FAO Commission of Plant Genetic Resources

EFFECTIVE UTILIZATION OF TROPICAL PASTURE GERMPLASM

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1. Introduction

Ruminant production in tropical regions of the world, especially in tropical America, is based on the utilization of available native grasslands where extensive ranching systems have developed. This is the case of the Cerrados of Brazil, the Llanos of Colombia and Venezuela, the Beni savannas of Bolivia as well as the nomadic herding in the sub-humid belts of Africa. These animal production systems are generally in balance with the available feed resources; however, their productivity is very low due to soil and climatic constraints for plant growth.

The movement of African grasses into tropical America has been a major determinant of cattle expansion in this region in the past. The grasses Hyparrhenia rufa and Panicum maximum were introduced accidentally through slave trading in the late 17th and early 18th centuries. Similarly, Melinis minutiflora and Brachiaria mutica were also accidentally introduced in the 18th century (Parsons, 1972). These grasses rapidly spread throughout the region becoming naturalized in specific environments, for example B. mutica in the more humid flooded areas; M.

minutiflora in the humid and subhumid regions with marked temperature fluctuations; H. rufa in sub-humid to semi-arid environments with acid, medium fertility soils as in some areas of the Cerrados and Central America; while P. maximum became naturalized in the more humid environments with fertile soils. However, large areas of the tropical American savannas as well as degraded lands in the humid tropics remained with native species of low productivity where the above mentioned African grasses were unable to naturalize themselves.

Originally, cattle production was based on prime fertile land where settlers developed crop and animal production systems. As population grew, crop production expanded increasing the competition for land with cattle production. Today, tropical America has more than 200 million head of cattle (about 17% of the total world herd) and development is strongly pushing cattle production to the poorer marginal and frontier lands (Toledo & Nores, 1986).

The land endowment of tropical America is large in relation to population. However, the predominant very acid, low fertility Oxisols and Ultisols are a major limiting factor to expansion of forage production. Native grasslands will not support increased cattle numbers per unit area due to their low quality and productivity. For the effective expansion of cattle production in these marginal and frontier lands, the need for the development of adapted and productive high quality grasses and legumes into pasture and forage production systems was recognized.

To fulfill this need for the heterogeneous complex of ecosystems and cattle production systems that exist in this region, a broad genetic germplasm base is essential to screen for the multiple roles which germplasm must play. Such a base is being established through extensive collecting of grasses and legumes in tropical Africa, America and Southeast Asia by CIAT's Tropical Pastures Program (TPP) as well as in collaboration with other international (IBPGR, FAO, ILCA, etc.) and national (CSIRO, ORSTOM, EMBRAPA, MARDI, etc.) research organizations (Schultze-Kraft, 1985). A considerable amount of germplasm is also assembled through exchange among institutions.

2. Important tropical pasture genera and their origins

The three major centers of origin and diversity of tropical pasture species are Africa, tropical America and Southeast Asia. Africa is recognized as the major source of valuable pasture grasses such as Andropogon gayanus, Brachiaria spp., Hyparrhenia spp., Panicum spp., and others. Tropical America is the center of origin of some grasses such as Axonopus spp. and Paspalum spp., however, it is known more as the major source of tropical pasture legume genera including Aeschynomene, Centrosema, Desmodium, Leucaena, Macroptilium, Stylosanthes, Zornia, and while Southeast Asia is recognized as the source of legumes such as Pueraria and some important species of Desmodium and related genera (Williams, 1983; Clayton, 1983).

3. Size of germplasm collection

From 1976 to 1985, CIAT's tropical pasture grass and legume germplasm collection increased ten-fold from 1600 to 16,000 entries (Figure 1). The growth in legume germplasm was more or less steady over the period however, the rate of growth of grass germplasm increased during 1983 to 1985 mostly due to intensive collection of Brachiaria spp. in East Africa and by the introduction of a Panicum maximum collection from ORSTOM. As of October 1985, this collection included 3100 accessions of Stylosanthes spp., 1900 accessions of Desmodium spp., 1500 accessions of Centrosema spp., 900 accessions of Zornia spp., 750 accessions of Aeschynomene spp. and 120 accessions of Pueraria spp. as well as 900 accessions of Brachiaria spp., 720 of P. maximum and 100 of Andropogon gayanus (CIAT, 1985; Schultze-Kraft, 1985). CIAT's tropical pasture germplasm collection has been developed through specific collection efforts as well as by exchange. Up till 1983, 36% of the collection had been obtained by exchange with other institutions. The proportion of the collection obtained through collaborative expeditions between CIAT and other institutions was 43% of the total collection, the remaining 22% corresponding to core-funded independent germplasm collections directly by CIAT scientists.

The CIAT collection is an active working collection assembled to serve as a base for selection of germplasm for the acid poor soils in sub-humid and humid environments. Consequently, its origin is largely from such environments (Schultze-Kraft and Giacometti, 1979; Schultze-Kraft, 1985). However, for some species, material collected on contrasting

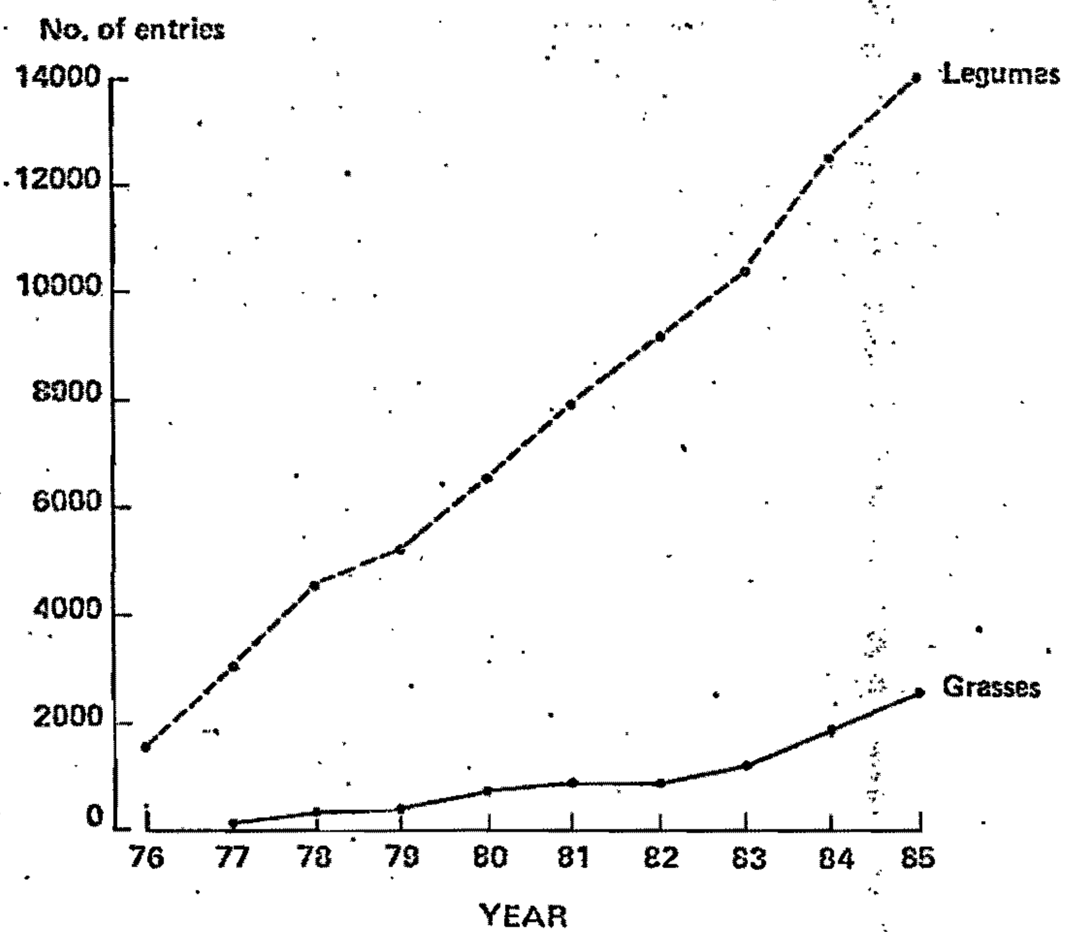

Fig. 1. Increase of CIAT's Tropical Pasture grass and legume germplasm from 1976 to 1985.

medium to high fertility soils with almost neutral pH levels, is exhibiting outstanding adaptation to very acid, low fertility Oxisols and Ultisols. This is, for example, the case of Centrosema macrocarpum (Schultze-Kraft et al., 1985).

4. Proportion of the collection actively evaluated

At the end of 1985, CIAT's TPP germplasm collection numbered approximately 16100 entries (Table 1). At this stage, all accessions obtained in 1985 are still in the process of post quarantine health control and initial seed multiplication. Of the total germplasm collection at the end of 1984, 63.7% were key genera specifically collected for acid poor soils (Table 1).

The 9020 accessions of key genera for acid, low-fertility soils include Andropogon gayanus, Axonopus spp., Brachiaria spp., Hemarthria, Hyparrhenia spp., Melinis spp., Panicum spp. and Paspalum spp., among grasses (15.7%), as well as the legumes (84.3%) Aeschynomene spp., Arachis spp., Calopogonium spp., Centrosema spp., Desmodium spp., Pueraria spp., Stylosanthes spp., and Zornia spp.

In the multilocation evaluation and selection activities of CIAT's TPP, a large proportion of the collection has been actively and selectively screened for its adaptation to major ecosystems (Table 1). From 1976 to 1985, 47.7% of the acid soil germplasm was evaluated and screened at the Carimagua Station for the Llanos ecosystem; from 1978 to 1985, 17.7% was evaluated and screened at CPAC for the Cerrados ecosystem; while the initial exposure of acid soil germplasm to the humid tropics ecosystem at the Pucallpa site began in 1985 with the planting of 8.9% of the collection (Table 1).

Table 1. Utilization of CIAT Tropical Pastures Germplasm Collection

Breakdown of Collection		No.	%
Total germplasm collection to 1985		16091	
Germplasm presently under post quarantine health control and initial seed multiplication		1931	12.0
Total germplasm collection to 1984		14160	88.0
Germplasm of key genera for acid poor soils collected up to 1984		9020	63.7*
Germplasm of key grass genera		1418	15.7**
Germplasm of key legume genera		7602	84.3**
Multilocational screening by major ecosystems			
Llanos-Carimagua	1976-1985	4300	47.7**
Cerrados-Brasilia	1978-1985	1600	17.7**
Humid Tropics-Pucallpa	1985-	800	8.9**

* % of total germplasm collected to 1984.

** % of germplasm of key genera for acid poor soils.

The most promising germplasm selected for its adaptation and potential as pasture plants at major screening sites has passed to the International Tropical Pasture Evaluation Network (RIEPT) where presently about 400 entries are in the hands of scientists from national pasture research programs for final selection and technology adjustment for specific sub-ecosystems and farming systems.

5. Constraints for collecting and moving germplasm

Basically, two kinds of collecting operations are carried out by the Tropical Pastures Program. Firstly, as much variation as possible is sought in particular species to solve well-defined problems. For example: specific collecting expeditions were made in East Africa to collect grass germplasm, especially *Brachiaria* spp., to obtain as much variability as possible in the search for resistance to the major pest spittlebug (Calderón, 1983). Similarly, both *Desmodium ovalifolium* and *Pueraria phaseoloides* were specifically collected in Southeast Asia; the former because of the need for resistance to two important diseases stem gall nematode and Synchytrium false-rust and the latter because of the need for *P. phaseoloides* adapted to dryer and less fertile environments (Pattanavibul and Schultze-Kraft, 1985). In all cases, a considerable range of variation was collected. Secondly, in specific areas rich in legumes and grasses, and of high risk with respect to genetic erosion, as much germplasm as possible, especially of key species, is collected to preserve potentially valuable germplasm.

Collecting and processing of tropical pasture germplasm is a specialized and costly operation that is not expected to be carried out by many pasture research programs. In fact, active forage collection activities are only conducted by a few institutions. International collecting expeditions have been and/or are carried out by CIAT from Colombia, ILCA from Ethiopia, CSIRO and QDPI from Australia, FAO from Kenya, ORSTOM from Ivory Coast, University of Florida, USA, and IBPGR from Italy. These expeditions are mostly conducted as joint efforts in collaboration with the respective national institution. Only in few cases national research organizations have carried out major and systematic collection expeditions, such as EMBRAPA and EPAMIG in Brazil.

The main constraints are firstly, the limited number of experts in forage grass and legume collecting due to the fact that expertise in this field is largely developed by experience and no formal training is available. Secondly, the size of the target area to be collected in the three continents, especially considering the wide range of species involved and the wide geographical distributions of many of these, is a major constraint. This implies that time and financing requirements are high. In terms of CIAT's TPP most of the funding has come from core budget however important IBPGR contributions have enhanced our capacity for collecting in Southeast Asia.

Other constraints encountered in the collection of germplasm are related to political matters. These include the difficulty of obtaining permission to collect in some countries due to non-technical reasons. This problem should be recognized by international forums so that presently unutilized resources could be used for the benefit of mankind and preserved from possible genetic erosion due to population growth and development.

International and national regulations regarding the movement of tropical pasture germplasm among countries have to be complied with. However, we are experiencing a wide range of international country control levels ranging from no regulations whatsoever to extremely inflexible controls that delay the efficient movement of experimental germplasm. Often, those countries with the most strict quarantine regulations for experimental seeds are relaxed concerning the introduction of large shipments of commercial seed of tropical pasture cultivars. The importance of preventing the movement of pests and diseases between countries should be recognized and specific procedures are being developed for the species for which problems have been defined. This has been done for several legumes species (Salas and Lenné, 1985; Torres and Lenné, 1985). However, with potentially valuable new forage species largely unknown pathologically, careful quarantine procedures are being followed after collection either in the country of collection or by the receiving country to reduce to a minimum the risk of introducing seed-borne pathogens.

6. Storage and rejuvenation

The CIAT tropical pastures germplasm collection is stored under medium-term conditions in CIAT's Genetic Resources Unit (5–8°C and 60% relative humidity). Two years ago, a systematic seed rejuvenation program with the objective of obtaining sufficient seed for long term storage was initiated. As a first result, recently approximately 1400 accessions representing 8 major legume genera have been placed into long term storage in laminated foil bags at -15°C to -20°C (Table 2). Improvement of the medium- and long-term storage facilities of CIAT's Genetic Resources Unit is in progress, financed by the Italian government. When completed, dehumidified conditions will be available for medium-term storage while the increased capacity for long-term storage to 110,000 samples will completely satisfy present and near-future needs.

It is expected that movement of the whole of the collection from medium- to long-term storage will be completed within the next 5-10 years. This however will take considerable resources on rejuvenating and multiplying of accessions. Additional funds are needed to accelerate the movement of the collection to long-term storage. Emphasis is being given to key species of such legumes as *Stylosanthes*, *Centrosema*, *Desmodium*, *Zornia*, *Pueraria*, *Aeschynomene* and to grasses such as *Andropogon gayanus*, *Brachiaria* spp. and *Panicum* spp. However, the oldest accessions of other species are also receiving particular attention.

With relation to germplasm conservation, considerable research needs still to be done to determine optimum storage conditions in relation to seed longevity, particularly for grass germplasm.

The CIAT collection is as yet not duplicated and stored elsewhere. This is a risk due to the possibility of natural disasters. Negotiations are

Table 2. Pasture germplasm in long-term storage (October, 1985)

Genera	No. of Accessions
Stylosanthes guianensis	540
Stylosanthes hamata	60
Macroptilium spp.	141
Vigna spp.	81
Aeschynomene spp.	243
Leucaena spp.	75
Crotalaria spp.	134
Pueraria spp.	41
Desmodium ovalifolium	81
	1,396

Storage conditions: 13.9 m^3
Temperature: -15° to -20°C
Packed: In laminated foil bags

in progress in the search for a duplicate site for long-term storage and the possibilities include CATIE in Costa Rica, EMBRAPA-CENARGEN in Brazil and CSIRO in Australia. However, a significant proportion of the promising key species of the collection is already duplicated under medium-term storage in CENARGEN, Brazil. In addition, the most promising accessions of several key grasses and legumes are in the hands of national pasture research programs throughout Latin America as living collections within the scheme of the International Tropical Pasture Evaluation Network, RIEPT.

7. Availability of Tropical Pasture Germplasm to Publicly Funded Research and Development Agencies

Accessions with promise as pasture plants are available for distribution to publicly funded organizations. About 30 seeds per accession are provided free of charge. CIAT reserves the right to decide on the suitability of the materials requested in relation to the environmental conditions in the region for which the material is intended. This reservation is not placed in order to restrict the free movement of germplasm but is necessary in order to conserve precious seed supplies of particular materials.

In cases where requests for large numbers of accessions are received it may be necessary to charge a service fee. This is decided on a case-by-case basis taking account of the species in question and the problems associated with seed production.

Highly promising materials in larger quantities for the establishment of agronomic trials are also being made available to collaborating institutions throughout tropical America within the RIEPT. This is a cooperating mechanism to evaluate new germplasm multilocationally that will be further discussed later.

8. Relationship between the Tropical Pastures Program (TPP) and the Genetic Resources Unit (GRU) at CIAT in the movement of germplasm

Pasture germplasm enters the TPP through direct collection or exchange, as mentioned previously (Figure 2). After passing through Colombian phytosanitary regulations, all germplasm entering as seed passes through postquarantine health control (inspection by plant pathologists and entomologists) in the glasshouse. Germplasm then goes to initial multiplication at the field station at Quilichao. This has the advantage of also allowing some initial characterization especially of morphological and forage characters and seed production potential, most important for new unknown germplasm. This is the responsibility of the TPP. In some cases, meristem culture techniques have been used to introduce germplasm from other countries, for example, in the case of a large collection of Brachiaria spp. from Kenya, Zimbabwe, Ethiopia, Burundi, Rwanda and Tanzania. This was done firstly because of some problems of obtaining seed from these plants and to reduce to a minimum introduction of pests and diseases from East Africa. Meristem cultures were then grown into mature plants from which seed was collected for initial germplasm evaluation and seed multiplication after phytosanitary inspection. This was achieved by TPP in collaboration with the GRU and CIAT's Biotechnology Unit.

Part of the seed resulting from initial multiplication, goes to the GRU for conservation, maintenance and distribution as was described previously; the rest goes to TPP and to RIEPT for agronomic characterization, evaluation of adaptation to climatic and edaphic conditions and of resistance to pests and diseases.

The responsibility for seed health testing is also shared by the Plant Pathology Section of TPP and the Seed Health Testing Laboratory of the GRU. Prior to the 1970's, almost no work had been done on seed-borne pathogens of tropical pasture germplasm world-wide. Because of this, the Plant Pathology Section of TPP has taken this important research responsibility. Once seed-borne pathogens of tropical pasture germplasm have been identified and characterized and the appropriate seed detection methods developed, the Seed Health Testing Laboratory of the GRU assumes the responsibility for testing suspect seed. According to the results, recommendations for seed treatment based on the origin and destination of the material are then made by TPP.

Further research is needed on seed-borne pathogens of these largely unknown plants. Financial assistance and expertise from specialized seed pathology institutions such as the Danish Seed Pathology Institute would be of value to the efficient movement of some germplasm.

As previously mentioned, the GRU has the important responsibility of maintaining the collection including rejuvenation, storage, distribution and part of the documentation process.

9. The role of breeding

Unlike crops, tropical pastures and forages are not confined to one species, one genus or even one family. Also unlike crops, perennial pastures are generally not managed to maximize the genetic potential of the plant but rather to utilize the naturally available diversity of resources such as soil, and climatic conditions in stable long-term production systems. Especially in the low-input systems predominant in the marginal and frontier lands, close adaptation of species as well as ecotypes within species to the diversity of environments is needed. There exists a tremendous amount of natural variability in these legumes and grasses that is just beginning to be collected, evaluated and recognized. In this situation, it is obvious that the first step in searching for superior germplasm is the intensive evaluation of natural variability under different environments. Once the promising species are identified and characterized for specific environments, breeding may be considered as a strategy when a sufficiently large amount of natural variability has been explored; when specific problems have been well-identified and parental material selected.

The CIAT Tropical Pastures Program germplasm evaluation methodology is based on the multilocational evaluation of naturally occurring variability of materials collected in the wild. In the specific case of Stylosanthes guianensis, over 1000 accessions were intensively evaluated in the savanna ecosystems of tropical America from 1974 to 1980 (Lenné, 1985). Not one accession was found with the combination of traits desired. Some promising accessions with high forage production and quality as well as high seed production were susceptible to anthracnose, the most serious disease of this genus. At the same time, highly resistant accessions with low seed production and lower forage quality and production were identified. A multi-faceted breeding program was therefore initiated to combine the desired traits using pedigree advance, bulk selection and natural selection under grazing (Cameron et al., 1984; J.W. Miles, personal communication). Selected promising hybrids are now being screened in several savanna sites.

10. Strategies of the Tropical Pastures Program in relation to efficient evaluation and utilization of germplasm

The main strategy of the TPP is to develop a broad germplasm base and to systematically screen it to select materials adapted to the diversity of ecosystems of tropical America (Toledo, 1985). The program has already established three major screening sites and will establish a fourth in 1987 in cooperation with National Research Programs. These are the Carimagua Research Station in cooperation with ICA in Colombia, representing the Llanos or isohyperthermic savanna ecosystem (Cochrane et al., 1985); the Centro de Pesquisa Agropecuaria dos Cerrados (CPAC) near Brasilia in cooperation with EMBRAPA, representing the Cerrados or isothermic savanna ecosystem; and the humid tropics site in cooperation with INIPA and IVITA at Pucallpa, Peru. In 1987, a fourth major screening site will be established in Costa Rica, in Central America and the Caribbean, representing the moderately acid soils in cooperation with CATIE and IICA. These major screening sites constitute the base of germplasm development. Here, germplasm experts, agronomists, plant pathologists, entomologists and breeders work collaboratively in efficient agronomic characterization, evaluation and selection of germplasm (natural and bred) for adaptation to soil and climatic factors and resistance/tolerance to prevailing pests and diseases (Figure 2).

Selected germplasm passes into the pasture development phase where a low-input philosophy is emphasized in the development of technologies based on adapted germplasm that will make efficient use of naturally available resources and limited purchased inputs (Toledo, 1985). In this phase, grasses and legumes are evaluated in associations with the development of low-cost pasture establishment methods; pastures associating grasses with N-fixing legumes and optimization of nutrient cycling through appropriate fertilizer use and grazing management (Figure 2). The plant nutritionist, soil microbiologists, animal production scientist, ecophysiologist and pasture establishment specialist collaborate directly with each other and other program scientists to develop promising adapted germplasm into adapted productive pastures as efficiently as possible.

On-farm research and economic evaluation of pastures in production systems give the opportunity for feed back from farmers including their management and utilization preferences which is most important to the recognition of their needs and to understanding problems which might hinder adoption (Toledo, 1985). The economist and farming systems specialist interact closely to ensure the efficient movement of productive pasture germplasm into farming systems. This farming systems perspective is an essential approach and strategy for the program in order to reliably and effectively deal with the complexities of ecosystem/farming system conditions where the adaptation and different role of pastures will require different sets of germplasm and management. Although the man-power resources in this group are limited, close collaboration with National Research Programs not only in on-farm trials and adoption surveys but also in methodological research is collaboratively developing simple reliable techniques for assessment of the potential role and evaluation of new pasture technology at farm level.

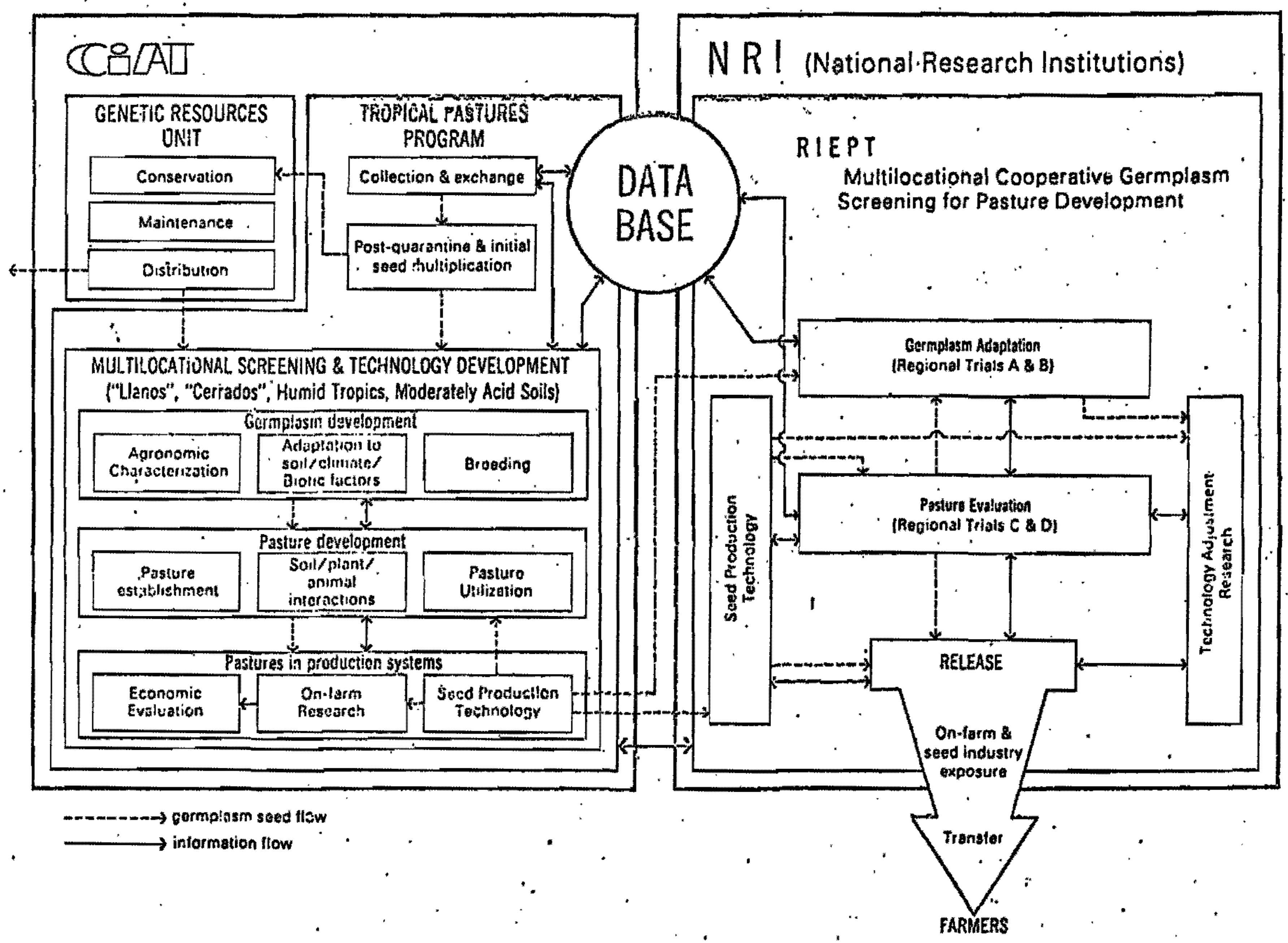

Figure 2. Pasture germplasm flow in the evaluation process in tropical america

A major constraint to the efficient flow of germplasm through a perennial pasture evaluation process can be inadequate seed production to service the scientists working at various levels in the program, i.e., on-farm research, and, especially in the case of CIAT's Tropical Pasture Program, collaborative work with National Research Programs through the RIEPT. This is magnified by the fact that many tropical perennial pasture species produce only one crop a year and, in many cases, the seed production potential and appropriate conditions required of new experimental germplasm are unknown. At the same time, the range of ecosystem/farming system complexes means that at any one time a wide range of legumes and grasses often with quite different seed production requirements are under production. This implies working at a number of different sites to satisfy these requirements. The seed production specialist who collaborates closely with the economist and production systems specialist in the Pastures in Production Systems phase to fulfill both the research role as well as the basic seed production role to move germplasm efficiently.

A multilocational and decentralized approach is essential to moving germplasm as efficiently as possible from the major screening sites in each ecosystem into the wide variety of environmental and farming system conditions in the marginal and frontier lands of tropical America (Toledo, 1985).

RIEPT, the International Tropical Pasture Program Evaluation Network, was created by National Research Programs and CIAT's Tropical Pastures Program after recognition of the need for <u>in situ</u> pasture development

(Toledo, 1982). National pasture research programs, large and small, are joined together and geared towards efficient germplasm evaluation and flow and development of new pasture technology based on adapted germplasm.

RIEPT efficiently screens large numbers of experimental germplasm through a sequence of regional trials (RT) A, B, C and D at over 170 sites covering the acid low-fertility lowland region of tropical America (Figure 3). As only those materials which have passed through initial screening at CIAT's major screening sites in the specific ecosystems pass to the RIEPT, germplasm with little value as pasture plants is eliminated from wide-scale evaluation. This improves the efficiency of the process. Selections from RIEPT RT-A (evaluation of adaptation and survival of 80-150 entries) and RT-B (seasonal assessment of productivity of 20-30 entries) are passed by National Research Programs into small plot pasture management trials under grazing (RT-C) and finally to large plot pasture productivity and persistence trials under grazing (RT-D) prior to release by the national program to on-farm and seed industry exposure (Figure 2).

Seed production technology and pasture technology adjustment research is carried out collaboratively between National Research Programs and CIAT's Tropical Pasture Program during the advancement of <u>in situ</u> selected germplasm through the different stages of evaluation (FigurFigure 2). This ensures that released germplasm has the back-up of solid pasture technology for its use by farmers and helps in the efficient movement of germplasm. This is particularly important in the case of seed production. With the growth of RIEPT and the advancement

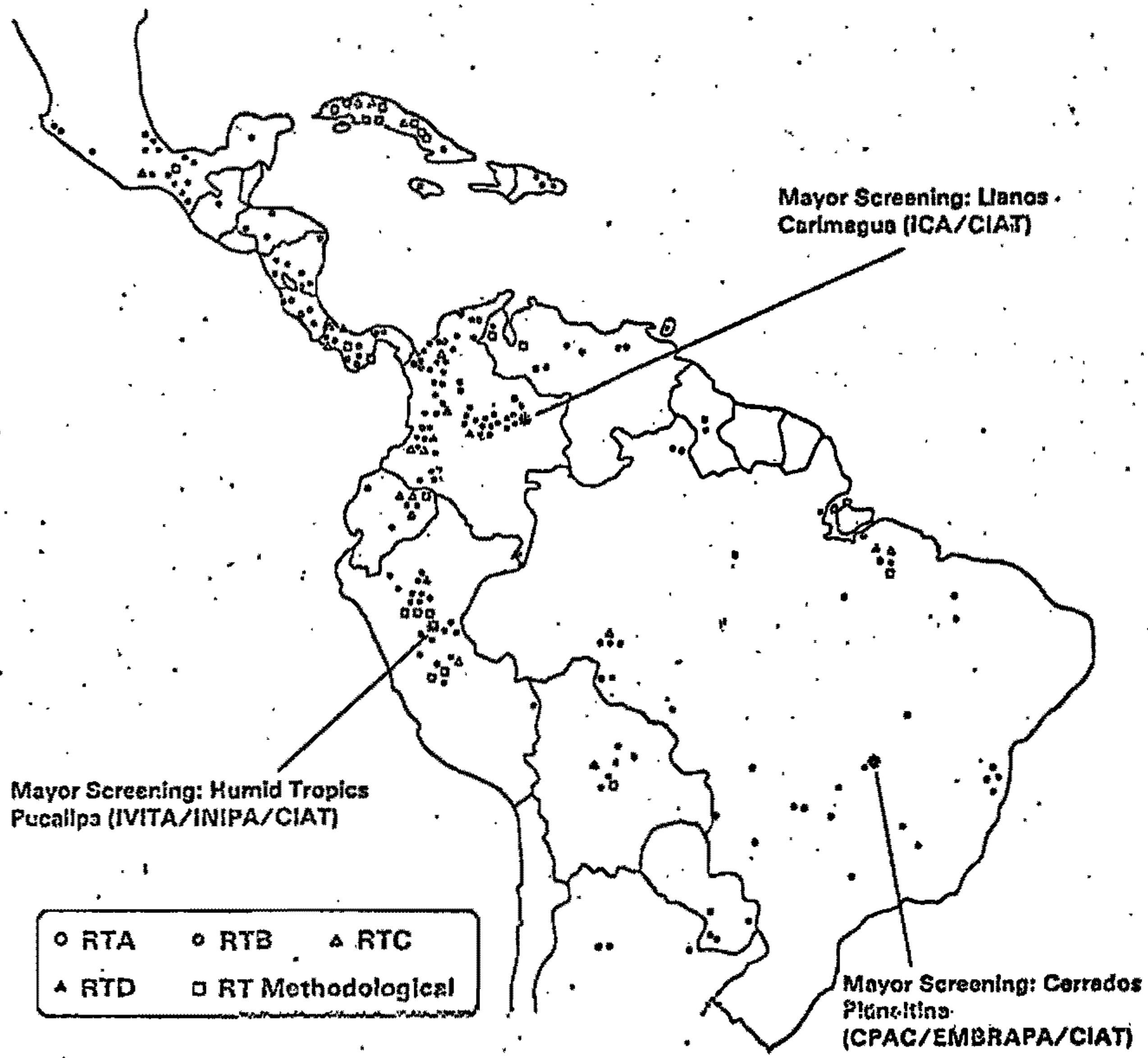

Figure 3. Sites (1978-85) of the International Tropical Pastures Program Evaluation Network (RIEPT) and Mayor Screening Sites*.
(CIAT/TPP 1985 Annual report)

materials to grazing trials and eventual releases, there is increasing pressure to develop pasture seed production projects to produce promising experimental and basic seed to prevent bottlenecks to the efficient germplasm flow to release and farmer adoption.

Through this network, important economies of scale are being achieved and National Research Programs are not only rapidly advancing promising germplasm into pastures, but are also exchanging methodologies for local adjustment of technology especially with respect to management to better suit the environmental and farming systems conditions encountered in areas of immediate influence.

The organization of workshops, training courses and the opportunity to exchange experiences through the CIAT bulletin "Pasturas Tropicales", an excellent communication mechanism ensures continuous interaction among members of this network and fosters more efficient germplasm utilization.

Information flows freely in both directions from both parts of the evaluation process (TPP and RIEPT). In addition, all data coming from evaluations made directly by RIEPT and CIAT's TPP are linked in a common data base. The data base is important to TPP in storing all information from germplasm evaluation and development trials at major screening sites in each ecosystem, that is, detailed characterization of germplasm from collection site data, adaptation to specific soil and climatic conditions, agronomic characters, reaction to pests and diseases, soil-associated plant - animal interactions, seed production potential, etc.

At the same time, the development of the RIEPT data base and the methodologies for statistical processing of large numbers of data and information coming from national programs in close collaboration with the CIAT Data Service Unit has been instrumental and essential to the cross-locational analysis and documentation of the performance and thus secure advance of germplasm throughout the network.

As a result of this collaborative continental effort on multilocational evaluation, screening, selection, technology development and transfer, new cultivars of grasses and legumes have been released by national research programs in tropical America. In 1980, *Andropogon gayanus* CIAT 621 was released by ICA in Colombia and EMBRAPA in Brazil; and also released in 1982 and 1983 in Venezuela, Panama and Peru. It is estimated that at present more than 200,000 ha have been planted to this grass in tropical America (Ferguson *et al.*, 1985), especially for its tolerance to poor acid soils, drought and the major pest spittlebug.

In 1983, the first legume *Stylosanthes capitata* was released by ICA in Colombia and named Capica (CIAT 10280). This is a blend of five accessions selected for its resistance to anthracnose, the major problem for *Stylosanthes* spp. in tropical America and its excellent performance under grazing increasing animal productivity in association with *A. gayanus* in the isohyperthermic savannas.

Similarly in 1985, IVITA, Pucallpa, Peru released *Stylosanthes guianensis* CIAT 184 as cv. Pucallpa for its resistance to anthracnose in the humid tropics ecosystem and its good performance under grazing in association with _Hyparrhenia_ _rufa_, _A._ _gayanus_ and native grasses. Several promising grasses and legumes are presently at the pre-release stage and being exposed to farmers. Among these are _Centrosema_ _brasilianum_ CIAT 5234, _C._ sp. nov. CIAT 5277, _Arachis_ _pintoi_ CIAT 17434 and the grass _Brachiaria_ _dictyoneura_ CIAT 6133.

11. Cost of maintenance, processing and utilization

The collection and exchange activities of germplasm in the Tropical Pastures Program constitute a skillful and expensive operation which has an estimated cost ranging from $60-100 per gram of seed. This is due to the large expenditure on international travel and the need to cover three continents as well as the post collection handling (post quarantine health control). After initial seed multiplication, the cost per gram of seed is reduced to about $6-8.

The process of storage, maintenance and distribution adds further to the cost of germplasm seed. Through a rough approximation it is estimated that five years of storage including one cycle of rejuvenation may cost between $5 and $15/gram. Consequently, the total cost of one gram of seed for distribution to other institutions is estimated at $10-25/gram (for example approximately 500 seeds/gram for small seeded legumes such as _Stylosanthes_ and approximately 20 seeds/gram for larger seeded legumes such as _Centrosema_ _macrocarpum_).

Once the first selections are made, the subsequent evaluation procedures are handling larger seed volumes of fewer materials. Consequently, although the investment in screening and technology development is large

(Figure 2), the cost of seed of selected materials to be distributed to national research programs is reduced by large plot experimental seed multiplication. It is estimated that one gram of seed distributed to national programs costs between $10 to 12 for agronomic evaluation trials in small plots. If this selected distributed material has undergone manipulation in a breeding program, the estimated cost per gram is increased to $15 to 18. These figures reflect the total costs including 60% of the total annual budget of CIAT's TPP and about 20% of the Genetic Resources Unit budget. This germplasm in different stages of evaluation is freely distributed as experimental material to National Research Programs especially within the RIEPT.

Due to lack of adequate germplasm documentation (passport data) during exchange activities between institutions, collections consisting of non-original material very often include a considerable quantity of genetic duplicates. This problem is well-recognized as a factor increasing the cost of storage and handling of germplasm as well as affecting the efficiency of evaluation. Attention is called to the need to solve this problem (1) through appropriate passport data recording and transmitting, and (2) through the development of biochemical "finger point" techniques such as electrophoretic analysis of proteins and isozymes.

12. Future collecting strategies

Plans for future germplasm collections are characterized by two strategies: 1. To continue broadening the genetic base of those species which on the basis of multilocational evaluation are recognized as key species for a given ecosystem, with the aim to eventually select superior ecotypes for direct use or plant breeding. 2. To continue conducting exploratory collecting missions by sampling in as yet overlooked or neglected regions, with the aim to (a) preserve germplasm from genetic erosion, and (b) to extend the available species and ecotype range in the collection for future identification of key species.

Both types of collecting missions are expected to be conducted in tropical America as well as in Africa and Southeast Asia. It should be pointed out that such expeditions are planned and carried out in efficient response to research developments. Therefore, rather than complying with a rigid time and geographic frame work, they represent a flexible dynamic approach to solve problems and to overcome limitations encountered in germplasm evaluation. It also should be pointed out that the identification of problems and limitations in germplasm evaluation is a very dynamic, continuous process due to the nature of the plant material involved: contrary to traditional crops, tropical pasture plants are exclusively wild, undomesticated species which are almost not researched at all.

The diversity of environments and farming systems in the tropical American lowlands has required the development of a broad germplasm base. CIAT's TPP has now accumulated a wealth of variability of grasses and mostly herbaceous legumes adapted to acid (pH 3.5-5.0), low fertility soils which constitute a solid base for pasture technology development for extensive and semi-extensive farming systems in the frontier lands of tropical America. Although this germplasm base will provide valuable pasture materials for the more-intensive farming systems on moderately acid soils that occur in marginal lands in more populated areas as in Central America, it is recognized that new germplasm options, such as fodder species for cut and carry systems including leguminous shrubs and trees, will be needed. The expansion of the RIEPT and CIAT's TPP research activities into these marginal lands is demanding a widening of the genetic base to include more germplasm of grasses such as *Pennisetum* and *Tripsacum* for cut and carry and *Hyparrhenia* spp. for the dryer sub-humid conditions in Central America; and of legumes including *Acacia*, *Calliandra*, *Dendrolobium*, *Erythrina*, *Flemingia*, *Gliricidia* spp.. In order to facilitate continued cooperation with other institutions and to avoid duplication of efforts, the planned collection trips will be coordinated through IBPGR. Furthermore, it is intended to continue efficient use of already existing collections by selective germplasm introductions from other institutions by exchange.

13. Concluding remarks

During the last ten years, considerable efforts have resulted in the development of a broad valuable germplasm base for tropical pasture development with emphasis on acid, low-fertility soils. It should be recognized, however, that there still exists a wealth of untapped variability to be explored and collected. In view of this, breeding should only be considered after a sufficiently wide range of natural variability has been evaluated for the desired characters.

Tropical pasture germplasm collection, maintenance and conservation, is a specialized expensive activity not expected to be carried out by many pasture research programs. To maximize the effective utilization of collected germplasm and information, it should be made freely available to national research institutions. National pasture research institutions and CIAT's TPP have developed a well-structured evaluation scheme that efficiently makes use of available germplasm providing a mechanism for rapid flow from introduction gardens to pasture evaluation under grazing and on farm exposure of the promising selected germplasm and pasture technology. This multi-institutional co-operative effort (RIEPT) is already yielding new pasture cultivars of grasses and legumes.

Several constraints to the effective assembling of tropical pasture germplasm have been recognized. These include: (1)limitations to collecting in some countries and regions due to non-technical reasons; (2) germplasm duplication due to inadequate passport data; (3) lack of information on seed-borne pathogens of little known genera; (4) lack of information on optimum storage conditions especially for tropical grasses. International collaborative efforts are required to solve these problems.

With respect to the efficient utilization of tropical pasture germplasm, the major constraints are the lack of financial continuity at the national program level to maintain a rapid flow of germplasm through the evaluation process as well as the problem of multiplying large enough quantities of seed of selected experimental material for advanced pasture evaluation and transfer to farmers.

14. Referencias

Calderón, M.A. 1983. Insect pests of tropical forage plants in South America. In: Smith, J.A. and Hays, V.W. (eds.) XIV International Grasslands Congress. Lexington, Kentucky 1981. Proceedings. pp. 778-780.

Cameron, D.F., Hutton, E.M., Miles, J.W. and Brolmann, J.B. 1984. Plant breeding in Stylosanthes. pp. 589-606. In: The Biology and Agronomy of Stylosanthes (Eds.) H.M. Stace & L.A. Edye. Academic Press.

CIAT. 1985. Tropical Pastures Program Report, CIAT, Cali, Colombia.

Clayton, W.D. 1983. Tropical grasses. pp. 39-46. In: Genetic Resources of Forage Plants. Ed., J.G. McIvor and R.A. Bray. CSIRO, Melbourne, Australia.

Cochrane, T.T., Sánchez, L.G., de Azevedo, L.G., Porras, J.A., and Garver, C.L. 1984. Land in tropical America - a guide to climate, landscapes, and soils for agronomists in Amazonia, the Andean Piedmont, Central Brazil and Orinoco. Vol. 1-3. CIAT, Cali, Colombia, and EMBRAPA-CPAC, Brazil.

Ferguson, J.E., Seré, C. and Vera, R.R. 1985. The release process and initial adoption of Andropogon gayanus in tropical Latin America. Proceedings XV International Grasslands Congress, Kyoto, Japan, Aug. 1985. (In press).

Lenné, J.M. 1985. Recent advances in the understanding of anthracnose of Stylosanthes in tropical America. Proceedings XV International Grasslands Congress, Kyoto, Japan, Aug. 1985. (In press).

Parsons, J.J. 1972. Spread of African pasture grasses to the American tropics. Journal of Range Management 25: 12-17.

Pattanavibul, S. and Schultze-Kraft, R. 1985. Collecting germplasm of Desmodium and Pueraria phaseoloides in Thailand and Peninsular Malaysia. Proceedings XV International Grassland Congress, Kyoto, Japan, Aug. 1985. (In press).

Salas, I.N. and Lenné, J.M. 1985. Reconocimiento de la presencia de Pseudomonas fluorescens Biotipo II en semillas de 50 lotes de Centrosema spp. Proceedings XI Panamerican Seed Seminar, Cali, Colombia, Nov. 1985. E81.

Schultze-Kraft, R. 1985. Development of an international collection of tropical forage germplasm for acid soils. Proceedings XV International Grassland Congress, Kyoto, Japan, Aug. 1985. (In press).

Schultze-Kraft, R. and Giacometti, D.C. 1979. Genetic resources of forage legumes for the acid, infertile savannas of tropical America. pp. 55-64. In: Pasture production in acid soils of the tropics. Ed. P.A. Sánchez and L.E. Tergas. CIAT, Cali, Colombia.

Schultze-Kraft, R., Keller-Grein, G., Belalcázar, J., and Benavides, G. 1985. Centrosema macrocarpum Benth., a promising tropical forage legume for acid soils. Proceedings XV International Grassland Congress, Kyoto, Japan, Aug. 1985. (in press).

Toledo, J.M. 1982. Objetivos y organización de la Red Internacional de Evaluación de Pastos Tropicales. pp. 13-21. In: Manual para la evaluación agronómica RIEPT (Ed.) J.M. Toledo. CIAT, Cali, Colombia.

Toledo, J.M. 1985. Pasture development for cattle production in the major ecosystems of the tropical American lowlands. Plenary Paper. Proceedings XV International Grassland Congress, Kyoto, Japan, Aug. 1985.

Toledo, J.M. and Nores, G.A. 1986. Tropical pasture technology for marginal lands of tropical America. Outlook on Agriculture; Pergamon Press, Oxford, England. (in press).

Torres, C. and Lenné, J.M. 1985. Efecto de varios tratamientos en la supervivencia de Corynebacterium flaccumfaciens (Hedges) en semillas de Zornia glabra CIAT 7847. Proceedings XI Panamerican Seed Seminar, Cali, Colombia, Nov. 1985, E85.

Williams, R.J. 1983. Tropical legumes. pp. 17-37. In: Genetic Resources of Forage Plants. Ed., J.G. McIvor and R.A. Bray. CSIRO, Melbourne, Australia.