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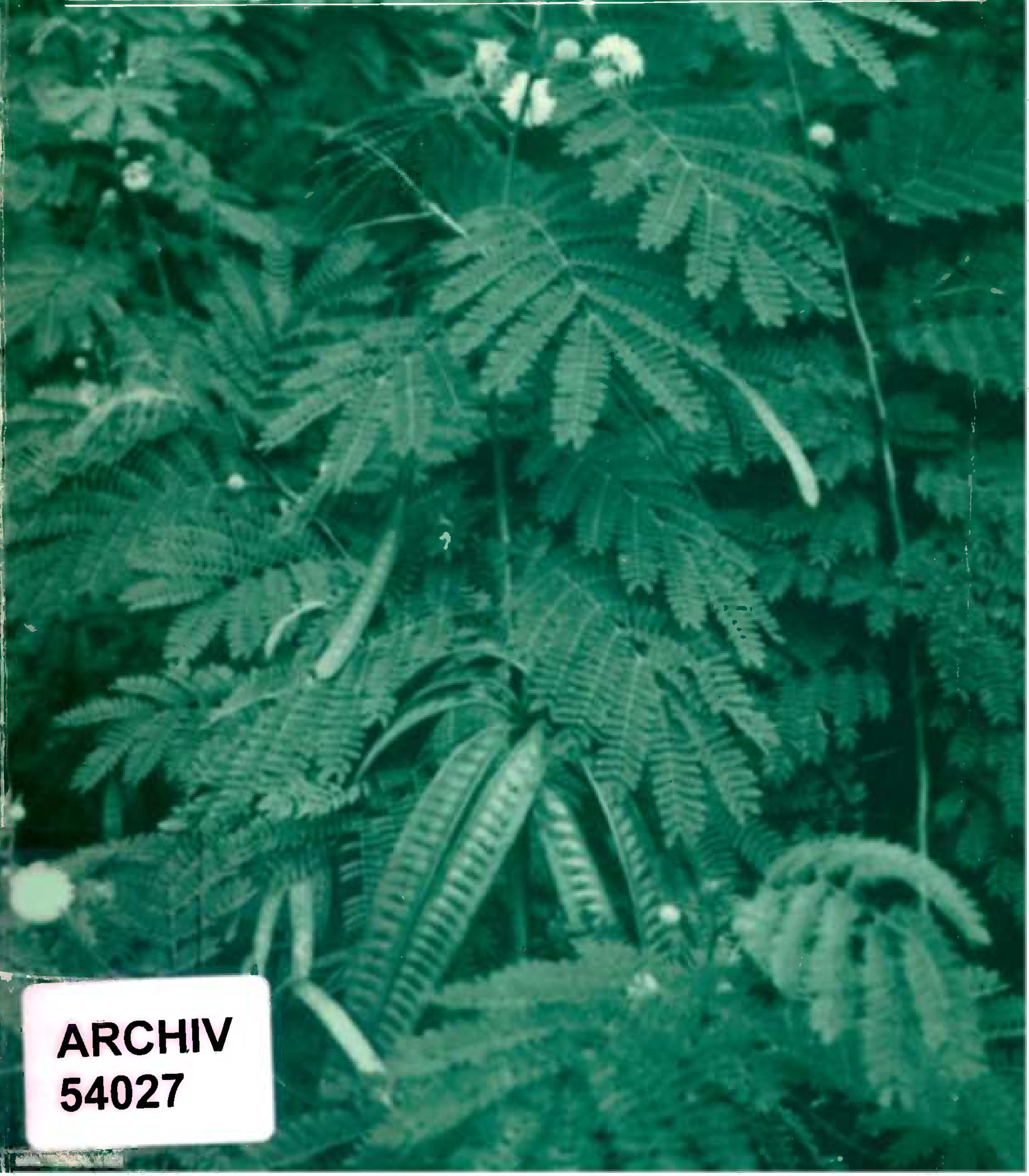
Leucaena Research in the Asian-Pacific Region

Proceedings of a workshop held in Singapore, 23-26 November 1982



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Leucaena Research in the Asian-Pacific Region

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Abstract

Because of *Leucaena leucocephala*'s multiple uses as forage, fuelwood, poles, green manure, etc., this fast-growing, nitrogen-fixing tree has been the subject of much research in the last decade. The results have clarified the capabilities of the plant as well as its limitations. One main constraint to cultivation in vast areas of Latin America and Southeast Asia has been leucaena's inability to survive on acidic, aluminum-saturated soils. At low pH, the aluminum complexes with calcium, which is essential for good growth. Trials have shown that some varieties of *L. diversifolia* can make use of the calcium from the complexes and that crosses between these varieties and *L. leucocephala* perform well on acidic soils. The main constraint to use of leucaena as a forage derives from the plant's content of mimosine, a toxic, nonprotein amino acid. Although leucaena has proved to be a highly nutritious animal feed, the mimosine and its breakdown product, DHP (3-hydroxy-4[1H]pyridone), have caused toxicity among animals fed high levels of leaf meal. Scientists now have evidence that the mimosine is converted into DHP when brought into contact with an enzyme contained in some of the plant's cells harbouring mimosine. This finding needs follow up; it suggests that simple processing, such as chopping fresh leaves, will convert all the mimosine into the less-toxic DHP. Elsewhere, researchers have found that DHP can be metabolized by anaerobic microorganisms that have been found in the guts of ruminants in countries like Indonesia. They have successfully transferred the microorganisms to animals in Australia where toxicity from DHP has deterred graziers from using leucaena as forage. Other research has defined optimal approaches to breeding and genetic improvement of leucaena; characteristics of rhizobia that effectively provide the plant with nitrogen-fixing ability; biomass production under widely different soil conditions; effects on fish, poultry, cattle, goats, and sheep fed leucaena leaf meal; management and cultural practices for both large-scale and smallholder operations; etc. The results are the subject of this publication, which comprises 30 papers from researchers in the Asian–Pacific Region.

Résumé

Leucaena leucocephala a fait l'objet de nombreuses recherches au cours de la dernière décennie, cet arbre légumineux fixateur d'azote et de croissance rapide ayant de nombreux usages comme fourrage, combustible, poteau, engrais vert, etc. Ces études ont permis d'en délimiter les fonctions. L'un des facteurs limitants de sa culture dans de vastes régions de l'Amérique latine et de l'Asie du Sud-Est est l'incapacité de *Leucaena* de survivre dans des sols acides, saturés d'aluminium. Dans le cas d'un faible pH l'aluminium complexe le calcium, essentiel à une croissance régulière. Des essais ont démontré que certaines variétés de *L. diversifolia* peuvent utiliser le calcium présent dans les complexes et que les croisements entre ces variétés et *L. leucocephala* prospèrent dans des sols acides. Le principal obstacle à l'utilisation de *Leucaena* comme fourrage est sa teneur en mimosine, acide aminé non protéique toxique. Bien que ce fourrage soit hautement nutritif, la mimosine et DHP (3-hydroxy-4[1H]pyridone) ont provoqué des cas de toxicité chez les animaux consommant de grandes quantités de farine de feuilles. Les scientifiques ont découvert que la mimosine se décompose en DHP lorsqu'elle entre en contact avec une enzyme contenue dans certaines cellules où elle est présente. Cette découverte a permis de déterminer des moyens simples de neutraliser cette substance toxique, tel que le hachage des feuilles vertes qui décompose la mimosine en DHP moins toxique. Ailleurs, des chercheurs ont trouvé que le DHP peut être métabolisé par des microorganismes anaérobiques présents dans l'intestin des ruminants dans certains pays comme l'Indonésie. Ils ont réussi à transférer ces microorganismes à des animaux en Australie où les pasteurs refusent l'emploi du fourrage de *Leucaena* à cause de la toxicité de DHP. D'autres recherches préconisent une approche optimale: de la sélection et de l'amélioration génétique de *Leucaena*; des caractères des rhizobiums qui assurent la fonction de la fixation d'azote chez la plante-hôte; de la production de bio-masse dans diverses conditions de sols très variés; des effets des rations de farine de feuilles sur les poissons, les volailles, le bétail, les chèvres et les moutons; de la gestion et des pratiques culturales des opérations des petites et des grandes exploitations, etc. Tous ces résultats sont détaillés dans la présente brochure qui contient trente communications exposées par des chercheurs de la région du Pacifique asiatique.

Resumen

Debido a los múltiples usos de la *Leucaena leucocephala* como forraje, combustible, madera, abono, etc., este árbol, de rápido crecimiento y habilidad para fijar el nitrógeno, ha sido objeto de abundante investigación en la última década. Los resultados han aclarado las capacidades de la planta, así como sus limitaciones. Uno de los problemas para su cultivo en vastas áreas de Latinoamérica y el Sudeste Asiático ha sido su incapacidad para sobrevivir en suelos ácidos, saturados de aluminio. A niveles bajos de pH, el aluminio forma complejos con el calcio que es esencial para un buen crecimiento. Las pruebas han mostrado que algunas variedades de *L. diversifolia* pueden usar el calcio de los complejos y que los cruces entre estas variedades y la *L. leucocephala* se desempeñan bien en suelos ácidos. El principal inconveniente para usar la leucaena como forraje proviene de su contenido de mimosina, un aminoácido tóxico no proteínico. Aunque la leucaena ha probado ser un alimento animal altamente nutritivo, la mimosina y su producto de descomposición, el DHP (3-hydroxy-4[1H]pyridone), han causado toxicidad entre los animales alimentados con altos niveles de harina de follaje. Los científicos tienen ahora evidencia de que la mimosina se convierte en DHP cuando entra en contacto con una enzima que se encuentra en algunas células de la planta que contienen mimosina. Este hallazgo necesita seguimiento, pero sugiere que un simple procesamiento, como picar las hojas frescas, convierte toda la mimosina en el menos tóxico DHP. En otras partes, los investigadores han encontrado que el DHP puede ser metabolizado por microorganismos anaeróbicos que han sido hallados en el intestino de rumiantes en países como Indonesia. Ellos han traspasado con éxito los microorganismos a animales en Australia donde la toxicidad del DHP ha impedido que los ganaderos empleen la leucaena como forraje. Otras investigaciones han definido los enfoques óptimos para el fitomejoramiento de la leucaena, las características de la rizobia que efectivamente dotará a la planta de la habilidad de fijar nitrógeno, la producción de biomasa bajo condiciones edáficas ampliamente distintas, los efectos sobre los peces, las aves, el ganado, las cabras y las ovejas alimentadas con harina de hoja de leucaena, las prácticas culturales y de manejo para las actividades a gran escala o del pequeño agricultor, etc. Los resultados son el tema de esta publicación que abarca 30 trabajos de investigadores en la región Asiopacífica.

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Contents

Agronomic Research in the Development of Leucaena as a Pasture Legume in Australia

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Research has established leucaena's value as a persistent, productive, and nutritious leguminous shrub for the coastal and subcoastal areas of subtropical and tropical Australia; however, difficulties in establishing the plant and fear of its toxic effects on livestock have resulted in poor acceptance by graziers. Research has identified some of the factors involved in the slow establishment. These are an inherently low seedling-growth rate, inability to compete well with weeds, delayed nodulation, and high palatability to native fauna. Plant introduction and plant breeding have resulted in the release of three cultivars — Peru, El Salvador, and Cunningham. Efforts to produce a fertile, low-mimosine, high-yielding cultivar using L. pulverulenta *as the female parent have been unsuccessful. If seed-production technology can be developed, F_1 interspecific hybrids could be produced commercially. A large collection (about 700 accessions) is under study at the CSIRO Davies Laboratory. Lines with yield potential higher than Cunningham have been identified, although site × line interactions have complicated evaluation.*

The complex nature of the toxic effects of leucaena on ruminants has largely been unraveled. There is now hope that biological control of toxicity can be achieved. In the absence of clinical signs of toxicity, good weight gains have been recorded in steers and high levels of milk production in dairy cattle. In southeast Queensland, steers on leucaena pastures gained 50–100% more than those on pastures containing siratro, the best-adapted alternative. Priorities for future research in Australia are discussed.

Des études ont démontré la valeur du Leucaena *comme arbuste légumineux persistant, productif et nutritif pour les régions côtières et avoisinantes de l'Australie tropicale et subtropicale. Cependant, les difficultés d'établissement du végétal et la crainte de ses effets toxiques sur les bestiaux l'ont empêché d'être apprécié à sa juste valeur par les herbagers. Des enquêtes ont permis de préciser certains facteurs responsables de ces réticences. Essentiellement celles-ci ont trait à la lenteur de croissance des jeunes plants, à leur difficulté à se défendre contre les mauvaises herbes, à la formation tardive de nodosités et à leur saveur hautement appréciée de la faune indigène. L'introduction de plants et la sélection dont ils ont fait l'objet ont permis d'obtenir trois cultivars : Peru, El Salvador et Cunningham. La recherche d'un cultivar fertile, à rendement élevé et à faible teneur de mimosine, utilisant* L. pulverulenta *comme parent femelle a été infructueuse. S'il était possible de perfectionner les techniques de production de semences, on pourrait produire commercialement des hybrides interspécifiques F_1. Une collection considérable (environ 700 spécimens) est actuellement à l'étude au laboratoire Davies du CSIRO. On a découvert des lignées dont le potentiel de rendement est supérieur à Cunningham, bien que des interactions de lignée et d'endroit viennent compliquer l'évaluation.*

On a, en grande partie, réussi à éclaircir les complexités entourant les effets toxiques de Leucaena *sur les ruminants et l'on peut aujourd'hui espérer les annihiler par des moyens biologiques, ce qui éliminerait l'un des obstacles majeurs à un usage plus répandu de ce végétal. En l'absence d'indices cliniques de toxicité, on a enregistré de bons gains de poids chez les bouvillons et une production laitière abondante des vaches. Dans le sud-est du Queensland des bouvillons sur pâturages de* Leucaena *ont enregistré des gains pondéraux de 50 à 100 % supérieurs à ceux obtenus de pâturages contenant du siratro, autre plante la mieux adaptée. L'exposé discute des priorités futures de la recherche dans le contexte australien.*

La investigación ha establecido el valor de la leucaena como un arbusto leguminoso persistente, productivo y nutritivo para las áreas costeras y subcosteras de Australia tropical y subtropical. Sin embargo, las dificultades para establecer la planta y el temor a sus efectos tóxicos sobre el ganado han resultado en una baja aceptación. La investigación ha identificado algunos de los factores involucrados en el lento establecimiento. Estos son una tasa baja de crecimiento de plántulas, la incapacidad para competir con las malezas, la tardía nodulación y la alta palatabilidad para la fauna nativa. La introducción y el mejoramiento genético han resultado en la liberación de tres cultivares —Perú, El Salvador y Cunningham. Los esfuerzos para producir un cultivar fértil bajo en mimosina y de alto rendimiento usando L. pulverulenta *como progenitor femenino no han tenido éxito. Si se desarrolla la tecnología*

para la producción de semilla se podrían producir comercialmente híbridos interespecíficos F_1. En el Laboratorio Davies del CSIRO se estudia una gran colección (de unas 700 entradas). Ya se han identificado líneas con potencial de rendimiento superior a la Cunningham, aunque las interacciones lote × línea han complicado la evaluación.

La compleja naturaleza de los efectos tóxicos de la leucaena sobre los rumiantes ha sido despejada en buena parte y ahora existe la esperanza de lograr el control biológico de la toxicidad —lo que eliminaría una de las barreras al uso más amplio de la planta. Cuando no hay signos clínicos de toxicidad, se han registrado buenas ganancias de peso en novillos y altos niveles de producción lechera en este ganado. En el sudeste de Queensland, los novillos alimentados con pasturas de leucaena ganaron de 50 a 100% más que aquellos con pasturas que contenían siratro, la alternativa mejor adaptada. Se discuten las prioridades para la investigación futura en Australia.

One type of *Leucaena leucocephala* grows naturally in small areas along the coast of northern Australia from Brisbane (27°28'S) to Darwin (12°27'S) (Hutton and Gray 1959) and, according to Seawright (1963, quoting S.L. Everist, the government botanist), has done so for at least 50 years (now 70 years). It grows best in rainforest areas where significant rain falls during each month of the year. This naturalized leucaena is early flowering, free seeding, and fine leafed, known generally as the Hawaiian or common type and thought to have been introduced as seed from New Guinea and Fiji (Hutton and Gray 1959). Most research work in the country has been done with introductions from overseas rather than with the local, naturalized material. In this paper, we discuss the research during the past 25 years that has contributed to a better understanding of leucaena as a pasture legume and highlight areas where more research is required.

Genetic Resources and Evaluation

Between 1955 and 1967, more than 100 introductions were tested by the CSIRO Division of Tropical Crops and Pastures (then the Division of Tropical Pastures). Most of these introductions were similar to the low-yielding, naturalized type (Gray 1968). Two cultivars were released to the grazing industry, Peru (CPI[1] 18614) and El Salvador (CPI 18623) (Barnard 1972). Both cultivars were higher yielding than the local Hawaiian type, with Peru giving the highest yields (Hutton and Bonner 1960). El Salvador is atypical of the Salvador giant types (Bray 1980) and, as it is less productive than Peru, has been little used in subsequent experiments or on commercial farms.

In 1976, Cunningham, derived from a cross between Peru and a line from Guatemala (CPI 18228), was released (Mackay 1976). It was bred by E.M. Hutton and has significantly outyielded Peru in some situations (Jones 1974; Hutton and Beattie 1976) but not in others (C.G. Blunt and R.J. Jones, unpublished data; D.G. Cooksley, unpublished data;

[1] CPI = Commonwealth plant introduction number.

Table 1. Annual yields (kg/ha) of three leucaena cultivars (edible dry matter[a] or leaves) at three sites in Queensland, Australia.

Site[b] and harvest method[c]	Cultivar[d]			Reference
	Hawaii	Peru	Cunningham	
Samford				
Plucking	1500	12500**	—	Hutton and Bonner 1980
Cutting	—	3600	5480**	R.J. Jones and Cardoso (unpublished)
Lansdown				
Plucking	—	1500	1900*	Hutton and Beattie 1976
Cutting	—	3820	5460**	Hutton and Beattie 1976
South Johnstone				
Cutting[e]	—	9150	10300	Ferraris 1979

[a] Edible dry matter comprises leaves plus young stems <6 mm in diameter.
[b] Latitude and mean annual rainfall for Samford, Lansdown, and South Johnstone respectively are 27°22'S, 1097 mm; 19°40'S, 862 mm; 17°36'S, 3219 mm.
[c] Plucking is removal of the edible matter from intact stems; cutting is removal of aerial part of plant 15–30 cm above ground.
[d] Significant differences from control: * = P<0.05; ** = P<0.01.
[e] Yield of leaves only.

Ferraris 1979) (Table 1). In general, its performance is similar to Peru, and it has a similar mimosine content, although the xanthophyll concentration in its leaves is much higher (Savory 1979). Cutting management has such a strong influence on the yield of edible dry matter (Table 1) that the relevance of experiments where leucaena is cut low is questionable in relation to production under grazing.

Since 1967, the germ-plasm collection at CSIRO has increased markedly and, at present, comprises *L. trichodes* (3 accessions), *L. macrophylla* (31), *L. lanceolata* (22), *L. retusa* (9), *L. leucocephala* (ca 500), *L. collinsii* (4), *L. diversifolia* (10), *L. pulverulenta* (45), *L. esculenta* (24), and 42 unknown or undetermined accessions. Many of these accessions have been collected since 1977, largely through the efforts of R. Reid during his visit to Mexico.

Within the *L. leucocephala* pool, there are several lines with higher yielding ability than Cunningham, notably CPI 61227 from Mexico and CPI 58396 from Barcelona. Large increases in yield are also possible from crosses derived from *L. pulverulenta* and *L. leucocephala*, although marked site × line interactions complicate evaluation procedures (Bray 1981).

Establishment and Nodulation

The palatability of leucaena seedlings to marsupials, rabbits, and hares, as well as domestic stock, means that pastures must be fenced if the plants are to be established successfully. Leucaena is slow to establish in the field, and seedlings compete poorly with weeds (Cooksley 1974). These characteristics have contributed to the slow acceptance of the species by graziers in Australia. Rapid and uniform germination can be obtained, however, if seeds from ripe pods are scarified. The standard treatment is to immerse the seeds for 2–4 minutes, in water maintained at 80°C, followed by rapid drying (Gray 1962). A more rapid and uniform emergence of seedlings (80% versus 10% after 6 days) was obtained in laboratory studies in which treated seeds were allowed to imbibe water for up to 72 h, or until radicles began to emerge, and then dried (Jones 1970). Beneficial effects in the field were, however, much smaller.

Although seeds are large (52 mg) compared with the seeds of grass weeds such as *Eleusine indica* (0.4 mg), relative weekly growth rate is slow (0.55 g/g) (Egara and Jones 1977). In competition with *E. indica* in the ratio of 1 : 1, yield of leucaena was reduced to 26% of that in pure stands. Individual-plant weight for leucaena grown alone was 0.9 g compared with 3.1 g for *E. indica* after 3 months, and respective heights were 13.7 cm and 35.6 cm (Jones and Aliyu 1976). Subsequent work showed that shoot competition (shading) only accounted for 15% of the yield depression, whereas 85% was caused by root competition (Jones and Egara 1977).

Difficulty in establishment on some soils may also reflect delays (up to 50 days) in nodulation. Even with inoculant levels at 200 times the normal rate, the time to nodulate was only slightly reduced (Bushby 1982). This delayed nodulation means that the plant must compete for nitrogen during this period, and, unless weeds are controlled, either the sowing will fail or establishment will be prolonged.

Unlike some other tropical-pasture legumes, the seedlings of leucaena tolerate shade well (Egara and Jones 1977). Even at 35% relative photosynthetic quantum flux in a glasshouse, relative growth rate of shoots was affected little, and the leaf-area index was increased. Root growth, however, was greatly reduced (Egara and Jones 1977), with a resultant reduction in the plant's ability to compete for nutrients.

Thus, weed control is essential for rapid establishment, and various herbicides and methods of application have been studied. Unfortunately, few studies have been published. Under irrigated conditions in the Ord Valley, northwest Australia, the slow emergence of leucaena enables paraquat to be used to control the faster-emerging weed seedlings. Spraying when the first leucaena seedlings emerge may kill 5% of the leucaena but gives good weed control (C.G. Blunt, personal communication).

No clearcut recommendations for weed control have been developed in Australia, and the variations in soils and rainfall conditions would probably militate against standard treatments. Cultivation to destroy weeds before planting is considered to be the most reliable way of reducing weed competition (D.G. Cooksley, personal communication). Of the preemergent herbicides used, 2,4-D is one of the cheapest and most effective, particularly against dicot weeds (Shaw 1965; Cooksley 1974; Jones 1975). Unfortunately, 2,4-D Trifluralin and Dacthal (DCPA) reduce leucaena growth, and

Dacthal can cause serious taproot damage (Jones and Aliyu 1976).

Use of activated charcoal above the seed alleviates the adverse effects but unexpectedly reduces yields when used alone (Jones and Aliyu 1976). In a field study, a combination of 2,4-D and Dacthal, applied as a preemergent spray over rows protected by activated charcoal (30 kg/ha), gave good weed control and leucaena yields that did not differ significantly from hand-weeded controls (R.J. Jones, unpublished data). However, the application of charcoal in suspension requires special equipment that may limit its use. Varying the type of charcoal used to bind specifically the herbicide formulations offers potential to maximize weed control and minimize toxicity to the leucaena.

In native pastures with low soil reserves of weed seeds, the use of glyphosate (Roundup®) applied in strips effectively removes competition and enables leucaena to establish successfully when drilled into the killed sward (G.H. Malcolmson, personal communication). The method offers promise for establishment of leucaena on steep hillsides without the erosion risks associated with plowing and cultivating and could have economic advantages in other situations. An alternative is the establishment of leucaena in strips along the contour with or without the use of herbicides.

In some experiments, sowing seeds 5 cm deep or deeper greatly reduced emergence of seedlings (Jones 1970), whereas, in experiments on a moist, clay soil, sowing at 6 cm with a combine planter gave good establishment (Cooksley, in press).

Rhizobium Requirements

Rhizobia effective on leucaena are consistently fast-growing, acid-producing strains (Norris 1965), some of which may nodulate *Medicago sativa*, though not effectively (Trinnick 1965). Large differences in effectiveness between isolates have been demonstrated in glasshouse experiments (Norris 1965), but strains effective under these conditions may not always perform well in the field. On a podzolic soil with pH 5.0, the mild acid-producing strain CB 81 nodulated leucaena whether the seed was lime-pelleted or not, whereas the fast-growing, acid-producing strain NGR8 failed to form nodules unless the seed was lime-pelleted (Norris 1973). Even on lime-pelleted seed, the percentage of nodules from NGR8 3 years after sowing was virtually zero and the percentage from CB 81 averaged only 35 (Bushby 1982). Further experiments have confirmed the low survival of NGR8 in acid soils and have shown that native rhizobia gradually replace the applied strains (Bushby 1982). Clearly, better *Rhizobium* strains and more effective methods of inoculation need to be developed if leucaena establishment is to be made more reliable.

Management

Experience in leucaena management in Australia has been documented by Jones and Jones (1979) and Jones et al. (1982).The leucaena is usually established in rows 2–4 m apart, fertilized with nutrients deficient in the soil, and grazed leniently and rotationally in the first few years until a good framework and strong root system are established. Grasses are sown or planted later so that competition in the year of establishment is minimal. When fully established, the leucaena pasture is grazed rotationally because the animals often completely defoliate the leucaena at each grazing and can eventually destroy the plants (Jones and Jones 1982). The plants recover well if grazed for 1–2 weeks and allowed to rest 4–6 weeks. A two-paddock system with 4 weeks of grazing followed by 4 weeks' rest has also been found suitable. It is easier to keep leucaena under control in the subtropics than in the tropics, particularly if the stems are frosted and killed in winter. In the tropics, increased stocking rates, combined with occasional mechanical slashing, may be needed to keep the leucaena within grazing height (1.5–2 m) during the summer. Leucaena plants grazed rotationally are usually long-lived, with good stands persisting for more than 20 years without the need for regeneration from seed (Jones and Harrison 1980).

Pastures of leucaena may be used in a rotation system with larger areas of native pasture (Shaw 1968; Anonymous 1981) or as the major feed supply for cattle (Table 2). If the leucaena is used as a supplement, then grazing of these pastures can be varied so that high-quality feed is accumulated for the dry season. A novel approach to using leucaena in conjunction with native pasture involves growing the leucaena as trees and using the lower branches and seedlings under the canopy as the supplemental protein source (Wildin 1980). This system, which was first used with regular mechanical harvesting of seed, needs to be tested under a variety of other conditions before being widely recommended.

Table 2. Animal production from grazed leucaena pastures in Australia.

Pasture[a]	Stocking rate (beast/ha)	Live-weight gain (kg/ beast)	Live-weight gain Annual (kg/ha)	Reference
Leucaena + setaria	2.0	200[b]	400[b]	Jones 1973
Leucaena + pangola	4.9	118	580	Blunt 1976
Leucaena + pangola	6.2	134	830	Blunt 1976
Leucaena + pangola	7.4	96	710	Blunt 1976
Leucaena + pangola	8.6	56	490	Blunt 1976
Leucaena + pangola	5.6	91	510[c]	Blunt and Jones 1977
Leucaena + pangola	7.4	76	562[d]	Blunt and Jones 1977
Leucaena + rhodes	1.9	171	325	Jones and Jones 1982
Leucaena + rhodes	2.5	125	311	Jones and Jones 1982
Leucaena + setaria	2.0	162[e]	427	Jones and Jones 1979
Native grass (1.2 ha/beast)	0.83	95	79	Anonymous 1981
Native grass + 17% leucaena	0.83	140	116	Anonymous 1981

[a] The leucaena plus pangola pasture was irrigated.
[b] Gain over 215 days.
[c] Gain over 308 days.
[d] Gain over 280 days.
[e] Mean gain over 5 years for yearlong grazers with cv Cunningham.

Often, leucaena pastures require fertilization for high production. At establishment, fertilizer requirements are expected to be similar to those required for pastures of siratro, desmodium, or neonotonia. On acid soils (pH 5.4), lime is required. Maintenance requirements have not been studied but would vary with soil type, rainfall, and intensity of management. Deficiency symptoms are a clue to the need for application of specific nutrients (Gonzales et al. 1980).

Diseases and Pests

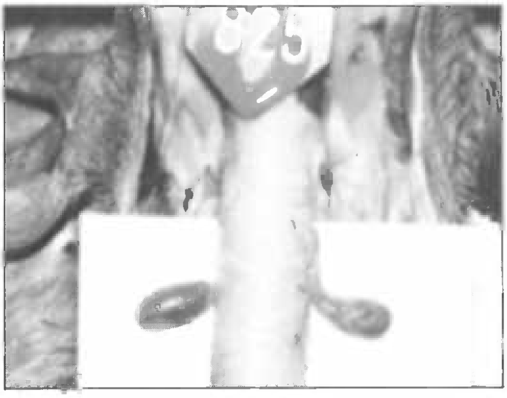
There have been no major disease or pest problems in leucaena to date. Attacks of cutworms and termites at establishment and soft scale (*Cocus longulus*) on mature stems have been encountered but are not regarded as serious. Recently, larvae of the moth *Ithome lassula* have been found attacking the inflorescences and young pods of leucaena in north Queensland (Common and Beattie 1982). Although not a direct problem for the grazier, seed yields could be seriously affected.

Seedlings of leucaena are very susceptible to damping-off when grown in wet conditions and should be treated with fungicides or post-emergence sprays in midsummer in areas where rainfall is heavy.

Toxic Effects

The presence in leucaena of the amino acid mimosine makes it potentially toxic to livestock. Originally, ruminants were thought to be unaffected, but experience in Australia proved otherwise. Hair loss has been observed in cattle grazing leucaena pastures (Hutton and Gray 1959) and in a buffalo calf fed fresh leucaena as part of the diet, although the latter regrew hair when leucaena feeding ceased (Letts 1963). Sheep fed diets of leucaena shed their fleece within 7–14 days (Hegarty et al. 1964) and may die (Reis et al. 1975). Mimosine is a powerful depilatory agent that cannot be degraded after absorption but can be extensively degraded to 3-hydroxy-4(1H) pyridone (DHP) in the rumen if the sheep are gradually conditioned to high levels of leucaena (Hegarty et al. 1964). When pregnant ewes were fed, ad libitum, leucaena during their pregnancy for 30 or 90 days, they failed to maintain weight; produced lightweight, goitrous lambs, devoid of thymus tissue; and had higher neonatal losses than did comparable ewes fed lucerne. No fleece shedding was observed, but the ewes had ulcers in the esophagus (Bindon and Lamond 1966). In a similar experiment (Little and Hamilton 1971), ewes fed leucaena at 1% mimosine content for the last 60 days of pregnancy failed to show the adverse responses noted above. However, elevated protein-bound iodine (PBI) values were recorded in the lambs, and these were not prevented by supplements of iodine to the dams (Little and Hamilton 1971).

In experiments with cows, leucaena did not affect estrous cycle length, conception rate, or gestation length, although some cows experi-



Thyroid glands of goat fed grass — no abnormalities; weight is 2–3 g.

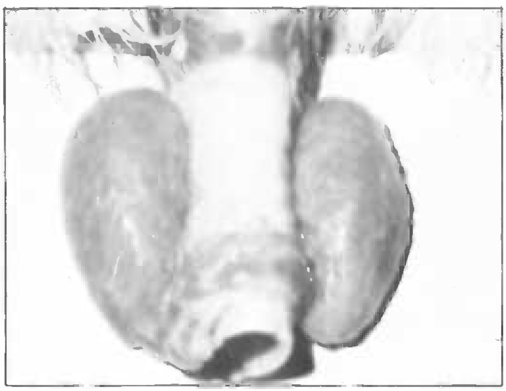
enced mild incoordination and nervous symptoms for a short period during gestation and lost some hair (Hamilton et al. 1971). Calves from cows fed leucaena had lower birth weights than did calves from lucerne-fed controls (19.6 kg versus 25.8 kg), were goitrous, and had elevated PBI levels (Hamilton et al. 1971). Enlarged thyroid glands were also a feature of cattle grazing mixed grass–leucaena pastures and were associated with low serum thyroxine (T_4) levels (Jones et al. 1976). Cumulative effects of leucaena were evidenced by depressed weight gains and development of clinical signs. New animals introduced to the pasture gained 1 kg/day compared with gains of 0–0.2 kg/day for resident animals. In subsequent experiments, a linear relation between serum T_4 levels and live-weight gains of cattle, grazing pangola–leucaena pastures, was established over the range 10–80 nmol/L (Jones and Winter 1982). Since clinical signs of toxicity were not recorded until T_4 levels fell below 30 nmol/L, considerable losses in productivity could be experienced well before any observable signs of toxicity.

Although mineral supplements containing zinc, copper, and iron alleviated the skin lesions and excessive hair losses of steers fed solely on leucaena, neither these nor iodine injections prevented the decline in T_4 levels (Jones et al. 1978). Goitre was clearly not simply caused by iodine deficiency and was unlikely to have been induced by thiocyanate.

In a fruitless search for potential goitrogens in leucaena, it was shown that mimosine was not goitrogenic (Hegarty et al. 1979) but that its degradation product in the rumen, DHP, was a potent goitrogen of the thiouracil type (Hegarty et al. 1979). Inhibition of ^{125}I uptake by the thyroid appeared to occur at the iodine-binding step and not at the iodine-trapping step as with thiocyanate (Hegarty et al. 1979).

Identification of the goitrogen was a major step in creating an understanding of the reaction of ruminants to leucaena feeding. It explained why ruminants in Australia showed leucaena toxicity, even though they were capable of completely degrading mimosine in the rumen. The adverse effects of DHP could not be overcome by iodine supplementation but were reversible. When leucaena was removed from the diet, appetite increased and T_4 levels returned to normal in 4 weeks (Jones et al. 1978). Steers that alternately grazed pangola grass and leucaena–pangola pastures made better gains than those permanently on leucaena pastures (Blunt and Jones 1977). Steers fed diets with 10% or 20% young leucaena shoots showed none of the clinical signs associated with leucaena toxicity after prolonged feeding. At dietary levels of 40%, 80%, and 100%, leucaena depressed serum T_4 and serum T_3 (triiodothyronine) levels, and steers lost weight on the 80% and 100% leucaena diets (Jones 1979).

The depressed appetite of animals on high-leucaena diets is probably associated with levels of DHP in the circulatory system rather than with low thyroxine levels per se as daily administration of thyroxine to maintain normal T_4 levels failed to increase feed intake significantly (Megarrity and Jones, in press). Restricting intake of leucaena would, therefore, be effective in preventing toxicity but would be difficult in grazed pastures.



Thyroid glands of goat fed leucaena for 3 months — enlarged to 16 g.

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. Absence of such adverse reports prompted a study by one of us (R.J.J.) with goats in Hawaii in 1979. The results showed that goats were not adversely affected even when fed a sole diet of fresh leucaena (Jones 1981). Degradation of both mimosine and DHP occurred when incubated with rumen fluid in vitro. The results were completely different from a similar study in Australia, in which goats fed solely leucaena rapidly became hypothyroid, lost appetite, did not degrade DHP in their rumen, and excreted large quantities of DHP in urine (Jones and Megarrity, in press). From these studies, it was hypothesized that the failure to metabolize DHP in Australia reflected an absence of rumen microorganisms capable of degrading DHP (Jones 1981; Jones and Megarrity, in press). Further support for this hypothesis has recently been obtained by researchers transferring rumen fluid from an Indonesian goat known to be degrading DHP to Australian goats fed on Australian-grown leucaena. After only one infusion, the recipients acquired the ability to degrade DHP (Jones and Lowry, in preparation). Mixed cultures of the DHP-degrading bacteria have been grown successfully in vitro with anaerobic techniques and have been introduced from Hawaii into Australia where they will be used under strict quarantine to introduce the DHP-degrading capacity into Australian goats and cattle (R.J. Jones and R.G. Megarrity, unpublished data). If successful, these experiments will provide a biological solution to the leucaena-toxicity problem in Australia and so remove one of the hindrances to wider use of leucaena in pastures.

Problems similar to those described in Australia have been reported for cattle fed high levels of leucaena in Africa (Compere 1959; Vohradsky 1972) and in Papua New Guinea (Holmes 1981). The presence or absence of DHP-degrading microorganisms in any area can readily be confirmed by urinalysis for DHP (Megarrity 1981) in animals on diets containing more than 50% leucaena on a dry-matter basis.

Feeding Value and Animal Production

The nutritive value of leucaena has been reviewed elsewhere in some detail (Jones 1979). It is sufficient to note that, although sodium is consistently low in the plant and iodine may be low, the mineral composition of well-grown leucaena is usually adequate for productive livestock. In areas where pastures are a mixture of leucaena and low-sodium grasses, such as *Panicum*, or where leucaena forms a large part of the diet, iodized salt may be needed to prevent deficiencies.

In Australia, studies to measure intake and digestibility of leucaena have been plagued by toxicity problems in the animals. Until the problem is solved, it will be impossible to get meaningful figures on the potential nutritive value of the material.

Studies that compare the feeding values of leucaena with other shrub species have been few, although Bamualim et al. (1980), using the nylon-bag technique, found that the digestibility values for leucaena cultivars and introductions were generally higher than those from a number of other shrubs, including *Acacia*, *Desmanthus*, *Albizia*, *Bauhinia*, *Calliandra*, *Cajanus*, and *Lysiloma*. Digestibility of the leaves varied little with season — a finding that contrasts with the rapid decline in digestibility of native grasses during the dry season (Bamualim et al. 1982).

Data on animal production from grazed pastures are also relatively few. Under irrigated conditions in northwest Australia, however, grazing experiments have shown that cattle on the irrigated leucaena–pangola pastures are invariably hypothyroid, and those on the leucaena–rhodes and leucaena–setaria consistently have an enlarged thyroid gland within 1 year (Jones et al. 1976; Jones and Jones 1979). Milk yields for 9 months from cows on leucaena and green panicum (4.78 cows/ha) were 1316 kg/cow or 6.3 t/ha (Stobbs 1972).

In a comparative study in northern Australia, a leucaena–*Cynodon dactylon* pasture gave higher live-weight gains than did adjacent pastures of Townsville stylo (TS)–*P. maximum* var *trichoglume* or TS–*Cenchrus ciliaris*, which contained 35% TS (Falvey 1976). Heifers rotationally grazing leucaena pasture in conjunction with a TS–grass pasture gained 16 kg more during the dry season than did those grazing the TS pasture only — a response associated with low-legume content in the base pasture (Falvey 1976).

There are no other direct comparisons of leucaena pastures with other legume-based pastures. However, maximum annual live-weight gains (1330 kg/ha) from irrigated, nitrogen-fertilized (310 kg N) pangola grass in the Ord Valley (Blunt 1978) were higher than those from leucaena–pangola (830 kg/ha) (Blunt 1976). At Samford, southeast Queensland, annual live-weight gains (311 kg/ha) on leucaena–setaria were higher than those from siratro–setaria pastures (200 kg/ha) under similar conditions (Jones and Jones 1982). Leucaena toxicity has not been as severe or as consistent in southeast Queensland as in the more tropical areas of Townsville and Kununurra, in the Ord Valley. At the warmer sites, a marked improvement in animal production could be expected if the toxicity problem could be overcome.

Breeding performance of beef cattle on leucaena pastures has also varied. At Samford, heifers solely grazing leucaena–grass pastures showed a 78% calving compared with 89% calving for a farm herd grazing other pastures (Jones and Jones 1981). All cows grazing leucaena pastures at Kununurra produced goitrous calves in the wet season, most of which died within 3 days of birth (Jones et al. 1976). These results may be compared with those in New Guinea where heifers had low conception rates on leucaena pastures despite good body condition and some had cataracts (Holmes 1981).

In contrast, supplementary grazing of leucaena in conjunction with native pastures proved beneficial near Gayndah, southeast Queensland: the calving rate of cows that had calved the previous year and had access to leucaena (17% of total area) was 70% compared with 50% from cows at the same stocking rate without leucaena (Anonymous 1981).

Priorities in Research

The problems for the future are largely those that have been recognized for a long time (Jones 1979) but are now better understood. Efforts should be to:

- Explore the existing germ-plasm collection to describe the variation encountered, to define the areas of climatic and edaphic adaptability, to identify superior introductions capable of higher yields, of wider adaptability, and with better agronomic or nutritional attributes than the existing cultivars. So far, all Australian work has been on *L. leucocephala*, but, with testing of the accessions available at CSIRO, major advances can be expected.
- Develop reliable establishment strategies, through the selection of leucaena germ plasm or *Rhizobium* for rapid nodulation to reduce the period during which the seedling behaves as a nonlegume and to develop inoculation techniques to aid multiplication of the *Rhizobium* in the soil and rhizosphere (Bushby 1982). In addition, herbicides to control or eliminate competition from weeds will need to be combined with suitable sowing equipment to foster rapid establishment, reduce costs, and prevent erosion.
- Eliminate the toxicity problem. Thus far, it has not been possible to combine vigour with low-mimosine concentration through plant breeding. Although F_1 hybrids between *L. pulverulenta* and *L. leucocephala* show promise, the use of rumen microorganisms to degrade the goitrogen DHP in the rumen offers hope that a biological solution will be found (Jones and Megarrity, in press). The problems in introducing the DHP-degrading microbes into commercial herds need to be explored, and suitable techniques developed.
- Define the production systems in which leucaena will make the greatest contribution. Rarely will leucaena occupy a large proportion of a grazing property; producers need to know in what situations it will grow best and in what part of the cattle-production system it will make the greatest contribution, e.g., fattening steers, supplementing breeders at mating, or providing pasture for weaners.
- Identify the soil characteristics that result in poor production. On the basis of these results, the area of adaptability in northern Australia could be better defined.
- Determine the fertilizer requirements for establishment and maintenance of grazed leucaena pastures and develop reliable techniques for predicting nutrient requirements.
- Measure the feeding value of leucaena. In particular, the role of tannin in the natural protection of protein through the rumen and its subsequent fate in the digestive tract need clarification.
- Develop seed-production and management systems that enable seed to be sold at a more reasonable price than the current AU$ 20+/kg, which is high enough to discourage some potential users. The possibilities of mechanical seed harvesting also should be investigated.