Series 03 EG 5
March 1979

Seminar on

PASTURE PRODUCTION IN ACID SOILS OF THE TROPICS

Proceedings of a Seminar held at CIAT,
Cali, Colombia
17-21 April, 1978

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GENETIC RESOURCES OF FORAGE LEGUMES FOR THE ACID INFERTILE SAVANNAS OF TROPICAL AMERICA

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ABSTRACT

Observations made during collecting expeditions in introduction plots and under grazing conditions indicate that the following main genera and species demonstrate clear potentials as forage legumes for savannas with acid infertile soils in tropical America *Stylosanthes (S capitata) Desmodium (D ovalifolium D barbatum* and others) *Zornia* (from the group of species with bifoliate leaves) *Aeschynomene (A histrix* and *A brasiliana) Centrosema Macroptilium/Vigna* and *Galactia* However these genera along with others that appear adapted to acid infertile soils still require considerable research attention with respect to systematic collections and evaluations

Until about 40 years ago the importance of tropical legumes was limited to their use as cover crops on oil palm or rubber plantations (12) Although in earlier literature there were some indications of the great potential of tropical legumes as forage plants (4 5 9) it was only during the 1940 s that research on using legumes as forage began in Australia These early efforts consisted of various trips to collect germplasm throughout the tropics (1 7 8) followed by systematic evaluations and occassionally some plant breeding efforts The work done by Australian scientists resulted in a series of cultivars of tropical forage legumes that were released during the last 15 years

Interest in forage legumes for tropical America dawned during the last decade In most cases research was limited to maintaining a few plots of Australian cultivars in introduction gardens and collecting data on fresh matter production This situation was problematic as well as paradoxical the importance that forage legumes would eventually have in research projects of individual institutions depended on the behavior of a few commercial cultivars selected in Australia for specific climatic and edaphic conditions of that country meanwhile no attention was being given to native genetic resources

Brazil was one of the first Latin American countries to become interested in developing its own forage legume genetic resources The Ministry of Agriculture began to study them in 1941 (9) and between 1961 and 1965 the IBEC Research Institute (IRI) made a series of surveys from

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which an important collection was assembled consisting of a wide range of genera species and ecotypes of native Brazilian legumes (3)

Only more recently Latin American and international institutions have begun to carry out systematic collection trips in tropical America and to show interest in preserving and evaluating the collected germplasm At present there are approximately 10 000 ecotypes of many genera and species of tropical legumes available from the following institutions

1 Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) through its Centro Nacional de Recursos Geneticos (CENARGEN) Brasilia D F Brazil

2 Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG) Belo Horizonte Minas Gerais Brazil

3 Empresa Goiana de Pesquisa Agropecuaria (EMGOPA) Goiânia Goias Brazil

4 Instituto de Pesquisas IRI Matao São Paulo Brazil

5 Instituto de Zootecnia Secretaria de Agricultura do Estado de São Paulo Nova Odessa São Paulo Brazil

6 University of Florida Fort Pierce Florida U S A

7 University of the West Indies/International Development Research Centre Antigua and Belize

8 Centro Internacional de Agricultura Tropical (CIAT) Cali Colombia

Major international efforts were consolidated during a recent Workshop on Collection Preservation and Characterization of Genetic Resources of Tropical Forage Plants held April 10 15 1978 at CIAT and attended by the world s leading scientists in tropical forage germplasm (6) An important result of this workshop was an agreement for free exchange of all available germplasm This agreement includes the institutions listed above and others in Latin America which keep smaller collections of native germplasm (i e in Cuba Ecuador and Panama) Also participating will be institutions outside of Latin America which have important collections comprising species native to tropical America and of exotic origin (i e the Commonwealth Scientific and Industrial Research Organization (CSIRO) Australia and the Food and Agriculture Organization (FAO) Forage Collection and Evaluation Project in Kenya)

In tropical America CIAT— in an intensive way— and EMBRAPA—in a partial way—have concentrated their work on collecting introducing and evaluating tropical forage legumes for acid infertile soils (Oxisols and Ultisols) EMBRAPA works through CENARGEN and its Active Germplasm Banks in the Centros de Pesquisa Agropecuaria dos Cerrados (CPAC) near Brasilia dos Tropicos Umidos in Belem and de Gado de Corte (CNPGC) in Campo Grande

The final objective of efforts at CIAT and EMBRAPA is the identification of genetic material adapted to the edaphic and climatic conditions of approximately 300 million ha of tropical savannas and 550 million ha of humid tropics in Latin America with acid infertile soils Legumes adapted to these conditions must combine the following characteristics collectively known as persistence under grazing (a) tolerance to low pH values (including high concentrations of Al and Mn) (b) low requirements for P and other elements (c) effective nodulation with *Rhizobium* (d) compatibility with grasses (vigorous growth and regrowth and adequate growth habits) (e) tolerance to diseases and insect attacks (f) adequate palatability (absence of toxic factors and of excessive palatability) and (e) tolerance to drought and flood stress

MAJOR GENERA—COLLECTION AND EVALUATION

The following notes about the most important genera summarize CIAT s and EMBRAPA s collection and evaluation experiences up to the present

Stylosanthes Sw

Among all the tropical legumes researchers have given their greatest attention to the genus *Stylosanthes* and its several interesting characteristics *Stylosanthes guianensis* (Aubl) Sw (Fig 1) is the species with the greatest genetic diversity a fact reflected in the recent attempts to establish new botanical species and varieties (2 10) Geographically it is found from Mexico to Argentina and from Ecuador to Bahia Brazil Although *S guianensis* is an indicator plant for acid (but not necessarily infertile) soils some ecotypes have been found in alkaline soils

Other important *Stylosanthes* species that are also indicator plants for acid soils include *Stylosanthes scabra* Vog *Stylosanthes viscosa* Sw *Stylosanthes humilis* H B K and *Stylosanthes capitata* Vog (Fig 2) All of these are well adapted to the Oxisols and Ultisols of the South American tropical savannas Moreover *S capitata* needs a low pH and low fertility and has been observed to not grow well on fertile soils Geographic distribution of these species is more limited than that of *S guianensis* For example in Colombia it has been impossible to find *S scabra S viscosa* or *S capitata* Existence of *S humilis* in that country seems limited to acid soils in regions bordering Venezuela

With the exception of *S humilis* all the species mentioned above show the advantages of vigorous growth high DM production and good resistance to drought Averaging the combined observations of Colombian and Brazilian experiences the species could be ranked according to their productivity as follows (highest to lowest) *(S guianensis* $\geq$ *S scabra* $>$ *S viscosa* $\geq$ *S capitata*

S capitata appears to be native only in

Figure 1 *Stylosanthes guianensis* **CIAT 136**

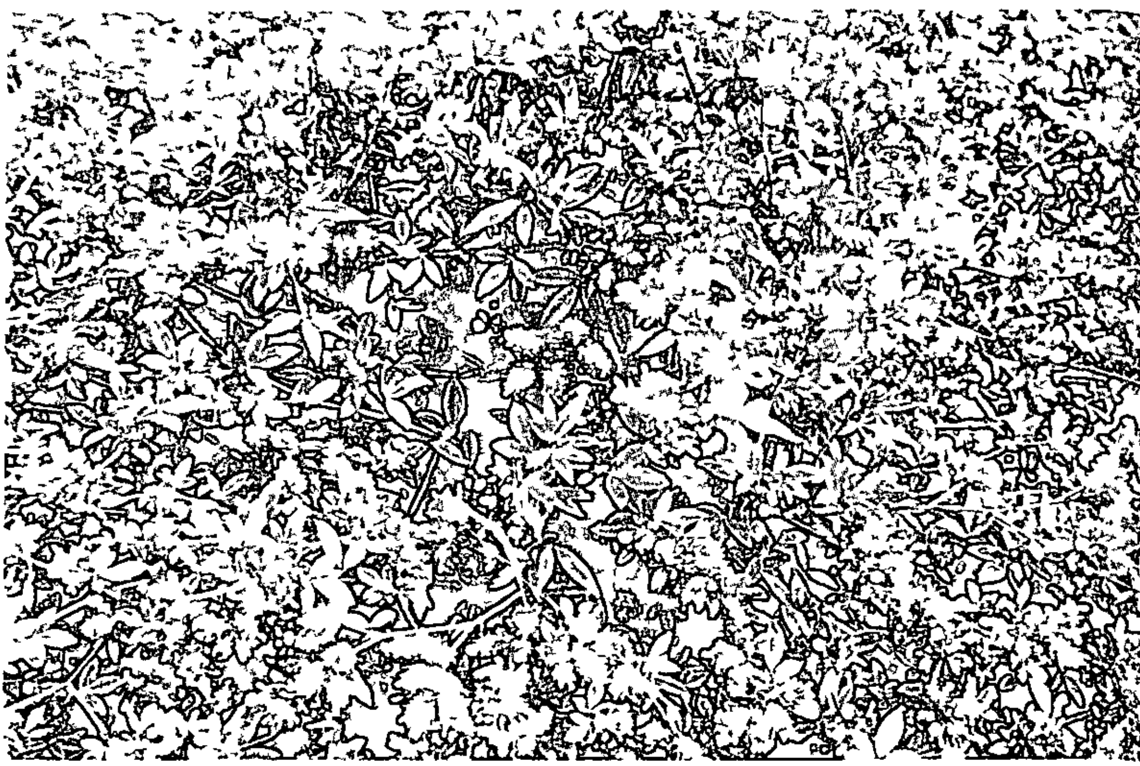

Figure 2 *Stylosanthes capitata* **CIAT 1019**

Brazil and certain regions of Venezuela Three markedly different types have been identified in this species

A Early flowering germplasm native to central Brazil with high seed production and relatively low DM production

B Intermedia flowering germplasm native to the states of Maranhão and Piaui Brazil lower seed production and higher DM production than (A)

C Late flowering plants morphologically different from (A) and (B) germplasm native to Bahia Brazil apparently smaller seed production but high DM production especially during the dry season

To these we could add a fourth ecotype of *S capitata* collected in the states of Anzoategui Bolivar and Monagas Venezuela Morphologically it should be classed as late flowering although it flowers earlier Plants of this type along with some of those of ecotypes (A) (B) and (C) apparently are resistant to burning

Productivity of the species *S humilis* is restricted by its annual growth habit Its best potential is in regions with acid soils where average annual rainfall (AAR) is less than 1000 mm/yr and the dry season is long However in the jungle area of the state of Maranhão Brazil some very vigorous ecotypes have been collected whose productivity in environments having an AAR of 2000 mm/yr (at Carimagua in the Colombian Llanos) equals that of many *S guianensis* ecotypes

Stylosanthes hamata (L) Taub deserves mention because one cultivar of this species has replaced large areas of *S humilis* in Australia All of the CIAT germplasm of *S hamata* is native to the Caribbean area and was collected in areas of low AAR from fertile soils having a slightly acid to alkaline pH One ecotype however shows some adaptation to infertile soils of very low pH in contrast to the rest of the *S hamata* germplasm The ecotype appears to be native to the Calabozo region of Venezuela (state of Guarico) where the vegetation is typical savanna on an acid soil of medium fertility

Stylosanthes angustifolia Vog and *Stylosanthes bracteata* Vog are other indicator plants for acid infertile soils Although not enough work has been done yet with germplasm of these species the productivity of *S angustifolia* seems to be very low

Despite the several positive characteristics of *S guianensis* *S scabra* and *S viscosa* their potential is seriously limited by their lack of resistance to anthracnose (*Colletotrichum gloeosporioides* Penz) and to a stem borer (*Caloptilia* sp) A rather wide range of susceptibility has been found in the germplasm evaluated in the greenhouse and observations of materials in introduction plots and under grazing Many materials of a determinant type of *S guianensis* distinguished by their fine stems abundant pubescence and late flowering apparently are more tolerant to attacks of both the disease and the insect This tolerance is not sufficiently great however to assure persistence of plants under grazing

S capitata is the only *Stylosanthes* species that up to now appears sufficiently tolerant to anthracnose as well as to stem borer attacks Therefore this species is considered of very high priority for further work including additional germplasm collections to widen the available genetic variability as much as possible

Desmodium Desv

The potential of this genus which includes approximately 200 species has not been sufficiently explored *Desmodium barbatum* (L) Benth and *Desmodium cajanifolium* (H B K) DC are the two species found most frequently on collection trips to regions of acid infertile soils

Preliminary observations indicate that *D barbatum* includes ecotypes with a surprisingly wide range of growth habits foliage densities and productivities From observations at many collection sites a group of ecotypes is evidently well adapted to high rainfall conditions

D cajanifolium is part of a group of very erect species that reach heights of up to 3 m with little branching and very little foliage but which produce abundant seed *Desmodium distortum* (Aubl) MacBr and *Desmodium discolor* Vog also belong to this group but they require more fertile soils The main potential of these plants is in their eventual use for browsing

Few species of *Desmodium* native to southeast Asia have been tested on Oxisols and Ultisols of tropical America The most promising of these few is a subspecies of *Desmodium heterocarpon* (L) DC that is commonly known by its older name *Desmodium ovalifolium* Wall (Fig 3) Little is known about its genetic variability The only material available is a commercial variety marketed in Singapore which is well adapted to Oxisols of the Colombian Llanos The very vigorous stoloniferous growth of *D ovalifolium* permits its successful establishment with a grass as aggressive as *Brachiaria decumbens* Stapf It apparently has good drought tolerance and up to now has shown no specific problems caused by diseases or insects

Zornia J F Gmel

This genus which includes some 60 species was until a short time ago completely unknown to tropical forage plant researchers CIAT s experience with this genus began two years ago and can be summarized as follows

1 All de *Zornia* species and ecotypes collected so far are indicator species for acid and very often infertile soils Materials evaluated do not have adaptation problems on Oxisols and Ultisols

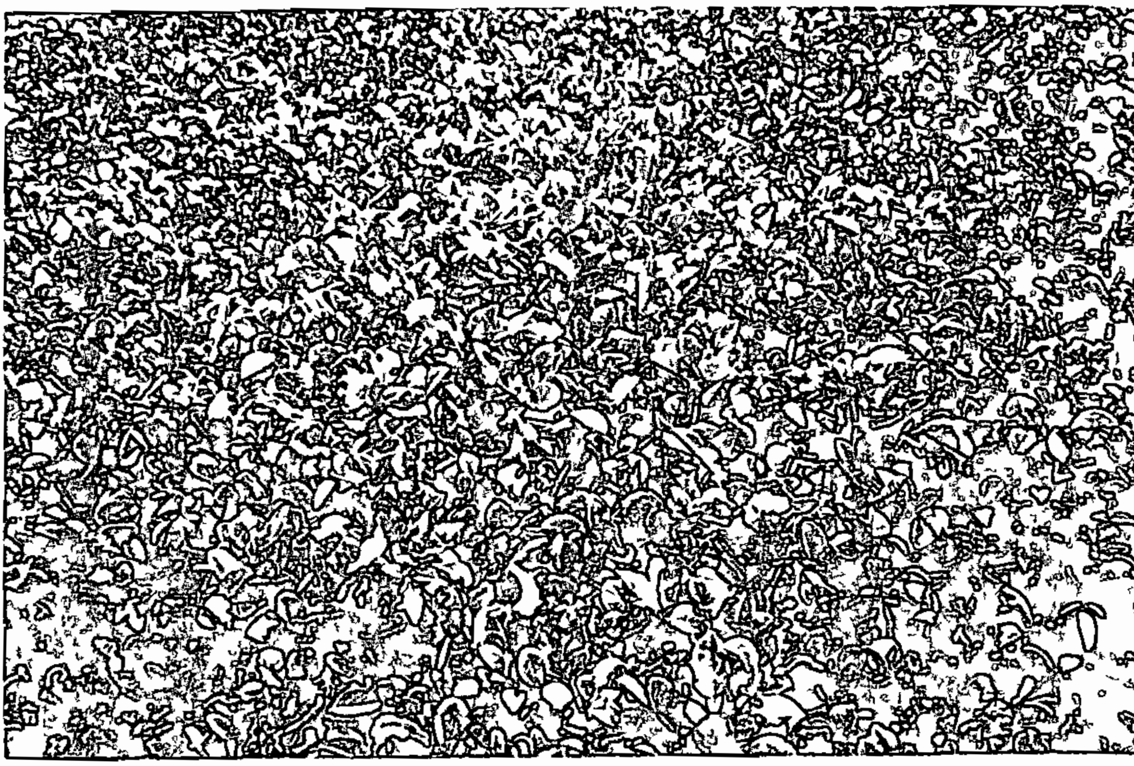

Figure 3 *Desmodium ovalifolium* **CIAT 350**

2 Apparently the most promising germ plasm comes from species with com pound leaves of two leaflets (i e *Zornia* aff *latifolia)* (Fig 4) Very extensive genetic variability has been observed in DM production flowering date and foliage density Many of the ecotypes are more than annuals under grazing They also appear resistant to burning

3 The few *Zornia* ecotypes with com pounds leaves of four wide leaflets that have been studied (i e *Zornia* aff *brasiliensis* Vog) show little produc tivity and seem markedly annuals

Aeschynomene L

Although the genus *Aeschynomene* L is known to scientists studying tropical forage legumes only recently has research been initiated to identify germplasm adapted to acid infertile soils Among the most in teresting species is *Aeschynomene panicu lata* Willd ex Vogel and material of other species having procumbent to prostrate growth habits fine stems many branches and frequently heavy pubescence (i e *Aeschynomene histrix* Poir and *Aeschynomene brasiliana* (Poir) DC

Several observations made during collec tion trips and from introduction plots on an Ultisol of pH 4 0 suggested further evalua tion Ecotypes of the above mentioned species are frequently found in savanna regions with acid infertile soils vary widely in their productivity flowering date and persistence show good drought resistance produce considerable quantities of seed and up to now have not shown problems of diseases or insect attacks

Centrosema (DC) Benth

The genus *Centrosema* like *S guianen sis* has a very wide geographic distribution However unlike that species *Centrosema* is not a genus of indicator plants for acid soils Most *Centrosema* species are native to regions with rather high soil fertility Conse

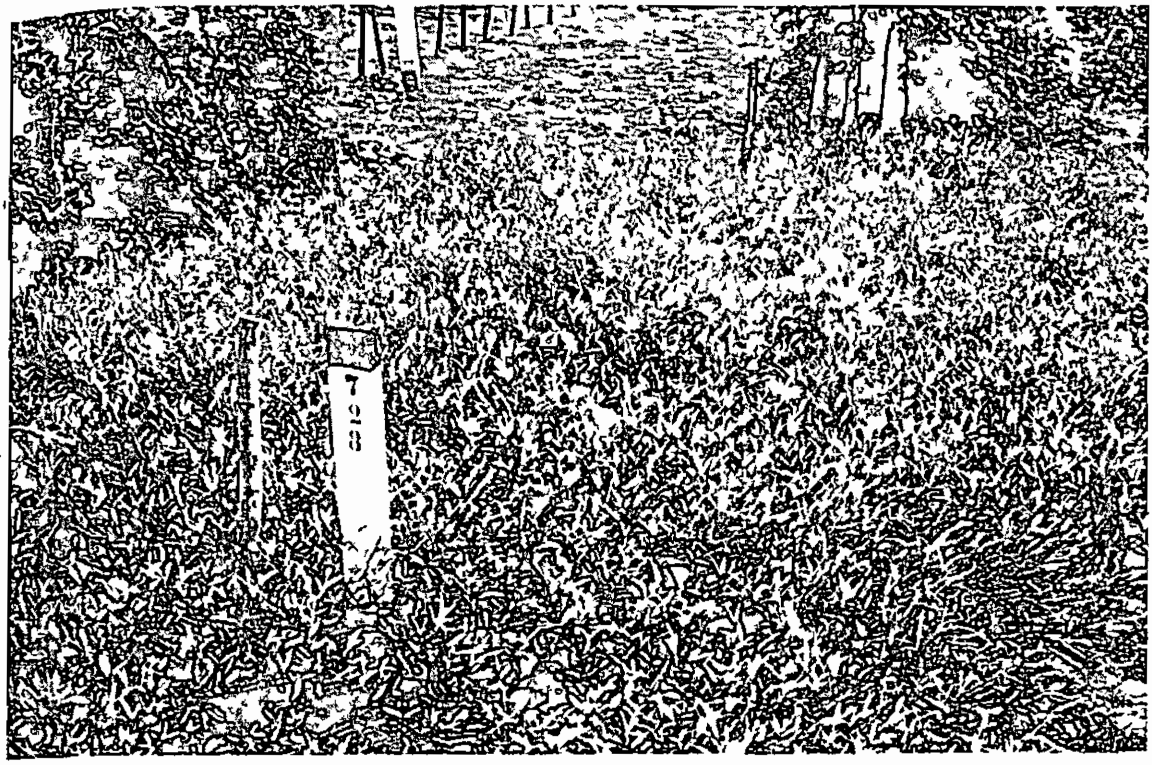

Figure 4 *Zornia latifolia* **CIAT 728**

quently the commercial varieties as well as the rest of the germplasm that has been available for study were mostly materials lacking sufficient adaptation to acid infertile soils

When *Centrosema* does occur in acid infertile soil regions it has been observed that on open savanna areas the species tend to be of a trailing growth habit (i e *Centrosema venosum* Mart) rather than of a climbing habit This can be attributed to the frequent burning practices in these areas For the same reason it has been found that some species especially *C venosum* have the ability to produce fruits underground in sandy soils In savanna areas protected from frequent burnings (i e around the borders of gallery forests) and in regions where vegetation is jungle like *Centrosema* species with climbing growth habits do occur among them *Centrosema pubescens* Benth *Centrosema macrocarpum* Benth and *Centrosema angustifolium* (H B K) Benth The latter species is very typical of the plains of Colombia and Venezuela

Because species wihh creeping growth habits have rather low productivity collection and evaluation of germplasm from the climbing group have been intensified Within this group have been found vigorously growing ecotypes well adapted to acid infertile soils

Macroptilium (Benth) Urb and *Vigna* Savi

Like *Centrosema* these genera have a very wide geographic distribution And also like *Centrosema* their potential for acid infertile soils has not been sufficiently explored From travels through savanna regions as well as other Oxisol and Ultisol zones a considerable quantity of germplasm of these genera has been collected and very wide ranges of productivity and phenotypes have been found Some of the extraordinary characteristics encountered include unifoliate leaves tuberous roots and underground fruiting Much of this material is probably annual In the systematic evaluation of this germplasm which has only begun recently special attention will have to be given to resistance to *Rhizoctonia* an especially important criterion for selecting material in these genera

Galactia P Browne

Up to the present agronomic studies of this genus have been directed to just one commercial variety of *Galactia striata* (Jacq) Urb (IRI 1220) This variety has the desirable characteristics of good adaptation to acid infertile soils high productivity and considerable resistance to drought However under the more humid conditions of the climate of the Colombian Llanos this species is seriously affected by anthracnose (*Colletotrichum* spp)

Like *Centrosema Macroptilium* and *Vigna* genera *Galactia* species with climbing growth habits (i e *G striata)* have very wide geographic distribution and are more frequently found in regions with fertile soils However a series of ecotypes of this genus has also been collected from unburned savanna regions and other acid soil regions of the South American tropics

It is important to mention two other *Galactia* species very frequently found in tropical South American savannas where bushy vegetation is scant and frequent burnings occur The first is *Galactia glaucescens* H B K a species with unifoliate to trifoliate leaves and an erect growth habit up to 1 m in height The other is *Galactia jussiaeana* H B K a species with semi erect to procumbent growth habits The potential of both species as forage plants is still unknown Both have a rather rough appearance and do not seem to be very productive but they share the very special trait of being extraordinarily resistant to burning It has often been observed that the initial growth of *G jussiaeana* after burning is much more vigorous than the growth of other surrounding plants on the savanna This resistance to burning is due to a rather common characteristic among typical savanna plants the pressence of tuberous roots (xylopodia) as special organs for food reserves as well as for regrowth points

Xylopodia have also been found very frequently in other leguminous savanna species such as *Erinosema* spp *Clitoria guianensis* and *Vigna* sp and sporadically in some types of *S guianensis S bracteata Stylosanthes* sp *Zornia* sp and *Alysicarpus* aff *vaginalis*

Other genera

The genera *Pueraria Calopogonium* and *Rhynchosia* have also shown potential as forage species for the tropical savanna regions of South America

Another group of genera deserving future attention include *Cassia Mimosa* and *Tephrosia* Within these genera have been found some species of very vigorous growth and excellent adaptation to acid infertile soils However preliminary studies are needed to determine the presence of toxic factors that undoubtedly exist in most species within these genera

Finally it is important to stress the need to investigate the potential that might be found in bushy and shruby species either because of their fruits or their possible use as browsing plants on acid infertile soil savannas in the dry season Some of the better known genera of this kind are *Leucaena Prosopis* and *Piptadena* However their geographical distribution is limited to regions with long dry seasons and relatively high pH soils

CONCLUSIONS

Experiences in CIAT EMBRAPA and at other institutions indicate that the genetic resources of tropical forage legumes have been explored only superficially The eight genera or groups of genera mentioned in this paper represent a great germplasm potential for tropical savannas with acid infertile soils The variability of the genetic material seems to be ample enough to justify no major efforts in hybridization projects at this time It appears more convenient to continue increasing the genetic variability in these promising genera by further collec tions Special emphasis sould continue to be placed on collecting in regions with acid soils since it is much more likely that germplasm native to these areas will also be adapted to the edaphic conditions of the tropical savannas

There are two important reasons for continuing germplasm collections (a) the need to obtain the maximum possible genetic variability in order to proceed with the selection of the most promising materials and (b) the need to guarantee the preservation of the available genetic resources **while they still exist** An impor tant reason to stress the latter need is the very clear evidence that genes of tropical legumes are being lost On more than one occasion upon returning to a collection site of especially promising genetic material it has been found the material no longer exists The area has often been cleared for agricultural cultivation and because agricultural development is accelerating in many tropical regions the need to collect existing germplasm material is urgent

The collection of germplasm to guarantee the preservation of available genetic resources is only a first step The second step would be the characterization and evaluation of the germplasm collected that is to identify its potential as a forage This stage—already utilized in selecting the most promising material—is too important to restrict evaluation of the most interesting characteristics to overvations of periodic fresh matter yields on introduction plots It is well known that some of the most important characteristics of a forage plant especially those determining persistence depend on the way plants are utilized Since the product being developed is a plant for grazing beef cattle as the eventual consumers should enter the evaluation process as soon as possible

Stylosanthes is the most intensively collected genus up to now In spite of the problems of disease and insect attacks species with capacity for high productivity still deserve major attention According to the Law of Homologous Series (11) the resistance shown by *S capitata* to anthrac nose and to stem borer attacks offer good reason to expect some other resistant ecotypes might also be found among related species such as *S guianensis*

It is worthwhile to stress again the need to continue collecting and increasing the germplasm of those other major genera having potentials— so far insufficiently explored—for use on the tropical savannas of South America Experience with *D ovalifolium* indicates that efforts should not be limited to germplasm native to the American tropics the diversification center for most of the tropical legume species Rather collections should extend to tropical Asia and Africa In the case of *D ovalifolium* special efforts should be made to increase the germplasm collection

Since vigorous growth is one of the most important characteristics of a forage plant it is necessary to emphasize the importance of an effective legume/*Rhizobium* symbiosis The *Rhizobium* strains found in association with the plants being collected as germ plasm should also be considered as genetic resources The potential that a legume might have as a forage plant for acid infertile soils could be much greater if the *Rhizobia* occurring at the collection site are utilized when possible

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