested with a combine harvester, and at the same time the pastures were cut and left out in the field. Andropogon gayanus was 3 meters high, which slowed harvesting, while Brachiaria dictyoneura was about the same size as the rice and had already seeded at harvest time. Stylosanthes capitata was the most vigorous species in the field and C.acutifolium was starting to climb on the rice at harvest time. At the end of the harvest both pastures systems left in the field were well established. None of these pastures species affected the rice seed, which was clean and of excellent quality.

Once the field was fertilized for the rice crop (i.e. with higher levels than those needed for pastures alone) weed development was the limiting factor to rice grain yields. The field was originally native savanna with a very diverse and irregularly distributed vegetation that rapidly turns into a weed population.

These diverse weed populations can be difficult to control chemically due the diverse range of products probably needed and the application problems inherent for mixed rice-pastures systems. To make this kind of system more sustainable, through increasing pastures establishment, rice production and weed suppression, it would seem wise to work towards developing better methods and machinery for land preparation, weed control, soil conservation, and fertilizer needs and application rates.

The effect of row spacing and rice seed rate on the establishment of rice-pasture systems

As shown in Table 3, there were no economic differences when rice monoculture yields were compared to yields of rice grown associated with pastures planted 30 days after rice planting (together with the first N and the second K application). In addition, there were no economically important differences in rice yields when grown in different combinations of distances between rows and rice seed rates. This means that 60 kg of rice seed per ha sufficient to establish rice with pastures.

The pastures species, A.gayanus and S.capitata, despite having been planted 30 days after the rice, showed good establishment in all the treatments. A.gayanus was as high as the rice plants at harvest time making the harvest easier than simultaneous planting would have allowed.

It is important to note that A.gayanus yielded more dry matter in all association combinations with rice, than it does normally when planted in a monocrop with fertilizer applied at the rate recommended for pastures in the Llanos. S.capitata had lower dry matter yields in the associations perhaps due to the shading of the taller species, but its population in the field was very good.

Table 2. Field distribution and total biomass production above ground of 1 ha plots with rice monoculture and rice-pastures systems.

----- 100 m -----

Rice+Bd+Ca	Rice+Ag+Sc	Rice
Rice = 1954 kg Weeds= 898 kg Bd = 1077 kg Ca = 149 kg	Rice = 1734 kg Weeds= 658 kg Ag = 1740 kg Sc = 448 kg	Rice = 1881 kg Weeds= 1118 kg

100 m

Rice+Bd+Ca	Rice	Rice+Ag+Sc
Rice = 2285 kg Weeds= 575 kg Bd = 1962 kg Ca = 314 kg	Rice = 2290 kg Weeds= 560 kg	Rice = 1779 kg Weeds= 448 kg Ag = 1464 kg Sc = 437 kg

Rice+Bd+Ca	Rice	Rice+Ag+Sc
Rice = 2027 kg Weeds= 542 kg Bd = 609 kg Ca = 198 kg	Rice = 2515 kg Weeds= 280 kg	Rice = 2367 kg Weeds= 292 kg Ag = 2103 kg Sc = 448 kg

Bd = *Brachiaria dictyoneura*

Ca = *Centrosema acutifolium*

Sc = *Stylosanthes capitata*

Ag = *Andropogon gayanus*

Table 3. Total biomass production above ground for different row spacings and seed densities of rice in rice-pastures systems.

	Rice	Weeds	A.gayanus	S.capitata
	kg/ha			
Rice monoculture				
34 cm, 60 kg/ha	2185	1171	-	-
34 cm, 90 kg/ha	2000	886	-	-
51 cm, 60 kg/ha	2277	663	-	-
51 cm, 90 kg/ha	2340	689	-	-
Rice + A.gayanus+ S.capitata (pastures 30 days after rice)				
34 cm, 60 kg/ha	2066	742	480	135
34 cm, 90 kg/ha	2103	1061	765	187
51 cm, 60 kg/ha	1811	1027	521	160
51 cm, 90 kg/ha	1974	476	453	160
A.gayanus + S.capitata				
Fertilizer for rice	-	844	1265	1329
Fertilizer for rice-N	-	515	1158	1449
Fertilizer for pastures	-	445	319	732
Nil	-	298	151	341

Weeds were also a problem in this experiment. Their incidence was independent of distances between rows and seed densities of rice. They appeared indiscriminatedly in different sites of the field, perhaps where they were growing initially or where they were deposited during land preparation. This points out again the need to put emphasis on land preparation and on fertilizer, quantities and placement.

The experiment above had *A.gayanus* + *S.capitata* planted simultaneously with rice in rows 34 cm apart; *A.gayanus* grew up to 3 meters tall. In addition, *A.gayanus* + *S.capitata* were planted 30 days later than the rice in rows 34 cm apart, and *A.gayanus* again grew very well. It would be worthwhile investigating closer planting densities of rice (in rows 17 cm apart) along with simultaneous planting of rice and pastures to see if this helps control weeds.

Results of different fertilization packages for pastures monocropped are shown in Table 3. One treatment used rice fertilization levels and acted as control for this experiment. When the same level of fetilization for rice, but without its nitrogen component, was applied to *A.gayanus* + *S.capitata*, there was no reduction in dry matter yield of either of the two pasture species, and weeds were reduced by 40%. This shows the good adaptation of the pastures species to low N levels and the importance of N fertilizer management in weed control. When the fertilization was reduced to the quantities recommended for improved pastures, (2.5 times less P, 5 times less K and 0.3 times less Ca and Mg than for rice), *A.gayanus* and *S. capitata* dry matter yields are severely reduced. Field observation showed that the *S. capitata* plant population was high despite the drop in fertilizer. *A.gayanus* not only grew less but the plant population was seriously reduced.

The P and K reduction did not affect the weeds as much as it affected the pastures, whereas treatment with no fertilization were equally damaging for both pastures and weeds. Pastures are therefore more responsive to increased levels of P and K than the weeds, but the weeds will proliferate even at the lower P and K levels.

The effect of different sowing dates for pastures on the establishment of rice-pastures systems

This experiment unfortunately was established on a compacted soil (an old road) with an extremely high weed population characterized by a small and agressive native gramineae (not classified). Most of the rice yields obtained for the different treatments in this experiment are not worth mentioning. Nevertheless, the pastures and rice plants grew and the results are useful for selecting the correct times to plant the pastures with the rice. Table 4 includes the results for the two pastures associations planted at different times with the rice. *B.dictyoneura* + *C.acutifolium* established very well with rice only when planted simultaneously. *A.gayanus* + *S.capitata* established very well when planted simultaneously with rice, and still managed to establish when sown 30 days after the rice.

Results-Carimagua

Types of land preparation and rice planting systems in different rice-pastures associations

Despite the high sand content of the soil (together with several drought periods at different stages of the rice crop mainly at flowering time) the rice yields for the early plough treatment either in monoculture or in

Table 4. Total biomass production above ground for pastures systems associated at different times with rice.

	Rice	Weeds	Gramineae	Legume
	kg/ha			
Rice + *B.dictyoneura* + *C.acutifolium*				
Simultaneously	1134	1090	640	203
Pastures 30 days after	994	1745	1	11
Pastures 60 days after	1464	976	9	4
Rice + *A.gayanus* + *S.capitata*				
Simultaneously	1087	688	1117	275
Pastures 30 days after	1074	1133	190	41
Pastures 60 days after	1611	1209	0	1

association with B. dictyoneura and C. acutifolium were very similar and above the break even point of 1.25 t/ha for rice and 2.0 t/ha for the association (Table 5).

The rice yields from the early plough treatment, were about twice as much as those in the late plough treatment with the minimum extra investment of one disc pass at the end of the previous rainy season. Such a dramatic yield increase is likely due to the increased mineralization of the soil, from vegetation residues left after the early plough, together with some weed reduction that took place. The associated pastures were sown 30 days after the rice and as was already observed in the experiments with relative dates of planting of pastures with rice, the pastures association only established well when sown simultaneously with the rice crop. Pastures systems when monocropped, had good establishment.

Within the early and late plough treatments, rice planting systems were tested in monoculture and in association with A. gayanus and S. capitata (Table 6). For the early plough there were no differences between broadcast and drill rice whereas for the late plough there was a trend for the drill rice to yield more than the broadcast rice. In this sandy soil the conditions are more adverse for rice than for pastures, because of the low soil water retention in a season with several drought spells. These conditions cause the association crops to compete more. Early plough benefitted the rice, whereas late plough benefitted the associated pastures.

In this site, rice monoculture by broadcast or drill with early plough tends to yield more than in the association with A. gayanus and S. capitata sown 30 days after.

The effect of ten years previous pastures growth on rice establishment and production

Rice planted after a pasture that had already been established and grazed for ten years (B. decumbens and P. phaseoloides) with a small amount of fertilization applied every two years before, gave yields of more than 3 t/ha (Table 7). This was true even for the treatment with zero N and 25 kg/ha. The increase of applied N from 0 to 80 kg/ha, resulted in 0.5 extra t/ha. Doubling applied P to 50 kg/ha did not have a further effect on rice yield. The discussion above corresponds to treatments where no weed control was carried out. Figures in brackets were hand-weeded plots and yields had an increase of about 1 ton in comparison to the non-weeded plots.

Rice after B. decumbens alone with no applied N either at 25 or 50 kg P/ha gave low yields. An application of only 40 kg N/ha increased yields up to 3 t/ha, which is the same as that of the zero N treatment where the legume P. phaseoloides was in association with B. decumbens. A level of 80 kg N/ha increased yield by 0.5 tons relative to the 40 N level. There was no difference in rice yields between 25 or 50 kg P/ha at the N levels studied.

Rice yields after native savanna gave lower yields than after improved pastures. It responded to N levels to the point of about 2 t/ha yield at 80 kg N/ha and 50 kg P/ha. This is a similar yield to that obtained in other sites with the same fertilization and similar soils. Improved pastures established after some years can be ploughed, to allow a crop. The rice yields in this case can be about

Table 5. Effect of early and late plough of a sandy soil (> 40% Sand) on rice-pastures systems.

	RICE	*B.decumbens*	*C.acutifolium*	Weeds
	Dry Matter Kg/Ha			
EARLY PLOUGH				
RICE	2322	-	-	195
RICE+Bd+Ca 30 days	2440	5	30	53
Bd+Ca	-	486	276	790
LATE PLOUGH				
RICE	1219	-	-	288
RICE+Bd+Ca 30 days	1496	10	6	107
Bd+Ca	-	493	90	713

Table 6. Broadcast and drill rice in rice-pastures systems grown on a sandy soil (> 40% sand).

		RICE	*A.gayanus*	*S.capitata*	Weeds
		Dry Matter Kg/Ha			
EARLY PLOUGH					
RICE BROADCAST	B	2434	-	-	44
DRILL	D	2322	-	-	195
RICE+Ag+Sc 30 days	B	1934	44	98	29
	D	2090	34	47	119
LATE PLOUGH					
RICE	B	860	-	-	237
	D	1219	-	-	288
RICE+Ag+Sc	B	947	266	155	142
	D	1215	146	47	118

Table 7. The effect of ten years previous pastures growth on rice establishment and production.

Fertilization P	N	Rice + Bd + Pp	Rice + Bd	Rice + n.s.
--- kg/ha ---			Rice yield kg/ha	
25	0	3068 (3882)	1358	1048 (1504)
25	40	3129	3079	1739
25	80	3542 (4241)	3574	1774 (2248)
50	0	3208 (4340)	1344	914 (1399)
50	40	3214	2952	1499
50	80	3356 (4515)	3566	1978 (2366)

Bd = Brachiaria decumbens
Pp = Pueraria phaseoloides
ns = native savanna

Numbers in brackets are hand weeded plots.
Bd+Pp and Bd were fertilized with 250 kg/ha Calfos and 50 kg/ha Sulpomag on 20-4-87.

twice as much as those obtained after native savanna. This is true even without applied N in pastures with the legume component.

Production Costs Rice-Pastures

A summary of production costs for rice-pastures production, based on actual costs, is presented in Figure 1. Total costs for establishing the system are equivalent to 2.008 t/ha of paddy rice at current market prices. This may be considered as a break-even point, where pasturs establishment has no cost. At this cost, pastures are established at approximately 0.4 t/ha paddy equivalent, or approximately US$75/ha. This compares favorably with costs of approximately US$150/ha to establish pastures using current technology.

Removing the direct costs for the pastures seeding component, gives a cost equivalent for rice production alone of 1.6 t/ha paddy rice equivalent.

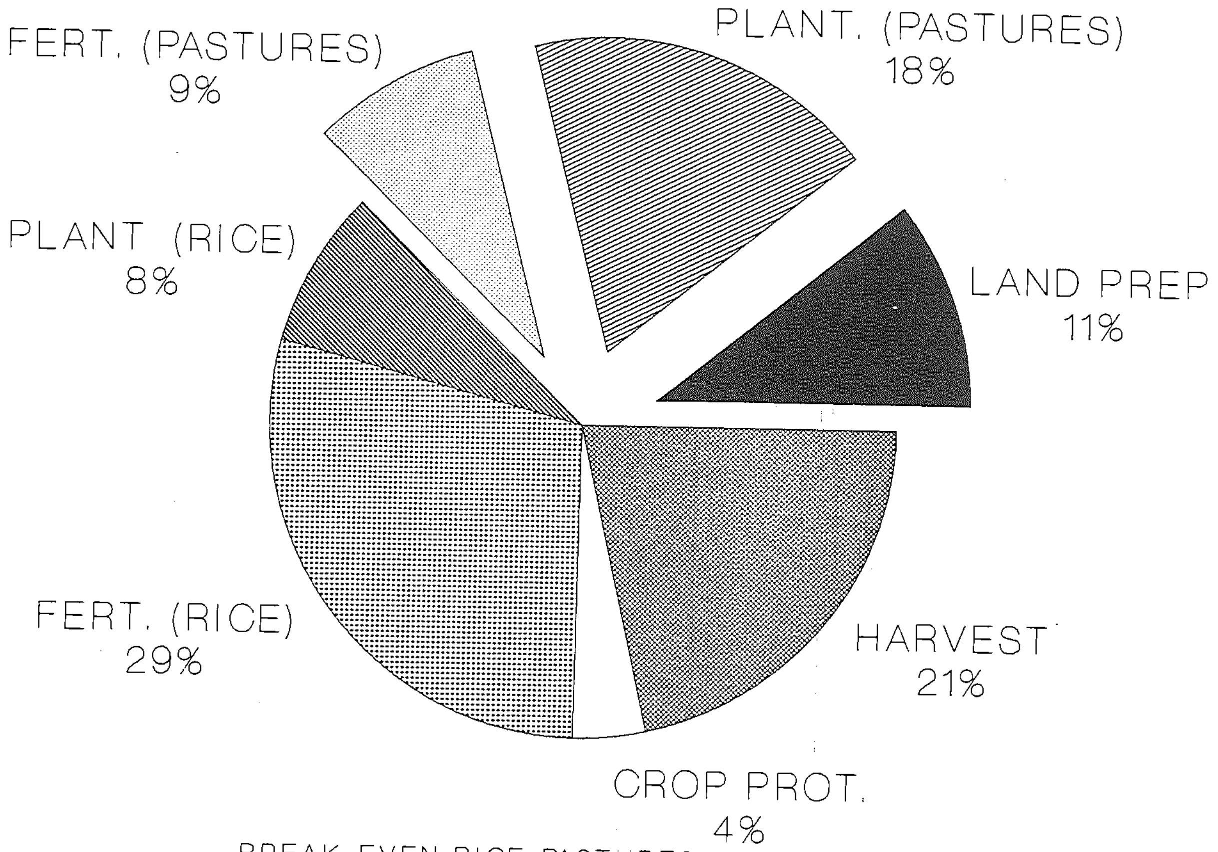
SUMMARY

Matazul

- 1.25 tons rice are needed to break even in savanna rice production. The only extra cost involved in rice-pastures associations is that of seed, while the extra benefit is big.

- Rice yields from both monoculture crops and pastures associations do not differ in cost-benefit analysis. In addition, at rice harvest time there is a well established pasture mixtures.

- Rice-pastures associations (simultaneous planting), produce good rice yield and pasture establishment. *A. gayanus* grew up to 3 meters high;



BREAK-EVEN RICE-PASTURES 2,008 Kg/Ha.
BREAK-EVEN RICE PORTION: 1,251 Kg/Ha

Figure 1. Direct cost of production for Rice-Pastures in Matazul-Meta, 1989A.

B.dictyoneura and S. capitata grew to the same height as the rice plants; and C.acutifolium was already climbing on the rice and the grass at harvest.

- An increase of rice seed sowing rate from 60 to 90 kg/ha does not translate into increased yields.

Distances of 34 or 51 cm between rice rows has no positive effect on rice yields.

- A. gayanus in association with rice (30 days after) and fertilized with rice crop rates, yielded more dry matter at rice harvest than A. gayanus grown alone with conventional pasture fertilization.

- Weeds became a problem when rice-pastures were sown after native savanna and the rice crop was fertilized with the recommended level. In pastures plots, when N was not included in the fertilization there was a considerable decrease in weeds. When P and K rates were reduced, S.capitata was affected in its growth and A.gayanus was reduced in its number of plants.

- Chemical weed control will be difficult to use effectively, due to the irregular distribution and diverse weeds inherent in rice-pastures systems in savannas. Improved methods and tools for land preparation as well as a better understanding of the optimal fertilization methods should be investigated as an important alternative to chemical weed control.

Carimagua

- The rice yield was twice as much when an early plough was applied, in carried out, in comparison to a late plough treatment.

- Rice after a 10 year B.decumbens establishment has higher yields than after a native savanna field and yields become even greater when the previous pasture was B. decumbens with P. phaseoloides. The contribution of the legume to rice yield is very high, even without applied N to the rice crop.

- Ten year old pastures reestablishment in association with rice follows the same trend as rice yields in the point mentioned above.

- These first year results, show that productivity can be significantly increased in acid savanna soils. In addition, it seems very probable that sustainability can be achieved with these rice-pastures systems.

International Cooperation

The rice-pastures project has proved so stimulating, that a cooperative effort with this type of research in CNPAF/EMBRAPA, Brazil has begun. This should make research quite efficient as Colombia's rainy seasons coincide with Brazil's dry seasons and vice-versa. Researchers from ICA Colombia and farmers from the region around the plots in the Llanos have been following the experiments and are quite keen to join in or to collaborate. Research data on this kind of sustainable cropping system with multiple products are practically non-existent for Latin America, outside of this particular experiment.

25. Publications

AMEZQUITA, M.C.; PIZARRO, E.A. y TOLEDO, J.M. 1989. Rango de adaptación de *Andropogon gayanus*. *En*: TOLEDO, J.M.; VERA, R.; LASCANO, C. y LENNE, J. (eds.). *Andropogon gayanus* Kunth. Un pasto para los suelos ácidos del trópico. CIAT. Cali, Colombia. pp. 398-68.

BOTERO, R. 1989. Manejo de explotaciones ganaderas en las sabanas bien drenadas de los Llanos Orientales de Colombia. CIAT, Programa de Pastos Tropicales, Serie Boletines Técnicos No.2, Cali, Colombia. Febrero. 100 p.

BOTERO, R. y O. GARCIA. 1989. Implemento para la siembra de pastos en pequeñas explotaciones. Pasturas Tropicales, Volumen 11, No.3, Diciembre.

BURDON, J.J. and LENNE, J.M. 1989. The *Phakopsora pachyrhizi* - Kennedia *rubicunda* host-pathogen associated and its relation to leaf rust of *Glycine* spp. AJAR 40: (in press).

CADISCH, G., SYLVESTER-BRADLEY, R. and NOSBERGER, J. 1989. ^{15}N- based estimation of nitrogen fixation by eight tropical forage legumes at two levels of PK-supply. Field Crops Research.

DIULGHEROFF, S., E.A. PIZARRO y J.E. FERGUSON. 1989. Actividades de semillas de especies de forrajeras tropicales en Costa Rica. Reunión PCCMCA, Honduras, 3-5 Abril 1989.

FERGUSON, J.E. Ed. Coord. 1989. Semillas de especies forrajeras tropicales en la selva peruana: Memorias taller organizado por INIAA-IVITA-CIAT, 30 Mayo - 4 Junio, 1988. Tarapoto, Perú. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia, 166 p.

FERGUSON, J.E. 1989. Producción de semillas de *Andropogon gayanus*. *En*: *Andropogon gayanus*, Kunth: Un pasto para los suelos ácidos del trópico. Toledo, J.M., Vera, R., Lascano, C. y Lenné, J.M. (eds.)., CIAT, Cali, Colombia. pp. 295-321.

FERGUSON, J.E., R. SCHAUS and A. PERALTA. 1989. The integration of seed activities into an International Pastures Network. XVI International Grassland Congress, Nice, France. pp. 683-684.

FERGUSON, J.E., R. VERA and J.M. TOLEDO. 1989. *Andropogon gayanus* and *Stylosanthes capitata* in the Colombian Llanos - The path from the wild towards adoption. XVI International Grassland Congress, Nice, France. pp. 1343-1344.

FERRUFINO, A., and S.L. LAPOINTE. 1989. Host Plant Resistance in *Brachiaria* grasses to the spittlebug *Zulia* colombiana. Entomol. exp. appl. 51(2):155-162.

JANSSEN, W.G., L. SANINT y C. SERE. 1989. Multiple objective decision making at CIAT. CIAT-Documento Interno, Octubre.

LANGE, LENE, JILLIAN M. LENNE, and LAURITZ W. OLSON. 1989. Ultrastructural studies of zoosporangium and resting sporangium of *Synchytrium desmodii*. Journal of Phytopathology 125:361-372.

LAPOINTE, S.L., G. ARANGO and G. SOTELO. 1989. A methodology for evaluation of host plant resistance in *Brachiaria* to spittlebug species (Homoptera: Cercopidae). Proc. XVI Internat. Grassland Cong., Nice, France, 1989:731-732.

LAPOINTE, S.L., G. SOTELO, and G. ARANGO. 1989. Improved rearing technique for spittlebugs (Homoptera:Cercopidae). J. Econ. Entomol. 82(6):1764-1766.

LENNE, J.M. 1989. Problems associated with evaluation of diseases of perennial pasture plants - some recommendations. Proc. XVI Int. Grassl. Congress. pp. 695-696.

LENNE, J.M. and M.A. CALDERON. 1989. Problemas causados por plagas y enfermedades en *Andropogon gayanus*. pp. 191-238. *In*: *Andropogon gayanus* Kunth - un pasto para suelos ácidos del trópico. eds. Toledo, Vera, Lascano, Lenné, CIAT, Cali, Colombia.

LENNE, J.M., G. OLAYA and J.W. MILES. 1989. Importance of Rhizoctonia foliar blight of the promising tropical pasture legume genus *Centrosema*. Proc. XVI Int. Grassl. Congress. pp. 697-698.

LENNE, J.M., ZAMORANO, E. and VARGAS DE ALVAREZ, A. 1989. Estrogenic activity in Sphaceloma scab infected *Zornia latifolia*. Phytopath. 79: (in press).

OLAYA, G. and LENNE, J.M. 1989. Isozyme variation between and within species of the genus *Rhizoctonia*. Phytopath. 79: (in press).

PIZARRO, E.A.; FRANCO, L.H. and RAMIREZ, A. 1989. Introduction and evaluation of tropical forages in the savannas of Colombia. Proceedings of the XVI International Grasslands Congress, Nice - France. pp. 211-212.

PIZARRO, E.A.; DIULGUEROFF, S. and ARGEL, P. 1989. Introduction and evaluation of tropical forages in various ecosystems of Costa Rica. Proceedings of the XVI International Grasslands Congress, Nice - France. pp. 237-238.

PIZARRO, E.A.; and VERA, R.R. 1989. Yield and quality of signal grass stockpiled at different dates. Proceedings of the XVI International Grasslands Congress, Nice - France. pp. 1575-1576.

RAMIREZ, A., R. BOTERO y A. BERMEO. 1989. Potencial económico de un programa de transferencia de tecnología de pasturas en la altillanura oriental de Colombia. CIAT, Pasturas Tropicales, Volumen 11, No.2. Agosto.

RIVAS, L., SERE, C., SANINT, L.R y J.L. CORDEU. 1989. La situación de la demanda de carnes en países seleccionados de América Latina y el Caribe. FAO/CIAT, Cali, Colombia. 196 p.

SERE, C. y J. FERGUSON. 1989. Release and initial evidence of adoption and impact of *Andropogon gayanus* in tropical America. *In*: Toledo, J.M., Vera, R., Lascano, C. y J. Lenné (eds.). *Andropogon gayanus* Kinth: a grass for tropical acid soils. Cali, Colombia, August. pp. 357-387.

SERE, C., W. JANSSEN, L.R. SANINT, W. GRISLEY, L. RIVAS y J. COCK. 1989. The outlook for CIAT commodities towards the year 2000. *In*: Trends in CIAT Commodities, Internal Document-Economics 1.14, July.

SERE, C. y L.S. JARVIS. 1989. The betting line on beef: ex-ante estimates of improved pasture research benefits for the Latin American tropics. *In*: Trends in CIAT Commodities, Internal Document-Economics 1.14, July.

THOMAS, D. and S.L. LAPOINTE. 1989. Testing new accessions of Guinea Grass (*Panicum maximum*) for acid soils and resistance to spittlebug (*Aeneolamia reducta*). Tropical Grasslands (in press).

TOLEDO, J.M., J.M. LENNE and R. SCHULTZE-KRAFT. 1989. Effective utilization of tropical pasture germplasm. pp. 27-87. *In*: Utilization of Genetic Resources: Suitable Approaches, Agronomical Evaluation and Use. FAO Plant Production and Protection Paper No.94.

TOLEDO, J.M., C. SERE y M. LOKER. 1989. Pasture-crop technologies for acid soil savannas and rain forests of tropical America. *In*: Proceedings of the Ninth Agricultural Symposium of the World Bank - Innovations in Resource Management, Enero 10-11.

TORRES, C., BRADLEY, R.S., LENNE, J.M. and CHAVERRA, M. 1989. Survival of *Bradyrhizobium* in contact with chemical protectans on seed of *Centrosema acutifolium*. Phytopah. 79: (in press).

VALLEJOS, A.; PIZARRO, E.A.; CHAVES, C.; PEZO, D. y FERREIRA, P. 1989. Evaluación agronómica de gramíneas en Guápiles, Costa Rica. 1. Ecotipos de *Brachiaria*. Pasturas Tropicales 11(2):2-9.

VALLEJOS, A.; PIZARRO, E.A.; CHAVES, C.; PEZO, D. y FERREIRA, P. 1989. Evaluación agronómica de gramíneas en Guápiles, Costa Rica. 2. Ecotipos de *Panicum maximum*. Pasturas Tropicales 11(2):10-15.

VARGAS DE ALVAREZ, A., TORRES, C. and LENNE, J.M. 1989. Effect of various fungicides on mycelial growth of *Colletotrichum gloeosporioides* and *Rhizoctonia* species *in vitro*. Phytopath. 79: (in press).

VERA, R.R.; PIZARRO, E.A.; TOSCANO, A. and RODRIGUEZ, N.M. 1989. Sites of digestion of nitrogen of hays made with the tropical legume *Neonotonia wightii*. 1989. Proceedings of the XVI International Grasslands Congress, Nice - France. pp. 921-922.

VERA, R.R. y C. SERE. 1989. On-farm results with *Andropogon gayanus*. *In*: Toledo, J.M., Vera, R., Lascano, C. y J. Lenné (eds.). *Andropogon gayanus* Kunth: a grass for tropical acid soils. CIAT, Cali, Colombia, August. pp. 323-355.

26. List of Members of the Program

Científicos Principales

José M. Toledo, Ph.D., Agrostologist, Leader

Pedro J. Argel, Ph.D., Agronomist, Agronomy/RIEPT Central America and the Caribbean (San José, Costa Rica)
* Rosemary S. Bradley, Ph.D., Microbiologist, Microbiology
John Ferguson, Ph.D., Agrostologist, Seed Production
Myles Fisher, Ph.D., Ecophysiologist, Ecophysiology
* Bela Grof, Ph.D., Agrostologist, Agronomía/RIEPT-Cerrados (Brasilia, Brazil)
Gerhard Keller-Grein, Dr. agr., Agronomy/RIEPT-Amazonas (Pucallpa, Perú)
Stephen Lapointe, Ph.D., Entomologist, Entomology
Carlos Lascano, Ph.D., Ruminant Nutritionist, Pasture Quality and Productivity
John W. Miles, Ph.D., Plant Breeder, Forage Breeding
Yoichi Nada, Ph.D. (TARC-Japan), Pasture Scientist
Esteban A. Pizarro, Ph.D., Agrostologist, Agronomía/RIEPT-Cerrados (Brasilia, Brasil)
** Idupulapati Rao, Ph.D., Plant Nutrition Physiologist, Soil/Plant Relationships and Nutrients Cycling
** Georges Rippstein, Dr. agr., (IEMVT-CIRAD/CIAT), Pasture Ecologist, Improved Native Grasslands Research
* José G. Salinas, Ph.D., Soil Scientist, Pasture Reclamation Humid Tropics (Pucallpa, Perú)
Rainer Schultze-Kraft, Dr. agr., Agrostologist, Germplasm
Carlos Seré, Dr. agr., Agricultural Economist, Economics
James M. Spain, Ph.D., Soil Scientist, Pasture Development, Cerrados (CPAC, Brasilia, Brazil)
* Derrick Thomas, Ph.D., Agrostologist, Agronomy/RIEPT-Llanos
** Richard Thomas, Ph.D., Plant/Microbial Physiologist, N Cycling and Nitrogen Fixation
** Peter Trutmann, Ph.D., Plant Pathologist, Plant Pathology
Raul R. Vera, Ph.D., Animal Scientist, Livestock Production Systems

Visiting Scientists and Posdoctorals

** Miguel Ara, Ph.D., Soil Scientist, Pasture Reclamation Humid Tropics (Pucallpa, Perú)
Miguel A. Ayarza, Ph.D., Soil Scientist, Soil/Plant Relationships and Nutrient Cycling
* William Loker, Ph.D. (Rockefeller Fellow), Anthropologist, On-farm Research (Pucallpa, Perú)
** Brigitte L. Maass, Dr. sc. agr., Posdoctoral Fellow, Agronomist, Germplasm

Alvaro Ramirez, Ph.D. (FUNDAGRO), Economist, Production Systems (Napo, Ecuador)
Roberto Sáez, Ph.D., Economist, Production Systems (Brasilia, Brasil)
José Ignacio Sanz, Ph.D., Soil Scientist, Rice-Pasture Project, stationed at Villavicencio, Colombia

Research Associates

Amparo de Alvarez, Agr. Eng., Plant Pathology
Raul Botero, DVMZ, M.Sc., Economics
Stephano Diulgheroff, Agrostologist (FAO), Agronomy Seed Production/RIEPT, (San José, Costa Rica)
Manuel Arturo Franco, Mech. Eng., Data Base Unit
Luis Horacio Franco, Agr. Eng., RIEPT
Obed García, DVMZ, CIAT/TUB/GTZ Dual Purpose Project (Villavicencio, Colombia)
Hernán Giraldo, Agr. Eng., Ecophysiology (Carimagua, Colombia)
Ramón Gualdrón, Agr. Eng., Soil/Plant Relationships and Nutrient Cycling
Phanor Hoyos, Zootech., Pasture Quality and Productivity, Puerto López
Silvio Guzmán, DVMZ, Livestock Production Systems
Eloína Mesa, Statistician, Biometrics, Data Services Unit
Neusa Massae Asakawa, Biologist, N Cycling and Nitrogen Fixation
Kenneth Reátegui, Agr. Eng., M.Sc., On-Farm Research (Pucallpa, Perú)
Libardo Rivas, Economist, M.Sc., Economics
Manuel Sánchez, Agr. Eng., Seed Production
Miguel Santiago Serrano, Biologist, Entomology
Christian Ulrich, Dipl. Agr. Eng., Visiting Scientist, CIAT/TUB/GTZ Dual Purpose Project (Villavicencio, Colombia)

Research Assistants

Guillermo Arango, Biologist, Entomology
Patricia Avila, Zootechnist, Pasture Quality and Productivity
Julián Azañero, Agr. Eng., Pasture Reclamation (Pucallpa, Perú)
* Gustavo Benavides, Agr. Eng., Germplasm (Quilichao, Colombia)
María Cristina Bolaños, Bacteriologist, N Cycling and Nitrogen Fixation
** José Vicente Cadavid, Agr. Econ., Economics
Javier Asdrúbal Cano, Economist, Leader Office
Carlos Iván Cardozo, Agr. Eng., Seed Production
Fernando Díaz, Agr. Eng., Agronomy (Carimagua, Colombia)
Martha Lucía Escandón, Agr. Eng., Plant Breeding
Fernando Fernandez, Animal Scientist, Economics (Florencia, Colombia)
Luis H. Franco, Agr. Eng., Agronomy, Regional Trials
César Augusto García, Agr. Eng., Entomology and Plant Pathology (Carimagua)
Fulvio Hidalgo, Agr. Eng., Seed Production (Pucallpa, Perú)
* Carlos H. Molano, Agr. Eng., Plant Breeding (Quilichao, Colombia)
* Diego Molina, Agr. Eng., Ecophysiology (Carimagua, Colombia)
Dacier Mosquera, Agr. Eng., N Cycling and Nitrogen Fixation
Gloria Navas, Agr. Eng., Agronomy (Carimagua, Colombia)
Fernando Passoni, Agr. Eng., Agronomy Humid Tropics (Pucallpa, Perú)
* Carlos E. Perdomo, Agr. Eng., Soil/Plant Relationships and Nutrient Cycling (Carimagua, Colombia)
Camilo Plazas, Agr. Eng., Pasture Quality and Productivity (Carimagua, Colombia)

Carlos A. Ramirez, DVMZ, Livestock Production Systems
Julio Rosales, Agr. Eng., Pasture Reclamation (Pucallpa, Perú)
Edgar Salazar, Agr. Eng., Agronomy (Carimagua, Colombia)
Sigifredo Salgado, Agr. Eng., Seed Production (Villavicencio, Colombia)
Blanca Torres, Bacteriologist, Livestock Production Systems
Celina Torres, Agr. Eng., Plant Pathology
Alfredo Valerio, Agr. Eng., Agronomy/RIEPT, Central America and The Caribbean (San José, Costa Rica)

Scientific Staff of CPAC and EMBRAPA/CPAC/CIAT Agreement (Brasilia, Brazil)

Ronaldo Pereira de Andrade, M.Sc.
Gilberto Leite, Ph.D.
Carlos Magno da Rocha, M.Sc.
Mario Soter, Ph.D.
Lourival Vilela, M.Sc.
José Zoby, Ph.D.

Scientific Staff of INIAA/IVITA and INIAA/IVITA/CIAT Agreement (Pucallpa, Perú)

Abraham Díaz, Agr, Eng. (INIAA)
Héctor Huamán, M.Sc. (IVITA)
Hugo Ordoñez, M.Sc. (IVITA)
Luis Pinedo, M.Sc. (IVITA)
César Reyes, Ing. Agr. (IVITA)
* Rodolfo Schaus, M.Sc. (INIAA)
Jorge Vela, Ing. Agr. (INIAA)

---

* Left during 1989.

** Joined the Program during 1989.