Potential for Development and Priorities for Research

Leucaena in East Africa

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Abstract

The east African highlands face severe erosion problems, declining soil fertility and acute shortages of fodder and fuelwood. These problems are worsened by the region's rapid population growth, but may be reduced if leguminous trees are integrated into the farming systems. Adapted leucaena species and provenances have the potential to control erosion and conserve soil on sloping lands, to improve soil fertility and to supply quality fodder and wood products. Wide use of leucaena in the highlands of eastern Africa has been limited by poor adaptation of *Leucaena leucocephala* to the highly acidic, aluminium rich soils and the high altitudes. L. *diversifolia* provenances have shown tolerance to acidity, and recorded biomass yields comparable to the adapted tree, *Calliandra calothyrsus.* Use of *L. diversifolia* as green mulch and fodder has also shown very promising results. This paper outlines the potential for leucaena development in the east African highlands (rainfall > 1000 mm, altitude 1500-2900 m.a.s.l.), and discusses priorities for Leucaena research in the zone.

THE genus *Leucaena* has attracted considerable attention among scientists, development agencies and farmers in many parts of east Africa. Their interest is due to leucaena's potential to improve soil fertility, conserve soil, supply fuelwood, and as feed for livestock. Leucaena is also attractive because of its adaptation to a wide range of soil and climatic conditions, fast growth and ease of propagation (NAS 1977; Hulman et al. 1983). Recently, the Leucaena psyllid *(Heteropsylla cubana)* has devastated *Leucaena leucocephala* trees in many parts of the region, but other *Leucaena* species and provenances show great promise for fodder and soil fertility improvement in the highlands.

This paper presents brief results of leucaena performance in various technologies, discusses its potential for development and gives priorities for leucaena research in the highlands of east Africa.

The East African Highlands

The East African highlands zone is defined as land at 1000-2500 m above sea level, with a bimodal rainfall of at least 1000 mm/yr and a crop growing period of 90-270 days. The zone occupies a significant proportion of the total land area of Ethiopia, Kenya, Uganda, Burundi, Rwanda and a small area of Northern Tanzania (Fig. 1, Table l), and makes a large contribution to their total agricultural productivity.

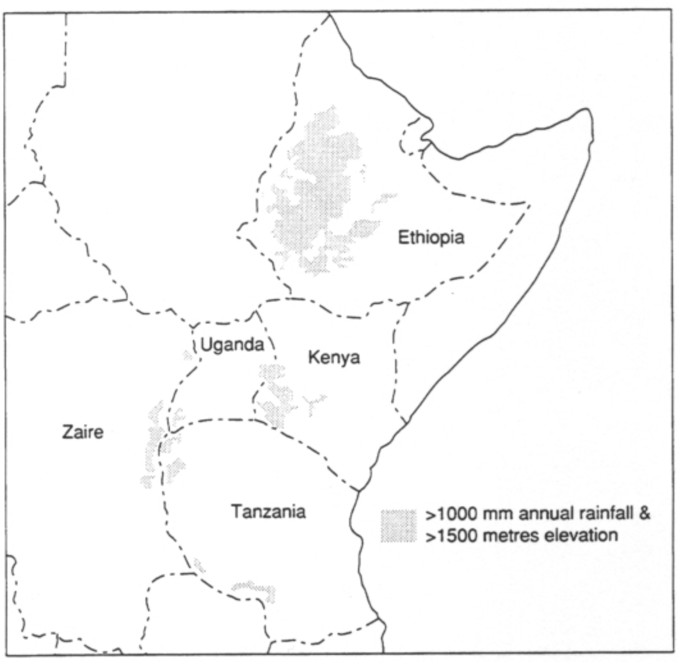

Figure 1. Delineation of the highlands of eastern and central Africa.

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Table 1. Land area covered by the bimodal highlands in East Africa.

Country	Land Area (km’)	% of Land Area
Ethiopia	1 223 000	43
Kenya	72 000	51
Uganda	96 000	40
Rwanda	16000	62
Burundi	23 000	85
Tanzania	2000	<5

From Hoekstra 1988.

The highlands comprise diverse land forms including very steep slopes, moderately steep and gentle slopes, plateaux and highland valleys. In the uplands or hillsides, common soil types are ferralsols, acrisols and nitosols. Predominant soils in the valley bottoms include vertisols, greysols and fluvisols (Hoekstra 1988; Hoekstra et al. 1990). Upland soils are acid in reaction (pH 4-6) and exhibit high aluminium and manganese phytotoxicity (Rowell 1988).

Rainfall is bimodal with peaks in March/April and in September/October. Total annual rainfall is generally 1000-1800 mm, with more rain in some areas (Hoekstra 1988). Mean annual temperature range is 14-20ºC, with a minimum of 8-14°C and a maximum of 20-30°C. Potential evapotranspiration varies between 1400 and 1900 mm/yr.

Landuse systems

The major landuse system is subsistence farming with highly fragmented holdings on all land forms. Mixed cropping is popular; main crops include coffee, tea, bananas, maize, wheat, potatoes and beans. Fallowing is possible in less densely populated areas, but continuous cropping is dominant (Hoekstra 1988; Hoekstra et al. 1990; Loevinsohn and Wang’ati 1993).

Livestock (cattle and small ruminants) are of secondary importance in the zone. Herding is common on natural grazing lands in less populated areas, but intensive production systems are necessary where there is high population pressure (Akyeampong 1993). Here, very little grazing land is left, and intensive cut and carry systems and tethering of animals are practised.

Major constraints include:

- increasing land degradation and deforestation accompanied by severe erosion of the top soil. This is further aggravated by increasing population densities in all countries. For example, in Burundi and Rwanda there are 180-250 persons/km* (Hoekstra 1988);
- soil acidity and aluminium toxicity, particularly on acrisols and ferralsols;
- insufficient fodder, of poor quality;
- scarcity of wood products, such as fuelwood, poles, timber and staking poles.

Current Research and Potential for Development

Current research results reviewed in this section are based on work carried out at the ICRAF, AFRENA sites in Burundi, Rwanda, Kenya and Uganda and at ILCA, Ethiopia.

Germplasm evaluation

Although a considerable amount of leucaena germplasm has been acquired by the ILCA genebank, few collections are suited to the cool, high altitudes and acid soil conditions of the east African highlands, so very limited multilocational trials have been done in the region. Preliminary results show good performance of *L. diversifolia* on the acid highland soils of Burundi, Rwanda and Kenya. *L. leucocephala* (Ethiopia) recorded high biomass yields, comparable to *L. diversifolia* and *Calliandra* after the first cutting at Maseno, Kenya (Otieno et al. 1991).

The highly variable performance of *Leucaena* species and provenances across sites in the zone provides a good opportunity for intensive screening and evaluation of suitable species and provenances adapted to the environmental conditions in east Africa.

Soil fertility maintenance and improvement

Agroforestry research in the region has concentrated on soil fertility improvement and erosion control through integration of multipurpose trees (MPTs).

Leucaena species yield variable amounts of mulch in alley cropping arrangements. At Maseno, two lines of *L. leucocephala* gave high initial leaf biomass yields, comparable to *Calliandra* and *Gliricidia* (Table 2). However, in Burundi *L. leucocephala* provenances performed very poorly compared to *L. diversifolia* and *Calliandra*. Acid-tolerant *L. diversifolia*, especially the locally adapted provenances Murongwe and Ruhande, gave consistently high biomass yields, comparable to calliandra, in repeated cuttings over four years (Table 3). In Rwanda, similarly high leaf biomass yields (Ruhande 4.19 t/ha/year) were reported for *L. diversifolia* (Niang et al. 1993).

Nutrient yields in fresh prunings followed a similar trend. Nitrogen yields were highest in calliandra (80 kg/ha/season) followed by the *L. diversifolia* provenances Ruhande and NFTA, which

Table 2. Fresh leafy biomass (t/ha) of MPTs under alley cropping.

Species/provenance	1st yr. Initial yield (t/ha)	2nd yr. Coppice yield (t/ha)
Leucaena leucocephala (China)	11.4	24.2
L. leucocephala (Belize)	10.9	24.4
Calliandra calothyrsus	17.3	36.7
Gliricidia sepium (Guatemala)	4.2	18.3
Sesbania sesban (Kakamega)	20.3	10.8
Cassia siamea (Siaya)	8.3	8.9
Anithrina caffra (Siaya)	7.4	17.1

From Heineman et al. 1990.

Table 3. Dry weight of prunings and woody material harvested over four years at Burundi.

	Prunings (t/ha)				Woody (t/ha)			
	1989	1990	1991	1992	1989	1990	1991	1992
C. calothyrsus (Guatemala)	0.9	3.6	1.9	2.8	1.0	3.6	3.0	3.4
L. diversifolia (Murongwe)	0.4	2.9	1.9	2.3	0.7	2.9	2.9	2.3
L. diversifolia (Ruhande)	0.4	3.3	1.9	2.3	0.5	2.4	3.1	2.6
L. diversifolia (Colombia)	0.5	1.8	1.0	1.5	0.3	1.1	1.0	1.5
C. spectabilis (Embu)	0.0	1.9	1.0	1.4	0.2	1.1	0.8	0.5
L. leucocephala (Siaya)	0.1	1.0	0.6	0.7	0.0	0.4	0.5	0.2
L. leucocephala (Kimberley)	0.2	0.8	0.5	0.4	0.0	0.6	0.2	0.1
L. leucocephala (Murongwe)	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
L. collinsii (Kibwezi)	0.0	0.3	0.3	0.2	0.0	0.1	0.0	0.0
SED	0.2	0.3	0.2	0.3	0.2	0.4	0.4	0.4

averaged 79.2 and 73.6 kg/ha/season respectively. *L. leucocephala* produced 40 kg/ha/season (Niang et al. 1993).

Maize yield responses to mulches applied in alley cropping were also variable. With *L. leucocephala* mulch, maize achieved a significant 45% increase in grain yield over no-hedge controls at Maseno, Kenya (Otieno et al. 1991) while, in a similar experiment in Burundi, yield increases were observed only after three years (Akyeampong 1993). In the Burundi trial, calliandra enhanced maize yields by *37-63%) L. diversifolia* by 27-43% and *Cassia siamia* by 33-38%. There was no apparent correlation between biomass applied and maize yield. Other trials in Burundi reported higher maize and bean yields following heavier applications of prunings from calliandra and leucaena or of farm-yard manure. The yield increases were attributed to decreased aluminium activity (Wong et al. 1993).

Clearly, the high-yielding provenances of *L. diversifolia* could be useful for supplying organic matter and nutrients, mainly nitrogen, to the soil. If growers apply mulches and green manures to crops they could reduce the problem of aluminium toxicity and improve soil fertility on acid soils (Hue and Amien 1989). The potential for soil fertility improvement is greatest in the food crop and livestock systems and coffee-based systems on ferralsols, acrisols and lithosols at altitudes below 2500 m.

Terracing and contour bunds are strategies adopted by farmers to reduce runoff and erosion. Multipurpose trees such as leucaena planted along contour bunds could play a significant role in stabilising contour bunds and reducing soil loss. Potential agroforestry technologies include hedge-rows of MPTs and grasses along contour bunds and upper-storey trees around croplands.

Livestock and fodder production

Fodder research has focused on improvement of fodder quality and quantity through integration of MPTs into the landuse systems. Experiments at Maseno, Kenya, reported fresh fodder yields from *Calliandra calothyrsus* of 12.6 kg/m, and of 9.7 kg/m for *L. leucocephala* on contour bunds. In Burundi, *L. diversifolia* associated well with *Tripsacum laxum* on contour bunds and did not affect yields of associated crops. Both tree and grass species benefited positively from the tree/grass associations. *L. diversifolia* and *C. calothyrsus* have so far proved the most productive and adapted fodder browse species in the zone.

Recent economic analysis indicates leucaena prunings would be more useful as a fodder supplement than as mulch in smallholder dairy systems in Kenya. Because of leucaena's high biomass and nutritional characteristics it can improve both fodder supply and fodder quality, offering most potential in intensive systems where cut and carry management is practiced. Fodder can be produced from hedgerows on croplands, contour bunds, fodder banks, boundary hedges and terrace planting of potential fodder trees.

Other uses

Rural household needs for wood are usually met by harvest from woodlots and pruning of trees such as *Grevillea robusta* on boundaries and croplands. Fast growing leucaena species and provenances, adapted to local soil conditions and altitudes, could supply needed wood products as by-products of soil fertility improvement, conservation and fodder improvement systems. *Leucaena* species can also be used as shade trees in coffee plantations, wind breaks around tea plots and banana fields (upper storey) and woodlots.

Research and Development Priorities

There is a gradual shift in research emphasis from *Leucaena* to other genera, such as *Sesbania, Calliandra, Mimosa* and *Alnus,* which seem to be more adapted to the acid soils and high altitudes. The arrival of the leucaena psyllid in the region has further reduced interest in leucaena research. As a result, there are major research needs to be addressed before leucaena can attain its full potential in the region. These include:

- suitable leucaena germplasm adapted to acid and aluminium toxic soils;
- proven psyllid tolerant or resistant leucaena species and provenances;
- understanding below- and above-ground interactions between leucaena and associated crops;
- knowledge of nutrient cycling potential in leucaena and the use of microsymbionts, especially mycorrhyzae, to increase nutrient availability on low P and N soils;
- simple and cost effective management methods appropriate to farmers' conditions;
- sources of certified seed.

Germplasm development and evaluation

Germplasm development should concentrate on the introduction, screening and evaluation of a wider range of species and provenances of *Leucaena.* The aim is to identify material adapted to the acid soils, high altitudes and rainfall regimes, tolerant of aluminium, and resistant to the psyllid and other potential pests.

Researchers need to assemble and evaluate a wider range of germplasm for its nutritional quality and anti-nutritional factors. Then they can select agronomically-superior accessions with good nutritional quality that are well-adapted to the east African highlands. Collections from the highlands of south and central America could have promise in east Africa.

We need quality seed of proven genotypes, and schemes promoting its marketing and distribution to smallholder farmers.

Soil fertility improvement and erosion control

Farmers need appropriate and cost-effective technologies for soil improvement and erosion control. Researchers should develop and evaluate methods to encourage fast establishment, such as direct seeding or use of cuttings. The productive potential of single- and mixed-species hedges must be examined. Techniques need to be studied further, such as optimum cutting regimes and the effects of management on the interbund crops.

Special research attention should focus on understanding below- and above-ground interactions between tree and crop components to determine any net biophysical benefits of such associations. The effects of organic matter applied as prunings should be investigated — does it reduce aluminium and manganese phytotoxicity, and does it contribute nutrients other than nitrogen? Researchers should examine the use of microsymbionts, such as mycorrhyzae, to increase nutrient (nitrogen and phosphorus) availability to both trees and crops.

Fodder production

Intensive management systems are needed to improve both the quantity and quality of fodder. As a priority, palatable and nutritious *Leucaena* species and provenances must be identified. Their optimum densities in pure and mixed-species stands must be determined. Research must define cutting management strategies to optimise dry season fodder quantity and quality, and evaluate fodder species with low mimosine and anti-nutritional compounds. Research results from other parts of the world may be applicable to this region.

Wood production

Research priorities for wood production should be linked to the development of technologies such as boundary and contour planting, providing wood as a secondary product. Appropriate species must be screened and evaluated. Establishment methods, thinning management and sustainable utilisation must be determined.

Conclusion

The genus Leucaena can potentially alleviate many landuse constraints identified in the east African highland region. Its greatest potential is in fodder production and soil fertility improvement. Current leucaena research is preliminary and limited to a narrow range of species and provenances. Identification of adapted *Leucaena* species and provenances, and evaluation of effective methods of integration and management in farming systems in the region, would go a long way towards meeting farmers' needs for food and wood production as well as soil conservation. Coordinated research efforts should be encouraged, involving farmers, national research institutions and international research centres.

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Leucaena in Subhumid Southern Africa

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Abstract

The genus *Leucaena* is recognised throughout the tropics as potential livestock fodder, green manure and fuelwood, and for other uses. This paper briefly reviews trials at sites across Southern Africa that are evaluating the adaptation of a range of *Leucaena* species and provenances to the region's sub-humid and low soil-fertility conditions. Alternatives to *L. leucocephala* are emerging, including *L. diversifolia, L. pallida, L. esculenta* and specific hybrids of *L. diversifolia* and *L. leucocephala.* Some of the best performing species are also known to be resistant to the leucaena psyllid while others tolerate the region's acid soils, droughts and frosts. The paper highlights the potential for future development of leucaena as a crop and priorities for research.

MALAWI, Zambia and Zimbabwe are among several Southern African countries that have recognised the potential of leucaena, growing it for fodder and agroforestry systems. Plantings have been based on the single species Leucaena leucocephala which, because of its narrow genetic base, has facilitated the widespread impact of the leucaena psyllid (Het*eropsylla cubana)* throughout the tropics. In addition *L. leucocephala* grows poorly on acid soils and lacks cold and drought tolerance (Brewbaker, 1985; Hughes, 1993).

Within its natural range the genus *Leucaena* comprises some 17 species, spread over 30 degrees of latitude and 2000 m altitude, found in Mexico, Central America, and northern South America (Zarate 1984; Brewbaker 1987; Hughes 1993). Such wide genetic variation in diverse natural populations and environments makes it probable that alternative *Leucaena* species and provenances will be found that overcome the limitations of *L. leucocephala.* However, the potential of such alternatives remains largely untapped in the Southern African region.

Recent introductions of *Leucaena* species and provenances, representing much of the spectrum of germplasm available, are currently being evaluated. These introductions, from all known taxa of natural populations from northern South and Central America, have been collected by the Oxford Forestry Institute (OFI) in the United Kingdom (Hughes, 1993), the Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO) and the Centro International de Agricultural Tropical (CIAT) of Colombia.

By describing what has been learnt in the regional evaluation exercise, this paper identifies the potential for development of leucaena as a crop in Southern Africa, and sets priorities for future research.

The New Introductions

Table 1 lists the major species and provenances recently introduced into the Southern African region. The species are known to vary considerably in growth and biomass production. At sites across Malawi, Zambia and Zimbabwe, total biomass yield ranged from 2 to 20 t/ha when the species and provenances were harvested after 18 months of growth (Dzowela 1993a; Kamara et al. 1993; Maghembe et al. 1993).

Thirty accessions of the genus were evaluated for adaptation to sub-humid conditions at high altitude (> 1200 m) on acid soils in Zimbabwe. These species and provenances showed up to a twenty-fold variation in total biomass production (Maasdorp 1992). Despite the wide range of results, two clusters of species and provenances emerged, one which performed well and another which performed poorly. In the top-yielding group were provenances of *L.*

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Table 1. Seed sources of *Leucaena* species and provenances recently introduced to the Southern African region (Zambia, Malawi and Zimbabwe).

Name of species	OFI or provenance code	Origin	Country	Rainfall (mm)	Altitude (m above sea level)
L. collinsii	45/85	Guatemala	Mexico	400-550	948
L. collinsii	45/88	Marcisco Mendoza	Mexico	400-550	400-500
L. collinsii	51188	Aldea chacaj	Guatemala	1000	700
L. collinsii	56188	Gualan	Guatemala	723	100-200
L. collinsii	57/88	El Carrizal	Guatemala	na	500-600
L. esculenta subsp. *matudae*	49/87	Mezala	Mexico	730	550-750
L. esculenta	47/87	Pachivia	Mexico	1264	1610
L. esculenta	48/87	Tiringucha	Mexico	na	600
L. esculenta	52/87	Chapulco	Mexico	528	2100
L. diversifolia	45/87	Corral falso	Mexico	na	800
L. diversifolia subsp. *stenocarpa*	53/88	Los Guates	Guatemala	na	1400-1500
L. diversifolia subsp. *diversifolia*	46/87	Jalapa	Mexico	na	1200-1350
L. diversifolia subsp. *stenocarpa*	35188	Zambrano	Honduras	na	1150
L. lanceolata	43/88	San Jon	Mexico	na	0
L. lanceolata var. *glabrata*	50187	Cacalote	Mexico	na	0-100
L. leucocephala	K28	Isiolo	Kenya	na	na
L. leucocephala subsp. *glabrata*	32/88	Bulk collection	Haiti/Guatemala	na	na
L. macrophylla subsp. *nelsonii*	47/85	San Isidro	Mexico	1040	10
L. macrophylla	55/88	Vallecitos	Mexico	na	1150
L. multicapitula	81187	Las Santos	Panama	na	10-15
L. pulverulenta	83/87	Atlas Cumbes	Mexico	749	1000-1500
L. pulverulenta	84/87	S. Texas	USA	na	10-30
L. salvadorensis	17/86	Lagarita	Honduras	1120	480-600
L. salvadorensis	34/88	Calaire	Honduras	200	350-500
L. shannonii	19/84	Chiquimula	Guatemala	928	900-950
L. shannonii	53187	Champoton	Mexico	1132	0-20
L. shannonii	58187	Quetzaltepeque	Guatemala	928	500-600
L. trichodes	2/86	Cuicas	Venezuela	751	450-700
L. trichodes	6/88	Jipijapa	Ecuador	na	150-400
L. pallida	G2137	Oaxaca	Mexico	470	2150
L. leucocephala x *diversifolia*	CPI85890 29A-12	na	Brazil	na	na
L. leucocephala x *diversifolia*	K743 =K8 x K156	na	na	na	na
L. diversifolia	CIAT17388	na	Mexico	na	na
L. macrophylla	CIATl7241	na	Mexico	na	na
L. lanceolata	CIAT17255	na	Mexico	na	na

esculenta, *L. leucocephala*, *L. diversifolia*, *L. collinsii*, *L. pallida* and hybrid materials from specific crosses involving *L. leucocephala* and *L. diversifolia*. The low yielding group included some provenances of *L. collinsii*, *L. salvadorensis*, *L. trichodes* and *L. shannonii* which showed poor survival of the record drought of the 1991-92 season.

All species and provenances had adequate foliar levels of mineral nutrients, particularly phosphorus (Maghembe, unpublished data). This is important if the plants are to be used for fodder during dry seasons in the tropics, when these minerals may be deficient in the usual basal diet of poor quality crop residues and native grasses.

Psyllid Resistance

Work is currently underway to find Leucaena species and provenances which resist the Leucaena psyllid *(Heteropsylla cubana)*. The psyllid arrived on the African continent in 1992 in East Africa and Southern Africa (Malawi, Tanzania and Kenya). Some of the newly introduced leucaena accessions appear to show excellent resistance (Moses Karachi, pers. comm.). Among these are *L. collinsii*, *L. diversifolia*, *L. pallida*, *L. esculenta* and the interspecific hybrids derived from crosses of *L. diversifolia* x *L. pallida*, as previously reported by Wheeler and Brewbaker (1990).

Growth in Adverse Conditions

Low soil fertility

The high rainfall areas (> 1200 mm) of Northern Zambia have highly acidic soils (pH 4.5 in H_2O) associated with a high aluminium saturation. Most *L. leucocephala* plantings do not grow well in soils that are so acid and relatively infertile unless the soils are supplemented with lime and fertilizers. In Northern Zambia, one exception has been the superior performance of *L. diversifolia* x *L. leucocephala* hybrid KX3, which is derived from the specific cross of K156 x K8 (Lungu and Solberg 1988). In drier environments (but in acid, infertile, granitic sandy soil conditions) in Zimbabwe, Maasdorp (1992) found *L. pallida*, *L. diversifolia* and hybrids of *L. leucocephala* and *L. diversifolia* to be better adapted. These findings are particularly important because these accessions are potentially tolerant to the Leucaena pysllid.

Tolerance to drought and frost

For *Leucaena* species to be adapted to the Southern African subregion they must withstand the seven month dry season from May to November. This is coupled with ground frosts in winter in Zimbabwe in June and July, when average mean temperatures are as low as 6°C and for two to three weeks the minimum temperatures can go below 0°C. Consequently, growth ceases, and frost at this time can result in damage to growing tips and dieback of main stems and primary and secondary branches. Several *Leucaena* species and provenances are currently being assessed for resistance to frost damage in Zimbabwe, through the agroforestry project supported by ICRAF. The introductions with best potential to withstand frost are *L. shannonii* OFI 58/88 and OFI 19/84, *L. diversifolia* OFI 53/88 and *L. pulverulenta* OFI 83/87 (Table 2).

Fodder production in these areas depends on species and provenances retaining their foliage during the dry season. In general, plants that are able to retain their foliage are also able to initiate growth in spring (August-October) before the main rainy season begins. The same species and accessions that show best frost tolerance (above) also retain more leaves during the dry season months (Table 2). When left uncut during the whole dry season they initiate new growth much earlier and at a faster rate

Table 2. The performance of some *Leucaena* species and provenances in adverse conditions in Zimbabwe.

Leucaena species or provenances	Damage by cold or frost on 0-5 scale	Retention of foliage in dry season on 0-5 scale	Initiation of dry season growth on 0-5 scale	Dry season 5-month coppice height (cm)
L. diversifolia No. 53/88	0.67	2.33	1.33	58.7
L. shannonii No. 58/88	0.33	3.33	1.67	42.0
L. esculenta No. 52/87	2.67	0.33	0.33	0.0
L. pallida No. CPI8590	1.33	1.00	0.67	114.0
L. trichodes No. 61/88	1.67	1.33	1.00	112.0
L. trichodes No. 2/86	2.00	0.33	1.33	0.0
L. salvadorensis No. 34/88	0.67	1.00	2.00	57.0
L. esculenta No. 47/87	1.00	1.67	0.00	31.3
L. Ieucocephala x *L. diversifolia* No. 172	1.67	0.33	2.33	80.0
L. diversifolia No. 35/88	1.33	1.67	0.67	129.3
L. pulverulenta No. 83/87	0.67	1.33	1.67	58.7
L. shannonii No. 19/84	0.33	2.67	1.67	36.7
L. leucocephala x *L. diversifolia* No. 171	1.33	2.33	2.33	78.7
L. diversifolia No. 45/87	1.33	1.00	0.00	3.7
L. diversifolia No. 46/87	2.33	0.00	0.00	0.0
Mean	1.29	1.38	1.13	53.4
SED ±	0.52***	0.45***	0.45***	21.67***
CV(%)	24.4	17.0	15.6	14.5

*** significant at p<0.001

Characteristics scored on a scale of 0-5 as follows:

Damage by cold:	0 = no damage	5 = maximum stem & twig dieback
Retention of foliage:	0 = maximum leaf fall	5 = all foliage retained
Initiation of dry season growth:	0 = no new growth	5 = early initiation of new growth

than other introductions. However, when all the plants were cut back at the end of the wet season of 1992/93 the two hybrid materials involving *L. leucocephala x L. diversifolia* (Nos. 171 and 172) and *L. salvadorensis* OFI 34/88 demonstrated a better capacity for regrowth.

Directions for Future Research and Potential for Development

Biological control of the leucaena psyllid is urgently needed to safeguard successful research on Leucaena itself. One way to achieve this control is by avoiding *L. leucocephala* provenances and concentrating instead on alternative resistant species and provenances in the region. For instance, *L. collinsii, L. diversifolia, L. pallida, L. esculenta* and hybrids between *Leucaena* species could all be checked for possible resistance, as could other high yielding species such as *Acacia angustissima* syn. *boliviana* and *Calliandra calothyrsus.*

To make this possible, seed resources need to be widely available for testing and development. This could result from concerted efforts between national, regional and international institutions operating in Africa. Centres such as the International Livestock Centre for Africa (ILCA) and the International Centre for Research in Agroforestry (ICRAF) could contribute germplasm, facilitating its evaluation across different ecological regions.

There is potential for leucaena to be developed as part of smallholder agroforestry systems that integrate crops, trees and animals. Farming households and communities would appreciate leucaena's multiple products such as fodder, fuelwood and organic fertilizer. Some *Leucaena* species and provenances may reduce soil erosion while growing good quality fodder and fuelwood, and these would have more appeal to farm families than would herbaceous forage legumes (Dzowela 1993b).

Shortage of fuelwood is common in most, densely populated areas of the Southern African region. As a result, localised environmental degradation has followed massive deforestation of the tropical forest cover, especially the Miombo woodlands. Most countries in the region now set aside days when communities get involved in tree planting. However, these activities are invariably based on traditional plantation genera such as *Eucalyptus* and *Pinus.* If *Leucaena* species and provenances were grown they could have long-lasting environmental impact, and produce substantial quantities of wood products. Species such as *L. diversifolia, L. pallida* and *L. pulverulenta* could easily be included in these plantings once their wood quality has been assessed.

Ruminant livestock appear to reject some *Leucaena* species — for example *L. pulverulenta, L. esculenta* and *L. pallida* — and may not eat them at all. In a preliminary study in Zimbabwe, Dzowela and Hove (unpublished data) found that goats rejected these species in favour of *L. leucocephala* in a cafeteria palatability test. High tannin levels are suspected as the cause. Further work is needed to test the potential for feeding these new *Leucaena* species to livestock.

Research is essential to test how rainfall regimes (moisture-drought) and nutrient uptake affect the biomass yield responses of a range of *Leucaena* species and provenances. To be effective, this research needs a collaborative network of scientists, disciplines and countries, so that genetic resources, research methods and information may be shared.

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Leucaena in the Humid Lowlands of West Africa

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Abstract

The potential for development of leucaena in the humid lowlands of west and central Africa is reviewed. Factors limiting the use of the species in the region are highlighted, as are the research priorities required to overcome the species' limitations. Leucaena has fast growth, has high biomass production and is good value as fodder. These characteristics make it a potentially useful 'fodder bank' or live-fence to improve the management of small livestock (goats, sheep, poultry and pigs). Leucaena is a potentially useful source of nitrogen when planted as hedgerows for intercropping with vegetables or cereals, substituting for the traditional fallow phase to improve soil fertility. If well managed, leucaena can give high quality shade for cash crops. Constraints include leucaena's intolerance to the region's acid soils, and its tendency to spread as a weed. Selection of appropriate provenances or varieties is a major research priority, as is knowledge of leucaena's management requirements in the context of region's farming systems.

WITHIN the genus *Leucaena*, *L. leucocephala* (Lam) de Wit (known as leucaena) is a thoroughly researched tropical tree legume of immense potential that has been widely introduced throughout Africa and Asia. Currently, it grows throughout the tropics in cultivated areas and abandoned farm lands (Keay et al. 1964; Brewbaker and Sorensson 1993). Leucaena produces good quality wood for timber, construction, firewood and pulp and paper manufacturing. Several research studies have demonstrated its potential for soil conservation through nitrogen fixation, nutrient cycling and erosion control. The leaves are known to be fodder of excellent quality (NAS 1979a; 1980).

In West and Central Africa, leucaena is used to improve poor soils and to provide fodder. Most of the on-going agroforestry research and development in the region uses *L. leucocephala* and focuses on soil fertility improvement and fodder production. Under optimum growth conditions, the species could be of remarkable benefit. However, genetic, environmental and management factors limit the full exploitation of the species. For example, it is poorly suited to the acid soils which constitute most of those of the humid lowlands of west and central Africa. Even on non-acid soils, the species requires a minimum level of soil fertility for initial establishment (NAP 1984). The well known pest, the leucaena psyllid, is already severely damaging plantations in Kenya and Tanzania and may soon reach West Africa.

This paper reviews leucaena's potential and some research findings relevant to the humid lowlands of west and central Africa. It also highlights the major constraints limiting leucaena's use and distribution in the sub-region and indicates research priorities.

The Humid Lowlands of West and Central Africa

The humid tropics can be defined as areas with annual precipitation of more than 1500 mm and a growing period of 270-365 days, often covered by rainforest vegetation. The mean annual temperature is usually above 22°C, with little (< 5°C) seasonal or diurnal variation (Brooks 1979; National Research Council 1982).

Most of the soils of West and Central Africa are highly weathered, of low inherent fertility and erodible. They generally exhibit good physical properties but poor chemical properties. The clay fraction of these soils contain iron and aluminium oxides, and the soils often are of very low pH. These acid soils limit the wider use of leucaena in the sub-region.

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The dominant farming systems in these areas are based on shifting cultivation practices designed to produce both staple food and cash crops.

Food crop production

The productivity of the system depends on the length of the fallow period allowed between the cropping phases. With increasing human population this essential phase is being reduced, so declining soil fertility is one of the major constraints associated with the cropping cycle. Fast-growing, nitrogen-fixing tree legumes, such as leucaena, may be able to enhance soil fertility in the sub-region. Many research activities, some of which are discussed in this paper, are testing leucaena's potential to do so.

Cash crop production

Cocoa and coffee are the dominant tree crops grown by the small scale farmers of the region. From an agroforestry perspective, the system is limited by low quality shade and poor soil fertility (Duguma et al. 1990). If properly managed, leucaena may help solve these problems. However, the recent drop in world market prices for both cocoa and coffee means the decision to invest to improve such systems needs to be carefully evaluated.

Livestock production

Small livestock dominate the animal component in the land use system of the humid lowlands of West and Central Africa. Rudimentary management techniques, lack of quality feed sources and problems such as the destruction of crops by animals, limit the number of livestock managed per household. If high quality leucaena fodder were cultivated as a fodder bank or live-fence near the homestead, farmers would be encouraged to manage more animals in enclosures.

Potential for Using Leucaena in the Region

Fodder

The small livestock are either run free-range or are tethered. In some cases, they are kept in enclosures and fed with household wastes (Orok and Duguma 1987; Duguma et al. 1990). In densely populated areas such as southeastern Nigeria, animal feed is scarce. Consequently, farmers walk long distances and spend several hours collecting and transporting fodder from the wild to feed their enclosed livestock. As untethered animals destroy crops, free-ranging is allowed only during the brief dry period when no food crops are grown. Even then, the practice is a major cause of disagreements between villagers, as the animals often damage stored products or those being processed after harvesting.

To overcome the problem of feeding livestock, the Humid Program of the International Livestock Centre for Africa (ILCA) developed a technology referred to as 'intensive feed garden' or 'fodder bank' (Atta-Krah et al. 1986). Mixtures of high quality legumes and/or legume and grass are planted around the homestead to produce adequate, high-quality fodder on relatively small plots, on a sustainable basis at low cost. Leucaena is top of the list for this technology because of its fast growth, high biomass production and high leaf protein content (19-26% crude protein by weight). The amino acid value, digestibility and other nutritional qualities of leucaena foliage are comparable to those of cultivated fodders such as alfalfa (Akbar and Gupta 1984).

In drier areas of the humid lowlands, fodder supply can be critically low during the short dry period. Leucaena produces green foliage during the dry period when the grass and other shrubs are unavailable or provide only lower quality fodder (Duguma et al. 1988a). Under favourable conditions, leucaena can yield 10-20 t/ha/yr of edible dry matter, compared with 8-9 t/ha/yr for alfalfa (NAS 1979b).

However, the biomass production of the genus *Leucaena* is highly variable, depending on species, varieties and/or provenances. In a browse productivity evaluation study conducted on the acid soils of eastern Nigeria, the total biomass yield from one year's primary growth of *L. leucocephala* accessions, planted at 0.2 m x 1 m spacing, ranged from 0.76 t/ha for K8 to 7.04 for K28. With three prunings carried out between June and May, the total biomass of the coppice growth varied from 3.53 t/ha to 16.64 t/ha with fodder harvest index of over 40% (Table 1). Most of the lesser known *Leucaena* species *(L. esculenta, L. lanceolata, L. macrophylla, L. pallida, L. retusa, L. salvadorensis* and *L. shannonii)* are browsed in their natural habitat or lopped for fodder (Brewbaker and Sorensson 1993).

It is obvious that adequate, sustainable and nutritious fodder needs to be grown to improve livestock productivity in the humid zone. The high genetic diversity of leucaena in its natural habitat offers an excellent opportunity to satisfy this need.

Soil improvement

Since the early 1970s, researchers in the West African region have been working to develop a low input technology to improve soil fertility as an alternative to shifting cultivation. The aim is to promote productive and sustainable permanent farming

Table 1. Total biomass yield (t DM/ha) of primary and coppice growth of leucaena and gliricidia accessions grown on acid soils (from Cobbina et al. 1990).

Tree species	Primary growth[1]	Coppice growth				Fodder harvest index
		First Jun-Aug	Second Sept-Jan	Third Feb-May	Total[2]	
Leucaena K28	7.04a	4.23a	5.51a	6.90	16.64	0.45
Gliricidia HYB	5.02ab	3.75a	1.19c	5.33ab	10.27abc	0.45
Leucaena K150	4.10bc	2.68ab	4.15ab	6.48ab	13.32ab	0.42
Leucaena K309	3.84bc	2.32ab	1.67c	3.46ab	7.46bc	0.47
Gliricidia STP	3.37bc	3.05ab	1.0%	4.25ab	8.37bc	0.45
Gliricidia ILG-50	2.34c	2.50b	1.09c	2.95ab	6.54c	0.41
Leucaena K4	2.04cd	1.56c	2.08bc	4.60ab	8.24bc	0.38
Leucaena K304	1.14d	0.70c	0.37d	2.93b	4.01d	0.40
Leucaena K8	0.76e	0.76	0.62d	2.14b	3.53d	0.43
cv (%)[3]	5.24	5.30	7.15	7.49	3.89	

[1] Harvested 12 months after planting
[2] Total of three prunings made in a year
[3] Analysis of variance was carried out on log,, transformed data
a-e Means followed by same letter(s) are not significantly different (p = 0.05) by Duncan's multiple range test

through efficient and appropriate use of locally and/or naturally available resources. However, earlier and on-going forestry experiments in the region have given inconclusive results. Yields of maize intercropped with green manure from leucaena hedgerows are better than yields from traditional systems (Kang et al. 1981; Kang and Duguma 1985; Siaw et al. 1991). However, reduced yields have been reported for root and tuber crops and for some legumes like cowpeas (Duguma et al. 1988a; Karim et al 1991; IRA/ICRAF 1992; Rosecrance et al. 1992).

L. leucocephala is the species most widely used to develop low input systems. In the humid lowlands of Nigeria, leucaena inoculated with a suitable rhizobium strain fixed an equivalent of 133 kg/ha of nitrogen (Sanginga et al. 1989). Approaches being evaluated include the use of leucaena in hedgerow intercropping and in rotational fallow.

In a hedgerow intercropping trial in southern Nigeria, vegetable yields increased by as much in a leucaena fallow as they did from application of leucaena mulch plus inorganic fertilizer (30N, 13P at 14 kg/ha). Yields were about double those recorded for the control plot (natural fallow without fertilizer) (Palada et al. 1992). In the humid lowlands of Cameroon, a two-year rotational fallow with mixed leucaena and gliricidia hedgerows improved maize grain yield by more than 150% for two consecutive years compared to the yield from continuous cropping with no hedge (Table 2) (IRA/ICRAF 1992, 1993). Similar results are reported by Mittal et al. (1992).

These results show that leucaena could play a major role in developing a sustainable low-input technology to improve productivity in the farming systems of the humid zone.

Table 2. Maize grain yield response to various leucaena and gliricidia fallow managements in a rotational hedgerow system (from IRA/ICRAF 1992, 1993).

Treatment	Maize grain yield (t/ha)	
	1992	1993
Continuous cropping + no tree	3.54	2.54
Continuous cropping + leucaena and gliricidia	4.79	5.09
Two years of leucaena and gliricidia fallow + two years of cropping	6.28	6.94
SED	0.35*	0.36*

* Significant at p = 0.01

Shade

In the cash crop farms at present, naturally existing trees of economic importance are retained as shade trees. Most are mature tropical timber species, without controlled densities. Improving the shade quality of these would be very difficult. Although little research has been done, fast-growing nitrogen-fixing species like leucaena are known to have good shade characteristics (NAP 1984). Planted at chosen densities, they could provide adequate shade in relatively short periods of time, and later pruning could enhance shade quality.

Constraints to Using Leucaena in the Region

Adaptation

Leucaena can only be exploited if the species can be propagated easily and optimum growth is maintained. Many of the soils of the humid tropics are acidic, although most of the areas under cultivation are not (Sanchez 1976). It is very difficult to establish leucaena on acid soil (Hu and Cheng 1980; Fox and Sheldon 1981; IRA/ICRAF 1993). Aluminium toxicity and limited availability and uptake of phosphorus are among factors affecting plant growth on acid soils (Juo and Uzu 1977), but an added factor in leucaena's intolerance is the difficulty of establishing effective nitrogen-fixing symbiosis at low pH (Halliday 1981). The early establishment and growth of leucaena can be improved by applying lime and phosphorus (Duguma et al. 1988b). While this seems economically and scientifically sound, it would be very difficult for resource-poor farmers to put into practice.

The need for acid-tolerant species remains vital to the developing soil improvement technology in the region. Most known *Leucaena* species seem to favour calcareous soils, though Brewbaker and Sorensson (1993) have suggested *L. diversifolia, L. collinsii* and *L. multicapitulata* as possible sources of acid tolerance. However, these species may not be good fodder and a simple screening program may not be adequate.

Weediness

Leucaena's rapid spread over a wide geographical area has been fostered by its profuse seeding and hence easy availability of germplasm. However, this attribute also means that leucaena can easily invade an area and become a noxious weed.

Leucaena leucocephala was brought into the cropping system of the humid lowlands of Cameroon in early 1987 to evaluate the species' potential for improving soil fertility when managed as intercropped hedgerows. Five years later, farmers acknowledged the species' benefit to soil fertility, but complained about its weediness. Some farmers intended to uproot the trees before it was too late, while almost all of them preferred *Calliandra calothyrsus* and *Cajanus cajan* rather than leucaena. Weediness is most pronounced in the self-fertile species characterised by high seediness, but there are several self-sterile species which could be included in future improvement work.

Pests and diseases

Currently, there are no known pest or disease problems associated with leucaena in the humid lowlands of west Africa. However, attack by the much publicised leucaena psyllid, which is spreading from southern and eastern Africa, seems to be inevitable in the near future.

In 1989, the African continent was virtually free of the insect. By 1993, the pest was causing considerable damage to leucaena plantations throughout Kenya, Tanzania and Uganda. By early 1994, the psyllid had reached Malawi in southern Africa. Its arrival in west Africa may be imminent. This prospect is causing concern, and appropriate prevention strategies need to be developed.

Research Priorities

Provenance and variety evaluation

Much of the *Leucaena* germplasm (mainly *L. leucocephala)* used in early research in the humid lowlands of West and Central Africa came from the Oxford Forestry Institute (OFI) in the UK and Nitrogen Fixing Tree Association (NFTA) in Hawaii. Since then seeds have been produced, distributed and exchanged freely, without effective control or appropriate documentation.

The Gliricidia Evaluation Network, which operated in the 1980s in the region, provided excellent opportunities to select the best performing lines for specific locations in the region. It is very important for *Leucaena* species and provenances to be similarly evaluated in the region before carrying out any improvement work.

Since the region's soils are mainly acidic, the use of leucaena is limited until promising provenances and varieties are subjected to selection and breeding for acid tolerance. Some lines of *L. leucocephala, L. macrophylla* (NAP 1984), *L. diversifolia, L. collinsii* and *L. multicapitulata* (Brewbaker and Sorensson 1993) are reported to tolerate acid soil. However, no systematic screening or breeding work has been done in the region. With some 17 *Leucaena* species available, and the genus known to grow over a wide geographical area, there is a good chance of overcoming the problem.

Another concern is leucaena's weediness when grown as part of systems with a fallow period. Although the problem is aggravated by self-fertile species, there are also less seedy self-sterile species capable of hybridising with species having desirable properties. There is good potential for improving the situation, but to be effective, concerted international effort is crucial. The OFI, the University of Hawaii (UH) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, with their long experience of collecting and breeding *Leucaena* germplasm, could initiate and coordinate research networks and make germplasm available. Other international centres — for example, the International Centre for Research in Agroforestry (ICRAF), the International Livestock Centre for Africa (ILCA) and the International Institute of Tropical Agriculture (IITA) — could facilitate evaluation across a wide range of sites depending on local needs and requirements. These agencies have close contact with national programs, and research facilities in West and Central Africa.

Management studies

Most leucaena research in the region focuses on managing the species for soil fertility or for fodder production. So far, the results obtained appear variable, as if they are location-specific. Strategic research, essential to develop a viable technology, is conspicuously absent. In-depth investigations are needed to make best use of leucaena, in particular to identify its management requirements in various systems and to understand its characteristics and responses under selected management practices.

Conclusion

In conclusion, in the humid lowlands of West and Central Africa, leucaena is most likely to be used for animal fodder and for soil fertility improvement and conservation. Its potential as a shade tree in cash crop production is also high. In this region leucaena is less likely to be used as timber or firewood or for pulp and paper production, though these could be significant uses in other locations.

The most important constraint limiting leucaena's introduction to the region is its inability to grow on acid or aluminium toxic soils. Pest and diseases are not a major problem at present, but steps need to be taken to prevent future problems. The tendency of earlier leucaena introductions to become weeds seems to discourage the region's farmers from planting leucaena.

Important research priorities for this region include selection of suitable provenances for specific locations, and selection and breeding for acid tolerance and for non-weediness. Further research is also required on the management requirements of the species when grown in some of the region's farming systems.

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Leucaena in Central and South America

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Abstract

This paper briefly reviews the abundant research on *Leucaena leucocephala* and other *Leucaena* species in Central America, the Caribbean and South American countries. Germplasm has been evaluated; establishment, forage quality and toxicity, animal responses, pests, diseases and breeding have been studied. Existing cultivars of leucaena mainly suit large areas on the Pacific coast of Central America and in the Caribbean, particularly Cuba, Haiti and the Dominican Republic, and some 'niches' in South America extending from northern South America (i.e. Venezuela, Guyana and Colombia) to eastern Brazil and northern Argentina. These regions could greatly benefit from leucaena as a source of protein, fuelwood and fence-posts. Leucaena can also play an important role in minimising soil erosion. In spite of its usefulness, leucaena has *not* been widely adopted in the region. This paper suggests ways to encourage the growing of leucaena and proposes research priorities.

THE genus *Leucaena,* native to Mexico and Central America, consists of a large number of species ranging from shrubs to large trees. This paper briefly reviews research with leucaena between 1980 and 1992 in countries of Central America, the Caribbean and South America. It describes macro-regions and agricultural production systems which could benefit from leucaena, and identifies needs for research and development with *Leucaena* species.

Research on Leucaena

Germplasm evaluation

In the early and mid-1980s, *Leucaena* germplasm from the University of Hawaii was evaluated for forage yield, mimosine content and, to a lesser extent, for wood production. For example, forage yield was high from *L. leucocephala* K62 in Tocumen, Panama (Mendoza 1981), and from K4 in Chiriqui, Panama (Sanchez 1982). Also in Panama, K324 showed consistently lower levels of mimosine than did other accessions (Vargas and Tempone 1982). In Brazil, *Leucaena* genotypes were screened for Al tolerance (Maluf et al. 1984) and the genotype X environment interaction was examined (Costa and Alves 1987). In the Rondonia area, cv. Peru was more productive on a soil of pH 6.5, but cv. Cunningham performed better on a soil of pH 5.9.

Currently, an important source of *Leucaena* germplasm for the region is Centro International de Agricultura Tropical (CIAT). Its Genetic Resources Unit 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 (more than 50 accessions which mostly orginated from Mexico), the Nitrogen Fixing Tree Association (about 20 accessions) and the IDRC (Canada) collections in Antigua and Belize (about 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 is duplicated in a field collection at Palmira (Table 1).

Leucaena germplasm has been distributed in the region largely through the International Pastures Evaluation Network (Red International de Evaluación de Pastas Tropicales, RIEPT) which was established by CIAT in the early 1980s. During the last 10 years, about 150 samples of *Leucaena* germplasm have been distributed each year to a total of 11 countries in Central America, the Caribbean and South America. As a result, superior accessions have been identified for different environments (Table 2).

[1] Tropical Forages Program, Centro International de Agricultura Tropical (CIAT), Apartado Aereo 6713, Cali, Colombia

[2] AFN-SAREC Project, Centro Agronomico Tropical de Investigation y Ensenanaza (CATIE), Turrialba, Costa Rica

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 (0.345 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).

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 specimens (No.)
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. %	Annual rainfall (mm)	Dry months	No. of accessions evaluated	Outstanding accessions* (CIAT No.)
Costa Rica	Atenas	200	5.9	-	1600	6	84	7986, 9993, 17263, 17474**, 17500, 18481 and 18483
Panama	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

* High edible forage yield and good dry season production
** Hybrids of *L. leucocephala* x *L. pulverulenta,* backcrossed to *L. leucocephala* (E.M. Hutton)

Several trials in RIEPT have confirmed the poor adaptation of leucaena to acid soils with high Al saturation (>40%), which are prevalent in the Amazon forest margins (Florencia, Caqueta in Colombia; Pucallpa in Peru) and in some locations in the Andean hillsides (Mondomo, Cauca in Colombia). Work in the cerrados of Brazil suggested that leucaena's poor adaptation to acid soils is related to calcium deficiency rather than to aluminium toxicity (Hutton 1984).

In Costa Rica, Honduras and Nicaragua, several projects outside RIEPT (eg. MADALENA, AFN-SAREC) are evaluating *Leucaena* germplasm for forage and wood production. For example, AFN-SAREC is a project in the Centro Agronómico Tropical de Investigation y Ensenanza (CATIE) which 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* had grown better than *L. leucocephala*. In a project in Honduras, some provenances of *L. collinsii* ssp. *collinsii* and *Zacapana*, *L. diversifolia*, *L. macrophylla* ssp. *nelsonii*, *L. multicapitulata* and *L. salvadorensis* have yielded at least as much wood as well known cultivars of *L. leucocephala* (K8, K636).

Evidently there is plenty of *Leucaena* germplasm in the region and its performance in different environments is known, particularly in terms of forage production. However, lesser-known species of *Leucaena* must be evaluated for wood production and quality.

Establishment

Leucaena is limited by its slow establishment. Researchers have investigated seed treatment, planting patterns and density, weed control, fertilizing and liming, and inoculation with rhizobia and mycorrhiza.

Of 22 research papers reviewed, two considered the use of a nurse crop to reduce the cost of establishment. In Brazil and in Panama, leucaena intercropped with corn had a yield that was depressed by up to 50% at 150 days, but with considerable decreases in establishment costs (Gonzalez and Rivera 1983; Andrade and Alcantara 1985). Corn yields were highest when it was sown 15 or 30 days after the leucaena.

Weed control practices have been examined in some site-specific research. In Cuba, Ruiz et al. (1989) found that pre-emergent herbicides combined with mechanical cultivation helped control annual grasses and broadleaf weeds. Effective weed control at establishment has been achieved in Caribbean countries by allowing broadleaf weeds and grasses to germinate after land preparation, and then applying glyphosate (Proverbs 1983).

Most reports indicate that leucaena responds positively to applications of phosphorus, calcium and sulphur in fertilizers. Leucaena has been shown to nodulate with native rhizobium strains, but the introduction of more effective strains has resulted in significant forage yield increases (Lopez and Taboada 1983; Tang et al. 1983; Valarini and Bufarah 1984; Bueno et al. 1985).

Forage quality and animal responses

There is abundant regional information on the chemical composition of leucaena forage, and some data on mimosine levels and their toxic effects in cattle and sheep. In Brazil, sheep fed only leucaena hay (cv. Peru) showed toxicity in some studies (Franzolin 1984) but not in others (Saavedra 1986). This difference was probably related to absence or presence of DHP-degrading bacteria. Rodríguez and Borges (1989) found that only 40% of the plant protein was digested in the rumen. This high level of by-pass protein is possibly related to condensed tannins present in the leucaena.

Liveweight gain (LWG) and milk yield responses to leucaena have been variable. For example, in Campo Grande, Brazil, LWG of steers did not respond to a protein bank of Leucaena (30% of the area) mainly because the plants grew poorly in the location's acid soils (Seiffert 1982). In contrast, in Bolivia, steers with access to a leucaena protein bank (30% of the area) gained three times more liveweight (700 g/day) during the dry season than steers grazing only *Hyparrhenia rufa* (Paterson et al. 1983).

Milk yield responses depend on the cows' potential for milk production. For example in Colombia, cows with a high proportion of European blood (giving 7-8 L of milk/day) with access to a leucaena protein bank gave 22% more milk than cows grazing only Pangola/paspalum pastures (Suarez et al. 1987). In Honduras, cows with a high proportion of zebu blood (2-3 L milk/day) grazing *Panicum maximum* gave no extra milk when supplemented with leucaena (cited by Alvarado 1984). Leucaena can partially replace concentrate supplements in milking cows (in Cuba, cited by Ruiz et al. 1982) and can supplement calves in dual-purpose cattle production systems. Calves in the Dominican Republic offered chopped leucaena (3% of body weight), as well as residual milk and a molasses-urea mixture, gained 530 g/day, while calves with the same basal diet and with access to a leucaena bank gained 430 g/day (Baez et al. 1983).

Pests and diseases

There are few studies on leucaena pests and diseases in the region. In a humid forest environment in Costa Rica, leucaena was attacked by several fungi

(Rhizoctonia solani, Cercospora sp., *Colletotrichum* sp. and *Fusarium* sp.), with some death, wilting and chlorosis in seedlings and adult plants (Perez-Guerrero 1982). In Colombia, Moreno et al. (1987), reported that the fungus *Camptomeris leucaenae* attacked mainly *L. leucocephala,* while 'brown spot' (causal agent not identified) severely attacked *L. macrophylla*. Boa and Lenne (1993) surveyed diseases on woody legumes in Mexico and Central America and reported leucaena rust in native populations in the area, but no serious damage. However, a *Ravnelia-Fusarium* complex damaged pods in trials with *L. salvadorensis* in Honduras.

Attacks by the leucaena psyllid *(Heteropsylla cubana)* have been observed several times in Central America (Boa and Lenné 1993). However, the psyllid may have natural enemies (i.e. *Cycloneada sanguinea*, *Dioumus* sp., *Chrysopa* sp. and *Tamaraxira leucaena)* and as a result the insect appears to have caused little damage of economic importance (Proverbs 1983; Boucek 1988). We found no published reports of psyllid damage in South America, but it attacks leucaena periodically in the Cauca Valley of Colombia, particularly during periods of moisture stress (Rainer Schultze-Kraft, pers. comm.). Leaf-cutting ants *(Atta* sp.) appear to be a serious problem for leucaena establishment in Central America, particularly at the seedling stage (Gutierrez and Rodriguez 1984).

Breeding

Breeding low-mimosine leucaena has been attempted by intercrossing *L. pulverulenta* with *L. leucocephala* cv. Cunningham and back-crossing with Cunningham (Hutton 1985). The results showed it was difficult to retain the low-mimosine levels found in *L. pulverulenta* through to the fertile back-crosses. Introduction of acid soil tolerance into leucaena was attempted by interspecific crosses of *L. leucocephala* with *L. pulverulenta, L. diversifolia* and *L. shannoni* (Hutton 1984). This breeding program has not resulted in commercial lines, possibly because selected progeny lack convincingly superior performance in acid soils.

Areas in the Region with Potential to Grow Leucaena

Leucaena can grow well in a wide variety of environments in the tropics and sub-tropics, but it has some well-defined limitations, such as acid soils with low base saturation, soils with poor drainage and environments with low temperature. A multi-locational 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 Mexico, 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.1.;
(4) dry periods of 3, 4, 5 and 6 months.
(For the South American map, CIAT included a July temperature >6°C as one criterion.)

The map of Mexico and Central America (Fig. 1) shows that large areas of southern Mexico (e.g. Yucatan Peninsula) and the dry Pacific region of Central America (e.g. Guanacaste in Costa Rica, Choluteca in Honduras and Peninsula of Azuero, Panama) are suitable for growing leucaena. Most of the beef cattle are located in these drier areas in Central America. In the Caribbean region, large areas have the potential to grow leucaena, such as in Cuba, Haiti, Dominican Republic and other Caribbean Islands not highlighted on the map (e.g. Puerto Rico, Jamaica). For the drier areas of Central America identified in the map, studies by CATIE/ROCAP in Costa Rica (Salazar et al. 1987) have indicated *L. leucocephala* to be the best species to grow at elevations of up to 800 m a.s.1. On the other hand, *L. diversifolia* would be the species to grow in areas with higher elevations up to 1200 m a.s.1.

In South America (Fig. 2), leucaena can grow in parts of Colombia, Venezuela, Guyana, Ecuador, Bolivia, Paraguay, northern Argentina and east and northeast Brazil. In Colombia, the areas suited for leucaena are mostly on the north coast, where there are large populations 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. Guarico, Anzoategui and Monagas) where cattle production is a major activity. Moving south, there are areas suited to leucaena in Ecuador around Guayaquil and Porto Viejo, in Bolivia around Santa Cruz and in Central Paraguay, all of which have large numbers of cattle. In northern Argentina, leucaena has been grown experimentally in Formosa, Corrientes and Mercedes. On the INTA research station (Instituto National de Tecnologia Agropecuaria) at Mercedes, leucaena was introduced in the mid-1960s from Paraguay (Anon. 1981). It established slowly, but persisted well under cutting and grazing. Winter frost in northern Argentina causes little dieback on well developed leucaena plants and, although plants lose most of their 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

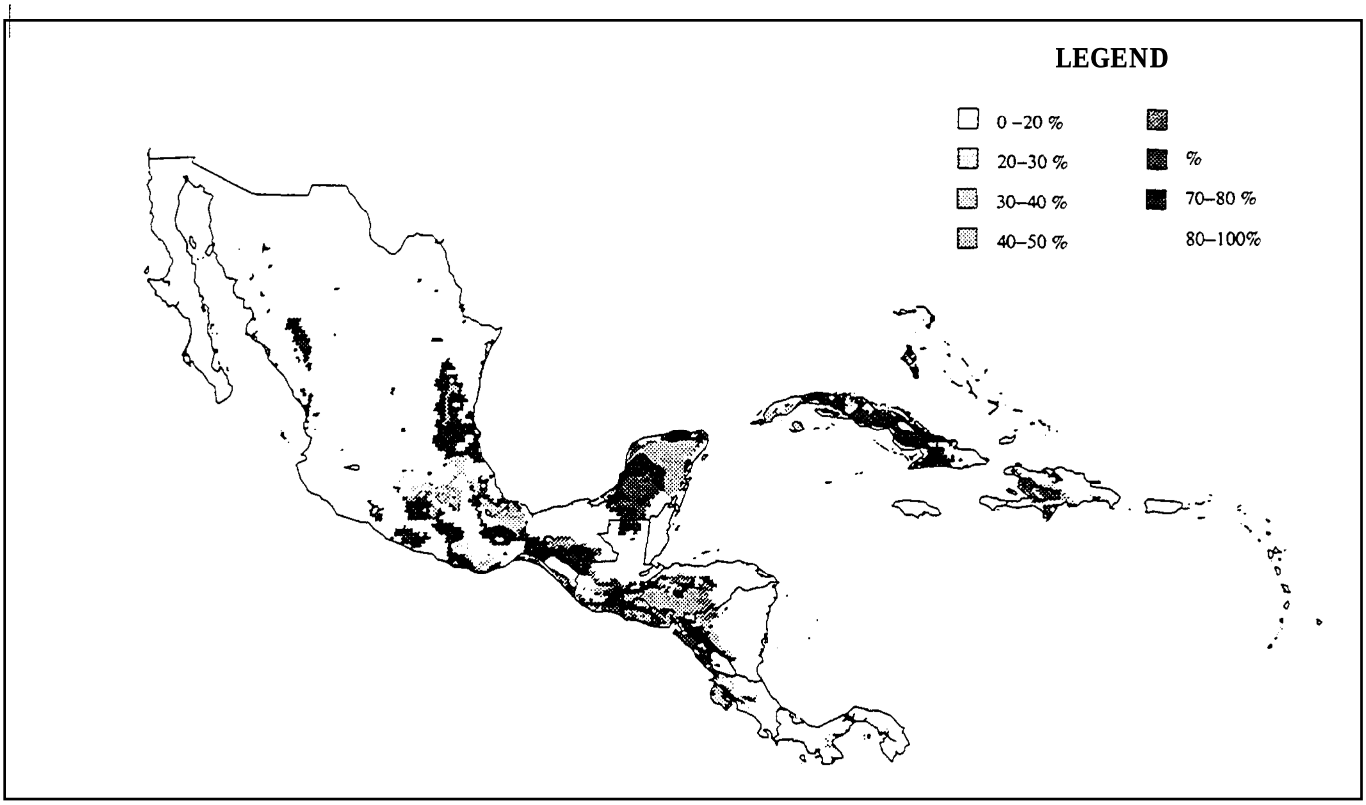

Figure 1. Areas in Mexico, Central America and the Caribbean with potential to grow leucaena. The range (%) indicates the proportion of the area mapped that fits the criteria (i.e. soil pH, temperature) stipulated to grow leucaena.

tolerate frost in S.E. Queensland, Australia (Gutteridge and Sorensson 1992).

In Brazil, areas suited for leucaena include parts of the so called 'Matta Atlantica', characterised by rolling hills and dairy cattle, and areas in Minas Gerais and Bahia. During the prolonged dry seasons of northeast Brazil (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 during an extreme, five month dry season, cattle grazing *Cenchrus ciliaris* with a leucaena protein bank gained 10 kg more than those grazing only grass (Carvalho Filho et al. 1984).

Use of Leucaena in Production Systems

Leucaena's multiple uses for fodder, wood, soil nitrogen fixation, green manure, mulch, hillside erosion control and shade for some perennial crops (e.g. coffee) make it adaptable to a wide range of production systems, particularly in areas with a well defined dry season. These systems can be broadly defined as

- 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,

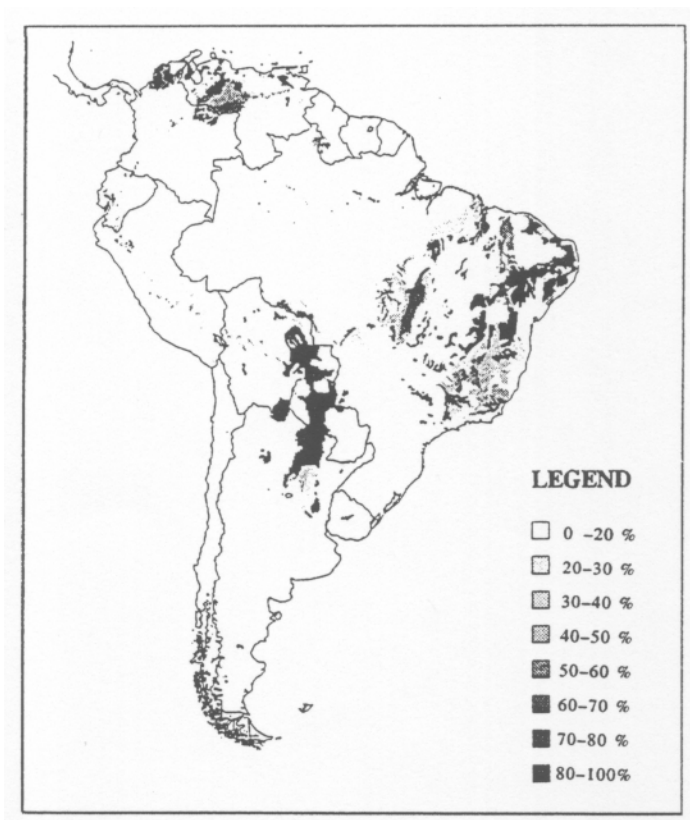

Figure 2. Areas in South America with potential to grow leucaena. The range (%) indicates the proportion of the area mapped that fits the criteria (i.e. soil pH, temperature) stipulated to grow leucaena.

Colombia, Venezuela, Paraguay, Argentina and Brazil)

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

These two production systems are characterised by low animal and pasture productivity (because of limited species, lack of moisture and lack of fertilizers). Smallholders are also constrained by lack of capital. In these systems leucaena can provide nitrogen to associated grasses or crops and be a dry season protein supplement. Properly managed hedgerows of leucaena can effectively reduce runoff and control erosion from hillsides of Central America and the Caribbean (Logan and Lal 1990). In Costa Rica and Nicaragua, CATIE researchers are evaluating leucaena in alley-cropping systems with maize, sorghum and beans. Many leucaena seedlings have to be weeded out of the alleys so that they do not compete with the annual crops.

In spite of its potential, leucaena is not widely used by farmers, although the authors do know farms where leucaena is a successful part of beef cattle operations. For example, in the Cauca Valley of Colombia, two farmers have established leucaena with either star grass or, on a clay soil, with *Panicum maximum* cv. Tobiata and a mixture of the herbaceous legumes *Centrosema acutifolium, Arachis pintoi* and *Desmanthus virgatus.* Steers on these pastures have gained 500-800 g/day (Libreros 1992). In a livestock development project in the Dominican Republic, farmers are planting leucaena as a dry season supplement for calves and milking cows.

Future Needs

We propose two reasons for the low adoption of leucaena:

- farmers do not know what benefits they can gain from leucaena, partly due to poor communication of research results and a lack of convincing on-farm demonstrations;
- establishing leucaena is expensive and risky because of its hard seed, low seedling vigour, slow initial growth, weed competition and attack by leaf-cutting ants and termites.

To encourage farmers in suitable regions to grow existing leucaena cultivars, a major effort should be made to develop low-cost establishment methods, such as intercropping. Leucaena should be evaluated in farmers' fields, using participatory research methods. This could be best accomplished through forage networks. The network approach would provide opportunities to learn about methods of on-farm evaluation of leucaena and about successful experiences with leucaena in different production systems. We suggest that more leucaena would be grown in the region if an effective seed multiplication and delivery system were developed, linked to on-farm research and development projects to create the demand for seed (Ferguson 1993).

Finally, we suggest that the following research questions are important for the region:

1. How effective is the natural control of leucaena psyllid, and what effect does dry season stress have on psyllid damage?
2. How much wood, of what quality, do less-known species of leucaena produce?
3. Can leucaena cultivars be developed which tolerate the acid-infertile soils on which a large proportion of livestock in Central and South America is found (e.g. Llanos of Colombia, Cerrados of Brazil)?

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Leucaena in the Northwest Region of Corrientes Province, Argentina

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Abstract

Two grazing trials were conducted in the humid subtropical northwest of Corrientes Province in northeast Argentina. In the first trial, cattle allowed access to a leucaena protein bank during each of three successive winters gained 44-100% more weight daily than control animals fed only native pasture. In the other trial, steers kept on a mixed leucaena-pangola grass pasture gained 36 ± 1% more weight per year than control animals grazing native pasture. Leucaena is the only legume used extensively in pastures in Corrientes, and its use has potential to significantly raise production indices of growing and finishing animals.

CORRIENTES Province is an area of about 8 million ha, situated in the extreme northeast of Argentina from latitude 27ºS to 31ºS. Bounded on the west by the Parana River and on the east by the Uruguay River, Corrientes borders Paraguay to the north, Brazil to the east and Uruguay to the southeast. Corrientes is one of the major grazing areas of Argentina, supporting about four million cattle, two million sheep and three hundred thousand horses.

The region is in the humid subtropics and is described as a subtropical 'campos and bosques' ecosystem (Royo Pallares 1990), with no dry season (Pappadakis 1975). The average temperature decreases from north to south. December and January are the warmest months, with average daily temperatures up to 26°C. July is the coldest month, with average temperature 13ºC. Between May and October each year there are about a dozen light frosts, with three severe frosts (to –8ºC) during June, July and August. Average annual rainfall is 1210 ± 309 mm, with January and February being the driest months.

Local soils vary considerably. Many are acidic and infertile, deficient in nitrogen, phosphorus, sodium and organic matter, and often lacking calcium and magnesium as well. Sandy soils are frequently deficient in sulfur. Most of the soils have structural problems that lead to poor drainage. Semi-annual flooding is common in some regions.

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Most livestock feed on native pastures ('range') comprising primarily perennial grasses and grass-like plants. Legumes are scarce and contribute little to total dry matter yield, which is high in spring and summer but almost zero in winter. Annual dry matter yields vary from 2.5 t/ha to 10 t/ha on the range. In some places, improved pastures raise the level of nutrition of livestock. The principal improved species grown in the region are *Digitaria decumbens, Setaria sphacellata* var. Sericea cvs. Narok and Kazungula, *Cynodon plectostachyus, Cynodon dactylon* x *C. nlemfluensis* Coast Cross 1, *Hermathria altissima* and *Pennisetum purpureum. Leucaena leucocephala* is the only legume used extensively.

Most beef cattle graze range pastures continuously, with little or no supplemental feeding and little access to improved pastures (Goldfarb et al. 1993). Heifers are first mated at 36 months. The number of calves that are branded averages 40-45% the number of cows, with an average weight of 150 kg at weaning. Meat production is 30 kg/ha/year. This productivity is low mainly because of poor nutrition, though other factors also contribute.

Leucaena Grazing Trials

Protein bank trial

In the northwest of Corrientes Province, the forage is deficient in nitrogen in winter. Protein supplements combined with improved or native pastures can overcome the nitrogen and energy deficiencies that are the main factors causing low production indices in growing and finishing animals (Gándara et al. 1986).

Weight gains of heifers and dry cows grazing range pasture were measured during three successive winters (198 l-l 983) with and without supplementation from *Leucaena leucocephala* cvs. Peru and Cunningham as a protein bank. Treatment animals had access to this bank for between 8 and 11.5 hours each day. The control group of cattle were kept on native range. In 1981, 18 month-old heifers were used; in 1982, dry cows, and in 1983, six-month weaned heifers.

The control group's pasture had a standing dry matter yield of 2.5 t/ha and 2.1 t/ha at the beginning and end of winter respectively (averaged over the three years). The leucaena-supplemented animals grazed range with a standing dry matter yield of 2.2 t/ha and 1.5 t/ha for the same period. Standing dry matter yield of leucaena (averaged over three years) was 1.9 t/ha, comprising 72% leaf and stem and 28% pods.

The animals grazing leucaena showed no symptoms of mimosine toxicity. Half the heifers grazing leucaena reached breeding weight at an average age of 18 months. Animals with access to leucaena gained 44%, 113% or 110% more weight per day than control animals in 1981, 1982 or 1983, respectively (Table 1 gives further details).

Pangola grass-leucaena trial

Daily weight gains of six-month-old steers were measured during 1989/90 and 1990/91 (Gándara and Casco 1993). Leucaena had been sown in spring 1987 in rows five metres apart, with pangola grass between the rows. Grazing began in 1989 at 2 steers/ha/year. Different animals were used in the following year. Control animals grazed a native pasture at 1 steer/ha/yr. Pangola-plus-leucaena pasture was more efficient than native pasture, since animal production from 1 ha of the mixed pasture was equivalent to that from 3 ha of native pasture (Table 2).

Conclusions

Leucaena has excellent potential to increase animal production in the northwest of Corrientes Province in Argentina. Leucaena produces good quality forage in reasonable quantity, and seeds well.

Table 1. Details of the protein bank trial and resulting weight gains.

	Control			+ Leucaena		
	1981	1982	1983	1981	1982	1983
Initial weight (kg)	221	307	115	217	317	115
Area of native pasture (ha)	27.6	30.0	13.5	21.2	76.0	11.1
Area of leucaena (ha)	-	-	-	4.5	21.0	4.7
Total area (ha)	27.6	30.0	13.5	25.7	97.0	15.8
No. of animals	19	22	12	18	75	14
Stocking density (animals/ha)	0.69	0.73	0.89	0.70	0.77	0.89
Stocking rate (AUE/ha)	0.42	0.55	0.44	0.43	0.58	0.44
Daily weight gains (g/animal/day)	357	114	190	541	243	399

Table 2. Weight gains of young steers on pangola + leucaena or native pastures.

	Animal Weight Gain (kg/an/yr)		
Pasture	1989/90	1990/91	Average
Native	95	140	117
pangola + leucaena	127	191	159
% increment of mixed vs native	35	36	36

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Leucaena in Honduras

E. Ponce[1]

Abstract

Four native species of *Leucaena* which occur naturally in Honduras are being investigated and their use is being promoted by projects initiated by CONSEFORH and Oxford Forestry Institute. Previously, *Leucaena leucocephala* had been widely introduced and planted. Leucaena's most important local uses are as live fencing, construction timber, fuelwood and green manure. Sometimes leucaena leaves are fed to rabbits, pigs and cattle. *Leucaena salvadorensis* is well managed in natural stands by local farmers who appreciate its production potential. *Leucaena shannonii* has been overused and few trees remain. *Leucaena diversifolia* is not as good a fuel as trees of other genera, so its in situ conservation status is probably good. The potential of a new species, *L. lempiriana* ined., recently identified by CONSEFORH, is being tested. CONSEFORH is concentrating on developing management methods to show farmers how to grow local *Leucaena* species for specific end uses. Ideally, in situ conservation of leucaena will become part of the general reforestation of Honduras, and local stands will be kept genetically pure by not introducing exotic species into those areas.

CONSEFORH is a bilateral project between the governments of Honduras and Great Britain, started in 1987 to combat the depletion of the Honduran forest estate including dry forest, cloud forest, conifer forest and humid forest zones. The project aims to assist forest conservation by:

- exploring genetic resources, especially of priority species, and recording these species' uses, silviculture and conservation status;
- collecting seed from endangered or threatened native species;
- importing seed of fast-growing exotic tree species; nursery production, trial and seed orchard establishment;
- production of improved seed;
- developing conservation strategies for forest remnants;
- demonstrating agroforestry techniques;
- controlling and managing data with a computerised database;
- doing applied research in cloud forests to develop strategies for their conservation and management;
- transferring technology.

Over the last ten years the potential of the genus *Leucaena* has been much discussed and researched, and leucaena trees have been introduced for several different reasons. At the same time, several institutions have become interested in multipurpose tree species.

The seventeen species of *Leucaena* are native to Central America, Mexico and the southern United States (Hellin and Hughes1993). Central American institutions, such as MADALENA, INAFOR and BANSEFOR, have promoted the use of leucaena in many different ways, but without adequate knowledge of the potential of each species to produce specific end products under optimum management. In Honduras, the MADALENA, LUPE and COHASA projects promoted *L. leucocephala,* especially to small farmers, hence the country's widespread planting of this species.

Exploratory work by Oxford Forestry Institute (OFI) has identified other native *Leucaena* species that offer potential at least equal to that of *L. leucocephala*. Early research and promotion by CONSEFORH has encouraged use of other Leucaena species in small scale reforestation programs and agroforestry. One very important aim is for the in situ conservation of *L. salvadorensis,* a species which has shown itself to be of considerable value in plantations (Hellin and Hughes 1993).

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Table 1. *Leucaena* species native to Honduras.

Species	Distribution	Elevation (m.a.s.1.)	Forest zone
L. salvadorensis	Southern region	200-800	Tropical dry forest
L. shannonii sub. *shannonii*	Central and northern valleys	100-950	Tropical dry and humid forests
L. diversifolia	Some buffer zones	1000-2000	Tropical montane forest and coniferous forest
L. lempiriana new species	Northern valleys	200-600	Tropical dry forest
L. leucocephala subsp. *glabrata*[1]	Central northern and southern valleys	100-1200	Tropical dry forest and tropical humid forest

[1] Species naturalised in the country

Species Distribution and Status

Five *Leucaena* species grow in Honduras (Hellin and Hughes 1993), varying in distribution according to their natural habitat and conservation status (Table 1). Some have a restricted range and others, such as *L. shannonii*, have suffered significant genetic degradation. Four species are native to the country and the fifth, *L. leucocephala*, is now regarded as naturalised. It has been widely planted because technicians have been ignorant of the qualities of other *Leucaena* species. However, local people have used native *Leucaena* species for a long time, fully aware of the benefits of each and its most appropriate management.

For some of the native species, an exact distribution is not known. Only a few stands have been encountered in specific areas. The distribution of *L. salvadorensis* is limited to the southern regions — Choluteca, El Paraiso, Francisco Morazan and Valle. In Nicaragua it is restricted to the northwest of the Departamento de Leon and the south of the Departamento de Madriz. Apparently in El Salvador it is found only in the east, but its exact location has not been verified (CONSEFORH 1991; Hellin and Hughes 1993). This species has been exploited in some areas where it grows naturally, but its in situ conservation status can be considered secure. This is particularly true in areas where campesinos (farmers) manage *L. salvadorensis* variously for forage, construction timber, fuelwood, agroforestry benefits and live fencing. The last use is crucial to conservation, even if the genetic resource is reduced.

Leucaena shannonii has a relatively large range, but to date no pure stands of this species have been found. The only records are of isolated trees or groups of three or four trees which local people maintain for use as posts. The species has a distribution concentrated in the dry forests of the centre of the country, such as in Comayagua and Jesus de Otoro, but it extends into humid forest and in some cases grows at up to 950 m a.s.l. This is possibly the most endangered of the native species, with its genetic variation limited to just a few isolated individuals, probably because of overuse.

As *L. diversifolia* has been identified only during exploratory visits by OFI and CONSEFORH, details of its natural range are unknown. As the habitat of this species has not been promoted, its conservation status is likely to be relatively well assured. Although this species provides fuelwood, local people traditionally prefer to use the *Quercus* spp., which occur in the same areas.

During one of many exploratory visits of the CONSEFORH project, a new species of leucaena was identified and named *L. lempiriana* ined. The exact distribution of this species is not known, nor is its potential, though local people say they use it for fuelwood and posts. It has been included in trials, but these are too recent to have yielded results.

Uses

Despite the widespread occurrence of native Leucaena species in Honduras, some species are used only locally, especially *L. salvadorensis, L. shannonii* and, to a lesser extent, *L. diversifolia.* The most important local uses are as posts, construction timber, fuelwood and green manure. Some leucaena leaves are fed to rabbits, pigs, cattle, etc. In some leucaena provenances, farmers manipulate the form of young trees, depending on the desired end product. This type of management has been tested by field evaluation, especially with *L. salvadorensis* which is pruned early. Once a clean bole of 2.5 m is obtained the tree crown may be pruned to encourage increment growth, with a resulting increase in basal area.

Conservation

CONSEFORH wants most conservation effort to be focused on species that are under threat, such as *L. shannonii.* The present critically-degraded state of this species is mainly the result of uncontrolled use in the past. *L. salvadorensis* is less at risk, but care is still needed to prevent this valuable resource being lost through contraction of its natural distribution. Various methods for conserving these species are discussed below, together with conservation work carried out by other institutions.

Natural stands

Natural stands make a major contribution to the in situ conservation of *Leucaena* species. For example, in some places where *L. salvadorensis* occurs naturally, certain local people know how to manage the trees for optimum production. These people protect the trees' natural regeneration. In agricultural areas, naturally-growing trees are left and pruned annually to supply the fuelwood needs of individual families.

Use on small farms

Projects such as MADALENA, LUPE, Recursos Naturales and COHDEFOR have encouraged the use of leucaena trees for agroforestry and live fencing. Although *L. leucocephala* has been most widely promoted, these projects have, since 1991, also started small-scale growing of *L. salvadorensis,* with technical advice provided by CONSEFORH. The widespread use of *Leucaena* species for live posts is a large, positive step towards conserving this important resource, which becomes more uncommon day by day.

Work by OFI and CONSEFORH

For many years, OFI's research has added significantly to our understanding of local species that were hardly known previously. OFI staff have explored, collected botanical samples and seeds and promoted species at the scientific level.

CONSEFORH's work on *Leucaena* species has aimed principally at discovering the general potential of the genus. In collaboration with OFI, CONSEFORH has established series of trials that are already yielding results, giving practical demonstration of the uses of each *Leucaena* species. Groups of clients have observed the results during numerous visits to CONSEFORH's experimental sites, and become very interested in these species.

Initially, CONSEFORH investigated the phenology and uses of each *Leucaena* taxon and its potential to produce specific products, such as green manure, construction poles, etc. After four years this research has been extended to include demonstration and 'validation' of the performance of leucaena species on the land of interested farmers. The types of trial set up on three sites to explore the range of variation between provenances are summarised in Table 2. Preliminary results from these trials could vary as the species develop. Some results have been published, the most important of which are shown in Table 3. Measurements are continuing.

Future Opportunities

The future of the genus *Leucaena* is likely to be limited to small scale use, in spite of laws passed in recent years offering incentives for reforestation. Leucaena is being promoted only for use in agroforestry and in the general environment, but may be promoted for fuelwood production in the future.

CONSEFORH

It is crucial for CONSEFORH to study management techniques for leucaena and to 'sell' these techniques to interested users. This research starts with a given end-product, develops optimum management methods to produce it, then demonstrates these methods to clients. For example, there is increasing demand for charcoal in Honduras, so CONSEFORH is beginning to examine the production and manufacture of charcoal. The findings and ideas will then be passed on to farmer groups that have land available for plantations.

CONSEFORH also proposes to conduct more validation work, especially in buffer zones, to encourage use of local native leucaenas. This should both increase in situ conservation, and minimise the crossing between taxa that could negatively affect the genetic conservation of the existing resource.

Improved seed, from the seed orchards established by the project, will be made more readily available to interested groups.

Honduras in general

It should be possible to stimulate interest in the genus through practical demonstrations and better knowledge of each species' qualities, especially with the new reforestation laws. Now fewer forests are being cut down to supply fuelwood, so the future of reforestation programs is brighter, particularly when combined with Leucaena's rapid growth rate.

Table 2. Summary of trials established by CONSEFORH.

Code	Site	Type of trial	Summary of design and source of seed
E1-89	La Soledad	Species evaluation (*L. salvadorensis)*	10 Honduran provenances, 106 families, 25 replicates, spacing 2 x 2 m
E4-89	La Soledad	Species evaluation	39 species and provenances, 2 replicates, spacing 1.5 x 1.5 m random blocks
E13-89	El Zamorano	Species evaluation	30 provenances with 20 taxa of *Leucaena* spp.; 2 replicates, spacing 1 x 3 m random blocks
E16-88	La Soledad	Seed orchard (*L. salvadorensis)*	30 families from Choluteca, Honduras, spacing 2 x 2m random blocks
E15-89	La Soledad	Species evaluation	7 families, 5 Honduran provenances, 3 replicates, spacing 2 x 2 m random blocks
E20-89	La Soledad	Observation of phenology	13 treatments, 2 replicates, spacing 1.5 x 1.5 m random blocks.
E1-91	Santa Rosa	Seed orchard (*L. salvadorensis)*	44 families Honduran provenances, 4 replicates, spacing 1.5 x 1.5 m random blocks
E31-91	La Soledad	Observation of phenology	*4 Leucaena* taxa, spacing 2 x 2 m random blocks
El0-92	Santa Rosa	Species evaluation (*L. salvadorensis)*	4 provenances, 3 Honduran and 1 from Nicaragua, 4 replicates, spacing 2 x 2 m random blocks
E16-93	La Soledad	Species evaluation	10 species of *Leucaena* from Honduras, Guatemala, Nicaragua, Haiti and Mexico provenances, 4 replicates, spacing 2 x 2 m random blocks.
E17-93	Santa Rosa	Species evaluation	10 species of *Leucaena* provenances from Honduras, Guatemala, Nicaragua, Haiti and Mexico, 4 replicates, spacing 2 x 2 m random blocks
E18-93	Santa Rosa	Management techniques (*L. salvadorensis)*	4 replicates of 5 treatments, spacing 1.5 x 1.5m Honduran provenance random blocks

Table 3. Summary of results of recent trials.

Type of trial	Parameters measured	Age	Species	Place of publication
Elimination of species	Diameter, height, survival	1 and 2 years	various	Serie Miscelánea CONSEFORH 1993
Elimination of species	Green weight and dry weight'	1 and 2 years	various	Serie Miscelanea CONSEFORH 1993
Elimination of species	Diameter, height, density	8 years	*L. salvadorensis* *L. leucocephala*	Serie Miscelánea CONSEFORH 1992
Elimination of species	Length of bole, weight of timber	1 and 2 years	various	Serie Miscelánea CONSEFORH 1993
Seed Orchards (2)	Diameter, height, straightness of bole	2 and 5 years	*L. salvadorensis*	In preparation
Observation of phenology	Flowering and fruiting	5 years	various	In preparation

[1] Stewart et al. 1993

To try to preserve the variation present in natural populations, in situ conservation techniques can be implemented. CONSEFORH has set up Breeding Seedling Orchards (BSOs), where a broad genetic base is assembled. Silvicultural treatment (thinning) is carried out, selecting for desirable characteristics. Then seed can be collected for the reforestation of areas in the natural ranges of those species. Richard Barnes designed the BSO concept because it was impractical to maintain a conventional full hierarchy of populations and species for testing, selection and seed production (Barnes 1981). In BSOs these functions are combined, where possible, in a single planting, depending on the type of multiple population being used. The BSO should be considered as being neither a dedicated Seedling Seed Orchard nor a dedicated Progeny Test, but something in between.

Recommendations

1. Use local species in areas where there is good local knowledge of them and their products, in preference to promoting exotic leucaenas. This action should help maintain an uncontaminated genetic base.
2. Direct research towards management problems identified by communities that have access to leucaenas but do not know how to manage them.
3. Promote community-based reforestation activities.
4. Continue to explore and investigate areas, especially buffer zones, to learn more about leucaena and its potential.
5. Direct information and management publications towards the farmers who will be involved in reforestation.

Acknowledgments

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Leucaena in Rio Grande do Sul (Southern Brazil)

M.T. Schifino-Wittmann, N.R. Paim, L.H.C. Freitas and C. Simioni[1]

Abstract

Leucaena research in Rio Grande do Sul (Southern Brazil) aims at the selection of cold and frost tolerant plants, germplasm characterization and development of a strong genetic breeding program. Hybrids between *L. leucocephala* and tetraploid *L. diversifolia,* previously selected for acid soil tolerance have been evaluated in field trials and most of the plants survived frosty winters. Experiments underway aim to select productive, non toxic cold and frost tolerant plants, which will enhance the use of *Leucaena* as a forage especially during the winter months. Beside interspecific hybrids other species and accessions will also be evaluated.

RIO GRANDE DO SUL is the most Southern State of Brazil, with a temperate/subtropical climate, hot summers and frost during winter. Acid soils with high aluminium and manganese contents are widespread. Agriculture, beef and dairy cattle raising are the basis of the State's economy. Cattle feeding depends mostly on the native pastures, with about 800 grasses and 200 legume species. However, most of the species are summer growing and during winter there is a feed gap, requiring diet supplementation. An alternative is the use of winter productive or perennial forages such as leucaena.

Research Activity

Leucaena research in our institution began in 1983 with cytogenetic (Freitas et al. 1988) and esterase pattern (Schifino-Wittmann and Schlegel 1990) analyses of Fl, F2, and F3 hybrids between *L. leucocephala* (2n = 104) and diploid *L. diversifolia* (2n = 52), from crosses made by Dr. E.M. Hutton, who promoted our interest in leucaena. Since 1988, 52 families of selected F2, F3 and F4 hybrids between *L. leucocephala* and tetraploid *L. diversifolia* (2n = 104) also provided by Dr. Hutton, were evaluated in a field trial for several morphological characteristics including leaf size, number of leaflets, number of flowers per inflorescence, colour and arrangement, number of pods per inflorescence and seeds per pod. Cytogenetic analysis including chromosome number, meiotic behaviour and pollen fertility was also performed (Freitas et al. 1991 a, b). The hybrids grew very well despite soil acidity, since they had been previously selected for acid soil tolerance and almost all survived even after the first frosty winter soon after establishment. Considerable morphological variation was observed in the hybrid population which, despite being intermediate between parental species for several characteristics, mostly resembled *L. leucocephala.* However, for SOD (superoxido dismutase) patterns there was a clear dominant expression of *L. diversifolia* genes (unpublished results). A special feature was flower colour: 50% of the population presented inflorescences with different shades of pink (different floral parts) in contrast to the characteristic white color of *L. leucocephala.* Chromosome number was almost 2n = 104, as expected, with eventual aneuploids, and mostly regular meiotic behaviour. Apart from some variation, 65% of the plants had over 80% viable pollen. Seed production was normal despite the hybrid condition and growth in acid soils.

These results encouraged additional work with these hybrids and in December 1993 a field trial with the twenty most productive mother plants (30 plants in each family) was established. Several characteristics such as growth rate, dry matter yield, raw protein content, tanin and mimosine contents, will be recorded with the main objective being the selection of productive, non-toxic, cold and frost tolerant plants. Characterisation by isozyme patterns will also be performed.

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The goals of the Leucaena Research Group in Rio Grande do Sul are:

a) germplasm characterisation by cytogenetics and electrophoresis; b) selection of cold and frost tolerant productive plants; c) establishment of a strong genetic breeding program; d) amplification of the scope of investigation, including other Leucaena species and accessions, besides the *L. leucocephala* x *L. diversifolia* hybrids.

The prospects for more widespread use of leucaena in Southern Brazil are promising, especially considering the interspecific hybrids, which have shown very good performance in environmental conditions somewhat different to their original native range. As a perennial tree leucaena would be an excellent alternative for cattle feeding during winter and as a diet supplement during the rest of the year.

Acknowledgments

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Leucaena in Central America

E. Víquez[1]

Abstract

This paper provides a brief review of trials conducted in Central America and Mexico to evaluate the potential of leucaena species to increase fuelwood production and provide a protein source for animals in association with grasses.

SPECIES of the leucaena genus are native to Central America and Mexico, where they grow in environments from semi-arid to sub-humid and from sea level to a little more than 2000 m asl.

The widespread distribution of the genus in Central America suggests considerable genetic variation. However, most plantations have been established from seed collected from a single species, *Leucaena leucocephala*.

L. leucocephala was carried during the 16th century from Mexico to the Philippines and from there to other Pacific Islands, Indonesia, Malaysia, Papua New Guinea and Southeast Asia. Later the species was introduced to Hawaii, Fiji, Northern Australia, India, Africa and the Caribbean where it has been naturalised.

Its high edible biomass and wood production, protein content and capacity to support continuous pruning have made *Leucaena leucocephala* the most widely planted fast growing nitrogen fixing tree in the tropics. However the very narrow genetic base used for most of these plantations has shown predictable results, as many of these plantations have been devastated by the psyllid *(Heteropsylla cubana)*.

In Central America, most of the human population is also concentrated in the semi-dry and sub-humid regions. The demand for agricultural land, products from forests, and urbanisation has depleted almost all of the natural forest, and for many tree species, it is difficult, if not impossible, to find natural stands. This is the case for most of the Leucaena species.

An effort to preserve and to systematically evaluate untested Leucaena genotypes should be commenced before they have become extinct.

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State of Research on Leucaena

Most of the research on Leucaena in the region deals with the establishment and silviculture of a few 'varieties' of *L. leucocephala* and even fewer of *L. diversifiolia.*

In 1980, the Tropical Agricultural Research and Training Center (CATIE), started an evaluation, through the Firewood Project, of species with potential for firewood including *L. leucocephala* and *L. diversifolia*. These trials were established in different ecological zones throughout Central America. A total of 114 single plots of *L. leucocephala* were established at 89 experimental sites. Of the experimental plots, 15 were planted with the objective of evaluating different establishment or management traits; 4 were comparisons of provenances of *L. leucocephala*, and the other 70 were species trials including plots of *L. leucocephala* and *L. diversifolia.*

Most of these trials included seed collected by the Latin American Seed Bank at CATIE and a great number were established from seed of the *L. leucocephala* K8 variety. One trial in Guatemala and two more in Honduras evaluated several K 'varieties' from the University of Hawaii leucaena germplasm collection. Another trial in Panama included eight genotypes of *L. leucocephala* and one each of *L. multicapituluta* and *L. pulverulenta.* Data on biomass production as well as the proportion of branches, foliage and bole, were influenced by plantation density, plantation management and site quality.

The results of these trials are available through the MIRA data base at CATIE, Costa Rica. Most were published in a series of silvicultural guides (Anon. 1986 and 1991; Salazar et al. 1987) that describe the best ecological conditions, nursery techniques, plantation density, fertilisation, weed control, coppice management and biomass production of L. feuco-*cephala* and *L. diversifolia.* Table 1 summarises some of these results.

The NFT-CATIE-SAREC Project, included *L. leucocephala* in several alley cropping and windbreak trials in Nicaragua and Costa Rica.

A silvo-pastoral trial with *Gliricidia sepium* and *L. leucocephala* planted with star grass *(Cynodon nlemfuensis),* was also established in the tropical dry forest of Costa Rica. The trees were planted from seedlings of local genotypes. Damage by grazing animals was great and the area was replanted using air-layered rooted cuttings of 2.5 m length. The trial is in its third year and leucaena has shown better survival and growth than *G. sepium.* The results have not yet been published.

Alley cropping systems were also established using *L. leucocephala* and annual crops such as beans, corn and sorghum. Excellent growth, biomass production, coppicing ability and lack of diseases made leucaena a high potential species for this system. Since the trials are only two years old, the results are considered preliminary. *Leucaena leucocephala* has also shown excellent growth when associated with *Eucalyptus camaldulensis, Azadirachta indica* and *Mangifera indica* in windbreaks.

Trials have also been established to evaluate the potential of *L. leucocephala* as a protein source for animal feeding in association with different grass species.

The greatest problem encountered with *L. leucocephala* in agroforestry systems is its high seed production, even with two prunings a year. In some trials there were severe attacks from ants of the genus *Atta* sp. There have been sporadic reports of attacks by rats and an insect identified as *Centrimospis linnelus* (Leconte), which rings the tree at a height of about 2 m (Anon 1991). No economically important damage by pests and/or diseases have been reported as no large plantations have been established.

Table 1. Growth of *L. diversifolia* and *L. leucocephala* in Central America.

Site	Country	Variety	Age (months)	Initial density (trees/ha)	Survival (%)	Tree height (m)	Diameter at 1.3 m (cm)
L. diversifolia							
El Progreso	Guatemala		21	2500	100	4.0	3.1
San Pedro Sula	Honduras		13	3333	50	2.9	2.3
San Pedro Sula	Honduras		13	3333	54	4.7	3.3
La Máquina	Guatemala		24	2500	96	5.2	3.4
La Máquina	Guatemala		33	2500	88	7.1	4.9
La Máquina	Guatemala		46	2500	85	7.1	5.2
Piedades Sur	Costa Rica		16	833	44	3.3	2.9
Piedades Norte	Costa Rica		22	2000	85	2.3	1.1
La Garita	Costa Rica		31	2500	90	6.0	4.7
L. leucocephala							
San Pedro Sula	Honduras	K6	13	1666	54	3.0	2.2
Deazúcar	Nicaragua	K6	28	3125	76	5.2	4.2
San Pedro Sula	Honduras	K 28	13	1666	50	4.2	3.3
Deazúcar	Nicaragua	K 28	28	3125	92	5.5	4.2
Deazúcar	Nicaragua	K 28	28	2500	87	6.7	5.4
La Libertad	Costa Rica	K 28	30	5000	97	4.9	2.7
Deazúcar	Nicaragua	K 29	28	2500	95	7.6	6.3
San Pedro Sula	Honduras	K 29	13	1666	62	3.1	2.2
San Pedro Sula	Honduras	K 67	13	1666	50	4.6	3.7
Deazúcarr	Nicaragua	K 67	28	3125	84	6.3	4.9
Rio de Oro	Costa Rica	K 67	30	416	92	5.8	6.2
Tocumen	Panama	K 72	19	1000	100	11.8	9.1
Parita	Panama	K 72	27	2500	81	2.9	2.9
San Pedro Sula	Honduras	K 132	13	1666	50	4.3	3.8
San Pedro Sula	Honduras	K500	13	1666	40	2.6	2.1
Deazúcar	Nicaragua	K500	28	2500	87	4.2	3.0
Deazúcar	Nicaragua	Cunningham	28	2500	95	4.9	3.4
Deazúcar	Nicaragua	Cunningham	28	3125	76	4.7	4.5
Deazúcar	Nicaragua	Taiwan	28	3500	95	5.9	5.1
Deazúcar	Nicaragua	Taiwan	28	3125	100	4.6	3.2

Source: Anon. 1986

Table 2. Stem length, diameter at 0.3 m and dry weight of wood of 39 *Leucaena* genotypes at an age of 24 months in Honduras.

Genotype number	Species and subspecies	Survival (%)	Stem length (m)	Maximum diameter (mm)	Wood dry weight (kg)
4585	*L. collinsii* collinsii	90	5.56	61.7	6.64
5188	*L. collinsii* collinsii	86	5.13	57.8	6.59
1884	*L. collinsii* zacapana	84	5.94	55.7	6.35
5688	*L. collinsii* zacapana	92	6.25	62.5	7.74
5788	*L. collinsii* zacapaua	82	6.26	65.9	6.91
3588	*L. diversifiolia* stenocarpa	90	4.69	31.2	1.05
5388	*L. diversifolia* stenocarpa	84	5.79	58.3	8.48
4587	*L. diversifolia* diversifolia	92	5.31	55.2	4.43
4687	*L. diversifolia* diversifolia	82	5.37	57.8	4.97
4787	*L. esculenta* esculenta	92	5.14	71.9	6.71
4887	*L. esculenta* esculenta	88	4.70	70.3	6.24
4987	*L. esculenta* matudae	98	2.98	44.3	3.80
5287	*L. esculenta* paniculata	94	5.56	46.6	4.08
8287	*L. greggii*	62	2.91	18.3	0.53
4385	*L. lanceolata* lanceolata	94	6.19	58.8	7.23
4485	*L. lanceolata* lanceolata	94	4.69	44.9	3.47
5087	*L. lanceolata* sousae	90	4.96	44.7	3.48
5187	*L. lanceolata* sousae	86	6.25	52.6	4.45
5588	*L. macrophylla* macrophylla	90	5.54	45.3	3.19
4785	*L. macrophylla* nelsonii	90	7.44	73.4	6.90
8187	*L. multicapitulata*	96	5.98	73.1	6.94
8387	*L. pulverulenta*	94	5.92	57.9	4.77
8487	*L. pulverulenta*	80	4.38	61.8	4.14
2386	*L. retusa*	42	2.98	19.3	0.50
1786	*L. salvadorensis*	84	5.46	57.9	8.98
3488	*L. salvadorensis*	76	5.76	67.5	8.89
2684	*L. shannonii shannonii*	80	3.98	36.5	1.64
5387	*L. shannonii shannonii*	80	5.02	49.8	4.23
1984	*L. shannonii magnifica*	80	6.21	57.4	5.83
5888	*L. shannonii magnifica*	78	5.97	59.6	6.13
286	*L. trichodes*	72	5.82	55.5	5.88
6188	*L. trichodes*	92	5.99	54.6	6.74
3288	*L. leucocephala* (K8)	96	5.49	52.6	4.16
8289	*L. leucocephala* (K636)	88	6.18	64.8	6.82
9989	*L. diversifolia* diversifolia	96	6.27	55.8	5.57
8889	*L. diversifolia diversifolia* X *L. esculenta paniculata* (KXI)	90	5.09	48.0	6.22
8789	*L. leucocephala* X *L. esculenta paniculata* (KX2,88-1)	84	5.59	60.2	8.12
8489	*L. leucocephala* (K8) X *L. diversifolia diversifolia* (KX3)	94	6.27	63.6	7.27
8689	*L. leucocephala* (K636) X *L. diversifolia diversifolia* (KX3)	96	6.28	56.8	4.72

Source: Stewart et al., 1991

A number of germplasm collections have been carried out, which have led to the establishment of gene banks outside the region — at the University of Hawaii, USA and another in Queensland, Australia. Very little effort has been made to evaluate genotypes of leucaena in Central America. Most of the trials include some of the K 'varieties' of *L. leucocephala,* known to be highly self-pollinated. Just a few of them include lesser known leucaena species and varieties. Moreover, some of the results have never been published.

The Oxford Forestry Institute (OFI) started a collection in 1984 of a wide range of leucaena genetic material from throughout Central America, Mexico and northern South America. Some. previously untested taxa are included in this collection (Hughes 1988).

In 1989 a trial with 39 *Leucaena* genotypes from this collection was established in the Comayagua Valley, Honduras. The first results from this trial showed great variation in vigour, woody biomass production, taper, branching habits, phenology, number of stems and wood density among and within species (Table 2). Some lesser known taxa out-performed the selected varieties and hybrids of the widely cultivated *L. leucocephala.* Some of the best groups are *L. collinsii* subspecies *collinsii* and *zacapana;* and some provenances of *L. diversifolia, L. macrophylla* subspecies *nelsonii, L. multicapitulata* and *L. salvadorensis* (Stewart et al. 1991).

Seed of 24 genotypes was obtained from OFI and a trial was established in April 1991 in Caiias, Costa Rica by the AFN-CATIE-SAREC Project. The main objective was to evaluate and select the best species and/or varieties of leucaena for the different agroforestry systems under study.

To date, there have been four growth measurements, and a five months evaluation of phenology. The fifth measurement (2 years old) included biomass production (leaf, soft stem and woody stem) and wood density. The biomass results are not yet analysed, however, the first two measurements (6 and 12 months old) showed significant differences among and within species (Table 3). Some of the best taxa were *L. macrophylla* subspecies *nelsonii, L. diversifolia* subspecies *stenocarpa* and *L. trichodes.*

Conclusions and Future Developments

In Central America the genus has great potential as a source of firewood, forage and construction material. It has high biomass yields, is adapted to a wide range of ecological conditions and also grows naturally where most of the human population is concentrated, so farmers are quite familiar with leucaena.

These new materials offer a wider range of germplasm for selection and for genetic improvement. However, they need to be preserved in gene banks and systematically evaluated under different ecological conditions for growth, biomass production and quality, coppicing ability, phenology and tree form. This evaluation and selection has to be for specific uses and objectives.

Table 3. Survival, height and basal diameter means of 24 *Leucaena* genotypes at an age of 6 and 12 months. Cañas, Costa Rica.

Genotype number	Species and subspecies	Survival (%)	First measurement (6 months)		Second measurement (12 months)	
			Basal diam (cm)	Height (m)	Basal diam (cm)	Height (m)
43/85	*L. lanceolata* lanceolata	92	1.3 a	0.9 ab	4.2 abc	3.4 abc
53/88	*L. diversifolia* stenocarpa	77	1.2 a	1.0 ab	4.7 a	3.7 ab
45/85	*L. collinsii*	90	1.2 a	0.8 ab	4.4 ab	2.4 abcde
52/87	*L. esculenta* paniculata	87	1.1 a	0.8 ab	3.6 abc	3.5 abc
56/88	*L. collinsii* G.f.	85	1.1 a	1.3 a	4.1 abc	3.2 abcde
47/85	*L. macrophylla* nelsonii	94	1.1 a	1.1 ab	4.3 ab	4.0 a
51/88	*L. collinsii*	65	1.0 a	0.9 ab	1.7 abc	2.0 bcde
32/88	*L. leucocephala* glabrata	97	1.0 a	0.8 ab	4.0 abc	3.4 abed
17/86	*L. salvadorensis*	87	1.0 a	1.1 ab	2.8 abc	2.2 abcde
55/88	*L. macrophylla* macrophylla	85	1.0 a	0.6 ab	2.3 abc	2.1 abcde
19/84	*L. shannonii* G.f.	72	1.0 a	1.0 ab	3.1 abc	2.7 abcde
2/86	*L. trichodes*	87	1.0 a	1.0 ab	3.8 abc	3.6 ab
34/88	*L. salvadorensis*	90	1.0 a	1.0 ab	3.3 abc	2.8 abcde
53/87	*L. shannonii*	100	0.9 a	1.0 ab	3.4 abc	3.3 abed
61/88	*L. trichodes*	70	0.9 a	0.7 ab	3.0 abc	2.9 abcde
57/88	*L. collinsii* G. f.	67	0.9 a	1.0 ab	3.1 abc	2.6 abcde
58/88	*L. shannonii* G.f.	44	0.7 a	0.6 ab	1.6 c	1.3 e
81/87	*L. multicapitulata*	61	0.7 a	0.5 ab	1.8 bc	1.4 de
46/87	*L. diversifolia* diversifolia	70	0.7 a	0.6 ab	1.9 bc	2.0 bcde
47/87	*L. esculenta* esculenta	87	0.7 a	0.4 b	2.6 abc	1.8 bcde
84/87	*L. pulverulenta*	80	0.7 a	0.5 ab	1.9 bc	1.6 cde
50/87	*L. lanceolata* sousae	85	0.6 a	0.4 b	1.7 bc	1.9 bcde
83/87	*L. pulverulenta*	62	0.6 a	0.4 b	2.2 b	1.9 bcde

Values in columns followed by a similar letter are not significantly different

Efforts should also be made to collect material from varieties, provenances, or even families of the best performing species, and to evaluate their genetic variation. This work must start with a comprehensive review of previous research within and outside the region.

To study the genetic variation between and within species, isozyme analyses will be useful. This technique may also help to establish a key code for their identification.

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Leucaena in the Southern United States: Potential for Development and Priorities for Research

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Abstract

Work on the agronomic potential of leucaena in Southern USA was first reported in the mid 1980s. Subsequent work in Florida, Iowa, Oklahoma and Texas has investigated the ruminal fermentation of mimosine and dihydroxypyridines (DHP), leucaena toxicosis, mimosine and DHP metabolism, varietal introductions and psyllid control, and production strategies and harvesting methods. This paper outlines current and planned research at our locations, focusing on grazing management, harvesting methods and post-harvest utilisation, as well as on the mechanism of DHP degradation in *Synergistes jonesii,* and the metabolism of mimosine and DHP in ruminants. Although much of the current effort is aimed at utilisation of leucaena in Southern USA, objectives also include development of technologies for the utilisation of leucaena throughout the tropics and subtropics.

LEUCAENA'S agronomic potential in Southern USA was demonstrated by work conducted primarily at Gainesville, Florida (Othman et al. 1985; Cunilio and Prine 1992) and at Kingsville and College Station, Texas (Glumac et al. 1987; Dovel et al. 1993a, 1993b). This, and other interests, prompted work on the ruminal fermentation of mimosine and dihydroxypyridines (DHP) at Ames, Iowa (Allison et al. 1990, 1992; Allison 1991) and at Langston, Oklahoma (Jacquemet et al. 1990; Fernandez et al. 1991; Al-Dehneh et al. 1992). At Brooksville, Florida, work began on leucaena toxicosis (Hammond et al. 1989a, 1989b, 1992) and on varietal introductions and psyllid control (Austin et al. 1990a, 1990b, 1991), while staff at Kingsville, Texas, researched production strategies and harvesting methods (Felker et al. 1991).

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Current work at our locations focuses on grazing management, harvesting methods and post-harvest utilisation, efficient detection and inoculation techniques for ruminants in areas where leucaena is not indigenous, the mechanism of DHP degradation in *Synergistes jonesii,* and the metabolism of mimosine and DHP in ruminants. Although much of the current effort is aimed at utilisation of leucaena in Southern USA, objectives also include development of technologies for the utilisation of leucaena throughout the tropics and subtropics.

Research in Progress

At Kingsville, Texas, emphasis is on developing technology for local commercial production of leaf meal. The technology may also be useful for middle-income and other developed countries. The research tasks include finding alternatives for sickle blade harvesters, and developing techniques to avoid excessive leaf drop when leucaena is field-dried. As well, growers need to know how to direct-seed leucaena with commercial sorghum, and they need herbicides, for weed control, which have been cleared by regulatory agencies.

At Ames, Iowa, the metabolic pathway of DHP degradation by S. *jonesii* is currently being investigated. Few other bacteria have been found with the capacity to degrade DHP. We expect that *S. jonesii*, an anaerobe, may degrade pyridinediol using mechanisms different from those described for aerobes. So far, results suggest that a reductive step must take place before the pyridinediol ring cleaves. Further work will focus on defining factors that regulate DHP-degrading activity in cells, and on defining the products of DHP degradation, so that we may propose a degradation pathway.

At Langston, Oklahoma, current research is examining the effects of feeding leucaena to goats. The gastrointestinal absorption of mimosine, 2,3-DHP and 3,4-DHP, and their hepatic clearance are being investigated in goats which have, or have not, been rumen-inoculated with *S. jonesii.* Other studies are determining the effects of these toxins on the liver processes that control carbohydrate, lipid and nitrogen metabolism. The first experiment was designed to assess the animals' ability to produce glucose from propionate and to detoxify ammonia, when given various 'loads' of propionate and urea. Short-term exposure to 2,3-DHP did not affect the goats' responses.

New Research

At Brooksville, Florida, grazing systems are to be developed for Florida's well-drained soils. Initial experiments will be based on leucaena pastures planted in summer 1994, on fine sands (Entisols). Average annual rainfall there is 1370 mm, with an average year-round temperature of 22°C though one or more killing frosts usually occur during the winter (November-March).

Leucaena selections K636 and K340 are being no-till planted into two of six 16 ha bahiagrass pastures *(Paspalum notatum)*, in a skip-row pattern (two rows, 0.75 m apart every 6 m). In grazing trials, from May to October 1995, young bulls 13-16 months old will compare the bahiagrass-leucaena pastures with bahiagrass alone or bahiagrass supplemented with a corn plus soybean meal mixture. Two bulls in each treatment/replicate group will be inoculated with a culture of *S. jonesii*, unless a preliminary screening finds that DHP-degrading ruminal bacteria are already present. The trials will measure body weight, body condition score, back fat thickness using ultrasound, hip height, scrotal circumference, and the concentration of urea nitrogen in the blood. Researchers will monitor the distribution of *S. jonesii* and its colonisation in the rumens of cattle on the bahiagrass-leucaena treatment during the grazing season. At the end of the grazing trials, all the bulls will be examined for breeding soundness.

At Ona, Florida, there is potential for using leucaena in the region's forage-based cow-calf production systems. Researchers will run applied grazing studies and demonstration projects on the poorly drained flatwood soils (spodisols). If improved forage systems can be developed for the region, they can be used to produce replacement heifers which calve at two years of age.

A two-year grazing study is planned to start in the 1994 season with *Bos indicus* x *Bos taurus* heifers. Eighteen weaned heifers (three per treatment/replicate) will be grazed each year on 0.80 ha of bahiagrass, or on bahiagrass and Leucaena (0.40 ha each), from June to November. The heifers will be inoculated with *S. jonesii* beforehand, because leucaena is not indigenous to the area. The study will monitor excretion of DHP in urine, body weight, body condition score and hip height, during the grazing season. Researchers will measure oestrus activity (serum progesterone) at the end of the grazing season, and pregnancy after a 90-day breeding season (December to February).

In a demonstration project, to be run on a commercial ranch, 12 ha of leucaena will be planted in 1.5 m raised beds with 3 rows each and 5 m between beds, in the middle of a 120 ha field of 'Floralta' limpograss *(Hemarthria altissima)*. Limpograss is a productive tropical grass for the flatwoods soils of Florida, with adequate digestibility but relatively low crude protein content. Once established, the limpograss/leucaena will be grazed by cows and calves. The trial will measure costs of establishment and persistence.

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Development of Leucaena in China

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Abstract

Leucaena leucocephala was first introduced to south China in 1961, and the Academy of Tropical Crops (SCATC) has worked on its research and extension since that time. Leucaena has been planted in ten provinces of tropical and subtropical China covering an area of more than 2000 ha. As a new kind of multipurpose tree (forage, fuelwood, postwood, green manure, shade and nurse tree for coffee and tea, mushroom stock and health-giving tea), Leucaena's further development in tropical and subtropical China is desirable and feasible. However, the promotion of leucaena has not been straightforward. This paper describes some experiences with leucaena, and also identifies problems and recommends solutions.

TAIWAN province first introduced leucaena to China more than 300 years ago, with a more recent introduction to Guangdong in the 1920s (Jiang and Xin 1962). The introduced leucaena, mainly the common Hawaii type, was not planted as a crop, and because it seeded prolifically and was widely adaptable, this type of leucaena became a wild shrub. The largest growing area is about 40 ha in two small islands in Baihai, Guangxi province. The 'wild leucaena' is also found in Hainan, Zhejiang, Guangdong and Fujian provinces.

In August 1961, a few Salvador leucaena seeds were introduced to SCATC. These were planted in 1962 and harvested in 1965 for use in developing larger growing areas. This three-year observation suggested the Salvador-type was better in vigour and yield, and it was named 'New Leucaena' in 1965 by the SCATC agronomists (Jiang and Xin 1982). During 1966-1976, scientific research was disrupted by the Cultural Revolution. From 1976, there has been emphasis on leucaena research, production and teaching in the fields of agriculture, forestry and animal husbandry.

The main leucaena-growing areas are Hainan, Guangdong, Guangxi, Fujian, Zhejiang and Yunnan. They include nearly every county of Hainan province and Guangzhou, Shaoguan, Zhangjiang, Fushan, Doumen, Jiangmen, Shantou, Zhaoqing and Meixian of Guangdong province. At present, Fujian has a growing area of about 670 ha concentrated in the Jinjiang district. Louyan county of Ningde district of Fujian has 134 ha and leucaena also occurs in other districts such as Longhai, Shaoan, Dongshan, Zhangpu, Tongan, Xianyou, Putian, Yongchun, Pingtan, Fuzhou, Xiamen, Sanming, Longyan, Yongding, Changting and so on. In Guangxi, leucaena mainly grows on Weizhou and Xiayang Islands, and there is some in most of South Guangxi. The main districts in Yunnan are Xishuangbanna, Lujiangba, Baoshan and Chuxiong, and those in Zhejiang are Jingshan, Dingtou, Jinhua, Yunkou, Linhai, Dachen and Juzhou.

Ecology and Growth in South China

Leucaena is native to Yucatan, Mexico, where minimum temperatures are higher than 0°C, annual rainfall is about 700 mm and the soil is alkaline (Jiang and Xin 1982). Chinese experience in growing leucaena has been gained from its habit in South China.

Leucaena grows well in ambient temperatures of about 25-30ºC. Under appropriate conditions, for instance in Danxian county of Hainan province, four-year-old plants reach 9.2 m in height and 7 cm d.b.h. Leucaena stops growing if the temperature is lower than 10°C but, although a tropical tree, leucaena tolerates some chilling. In Gulin, one-year old plants reached 1.5 m in height, but in winter their leaves fell and all parts of the plant 40 cm or

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more above-ground died. Three-year-old plants carried dead (frosted) shoots about 60 cm long, every year. The situation is similar in Wenzhou, where shoots died back to half of their height during winter cold. Xin and He (1982) have documented leucaena's response to winter in various places in China (Table 1).

In China, leucaena grows best in the rainy season with high temperatures and worst in the drought season with low temperatures. In Danxian county, Hainan province, growth is best during June-November and poorest during January-March (Jiang and Xin 1982).

Although it can grow in nearly any type of soil, leucaena is extremely sensitive to soil pH. Liu and He (1987) reported that best yields of fresh material occur on deep fertile well-drained soil and the plant usually grows well in soils with pH > 5.5, although it grows weakly or even dies in soils of lower pH (Tables 2 and 3).

Table 1. Production of leucaena in various areas of China.

Locality	Xisa (Yongching)	Hainan (Danxian)	Guangxi (Mashan)	Fujian (Yongding)	Guangxi (Guilin)	Zhejiang (Jingshan)	Hubei (Wuchang)
Latitude (N)	16° 15'	19° 30'	23° 45'	24°	25° 20'	28° 01'	30° 18'
T1* (°C)	23.8	16.7	n.d.	n.d.	7.7	7-8	3.9
T2** (°C)	15.3	6.0	- 0.7	n.d.	- 3.6	-2.3	-5.9
Age (months)	33	42	18	25	15	76	6
Height (m)	5.5	8.9	4.3	3.5	1.5	8.7	2.5
D.B.H. (cm)	4.9	4.9	2.7	3.2	2.6***	10.0	1.6***
Fruit	good	good	good	common	common	common	fruit damaged
Seed weight (g/'000)	58.6	60.8	44.8	44.0	40.5	44.6	n.d.
Seed Germination (%)	85.0	89	74	46	27	21	n.d.
Winter growth	good	good	good	dead 60 cm from ground	dead 40 cm from ground	young part dead	aboveground dead

* T1: average monthly minimum
** T : absolute minimum temperature
*** diameter near ground

Table 2. Effect of soil on plant growth and chemical composition of leaves.

	site number	1	2	3	4	5	6	7	8	9
soil characters	pH	6.8	6.5	6.4	6.5	6.5	6.2	6.5	6.7	6.6
	organic matter (%)	2.56	2.56	1.12	1.25	0.74	2.20	0.74	2.27	1.92
	total N (070)	0.102	0.103	0.045	0.047	0.029	0.079	0.027	0.091	0.071
	avail P (ppm)	6.5	4.0	6.2	4.8	2.7	2.2	24.9	3.4	4.8
	avail K (ppm)	137.0	170.0	70.7	78.0	26.8	127.0	44.5	216.0	157.0
	effective S (ppm)	8.0	6.0	9.0	9.0	10.4	8.0	10.2	8.2	6.2
plant growth	age (days)	95	95	95	95	95	95	95	95	95
	height (cm)	141.5	141.5	80.5	73.0	45.0	42.0	36.5	28.0	17.0
	growth gain (cm/day)	1.49	1.49	0.85	0.77	0.47	0.44	0.38	0.27	0.18
	weight/plant (g)	88.2	86.0	22.9	29.5	11.0	7.9	6.7	3.0	1.8
leaf nutrition	**N (%)**	2.25	2.23	2.54	2.77	2.57	2.65	2.05	2.97	2.20
	P (%)	0.17	0.17	0.20	0.21	0.15	0.18	0.18	0.24	0.18
	K (%)	1.75	2.09	0.13	0.17	1.19	1.89	1.48	2.28	1.16
	Ca (%)	1.62	1.88	1.52	1.61	1.59	0.91	1.43	1.41	1.23
	Mg (%)	0.42	0.45	0.42	0.50	0.50	0.35	0.38	0.52	0.48

Table 3. Growth of leucaena in soils with various pH values.

Area	Hainan (Wenchang)	Guangdong (Pingyan)	Hainan (Danxian)	Guangdong (Qiaoqing)	Guangxi (Mashan)	Guangdong (Doumen)
soil type	red sandy	red soil	laterite	limestone soil	limestone soil	beach deposit soil
pH	4.5	5.0-5.5	6.1	6.5	7.2	7.4
age (months)	12	18	9	21	18	18
height (m)	0.15	1.60	3.14	5.5	4.30	7.91
girth (cm)	-	-	3.6	7.1	8.4	7.0

Progress in Research and Production

Since the 1960s when New Leucaena was introduced, fundamental research has included studies of:

- adaptation of Leucaena to different environments (Jiang and Xin 1982; Xin and He 1982)
- biology and ecology of leucaena (Jiang et al. 1985)
- methods of cultivating leucaena (Xin and Liu 1990)
- plant nutrition (Cheng n.d.)
- methods of testing for mimosine (Cheng and Chen 1985)
- extraction and purging of mimosine from seed (Wu et al. 1985)
- forage production (Liu 1987; Jiang and Liu 1986, 1988, 1991)
- methods of producing leaf meal and compound feeds for different animals (Liu 1987; Wang 1989)
- use of leucaena leaf as animal feed (Wang 1989)
- fuelwood production (Xin et al. 1986)
- seed production (Liu 1993)
- detoxification methods (Cheng and Hong 1986; Liu and Wang 1990)
- tissue culture (Cui 1983)
- paper pulp production using leucaena wood (Zhejiang province) (Xue et al. 1989)
- chemical control of psyllid and other insect pests (Zhu and Liu 1988)
- selection of psyllid resistant genotypes (Jiang et al.)
- use of leucaena leaf to raise edible fungi (Liu and Jiang 1990)
- production of health-giving tea from leucaena leaf.

All these themes are reported in Tropical Crops Research Reports, published by SCATC. Research has been done to stimulate production and utilisation, including comparison of varieties, fertilizer trials, inoculation tests and feeding trials. Two leucaena plantations have been established, one with nine species of leucaena and the other with 72 genotypes of *L. leucocephala*.

Several research, production and teaching organisations in the provinces of Guangxi, Fujian and Wunzhou have also undertaken a great deal of research on leucaena. This research has included feeding trials with cattle and pigs, mixed plantings of leucaena with other grasses, measurement of nitrogen fixation by leucaena nodules, culture of edible fungi using leucaena leaf, adaptation of New leucaena to conditions at high latitudes (Wunzhou), forest establishment techniques and uses for shoots and leaf meal.

Extension work is limited. At present there is about 70 ha of leucaena on Dongfang model cattle farm in Hainan, and Fengmu deer farm uses leucaena to raise deer. Some of the state farms in Hainan use leucaena to shade their coffee plantations and some farmers use leaf meal to raise chickens and pigs. Xishui cattle farm of Baisha county has planted leucaena as a source of quality forage meal. In Doumen county, Guangdong, more than 400 ha of leucaena has been planted as a windbreak forest. In Fujian, a roadside forest of leucaena extends for dozens of kilometres. In Guangxi, 67 ha of leucaena has been planted for paper making. Most of these developments are at a preliminary stage and large-scale development and utilisation of leucaena is many years away. During 1994, Pinhe Co. hopes to plant 600 ha of leucaena in Hainan as the raw material for health-giving tea. Over the next five years, they plan to plant 1200 ha of New Leucaena.

Diseases and Insects

Apart from psyllid, few diseases and insects cause significant damage to leucaena. In China, the leucaena psyllid was first found at SCATC in November 1986 when more than 7 ha of leucaena was heavily damaged and more than 90% of yield was lost (Liu 1986). The insect was also found in Dongfang model cattle farm and Hainan cashew centre and at Nanning in Guangxi province.

Research workers used insecticide to control the psyllids and then studied the effects of insecticides. The experiments showed that pyrethrin at 150 ml/ha was most effective, giving 90% control (Zhu and Liu 1988). Biological control may be possible.

Prospects for Development

At present, animal production in China is limited by the quality and quantity of available fodder, usually rice crop residues, with predictions that the country could lack 10 million tonnes of protein fodder by the year 2000. Leucaena, with high protein and mineral content as well as chlorophyll and carotene, is potentially an excellent source of protein fodder for animal husbandry in tropical and sub-tropical China. Initial experiments confirm this potential, showing dry leucaena leaf is good feed for chickens and pigs.

Leucaena can also provide wood quickly to help solve the fuel shortage in the countryside of South China. In Yulin alone, the annual requirement for fuel is 0.7 million tonnes, which is currently supplied from 0.25 million tonnes of crop residues and 0.45 million tonnes of shrubs and grass from the mountains. Such large-scale removal of mountain vegetation is extremely harmful to ecological equilibrium.

Large areas of South China are suitable for growing leucaena. For example, if 10% of the area available in Guangdon (533 thousand ha) was devoted to leucaena which yielded 45 t/ha of shoot and leaf annually, then 1.2 million tonnes of leaf meal could be produced each year (assuming 50:50 production of leaf and wood).

The seeds of leucaena are easy to obtain and propagate. Under normal conditions in southern China leucaena can fruit twice each year, producing 0.25 to 0.5 kg of seed per plant on a three-year-old tree. More than 5 kg of seed can be obtained from seven-year-old plants.

It may be possible to grow leucaena even in mountain areas. Measurements in the mountains of SCATC's farm show leucaena can grow to 7.3 m in height and 4.71 cm in girth when the plant is five years old. More work is needed, but it is considered the plant has good potential for mountain areas in southern China.

Problems and Recommendations

It is more than 20 years since leucaena was first introduced into China, but its promotion has not been straightforward. The main reasons are inappropriate geographic conditions, poor growing methods, poor management, and disharmony between production and utilisation.

Here are some of the problems and recommended solutions.

- Leucaena is a tropical tree which grows well in conditions similar to its native home. Plant growth is reduced by chilling in high altitudes and latitudes and more work is required to identify and develop cool-tolerant species and varieties.
- Leucaena's fertilizer requirements are not well understood, but species or varieties adapted to low fertility situations are needed.
- Appropriate planting techniques are needed.
- Robust genotypes, that do not require high levels of management, are needed.
- People in the countryside do not understand how to use leucaena as fodder. Practical systems of use need to be developed. These systems should be field tested, demonstrated and promoted to encourage growers.
- Leucaena contains toxic mimosine at levels of about 3.8% in the leaf and 8.0% in the seed. This toxicity problem must be overcome for feeding purposes.

We recommend that leucaena be planted as a crop and that a model farm should be established to study and demonstrate cultivation and utilisation. A research priority should be the breeding and selection of acid tolerant varieties with low mimosine content and psyllid resistance.

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Leucaena in India

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Abstract

Leucaena was introduced into India in the 1950s ut only became popular after the Salvador types of *Leucaena leucocephala* were introduced from Hawaii in 1976. Although initially grown as fodder for ruminants, leucaena's uses now include fuel, timber, polewood, pulp, shade, and rehabilitation of degraded wastelands. The psyllid infestation set back the promotion of leucaena, but its potential can be revived if lines become available with superior psyllid resistance, timber qualities, tree form, and drought and salinity resistance. This is an opportune time to exploit leucaena's multiple uses and develop networks for information and seed exchange.

The History of Leucaena in India

LEUCAENA leucocephala was brought into India in the early 1950s for use in soil reclamation and as green manure. However, the Agricultural Development Bureau of the erstwhile Madras state (which now covers four states) largely failed to interest Indian farmers in intensively planting leucaena, so it became a hedge plant on boundaries and in backyards.

In the 1970s Australian scientists published several papers about leucaena's use as a high protein, mineral rich fodder. The Indian Council of Agricultural Research (ICAR), impressed by leucaena's drought tolerance, freedom from pests and diseases, and rapid growth, undertook to promote leucaena as fodder and fuel in India, notwithstanding Australian reports of mimosine toxicity. Agricultural universities and other agencies also promoted leucaena. After Dr Brewbaker (University of Hawaii) began providing seed of his 'Hawaiian Giant' leucaena (Salvador type) in 1976, the popularity of leucaena rapidly increased, despite the recognition of problems of overproduction of seed and limited site adaptability in certain arid or saline soils.

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The Federal Ministry of Agriculture imported a few tonnes of seed from the Philippines and passed the seeds on to agricultural universities and State Government Departments of Forestry, Agriculture, and Animal Husbandry. Several organisations began to research leucaena's agronomic management for sustained or optimal yields of wood and edible biomass. The Bharatiya Agro-Industries Foundation (BAIF) and the Indian Grasslands and Fodder Research Institute at Jhansi (IGFRI) played major roles in popularising leucaena in India for fodder and fuel. Both institutions began extension to farmers and both conducted extensive research trials. The escalating popularity of Salvador-type leucaena in India in the late 1970s coincided with a wave of feeling against the planting of eucalypts. Leucaena was accepted as a major species to grow in social forestry programs which encouraged people to participate in forestry and harvest the trees for fodder, fuel and small timber.

The Government of India organised three national seminars on leucaena in three years. This drew the attention of foresters, field workers and non-forestry groups such as the Indian Railways, which asked its station-masters to plant Hawaiian Giant leucaena at their stations and along tracks. Paper mills, faced with a decreasing supply of eucalyptus, started evaluating leucaena for paper pulp and soon learned it made an excellent pulp for kraft paper. Early in 1980, ICAR signed an agreement with ICRAF (Nairobi, Kenya) to promote agroforestry across India. Twenty-five agricultural research institutions and Universities began to study leucaena in alley-cropping or agroforestry systems.

Leucaena had already become established throughout central and southern India northwards to Jammu and Kashmir states, in the plains of Assam in the east and along irrigation canals in Rajasthan. In these areas leucaena tolerated temperatures from 4-46°C and more than 400 mm annual rainfall (Fig. 1). Leucaena is the only species planted on marginal country and wastelands where soil pH is between 6.0 and 8.5.

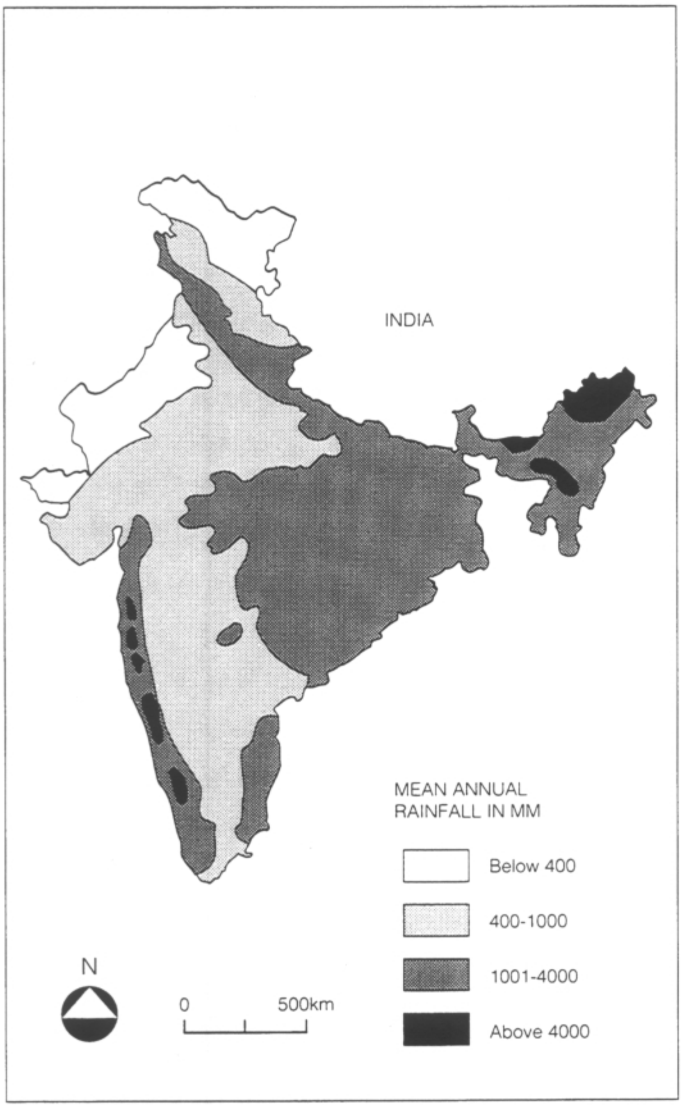

Figure 1. Distribution of rainfall in India.

The leucaena psyllid *(Heteropsylla cubana)* first entered India at Tamil Nadu in 1987. Within a few months it reached Maharashtra. After that it moved northwards much more slowly. In 1989 infestations were mild and restricted in area. Severe infestations of psyllids occurred in Khandwa, Raipur and Jabalpur in 1991, although the plantations in Rewa and Gwalior in the Madhya Pradesh state remained psyllid-free (Joshi et al. 1993). Similarly, leucaena plantations in large parts of Uttar Pradesh, Bihar, Orissa, Rajasthan and northern parts of Gujarat are still free from psyllid infestation. The plantations in South India have recovered from their initial attack. Encouraged by this favourable change, Andhra Pradesh State revived the cultivation of leucaena for fodder, fuelwood, and pulpwood in 1993.

The Use of Leucaena in India

As leucaena could grow in marginally productive land and wastelands, it was promoted as being superior to traditional fodder crops such as sorghum and maize, which compete with food crops for good land, fertilizer and labour. Self-pollinated leucaena plants produce seed in the first year, so propagation was simple.

However, for several reasons small farmers did not accept leucaena's value as fodder as well as expected. First, their poor quality livestock were unable to respond to the supplement. Of the 430 million livestock in the country, only 8-10% contribute to the economy in terms of their milk or draught power. More than half the livestock, i.e. sheep and goats, depend on free grazing. Due to high costs of fencing, there is often little incentive for farmers to plant leucaena to feed their own livestock (Hegde 1991). Second, some provenances of leucaena do not carry enough green leaves in dry periods to be useful as drought-fodder. Third, most veterinarians and extension personnel were apprehensive about the risk from mimosine toxicity. Several reports from Australia had indicated some level of adverse effects from feeding high proportions of leucaena in the diet.

Leucaena was also promoted as a multipurpose tree species, for fuel, timber, pulp, shade and shelter. Its favourable characteristics included its profuse regeneration after lopping or pollarding, and its superiority over eucalypts as pulp for newsprint and paper (Hegde 1988). However, there were some drawbacks. The leucaena was heavily browsed, so needed expensive fencing to protect it from animals, even in forests. Also, leucaena's calorific value and timber qualities were inferior to those of casuarinas and eucalpyts. Another problem was that, as leucaena bends towards sunlight or open space, it produced crooked poles, and the wood was not very durable because it was prone to insect and fungal attack.

There were also other problems, apart from psyllids. Heavy seeding was a drawback when leucaena was grown as a windbreak. Although it was promoted as an alley-crop, farmers were reluctant to establish permanent rows of perennials in the middle of their fields. Instead they planted leucaena around the edges, and did not use the foliage as mulch or manure, preferring other forms of organic manure for food crops. In some areas waterlogging caused the leucaena to wilt. Some farmers failed to get good prices for leucaena wood because higher quality timbers were readily available.

In 1987 a disease called gummosis began to occur in central and northern India. The Forest Research Institute (FRI) determined the cause as a species of *Fusarium*, probably related to, or the same as, the organism that causes wheat wilt. So FRI cautioned farmers against planting the two crops near each other. Gummosis research by BAIF concluded that gummosis was a physiological response, healing the wound when the bark was damaged by beetles or high salinity conditions (Hegde 1984). An IGFRI study suggested that gummosis occurred in the Peru type more frequently than Salvador types.

Leucaena Research in India

Five areas of research have received concerted effort by Indian scientists: agronomic management to optimise sustained yields; agroforestry studies of mixed cropping systems; mimosine toxicity; germplasm testing; and economic evaluation.

Most (58%) of the 350 papers on leucaena written by Indian scientists until 1993 were about the first aspect, agronomic management and performance evaluation (Table 1). These 203 papers covered such topics as seed treatment, nursery practice, vegetative propagation, fertiliser use, diseases and pests, stocking and cutting heights for forage yield, tree growth, and adaptability to wastelands. Most of the studies, except those by paper mills and a few non-government organisations, lacked cost-benefit analyses, and could not motivate extension workers and farmers to promote leucaena cultivation.

Mimosine toxicity research

Some level of mimosine toxicity was accepted as an unavoidable aspect of leucaena because of the lack of laboratory facilities for quantitative evaluation. Organisations promoting leucaena initially cautioned farmers to feed animals on daily diets containing 30% or less of leucaena foliage. Then BAIF fed six bull calves on 100% leucaena diets for six months and recorded weight gains and general health. This study failed to find any deleterious effects from feeding pure leucaena. Another trial tested the performance of adult bulls fed diets with varying proportions of leucaena supplementation for about 30 months. Blood analyses showed normal serum values of protein-bound iodine, indicating normal thyroid function, and again contradicting the toxicity hypothesis. These studies were then extended to heifers and milking cows with favourable results. Dr Raymond Jones (CSIRO, Australia), visiting BAIF, confirmed that mimosine and DHP (3,4-Dihydroxy-pyridone) were being broken down, and so were non-toxic.

Table 1. Research publications on leucaena in India.

Description	up to 1984	1985-1988	1989-1993	Total	%
Germplasm collection and breeding	5	14	6	25	7
Seed treatment, germination, rhizobia, mycorrhiza, nitrogen fixation	7	15	9	31	9
Nursery raising and seedlings	7	1	1	9	3
Vegetative propagation	2	-	2	4	1
Fertilizer and mineral nutrition	9	12	6	27	8
Tree growth	15	17	3	35	10
Tree-crop interaction	10	8	24	42	12
Spacing, density, cutting ht vs fodder yield	3	9	10	22	6
Forage yield vs variety	5	5	-	10	3
Nutritional value, toxicity	6	7	6	19	5
Diseases, pests etc.	16	12	13	41	12
Adaptability to wasteland compared to other spp.	4	11	9	24	7
Use and economics (other than fodder)	11	18	8	37	10
General articles	15	3	6	24	7
Total	115	132	103	350	100

In later trials elsewhere in India, researchers evaluated leucaena's nutritive value, digestibility and mimosine toxicity to livestock. Some reported reduced feed intake, suppressed weight gains, coarse skin and hair shedding in ruminants. It appears that detoxifying micro-organisms were not present in large enough populations in the rumens in these studies. Some other studies reported methods of 'destroying' mimosine, but few, if any, of these studies also tested for the first degradation product, DHP, which is itself toxic.

Germplasm research

Breeding work on leucaena has been done at IGFRI which has a collection of 96 provenances. Other institutions are evaluating *Leucaena* germplasm for fodder, fuelwood and biomass production. Until fairly recently, *Leucaena leucocephala* 'Hawaiian Giant' cv. K8 was the most popular and the most widely tested provenance in India. IGFRI has identified ten provenances of *L. leucocephala,* one hybrid of *L. leucocephala x L. pulverulenta,* KX2 and KX3 as being superior to K8. A newer release from the University of Hawaii, K636, is also superior, but has been slow to gain acceptance because it yields little seed.

In 1989, BAIF participated in a network trial sponsored by the Nitrogen Fixing Tree Association in Hawaii to evaluate resistance to leucaena psyllid. The trial, at Urulikanchan near Pune, tested 16 hybrids and composites over four years. Although none of the hybrids was resistant to psyllids, *L. esculenta* and *L. collinsii* showed least damage. The trial found no hybrids or composites suitable for timber or industrial wood production,and none out-yielded or was more vigorous than K8, but *L. leucocephala* (4N) and *L. leucocephala* K397, grew faster than the rest, and some would be useful for fodder and fuelwood where K8 was infested with psyllid.

Research Priorities for Leucaena in India

The research agenda for leucaena in India needs to be revised to solve the existing gaps between growers' expectations and leucaena's performance. Growers expect the following features:

for timber and industrial raw material

- psyllid resistance
- straight boles suitable for polewood
- low seed production
- high proportions of wood for timber with less branches and twigs

for fodder and soil conservation

- psyllid resistance
- ease of establishment, fast growth and regeneration
- low mimosine
- tolerance to drought, salinity and acid soils

Research and promotion of leucaena for timber and industrial raw materials has brighter prospects because of high demand and profitability. Research for soil conservation and fodder production will need to be supported by a suitable extension network to persuade farmers to use leucaena.

Research should concentrate on:

(i) germplasm collection and breeding to identify lines with straight boles and psyllid resistance, new lines and hybrids for field evaluation and provenances for drought-prone and saline areas;

(ii) studies to explore multiple uses of leucaena wood for higher returns, including methods for producing good quality leaf meal post-harvest;

(iii) the economics of leucaena cultivation in various agroclimatic conditions and farming systems.

These objectives will be fostered by establishing links between the research agencies, growers and end-users. Newsletters, conferences and germplasm banks could be set up, and such a network could attract funds for research, development, training and extension. LEUCNET will serve to link local and overseas research agencies, and greatly help the promotion of leucaena throughout the tropics.

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Leucaena in Indonesia

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Abstract

When the leucaena psyllid caused extensive damage to Indonesian leucaena crops in 1986, former leucaena growers tried replacing it with other tree legumes. Researchers have since identified psyllid-resistant species, accessions and hybrids of leucaena for shading coffee and cocoa plantations, providing fuelwood to dry the beans, and controlling soil erosion. If psyllid-resistant leucaena trees become commercially available, they will need to be economical to propagate, tolerant of acid soils, and readily inoculated with rhizobia and mycorrhizae to stimulate early growth, as well as yielding high quality animal feed. Seven other tree legumes, including *Cassia, Acacia* and *Enterolobium* species may yield more forage than leucaena on certain sites, while *Gliricidia, Calliandra* and *Sesbania* species appear to complement leucaena as a feed supplement for ruminants in some circumstances. The paper discusses problems researchers need to solve before psyllid-resistant leucaena becomes widely used.

LEUCAENA leucocephala (Lam.) de Wit., locally known as lamtoro, was introduced to Indonesia in the 18th century. In the forest gardens of west Java, it was traditionally used by farmers as an occasional source of fuelwood and forage (Wiersum 1982). In Timor and Flores, lamtoro was planted in contour-hedges to stabilise some 100 000 ha of eroded hill-slopes. These were subsequently brought back into livestock and crop production as a result of improved soil fertility and soil moisture regimes (Piggin and Parera 1985). Other uses have included reforestation and soil reclamation, charcoal and fuelwood production, green manure and timber. In Sulawesi, Sumatra and Nusa Tenggara Timur, Leucaena is a common shade tree species in coffee and cocoa plantations.

Beginning in the 1970s, recognition of the potential of *Leucaena leucocephala* for controlling erosion and for improving ruminant nutrition in Indonesia prompted widespread plantings of new varieties and cultivars (including K8, Peru, K28 and Cunningham). *L. leucocephala* has played an important role in forestry in Java since 1970 when it was introduced as a component of the silvicultural system. The calorific value of the wood is high (4,200 kcal/g) and it produces good quality charcoal. Before 1986, leucaena also had good prospects as a source of raw material for pulp industries as the fibre quality is not significantly different from that of many other forestry species (Wirjodarmomodjo and Wiroatmodjo 1983).

In 1986, the leucaena psyllid spread throughout Indonesia causing severe defoliation, die-back and disease. This paper discusses the prospects for new psyllid-resistant accessions and hybrids within the plantation and animal production sectors, and suggests some priorities for future research.

Leucaena as a shade crop

Leucaena leucocephala is a common shade tree for cocoa and coffee. Before 1986 it was also used to provide fuelwood for the drying of cacao seeds and coffee beans. The most important advantages of leucaena were wood of a relatively high calorific value, drought tolerance and small leaves providing a diffuse shade. Following the devastation caused by the leucaena psyllid, the plantation companies and smallholders tried alternative shade tree species, including *Cassia siamea, Acacia villosa* Wild., *Gliricidia sepium, Tephrosia* sp., *Elaeis guineensis* and *Cocos nucifera*. The large estates mostly switched to *Gliricidia sepium*. However, gliricidia has some disadvantages as a shade crop because of

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its poor drought tolerance, abscission of leaves in response to moisture stress, wood of lower calorific value and a sparse uneven canopy. Many plantations in North Sumatra now use mixtures of gliricidia and leucaena. If psyllid-resistant Leucaena species become commercially available there is likely to be a large demand from the existing plantations. Extra demand would also be created by the planned expansion of the coffee and cacao industry in the sixth five-year-plan (Table 1).

Table 1. Projected areas of plantations and increases in exports of coffee and cocoa during the sixth five-year-plan (Source Departemen Pertanian 1993).

Commodity	Area (000 ha)		Annual Growth (%)	
	1993	1998	Area	Exports
Coffee	1114	1230	2.00	3
Cacao	430	632	8.00	10

In 1998, researchers at the Pondok Gedeh research station of the Bogor Research Institute for Estate Crops (BRIEC) began identifying psyllid-resistant *Leucaena* species for these plantations. By 1993 more than 411 accessions and hybrids of eight species of *Leucaena* had been evaluated consisting of germplasm introduced from Hawaii (NFTA) and Indonesian introductions from North Sumatra, East Java, and Maluku. This collection was designed to increase the range of variation available, both by increasing the number of species represented in the collection, and by widening the range of accessions within each species (Suhendi 1990; Suhendi and Buana 1991). Some of the accessions (numbered in a PG series for Pondok Gedeh) that showed potential for plantations (high wood production, psyllid resistance) included PG 08 (K363), PG 20 (K156), PG 25 (K 743) and PG 402 (local hybrid of *L. diversifolia* x *L. leucocephala*). Wood production was in the range 38-53 tonnes/ha in four-year-old plantings (Toruan-Mathius and Suhendi 1992).

If superior psyllid-resistant hybrids become available, commercialisation will require either hybrid seed production or economic methods of propagation by vegetative means such as stem cuttings, graftings or tissue culture. Vegetative propagation has been successful with *L. leucocephala* and hybrids of *L. diversifolia* x *L. leucocephala* using stem cuttings treated with root growth stimulant, but not with *L. diversifolia*. Bud grafting has been successful with hybrids of *L. diversifolia x L. leucocephala* using *L. diversifolia* root stock. Although some success has been achieved in propagation of leucaena by tissue culture, plantlets do not survive well following transplanting into pot culture (Dhawan and Bojhwani 1985; Toruan-Mathius 1992).

Most of the coffee and cacao plantations in Indonesia are located in areas of acid soils with a pH (in water) of 4.5-5.0. Although *Leucaena leucocephala* is reported to be intolerant of strongly acid soils in other countries, it has yielded and persisted well on acid soils in the plantations of Java and Sumatra. Its growth on acid soils is inhibited partly by low calcium availability and high levels of exchangeable aluminium (Blair et al. 1987), but these do not occur in all acid soils. The other major limitation is pH-induced phosphorus (P) deficiency. Uptake of P and/or nitrogen (N), as well as growth, may be stimulated on acid soils in very young seedlings by either single or dual inoculation with rhizobium and vesicular-arbuscular mycorrhizae (VAM) tolerant of acid conditions, as shown in a pot experiment in Bogor on a selected psyllid-tolerant hybrid of *L. diversifolia* x *L. Ieucocephala* (Table 2). However, these differences may disappear later when mycorrhizae infection builds up.

Table 2. Effect of rhizobium, VAM, and rhizobium + VAM inoculation on growth and N and P uptake of hybrid *L. diversifolia* x *L. leucocephala* in a non-sterile acid soil, with pH 4.3 (in water). (Source: Widiastuti and Toruan-Mathius 1992).

Inoculation Treatment	Plant dry weight (g/pot)					Nutrient recovery (mg/pot)	
	Stem	Leaf	Shoot	Root	Total	N	P
Control	0.63c	0.30b	0.93d	0.69c	1.62d	1.64d	0.29~
Rhizobium	1.37b	1.12a	2.48c	1.32b	3.80c	4.32c	0.58b
VAM	1.74b	1.15a	2.89b	1.36b	4.25b	5.24b	0.65b
VAM + Rhizobium	2.32a	1.43a	3.75a	1.79a	5.56a	6.12a	0.81a

Numbers in columns with similar letters are not significantly different (p>0.05)

Leucaena as a feed supplement

There is considerable potential in Indonesia for psyllid-resistant *Leucaena* species to be used as a readily available, cheap feed supplement for ruminants, as shown by recent trends in livestock production (Table 3). Indonesia supports the majority of small ruminants in southeast Asia: the numbers of sheep and goats have been rising faster than the average for developing countries in the Asia/Pacific region. In 1991, per capita meat production in Indonesia was 3.8 kg compared with an average of 10.2 kg for all the developing countries of Asia and the Pacific. The livestock sector is being expanded to close this gap as well as to increase exports of live animals and meat by 5% and 10% per annum respectively over the period 1993-1998 (Departemen Pertanian 1993).

Table 3. Livestock numbers in Indonesia in 1991 and trends since 1981 (FAO 1992).

	Million head (1991)		Annual growth since 1981 (%)	
	Indonesia	SE Asia	Indonesia	DC-Asia/ Pacific[1]
Buffalo	3.5	15.1	3.8	1.2
Cattle	10.4	34.3	3.5	1.5
Sheep	5.8	6.4	3.8	1.5
Goats	11.3	15.5	4.0	2.8

[1] Average for the developing countries in the Asian/Pacific region

Approximately 70% of the sheep and goats in Indonesia are located in Java where they are raised by smallholders in areas of intensive cropping. However, in the last five years, this percentage has declined because of increased numbers of livestock being managed by semi-intensive and extensive producers. The two main areas targeted for expansion are goat production in Nusa Tenggara Timor and sheep production in the plantations of North Sumatra for export to Malaysia and the Middle East.

Research on the agronomy of species in the genus *Leucaena* (and particularly accessions and cultivars of *L. leucocephala)* in Indonesian farming systems has been extensively reviewed in recent years (Wirjodarmomodjo and Wiroatmodjo 1983; Panjaitan and Blair 1985; Rangkuti et al. 1989; Blair et al. 1990). Forage yields, reported from experiments over a broad range of climatic and edaphic conditions in Indonesia, vary from 8-18 tonnes DM/ha/year (Piggin and Parera 1985; Catchpoole and Blair 1990; Horne and Blair 1991; Toruan-Mathius and Suhendi 1991). Feeding trials have confirmed results from other countries that supplementing low-quality grass diets with *Leucaena leucocephala* leaf meal can significantly increase ruminant growth rates at minimal cost (Table 4). The main reasons for this are higher intakes of digestible dry matter, provision of both fermentable and escape (bypass) protein and alleviation of some mineral deficiencies.

Since the psyllid infestation in 1986, other tree legume species have been evaluated to identify those that may be used to complement leucaena as a feed supplement. Blair et al. (1988) compared the agronomy of 17 selected species on an acid soil in southern Sumatra. *Cassia siamea, Acacia auriculiformis, A. angustissima* and *Enterolobium cyclocarpum* were among seven species that gave higher forage yields than *L. leucocephala* K8. Several other species of tropical tree legume, including *Gliricidia sepium, Albizia falcataria, Calliandra calothyrsus* and *Sesbania grandiflora,* have been evaluated as feed supplements for the seasonally wet/dry and humid tropics (Table 4). Panjaitan et al. (1993) compared forage production from these tree legume species in four agro-ecological zones and found large differences in yields between species and sites. Leucaena was better adapted to the seasonally wet/dry areas and calliandra gave best yields in the higher rainfall areas.

Although these species are easy to manage and potentially useful forage sources, each species has characteristics which limit its feed value in certain conditions. Perhaps the greatest advantage of *L. leucocephala* for smallholders is that it is able to persist under irregular and harsh management. *G. sepium* is more susceptible than leucaena to moisture stress while *S. grandiflora* is easily killed by frequent cutting (Ella et al. 1989, 1991; Catchpoole and Blair 1990). *C. calothyrsus* has some anti-nutritive factors that limit its potential, but it is a hardy and productive species that shows promise as a source of non-fermentable nitrogen (Jones et al. 1992). *Albizia falcataria* leaf is less digestible than that of *L. leucocephala* and it is slow to regrow after lopping. Perhaps the main outcome of the search for complementary species is the awareness that no single species, including psyllid resistant hybrids or accessions of leucaena, will be ideal for all circumstances.

Table 4. Feed intakes and average daily gains (ADG) from growth trials with sheep and goats in Indonesia using *L. leucocephala* and other tree legumes as feed supplements. (After Yates and Lowry 1982; Sitorus et al. 1985; Johnson and Djajanegara 1989).

Supplement	Intake (g $kg^{-0.75}$)[1]		ADG (g)
	Digestible DM	Crude protein[4]	
Leucaena leucocephala fed to sheep[2]			
• Control	-	-	20
• 500 g/head/day	33	8	35
• 1000 g/head/day	30	9	44
• 2000 g/head/day	39	14	43
• 2000 g/head/day	55	14	50
Leucaena leucocephala fed to sheep[3]			
• Control	-	-	9
• 180 g Leucaena	49	9	6
• 360 g Leucaena	47	10	24
• 540 g Leucaena	53	12	25
Leucaena leucocephala fed to goat?			
• Control	-	-	–24
• Leucaena + Napier grass ad lib	38	-	60
• As above + concentrate ad lib	37		66
• Control	-	-	5
• Leucaena at 15% of intake	37	9	22
• As above + 6 g urea	51	13	30
Sesbania grandiflora fed to sheep[2]			
• Control	-	-	21
• 500 g/head/day	35	8	57
• 1000 g/head/day	41	11	63
• 2000 g/head/day	53	14	100
Gliricidia sepium fed to sheep[2]			
• Control	-	-	20
• 500 g/head/day	50	11	41
• 1000 g/head/day	52	15	56
• 1500 g/head/day	55	17	63
• 2000 g/head/day	59	15	53

[1] Metabolic body weight; [2] basal diet (BD) of Napier grass; [3] BD + rice straw; [4] estimated requirement for a 15 kg lamb to gain 100 g daily is 12.4 g crude protein $kg^{-0.75}$

Research Needs for Leucaena in the Plantation and Animal Production Sectors

Psyllid resistance/tolerance

A research program to develop psyllid resistant/ tolerant hybrids or accessions is in progress in Indonesia. It includes:

(i) a germplasm collection with the aim of identifying useful high-yielding genotypes for good growing conditions, as well as genotypes suited to marginal environments;

(ii) a breeding program which aims to develop superior hybrids resistant to psyllids with the specific agronomic characters necessary for use as shade trees, for animal fodder, as a source of wood or for soil erosion control.

Plant propagation

Leucaena is most commonly propagated from seed. However, vegetative propagation appears to be feasible for psyllid resistant hybrids that are not self-pollinating or are seedless triploid hybrids. The development of hybrid *Leucaena* species that are both psyllid resistant and productive may have limited benefit for semi-intensive and intensive producers if they are to be faced with all the problems associated with production, certification and supply of seed. Many smallholder farmers within Indonesia are familiar with grafting techniques for fruit trees. Researchers need to find out the applicability of grafted hybrid *Leucaena* species for semi-intensive and intensive livestock producers, and to develop tissue culture techniques to increase survival of transplanted plantlets.

Evaluation trials

Selected hybrids/accessions should be evaluated across as wide a range of agro-ecological zones as possible. In West Java, where seasonal climatic variation is negligible, large differences still occur in the composition of the diet fed to small ruminants between the wet and dry seasons (van Eys et al. 1983). For semi-intensive cattle and goat producers in the markedly seasonal wet-dry areas of eastern Indonesia, seasonal shortages of feed supply and feed quality are a major problem. In West Timor, nutritional limitations during the dry season lead to very high kid mortality rates among goats raised by smallholders (Budisantoso et al. 1993). Drought tolerance of new psyllid resistant *Leucaena* species and possible complementary species should be evaluated for these areas where *L. leucocephala* played an important role as a feed supplement before psyllid infestation. Species which tolerate moisture stress better than Leucaena (such as *Albizia* lebbeck) should be more widely evaluated.

After agronomic performance, effect on animal production is the most important measure of the value of new psyllid-resistant *Leucaena* species and possible complementary species as feed supplements. *L. diversifolia* and *L. pallida*, for example, are very productive but have a lower dry matter digestibility than *L. leucocephala* (Shelton et al. 1991). Animal production studies should be included at an early stage of evaluation trials of new *Leucaena* species intended for feed supplementation within Indonesia. In particular, the capacity of new hybrids/accessions to provide extra dietary energy and both fermentable and by-pass nitrogen should be established.

A major advantage of leucaena for intensive livestock producers in the past was its persistence under heavy and irregular defoliation. Evaluations of new psyllid-resistant *Leucaena* species and possible complementary species should not only include agronomic trials on-station, but also be conducted in the target agricultural systems, where methods of use are rarely regular or predictable.

Selection for acid soils

Many of the areas where leucaena has potential as a shade crop for coffee, cocoa and tea are characterised by acid soils. Tolerance for acid soils will therefore need to be a criterion at the early stage of selection of hybrids for shade crops. The effects of dual VAM and rhizobium inoculation need to be clarified and considered in terms of economic benefit.

Leucaena for plantation crops

New psyllid-resistant *Leucaena* species may have a role in integrated farming systems that combine plantation and small ruminant production for semi-intensive and extensive producers in rubber and oil palm plantations. A major limitation of the forage resource in conventional tree crop plantations is the long period of negligible yield following canopy closure. One solution is to alter the planting pattern of the trees (or the number of trees per hectare) to allow more light to reach the ground. This would allow sustainable production of higher yielding grasses and tree legumes (for both forage and pulp wood) as an integral part of the plantation. Experiments on alternative planting patterns are already being conducted in Malaysia and Indonesia (Tajuddin et al. 1991). Widely spaced rows of leucaena underplanted with shade tolerant grasses might be an ideal system of managing such mixed plantation-grass systems.

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Leucaena in the Philippines

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Abstract

Before the leucaena psyllid arrived in 1985, the potential for development of *Leucaena leucocephala* in Philippine agriculture was demonstrated by its multiple uses and the technology developed to exploit them. Leucaena-fed animals made large liveweight gains; the wood produced excellent pulp, paper and fuel; and leucaena herbage could be used as organic fertilizer for rice and maize. Since the devastating psyllid *(Heteropsylla cubana)* outbreak, research has been diverted to biological control of pysllids, based on the natural resistance of some lesser-known *Leucaena* species. Attempts have been made to find alternative tree legumes, but their intakes and digestibilities are inferior compared to leucaena. Priorities for leucaena research and development in the Philippines will focus on the screening and selection of promising lines and hybrids. These will be evaluated in the different ecological zones, and their forage quality and yield, wood production and seed production potential will be tested.

AMONG 16 species in the genus *Leucaena* (Sorensson 1993), *L. leucocephala*, or leucaena, is the most popular in the Philippines. Known locally as Santa Elena or Ipil-ipil, leucaena is thought to have been introduced by Spanish Conquistadors (Brewbaker et al. 1985). The species' multiple uses - as livestock feed, live fences, fuelwood and shade trees for plantation crops - are well-recognised.

Interest in *Leucaena* species was renewed when Professor J.L. Brewbaker of the University of Hawaii introduced the 'giant' K-lines in 1969. In 1973, a comprehensive research program began on leucaena in response to the pressing need for cheap non-conventional alternatives for major oil-based agricultural commodities such as fertilizers. The program developed technologies for many of leucaena's uses, and leucaena was considered a 'miracle' tree until the psyllid *(Heteropsylla cubana)* arrived in late 1985. The effects of psyllids were more devastating on smallholder farms where leucaena was the most valuable component of the feeding systems (Moog 1993). To try to overcome the psyllid problem, researchers have been screening and selecting resistant leucaena species and hybrids, and have promoted alternative tree legumes such as *Gliricidia sepium*. Newly introduced leucaena lines that consistently show moderate to high psyllid resistance include *L. pallida* K376, *L. diversifolia* K156 and their hybrids with *L. leucocephala* (Luego 1990).

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Leucaena Research and Development before Psyllid Infestation

The results of a pre-psyllid national integrated leucaena research program highlight the potential of ***L. leucocephala*** in the development of Philippine agriculture.

Use as livestock feeds

Feeding trials have shown leucaena's value to the animal industry. Bulls made high, economical liveweight gains when fed 35% leucaena, 30% commercial concentrate and 35% rice straw (Sevilla et al. 1976). The average daily gain, daily feed consumption and feed conversion efficiency were 0.71 kg, 6.54 kg and 9.36 kg/kg respectively. Santa Gertrudis steers gained 0.52 kg/day on average when fed rice straw supplemented with 50% fresh leucaena leaves (Marbella et al. 1981).

Native goats fed 30% rice straw, 50% dried leucaena leaves, and 20% rice bran gained up to 69 g/day on average (Rasjid and Perez 1982).

However, goats fed a higher proportion of dried leucaena leaves (70%), gained only 36 g/day on average. The quality of goats milk was improved when supplemented with 30% leucaena in combination with *Brachiaria mutica* (Angelo 1986). Similarly, dairy calves fed starters containing 25% leucaena leaf meal gained more liveweight at lower cost than when no leucaena was included (Palo et al. 1984). For heifers, leucaena leaf meal (22.5-45% of the ration) made a good supplement to rice straw (Trung et al. 1984). Leucaena can also be a valuable ingredient in poultry feeds, contributing to desirable yellow-yolked eggs and yellow-skinned broilers (Daffon and Gerpacio 1973; Labadan 1976).

Wood, charcoal, and paper pulp

In the absence of psyllids, the arboreal types of *L. leucocephala* (e.g. K-28) produce pulp and paper of quality higher than that from Philippine mahogany and other reforestation species (Bawagan and Villanueva 1976; Escolano et al. 1978). Fibre dimensions of arboreal and shrubby types are comparable to those of Philippine hardwoods. Heating values are also high, with the shrubby type giving a higher value (4640-4673 cal/g) than the arboreal type (Bawagan 1984). The quality of charcoal easily meets industrial requirements (Alvia 1984).

Organic fertilizer

Leucaena leaves were comparable to ammonium sulfate in supplying the nitrogen requirement of rice plants in flooded and non-flooded soil conditions (Mabbayad et al. 1984). Maize grain yields were equally as high whether fertilised with herbage from intercropped leucaena in single hedgerows or with inorganic fertilizer at 60 kg/ha N, 30 kg/ha P_2O_5 and 30 kg/ha K_2O (Mabbayad et al. 1984). Leucaena's potential as a source of N-fertilizer for food crops has also been reported by Guevarra et al. (1978), Lao-Lao et al. (1978) and Alferez et al. (1980).

Introduction and breeding

From 1979 to 1982, hybridisation studies between the shrubby type leucaena (naturalised leucaena) and the arboreal type were conducted at the Institute of Plant Breeding, University of the Philippines at Los Banes. Cytological studies revealed that the shrubby type, the arboreal type and their hybrids are all tetraploids (2n = 104) except for one line (K-67) from El Salvador (2n = 112). This could possibly be a different biotype of *L. leucocephala* (de la Vina and Engle 1991). Pollen was more fertile from the shrubby type than from the arboreal type and their hybrids. The researchers postulated the existence of a certain degree of differentiation, either genie or chromosomal, between these two types of *L. leucocephala*. Most of the hybrids evaluated yielded more forage and wood than the shrubby parent.

Current Leucaena Research Activities

Recent leucaena research has studied the biology, ecology, population dynamics and biological control of the leucaena psyllid (Adalla 1990; Sanchez 1990; Villacarlos and Robin 1990), and the search for psyllid-resistant *Leucaena* germplasm (Crizaldo 1990; Luego 1990; Acasio et al. 1993; Alvarez 1993). Although indigenous predators are exerting some psyllid control (Sanchez 1990; Villacarlos and Robin 1990), integration of genetic resistance with biological control is believed to be a more effective approach. Attempts have been made to find alternative tree legumes *(e.g. Gliricidia sepium, Sesbania sesban* and *Desmanthus virgatus)* as sources of fodder for smallholder farms (del Barrio et al. 1988; Trung et al. 1990; Battad et al. 1993; del Barrio et al. 1993). Although results are promising, the intake and digestibility of alternative forage species are lower than for leucaena.

In other studies, *L. leucocephala* and other multipurpose trees have been grown as mulch and as hedgerows for alley cropping in upland farms (Calub 1992; Lasco and Dalmacio 1992; Lasco and Malinao 1994), as well as in fallow systems (Kungu 1993). In spite of psyllid infestation, *L. leucocephala* performs well, although its yield is reduced (Calub 1992). Mulch from leucaena has been observed to have higher soil ameliorative effects than other woody legumes (Lasco and Dalmacio 1992).

Priorities for Research and Development

It has been amply demonstrated that *L. leucocephala* is a useful multipurpose tree legume in Philippine agriculture. Despite its inherent limitations, local researchers agree that no other currently available tree legume species can surpass the proven versatility of leucaena.

A research and development program designed to promote the expanded use of leucaena as a source of fodder and fuelwood in the Philippines should include the following activities:

1. Screening and selection of promising *Leucaena* species and hybrids

The use of natural resistance is the most practical and economic way to control plant pests and diseases in different farming systems (Ceccarelli et al. 1992). Castillo (1993) evaluated 16 *Leucaena* species and hybrids and found ten which exhibited moderate to high psyllid resistance, fast seedling establishment, high biomass production and a considerable degree of cold tolerance. These promising lines and hybrids need to be screened.

2. Assessment of nutritional quality through feeding trials

Though only sufficiently well understood for *L. leucocephala*, forage quality is thought to be generally lower in other *Leucaena* species.

3. Regional performance evaluation

Agro-climatic factors have significant effects on plant establishment and production. In the Philippines, the performance of different *Leucaena* species depends on the amount and distribution of rainfall, and on soil fertility (Dacayo 1976). Psyllid-resistant lines identified elsewhere must be evaluated in a wide range of local conditions and management schemes for fodder, green manure and fuelwood production.

4. Wood production

Research to evaluate new lines should consider wood production as well as leaf yield (herbage). Fodder trees are an important source of fuelwood among smallholder farmers in the Philippines, not only for home use but for commercial production too.

5. Seed technology

Past experience has shown that unreplicated evaluation trials, because of inadequate supplies or quality of seeds, hinder the development of multipurpose trees in local agriculture (e.g. Crizaldo 1990). If one agency controls seed production and supply, the availability and purity of the seed should be easier to maintain. Pasture seeds in the Philippines are not covered by any seed certification scheme. Nevertheless, there is a move towards the formulation of seed quality standards for legumes such as leucaena. The seed storage requirements of selected lines and hybrids need to be explored.

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Leucaena in Sri Lanka

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Abstract

Results of three experiments are reported. In the first (a site of the NFTA International Psyllid Trial) *Leucaena diversifolia #46568*, *L. collinsii*, *L. pallida* K376 and Hybrid KX1 were identified as being highly resistant to psyllids. In a species evaluation trial, *L. pallida* K817, *L. diversifolia* RSB01 and K785 grew well, but were moderately susceptible to psyllid. In the nursery stage evaluation of the *L. diversifolia* complex, several of the *L. diversifolia* ssp. *stenocarpa* provenances show early promise. The field performance of these has yet to be assessed.

ABOUT a decade ago, *Leucaena leucocephala* was introduced to Sri Lanka in a joint research program between Sri Lanka and the International Institute of Tropical Agriculture (IITA), Nigeria. The performance of leucaena under rainfed highland conditions was remarkable. It replaced most of the other fast-growing tree species. Since then this legume has become naturalised both in the dry and wet zones of Sri Lanka, except at higher elevations where soils are too acid for its growth.

Leucaena's greatest impact has been in the livestock industry, because of the high protein content and good palatability of its foliage. This forage legume has potential as a supplement for the protein deficient pasture grasses in the tropics (Ravindran 1979). Nestle's Limited successfully planted 300 ha of leucaena on very sandy coastal soil where other crops had failed. The leaf meal produced after sun-drying and grinding was substituted, by the Oil and Fats Corporation, for up to 15% of the feed formula without any deleterious effects on livestock (Gunasena et al. 1990). However, it is known that the mimosine in leucaena can cause loss of hair and tainting of milk, although the toxic effects of mimosine are expressed only when the leucaena content of the diet is consistently above 30% (Wijewardene and Waidyanatha 1984).

The greatest constraint to using leucaena in agriculture and in animal husbandry is its susceptibility to the leucaena psyllid *Heteropsylla cubana,* which was first observed in the mid-country of Sri Lanka around February 1987. Since then, the psyllid has spread to all parts of the country where leucaena had been established.

This paper reports the results of three experiments (one still in progress) to evaluate new *Leucaena* germplasm.

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Experiment 1. International Leucaena Psyllid Trial Network

A trial was conducted at the University Experimental Station, Dodangolla, Kundasale in the mid-country intermediate zone of Sri Lanka from June 1988 to August 1989. Twelve species or hybrids of *Leucaena* (Table 1) were grown in two-row plots, each piot containing 40 trees spaced at 25 cm intervals. Rows were 1 m apart. Monthly observations were made of plant height and biomass production, of psyllid counts and damage using the empirical rating scale developed by the NFTA (Wheeler 1988), and of predator counts.

Table 1 summarises some of the data obtained one year after planting. Although *L. diversifolia* #46568 was the tallest entry, Hybrid KX2 recorded the highest leaf yield, followed by *L. diversifolia* K785. Leaf yields of more than 7 t/ha were measured in *L. diversifolia #46568, L. diversifolia* #33820 and *L. pallida* K376. *L. diversifolia* K156 and *L. leucocephala* K8 and K636 yielded poorly, although *L. leucocephala* K636 showed a faster recovery than K8 after psyllid damage. The forage quality of all entries is being evaluated.

Table 1. Tree height, leaf production, and psyllid damage recorded on 12 *Leucaena* species and hybrids.

Species/hybrid	Tree height (m)	Leaf dry weight (t/ha)	Psyllid damage rating'
L. diversifolia #46568	4.71	7.89	1.18
L. pallida K376	4.56	7.31	1.36
Hybrid KX1	4.14	5.55	1.45
L. collinsii	3.96	5.40	1.36
L. diversifolia K785	3.54	14.19	2.09
L. diversifolia #33820	3.50	7.45	2.18
L. esculenta	3.43	4.84	1.73
L. diversifolia K156	3.16	1.73	3.36
Hybrid KX2	3.08	19.58	1.82
L. leucocephala K636	2.41	1.58	5.36
L. leucocephala K8	1.67	0.53	6.64
Hybrid KX3	1.38	0.64	5.46

[1] Rating on NFTA scale, where 1 is no damage observed, 6 represents loss of up to 50% of young leaves, and 9 represents blackened stem with total leaf loss

Table 2. Tree height, stem number, and psyllid damage ratings for 10 *Leucaena* species and hybrids.

Species/hybrid	Tree height (m)	Number of stems	Psyllid damage'
L. pallida K817	4.07	1.51	2.64
L. diversifolia RSB-01	3.69	1.69	2.22
Hybrid DL88	3.67	1.67	3.87
L. diversifolia K785	3.25	1.61	3.84
L. collinsii K740	2.97	1.26	2.44
Hybrid KX3	2.93	1.61	3.00
L. pallida K806	2.92	1.17	2.78
L. leucocephala K58	2.56	1.36	3.33
L. leucocephala K636	2.54	1.46	3.83
L. diversifolia K156	2.12	1.14	2.11

[1] Rating on NFTA scale, where 1 is no damage observed, 6 represents loss of up to 50% of young leaves, and 9 represents blackened stem with total leaf loss

The greatest amount of psyllid damage, with severe defoliation, was recorded on the two entries of *L. leucocephala* (KS and K636) and on Hybrid KX3. *L. diversifolia* K156 was moderately damaged. The other entries were only damaged slightly if at all, with *L. diversifolia* #46568, *L. collinsii*, *L. pallida* K376 and Hybrid KX1 showing high resistance to psyllids. These results are generally consistent with those from other sites in the international trial.

Adults and larvae of the coccinellid beetle *Olla abdominalis,* as well as spiders, dragon flies and wasps, were found preying on psyllids in very low numbers. It is difficult to determine how effective they were in controlling psyllids.

Experiment 2. Leucaena species evaluation trial

A second trial was established at the Dodangolla Experimental Station in November 1992 with 10 accessions (Table 2). The objective of the trial was to assess various growth parameters and resistance to the leucaena psyllid. Trial entries were arranged in a randomised complete blocks design with three replicates, and 32 trees per plot. Tree height and stem number were measured on the 12 internal trees per plot. Psyllid damage was again assessed using the NFTA scale. Results are summarised in Table 2.

L. pallida K817 was the tallest, followed closely by *L. diversifolia* RSB01 and Hybrid DL88. The shortest trees were *L. diversifolia* K156 and the two *L. leucocephala* entries. The psyllid damage rating was comparatively low for all accessions in this trial. Moderate damage scores were recorded for Hybrid DL88, *L. leucocephala* K636, and *L. diversifolia* K785. The least damaged accession (rated 2.11) was *L. diversifolia* K156.

Experiment 3. Leucaena *diversifolia* complex provenance trial

A third trial began at the Dodangolla Experimental Station in July 1993 (nursery sowing), with field planting in December 1993. The objective of this trial was to investigate the pattern of genetic variation within the *L. diversifolia* complex. The trial comprised nine provenance seedlots collected by the Oxford Forestry Institute from natural populations of *L. diversifolia* in Central America, with seven additional seedlots as controls (Table 3). These control seedlots are from *L. leucocephala* and *L. pulverulenta,* two species which have shown susceptibility to psyllids in provenance trials, and from *L. esculenta* ssp. *esculenta,* which has proved to be resistant.

Table 3 shows data obtained in the nursery for plant height, leaf number, and psyllid damage. Plant heights differed significantly. In general, tallest plants were from seedlots *L. diversifolia* ssp. *stenocarpa* and *L. esculenta* ssp. *paniculata* (synonym *L. pallida),* followed by *L. esculenta* ssp. *esculenta* and *L. diversifolia* ssp. *diversifolia.* Plants from *L. pulverulenta* were the smallest. On a species basis, these growth patterns were also reflected in the number of leaves produced, with *L. diversifolia* ssp. *stenocarpa* and *L. esculenta* ssp. *paniculata* producing more leaves than *L. diversifolia* ssp. *diversifolia.*

Table 3. Plant height, leaf number, and psyllid damage on nursery plantings of 16 *Leucaena* species.

Species	Seedlot	Plant height (cm)	Number of leaves	Average psyllid damage'
L. diversifolia ssp. *stenocarpa*	3/91	73.8	23.1	2.53
	35/88	77.3	13.6	2.17
	4/91	89.8	10.3	2.63
	138/92	68.3	18.5	2.61
	53188	78.6	17.2	1.97
L. diversifolia ssp. *diversifolia*	45/87	62.4	9.4	2.06
	46/87	43.1	9.6	2.00
	83/92	53.2	9.8	2.19
	82/92	45.2	7.4	3.03
L. leucocephala ssp. *glabrata*	32/88	54.2	12.1	3.24
L. esculenta ssp. *paniculata*	52/87	81.5	9.7	2.38
synonym *L. pallida*	78/92	72.5	12.1	2.92
	79/92	71.4	12.8	2.60
L. esculenta ssp. *esculenta*	47/87	69.8	10.8	1.98
L. pulverulenta	84/87	33.5	7.4	3.64
	83/87	20.9	6.8	3.68

[1] Rating on NFTA scale, where 1 is no damage observed, 6 represents loss of up to 50% of young leaves, and 9 represents blackened stem with total leaf loss

In no case was bad psyllid damage recorded. Moderately bad damage scores were recorded in *L. leucocephala* and *L. pulverulenta*. The least damaged were *L. esculenta* ssp. *esculenta* 47/87 and *L. diversifolia* ssp. *diversifolia 53/88.*

This experiment will need to be continued for some time to provide meaningful data.

Research Priorities in Sri Lanka

The main priorities for research are:

- The introduction and evaluation of *Leucaena* species that are resistant to psyllids: important criteria are rapid growth, good coppicing ability and high forage quality.
- Selection of varieties for mid-country areas where the soils are acidic.
- Ecological evaluation of varieties for use in agroforestry (fodder, manure and fuelwood) in different zones.
- The establishment of seed orchards using the best varieties, and the distribution of this seed to farmers.

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Leucaena in Thailand

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Abstract

In recent years interest in leucaena in Thailand has focused on its use for wood production, forage, soil erosion control and soil fertility improvement. Leucaena has proved to be a valuable multipurpose tree species. It is a relatively fast-growing tree and productive forage. However, users lost confidence in leucaena research and development because of the devastating effect of the leucaena psyllid in 1986. It is doubtful if interest in Leucaena will recover without substantial effort and funding.

IN Thailand, *Leucaena leucocephala* has long been grown throughout the country. It is mainly used as poultry feed (leaf meal) to colour egg yolks and broiler skins, and as a living fence. Young shoots are also eaten as a green vegetable. However, leucaena is not widely used for grazing or other forage purposes. In recent years, interest in it has grown, for its potential in wood production, soil erosion control, soil improvement on steep land and other uses like turnery and parquet flooring. There has been very little research on its agronomy or use as ruminant feed.

Current Research and Development

Forage production

Leucaena leucocephala has been shown to be a productive forage for lowland areas and is especially useful as a source of protein for cattle. However, few studies have compared its performance with that of other tree legume species in different environments. There is no network of experiments to assess varieties or soil and management practices for forage production. The research, done by individuals, has concentrated on cut and carry systems used by the smallholder farmer.

For example, at Chiang Mai (latitude 19ºN), which is an area with wet and dry seasons, Sampet and Pattaro (1979) showed that cv. Cunningham gave a higher edible dry matter (EDM) yield than the local and some other introduced cultivars. Sampet and Pattaro (1987) showed that Leucaena cv. Cunningham produced more wood and EDM than *Sesbania grandiflora* and *Gliricidia sepium* (Table 1). In an experiment on the effects of frequency and height of cutting and plant density, the

Table 1. Edible dry matter (EDM) yield of *Leucaena leucocephala*, *Sesbania grandiflora* and *Gliricidia sepium* at different cutting heights.

Cutting height (cm above ground)	EDM (t/ha)			Mean
	Leucaena	Sesbania	Gliricidia	
	1st year			
25	5.27	7.75	4.79	5.94a
50	6.75	6.38	4.67	5.93a
Variety mean	6.01a	7.01a	4.73	Inter. (NS)
	2nd year			
25	10.68	2.48	4.85	6.00a
50	12.07	3.30	5.39	6.92a
Variety mean	11.38a	2.89b	5.12c	Inter. (NS)
	Total EDM			
25	15.95	10.23	9.64	11.94
50	18.82	9.68	10.06	12.85
Variety mean	17.39a	9.96b	9.85b	Inter. (NS)

Values with the same letter in either row or column are not significantly different at 5% level.
N.S. = non significant ($p < 0.05$)

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EDM yield was greatest at a cutting height of 50 cm and cutting frequencies of 6-8 weeks. A hedgerow planting configuration gave lower EDM yields than 4-8 plants/sq. m (Sampet 1983a, 1983b). Studies are continuing on the productivity of leucaena mixed with grasses such as Guinea and Ruzi in a cut and carry system (Sampet 1991).

Soil conservation and soil improvement

In Northern Thailand, hill farmers commonly practice shifting cultivation or slash and burn farming on steep land. This traditional farming practice can lead to very serious soil erosion and degradation when land becomes limited and the failow period is shortened. In recent years, several development agencies (e.g. Department of Land Development (DLD), Thai-German Highland Development project (TG-HDP), Thai-Australia World Bank Land Development Project (TAWLD), the Mckean Rehabilitation Institute, Thai-Norwegian Project and other non-governmental organisations), have tried to develop and evaluate appropriate soil conservation techniques as viable alternatives to shifting cultivation, and to introduce sustainable systems to the highlands. These trials have used many species of tree legumes or shrubs, including leucaena. Alley cropping has become the dominant conservation practice for the sloping lands.

Experiments have shown alley cropping to be effective in increasing crop yields (Inthapun and Boonchee 1990; Sampet 1992). However, hill farmers are not willing to adopt the practice as it needs more labour and greater management skills, and reduces their arable cropping area. The spacing between leucaena hedgerows influences the amount of green manure available to maintain soil fertility, whereas for effective soil erosion control, spacings vary according to the slope. The two uses may not be compatible. When the erosion risk is low, hedgerows could be further apart but then they may not maintain soil fertility.

Wood Production

In the past, leucaena wood was used only for charcoal-making and as fuel for pottery kilns. More recently, it began to be accepted as a piling timber, and there was some research into other uses, such as for turnery and parquet flooring.

Research in Thailand over the past 15 years has shown *L. leucocephala* to be a relatively fast growing tree. However, its performance is highly site dependent, much more so than favoured exotic species such as *Eucalyptus camaldulensis* and *Casuarina junghuhliana.*

There are several species trials in Thailand comparing leucaena with other multipurpose tree species (MPTS). Among these are the species/ variety/management trials of the F/FRED Project's MPTS Research Network established in 1987. These trials compared the growth of *L. diversifolia* (K156) with KX3, two provenances of *Acacia mangium,* and two of *A. auriculiformis.* Although there was little statistical difference between the entries, KX3 performed best across all sites, averaging 9.97 m in height after 3 years, about a metre taller than K156.

In 1991, the MPTS Research Network established another series of trials. The multilocational study has 33 sites in SE Asia (8 in Thailand) comparing the growth of K636 *(L. leucocephala)* with KX3 and *A. auriculiformis* provenances from Papua New Guinea and Queensland. Although only the first year's data are available (Table 2), K636 is emerging as the better of two leucaena entries in the trial. Plot variances for the two accessions at the six sites in Thailand do not differ statistically. Analysis of all individual trees from three of the sites in different countries indicates that KX1 is slightly more variable than K636 on a tree-to-tree basis. It will be interesting to maintain these trials to monitor stability of the hybrid and its growth relative to K636 and the *A. auriculiformis* origins.

A leucaena seed production (LSP) orchard was established by the Thai Institute of Scientific and Technological Research (TISTR) in 1988 in collaboration with the University of Hawaii, Nitrogen Fixing Tree Association and F/FRED. The LSP Orchard, located in Chan Tuk, comprises ten entries of species and hybrid composites. Seed has been harvested from the LSP Orchard, but without further funding the stand is unlikely to be maintained and improved.

Table 2. Means and variances for height (m) of *Leucaena leucocephala* (K636) and KX1 at seven sites in Thailand.

	KX1		K636	
Site	Mean	Variance	Mean	Variance
Chachoengsao	3.6	0.07	4.5	0.72
Ulthai Thani	4.0	1.19	4.3	1.47
Chiang Mai	1.5	0.27	2.6	0.46
Chiang Mai	3.3	0.35	3.7	0.38
Ratchaburi	4.4	0.66	4.0	0.83
Kohn Kaen	5.1	0.49	6.1	1.29
Praachuab Khiri Khan	2.3	0.14	2.3	0.29

Note: n = 12. F-test for Fll (0.05) = 2.82 indicate the population variances are not significantly different from each other at all locations.

The Psyllid Problem

The leucaena psyllid *(Heteropsylla cubana)* arrived in Thailand in 1986 and had a devastating effect on leucaena's use and role in research projects. Although the psyllid threat in Thailand has largely disappeared (see Geiger et al., these Proceedings), farmers, extension agents and researchers still think of leucaena as having a pest problem. Meanwhile, several favoured plantation species have shown high productivity, and substitutes have been found by charcoal producers and animal feed manufacturers. It is doubtful if interest in leucaena will recover without substantial effort and funding.

Future Research and Development

Soil improvement and erosion control

As population pressure increases, crop production is moving to upland areas while the traditional shifting cultivation on the highlands is no longer practiced. As a result, crop production is often limited by declining soil fertility. Farmers are not usually able to afford fertilizers for improving crop yields. Alley cropping, or a similar system, with leucaena or other tree legumes thus has great potential for improving soil fertility. Management factors, such as when, how often, and how to prune the leucaena trees, must be determined to assist farmers to adopt this technology.

Seed production and related research

Numerous trials still have leucaena entries in Thailand. It would cost little to maintain them and continue collecting data. Among these, the trials sponsored by the MPTS Research Network have the greatest potential. These trials feature psyllid-resistant and fast-growing material and allow for inter-site comparisons. TISTR's LSP Orchard program should be maintained. Together, these two trials could provide the basis for a seed dissemination program.

Use of Leucaena

Research on the use of leucaena for animal feed and wood products must be revived and accelerated in Thailand.

Networking

Thailand has been among the strongest supporters of the MPTS Research Network. Undoubtedly LEUCNET would find many willing partners in Thai institutions.

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Leucaena in Vietnam

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Abstract

In Vietnam's tropical climate, leucaena is a significant part of the agroforestry farming system, for soil productivity, environment protection and production of wood. There is good potential to further develop leucaena for different uses - intercropping, hedgerows for soil erosion control, soil improvement, shade and shelter, boundary plantings and livestock fences for forage and fuelwood. Four priorities for research and development in leucaena are: selection of species which tolerate varying environmental conditions and different soil problems; biology and control of psyllid; establishment and management of leucaena in small-scale farm and household situations, especially the number of trees, their spatial arrangement and which species suit the associated agricultural crops on the same land; and extension to help the public grow and manage this important tree.

LEGUMINOUS plants fix nitrogen from the atmosphere, and enrich the soil by improving its nitrogen status and increasing its organic matter content through leaf and root decay. There is a great variety of leguminous species in Vietnam, ranging from large trees to tiny plants, and *Leucaena leucocephala* is among those used as multipurpose crops.

Leucaena must be developed for community forestry in Vietnam. Apart from its role on the farm, leucaena maintains environmental quality, conserves biodiversity, restores degraded lands, augments the supplies of many products and contributes to the socio-economic development of rural people.

Leucaena has been developed in Vietnam by many farmers using simple traditional techniques on their relatively small land holdings. Their main aim was to meet needs for fuelwood, forage and green manure, and to control soil erosion. The Vietnamese Government has provided technical assistance and guidance for the farmers through the Reforestation Project to facilitate development of leucaena plantations.

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Potential for Further Development

Climatic conditions

Vietnam has a tropical monsoon climate with pronounced dry and rainy seasons. The mean annual rainfall range is 1500-2000 mm, with the highest values reached in the uplands, the southernmost part and the coastal areas. About 80% of the rain falls in the four-month rainy season from May to October. Throughout the country, mean annual temperature is about 23°C, with only 5 "C difference between the mean minima and maxima. Humidity remains high throughout the year. Conditions are thus very favourable for leucaena growth.

Waste land potential

Vietnam covers an area of 33 million hectares, of which three quarters are hilly and mountainous landscapes of varying slopes. The main soils in this region are ferrisols derived from schist, basaltic limestone and old alluvium. During the last fifty years the population has nearly tripled, reaching 70 million inhabitants in 1993. With increasing population, farmland is becoming more and more scarce.

There are extensive areas of waste land (Table 1). The population growth in Vietnam is causing problems that are very complex and interrelated.

Table 1. General land use in Vietnam.

Land-use type	Million ha	%
Agriculture	6882	20.9
Forestry	9769	29.6
Waste lands (bare hills)	12966	39.3
Urban areas, roads	1659	5.0
Other areas	1728	5.2
Total	33044	100.0

One of these is the increasing pressure on natural resources. Many steep areas are used for seasonal farming, involving intensive gardening under shifting cultivation with reduced fallow periods. This approach has caused many impacts such as erosion, flooding and decreasing productivity.

Through the program 'State and Farmers Work Together', the Government is now providing incentives for farmers to adopt appropriate strategies. This is helping the development of community forestry. The program centres on denuded forest lands, promoting the introduction of *Leucaena leucocephala* before the fields are abandoned, both to protect the environment and to produce wood. This perennial system allows successive harvests after the initial establishment cost.

Production of fuelwood

In Vietnam more than 90% of rural energy is provided from wood combustion. At present, about 21 million tonnes of fuelwood and 0.5 million tonnes of charcoal are used by households annually, with a further 2 million tonnes used by industry. A further 30 million tonnes of agricultural biomass, mostly crop residues, are burnt as fuel. These residues would probably be better used to improve the soil or as fodder for animals.

Shortage of fuelwood is a very serious problem. Leucaena growing in farming systems is a very useful source of village wood, providing adequate supplies because of its good growth rate and ability to coppice after cutting. The growing, harvesting, using or processing of leucaena also creates job opportunities for women, youths and children. Although farmers and landowners are not easily persuaded to plant trees solely for fuelwood, they can probably be encouraged to include leucaena and other legumes in gardens in different ways, such as intercropping, boundary plantings and use as livestock fences, to provide shade and shelter as well as fuelwood and poles. Locally grown leucaena not only saves time that is otherwise spent collecting fuelwood from distant forests, but also helps protect those forests from destruction.

Soil erosion control and cropping strategies

Shifting cultivation is common in Vietnam, with each household using at least 15 ha. The cycle of cultivation is shortening, causing increasing deterioration of soils. Nowadays, after two to three years of fallow the farmers reuse the former plot. This is insufficient time for the land to recuperate satisfactorily. Soil loss varies widely, with maximal values of 200-280 t/ha/yr recorded on sloping land cleared by heavy machinery, and other data suggesting losses of 150-200 t/ha/yr on bare soil, and 70-100 t/ha/yr under annual crops such as upland rice and cassava in monoculture.

Although conservation methods in the agricultural sector are diverse, leucaena-based cropping systems are preferred and widely adopted. Farmers with a low input capacity can minimise erosion by using appropriate systems, normally a main crop (cereal or perennial) with leucaena. Some commonly used patterns are leucaena in shelterbelts, leucaena intercropped with coffee, pepper and oranges, or leucaena as village shelter.

The economic benefits of leucaena shelterbelts are recognised by rural people and farmers. Field tests done in Tay Hieu-State Farm indicated 25-30% reduction of wind velocity; 10-15% increase in relative humidity; 20-30% more soil moisture; 10% better coffee yields; and 5-10% better orange yields. Coffee, pepper and orange are planted in farmland at very large spacings. Leucaena is the best species for intercropping. In the Tay Nguyen-Plateau the area of leucaena intercropping totals 1.5 million ha. In coffee and orange plantations, leucaena seedlings are planted at densities of 550, 1200 or 4000 per ha, and are very important in preventing erosion, retaining moisture, conserving and recycling nutrients, and fixing nitrogen. Leucaena leaves are small, allowing enough light to penetrate for lower crops, yet providing necessary shade in summer.

Periodically, leucaena plants are pruned and the branches spread in the alley ways as mulch and organic manure. In the inter-rows, different annual crops can be grown to gain a subsidiary income, and their residues also provide material for mulching. Such a system can save from one quarter to one third of the recommended fertilizer input while meeting the same yield target. This use of leucaena in hedgerows immediately gained popularity when it was shown that using leucaena leaves as green manure produced dramatic increases in crop yields. The relative place of leucaena among Vietnam's most popular green manure species is shown in Table 2. The benefits of mulching are demonstrated by the better growth of coffee in mulched treatments. Mulched coffee can be harvested one year earlier and coffee yields in the fifth and sixth years are much higher with mulching (Table 3.)

Leucaena plantations are commonly planted around villages by village committees and managed by villagers. Such leucaena forests not only protect village environments but also generate benefits such as wood and forage.

Table 2. Main green manure plants in Vietnam.

Plant species	Green matter (t/ha)	% N	dry matter P	K
Acacia mangium (leaves)		2.65	0.35	0.40
Crotalaria striata	15.6	2.70	0.30	1.26
Crotalaria juncea	15.0	2.65	0.27	1.00
Leucaena leucocephala	16.4	3.25	0.67	2.55
Sesbania canabina	15.8	2.88	0.54	1.40
Tephrosia candida	17.2	3.58	0.33	1.82

Table 3. Effect of mulch on coffee yield (kg/ha green beans).

Treatment	Without green manuring	With green manuring
Coffee yield in 5th year	1100	1600
Coffee yield in 6th year	1900	3240

Rehabilitation of degraded land

Many hilly areas are suffering from the destruction of forest and consequent land degradation, together with fire hazards from the invasion of alang-alang *(Imperata cylindrica)*. Many areas that are being developed, such as mining areas in Quang Ninh and Bat Thai Provinces, need rehabilitation urgently. Introducing fast growing leucaena could restore this land to production (eg. cattle raising or fuelwood) while protecting the environment.

As a legume, leucaena can fix atmospheric nitrogen through symbiotic association with rhizobium bacteria. Mycorrhizal fungi also form associations with leucaena roots, and their presence helps the plants absorb soil nutrients, especially phosphorus which is commonly very deficient in tropical ferrisols. Mulching with leucaena can increase soil porosity, soil moisture, field capacity and available water (Table 4). If green manure is incorporated into these degraded soils, their chemical properties improve (Table 5).

Table 4. Physical properties of degraded basaltic ferrisols after 3 years cultivation and incorporation of leucaena green manure (80 t/ha).

Soil Properties	Without leucaena	With leucaena
Porosity (%)	59.0	63.4
Soil moisture ((r/o)	26.2	29.3
Max. field moisture holding capacity (070)	39.6	43.2

Forage potential

In the dry season (from October to March) the monthly rainfall decreases considerably to only a few millimetres in the northwest and on the Central Plateaux. Evaporation may exceed rainfall, and for four to five months the land may be too dry for any crop. Lack of fodder is a major reason why cattle raising fails in the dry season. Clearly, continued and sustained animal production must be based on improved pastures. Leucaena, which can adapt to dry conditions and resist pests and diseases, and which has a high protein content is a very useful forage legume (Table 6).

In Vietnam, leucaena is also a human food, with young shoots and leaves being eaten. Seeds can also be eaten after cooking to protect consumers against nematode disease.

Table 5. Soil chemical properties of degraded basaltic ferrisols after three years of cultivation and incorporation of green manure.

Treatment	pH	OM (%)	Avail. P_2O_5 mg/100 g soil	Exch. $Ca^{2+}Mg^{2+}$ meq/100 g soil	CEC meq/100 g
Tephrosia candida	3.92	4.83	4.40	6.10	31.2
Leucaena leucocephala	3.97	4.68	4.25	5.70	29.5
Crotalaria uras	4.00	4.10	3.18	5.52	31.1
Vigna sp.	3.50	3.00	1.75	3.84	23.6

Table 6. Fodder value of *Leucaena leucocephala* in Vietnam.

Feed	Production (t/ha/yr)	Crude protein (kg/ha/yr)	(g/kg DM)	Carotene (mg/kg DM)
Green foliage	13.5	3421	254	156
Leaf meal	6.1	1769	290	221

Priorities for Research

Rural people comprise 80% of Vietnam's total population. Meeting social need is thus largely equivalent to meeting the demands of rural people. What are these demands? As Vietnam is a developing country, rural people need five things - food, fuel, building materials, forage and cash income.

Vietnamese foresters, agriculturalists and many provincial authorities advocate the use of leucaena for environmental protection and to supply many necessary products. The following are the recognised priorities for leucaena research to benefit Vietnam.

Species comparisons

Twelve *Leucaena* species have been tested in Vietnam and found to have varying growth rates (Table 7). The genus contains a wide range of characteristics such as adaptability, higher yield, resistance to pests and diseases, so it is highly likely that some species will be especially valuable in Vietnam. More work is needed to select species that can adapt to, and survive, various local environmental conditions and problems, such as: saline/alkaline soils; arid/semi-arid climates; sandy/coastal environments; acidic, toxic, degraded, and waterlogged soils; cooler temperatures; and high pest (psyllid) and disease pressure.

Table 7. Daily rate of growth for 12 *Leucaena* species tested in Vietnam.

Species	Height (cm)	Rate of growth (cm/day)
Leucaena esculenta	80	0.40
L. pulverulenta	100	0.50
L. diversifolia	150	0.75
L. pallida	160	0.80
L. leucocephala	253	1.26
L. greggii	60	0.30
L. shannonii	151	0.75
L. collinsii	154	0.77
L. trichodes	died	-
L. macrophylla	160	0.80
L. lanceolata	240	1.20
L. retusa	40	0.20

Leucaena psyllid

The leucaena psyllid, a tiny homopterous insect, has infested leucaena in Vietnam, causing widespread economic damage. Research on the psyllid is urgently needed. We need to find integrated control measures, such as biological control agents, and to exchange and test genetic material for resistance.

Small scale management of Leucaena

In Vietnam, land is now allocated to farmers. The State recognises farmers' rights to long-term use, to heritage exchange and ceding of the profits from land cultivation. Farm households have become self-governing production units instead of cooperatives. Farmer benefits are assured through land-use contracts lasting 20 years for annual crops and 50 years for forest and perennial trees. This encourages farmers to invest in soil conservation and reforestation. In this context, we need to study the use of leucaena by small scale farms and households. The key factors are the number of trees, their spatial arrangement, and which species are most compatible with the associated agricultural crops on the same unit of land.

Local extension

Governments have limited finance and staff, so the expanding opportunities for leucaena development cannot be realised without public participation. However, governments can encourage the public to contribute their skills in many different forms. Public participation will depend on well planned and organised extension services, using many different methods and resources, e.g. the mass media, group media such as plays and pictures, and demonstration plots. The extension program will help the public grow and manage the trees by informing and convincing them and providing links. Useful features may include:

- discussions to discover people's tree-related needs and ways of meeting those needs;
- dissemination of necessary information;
- provision of necessary technical information and skills concerning leucaena;
- encouraging local participation in the initiation, planning, growing and management of leucaena.

Extension agents will help farmers with basic tools and equipment, seeds and seedlings, and the design and establishment of projects. One goal of any extension service must be to include the rural women in all processes and services, because it is they who are responsible for collecting fuelwood and water for cooking, and for caring for the house and children. Teaching and motivating school-children about raising seedlings and planting trees can also be very important.

International Support

International assistance for training programs and extension education is needed. Leucaena research and development in Vietnam would be greatly enhanced by collaboration in a project with overseas research and development expertise. A major function of such a project would be the exchange of information among scientists working on multipurpose tree species and their use on small farms. Research on priority constraints, such as adaptability, psyllid resistance and forage value, would also occur, as would workshops, seminars, conferences, and exchanges with a wide range of experts in the field of leucaena development.

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Leucaena in Papua New Guinea and the South Pacific

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Abstract

Leucaena leucocephala was widely used in plantation and other agricultural systems in the South Pacific until the devastation caused by the leucaena psyllid in the mid-1980s. This has lead to a greater use of other *Leucaena* species and multipurpose trees for agriculture and forestry. Highlights of the national MPTS evaluation program in Papua New Guinea are presented as an example of the commitment and need for sustainable agriculture and food production. The use of leucaena and MPTS to compliment natural pastures in native grasslands and under plantation crops show promise for the expansion of the livestock industries in the South Pacific island countries. A greater international collaboration on R & D in leucaena and MPTS in general is necessary to ensure rational use of limited resources of the small island nations.

SOUTH PACIFIC countries are relatively small in population and land area. A total land area of approximately 540 000 km^2 spread over 1200 major island groups, supports a population of about 6 million people. Papua New Guinea (PNG) is the largest country with 85% of the land area and 70% of the population (Table 1). Up to 80% of the population in most of the South Pacific island nations rely on agriculture or related activities for their basic subsistence and source of income.

Table 1. Population, land area and the Gross Domestic Product (GDP) per capita for Pacific Island countries.

Country	Population	Area (km^2)	GDP (A$)
Fiji	800 000	18272	2312
New Caledonia	176900	19 105	16 350
Papua New Guinea	4056000	462 242	1302
Solomon Islands	400 000	28 556	734
Tonga	97 400	697	1297
Vanuatu	156500	12 190	1379
Western Samoa	163000	2 842	936

Source: South Pacific Commission (1993)

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Major island states and territories of the Southwest Pacific covered in this paper lie between 5°N and 23°S latitude and include PNG, Solomon Islands, Vanuatu, New Caledonia, Fiji, Tonga and Western Samoa. Temperatures in the lower latitudes or the region average 32-29°C in January and 29-23°C in July. In general temperature is not a limitation to pasture growth except at high elevations (> 1500 m a.s.l.) in PNG. Soils in the region vary from infertile coralline sands to extremely fertile clays and clay loams of volcanic origin. In most of the larger land masses however, a high proportion of the land area is unsuitable for agriculture due to inaccessibility of the steep and rugged mountainous terrain.

Rainfall is a significant climatic factor influencing vegetation type and plant growth, and it is affected by topography due to rainshadow effects. Extremely high rainfalls (> 4000 mm) can occur on the southeast sides of the central mountainous areas of PNG, Fiji, Solomon Islands and Western Samoa. In rainshadow areas of the north-western side of the islands, precipitation may be as low as 800 mm with water deficits occurring between May and October.

Agriculture in the region is based on the traditional system of shifting cultivation which may require bush fallow periods of up to 10 to 15 years to replenish soil fertility. With increasing population pressure, coupled with competition for land for plantation agriculture, forestry and urbanisation, bush fallows are becoming shorter and indeed less practiced. This increased intensity of landuse and farming on steep slopes has lead to land degradation.

The current use of leucaena in the South Pacific region is as a multipurpose tree species (MPTS). Such species are needed in agroforestry systems to provide sustainable food production, wood products for energy (fuelwood), construction (poles, fencing stakes) or industry (woodchips) and to reduce the high rate of deforestation in the region. Promotion of leucaena and other MPTS for forage is also an option for increasing utility of limited and marginal lands, such as pastures under plantation crops.

The aim of this paper is to describe and assess the current use of leucaena and other MPTS in the region; to identify potential for further development; and to identify research priorities to increase use of leucaena for community and industry purposes.

Current Use and Occurrence of Leucaena and MPTS

Leucaena was probably brought to the South Pacific through the Philippines by Spanish galleons sailing from the Americas in the early 1600s (t'Mannetje and Jones 1992). Today leucaena has become naturalised throughout the region, especially on coral-derived soils surrounding many of the islands. In some instances it has beccme the dominant vegetation, and in Vanuatu the local shrubby leucaena occurs in dense stands and is considered a weed. This naturalised leucaena is described generally as the Hawaiian type, and its development as a protein rich forage for livestock and as a source of wood products has been hampered by the psyllid pest, *Heterophylla cubana.*

Papua New Guinea

Leucaena at a height of 8 to 12 m with an open self-pruning canopy was an ideal shade tree for plantation agriculture in PNG and the island states until its devastation by the psyllid pest in the mid-1980s (Merret 1988). Other species then became prominent, particularly *Gliricidia (Gliricidia sepium),* as a shade for cocoa in the lowlands.

In 1988 the Department of Agriculture and Livestock (DAL) introduced and evaluated many MPT species for enhancing sustainable food crop production. The national MPTS evaluation program was initially aimed at introduction and evaluation of exotic species but now emphasises identification and testing of local species (Kanua and Sitapai 1992).

The main objectives of the work have been to identify and select suitable species and provenances under appropriate management (coppicing) for alley or fallow cropping systems, based on measurements of height, girth and foliage yield. Several species have been identified for highland and lowland conditions (Table 2). Some highlights are summarised here.

Table 2. Some promising (+) Multipurpose Tree Species (MPTS) evaluated for agroforestry in the highlands and the lowland dry and moist conditions in PNG.

Tree species	Highlands (1000-2000 m ASL)	Lowlands (0-1000 m ASL)
Acacia angustissima	+	
A. aulacocarpa		
A. auriculiformis		
A. crassicarpa		
Calliandra calothyrsus	+	
C. houstoniana		+
Casuarina oligodon	+	
C. grandis		
Erythrina var. *orientalis*		
Erythrina var. *variegata*		
Gliricidia sepium		
Leucaena collinsii		
L. diversifolia	+	+
L. lanceolata		
L. leucocephala local		
L. leucocephala K8		
L. leucocephala K28		
L. leucocephala K67		
L. leucocephala K636		+
L. leucocephala El Salvador		
L. macrophylla		
L. mexicana#	+	+
L. pallida		
L. shannonii		
Ormocarpum orientale		
Piper aduncum		
Pterocarpus indicus		
Samanea saman		
Sesbania sesban		
Schleininia novo-guineensis		+

#Promising accession, requires verification
Source: Kanua and Sitapai (1992)

The highlands (1000-2000 m asl) MPTS evaluation program

Work on MPTS for the highlands is based at the DAL Highlands Agricultural Experimental station in Aiyura (1660 m asl), Eastern Highlands Province. The objectives are broad and include study of suitability for alley cropping, improving soil fertility, site stabilisation of steep slopes under cultivation, and production of fuelwood, building poles and fencing material.

Preliminary results showed that *Acacia angustissima* performed consistently well from sea level to 2000 m a.s.l., however its prolific seeding has raised concern regarding its weed potential. Despite this concern, *A. angustissima* is being tested off-station for adoption in alley cropping. Its promotion as a fallow species may be more successful, as with many other MPTS, since this is the traditional system to which people are most accustomed (Kanua and Sitapai 1992).

Calliandra calothyrsus has also shown promise, particularly for alley cropping in the highlands. A provenance of leucaena known locally as Mexican leucaena and *L. diversifolia* both have potential for building timber and fencing posts and may be managed in woodlots or planted as a fallow. Nonetheless, there appears to be no substitute for *Casuarina oligodon* in the highlands. This species was domesticated some 2500 years ago and its influence and use penetrates to the very heart of highland agriculture and livelihood (Kanua and Sitapai, 1992). Above 2000 m a.s.l., *C. oligodon* is the most significant tree for highland people. Its growth is slow but it produces good quality fuelwood, building and fence posts. It is usually planted as a fallow species. The fertility of fallowed sites, and hence time to return to cropping, is judged by the growth and performance of *C. oligodon.* Research into this species is poor and requires immediate attention.

The lowlands (0-1000 m asl) MPTS evaluation program

Work on MPTS for lowlands agriculture is conducted on DAL research stations at Bubia (50 m a.s.l.) and Saramandi on the northeast coast, Laloki and Popondetta on the southeast coast, and the Lowlands Agricultural Experimental station (LAES) at Keravat in the New Guinea Islands. The objectives and measurements are similar to the highlands program, but including soil and foliar chemical analysis. Generally, these sites are fairly representative of the dry and moist lowland conditions. The lowland trials also monitor the effects of the leucaena psyllid infestation (Moxton and Kusunan 1990; Brook 1992).

The data obtained indicate that *L. leucocephala* K636, *Leucaena* spp. Mexican provenance and *C. houstoniana* hold the highest promise for use in agriculture. The leucaenas produce good quality timber and have potential for fallow and alley cropping. Of the leucaenas in trials at Bubia and Saramandi, only K636 showed relative tolerance to psyllid attack. However, Moxon and Kusunan (1990) recorded psyllids on K636 and on the local leucaena at LAES, and casts doubt on K636 as an accession resistant **to** psyllids as reported elsewhere in PNG. *L. lanceolata, L. macrophylla* and *L. shannonii* were moderately tolerant and the remaining leucaenas (K8, K28, K67, Mexican Hybrid) were highly susceptible.

The growth of *A. angustissima* was also very vigorous in the lowlands but branches snapped under the weight of a heavy foliage canopy. The indigenous species *Schleinitzia novo-guineensis* had a fast growth habit and showed promise as a shade tree for robusta coffee and cocoa in the lowlands. It grew vigorously and produced large quantities of biomass. To broaden the genetic base of gliricidia, 15 provenances were introduced four years ago (Kanua and Sitapai 1992) and further testing is underway to establish the suitability of both local and introduced material.

Eight MPTS are currently being evaluated at the LAES (Keravat) in an alley cropping trial and results to date are summarised in Table 3. The species tested included *A. angustissima, C. calothyrsus, C. houstoniana, G. sepium, L. diversifolia, L. leucocephala* K636, *L. macrophylla, O. orientale.* Of these species the most vigorous were *A. angustissima, C. calothrysus, C. houstoniana* and *G. sepium.*

Table 3 shows the effect of coppicing (CO, Cl) and mulch treatments (M+,M-) on the marketable tuber yield of sweet potato. It is interesting to note that the M- treatments initially resulted in higher yield than M+ treatments. This could have been related to the applied mulch cooling the soil and reducing the rate of mineralisation of organic matter. It could also have been due to the soil (slightly weathered young volcanic ash) being sufficiently fertile to maintain good yield initially. Significant changes in sweet potato yield were therefore not observed until the fourth harvest when M+ treatments resulted in a 42% higher yield than M- treatments. Further croppings are likely to increase the relative benefits of hedgerows as soil nutrients in the control treatments become depleted. This work is continuing. Future work is planned to include socio-economic assessments, particularly to determine labour costs and likely returns.

Table 3. Effect of coppicing and mulching of eight species of MPTS on sweet potato tuber yield (t/ha).

	Treatments	n	Second harvest	Third harvest	Fourth harvest
8 species	C0	48	7.57	4.38	5.12
	Cl	48	8.15	4.57	6.65
	M+	48	7.41	4.89	6.90
	M–	48	8.31	4.06	4.86

C0 = coppice at planting; C1 = coppice 4 wks after planing; M+ = plus mulch; M– = mulch removal
(Source: Humphrey and Igua, 1994)

Role of the PNG Forest Research Institute (FRI)

The PNG FRI at Lae has introduced and evaluated MPTS for wood products, viz. building poles, pulpwood and fuelwood and general agroforestry uses. The FRI runs the National Tree Seed Centre and is a major MFTS seed source for the country.

Howcroft (1992a) reviewed leucaena research and its utilisation for the forestry industry in PNG. Giant varieties of *L. leucocephala* were introduced in 1976 to test their potential for woodchip but were found to be unsuitable. Interest was maintained in the leucaenas as MPTS for community, forestry and agroforestry. The giant mexican variety has proven ideal for conditions at altitudes from 500 to 1500 m asl and has been successfully used as shade for arabica coffee. There is, however, some doubt as to the identity of the mexican variety and it is referred to locally as 'Mexican leucaena' or even as the species as *L. mexicana* (Table 2). The PNG *Leucaena* germplasm collection therefore requires verification.

An interesting use of leucaena and other MPTS by the PNG FRI is in the reclamation of abandoned mine sites (Howcroft 1992b). Alluvial gold mining operations in Wau over 50 years has left much of the landscape unsuitable for agriculture and the area is considered of no economic value. The soils are soft rock, highly weathered clays, with substantial patches of sulphide. Initially, 25 species were introduced to the mine site in Wau. Species that showed promise for this land reclamation project were *A. angustissima, Albizia chinensis, C. callothrysus, C. houstoniana, Casuarina oligodon, Gymnostoma papuana, L. macrophylla,* 'Mexican Leucaena', *L. pallida* and *Schleinitzia novoguineensis.* Nine of the species planted are indigenous to New Guinea and the remainder are exotic.

Fiji

Fiji is an agricultural country. Livestock of major importance are beef, dairy cattle, goats, sheep, pigs and poultry. Fiji is almost self-sufficient in pigs and poultry but self-sufficiency for beef is 55%, dairy 42% and goats 85%. In 1991, about 10 000 t of mutton were imported valued at F$20M.

Fiji has locally adapted breeds of animals but poor nutrition is the major constraint. Good flat lands are cropped with sugarcane leaving poor hill land for livestock grazing. There are about 170000 ha of pasture land in the country. Of this, 40000 ha is under improved native pastues and 6000 ha is improved with exotic species, mainly in the dairying area. The crude protein content of grass is poor in the wet season, even lower in the dry season and is not sufficient for good growth of cattle. As a result, the animals lose weight in the dry season. The introduction of legumes (herbaceous and tree legumes) for use in native pastures, with proper fertilisation and stock management, may reduce losses and perhaps even result in liveweight gains during drier months.

Research on leucaena in Fiji

Leucaena leucocephala locally known as 'Vaivai' is commonly found on coralline soils around the coasts of the islands of the Fiji group, having been first recorded by Seeman in 1867. Local farmers have claimed better growth and condition on cattle browsing leucaena although horses frequently suffer hair loss from mane and tail. The use of leucaena as a forage crop was investigated in Hawaii by Takahashi and Ripperton (1949) and was recommended to Fiji as early as 1942 in a letter from Ripperton (Jack 1942). Payne et al. (1955) observed the growth of a local line but little work was done in Fiji until 1968 when different lines of leucaena were received from overseas and evaluated at Sigatoka (Table 4).

Yield trials (Partridge and Ranacou 1973) showed the Mexico line produced the highest total edible dry matter (42 900 kg/ha of leaves and fine stem) over the two years of the trial (19701971) but it did not differ significantly from Ivory Coast (41900 kg/ha), Peru (40 600 kg/ha) or the Yucatan line (39 700 kg/ha). The ratio of leaf to fine branches was approximately 65:35 with no significant difference between the lines. The average crude protein values for leaves and fine stem was 33 and 13% respectively, with no difference between the lines. There was a small variation in crude protein levels at different harvesting dates but no seasonal pattern was apparent. The Ivory Coast strain with its profuse external branching appeared to have the most suitable growth habit as a browse feed.

Table 4. Strains of *Leucuena leucocephala,* plant introduction numbers, and observations of the branching habit of individual unpruned trees in 3 x 4 m rows (1968-1969).

Strain	F.D.A.[1]	Hawaii Seed No.[2]	C.P.J. No.[3]	Branching habit
Peru	15346	-	18614	Tall growth, less branching
Mexico	16436	K8	-	Tall growth, less branch
Yucatan, Mexico	16437	K28	-	Good branching
Honduras	16438	K29	-	Fairly good branching
Ivory coast	16439	K62	-	Numerous lateral branches
Salvador	16440	K67	-	Tall growth, fairly good side branching

[1] Fiji Department of agriculture (FDA) number
[2] Central America leucaena collection, 1967 (Brewbaker, pers. comm.)
[3] CSIRO Plant Introduction number.
Source: Partridge and Ranacou (1973).

In a grazing trial, Brahman cattle grazing unimproved Nadi blue grass *(Dichanthium caricosum)* were periodically allowed to graze 10 to 20% of paddocks fenced and planted with leucaena. The liveweight gains of animals grazing the Nadi blue and leucaena was more than double that of animals grazing Nadi blue alone (Partridge and Ranacou 1974, Table 5).

Table 5. Liveweight gain (LWG) of cattle grazing unimproved Nadi blue pasture with varying levels of leucaena.

Leucaena (%)	g/hd/d LWG	kg/ha LWG
0	21.5	110
10	300	170
20	500	270

Yield of leucaena on humic latosols was depressed compared to alluvial and nigrescent soils. However, the important limitation to the widespread use of leucaena in Fiji is its poor establishment under field conditions. Many cultural practices were used but were generally found to be expensive and time consuming.

Further work on the establishment of leucaena was abandoned following the psyllid attack which was first recorded in 1985 (Chand 1990). The attack completely denuded the plants. But since then, the psyllid population has reduced and growth has improved. However, there is still not enough interest among the farmers to plant leucaena, even though departmental officers feel that there is good potential for feeding leucaena to ruminants. A program is currently underway using demonstration farms, to create interest among farmers to plant and feed leucaena. There is also a need for psyllid resistant lines and other tree legumes with similar potential as leucaena.

Vanuatu and other Island States

In Vanuatu leucaena occurs naturally in dense stands on calcareous coralline, sedimentary and volcanic ash parent material soils with a pH greater than 6.5 and receiving a mean average rainfall of 1500-2500 mm. Despite concerns regarding its weed potential, smallholders on eastern Efate have fenced small areas of leucaena thicket and daily cut 6-10 m saplings which they feed to their animals. Some of the best smallholder cattle in Vanuatu are produced under this system (Macfarlane and Shelton 1986) although the leucaena psyllid has substantially reduced the productivity of this valuable legume fodder. In New Caledonia, leucaena productivity has been reduced by an estimated 95% by the psyllid, placing great pressure on other forage resources. This has led to overgrazing and the development of a weed problem in some areas.

The Vanuatu Pasture Improvement Project (Evans et al. 1992) evaluated the leucaena cultivars Cunningham, Peru and the local variety, as well as promising lines from Hawaii. The strongly branching, woody, K636 was more productive and psyllid tolerant than cv. Cunningham. Research trials at Tagabe and Mon Biftek over three years have shown that the *Leucaena leucocephala x L. pallida* and *L. diversifolia* x *L. leucocephala* hybrids to be psyllid tolerant and more productive in terms of edible forage. Palatability trials at Tagabe have indicated leucaena and Glenn joint vetch *(Aeschynomeue americana)* to be the most palatable of the shrub legumes tested.

Leucaena is shade tolerant and is an ideally suited species to supplement natural pastures under coconut plantations in Vanuatu. Generally, this is an underutilised feed resource and its exploitation is envisaged to increase grazing animal production in the South Pacific island states.

Development Potential and Research Priorities

Development of leucaena and MPTS in the Pacific island states is a necessity to diversify farmer income and to improve livelihood. It is an option for more intensive use of limited arable land as the traditional bush fallow system of agriculture becomes less feasible. Moreover, the high rate of deforestation as a result of increasing population pressure may be slowed through the promotion of leucaena and MPTS in general. Research needs to address medium- and long-term needs to achieve overall agricultural sustainability as well as economic and social development.

Damage to leucaena caused by the psyllid *H. cubana* has become less severe over the years since its initial impact in the mid-1980s. However, it is still a problem and evaluation and selection of less susceptible varieties needs to be encouraged. Forage evaluation work should include palatability and forage quality assessment of the nutritive value of any new leucaena variety or hybrids (see Norton et al., these Proceedings).

Leucaena toxicity due to the presence of mimosine and its goitrogenic metabolites (DHP) have been solved through the discovery of the rumen microbe, *Synergistes jonesii,* which can degrade the toxins in the rumen (see Bray, these Proceedings). However, whilst the microbe had been promoted in Australia through deliberate inoculation programs, no such activity has been encouraged in neighbouring Pacific island nations. In PNG, evidence of presence of the DHP degrading microbe was recorded in cattle (Raurela and Jones 1985) and sheep and goats (Sriskandarajah and Komolong 1986). This was due to co-grazing Javanese cattle and sheep (priangon) respectively with previously susceptible breeds imported from Australia and New Zealand. It is possible that larger ranches in PNG with no history of grazing Asian cattle may still lack this microbe. A formal evaluation of the presence of the microbe needs to be investigated in PNG and the isolated South Pacific island nations.

Other fodder tree legumes such as *C. calothyrsus* and G. *sepium* may also have a role in providing a protein supplement to shade tolerant grasses under coconuts or in the case of gliricidia as a living fence. These species should be widely evaluated in the region. Increased use of multipurpose tree legumes also offer great potential for development of the beef cattle industry in the South Pacific. In PNG, it is unfortunate that evaluation for livestock feeding was not an objective of the national MPTS evaluation program (Kanua and Sitipai 1992). However, the infrastructure is in place for evaluation of the existing leucaenas or new hybrids for fodder use.

Conclusions

Greater utilisation of leucaena and other MPTS in the South Pacific island nations may be achieved when they are promoted for use in viable agroforestry systems for the smallholder farmer. The island nations are challenged by rapid sociocultural, economic and political changes. Their average population growth rates exceeds 2% among the highest in the world. All these factors have a profound effect on traditional agricultural systems and an understanding of this context may assist in the formulation of appropriate agroforestry technologies. The most immediate situations to address with the use of leucaena and MPTS are soil degradation, removal of forests, and food and cash crop production to reduce dependence on imported food. Production of building poles, fuelwood and material for home wood consumption and industry needs are also objectives that need to be addressed.

Training is an essential component for any new technology changes to be adopted successfully. Village farmers are generally sceptical of change due to their low level of literacy. Officers and agents, including policy makers, promoting these changes should be well informed of the potential for development and the limitations of new technology. Collaboration with workers in other countries and regions of the tropics will also be of great value in increasing confidence and will hasten the adoption of new and superior technology involving leucaena by village farmers.

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Leucaena in Northern Australia

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Abstract

In Australia, about 35 000 ha of *Leucaena leucocephala* is grown, mostly on alkaline clay soils in 600-750 mm annual rainfall, with small areas under irrigation. Planted in rows with companion grasses in the inter-row space, it is grazed in situ, carrying 50000 head of cattle annually. Animal production from systems based on leucaena is higher than for any other grazing system in tropical Australia. There is great potential for growing more leucaena in sub-tropical and tropical Australia, but its wider use is limited by psyllids, low rainfall, frost, poor soils and establishment difficulties. This paper outlines current agronomic practices in Australia and areas for research and funding. Selection of new leucaena lines should aim to retain the extremely high nutritive value of *L. leucocephala.*

LEUCAENA *(Leucaena leucocephala)* is grown in tropical and sub-tropical Australia mainly as a forage for grazing cattle. It is recognised as having exceptionally high potential for animal production. Though leucaena has been naturalised in Australia for more than 100 years, its potential forage value was recognised only 40 years ago (Hutton and Gray 1959) and growers have been slow to adopt it. Currently only about 35 000 ha are planted to leucaena for grazing.

Initially, leucaena was little used commercially because not enough was known about its management, potential value, agronomy, geographic limits, establishment requirements and its mimosine toxicity problem (Gray 1968). By 1980, although more was known, some problems remained — slow establishment, mimosine toxicity, poor performance on acid and waterlogged soils and difficult grazing management (Jones 1979). Leucaena's potential productivity was not fully appreciated. By the mid-1980s the toxicity problem had been solved (Jones 1985; Jones and Megarrity 1986). However, the psyllid *(Heteropsylla cubana)* problem arrived in 1986 causing serious loss of production in coastal humid areas of Queensland.

At present, wider adoption of leucaena is still restricted by the psyllid problem; establishment difficulties; environmental limitations (frost, soils, rainfall); and management limitations.

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The Psyllid Problem

Leucaena psyllids were first recorded in Australia in April 1986. By December of the same year psyllids had spread to all growing areas. Though variable and unpredictable, damage can be severe. Yield reductions in coastal Queensland have ranged from 5 to 80% (Palmer et al. 1989; Bray and Woodroffe 1991; Elder 1993; Room et al. 1993).

Studies of the psyllid in Australia have not found a clear relationship between psyllid populations and rainfall, temperature, relative humidity and damage (Bray 1994; Elder 1993). However, evidence suggests that psyllid populations do not build up in hot dry conditions, nor in sustained rainfall or frost (Bray 1994). Rather they are more likely to develop in the milder weather of spring and autumn (Elder 1993), when there is an abundance of new foliage after summer rain (Room et al. 1993), and in dense, close-row stands (Elder 1993). In central Queensland, where most leucaena is currently grown, psyllid damage has been much less severe in inland drier areas (600-750 mm mean annual rainfall) than in coastal humid areas with more than 800 mm rainfall (Elder 1993).

At present, neither biological control, chemical methods (spraying with 0.03% Dimethoate) nor management options appear to offer long-term solutions to the psyllid problem. Bray (1994) has suggested several other ways of tackling the pest:

- select psylhd resistant genotypes within *L. leucocephala;*
- select resistant lines from other species such as *L. diversifolia* and *L. pallida*, although they are less digestible; and/or
- select psyllid-resistant interspecific hybrids between *L. leucocephala* (high quality) and other species such as *L. pallida.*

Castillo (1993) tested a range of *Leucaena* species and hybrids at sites where psyllids were abundant. He found that *L. pallida* and its hybrids with *L. leucocephala* and some lines of *L. diversifolia* were resistant to psyllids. One *L. pallida* x *L. leucocephala* F1 hybrid (K748 x K636) was outstanding. Castillo (1993) also found large variation in psyllid resistance within F3 progeny of *L. pallida* x *L. leucocephala.* This confirms the strategy of Brewbaker and Sorensson (1993), who are selecting for psyllid resistance in segregating populations and who are developing stable, open-pollinated hybrid lines. However, Castillo (1993) found forage from *L. pallida* lines was of poorer quality than *L. leucocephala.* He noted that even interspecific hybrids may produce forage of comparatively low quality.

There is an urgent need to select for, or breed, psyllid resistant leucaena cultivars in Australia. It is essential that these have nutritive value similar to that of *L. leucocephala.*

Establishment Difficulties

Leucaena is grown on a large scale in Australia (100-5000 ha per property), mostly in rows (4-10 m apart) with grass in the inter-row space, without irrigation. Sowing is mechanised. Most leucaena is grown at the limits of its climatic tolerance, in areas with low and seasonal rainfall, and winter frosts, because the soils there are suitable.

Seedling establishment has been unreliable, but can be significantly improved by using known techniques for seedbed preparation, seed treatment and sowing. These make soil moisture available to the establishing seedling and promote rapid seedling growth.

Planting

A thoroughly cultivated seedbed is less likely to grow weeds and can better store subsoil moisture. In clay soils, deep ripping (30-50 cm) along the rows before planting may improve water penetration and leucaena's root development (Wildin 1993).

Seed should be scarified and inoculated with rhizobia to ensure rapid and even germination, root nodulation and seedling establishment in limited soil moisture (Shelton and Brewbaker 1994).

Non-irrigated leucaena is best sown at rates of 3-5 kg/ha (rows 8-12 m apart) in the warmer and wetter summer months, with mean daily minimum temperature of more than 15°C (Cooksley 1986), or after good rainfall to ensure moisture throughout the profile. For irrigated leucaena, 10-13 kg/ha of seed is used when sown in 3-4 m rows (Pratchett and Triglone 1989).

In clay soil, emergence can be reduced if the seed is planted deeper than 5 cm, but if seed is sown shallower than 1 cm soil moisture will quickly become limiting for germination and emergence. The use of side-press wheels greatly assists establishment whereas top-press wheels tend to increase 'crusting' which impedes seedling emergence.

Plant nutrition at establishment

Most leucaena has been planted in fertile soils where nutrient deficiencies are unlikely to occur, but there has been little research into soil fertility and plant nutrition on any soils. Problems occur on acid soils where aluminium and manganese toxicity can seriously affect nodulation and nitrogen fixation. Ruaysoongnern et al. (1989) showed that readily available phosphorus and calcium promoted nodulation and rapid seedling growth. They established critical nutrient concentrations in seedlings for the nutrients nitrogen, phosphorus, potassium, calcium, sulphur and manganese.

If mycorrhizae do not infect the seedling roots soon enough, the resulting poor uptake of phosphorus can slow down the seedlings' early growth. This also causes short-term depression in nodulation and nitrogen fixation, and nitrogen and phosphorus deficiency (Brandon and Shelton 1993). Slow nodulation is an important factor in poor seedling growth. It often takes up to seven weeks before seedlings are effectively nodulated in the field.

Weed control

Where moisture is limiting, effective weed control before and after planting is essential to prevent establishment failure (Maasdorp and Gutteridge 1986; Cooksley 1987). The weed problem is less severe where soil moisture is not limiting (Pratchett and Triglone 1990). Weed-free inter-row cultivation is practised for up to 12 months before companion grasses are planted. Pre-emergent (Trifluralin) and post-emergent (Fluazifop) weedicides are frequently used where weeds occur within the rows.

In rare cases leucaena is sown directly into established grass pasture, but to be successful the grower must create a wide grass-free area on both sides of the row by cultivation or chemicals.

Post-emergence predators

Leucaena seedlings may need spraying with Chlorpyrifos to stop atack by insects *(Pterohelaeus* sp. and *Gonocephalum* sp. or false wire worm). Thrips often cause serious damage to establishing leucaena in the Ord area of northeast Western Australia, but can be controlled by spraying with 0.03% Dimethoate.

Native mammals such as kangaroos and wallabies, and exotic species such as hares, can destroy areas of establishing leucaena. The scale of the problem is reduced by fencing or by planting larger areas.

Research and funding for establishment

Effective extension and training are urgently needed to improve seedling establishment. Graziers must appreciate the importance of providing conditions which allow rapid, even germination and rapid, weed-free seedling growth.

Researchers need to define more clearly the interactions between *Rhizobia,* nodulation, mycorrhizae and nutrient availability to the young seedling, aiming to maximise seedling growth rates. Lines must be selected with faster seedling growth, an objective that may be achieved in interspecific hybrids (Sorensson et al. 1994).

Environment Limitations

In Australia, the three major environmental limitations to leucaena are soils, rainfall and temperature.

Leucaena does best on deep, well drained neutral to calcareous soils (Shelton and Brewbaker 1994). In Australia, best performance has been on deep, fertile soils with pH > 5.5 with good calcium levels and water holding capacity (Jones 1991). It is one of the few legumes to grow well on structured neutral to alkaline clay soils (Foster and Blight 1983; Jones 1991). Leucaena does not like waterlogging, or shallow soils which prevent root penetration, or high acid and low calcium soil, or clay soil with impeded drainage. In wetter areas it will grow on shallower soils but extra fertilizer is needed (Jones 1991).

Although leucaena is best suited to tropical environments with > 1000 mm of rain per year, in Australia it is commercially grown successfully in areas of 600 mm/year. Very little leucaena is grown in the higher rainfall (> 800 mm mean annual rainfall), lower frost coastal areas characterised by predominantly shallow, infertile, acid, low calcium soils. Furthermore the psyllids are a more serious problem in coastal areas. Most leucaena is grown in central Queensland, 100-300 km from the coast, on alkaline clay soils with an annual rainfall average of 600-750 mm, in wide rows (5-15 m). Marginal and variable rainfall increases the establishment risk and reduces productivity, but this is more than offset by better soil and much less psyllid damage.

Leucaena is readily frosted south of about 23°S latitude, which can make considerably less green forage available in winter. Even under irrigation in the Ord River valley of northeast Western Australia (latitude 17°S) leucaena growth and animal performance are depressed in the winter (mean minimum temperature in June and July is 14°C).

If leucaena were adapted to a wider range of environments it would have more potential for use in Australia. Selection or breeding could produce lines better adapted to the acid, low calcium soils of the higher rainfall coastal areas, with better cold tolerance, and increased drought/low rainfall tolerance.

Forage Quality

Leucaena leucocephala has a proven record as a palatable nutritious forage. Now that the mimosine/DHP problem has been solved for ruminants in Australia (Jones and Megarrity 1986), the major nutritional problem has been overcome. In Australia, most graziers with large areas of leucaena rumen-inoculate their herds to prevent mimosine toxicity.

Leucaena's low sodium and iodine levels can be overcome by growing it with high sodium grasses like Rhodes grass and pangola grass or by feeding animals a sea-salt lick (Jones 1979).

If we understood why *L. leucocephala* is such a good forage it would help in our search for other useful shrub legumes. As well as the high mineral, protein and digestibility levels in actively growing leucaena, its high value as a grazed feed may be due to the accessibility of the edible material and its high dry matter content. There is speculation that *L. leucocephala* has optimum levels of tannins which allow efficient utilisation of the protein by assisting amino acids to bypass complete degradation in the rumen.

The importance to animal production of leucaena's high feeding value needs special emphasis. There is little point in growing other, lower value, shrub legumes if existing herbaceous legumes may achieve similar animal production at lower cost. For example, other leucaena species with psyllid tolerance will need to be carefully assessed for their nutritive value, animal production potential and reaction to grazing. Two species with some psyllid resistance *(L. diversifolia* and *L. pallida)* have potential value. However, some lines of *L. diversifolia* are less digestible than *L. leucocephala* (Bamualim 1981). *L. pallida* contains higher tannin levels than *L. leucocephala* and may be expected to have a lower feeding value (Castillo 1993).

Since *L. leucocephala* has such exceptionally good value as feed, any future research should include attempts to correct this species' current main limitations (psyllids, acid soils, cold temperature). This may be more rewarding than using different *Leucaena* species or other tree legume genera in Australia.

Management Limitations

Production from leucaena-based systems is high compared to that from other grazing systems. Non-irrigated leucaena, raingrown in 600-750 mm MAR, in wide rows with grass, is normally stocked at 0.6 to 1.0 steer/ha, producing 255-330 kg liveweight gain/steer/year (0.7-0.9 kg/steer/day) (Wildin 1993). A highly productive irrigated system has been developed in the Ord River irrigation area of north-east Western Australia. Leucaena is grown in 2-3 m rows with pangola grass inter-row, stocked at 6-7 steers/ha and grazed rotationally. Animal daily liveweight gains range from 0.5 kg (winter) to 0.85 (summer) with a yearly production of 1500-1730 kg liveweight/ha (Pratchett and Triglone 1989).

Most management systems have evolved to suit low labour operations and range from continuous grazing (with strategic spelling) to strict rotational grazing (1-2 weeks on and 4-6 weeks off). Leucaena is also used as a grazed protein supplement to low quality pasture.

While we have high production systems in operation, few of the management variables have been researched. Important examples include:

- *Soil moisture relationships.* In an environment where water is limiting we know little of the relationships between row spacing, leucaena growth, grass growth and animal performance. The same applies to irrigated leucaena, where more efficient irrigation strategies are also needed.
- *Grazing management.* The tall-growing leucaena types can present a forage accessibility problem. They often have to be either excessively heavily grazed or slashed for control. Similarly, the threat of frost and psyllid damage can make graziers hurriedly over-utilise the forage at a critical period of the year (early to mid-winter).
- *Fertilizer management.* Hardly anything is known about the maintenance fertilizer needs and responses of mature stands of leucaena plus grass, in the soils on which it is grown in Australia. Prinsen et al. (1992) demonstrated a sulphur deficiency in old stands of leucaena on clay soil. Plant nutrition problems will become increasingly important if more leucaena is grown in the less fertile soils. The critical value of nutrients in index leaves of leucaena can be used as a guide to deficiency of some nutrients (Ruaysoongnern et al. 1989).

Research is needed on the dynamics of row spacing and water relations, and their effects on the productivity (plant and animal) of leucaena plus grass systems. The fertilizer requirements of established stands need to be studied, in the soils in which leucaena is grown. As well, shorter growing varieties would make grazing management much easier.

Potential for Development

The potential for further plantings of leucaena is very large, but it is essential that growers recognise and adopt better cultural practices, which reduce establishment risks. Markets require animals which reach slaughter-weight at a younger age, and that should encourage the use of high-quality systems involving Leucaena, which give high production.

There are about 11 million hectares of brigalow and bluegrass downs clay soils, with 600-800 mm annual rainfall, in tropical eastern Australia. Even with existing insect and environment limitations, the 35 000-40 000 ha of suitable clay soil currently cropped to leucaena is less than 5% of the potential area. Over 2 million ha could be used for leucaena. Leucaena cultivars with increased drought and cold tolerance would also benefit expansion onto these soils.

Many of the deeper soils, occupying about 3 million ha of the coastal speargrass region in north-eastern Australia (700-1200 mm rainfall), could be developed with psyllid and acid soil tolerant cultivars.

There are large areas of fertile clay soils in the semi-arid Mitchell grass downs (29 million ha) and gidgee (9 million ha) areas in central western Queensland. More than 5 million ha of this area receives more than 400 mm rainfall per year. Cultivars with low rainfall or drought tolerance and reliable establishment would substantially increase the potential for leucaena on much of this area. Indeed, an exotic tree legume of inferior quality *(Acacia nilotica)* has already colonised large areas of this zone.

Better drought tolerance would improve the scope for use of dryland leucaena in the far northern areas of Australia with very seasonal (summer) rainfall distribution. However, in the hotter areas with marginal rainfall (< 650 mm/year), the high evaporation rates severely limit establishment and subsequent yield.

The Hawaiian interspecific hybrids of *L. leucocephala* and *L. pallida*, which better tolerate psyllids and cold (Castillo 1993) and show better seedling vigour (Sorensson et al. 1994), may provide significant opportunities to expand leucaena use in Australia.

It is difficult to predict the future because of changing economic and market demands. However it is not unrealistic to suggest that 3-5 million ha of leucaena could be grown in Australia, provided production constraints can be overcome.

Summary of Research and Development Priorities

Table 1 lists the important areas requiring research and/or training and extension activity that have been addressed in each section of this paper. Our point is that large areas can already be developed with existing technology. With improvements in technology this area can be expanded enormously.

Table 1. Leucaena research and development needs in Australia.

Problem	Cause	Status*	R & D Needs
Predator damage	• Leucaena psyllid	H	• select/breed resistant plants • develop control measures
	• long soft scale	M	• find resistant plants
	• false wire worm	L-M	• apply known technology
	• die-back fungus (Ord River)	M	• find control measures or plant resistance
	• thrips (Ord River)	L-M	• find resistant material
Slow or failed establishment	• seedbed & planting	M	• training/extension to apply existing technology
	• seed treatment	L	• training/extension to apply existing technology
	• slow seedling growth	M	• select accessions for seedling vigour
	• slow/poor nodulation	M	• Rhizobia/nodulation research
	• weed competition	H	• extension/training to apply existing technology
	• soil infertility	L-M	• research on nutrition needs
	• VAM inactivity	M	• research to clearly define its interactions and role
Environment adaptation limits	• unsuitable soils (shallow, acid, poor drainage)	M	• define suitable soil areas • select accessions for acid soil tolerance
	• cold temperature/frost	H	• select accessions for cold tolerance
	• low/seasonal rainfall	H	• select accessions for drought tolerance
Nutritive value *L. leucocephala* (high)	• high protein digestibility and utilisation	L	• define why *L. leucocephala* has such high nutritive value • determine factors causing reduced nutritive value
Other *Leucaena* spp. (lower)	• tannins lower digestibility?	H	• select for high nutritive value
Management/ production limitations	• soil moisture	M	• research row spacings, interactions and effects on yield, associated grass, animal production in raingrown areas • define irrigation strategies • select short, bushy lines
	• uncontrolled growth	M	

* H = high, M = medium, L = low

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