External Program Review 1984

TROPICAL PASTURES PROGRAM

Contents:

CHAPTER I

THE ROLE OF THE TROPICAL PASTURES PROGRAM IN LIVESTOCK DEVELOPMENT IN TROPICAL AMERICA

1. Compared to other continents like Asia and Africa where cattle have been part of the food production system for thousands of years in Latin America, cattle raising is a relatively recent enterprise.

2. In tropical Latin America cattle were introduced by the Spaniards in the sixteenth century. They adapted very successfully to the resource base of the region and now number approximately 200 million heads.

3. While Asia has only limited areas of pastures they are more prevalent in Africa and Latin America. In Africa, however, pastures are frequently in very low rainfall areas; in higher rainfall areas, tripanosomiasis and its vector, the tse-tse fly, are serious constraint.

4. The particular resource endowment of tropical Latin America--i.e., ample regions with practically no alternative land use but range, either due to soils, rainfall, location or land tenure--led to the development of a very extensive, low output, low-risk livestock production pattern which, by international standards, is supplying beef at low costs. This relatively cheap supply of beef and milk has led these products to become major items in the diets of most Latin Americans.

5. In the meantime, population growth has come to significantly outpace growth in supply. The low supply elasticity of traditional beef production systems is related to its low reproductive efficiency, lack of technologies to increase animal performance, low cash flow availability for financing investments, among other factors. Consequently, prices for beef are on an upward trend. Nevertheless, beef and milk have remained important ingredients in the food basket of Latin American consumers as is documented by the high expenditure shares and income elasticities of demand even among the lowest income strata of the region.

6. The productivity of the livestock sector of tropical Latin America remains very low, producing about 24 kg of beef per head of cattle inventory. In temperate zones like Argentina, 52 kg are produced. (By comparison, the USA produces 90 kg per head of cattle inventory.)

7. While substantial potential for the intensification of beef production exist, this potential is limited by the need to allocate resources with increasing opportunity cost to livestock (such as fertilizers, concentrates, and particularly land with cropping potential).

8. On the other hand, the existance of vast areas of marginal, presently almost unused lands, has made it relatively more attractive to expand production horizontally rather than to intensify livestock

production. Countries in the region have expended substantial efforts to foster increased livestock production in those marginal areas. Nevertheless, results have generally been disappointing, a fact frequently related to lack of appropriate technology.

9. In tropical America milk production presently concentrates on lands with high crop potential, frequently at altitudes above 1500 masl. High population densities and pressures for alternative uses of the land are contributing to the decline of dairy farming at these locations and are resulting in high milk prices for the consumers.

10. This was the context within which CIAT's beef production systems program was conceived in 1966 in Roberts and Hardin's proposal to create the center. The vast savanna and forest regions of the continent were considered to offer great potential for livestock production. It was realized that research was needed to bring these vast lands into production for the benefit of a hungry world.

11. The strategy to achieve the Tropical Pasture Program's goal of developing low-cost, low-input pasture technology for tropical America's acid, infertile soils is based on:

a) Selecting pasture germplasm adapted to environmental and biotic constraints;
b) developing persistent and productive pastures, along with improved practices for pasture utilization and management; and
c) developing an understanding of the role of improved pastures in the production systems, and developing complementary animal practices.

12. From an originally broad-focused program that was generally concerned with livestock systems and management practices, has evolved a germplasm program for the acid, infertile soils areas; with characteristics quite different from those of most other commodity programs in the CGIAR system:

- Research is not focused at a single species but at a wide range of virtually "wild" species of tropical legumes and grasses;
- These materials are not harvested for consumption by humans but are the primary product to feed cattle, thus adding another dimension to the problem;
- These species are not grown alone but in mixed stands. Mixtures do not only have to achieve high productivity, both in terms of quantity and quality, but also have to be compatible and persistent under a wide range of conditions;
- The frontier nature of the region of interest implies rainfed systems with limited possibilities for major improvements (liming, fertilization, pest and disease control) to the environment;
- The problems of pest and disease management are further complicated by the existence of a marked pathogen-by-germplasm-by-ecosystem interaction which heavily influences the performance of germplasm across the region of interest.

13. These circumstances have led to a research strategy markedly distinct from the traditional crop improvement scheme, concentrating efforts on (a) developing a broad germplasm base, (b) undertaking basic germplasm characterization research, (c) screening of materials for each distinct ecosystem, and (d) developing research methodologies. All these activities are geared to improve the efficiency of national pasture research programs.

14. This strategy is based on the following research axioms:
Use of legumes. One major contribution of CIAT to the development of tropical pastures is seen to be the introduction of forage legumes to traditionally only grass-based pasture systems. Legumes are expected to directly contribute to the diet of the animals in terms of protein supply (particularly during the dry season) and to improve the yield and quality of the grasses due to improved nitrogen availability in the system. While the main thrust is the development of legume/grass associations, other alternatives for the utilization of legumes (i.e., supplements of native pastures) are also evaluated.

15. Exploitation of natural genetic variability. Due to the fact that the program is working on a wide range of "wild" species the emphasis is on the selection of materials based on natural variability, rather than plant breeding. Nevertheless, specific problems of otherwise promising materials are tackled through breeding.

16. Development of frontier systems. Consistent with the resource base of tropical America and the demand for low-cost beef and milk, the program works on the development of technology suited to expand the livestock frontier on land resources with low opportunity costs. Thus the program seeks to develop pasture systems that are viable under conditions of poor soils, high transportation and input costs, and predominantly cow-calf systems producing store cattle to be fatten closer to the market. Lately the program has initiated a research effort in dual purpose systems in view of their potential for increasing the supply of beef and milk from small- to medium-sized farms of the lowland tropics.

17. Low external input philosophy. Given the long-term nature of pasture research, it is deemed appropriate to focus research on the future economic framework within which farms in the area of interest will operate. The prospects are for scarce fertilizer and lime resources, high transportation costs, as well as a political pressure for low beef prices. This scenario, together with the present characteristics of the frontier production systems (extensive operations, limited cash availability, limited managerial resources) point to the need of focusing research on low external input systems based on adaptation of germplasm and efficient utilization of available native resources.

CHAPTER II

ACHIEVEMENTS OF THE TROPICAL PASTURES PROGRAM (1977-1983)

Characterization of the Area of Interest

Consumption of Beef and Milk in the Region

18. While the importance of the cattle sector in the Latin American tropics in terms of land use and income generation is well documented, the importance of beef and milk as staple foods for low income strata of the population used to be questioned in view of the limited role of beef and milk in the diets of the poor in other regions of the world.

19. Based on data from large-scale consumer expenditure surveys of 14 important urban centers of Latin America, beef and milk expenditure shares and income elasticities were estimated for individual income quartiles of the population of these cities.

20. Table 1 presents the estimates for the lowest income quartile. In this strata income elasticity of demand for beef ranges between 0.8 and 1.28. reflecting a high preference for beef consumption. This elasticity decreases for higher income strata. Expenditure shares for beef among the lowest income quartile range between 12.4% and 26.0% of total food expenditure, confirming the importance of beef as a wage good in the Latin American setting.

21. Income elasticities of demand for milk and dairy products are of the same order of magnitude, while expenditure shares tend to be somewhat lower than those of beef. In the aggregate, expenditures for beef plus milk and dairy products comprise between 21% and 37% of the total food budget of the lowest income quartile. Thus, technology that will lead to increase the supply of beef and milk in Latin America will provide large absolute benefits to all income strata, with a larger relative impact on the protein and energy intake among low income groups, and with consumer benefits from increasing beef and milk supply distributed less regressively than current income.

Ecosystem Classification

22. The area of interest of the Tropical Pastures Program is confined to the lowlands of tropical America. The Oxisol and Ultisol (acid infertile soils) lands of this region extend from southern Mexico to northern Paraguay. Countries including Brazil, Colombia, Peru, Venezuela, Bolivia, Guyana, Surinam, French Guyana, Panama, Jamaica, Trinidad, Guadalupe and Martinique have more than 40% of their territories in this type of acid, infertile soils (Cochrane, 1978).

23. Approximately 850 million ha--about half of tropical America's land surface--have been characterized as low fertility, acid soil regions with varying rainfall intensity and distribution. Approximately 300 million ha are covered by savannas, and the remainder by forests. Since published information relating to the climate, landscape, vegetation, and soils of these lands was far from comprehensive and was not reduced to a common basis, from 1978 to 1981

Table 1. Expenditure shares and income elasticities of beef and milk demand of the lowest income quartile of selected Latin American cities

Country	City	Expenditure Share (Percentage of food expenditure)		Income Elasticity	
		Beef	Milk	Beef	Milk
COLOMBIA	Bogotá	18.6	9.6	1.09	0.91
	Cali	24.2	7.0	1.28	1.02
CHILE	Santiago	14.1	6.9	0.90	1.16
ECUADOR	Quito	12.9	8.7	1.28	0.87
PARAGUAY	Asunción	26.0	11.2	0.80	1.02
PERU	Lima	18.6	11.7	0.92	-
VENEZUELA	Caracas	12.4	13.1	0.80	1.06

the Tropical Pasture Program assembled the existing studies and carried out systematic survey work in order to classify and map the land resources of the vast, acid, infertile lands of the frontier of tropical America.

24. After analyzing the relationship of many climatic factors with the physiographic types of vegetation throughout the region, it was found that the total wet season potential evapotranspiration (TWPE) and the wet season monthly temperature (WSMT) were parameters that, with a high degree of accuracy, allowed for the delineation of major ecosystems.

25. Using the climatic data available from 251 locations, the area of interest was classified into five major ecosystems (see Figure 1):

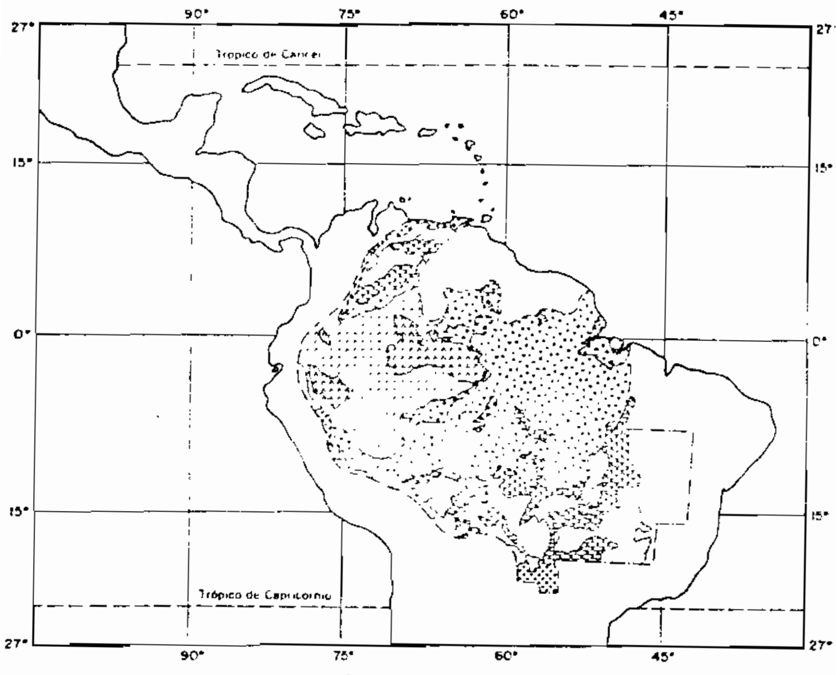
a) Well drained isohyperthermic savannas (mainly "Llanos"). with TWPE between 901-1060 mm, and 6 to 8 wet-season months with a WSMT $\geq$ 23.5°C;
b) Well drained isothermic savannas (mainly "Cerrados"), with TWPE between 901-1060 mm, and 6 to 8 wet-season months with a WSMT $\geq$ 23.5°C;
c) Tropical semievergreen seasonal forests with TWPE between 1061-1300 mm, and 8 to 9 wet-season months with a WSMT $\geq$ 23.5°C;
d) Tropical rainforest with TWPE 1300 mm, and more than 9 months of wet season with a WSMT $\geq$ 23.5°C;
e) Poorly drained savanna under various sets of landscapes and edaphic conditions throughout the lowlands of tropical America.

26. This classification of major ecosystems is being utilized as a basis for the strategic location of major screening sites, and for germplasm differentiation and testing.

Characterization of Prevailing Production Systems

27. Lack of agroeconomic information of Latin America's frontier lands induced the program to undertake a series of farm surveys to gain some understanding of the prevailing production systems. While these one-shot surveys were capable of supplying reasonably good information on the resource endowment of the farms, they were unsuited to convey information on important flow variables of the system (such as weight gains across seasons, reproductive performance, use of inputs, and management practices).

28. This led to the implementation of the ETES project ("Estudio Técnico-Económico de Sistemas") in cooperation with the GTZ (German Agency for Technical Cooperation) and the Department of Animal Production of the Technical University of Berlin. In each of three well-drained savanna regions (Cerrados, Brazil; Llanos Orientales, Colombia; and Llanos Nororientales, Venezuela) 15 to 20 purposively selected farms with varying levels of livestock management, resource endowment, and input use were monitored over a period of two years by means of periodic visits by an interdisciplinary team that collected information on resource endowment, individual animal productive and



Well drained isohyperthermic savanna

Poorly drained savanna

Well drained isothermic savanna

Tropical rain-forest

Semi-ever-green seasonal forest

Desiduous forest

Poorly drained forest

Others

Figure 1. Agroecological classification of the area of interest

reproductive performance, farm output, sales, use of inputs, and labour.

29. These studies led to a thorough description of the systems encountered. Major findings of the study were:

a) Frontier systems are extensive and have evolved to be in a stable equilibrium with the resource endowment. Contrary to the initial hypothesis, differences in productivity across farms were found to be more related to the quality of the land resource than to herd management practices.
b) Farmers have adapted to constraints of the systems, particularly to the dry season stress, by using poorly drained savannas for dry season grazing and well drained savannas for rainy season grazing (particularly in Colombia and Venezuela); and by using crop stubbles (mainly rice in the Brazilian Cerrados, and sorghum in the Venezuelan Llanos). In two of the three study regions, important crop-by-livestock interactions were found to exist within farming systems.
c) Differences between the farming systems in the three savanna regions studied were found to be determined, to a large extent, by the socioeconomic frame of each country; the natural resource endowment was found to present much lower variability across the three regions.

30. The study has made evident that better utilization of available cattle and land resources is only possible through the introduction of additional resources, particularly phosphorus and adapted germplasm.

31. The study also underlined the need to decentralize technology development to take account of the varying biophysical and economic settings in which the technology will have to perform.

32. In 1981 a similar but smaller study was undertaken in cooperation with the Banco Nacional de Panama and the Technical University of Berlin to monitor the performance of dual-purpose beef/milk production systems in the Central Provinces of Panama. Initial results from this study clearly document that this system can provide for competitive employment of labor in small-scale farms on acid soils with limited cropping potential. The deployment of available improved pasture technology can be expected to induce a rapid expansion of this type of system into savanna regions and markedly contribute to a socially desirable development of these regions.

33. Information on a farm survey undertaken by IVITA-Peru for the Pucallpa region and made available to the Tropical Pastures Program, has contributed to the program's understanding of the pasture and livestock situation in the humid tropics. In the Peruvian jungles, autonomous forest clearing and the establishment of settlements are taking place as a result of the high population pressure in the Andes. This is leading to systems in which slash-and-burn agriculture is followed by pastures and/or bush fallow. Rapid deterioration of the soil fertility status due to the use of high-requirement pasture species (such as _H. rufa_) leads to pasture degradation and attendant

productivity decreases, thus inducing additional forest clearing which further exacerbates the deterioration of this fragile ecosystem.

Organizational Achievements

Structure and Flow of Germplasm

34. During the formative stages (1969-74), the Beef Production Systems Program dealt with the identification of problems and potential solutions in the areas of animal health, animal management, and cattle production systems. A relatively small proportion of program resources was devoted to pastures and forages. Most field research was conducted in Colombia. Information collected during this period showed that low cattle productivity in tropical Latin America was due mainly to malnutrition and nutrition-related diseases. Lack of good-quality, year-round forage was identified as the most common critical constraint to increased production.

35. Between 1975 and 1977, the (new) Beef Production Program concentrated more on the acid, infertile savannas of Latin America. The program broadened the geographical scope of its activities to include other countries, and narrowed its research focus to pastures with the aim of removing the principal production constraints in the savanna ecosystem.

36. During the 1978-79 period the Program consolidated its focus on the development of new germplasm alternatives for low-cost, low-input pasture technology for the acid, infertile soils of the savannas. To reflect this focus, the Program was renamed the Tropical Pastures Program.

37. These changes of emphasis and orientation required a concomitant adjustment in the structure of the program. The present structure was defined in 1980 and was put in place to provide continuity to the research endeavor to accelerate the flow of the germplasm through the screening process.

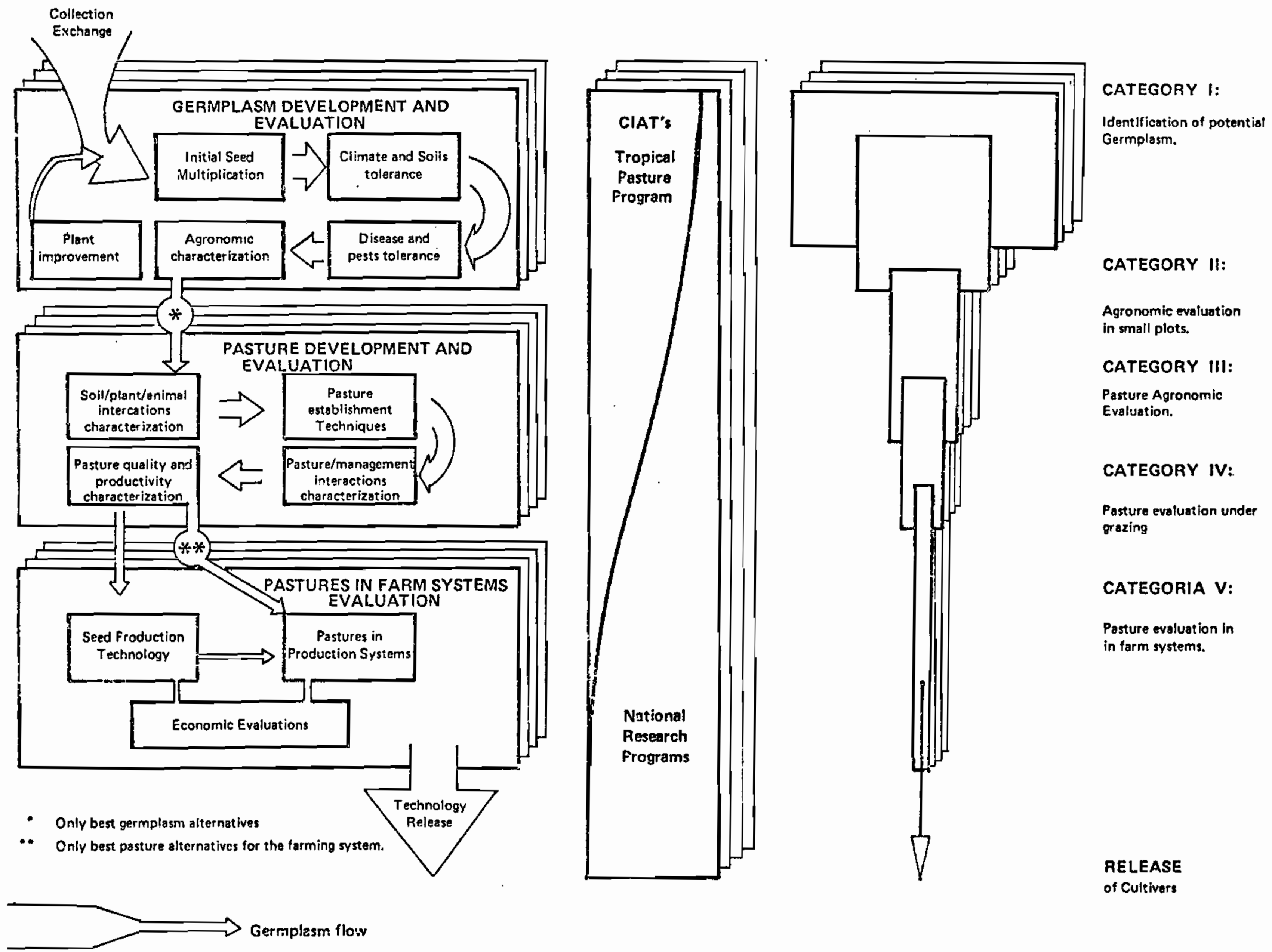
38. The Tropical Pastures Program is a multidisciplinary team comprised of 16 sections organized into three functional groups (see Figure 2) as follows:

39. Germplasm development and evaluation. This group, comprised of seven sections, includes the agronomist and breeders working in collection, breeding, and agronomic evaluation of germplasm at the major screening sites and in Regional Trials. It also includes specialists in the areas of plant pathology and entomology, who monitor the prevailing diseases and pests throughout the area of interest and support the screening process for the identification of tolerance to pests and diseases.

40. Pasture development and evaluation. This six-section group includes pasture specialists, plant and animal nutritionists, and soil microbiologists, and is dedicated to the characterization of the soil/plant/animal relationship and the development of pasture establishment and pasture management technologies.

41. Evaluation of pastures in farm systems. This group, consisting of three sections, includes animal scientists, seed production

Figure 2 Organizational structure of the Tropical Pastures Program, germplasm flow and interaction with National Research Programs.



specialists, and economists who characterize the setting in which new technology will be adopted, and define appropriate pasture options in alternative cattle production systems. This group also develops seed production technology and provides experimental and basic seed to the program and national research institutions.

42. The activities of these groups are based on a dynamic flow of germplasm and a continuous interaction of scientists across sections and units.

43. Germplasm accessions are advanced along a germplasm classification hierarchy based on the degree of promise shown by the accessions in the systematic screening and evaluation process. Those accessions that meet desired requirements are promoted to a higher category where they form the basis for the planning of the next phase of the evaluation. The relative ranking of accessions within species is done separately for each ecosystem. Requirements for progression to a higher category vary with the species, depending upon their principal limitations.

44. The germplasm bank (Category I accessions) is maintained at CIAT-Palmira as seed and/or single potted plants, and at CIAT-Quilichao as individual plants in the field. Activities at these locations include identification, maintenance, multiplication, and initial characterization of materials. All Category I accessions are evaluated for adaptation to edaphic conditions in introduction gardens at both Carimagua and Brasilia, the major screening sites for the Llanos and Cerrados ecosystems, respectively. Accessions which are advanced to Category II status undergo agronomic evaluation at both Carimagua and Brasilia.

45. Selected accessions advanced to Category III are combined into grass/legume associations, and placed under heavy, intermittent grazing to assess their resistance to trampling, competitive ability, dry matter productivity, nutritional quality, and relative grazing preference. These evaluations are conducted at Carimagua, Brasilia, and CIAT-Quilichao.

46. In Category IV the pastures are evaluated for potential animal productivity, and pasture-specific grazing management practices are determined. Measurements are made of sward botanical composition trends, presentation yields, animal grazing preferences, and nutritive value of the species, in order to explain the recorded animal productivity.

47. Finally, in Category V, the best pasture options are evaluated under experimental and commercial farm conditions prior to the new cultivar release by national programs.

48. The higher categories of germplasm evaluation require a relatively higher involvement of the national research programs which are responsible for the decision and implementation of the release of new cultivars (Figure 2).

Decentralization

49. During the last few years, the Tropical Pastures Program has moved from a basically centralized research program working only in Colombia for the acid soils of tropical America, to a more decentralized research program that recognizes the differences among ecosystems in the area of interest and the limited range of adaptability of germplasm to climatic, biotic, and farming system constraints (in addition to the soil constraints) across the various ecosystems.

50. In 1977 the Tropical Pastures Program initiated activities in the newly established Quilichao sub-station. This station, which is characterized by acid soils, is used by the program primarily for initial multiplication and characterization of germplasm, methodological research, and seed production.

51. During 1977 a cooperative pasture research program was initiated with the Centro de Pesquisa dos Cerrados (CPAC) from EMBRAPA at Planaltina, Brazil. Initially, three senior scientists were located at this center: an agronomist working in germplasm screening and agronomic evaluation, a soil scientist working in pasture establishment and soil fertility problems, and an animal scientist studying the role of pastures in animal production systems. This CIAT staff was complemented by competent and well-trained Brazilian scientists. Recently, the CIAT staff at CPAC was reduced to one core-funded scientist (agronomist); through an agreement with EMBRAPA, the soil scientist is now a visiting scientist of CIAT funded by EMBRAPA/IICA.

52. The station at Planaltina is the major screening site for the central region of the Cerrados, in the same way that the Centro Nacional de Investigaciones Agropecuarias (CNIA) Carimagua is the major screening site for the Llanos ecosystem. The fact that there exist important differences among sub-ecosystems within these major ecosystems requires a mechanism to adequately cover these differences in the testing of the new germplasm in cooperation with national programs. To this end, in 1979 the International Tropical Pastures Evaluation Network (RIEPT) was organized and initiated.

53. Early in 1983, in cooperation with Instituto de Investigaciones Agropecuarias, Panama (IDIAP), and Rutgers University, a pasture research program was initiated to develop new pasture alternatives and technology for the several ecosystems of Panama, where acid soils comprise 63% of the territory, and where small- to medium- sized cattle farms are predominant.

54. The humid tropics are not yet adequately covered by the program's research strategy. After the advances made in identifying new germplasm alternatives for the two major savanna ecosystems, increased efforts will be directed to the humid tropics.

Network Structure and Development

55. As an important element of the strategy to decentralize the research of the Tropical Pastures Program, the International Tropical Pastures Evaluation Network (RIEPT) was formed in cooperation with national programs. It was organized based on principles worked out at the first workshop of the RIEPT in September 1979.

56. The RIEPT was conceived and organized as a mechanism to more efficiently utilize the germplasm bank resources of CIAT and the national programs, and to study the range of adaptation of grass and legume germplasm through the lowlands of tropical America (Figure 3). Four types of Regional Trials were conceived: Regional Trials A (RT-A) to evaluate survival of a large number of entries (100-150) in few, highly representative sites of major ecosystems. Regional Trials B (RT-B) to measure seasonal dry matter productivity of a reduced number of promising entries (20-30) resulting from RT-A and major screening sites in sub-ecosystems within the respective major ecosystems. (These two sets of agronomic regional trials utilize uniform methodologies to allow for comparisons of the performance of the germplasm in RT-A, and for cross-location analyses of seasonal productivity of germplasm in RT-B.)

57. Regional Trials C (RT-C) are designed for the evaluation under grazing of a reduced number (10) of accessions of grass/legume mixtures to assess the dynamics of the productivity and the botanical composition of the swards under different intensities of grazing utilization. These RTs-C are conducted with different designs and at only relatively few sites of the network, since most of the generated information in terms of effect of trampling, defoliation, and compatibility of grasses and legumes can be extrapolated from the design of the more advanced, large grazing trials.

58. Regional Trials D (RT-D) are designed to assess pasture productivity in terms of animal gains and persistence. They are conducted in the form of large grazing trials and are made up of the best pastures, and incorporate in the treatments the management that is commonly used in the prevailing farming system. RTs-D are designed to be conducted in as many locations as possible, but following independent designs since they must be programmed to improve specific, existing farm pastures and utilization systems.

59. Figure 3 shows the organizational scheme of the RIEPT, in which germplasm is sequentially passed through the different regional trials in each ecosystem, and information generated is shared by all members of the network by means of direct communications, meetings, workshops, the Tropical Pasture Bulletin (published 3 times/year) and by direct consultation of the data base of the network.

60. The RIEPT is a shared cooperative activity in which national programs and CIAT participate on an equal basis. The network is coordinated by CIAT in continuous consultation with the advisory committee of the RIEPT, which is made up of national pasture research leaders. The latter have been instrumental and effective in promoting

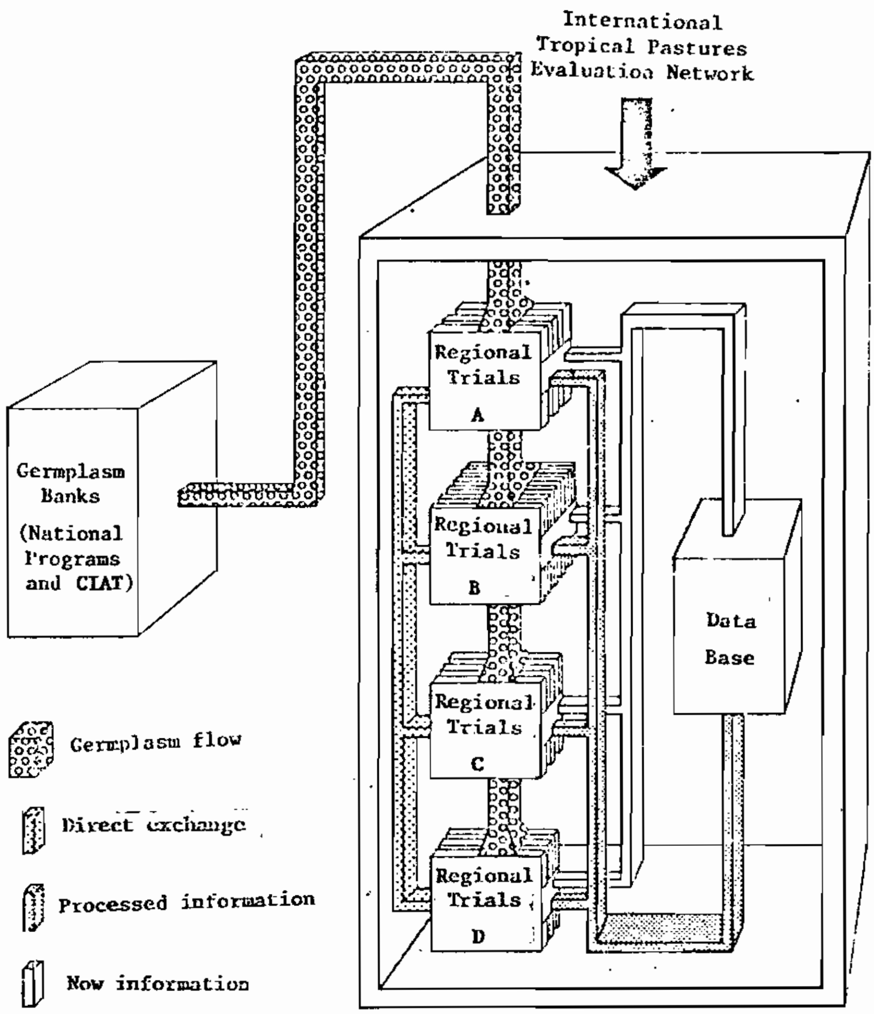


Figure 3. Diagram representing the organization of the RIEPT

the development of both the international and national pasture networks.

61. The design of the RIEPT together with the active exchange of information which is an integral feature of the network, allow national programs to skip certain stages in the germplasm screening sequence. Frequently national programs move directly from RT-B to RT-D, using information generated at a few major research sites where the complete screening sequence is gone through.

62. On the other hand, national programs further develop the use of promising germplasm by determining fertilizer and Rhizobium requirements to optimize performance of the new germplasm under specific soil conditions.

63. To back up this cooperative effort, the Tropical Pastures Program is supporting methodological research and is developing widely adaptable measurement techniques for assessing pasture performance under grazing. At the same time, the program is helping national programs to implement regional trials C and D, and to be in a position to make necessary adjustments of fertilizer and Rhizobium recommendations in accordance with the requirements of local conditions.

64. The rapid growth of the RIEPT since 1978 and the broad regional coverage of the network is shown in Table 2.

Systematization of Program Information

65. To facilitate the recording and exchange of information generated by each section of the program as well as the RIEPT, a computarized data base was developed.

66. Basically, each section maintains separate data banks for the recording of the most relevant information for each germplasm entry. Information across sections of the program as well as across the network with national programs is made available to members of the program and to national program researchers.

67. All information generated in the various locations of the RIEPT is already included in the data base. Additionally, germplasm evaluated in Category I in Quilichao and Carimagua is included for the period 1980-1983; also included is the data bank of Rhizobium strains, the information of plant pathology (evaluations and information on pathogens), the inventory and movement of experimental seed; and information on prices of cattle and related inputs at RIEPT locations.

68. Data banks are being developed containing information generated on germplasm in Categories II, III, IV and V.

Table 2. Active[1] Regional Trials A, B, C and D in the RIEPT between 1978 and 1983 by countries

Countries	1978	1979	1980	1981	1982	1983
Bolivia	1	1	1	2	2	2
Brasil	1	8	12	9	9	16
Colombia	3	5	12	11	13	13
Costa Rica	-	-	1	1	1	2
Cuba	1	1	-	-	1	1
Ecuador	2	2	3	3	4	6
Guyana	-	-	2	1	1	-
Hawaii	-	-	1	1	1	-
Honduras	-	-	-	-	-	1
Mexico	-	-	-	1	1	7
Nicaragua	-	-	2	3	3	3
Panama	-	-	3	3	3	10
Paraguay	-	-	-	-	1	-
Peru	3	3	5	7	11	13
Dominican Republic	-	-	-	-	-	4
Trinidad	-	-	1	1	1	-
Venezuela	4	4	5	5	5	-
Total	15	24	48	48	57	78

1/ Active = sown trials reporting information or with a maximum a two-years after establishment.

Generation of New Technological Alternatives

Germplasm Base

69. As a consequence of the redefinition of the former Beef Production Program's mandate in 1976, a program to collect and introduce germplasm with potential as forage plants for the Program's target area was initiated in 1977 . Between 31 December 1977 and 31 October 1983 the total collection increased from 3,000 to 11,300 accessions. As shown in Table 3, approximately 90% of the total collection are legume accessions, mostly from tropical America. This not only reflects the relative emphasis of the Tropical Pastures Program's work on forage legumes, but also the fact that the New World tropics are the major center of diversity of tropical legumes which, until the initiation of CIAT's collection activities, had only been superficially sampled. Legumes that are native to tropical America are of particular interest to the Tropical Pastures Program due to the mostly very acid, infertile soil conditions under which they evolved. Among tropical grass germplasm, the species with the highest potential as forage plants originate in Africa. Broadening of the genetic base of species of interest to the Tropical Pastures Program was limited to plant introductions from already existing collections through germplasm exchanges with other institutions; only 4% of the total grass material in the CIAT collection was obtained through CIAT collection activities.

70. Table 3 shows that after 1977 there has been a considerable shift with respect to the relative importance of collaborative collections: whereas up to 1977 only 23% of the total collection were the result of joint ventures by 1983 the percentage of collaboratively collected accessions had reached 43, with only 22% of the bank representing independent CIAT collections. These figures reflect the increasing integration of the research activities of CIAT and national institutions in the field of forage germplasm collection activities.

71. Table 4 compares the 1977 and 1983 inventories of promising germplasm materials under evaluation in grazing trials. It is noteworthy that the 1977 list (a) does not yet differentiate between ecosystems, and (b) is partially still based on information of germplasm performance on less acid, more fertile soils outside the Oxisol/Ultisol complex. In 1977 a series of species were considered to be sufficiently promising to warrant evaluation in grazing trials. Eventually, these trials showed that many of these species were not adapted to the conditions of acid, infertile soils in the Llanos and/or Cerrados ecosystems. Consequently, such species as *Centrosema pubescens*, *Desmodium distortum*, *D. heterophyllum*, *Desmodium* sp. aff. *D. intortum*, *Neonotonia wightii*, and *Stylosanthes hamata* are not listed anymore in the 1983 lists. Other materials did prove to be adapted to the marginal soil conditions of the savanna ecosystems, but failed to tolerate disease and insect problems, such as several leaf diseases in *Macroptilium* spp., stemborer and anthracnose in the common forms of *Stylosanthes guianensis*, and Sphaceloma Scab in *Zornia latifolia*. In the case of *Desmodium ovalifolium*, five years after accession CIAT 350 was classified in Category IV, this material was found to be susceptible to a devastating stem-gall nematode. Species

Table 3. Evolution of the Tropical Pastures Program germplasm base: inventory of the collection as of December 31, 1977 and November 30, 1983 (No. of accessions)

	Own collections		Collaborate collections		Other sources		Total	
	1977	1983	1977	1983	1977	1983	1977	1983
Legumes	1285	2446	701	4683	927	3038	2913	10157
Grasses	5	25	2	22	117	1087	124	1134
TOTAL	1290	2471	703	4705	1044	4125	3037	11291
Percentage	42%	22%	23%	43%	34%	36%		

Table 4. Advance of the Tropical Pastures Program germplasm 1977-1983: No. of forage species accessions nominated for or under evaluation in grazing trials (Categories III and IV/V) in 1977 and 1983

Species	1977		1983			
			Llanos		Cerrados	
	Cat. III	Cat. IV/V	Cat. III	Cat. IV/V	Cat. III	Cat. IV/V
LEGUMES:						
Arachis pintoi	-	-	1	-	-	-
Centrosema pubescens	3	-	-	-	-	-
Centrosema brasilianum	-	-	-	1	1	-
Centrosema macrocarpum	-	-	1	1	5	-
Centrosema sp.n.	-	-	3	-	1	-
Desmodium distortum	1	-	-	-	-	-
Desmodium sp. aff. *D. intortum*	1	-	-	-	-	-
Desmodium heterophyllum	1	-	-	-	-	-
Desmodium canum	-	-	1	-	-	-
Desmodium heterocarpon	-	-	1	-	-	-
Desmodium ovalifolium	-	1	3	-	-	-
Macroptilium sp.	1	-	-	-	-	-
Neonotonia wightii	2	-	-	-	-	-
Pueraria phaseoloides	1	-	-	1	-	-
Stylosanthes hamata	2	-	-	-	-	-
Stylosanthes guianensis (común)	1	1	-	-	-	-
Stylosanthes guianensis "tardío"	-	-	7	-	7	1
Stylosanthes capitata	-	4	5	5	2	2
Stylosanthes leiocarpa	-	-	1	-	-	-
Stylosanthes macrocephala	-	-	4	1	5	1
Zornia latifolia	-	1	-	-	-	-
Zornia brasiliensis	-	-	1	-	5	-
Zornia sp. (type CIAT 7847)	-	-	1	-	1	-
Total legume accessions	13	7	29	9	27	4
GRASSES:						
Andropogon gayanus	-	1	3	1	-	1
Brachiaria brizantha	-	-	4	-	3	-
Brachiaria dictyoneura	-	-	1	1	-	-
Brachiaria humidicola	-	-	-	1	-	-
Brachiaria ruziziensis	-	-	1	-	-	-
Panicum maximum	1	-	-	-	3	-
Total grass accessions	1	1	9	3	6	1

which back in 1977 had been identified as promising, and since that time have successfully passed all screening tests up to large-scale grazing experiments are Pueraria phaseoloides in the Llanos, and, in both savanna ecosystems, Stylosanthes capitata and Andropogon gayanus.

72. A wide range of promising materials listed in Table 4 belongs to species which in 1977 were virtually unknown. In both ecosystems these include, among legumes, several Centrosema species (C. brasilianum, C. macrocarpum and a new, yet undescribed species), Stylosanthes spp. (including the "tardío" forms of S. guianensis and S. macrocephala), and Zornia spp. (Z. brasiliensis and a still unidentified species from eastern Brazil). Among grasses, new species include principally Brachiaria spp. (B. brizantha, D. dictyoneura, B. humidicola, and B. ruziziensis). The outstanding trait of most accessions within these species is their adaptation to the conditions of acid, infertile soils which, in the case of the legumes, reflects the concentration of collection activities on regions where such edaphic conditions prevail.

73. On the basis of the Program's evaluation activities during the past six years at the major screening sites as well as within the International Tropical Pasture Evaluation Network activities, a range of promising "key" species has been identified (Table 5). The fact that this list--with the exception of Pueraria phaseoloides, and in the Brachiaria complex, B. decumbens--does not comprise any traditional, agronomically well-known tropical forage species, but rather consist of new, undomesticated material, is one of the fundamental achievements of the Tropical Pastures Program; it illustrates the Program's pioneer role in the development of a germplasm-based, low-input technology. Table 5 also illustrates the dynamism with which the Program during the past years has been able to broaden the genetic base of the germplasm identified as new key species; the collection of the key species shows a 10-fold increase between 1977 and 1983.

74. The Rhizobium germplasm bank now contains about 3,000 accessions, and the computerized strain catalog has been updated and includes information concerning strain effectiveness under different sets of conditions. In order to ensure that legume screening is carried out under non-N-limiting conditions, the initial introductions are fertilized with N and not inoculated with Rhizobium. Once the most adapted legumes have been selected, they are screened in soil cores for response to inoculation with a range of Rhizobium strains. If responses to inoculation occur, inoculation with the most effective strains is recommended for further grazing trials.

Adaptation to Soils

75. Nutrient requirements. In 1977 the nutritional requirements of the tropical grasses and legumes species being evaluated agronomically by the program had not been determined. The large variation in the reaction of different species and ecotypes to adverse soil conditions is illustrated in Table 6. Among grasses, the last three species mentioned which are identified as Al-sensitive species, are the traditional and still promising forage grasses for several tropical

Table 5. Evolution of the Tropical Pastures germplasm base: inventory of the collection of 1983 key species in 1977 (December 31) and 1983 (November 30).

Species	No. of Accessions	
	1977	1983
LEGUMES:		
Stylosanthes capitata	45	266
Stylosanthes guianensis "tardío"	33	194
Stylosanthes macrocephala	4	159
Centrosema brasilianum	4	129
Centrosema macrocarpum	3	102
Centrosema sp.n.	2	11
Desmodium ovalifolium	1	84
Pueraria phaseoloides	11	76
Zornia sp. (type CIAT 7847)	-	21
TOTAL legume accessions	103	1021
GRASSES:		
Andropogon gayanus	5	66
Brachiaria spp.	24	197
TOTAL grass accessions	29	263

areas in Latin America. A similar situation can be observed with the legume species. At present, the most Al-tolerant species indicated in Table 6 are among the most promising ecotypes for the lowland areas in tropical America.

76. Table 7 presents the external nutrient requirements of selected grasses and legumes. The low levels of these elements required for establishment are a reflection of the outstanding adaptation to low fertility soils of most of the germplasm with which the program is working.

77. Often, the new germplasm alternatives face temporarily high soil fertility situations (e.g., after clearing and burning in the humid tropics, after fertilized crops). Under such conditions, the pastures must respond to and utilize the increased soil fertility and still be able to produce and persist when soils later reach the low equilibrium level of fertility. A case in point is the response of A. gayanus compared to other commercially available grass cultivars, such as P. maximum in the Cerrados (Figure 4).

78. Soil microbiology studies. Low-cost legume/grass pastures rely heavily on nitrogen fixation by the legume component. Resources of the program are allocated to the screening of effective strains for promising germplasm.

79. A method for Rhizobium strain selection in cores of undisturbed Carimagua soil has been developed and used to identify superior strains for the inoculation of promising legume ecotypes of Stylosanthes capitata, and in the genera Desmodium, Centrosema and Pueraria. Stylosanthes guianensis, S. macrocephala and Zornia spp. apparently nodulate effectively with native strains and, therefore, do not respond to inoculation in this soil. An example of a screening trial with Pueraria phaseoloides and field performance of selected strains is shown in Figure 5.

80. This confirms that strains selected in soil cores can also be effective in the field. Selected strains have also shown ability to persist into the second year after establishment.

81. N mineralization studies have shown that plowing stimulates N mineralization in Carimagua soil and can provide a significant source of N for pasture plants during establishment. Plowing before the dry season caused higher growth rates of pasture grasses sown in the following wet season than when the soil was plowed immediately before planting (Table 8), which may be due to stimulation of NH_4^+ production in plowed soil during the dry season. Response was shown to be larger in materials with higher nutrient requirements. The effect of minimum tillage versus conventional tillage on legume establishment is also being evaluated.

82. Mycorrhizae are known to play an important role in the uptake of phosphorus by plants mainly due to physical expansion of the root system (more length and less diameter) by the mycorrhizal hyphae. The lower the native soil fertility and fertilization levels and the more adapted and perennial the plant, the more important this interaction

Table 6. Dry-matter production and differential tolerance of several tropical forage species to aluminium toxicity

Species	CIAT Accessions No.	Dry-matter yield/cutting Low Soil Al (25% Al Sat)	High Soil Al (90% Al Sat)	Relative index[a] (High Al/ Low al)
		- t/ha -		
GRASSES:				
B. humidicola	679	2,53	2,93	1,20
M. minutiflora	608	3,03	2,79	0,92
A. gayanus	621	4,35	3,64	0,84
B. decumbens	606	3,59	2,62	0,73
D. decumbens	659	3,58	1,49	0,42
P. maximum	604	3,40	1,63	0,48
P. purpureum	-	5,68	1,38	0,24
LEGUMES:				
S. capitata	1315	2,57	3,66	1,42
S. guianensis	148	2,66	2,31	0,87
D. ovalifolium	350	2,82	2,81	1,00
C. hybrid	438	1,71	1,22	0,71
D. heterophyllum	349	1,88	0,56	0,30
L. leucocephala	734	2,53	0,46	0,18

a/ The higher the index value the more adapted the material is to Al toxicity.

Table 7. Nutrient requirements for the establishment of various tropical grasses and legumes in an well-drained Oxisol of the Carimagua savanna

Species	Maximum DM yield	External Requirements[1]			
		P	K	Ca	Mg
		- kg/ha -			
GRASSES:					
A. gayanus 621		20	20	100	10
B. decumbens 606		20	20	100	10
B. humidicola 679		10	10	50	10
B. brizantha 665		20	20	100	10
P. maximum 604		40	30	250	20
LEGUMES:					
S. capitata 1315		20	20	50	10
P. phaseoloides 9900		20	20	100	20
C. brasilianum 5055		20	20	100	10
C. macrocarpum 5065		10	10	100	10
D. ovalifolium 350		20	20	100	10
C. pubescens 5053		20	20	400	10

1/ External requirements associated with 80% of maximum yields obtained at eight weeks of plant growth.

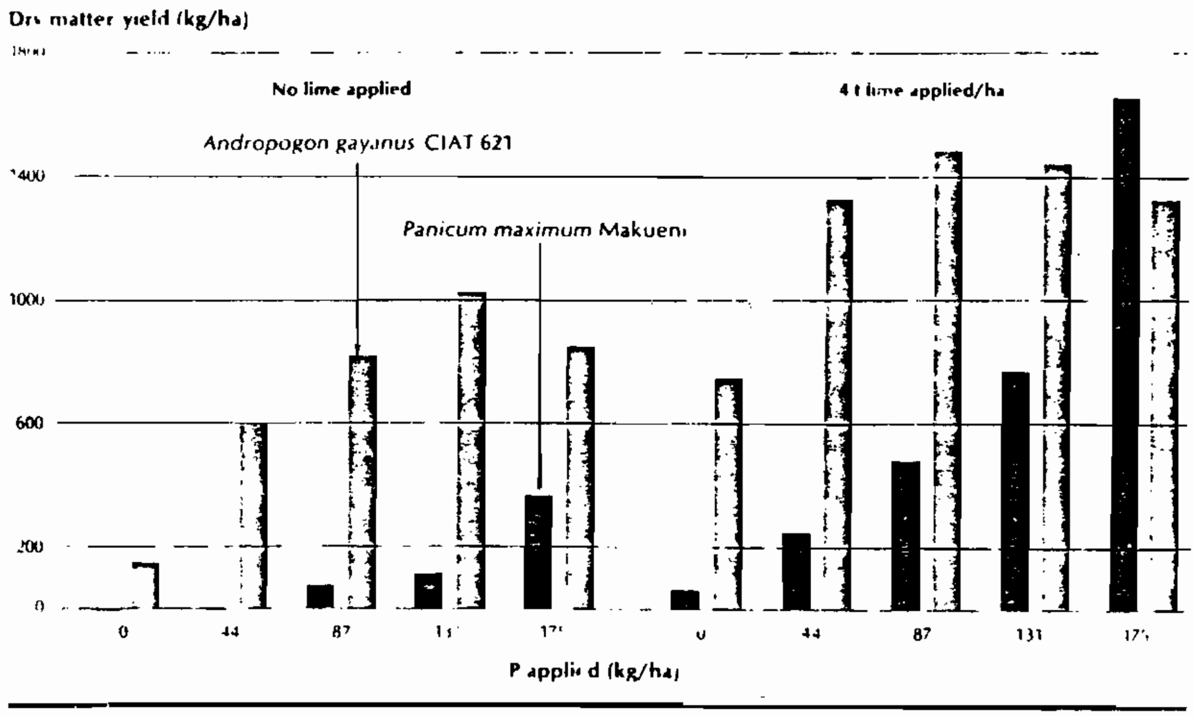


Figure 4. Residual effect (10 years) of lime and phosphorus applied on dry matter yield of *A.gayanus* CIAT 621 and *P.maximum* var. "Makueni". Mean of three cuttings

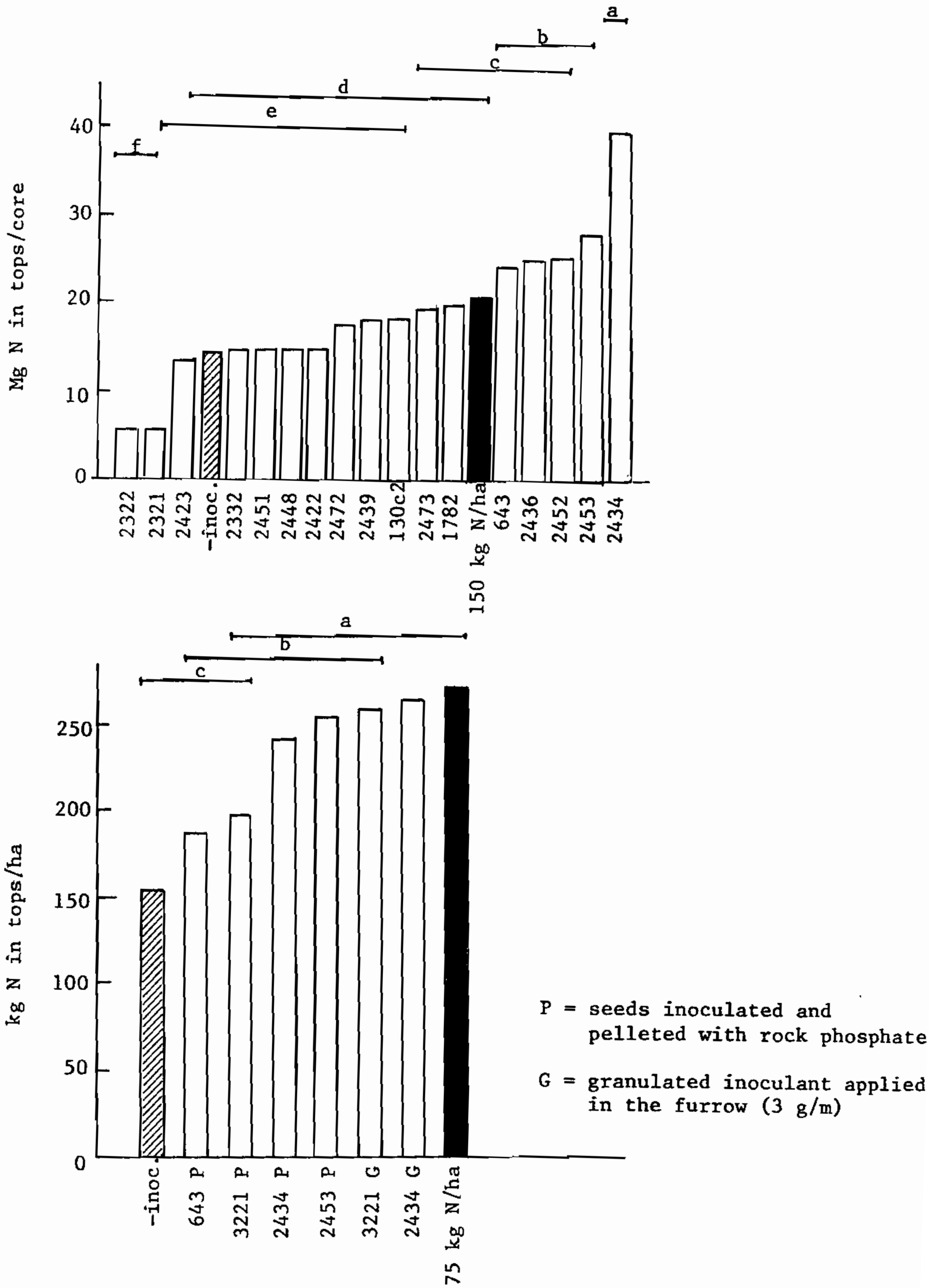


Figure 5. Response of P. phaseoloides to inoculation in cores of undisturbed soil (above) and in the field during establishment (below) at Carimagua

Table 8. Effect of time of land preparation on production (kg DM/ha) of grass pastures without N fertilization in Carimagua

Grass	Land Preparation		
	Before previous dry season	Immediately before sowing	Average increase
	- kg DM/ha[1] -		%
B. humidicola	1940	1606	21
M. minutiflora	2495	1832	36
A. gayanus	1797	956	88
B. decumbens	3270	1576	107
P. maximum[2]	1206	431	179

1/ 4 months of growth after sowing at the beginning of the wet season

2/ 2 months of growth

can be expected to be. Therefore the program has started research in this field. This research showed that materials such as A. gayanus, S. capitata, and P. phaseoloides, with low levels of applied fertilizer, induced higher native mycorrhizal populations than those in native savanna. This suggests that improved pastures depend on the mycorrhizal association more than native savannas. Significant responses to mycorrhizal inoculation at the field level have been identified in unsterilized plots for P. phaseoloides, S. capitata, and A. gayanus (Figure 6).

83. This response indicates the relevance of further study of the role of mycorrhizae in soil/plant interactions and evaluation of methods of management of mycorrhizae as part of the new pasture technology. The existence of important interactions between Rhizobia, Mycorrhiza, and fertilization has been documented. This justifies the need for integrated research to optimize the utilization of natural resources and the use of alternative fertilizer sources.

84. Alternative sources of fertilizers. The high leaching potential (well drained soils and high seasonal rainfall) and phosphorus fixing capacity of the soil, and the fact that pastures are perennial species make slow-release fertilizers particularly attractive. Natural rocks such as phosphate rocks, potassium feldspars, magnesium serpentine or carbonates, and gypsum or elemental sulphur rocks could make a valuable contribution as more economical sources of P, K, Ca, Mg and S, respectively, for pasture fertilization in the acid, infertile soils of Latin America.

85. The high acidity of the soils makes the direct use of less soluble mineral rocks possible. In conjunction with IFDC the program is, therefore, working on the alternative use of indigenous materials such as rock phosphate, feldspars, etc. Research on rock phosphate use is well underway and indicates that total substitution of soluble phosphate sources is feasible for long-term pasture yield (Table 9). In fact, farmers of the Eastern Plains of Colombia and the Cerrados of Brazil are already using phosphate rock applications for pasture establishment.

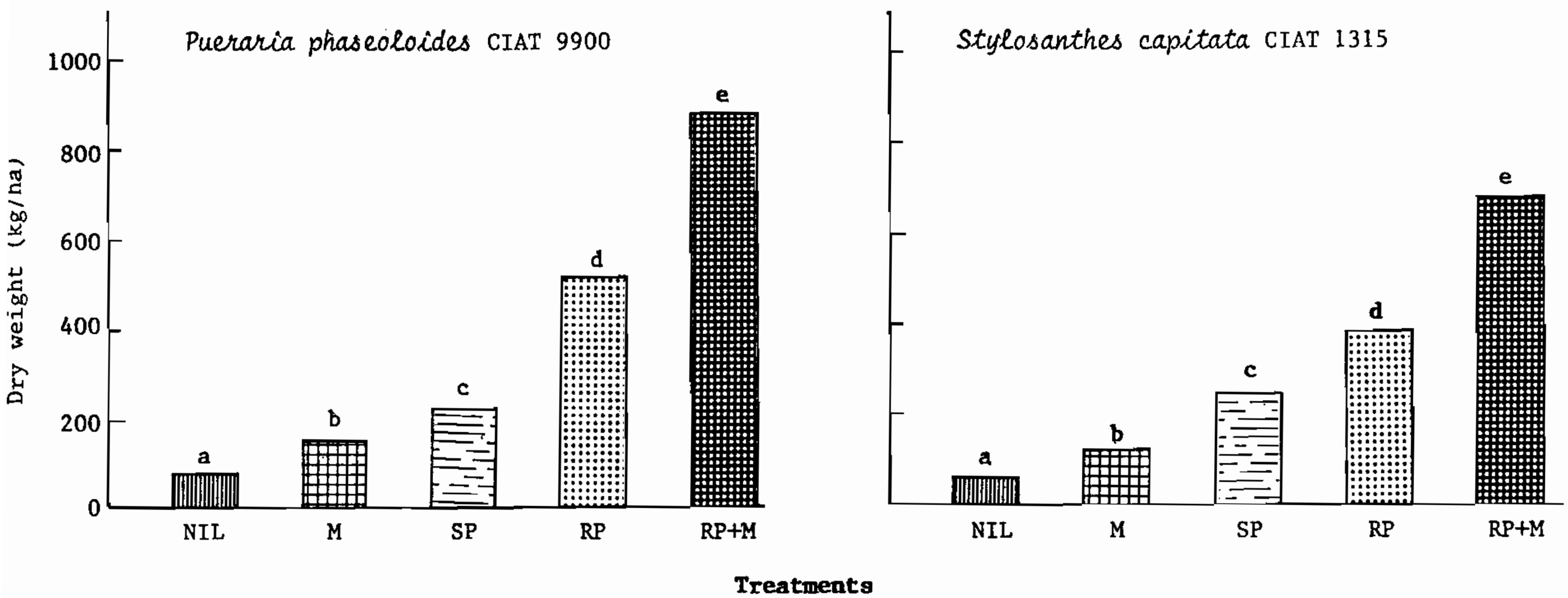
86. Preliminary results on substitution of conventional potassium sources (KCl, etc.) by feldspars suggest the high agronomic efficiency of the latter (Table 10).

87. It should be stressed that potential benefits of research on alternative sources of slow-release fertilizers could expand well beyond their use for tropical pastures into annual and perennial crops.

Plant Health

88. In view of the overriding importance of pests and diseases, in 1978 the Tropical Pastures Program decided to undertake research on plant health.

89. Monitoring of pest and disease problems. A continuous and systematic monitoring of pest and disease prevalence in the major



NIL, O P; M, inoculated with mycorrhiza (O P); SP, soluble phosphate; RP, rock phosphate Huila and RP + M, rock phosphate plus inoculation with mycorrhiza. P rate 20 kg/ha. Different letters represent significant differences at P = 0.05

Figure 6. Dry weight of *P. phaseoloides* and *S. capitata* grown in unsterilized Oxisol under field conditions. Data are of 1st. cut three months after sowing

Table 9. Relative agronomic efficacy of rock phosphates of various sources determined by means of yields of *Brachiaria decumbens* in Carimagua (accumulated DM production of 11 clippings over a period of 40 months)

Phosphorous source	Relative yield (kg P_2O_5/ha)			
	25	50	100	400
Triple superphosphate	100	100	100	100
Florida (USA)	124	92	101	105
Fosbayovar (Peru)	121	79	105	106
Huila (Colombia)	93	112	100	109
Pesca (Colombia)	109	81	112	113

Table 10. Relative agronomic efficacy of Colombian felspars as potassium sources as determined by greenhouse DM yields of *Pueraria phaseoloides* grown on Carimagua soils.

Potassium source	Relative yield (kg K/ha)			
	10	20	40	80
KCl	100	100	100	100
Hobo	105	76	100	38
Algeciras 1	31	91	101	102
Ospina	100	93	95	131

screening sites and regional trial sites across all ecosystems allowed the program to detect several previously unrecorded pests and diseases (Tables 11 and 12), as well as assess their importance across ecosystems.

90. The major problems are in Stylosanthes spp., Anthracnose, stemborer, sucking insects. In Centrosema spp. the main diseases are Rhizoctonia bacterial leaf spot and Cercospora, while the main pests are Chrisomchidae and leaf-eating insects. Desmodium spp. in the Llanos ecosystems present two major problems: the stem-gall nematode recently discovered and named Pterothylenchus ceadogenus, and the false rust Synchytrium desmodii. In the humid tropics this material seems to be quite healthy. In Zornia spp. the major disease constraint is Sphaceloma zorniae scab affecting mainly Zornia latifolia. One unidentified species of Zornia, of promise for the Llanos ecosystem, presents a high degree of tolerance to this disease.

91. Among grasses, Andropogon gayanus has no major problems. B. decumbens is highly susceptible to spittlebug.

92. Stylosanthes spp. and anthracnose. The genera Stylosanthes spp., which is native to Latin America, includes a series of good forage legumes. However, a large proportion of those materials are susceptible to anthracnose. A series of very productive commercial ecotypes of Stylosanthes guianensis, Stylosanthes hamata, and Stylosanthes scabra, reintroduced from Australia where they had been selected under no disease pressure, failed due to high susceptibility to this disease. The fact that the program is evaluating germplasm at many sites within the centers of origin of these species facilitates selection of productive materials resistant to high anthracnose pressure.

93. One outcome of this work has been the selection of Stylosanthes macrocephala lines which thus far have demonstrated resistance to anthracnose across ecosystems (Cerrados and Llanos). On the other hand, selections of S. capitata lines which are highly resistant to anthracnose under Llanos conditions are presenting problems in the Cerrados and are not adapted to forest ecosystems. Ecotypes of Stylosanthes guianensis, while susceptible in the Llanos and Cerrados ecosystems, show excellent performance after several years of evaluation in forest ecosystems. Progress has been achieved in understanding this differential reaction which may lead to more effective techniques to select resistant or tolerant lines. This tolerance of Stylosanthes guianensis to anthracnose in the forest ecosystem cannot be attributed to differences in pathogenicity of the anthracnose races; races isolated in the forest have been shown to be at least as pathogenic as races isolated in the savanna ecosystem. The presence of antagonistic phylloplane bacteria, as well as late infection, appear to be responsible for a lower degree of spread of anthracnose in the humid tropics. Additionally, smaller daily temperature fluctuations in the humid tropics tend to reduce the development of latent infection (Figure 7).

94. Breeding for anthracnose resistance in S. guainensis. While the primary objective of all breeding work is the combination of

Table 11. Summary of the distribution of pasture diseases in different ecosystems.

FORAGE DISEASE	Tropical Savanna Isohyperthermic (Llanos)	Tropical Savanna, Isohyperthermic (Llanos) Carimagua, Colombia	Tropical Savanna Isothermic (Cerrado)	Tropical Savanna, Isothermic (Cerrado) Brasilia, Brazil	Tropical Savanna, Poorly drained	Tropical Rainforest	Tropical Sub-montane Seasonal Forest Quilichao
	9[b]		4		2	22	
1. ANTHRACNOSE	+	+	+	+	+	+	+
2. CERCOSPORA LEAF SPOT - GRASSES	+	+	+		+	+	+
3. CERCOSPORA LEAF SPOT - LEGUMES	+	+	+	+	+	+	+
4. ROOT-KNOT NEMATODE	+	+	+[a]			+	
5. BLIGHT	+	+	+			+	
6. SPHACELOMA SCAB	+	+	+	+		+	+
7. SMUT - TILLETIA	+	+	+	+		+	+
8. SMUT - UROCYSTIS			+[a]			+	
9. CAMPTOMERIS LEAF SPOT		+				+	+
10. RUST - UROMYCES	+		+	+		+	+
11. RUST - PUCCINIA						+	
12. FALSE RUST		+	+	+		+	+
13. RHIZOCTONIA SOLANI	+	+	+[a]	+	+	+	+
14. RHYNCHOSPORIUM LEAF SPOT	+	+				+	+
15. DRECHSLERA LEAF SPOT - LEGUMES	+[a]	+	+	+	+	+	+
16. DRECHSLERA LEAF SPOT - GRASSES	+	+	+	+	+		
17. LITTLE LEAF PHYLLODY	+	+	+	+		+	+
18. ERGOT		+	+[a]			+[a]	+
19. GIBERELLA INFLORESCENCE BLIGHT			+[a]			+[a]	
20. BOTRYTIS INFLORESCENCE BLIGHT						+[a]	
21. BLACK MOLD			+	+			
22. POWDERY MILDEW	+	+	+	+		+	+
23. SLIME MOLD	+	+					+
24. BACTERIOSIS	+	+				+	+
25. BACTERIAL POD BLIGHT						+	+
26. BOTRYOSPHAERIA CANKER		+				+	
27. MACROPHOMINA PHASEOLINA		+					
28. TWISTED TOP	+	+				+	+
29. CEREBELLA INFLORESCENCE BLIGHT		+				+[a]	
30. VIRUSES	+	+	+	+		+	+
31. RHIZOPUS INFLORESCENCE BLIGHT	+	+					
32. SOOTY BLOTCH		+					
33. BACTERIAL WILT		+					+
34. ALTERNARIA LEAF SPOT	+	+					
35. STEM GALL NEMATODE	+	+					

a Only at one site.
b Number of sites surveyed.

Table 12.

Importance of insect groups in relation to the degree of damage caused to legumes and grasses in various ecosystems.

Ecosystem	Stylosanthes spp.	Zornia spp.	Centrosema spp.	Desmodium spp.	Pueraria spp.	Andropogon spp.	Brachiaria spp.
BRAZIL (CPAC)	SI +++	SI +	SI +				SI +++
WELL-DRAINED ISOTHERMIC	LI +++	LE +++	LE +++	LE ++	LE +++		
SAVANNA -CERRADO	SB +	LM +++					
	BW +	BW +					
CARIMAGUA	SI +++	SI +++	SI +++				SI +++
WELL-DRAINED ISOHYPER-THERMIC SAVANNA - LLANOS	LE +	LE +	LE +	LE ++	LE +++	LE +	RI ++
	SB +	LM +				AP +	
	BW +	BW +					
VENEZUELA (EL TIGRE)	SI +++	SI +++					SI +++
WELL-DRAINED ISOHYPER-THERMIC SAVANNA -LLANOS	LE ++	LE ++	IC ++				
	SB +	S +++					
	BW +						
PERU (PUCALLPA)	SI +++	SI +++					SI +++
SEASONAL SEMI-EVERGREEN FOREST	LE +++		LE +++	LE ++	LE +++		RI +

SI = Sucking Insects
LE = Leaf Eating Insects
SB = Stem Borers
BW = Bud Worm
RI = Rasping insects
LM = Leaf Miner
AP = Aphids
S = Spidermites

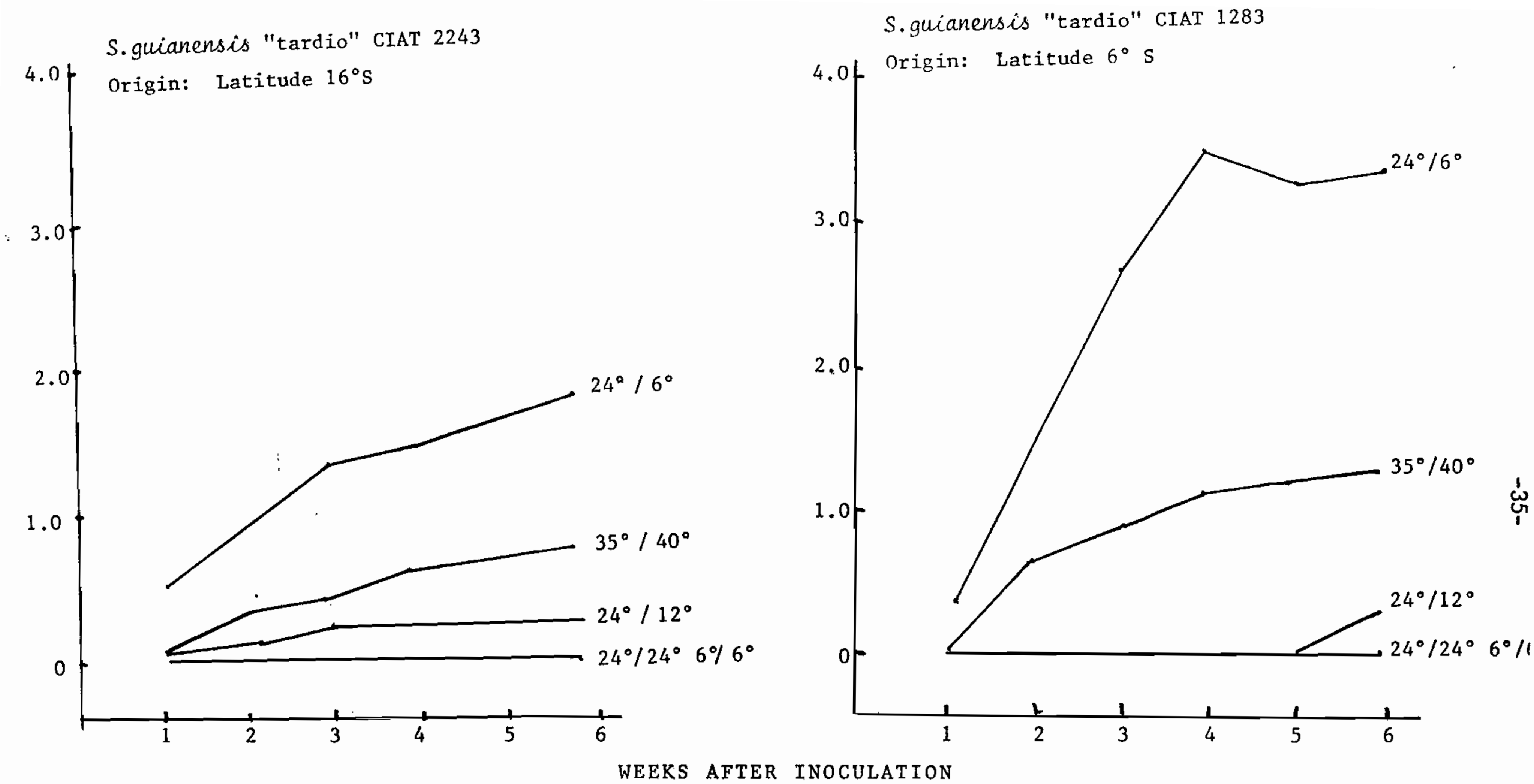


Figure 7. Effect of diurnal temperature fluctuations on the development of latent infection by *Colletotrichum gloeosporioides* in two ecotypes of *Stylosanthes guianensis* "tardio" (Lenné and Toledo, 1984)

characters not found in the natural germplasm, a very important secondary objective is the generation of information which will improve the efficiency of breeding methodologies in species which heretofore have received limited, if any, attention from plant breeders.

95. The specific objective of the S. guianensis breeding program is to combine the traits of anthracnose tolerance and high seed yield which occur separately in "tardío" and "common" types. This program is still in its early stages, with the first series of F_2 populations being established for field evaluation at Carimagúa and Brasilia in 1983. A continuing flow of new breeding materials is assured by an active crossing program.

96. This work has resulted in a clarification of the genetic compatibility relationships among the different botanical varieties within the species S. guianensis. Photoperiod studies with late-flowering S. guianensis lines resulted in a simple methodology with which generation time can be reduced by as much as three months.

97. Quantitative estimates of outcrossing rates in S. guianensis have been obtained. This information is of crucial importance in designing a plant breeding strategy and has allowed the development of novel breeding schemes which will allow greater efficiency in reaching breeding objectives.

98. The genetic heterogeneity for disease reaction found in a detailed study of a natural S. guianensis population has helped to clarify breeding objectives in terms of the genetic structure of bred cultivars.

99. Previous plant breeding projects in Centrosema, Leucaena and S. capitata have been terminated, but several advanced generation breeding lines are considered of sufficient promise to warrant wider testing in the program's regional trials network.

100. Spittlebug research. With respect to grasses, one of the major challenges is to cope with the "spittlebug" problem. Spittlebugs belong to the genera Zulia, Aeneolamia, Tomapsis, and Deois, and cause serious damage to the widely used Brachiaria spp., particularly B. decumbens. Due to the importance of the Brachiaria genus with species very well adapted to poor, acidic soils, a two-pronged strategy is being pursued. One strategy is based on biological control mechanisms for the insect using the fungus Metarhizium anisopliae which parasitizes spittlebugs and exerts a more persistant control of the insect population than commercial insecticides.

101. The other strategy is based on the selection of other species of Brachiaria with higher tolerance, or even resistance, to "spittlebug". With a base of a collection of 70 Brachiaria spp., screening trials for spittlebug resistance are being undertaken at 15 locations in Colombia, Peru, Brazil, Bolivia, Panama, Ecuador, and Cuba, which, together, represent the major ecosystems. First results from a location with high spittlebug pressure suggest that selected

accessions of the species B. brizantha, humidicola, and dictyoneura offer some tolerance.

Pasture Development

102. With the selection and advancement of forage germplasm to higher categories of evaluation, the program has had to face new research challenges in pasture development, including the question of the potential compatibility of grasses and legumes, both in terms of agronomic factors and the consumption/selection patterns by the grazing animal. Extensive research has also been conducted for the development of low-cost pasture establishment techniques.

103. Compatibility studies. The potential compatibility of grass/legume mixtures is initially assessed in cutting trials in which yields of grasses and legumes are measured in associations. From these studies it has become evident that Brachiaria species show different degrees of aggressiveness with different legumes, as indicated by relative yields after several harvests. For example, B. humidicola is more compatible with D. ovalifolium than with B. bryzantha and B. decumbens. In contrast, bunch-type grasses such as A. gayanus, P. maximum, and H. rufa exhibit similar compatibility with legumes as does S. capitata (Figure 8).

104. Other studies of compatibility have compared yields of grasses and legumes in monoculture versus yield in mixture. In general, the productivity of grasses has been favored by the companion legume, whereas the legumes have been negatively affected by the associated grass. Of the legumes evaluated, D. ovalifolium has been found to be least affected by the grass, indicating a high degree of aggressiveness and thus a high potential compatibility with aggressive grasses such as B. humidicola. This potentially good compatibility has been confirmed by other studies.

105. It is recognized that the information on grass/legume compatibility obtained in clipping trials can be modified by the grazing animal, especially if differences exist in relative acceptability. Therefore, agronomically compatible grasses and legumes are assembled in small plots, and measurements are made with esophageal fistulated animals of the relative selection of the grass and legume components. As a result of these studies it has been possible to learn that legumes such as D. gyroides and S. guianensis "tardío" are of low acceptability relative to A. gayanus, and that legumes such as Z. brasiliensis are completely rejected. On the other hand, legumes like S. capitata are of high acceptability when associated with A. gayanus. The information on relative acceptability is useful not only in making decisions on grass/legume compatibility but also in designing grazing management strategies that attempt to keep grass/legume mixtures in proper balance in a given ecosystem.

106. Pasture establishment studies. Research on pasture establishment has been carried out both in the Llanos of Colombia and the Cerrados of Brazil. Emphasis has been on the following areas:

- -Tillage and vegetation control methods;
- -Planting methods and spatial distribution systems;

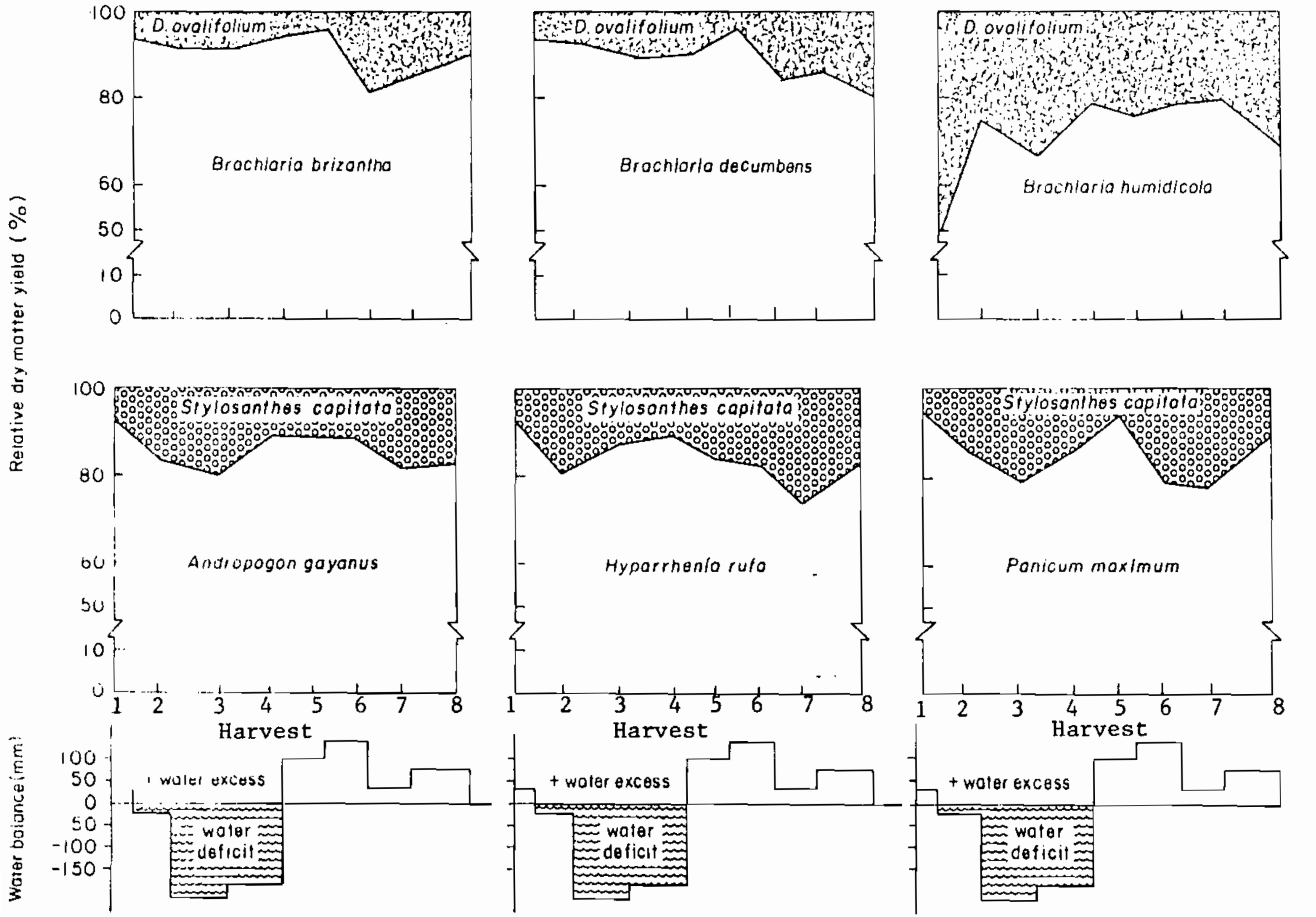


Figure 8. Relative dry matter production of postrate and bunch type grasses and companion legumes.

-Savanna replacement with improved grasses and legumes, and legume strip seeding in native and degraded pastures.

107. Tillage and vegetation control. Achievements with different systems of seedbed preparation and vegetation control can be summarized in terms of their advantages over conventional tillage (plowing/disking) which, aside from high cost, can result in an unfavorable seedling environment and erosion hazard, if overdone. Some of these disadvantages have been overcome by minimum tillage or zero inter-row tillage. Successful establishment of *A. gayanus*, *B. humidicola*, *D. ovalifolium*, and *P. phaseoloides* has been achieved in Carimagua with minimum or zero tillage.

108. Planting methods and spatial distribution. Conventional seeding (broadcast) has been associated with high seed requirements, weed problems, and low fertilizer efficiency. Alternative methods of planting evaluated by the program, such as row seeding or strip planting, have proven to be effective in reducing seed requirements, improving fertilizer efficiency, and in allowing a better initial establishment of grasses and legumes by reducing early competition for soil nutrients and light.

109. The program has developed a low density seeding method which has proven effective in reducing labor, seed, and initial fertilizer requirements, and in minimizing the risk of failure inherent in pasture establishment. The system has proven to be very effective for the establishment of *A. gayanus* in the Llanos ecosystem.

110. Another important achievement in pasture establishment has been the development of a simple planter for vegetative material. The planter has been used successfully to plant commercial-scale pastures of *B. humidicola*. The same basic implement can be used for planting legumes in degraded pastures and in native savanna.

111. Savanna replacement and legume strips seeding. A series of large-scale experiments in Carimagua has assessed the feasibility of replacing native savanna with introduced grasses and legumes through strip seeding. The approach has been to replace 20% of the area each year using mixtures of *A. gayanus* and *B. humidicola* with *D. ovalifolium* and *P. phaseoloides* in strips varying in width (0.5, 2.5 and 5.0 m). After three years, all treatments have covered at least 60% of the total area, with the exception of the 5.0 m strip of *D. ovalifolium*. The paddocks have carried 1.0-1.5 animal/ha (the animals are rotated within a single association). Animal performance has been good, particularly in the *B. humidicola* + *P. phaseoloides* treatment. Due to the presence of the legume in the diet, the consumption of unburnt native savanna species has been high.

112. The results of these experiments indicate that with certain improved forage species it is possible to gradually replace native savanna. In addition, it has become clear that a possibility exists to manage native savanna without burning, thus making more efficient use of the biomass produced. The program is now looking at strip-seeding of legumes to supplement unburnt savanna as a means of

improving the animal performance and the carrying capacity of the system.

113. Research aimed at improving productivity of Brachiaria species in the Cerrados has yielded successful results. Significant increases in forage production have been achieved with degraded pastures of B. ruziziensis by means of mechanical disturbance using a turbotiller combined with maintenance fertilizer application or with sub-seeding of legumes (Figure 9). The introduction of legumes into degraded pastures is an alternative that seems economically feasible and has the potential to make a considerable impact in the Cerrado region with its large areas of degraded Brachiaria pastures.

Pasture Quality

114. Seasonal consumption of legumes. The selection of forage germplasm adapted to low natural fertility, minimum purchased inputs, and tolerance to pests and diseases, may be expected to lead to forages of overall poor or medium quality. This holds particularly true with tropical grasses, which have lower protein and P contents than tropical legumes, especially during the dry season (Table 13), even though their productivity is greater. This had led the program to emphasize the use of grasses and legumes in association, not only as a means to introduce nitrogen in the system, but also to balance the protein and mineral level of the diet of the grazing animal, particularly during the dry season. To achieve this balance, both grasses and legumes have to be consumed in appropriate proportions in different seasons of the year.

115. Experimental results have demonstrated variations in consumption of legumes over seasons, with intake being higher during the dry season (Figure 10). As a result of this consumption pattern, protein intake in grass/legume associations has been adequate to sustain liveweight gains during the dry season, while on grass pastures liveweight gains cannot be maintained (Table 14). The nitrogen recycling of the legume to the grass has also been documented in terms of higher protein content of the grass and the diet (and thus better animal performance), particularly during the wet season (Table 14).

116. Effect of fertilizer on legume consumption. The combined effects of aggressiveness and low acceptability of certain legumes can result in a legume-dominant pasture with negative consequences on animal performance. For example, this has been the case with D. ovalifolium, a legume well adapted to acid infertile soils. The lack of palatability of D. ovalifolium was associated with high tannin content, which also affects protein availability to the animal.

117. Research showed that the problem of acceptability of D. ovalifolium can be alleviated by the strategic application of maintenance sulphur fertilizer, which possibly is reducing tannin content. In addition, fertilization with S has resulted in increases in biomass, and in protein and S content in the tissue (Table 15). These results indicate that the program has identified a valuable tool to improve the consumption of certain legumes of high agronomic value for acid, infertile soils.

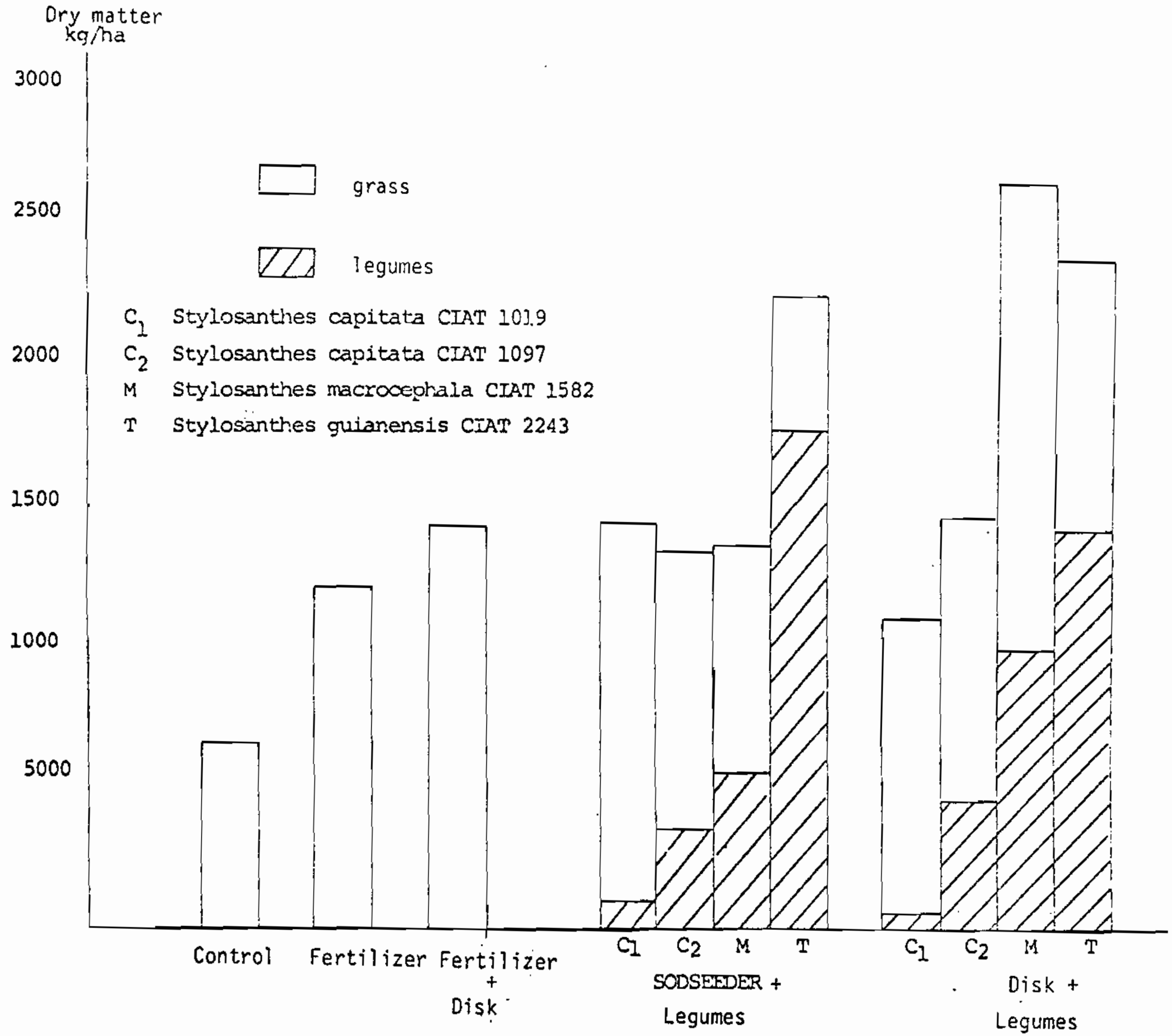


Figure 9. Dry matter yield in B. ruziziensis following renovation practices (Cerrado, Brasil)

Table 13. Protein and phosphorus content of selected grasses and legumes during the dry and rainy season at Carimagua (percentage)

Species	Crude Protein		Phosphorus	
	Rainy	Dry	Rainy	Dry
GRASSES:				
A. gayanus 621	7.2	3.4	0.10	0.04
B. decumbens 606	6.6	5.5	0.08	0.05
B. humidicola 679	5.0	3.9	0.08	0.05
B. brizantha 665	6.1	5.2	0.09	0.05
LEGUMES:				
S. capitata 1315	11.6	10.4	0.18	0.08
P. phaseoloides 9900	15.6	16.1	0.22	0.10
C. Brasilianum 5055	14.4	12.5	0.14	0.09
C. macrocarpum 5065	16.9	13.4	0.16	0.09
D. ovalifolium 350	10.6	10.0	0.10	0.08

Fertilization:

(a) Grasses: 50 kg N/ha; 20 kg P/ha; 30 kg K/ha; 100 kg Ca/ha; 20 kg Mg/ha
(b) Legumes: no N; 20 kg P/ha; 30 kg K/ha; 100 kg Ca/ha; 20 kg Mg/ha

A. gayanus + *P. phaseoloides*

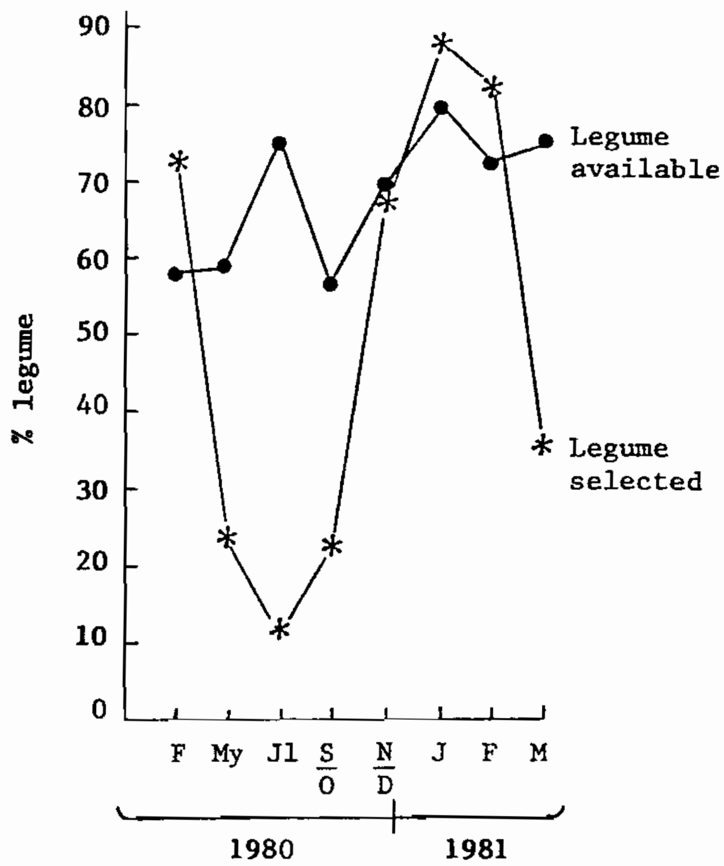


Figure 10. Dynamics of legume available and selected by esophageal fistulated steers grazing mixtures of *A. gayanus* and *P. phaseoloides* (Carimagua)

Table 14. Relationship between quality of the grass on offer and selected diet with changes in liveweight of animals grazing *A. gayanus* alone and in association with *S. capitata* (Carimagua)

Pasture	Season	Protein content		Legume in diet	Changes in liveweight
		Grass (leaf)	Diet		
		- % -		%	g/A/day
A. gayanus	Dry	4.7	4.9	-	- 36
	Wet	6.4	8.5	-	+454
A. gayanus + *S. capitata*	Dry	5.1	6.3	17.1	+147
	Wet	8.2	10.1	4.3	+666

Table 15. The effect of sulfur maintenance fertilization in production and quality of *D. ovalifolium* (Carimagua)

Fertilization[1]	Yield	Chemical analysis		
		Tannins	Nitrogen	Sulfur
	TDM/ha	--	%	--
- S	1.4 [a]	18.3 [a]	1.92 [a]	0.14
+ S	3.0 [b]	11.0 [b]	1.51 [b]	0.09

1/ Basal application of P + Ca + K + Mg

a,b, Means different ($P < .05$)

Pasture Productivity and Persistence

118. Latin American savannas have relatively high biomass production levels; 4-5 tons of dry matter on offer per hectare are frequently encountered. However, due to low palatability and rapid drop in quality of the forage with maturity, burning is a common practice; as a result, the system has a very low output. Early work in Carimagua showed that little benefit could be obtained with improved burning or grazing management of savannas. In subsequent years, pasture research in the savannas indicated that considerable improvement in carrying capacity was possible with the use of improved grasses, and that there was a potential to improve individual animal gains during the dry season.

119. With the selection of adapted forage germplasm, especially legumes, the program can now show significant increases in both individual animal performance and carrying capacity (Table 16). Improved pastures based on grass/legume mixtures have consistently produced about 30% higher gains per animal and 15% higher gains per hectare than grasses alone, with the major benefit occurring during the dry season.

120. Adapted legumes have also been successfully tested as supplement to native savanna pastures. Results indicate that when traditional burning practices are enhanced by the use of P. phaseoloides banks, the productivity of the savanna can be increased both in gains per animal and per hectare (Table 17).

121. Productivity of pastures must also be assessed in terms of persistence. Persistence is particularly critical with legumes. Three very productive associations (B. decumbens + P. phaseoloides, A. gayanus + P. phaseoloides, and A. gayanus + S. capitata) have persisted in Carimagua for four years with excellent animal performance over time (Table 17). In the case of S. capitata associated with A. gayanus, some problems of seedling vigor have been encountered. Research has shown that high competition of A. gayanus for soil nutrients (other than P) is responsible for this inadequate legume seedling development, and that this can be partially overcome with strategic fertilization (Table 18).

122. Other factors affecting pasture persistence have been related to grazing management. In the past, continuous grazing was considered to be the only suitable method to evaluate improved pastures, based on the assumption that this was a common practice with sown grasses in Latin American savannas.

123. The program's research on prevailing farm systems has clearly documented that, contrary to conventional belief, ranchers use forms of rotational grazing to manage their improved pastures. This has introduced a new dimension in the program's strategy for evaluating pasture productivity and persistence, and has led to some working hypotheses which are currently being tested. These hypothesis can be summarized as follows:

Table 16. Productivity of improved pastures in terms of weight gains of young steers in Carimagua (average of four years)

Treatment	Liveweight gains per year (kg)	
	Per animal	Per hectare
Native pasture:		
- Savanna + burning	75	15
Supplementary legume grazing:		
- Savanna + bank of *Pueraria phaseoloides*	101	51
Improved grass pastures:		
- *Brachiaria decumbens*	145	250
- *Andropogon gayanus*	120	268
Legume grass associations:		
- *Brachiaria decumbens* + strips of *P. phaseoloides*	183	294
- *A. gayanus* + *P. phaseoloides*	182	308
- *A. gayanus* + *Stylosanthes capitata*	193	320

Table 17. Annual liveweight gains over time in grasses alone and in association with legumes in the Llanos of Colombia (kg/A/year)

Year	Grass alone[1]		Association[2]		
	B. decumbens	*A. gayanus*	*B. decumbens* + *P. phaseoloides*	*A. gayanus* + *P. phaseoloides*	*A. gayanus* + *S. capitata*
1979	136	-	178	218	230
1980	129	129	181	169	175
1981	182	145	204	191	199
1982	134	89	170	149	169
Mean	145	121	183	182	193

1/ Stocking rate 1.2 / 2.0 dry and wet season.

2/ Stocking rate 1.2 / 1.9 dry and wet season.

Table 18. Response of *S. capitata* seedlings in association with *A. gayanus* to maintenance fertilization[1] during the rainy season at Carimagua

Residual P rates[2] (kg/ha)	Dry matter yield (kg/ha in 5 cuts)	
	Without maintenance fertilization	With maintenance fertilization
0	880	1433
20	974	1901
40	1014	1891

1/ Fertilization rate 30 kg K, 20 kg Mg and 20 kg S/ha applied in March, 1983.

2/ P applied in 1981.

a) Continuous grazing during the rainy season will favor the legume in the association; therefore, an appropriate management for pastures is one that gives the grass a competitive advantage;
b) Some forms of rotational grazing during the rainy season will favor the grass in the association; in these cases an appropriate management for pastures is one that gives the legume a competitive advantage.

124. Presently, combinations of grazing system and stocking rate are being studied to evaluate pasture productivity and persistence of different grasses and legumes in association.

Seed Production and Related Technology

125. Between 1977 and 1983 the total amount of grass seed produced by the program was 17.6 tons. Of this total, 17 tons were of A. gayanus CIAT 621 (including 4 tons distributed as basic seed to national programs), and the remainder of Brachiaria spp. and Panicum maximum. During the same period, the total amount of legume seed produced of accessions in Category III and above amounted to 15.5 tons. The number of legume accessions under multiplication in any one year varied from 40 to 108, mainly representing species of the genera Stylosanthes, Centrosema, Desmodium, and Zornia. These significant volumes of seed have provided the program with the critical seed supplies needed with which to conduct its diverse and widespread activities in germplasm and pasture research.

126. The major production effort upon A. gayanus allowed for the concurrent study of various production factors. Specific achievements obtained were:

a) Defoliation management. In established seed crops, a response in seed yield to a harvest cut, or to the discontinuation of controlled grazing, at approximately eight weeks prior to the onset of floral induction, was demonstrated;
b) A manual harvesting method was developed and documented. The method includes the phases of cutting inflorescences, swating in horizontally constructed heaps, separating spikelets over a horizontal screen, followed by natural drying;
c) A prototype de-awner was designed, constructed and used, allowing a mechanical cleaning process to raise purity of seed lots to a 40-50% range (vs. 20-25% for awned seed lots).
d) A mobile, inclined vibrating screen for in-field use in grass seed harvesting was designed, constructed and used;
e) Appropriate laboratory techniques have been developed for the measurement of pure seed, germination, and viability of seed lots.
f) Combine harvesting was determined to be feasible only in crops whose plant height is limited by prior defoliation management. Otherwise, pure seed yields are reduced by 50% compared to manual harvesting.

127. Studies of cultural practices and the relative efficiency of various harvest methods are in progress for S. capitata 'Capica'. At Carimagua, plantings after June have low yield potential. Harvesting is confined to the November-December period, with a single annual harvest. Using conventional combine harvestors, commercial seed yield in the range of 150-200 kg/ha of seed in pod are predicted.

128. During the period 1978-1981, a collaborative experiment with several national institutions was conducted in regions of Colombia, Bolivia, and Brazil to make preliminary assessments of seed yield potential and the major determinants thereof, for five legume and four grass species. While maximum multiplication rates ranged between 34 and 190 ha/year for legumes, and 70 and 160 ha/year for grasses, low or zero seed yields were recorded frequently. Important determinants of seed yield for legumes were foliar diseases, soil moisture effects on reproductive vigor, and weed; for the grasses they were defoliation management, soil fertility limitations, and inflorescence diseases. The experimental work stimulated both seed and forage evaluation research at each location and provided directions for follow-up research.

Technology Adaptation and Transfer

Germplasm Performance Across Ecosystems

129. Using data generated by the RTs-B in the RIEPT from the Llanos and the two major forest ecosystems, statistical cross-location analyses were conducted. The conclusions arrived at were:

a) For the Llanos (well-drained isohyperthermic savannas) the legume with the the highest degree of adaptation was *Stylosanthes capitata* which was represented by six ecotypes (CIAT 1315, 1318, 1342, 1405, 1693, and 1728). *Stylosanthes guianensis* "tardío", represented in the several trials by only one entry (CIAT 1280), was particularly productive during the dry season.

b) In the forest ecosystems (rainforest and semi-evergreen seasonal forest), the most adapted and productive legumes were *Stylosanthes guianensis* (CIAT 136 and 184) and *Zornia latifolia* (CIAT 728)--legumes which were discarded under Llanos conditions. Two additional well-adapted species in these ecosystems were a late flowering *S. capitata* (CIAT 1097) and *D. ovalifolium* (CIAT 350).

c) Among grasses, *Andropogon gayanus* (CIAT 621) and *Brachiaria decumbens* (CIAT 606) were shown to be broadly adapted throughout the Llanos and forest ecosystems.

d) The separation of CIAT germplasm in terms of adaptation by ecosystems, especially among legumes, is mostly due to biotic (diseases and pests) and climatic factors, rather than to differences in soil characteristics (soil acidity and low fertility status are common throughout the sites where the germplasm was tested).

Pastures in Animal Production Systems

130. The first herd systems experiment (1973-77) documented the many nutritional deficiencies of the native savannas of the Eastern Plains of Colombia which are responsible for very low conception rates and animal weight gains. Compared to animals fed with common salt, mineral supplementation resulted in large decreases in abortions and perinatal deaths (38 vs. 5%, respectively), lower calving to conception intervals (8 vs. 4.5 months), increased weaning weights (169 vs. 131 kg), and overall improved productivity. Sown grasses available at the time (*M. minutiflora* and *H. rufa*), when incorporated in the grazing system, did not significantly improve animal performance. Application of management practices such as early weaning, although highly successful at the experimental level, was impractical due to the absence of good quality pastures to raise the early-weaned calves.

131. A subsequent herd systems experiment at Carimagua (1978-81) incorporated newly available grasses and legumes as 10% of the area of the whole system. It was found that the strategic use of the improved pastures for cows in late pregnancy, and for lactating cows during the mating season, resulted in significantly higher reconception rates of

the latter (27 vs. 15% in savanna), and decreased overall inter-calving intervals (484 vs. 546 days in savanna alone), regardless of the cows' post-calving weight. At the same time, a decreased rate of mortality in calves in the sown pasture/savanna systems was recorded (6.8 vs. 10.3%). This experiment also showed that a restricted seasonal mating was only feasible when improved pastures were available; the latter is important if early weaning and other intensive management practices are utilized.

132. A concurrent herd systems experiment was carried out at CPAC in the Cerrado region of Brazil, including a number of complementary trials. It was demonstrated that early weaning (3 months of age) increases the reproduction rate when using a controlled mating season of 90 days. After four years, cows that had their calves removed at three months of age had an average annual calf crop of 83%, while those weaned at five months had a calving rate of 66%. The experiment reconfirmed that nursing cows grazing savanna have the lowest reconception rates. Access of this category to a sown, grass-alone pasture during the mating season increased reconception from 4% in the native pasture to 17% in the sown pasture. It is believed that this rate could be further improved by using grass/legume pastures as they become available.

133. Some of the above-mentioned strategies are being tested in collaborating farms in the Eastern Plains of Colombia. A total of 760 ha of promising grass/legume pastures have been sown since 1979 on seven farms. In one of these, 5.5% of the farm was sown to A. gayanus/S. capitata and B. decumbens/D. ovalifolium. The pastures are used by nursing cows to improve their reconception rate and calf weaning weights. The results of the first four years are shown in Table 19. These results led to marginal rates of return of 19% to 35% per year, depending on the assumptions made about pasture persistence and maintenance fertilization. If calves are sold at weaning, three years of negative marginal cash flows are involved, followed by a doubling of net income in subsequent years.

134. The use of improved grass/legume pastures to increase the rate of growth and diminish the age of the first calving of replacement heifers is being tested in two other farms, and compared with savanna-grown animals subject to the farmers' usual management. The result of the initial two years of these experiments are shown in Table 20. A marginal internal rate of return of 17% was calculated for this alternative, which makes it comparatively less attractive than sown pastures for improved feeding of breeding cows, or for early weaning.

Economic Performance of the New Pasture Technology

135. Economic analyses over the last six years have gradually shifted from ex-ante simulations to ex-post analyses, even though persistence and refertilization requirements are still treated as rather uncertain variables.

136. Using experimental weight gain results obtained at Carimagua, an estimate for persistence of six years, and re-fertilization costs to

Table 19. On-farm productivity impact of improved pastures used strategically to raise reproductive performance, case study, Colombian "Llanos". 1979-1983

Productivity parameter	1979	1980	1981	1982	1983	Increment 1979/1983 (%)
Cow weight (kg)	255	325	325	333	330	29
Weaning rate (%)	50	53	53	57	57	14
Weaner weight (kg)	109	129	129	144	162	49
Stocking rate (AU/ha)[1]	0.13	0.17	0.17	0.22	0.24	85

Marginal internal rate of return:

- assuming zero residual value of pasture after 1983 . . . . 19%
- assuming 12 year persistence with refertilization every third year at 1983 level 35%

1/ 1 AU = 300 kg liveweight

Table 20 Conception rate of heifers on sown pastures and native savanna in on-farm trials.
Data for May 83

Pasture regime	Altagracia			Las Leonas		
	Conception, %	LW, kg	Age, mo.	Conception, %	LW kg	Age, mo.
Savanna	0	200±26	29±1	0	222±18	34±2
Brachiaria humidicola/ Desmodium ovalifolium	21.0	220±36	29±3	-	-	-
Andropogon gayanus/ Stylosanthes capitata	45.1	298±48	29±3	87.5	340±32	34±1
Andropogon gayanus/ Stylosanthes capitata + Savanna[a]	-	-	-	85.0	322±28	34±1

a Sown pasture during the rainy season; savanna in the dry season be incurred every second year, rates of return to total capital (excluding land) of between 17 and 24 percent per annum have been calculated (see Table 21). In the meantime, fertilization requirements have been determined to be less than previously recommended for establishment after conventional soil tillage, due to the contribution of soil mineralization. Furthermore, it is realized that persistence has to be considered in a somewhat more complex frame. While persistence beyond five years of the legume is not documented, grasses such as B. decumbens are known to persist for more than ten years under farmer management conditions in the savannas. Thus, latest economic analyses assume a four- to five- year persistence of the legume, and unlimited persistence of the pure grass pasture thereafter. It is considered that, given the low percentage of the farm area under improved pastures, farmers will prefer to turn additional savannas into legume/grass associations rather than re-establish legume/grass associations on grass pastures.

137. These factors have, therefore, further enhanced the attractiveness of pasture investments.

138. To improve the understanding of the role of the new pasture technology within the area of interest, alternative pastures and pasture uses were simulated for locations with varying land prices within a linear programming frame.

139. Even at very low prices, milk production based on dual purpose herds proved very competitive, followed by the strategic use of legume/ grass associations for breeding herds (pure fattening operations were not included in this exercise but are a very competitive option).

140. A family farm unit was established in Carimagua in 1974. After early failures associated with the lack of suitable germplasm, with the advent of new, adapted materials (A. gayanus, P. phaseoloides, D. ovalifolium, B. humidicola) productivity increased markedly in terms of whole-herd animal performance.

141. Based on the above information, a feasibility study of small-scale livestock operations in the Colombian Llanos was undertaken. With the prevailing (subsidized) loan conditions, and assuming a willingness of the owners to limit their consumption for a number of years, the development of small farms appears feasible. Performance was calculated to improve substantially when milking of dual purpose cattle on improved pastures is included. Consequently, the program decided to gradually turn the family farm unit into a dual purpose operation. The first Brown Swiss/Zebu crossbred heifers are already calving on the farm.

142. Given the importance of strategic use of small areas of improved pastures within breeding systems, an ex-ante simulation of three alternative uses of such pastures was undertaken:

- -feeding of early-weaned calves;
- -feeding of heifers to reduce age at first mating;
- -feeding of cows to improve reconception and weaning weights.

Table 21. Profitability of fattening operations with various pasture production technologies estimated for the Llanos piedmont and the inner Llanos regions of Colombia.

Pasture production system	Internal rate of return (%)[a]			
	Piedmont (Puerto López)[b]		Llanos (Carimagua)	
	6-year persistence	12-year persistence	6-year persistence	12-year persistence
Brachiaria decumbens alone	22.6	24.6	18.5	20.7
B. decumbens + blocks of *Pueraria phaseoloides*	20.8	23.1	16.8	19.2
B. decumbens + strips of *P. phaseoloides*	26.8	28.9	22.6	24.9
Andropogon gayanus + *Stylosanthes capitata*	28.1	30.4	24.2	26.2
A. gayanus + *P. phaseoloides*	21.0	23.8	16.9	17.8
A. gayanus + *Zornia* sp.	21.8	24.4	18.0	20.9
Native savanna + *P. phaseoloides*	24.2	24.9	20.0	20.9

a. Internal rate of return for the 300 ha model without including the price of the land.

b. Sensitivity analysis of Carimagua biological parameters in close distance to the Bogota market.

143. Results indicate that early weaning may yield the highest returns, followed by feeding cows. While supplementation of heifers produced the lowest internal rates of return, they nevertheless are moderately attractive.

Support To National Programs

Training

144. In the early years, the Beef Program undertook training activities with a broad focus on livestock production. Courses were aimed at extensionists and farm managers without any priorities among regions.

145. With the refocusing of the program in 1977, training activities were concentrated on building a strong pasture research base within national programs. To this effect, candidates were selected mainly from among researchers, and preferentially from institutions working in acid soil regions. This is reflected by the distribution of trainees by countries (Table 22). The major instrument has been an annual 10-week intensive course (see Table 23). Out of a total of 255 researchers receiving training from 1977 onwards, 173, or 68%, participated in these courses which typically are followed by a specialization phase in which the training participant works side-by-side with one of the program's senior staff during an average period of three to four months.

146. This training effort is closely interlinked with the development of the International Tropical Pastures Network. Many trainees have become network collaborators over time. At the same time, senior staff travel to coordinate regional trials has proven an effective means to promote participation in the training courses and to select candidates. One interesting case documenting this interaction is the one of Peru. With 21 professionals trained between 1977 and 1983, Peru has the fastest growing national pastures network outside of Colombia where CIAT is managing many trials by itself.

147. In view of the shortage of scientists with higher degree training who are actively involved in pastures research, the program has been active in promoting higher degree studies in this field. This has been achieved through cooperation with universities both in the region and in developed countries (particularly in the USA and the Federal Republic of Germany). Usually, the thesis research is conducted at CIAT, while course requirements are completed at the universities. Research is jointly supervised by CIAT staff and faculty members. Thirteen Ph.D. and 19 M.S. students have participated in this type of activity since 1977.

148. Eighteen postdoctoral fellows have been attached to the program from 1977 onwards. Most of them have either become senior staff members of the program or are nowworking in other institutions related to the field of pasture and animal production in the tropics.

Networking Activities

149. The program maintains and active exchange of information with pasture researchers from national institutions and other specialists through various mechanisms, including senior scientist travel through

Table 22. Tropical Pastures Program training activities by country of origin of trainee and year. 1977-1983

Country of origin	1977	1978	1979	1980	1981	1982	1983	TOTAL
Argentina	-	2	-	-	-	-	-	2
Bolivia	4	2	2	2	2	-	1	13
Brazil	2	9	5	6	5	15	2	44
Colombia	6	5	8	8	4	6	6	43
Costa Rica	-	-	-	2	1	1	-	4
Cuba	-	1	4	7	6	-	2	20
Dominican Republic	-	1	1	1	-	4	2	9
Ecuador	-	3	2	1	1	-	2	9
Guatemala	13	-	-	-	-	-	-	13
Haiti	-	-	-	-	1	1	1	3
Honduras	1	-	-	2	1	-	-	4
Mexico	1	-	-	1	2	-	-	4
Nicaragua	1	2	2	2	-	1	3	11
Panama	1	2	-	4	3	3	6	19
Peru	-	3	5	4	2	2	5	21
Venezuela	-	1	8	2	2	1	-	14
Belize	-	-	3	-	-	2	-	5
U S A	1	1	3	-	1	-	-	6
Germany F.R.	2	-	1	3	1	-	-	7
Holland	-	-	1	-	-	-	-	1
Thailand	-	-	-	-	-	2	-	2
Antigua	-	1	-	-	-	-	-	1
TOTAL	32	33	45	45	32	38	30	255

Table 23. Tropical Pastures Program: training activities by type of trainee and year. 1977-1983

	1977	1978	1979	1980	1981	1982	1983	TOTAL
Associate visiting researcher PhD thesis	4	1	2	2	3	0	1	13
Associate visiting researcher	0	2	3	3	0	5	0	13
Visiting researcher MS thesis	2	2	6	2	0	3	4	19
Visiting post-graduate researchers	17	24	31	29	22	28	22	173
Special	9	4	3	2	2	0	0	20
Short course	0	0	0	7	5	2	3	17
TOTAL	32	33	45	45	32	38	30	255

the region, visits by researchers to the program's facilities at Palmira, Quilichao, Carimagua, and Planaltina, and a series of meetings and workshops. The major events organized from 1977 onwards were:

1978:	-Workshop on Collection, Preservation, and Characterization of Forage Resources (University of Florida/AID/CIAT);
	-Seminar on Pasture Production in Acid Soils of the Tropics (CIAT);
1979:	-I Meeting on the Organization of the International Tropical Pasture Evaluation Network, RIEPT (CIAT);
1980:	-Amazonia: Agriculture and Land Use Research (Rockefeller Foundation/GTZ/NCSU/ICRAF/CIAT);
1982:	-II Meeting of the International Tropical Pasture Evaluation Network, RIEPT (CIAT);
	-Workshop on Methodologies for Pasture Evaluation under Grazing in Small Plots (CIAT);
	-Workshop on Results of Technical and Economic Analysis of Beef Cattle Production Systems (ETES) in Savannas of Tropical South America (GTZ/TUB/CIAT);
1983:	-First Meeting of the Advisory Committee to the International Tropical Pasture Network, RIEPT, held in Brasilia (CPAC, EMBRAPA/CIAT)

Publications

150. As part of the RIEPT activities the program produces a quarterly bulletin with reports on research information on pasture and animal production supplied by participants of the network, advances of CIAT research, information on scientific meetings, book reviews, and other news. The purpose of the bulletin is to enhance the communication among pasture researchers of the region.

151. Between 1976 and 1983 the program produced 288 publications, 38% of which are scientific journal articles and technical reports.

152. The Tropical Pastures Information System contained 3,614 documents as per November 1983 and served 507 subscribers.

Distribution of Experimental and Basic Seed

153. Grasses. Some 1500 kg of seed of *A. gayanus* and *Brachiaria* spp. have been supplied to national programs both for their own experiments and for use within the network of regional trials. A total of 4000 kg of basic seed of *A. gayanus* CIAT 621 was supplied to ICA in Colombia, and SPSC-EMBRAPA in Brazil,as part of their release of "Carimagua 1" and "Planaltina", respectively.

154. In addition, 2000 kg were delivered to FONAIAP, Venezuela, to back up the release of "Sabanero"; 200 kg were sent each to IDIAP, Panama, and to INIPA, Peru for the release of *A. gayanus* in the respective countries.

Status of the Release Process

Andropogon gayanus CIAT 621

155. Andropogon gayanus, originally introduced from Africa, is a very productive, bunch-type grass, highly adapted to high aluminum, low fertility, acid soils, and characterized by additional desirable characteristics, such as tolerance to pests and diseases, high drought and fire tolerance, high seed-yielding ability, and good compatibility with legumes. In 1980, seven years after its introduction, it was released by ICA in Colombia under the name of "Carimagua I", and by CPAC/EMBRAPA under the name of "Planaltina". In both cases the program made available large volumes of basic seed to the national institution making the release.

156. Subsequently, as the potential of A. gayanus was recognized more widely, CIAT 621 was released in 1982 by INIPA in Peru as "San Martín", and by FONAIAP in Venezuela as "Sabanero". In 1983, three institutions in Panama (IDIAP, BNP and University of Panama) decided upon a joint release under the name of "Veranero". In these cases basic seed was made available by the CIAT Seed Unit.

157. In 1983, adoption monitoring of this material was started. In Colombia, a survey was conducted of farmers who have planted "Carimagua 1". It was found that the characteristics which are determining farmers' use are dry season performance, resistance to spittlebug, and good growth on very poor soils.

158. The conspicuous lack of "compatibility with legumes" as a reason for adoption is due to the fact that suitable companion legumes were not available at the time of the survey.

159. This first survey of early adopters covered 57 farm with a total area of 64,524 ha and an area of 5,002 ha of Andropogon gayanus. Table 24 shows the evolution of the areas of Andropogon on these farms.

160. An interesting feature of this early process of adoption is the fact that Andropogon has already moved to areas of Colombia outside the Eastern Plains for which it was originally developed.

161. This adoption process has, up until now, been based almost exclusively on the private initiative of commercial farmers.

162. In the Cerrados of Brazil, the area planted to "Planaltina" has expanded rapidly. The major factor determining farmer use is resistance to spittlebug.. This characteristic is an important factor in view of the fact that the best-known sown grass of the region, Brachiaria decumbens, is highly susceptible.

Stylosanthes capitata CIAT 10280

163. Among Stylos, S. capitata is a newcomer to the cattle industry of tropical America. The main features of this species are:

Table 24. Evolution of the area of Andropogon gayanus on 57 early adopter farms in Colombia. 1979-1983

Region	1979	1980	1981	1982	1983
Eastern Plains	5	191	560	1682	2087
Middle Magdalena	8	36	205	705	1013
North Coast	29	129	624	1208	1902
TOTAL	42	356	1389	3595	5002

-high tolerance to anthracnose under "Llanos" conditions;
-high relative palatability;
-good adaptation to poor acid soils;
-high seed yielding ability;
-drought tolerance;
-compatibility with A. gayanus and other moderately aggressive grasses.

164. In 1983, ICA released a blend of five entries, collected by the program in the Brazilian Cerrados between 1975 and 1977, under the name of "Capica" as a legume for the well-drained acid savannas of eastern Colombia.

165. Basic seed produced by CIAT (160 kg) was made available by ICA to the commercial seed industry in 1982; at present, small amounts of CAPICA seed are being sold to commercial farmers.

Stylosanthes guianensis "tardío" type CIAT 2243

166. This material which originates from the central Cerrados, has proven to be quite resistant to anthracnose, tolerant to drought stress, compatible with bunch-type grasses, and produces a large amount of dry matter of intermediate to low palatability, which is an advantage for the supply of forage during the long dry season prevailing in the Cerrados.

167. EMBRAPA/CPAC is in the process of releasing this material under the name of "Bandeirante".

Stylosanthes macrocephala CIAT 1281

168. This Stylo has shown very good resistance to anthracnose throughout several ecosystems, is a good dry matter and seed producer, has a relatively high palatability, and is compatible with bunch-type grasses.

169. This material is also in the release process by CPAC for the Cerrados.

Other Legumes

170. Among the legumes that will be released in the near future is S. guianensis CIAT 136 for the Peruvian Amazon. It is expected that this material will be jointly released by IVITA and INIPA. Already, 150 kg of basic seed have been produced by IVITA. This legume, which failed under savanna conditions, has performed very well throughout the ecosystem since 1978 despite the presence of anthracnose.

CHAPTER III

FUTURE DIRECTIONS OF THE TROPICAL PASTURES PROGRAM: MODIFICATIONS TO THE LONG-RANGE PLAN

While the research emphasis and strategy described in the Long-Range Plan are still considered appropriate, the rapid advancement in knowledge of the ecosystems and germplasm performance gained by the program during recent years, suggested shifts in the relative importance of the ecosystems and thus the organizational perspective of the program.

The Mandate

The present mandate of the program restricts the action radius of the program to the lowlands of tropical America.

The program's work is already starting to have an impact in the savanna ecosystem. During 1984 the Program plans to initiate direct action in the humid tropics ecosystem. Other ecosystems of potential importance within Latin America are: (a) the moderately acid soil regions, (b) the poorly drained savannas, (c) the Chaco, and (d) the sub-humid and semi-arid regions.

The program has accumulated experience and germplasm for tropical savannas and forest ecosystems with annual precipitation above 1200 mm that could be transferred to similar conditions in other continents. National and international institutions in Africa and Southeast Asia are increasingly requesting CIAT pasture germplasm, which they consider suitable for humid and sub-humid environments in those continents.

On the other hand, many of the grass and legume species with excellent potential in the savanna and forest ecosystems in Latin America have their center of diversity in Africa and Asia. Thus, collaboration in collection and transfer of germplasm with institutions in these regions is highly appropriate.

Thus, while concentrating its efforts in Latin America, in the coming years the Program will gradually initiate exploratory action in Africa and Southeast Asia. In this context, the mandate should be extended to include, in a restricted manner, ecosystems with acid soils and annual rainfall above 1200 mm.

Work in Africa is expected to start in 1985 with an outposted liaison scientists who in close coordination with ILCA, is to oversee the establishment of regional trials.

Work in Southeast Asia will need to be preceded by a characterization of the ecosystems and prevailing pasture-based production systems in order to identify constraints to pasture production and to assess the potential of improved pasture technology. If the potential for CIAT action is sufficiently justified after 1986 a regional cooperation staff would be outposted with similar functions as those assigned to the person located in Africa.

Relative Importance of Various Ecosystems

Over time, the program has accumulated systematic information on the main ecosystems of tropical America, and the performance of its germplasm, which influences the present perception of the potentials for action in the different ecosystems.

Humid Tropics

The humid tropics is a broad ecosystem characterized by:

- an accelerated process of degradation of the ecosystem due to the lack of ecologically stable and economically competitive pastures in farming systems. Pastures are not, at present, a stable land use alternative due to the lack of germplasm adapted to the edaphic, climatic, and biotic conditions of the ecosystem;
- clear intentions of the governments of countries (such as Peru and several Central American countries) to accelerate the process of spontaneous colonization of the region in response to demographic and socioeconomic pressures;
- the possibility of introducing more intensive agricultural/ livestock farming systems (including dual purpose systems), due to the higher land clearing cost and the higher soil fertility levels available after clearing and burning; and
- the existence of a wide range of germplasm with potential in this ecosystem. New germplasm options are required to reclaim presently degraded pastures. In addition to the herbaceous germplasm that the program presently is working with, an important role is foreseen for leguminous trees and shrubs within an agro-silvopastoral ecological approach. A major limiting factor for livestock development in this ecosystem is the low number of available stock. The present strategy of the program is to capitalize on this circumstance to reduce existing land clearing pressures by concentrating its research on the improvement of already degraded pastures to substantially increase their productivity and carrying capacity.

Poorly Drained Savannas

The poorly drained savannas are found in Colombia (Casanare), Venezuela (Apure), Bolivia (Beni), and Brazil (Pantanal, Maranho Islands, etc.) and in micro-regions in Mexico and Central America. They usually have a somewhat higher natural fertility and higher cattle inventories than the well-drained savannas. Cattle productivity is somewhat higher, too. On the other hand, distance to markets, and difficulties for road construction due to flooding, seriously limit system intensification, particularly crop production. Native species (*Leersia hexandra*, *Hymenacme amplexicanlis*, *Eriochloa* spp. and *Echinocloa* spp.) under flooded conditions are of high quality and productivity, but are only available during the dry period.

During the periods of flooding, the quality and availability of forages in the unflooded areas ("Bancos and Tesos") is limited. Some materials selected by the program, which tolerate high grazing pressures, are considered promising for these unflooded areas.

On the other hand, limited germplasm exists for the poorly drained and flooded conditions. Strategies to solve the problem of excess water in the soil would imply a substantial change in the genetic base (germplasm) and actual focus of the program.

Less Humid and Semi-arid Ecosystems

The less humid and semi-arid ecosystems with 600 to 1200 mm annual rainfall are mostly encountered in Northeast Brazil, among the continent's lowlands, and scattered in smaller regions throughout the continent. Prevailing production systems are more extensive and often include other livestock species such as sheep and goats. Present CIAT germplasm has only limited potential under these conditions. Tree legumes and herbaceous annuals are alternatives to be considered for these ecosystems. Other international institutions such as ILCA, ICARDA, CSIRO are presently working for these ecosystems.

Moderately Acid Soil (pH 5.0 - 6.0) Ecosystems

These ecosystems are found scattered across tropical Latin America, such as the Piedmont of the Llanos and Amazon, certain regions within the Llanos and Cerrados, and in large areas of Central America. Rainfall patterns range from savanna to rainforest type.

Due to their higher pH these soils support more intensive farming systems. The importance of small farms and dual purpose systems is larger than in typical low-fertility savannas. Infrastructure is also better than in the savannas, and the cattle population of these regions is substantial.

On the other hand, experimental evidence suggests that CIAT germplasm selected under more stressful conditions frequently responds very well under these better environmental conditions. This leads to the hypothesis that the potential for short and medium-term adoption of improved materials may be higher than in the savannas. This may be somewhat offset by the fact that a number of commercial pasture species already exist for this type of ecosystem, and that other aspects of pasture management, such as weed control, are as important as germplasm.

Chaco Ecosystem

The Chaco region (Eastern Bolivia, Western Paraguay and Northeastern Argentina) is a very distinct environment from the other ones that the Tropical Pastures Program is working for. It has a subtropical climate with occasional frosts, and is characterized by a relatively longer dry season with excess water during the wet season. Predominant soils are alkaline with salinity problems. Again, other institutions such as CSIRO, and to some extent ILCA, are already working for similar ecosystems.

Proposed Future Plans

The above brief description of the ecosystem characteristics as seen from the perspective of the Program points to some of the trade-offs involved in defining priorities. These trade-offs are:

1) Immediate vs. longer run potential impact across ecosystems in light of: (a) livestock numbers; (b) small vs. large farmers, and (c) need for new ecosystem-specific germplasm.

2) Expanding to new ecosystems in Latin America vs. initiating limited actions for savanna and humid ecosystems in Africa and Southeast Asia in collaboration with regional institutions.

3. Germplasm emphasis in the new ecosystems vs. production systems research in the savanna and humid tropics ecosystem.

Based on an analysis of the above trade-offs, the program proposes the following strategy:

- To maintain a germplasm focus;
- To consolidate its research and collaborative efforts in the savannas and humid tropics of Latin America;
- To expand its research and collaboration activities to the less acid regions where there is a more immediate pay-off potential, by initiating a major screening effort in Central America in 1987;
- To coordinate the work for different ecosystems with other international institutions such as ILCA, ICRISAT, ICARDA, and CSIRO;
- To establish active collaborative programs with ILCA for the sub-humid and humid ecosystems in Africa;
- To explore the feasibility of a similar endeavor in Southeast Asia.

Organizational Perspective

In its initial stage the Tropical Pastures Program was a very centralized program with most of its staff working in Palmira, and research strongly oriented to the Colombian setting. The establishment of a major screening site in Brasilia and the development of the International Network of Tropical Pastures Regional Trials (RIEPT), constituted important steps towards research decentralization. In 1984 the program will be establishing a major screening site in the humid tropics, most probably in Pucallpa, Peru. Decentralization is also complemented by bilateral programs. In 1983, through a collaborative bilateral effort between USAID-Rutgers University and IDIAP and with CIAT backstopping support, a pasture research program was established in western Panama. A similar project is being executed in Brazil with EMBRAPA/IICA and CIAT; and an additional similar project is presently being considered for Belize.

It is felt that the Program will have to continue decentralizing its activities during the coming five to six years to appropriately fulfill its mandate. Nevertheless, this process of decentralization must be taking place with a strong central support system in place to sustain a solid research backstopping of the whole operation.

The staffing plan and projections reflect the move toward decentralization. For 1984, the ratio between centralized and decentralized staff is between 15:2 (minimal required staffing) and 15:5 (optimal staffing). This ratio is expected to change in the next years (until 1990) to values ranging between 12:8 (minimum staffing) and 16:9 (optimum staffing). It is hoped that through special and bilateral projects, decentralized activities may be even further expanded.

Table 25. Existing Senior Staff Positions and Projections for Minimum (x) and Optimum (o) Positions, 1983-1990.

Category Position	1982	'83	'84	'85	'86	'87	'88	'89	'90
A. Headquarters-Based Research in Colombia (Palmira, Quilichao, Carimagua)									
Coordinator		x	x	x	x	x	x	x	x
Germplasm		x	x	x	x	x	x	x	x
Plant Breeding		x	x	x	x	x	x	x	x
Legume Breeding		-	-	-	o	o	o	o	o
Agronomy (Carimagua)		x	x	x	x	o	o	o	-
Agronomy (RIEPT)		x	x	x	x	x	x	x	x
Entomology		x	x.	x.	x	x	o	o	o
Pathology		x	x	x	x	x	x	x	-
Soil Plant Nutrition		x	x	x	x	x	x	x	x
Soil Microbiology		x	x	x	x	x	x	x	x
Pasture development		x	x	x	x	x	x	o	o
Pasture Ecophysiology		x	x	x	x	x	x	x	x
Pasture Quality & Product.		x	x	x	x	x	x	x	x
Cattle Production Systems		x	x	x	x	x	x	x	x
Seed Production		x	x	x	x	x	x	x	x
Economics		x	x	x	x	x	x	x	x
TOTAL									
Minimum Program Projections		17	15	15	15	14	13	12	12
Optimum Program Projections		17	15	15	16	16	16	16	15
B. OUTPOSTED-Research and Regional Cooperation									
1. CERRADOS ECOSYSTEM									
Agronomist/Reg. liaison		x	x	x	x	x	x	x	x
Pathology		-	o	o	x	x	x	x	x
Production Systems (CNPGC)		-	-	-	o	o	o	o	o
2. HUMID TROPICS ECOSYSTEM									
Pasture Agronomy		-	x	x	x	x	x	x	x
Pasture reclamation		-	o	x	x	x	x	x	x
3. CENTRAL AMERICA AND CARIBBEAN									
Regional Coop.(RIEPT)		-	o	x	x	x	x	x	x
4. Moderately Acid Soils Ec.[1]									
Pasture Agronomy		-	-	o	o	o	x	x	x
5. AFRICA (ILCA-LIAISON)									
Regional Cooperation		-	-	o	x	x	x	x	x
6. SOUTH EAST ASIA									
Regional Cooperation		-	-	-	o	o	o	x	x
TOTAL OUTPOSTED									
Minimum		3	2	4	6	6	7	8	8
Optimum		5	5	7	9	9	9	9	9
TOTAL CORE	1982								
Optimum	na	na	20	22	25	25	25	25	23
Minimum	20	16	17	19	21	20	20	20	19
Long-Term Plan	21	21	21	22	23	23	23	23	23
Core Net Requirement	20	16	17	19	21	20	20	20	19

x. = on leave, appointed by EMBRAPA in CPATU, Belem, Brazil

1/ Based in Central America

Table 26. Actual and Projected Bilateral Staff Positions

POSITIONS	1983	1984	1985	1986	1987	1988	1989	1990
CERRADOS ECOSYSTEMS								
Soil/Pasture Dev.Bras.(CPAC)	1	1	1	-	-	-	-	-
HUMID TROPICS								
Entomology Belem (CPATU)	-	1	1	-	-	-	-	-
Pasture Agronomist, Panama (IDIAP/RUTGERS-AID)	1	1	1	-	-	-	-	-
Pasture Agronomy (Belice/RUTGERS-Winrock-AID)	-	-	1	1	1	1	-	-
*Pastures/farming systems	-	-	1	1	1	1	1	1
*Economist	-	-	1	1	1	1	1	1
CENTRAL AMERICA AND CARIBBEAN								
**Cattle Production Systems	-	-	-	1	1	1	1	1
**Silvopastoralist	-	-	-	-	1	1	1	1
TOTAL BILATERAL POSITIONS	2	3	6	4	5	5	4	-

* Joint Project with ICRAF
** Joint Project with CATIE

Table 27. Projected Special Projects Staff Positions

POSITIONS	1983	1984	1985	1986	1987	1988	1989	1990
CERRADOS ECOSYSTEMS								
Soil/pasture development	-	-	-	1	1	1	1	1
SOUTHEAST ASIA								
Regional Cooperation	-	-	-	1	1	1	-	-
Pastures/Farming Systems	-	-	-	-	-	1	1	1
TOTAL SPECIAL PROJECTS				2	2	3	2	2

CHAPTER III

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The program has accumulated experience and germplasm for tropical savannas and forest ecosystems with annual precipitation above 1200 mm that could be transferred to similar conditions in other continents. National and international institutions in Africa and Southeast Asia are increasingly requesting CIAT pasture germplasm, which they consider suitable for humid and sub-humid environments in those continents.

On the other hand, many of the grass and legume species with excellent potential in the savanna and forest ecosystems in Latin America have their center of diversity in Africa and Asia. Thus, collaboration in collection and transfer of germplasm with institutions in these regions is highly appropriate.

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Coordinator		x	x	x	x	x	x	x	x
Germplasm		x	x	x	x	x	x	x	x
Plant Breeding		x	x	x	x	x	x	x	x
Legume Breeding		-	-	-	o	o	o	o	o
Agronomy (Carimagua)		x	x	x	x	o	o	o	-
Agronomy (RIEPT)		x	x	x	x	x	x	x	x
Entomology		x	x.	x.	x	x	o	o	o
Pathology		x	x	x	x	x	x	x	-
Soil Plant Nutrition		x	x	x	x	x	x	x	x
Soil Microbiology		x	x	x	x	x	x	x	x
Pasture development		x	x	x	x	x	x	o	o
Pasture Ecophysiology		x	x	x	x	x	x	x	x
Pasture Quality & Product.		x	x	x	x	x	x	x	x
Cattle Production Systems		x	x	x	x	x	x	x	x
Seed Production		x	x	x	x	x	x	x	x
Economics		x	x	x	x	x	x	x	x
TOTAL									
Minimum Program Projections		17	15	15	15	14	13	12	12
Optimum Program Projections		17	15	15	16	16	16	16	15
B. OUTPOSTED-Research and Regional Cooperation									
1. CERRADOS ECOSYSTEM									
Agronomist/Reg. liaison		x	x	x	x	x	x	x	x
Pathology		-	o	o	x	x	x	x	x
Production Systems (CNPGC)		-	-	-	o	o	o	o	o
2. HUMID TROPICS ECOSYSTEM									
Pasture Agronomy		-	x	x	x	x	x	x	x
Pasture reclamation		-	o	x	x	x	x	x	x
3. CENTRAL AMERICA AND CARIBBEAN									
Regional Coop. (RIEPT)		-	o	x	x	x	x	x	x
4. Moderately Acid Soils Ec.[1]									
Pasture Agronomy		-	-	o	o	o	x	x	x
5. AFRICA (ILCA-LIAISON)									
Regional Cooperation		-	-	o	x	x	x	x	x
6. SOUTH EAST ASIA									
Regional Cooperation		-	-	-	o	o	o	x	x
TOTAL OUTPOSTED									
Minimum		3	2	4	6	6	7	8	8
Optimum		5	5	7	9	9	9	9	9
TOTAL CORE	1982								
Optimum	na	na	20	22	25	25	25	25	23
Minimum	20	16	17	19	21	20	20	20	19
Long-Term Plan	21	21	21	22	23	23	23	23	23
Core Net Requirement	20	16	17	19	21	20	20	20	19

x. = on leave, appointed by EMBRAPA in CPATU, Belem, Brazil

1/ Based in Central America

Table 26. Actual and Projected Bilateral Staff Positions

POSITIONS	1983	1984	1985	1986	1987	1988	1989	1990
CERRADOS ECOSYSTEMS								
Soil/Pasture Dev.Bras.(CPAC)	1	1	1	-	-	-	-	-
HUMID TROPICS								
Entomology Belem (CPATU)	-	1	1	-	-	-	-	-
Pasture Agronomist, Panama (IDIAP/RUTGERS-AID)	1	1	1	-	-	-	-	-
Pasture Agronomy (Belice/RUTGERS-Winrock-AID)	-	-	1	1	1	1	-	-
*Pastures/farming systems	-	-	1	1	1	1	1	1
*Economist	-	-	1	1	1	1	1	1
CENTRAL AMERICA AND CARIBBEAN								
**Cattle Production Systems	-	-	-	1	1	1	1	1
**Silvopastoralist	-	-	-	-	1	1	1	1
TOTAL BILATERAL POSITIONS	2	3	6	4	5	5	4	-

* Joint Project with ICRAF
** Joint Project with CATIE

Table 27. Projected Special Projects Staff Positions

POSITIONS	1983	1984	1985	1986	1987	1988	1989	1990
CERRADOS ECOSYSTEMS								
Soil/pasture development	-	-	-	1	1	1	1	1
SOUTHEAST ASIA								
Regional Cooperation	-	-	-	1	1	1	-	-
Pastures/Farming Systems	-	-	-	-	-	1	1	1
TOTAL SPECIAL PROJECTS				2	2	3	2	2