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SHRUB LEGUME RESEARCH in INDONESIA and AUSTRALIA

Proceedings of an International Workshop
held at
Balai Penelitian Ternak
Ciawi-Bogor, Indonesia
2nd February 1984

Editors: E. T. Craswell and Budi Tangendjaja

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The Australian Centre for International Agricultural Research (ACIAR)
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Contents

Foreword

Shortages of fuelwood and forage in tropical Asia have stimulated a great deal of interest in shrub legumes, some species of which have been hailed as miracle trees. Recent experience has however shown that their performance varies considerably from place to place.

The occasion of the ACIAR Policy Advisory Council (PAC) meeting, which was hosted by the Indonesian Agency for Agricultural Research and Development (AARD) in Bogor and Ciawi, provided an opportunity to review research on shrub legumes in Indonesia and Australia and to explore potential areas for collaborative work supported by ACIAR.

The AARD and ACIAR invited representatives of the Bogor research community to join PAC members at the one-day workshop, and would like to thank the participants for their valuable contributions to the discussions.

ACIAR wishes to thank Mr S.W. Sadikin, Director-General of AARD, and the Director and staff of Balai Penelitian Ternak, Ciawi, for making excellent arrangements for the meeting. We also express our thanks to the participants who presented the papers reproduced in this volume, and to J. V. Mertin for doing the technical editing.

The research results to date show that shrub legumes already contribute greatly to the farming systems of some areas in Indonesia, such as Nusa Tenggara Timur, but that further research is needed to select cultivars adapted to the less favourable environments found in other parts of the archipelago. ACIAR hopes that this challenge will be met through a research partnership between Indonesian and Australian scientists.

J.R. McWilliam
Director
ACIAR

Welcoming Address

S.W. Sadikin*

Ladies and gentlemen:

I welcome you all to this Workshop on leucaena and shrub legumes that has been organized by the Australian Centre for International Agricultural Research in conjunction with the Agency for Agricultural Research and Development.

World-wide interest in leucaena continues. A 1982 bibliography contained no less than 1308 entries, and new discoveries continue. We are faced with a flood of information, much of which is inapplicable to Indonesia, yet on the other hand some obvious questions remain to be answered. Leucaena has been known and used in unique ways in Indonesia for a long time. We believe it has further potential for increasing animal production and farmers' incomes, for improving soil fertility and decreasing erosion, and for providing fuel and wood products. There are distinctive research requirements in ruminant, monogastric, and even human nutrition.

Increase of animal production in Indonesia is limited by the availability of good quality animal feed. I expect that research will allow leucaena to become an important source of animal feed in the future. However, it may be that the emphasis in research should swing to one of the other woody legumes.

This Workshop brings together experts and their information from Australia and Indonesia. We hope it will enable us to identify opportunities and to decide on priorities for shrub legume research in Indonesia.

We should note that this field has already provided an excellent example of research co-operation between Indonesia and Australia. This is the experiment here at Ciawi that showed that the ability to completely detoxify leucaena can be transferred between animals by rumen fluid infusion - an experiment, one should note, of more obvious value to Australia than Indonesia!

But, I am sure there will be other research projects and/or activities arising from this Workshop, which will be valuable to Indonesia.

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Genetic Resources of Leucaena and Other Shrub Legumes in Indonesia

S. Sastrapradja*

In Indonesia there are many species of legumes that have been used as food, feed, fuel, timber, and traditional medicines. Some of these species are multipurpose ones, in that they are food producers, as well as sources for feed, fuel, or timber. Lamtoro (*Leucaena leucocephala* (Lam) de Wit) is such a species.

Although lamtoro has been successfully introduced into Indonesia for quite some time, it was not until recently that its role became much admired. The admiration is due to the introduction of the giant varieties, e.g. K-8, which are now locally known as 'lamtoro gung'. These varieties are being rapidly planted all over Indonesia. A number of samples have been evaluated for their development in North Sumatra Province (Tampubolon 1982).

Another introduced species that has received equal appreciation is kaliandra (*Calliandra calothyrsus* Meissn). It supplements lamtoro, which does not perform well at high altitudes. However, this species requires much more rainfall than lamtoro. As a producer of fuel, kaliandra is much liked due to its ability to sprout. Unlike lamtoro, the population of kaliandra in Indonesia is more or less uniform.

Because of the popularity of these two species, gaps in their development have been identified and research needs have been put forward (NAS 1977; NAS 1983 a, b). In 1982, a national seminar on lamtoro was organized in Indonesia to formulate a strategy for its development.

In addition to the above two mentioned species, there are several shrub legumes that need further evaluation as to their potentials. These species are generally fast growing, fix nitrogen, and are appreciated for their value as fuel, forage, or soil cover. Apart from their botany, not much has been done scientifically in these species. This paper, then, deals only with those that have value as feed and forage.

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Occurrence and Plant Description

Although all islands in Indonesia generally experience wet and dry seasons, the southeastern part is much drier than the rest of Indonesia. The rainy season extends only for approximately 3 months of the year and the annual rainfall may reach only 900 mm as compared with 2000-3000 mm in the western part. With such a variation in climate, there is also a variation in vegetation.

The following are the legume species that are commonly employed for feed or have potential for forage.

1. Papilionoideae

(1) *Gliricidia sepium* (Jacq.) Steud.

This species, which is native to Central and South America, is locally known as 'gamal'. It grows well below 500 m altitude, though it is not uncommon for it to be grown in much higher altitudes. Like kaliandra, gamal requires a high annual rainfall with a distinct dry season. Therefore, it is found much more often in the western part than in the southeastern region of Indonesia.

Gamal is an erect shrub or small tree, which is characterized by its short trunk and straight upright branches. Leaves are pinnately compound with 7-15 pairs of leaflets. From its flowers, it is easily recognizable as belonging to the same family as the pea or bean.

People in the villages in Java plant gamal as living fences. It is propagated generally by cuttings though seeds are abundantly available. Branches are numerous and villages harvest them for firewood. Leaves are fed fresh to cattle, being mixed together with all kinds of grasses. It is reported, however, that this foliage is toxic to horses (Little 1983).

(2) *Sesbania*

There are approximately 50 species of *Sesbania* distributed in tropical and subtropical regions (Verdcourt 1979). In Java, five species are reported to occur (Backer and Bakhuizen van den Brink 1963) of which "turi" (*Sesbania grandiflora* (L.) Pers.) is the most known.

Species that are found in Indonesia are either shrubs or small trees. The genus is characterized by large papilionoid flowers, pendulous linear pods, and numerous small seeds. Generally, they require an annual rainfall of more than 1000 mm.

The native country of turi is unknown, however, Indonesia is considered as a probable country of origin (Verdcourt 1979). Among the five Indonesian species, turi is the largest, the tree of which may attain 10 m height. Two kinds of turi are recognized, i.e. the red and the white flowering taxa. A hybrid between the two taxa also exists. Economically, this species is important due to its value as firewood, pulp, green manure, and a vegetable. Foliage and green pods are also valued for cattle feed.

Another species worthy of mention is "jayanti" (*S. sesban* (L.) Merr.). The plant is not as high as turi, but produces more drooping branches. The leaves may serve as fodder (Heyne 1950). Jayanti has yellow flowers instead of white or red as in turi. It is reported that a sample collected from Bali produced white flowers.

A thorny turi known as *S. bispinosa* is the smallest among the five species reported to occur in Java. It is also rarely found. Like jayanti, the species has yellow flowers. The growth rate is fast with numerous branches at the base of the stem. Besides its value as green manure, the leaves are good cattle fodder.

2. Mimosoideae

Acacia

Many species of acacias are natives of Australia. Some of them are also found in Indonesia. Species like *A. auriculiformis*, A. Cunn. ex Benth. and *A. mangium* Willd, are both indigenous to the eastern part of Indonesia. The two species are well known now due to their fast growing nature (Little 1983; NAS 1983). These two acacias are included among the list of trees recommended for reafforestation. In fact all over Indonesia, *A. auriculiformis* is planted for city beautification. The following species have some value as fodder.

(1) *A. farnesiana* (L.) Willd.

This species, which is a native of tropical America, was introduced as an ornamental plant but now it is naturalized. Though it is often planted in areas as high as 1200 m, it thrives well in lowland dry regions.

The shrub grows to 4 m high, and has bright golden yellow flowers that are arranged in heads. The flowers have a fragrant smell. The flattened pods, which are narrowed between the seeds, are browsed when young by livestock, together with the leaves.

(2) *A. villosa* Willd.

It is commonly found in many open areas, between 1-700 m. Sometimes a large population dominates the area such as that found in Gunung Kidul (Yogyakarta) region. Reported to be native in the West Indies, this species was introduced to Java in 1920 (Backer and Backhuizen van den Brink 1963).

The plant is a short shrub with plenty of branches. Leaves are bipinnately or sometimes tripinnately compound with small sized leaflets, which are compactly arranged. Such an arrangement allows a large amount of biomass production per plant.

(3) *Pithecellobium dulce* (Roxb.) Bth.

It is one of the South American species that are successfully naturalized in Indonesia. Locally known as "asem landa" (the Dutch tamarind), the shrub is valued for a number of reasons.

The shrub has a nice crown with an abundance of leaves, which are arranged bipinnately. Because of this character, it is planted for city beautification. By pruning, good hedges can be made.

Fruits are produced plentifully around May-December. The seed pulp is sweet and sour, resembling that of asem (tamarind), hence the name "asem landa". Leaves and pods are browsed by livestock.

3. Caesalpinioideae

(1) *Caesalpinia sappan* L.

It is a handsome shrub, with a distinct inflorescence. From the flower, it is easy to recognize that the species belongs to the same family with the common "Kembang merak" (*C. pulcherrima* (L.) Sw.). Locally known as "sapang", this species produces bright yellow flowers.

Though it is widely cultivated in South-east Asia, its native country is unknown. It is grown for hedges and wood. People also appreciate it for its coloring substance.

Leaves are produced in abundance. Flowering and fruiting are observed the whole year round.

There are a number of legume species with potential as forage or feed. Species belonging to tree legumes such as *Albizia falcataria, Acacia decurrens,* and *Prosopis juliflora,* or herb legumes such as *Calopogonium mucunoides, Desmodium purpureum,* and *Dolichos biflorus* are already known and utilized for feeding livestock in Indonesia. Many of these species are also recognized as having roles in improving soil fertility, producing fuel, timbers, or raw materials for traditional medicines. To appreciate and develop the potentials, thorough studies on their evaluation are necessary.

Current Status of Research and Development

The legume family is a large group that includes many useful species. Most of them however, are only known botanically. The food legumes are among the species that have been thoroughly studied because many of these species have been long in cultivation. Others are still wild and if they are cultivated, little is known in terms of their productivity.

Because of their ability to fix free nitrogen, legumes have a special status in agriculture. A group of research workers who are interested in nitrogen fixation associate themselves in a working group. They represent different research institutes, universities, and disciplines. They meet once every 6 months to discuss research results and problems. *Rhizobium* inoculum is one of the topics that they have agreed to work on for Indonesia, because of the great demand from the agricultural sector. Another group is working on the protein-rich property of the seed legumes. The latter group is part of the ASEAN-Australia group that is working on low-cost protein food.

Regarding lamtoro, BPPT (Badan Pengkajian dan Penerapan Teknologi, i.e. the Agency for Technological Adaptation and Assessment) has been working on it for 3 years, being mainly interested in the properties of this leucaena for greenery, fuel, and feed.

Meanwhile, Perhutani (Perusahaan Hutan Indonesia, i.e. the Government Forest Corporation) has long been interested in the development of kaliandra. As part of the greenery scheme, kaliandra has been planted in many areas in Java. From the recommendation and research needs (NAS 1983), it is obvious that many aspects of research and development are still needed despite its wide acceptance.

Future development

It has been mentioned that many species of herb, shrub, and tree legumes are found naturally in Indonesia. Because of their large numbers and wide usage, any attempt to develop them should be based on clear goals, otherwise no significant result can be expected in a given period of time. The following consideration might be of some importance.

1. Genetic Resources

Genetic resources of soya bean and minor food legumes such as *Mucuna pruriens, Dolichos lablab, Vigna unguiculata* have been collected from many areas of Indonesia and botanically evaluated (Komisi Pelestarian Plasma Nutfah 1982). Samples of the collections are maintained in the form of seeds in Lembaga Biologi Nasional.

In the botanic gardens of the Lembaga Biologi Nasional, living representatives of shrub and tree legumes are maintained. The collection is by no means complete. For the timber producing species such as *Sindora, Albizia,* and *Dalbergia,* samples of collection are still needed. Only a fraction of this group has ever been evaluated. Therefore, for Repelita IV, which will begin in April 1984, the Lembaga Biologi Nasional made tree legumes one of the top research priorities.

Because of their nature, the botanic gardens do not include forage legumes in their living collection, nor in the form of seeds. Due to their potential, the International Board for Plant Genetic Resources has appointed a plant collector for 1984-1986, who, in collaboration with the Lembaga Biologi Nasional, will collect this resource from eastern Indonesia. Meanwhile, a team from CIAT has expressed its interest in collecting forage resources in Indonesia. Lembaga Penelitian Ternak is prepared to collaborate with them.

2. Research Activities

As a group, the major food legumes have received much attention. Minor food legumes have been evaluated as far as their botanical properties are concerned, but there is no follow-up work on their development. The gaps between biological research activities and agricultural research activities lie in the importance of the research materials. The major food legumes are, of course, important from the agricultural viewpoint, but biologically minor food legumes are much more interesting.

The same holds true for shrub and tree legumes. From the forestry point of view, timber producing species are the priority. Compared with the dipterocarps, which are still in wild conditions, or teak, which has long been in cultivation, legume species are less important. However, legumes are considered valuable for firewood because of their fast growing property. So, for greenery purposes, a lot has been done. But, basic research on their mycorrhiza or rhizobium association is yet to be studied.

Lately, research on the use of legumes for feed has been intensified. Quite often, there is no systematic plan of co-operation between those who deal with the annuals and those who handle the plants.

Eighty percent of the Indonesian population lives in rural areas and in this type of community, the home garden is an important system for food production. In this system, the owners obtain their food; their carbohydrates, proteins, and vitamins; firewood to cook their food, and medicines. They depend not only on plants but also on domestic animals such as chicken, duck, pig, goat, water buffalo, and fresh-water fish. Such a system is comparable to a newly developed agroforestry system.

From the agroforestry system viewpoint, legumes are suitable candidates for including in the system. By planting multipurpose legumes, soil fertility can be improved, firewood can be gathered, feed for animals is secured, and timber for housing purposes is available. Moreover, some legumes produce fruits that are edible. At present, an agroforestry system for a specific locality is still to be developed, yet the potential is there. It requires a multidisciplinary approach to land development.

In attempting to develop the potentialities of legumes, one should not confine oneself to one goal, considering that a combination of goals can be easily set up at the same time. In this way, alternatives can be offered, to achieve a maximum benefit.

It will not be too long before the scarcity of land in Indonesia is evident. Java, Madura, and Bali are over-populated. In these islands feed is already a problem especially in dry seasons. It is a challenge to provide a sufficient amount of feed in the rural areas where animals are kept as part of the system.

Meanwhile, outside these three islands, cows are kept loose, grazing in open areas. Again in the dry season, feed availability becomes a problem. Not many shrubs remain green for the animals to browse, while the grasses have dried or sometimes have been overgrazed. Therefore, the evergreen tree legumes play an important role.

In savannah such as that in Nusa Tenggara Timur, the existence of herb legumes is taken for granted. These species are able to fix free nitrogen that in turn is released to their surroundings when the plants break down, and in this way, the grasses benefit. Studies on this kind of association may prove important in improving the natural grassland.

Close co-operation among research workers, as well as research agencies, is needed. Such a need is stressed in every scientific meeting, but somehow little is actually achieved. It would be ideal, of course, if linkages between those who work in basic biological sciences and those who deal with applied agricultural sciences could be put into effect so that significant contributions could be made in a much shorter time. At the work level, co-operation among the research workers has been developed, however, such co-operation needs institutional support for it to be effective. At the moment, there is no obligation by the participating member of the co-operative activity to make his or her commitment due to all kinds of reasons. Where there is support from the institution, the sense of commitment is elevated, and thus there is an assurance that the jobs will be accomplished as planned. Moreover, the pooling of energy and budget can be secured as well.

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Research on the Use of Leucaena and Other Tree and Shrub Legumes in Indonesia

Mas'ud Panjaitan and G.J. Blair*

The Indonesian archipelago consists of some 13 667 islands spread from 6° N-11° S of the equator and between 94° E and 141° E longitude. The total land area is 533 248 km^2 and this supports a population in excess of 145 million. The population pressure on the land varies greatly with the greatest density being on Java where some 65% of the population occupies 6.9% of the total land area of Indonesia.

In addition to marked differences in population pressure, there is a marked variation in climate and soils. These variations lead to a great diversity in agricultural systems.

Animals play an important economic and social role in the agriculture of the various areas.

Production systems

The production systems employed may be divided broadly into the following categories:

1. Intensive Producers

These producers, who are found mainly on the heavily populated inner islands, own about 81% of Indonesia's 6.2 million cattle and 2.3 million buffalo and at least 85% of the 10 million sheep and goats in the country. Farm size is usually very small (0.6-0.7 ha) and many animals are owned by the landless. Very little, if any, forage is produced from planted forage species. Animals are penned and sustained on crop residues and grasses, legumes, and herbs harvested from roadsides, rice bunds, and waste land.

2. Semi-intensive Producers

There are an estimated 440,000 holdings with cattle, 140,000 holdings with buffalo, and 345,000 holdings with sheep and goats that fall into this category. Semi-intensive producers are usually located in upland cropping areas, associated with estate crops and income from livestock can constitute in excess of 50% of total net farm income (Kristanto 1978; GMU-R 1979).

3. Extensive Producers

These are located on the less populated outer islands and appear to offer a large potential for increased productivity. Leake (1980) estimated that some 500 000 ha of land was occupied by large cattle ranches. Productivity from these areas and the estimated 16 million ha of *Imperata cylindrica* grassland could be increased markedly if appropriate species and grazing management strategies could be devised.

Forage research programs should be cognizant of the social/land tenure systems in operation in a particular area and fit new species and/or management systems into the existing structure, if at all possible.

The Role of Tree Species in Indonesian Agriculture

It follows that the great diversity in feeding systems practised in the various areas of Indonesia rely on a wide range of species. The leaves of tree legumes and non-legumes are an important component of animal feeding systems in intensive areas and offer a potential in less intensive areas where they could be used as a supplement to low-quality pasture.

Survey work has been undertaken in some regions of Indonesia to examine the composition of small ruminant diets throughout the year. Djajanegara *et al* (1982) surveyed 101 lowland and 139 upland farm families in West Java and found large differences in feeding practices between the two groups (Table 1). For

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example, whilst 20% of farmers in the lowland group fed sesbania to their small ruminants, this feed source was not used in upland areas.

A further survey conducted as part of the Small Ruminant CRSP program at BPT-Bogor (van Eys *et al.* 1983) found that the composition of the diet fed to sheep varied markedly between locations within West Java and between seasons (Table 2). At each location, cut native grass was the major component of the diet. Shrub and tree leaves made up a maximum of 15% of the diet in the dry season at Cirebon. At this time, 21% of the crop by-products fed consisted of *Sesbania grandiflora* leaf and 32% of *Hibiscus tiliaceus* leaf.

Similar locational differences in feeding systems have been measured by Nitis (pers. comm.) in Bali. His survey of goat diets found that the species of tree leaf fed varied markedly between agroclimatic zones (Table 3).

There are very little data available to show the impact of feeding tree leaves to ruminants in Indonesia. These data should be collected and collated to show when and where tree legumes are likely to have their major impact.

Table 1. Percentage of farmers feeding various forages to small ruminants in upland and lowland survey areas in W. Java (Djajanegara *et al.* 1982).

Forage	Lowland	Upland
	% of farmers	
Native grass	86	100
Corn top	2	70
Legume straw	1	32
Rice straw	0	13
Sesbania sp	20	0
Artocarpus sp	0	10
Banana leaves	0	72
Cassava leaves	3	22

N-fixing Tree Species

Brewbaker and Styles (1983) list some 46 species of N-fixing trees that are of importance (Table 4). The tribe Mimosoideae has the largest representation with 35 species covering 12 genera. The N-fixing tree species can be broadly classified into four major categories based on their usefulness which are (a) as an animal feed, (b) for fuel wood, (c) for pulp wood, and (d) for soil conservation.

Brewbaker and Styles (1983) list the major uses of the various species, which are presented in Table 4. This paper is confined to the above categories (a) and (b).

Table 2. Percentage of components hand-fed to small ruminants in the wet and dry seasons in 3 villages in W. Java (van Eys *et al* 1983).

		% of diet				
Location	Season	Grass	Herbs	Crop by-products	Shrubs & Trees	Notes
Garut	wet	65.2	3.1	20.8	9.8	Alt. 650 m
	dry	74.3	2.7	10.6	11.5	Rain 2000 mm
Ciburuy	wet	91.4	3.7	2.7	0.6	Alt. 500 m
	dry	94.1	2.9	1.9	1.8	Rain 4500 mm
Cirebon	wet	61.8	11.3	12.8	12.2	Alt. 0 m
	dry	80.0	1.9	2.8	15.0	Rain 1128 mm

Table 3. Amount of tree leaf fed (expressed as a % of total leaf) to goats during the dry season in various climatic zones in Bali (Nitis, pers. comm.).

		Climatic zone (Schmidt and Ferguson, 1951)				
		B	C	D	E	F
Genus	No. dry Months =	1.5-3	3-4.5	4.5-6	6-7.5	7.5-9
Legumes:						
Erythrina		9.9	7.0	13.4	14.4	0
Calliandra		0	0	2.1	2.6	0
Leucaena		2.8	2.0	2.3	2.8	35.4
Sesbania		1.8	9.7	1.8	8.2	2.4
Non-legumes:						
Kayu santen		3.5	19.6	8.4	2.9	24.8
Artocarpus		20.1	14.2	34.1	3.0	2.1

Table 4. Economically important N-fixing tree species in three Leguminosae tribes (Brewbaker and Styles 1983).

Mimosoideae		Papilionoideae		Caesalpinioideae	
Genus	No.spp	Genus	No.spp	Genus	No.spp
Acacia	10	*Dalbergia*	1	*Intsia*	1
Albizia	6	*Erythrina*	3	*Parkinsonia*	1
Alnus	3	*Gliricidia*	1		
Calliandra	1	*Inga*	1		
Casuarina	4	*Pangamia*	1		
Leucaena	2	*Robinia*	1		
Mimosa	1	*Sesbania*	1		
Parkia	2				
Pithecellobium	1				
Prosopis	3				
Pterocarpus	1				
Samanea	1				

Leucaena is an example of a species that has been widely planted in unsuitable areas. Hill (1971) reported that leucaena grows best on alkaline, calcareous, clayey soils. Poor growth on acid soils has been attributed to aluminium and/or manganese toxicity, the effect of hydrogen ions, and calcium deficiency. Wong and Devendra (1983) report results from solution culture experiments where a response to Ca was recorded at pH levels ranging from 3.5-6.0 and growth was severely retarded in 9 of 10 cultivars when solution concentration of Al exceeded 4 ppm. All cultivars were affected by a concentration of 8 ppm Al. Clearly there is a need for research to match particular tree legume species to particular soil conditions.

Very little work has been undertaken in Indonesia, or indeed anywhere, to compare the performance of various tree species in different locations. Many scientists and extension workers who have an interest in this field select for a single species, the choice of which is based on their experience with that species elsewhere. There is an urgent need to establish a network of experiments to ascertain the soil/climate/farming system constraints to the various productivities of the tree legume species.

Past and Current Agronomic Research Conducted on Shrub and Tree Legumes in Indonesia

Wood Production

Nitrogen-fixing tree legume research for fuel wood production is currently being conducted by the Centre of Soil Research and the University of Hawaii at Lampung in S. Sumatra and the Rubber Research Institute, N. Sumatra.

The experiment in Lampung is being conducted on an Ultisol soil of pH 5.01(in H_2O;4.03 in KCl) which is low in P, has a low base status and low Al saturation (6.02%).

The experiment is located in an environment with a marked dry season, which has received 3668 mm of rain during the 21 month experimental period from January 1982 until October 1983. Solar radiation ranged from 402-442 g.cal cm^{-2} day^{-1} : the day and night temperatures ranged between 23.5 and 37.9°C and the relative humidity ranged between 31 and 99%.

Seventeen tree legumes were grown in the nursery for 2 months with minimal fertilizer inputs and transplanted to unfertilized plots at a spacing of 1 m x 1 m (10 000 ha^{-1}). Up until 3 months of age the seedlings were hand-watered when necessary, and sprayed with a mixture of Dithane M45 and Busban to prevent disease and insect attack. After this 3 month period the trees were left to grow without fertilizer or pest and disease control measures. Under these management conditions some species succumbed. *Mimosa scabrella* suffered from a wilting disease, most likely due to a root pathogen and *Calliandra calothyrsus* was attacked by a top shoot borer at flowering. In addition, some trees of *Sesbania grandiflora* died during the severe 7 month drought, which commenced 5 months after transplanting.

Throughout the experiment, tree height and trunk diameter at breast height or 1.25 m (DBH) was measured at monthly intervals and wood calculated from these measurements.

As early as 2 months from transplanting, height differences between species were obvious with *Sesbania grandiflora* being the tallest species. The growth rate of all species was reduced by drought conditions, which persisted from June-December 1982.

Marked differences were recorded between species in estimated wood production (Table 5). Maximum production of wood yield (m^3 ha^{-1} yr^{-1}, was recorded in *Acacia mangium* where yields exceeded 45 m^3 ha^{-1} yr^{-1}. The yield of the next most productive species, *Albizia falcataria,* was only 60.4% of *A. mangium* whilst production from the lowest yielding species, *Albizia procera,* was less than 0.2% of *A. mangium* (Table 5).

Table 5. Relative wood yield of tree species grown for 20 or 21 months at Lampung, S. Sumatra (Manuelpillai, pers. comm.).

Tree species	Relative wood yield
Acacia mangium +	100.0
Albizia falcataria +	60.4
Cassia siamea +	45.6
Acacia auriculiformis +	36.4
Enterolobium cyclocarpun	27.6
Leucaena leucocephala	22.7
Leucaena diversifolia	19.8
Eucalyptus saligna *	12.0
Calliandra callothyrsus	9.6
Sesbania grandiflora	6.6
Mimosa scabrella	5.6
Cassia fistula	2.7
Gliricidia sepium	2.3
Cassia orraria	1.8
Samanea saman	1.7
Dalbergia sissoo +	/0.5
Albizia procera	/0.2

* Non-legume + Native Species

These data show the very large differences in wood production that exist between species and indicate the need to examine both local and introduced material in any evaluation program.

Additional work is needed to evaluate the forage value of these tree species so an economic value can be placed on that component of the tree. These studies should include toxicology studies to indicate potentially dangerous species.

Forage Production

1. General

The following is not intended as a detailed summary of all activities but rather as a survey to indicate the scope of past and present research activities. For a more detailed summary, the reader should refer to the Proceedings of the Lamtoro Gung Workshop August 19-21, 1983 sponsored by the Ministry of Home Affairs, Indonesia; The Proceedings of the National Lamtoro Seminar, August 23-25, 1983, hosted by the Indonesian Agency for Research and Application of Technology (BPPT); the Proceedings of the Singapore Workshop (sponsored by IDRC) and papers presented at a Discussion on Practical Establishment and Management of Leucaena held at BPT, (Balai Penelitian Ternak), Ciawi, July 29, 1983.

There is much interest in *Leucaena leucocephala* in Indonesia but there has been very little research on the agronomic aspects of this or other tree legume species.

The effect of cutting interval on the production of *Sesbania grandiflora* has been reported by Budhi *et al.* (1982) from Gajah Mada University, Yogyakarta. Their experiments found that dry leaf production increased as the cutting interval was extended from 3 to 6 months. Similar data for *Leucaena leucocephala* (Semali et al. 1983) showed that increasing the cutting interval from 4 to 16 weeks increased leaf yield from 1.3 to 5.0 kg/tree.

Experiments on the effect of cutting height on leaf yield of *Leucaena leucocephala* have been reported by Siregar and Prawiradiputra (1982) from Balai Penelitian Ternak, Bogor. They found that yield was maximized at a cutting height of 1 m. A similar cutting height was reported to be optimal for *Flemingia congesta* and *Calliandra callothyrsus* (Siregar 1983).

There is a lack of information on the long-term effects of cutting management on the productivity and persistence of tree legume species. Similarly, data are generally reported as annual production whereas production in the various seasons (wet/dry) and leaf retention data are what is required.

A series of agronomic trials on *Leucaena leucocephala* have also been conducted by the Village Biology Project, PARD, Ciawi (Petheram *et al.* 1982). Weeding in the first year after transplanting resulted in an approximate doubling of yield and in a second trial leaf dry matter yields declined from 3870 kg ha^{-1} to 2460 kg ha^{-1} when cutting height was reduced from 50 to 10 cm. Another experiment showed that leucaena stem cuttings could be stored under wet sacks for 15 days before transplanting mortality without increasing the post-transplanting mortality rate.

Pot experiments conducted by Kartika and Blair (unpubl) (Table 6) confirm the slow early growth of *Leucaena leucocephala, Gliricidia maculata*, and *Calliandra callothyrsus* compared with *Sesbania grandiflora* and show the advantage of fertilization on tree height at 5 weeks of age.

Table 6. The effect of fertilizer (0 NPKS) on the height (cm) of tree legume species at 5 weeks when grown in pots on 3 soils from Bali (Kartika and Blair, unpubl).

	Bukit		Kuta		Gunaksa	
Gliricidia	20	26	22	26	26	30
Calliandra	10	18	8	11	16	26
Sesbania	29	44	38	45	42	50
Leucaena	16	30	17	23	27	32

In this same experiment plants were uninoculated and the response to N fertilizer (a measure of nodulation effectiveness) was found to vary between species and soils (Table 7).

No information exists on the rhizobium requirements of various tree legume species in Indonesia and research is urgently needed on this subject.

2. Forage Research Project (FRP) Tree and Shrub Legume Research

There are a number of tree legume research

Table 7. Effectiveness of nodulation (measured as response to N) of various tree legume species grown in 3 soils from Bali (Kartika and Blair, unpubl).

Response to N (NPKS/PKS D.M. yield x 100)			
	Bukit	Kuta	Gunaksa
Species			
Gliricidia	3	26	2
Calliandra	62	-7	44
Sesbania	12	-6	9
Leucaena	11	27	24

projects being undertaken as part of the FRP. These range from nursery evaluation to competition studies.

(1) NURSERY EVALUATION

A range of tree and shrub species is currently under nursery evaluation at key locations in Java, S. Sulawesi, and Sumba. These locations represent a wide cross-section of climatic zones in Indonesia. A list of the species and cultivars under test and their location is presented in Table 8.

At each location each nursery entry is evaluated in terms of seedling establishment, plant survival, growth, disease, insect and drought resistance, flowering, and seed set at regular intervals throughout the year. When the most agronomically important entries have been identified, work will commence on feed quality evaluation studies.

(2) REGIONAL EVALUATION OF TREE LEGUMES

A regional network experiment is being established in Indonesia to examine the production capability of six potentially important species. Experimental sites have been established at Sungai Putih (N. Sumatra), Jakarta (W. Java), Grati (E. Java), and Cisarua (W. Java).

The species under test at each site are *Albizia falcataria, Calliandra callothyrsus, Gliricidia maculata, Leucaena leucocephala* cv Cunningham, *Leucaena leucocephala* cv El Salvador and *Sesbania grandiflora.*

Two additional species, *Leucaena leucocephala* cv local and *Sesbania sesban* are included at Grati.

At each site, 2 m x 0.5 m spaced trees have been or will be planted in plots 10 m x 4 m. With and without fertilizer and ± rhizobium treatments are used on each species. Regrowth of leaf and wood from a 1 m cutting height is being measured four times/year and leaf chemical composition monitored.

Marked differences between species have been recorded in leaf and wood yield in the harvest taken 11 months after transplanting (Table 9) at Grati.

These data clearly show the advantage of improved introductions of leucaena over the local cultivar and the marked superiority of *Sesbania* species in terms of wood production. *Calliandra* and *Albizia* are clearly unsuited to the conditions at this site whereas *Albizia* and *Gliricidia* appear to be the best adapted species at Sungai Putih in N. Sumatra.

These data demonstrate the need to identify the appropriate species for particular sites and to ascribe a value to both the leaf and wood components of the trees.

This valuable multi-locational experiment will have to be curtailed for lack of travel and support funds unless complementary funding can be obtained.

(3) THE CONTRIBUTION OF TREE LEGUMES TO FORAGE SUPPLY AND NITROGEN ECONOMY AT GOWA, S. SULAWESI

This experiment is investigating the effect of *Rhizobium,* fertilizers and cutting frequency on leaf and wood yield, and on the N contribution to the soil/animal system. Four species, viz. *Leucaena leucocephala* cv Cunningham, *Sesbania grandiflora, Gliricidia maculata,* and *Calliandra callothyrsus* are cut to 1 m and allowed to regrow to 1.5, 2.0, or 2.5 m before re-cutting.

Nitrogen accumulation is measured by N removal in leaf material and by N uptake by grass that will be underplanted after 1 year. The effectiveness of the inoculation treatment is being evaluated by comparison with N fertilized trees.

(4) PRODUCTIVITY OF LEUCAENA/ GRASS MIXTURES IN RELATION TO LIGHT PROFILES, CANOPY ARCHITECTURE, AND AVAILABLE SOIL WATER

An existing leucaena stand, planted at 1 m x 0.5 m spacings, has been cut to either 0.2 m or 1 m and interplanted with either *Pennisetum purpureum* or *Setaria splendida* to give a 2 cutting height x 2 grass species factorial experiment. In addition the grasses and leucaena are grown in pure stands.

The stands are being instrumented with linear solarimeters and thermocouples at various heights in the canopy linked to a data logger. Soil moisture will be monitored by neutron probe measurements.

The objective of the experiment is to collect data to construct a growth model of tree/grass stands. Such a model will allow extrapolation of results from one climatic region to another and

Table 8: N-fixing tree and shrub legumes species and cultivars currently under nursery row evaluation in the Forage Research Project.

		Site Planted			
				Java	
Name	Introd. No. +	Sumba	S.Sul	Jkt	Ciawi
Acacia angustissima	51651	x	x	-	x
Albizia falcataria	local	-	x	x	x
Calliandra callothyrsus	local	-	x	-	x
Codariocalyx gyroides	76104	-	x	-	x
Codariocalyx gyroides	CQ 1465	-	x	-	x
Desmanthus virgatus	38351	x	x	-	x
Desmanthus virgatus	55718	-	x	-	x
Desmanthus virgatus	55719	-	x	-	x
Desmanthus virgatus	82285	-	x	-	x
Desmanthus virgatus	87521	x	x	-	x
Desmanthus virgatus	87822	-	x	-	x
Desmanthus virgatus	89197	-	x	-	x
Desmanthus virgatus	90315	-	x	-	x
Desmanthus virgatus	91439	-	x	-	x
Desmodium sp	46556	-	-	-	x
Desmodium discolor	39075	-	x	-	x
Desmodium gangeticum	52418	-	x	-	x
Desmodium rensonii	46562	-	x	-	x
Desmodium salicifolium	52427	-	x	-	x
Flemingia congesta	local	-	x	-	x
Gliricidia maculata	local	-	x	-	x
Leucaena leucocephala	cv Cunningham	x	x	-	x
Leucaena leucocephala	cv Peru	-	x	-	x
Leucaena leucocephala	70544 (K8)	x	x	-	x
Sesbania formosa	CQ 1614	-	x	-	x
Sesbania grandiflora	local	-	x	-	x

+ Commonwealth Plant Introduction (CPI) number, unless otherwise indicated.

Table 9. The leaf (g DM/tree) and wood (g wood/tree) yield of eight tree legume species grown for 11 months at Grati, E. Java.

Species	Yield at 11 months (g/tree) Leaf	Wood
Leucaena leucocephala cv Local	3.4	8.9
Leucaena leucocephala cv Cunningham	18.2	60.1
Leucaena leucocephala cv El Salvador	15.4	58.1
Gliricidia maculata	7.0	21.4
Sesbania grandiflora	15.0	303.5
Sesbania sesban	14.5	260.5
Calliandra callothyrsus	0*	0*
Albizia falcataria	0*	0*

* Most plants died, with those surviving being less than 1 m in height.

assist in making management decisions on factors such as cutting height and frequency in mixed or pure stands in many tropical ruminant feeding systems and offers scope for further development. Research is required to identify the most productive and persistent species/cultivars for specific climatic/soil/farming system situations. For this, long-term comparative studies of tree and shrub species must be undertaken.

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The Use of Leucaena in Nusa Tenggara Timur

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Nusa Tenggara Timur (NTT) comprises the eastern Lesser Sunda Islands and includes West Timor, Flores, Sumba, Roti, Savu, and numerous smaller islands. The total area is about 50 000 km^2 and the total population about 3 million. Population densities range from 15-100 persons km^{-2}. Conditions in NTT have been described by Ormeling (1955), Fox (1977), and Metzner (1982).

The climate is dominated by an extreme dry season that extends usually from April-May to October-November. This is caused by south-east monsoon winds that are dry after blowing over the Australian continent. North-west monsoons bring rain from November-December to March-April. The timing and quantity of rainfalls are characterized by extreme variation. Average rainfalls vary from 1000-1500 mm and generally increase with altitude. As an indication of extremes, total rainfall at Lahurus was 1041 mm in 1930 and 7482 mm in 1934. January rainfall at Sukabi-hanawa was 19 mm in 1935 and 542 in 1938; February rainfall at Kupang was 7 mm in 1931 and 632 mm in 1887; and March rainfall at Lahurus was 136 mm in 1941 and 2776 mm in 1934 (Ormeling 1955). Temperatures range from maximum/minimums of 38-35° to 25-22°C in the wet season and 35-32° to 22-19°C in the dry season, with more extreme temperatures in elevated regions. Evaporation rates range from 4 to 9 mm per day with yearly totals of around 2000 mm.

The islands rise from the seas to altitudes of up to 2500 m along central mountain ridges. Mountain areas are steep and rugged and cover most of the islands. Deep, eroded streams carry water from the mountains to wide, shallow rivers that flow along narrow plains to the sea. Most streams flow intermittently, raging after rains but without water for most of the time. Bigger rivers flow strongly after rains and become trickles as the dry season progresses.

Geological formations and soils vary greatly throughout NTT. Soils in the outer southern arc of islands are neutral to alkaline (pH 7-9) grey, black, or red clays that have developed on sedimentary limestone, fine textured marls and raised coral reefs. They mostly swell and become sticky, and can be very unstable after rain, but crack and become quite impermeable in the dry season. In contrast, soils of the inner arc of islands (Flores group) are slightly acidic to slightly alkaline (pH 6-8), grey black, or red, and largely of volcanic origin.

Most of the forest has been cut from the mountain areas by decades of slash and burn cropping. Consequently, floods and erosion are common and streams dry quickly after rainfall because of the lack of vegetation to catch and hold moisture in catchment areas.

Most cropping in NTT is traditional, slash and burn cultivation of corn with some sorghum, mungbean, peanut, cassava, pumpkin, and other vegetables. Most farmers cultivate up to a hectare of land under the shifting slash and burn system and also have up to half a hectare of garden around their house. In flatter areas, farmers may grow up to a hectare of irrigated rice.

Most farmers raise chickens, goats, pigs, cattle, and buffalo. Mostly these feed as scavengers, or under a free-range system and management inputs are low.

Most crop produce is consumed on the farm. Livestock are only usually killed and eaten on traditional or festive occasions and contribute little to the nutrition of the rural population. Some areas, however, especially where access and management are improved, produce for expanding local, provincial, and national markets.

Various authors have suggested that traditional slash and burn systems can carry a maximum of 30 to 50 persons/km^2 (Fox 1977). Above this limit, there is often progressive degradation of the entire system with a shortening of the fallow

* NTT Livestock Development Project, Indonesia/Australia, Kupang, NTT, Indonesia; and Dinas Pertanian TkI, Kupang, NTT, Indonesia, respectively.

cycle, a succession from forest to grassland, and severe water imbalance.

There has been severe and increasing land degradation throughout much of NTT because of:

1. An increasing human population that has continued to depend largely on slash and burn agriculture using longer crop and shorter fallow cycles with corresponding increased deforestation and reduced forest regeneration.

2. An increasing cattle population since introduction in 1912 that has reduced forest regeneration and placed increasing grazing pressure on grassland.

3. The introduction in about 1912 of *Lantana camara*, a shrub that is not eaten by livestock but had, by 1955, spread to cover 25-50% of the province and placed increased grazing pressure on lantana-free areas.

4. The long and extreme dry season when most forest and grassland vegetation dries off and is burnt indiscriminately to leave soil bare of old vegetation cover.

5. The short and variable wet season, when high intensity rainfalls are quite common and cause severe erosion of unvegetated slopes and consequent silting of rivers.

There are several areas in NTT where this severe land degradation has been arrested and reversed through the development, largely by local administrators and farmers, of stable farming systems based on *Leucaena leucocephala* (leucaena). It is interesting to trace the history of the development of these somewhat contrasting systems in the Sikka district on the island of Flores and the Amarasi district in West Timor. Some figures illustrating changes between 1930 and 1982 in human population, cattle numbers, area of leucaena and crop production in the whole province of NTT and within Amarasi and Sikka are presented in Table 1. Significant features are the high population density in Sikka, the recent increase in area of leucaena in Amarasi and Sikka and corresponding increases in cattle numbers, and the relatively stable crop production. The history and significance of some of these features are discussed below.

Organized scientific agrarian advice under central direction began only in NTT in 1930. The establishment of an agricultural extension service branch in Kupang was closely connected with increased concern about the problem of shifting agriculture (Ormeling 1955). At this time, the Dutch promoted improved systems of food cropping through the use of various legumes, including leucaena and *Sesbania grandiflora* for crop rotation and soil stabilization.

A bushy, Hawaiian type of leucaena is said to have served on Java and Sumatra to provide shade and firewood, promote soil fertility, and reduce erosion since the early 1800s (Metzner 1976). The plant has probably also been known for several hundred years on the eastern lesser Sunda Island (Metzner 1982). According to Dijkman (1950) the plant was brought to Indonesia from Central America by early Spanish explorers.

1. Kabupaten Sikka, Flores

Efforts were first made by the Dutch in the 1930s to popularize leucaena in Sikka. The agricultural services recommended cultivation of the plant to promote thickets on non-arable land but adoption was poor because of fears by the farmers that thickets would get out of control on arable land, unless controlled by regular cutting (Metzner 1976).

Other attempts to control erosion using low bamboo fences pegged along the contour, often anchored with cassava sticks and covered by grass, were promoted by the Dutch before the 1960s. These structures, however, were ineffective and adoption was poor. Traditional terrace construction was also promoted, and about 750 ha were terraced between 1966 and 1973; enthusiasm, however, was not great because the technique was slow, labour intensive, and often ineffective without accompanying vegetative stabilization.

Interest in cropping was stimulated, and the need for effective soil stabilization became more critical, when the need for expensive and time consuming fencing was eliminated by the decision in 1964 by common consent of farmers that small livestock (pigs, goats) and horses had to be penned or tethered. At that time, cattle were and still are of minor importance in Sikka, apparently because of the lack of water and extensive productive pastures (Metzner 1982). Cropping was further stimulated in 1974 by the introduction of BIMAS, the national food crops intensification program, into Sikka; this program specified that only farmers who planted leucaena on their land could receive credit (Parera 1982b).

Table 1. Area, human population, cattle numbers, area of leucaena, corn and rice production in Nusa Tenggara Timur Province, Kecamatan, Amarasi and Kabupaten Sikka between 1930 and 1982.

		NTT (50 000 km²)		Amarasi (740 km²)		Sikka (1670 km²)	
		Total	No km⁻²	Total	No km⁻²	Total	No km⁻²
Population	1930			16 800[4]	23	123 000[8]	74
	1949/50			17 600[4]	24	131 500[8]	79
	1970	2 260 000[1]	45	25 000[1]	34	188 000[1]	113
	1980	2 737 000[1]	55	30 000[1]	41	215 000[1]	129
Cattle	1915	234[5]	0.005				
	1921	2 700[5]	0.5				
	1948/52	108 000[5]	2.2	500[4]	0.7		
	1970					50[2]	0.03
	1975/76	375 000[1]	7.5	13 000[4]	18		
	1980	414 000[1]	8.3			500[1]	0.3
	1981			17 000[7]	23		
	1982					2050[2]	1.2
Leucaena area (km²)	1955			4.4[5]			
	1975					80[6]	
	1982			500[4]		270-435[2]	

Crop	Year	Area (ha)	Production (t)	Area (ha)	Production (t)
Corn	1970	185 000[1]	153 000[1]	12 000[1]	8 000[1]
	1980	229 000[1]	180 000[1]	17 000[1]	12 000[1]
Rice	1970	149 000[1]	197 000[1]	10 000[1]	12 000[1]
	1980	152 000[1]	238 000[1]	13 000[1]	14 000[1]

1. Provincial Annual Reports (Dinas Peternakan, Dinas Pertanian)
2. Cunha (1982)
3. Borgias (1978)
4. Metzner (1980)
5. Ormeling (1955): cattle nos. for West Timor only.
6. Metzner (1976)
7. Jones (1983a)
8. Metzner (1982)

The pressure to stabilize an estimated 30 000 ha of erosion-prone land stimulated the development of indirect terracing through the establishment of contour rows on leucaena. In 1967, a Catholic priest, Fr. P. Bollen, who was impressed with the potential of leucaena for land stabilization and rehabilitation, established a small demonstration garden with contour rows of the local Hawaiian variety near his church at Watublapi, about 30 km south east of Maumere. The success of this demonstration prompted a local farmer, Moa Kukur, in 1968 to establish a terraced garden at Wair Muut using leucaena hedges. Over the three years to 1971, yields from this garden were stable, obviating the need to shift to a new garden area (Cunha 1982).

Experience at Watublapi and Wair Muut prompted the farmers cooperative, Ikatan Petani

Pancasila (IPP), to demonstrate indirect terracing by establishing a demonstration plot in 1972 at Kloangpopot, 40 km south of Maumere, using contour rows of local leucaena spaced at 5 m intervals with clove trees between the rows. This demonstration was shown regularly to farmers and participants in IPP training courses and stimulated great interest and activity in indirect terracing (Metzner 1976, Borgias 1978, Cunha 1982).

In 1973, the district government of Sikka and Biro Sosial Maumere (Roman Catholic Mission), with the support of IPP, which became YASPEM (Yayasan Pembangunan Sosial) in 1974, established a Program Penanggulangan Erosi Kabupaten Sikka (program to solve erosion) to stabilize 30 000 ha of land in five years (1973-74 to 1978-79). In 1978, the program was expanded to become the Program Pencegahan Erosi dan Pengawetan Tanah (erosion prevention and soil conservation program). At this time, Hawaiian giant leucaena varieties were introduced from the Philippines and Hawaii, and further stimulated leucaena planting. These programs held farmer training courses, distributed water levels for making contours, purchased and distributed seed, encouraged farmer cooperation through prizes, and supervised and evaluated plantings (Metzner 1976, Borgias 1978, Cunha 1982). By 1982, it was estimated (Parera 1982b) that about 20 000 ha of hilly land had been terraced with local leucaena and a further two million giant leucaena trees had been planted.

With the indirect terracing technique, about 70 kg ha^{-1} of leucaena seed is sown in 10-15 cm high earth walls along contour lines that are constructed by surveying with an A-frame or water level and hoeing to leave a furrow, where water collects, above the wall (Metzner 1976). According to Parera (1982b), this is more effective than the old Dutch technique of sowing directly into the furrows. Seed is sometimes scarified in hot water before sowing to increase germination (Metzner 1976) although Parera (1982b) considers this unnecessary with October sowing because high temperatures before the wet season break hardseededness.

Sowing costs were estimated (Metzner 1976) to be about Rp 3900-5400/ha plus labour. (Rp 1000 = $US 1.00)

Early establishment is slow and can be reduced by weeds and grazing. With reasonable management, thick hedges form within two years and collect soil washed from upper slopes by the rain and gradually form terraces. Once established, hedges are generally cut each 6-8 weeks at a height of 75-80 cm during the rainy season and before formation of fruit. Cut material is thrown on the upper slope to fertilize the soil (Metzner 1976). In recent times (Parera 1982 a,b) several variations on this cutting system have been developed with farmers either breaking branches down, or girdling the leucaena trunk, and allowing the leaves to fall and fertilize the soil. With this system, there are no leucaena trunks to be burnt nor harbour vermin.

The primary aim of this leucaena planting program in Sikka has been control of erosion. A measure of the improvement of water balances can be seen from the facts that the Batikwair River, which ceased to flow in the dry season about 60 years ago, has been flowing continuously since 1979 and Maumere, once a flood-prone town, has not been flooded since 1976 (Parera 1980, Prussner 1981, Metzner 1982).

Other benefits have followed. Established areas are now being cropped more intensively and are more productive. Unterraced fields can be cropped for 3-4 years and need a recovery period of 4-9 years because of loss of soil and soil fertility. Terraced slopes can be cropped continuously if leucaena herbage is used as green manure and cereal/legume rotations are used. Leucaena also discourages the build-up of the weed *Imperata cylindrica* that often causes abandonment of unterraced fields. Many terraced fields have been planted to permanent tree crops such as coconut, coffee, cacao, cloves, and pepper with the contour hedges of leucaena providing shade, soil stabilization, increased soil fertility, and improved moisture infiltration (Parera 1980, 1982 b; Metzner 1982).

Leucaena herbage is fed to small animals (chickens, pigs) in Flores. Cattle have not traditionally formed a significant role in the livestock industry. Efforts to encourage cattle farming commenced in 1967 with the introduction of 100 head of Bali cattle under a government credit program. However, according to Cunha (1982) there were only 50 cattle in Sikka in 1970, owned mainly by Dinas Peternakan (Department of Husbandry) and the Roman Catholic Mission. The cattle industry received a further stimulus with the introduction, by Mr. V. Parera of Dinas

Pertanian and Fr. H. Bollen of the Catholic Mission, of giant leucaena (K8, K28, Peru, K67) from the Philippines and Hawaii in 1978-79. These giant varieties have been planted quite widely in areas not used for cropping although it is still considered that the less vigorous Hawaiian local type is more suitable for terracing cropping land. Further Bali cattle introductions, including 1500 head in the last two years of the rural credit program, have brought the cattle population to over 2000 head by mid-1982 (Cunha 1982).

It is likely that the leucaena farming systems in Sikka will be developed in the future to include intensive cattle breeding and fattening, using cut-and-carry leucaena. Farmers are familiar with tethered livestock, as horses are traditionally tied. Road improvement, however, will be essential in the rural areas to allow access by trucks and free movement of cattle.

2. Kecamatan Amarasi, Kabupaten Kupang, West Timor

Amarasi occupies a 738 km² strip of land 10-25 km wide and 65 km long located on the south coast of West Timor. It is undulating with an average elevation of 300 m. The area originally supported dense monsoon rainforests, which were seen as late as 1829 by the naturalist Salomon Muller during his travels through Amarasi (Metzner 1980). Slash and burn agriculture, however, had led by the 1930s to the development of extensive grass savannahs. Crop yields in turn decreased because the build-up of soil fertility is slower under grassland than forest, and famine became an almost seasonal occurrence.

Bali cattle, introduced around 1912 under Dutch encouragement, adapted well to the Timor situation but did little to solve the problems of feeding the population. Livestock (horses, water buffaloes) were mainly used for social and ritual purposes and rarely eaten. Rulers and heads of villages commonly received the distributed livestock and sold the offspring for slaughter in major centres, or for export from Timor. Lack of knowledge on livestock and grazing management systems and the lack of watering facilities and improved pastures also resulted in a high mortality and low productivity (Ormeling 1955, Fox 1977, Metzner 1980).

Lantana camara, a woody shrub, also entered Timor around 1912. It was probably introduced as a pot plant or with cattle to Kupang and spread eastwards, probably through birds, between 1915 and 1935. By 1949 about 80% of Amarasi was covered with the weed (Ormeling 1955, Fox 1977, Metzner 1980).

Livestock owners and cropping farmers had differing opinions on the plant. To the grazier, the plant was a weed because it dominated grasslands and was not eaten by stock. Metzner (1980) suggested that the decline in livestock numbers (cattle, water buffaloes, horses) in Amarasi from 6000 in 1916 to 4000 in 1948 was due largely to lantana. Ormeling (1955) considered that livestock numbers in the early 1950s were lower in Amarasi (60 per km² and 50 per 1000 inhabitants) than the Timor average (170 and 450 respectively) because of lantana.

Shifting cultivators, however, liked the plant because it grew rapidly, reduced fallow periods in rotations from perhaps 15 to 5 or 6 years, provided a rapid soil cover, maintained good soil structure, and reduced weed growth and land preparation time in subsequent crops (Ormeling 1955).

Under the influence of powerful cattle owners, attempts were made around 1955 to control lantana biologically with the beetle *Teleonemia lantanae* and with herbicides (Ormeling 1955, Metzner 1980). These methods, however, had little effect and control was ultimately achieved by replacing lantana with leucaena, an acceptable solution to graziers and cultivators alike.

In the 1930s, experimental plantings of leucaena were made under the guidance of the Dutch administration on abandoned fields around Baun (Ormeling 1955, Metzner 1980). The plant was then sown widely around Baun in response to an adat (traditional) regulation pronounced in 1932 by the local ruler (raja) in accordance with the local council, which obliged every farmer in Amarasi to plant contour rows of leucaena not more than 3 m apart on cropping areas before they were abandoned. Failure to comply carried the threat of a fine and/or jail. Planting expanded eastwards as the adat decree was implemented around Oekabiti and Burain in the early 1940s (Metzner 1980). Adat planting regulations were reinforced in 1948 when the government introduced the Peraturan Tingkat Lamtoro (Leucaena Planting Regulation) that compelled all shifting cultivators to plant lamtoro hedges along contour lines (Ormeling 1955). In fact the plant has formed an even cover where it grows, and rows and indirect terracing are not evident in Amarasi today. This is apparently because hedges were not trimmed and leucaena quickly colonized the spaces between the rows (Metzner 1980).

According to Ormeling (1955), the local area of gardens containing leucaena in Kabupaten Kupang was 465 ha in 1948 with 437 ha of this in Kecamatan Amarasi. More recently, Metzner (1980) has estimated that leucaena covered two-thirds of the Amarasi area and that lantana had been largely eliminated as a weed problem. Jones (1983a) considered that leucaena was continuing to spread in the south and east of Amarasi.

The successful adoption of leucaena in Amarasi was only possible because of the introduction of a series of supportive regulations, introduced and enforced by the adat ruler, who was later also appointed as administrative head (camat) of the Amarasi kecamatan, and the local council.

In 1938, land-use zoning regulations, which set aside 10 zones exclusively for cropping, were introduced. In these zones, which were amalgamated and expanded in 1960 and 1967 to include most of western Amarasi, small livestock (pigs, goats, sheep) had to be penned and large livestock (cattle, buffaloes, horses) had to be tethered. Any livestock straying into cropping land could be killed on the spot. Outside these zones, cattle could graze freely but had to be coralled once a week. The successful implementation of land-use zoning allowed farmers more time for other agricultural activities by eliminating the need for fencing. According to Ormeling (1955) one quarter to one third of a farmers total work input in cropping is taken up with the construction of traditional wooden Timor fences.

The local ruler also promoted the cultivation of cassava and fruit trees in the late 1940s and by the 1960s seasonal famine had been eliminated and food was being exported from Amarasi.

Such direction has been possible because of an adat regulation dating from 1940, which stipulated that all land belonged to the ruler. Local farmers were given the right without payment to cultivate the land by representatives of the local ruler in each of the 62 communities in Amarasi. A farmer's right to a particular piece of land expired as soon as he ceased to cultivate it. Such a system still operated in 1976; up to this time only 100 farmers in Amarasi had decided to have their land surveyed and registered, the majority opting for a continuation of the right of usufruct since individualization and registration involve surveying costs and the payment of a tax (Metzner 1980).

After 1960, most farmers opted to tether and hand-feed cattle near their houses rather than let them graze freely in eastern Amarasi. Because fence construction was no longer necessary, farmers had time to look after their cattle (Metzner 1980).

Cattle production was further stimulated by the provincial government with the introduction in 1971 of the paron cattle fattening scheme. The government brought store cattle from central Timor and gave them to interested farmers for fattening by feeding with cut-and-carry leguminous fodder (leucaena, *Sesbania grandiflora, Acacia leucophoaea, Tamarindus indica*). After reaching slaughter weight, cattle were sold through intermediaries for export off Timor with 85% of the profits going to the farmer and 15% to the government. More recently, many farmers have bought and sold animals on their own account.

Amarasi farmers have benefited most from the paron system because Amarasi was the only district in NTT with abundant cut-and-carry fodder. An adat law obliging each family to fatten 2-7 head has increased cattle numbers and evened livestock distribution in Amarasi; according to Metzner (1980), there were approximately 500 head of cattle owned by less than 1% of the population in 1949, and 13,000 head owned by 100% of families in 1974.

According to Metzner (1980) and a recent survey by Jones (1983b), the average farmer in Amarasi supports a family of 6 persons and works 2 ha of land. Leucaena is established at a density of about 10 000 trees ha^2 over the whole area and 1.0-1.3 ha are used to provide fodder for tethered livestock while 0.6-1.0 ha are used for maize and other crop production.

The average farmer raises three head of Bali cattle. Cattle are bought at local markets at about 12 months of age for about Rp 75 000, most farmers preferring to buy near the end of dry season. They are fattened for about 18 months and sold, often at the end of the second wet season, for about Rp 200 000. This represents an average return per family from cattle of about Rp 240 000.

Cattle are fed 15-20 kg of fodder of lamtoro and other legumes each morning and afternoon. This represents a requirement of over 100 kg of cut-and-carry fodder per family per day. About 1 ha of dense leucaena seems able to supply this need.

Water supply for tethered cattle was a problem given the extended dry season and the porous soils; very deep wells are evident in many areas. More recently, banana cultivation has developed and all water requirements (30-40 litres day^{-1}) are usually provided by feeding banana stems that contain 80% water and provide essential minerals such as Na that is commonly deficient in leucaena.

Maize and other crops are grown on one third to one half of the farm area on a 1-3 year rotation. All leucaena and other vegetation is cut to ground level up to 4 months before the start of wet season. Cut vegetation is windrowed at right angles to the contour to facilitate burning, usually 1-2 weeks before the first rains are expected. Dry mulching has been tried (Metzner 1980) but was not generally adopted because the dry leucaena stems provided a harbour for rodents, which seriously affect maize yields (Jones 1983b).

At the onset of rains, maize is sown on a one metre grid using a dibble stick and 3-4 seeds per hole. Cassava, beans, and melons are often sown amongst the maize. The crop is harvested after 4-6 months when the rainy season finishes. Yields in Amarasi vary between 10 000 and 20 000 small cobs (1000 to 2000 kg grain) ha^{-1}.

It is unnecessary to resow leucaena after cropping because of the strong regrowth of cut stems and re-establishment from seed in the soil. Green stem regrowth of leucaena is normally broken off to reduce competition in the crop and to provide some mulch.

Tree crops including banana, papaya, and coconut are generally grown in leucaena areas, and especially around houses, once moisture regimes have been restored. Families in Amarasi in 1983 were shown to own 5-100 coconut trees and 10-700 banana trees (Jones 1983b). Also, Jones (1983b) estimated a per capita output of about Rp 100 000 per year from sales of cattle, chicken, maize, banana, and coconuts and a similar per capita consumption of leucaena firewood, chicken, maize, banana, and cassava. Real incomes were estimated to be 20-30% higher than the average in West Timor and this was attributed to the stable farming system developed around leucaena.

The prosperity of the residents of Amarasi is evidenced by the number of houses with concrete floors and walls, and tin roofs replacing the traditional palm leaf houses.

To date, Amarasi has been a fattening area dependent for its cattle supply on surrounding areas. As these other areas develop fodder production systems, it is likely that breeding systems will have to be developed in Amarasi. This should represent the final step from extensive, shifting agriculture to intensive, stable agriculture.

Current Activity on Leucaena in NTT

There are several projects in NTT other than those described in Sikka and Amarasi that are currently promoting the use of leucaena for soil stabilization and increased agricultural production. Some research is also being conducted to investigate the most appropriate establishment and management technology in the province.

1. Provincial Area Development Program (PDP)

The PDP aims to promote leucaena farming systems in areas where swidden agriculture has led to severe land degradation. It is run jointly by the Directorate General of Regional Development, Ministry of Home Affairs, Government of Indonesia, and the US Agency of International Development (USAID) and has been described by Prussner (1981) and Monserrat (1982). Since January 1980, the project has distributed seed of giant leucaena (K8, K28, K67) to some 5000 farmers and encouraged them through training courses to establish and manage it properly in the districts of Belu, Timor Tengah Utara, and Alor. Some farmers have harvested and sold seed from these plantings.

Food crop variety trials in farmers fields and at the dryland cropping station, Sukabitetek, Belu, have been undertaken to provide local information on appropriate systems for cropping maize, upland rice, mungbean, and soybean with leucaena. An experiment on the production of various leucaena varieties at the Belu station showed in the 12 months since sowing on 4.12.1980 that production is much higher from giant than local varieties, as presented below:

Variety	Wood production ($t\ d.m.ha^{-1}$)	Green production ($t\ f.w.ha^{-1}$)
K6	9.5	11.6
K8	10.1	11.1
K28	7.2	9.3
K67	7.1	7.6
Local	2.5	2.6

2. NTT Livestock Development Project

The NTT Livestock Development Project aims to promote improved and stable farming systems in NTT through the provision of stock and domestic water, perennial pastures, improved livestock management, and stable cropping. A pilot project to determine appropriate technology is being implemented on a 4000 ha area in Timor Tengah Selatan. It is run jointly by the Department of Animal Husbandry, Directorate General of Livestock Services, Government of Indonesia, and the Australian Development Assistance Bureau.

The Project commenced in March 1982. By January 1984, about 400 ha had been sown with contour rows of leucaena (K8, K28, Cunningham), *Sesbania grandiflora, Macroptilium atropurpureum, Stylosanthes hamata, Stylosanthes scabra, Bothriochloa pertusa,* and *Chloris gayana* to demonstrate catchment stabilization and fodder production. Rows were cultivated by hoe using a water level, and seed and fertilizer (20 kg ha^{-1}) were sown into the furrow and covered. Initial establishment has been excellent.

Leucaena has also been established in cropping demonstration areas of 1-3 ha at five locations in the four desa (Mio, Linamnutu, Polo, Oe Ekam) surrounding the project area to demonstrate stable cropping systems.

Several research trials on leucaena have been established to investigate:

(1) productivity of leucaena (K8, Cunningham, local) and *Sesbania grandiflora* with and without P fertilizer.

(2) nitrogen input into the soil by leucaena and various other legume rotation crops/pastures.

(3) establishment of leucaena and other pasture species at different times of planting (August, October, December, February), sowing methods (broadcast, buried, buried and covered with dry grass), and seed treatments (scarified, inoculated).

Once appropriate technology is determined, the project will be duplicated around NTT. Farmers and government staff from agricultural agencies will be trained and encouraged to adopt the technology in their own areas.

Initial experience with leucaena suggests that (a) giant varieties are more productive than the local variety, (b) planting can be undertaken successfully months before the onset of the wet season, and (c) effective nodulation and establishment are encouraged by inoculation, most appropriately with soil from an established leucaena area.

3. World Neighbours Project

The World Neighbours Project based at Waingapu, East Sumba, NTT aims to improve water supply and agricultural production in the particularly dry island of Sumba. The project has been active in promoting improved, stable cropping systems, land stabilization, and erosion control through the use of giant leucaena.

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Leucaena in Animal and Human Nutrition in Indonesia

Budi Tangendjaja and J.B. Lowry*

The role of leucaena is more than usually complex in Indonesia, so we will attempt a brief overall summary. Leucaena was introduced to the region some three hundred years ago, in the form of the weedy, free-seeding Hawaiian type. This established itself vigorously in certain regions, particularly those with calcareous soils or a marked dry season. It is very hard to find in acid or peaty habitats, such as much of Kalimantan. In certain areas, not necessarily where it did best, it became thoroughly established in local human use. This may range from the use of green seeds as an occasional snack and the green shoots in salads and soups, to the large-scale use of the seeds as a soybean substitute. Use of the green parts as livestock feed is traditional, but to that is added the use of the dried leaflets, as leaf meal, in monogastric animal feeds; the leaf meal then being a commercial product produced locally for cash, and used in a quite different place. Superimposed on this pattern has been the introduction of high-yielding varieties, by several official bodies, and the further distribution of these by individual enterprise. This has sometimes resulted in introduction of leucaena to unsuitable habitats. Finally there is the use of it in plantation forestry, and the presence of other species and hybrids in limited areas, mainly as nurse trees on upland estates.

Leucaena in Human Nutrition

The range of human use is indicated by considering two very different areas.

1. West Java

This has fertile soils, high rainfall, intensive and diverse cropping systems. It has been claimed the Sundanese eat a greater variety of green leaves than any other people (Martin and Ruberte 1975). Leucaena is used as green pods, green seeds, and young stem tips in salads, in cooked soup, and as a snack *in situ*. Intake is impossible to estimate, but the plant is ubiquitous as a houseyard tree, and always plucked, giving a distinctive growth habit. It probably acts as a minor but useful protein and vitamin supplement. Despite its prevalence, the tree does not perform well in biomass yield compared with some other species in this habitat.

Indonesian people consume leucaena in other ways. In Central or East Java, young pods and mature seeds are cooked with other ingredients, such as coconut and small fish, and steamed in banana leaf (botok). Trenggalek is one area where this type of food is popular. In Sulawesi and elsewhere the mature seed is roasted and used as a coffee extender. The utilization of leucaena seed for making tempeh (a fermented product using *Rhizopus* sp) is well known in Central Java; mimosine content has been found to be decreased after fermentation (Slamet 1982). The use of leucaena bean sprouts has been recorded also (Ochse and van den Brink 1931). Although the first report on mimosine toxicity to humans was from Soemedang, West Java (Kostermans 1946), nowadays actual cases are rarely reported. It is likely that leucaena consumption is too low to cause toxicity and normally, it is not used as a staple food by Indonesians. However it is possible that some people consume a large amount of leucaena because of individual taste preferences. Also in areas in which food crop production is occasionally low leucaena may be the only resource available, and a high consumption of it may occur.

2. Gunung Kidul, Central Java

This area has eroded limestone soils, and a marked dry season. It is a classic area for malnutrition due to cassava-based diet. In this area leucaena performs relatively well in DM

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production, and may sometimes be used as food from necessity, particularly mature seeds as a soybean substitute. Thus the protein contribution is potentially important. The seed is also exported from the area as an economic product.

Despite the contrasts, we suggest that a main question throughout is the possible role of DHP (3-hydroxy-4(1H) pyridone) as a human goitrogen.

1. Mimosine toxicity has been noted occasionally in humans, and the effects appear to be rather widely known.

2. Under the conditions in which leucaena is used, the autolytic conversion of mimosine to DHP would easily occur (Lowry *et al.* 1983).

3. Any observed cases of acute (mimosine) toxicity imply a much more pervasive exposure to DHP since this has no obvious acute effects.

4. Goitrogenicity of DHP is known only from ruminant research, and the compound has never been considered as a possible plant goitrogen in human diets.

5. There is a massive goitre problem in Indonesia, some 10% of the population being affected.

The possibility has been raised in a limited forum in Indonesia (Lowry and Tangendjaja 1983). It is important that research establish the real role of DHP in goitre in Indonesia.

It would be too easy to make a dramatic case for the possible hazards that might prejudice the use of the plant unnecessarily.

Leucaena for Animal Feed

1. Ruminants

The degree of use varies from virtually 100% of the ration to nil, but it is almost always fed under a cut-and-carry system. The most important feature of leucaena utilization in Indonesia is the apparent absence of any chronic DHP toxicity, and the evidence for a positive detoxification process in the form of rumen microbial degradation of DHP (Jones and Lowry 1984; Lowry 1983; Wahyuni *et al.* 1982).

From results to date it seems very unlikely that toxicity would occur in areas where ruminants and leucaena are both naturalized. There remains the possibility of problems with imported animals or with major plantings of leucaena in new areas but the solution via infusion of rumen fluid is already demonstrated. Considerations for better utilization of leucaena involve nutrition rather than toxicology. They include (a) ensuring adequate Na at high intakes (Yates 1983), (b) checking the role and need for S at high intakes, (c) making best use of leucaena as a dry season supplement for low quality fibrous feeds, and (d) comparison of dry matter production with other forages.

There seems little doubt the leucaena can and will make a further contribution to ruminant production in the areas where it performs well, but that it is important to not expect such results in areas where it performs badly, viz. on acid, Ca deficient soils.

2. Non-ruminants

At present this mainly concerns production of leaf meal for use in compounded, mainly poultry, feeds. The leaf meal itself is a commercial product. It is produced (cutting, drying, separating leaflets, pounding) entirely in the villages and provides a direct source of employment and income to the farmer (Lowry *et al.* 1982). Although used at low levels in layer diets mainly as a source of xanthophyll and vitamin A, the potential market seems large (Thailand exports a very inferior leucaena leaf meal to the EEC) and development of this enterprise along appropriate lines is very important.

In future, the utilization of leucaena leaf meal for chicken industries should be improved. If the importation of feed ingredients, especially high protein materials such as fishmeal and soybean meal, can be reduced by a protein contribution from leucaena leaf meal there is benefit for both the national economy and the local producers. However, the reason for growth depression when leucaena is included above levels of 5% in poultry diets (Table 1) is still not clear.

Mimosine has been reported as the main cause of the problem, although with no direct evidence. Our recent results indicate that mimosine is not really the main cause of growth inhibition. Dosing of chicks with mimosine or DHP results in growth inhibition only at a very high level (Tangendjaja *et al.* unpubl; Table 2). Digestible energy and protein seem to contribute to the problem. From the chemical composition, it would seem that leucaena leaf meal can be used at a higher level in the diet.

Ducks are important animals for Indonesia

Table 1. Performance of chicks fed leucaena leaf meal (LLM) containing largely mimosine and DHP at different levels.

	% LLM in ration	4 weeks body weight gain (g)	Feed/gain ratio
Control	0	685	1.89
LLM (mimosine):	5	716	1.89
	1	699	1.93
	20	589	2.16
LLM (DHP)	5	693	1.94
	10	660	1.96
	20	480	2.08

and in some areas provide direct income for farmers. Indonesia has the highest population of ducks in the world. The fact that ducks may tolerate a higher fibre diet than chicken together with the high protein, calcium, and pigment of leucaena may open a new dimension of the utilization of leucaena for duck raising.

The utilization of leucaena for pigs has been tried in Taiwan and a higher level could be tolerated in the diet than that for chicken. Although some pig farmers in Indonesia have been practising to use leafy material for feeding, leucaena has not been utilised yet. The potential use of leucaena as forage of leaf meal in Indonesia should include the utilisation of seed. With an increase in planting of leucaena in many areas in Indonesia, especially with a new cultivar, viz. lamtoro gung (K8), more leucaena seed will be produced. Although seed at present is being utilised for human consumption, the potential use will probably be as animal feed.

3. Rabbits

With government interest and encouragement, this animal may become an important protein source for human consumption, specially for villagers in the future, owing to its productivity and small-scale production. At present the few farmers use common grasses (rumput lapangan) supplemented with rice bran. Leucaena and other tree legumes could be used directly by rabbits and can be a very good source of feed as rabbit can extract protein from leafy materials, whether the fibre is utilized or not.

Evaluation of leucaena and other shrub legumes should be examined. The question of leucaena (mimosine) being toxic to rabbits has not been investigated thoroughly. A recent trial

Table 2. Performance of chicks dosed with mimosine and DHP at different levels for two weeks.

	Dosing level (mg mimosine equivalent/ g body weight)	2 weeks body weight gain	Feed consumption (g)	Feed/ gain
Control	0	119.0	163	1.37
Mimosine:	1.0	95.8	145	1.52
	0.75	115.8	169	1.37
	0.50	121.4	160	1.32
	0.25	122.6	173	1.40
DHP:	1.0	62.4	98	1.58
	0.75	90.4	137	1.51
	0.50	94.6	145	1.53
	0.25	114.8	157	1.37

shows a growth depression when dried leucaena was included in the ration (Table 3).

Dried leucaena in which mimosine has been converted to DHP, did not improve the performance (Tangendjaja *et al.* unpublished). Goitre may occur when fresh leucaena is fed for a longer time. A simple technology for overcoming the problem will be desirable as small-scale rabbit production is promoted, because leucaena is already found throughout the villages in Indonesia.

Table 3. Performance of rabbits fed leucaena leaf meal (LLM) at different levels.

	% LLM in diet	Weekly body weight gain	Feed/gain ratio
Control	0	161	5.9
LLM (mimosine)	20	122	6.7
	40	66	11.1
	60	41	17.6
LLM (DHP)	20	112	8.7
	40	83	10.5
	60	5	19.9

Leucaena in Relation to Other High Quality Tree Forages — The Case for Mixing Species

1. Leucaena is already used (and being developed) in areas where it cannot realize its maximum DM production, and where other species (e.g. *Gliricidia*) probably do better.

2. A range of other species with rapid growth and relatively high-protein low-fibre leaf are available (Table 4).

3. Most of the factors limiting intake of tree leaves are secondary compounds that may be restricted in occurrence to a very few species (e.g. mimosine). In general there would not be any interaction between them, and in mixture each would be diluted according to the amount of other material added. A blend of species could be used at a higher level than any of the species individually.

This of course is a strategy of the free ranging animal, but may well be incorporated more deliberately in the cut-and-carry system. However it seems both novel and obvious to introduce this concept to leaf meal utilization. Our case for research on mixed-species leaf meal has been elaborated elsewhere and is available.

4. Both the biological diversity and the human resources (much under-employment and high agricultural skills) make production of mixed leaf meal, as blends of known species, a practical possibility in Indonesia.

Table 4. Composition of some tree legumes analysed at BPT Ciawi.

Species	P	E.A.	F	Na	T.P.	T
Acacia auriculiformis	15	3.9	45	-	10.8	1.1
Acacia villosa	27	4.8	24	.01	12.6	6.0
Albizia falcataria	24	4.6	37	.04	7.5	2.7
Calliandra callothyrsus	24	4.1	24	.00	11.3	6.8
Gliricidia maculata	25	3.8	35	.04	1.0	0
Leucaena diversifolia	22	8.4	26	.01	-	-
Leucaena pulverulenta	26	3.4	21	.01	10.0	9.5
Leucaena cv Cunningham	23	4.6	34	.02	4.2	1.5
Mimosa pigra	22	4.3	40		9.3	8.1
Samanea saman	24	4.6	48	.03	4.1	-

P = crude protein: E.A. = ether extract; F = N.D.F.; T.P. = total phenolics; T = tannins.

Conclusion

1. We consider that one major direction for increased utilization of leucaena for animal feed is in conjunction with other species of tree legumes.

2. Research on the utilization of leucaena and other shrub legumes should be directed more closely to non-ruminant species. The problem related to growth depression should be clearly defined and a simple technology should be developed to overcome this.

3. Utilization of leucaena leaf as an animal feed should be expanded to leucaena seed.

4. Although prevalence of goitrogenic toxicity in humans due to leucaena consumption is probably low, it is important that it be studied further, and the level at which leucaena causes a problem should be defined.

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Shrub Legumes for Forage in Tropical Australia

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Shrub and tree legumes have received little attention compared with herbaceous legumes in the development of forages for tropical regions (National Academy of Sciences 1979). Although many species in tropical regions have been recorded as being browsed in natural situations, few species have aroused sufficient interest to be planted specifically as fodder.

This situation also applies in Australia. Interest in the past has centred largely on native species, particularly *Acacia* (Everist 1969; Askew and Mitchell 1978). These trees have been regarded as a reserve feed for use in times of drought, or during the dry season, and the few data that exist suggest that the quality of this feed is often not high (McLeod 1973; Askew and Mitchell 1978). However in recent years interest in the development of shrub legumes has increased.

What characteristics are needed in a successful shrub legume? There are four that are immediately apparent:

1. High yield of edible material (including the ability to persist under grazing, and to regrow after cutting).
2. An acceptable level of quality (not only in levels of protein and minerals, but also in digestibility).
3. The ability to retain leaf during the dry season.
4. Ease of propagation, preferably by seed.

At CSIRO Pasture Research Station at Lansdown, 50 km south of Townsville, in Queensland, Mr R. Reid has assembled a collection of shrubs and trees judged to have some potential as browse species. A total of 30 genera and 54 species are represented.

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Of these accessions, few (if any) fulfil all the above criteria. Firstly, many shrub and tree legumes have the characteristic of being low yielding in their establishment year, and may take several years to achieve 'reasonable' yields. Others are not suited to recurrent cutting or browsing, and will not consistently produce useful amounts of forage.

Secondly, the level of quality of shrub legumes is very variable. The data of Bamualim *et al* (1980) showed that in a range of 27 accessions having digestibility above 60%. Thus the low digestibility of many of these shrubs may limit their usefulness. The presence of tannins (Bamualim 1981) is another factor to be considered.

Thirdly, seed production is a major problem with many of the accessions. Many trees take years to flower, and others set only small amounts of seed. This then represents a major bottleneck both to further testing and large scale exploitation.

Bamualim (1981) concluded that, within the material presently available, that the genera *Albizia, Gliricidia,* and *Leucaena* seemed to offer the most promise. However, it must be remembered that the collection has only been grown at one site, in the semi-arid tropics, and is constantly being enlarged. Further evaluation in other environments might reveal further promising accessions, once seed production problems can be overcome, or vegetative propagation undertaken.

In the remainder of this paper we will summarize the Australian work on leucaena. A recent comprehensive review of this subject has been published (Jones and Bray 1983), and thus the current emphasis will be on these aspects of the work which have, or could have, particular relevance to Indonesia or other south-east Asian countries. We have not cited specific references to support each point, but have listed a few important papers in the bibliography.

Genetic Resources

Between 1955 and 1967 more than 100 introductions of *L. leucocephala* were tested by CSIRO in south-east Queensland. Most of these introductions were low yielding and prolific seeding, similar to the weedy 'common' strain naturalized in much of the tropics. Two higher yielding introductions (CPI 18164 and CPI 18623) were released (as cv Peru and cv El Salvador respectively) to the grazing industry. El Salvador (which is not typical of the Salvador giant types) has been little used, while Peru has been widely grown.

In 1976 cv Cunningham was released. It was bred by Dr E.M. Hutton from a cross between Peru and CPI 18228 (from Guatemala). In general, its performance is similar to that of Peru, although Cunningham has significantly outyielded Peru in some experiments. The two cultivars have similar contents of the toxic amino-acid mimosine.

Since 1967, CSIRO has markedly increased its germplasm collection of *Leucaena*. The greatest increase has been through the collecting of R. Reid in Mexico and Colombia in 1978-79. This collecting 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. In particular, an increased pool of *L. pulverulenta* was sought (for low mimosine breeding), and a range of *L. leucocephala* from marginal environments.

The current state of the collection is summarized in Table 1 below. All accessions have been quarantined, grown, and described, and seed multiplied. It is anticipated that an extensive testing program will be needed to identify useful high-yielding genotypes for good growing conditions, as well as genotypes suited to marginal environments. Selection of the latter will be made easier by the existence of extensive data relating to climatic and soil conditions at the collection site that can be used in choosing suitable genotypes for testing in any area.

The 34 accessions listed as unknown or undetermined reflect the uncertain state of *Leucaena* taxonomy; some of them show great potential particularly for wood production. Many show similarities to *L. diversifolia;* how-

Table 1. Details of the *Leucaena* collection held by CSIRO Divison of Tropical Crops and Pastures.

Species	No. of accessions	Main area of collection	Likely usage*
L. esculenta	8	Central Mexico	human food (pods)
L. diversifolia	13	Mexico	wood production; cool climates
L. pulverulenta	39	NE Mexico	low mimosine
L. collinsii	6	Guatemala	ornamental; shade
L. leucocephala	ca. 500	Yucatan	marginal environments
L. shannoni	10	S. Mexico	ornamental?
L. lanceolata	20	SW coast of Mexico	acid soil tolerance?
L. macrophylla	32	SW Mexico	forestry?
L. trichodes	14	Colombia	
L. retusa	5	Texas	ornamental
unknown or undetermined	34		

* All species are browsed in their native environment, and therefore may have some potential as browse plants.

ever, some may yet prove to be distinct enough to be accorded species status.

There is no doubt that one of the important uses of the collection will be in the study of taxonomy and species relationships. The knowledge thus obtained will be useful in the exploitation of the current trend towards the development of interspecific hybrids as high-yielding forage and timber plants.

The self-incompatibility (or at least cross-fertility) of many species makes the maintenance of 'pure' accessions difficult, and much seed harvested in nurseries is of outcrossed origin. Indeed, hybrids can readily be made between almost all species, and while this can be an advantage in creating new genetic combinations, it also poses obvious problems in the maintenance of existing genetic resources.

Agronomy

Agronomic research on leucaena in Australia has concentrated on two main areas: establishment (including nodulation), and management.

The slow establishment of leucaena in the field is one of the main factors limiting its use in Australia. Although rapid, even germination can be obtained after seed scarification, seedlings compete poorly with weeds, probably due mainly to root competition. Although weed control is essential for rapid establishment, few studies on this aspect have been published. Cultivation to destroy weeds before planting may be the best way of reducing weed competition, and establishment is often no problem when sowing into previously uncultivated land. The use of herbicide applied in strips can effectively remove weed competition and enable leucaena to establish successfully when drilled into the killed sward.

Difficulty in establishment on some soils may also reflect the long time taken to nodulate (often up to 50 days). Two strains of *Rhizobium* have been selected - CB 81 for use on acid soils, and NGR 8, which may perform better on alkaline soils.

Pastures of leucaena may be used as a supplement in a rotation system with larger areas of native pasture, or as the major feed supply for cattle. If the leucaena is used as a supplement, the pastures are managed to accumulate high quality feed for the dry season.

Leucaena is usually established in rows 2-4 m apart, and grazed leniently and rotationally in the first few years until a good framework and strong root system have been established. Any grasses to be sown are planted later so that competition in the year of establishment is minimal. Leucaena plants grazed rotationally (1-2 weeks grazing then 4-6 weeks rest, or 4 weeks grazing followed by 4 weeks rest) are usually long lived, with good stands persisting for more than 20 years without the need for regeneration from seed.

There has been little work done on the mineral nutrition of leucaena. Like any plant, leucaena needs adequate levels of all essential elements to make satisfactory growth. In keeping with its site of origin in Mexico, leucaena is especially adapted to alkaline soils, and has a higher lime requirement than many other legumes. Specific deficiency symptoms have been established for a range of elements, and they enable preliminary diagnosis of nutritional problems.

Toxicity Problems

The presence in leucaena of the amino-acid mimosine makes it potentially toxic to livestock. Mimosine is a powerful antimitotic and depilatory agent that cannot be degraded after absorption but can be degraded to 3-hydroxy-4(1H) pyridone (DHP) in the rumen. DHP is a potent goitrogen. Enlarged thyroid glands frequently occur in cattle grazing leucaena pastures, and are associated with low levels of serum thyroxine. Cumulative effects of leucaena result in depressed weight gains and clinical signs, which include hair loss, depressed appetite, hypothyroidism, ulceration of the oesophagus, and death of newborn goitrous calves.

Attempts to overcome toxicity problems have followed three main avenues.

1. Management

The nutritive value of leucaena far outweighs its potential toxicity, and feeding trials have established that no major detrimental effects would be apparent if cattle had less than 30% leucaena in their diet. Animals grazing mixed pastures where leucaena is grown in widely spaced rows would be unlikely to exceed this level. However, it is probable that even at low levels of intake of leucaena there are sub-clinical effects due to depressed appetite.

2. Breeding of Low Mimosine Varieties

There is no usable variation in mimosine content in *L. leucocephala*. Thus attempts to produce low mimosine lines have concentrated on the use of interspecific hybrids with *L. pulverulenta* (a species with low mimosine). The breeding program of Dr E.M. Hutton involved backcrossing hybrids of *L. pulverulenta* and *L. leucocephala* to their *L. leucocephala* parent (cv Cunningham) and selecting for seed production, low mimosine, and vigour. Unfortunately, when tested after two backcrosses, the low mimosine selections were only two-thirds as vigorous as Cunningham. Another approach has been the direct usage of *L. pulverulenta* and *L. leucocephala* hybrids, which can give up to 70% more leaf, and 100% more wood than Cunningham with a slightly lower (80%) mimosine content. Their limitation is in the need for continual F_1 seed production, or some form of vegetative reproduction.

Some problems with breeding for low mimosine include an apparent correlation with vigour (low mimosine/low vigour), together with a variation in mimosine content due to a range of ontogenetic (leaf age, leaf position) and environmental (e.g. moisture stress) factors.

3. Rumen Micro-organisms

The toxicity in ruminants fed leucaena in Australia has not been reported in Hawaii, where the shrub is naturalized and is grazed by cattle or cut and fed to goats. This lack of toxicity in Hawaii is apparently due to the degradation of both mimosine and DHP in the rumen. Apparently animals in Australia lack rumen micro-organisms capable of degrading DHP. The successful isolation and culture of these organisms, and their subsequent transfer to, and effectiveness in, goats and steers in Australia offers exciting new prospects for high levels of animal production from leucaena.

Feeding Value and Animal Production

The mineral composition of leucaena (growing in a soil of reasonable nutrient status) is usually adequate for animal production, although sodium and iodine levels are consistently low. In Australia, studies to measure intake and digestibility have been complicated by toxicity problems in the animals, and it will be impossible to get meaningful figures on potential nutritive value until a practical solution to this problem is found.

However, it is clear that leucaena has higher digestibility than most other shrubs, and that digestibility does not vary greatly between seasons.

Data on animal production on grazed pastures are also relatively few, and rather variable. Again, such evaluations are complicated by toxicity, especially in the warmer areas of northern Australia.

The breeding performance of beef cattle on leucaena pastures has also varied, with depressed calving rates in some areas, but pronounced improvements (due to supplementary grazing of leucaena) in others.

Research Priorities

Within such a complex genus as *Leucaena*, which has numerous potential uses, there are obviously many areas needing investigation. Specific problems that are within our sphere of expertise are given below (not in any order of priority).

1. Characterization and exploitation of the existing germplasm collection, both of *Leucaena*, and other shrub legumes. This will assist in defining the areas of climatic and edaphic adaptability, and in the identification of superior accessions capable of higher yields, of wider adaptability, and with better agronomic or nutritional attributes than the existing cultivars. It has become clear from Australian testing that genotype-environment interactions are often substantial, and thus it is essential that testing be carried out over as wide a range of conditions as possible.

2. Elimination of the toxicity problem. In ruminants, it appears that a biological solution using introduced micro-organisms may be feasible. However, much remains to be done regarding the introduction of these organisms to commercial herds, and their maintenance therein. The problem still remains of the toxic effects in non-ruminants such as pigs, chickens, and fish. The breeding of low mimosine varieties offers one solution, and various processing methods and treatments another. In humans, although it is known that consumption of seeds can result in

alopecia, the extent of possible toxicity problems is unknown. With potential seed yields of up to several tonnes per ha from bushy, weedy types, the possibilities for improving human food supply are great.

3. Definition of production systems in which leucaena will make the greatest contribution. Not only do we need to investigate this from an Australian grazing point of view, but also for other systems producing both forage and fuel. We know little about evaluation and management strategies necessary to first select suitable varieties and then subsequently to optimize production of various components of the system.

4. Study of plant nutrition. It is well known that leucaena does not flourish on acid soils. However, there is a dearth of information on the precise nutrient requirements of Leucaena. In a recent bibliography on *Leucaena* (Oakes 1982) there is not a single reference that could be classed as a definitive study of the nutrition of the genus. There is a similar lack of information on other genera that may have potential as shrub legumes, and there have been very few studies comparing the requirements of species within *Leucaena,* across different genera of shrub legumes, or with other tropical legume species.

The reasons for the poor performance of leucaena on acid soils remains unclear. The need to distinguish between low calcium and high aluminium in soils as a cause of the poor performance is particularly important since it is much easier to correct low Ca than it is to alleviate toxic levels of Al. Evidence is accumulating that calcium deficiency may be the critical factor, leading to poor root development in the subsoil. It is anticipated that techniques developed for investigating nutrient disorders in other tropical legumes (notably Siratro and various *Stylosanthes* species) could be applied to leucaena and other shrub legumes. Once the specific factors responsible for nutritional problems have been pinpointed, they can either be alleviated chemically, or provide specific objectives for breeding programs.

5. Seed production strategies. Even though the potential for seed production in leucaena is high, actual harvested yields are often quite low, due to problems associated with the occurrence of pods some metres above the ground, and the need for multiple harvests to pick pods before they shatter. Techniques are needed to obtain high recoverable seed yields close to the ground.

Another aspect of seed production is the necessity that a cultivar be true to label and reasonably pure. Due to the general similarity of many leucaena types, the lack of familiarity of most people with the distinguishing characteristics of particular cultivars, and the fact that a certain amount of outcrossing is occurring, it is essential that reliable seed production areas of foundation seed of promising lines be established and maintained.

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Summary of General Discussion

Discussion Leader: Professor J.R. McWilliam*
Reporter: E.T. Craswell**

The discussion leader introduced the topic by pointing out the six 'Fs' of shrub legume research. These are - FOOD, FODDER, FUEL, FERTILITY, FLOOD CONTROL, and "FARMICEUTICALS". The papers given at the workshop had shown that there was extensive research on shrub legumes over wide areas of Indonesia and Australia. The purpose of this final discussion was to identify gaps in our knowledge of the use of these plants. Six topics can be delineated within the general field of research.

1. **Genetic Resources:** There is a need to determine the extent of variability both within and between the various species and to evaluate promising varieties.
2. **Adaptation:** Work is needed on the adaptation of various species and varieties to soil and climate, nutritional regime, low pH, and biological nitrogen fixation.
3. **Agronomy:** Further work is needed on the management of shrub legumes in relation to their establishment and productivity as sources of fuel and fodder, as well as on their role in soil conservation and erosion control.
4. **Animal and Human Nutrition:** Aspects of the problem of toxicity require further research.
5. **Breeding:** Work here could focus on aspects of flowering and seed biology, and the selection of cultivars better adapted to specific environmental and edaphic conditions.
6. **Systems:** Research is needed on novel and conventional uses of shrub legumes in farming systems.

These comments led into a broad ranging discussion, which is summarized below. A number of the comments concerned the question of whether or not any co-operative research project should focus only, or largely, on leucaena. This shrub does not grow well in some areas of Indonesia where farmers are using *Gliricidia* and *Sesbania* instead. In other areas of the outer islands, where land has been damaged by bulldozers used for clearing, creeping legumes such as *Centrosema* grow well and would be preferable to leucaena. The key to the success of leucaena in Timor may be that the soils are alkaline. Leucaena is an introduced species in Timor, but experiments have shown that it grows a lot better in the first year than legumes such as *Sesbania.* Other species requiring further evaluation include the acacias, which grow well on acid soils. Acacias may have potential since they are eaten by stock and have satisfactory leaf protein levels.

A lot of the discussion focussed on the farming systems in which shrub legumes might be employed. A thorough study of existing systems in which shrub legumes are employed would be a valuable first step in the introduction and further development of these legumes in Indonesia. The Indonesian government wants a focus on small-scale farmers in the outer islands as well as in Java. If work is aimed at helping small-scale farmers, polyculture systems rather than monoculture systems should be considered. Farm size, labour cost, and the availability of shrub legumes will influence their use. For example, in Java upper branches of *Albizia* trees are lopped and used as an animal feed. The trunks that remain are removed and used as construction timber for housing. Thus research on the legumes should focus on possible end uses for the whole shrub or tree. *Crotalaria* and *Sesbania* build up the nitrogen fertility in soils better than leucaena, which is less suitable for intensive systems than marginal systems. In marginal systems, alley-cropping with shrub legumes is a good way to improve soil fertility, and in some areas the shrub legumes may be put through an animal before it is added to the soil. The real benefit of leucaena is that no other shrub legume has shown itself so suitable for multipurpose use.

The difficulty of adapting leucaena to acid soils was raised a number of times during the discussion. One solution to this problem may be

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simply to apply lime to enhance leucaena growth on acid soils. Research is needed to determine whether or not the problem is one of calcium nutrition, aluminium toxicity, or ineffective nodulation in acid soils. The prospects for successfully selecting *Leucaena* species that are adapted to acid soils are quite good. For example, *Leucaena macrophylla,* which was collected from Mexico, comes from areas with acid soils. The question of how to develop leucaena or other multipurpose shrub legumes for acid conditions emerged as one of the major areas for a possible ACIAR collaborative project.

The problem of shrub legume establishment was the main agronomic aspect discussed. Leucaena is hard to establish using cuttings, but it is easy to graft. More research is needed on vegetative establishment, although the establishment of leucaena as seedlings is standard practice in Bangladesh. In other areas, shrub legume seeds are sown directly because larger areas can be covered more quickly in this way.

The problems of animal nutrition associated with the use of leucaena were discussed in some detail. Apart from its use as a browse shrub, leucaena can be fed to animals as a supplement to rice straw or other low quality roughage. Such supplementation lessens the effects of the toxic mimosine in the leucaena foliage. One participant commented that the name 'mimosine' suggests that this substance may occur in many legume shrubs. Unfortunately, very little research has been done on toxins in other shrub legumes available in Indonesia. Further research is needed because it cannot be assumed that these other shrub legumes will not also contain toxic substances.

Leucaena seed contains mimosine, but does not appear to contain the enzyme that converts mimosine into the more toxic DHP. It is the presence of this enzyme in the leaves that makes leucaena foliage toxic. It was suggested that because of the close relationship between leaflet size and mimosine content across leucaena species, small leaflet size could be used as an initial selection criterion for reducing mimosine content.

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