POTENTIAL FOR DEVELOPMENT AND PRIORITIES FOR RESEARCH INTO LEUCAENA IN CENTRAL AND SOUTH AMERICA[1]

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ABSTRACT

This paper briefly reviews research with *Leucaena leucocephala* (leucaena) and other species within the *Leucaena* genus in Central America, Caribbean and South American countries and within these geographical boundaries describe macro regions and production systems which are suited for this legume. Research on leucaena in the region has been abundant, covering topics related to germplasm evaluation, establishment, quality and toxicity, animal responses, pest and diseases and to a lesser extent breeding. Large areas suited to grow existing cultivars of leucaena are mainly found in the pacific coast of Central America and in the Caribbean, particularly Cuba, Haití and the Dominican Republic. In South America there are "niches" for leucaena which extend from northern South America (i.e. Venezuela, Guyana, Colombia) to eastern Brazil and northern Argentina. In these regions there are contrasting production systems which could greatly benefit from leucaena as a source of protein, fuelwood and fence-post. These include grazing with supplementation of leucaena as a protein bank (e.g. large to medium beef and dual purpose cattle farms) and limited grazing with supplementation of leucaena together with crop-residues and agricultural by-products (e.g. smallholder integrated crop-livestock farms). In steeper areas, such as the hillsides of Central America, leucaena can also play an important role in minimizing soil erosion. In spite of the numerous uses of leucaena and of the positive research results on animal production, there has only been limited adoption of this legume in the region. This could be due to poor communication of research results to farmers and/or high cost and risk of establishing leucaena, due to its slow initial growth and thus susceptibility to weeds, leaf cutting ants and termites. To enhance adoption of existing cultivars of leucaena, a major effort should be given to development of low cost establishment methods (e.g. intercropping), and seed multiplication and delivery systems and to the evaluation of leucaena with farmers in different production systems using participatory research methods. Priority should also be given to: (1) defining effectiveness of biological control of pysillid in Central America and Caribbean countries, and to clarifying the effect of dry season stress on attack and damage by the insect, (2) evaluating less known species of *Leucaena* for wood production and quality, and (3) developing acid soil tolerant leucaena genotypes for large areas of tropical America where existing cultivars of leucaena can not presently be grown (i.e. Llanos of Colombia, Cerrados of Brazil) and where livestock production is an important activity.

INTRODUCTION

The genus *Leucaena*, native to Mexico and Central America, consists of a large number of species ranging from shrubs to large trees. Within the genus, *L. leucocephala* (leucaena) has received considerable attention due to its value as a source of high quality forage, fence-post and fuelwood. In addition, it is widely recognized that leucaena can play an important role in soil enhancement and erosion control.

The purpose of this paper is to briefly review research with leucaena in countries of Central America, Caribbean and South America, to describe macro-regions and agricultural production systems which could benefit from leucaena, and to identify needs for research and development with *Leucaena* species.

RESEARCH ON LEUCAENA

To review research on *Leucaena* species in the region we used the library database (1980-1992) of the Centro Internacional de Agricultura Tropical (CIAT). In this database we found 17 review papers on leucaena from 12 countries. Most of the reviews dealt with origin, plant description and morphology, agronomy, management and utility of leucaena as a source of fodder. A total of 65 research papers, technical notes and theses were reviewed. The most common research topics were: (1) establishment (38%), (2) germplasm evaluation (31%), (3) quality and toxicity (16%), (4) animal responses (8%), (5) pest/disease (6%) and (6) breeding (1%). In Central America, and the Caribbean most of the research reviewed was conducted in Panamá, Costa Rica, Cuba and Puerto Rico, whereas in South America most of the research was done in Brazil and to a lesser extent in Colombia. What follows is a brief description of research carried-out with leucaena in the region.

Germplasm evaluation. A great deal of effort has been given in the region to the evaluation of leucaena germplasm. In the early and mid-eighties most of the leucaena germplasm that was evaluated in different countries came from the University of Hawai. These evaluations were mainly concerned with forage yield, mimosine content and to a lesser extent wood production. An example of this work is the finding of superior forage yield of K62 in Tocumen, Panamá (Mendoza, 1981) and of K4 in Chiriquí, Panamá (Sánchez, 1982). Also in Panamá, K324 showed consistently lower levels of mimosine as compared to other accessions (Vargas and Tempone, 1982). In Brazil, there has been some effort on screening leucaena genotypes for Al tolerance (Maluf et al., 1984) and in examining genotype x environment interaction (Costa and Alves, 1987). In the area of Rondonia, cv. Perú was more productive at a site on a soil of pH 6.5, whereas cv. Cunningham was more productive at a site on a soil of pH 5.9.

Currently, an important source of leucaena germplasm for the region is CIAT. The Genetic Resources Unit in CIAT, maintains 198 accessions from 11 species of Leucaena, *L. leucocephala* being the most important (Table 1). The leucaena germplasm at CIAT has been largely donated by institutions such as CSIRO (>50 accessions which mostly orginated from Mexico), NFTA (~20 accessions) and the IDRC collections in Antigua and Belize (~20 accessions). A smaller number of accessions originated from direct collections by CIAT and national scientists. Part of the leucaena germplasm is preserved in the long-term base collection and it is duplicated in a field collection at Palmira (Table 1).

(Insert Table 1)

The distribution of leucaena germplasm in the region has been largely through the International Pastures Evaluation Network (Red Internacional de Evaluación de Pastos Tropicales, RIEPT) which was established by CIAT in the early 1980's. During the last 10 years, approximately 150 samples of leucaena germplasm have been distributed each year, to a total of 11 countries in Central America, Caribbean and South America. The evaluation of leucaena germplasm distributed by CIAT has resulted in identification of superior accessions for different environments (Table 2). For example, in Atenas, Costa Rica, an area with a long dry season, accession CIAT 17263 collected in Mexico, was outstanding in forage yield (3.6 kg/plant/cut) and regrowth during the wet season (170 cm in 8 weeks). In this study cv. Cunningham (CIAT 17502) had relatively low forage yield (.345 kg/plant/cut), and regrowth capacity (78 cm in 8 weeks). Some hybrids of leucaena (*L. leucocephala* x *L. pulverulenta*, backcrossed several times to *L. leucocephala*) produced by E. M. Hutton have given high forage yields in several locations with contrasting environments (Table 2).

A number of trials in RIEPT have been designed to investigate general adaptation of leucaena to soils and climate. This work confirmed the poor adaptation of leucaena to acid soils with high Al saturation (>40%), which are prevalent in the Amazon forest margins (Florencia, Caquetá, Colombia; Pucallpa, Perú) and in some locations in the Andean hillsides (Mondomo, Cauca, Colombia). Work of Hutton (1984) in the cerrados of Brazil, suggested that the lack of adaptation of leucaena to acid soils appeared to be related to Ca deficiency rather than to Al toxicity.

In some Central American countries (Costa Rica, Honduras, Nicaragua) there are several projects (MADELEÑA, AFN-SAREC) outside RIEPT, which are evaluating leucaena germplasm, in terms of forage and wood production. For example, a project in the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) entitled AFN-SAREC established 24 genotypes of leucaena in a dry zone of Costa Rica. At the end of the first year post-establishment, some accessions of *L. macrophylla*, *L. diversifolia* and *L. trichodes* showed superior growth compared to *L. leucocephala*. In a project in Honduras entitled "Mejoramiento genético forestal", some species of Leucaena (i.e. provenances of *L. collinsii* subspecies *collinsii* and

Zacapana, *L. diversifolia*, *L. macrophylla* subspecies *nelsonii*, and *L. multicapitulata*, *L. salvadorensis*) have shown equal or higher wood production potential compared to well known cultivars of *L. leucocephala* (K8, K636).

In summary, it is evident that there is plenty of leucaena germplasm in the region and that there is a large amount of information on the performance of this germplasm in different environments, particularly in terms of forage production. However, there is a need to evaluate less known species of *Leucaena* for wood production and quality.

(Insert Table 2)

Establishment. A great deal of research on leucaena establishment has been done in the region, possibly in recognition that slow establishment is a major limitation of this legume. Research on establishment has dealt with a wide variety of subjects such as: (1) seed treatment, (2) inoculation with rhizobia and *mycorrhiza*, (3) fertilization and liming, (4) planting patterns and density, and (5) weed control.

Of the 22 papers reviewed that dealt with subjects related to establishment of leucaena, only two considered the use of a nurse crops to reduce the cost of establishment. In Brazil, Andrade and Alcântara (1985), established leucaena with corn. Even though, the yield of leucaena was slightly depressed when intercropped, the cost reduction was large. In Panamá, González and Rivera (1983), also established leucaena with corn. Results showed that yields of leucaena at 150 days post-establishment were half (2 t DM/ha) of the yield obtained planting leucaena only, but there was a considerable reduction in the cost of establishment. The highest corn yields were recorded by establishing the crop 15 or 30 days after leucaena.

Weeds are a major constraint in the establishment of leucaena, and some site-specific research has been done to establish control practices. In Cuba, Ruiz et al. (1989) summarized results on 17 experiments dealing with establishment of leucaena. The use of pre-emergent herbicides combined with mechanical cultivation was a good practice to control annual grasses and broad leaf weeds. Effective weed control for establishing leucaena has also been achieved in Caribbean countries by allowing broadleaf weeds and grasses to germinate after land preparation, followed by the application of glyphosate (Proverbs, 1983).

In most reports reviewed on fertilization of leucaena, there has been a positive response to P, Ca and S. Although nodulation of leucaena with native rhizobium strains has been shown to occur, the introduction of more effective strains has resulted in significant forage yield increases (López and Taboada, 1983; Tang et al., 1983; Valarini and Bufarah, 1984; Bueno et al., 1985).

Quality and animal responses. There is abundant information in the region on chemical composition of leucaena forage. In addition, there has been some emphasis on determination of mimosine levels on leucaena germplasm and on toxic effects of this alkaloid in cattle and sheep. For example, reports from Brazil indicate that sheep fed only leucaena (cv. Perú) hay showed toxicity in some studies (Franzolin, 1984), but not in others (Saavedra, 1986), probably related to absence or presence of DHP-degrading bacteria. More recently, animal nutritionists in Brazil measured the sites of digestion of leucaena (Rodriguez and Borges, 1989). Results showed that only 40% of the plant protein was digested in the rumen, which translated into a high degree of by pass-protein possibly related to condensed tannins present in the leucaena.

A number of experiments have been conducted to determine liveweight gain and milk yield responses where leucaena was given as a protein bank. Liveweight gain (LWG) responses have been variable. For example, Seiffert (1982) in Campo Grande, Brazil did not find a positive effect on LWG of steers with access to a protein bank of leucaena (30% of the area) mainly because of poor growth of the plants in the acid soils of the location. In contrast, Paterson et al. (1983) in Bolivia found that steers with access to a leucaena protein bank (30% of the area) gained 3 times more liveweight (700 g/A/day) during the dry season than steers grazing only *Hyparrhenia rufa*.

Milk yield responses of cows supplemented with leucaena have also been variable depending on the potential of the cows for milk production. For example, in the coffee zone of Colombia, Suárez et al. (1987) found that cows with a high proportion of european blood (7-8 liters of milk/day) produced 22% more milk when they had access to a leucaena protein bank as compared to those grazing only Pangola/*Paspalum* pastures. In contrast, in Honduras cows with a high proportion of cebu blood (2-3 liters milk/day) grazing *Panicum maximum* did not increase milk production when supplemented with leucaena (cited by Alvarado, 1984). In other studies carried-out in Cuba, leucaena has been shown to partially replace concentrate supplements in milking cows (cited by Ruiz et al., 1982).

Leucaena has also been used successfully to supplement calves in dual cattle purpose production systems. In the Dominican Republic, Báez et al. (1983) found that milking calves offered chopped leucaena (3% of body weight) in addition to residual milk and molasses/urea gained 530 g/day, while calves with the same basal diet and with access to a leucaena bank gained 430 g/day.

Pests and diseases. There have been few studies on pests and diseases affecting leucaena in the region. In a humid forest environment in Costa Rica, leucaena was found to be attacked by several fungi (*Rhizoctonia solani*, *Cercospora* sp., *Colletotrichum* sp. and *Fusarium* sp.), with some death, wilting and chlorosis in seedlings and adult plants (Pérez-Guerrero, 1982). In Colombia, Moreno et al. (1987), reported that the fungus *Camptomeris leucaenae* attacked mainly *L. leucocephala*, while "brown spot" (casual agent not identified) severely attacked *L. macrophylla*. Recently, Boa and Lenné (1993) surveyed diseases on woody legumes in México and Central America. The report stated that leucaena rust occured in native populations in the area, but without causing serious damage. However, pod damage due to a *Ravnelia/ Fusarium* complex was noted on trials with *L. salvadorensis* in Honduras.

The most serious pest that affects leucaena worldwide is pysillid (*Heteropsylla cubana*). Several examples of pysillid attack have been observed in Central America (Boa and Lenné, 1993). However, there are claims that pysillid has natural enemies (i.e. *Cycloneada sanguinea*, *Dioumus* sp., *Chrysopa* sp., *Tamaraxira leucaena*) and as a result the damage caused by the insect appears to be of little economic importance (Proverbs, 1983; Boucek, 1988). In the data base reviewed we did not find published reports on pysillid attack on leucaena grown in South America. However, it has been observed that in the Cauca Valley of Colombia, leucaena is periodically attacked by pysillid, particularly during periods of moisture stress (Rainer Schultze-Kraft, personal communication). In several documents reviewed from Central America, leaf cutting ants (*Atta* sp.) were mentioned as a serious problem in the establishment of leucaena, particularly at the seedling stage (Gutiérrez and Rodriguez, 1984).

Breeding. Some effort has been given in the region to breeding leucaena for low mimosine and for acid-soil tolerance. Breeding low-mimosine leucaena was attempted by intercrossing *L. pulverulenta* with *L. leucocephala* cv. Cunningham and back-crossing with Cunningham (Hutton, 1985). Results from this breeding project showed that there was some difficulty in retaining the low-mimosine found in *L. pulverulenta* in fertile back-crosses. Introduction of acid soil tolerance into leucaena was attempted by interspecific crosses of *L. leucocephala* with *L. pulverulenta* and *L. leucocephala* with *L. diversifolia* and *L. shannoni* (Hutton, 1984). This breeding program has not resulted in commercial lines, possibly related to the lack of convincing superiority in performance in acid soils of selected progenies.

AREAS IN THE REGION WITH POTENTIAL TO GROW LEUCAENA

There is a great deal of information on edaphic and environmental requirements for leucaena. It is generally agreed that leucaena can grow well in a wide variety of environments of the tropics and sub-tropics.

However, there are some well defined limitations in growing leucaena, such as acid soils with low base saturation, soils with poor drainage and environments with low temperature. In addition, results from a multilocational trial in Costa Rica showed that leucaena performed better in sites with a well defined dry season (Salazar et al., 1987).

To define broad areas in México, Central and South America best suited to grow leucaena, the Land Use Program of CIAT produced maps using the following criteria based on results from the literature: (1) soil pH (H_2O) >5.5, (2) base saturation >40%, (3) altitude <1500 m.a.s.l. and (4) dry periods of 3, 4, 5 and 6 months. For the South American map, they also included as criteria, a July temperature >6°C.

After a careful analysis of the map of México and Central America, it is not surprising to see that large areas of southern México (e.g. Yucatán Peninsula) and the dry pacific region of Central America (e.g. Guanacaste in Costa Rica, Choluteca in Honduras and Peninsula of Azuero, Panamá) are suited to grow leucaena. Most of the beef cattle are located in these drier areas in Central America. In the Caribbean region there are also large areas with the potential to grow leucaena, such as in Cuba, Haiti, Dominican Republic and other Caribbean Islands not highlighted in the map (e.g. Puerto Rico, Jamaica). Based on work carried-out by CATIE/ROCAP in Costa Rica (Salazar et al., 1987) it would seem that for the drier areas of Central America identified in the map, *L. leucocephala* is the most suited species to grow in locations with elevations that do not exceed 800 m.a.s.l. On the other hand, *L. diversifolia* would be the species of choice for areas with higher elevation (i.e. up to 1200 m.a.s.l.).

(Insert map of Central America)

The areas in South America with a potential to grow leucaena cover parts of Colombia, Venezuela, Guyana, Ecuador, Bolivia, Paraguay, northern Argentina, east and north-east Brazil. In Colombia, the areas suited for leucaena are mostly in the north coast, where there is a high population of beef and dual purpose cattle. Potential areas for leucaena in Venezuela cover the Maracaibo region, east and west of the Lake, and parts of the eastern Llanos (i.e. Guárico, Anzoátegui, Monagas) where cattle production is a major activity. As we move south, there are areas suited for leucaena in Ecuador around Guayaquil and Porto Viejo, in Bolivia around Santa Cruz and in Central Paraguay, all of which have large cattle inventories. In northern Argentina, leucaena has been grown experimentally in Formosa, Corrientes and Mercedes. In the INTA station of Mercedes, leucaena was introduced in the mid-1960's from Paraguay (ANON., 1981). Research carried-out in Mercedes indicated that leucaena established slowly but had great persistence under cutting and grazing. Winter frost in northern Argentina, causes little dieback on well developed leucaena plants and eventhough plants loose most of the leaves, there is rapid recovery in the spring (ANON., 1981). It would be interesting to evaluate in this region the natural hybrid of *L. diversifolia* x *L. leuceophala*, which was found to be frost-tolerant in S.E. Queensland, Australia (Gutteridge and Sorensson, 1992).

Areas suited for leucaena in Brazil cover parts of the so called "Matta Atlantica" characterized by rolling hills and dairy cattle. Our map also shows that areas in Minas Gerais and Bahia are suited to grow leucaena. In some areas in north-east Brasil, characterized by prolonged dry seasons (semi-arid tropics), leucaena can be an important source of fodder for goats, sheep and cattle (Salviano, 1984). For example, in the state of Sergipe, cattle grazing *Cenchrus ciliaris* + a leucaena protein bank gained 10 kg more than those grazing the grass only during a 5 month extreme dry season period (Carvalho Filho et al., 1984).

(Insert map of South America)

USE OF LEUCAENA IN PRODUCTION SYSTEMS

It is widely recognized that leucaena has multiple uses: (1) fodder for ruminants, (2) wood for pulp, fuel, and fence-post, (3) soil improvement through nitrogen fixation, green manure, and mulch, (4) erosion control when grown as hedges in hillsides, and (5) shade in some perennial crops, (e.g. coffee). Therefore, leucaena is adaptable to a wide range of production systems either based on pasture or limited-grazing, particularly in areas of the region with a well defined dry season. These systems can be broadly defined as:

1. Pasture systems with a combination of improved and native grasses and limited fodder or concentrate supplementation (i.e. large to medium size beef and dual purpose cattle farms which predominate in many regions of Central America, Colombia, Venezuela, Paraguay, Argentina, Brazil).

2. Forage systems with limited or zero-grazing, based on grass, agricultural crop residues or by-products with little or no concentrate supplementation (i.e. small farms in dry hillsides of Central America and Caribbean countries which integrate crops and livestock).

The two production systems described are characterized by poor pasture productivity (due to species limitation, lack of moisture and low or no fertilization) and low animal output. Lack of capital is a significant constraint in smallholder systems. Thus, leucaena in these systems can act as a source of nitrogen to associated grasses or crops and as a dry season protein supplement. In addition, properly managed hedgerows of leucaena can effectively reduce runoff and control erosion in hillsides of Central America and the Caribbean (Logan and Lal, 1990). Researchers from CATIE are evaluating leucaena in Costa Rica and

Nicaragua in alley-cropping systems with maize, sorghum and beans. One problem encountered is large quantities of leucaena seedlings in the alleys, which imposes additional weeding to eliminate competition with the annual crops.

In spite of the numerous benefits of leucaena, it is not widely used by farmers in areas where it has good environmental adaptation. Nevertheless, the authors know cases where leucaena is being used successfully in beef cattle operations. For example, in a farm in the Cauca Valley of Colombia, leucaena was established 10 years ago with star grass (64 ha). These pastures are stocked heavily (5 steers/ha) and LWG are in the order of 0.8 kg per day (Libreros, 1992). In another farm in the Cauca Valley, leucaena was established on a clay soil with *P. maximum* cv. Tobiatá and a mixture of the herbaceous legumes *Centrosema acutifolium*, *Arachis pintoi* and *Desmanthus virgatus*. Liveweight gain of steers grazing this pasture have been 500-700 g/A/day during a 12 month fattening period (Libreros, 1992). Recently in the Dominican Republic, we visited a livestock development project and found farmers planting leucaena as a dry season supplement for calves and milking cows.

FUTURE NEEDS

The large amount of positive research results using leucaena, together with observations on the successful use of this legume by some farmers, makes us wonder why there has not been more adoption of leucaena by farmers in the region. We propose two reasons for the low adoption of leucaena:

1. Lack of knowledge by farmers of the benefits that can be obtained with leucaena, which is in part due to poor communication of research results, and to a lack of convincing on-farm demonstrations.

2. High cost and risk of establishment of leucaena, associated with hard seed, low seedling vigour, slow initial growth, competition from weeds and attack by leaf cutting ants and by termites.

To promote the adoption of leucaena in areas of the region suited for existing cultivars, a major effort should be placed on developing low cost establishment methods (i.e. intercropping) and on evaluation of leucaena on farmers fields using participatory research methods. This could be best accomplished through forage networks. The network approach would facilitate communication of methods for on-farm evaluation of leucaena and of successful experiences on the use leucaena in different production systems. We also suggest that adoption of leucaena in the region could be enhanced through the development of effective seed multiplication and delivery system, which should be linked to on-farm research and development projects, in order to create demand for seed (Ferguson, 1993). Finally, we suggest that there are three priority research areas in the region: (1) definition of the effectiveness of natural control of pysillid, and the effect of dry season stress on damage caused by the insect, (2) evaluation of less known species of leucaena for wood production and quality, and (3) development of acid soil tolerant leucaena cultivars, since a large proportion of livestock in the Central and South America is found in areas with acid-infertile soils (i.e. Llanos óf Colombia, Cerrados of Brazil).

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Table 1. Germplasm of leucaena maintained at CIAT, Colombia (No. of accessions as of September 30, 1993).

Species of leucaena	Active collection	Multiplied for distribution	Field collection Palmira	Base collection*	Herbarium (No. specimens)
L. diversifolia	16	14	11	2	1
L. esculenta	6	4	5	-	-
L. greggii	2	2	1	-	-
L. lanceolata	9	7	8	-	2
L. leucocephala	126	114	114	81	16
L. macrophylla	13	12	13	-	4
L. pallida	1	1	1	-	-
L. pulverulenta	2	2	1	1	1
L. retusa	1	1	1	-	1
L. shannonii	4	2	3	-	1
L. trichodes	6	3	2	-	1
leucaena sp. and hybrids	12	8	7	1	6
Total leucaena	198	170	167	85	33

*In long-term storage.

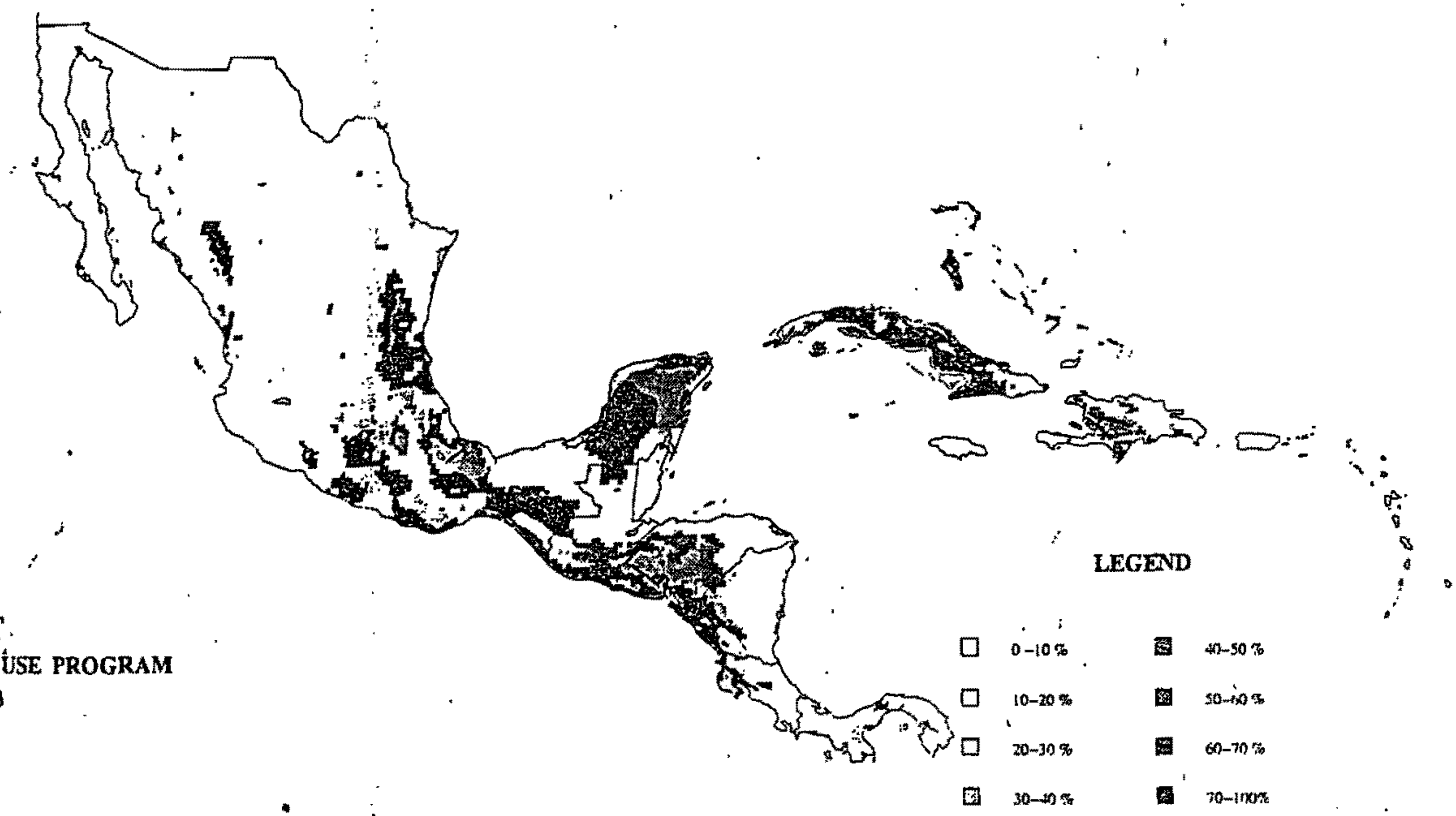
Table 2. Evaluation of *leucaena leucocephala* germplasm carried-out by researchers from national institutions in the International Tropical Pastures Network (RIEPT) in tropical America (Source: CIAT's Forage Germplasm database).

Country	Location	Altitude m.a.s.l.	Soil pH	Al Sat.	Rainfall (mm)	Dry months	No. of accessions evaluated	Outstanding accessions[1] (CIAT No.)
Costa Rica	Atenas	200	5.9	--	1600	6	84	7986, 9993, 17263, 17474*, 17500, 18481 and 18483
Panamá	Divisa	12	5.6	--	1700	4	10	17467, 17475*, 17478*, 17489 and 17502 (Cunningham)
Puerto Rico	Lajas	27	7.3	--	1100	5	21	7984, 17474*, 17491, 17502 (Cunningham)
Colombia	Tulenapa	24	5.8	--	2900	3	15	17475*, 17478* and 17491
Colombia	Palmira	1000	6.7	--	1100	5	13	17475*, 17488, 17491, 17498 and 17502 (Cunningham)
Colombia	La Romelia	1400	5.1	22	2700	2	33	17481, 17482, 17491, 17492 and 17502 (Cunningham)
Venezuela	El Tigre	260	4.9	8	930	6	20	7984, 17223 and 17474*
Paraguay	Caapucri	125	5.2	--	1500	--	26	734, 7385, 17493, 17498

[1]High edible forage yield and good dry season production.

*Hybrids of *L. leucocephala* x *L. pulverulenta*, backcrossed to *L. leucocephala* (M. Hutton)

AREAS IN MEXICO , CENTRAL AMERICA AND THE CARIBEAN WITH POTENTIAL TO GROW LEUCAENA



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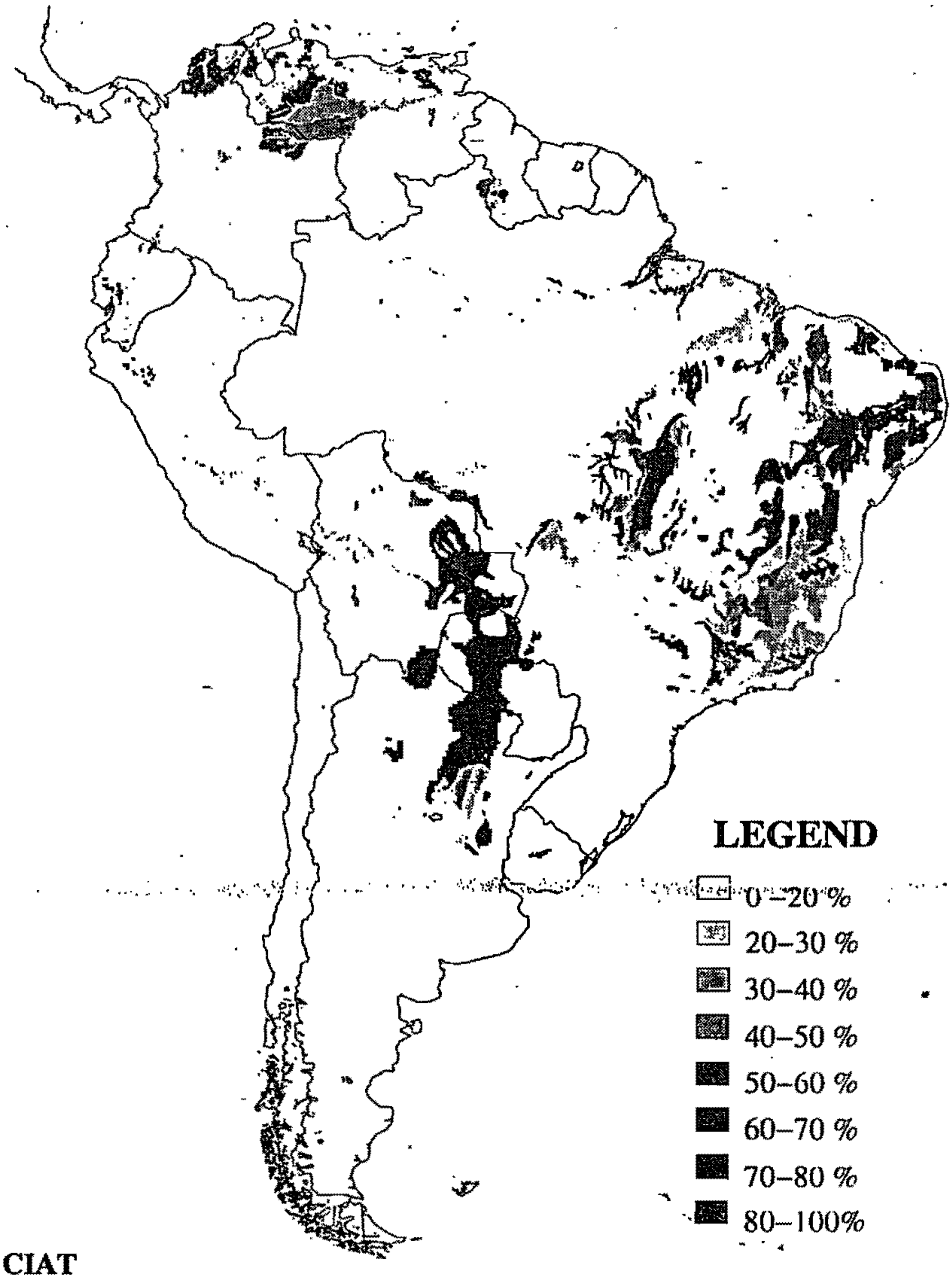
AREAS IN SOUTH AMERICA WITH POTENTIAL TO GROW LEUCAENA



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